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RADIOLOGICAL SCIENCES DEPARTMENT

EFFECT OF HANFORD PILE EFFLUENT UPON AQUATIC INVERTEBRATES IN THE COLUMBIA RIVER

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Experimental Biology and Medicine

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EFFECT OF HANFORD PILE EFFLUENT UPON AQUATIC INVERTEBRATES IN THE COLUMBIA RIVER

By

Jared J. Davis and Calvin L. Cooper

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HANFORD WORKS
RICHLAND, WASHINGTON

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ABSTRACT

This is the preliminary report of a radiological-ecological survey of the invertebrate fauna that inhabit the Columbia River within the confines of Hanford Works and downstream to the site of McNary Dam. The survey was carried out during the period of October, 1948 through February, 1950. Materials and methods are discussed and the results of extensive radioassays, qualitative and quantitative biological determinations, and hydrographic studies are given and analyzed. Twelve figures and twenty-three tables are included.

All aquatic invertebrates were found to be concentrating radioactivity from the river water. A maximum activity density of 4.4×10^{-3} $\mu c/g$ wet weight was found in the larvae of midges (Hydrobaeninae) collected near Hanford during September, 1949. Radioactive wastes were not found to be causing any apparent deleterious effects to the natural invertebrate fauna. Existing population variations are caused by biological and hydrographic conditions.

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EFFECT OF HANFORD PILE EFFLUENT UPON AQUATIC INVERTEBRATES IN THE COLUMBIA RIVER

INTRODUCTION

Determination of the effects of Hanford Works pile effluents on the Columbia River biota and determination of the extent of radiation hazard in these organisms are a part of the responsibility of the Aquatic Biology Group. A radiological-ecological study of the Columbia River is an essential part of the over-all program designed to fulfill this responsibility. Systematic sampling of river fish was initiated early in 1946 (1, 2) and was followed in the fall of 1947 by precursory sampling of benthos and plankton (3). These early studies demonstrated the importance of lower organisms as concentrators of radioactive materials and field studies were consequently intensified in the fall of 1948. This document reports the findings of field studies made upon macroscopic, bottom-dwelling invertebrate fauna of the Columbia River during the period from October, 1948 through February, 1950.

Sampling was disrupted during the spring freshet periods because of limited collecting facilities. Studies on crayfish have been omitted from this report since they are to be covered by another author at a later date.

METHODS

Selection and location of collection sites

When work was initiated upon the faunal benthos the same collecting sites were utilized that had been used during the past (3). These included a control station located at the western boundary of the Hanford Reservation, which is upstream from all pile areas, one station below each of the then existing pile areas, one near the 300 Area, one at Richland, and one near Pasco, (see Figure 1). Sampling

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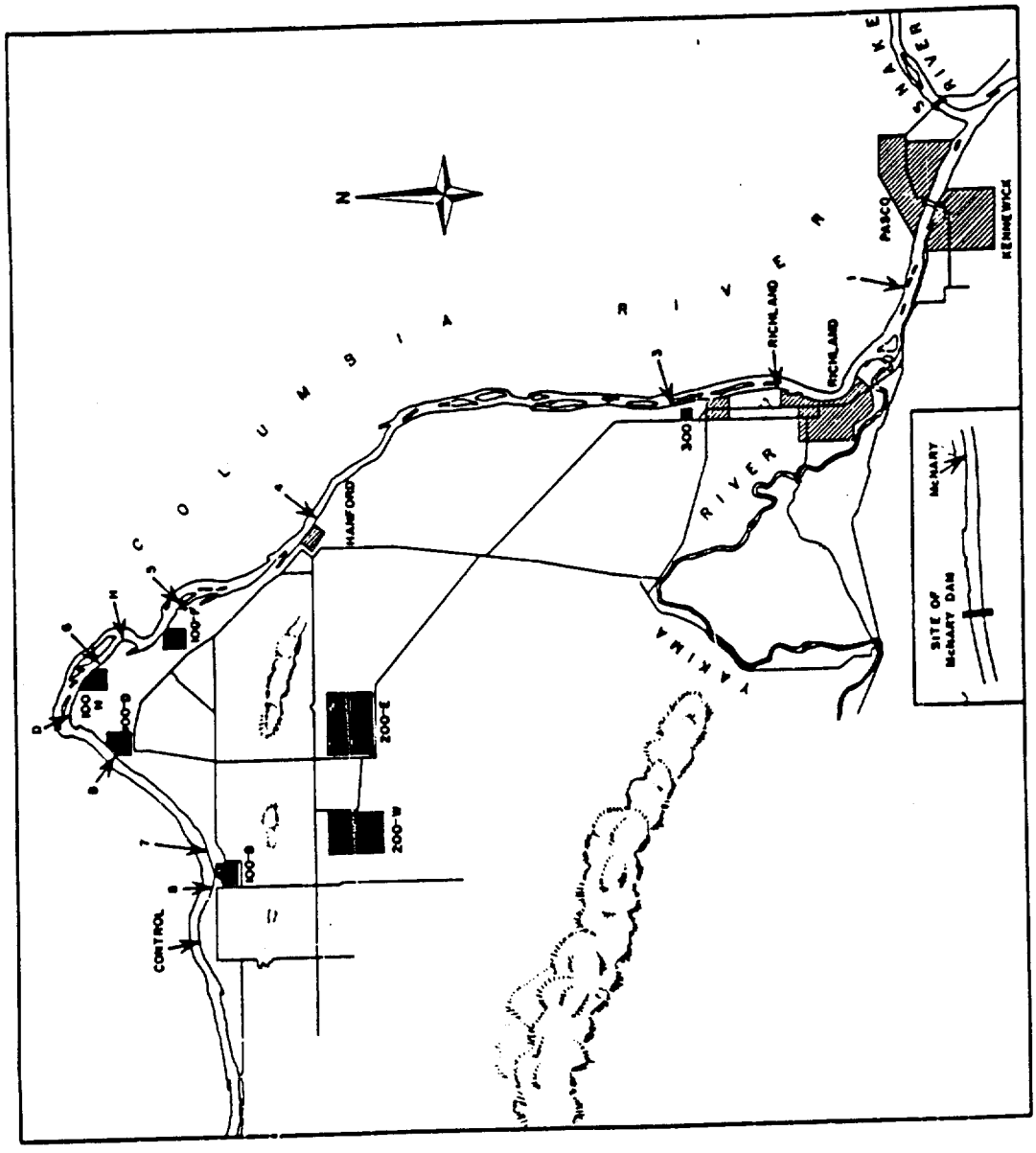

FIGURE 1. LOCATIONS OF SAMPLING SITES

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was continued from these sites until comparisons with the other benthonic studies (3) were made. It was then deemed necessary to alter the location of some of the collecting stations and to add some new sites so as to establish a series of stations that would better facilitate detection of the extent and variation of activity accumulation by the aquatic organisms, possible population variations due to radiological or chemical toxication from pile effluents, and correlation of population variations with natural causes. Consequently, sites were selected providing maximum activity and similar hydrographic conditions including fast water and cobblestone bottom which favor large populations of a maximum number of faunal forms.

