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This thesis reports the results of a study on the influence of biologically stabilized kraft mill effluent (SKME) on the food relations and production of juvenile chinook salmon, <u>Oncorhynchus</u> <u>tschawytscha</u> (Walbaum), in laboratory streams. Experiments were conducted at the Oak Creek Fisheries Research Laboratory, Oregon State University, during 1967 and 1968.

Kraft mill effluent used in this study was either collected raw and biologically stabilized at the laboratory, or collected already treated from a mill operating a stabilization pond. Stabilization of wastes was accomplished at the laboratory by sewage bacteria under constant aeration and with the addition of nitrogen and phosphorus.

One aspect of this study dealt with the relationship between salmon production and salmon biomass in streams stocked with salmon at different densities in three control and three streams receiving 1.5 percent SKME by volume. This design permitted an analysis of the relationships between the abundance of the food organisms and the growth rate and biomass of salmon. Another aspect of the study dealt with the production of fish stocked at similar densities in two control streams and four streams each of which received a different concentration of SKME.

In experiments conducted during the spring and fall periods, salmon production was lower in streams receiving a 1.5 percent SKME concentration than in control streams. This difference was attributed to a direct effect of SKME since no reduction in the abundance of food organisms or in the basic capacity of the streams to produce food organisms could be demonstrated.

In experiments during the summer salmon production was found to be greater in streams receiving up to 4.0 percent SKME than in control streams. Salmon production was greatest at a 1.0 percent concentration and declined at concentrations of 2.0 and 4.0 percent SKME. The increase in production can probably be attributed to an increase in the numerical density of the major food organism, an amphipod identified as Crangonyx sp. The decline in salmon production at concentrations above 1.0 percent suggested that SKME was directly effecting salmon growth rates during summer experiments also, although this influence may have been small in relation to beneficial effects on food abundance. Amphipod biomass was related to the biomass of organic material in the laboratory streams.

The Influence of Biologically Stabilized Kraft Mill Effluent on the Food Relations and Production of Juvenile Chinook Salmon in Laboratory Streams

by

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INTRODUCTION

In recent years there has been increased use of biological treatment of effluents from kraft pulp mills in the Pacific Northwest. This has resulted in a marked decrease in the biochemical oxygen demand (BOD) and toxicity of kraft mill effluent (KME). Although at the present levels of discharge these treated wastes may not add significantly to the oxygen demand in salmon rearing streams or result in increased mortality rates of fish, sublethal effects imposed directly on the fish or indirectly through the invertebrate community may influence the amount of salmon produced in these streams.

There is a dearth of information on the effects of chronic exposure of stabilized kraft mill effluent (SKME) on fish and other aquatic organisms although there are some recent studies on the effects of sublethal concentrations of unstabilized wastes. Fujiya (1965) reported seriological, histological and cytochemical aberrations in several fish species exposed to sublethal concentrations of KME. Servizi, Stone and Gordon (1966) found that growth of juvenile sockeye salmon, Oncorhynchus nerka (Walbaum), was reduced by exposure to a one percent solution of neutralized KME (bleach process), which was also found to retard yolk utilization in pink salmon, Oncorhynchus gorbuscha (Walbaum). Studies by the Washington State Department of Fisheries (1960) indicated that KME (bleach process) at a dilution of 1:169 reduced the growth of chinook salmon, Oncorhynchus tschawytscha (Walbaum). Tokar (1968) reported that the growth of juvenile chinook salmon fed unrestricted rations of live organisms and exposed to concentrations of KME ranging from 0.5 to 4.0 mg/l BOD was reduced from that of control fish. At low feeding levels there were no differences in growth that could be attributed to KME. Tokar reported these differences in growth were the result of decreases in the efficiency of food utilization by salmon.

Studies of the effects of kraft mill wastes on communities of plants and animals in laboratory streams have been underway since 1966 at the Oak Creek Fisheries Laboratory, Oregon State University. Ellis (1968) studied the influence of unstabilized wastes on the production and food consumption of juvenile chinook salmon. He found that KME at a dilution of 1:67 reduced the growth rate of the fish, but no reduction occurred at a dilution of 1:200. Ellis did not observe any reduction in food abundance, and he attributed the reduction in fish growth to a direct toxic action of KME. Studies were begun in 1967 on the effects of biologically stabilized kraft mill effluent on the laboratory stream communities. Harvey D. Williams, Department of Botany and Plant Pathology, Oregon State University, studied the effects of these wastes on the algae in the streams. Primary production was found to be greater in streams receiving SKME than in control streams, but the species composition of diatoms was altered and the abundance of organic material in treatment streams was reduced from that of control streams (Williams, 1969).

This thesis reports the results of a study of the influence of biologically stabilized kraft mill wastes on the food relations and production of juvenile chinook salmon in laboratory stream communities. The experiments were performed at the Oak Creek Fisheries Research Laboratory during 1967 and 1968. One aspect of the study dealt with the relationship between salmon production and salmon biomass. In these experiments three different salmon biomasses were stocked in treatment and in control streams during different seasons. The influence of the waste on the behavior of fish stocked at different biomasses was examined during one experiment. Another aspect of the study dealt with the production relationships of fish stocked at similar densities in control streams and in streams that received different concentrations of SKME.

The design of these experiments also permitted an analysis of relationships between the abundance of the food organisms in the streams and the biomass and growth rates of the experimental fish. Brocksen, Davis, and Warren (1968) have proposed a rationale for examining these relationships. Their model defines the production of a predator as a function of its biomass and the abundance of its food. This approach permits the use of relatively simple food density measurements (as opposed to determining production rates for food organisms) to interpret differences in the growth and production of predators. Further development of this point of view by Brocksen, Davis, and Warren (1969) and Brocksen (1969) indicates that the density of the predator is inversely related to the density of the prey within systems having a similar basic capacity to produce the prey. In contrast, the densities of the predator and the prey were found to be directly related between systems having a different basic productivity. This approach may be of value in the analysis of the effect of environmental change on aquatic ecosystems.

METHODS AND MATERIALS

Laboratory Streams

The six laboratory streams used in this study were similar in design and function to those described in detail by McIntire et al. (1964) and Ellis (1968). Each was composed of a wooden trough 3.3 m long, 66 cm wide and 25 cm deep, divided into two channels by a median partition open at each end. A riffle was formed in each channel by elevated sections of the stream bottom. The bottoms were covered with gravel and rubble collected from a nearby stream. Electrically driven paddle wheels provided current velocities of approximately 24 cm/sec in the riffles and up to 10 cm/sec in the pools. The water in each stream was exchanged at the rate of 2 liters per minute with filtered water from a small spring-fed stream. The rate of exchange was controlled with flow meters, and a constant water level was maintained with screened standpipes.

The building in which the streams were situated was covered with a translucent fiberglass roof. Light intensities were controlled with Saran shading material to prevent heavy algal growths. One layer of this material was suspended inside the building over the streams; another layer was placed over the roof when additional shading was required.

A large fan was operated during the summer to remove warm air from the building. Water temperature was continuously recorded in one stream (Figure 1).

Kraft Mill Effluent

Kraft mill effluent was hauled weekly from two local paper mills. Raw effluent from Mill A was pumped from the plant's settling lagoon and biologically stabilized at the Oak Creek Laboratory in an 800 gallon wooden tank. A bacterial floc was maintained in the tank with constant aeration and the addition of nutrients. Phosphorus was added at a ratio of 1 part to 100 parts of oxygen required to satisfy the 5-day biochemical oxygen demand (BOD) of the waste, and nitrogen was added at a ratio of 1 part to 20 parts BOD (Helmers and Frame, 1952). An average initial BOD of 200 mg/l was assumed for calculating the amount of nutrient to be added. After seven days of treatment the bacterial floc was allowed to settle before the stabilized effluent was pumped into two 350 gallon holding tanks inside the laboratory stream building. SKME from Mill B was collected near the outfall of the mill's stabilization pond and transported directly to the holding tanks. From these tanks a tubing pump delivered the waste into the streams through plastic tubing. Both SKME and exchange water flows were recorded and adjusted daily during each experiment. Samples of each batch of effluent were analyzed for BOD and other characteristics

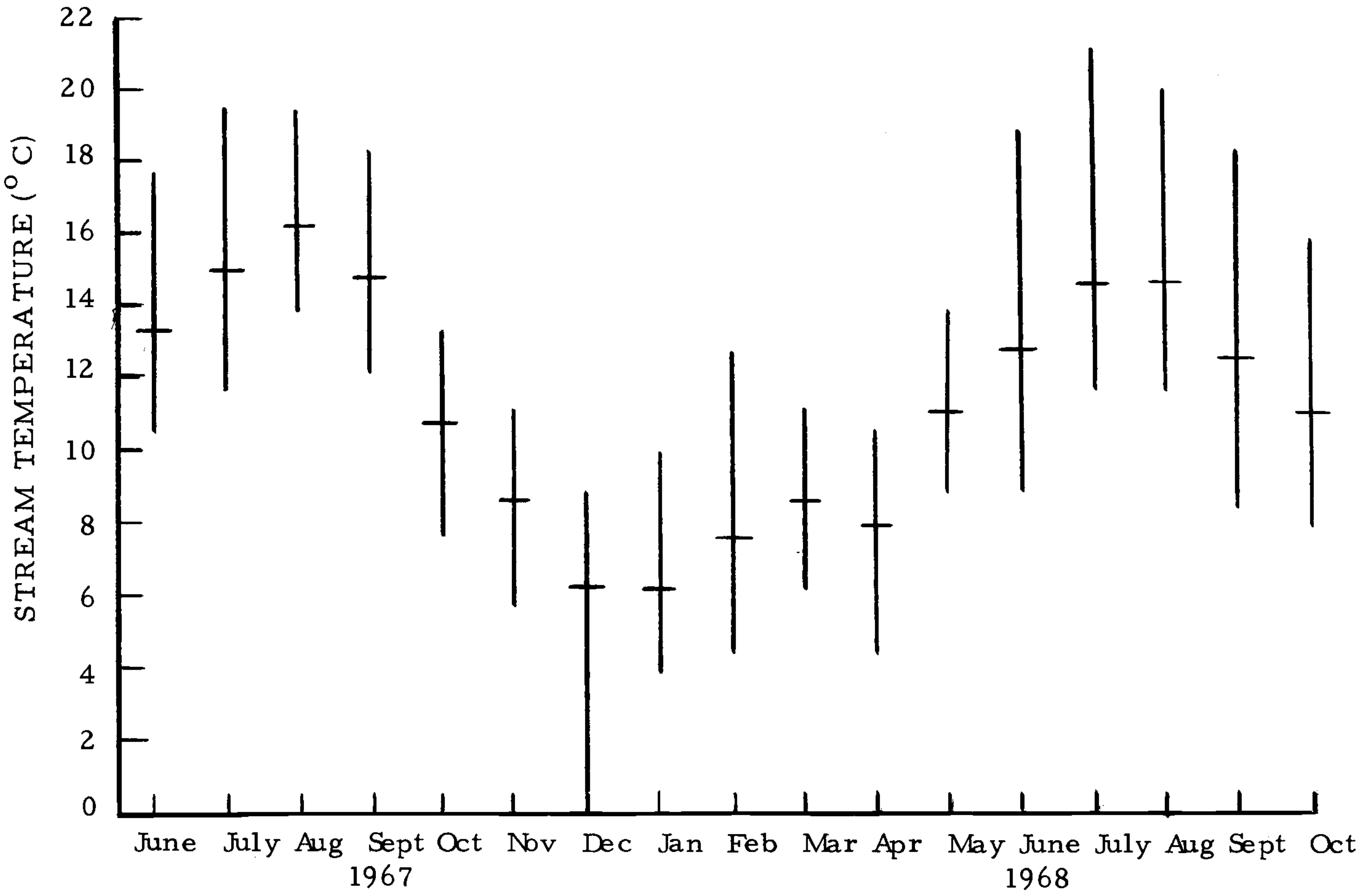

Figure 1. Monthly mean and range of temperatures in the laboratory streams from July 1967 through October 1968.

by personnel of the National Council of the Paper Industry for Air and Stream Improvement, Inc. (Appendix 1).

