AN EVALUATION OF TECHNIQUES FOR COLLECTION AND ANALYSIS OF BENTHIC INVERTEBRATE COMMUNITIES IN SECOND ORDER STREAMS IN REDWOOD NATIONAL PARK

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ABSTRACT

The benthic invertebrate communities in two second-order streams within a watershed rehabilitation project site were studied during the summer of 1981. Due to low water depths and the heterogeneous morphology of second-order streams, common benthic invertebrate sampling procedures were ineffective. A Small Artificial Substrate Basket (SASB) sampler was designed to allow sampling streams as shallow as 5 cm. Compared to conventionally sized artificial substrate basket samplers used in other northern California streams, the SASB sampler collected lower number of total individuals with a comparable number of taxa. Analysis of covariance was an effective statistical procedure to help compensate for the variability in the benthic invertebrate community due to the water depth and water velocity at each sample site and the settled solids (SS) and coarse particulate organic matter (CPOM) which deposited on each sampler. Functional group composition was found an effective descriptive variable for comparing benthic invertebrate communities.

INTRODUCTION

The major emphasis of Redwood National Park's watershed rehabilitation program is to minimize man-induced erosion and contribution of sediment to Redwood Creek tributary streams. Much of the work involves excavation of stream crossings as part of the process of removing roads. These streams are often ephemeral; however, some are perennial second-order streams which harbor an abundance of aquatic organisms. Monitoring the effects on the aquatic community from watershed rehabilitation is an important element of the overall restoration program. This study was undertaken to develop and evaluate techniques for collection and analysis of benthic invertebrates in second-order streams disturbed by watershed rehabilitation activities.

Benthic invertebrates are frequently used in detecting changes in the aquatic community (Warren 1971, Ehlke et al. 1977, American Public Health Association 1980); however, there are many difficulties with controlling sampling variability, especially in small, second-order streams. The primary difficulty is that benthic invertebrates do not distribute themselves uniformly on the stream bottom, and are often clumped in microhabitats which provide their unique environmental requirements. Resh (1979) described in detail the physical, biological and operational factors producing sampling variability in benthic studies.

Choosing the proper sampling device is important for reducing sampling variance. Of the many devices available (see review by Cummins 1962, Elliot and Tullett 1978), the most common is the Surber square-foot sampler (Surber 1936). It has been criticized, however, for its high rate of sampling variability (Needham and Usinger 1956, Chutter 1972). The Surber sampler as well as other common sampling devices (dredges and corers) destroy habitat and are limited by the type of substrate they can sample.

To prevent habitat destruction and reduce sampling variance in benthic studies, some investigators have recommended the use of artificial substrate basket samplers (Anderson and Mason 1968, Dickson et al. 1971, Ferreira 1976). They were originally designed for sampling large rivers (Anderson and Mason 1968, Mason et al. 1973, Benfield et al. 1974) and, as a result, the most

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on shapes described by Scott (1958) and Mason et al. (1967) are inadequate for use in small s. Roby et al. (1978) described an artificial substrate basket sample for small streams but it also be too large for most second-order streams.

In this study, a small artificial substrate (SASB) sample was developed for sampling benthic ebrates in second-order streams. To evaluate the effectiveness of the sampler, the composition of nthic invertebrate community in logged and unlogged portions of two second-order streams in a ilitation project site were compared using functional group, as well as more common descriptive bles. Finally, sampling and analysis techniques were evaluated for dealing with the heterogeneous hology of second-order streams.

STUDY SITE

North Fork and South Fork Slide Creek were used in this study. The Slide Creek watershed is ed on the east side of the Redwood Creek basin (Fig. 1). The total drainage area is 3.0 km^2 with orth Fork draining almost twice the area of the South Fork. For a detailed physical-chemical, gical and vegetational description of the Slide Creek watershed see Iwatsubo et al. (1976).

During the summer of 1981, two logging-haul roads located in the lower portion of the watershed ig. 1) were removed as part of a rehabilitation treatment. One of the roads, the 2005, crossed streams and provided access for this study. The area upstream from both the North and South road crossings had been selectively-logged and tractor-yarded in 1966 and then clear-cut in 1971. area downstream of both road crossings was unlogged. This provided four sample sites, an eam logged and downstream unlogged area on both North and South Fork Slide Creek. The ged sample area was 160 m downstream of the logged area on the North Fork and 100 m stream on the South Fork.

During the study, the North Fork's stream flow averaged 2 l/sec and the South Fork averaged 1 The North and South Fork of Slide Creek has an average stream gradient of 26%; however, the ents of small reaches such as the study areas were not constant. Numerous waterfalls created by ders and large woody debris formed pools ranging from 20 - 50 cm deep. Narrow (30 cm - 100 riffles ranging from 5 - 20 cm deep often separated them. The substrate was extremely ogeneous, ranging from large boulders and woody debris to pea-sized gravel and silt.

MATERIALS AND METHODS

The SASB sampler (Fig. 2) was constructed of 1.27 cm mesh hardware cloth cut into two 10 cm e panels and one 40 cm by 5 cm strip. The strip was formed into a square with one of the panels at each corner for the bottom and the other square panel hinged with wire to form a movable top. asked was filled with 2.54 - 7.62 cm commercially graded limestone chips. Sampler volume was m^3 and the weight was approximately 1 kg.

Twelve samplers were placed in each of the four study areas. Samplers were placed in the North n 22 June and in the South Fork on 25 June 1981. On 13 and 21 August the North Fork ers were retrieved, and on 7 and 10 September the South Fork samplers were retrieved by swiftly them out of the water and into a bucket which was slightly submerged and as close to the stream side of the sampler as possible. Each sampler was retrieved in the same manner and by me person. The samplers were then opened and their contents emptied into a bucket. Each rock rubbed with a toothbrush and examined for clinging organisms before discarding. As each er was collected, the water depth was measured and the water velocity recorded using a Pigmy meter.