It was apparent from the low activity densities that the original station below 100-B pile was by-passed by the major portion of the pile effluent from 100-B because of river currents. Consequently, Station 7 was replaced by Station B-1 which was established farther downstream where higher activity values were found. Station 6 was originally set up to detect effects from the 100-D Pile. When 100-H pile neared completion, Station D was established upstream from the 100-H Area in order to distinguish effects of the 100-D and 100-H Piles. Samples were collected from this station before the 100-H pile started operating. It was also quite apparent that Station 6 was by-passed by effluents from 100-H so Station H was established at a suitable site farther downstream. Station 5 was located at a site having exceptionally good collecting conditions and appeared to be in a position to receive near total effects of the 100-F effluent. Maximum effects of the effluent did not engulf Station 5, however, since highest activity was found in the vicinity of Hanford where Station 4 was established as a site providing less favorable collecting conditions but highest radioactivity.

Samples were collected from the stations every two weeks. Additional samples were occasionally collected from slack water areas

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located at Richland, Hanford, and a control (Station 8) located just above the 100-B Area. Whenever the opportunity availed, specimens were collected at Bigg's Junction which is located 75 miles downstream from the McNary Dam site, and a biologist for the Army Engineers collected and shipped specimens from Bonneville Dam each month.

Since equipment for offshore operations was not available, collections were restricted to shore line areas accessible by wading. The river bottom area thus available during an annual period is extensive, however, because of the fluctuating level of the river. In the vicinity of the 100-F Area the average water level fluctuation from the spring freshet crest to the mid-winter minimal flow is 20.5 feet. The lateral range at the different collecting stations varies from 100 to 500 yards in width.

Collecting techniques

Samples for determination of radioactivity were obtained from stones or other substratal objects which were picked up by hand from shallow water or from deeper water with a gravel fork which had the tines bent inward at approximately right angles to their normal position. Sponge was removed with a spatula and other organisms were obtained by brushing all materials from the stones into a bucket of water. Large scrub brushes proved to be the most satisfactory for this process. Material thus obtained was concentrated and cleansed of fine silt by use of a net bag 18 inches in length constructed of silk bolting cloth (50 1/2 meshes per inch) hung on a metal ring of one foot diameter. The concentrate was placed into 16 ounce wide-mouthed specimen jars for transportation to the laboratory. Water-inhabiting imagoes were collected with dip nets and terrestrial imagoes of aquatic insects were taken by conventional insect nets and light traps. Water samples for radioassay were obtained each time biological specimens were collected.

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For the collection of quantitative samples, a square foot marker constructed from one-quarter inch stainless steel rod was placed at random on the bottom and all encompassed substrata were carefully removed to a depth to include all attached animal life. The stones were carefully cleansed of all living organisms by brushing in a pail of water and the biological material thus obtained concentrated and cleansed as described above, and preserved in four per cent formalin. The average size of substratal components was determined by counting all stones or other objects removed for each square foot sample and determining their volume by water displacement. When great variations in size occurred separate volumetric determinations were made of the largest elements. The current velocity at the established collecting stations was determined routinely during the 1949 collecting season by taking three one minute readings with a "Price" current velocity meter.

Special garments worn by personnel while collecting from littoral zones included heavy rubber gloves with gauntlets extended to arm length. The gloves were large enough to permit the wearing of knitted wool gloves during winter months.

Laboratory processing of samples

Specimens for radioassay were segregated to genera and usually to species. An exception was the larvae of the Diptera commonly known as midges which were grouped only into subfamilies. Such separations were accomplished under stereoscropic microscopes. The isolated specimens were cleansed of all foreign material and blotted free of external moisture with filter paper. Samples of desired size, usually 0.10 to 0.75 g, were placed on one and one-half inch diameter stainless steel plates and weighed. Small samples were prepared by being mascerated, dried under an infrared lamp and charred on a hot plate. More bulky specimens were digested with concentrated nitric acid before being dried and charred.

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The processed samples were mounted in cardboard holders, covered with cellophane, and counted for gross beta activity with a standard mica-window G. M. counter. Counts were corrected for geometry including backscatter, air, cellophane and mica window absorption, and converted to microcuries per gram of live weight. No correction was made for decay. The time elapse between sampling and counting was usually less than six hours.

Water samples were processed by evaporating known volumes and depositing the concentrate on one and one-half inch stainless steel plates for counting.*

Quantitative samples of invertebrates were processed during the spring high water periods when it was impossible to make shore collections. After washing the samples to eliminate the formaldehyde the small and less dense organisms were separated from sand and gravel by an improvised flowing water centrifugal separator which washed the supernatant materials into a fine mesh bag. Residual material was purged of fine sand by sieving through a net made of bolting cloth of 25 meshes per inch. The remaining material was macroscopically sorted and the few remaining heavy organisms such as snails and caddis fly pupae in pebble cases were counted and recorded. The supernatant material was transferred to counting dishes and all organisms were identified and counted.

RESULTS AND DISCUSSION

Many species of animals representing diversified phyla are embodied in this study. A phylogenetic listing of all the forms referred to in this report is given on pages 63 - 65 . This list also includes a few aquatic animals found in the Columbia River which are not referred

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* It was known from tests by other sections that the activity due to gaseous or volatile components, lost by this technique, was negligible.

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to elsewhere in this report, but for which specific determinations have been made. Organisms of seemingly lesser importance which have not yet been studied are omitted. Common names, when available, are associated with the corresponding scientific names.

Some organisms assayed for radioactivity were sampled routinely, others infrequently. Regularity in sampling of specific types was governed by availability, which was influenced by such biological factors as abundance, life cycles, and hydrographic conditions. For the most part, those forms which were found to have the greatest activity densities were sufficiently abundant to enable frequent sampling. Types forming the largest masses of the total faunal composite occupy the more important links in the natural food chains of the aquatic animals.