Stream Communities

Communities of plant and invertebrate organisms were established in the laboratory streams during earlier experiments with raw kraft waste by Ellis (1968). The studies reported herein with stabilized wastes were conducted with the previously established communities. By retaining these communities established populations of food organisms were immediately available as a food resource for the young salmon. Subsequent stocking of the laboratory streams with invertebrates collected from nearby natural streams and import of eggs and early-instar larvae via the exchange water insured that most of the common benthic species were available for colonization of the streams. Laboratory stream communities were subjected to the test concentrations for 30 days before experiments were begun.

The benthic fauna was sampled during each experiment by sealing off a 0.093 m^2 section of stream bottom and scrubbing the enclosed substrate. After the gravel and rubble were cleaned and removed the water containing the plants and invertebrates were siphoned into a plankton net. These samples were taken from the same relative locations in each stream, and successive sampling followed a simple progressive pattern alternating between the two channels from one end of the apparatus to the other. A plankton net was placed below each standpipe drain for 24-hour periods to sample drifting organisms. A plastic sleeve placed around the standpipe was adjusted to permit sampling at different water depths. All samples were preserved in a five percent formalin solution. The organisms were later separated from the algae and other material in the sample. Large numbers of Crangonyx sp., an amphipod which was the most abundant organism in all the samples, were separated from the benthic materials by repeatedly decanting the upper layer of water from a shallow container holding the sample. Gentle agitation facilitated this technique. The remaining food organisms were removed with forceps. Examination of the processed samples with a binocular microscope indicated that very few organisms remained. After separating the macro-invertebrates to family or genus, each group was blotted dry and weighed. Drift samples collected within a given experimental period were combined before they were weighed because of the small quantities involved.

The numerical density of the amphipods in each stream was determined during the spring and early summer of 1968. Amphipods from a benthic sample were evenly spread over a 36-square grid in a shallow glass container. The numbers of individuals were calculated from counts taken within six randomly selected squares. The amphipods were divided into the following three arbitrary size groups: greater than 4 mm, 2 to 4 mm, and less than 2 mm in body length.

Experimental Fish

Underyearling chinook salmon were used in all of the experiments. Fall chinook collected from the Sixes River near Port Orford, Oregon, were used in the 1967 experiments, and spring chinook salmon supplied as fertilized eggs by the Oregon State Fish Commission and raised in the Laboratory were used in the 1968 experiments. The fish were kept in large wooden tanks and fed live tubificid worms. Except for salmon used in a behavior study, each experimental fish was marked with a "cold brand" (Groves and Novotony, 1965). Marking tools were cooled in a mixture of acetone and dry ice and then held against the side of an anesthetized fish for approximately two seconds. The salmon were anesthetized with MS-222 (tricaine methanesulfonate). To ensure a readable mark it was necessary to blot dry both the cooled marking tool and the side of the fish. These marks became visible after approximately one week and lasted for several months.

Salmon of similar size were selected for stream experiments from a group of previously marked fish. After starving the fish for 24 hours they were anesthetized, blot dried and weighed. From this group ten fish were dried at 70°C for five days, reweighed, and the mean percentage dry weight calculated. This value was then used to calculate an initial dry weight based on the initial wet weights of each fish used in the experiment. At the end of each experiment the fish were again starved for 24 hours, and their dry weights determined.

Salmon Production, Growth Rate and Biomass

Salmon production, defined as the amount of fish tissue elaborated during an interval of time irrespective of the fate of that tissue (Ivlev, 1945; Ricker, 1958), was calculated as the total change in weight of the fish in grams during an experimental period divided by the area of the stream bottom in square meters. When a fish was not recovered it was assumed to have lived through half of the test period. This number of days was then multiplied by the mean weight change per day of the recovered fish to arrive at an estimate of the contribution by the missing fish to the salmon production for that stream. The mean biomass was calculated from the mean of the initial and final salmon weights - including the estimated mean weight of any missing fish - divided by the area of the stream bottom ($1.55 m^2$). Salmon growth rate was calculated as the change in fish weight divided by the product of the mean weight of fish tissue present and the number of days in the experimental period.

Laboratory Stream Experiments

Six laboratory stream experiments were conducted within the period from August 14, 1967 to October 30, 1968 (Table 1). Experiments 1, 2 and 3, performed during early fall 1967, late fall 1967, and spring 1968, respectively, were designed to test the effects of 1.5 percent SKME from Mill A on the food relations and production of salmon stocked at three different densities in three control and three treatment streams. The use of different fish biomasses permitted examination of the effect of different fish densities on the invertebrate fauna.

Experiments 4 and 5, conducted between June 3 and August 30, 1968, were designed to measure the growth and food relations of salmon stocked at similar densities in two control streams and in four other streams receiving concentrations of 0.5, 1.0, 2.0, and 4.0 percent SKME by volume. Effluents from Mill A and Mill B were used in Experiments 4 and 5, respectively.

During Experiment 6 (September 28 to October 30, 1968) observations were made of the feeding movements of salmon stocked at three densities in treatment (2 percent SKME by volume) and in control streams. Color-coded plastic tags attached to each fish permitted identification of individual salmon. Observations were recorded during two 100 minute periods each day from a temporary

Table 1. Number stocked, number recovered, mean weight, and stocking density of salmon, and SKME concentration in percent by volume for each laboratory stream during Experiments 1 through 6.

Exper. number	Date	Number stocked	Number recovered	Mean weight (g)	Stocking density (g/m^2)	SKME concentration
1	Aug. 14 -	2	2	0.447	0.576	0
	Sept. 15,	2	2	0.459	0.592	1.5
	1967	4	4	0.453	1.169	0
		4	4	0.433	1.117	1.5
		6	5	0.427	1.653	0
		6	6	0.445	1.723	1.5
2	Oct. 23-	1	1	1.038	0.669	0
	Nov. 10,	1	1	1.040	0.671	1.5
	1967	2	2	1.052	1.358	0
		2	2	1.043	1.345	1.5
		3	3	1.052	2.036	0
		3	3	1.051	2.035	1.5
3	March 23-	3	3	0.136	0.262	0
	April 24,	3	3	0.134	0.259	1.5
	1968	6	6	0.129	0.498	0
		6	6	0.127	0.493	1.5
		9	9	0.132	0.769	0
		9	9	0.130	0.752	1.5
4	June 3-	6	6	0.186	0.722	0
	July 4,	6	6	0.185	0.716	0
	1968	6	6	0.188	0.728	0.5
		6	6	0.189	0.733	1.0
		6	6	0.187	0.725	2.0
		6	6	0.188	0.726	4.0
5	July 30-	5	5	0.284	0.917	0
	Aug. 30,	5	5	0.285	0.919	0
	1968	5	5	0.290	0.935	0.5
		5	5	0.293	0.945	1.0
		5	5	0.280	0.903	2.0
		5	5	0.295	0.951	4.0
6	Sept. 28-	2	2	0.252	0.324	0
	Oct. 30,	2	2	0.253	0.326	2.0
	1968	4	4	0.261	0.674	0
		4	3	0.240	0.6'8	2.0
		6	5	0.264	1.022	0
		6	4	0.268	1.040	2.0

platform suspended above each stream.

The stomach contents of groups of 24 fish were taken on five occasions during the course of the laboratory stream studies. The fish were left in the streams for one week before they were removed for analysis of their stomach contents. The contents were placed in a five percent formalin solution; later the food organisms were classified and their wet weights determined.

RESULTS AND INTERPRETATION

Invertebrate Fauna

Aquatic insect larvae of the groups Diptera, Ephemeroptera, Plecoptera, Trichoptera and Megaloptera were common organisms in the laboratory streams, but their biomass was small in comparison with that of the amphipod *Crangonyx* sp., which was the most abundant macro-invertebrate in the drift (Appendix II) and the benthos (Appendix III). The Megalopteran *Sialis* sp. emerged in the spring and was not observed in benthic samples after April 1968.

The biomass of amphipods in both control and treatment streams fluctuated markedly during the course of the study yet there were no consistent differences between the values for control streams and streams receiving a 1.5 percent SKME concentration (Figure 2, solid lines). Biomass values in this figure for the SKME streams after May 1968 are means of samples from streams receiving 1.5, 1.0, and 2.0 percent SKME (inverted triangles).

There was a general decrease in the numerical density of amphipods in both control and treatment streams from February until May 1968. This decline probably resulted from predation and export from the streams. Reproduction by *Crangonyx* began in May and June after which many young amphipods appeared in the drift and benthic samples (Appendix V). Differences in the numerical

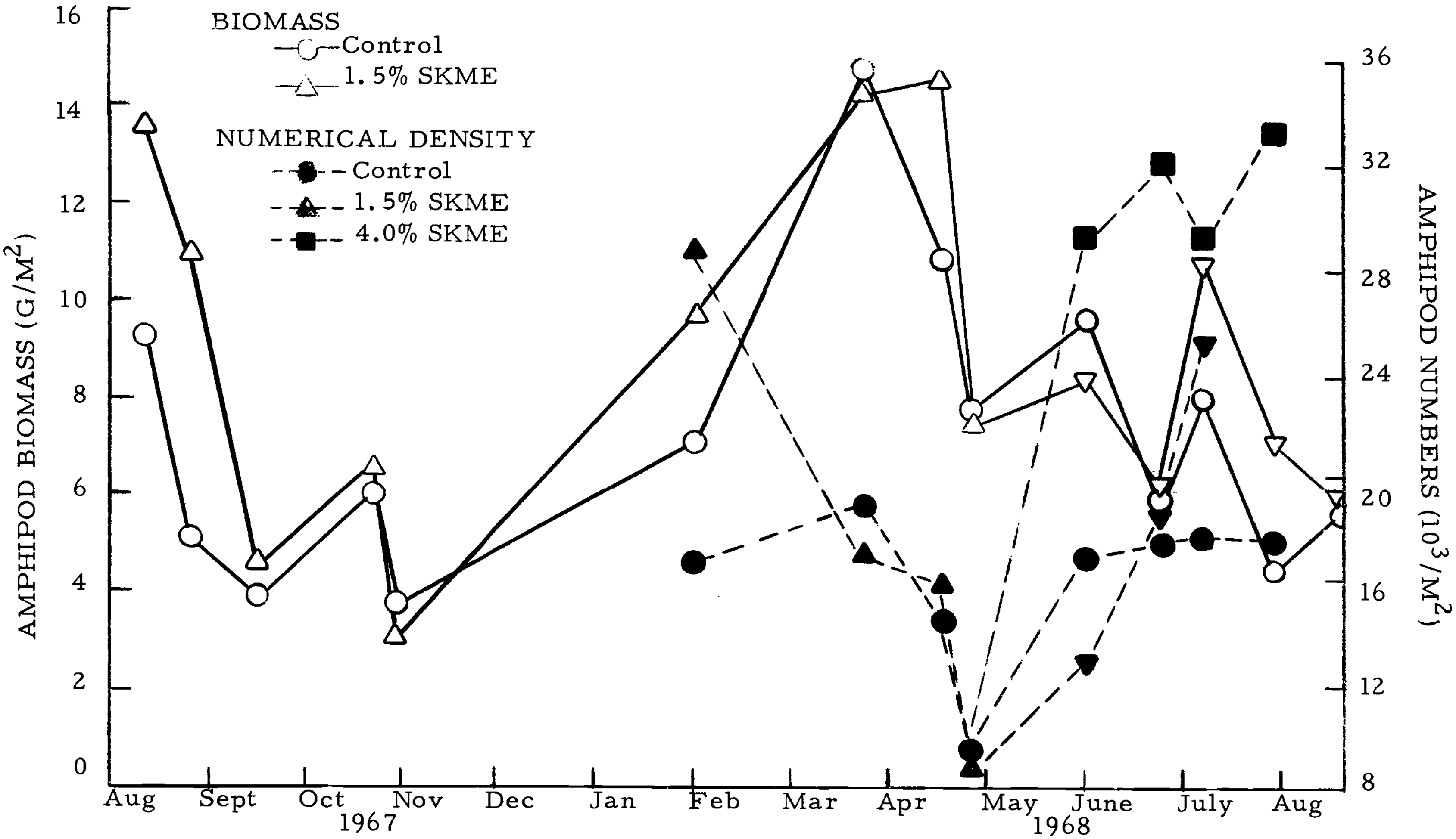

Figure 2. Biomasses and numerical densities of amphipods expressed as mean values for streams receiving 1.5 percent SKME, and for streams receiving 0.5, 1.0, and 2.0 percent SKME. Values for 4.0 percent SKME are based upon one stream.

density between control and treatment streams increased after May 1968 (Figure 2, dashed lines). The greatest increase was in the stream receiving 4.0 percent SKME. Amphipods less than 2 mm in length comprised 87 percent of the amphipod population in this stream by June 1968. Mean values of numerical density for streams receiving 0.5, 1.0, and 2.0 percent SKME were generally intermediate between those of controls and the 4.0 percent stream.

