Insect abundance and colonization rate in *Fontinalis neo-mexicana* (Bryophyta) in an Idaho Batholith stream, U.S.A.[1]

M.A. Maurer & M.A. Brusven
Water Resources section, Alaska Division of Geological and Geophysical Surveys, Eagle River, AK, U.S.A.
Department of Entomology, University of Idaho, Moscow, ID, U.S.A.

Keywords: insects, benthos, moss, sediment, stream, colonization

Abstract

Insect colonization rate and abundance in the aquatic moss, *Fontinalis neo-mexicana* were examined in the South Fork Salmon River, Idaho, June 1978–August 1979 to determine the importance of moss as a habitat for insects. The insect communities in moss as well as in the underlying and adjacent mineral substrates were examined. Insects were sampled with a nylon organdy net in moss and with a Hess bottom sampler in mineral substrate.

Insects colonized insect-free moss clumps to carrying capacity within one week. In a man-made stream channel where flow, depth and substrate were controlled, insect densities were 5 to 30 times greater in moss than the mineral substrate; insect biomass was approximately two times greater. Insect densities in pebble substrates underlying moss and in adjacent mineral substrate were comparable. Moss cover did not appreciably alter insect densities in the underlying hyporheic zone composed of screened pebbles (1–2 cm diameter). Insect ordinal and functional group composition was greater in moss than in the mineral substrate, however, species richness was similar. Chironomids were the most abundant insects in moss.

Introduction

The aquatic moss *Fontinalis neo-mexicana* is abundant in the upper reaches of many natural and perturbed Idaho Batholith streams. High levels of sedimentation is evident in many of these streams because of erodible granitic parent material. Enhanced sedimentation has resulted from man-caused disturbances such as road construction, logging, mining and cattle grazing. Sediments degrade the habitats of insects and fish in these streams (Bjornn *et al.* 1977); however, moderate amounts of moss cover may offset some of the adverse effects of sedimentation by providing a suitable habitat for aquatic organisms. Rosine (1955) reported that variations in leaf surfaces resulted in different invertebrate faunas among aquatic plants. In Ireland, Frost (1942) and Went (1940) indicated that *Fontinalis* spp. increased insect production and provided food and habitat for fish.

Because little is known of the insect–moss relationships in sedimented streams, especially in the Idaho Batholith, this study was undertaken to determine the rate of insect colonization in moss clumps and to compare insect densities and diversities in moss clumps with the underlying and adjacent mineral substrates.

[1]Published with the approval of the Director of the Idaho Agricultural Experiment Station as Research Paper No. 8169.

Study area

The upper reach of the South Fork Salmon River (SFSR) in Idaho, was intensively studied during 1978 and 1979. The SFSR lies in the Idaho Batholith, an area underlain with granitic parent material

Hydrobiologia 98, 9–15 (1983). 0018-8158/83/0981 0009/$01.40.
© Dr W. Junk Publishers, The Hague. Printed in The Netherlands.

PRIVATE LIBRARY
OF WILLIAM L. PETERS

which readily decomposes into coarse sand. The SFSR is slightly acid and noncalcareous. The study area was 17 km from the river's source. Two sites were selected for investigation, one in an oxbow of the SFSR, the other in a man-made channel that cuts across the oxbow. The oxbow site had a substrate of unembedded cobbles (63.5 127 mm) and moss clumps averaging *ca.* 0.3 m^2. Moss made up *ca.* 25% of the total streambed cover. The channel was built and previously used for spawning Chinook salmon. It is 3 m × 160 m long and drops 0.5 m in elevation over its length. A headgate at the upper end of the channel permitted regulated flows which were set at 0.09 m^3/s. Studies were conducted in two 15 m reaches covered with small cobbles (65–80 mm) and pebbles (15–32 mm), respectively.

Methods and materials

A block quadrat was set up at the SFSR oxbow site to determine the colonization rate of insects in moss clumps. All insects were removed from 30 moss clumps by multiple rinsing and handpicking. The moss clumps were trimmed to approximately 40 × 15 cm and placed on the streambed in five staggered, horizontal rows with three clumps per row. Insects were sampled weekly by analyzing the three lowermost moss clumps (test) and three undisturbed moss clumps (control) on each sampling date over five consecutive weeks.