Radioactivity density analyses

Tables 1 through 12 give the monthly average activity densities observed in all organisms collected from all sampling stations during the period of October 1948 through February 1950. Activity densities of water collected from the same locations during the same periods are illustrated in Figure 2. Comparative seasonal and interstation activity densities of three abundantly collected forms (Hydrobaeninae larvae, *Hydropsyche cockerelli* larvae, and *Fisherola nuttallii*) are graphically illustrated in Figures 3, 4, and 5.

The activity densities recorded for samples collected at the control station located above all pile areas is considered as background. Specimens collected downstream from pile outfalls showed progressive increases in activity density reaching a maximum at Hanford (Station 4). Below Station 4 the activity decreased quite uniformly as the distance increased; occasional exceptions occurred between the station at Richland and Station 1 (near Pasco). The progressive increase between Stations 7 and 4 can readily be attributed to the combining effects of the pile effluents and the decrease below Station 4 to the decay of

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TABLE I

AVERAGE ACTIVITY DENSITIES IN $\mu c/g \times 10^3$ AT CONTROL STATION

	Jan., 1949	Feb.	Mar.	Apr., May, June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan., 1950	Feb.	Mar.
TRUE FLIES													
Hydrobaeninae larvae	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	0.14	<0.01		0.02		<0.01
Hydrobaeninae adults		<0.01	<0.01										
Tendipedinae larvae							0.04			<0.01			
AQUATIC MOTHS													
Argyractis angulatalis larvae											0.01		
CADDIS FLIES													
Hydropsyche cockerelli larvae	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	0.01	<0.01		0.02	<0.01	<0.01
Hydropsyche cockerelli adults					<0.01								
Cheumatopsyche campyla larvae									<0.01				
Brachycentrus occidentalis larv.	<0.01		<0.01				<0.01	0.03	0.01		<0.01	<0.01	
MAYFLIES													
Paraleptophlebia bicornuta nym.							0.01						
TRUE BUGS													
Corixa sp.									<0.01				
SNAILS													
Stagnicola spp.										<0.01			
Fisherola nuttallii	<0.01	<0.01	<0.01				<0.01	0.01	<0.01	<0.01	<0.01	<0.01	
SPONGE													
Spongilla lacustris	<0.01	0.03	<0.01				<0.01	0.02	<0.01	<0.01			

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TABLE 2

AVERAGE ACTIVITY DENSITIES IN $\mu c/g \times 10^3$ AT STATION NO. 7

	Oct., 1948	Nov.	Dec.	Jan., 1949	Feb.	Mar.	Apr., May, June	July	Aug.	Sept.	Oct.	Nov.	Dec.
TRUE FLIES													
Hydrobaeninae larvae		0.01	0.01	0.03	0.01	<0.01		0.05	0.03	0.09	0.78	<0.01	
Hydrobaeninae adults						0.04							
Tendipedinae larvae											1.47		<0.01
CADDIS FLIES													
Hydropsyche cockerelli larvae	0.02	0.01	0.01	<0.01	0.01	<0.01		0.01	0.01	0.08	0.11	0.01	0.06
Cheumatopsyche campyla larvae						<0.01							
Hydroptila argosa larvae						0.03						0.04	0.05
Brachycentrus occidentalis larv.		0.01									0.03	0.01	0.07
MAY FLIES													
Paraleptophlebia bicornuta nym.									<0.01	0.07	1.47		
TRUE BUGS													
Corixa sp.											0.05		
SNAILS													
Stagnicola spp.										0.05		0.02	<0.01
Fisherola nuttallii			<0.01	0.01	0.01	<0.01				<0.01	<0.01	<0.01	0.01
FLAT WORMS													
Planaria sp.												0.03	0.06
BRYOZOA													
Plumatella sp.								<0.01					
SPONGE													
Spongilla lacustris			0.02	0.02	<0.01				<0.01	0.03	0.20	0.01	0.02

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TABLE 3

AVERAGE ACTIVITY DENSITIES IN $\mu c/g \times 10^3$ AT STATION B

	Dec., 1949	Jan., 1950	Feb., 1950	March, 1950
TRUE FLIES Hydrobaeninae larvae	0.44		0.36	0.22
CADDIS FLIES *Hydropsyche cockerelli* larvae *Hydroptila argosa* larvae	0.14 0.17		0.09	0.06
SPONGE *Spongilla lacustria*	0.24			

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TABLE 4

AVERAGE ACTIVITY DENSITIES IN $\mu c/g \times 10^3$ AT STATION D

	Aug., 1949	Sept.	Oct.	Nov.	Dec.	Jan., 1950	Feb.	Mar.
TRUE FLIES								
Hydrobaeninae larvae	0.73	1.62	1.20	1.48		0.93	0.62	0.44
Hydrobaeninae adults							0.18	0.27
AQUATIC MOTHS								
Argyractis angulatalis larvae				0.47				0.05
Argyractis angulatalis adults	0.34							
CADDIS FLIES								
Hydropsyche cockerelli larvae	0.49	0.75	0.69	0.59	0.32	0.41	0.17	0.11
Hydropsyche cockerelli adults	0.23	0.23						
Hydroptila argosa larvae				0.96	0.43			
Brachycentrus occidentalis larvae		0.75	0.80	0.39	0.42	0.45		
STONEFLIES								
Perlodes americana nymphs		0.61		0.72	0.43			
Perlodes americana adults								0.08
MAYFLIES								
Paraleptophlebia bicornuta nymphs		0.71						
WATER MITES								
Hydracarina				0.44				
SNAILS								
Stagnicola spp.		0.22	0.22					
Fisherola nuttallii			0.58	0.23	0.13	0.13		
SPONE								
Spongilla lacustris	0.33	0.49	0.75	0.63	0.26	0.40		0.09

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TABLE 5

AVERAGE ACTIVITY DENSITIES IN $\mu c/g \times 10^3$ AT STATION 6

	Oct., 1948	Nov.	Dec.	Jan., 1949	Feb.	Mar.	Apr., May, June	July	Aug.	Sept.	Oct.	Nov.
TRUE FLIES												
Hydrobaeninae larvae	1.26	0.42	0.42	0.29	0.25			0.66	0.90	0.92	1.33	
Hydrobaeninae adults					0.13	0.24						
AQUATIC MOTHS												
Argyractis angulatalis larvae		0.17										
CADDIS FLIES												
Hydropsyche cockerelli larvae		0.20	0.07	0.07	0.06			0.48	0.53	0.66	0.78	
Cheumatopsyche campyla larvae		0.10	0.09	0.04		0.06						
Hydroptila argosa larvae		0.23	0.23	0.13	0.11				0.89			
Athripsodes annulicornis larvae			0.22									
TRUE BUGS												
Corixa sp.										0.86	0.16	
WATER MITES												
Hydracarina										0.56	1.43	
SNAILS												
Stagnicola spp.			0.01		0.07				0.19	0.18	0.18	
Fisherola nuttallii			0.03	0.03	0.02	0.03					0.18	
SPONGE												
Spongilla lacustris					0.12	0.07				0.92		0.71