Salmon Growth Rate and Production

The growth rates of salmon stocked at different densities in streams receiving 1.5 percent SKME (Experiments 1, 2 and 3) were lower than those for salmon stocked in control streams (Appendix IV). This relationship is shown graphically in Figure 3 for Experiment 1 and 3. Growth rates decreased markedly with increased salmon biomass in both control and treatment streams in these experiments.

These differences in growth rate between the control and treatment streams can probably be attributed to a direct deleterious effect of the SKME on the salmon, since the food organisms were as abundant or in greater abundance in treatment streams than in control streams during Experiments 1, 2 and 3 (Table 2). Differences in the slopes of the relationships in Figure 3 are speculative considering the paucity of points and the fit of the curves to the data.

Salmon production was lower at comparable biomasses in

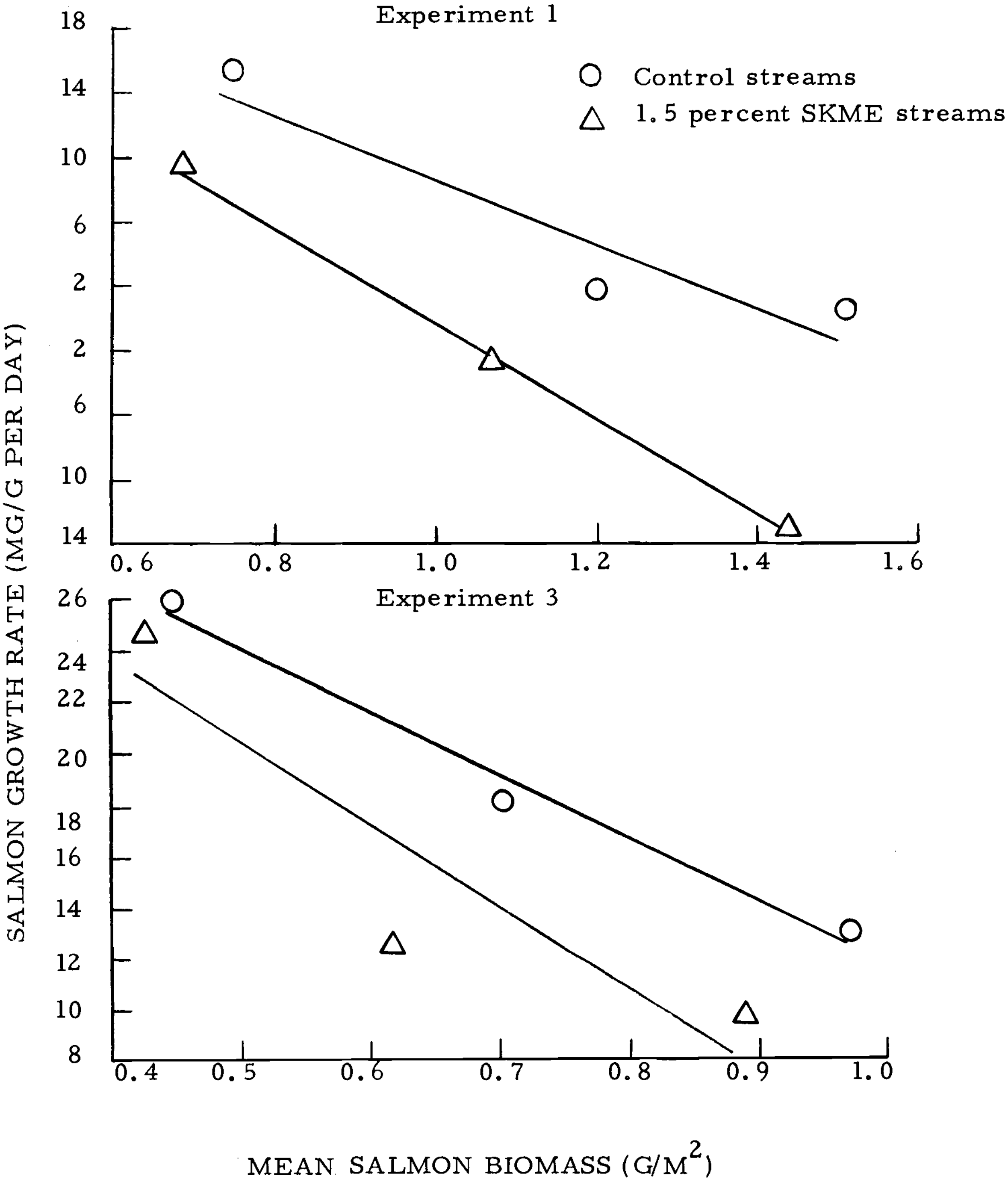

Figure 3. Relationship between salmon growth rate and mean salmon biomass for control and 1.5 percent SKME streams during Experiments 1 and 3.

Table 2. Mean biomass of benthic macro-invertebrates in grams per square meter of stream bottom for Experiments 1 through 5.

	Low salmon biomass		Intermediate salmon biomass		High salmon biomass	
Experiment	Control	1.5%	Control	1.5%	Control	1.5%
1	10.4206	10.8722	9.5921	12.5963	12.0183	13.5605
2	4.8590	5.6705	4.1410	4.5116	6.5594	4.8944
3	13.5193	13.8882	12.0898	10.1598	8.9165	13.5093
	SKME concentration in percent by volume					
Experiment	0	0	0.5%	1.0%	2.0%	4.0%
4	10.4708	7.1230	8.7837	11.7858	8.1411	8.0310
5	3.5678	8.6627	6.1181	9.6732	7.7694	9.8874

streams receiving 1.5 percent SKME than in control streams (Figure 4, Appendix III). There were greater differences in production between the control and treatment streams at high salmon biomasses in Experiments 1 and 3. During Experiments I and 2 some fish lost weight and negative values of production were recorded. The differences in production between these experiments can be related to differences in the salmon stocking levels and to seasonal changes in the abundance of food (Table 2).

The results of these production studies indicate SKME had a greater negative effect on fish production at high than at low salmon biomasses. The decrease in production at high salmon biomasses can not be attributed to food shortage (Table 2). Comparison of the level of salmon biomass at which production values would equal zero (Figure 4, Experiment 1) indicates that the control streams were capable of sustaining greater salmon biomasses than were treatment streams. A similar conclusion may be derived for Experiment 3.

The dashed portions of the curves in Figure 4 demonstrate the probable shape of the production function at low biomasses. Since production is the product of growth rate and mean biomass, values of production approach zero as mean biomass approaches zero.

Results of studies conducted during the summer of 1968 (Experiments 4 and 5) designed to test the effect of several concentrations of SKME on production of salmon stocked at similar densities in each stream, showed that production was greater in treatment

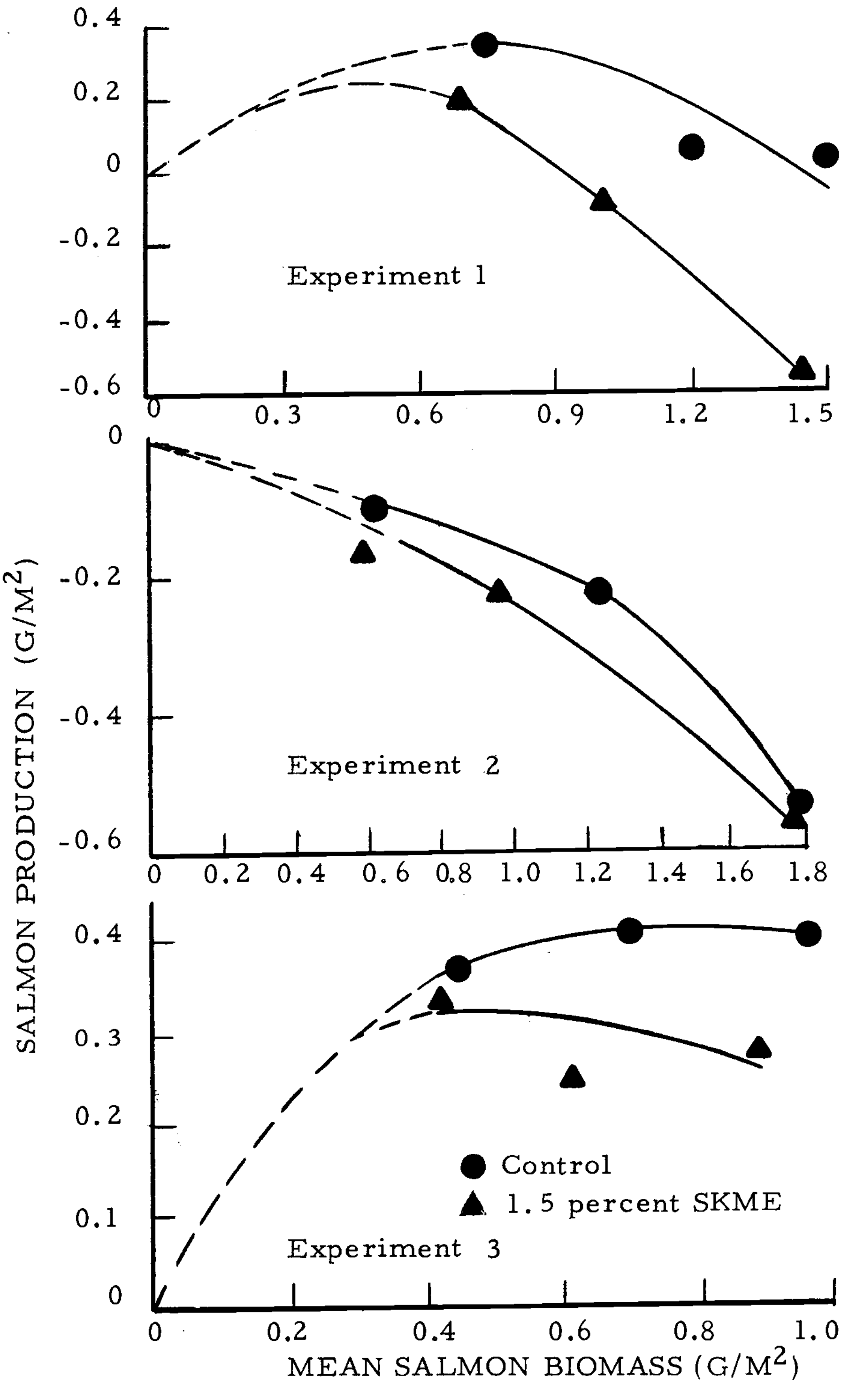

Figure 4. Relationship between salmon production and mean salmon biomass for control and 1.5 percent SKME streams during Experiments 1, 2 and 3. Duration of experiments was 30 days, 18 days and 32 days, respectively.

than in control streams (Figure 5). Production increased in streams receiving concentrations of up to one percent SKME, then generally declined with increasing concentrations. This decline may indicate a direct effect of SKME on the growth of salmon. The high growth rate at 1.0 percent SKME corresponds to high values of food density (Table 2). Lower values of production in Experiment 5 compared to Experiment 4 are attributed to the seasonal reduction in food density rather than to differences in the SKME from Mill A and Mill B.