At the SFSR channel site two moss clumps (*ca.* 42 × 31 × 11 cm) were positioned on each of three transects on pebble and cobble substrates during 1978 and 1979, respectively, to determine insect densities and diversities in moss vs mineral substrate. Thirty additional moss clumps were placed in the test reach to simulate moss cover conditions in the SFSR, and allowed to colonize for three weeks. Moss clumps and the underlying and adjacent mineral substrates were sampled monthly during the summer.

Four canister samplers, similar to those described by Gilpin & Brusven (1976) were used to examine the verticale distribution of insects in the hyporheic zone with and without overlying moss cover. Each canister was filled with 1–2 cm pebbles and embedded flush with the substrate in the pebble-sand reach. The canisters were equally divided into three sections by perforated plates having 1.24 cm holes, thereby allowing horizontal and vertical insect colonization. Two canisters were covered with moss clumps trimmed to *ca.* 0.0015 m^2, the other two canisters were left uncovered. The two moss clumps and the four canisters were removed and sampled after a three-week colonization period. Insects were rinsed from the pebbles with a wire sieve (6 mm mesh size) into an organdy net (250 μm mesh) and preserved in 70% ethanol.

Moss clumps were collected by placing them into nylon organdy net (250 μm mesh) while in the stream in order to minimize insect loss. Each moss sample was washed three times and filtered through a nylon organdy net. The moss was then visually examined and the remaining insects were removed by handpicking. A Hess sampler (750 μm mesh) was used to sample insects to a depth of 7.5 cm in mineral substrates. Samples were preserved in 70% ethanol and later sorted and identified to species or morphospecies; chironomids were identified only to the family level.

An area of 0.093 m^2 was used to standardize the number of insects in moss clumps in the insect colonization phase of the study. Moss clumps having similar height or 'loft' were selected for sampling. A noncompressed volume of 0.01 m^3 and 0.0015 m^3 was used to standardize insect numbers in the moss vs mineral substrate comparison study and the insect vertical distribution study, respectively. Moss clumps having a height of 7.5 cm were selected for comparison with mineral substrate samples, and 10 cm for comparison with canister sections in the vertical distribution study.

The insect community was described in terms of species richness, species diversity (H') and evenness. The functional description of insects was based on the classification of Merrit & Cummins (1978).

Results and discussion

Insect density, species richness, species diversity (H') and evenness in test and control clumps were relatively similar over a five-week colonization period (Table 1). Insect densities approached carrying capacity at the end of one week. An exponential increase in insect density in moss clumps was expected during the initial weeks of colonization, but was not apparent. The data suggest that colonization tending toward carrying capacity occurred

Table 1. Mean number of species, mean number of insects/0.093 m², species diversity (H') and evenness in three test (T) and control (C) *Fontinalis neo-mexicana* moss clumps during a five-week colonization period, 19 July 16 August 1978, in SFSR. Chironomidae (Diptera) included as a single taxon for species richness, diversity (H') and evenness computations.

	1		2		3		4		5	
	T	C	T	C	T	C	T	C	T	C
X̄ no. of species	18	20	18	20	15	14	13	14	17	17
Density/0.093 m²	1771	1868	2159	4568	2251	2493	1906	2566	2540	1610
Diversity (H')	2.62	2.85	2.37	2.72	2.11	2.54	2.50	2.33	2.86	2.78
Evenness	0.61	0.64	0.55	0.63	0.53	0.65	0.66	0.60	0.69	0.66

during the initial days of the first week, therefore, increasing densities were not reflected during the subsequent weeks. The caddisfly *Micrasema* sp. and the mayfly *Baetis parvus* Dodds were particularly prevalent during the time of the study and were the principal contributors to density variations among clumps. Mean species richness ranged from 13 to 20 over the five-week period, diversity (H') from 2.11 to 2.86, and evenness from 0.53 to 0.69. The evenness values suggest a fairly even distribution among species in test and control moss clumps since a value approaching zero indicates a preponderance of a single or few species and a value near 1.0 a highly equitable distribution in abundance among the species.