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TABLE 6

AVERAGE ACTIVITIES DENSITIES IN $\mu c/g \times 10^3$ AT STATION H

	Oct., 1949	Nov.	Dec.	Jan., 1950	Feb.	Mar.
TRUE FLIES						
Hydrobaeninae larvae	3.12	2.79		1.10	0.95	0.69
AQUATIC MOTHS						
Argyractis angulatalis larvae		1.66		0.42		
CADDIS FLIES						
Hydropsyche cockerelli larvae	0.24	0.92		0.47	0.22	0.20
Hydroptila argosa larvae		1.61				
Brachycentrus occidentalis larv.	0.97	0.73	0.51	0.32		
STONEFLIES						
Perlodes americana nymphs			0.55			
SNAILS						
Stagnicola spp.	0.23	0.13	0.06	0.02		
Fisherola nuttallii			0.19			
FLAT WORMS						
Planaria sp.						0.07
SPONGE						
Spongilla lacustris		0.96				

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TABLE 7

AVERAGE ACTIVITY DENSITIES IN $\mu c/g \times 10^3$ AT STATION 5

	Oct., 1948	Nov.	Dec.	Jan., 1949	Feb.	Mar.	Apr., May, June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan., 1950	Feb.	Mar.
TRUE FLIES																
Hydrobaeninae larvae	0.72	0.40	0.35	0.27	0.52	0.17		0.[illegible]9	1.19	1.39	3.24	1.68	0.88	1.53	1.34	0.90
Hydrobaeninae adults					0.21	0.12									0.20	
Simulium sp. larvae				0.33	0.28			0.70								
AQUATIC MOTHS																
Argyractis angulatalis larvae		0.22									0.95					
CADDIS FLIES																
Hydropsyche co[illegible]srellis larvae		0.26	0.22	0.12	0.06	0.05		0.43	1.05	0.86	0.87	0.82	0.61	0.51	0.27	0.29
Hydropsyche cockerellis adults									1.52							
Hydroptila argosa larvae												1.16	0.81	1.29		
Hydroptila argosa adults									1.25							
Brachycentrus occidentalis larvae	0.29	0.24	0.20	0.21		0.06			1.13		0.76	0.82	0.61	0.49	0.35	
STONEFLIES																
Perlodes americana nymphs																1.48
MAYFLIES																
Baetis sp. nymphs						0.13						0.93			2.64	
WATER MITES																
Hydracarina									2.44		1.35	0.21	0.23			
SNAILS																
Stagnicola spp.	0.07	0.04	0.01		0.02			0.22	0.30	0.43	0.36	0.18	0.05	0.04		
Fisherola nuttallii		0.06	0.05	0.03	0.02	0.03					0.44	0.37	0.18	0.15		

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TABLE 8

AVERAGE ACTIVITY DENSITIES IN $\mu c/r \times 10^3$ AT STATION 4

	Oct., 1948	Nov.	Dec.	Jan., 1949	Feb.	Mar.	Apr., May, Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan., 1950	Feb.
TRUE FLIES															
Hydrobaeninae larvae	0.79	0.75	0.92	0.98	0.63	0.54		0.94	3.13	4.14	3.90				
Hydrobaeninae adults			0.56	0.73	0.32	0.20		0.67	0.82	0.48					0.44
Tendipedinae larvae									2.64	3.78					
AQUATIC MOTHS															
Argyractis angulatalis adults									0.64	0.93					
CADDIS FLIES															
Glossosoma velona larvae						0.06									
Psychomyia flavida adults									0.69						
Hydropsyche sockerelli larvae	0.21	0.39	0.41	0.17	0.2[illegible]	0.20		1.43	1.82	1.62	1.63	1.28	0.87	0.51	
Hydropsyche sockerelli pupae									1.43	0.74					
Hydropsyche sockerelli adults								0.12	0.71	0.48	0.47				
Cheumatopsyche campyla larvae	0.24	0.22	0.33	0.16	0.23	0.18									
Cheumatopsyche campyla adults									0.02						
Hydroptila argosa larvae				0.69	0.66	0.31			2.79				2.30		
Hydroptila argosa adults									1.07						
Orthrypeodes annulicornis adults								0.04							
Brachycentrus occidentalis larvae					0.36	0.45				1.63	1.40	1.23	0.93		
STONE FLIES															
Perlodes americana nymphs									1.69	1.51	2.99	1.18			
MAYFLIES															
Paraleptophlebia bicornuta nymphs									2.18	1.83	2.22				
WATER MITES															
Hydracarina										0.17					
SNAILS															
Stagnicola spp.	0.09	0.07		0.03					0.35	0.46	0.63	0.39			
Gyraulus vermicularis										0.33					
Fisherola nuttallii			0.14	0.10	0.31	0.09				0.61	0.79	0.61	0.35	0.29	
LEECHES															
Hirudinea										0.06					
HYDRA															
Hydra sp.										0.38					
SPONGE															
Spongilla lacustris													1.22	0.81	1.02

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TABLE 9

AVERAGE ACTIVITY DENSITIES IN $\mu c/g \times 10^3$ AT STATION 3

	Oct., 1948	Nov.	Dec.	Jan., 1949	Feb.	Mar.	Apr., May, June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan., 1950	Feb.
TRUE FLIES															
Hydrobaeninae larvae	0.39	0.28	0.28	0.30	0.16	0.25		0.62	1.16	1.10	3.26	1.20		1.24	0.93
Hydrobaeninae adults						0.16									
Tendipedinae larvae									1.01				0.26	0.35	
AQUATIC MOTHS															
Argyractis angulatalis larvae												0.37			
CADDIS FLIES															
Hydropsyche cockerelli larvae	0.28	0.16	0.12	0.09	0.05	0.09		0.56	0.77	0.60	0.91	0.51	0.53	0.45	0.29
H. cockerelli adults										0.32					
Cheumatopsyche campyla larvae	0.16	0.08	0.07			0.08				0.64					
Hydroptila argosa larvae									0.48			0.53	0.60		
MAY FLIES															
Paraleptophlebia bicornuta nymphs									0.76	0.51					
TRUE BUGS															
Corixa sp.									0.36						
SNAILS															
Stagnicola spp.						<0.01				0.23	0.44	0.07			
Fisherola nuttallii			0.04	<0.01	0.02	0.02					0.27	0.17	0.14	0.12	
SPONGE															
Spongilla lacustris				0.10	0.08	0.05				1.21	0.80	0.58	0.16	0.21	