Once all the rocks were scrubbed and discarded, the entire contents of the bucket was poured h a No. 35 USA Standard Testing Sieve (mesh opening 0.5 mm) and the water retained in a tub the sieve. The benthic invertebrates along with all coarse particulate organic matter (CPOM) han 0.5 mm diameter were transferred to a container and preserved with 70% ethyl alcohol. The n the tub was allowed to settle, the clear surface water decanted and the water containing the

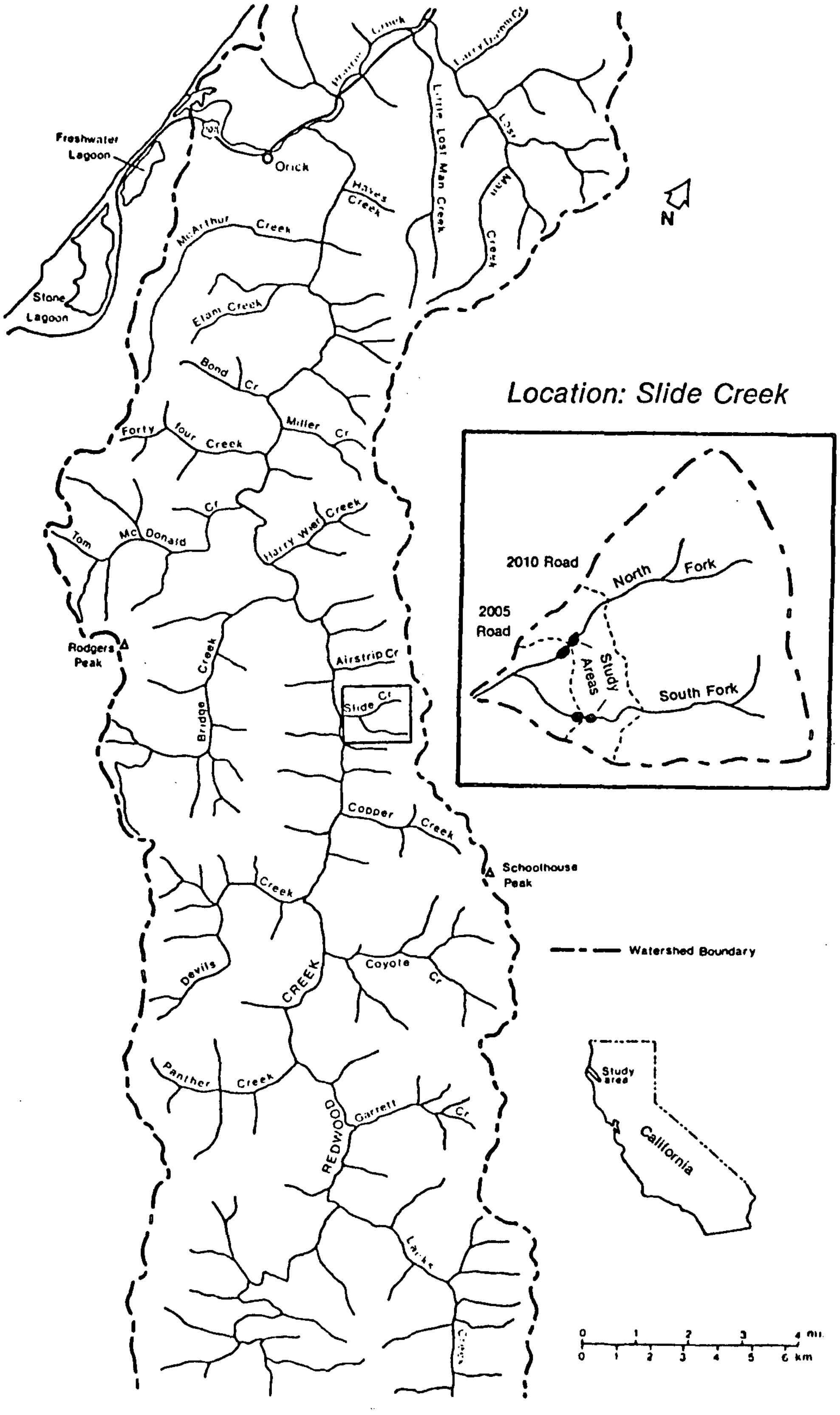

Figure 1

Map of Slide Creek Watershed in Relation to Redwood Creek Basin, Humboldt County, California