Density Dependent Relationships

During Experiment 3 the biomass of drifting food organisms in both treatment and control streams was inversely related to salmon biomass (Figure 6). This relationship indicated that the basic capacity of the streams to produce food organisms was not impaired during this period by SKME at a concentration of 1.5 percent. Values relating salmon growth rate and the biomass of drifting food organisms during Experiment 3 were lower in treatment streams than in control streams (Figure 7). A similar but more highly correlated relationship resulted when salmon growth rate was plotted against the number of food organisms in the drift (Figure 8), even though there were differences in the sizes and kinds of organisms. These relationships suggest that SKME influenced the efficiency of food utilization for growth by the

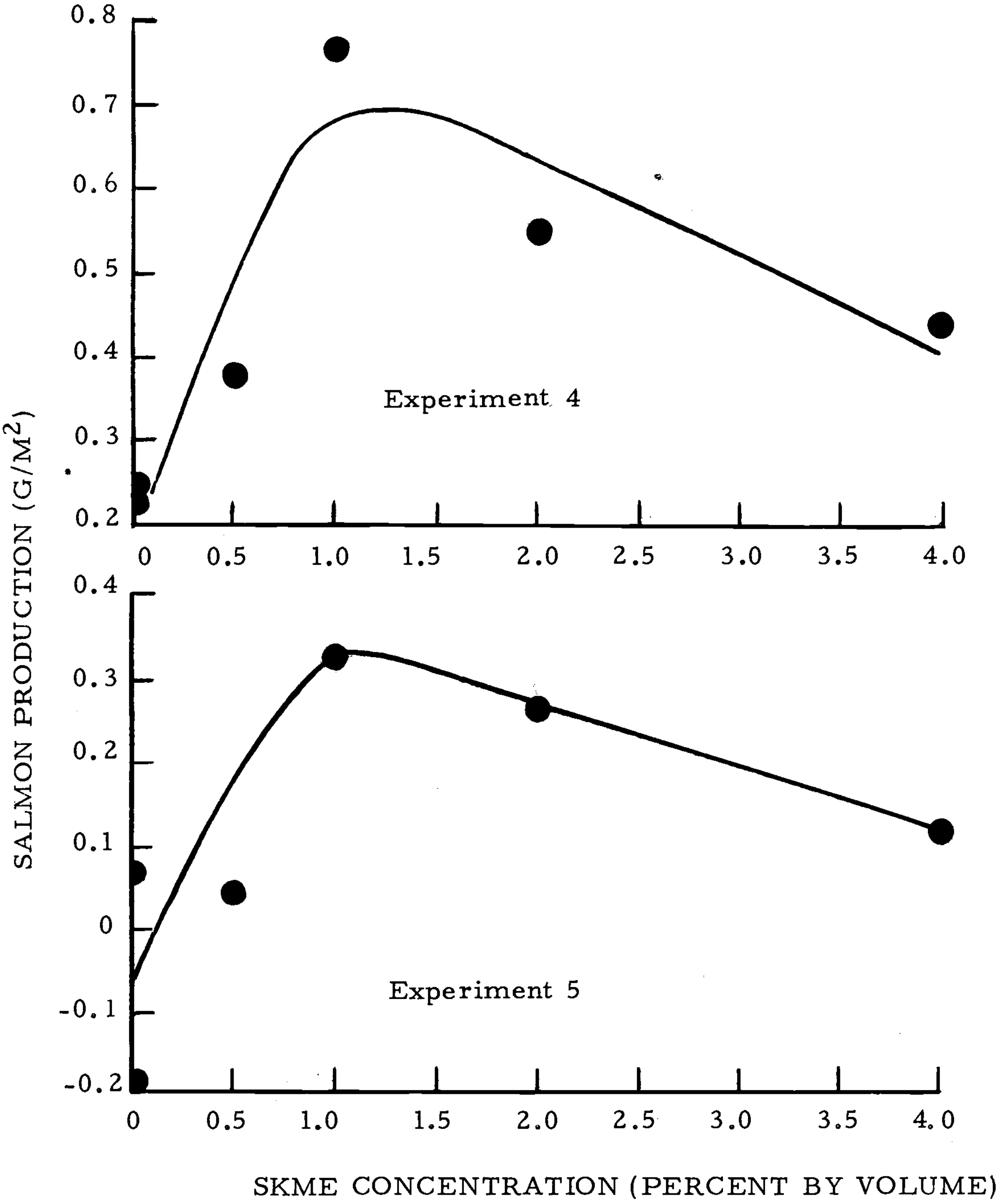

Figure 5. Relationship between salmon production and SKME concentration in laboratory streams during Experiments 4 and 5. The duration of each of these experiments was 32 days.

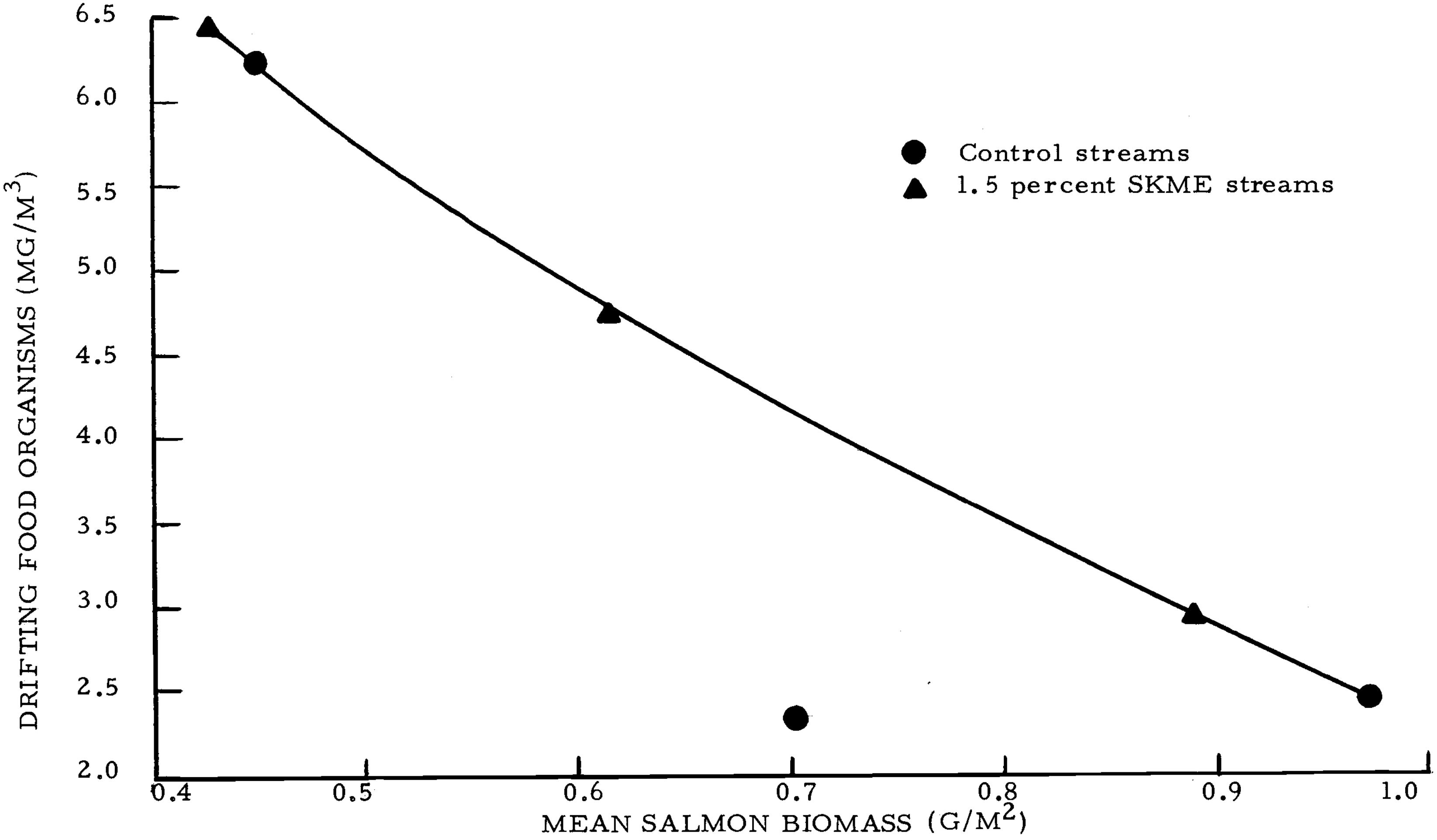

Figure 6. Relationship between the biomass of drifting food organisms and mean salmon biomass in control and 1.5 percent SKME streams during Experiment 3.

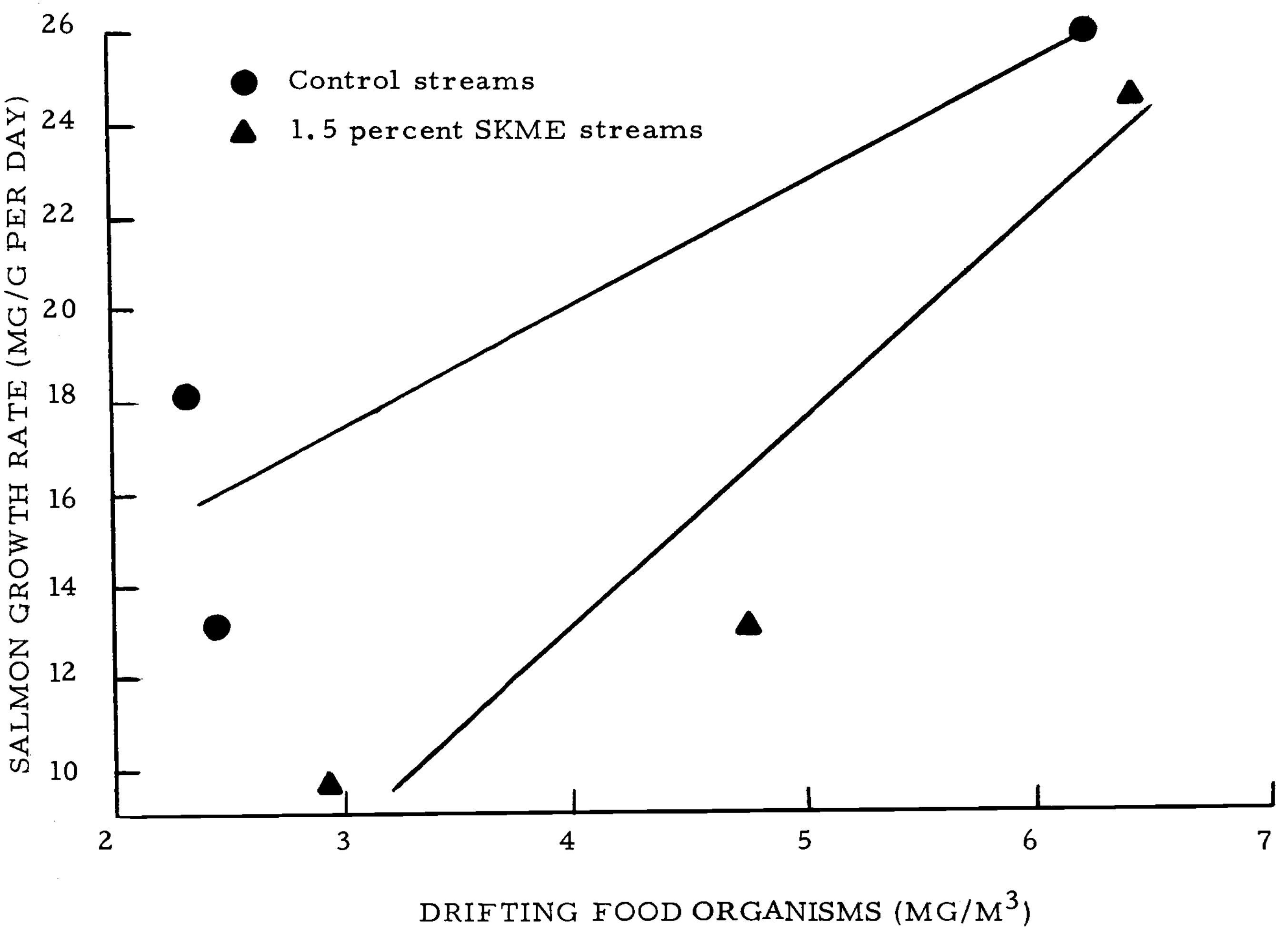

Figure 7. Relationship between salmon growth rate and the biomass of drifting food organisms for control and 1.5 percent SKME streams during Experiment 3.