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TABLE 10
AVERAGE ACTIVITY DENSITIES AT RICHLAND STATION
Activity density units $\mu c/g \times 10^3$

	Aug., 1949	Sept.	Oct.	Nov.	Dec.	Jan., 1950	Feb.
TRUE FLIES							
Hydrobaeninae larvae	0.68	1.06	1.25	1.22	0.85	0.87	1.17
AQUATIC MOTHS							
Argyractis angulatalis larvae				0.75			0.18
Argyractis angulatalis adults	0.16						
CADDIS FLIES							
Hydropsyche cockerelli larvae	0.41	0.61	0.52	0.48	0.55	0.31	0.30
Hydropsyche cockerelli adults	0.28						
Brachycentrus occidentalis larv.	0.51	0.59	0.78	0.50	0.41		
TRUE BUGS							
Corixa sp.				0.10			
SNAILS							
Stagnicola spp.		0.32	0.22	0.34	0.05		
Fisherola nuttallii			0.24	0.31			
FLAT WORMS							
Planaria sp.				0.04			
SPONGE							
Spongilla lacustris			0.97	0.01	0.33		

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TABLE 11

AVERAGE ACTIVITY DENSITIES IN $\mu c/g \times 10^3$ AT STATION 1

	Nov., 1948	Dec.	Jan., 1949	Feb.	Mar.	Apr., May, June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan., 1950	Feb.
TRUE FLIES														
Hydrobaeninae larvae	0.27	0.37	0.25	0.23	0.17		0.41	0.47	1.40	2.10	1.66	0.56	0.92	1.16
Tendipedinae larvae				0.06								1.24		
Simulium larvae														
AQUATIC MOTHS														
Argyractis angulatalis larvae												0.11		
CADDIS FLIES														
Glossosoma velona larvae								0.36	0.28			0.24		
Glossosoma velona pupae								0.24						
Psychomyia flavida adults							0.45	0.67				0.14		
Hydropsyche cockerelli larvae							0.39	0.46	0.53	1.08	0.63	0.35	0.33	0.27
Cheumatopsyche campyla larvae	0.19													
Hydroptila argosa larvae								0.55						
Brachycentrus occidentalis larvae											0.60	0.40		
STONE FLIES														
Perlodes americana nymphs									0.56		0.63			
MAYFLIES														
Baetis sp. nymphs											0.87	0.52		
SNAILS														
Stagnicola spp.					0.01				0.17		0.15	0.25		
Fisherola nuttallii			0.03						0.20	0.31	0.19	0.11	0.07	
FLAT WORMS														
Planaria sp.												0.41		
SPONGE														
Spongilla lacustris			0.05	0.03					0.75	0.71	0.69	0.19		

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TABLE 12

AVERAGE ACTIVITY DENSITIES AT McNARY DAM STATION

Activity density units $\mu c/g \times 10^3$

	Aug., 1949	Sept.	Oct.	Nov.	Dec.	Jan., 1950	Feb.
TRUE FLIES							
Hydrobaeninae larvae	0.54	0.77	0.52	0.93	0.63	0.27	
AQUATIC MOTHS							
Argyractis angulatalis larvae		0.54	0.21	0.14			
Argyractis angulatalis adults	0.12						
CADDIS FLIES							
Glossosoma velona larvae	0.07						
Hydropsyche cockerelli larvae	0.22	0.34	0.23	0.21	0.18		0.07
Hydropsyche cockerelli adults	0.15	0.22	0.26				
Cheumatopsyche campyla larv.			0.21	0.13	0.10	0.07	
Hydroptila argosa larvae				0.53	0.29		
Brachycentrus occidentalis larv.				0.28	0.13		
MAY FLIES							
Baetis sp. nymphs	0.45						
TRUE BUGS							
Corixa sp.			0.21	0.07			
SNAILS							
Stagnicola spp.		0.06	0.12	0.05			
Fisherola nuttallii		0.13	0.10	0.08	0.05		
BRYOZOA							
Plumatella sp.			0.12				
SPONGE							
Spongilla lacustris	0.19	0.23	0.21	0.15	0.02		

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FIGURE 2

ACTIVITY DENSITY OF WATER

μc/cc

(MULTIPLY ALL READINGS BY 10^{-9})