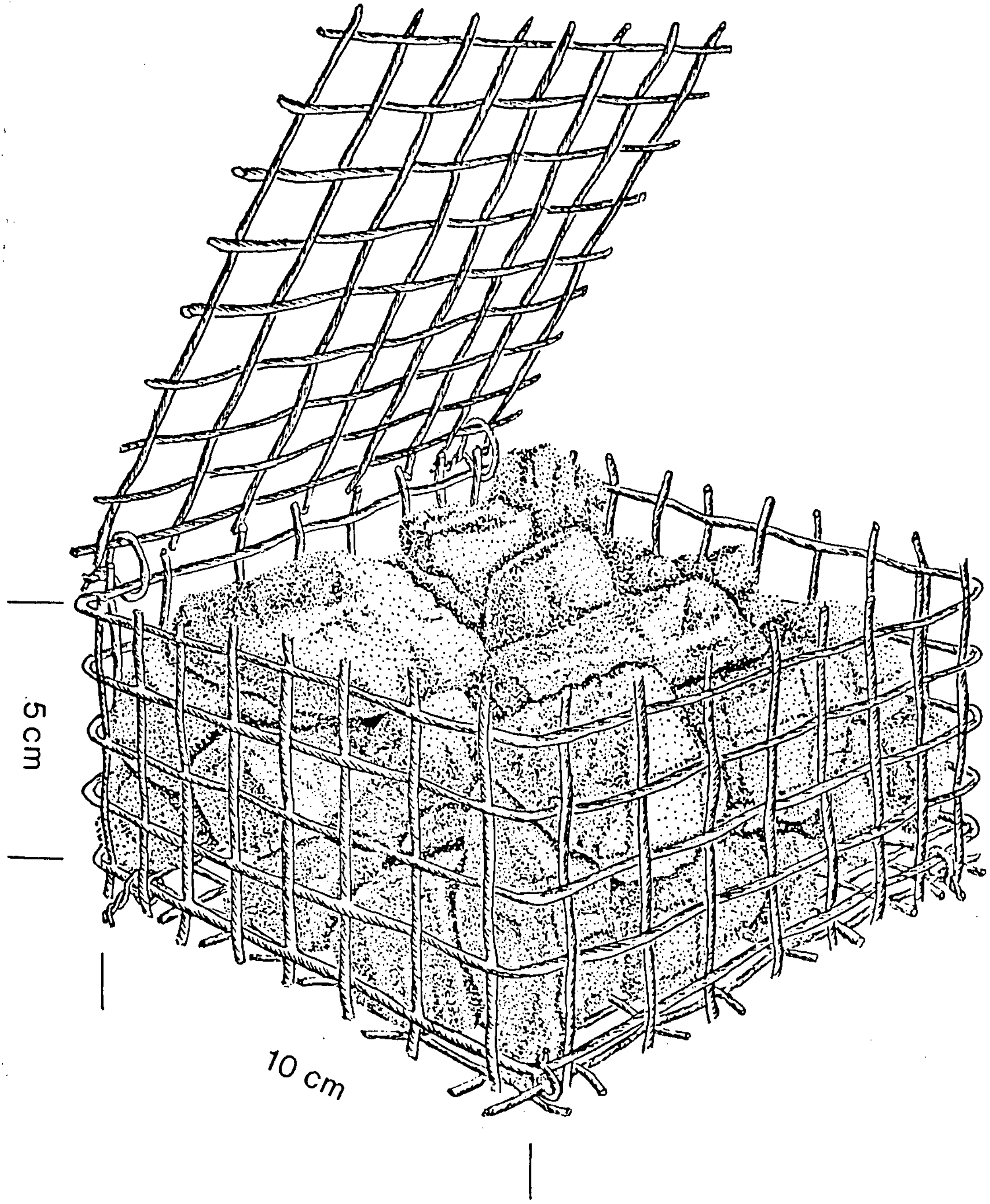

Figure 2

Illustration of the Small Artificial Basket (SASB) Sampler settlable solids (SS) less than 0.5 mm diameter retained in a liter bottle. As soon as the bottle was brought out of the field, it was kept at 4° C until processing.

The SS that had deposited on each sampler was poured into aluminum trays, dried in a convection oven at 100° C for approximately 24 hrs and weighed. After removing the benthic invertebrates from the container of preserved sample material, the CPOM was poured into aluminum trays, dried in an oven at 100° C for approximately 8 hrs and weighed.

Once the benthic invertebrates were identified and enumerated, each was classified according to its functional group. Merritt and Cummins (1978) was used to classify aquatic insects, while Iwatsubo and Averett (1981) was used to classify other organisms according to Merritt and Cummin's system. The works of Edmondson (1959) and Pennak (1978) were used to determine a suitable classification for other organisms not mentioned by Iwatsubo.

Four general functional group categories based on feeding mechanism were used:

1) **Predators:** Carnivores which feed by engulfing whole or parts of living animal tissue.

2) **Grazers:** Omnivores which feed by scraping periphyton, attached algae and associated material from mineral and organic surfaces.

3) **Shredders:** Herbivores and detritivores which process CPOM as a food source.

4) **Collectors:** Detritivores which feed by filtering suspended material or by gathering depositional material primarily consisting of decomposing fine particulate organic matter (FPOM).

A diversity index was calculated for each sample using the equation given by Wilhm and Dorris (1968):

$$\text{diversity index} = -\sum_{i=1}^{S} \frac{n_i}{n} \log_2 \frac{n_i}{n}$$

where n_i is the number of individuals in each taxon, n is the total number of individuals and S is the total number of taxa colonizing the sampler.

A two-way analysis of variance and covariance was used to analyze the data. Biomedical Computer Programs (BMDP) P2V (Dixon and Brown 1979) were used to perform the calculations. Water depth, water velocity, SS and CPOM were used as the covariates. With analysis of variance and covariance, treatment cell means were adjusted for the influence of the covariates by producing a regression line common to all data and then extracting the sum of squares due to the regression (Dixon and Massey 1969). The analysis of variance was then carried out on the adjusted data. Significance level for this study was set at $p = 0.05$. To test the assumptions of analysis of variance and covariance, residuals were analyzed using the method described by Box et al. (1978). BMDP programs P5D, P6D and P9D were used for the computations.

RESULTS

The means and ranges for water depth, water velocity, SS and CPOM for the logged and unlogged portions of North and South Fork Slide Creek are given in Table 1. The average water depth of the samplers was similar in all four locations. The average water velocity at the sampler sites was greater in both the logged and unlogged portion of the North Fork than the South Fork. Sampler sites in the unlogged portion of the South Fork were subjected to considerably greater water velocity than those in the logged portion. North Fork samplers contained a higher weight of SS and CPOM than the South Fork samplers and samplers in the lower unlogged area of both streams had a higher weight of SS and CPOM than the upper logged area.

Table 2 lists the benthic invertebrates, their functional group classification and the study areas where they were found colonizing the SASB samplers. Five classes of benthic invertebrates were identified. In the dominant class, Insecta, nine orders were represented by 38 families and sub-families.

Table 1

Means and Ranges for Water Depth and Water Velocity at Sampler Site and Settleable Solids (SS) and Weight of Coarse Particulate Organic Matter (CPOM) which Collected on Samplers Located in Logged and Unlogged Portions of North and South Fork Slide Creek, Summer 1981.