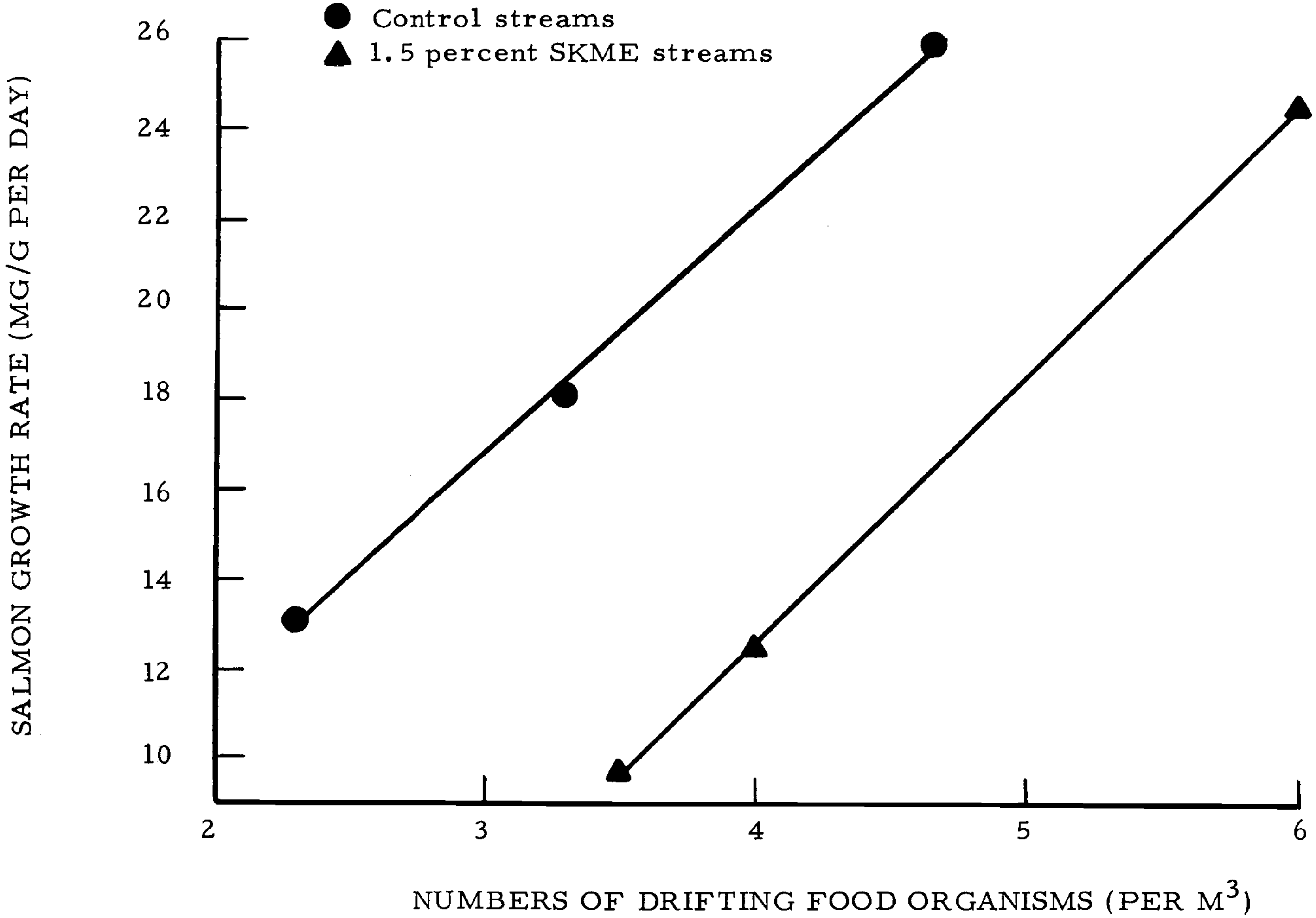

Figure 8. Relationship between salmon growth rate and the numbers of drifting food organisms in control and 1.5 percent SKME streams during Experiment 3.

salmon, since at comparable food densities, growth was greater in control than in treatment streams.

Values for the abundance of benthic organisms were variable during Experiments 4 and 5 and prevented the establishment of well-defined density dependent relationships. Nevertheless, salmon growth rate was found to be related to the abundance of drifting food organisms during Experiment 5 (Figure 9). This relationship does not indicate any deleterious effect of SKME on salmon growth rate during this period. Values for one of the control streams in Figure 9 is similar to values for the 0.5 and 4.0 percent SKME concentrations.

Experiment 6 was designed to determine if differences in feeding behavior could be related to the presence of SKME. Results of this experiment showed that the number of feeding attempts was inversely related to salmon biomass, and that lower numbers of feeding attempts per fish occurred in treatment than in control streams (Table 3). Since the differences between the streams in the abundance of drifting food organisms could have accounted for the differences in growth as well as in feeding attempts, the differences in feeding behavior could not be attributed to the presence of SKME.

Amphipods generally comprised 90 percent or more by weight of the contents of the salmon stomachs collected. The megalopteran Sialis sp., the coleopteran, Elmidae sp., and the case-bearing tricopterans were never observed in salmon stomachs. For this reason weights of these organisms collected in benthic samples were not included in the totaled values for food density.

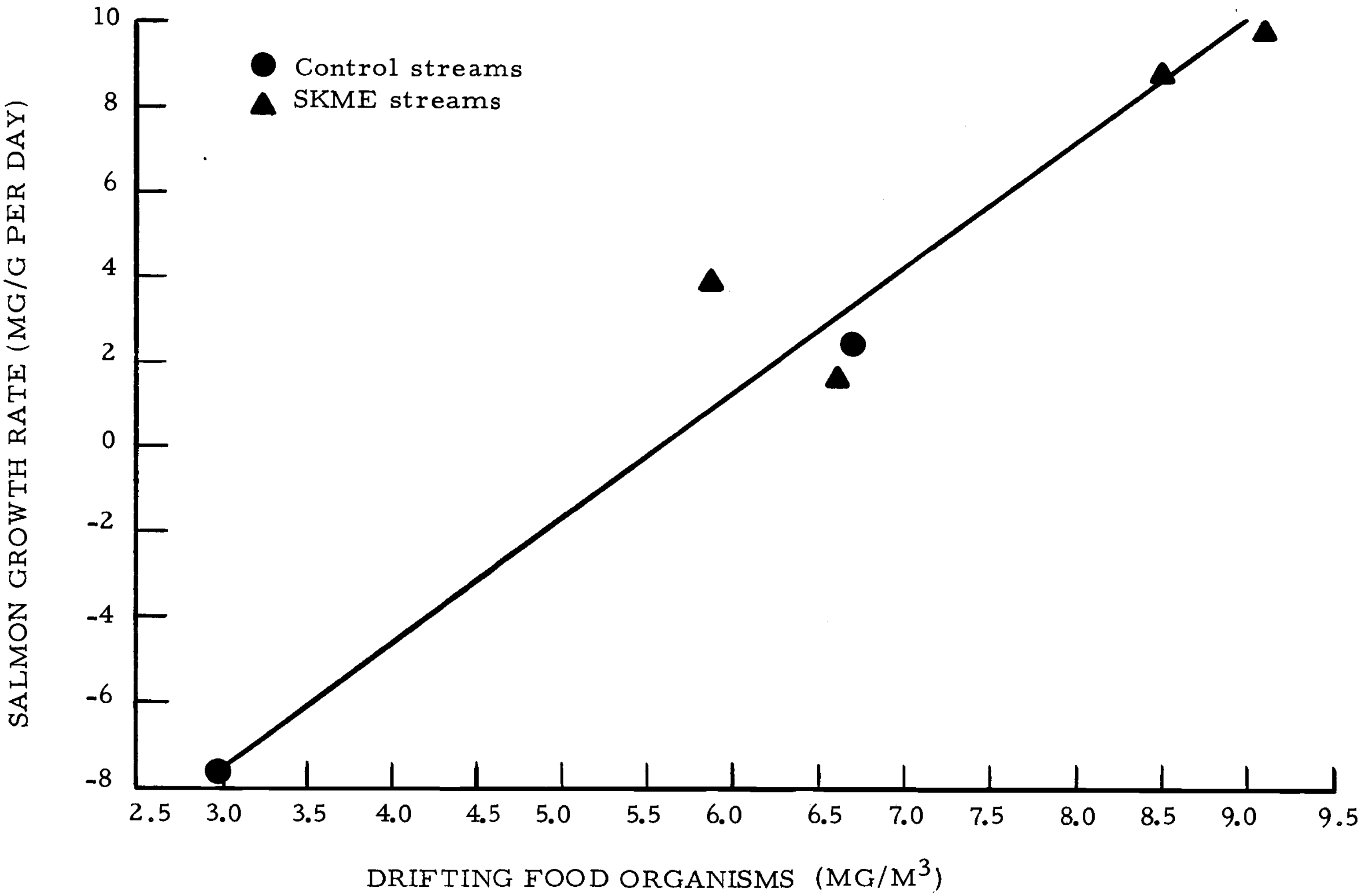

Figure 9. Relationship between salmon growth rate and the biomass of drifting food organisms in the laboratory streams during Experiment 5.

Table 3. Mean biomass, production, growth rate and mean feeding attempts for fish in laboratory streams during Experiment 6.

Treatment	Mean biomass (g/m^2)	Production (g/m^2)	Growth rate (mg/g per day)	Feeding attempts (per minute per fish)
Control	0.350	0.052	4.60	3.4
2.0% SKME	0.333	0.014	1.27	2.9
Control	0.610	-0.130	-6.65	2.7
2.0% SKME	0.551	-0.135	-7.67	2.0
Control	0.993	-0.188	-5.90	2.1
2.0% SKME	0.922	-0.235	-7.97	1.4

DISCUSSION

The results of studies on the effects of SKME on salmon stocked at different densities in the laboratory streams showed that exposure to the waste reduced the growth rate (Figure 3) and production (Figure 4) of the fish. Since food was not reduced in the treatment streams it was concluded that the waste had some direct effect on the fish.

A study of the relationship between rates of growth and food consumption for juvenile chinook salmon was performed during September 1967. The fish were kept in groups in aquaria at 0 and 1.5 percent SKME and fed at different rates. The results of this study (Figure 10) indicated that under these laboratory conditions there was no effect of SKME on the growth and food consumption of the fish. Further aquaria studies by Borton (1970) indicated that some batches of waste resulted in a depression of salmon growth while with other batches growth rates of exposed fish were not reduced even at 4.5 percent SKME. The different results between the laboratory stream studies and the aquarium studies suggests that there are important interactions in the complex stream communities that are not evident under aquarium conditions. In the laboratory streams the fish must seek out and capture food organisms, and the competition for food and space could be quite severe.