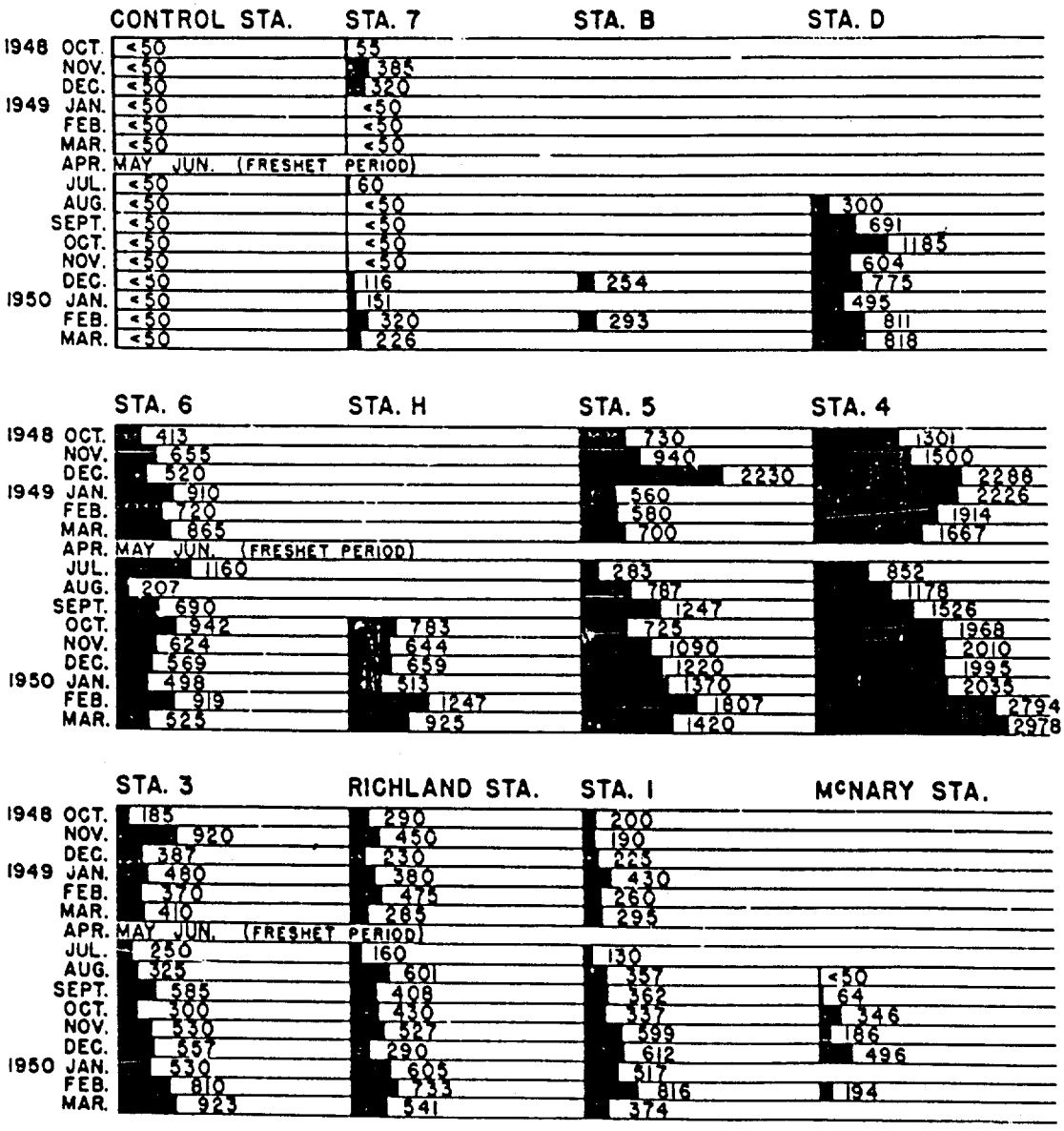

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FIGURE 3

COMPARATIVE ACTIVITY DENSITY OF MIDGE (HYDROBAENINAE) LARVAE
μc/g
(MULTIPLY ALL READINGS BY 10^{-3})

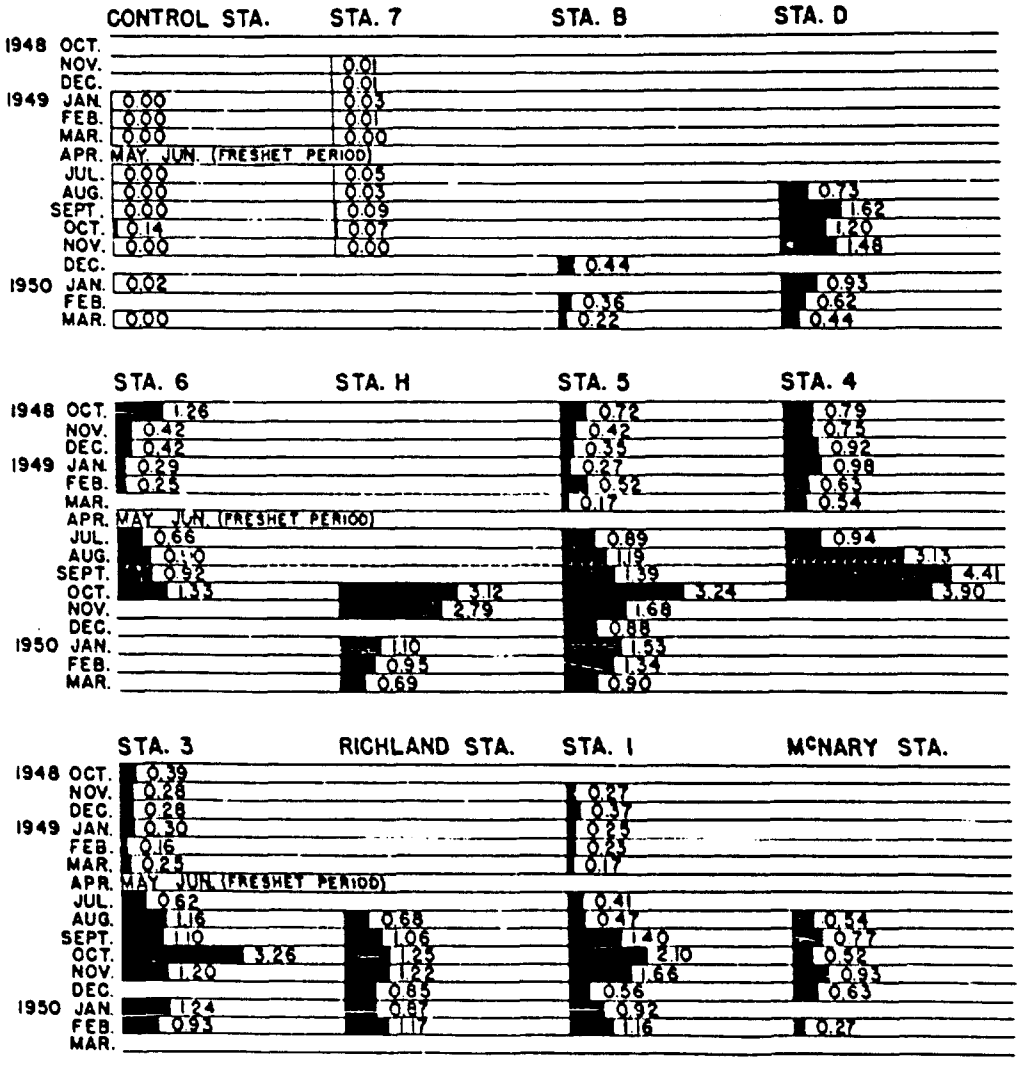

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FIGURE 4

COMPARATIVE ACTIVITY DENSITY OF CADDIS FLY (HYDROPSYCHE COCKERELLI) LARVAE

μc/g
(MULTIPLY ALL READINGS BY 10^{-3})

