

SALMON CARCASS DECOMPOSITION
AND ITS EFFECT ON STREAM PRODUCTIVITY

by

Charles D. Warren

A Thesis

Presented to

The Faculty of Humboldt State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

June, 1988

SALMON CARCASS DECOMPOSITION
AND ITS EFFECT ON STREAM PRODUCTIVITY

by

Charles D. Warren

Approved by the Master's Thesis Committee

Richard L. Ridenhour 17 June 88
Richard L. Ridenhour, Chairman Date

Terry D. Roelofs 16 June 1988
Terry D. Roelofs Date

Terrence D. Hofstra 22 June 1988
Terrence D. Hofstra Date

James Foy June 22, 1988
Director, Natural Resources Graduate Program Date

88/F-135/05/27

Natural Resources Graduate Program Number Date

Approved by the Dean of Graduate Studies

Alba M. Gillespie July 1988
Alba M. Gillespie Date

ABSTRACT

May Creek and Brown Creek in Redwood National Park and Prairie Creek Redwoods State Park were treated in 1983-1985 with 100 and 200 spawned-out salmon carcasses, respectively, to test the effect carcass decomposition has on stream productivity. Both streams are light limited and located in dense, primary and secondary growth redwood forests. Productivity was measured in terms of periphyton colonization rates on glass slides, invertebrate biomass, and fish growth. There was a significant increase in periphyton production in the treatment section during four out of six sampling periods in Brown Creek. May Creek had significantly different periphyton production between the treatment and control section during only one of the five sampling periods, and it indicated higher production in the control section. There were more invertebrate genera found in the control section than in the treatment section of Brown Creek but no significant difference in invertebrate biomass between the two sections. After treating with carcasses the average fork lengths of young-of-the-year coho salmon were significantly greater in the control section of May Creek. Salmo sp. average fork lengths were significantly greater in the treatment section of that stream after treatment. There were no significant

differences between Salmo sp. fork lengths in Brown Creek treatment and control sections before or after treating with carcasses. The growth trend measured by mean fork length gain over a two month period did indicate, however, a possible faster growth rate in the treatment section of both streams.

In comparing treatment with control section stream productivity at several trophic levels, there appears to be a growth stimulating influence on periphyton and possible indications of an influence at higher trophic levels because of the treatment with carcasses. Other factors not studied in this experiment that could have influenced productivity were light and an accrual of nutrients from decomposing carcasses over several spawning seasons.

ACKNOWLEDGEMENTS

I thank the Tyee Club for providing funds to assist in this study and the staff of Redwood National Park for their advice and assistance in collecting field data. I also thank John Ticer, Xabier Ertze and Barbara Hampton for their assistance in the field and library.

I also thank Dr. Terry Roelofs for his advice on aquatic ecology, Terry Hofstra for confidence, support, and knowledge of my study area, and Dr. Richard Ridenhour for his wisdom, support and willingness to have me work on his brainstorm.

I acknowledge Prairie Creek Redwoods State Park staff for permission to use Brown Creek for a study site, Iron Gate Hatchery personnel of California Department of Fish and Game for their salmon carcasses and cooperation, and Redwood National Park for access to much needed data, use of May Creek as a study site, and for employing me as a student appointment. I also thank Sawtooth Fish Hatchery of the Idaho Department of Fish and Game for access to a computer.

I especially thank my parents for their moral and financial support, and my wife Jackie for her unending patience and support, and Elsbeth who waited out hard times to enter this world.

TABLE OF CONTENTS

	Page
ABSTRACT	iii
ACKNOWLEDGEMENTS	v
LIST OF TABLES	vii
LIST OF FIGURES	ix
INTRODUCTION	1
STUDY AREA	4
MATERIALS AND METHODS	7
RESULTS	16
DISCUSSION	28
LITERATURE CITED	35

LIST OF TABLES

Table	Page
1 Carcass treatment record for May Creek, Redwood National Park, CA, 1983-1984, and Brown Creek, Prairie Creek Redwoods State Park, CA, 1984-1985 .	8
2 Approximate t-test (t') and t-test (t_s) comparisons of 21 day ^s periphyton biomass colonization on glass slides between the treated section and the control section, May Creek 1984, (*) significant at 0.05 level, (**) significant at 0.01 level. Date of slide collection, number of slide substrate samples (n), mean grams of biomass per square meter (m^2), and variances (s^2) are given.	17
3 Approximate t-test (t') and t-test (t_s) comparisons of 21 day ^s periphyton biomass colonization between the treated section and the control section, Brown Creek 1985, (*) significant at 0.05 level, (**) significant at 0.01 level. Date of slide collection, number of slide substrate samples (n), mean grams of biomass per square meter (m^2), and variances (s^2) are given.	18
4 Invertebrates collected from SASB basket samplers June 5, 1985 and their presence noted (X) for the treatment and control sections of Brown Creek after treating with salmon carcasses	20
5 T-test (t_s) comparisons between treatment and control section fork lengths of young of the year <u>Salmo</u> sp. and coho salmon (<u>Oncorhynchus kisutch</u>), May Creek, 1983 (pretreatment) and 1984 (Posttreatment). (*) significant at 0.05 level, (**) significant at 0.01 level, month of sample, species or genera, sample size (n), mean fork length (mm), two month gain in mean fork length, and variance are given	24

LIST OF TABLES (CONTINUED)

Table	Page
6 T-test (t_s) comparisons between treatment and control section fork lengths of young of the year <u>Salmo</u> sp., Brown Creek, 1984 (pretreatment) and 1985 (Posttreatment). (*) significant at 0.05 level, (**) significant at 0.01 level, month of sample, species or genera, sample size (n), mean fork length (mm), two month gain in mean fork length, and variance are given.	25

LIST OF FIGURES

Figure	Page
1 Prairie Creek drainage and the two streams used for the carcass - nutrient input study in northern California, 1983-1985.	5
2 Periphyton sampling device holding twelve 1 inch X 3 inch (2.5mm X 7.6mm) microscope slides. This device was used for the periphyton studies in May Creek and Brown Creek.	10
3 Mean fork lengths (mm) of May Creek young-of- the-year <u>Salmo</u> sp. and coho salmon as measured in 7/84 and 9/84.	26
4 Mean fork lengths (mm) of Brown Creek young- of-the-year <u>Salmo</u> sp. as measured in 8/84, 10/84, 7/85, and 9/85.	27

INTRODUCTION

The source of energy and nutrients for primary producers and consumers in lotic ecosystems has been noted in the past to be primarily of terrestrial origin (Hynes 1970; Chapman and DeMory 1963; Huntsman 1948). More recently it has been suggested that under certain conditions, some stream sections are autotrophic (Vannote et al. 1980; and others). These autotrophic sections of streams receive nutrients from upstream and through primary productivity. Uptake, release, and transport of nutrients downstream causes spiralling to occur, with time dependent on the distance downstream required to complete one cycle of the spiral (Newbold et al. 1981, 1982). Much of the nutrient phosphorous may not, however, be transported downstream but stored or even translocated through migration as fish biomass (Kitchell et al. 1979).

Juday et al. (1932) initially suggested that nutrients may be translocated upstream through decomposition of anadromous fish biomass in lakes used for spawning. This was later demonstrated in a study by Krokhn (1957) on Lake Dalnee by a description of the annual phosphorous budget. During years with high runs of sockeye salmon (Oncorhynchus nerka) entering the system, 4.7% of the phosphorous in the lake came from spawned out sockeye carcasses.