Ordinal insect composition was similar in test and control moss clumps and did not change appreciably over the first, third and fifth weeks of the colonization period (Fig. 1). Ephemeroptera was the most abundant order of insects in both test and control clumps, followed by Diptera, Trichoptera, Coleoptera and Plecoptera. *Baetis parvus* was the most abundant mayfly, *Micrasema* sp. the most abundant caddisfly; chironomids comprised ≅94% of the dipterans in both test and control clumps. The riffle beetle *Cleptelmis ornata* (Schaeffer) was the only species that was slow to colonize test clumps, attaining carrying capacity after 4 to 6 weeks.

The functional group composition was relatively similar in test and control clumps over the five-week colonization period (Fig. 2). Collector-gatherers were most numerous followed by shredders, collector-filterers, engulfers and scrapers. Collector-gatherers made up *ca.* 74% of the total density. The emergence of the collector-filterer *Brachycentrus* sp. (Trichoptera) and the scraper Hydroptila sp. (Trichoptera) after three weeks (3 August) decreased the percentage of those two functional groups.

We believe that the presence of fine particulate organic matter (FPOM) and epiphytic algae may be responsible for the rapid recolonization of insect-denuded moss. Moss clumps act as sieves in the water column to strain out suspended mineral, organic particles and algae. Coarse particulate organic matter (CPOM) settles out in the eddies behind moss clumps and serves as a source of food for

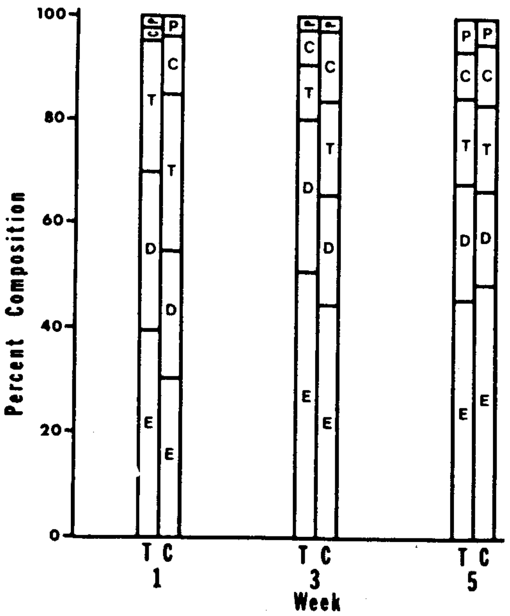


Fig. 1. Ordinal insect composition in test (T) and control (C) *Fontinalis neo-mexicana* moss clumps in SFSR after one, three and five weeks of colonization. 19 July-16 August 1978. E = Ephemeroptera, D = Diptera, T = Trichoptera, C = Coleoptera, P = Plecoptera.

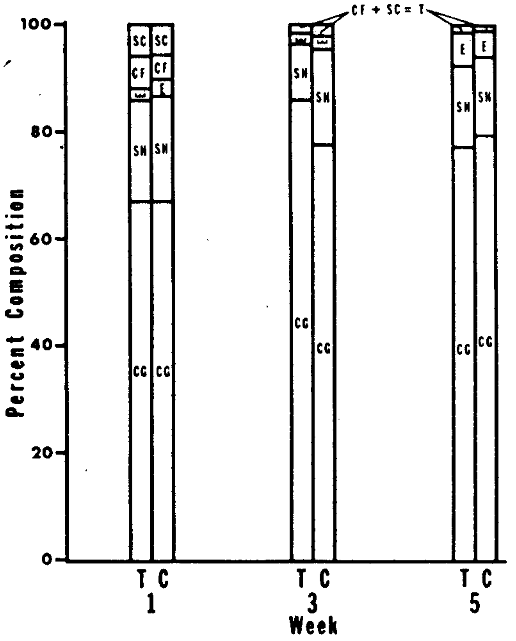


Fig. 2. Functional group composition in test (T) and control (C) *Fontinalis neo-mexicana* moss clumps in SFSR after one, three and five weeks of colonization, 19 July–16 August 1978. CG = collector-gatherer, CF = collector filterer, SH = shredder, SC = scraper, E = engulfer, T = trace representation of collector-filterers (CF) and scrapers (SC).

certain insects. The many-branched moss allows insects to occupy numerous microhabitats and to function in different food gathering tactics (Glime & Clemons 1972). In a lake study, Petr (1968) reported the aquatic macrophyte *Ceratophyllum dermersum* L. to be heavily silted and covered with periphyton, but provided an abundance of feeding opportunities for grazing and filter-feeding organisms.