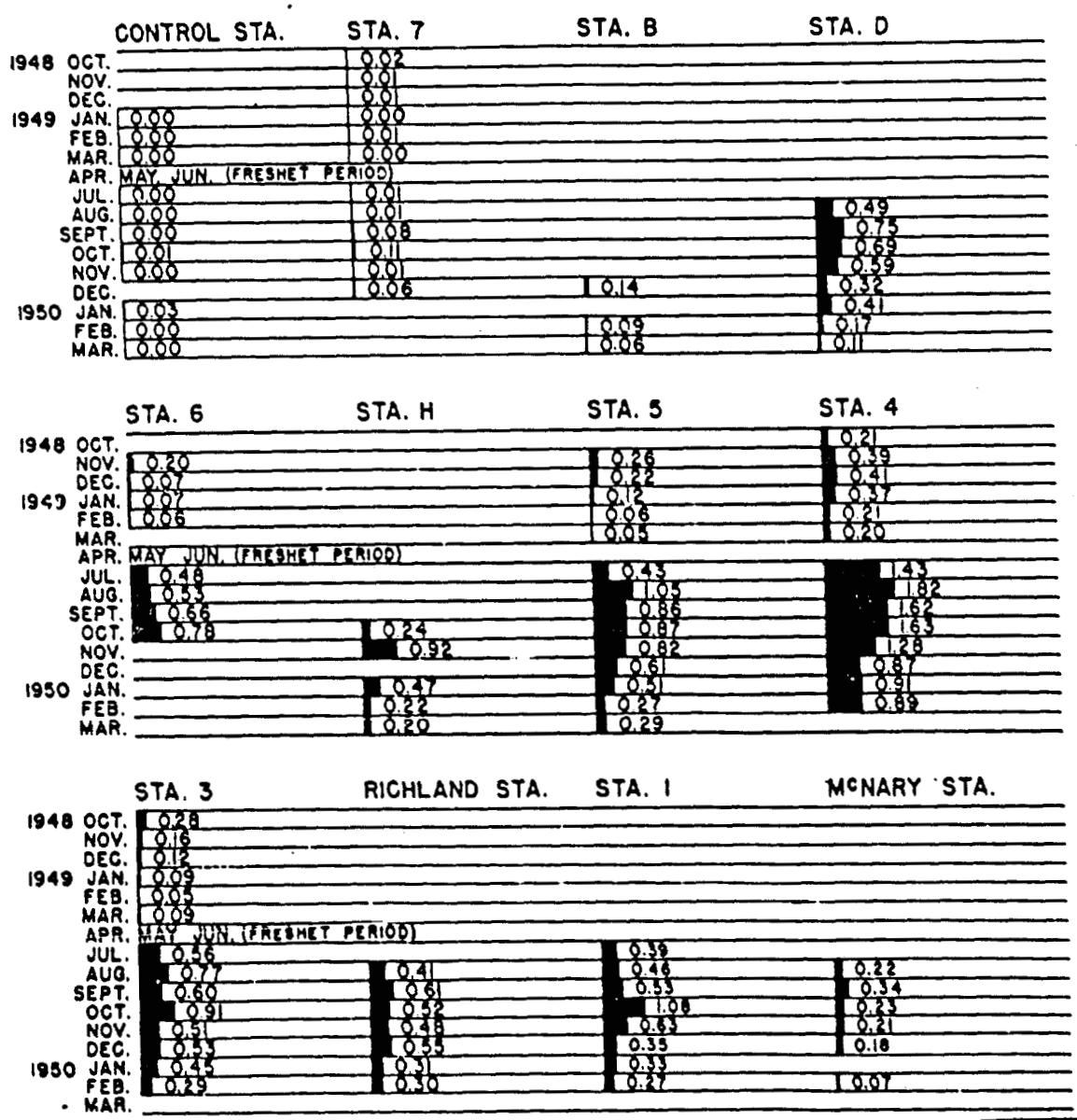

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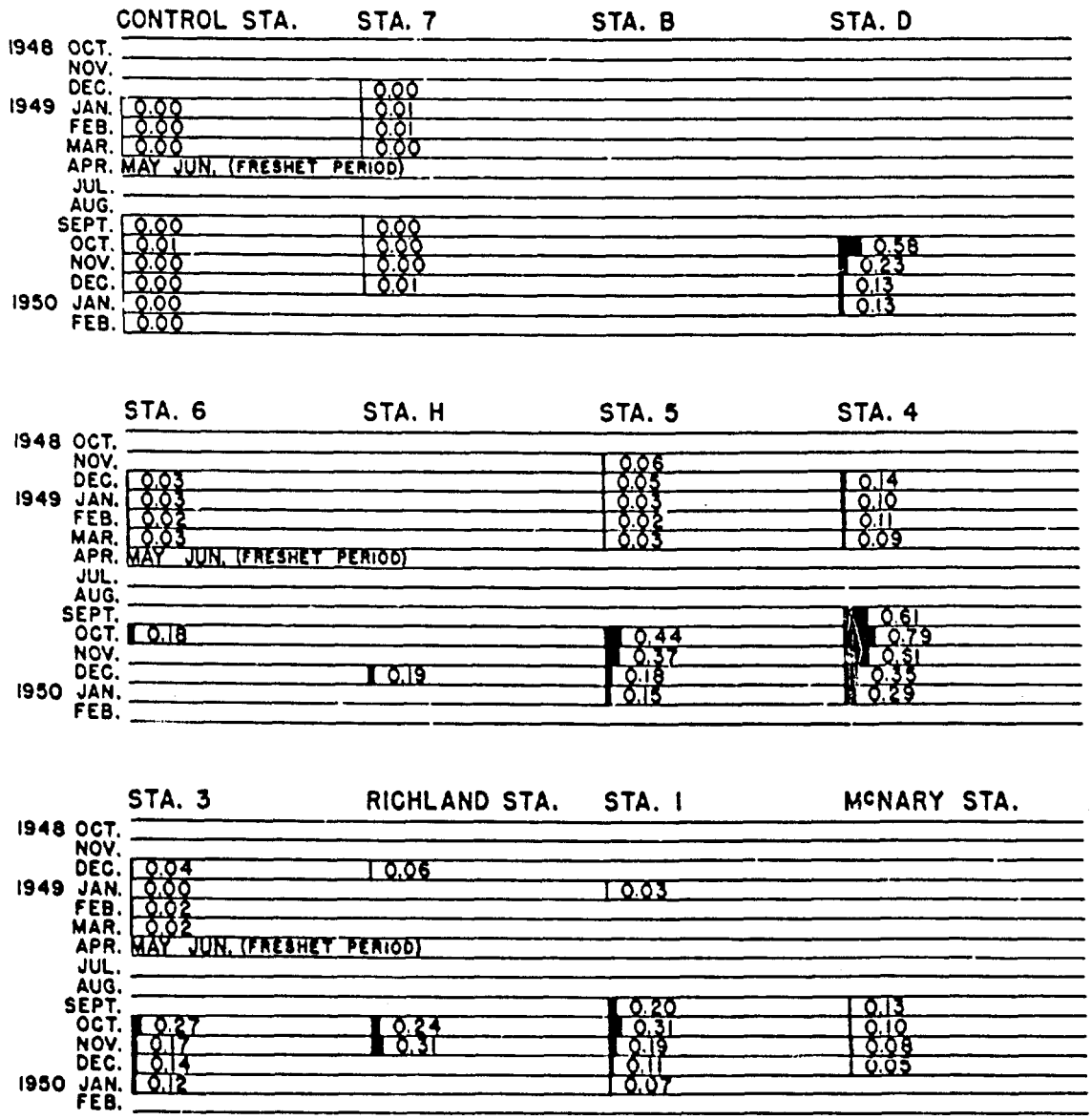
FIGURE 5