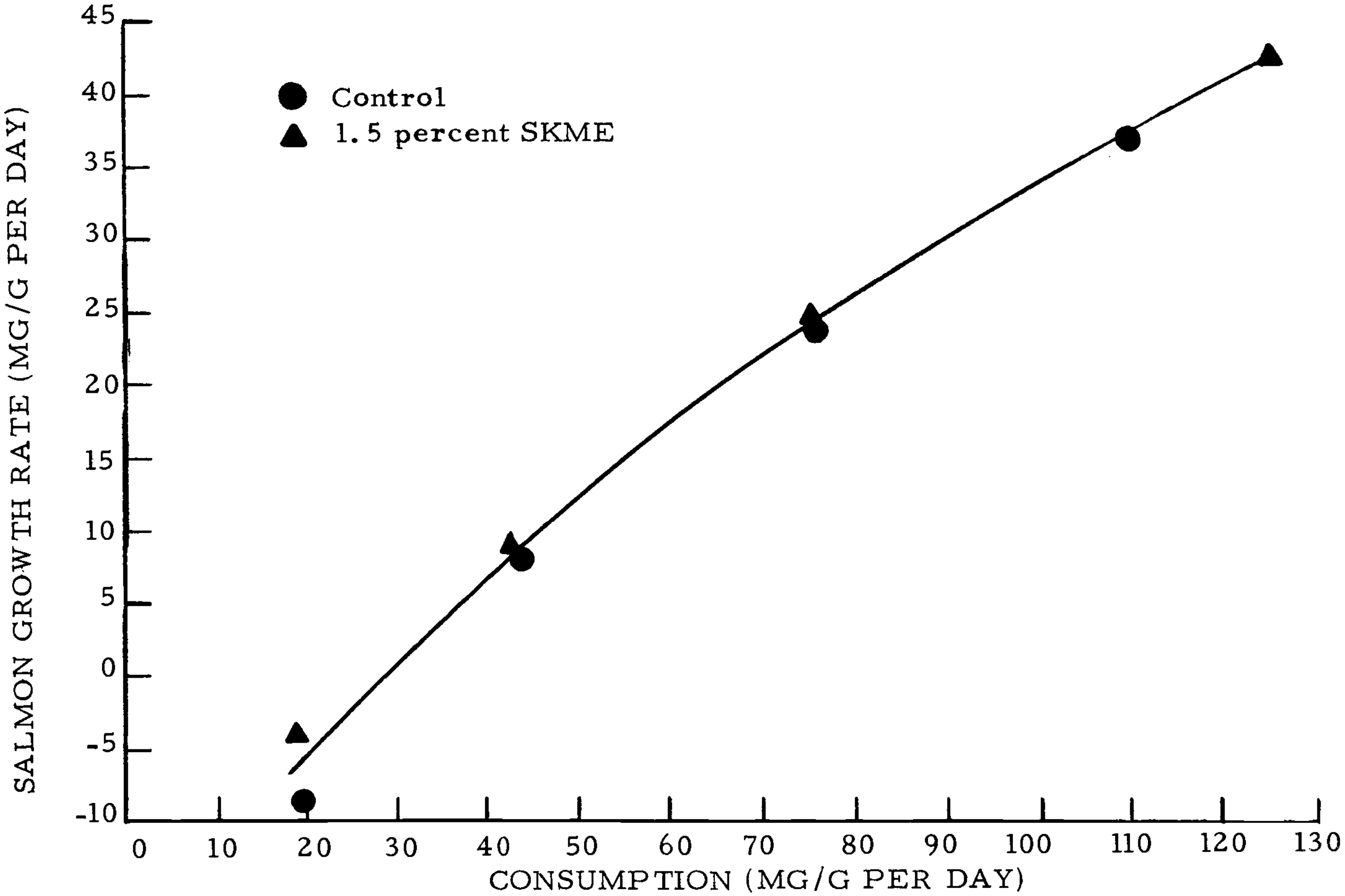

Figure 10. Relationship between rates of salmon growth and food consumption for groups of salmon kept in aquaria and fed different rations of tubificid worms.

Density dependent relationships have provided the basis for analyzing some of the observed differences in salmon production and growth rate in laboratory stream experiments. The result of Experiment 3 (Figure 7 and 8) show that at comparable food densities the growth rates of control fish were higher than those of fish in treatment streams. This difference was attributed to a direct effect on growth since it was shown there were no apparent differences in the basic productivity of the control and treatment streams. There was a single inverse relationship between the biomass of salmon and the biomass of drifting food organisms (Figure 6) for both control and treatment streams, indicating that the density of the prey was related to the density of the preditor in the same manner under both sets of conditions. That is, the density that the prey was able to maintain in the face of different levels of consumption by the preditor was the same in control and treatment streams. If the basic capacity of the streams to produce had been greatly different, the relationship between the biomasses of the preditor and the prey would have been direct rather than inverse.

This type of analysis was also applied to the results of Experiments 4 and 5. In these summer experiments salmon production was lower in control streams than in streams receiving SKME at concentrations up to 4.0 percent by volume. During these studies only one stocking density was used, and the changes of biomass, resulting from differences in growth rates in the different streams, were relatively small. Even with these small biomass differences a direct relationship occured between salmon biomass and the biomass of benthic organisms. The results for Experiment 5 (Figure 11) suggest that the capacity for food production was greater in streams receiving wastes at concentrations above 0.5 percent than in the control and 0.5 percent streams. The hypothetical relationships between salmon biomass and the biomass of food organisms within systems of similar productivity are shown as negatively sloped lines in Figure 11 (dashed lines).

Food density measurements suggest a positive influence of SKME on the Crangonyx populations during this summer period. Corroborative data from Ellis (1968) indicates that unstabilized waste (KME) ~~SKME~~ added at 1.5 percent by volume markedly increased the biomass of amphipods.

Data provided by Williams (1969) on algal biomass in the streams permitted some relationships to be established between the biomass of herbivorous organisms and the biomass of plant materials. The algal samples were taken for other purposes, which placed some restrictions on their usefullness for comparison with the herbivore density. Since the primary productivity in the laboratory stream communities could be expected to change throughout the year with changes in such factors as temperature and insolation, samples taken during one year should represent systems of different produc-

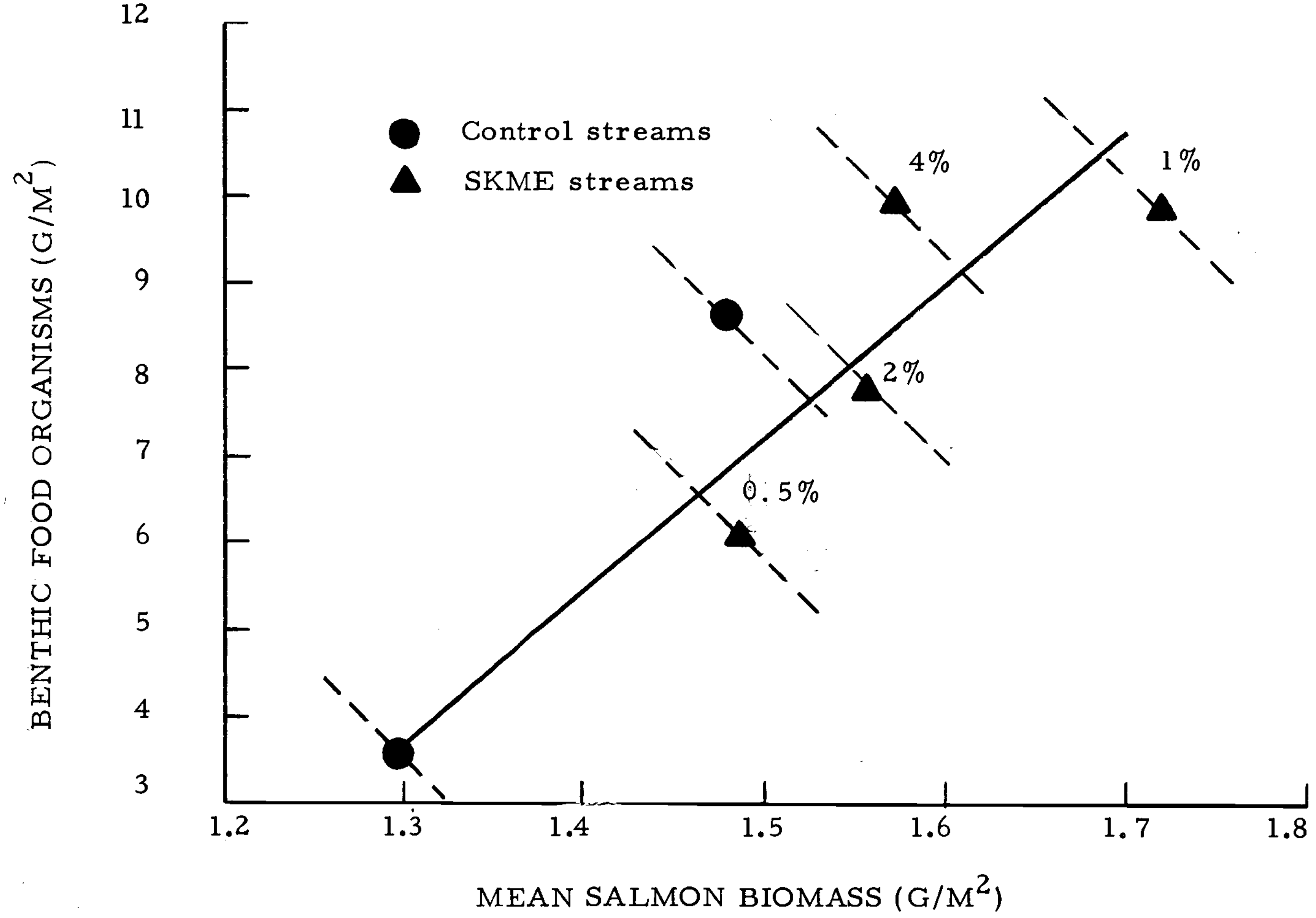

Figure 11. Relationship between biomass of benthic invertebrate organisms and mean salmon biomass demonstrating relationships between systems of similar productivity (dashed line) and between systems of different productivity (solid line).

tivity and should result in a direct relationship between consumer biomass and nutrient biomass if food is limiting. This relationship was not well defined, but in general the biomass of herbivores increased with increase of algal biomass (Figure 12, dashed lines). The few comparisons that could be made of values for samples collected at the same time period which represent streams of similar productivity are shown as negatively sloping lines in Figure 12.

Williams (1969) investigated the periphyton communities of the laboratory streams and found greater changes in community structure and function with stabilized KME than with raw KME. Williams postulated that nitrate and phosphate that was added in the stabilization process contributed to these changes. He noted increases in the abundance of the diatoms *Melosira varians*, *Rhiocosphenia curvata*, *Cocconeis placentula*, and the green algae *Oedogonium* sp. in streams receiving SKME from Mill A, and increases in *R. curvata* and *Oedogonium* sp. in streams receiving SKME from Mill B. A number of diatoms and the total diatom population was reduced by both raw and stabilized KME. Primary production was greater in streams receiving SKME during all seasons except winter.

The importance of these changes to the amphipod population is not understood. Detailed studies of the feeding habits of *Crangonyx* have not been pursued, but diatoms were found in the stomachs of amphipods in the laboratory streams.