	North Fork				South Fork			
	Logged		Unlogged		Logged		Unlogged	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Dep. (m)	0.13	0.07-0.24	0.11	0.06-0.19	0.12	0.07-0.23	0.11	0.08-0.18
Vel. (m/s)	0.08	0-0.28	0.08	0-0.32	0.02	0-0.08	0.05	0-0.18
SS (g)	1.6	0.6-4.6	12.8	0.6-61.0	1.4	0.4-4.5	2.3	0.7-5.9
CPOM (g)	0.37	0.10-0.91	0.52	0.10-1.16	0.22	0.10-0.36	0.28	0.10-0.51

Table 2

Summary of the Functional Group Classification and Occurrence of Benthic Invertebrates in the Logged and Unlogged Portion of North and South Fork Slide Creek, Humboldt County, Summer 1981

CLASS		OCCURRENCE			
Order		Slide Creek			
Family					
Subfamily	Functional		North Fork		South Fork
Genus species	Group	Logged	Unlogged	Logged	Unlogged
ARACHNOIDEA					
Acari	Predator	x	x	x	x
GASTROPODA					
Basommatophora					
Planorbidae					
Gyraulus sp.	Grazer	x			
Unknown	Grazer	x	x		
Mesogastrapoda					
Bulimidae					
Amnicola sp.	Grazer	x	x		
Pleuroceridae					
Juga sp.	Grazer	x	x	x	x
INSECTA					
Coleoptera					
Dytiscidae					
Rhantus/Colymbetes	Predator	x	x		
Elmidae					
Heterlimnius koebelei	Collector	x	x	x	x
Lara avara amphipennis	Shredder		x	x	x
Narpus concolor	Collector			x	x
Zaitzevia parvula	Collector	x	x		x
Hydraenidae					
Hydraena vandykei	Collector	x	x		
Psephenidae					
Eubrianax edwardsi	Grazer	x	x	x	x
Staphylinidae	Predator		x		
Collembola	Collector	x			
Diptera					
Chironomidae					
Chironominae					
Rheotanytarsis sp.	Collector	x	x	x	x
Orthocladiinae					
Eukiefferiella sp.	Collector	x	x	x	x
Tanypodiane					
Paramerina fragilia	Predator	x	x	x	x
Procladius sp.	Predator	x	x	x	x
Dixidae					
Paradixa sp.	Collector	x		x	
Empididae	Predator	x	x	x	x
Psychodidae					
Culicoides sp.	Predator	x	x		
Simuliidae					
Simulium sp.	Collector	x	x	x	x
Tipulidae					
Limonia sp.	Shredder			x	
Tipula sp.	Shredder		x		
Unknown	Shredder		x		
Unknown 1	Unknown		x		
Unknown 2	Unknown			x	
Ephemeroptera					
Baetidae					
Baetis sp.	Collector	x	x	x	x
Centroptilum sp.	Collector		x		

Table 2 (Continued)

CLASS Order Family Subfamily Genus species	Functional Group	OCCURRENCE			
		Slide Creek			
		North Fork		South Fork	
		Logged	Unlogged	Logged	Unlogged
Ephemerellidae					
Ephemerella coloradensis	Collector	x	x	x	
Heptageniidae					
Cinygma sp.	Grazer	x	x	x	x
Irondes sp.	Grazer	x	x	x	x
Leptophlebiidae					
Paraleptophlebia sp.	Collector	x	x	x	x
Siphlonuridae					
Ameleuts sp.	Collector		x		
Megaloptera					
Sialidae					
Sialis sp.	Predator		x		
Odonata	Predator			x	
Plecoptera					
Chloroperlidae					
Alloperla sp.	Predator	x	x	x	x
Numouridae					
Leuctrinae					
Lectra augusta	Shredder	x	x	x	x
Nemourinae					
Amphinemura sp.	Shredder	x	x	x	x
Peltoperlidae					
Peltoperla sp.	Shredder		x		
Perlidae					
Calineuria californica	Predator	x	x	x	x
Tricoptera					
Brachycentridae					
Amiocentrus aspilus	Collector		x		
Micrasema aspilus	Shredder	x	x		x
Calamoceratidae					
Heteroplectron californicum	Shredder	x	x	x	x
Glossosomatidae					
Agapetus sp.	Grazer	x	x	x	x
Glossosoma sp.	Grazer	x	x		x
Hydrosychidae					
Hydropsyche sp.	Collector	x	x	x	x
Hydroptilidae					
Hydroptila sp.	Collector	x			
Lepidostomatidae					
Lepidostoma sp.	Shredder	x	x	x	x
Limnephilidae					
Apatania sorex	Grazer	x	x	x	x
Farula sp.	Grazer	x	x	x	x
Hydratophylax hesperus	Shredder		x		x
Pseudostenophylax edwardsi	Shredder	x			
Psychoglypha sp.	Collector	x			
Odontoceridae					
Namamyia plutonis	Collector		x		
Polycentropodidae					
Polycentropus sp.	Predator	x	x	x	x
Rhyacophilidae					
Rhyacophila sp. 1	Predator	x	x	x	x
Rhyacophila sp. 2	Predator	x	x		x
OLIGOCHAETA	Collector	x	x		
PELECYPODA	Collector		x		

here were 60 taxa; 37 common to both streams, 19 found only in the North Fork and 4 in the South Fork. Eight taxa were found only in the logged portion and 12 were found nlogged portion of either stream. Two taxa (*Paradixa* and an unidentified *Tipulid)* were in the unlogged area of both streams.

tal number of individuals colonizing each sampler averaged 169 and ranged from 38 to 799. number of taxa per sampler was 15 and ranged from 8 to 28. The diversity index or each sampler averaged 2.47 with a range of 0.67 to 3.99. Actual and adjusted mean nvertebrates, number of taxa and diversity index from the creek treatment (North versus Slide Creek) and the location treatment (logged versus unlogged) are shown in Fig. 3, Fig. respectively. There were no significant differences in numbers of benthic invertebrates, taxa or diversity index due to the treatments or their interaction (Table 3).