We propose that moss may serve as a 'reservoir' for primary and secondary consumers when a river is experiencing moderate levels of perturbation from sediments. However, heavy moss cover in reaches experiencing heavy bedload movement may be counterproductive because deposition of fine sediments into and around the moss clumps cause changes in channel geometry and overall habitat quality.

At the SFSR channel site, insect densities were 5 to 30 times greater in moss clumps than in the underlying and adjacent cobble and pebble substrates (Table 2). Densities in moss clumps were greatest in the cobble reach during 1979; densities in the underlying and adjacent mineral substrates were comparable. Species richness in moss and adjacent mineral substrate was similar and averaged 18 species; substrate underlying moss averaged 13 species. Species diversity (H′) and evenness were slightly higher in the adjacent mineral substrates than in moss due primarily to the preponderance of chironomids and three species of mayflies in moss. The mean insect biomass (i.e. as dry weight) at the channel site was 0.32 g/0.01 m^3 in moss clumps, 0.21 g/0.01 m^3 in underlying mineral substrate and 0.14 g/0.01 m^3 in adjacent substrate. The moss clearly increased insect biomass at the channel site.

Ordinal composition was highly variable among moss and underlying and adjacent mineral substrates (Fig. 3). Although Plecoptera, Coleoptera and Trichoptera were not graphically shown because of very low densities from some mineral substrates, they were often present. Chironomids were the dominant insects making up over 82% of the

Table 2. Mean number of species, mean number of insects/0.01 m^3, species diversity (H′) (pooled data for 12 clumps) and evenness in (C), under (U) and adjacent (A) to *Fontinalis neo-mexicana* moss clumps from pebble and cobble covered reaches at the SFSR Channel site during summers of 1978 and 1979. Chironomidae (Diptera) included as one taxon for number of species, diversity and evenness computations.

	Channel					
	Pebble			Cobble		
	C	U	A	C	U	A
Diversity	1.32	1.76	2.73	1.59	2.50	2.80
Evenness	0.23	0.33	0.48	0.27	0.45	0.49
$\overline{X}$ no. species	18	10	16	18	15	20
$\overline{X}$ no. insects/0.01 m^3	3531	344	371	6954	339	663