Since then it has been demonstrated in other studies that decomposing anadromous fish carcasses do contribute to the productivity of lakes and streams (e.g. Narver 1967; Richey et al. 1975; Nriagu 1983; and others). The bioenergetic pathway making nutrients available for use by primary producers and higher trophic levels is through remineralization of a decomposing substrate (Durbin et al. 1979). Of the ten essential elements required by most plants, phosphorous and nitrogen are the two contributed in the largest quantities by decomposing fish carcasses (Krokhin 1959; Nriagu 1983).

Under normally lighted conditions, the most common limiting factor to primary production in a lotic ecosystem is either nitrogen or phosphorous, and sometimes the nitrogen/phosphorous ratio (Triska et al. 1983; Elwood et al. 1981). With an influx of phosphorous, primary productivity has been noted to increase a short while after enrichment of a stream (Elwood et al. 1981) with an increase in chlorophyll a and aufwuchs biomass (Stockner and Shortreed 1976). In lakes, enrichment with phosphorous and nitrogen increases the zooplankton population (biomass) over a long period of time while the overall level of primary producer biomass remains the same (LeBrasseur and Kennedy 1972). This indicates that consumers may regulate producers and that the net benefit to a system is an increased

standing stock of consumers following lake fertilization (Parsons et al. 1972).

The overall objective of this study was to determine how large numbers of decomposing, spawned-out salmon carcasses would influence stream productivity from the aufwuchs to the consumer trophic levels. This objective was accomplished by treating a section of a stream with spawned-out salmon carcasses and comparing it to a control section of the same stream to test the effect of added nutrients on productivity. The specific objectives of this study were to evaluate the effect decomposing carcasses have on the periphyton, macroinvertebrate, and young-of-the-year salmonid trophic levels.

STUDY AREA

The two streams chosen for this study, May Creek and Brown Creek, are first order streams (Strahler 1957) and tributaries to Prairie Creek, a tributary of Redwood Creek. Both streams are in Humboldt County, California and are within Redwood National Park and Prairie Creek Redwoods State Park (Fig. 1). Initially, all research was to be done on May Creek for two and a half consecutive years, 1983 through 1985, but progress on the U.S. Highway 101 Bypass project precluded using May Creek for the second year of study. Brown Creek was chosen as an alternate stream. Both streams are eastern drainages of Prairie Creek and all research was done upstream from the existing U.S. Highway 101 bridges crossing both streams.

Annual precipitation between 1976 and 1982 for the Prairie Creek Redwoods State Park gaging station 1.5 kilometers north of May Creek, averaged 175 cm (U.S. Department of Interior 1985). Because most of the annual precipitation occurs between October and March, winter flows are high and summer flows are low for most of the drainages in this region.

Discharges for May Creek in 1983 and Brown Creek in 1984, as measured in July, were between 0.2 and 0.3 cubic

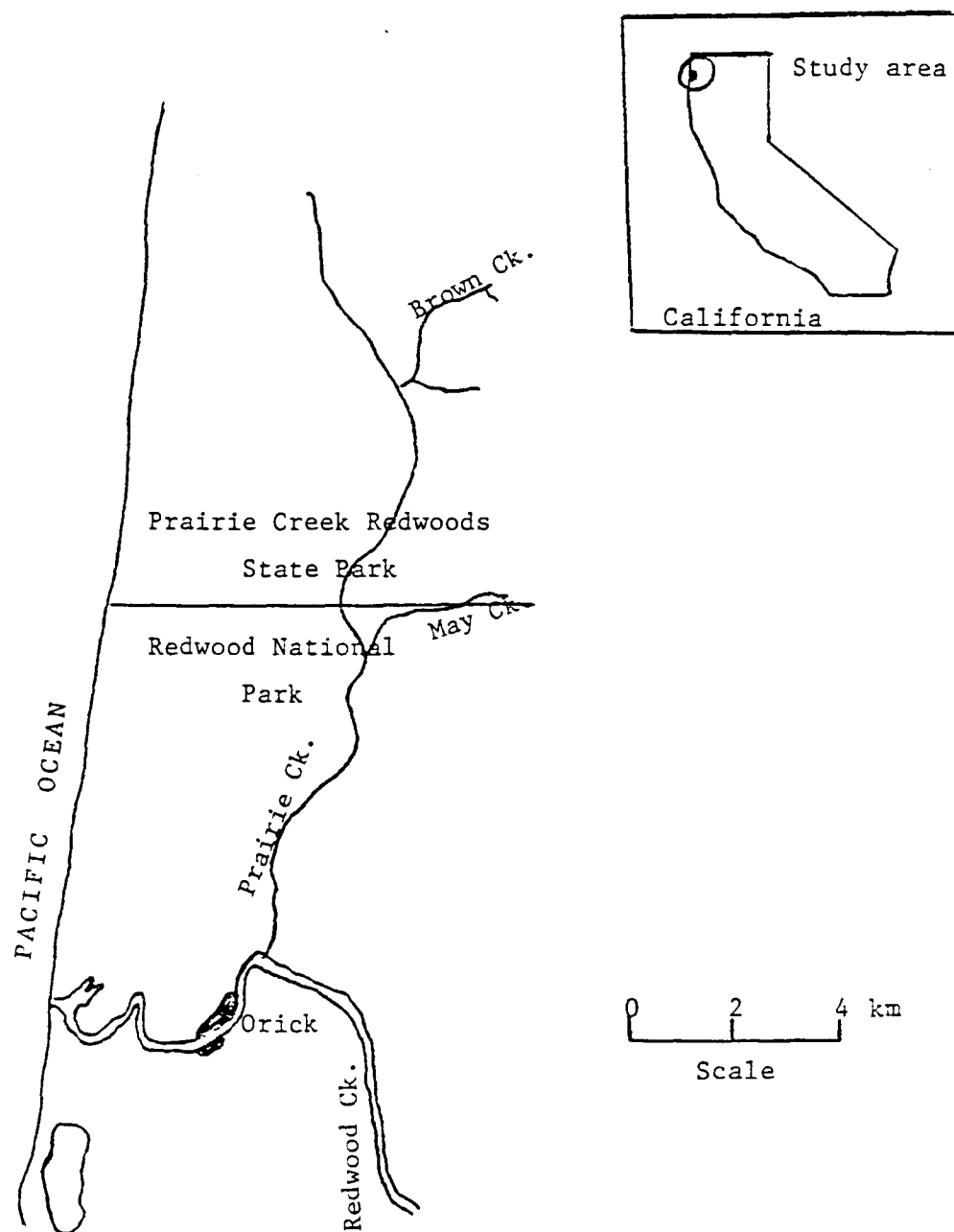


Figure 1. Prairie Creek drainage and the two streams used for the carcass - nutrient input study in northern California, 1983-1985.

meters per second (cms). Winter discharges increased to 3.0 cms or more in both streams, depending on precipitation patterns.

The study reach within May Creek had relatively uniform physical and biological characters with no major tributaries and was accessible to anadromous fish. The drainage area of May Creek is 3.02 km with a 0.046 (m/m) average gradient in the study reach. The riparian vegetation and canopy cover, identified with keys by Keator and Koelling (1978) and Watts (1973), consisted of secondary growth red alder (Alnus rubra), vine maple (Acer circinatum), coast redwood (Sequoia sempervirens), Douglas-fir (Pseudotsuga menziesii), salmonberry (Rubus spectabilis), elder berry (Sambucus sp.), huckleberry (Vaccinium sp.), and several species of ferns.