Table 3

ficance Levels (ns greater than p = 0.05) for Benthic Invertebrate Descriptive Variables on a Two-Way Analysis of Variance and Covariance Using Creek Treatment (North Versus South Fork Slide Creek), Location Treatment (Logged Versus Unlogged), Creek ocation Interaction and All Covariates Including the Single Covariates Water Depth Water Velocity (Wv), Settleable Solids (SS), and Coarse Particulate Organic Matter POM).

riable	Creek	Location	Creek x Loc.	All Covariates	Wd	Wv	SS	CPOM
umber of Individuals	ns	ns	ns	.0039	ns	.0006	ns	.0039
umber of Taxa	ns	ns	ns	.0002	.0484	ns	ns	.0006
versity Index	ns	ns	ns	.0040	ns	ns	ns	ns
rcent Predators	ns	ns	ns	.0386	ns	ns	ns	ns
rcent Grazers	ns	.0040	ns	.0007	.0011	ns	ns	ns
rcent Shredders	.0043	ns	ns	ns	ns	ns	ns	ns
rcent Collectors	ns	.0152	ns	.0067	.0256	ns	ns	ns

ual percent composition of predators, grazers, shredders and collectors for the logged and ortion of North and South Fork Slide Creek is shown in Fig. 6. Percent shredders did not he assumption of analysis of variance and covariance and was therefore subjected to an ormation (Sokal and Rohlf 1969).

ere 11 taxa of grazers identified in the study. Eleven were found in the logged and 10 in portion of the North Fork and seven in the logged and eight in the unlogged portion of rk. The combination of *Eubrianax edwardsi* and *Agapetus sp.* accounted for 79% of the

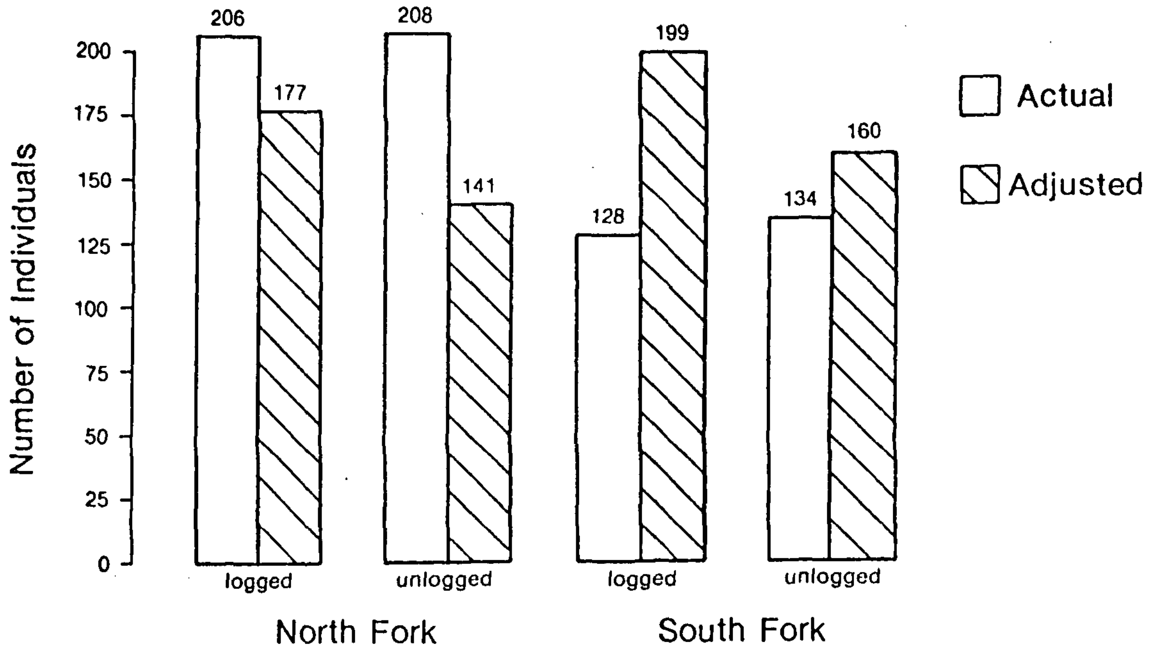

Figure 3

Actual and Adjusted Mean Number of Benthic Invertebrates Colonizing SASB Samplers in the Logged and Unlogged Portions of North and South Fork Slide Creek, Humboldt County, Summer 1981

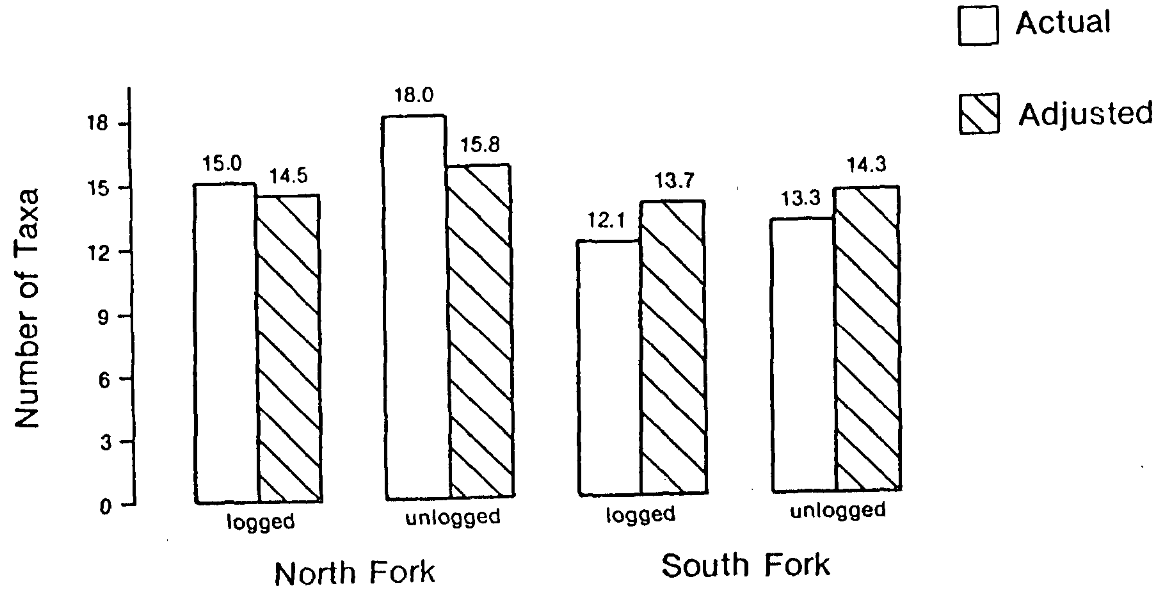

Figure 4

Actual and Adjusted Mean Numbr of Benthic Invertebrates Colonizing SASB Samplers in the Logged and Unlogged Portion of North and South Fork Slide Creek, Humboldt County, Summer 1981