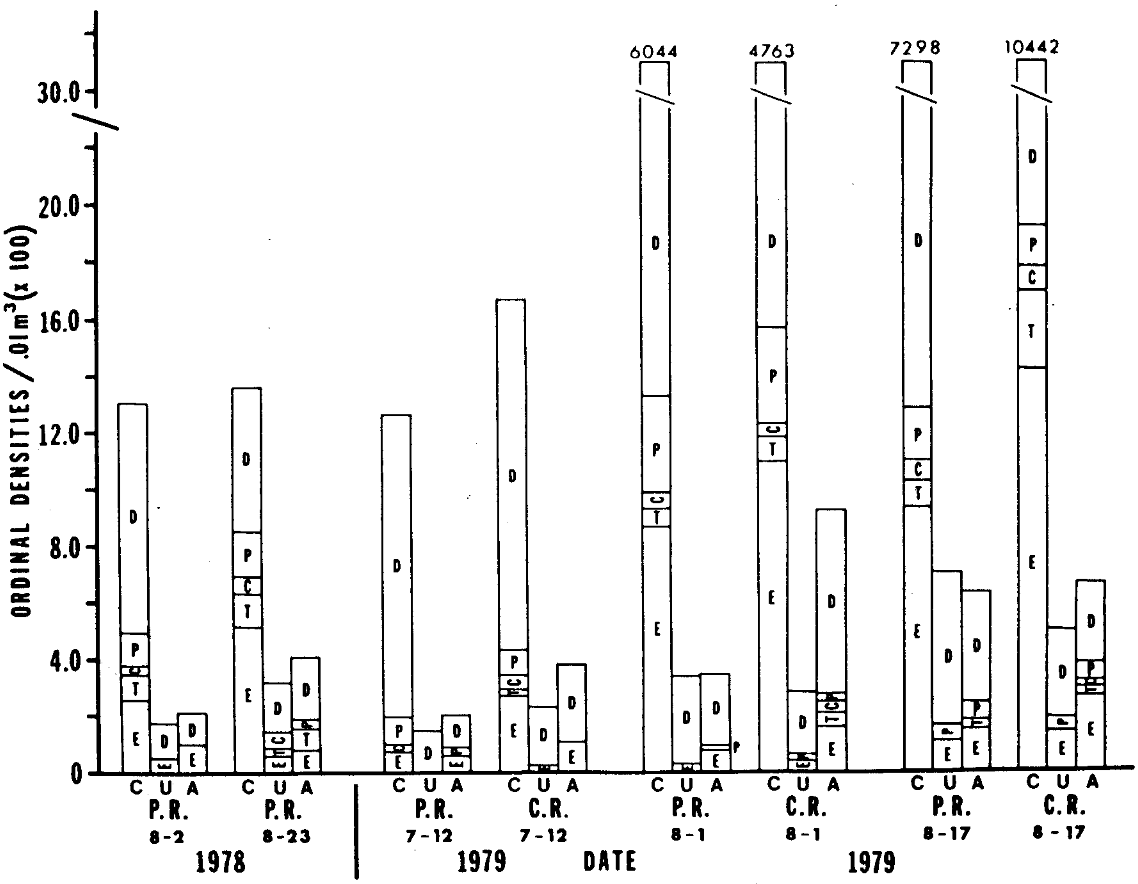


Fig. 3. Mean numbers of insects/0.01 m³ of five aquatic insect orders in *Fontinalis neo-mexicana* moss clumps and the underlying and adjacent mineral substrates in the pebble (P.R.) and cobble (C.R.) reaches, during August 1978 and July & August 1979 SFSR Channel site. E = Ephemeroptera, T = Trichoptera, C = Coleoptera, P = Plecoptera, D = Diptera, C = moss clump, U = mineral substrates under moss, A = mineral substrate adjacent to moss.

insects in moss clumps in the channel site. The mayflies *Baetis tricaudatus* Dodds, *Ephemerella infrequens* McDunn., *Paraleptophlebia heteronea* (McDunn.) and the stonefly *Cultus* sp. were also common in both moss and mineral substrates.

Functional group diversity was higher in moss than mineral substrates (Fig. 4). Collector-gatherers were the most abundant functional group in both moss and mineral substrates and were represented primarily by chironomids and mayflies. The stonefly *Hesperoperla pacifica* (Banks) was the dominant engulfer, *Lepidostoma* spp. (Trichoptera) the dominant shredders and *Simulium* spp. (Diptera) the dominant collector-filterers.

Moss cover did not appreciably alter insect densities in the hyporheic zone (Fig. 5). Densities in moss clumps and the upper level of pebble-filled canisters without moss cover were comparable with means of 143 and 126 insects/0.0015 m³, respectively. Canisters with overlying moss cover had slightly lower insect densities in the upper and lowermost canister levels, but comparable in the middle canister level. The significance of these findings is that moss does not apparently attract or repel insects from a clean pebble-sand hyporheic zone immediately beneath the moss and alter the subsurface insect community.

There was considerable similarity in ordinal and functional group composition between sites. However, we believe the insect densities were higher at the channel site because the low flows and depths produced an accumulation of FPOM which promoted collector-gatherers. Species richness was greater at the channel site for probably the same reason. Chironomids were by far the most abundant insects in moss. Hynes (1961) reported that chironomids are the 'key industry' organisms and a major and constant food source for carnivores.