Brown Creek is located 6.0 km north and upstream of May Creek. This entire drainage is within an old-growth redwood forest and most of the riparian cover and canopy is provided by ferns, coast redwood, willows (Salix sp.) and maple. The study section had no tributaries and was accessible to anadromous fish. The Brown Creek drainage area is 2.99 km with a 0.128 (m/m) average gradient in the study reach.

Sampling sites within each study reach were selected on the basis of similar percentage canopy closure. The combined lengths of the control and treatment reaches were 792 meters in May Creek and 955 meters in Brown Creek.

MATERIALS AND METHODS

Spawned-out chinook salmon (Oncorhynchus tshawytscha) carcasses obtained from the Iron Gate Hatchery salmon trapping and egg taking facility of the California Department of Fish and Game were used in the treatment sections of the two study streams. Treatment sections in both streams were directly downstream from control sections so treatment with carcasses would not influence the controls. The number of carcasses added per linear meter of stream was intended to match or exceed past densities of naturally spawning salmon as determined by the earliest accurate data available on spawner escapement of comparable sized streams (Gunsolus et al. 1953, Willis 1962, Richey et al. 1975).

May Creek had 100 carcasses weighing 265 kg placed in the stream in a 220 meter treatment section over a 25 day period from December 1983 until January 1984 (Table 1). Brown Creek had 200 carcasses weighing 655 kg placed in the stream in a 200 meter section over a 45 day period from December 1984 until January 1985 (Table 1). This time period approximated the normal timing of the spawning chinook salmon run in Redwood Creek.

All carcasses had been stored frozen then partially thawed and marked on the head or jaw with a shoat-ring and

Table 1. Carcass treatment record for May Creek, Redwood National Park, CA, 1983-84, and Brown Creek, Prairie Creek Redwoods State Park, CA, 1984-85.

Stream	Date	Number of Carcasses	Weight (kg)
May	12/19/83	20	51
	12/30/83	24	66
	1/4/84	32	86
	1/14/83	24	62
	Total	100	265
Brown	12/19/84	22	80
	12/31/84	32	113
	1/11/85	29	88
	1/25/85	38	127
	2/8/85	26	84
	2/17/85	28	92
	2/24/85	25	71
Total		200	655

15 cm piece of surveyor's flagging to distinguish them from carcasses of native spawners. Two-thirds to three-fourths of the carcasses were placed in the upstream half of the treatment sections. Each carcass was placed at the head of a pool and allowed to drift downstream. Carcasses would usually either rest on the stream bottom or against a natural barrier in a riffle. Each day that the streams were treated with carcasses, a visual survey was made of the treatment and control sections to determine if the streams were being utilized for natural spawning activity.

Since high stream discharges limit benthic algae biomass buildup (Bott 1983), periphyton colonization rates were studied in late spring and summer when Northern California coastal stream discharges are low (U.S. Department of Interior 1985).

Periphyton production between treatment and control sections in the spring and summer after treating with carcasses was compared by measuring periphyton colonization rates on bare artificial substrates. The substrates used were 12 one inch by three inch (2.54cm X 7.62cm) glass microscope slides held in a transparent plexiglass rack modeled after methods described by American Public Health Association (1981) (Fig. 2). The racks were attached to a metal stake driven into the substrate. Slides were placed in the racks parallel to the current, 15 to 22 cm below the

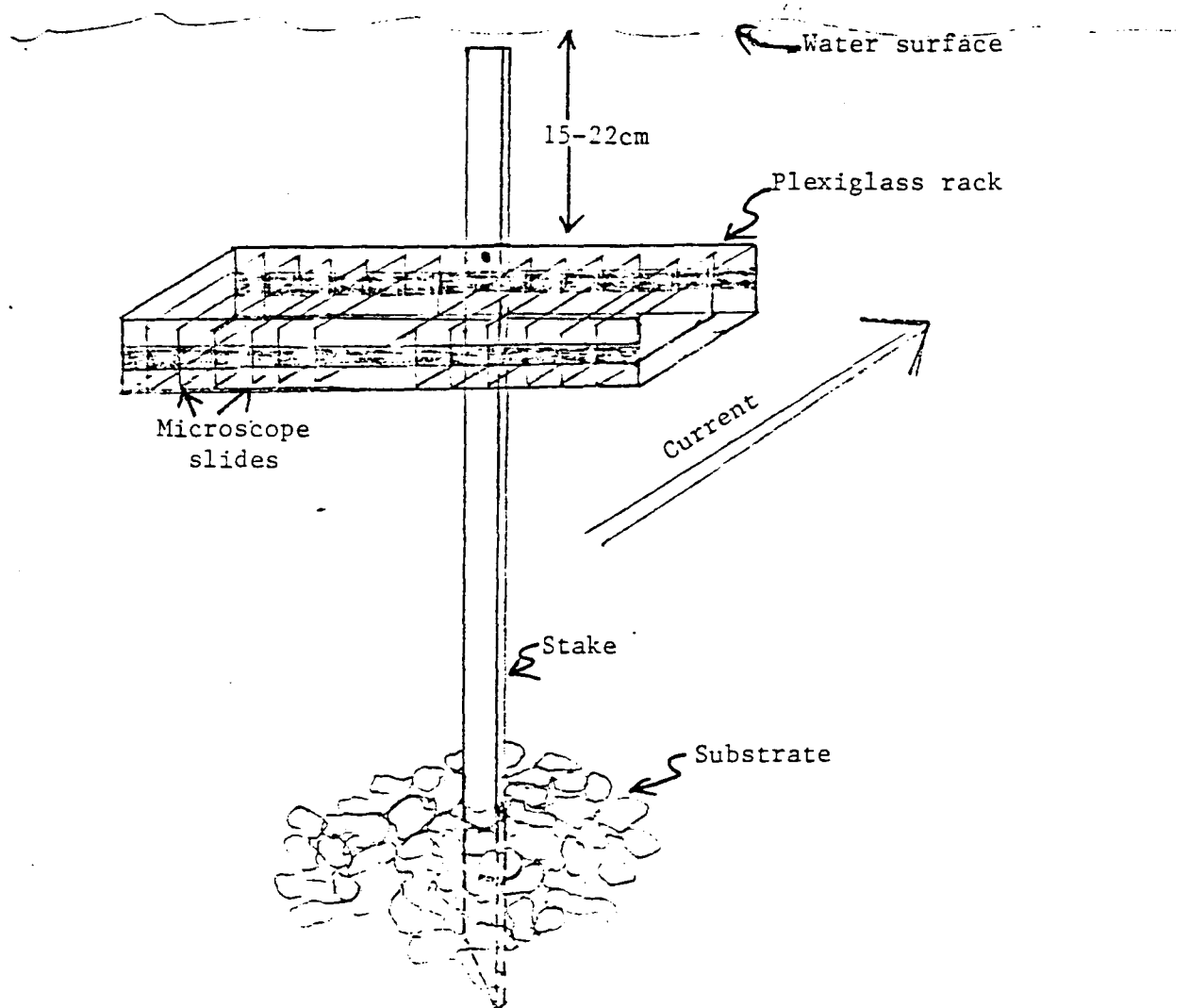


Figure 2. Periphyton sampling device holding twelve 1 inch X 3 inch (2.54 X 7.62cm) microscope slides. This device was used for the periphyton studies in May Creek and Brown Creek.

water surface, in a randomly selected grid block within each chosen pool for a 21 day colonization period.