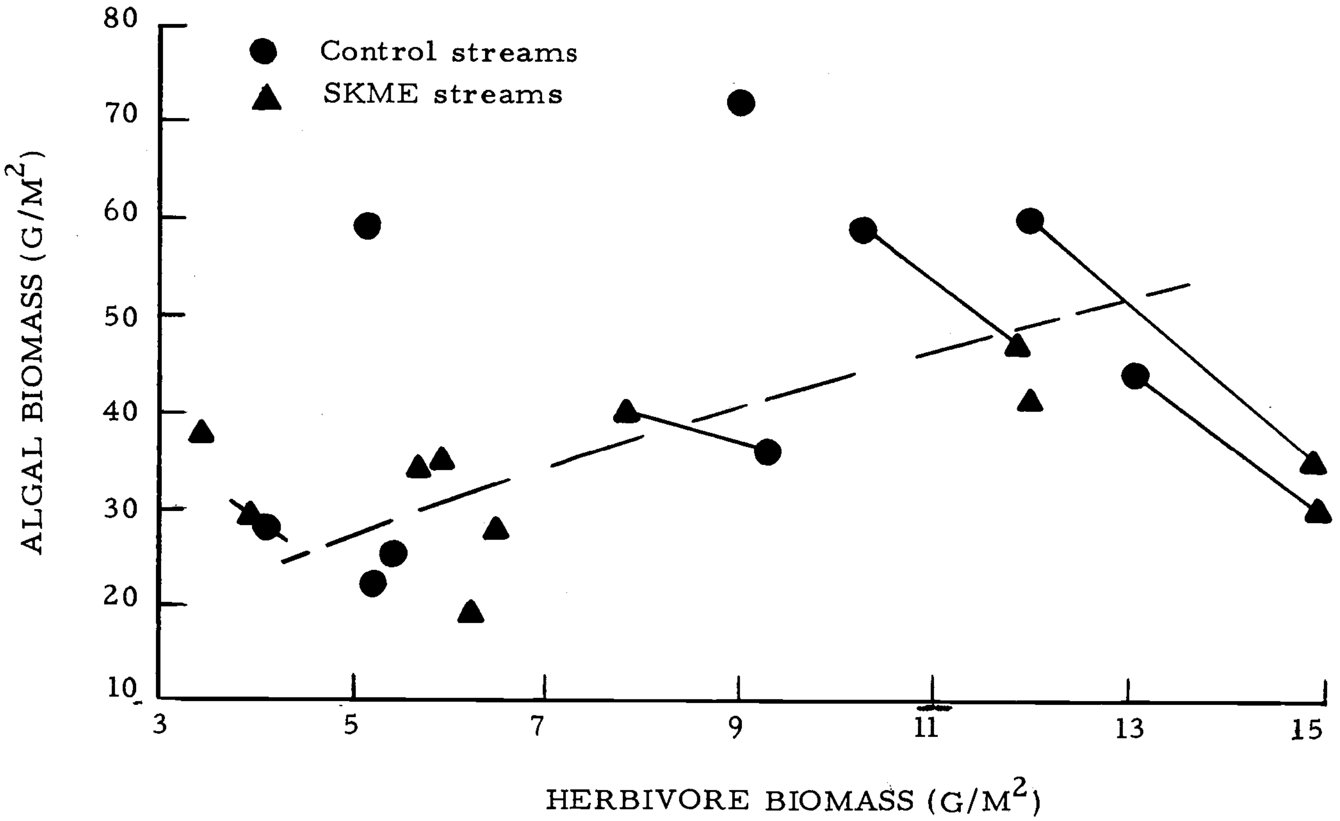

Figure 12. Relationship between algal biomass and herbivore biomass in the laboratory streams demonstrating relationships between systems of similar productivity (lines with negative slopes) and between systems of different productivity (positively sloped line).

In Experiment 4 salmon growth rate could not be correlated with the abundance of drifting food organisms and was correlated only generally with values of benthic food densities. The laboratory streams occasionally supported dense algal blooms followed by periods of heavy sloughing. Such high densities of algae may insulate food organisms from predation and reduce the living space for salmon, increasing social interactions. During Experiment 4 a control stream supported a dense bloom of a filamentous diatom. This may account for the relatively high biomass of benthic organisms in this stream in relation to fish growth, and the relatively low abundance of drifting organisms.

Measurements of salmon growth rate and production and food density in laboratory streams have provided a direct method of assessing the outcome of perhaps complex changes in the aquatic environment on salmon. Further study in such systems is needed to understand and possibly predict the effect on fisheries of the addition of sub-lethal concentrations of industrial wastes.

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APPENDICES

Appendix I. Five-day biochemical oxygen demand and chemical oxygen demand of kraft mill effluent before and after stabilization (Mill A).

Date	Before treatment		After treatment	
	BOD	COD	BOD	COD
July 12, 1967	183	512	6	---
July 17	135	431	5	---
July 26	170	---	8	---
August 2	156	422	6	---
August 9	156	439	5	---
August 16	135	481	8	---
August 23	188	---	2	---
August 30	138	---	1	---
September 6	192	---	7	---
September 13	143	---	3	---
September 20	184	---	0	71
September 27	191	594	0	122
October 11	174	481	--	---
October 18	201	412	5	---
October 25	252	442	3	78
November 1	214	436	3	70
November 8	195	473	2	75
November 22	262	716	10	---

Appendix I (Continued)

Date	Before treatment		After treatment	
	BOD	COD	BOD	COD
December 6	214	587	72	232
December 13	---	645	35	332
December 20	273	538	31	240
December 28	239	609	53	165
January 18, 1968	222	325	30	210
January 25	230	555	42	226
February 1	279	720	18	203
February 8	195	265	24	184
February 15	256	575	14	158
February 22	279	632	24	200
February 29	214	440	8	180
March 8	200	424	8	164
March 15	243	664	26	254
March 21	256	545	46	322
March 28	213	752	43	358
April 4	317	1008	55	396
April 12	224	675	53	349
April 18	279	719	90	365
April 26	245	674	7	195
May 16	236	608	15	226
May 23	246	731	15	227
May 26	220	644	15	---

Appendix I (Continued)

Date	Before treatment		After treatment	
	BOD	COD	BOD	COD
June 7	219	679	13	---
June 13	240	891	7	---
June 20	268	---	13	---

Appendix I (Continued)

Biochemical and chemical oxygen demand of kraft mill effluent from stabilization basin of Mill B.

Date	BOD	COD
July 3, 1968	72	183
July 11	43	252
July 18	44	224
July 25	24	123
August 1	20	90
August 8	9	63
August 15	35	67
August 22	--	--
August 29	--	--
September 5	19	220
September 12	37	131
September 19	26	116
September 26	28	66
October 4	34	145
October 8	40	215
October 16	69	193
October 22	52	121

Appendix II. Mean biomass of drifting food organisms in the laboratory streams for Experiments 1 through 6 expressed in milligrams per cubic meter.

Taxa	Low salmon biomass		Intermediate salmon biomass		High salmon biomass	
	Control	1.5%	Control	1.5%	Control	1.5%
Amphipods	7.7	8.5	3.8	6.6	9.1	11.0
Ephemeroptera	1.9	-	0.2	0.1	0.6	0.1
Diptera						
Chironomidae	4.7	5.2	3.8	3.7	3.6	4.7
Plecoptera	0.5	0.6	1.8	0.3	0.1	0.6
Terrestrial	0.2	0.1	0.1	0.6	0.6	-
Other	0.9	1.3	1.6	0.3	1.5	1.3
Total	15.9	15.7	11.3	11.6	15.5	17.7

Based on seven 24-hour sample periods taken between August 17, and September 12, 1967 for Experiment 1.

Amphipoda	1.1	2.7	6.7	3.0	2.5	3.9
Ephemeroptera	0.1	-	0.1	-	-	0.1
Diptera						
Chironomidae	-	0.1	0.1	0.1	0.1	0.5
Terrestrial	0.1	-	0.1	-	-	-
Other	0.1	-	0.6	0.1	-	-
Total	1.4	2.8	7.6	3.2	2.6	4.5

Based on four 24-hour sample periods taken between October 25 and November 8, 1967 for Experiment 2.

Amphipoda	5.8	5.6	1.7	3.1	1.8	2.6
Ephemeroptera	0.3	0.3	0.1	1.3	0.3	-
Diptera						
Chironomidae	0.1	0.1	0.4	0.3	0.2	0.2
Plecoptera	-	0.4	-	-	-	-
Other	0.1	1.4	0.7	0.1	0.2	0.3
Total	6.3	7.8	2.9	4.8	2.5	3.1

Based on five 24-hour sample periods taken between March 26, and April 23, 1968 for Experiment 3.

Appendix II. (continued)

Taxa	SKME concentration					
	0	0	0.5%	1.0%	2.0%	4.0%
Amphipoda	2.7	4.9	5.1	3.0	5.9	2.2
Ephemeroptera	0.6	0.3	0.2	0.2	0.1	0.5
Diptera Chironomidae	0.5	0.4	0.3	1.0	0.6	1.0
Plecoptera	-	0.1	-	-	-	0.2
Trichoptera	-	-	-	3.4	0.8	1.6
Other	-	-	-	0.1	0.1	1.1
Total	3.8	5.7	5.6	7.7	7.5	6.6

Based on six 24-hour sample periods taken between June 3, and July 4, 1968 for Experiment 4.

Amphipoda	2.4	6.2	5.0	8.7	7.1	4.7
Ephemeroptera	0.1	0.1	0.6	0.2	0.6	0.3
Diptera Chironomidae	0.2	0.2	0.1	0.1	0.3	0.3
Plecoptera	-	-	0.5	-	-	-
Terrestrial	0.1	0.2	0.2	0.1	0.5	0.1
Other	0.1	-	-	-	-	0.4
Total	2.9	6.7	6.4	9.1	8.5	5.8

Based on seven 24-hour sample periods taken between August 1, and August 30, 1968 for Experiment 5.

Appendix II. (continued)

Taxa	Low salmon biomass		Intermediate salmon biomass		High salmon biomass	
	Control	2.0%	Control	2.0%	Control	2.0%
Amphipoda	5.7	0.7	1.8	2.0	1.9	1.8
Ephemeroptera	-	0.2	0.1	-	0.1	0.1
Diptera Chironomidae	-	0.3	0.1	0.1	0.2	0.1
Plecoptera	-	0.3	0.1	-	0.1	-
Other	-	0.2	0.1	-	0.2	-
Total	5.7	1.7	2.2	2.1	2.5	2.0

Based on five 24-hour sample periods taken between September 28, and October 30, 1968 for Experiment 6.

Appendix III. Mean biomass of benthic macro-invertebrates in the laboratory streams during Experiments 1 through 5 expressed in grams per square meter of stream bottom.

Taxa	Low salmon biomass		Intermediate salmon biomass		High salmon biomass	
	Control	1.5%	Control	1.5%	Control	1.5%
Experiment 1. Based on 0.093 square meter samples collected on August 11, August 25, and September 15, 1967.						
Amphipoda						
Gammaridae						
Crangonyx	6.9185	8.5030	5.7409	9.9902	5.7350	10.6226
Ephemeroptera						
Baetidae						
Baetis	--	0.0018	0.0144	--	0.0167	--
Parleptophlebia	0.4527	0.0832	0.8744	0.1785	0.7302	0.0549
Heptageniidae						
Cinygmula	--	--	0.0126	--	--	--
Heptagenia	--	0.1048	--	0.0384	--	--
Diptera						
Chironomidae	1.4588	1.0534	1.3176	1.2241	1.4949	1.6229
Tipulidae	0.0965	0.0072	--	0.0428	0.0094	0.1116
Simulidae	0.0312	0.0144	0.0614	0.0228	0.9855	0.2429
Other Diptera	0.0082	0.0664	0.3882	0.0751	0.0189	0.2982
Trichoptera						
Hydropsychidae	0.0445	--	--	--	--	--
Limnephilidae*	--	--	0.0025	--	0.0189	--
Lepidostomatidae*	--	0.0233	0.0072	--	--	--
Plecoptera						
Chloroperlidae	0.0172	0.3624	0.0359	--	0.0018	--
Nemouridae	1.3413	0.6652	0.9677	1.0177	2.8775	0.5034
Perlidae	--	--	0.1460	--	0.1340	0.0861
Perlodidae	0.0517	0.0104	0.0226	0.0067	0.0044	0.0108
Leuctridae	--	--	0.0104	--	0.0100	0.0072
Coleoptera						
Elmidae*	0.0047	0.0050	0.0036	0.0005	0.0078	0.0025
Megaloptera						
Sialidae						
*Sialis**	0.5673	0.3703	0.0222	0.4061	0.0645	0.5102
Total	10.4206	10.8722	9.5921	12.5963	12.0183	13.5606

* Not included in the total.