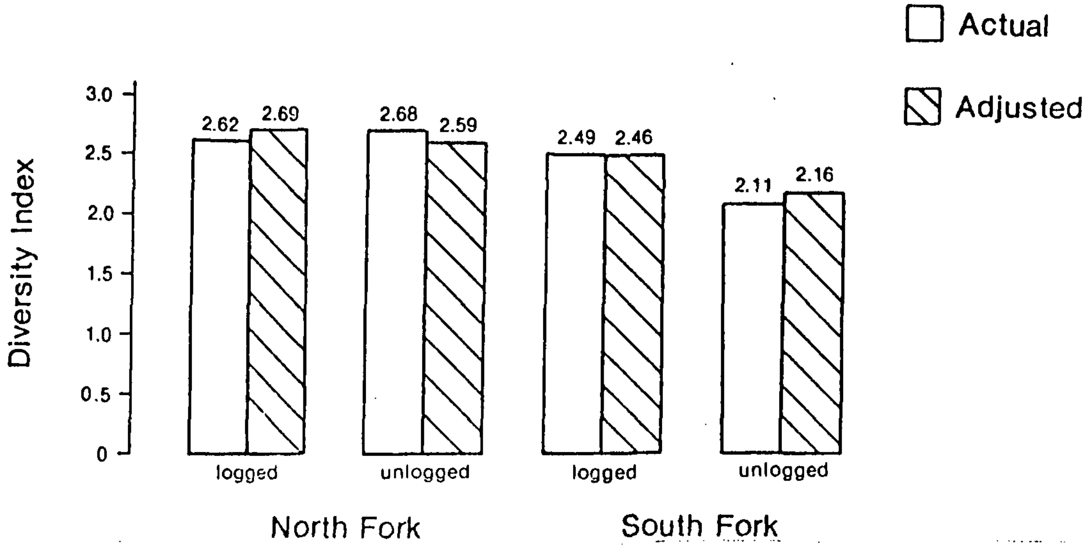

Figure 5

Actual and Adjusted Mean Diversity Index (Wihlm and Dorris 1968) of Benthic Invertebrates Colonizing SASB Samplers in the Logged and Unlogged Portions of North and South Fork Slide Creek, Humboldt County, Summer 1981

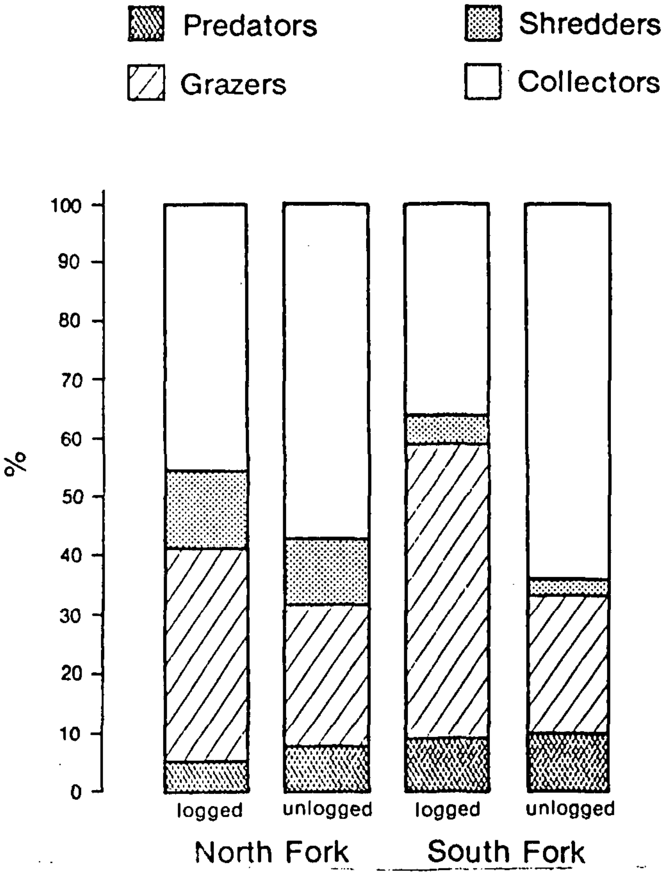

Figure 6

Mean Functional Group Composition in Percent Individuals for Benthic Invertebrate Communities Colonizing SASB Samplers in the Logged and Unlogged Portions of North and South Fork Slide Creek, Humboldt County, Summer 1981

grazers in the logged and 73% in the unlogged section of the North Fork. The combination of *Eubrianax edwardsi* and *Juga* sp. accounted for 95% of the grazers in the logged and 63% in the unlogged portion of the South Fork.

There were 21 taxa of collectors identified in the study. Thirteen were found in the logged and 18 in the unlogged portion of the North Fork and nine in the logged and eight in the unlogged portion of the South Fork. *Rheotanytarsus* sp. was the most abundant collector in all four locations. It accounted for 74% of the collectors in the North Fork unlogged area and 90% in the South Fork unlogged area. In the North Fork logged area, it accounted for 54% of the collectors and 58% in the South Fork logged area. In all four locations, *Baetis* sp. was the second and *Paraleptophlebia* sp. the third most abundant species.