Five pools in May Creek and six in Brown Creek from each of the control and treatment sections were chosen as periphyton sample sites. Pools were selected because many carcasses become stranded in backwaters (Houston 1983) creating areas of low velocity where carcass decomposition and nutrient accumulation may occur. All chosen pools had a canopy closure of 70% to 90%, as measured with a spherical densiometer (Lemmon 1956).

Colonized slides were collected by lifting them by their edges out of the racks and placing them in plastic slide storage boxes for transportation to the lab. Colonized slides were air dried in opened storage boxes prior to drying on wire racks in a convection oven at 95°C to constant weight. After drying, the slides were put back into storage boxes which were placed in a desiccator while cooling to room temperature. Slides were individually weighed to 0.1 mg on an analytical balance. After weighing, slides were thoroughly cleaned, dried and reweighed to obtain actual dry weight of periphyton. All periphyton dry weights were expressed as grams of biomass per square meter, produced per day. All slides at each study site were collected and replaced with clean ones on the same days for five colonization periods in May Creek and six colonization periods in Brown Creek.

Dry weights of periphyton of all slides within each study section were used to estimate mean weights and variances for each colonization period and study section. T-tests were used to compare treatment and control study section mean weights where the statistical assumptions were met (Sokal and Rohlf 1981). In the event an F-test indicated heteroscedasticity between the two sections for any one sampling period, an approximate t-test was used for comparisons (Sokal and Rohlf 1981).

Macroinvertebrates were identified and biomass production in treatment and control sections of only Brown Creek were assessed. Dry weights of all macroinvertebrates that colonized rock filled basket samplers similar to Small Artificial Substrate Baskets (SASBs) described by Harrington (1983) were measured. These samplers were of the same dimensions (10cm X 10cm X 5cm) as SASBs used by Harrington (1983) with 1/2 inch (1.27cm) mesh hardware cloth, but were filled with commercially graded 1 inch to 3 inch (2.54cm to 7.62cm) diameter river gravel.

Five sample sites were randomly chosen within a 250 meter length of each of the two study sections of Brown Creek with six SASB samplers placed 1 to 1.5 meters apart in each site in the thalweg of a riffle or center of a pool. All samplers were put into Brown Creek on May 11, 1985 and removed June 5, 1985, which matches a colonization period used by Harrington (1983).

SASBs were retrieved beginning with the lowermost sample site. A No. 35 U.S.A. Standard Testing Sieve (mesh opening 0.5mm) was held within a few centimeters below and downstream from the SASB as it was lifted out of the water and into a bucket. The SASB was opened and scraped clean in the bucket. All rocks and organic material collected from the SASBs and sieve were then put into individually marked sealable plastic bags for transportation back to the laboratory. Invertebrates and organic materials were sorted and scrubbed from the rocks with a toothbrush over the sieve. These organic contents were put back into the plastic bags and frozen for temporary storage. Invertebrates were later identified to family and generic levels, using taxonomic keys by Edmunds et al. (1976), Wiggins (1977), Pennak (1978), and Merritt and Cummins (1984). Total number of genera collected in the basket samplers was noted for each of the two study sections.

Identified invertebrates from each basket sampler were placed in preweighed 10cc crucibles and dried in a convection oven at 95⁰C to constant weight. After drying, the crucibles were allowed to cool in a desiccator prior to weighing on an analytical balance to 0.1mg. The weight of the clean crucible subtracted from the weight of the crucible with the dried invertebrates was used to obtain invertebrate dry weights for each basket sampler. To test the difference in invertebrate biomass between the

treatment and control sections, a Wilcoxon 2-sample test (Elliott 1977) was performed on the weights from all samplers.

Fish growth and lengths were measured in the treatment and control sections of both study streams. Three sampling sites totaling 150 meters in length in both the treatment and control sections of May Creek and 180 meters in the Brown Creek treatment section and 130 meters in the Brown Creek control section were chosen. A small mesh seine was set at each end of the fish sampling sites as they were being sampled with a direct current Coffelt BP-1C backpack shocker (Coffelt Electronics Inc., Englewood, Colorado 80110) set at 200 volts. One person operated the shocker while another person netted the stunned fish with a dip net. After sampling a site by working upstream with two passes of the electroshocker, all fish were identified, measured, and scale samples taken for age determination for all sizes of Salmo sp. to calculate a length-age relationship.

May Creek fish were sampled once in the summer of 1983 prior to treating the stream and twice in the summer of 1984 following treatment. Brown Creek fish were sampled twice from two fish sample sites in each of the two sections during the summer of 1984 before treating and twice from all three fish sampling sites in both sections in the summer of 1985 after treating. Using length

frequencies and scale samples, length classes were established for each study section of both streams to determine young-of-the-year size ranges. Since differences between juvenile cutthroat trout (Salmo clarki) and steelhead (Salmo gairdneri) were difficult to discern, they were grouped together as Salmo sp. in subsequent analyses. Only young-of-the-year coho salmon (Oncorhynchus kisutch) and Salmo sp. were used for comparisons between treatment and control section fish. A t-test (Sokal and Rohlf's 1981) was used to compare the length of fish sampled from the treatment section with those sampled from the control section of each stream. Growth trends during the summer were observed for the two sections of both streams by graphing average fork lengths of young-of-the-year fish sampled.

RESULTS

Spawning ground surveys in the treatment and control sections resulted in finding no redds in either Brown Creek or May Creek during the 1983 and 1984 spawning season and no redds in Brown Creek during the 1984 and 1985 spawning season. In January of 1984 only one native adult salmon carcass was found which was in the control section of May Creek.

An F-test for measuring differences in variances indicated heteroscedasticity between measurements of periphyton biomass in the treatment and the control sections for eight out of eleven colonization periods in both study streams. Tests of significant difference in mean weights between treatment and control sections were therefore made with an approximate t-test when heteroscedasticity was indicated and the t-test when heteroscedasticity was not indicated (Table 2 and 3).

Approximate t-test and t-test results indicated a significant difference ($0.05 > P > 0.01$, and $P < 0.01$) between the mean periphyton biomass in the treatment and control sections of May Creek in two out of five colonization periods (Table 2). The mean periphyton weight, however,

Table 2. Approximate t-test (t'_s) and t-test (t_s) comparisons of 21 day periphyton biomass colonization on glass slides between the treated section and the control section, May Creek 1984, (*) significant at 0.05 level, (**) significant at 0.01 level. Date of slide collection, number of slide substrate samples (n), mean grams of biomass per square meter (m^2), and variances (s^2) are given.

Date	n	mean grams per m ² per day	s ²	t _s (or t _{s'})
May 31				
Treatment	60	0.7233	0.083	9.05' **
Control	59	2.6383	2.560	
June 21				
Treatment	36	2.6512	3.860	1.92'
Control	52	1.9648	1.061	
July 12				
Treatment	59	1.1160	0.870	1.37'
Control	54	1.4065	1.638	
August 2				
Treatment	60	0.8211	0.321	0.58
Control	53	0.8852	0.359	
August 24				
Treatment	41	0.5453	0.118	2.07' *
Control	60	0.4250	0.029	

Table 3. Approximate t-test (t'_s) and t-test (t_s) comparisons of 21 day periphyton biomass colonization between the treated section and the control section, Brown Creek 1985, (*) significant at 0.05 level, (**) significant at 0.01 level. Date of slide collection, number of slide substrate samples (n), mean grams of biomass per square meter (m^2), and variances (s^2) are given.