Appendix III. (continued)

Taxa	Low salmon biomass		Intermediate salmon biomass		High salmon biomass	
	Control	1.5%	Control	1.5%	Control	1.5%
Experiment 2. Based on 0.093 square meter samples collected on October 23 and November 10, 1967.						
Amphipoda						
Gammaridae						
Crangonyx	4.4660	5.5392	4.0080	4.4192	6.2625	4.7716
Ephemeroptera						
Baetidae						
Baetis	0.0054	0.0425	0.0027	0.0010	--	0.0070
Paraleptophlebia	0.0156	0.0054	0.0016	0.0064	0.0936	--
Heptageniidae						
Heptagenia	0.0026	--	0.0076	--	--	--
Diptera						
Chironomidae	0.0819	0.0393	0.0200	0.0759	0.0549	0.0678
Helodidae	0.0054	--	--	--	0.0430	--
Trichoptera						
Hydropsychidae	0.0463	--	0.0710	--	0.0500	0.0388
Limnephilidae*	--	--	0.0850	--	0.0452	--
Lepidostomatidae*	--	--	0.0167	--	--	0.0442
Plecoptera						
Chloroperlidae	0.0156	0.0027	0.0086	0.0048	--	--
Nemouridae	0.0808	0.0016	0.0215	0.0043	0.0404	0.0092
Perlodidae	0.1394	0.0398	--	--	0.0150	--
Coleptera						
Elmidae*	0.0134	0.0092	--	0.0113	0.0161	--
Megaloptera						
Sialidae						
*Sialis**	0.6808	0.4316	0.1776	0.7454	--	0.4558
Total	4.8590	5.6705	4.1410	4.5116	6.5594	4.8944

* Not included in the total

Appendix III. (Continued)

Taxa	Low salmon biomass		Intermediate salmon biomass		High salmon biomass	
	Control	1.5%	Control	1.5%	Control	1.5%
Experiment 3. Based on 0.093 square meter samples collected on March 23, April 17 and April 26, 1968.						
Amphipoda						
Gammaridae						
Crangonyx	13.2207	13.6725	11.6097	9.8527	8.6600	12.8867
Ephemeroptera						
Baetidae						
Baetis	--	0.0330	--	0.0007	--	0.0068
Paraleptophlebia	0.0775	0.0154	0.1152	0.0524	0.0172	0.2508
Heptageniidae						
Cinygmula	0.0298	0.0280	--	0.0108	--	0.0359
Heptagenia						0.2034
Epeorus	--	0.0151	--	--	--	--
Siphlonuridae						
Ameletus	--	--	0.0919	--	--	--
Diptera						
Chironomidae	0.1306	0.1094	0.1407	0.1317	0.1937	0.0994
Helodidae	--	--	--	0.0007	--	0.0033
Tipulidae	0.0072	--	--	--	0.0011	--
Simulidae	--	--	--	0.0039	0.0237	--
Trichoptera						
Hydropsychidae	--	--	0.0721	--	--	--
Lepidostomatidae*	--	--	--	--	0.0165	--
Rhyacophilidae	--	--	0.0373	0.0111	--	--
Plecoptera						
Chloroperlidae	0.0427	0.0072	0.0154	0.0133	0.0097	0.0140
Nemouridae	0.0004	0.0007	--	--	--	--
Perlidae	0.0104	--	--	0.0725	0.0111	0.0090
Perlodidae	--	0.0047	--	--	--	--
Leuctridae	--	0.0022	0.0075	0.0108	--	--
Coleoptera						
Elmidae*	0.0040	0.0025	0.0047	0.0079	0.0025	0.0026
Megaloptera						
Sialidae						
*Sialis**	--	--	--	0.1514	--	0.2540
Total	13.5193	13.8882	12.0898	10.1598	8.9165	13.5093

* Not included in the total

Appendix III. (continued)

Taxa	SKME concentration					
	0	0	0.5%	1.0%	2.0%	4.0%
Experiment 4. Based on 0.093 square meter samples collected on June 1, June 24, and July 7, 1968.						
Amphipoda						
Gammaridae						
Crangonyx	9.7285	6.0573	7,6399	10,5667	7,3414	7,3220
Ephemeroptera						
Baetidae						
Baetis	0.0039	0.0265	0.0832	0.0355	0.0481	0.0352
Paraleptophlebia	0.0136	0.0359	0.1048	0.1274	0.0983	0.1087
Heptageniidae						
Cinygmula	0.0151	0.0531	0.0176	0.0108	0.0190	--
Epeorus	--	--	0.0036	--	0.0276	--
Diptera						
Chironomidae	0.7046	0.8442	0.8023	0.9784	0.5787	0.5529
Tipulidae	0.0011	0.0205	--	--	0.0233	--
Trichoptera						
Hydropsychidae	--	--	0.0692	--	--	--
Limnephilidae*	--	0.0014	--	0.1023	--	--
Lepidostomatidae*	0.0610	0.0014	--	--	--	--
Plecoptera						
Chloroperlidae	0.0029	0.0258	0.0344	0.0161	0.0029	0.0043
Nemouridae	0.0011	0.0230	0.0129	0.0093	0.0018	0.0043
Perlidae	--	0.0294	0.0158	0.0416	--	0.0036
Leuctridae	--	0.0036	--	--	--	--
Perlodidae	--	0.0046	--	--	--	--
Coleoptera						
Elmidae*	0.0122	0.0079	0.0047	0.0029	0.0014	--
Total	10,4708	7.1203	8.7837	11.7858	8.1411	8.0310

* Not included in the totals

Appendix III. (continued)

Taxa	SKME concentration					
	0	0	0.5%	1.0%	2.0%	4.0%
Experiment 5. Based on 0.093 square meter samples collected on July 30 and August 20, 1968.						
Amphipoda						
Gammaridae						
Crangonyx	2.8396	7.3319	4.8394	8.7775	6.2090	8.2178
Ephemeroptera						
Baetidae						
Baetis	0.0172	0.0554	0.0690	0.0011	0.0156	0.0044
Paraleptophlebia	--	0.0183	0.0027	0.0507	0.0318	0.0306
Heptageniidae						
Cinygmula	--	0.0022	--	0.0016	--	0.0097
Heptagenia	0.0092	--	--	--	--	--
Diptera						
Chironomidae						
Chironomus	0.0016	0.0920	0.1630	0.2271	0.6071	0.5711
Other Chironomidae	0.5426	1.0710	0.9660	0.6206	0.8692	0.9064
Dixidae	--	0.0054	--	--	--	--
Tipulidae	--	0.0452	--	0.0290	0.0064	--
Trichoptera						
Lepidostomatidae*	--	0.0011	--	--	--	0.0032
Limnephilidae*	0.0054	--	--	0.1130	--	--
Rhyacophilidae	--	--	--	--	--	0.0027
Psychomiidae	--	--	--	--	--	0.1022
Plecotera						
Chloroperlidae	0.0048	0.0204	0.0441	0.0092	0.0059	0.0064
Nemouridae	--	--	0.0307	0.0076	0.0242	0.0199
Perlidae	0.1480	0.0145	0.0032	--	--	--
Leuctridae	--	--	--	--	--	0.0162
Odonata						
Gomphidae	0.0048	0.0064	--	0.0388	--	--
Coleoptera						
Elmidae*	0.0194	0.0140	0.0108	0.0269	0.0086	0.0102
Total	3.5678	8.6627	6.1181	9.7632	7.7694	9.8874

* Not included in the total

Appendix IV. Mean biomass, production and growth rate for salmon during Experiments 1 through 5.

Treatment	Mean biomass (g/m^2)	Production (g/m^2)	Growth rate (mg/g per day)
Experiment 1			
Control	0.751	0.348	15.46
Control	1.201	0.065	1.81
Control	1.513	0.029	0.06
1.5%	0.693	0.201	9.68
1.5%	1.072	-0.089	-2.79
1.5%	1.441	-0.562	-13.00
Experiment 2			
Control	0.619	-0.102	-9.12
Control	1.244	-0.228	-10.20
Control	1.768	-0.535	-16.82
1.5%	0.585	-0.171	-16.26
1.5%	0.962	-0.226	-13.07
1.5%	1.755	-0.561	-17.91
Experiment 3			
Control	0.449	0.373	25.99
Control	0.703	0.409	18.18
Control	0.972	0.406	13.06
1.5%	0.427	0.336	24.63
1.5%	0.617	0.247	12.52
1.5%	0.890	0.277	9.71
Experiment 4			
Control	1.312	0.249	6.13
Control	1.288	0.230	5.76
0.5%	1.423	0.380	8.61
1.0%	1.732	0.769	14.32
2.0%	1.555	0.556	11.54
4.0%	1.467	0.440	9.68
Experiment 5			
Control	1.299	-0.192	-7.63
Control	1.479	0.070	2.45
0.5%	1.487	0.049	1.70
1.0%	1.719	0.328	9.85
2.0%	1.562	0.267	8.85
4.0%	1.568	0.120	3.97

Appendix V. Estimated numerical density per square meter of stream bottom of three size groups and mean weight in milligrams of amphipods in the laboratory streams.

Date	Treatment	Salmon Biomass	Size Group			Total	Mean weight (mg)
			>4 mm	2-4 mm	<2 mm		
Feb. 1, 1968	Control	Low	775	15500	4456	20731	0.41
		Medium	775	7363	4650	12788	0.48
	1.5%	Low	1356	19569	10656	31582	0.35
		Medium	1162	17050	7944	26156	0.36
March 23,	Control	Low	1668	14822	6394	22884	0.76
		Medium	1292	11044	6910	19246	0.76
		High	1485	9784	3584	14854	0.84
	1.5%	Low	1787	10366	3584	15737	1.02
		Medium	1324	10172	6394	17890	0.72
		High	1561	11625	4359	17545	0.80
April 17,	Control	Low	1851	8428	5813	16092	0.85
		Medium	1464	7492	6200	15156	0.70
		High	1076	5231	5942	12249	0.68
	1.5%	Low	2422	10807	5500	18729	0.90
		Medium	1346	3940	4844	10129	0.94
		High	2400	9978	6781	19160	0.92
April 26,	Control	Low	1302	4941	2616	8859	0.96
		Medium	1033	5296	6394	12723	0.76
		High	829	3423	2777	7029	0.73
	1.5%	Low	1259	5813	2131	9203	0.88
		Medium	1119	4392	3875	9386	0.78
		High	1324	4456	2325	8105	0.86
June 1,	Control	-	969	6588	9494	17050	0.68
		-	592	5716	10463	16771	0.45
	0.5%	-	915	6200	8525	15640	0.54
	1.0%	-	1195	3778	6006	10979	0.71
	2.0%	-	1023	4553	7072	12648	0.70
	4.0%	-	861	3444	11431	15736	0.41
June 24,	Control	-	624	3972	5813	10409	0.53
		-	700	3875	19860	24434	0.27
	0.5%	-	678	3972	14725	19375	0.37
	1.0%	-	1023	3778	16081	20882	0.36
	2.0%	-	366	2422	12788	15576	0.27
	4.0%	-	484	3584	27997	32066	0.18
July 7,	Control	-	840	12497	9881	23218	0.52
		-	194	3488	8331	12013	0.35
	0.5%	-	700	3972	13563	18235	0.40
	1.0%	-	1485	6878	23347	31710	0.52
	2.0%	-	1033	5522	18988	25543	0.35
	4.0%	-	409	3778	25091	29278	0.34
July 30	Control	-	678	7072	9784	17534	0.40
	4.0%	-	1162	9978	22185	33325	0.34

Appendix VI. Food comsumption, mean biomass and growth rate of salmon in aquaria during Experiment 6.

Treatment	Ration	Food consumed (mg/g per day)	Mean biomass (g)	Growth rate (mg/g per day)
Control	Low restricted	19.62	3.348	-8.46
1.5%	Low restricted	18.51	3.550	-3.82
Control	Medium restricted	44.26	3.710	8.14
1.5%	Medium restricted	42.80	3.836	9.24
Control	High restricted	75.60	4.492	23.81
1.5%	High restricted	75.49	4.499	24.84
Control	Unrestricted	110.44	5.018	36.97
1.5%	Unrestricted	125.31	5.254	42.61