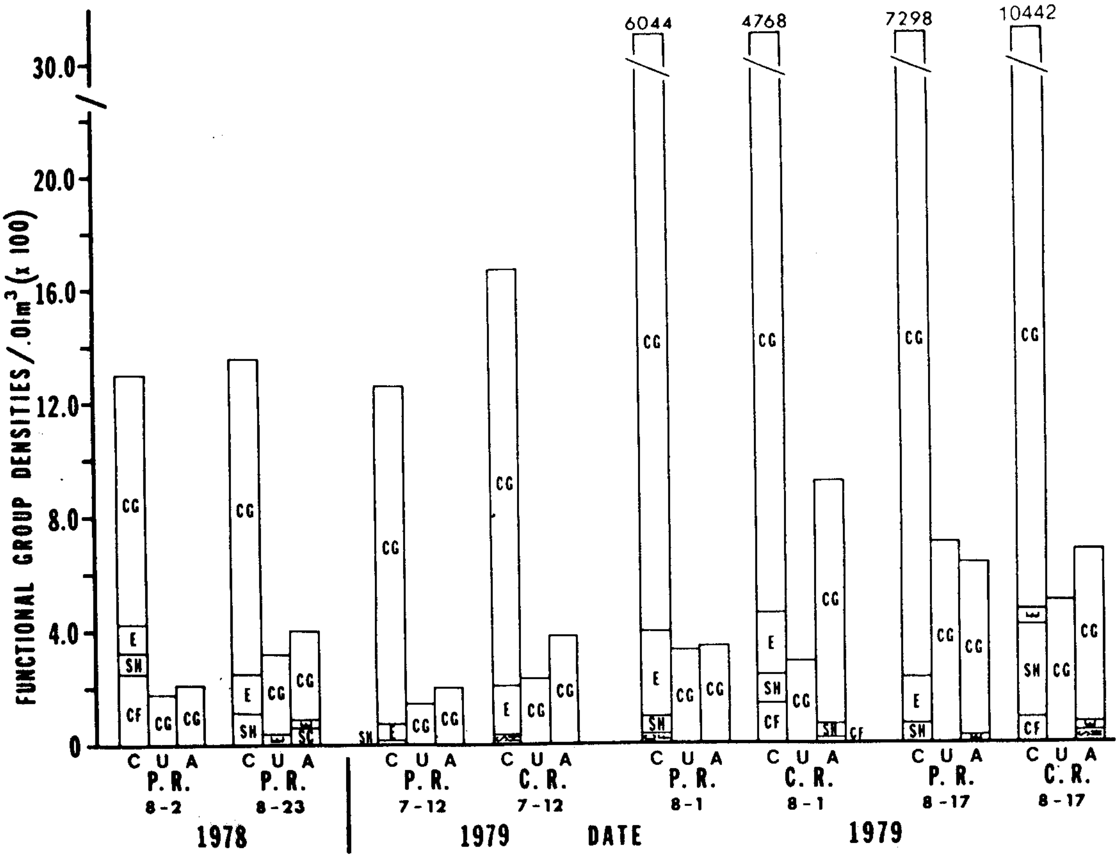
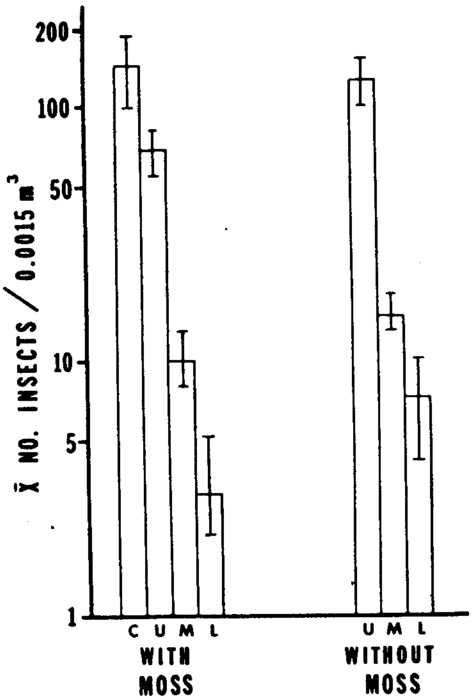


Fig. 4. Mean insect functional group densities/0.01 m³ in *Fontinalis neo-mexicana* moss clumps and the underlying and adjacent mineral substrates in the pebble (P.R.) and cobble (C.R.) reaches, during August 1978 and July & August 1979, at the SFSR Channel site. CG = collector-gatherer, CF = collector filterer, SH = shredder, SC = scraper, E = engulfer, C = moss clump, U = mineral substrate under moss, A = mineral substrate adjacent to moss.