Date	n	mean ² grams per m ² per day	s ²	t _s (or t' _s)
May 24				
Treatment	72	0.7766	0.129	2.97**
Control	72	0.5977	0.132	
June 14				
Treatment	72	0.7201	0.970	2.97'***
Control	72	0.3633	0.067	
July 5				
Treatment	72	0.4054	0.144	1.84
Control	72	0.2969	0.105	
July 26				
Treatment	72	0.2757	0.021	4.31'***
Control	72	0.1836	0.012	
August 16				
Treatment	72	0.3165	0.004	7.21'***
Control	72	0.2138	0.011	
September 6				
Treatment	72	0.2293	0.141	1.55'
Control	72	0.1592	0.006	

was higher in the control section than in the treatment section for one of these two colonization periods.

Approximate t-test and t-test results indicated significantly greater ($P < 0.01$) mean periphyton biomass in the treatment sections of Brown Creek in four out of six colonization periods (Table 3). Mean weights from the other two colonization periods, though not significantly different ($P > 0.05$), were also higher in the treatment section than in the control section.

Invertebrates collected from the 60 randomly placed invertebrate basket samplers in Brown Creek were identified to genus where possible and to at least family if too immature for full development of key morphological characters (Table 4). The total number of genera present in the control section was 44 and the total number of genera in the treatment section was 34.

Wilcoxon two-sample sum of ranks for total dry weights of invertebrates from each SASB were 896 and 889 for the treatment and control sections respectively. Test statistics U_s (treatment) and U_s (control) were 476 and 469 respectively. The absolute value of the normal deviate is 0.281, which is noticeably lower than the $t_{.05[30]}$ value of 2.042 indicating nonsignificance between the treatment and control sections. The mean dry weight of invertebrates per basket sampler in the control section was 0.0188 grams and the treatment section mean weight was 0.0199 grams.

Table 4. Invertebrates collected from SASB basket samplers June 5, 1985 and their presence noted (X) for the treatment and control sections of Brown Creek after treating with salmon carcasses.

Taxonomic Listing	Presence	
	Treatment	Control
Class Insecta		
Order Ephemeroptera		
Family Leptophlebiidae		
<u>Paraleptophlebia</u> sp.	X	X
Family Heptageniidae		
<u>Cinygma</u> sp.	X	X
<u>Ironodes</u> sp.	X	X
<u>Epeorus</u> sp.	X	X
Family Baetidae		
<u>Baetis</u> sp.	X	X
Family Ephemerellidae		
<u>Drunella</u> sp.	X	X
<u>Ephemerella</u> sp.		X
<u>Serratella</u> sp.	X	
Family Siphonuridae		
<u>Ameletus</u> sp.		X
Order Trichoptera		
Family Calamoceratidae		
<u>Heteroplectron</u> sp.	X	
Family Polycentropidae		
<u>Polycentropus</u> sp.	X	X
Family Brachicentridae		
<u>Brachycentrus</u> sp.	X	
<u>Eubrachycentrus</u> sp.		X
<u>Micrasema</u> sp.		X
Family Lepidostomatidae		
<u>Lepidostoma</u> sp.	X	X
Family Glossosomatidae		
<u>Agapetus</u> sp.	X	X
<u>Glossosoma</u> sp.	X	X
Family Hydropsychidae		
<u>Paraphyche</u> sp.	X	X
Family Philopotamidae		
Unknown genera		X
Family Rhyacophilidae		
<u>Himalopsyche</u> sp.		X
<u>Rhyacophila</u> sp.	X	X

Table 4. Invertebrates collected from SASB basket samplers June 5, 1985 and their presence noted (X) for the treatment and control sections of Brown Creek after treating with salmon carcasses. (continued)

Order Plecoptera		
Family Capniidae		
Unknown genera	X	X
Family Chloroperlidae		
<u>Alloperla</u> sp.	X	X
<u>Chloroperla</u> sp.	X	
Unknown genera	X	X
Family Leuctridae		
<u>Despaxia</u> sp.	X	
Family Nemouridae		
<u>Amphinemura</u> sp.	X	X
<u>Zapada</u> sp.	X	X
Family Peltoperlidae		
<u>Soliperla</u> sp.		X
Family Perlidae		
<u>Classenia</u> sp.	X	X
<u>Calineuria</u> sp.		X
<u>Hesperoperla</u> sp.		X
<u>Acroneuria</u> sp.	X	
Unknown genera	X	X
Family Perlodidae		
<u>Isogenus</u> sp.		X
<u>Isoperla</u> sp.		X
Unknown genera	X	
Family Pteronarcidae		
<u>Pteronarcys</u> sp.	X	X
Order Diptera		
Family Chironomidae		
Subfamily Chironominae	X	X
Subfamily Orthocladiinae		X
Subfamily Tanypodinae	X	X
Family Dixidae		
Unknown genera or subfamily		X
Family Simuliidae		
<u>Simulium</u> sp.		X
Order Coleoptera		
Family Dytiscidae		
<u>Agabus</u> sp.	X	X
<u>Rhantus</u> sp.		X
Family Psephenidae		
<u>Eubrianax</u> sp.		X
Family Elmidae (adult)		
Unknown genera		X

Table 4. Invertebrates collected from SASB basket samplers June 5, 1985 and their presence noted (X) for the treatment and control sections of Brown Creek after treating with salmon carcasses. (continued)

Family Elmidae (larvae)		
Unknown genera	X	X
Order Megaloptera		
Family Corydalidae		
<u>Corydalus</u> sp.	X	X
Family Sialidae		
<u>Sialis</u> sp.		X
Order Odonata		
Family Libelluloidae		
Unknown genera	X	
Class Gastropoda		
Family Pleuroceridae		
<u>Juga</u> sp.	X	X
Total	34	44

Mean fork lengths of Salmo sp. in May Creek were significantly higher ($.05 > P > .01$) in the treatment section than in the control section on the September 1983 pretreatment sampling day and on the September 1984 posttreatment sampling day (Table 5). Significantly higher ($.05 > P > .01$) average fork lengths of coho salmon were found only in the control section of May Creek in July, 1984. Brown Creek Salmo sp. average fork lengths were never significantly ($P > .05$) different between treatment and control sampling sites on any of the sampling days (Table 6).

The gain in mean fork length of Salmo sp. and coho between the two sampling periods in May Creek during the spring and summer of 1984 was greater in the treatment section (Fig. 3). Salmo sp. gained 16mm and 9mm in average fork length in the treatment and control sections, respectively, and coho salmon gained 14mm and 10 mm in the treatment and control sections, respectively.

Brown Creek mean fork length gain of Salmo sp. over a two month period was greater in the control section during the pretreatment and posttreatment periods. The gain, however, was less in the control section during the posttreatment period while the treatment section mean fork length gain increased from the gain in the previous year (Fig. 4).

Table 5. T-test (t_s) comparisons between treatment and control section fork lengths of young of the year Salmo sp. and coho salmon (Oncorhynchus kisutch), May Creek, 1983 (pretreatment) and 1984 (Posttreatment). (*) significant at 0.05 level, (**) significant at 0.01 level, month of sample, species or genera, sample size (n), mean fork length (mm), two month gain in mean fork length, and variance are given.