There were 12 taxa of shredders identified in the study. Six were found in the logged and 10 in the unlogged portion of the North Fork, and six in the logged and seven in the unlogged portion of the South Fork. The combination of *Amphinemoura* sp. and *Heteroplectron californicum* accounted for 96% of the shredders in the logged and 76% in the unlogged portion of the North Fork, and 94% in the logged and 61% in the unlogged portion of the South Fork.

There were 14 taxa of predators identified in the study. Ten were found in the logged and 13 in the unlogged portion of the North Fork and 11 in the logged and nine in the unlogged portion of the South Fork. There were no dominant taxa appearing in all four study areas; however, *Paramerina fragilis, Procladius* sp., *Calineuria californica, Alloperla* sp., *Polycentropus* sp. and Acari were the most abundant predator taxa found in the study areas.

Grazers dominated the upper logged portion of both streams and collectors dominated the lower unlogged portions. This produced a significant difference in percent grazers and collectors for the logged versus unlogged location treatment (Table 3). Shredders were significantly more abundant in the North Fork than the South Fork regardless of logging condition. There was no significant difference in percent predators in either of the creeks or in the logged or unlogged sections. There was no treatment interaction for any of the functional group categories.

The combination of the four covariates, water depth, water velocity, SS and CPOM, had a significant effect on all SASB sampler descriptive variable except percent shredders. Of the combined covariate variation, water depth provided a significant contribution for number of taxa, percent grazers and percent collectors. Number of taxa and percent grazers increased and number of collectors decreased with increasing water depth. Water velocity made a significant contribution to the combined covariate variation for number of individuals. There was an increase in number of benthic invertebrates with increasing water velocity. CPOM made a significant contribution to number of individuals and number of taxa. An increase in both number of individuals and number of taxa was observed with increasing weight of CPOM. There was no significant contribution produced by SS.

DISCUSSION

The small size of the SASB sampler made studying second-order streams possible. There was concern, however, as to whether it would collect a sample comparable to larger, conventional artificial substrate basket samplers. The most commonly used artificial substrate basket sample, called a barbeque basket (Anderson and Mason 1968), is cylindrical in shape and has a volume of approximately 6,000 cu cm. Roby et al. (1978) devised an artificial substrate basket sampler with a similar volume (5,500 cu cm), but with a cubical shape. The SASB sampler has a cubical shape, but its volume is only 500 cu cm.

Compared to the sampler of Roby et al. (1978) and the barbeque basket (Ferreira 1976) used in northern California streams, the SASB sampler collected a considerably lower number of total individuals but a comparable number of taxa. The SASB sampler collected a total of 60 taxa with a maximum occurrence of 28 and a sample average of 15. The total number of individuals per sample averaged 169 with a range of 799 to 38. Roby's sampler in San Leandro Creek collected a total of 48 taxa with a maximum of 25 in one sample. Ferreira, using a barbeque basket in Elder Creek and the South Fork Eel River, collected a maximum of 27 taxa in one sample with an average of 18. The number of individuals averaged 370 with a maximum of 1,435.

There could be several benefits to the small size of the SASB sampler. Collecting fewer numbers of individuals would produce a savings of time and money in processing (sorting and identifying) the samples. The savings could be transferred into collecting more samples which would reduce sample variance. Another benefit is its reduced weight. The barbeque basket weighs approximately 8 kg (Anderson and Mason 1968), Roby's sampler 5 kg and the SASB 1 kg. The reduced weight of the SASB sampler would make the use of artificial substrate basket samplers in remote areas possible and sampling road accessible streams easier.

The shape is another benefit of the SASB sampler. It lies flat in the stream substrate offering less resistance to the water current and providing less area for collection of unusual amounts of stream litter. This is confirmed by the low weight of CPOM collected on the SASB samplers (an average of 0.44 g for the North Fork and 0.25 g for the South Fork). Roby et al. (1978) were dissatisfied with the performance of their sampler because it collected high amounts of leaf litter. ***Lepidostoma*** which processes leaves as a food source (shredder) was attracted to this sampler and totaled 67% of the organisms collected. This was a product of design since the sampler is placed on stands above the substrate, thus making it a virtual trap for leaf litter.

Roby et al. (1978) placed their samplers on stands to prevent them from being clogged with sediment. Since the SASB samplers laid flat in the substrate, those which were placed in areas of sediment deposition contained high weights of SS. This was a benefit since seven taxa (Odonata, Oligochaeta, Pelecypoda, *Sialis* sp., *Limonia* sp., *Tipula* sp. and an unidentified Tupulid) of burrowing organisms were identified colonizing SASB samplers. Ten samples were colonized by these burrowers and most contained the highest recorded weights of SS. The sediment did not exclude other organisms from colonizing the samplers.

The SASB samplers were filled with commercially graded limestone chips. The chips were unlike the natural substrate in that they were white, of uniform size and different chemical composition. Limestone was used because it is easily available in graded form, inexpensive and the most commonly used substrate for artificial substrate basket samplers (Ehlke et al. 1977, Mason et al. 1967). It must be mentioned, however, that artificial substrate basket samplers are more commonly used in the eastern United States where limestone streams are prevalent. There was probably some selectivity of organisms to the sampler substrate. Mason et al. (1973) compared basket samplers filled with limestone chips and basket samplers filled with porcelain spheres. They found benthic invertebrates colonized both substrates in comparable numbers and diversity, but in different taxonomic proportions. If selectivity of organisms to the sampler does exist, it can be ignored as long as the selectivity exists equally for each sampler and the samplers collect a fairly representative composition of invertebrates inhabiting the stream benthos. Ferreira (1976) and West (1979) showed artificial substrate samplers in northern California streams did collect a representative composition of benthic invertebrates.

Stream bottom substrate, water depth, water velocity and debris accumulation can influence benthic invertebrate distribution and cause unusually high sampling variances. To prevent this problem, Elliot (1971) and the American Public Health Association (1980) recommend sampling uniform riffles. In North and South Fork Slide Creek, as in most second-order streams, there are no riffles large enough for an adequate number of samples. Therefore, instead of controlling the extraneous factors influencing benthic invertebrates, their influence was adjusted through the use of analysis of covariance. Nolan and Janda (1981) successfully used analysis of covariance to control the influence of water discharge on the mean values of suspended sediment discharge at sites in the Redwood Creek basin, California.