These insects along with other moss-dwelling organisms may be an important food source for Chinook Salmon fry in these streams. In Ireland, Frost (1939) and Frost & Went (1940) found that trout and young salmon stomachs contained a large proportion of moss-dwelling organisms. The greater standing crop of insects in moss likely contributes to higher fish production in fish-rearing areas which otherwise may be food limited. We contend that at least a moderate amount of moss cover promotes habitat diversity and production of benthic invertebrates in the SFSR.

Fig. 5. Mean number of insects/0.0015 m³ for three depths (U = 0–10 cm, M = 10–20 cm, L = 20–30 cm) in two pebble filled canisters with and without moss cover after a three-week colonization period, July 1978, SFSR Channel site. Bars indicate insect density ranges for moss clumps and canister levels. C = moss clump.

Acknowledgments

This study was funded in part by the U.S. Forest Service, Forestry Sciences Laboratory, Corvallis, Oregon, Project No. 1702-13. Appreciation is extended to Dr. W. Meehan that laboratory for his assistance and support; to Dr. William S. Platts, U.S. Forest Service, Boise, for providing data on stream macrophytic cover in the South Fork Salmon River; and to Dr. Doyle E. Anderegg, Department of Biological Sciences, University of Idaho, Moscow, Idaho, for moss identification.

References

Bjornn, T.C., Brusven, M.A., Molnay, M.R., Milligan, T.H., Klamt, R.A., Chacho, E. & Schaye, C., 1977. Transport of granitic sediment in streams and its effect on insect and fish. Res. Techn Compl. Rep. Project B-0360-IDA, Office Water Res. and Tech., USDI, Wash., D.C. 43 pp.

Frost, W.E., 1939. River Liffey Survey II. The food consumed by the brown trout (Salmo trutta Linn.) in acid and alkaline waters. Proc. r. Ir. Acad. 45B: 139-206.

Frost, W.E., 1942. River Liffey, Survey IV. The fauna of the submerged 'mosses' in an acid and an alkaline water. Proc. r. Ir. Acad. 47B: 293-369.

Frost, W. & Went, A.E.J., 1940. River Liffey Survey III. The growth and food of young salmon. Proc. r. Ir. Acad. 46B: 53-80.

Gilpin, B.R. & Brusven, M.A., 1965. Subsurface sampler for determining vertical distribution of stream-bed benthos. Progve Fish Cult. 38: 192-194.

Glime, J.M. & Clemons, R.M., 1972. Species diversity of stream insects on Fontinalis spp. compared to diversity on artificial substrates. Ecology 53: 458-464.

Hutchinson, G.E., 1975. A treatise on Limnology III. Limnological Botany. John Wiley, New York. 660 pp.

Hynes, H.B.N., 1961. The invertebrate fauna of a Welsh mountain stream. Arch. Hydrobiol. 57: 344-388.

Hynes, H.B.N., 1970. The Ecology of Running Waters. University of Toronto Press, Toronto. 555 pp.

Merritt, R.W. & Cummins, K.W., 1978. An Introduction to the Aquatic Insects of Norht America. Kendall/Hunt. Dubuque, Iowa. 441 pp.

Petr, T., 1968. Population changes in aquatic invertebrates living on two water plants in a tropical man-made lake. Hydrobiologia 32: 449-485.

Rosine, W.N., 1955. The distribution of invertebrates on submerged aquatic plant surfaces in Muskee Lake, Colorado. Ecology 36: 308-314.

Ruttner, F., 1963. Fundmetals of Limnology. University of Toronto Press, Toronto. 295 pp.

Received 23 November 1981; in revised form 25 April 1982.