Month	Species	Section	n	Mean Fk. Ln. (mm)	Mean Fk. Ln. Gain	2 s	t s
9/83	<u>Salmo</u> sp.	Treatment	51	65		92	2.09*
		Control	75	61		78	
9/83	Coho	Treatment	18	78		49	1.20
		Control	33	76		58	
7/84	<u>Salmo</u> sp.	Treatment	20	55		253	0.50
		Control	24	53		310	
7/84	Coho	Treatment	11	66		42	2.25*
		Control	13	71		24	
9/84	<u>Salmo</u> sp	Treatment	13	71	16	87	2.70*
		Control	28	62	9	151	
9/84	Coho	Treatment	17	80	14	45	1.02
		Control	14	81	10	33	

Table 6. T-test (t_s) comparisons between treatment and control section fork lengths of young of the year Salmo sp., Brown Creek, 1984 (pretreatment) and 1985 (posttreatment). (*) significant at 0.05 level, (**) significant at 0.01 level, month of sample, species or genera, sample size (n), mean fork length (mm), two month gain in mean fork length, and variance are given.

Month	Species	Section	n	Mean Fk. Ln. (mm)	Mean Fk. Ln. Gain	2 s	t s
8/84	<u>Salmo</u> sp.	Treatment	37	57		196	0.56
		Control	35	55		222	
10/84	<u>Salmo</u> sp.	Treatment	25	60	3	182	0.95
		Control	18	64	9	169	
7/85	<u>Salmo</u> sp.	Treatment	61	60		128	0.00
		Control	37	60		121	
9/85	<u>Salmo</u> sp.	Treatment	59	64	4	123	1.12
		Control	21	67	7	124	

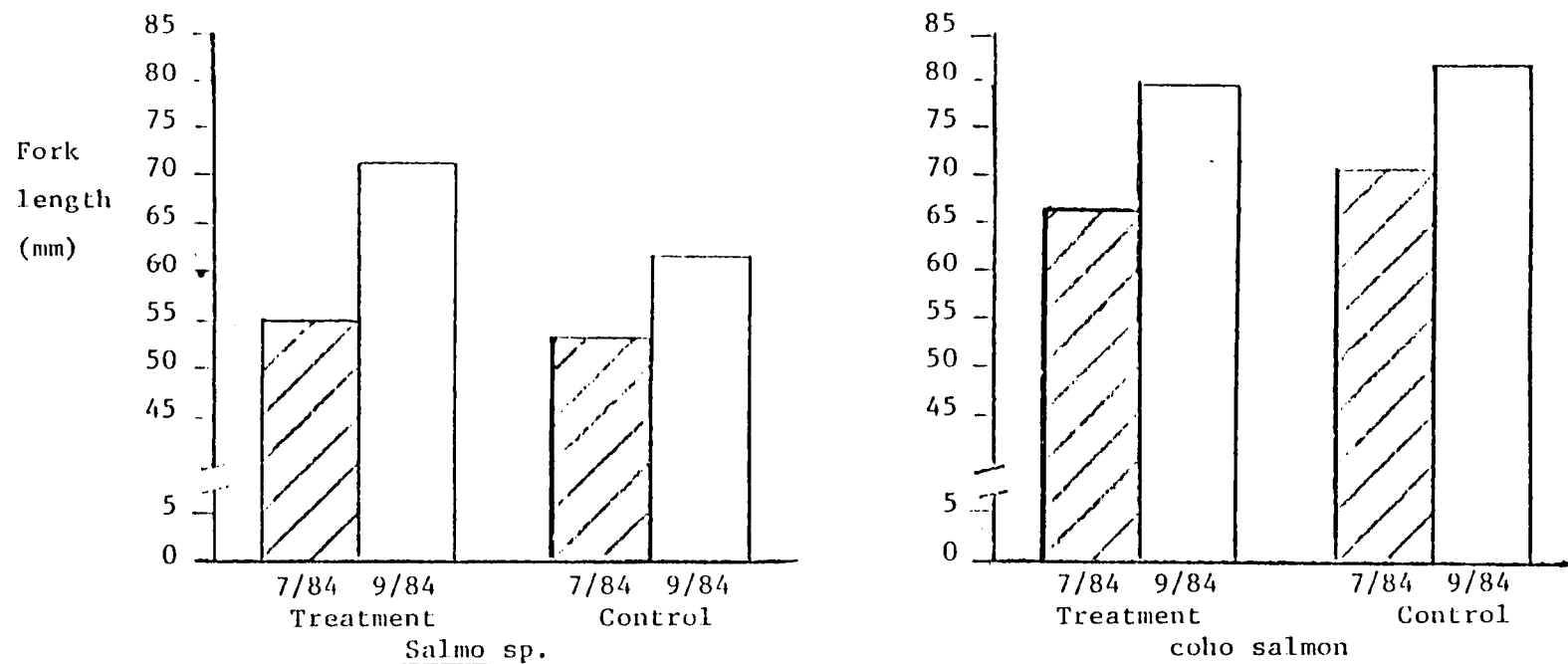


Figure 3. Fork lengths (mm) of May Creek young-of-the-year Salmo sp. and coho salmon as measured in 7/84 and 9/84.

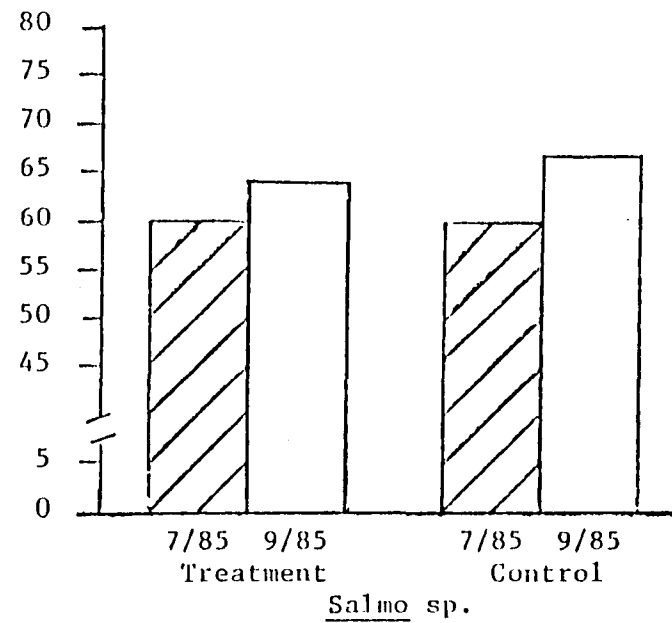
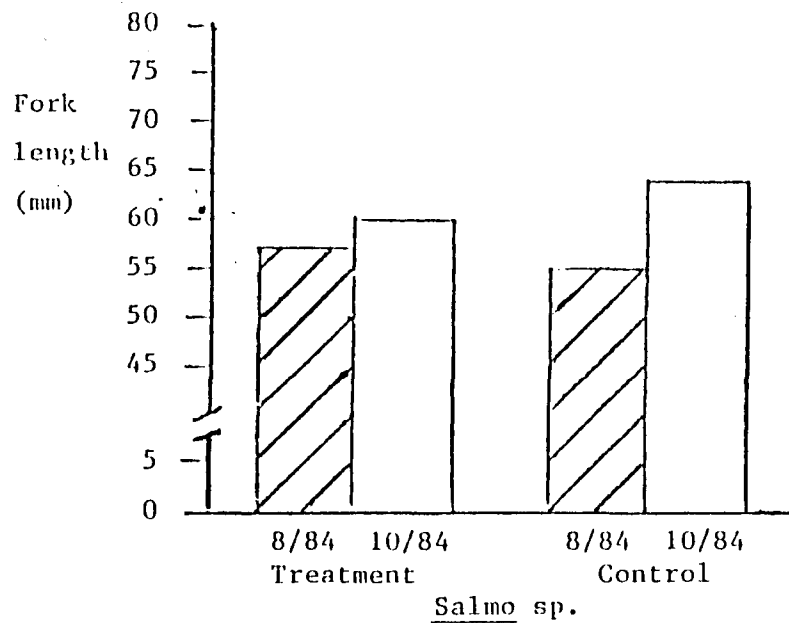


Figure 4. Fork lengths (mm) of Brown Creek young-of-the-year *Salmo* sp. as measured in 8/84, 10/84, 7/85, and 9/85.