Significance testing of the benthic invertebrate descriptive variables was based on means adjusted for the effects of water depth, water velocity, SS and CPOM. All the variables, except percent shredders, were significantly affected by the covariates. In most cases, the adjustment was slight; however, with a number of individuals the adjustment was consequential (see Fig. 3). The analysis of covariance showed that as water velocity and weight of CPOM increased the number of individuals also increased. This was primarily due to the high numbers of ***Rheotanytarsis*** which occur in fast flowing water and are attached to leaf surfaces. Since sampler sites in the North Fork had higher water velocities and the samplers contained higher weights of CPOM than in the South Fork, the values for mean numbers of individuals were adjusted lower for the North Fork and higher for the South Fork.

the result was no significant difference where otherwise the actual number of individuals in the North Fork would probably have proven significantly higher than in the South Fork.

Simple descriptive variables such as number of individuals, number of taxa and diversity index can often be misleading. If only these variables were used in this study to describe the benthic invertebrate community, the conclusions would have been that there was no significant difference between the North Fork and the South Fork or in the logged and unlogged areas. It is possible, as a result of a stream perturbation, to have an intolerant species replaced by a tolerant species without a significant change in the total number of individuals or taxa. There are numerous diversity indices and many have been criticized (Hendricks et al. 1974, Cook 1976, Masnik et al. 1976). Some researchers (Harrel and Dorris 1968, Mathis 1968, Winget and Mangum 1979) have cited actual increases in diversity as a result of moderate levels of pollution.

Viewing the benthic invertebrate community by its functional group composition provided more relevant results. Cummins (1974) recommended classifying organisms by their feeding mechanism, or, in other words, their function in the energetics of the stream community. Vannote et al. (1980) hypothesized that, as with the physical system, the biological system is in dynamic equilibrium and any perturbation to the stream will elicit a rapid adjustment and consequential redistribution of the functional group composition. This is evident by the significant difference in percent grazers and collectors in the logged and unlogged portions of both streams. Grazer organisms were abundant in the logged while collectors were abundant in the unlogged areas. Vannote et al. (1980) hypothesized that grazers should consist of approximately 6% and collectors 47% of the community composition of an undisturbed second order stream. Hawkins and Sedell (1981) showed that an undisturbed second order stream would be expected to contain approximately 15% grazers and approximately 10% collector/filterers. The portions of North Fork and South Fork Slide Creek which were disturbed by logging lacked heavy canopy cover and allowed more sunlight for the growth of periphyton which is the food source for grazers. Consequently, it supported a high (36% to 50%) population of grazer organisms. The unlogged sections had canopies of old-growth redwood and, therefore, little autotrophic food production. The grazer organisms were therefore less and the large (57% to 64%) collector population in the unlogged sections probably developed in response to what Vannote et al. (1980) termed "the collector's ability to capitalize on the inefficiencies of upstream processing," in this case, the processing of periphyton by upstream grazers.

Vannote et al. (1980) hypothesized that shredders are abundant (approximately 35%) in an undisturbed second-order stream because of the constant supply of leaf litter from the dense canopy. Hawkins and Sedell (1981) indicated that even in pre-autumn months shredders are indeed abundant (30% - 40%) in the undisturbed streams they studied. In North and South Fork Slide Creek, shredder populations were minimal (3% - 13%). This was due to the overshadowing affect of the abundant grazer and collector populations. However, it could also be due to the poor quality of the CPOM available to Slide Creek during the summer months. The quality (ability to be processed) of CPOM can influence the population growth and abundance of shredders (Anderson and Cummins 1979, Anderson and Sedell 1979) and redwood forests may not provide the quality necessary to support large shredder populations.

Data from this study do support the general correlation between shredder numbers and available CPOM. There was a significantly higher percentage of shredders (adjusted) in the North Fork than in the South Fork regardless of whether it was logged or unlogged. There was also approximately twice the weight of CPOM in North Fork samplers than in South Fork samplers.

Predators made up a minimal (5% - 10%) portion of the total population in North and South Fork Slide Creek. It was, however, an exceptionally diverse population being represented by 14 taxa and with no dominate taxa appearing in any of the four study areas. Vannote et al. (1980) hypothesized that the predator population in a undisturbed second-order stream should be approximately 12%. On the other hand, Hawkins and Sedell (1981) found approximately 30% predators. Roby et al. (1978) counted the predators colonizing his artificial substrate basket samplers and found the population to be 5% - 7%. The population of predators in North and South Fork Slide Creek could have been overshadowed by the high percentage of grazers and collectors, or perhaps, as reinforced by Roby's results, invertebrate predators avoid artificial substrate basket samplers.

MANAGEMENT RECOMMENDATIONS

Monitoring benthic invertebrates in Redwood National Park streams can provide park management with vital information regarding the condition of the aquatic community. For example, it an provide information on the immediate impacts of the aquatic community as a result of watershed ehabilitation activity, colonization rates in the disturbed stream sections and long-term recovery of the treams once the rehabilitation work is complete.

Developing effective sampling techniques is the first and most important step in establishing a benthic invertebrate monitoring program. It is recommended that the SASB sampler be used in all Redwood National Park streams. Its size and shape makes sampling small second-order streams possible without destroying the sampling area. In larger than second-order streams, it can be used to eliably determine the benthic invertebrate community composition at a low cost.

The variability in the benthic invertebrate community due to water depth, water velocity, SS and CPOM can be accounted for by the use of analysis of covariance. The use of this statistical procedure n the absence of enough uniform habitat for an adequate number of benthic invertebrate samples is ecommended.

Finally, the use of functional group analysis in all descriptions of benthic invertebrate communities is recommended. The functional group composition can provide more relevant information regarding the differences in aquatic communities than can taxonomic composition and diversity indices.

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