DISCUSSION

The total number of carcasses added per linear meter of stream treatment section was 0.45 in May Creek and 1.00 in Brown Creek. The total weight of carcasses added to the streams was 265 kg in May Creek and 655 kg in Brown Creek. In order to insure that Brown Creek and May Creek were receiving adequate amounts of carcass biomass, this treatment load was compared with some past run data from other streams. Gunsolus et al. (1953) surveyed several Snake River tributaries prior to the construction of McNary Dam for spring chinook escapement. That survey indicated the highest concentration of fish was 138 in a 2816 meter section of stream for 0.05 fish per linear meter of stream. Willis (1962), reported 224 coho and 83 chinook salmon spawned within a 4828 meter section of stream (0.06 fish per linear meter) with a flow that ranged from 5 cms to 995 cms. These were lighter treatment loads than what either Brown Creek or May Creek received. Richey et al. (1975) indicated that Taylor Creek of Lake Tahoe had 14,000 kokanee (Oncorhynchus nerka) averaging 875 grams per fish enter an 8 km section of that stream to spawn and die. The flow in Taylor Creek ranged from 0.1 to 6.0 cms and the concentration of carcass biomass was higher than the treatment load put into Brown Creek or May Creek.

Spawner counts of sockeye salmon entering other streams also indicate a much higher biomass added to those systems (e.g. Krokhin 1957). Enough carcasses were therefore put into May Creek and Brown Creek to simulate or exceed natural chinook and coho salmon runs but not enough to simulate some sockeye runs.

Mean grams of periphyton colonized per square meter of slides per day did not indicate a higher aufwuchs production in the treatment section of May Creek. In three out of the five periphyton colonization periods the mean periphyton weight was higher in the untreated section of stream. Of the two periphyton weights which were significantly different, only the last one (collected August 24, 1984) was higher in the treatment section.

The mean weight of periphyton on Brown Creek glass slide samplers indicated a more definite trend towards higher production in the treatment section of that stream than in May Creek (Table 4). Mean weights of periphyton colonized were higher in Brown Creek treatment sections during all colonization periods with treatment section periphyton weights significantly ($P > .01$) greater than the control section periphyton weights during four out of six of the colonization periods. This increased production may have been a result of the higher concentration of carcasses added to Brown Creek.

Triska et al. (1983) reported that one of the limiting factors to total periphyton biomass production was light. In that experiment nutrient enrichment did, however, under normally lighted conditions, increase the rate of biomass accumulation in nutrient enriched periphyton colonization channels but the total amount of biomass produced at the end of that experiment was not significantly different from periphyton colonization channels without nutrient enrichment.

The total number of invertebrate genera sampled from both sections of Brown Creek was greater in the control section (44) than in the treatment section (34). This indicates a slightly greater richness (Platts et al. 1983) in the section with no nutrient supplementation. Perhaps a more revealing comparison of invertebrate production would have been to compare numbers and biomass of invertebrate feeding functional groups as described by Merritt and Cummins (1984). If nutrient input from decomposing carcasses increased periphyton production, there may have been a shift in functional group composition to utilize this increased biomass. It was speculated that the increase would be in invertebrate grazers feeding on the aufwuchs and on predators feeding on the grazers. The problem with attempting to assign invertebrates to a functional group in this study was the incomplete identification of immature insects. In many cases, this

would mean not categorizing some invertebrates into a functional group since many larvae were too immature to exhibit key morphological characters for identification. Another problem with categorizing invertebrates into functional groups is that some genera have been found to be facultative feeders with changes in food habits noted to be diel, seasonal, and according to abundance of different food sources (Chapman and DeMory 1963).

While there may have been a greater number of invertebrate genera counted from control section samplers than from treatment section samplers, invertebrate biomass was greater, though not significantly greater, in the treatment section samplers. This is indicated by the sum of ranks of the Wilcoxon 2-sample test and mean dry weights of invertebrates sampled from the two sections of Brown Creek.

Since the mean fork lengths of Salmo sp. and coho salmon young-of-the-year in May Creek were not ($0.05 > P > 0.01$) significantly different between the pretreatment and posttreatment periods, there was little evidence to suggest that the carcasses added to the treatment section had any effect on fish length. Salmo sp. mean fork length comparisons in Brown Creek also reaffirmed the lack of treatment effects with no significant difference ($P > 0.05$) between treatment and control sections. The gain in mean fork length during the posttreatment

period, however, did indicate a growth trend which may be the result of treating with carcasses. The mean fork length gain of both Salmo sp. and coho salmon was greater in the treatment section during the posttreatment period in May Creek. Brown Creek mean fork length gains for Salmo sp. were greater in the control section during the pretreatment and posttreatment periods but decreased in the control section and increased in the treatment section during the posttreatment period. This increase in growth in the treatment section may have been resulted from treatment of the section with carcasses or sampling error. It would take several years of data on one stream to determine if growth increased because of carcass decomposition or possibly because of the downstream migration of larger fish from the control section into the treatment section. However, if fish migrated into the treatment section as they grew in size because of habitat preference, then it would seem that mean fork lengths would always be greater in the treatment section which was not the case in Brown Creek.

The higher response to the treatment with carcasses in Brown Creek than in May Creek may possibly be explained by two related reasons; innate stream productivity differences and the amount of carcasses added to each stream. The higher overall productivity of May Creek shortens the spiral length of nutrients moving downstream. Newbold et

al. (1981) state that nutrients spiral downstream with the length of each spiral dependent on consumer uptake, which controls the spiral length. If nutrient utilization increases, spiralling length decreases. May Creek had higher utilization than Brown Creek meaning that the spirals were shorter and it would take more nutrients added to that stream to have significantly increased periphyton production within the treatment section. With a lower productivity and possibly fewer nutrients in Brown Creek, it would probably take fewer carcasses than May Creek to show a significant increase in periphyton production as well as in higher trophic levels. With twice as many carcasses added to Brown Creek as May Creek, the increase in productivity was more significant.

This study simulated a high escapement for only one year in each of two streams and therefore did not allow nutrients to build up over several years. During the two years that both streams used for the study were observed, neither received spawner escapement numbers approaching the number of carcasses put into the streams for this study. Nutrient accumulation may have to occur over several high spawner escapement years to show significant effects at all trophic levels. During prior years with high historical runs of Pacific salmon for several consecutive years, there may have been significant increases in biotic productivity as demonstrated by Richey et al. (1975) where autotrophic

activity was higher below a barrier to kokanee spawning activity.

Results of this study indicate that there is a potential for increased stream productivity when there are large numbers of decomposing spawned-out carcasses present in the water. With a management strategy of allowing the harvest of all fish in excess of those needed to fully seed a stream there is no "excess" escapement of adult salmon to spawning areas, and therefore fewer carcasses. Fish management should thereby take into consideration that higher escapement may increase stream productivity, particularly in areas where rearing streams are exposed to substantial sunlight but have few nutrients. Annually supplementing rearing streams with hatchery obtained carcasses is a method of possibly increasing stream productivity when there is low spawner escapement and where habitat conditions would favor smolt production. Streams to be treated with carcasses would have to be selected carefully to prevent the possible spread of diseases from the hatchery stock. A method of enhancing stream productivity without risking the spread of hatchery stock diseases is through stream fertilization with artificially derived nutrients. Stockner and Shortreed (1978) observed an increase in algal biomass where they had added nitrogen and phosphorous to a treatment section of stream. While additions of nitrogen alone had little effect on algal

biomass, nitrogen and phosphorous in combination resulted in the highest algal biomass in that experiment.

LITERATURE CITED

- American Public Health Association and others. 1981. Standard methods for the examination of water and wastewater: New York, New York. American Public Health Association; 1976. 1193 p.
- Bott, T. L. 1983. Primary productivity in streams. Pages 29-54 in J. R. Barnes and G. W. Minshall, editors. Stream Ecology. Plenum Press, New York, New York. 410 pp.
- Chapman and DeMory. 1963. Seasonal changes in the food ingested by aquatic insect larvae and nymphs in two Oregon streams. Ecology 44: 140-146.
- Durbin, Ann Gall, S. W. Nixon, C. A. Oviatt. 1979. Effects of the spawning migration of the alewife, Alosa pseudoharengus, on freshwater ecosystems. Ecology 60(1):8-17.
- Edmunds, G. F., S. L. Jensen, and L. Berner. 1976. The mayflies of North and Central America. University of Minnesota Press, Minneapolis, Minnesota. 330 pp.
- Elliott, J. M. 1977. Some methods for the statistical analysis of samples of benthic invertebrates. Freshwater Biological Association. Scientific Publication no. 25, 2nd edition. 160 pp.
- Elwood Jerry W., J. D. Newbold, A. F. Trimble, and R. W. Stark. 1981. The limiting role of phosphorous in a woodland stream ecosystem: Effects of P enrichment on leaf decomposition and primary producers. Ecology 62(1):146-158.
- Gunsolus, R., R. Loeffel, J. Cicrich, and L. Korn. 1953. Spring chinook escapement into Snake River tributaries of Oregon and Washington. Washington Department of Fisheries and Oregon Fish Commission. 60 pp.
- Harrington, J. M. 1983. An evaluation of techniques for collection and analysis of benthic invertebrate communities in second order streams in Redwood National Park. Master of Science Thesis, Humboldt State University, Arcata, California. 46 pp.

- Houston, D. B. 1983. Anadromous fish in Olympic National Park: A status report. U. S. Dept. of Interior.
- Huntsman, A. G. 1948. Fertility and fertilization of streams. Journal of the Fisheries Research Board of Canada 7(5):248-252.
- Hynes, H. B. N. 1970. The ecology of running waters. University of Toronto Press. Toronto, Canada. 555 pp.
- Juday, C. W. 1932. Limnological studies of Karluk Lake, Alaska, 1926-1930. U. S. Bureau of Fisheries Bulletin 57:407-437.
- Keator, G., and J. C. Koelling. 1978. Pacific Coast berry finder. Nature Study Guide Publishers. Berkeley, California. 61 pp.
- Kitchell, J. F., R. V. O'Neill, D. Webb, G. W. Gallep, S. M. Bartell, J. F. Koonce, B. S. Ausmus. 1979. Consumer regulation of nutrient cycling. Bioscience 29(1):28-34.
- Krokhin, E. M. 1957. Sources of enrichment of spawning lakes in biogenic elements. Fisheries Research Board of Canada, Translation Series no. 207. 9 pp.
- Krokhin, E. M. 1959. On the effect of the number of spawned-out sockeye salmon (Oncorhynchus nerka) in a lake on its supply of biogenic elements. Fisheries Research Board of Canada, Translation Series No. 417. 4 pp.
- LeBrasseur, R. J., and O. D. Kennedy. 1972. The fertilization of Great Central Lake, II. Zooplankton standing stock. Fisheries Bulletin of the U.S. 70(1):25-36.
- Lemmon, P. E. 1956. A spherical densiometer for estimating forest overstory density. Forest Science 2:314-320.
- Merritt, R. W., and K. W. Cummins. 1984. An introduction to the aquatic insects of North America, 2nd edition. Kendall/Hunt Publishing, Dubuque, Iowa. 722 pp.
- Narver, D. W. 1967. Primary productivity in the Babine Lake system, British Columbia. Journal of the Fisheries Research Board of Canada 24:2045-2052.

- Newbold, J. D., J. W. Elwood, R. V. O'Neill, and W. Van Winkle. 1981. Measuring nutrient spiralling in streams. *Canadian Journal of Fisheries and Aquatic Science* 38:860-863.
- Newbold, J. D., R. V. O'Neill, J. W. Elwood, and W. Van Winkle. 1982. Nutrient spiralling in streams: Implications for nutrient limitation and invertebrate activity. *The American Naturalist* 120(5):629-652.
- Nriagu, J. O. 1983. Rapid decomposition of fish bones in Lake Erie sediments. *Hydrobiologia* 106:217-222.
- Parsons, T. R., K. Stephens, and M. Takahaski. 1972. The fertilization of Great Central Lake, I. Effect of primary productivity. *Fishery Bulletin of the U.S.* 70(1):13-22.
- Pennak, R. W. 1978. Fresh-water invertebrates of the United States, 2nd edition. John Wiley & Sons, New York, New York. 803 pp.
- Platts, W. S., W. F. Megahan, G. W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. General Technical Report INT-138. Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 70 pp.
- Richey, J. E., M. A. Perkins, and C. R. Goldman. 1975. Effects of kokanee salmon (Oncorhynchus nerka) decomposition on the ecology of a subalpine stream. *Journal of the Fisheries Research Board of Canada* 32:817-820.
- Sokal, R. R., and F. J. Rohlf. 1981. Biometry. 2nd edition. W. H. Freeman & Co., San Francisco, California. 859 pp.
- Stockner, J. G., and K. R. S. Shortreed. 1976. Autotrophic production in Carnation Creek, a coastal rainforest stream on Vancouver Island, British Columbia. *Journal of the Fisheries Research Board of Canada* 33:1553-1563.
- Stockner, J. G., and K. R. S. Shortreed. 1978. Enhancement of autotrophic production by nutrient in a coastal rainforest stream on Vancouver Island. *Journal of the Fisheries Research Board of Canada* 35:28-34.

- Strahler, A. N. 1957. Quantitative analysis of watershed geomorphology. Transactions of the American Geophysicists Union 38:913-920.
- Triska, F. J., V. C. Kennedy, R. J. Avanzino, and B. N. Reilly. 1983. Effect of simulated canopy cover on regulation of nitrate uptake and primary production by natural periphyton assemblages. Pages 129-159 in T. D. Fontaine, III, and S. M. Bartell (editors), Dynamics of lotic ecosystems. Ann Arbor Science.
- United States Department of the Interior. 1985. Water resource management plan, Redwood National Park. National Park Service, Redwood National Park, Crescent City, California. 103 pp.
- Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Science 37:130-137.
- Watts, T. 1973. Pacific Coast tree finder. Nature Study Guide Publishers. Berkeley, California. 61 pp.
- Wiggins, G. B. 1977. Larvae of the North American caddisfly genera. University of Toronto Press, Toronto, Canada. 401 pp.
- Willis, R. A. 1962. Gnat Creek weir studies, final report. Fish Commission of Oregon, Research Division, Clackamas, Oregon. 71 pp.