COMPARATIVE ACTIVITY DENSITY OF LIMPETS

(FISHEROLA NUTTALLI)

μc/g

(MULTIPLY ALL READINGS BY 10^{-3})



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radioactivity, dispersion, sedimentation, and assimilation by living organisms; below Richland there is the additional factor of dilution with waters from tributary rivers and streams. Exceptions to the decrease of activity density as the distance below Station 4 increased were probably due to currents producing unequal travel rates for different cross sectional parts of the river. Radioactivity densities would be affected by the time interval differences which are principally due to the variation in decay time and to a lesser extent from sedimentation, and by assimilation by living organisms.

Subsequent to the collection of these data, the Control Functions Section of the H.I. Development Division has taken a series of aerial photographs (4) which show the discoloration which appears in the river when the iron sulfate floc is flushed out of the settling basins in which it is precipitated during water purification. Since the rust colored material is discharged through the same sewers as the pile effluent, the discoloration pattern produced in the river is an excellent indication of the dispersion of the effluent. Three of the photographs have been redrawn with the addition of our associated sampling sites, see Figures 6, 7, and 8. The dispersion patterns shown in the photographs correlate well with our radioassays of water and aquatic animals. Figure 6 shows the effluent from the 100-B Pile flowing downstream as a narrow band by-passing collecting Station 7, which consistently showed low activity. Station B is located well beyond the limits of this illustration. Figure 7 illustrates the main discharge of the 100-H Area by-passing Station 6 to diffuse more completely by the time it reaches Station H. On October 26, 1950, aerial observation showed the discoloration closer to shore, engulfing the site of Station H. Figure 8 similarly shows the major portion of 100-F effluent by-passing Station 5 to produce a maximum concentration farther downstream at Station 4, the location of which was not included in the photograph.

The ability of aquatic organisms to concentrate radioactive elements to many times the amount present in the water has been

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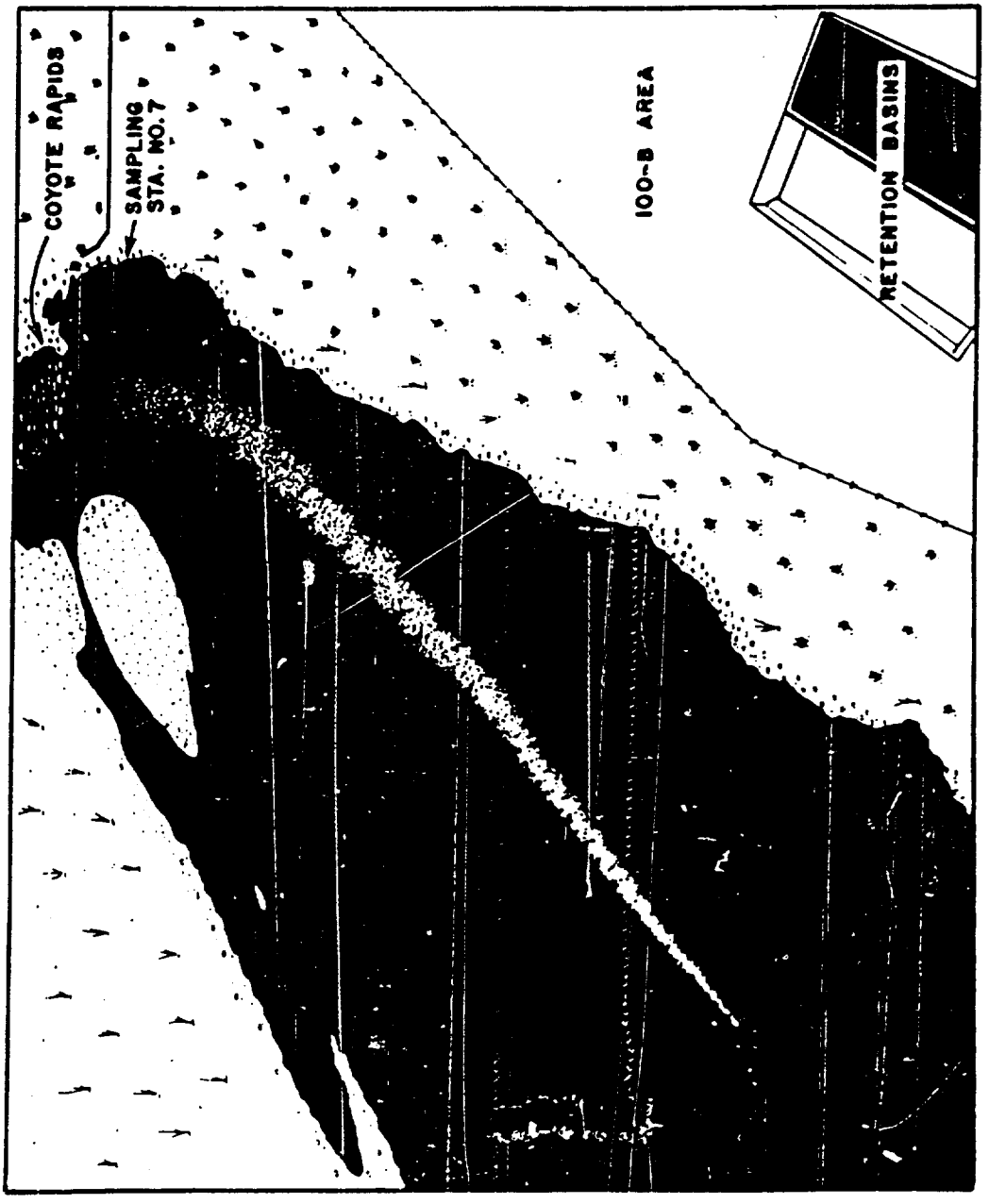

FIGURE 6. DISTRIBUTION OF EFFLUENT FROM 100-B AREA

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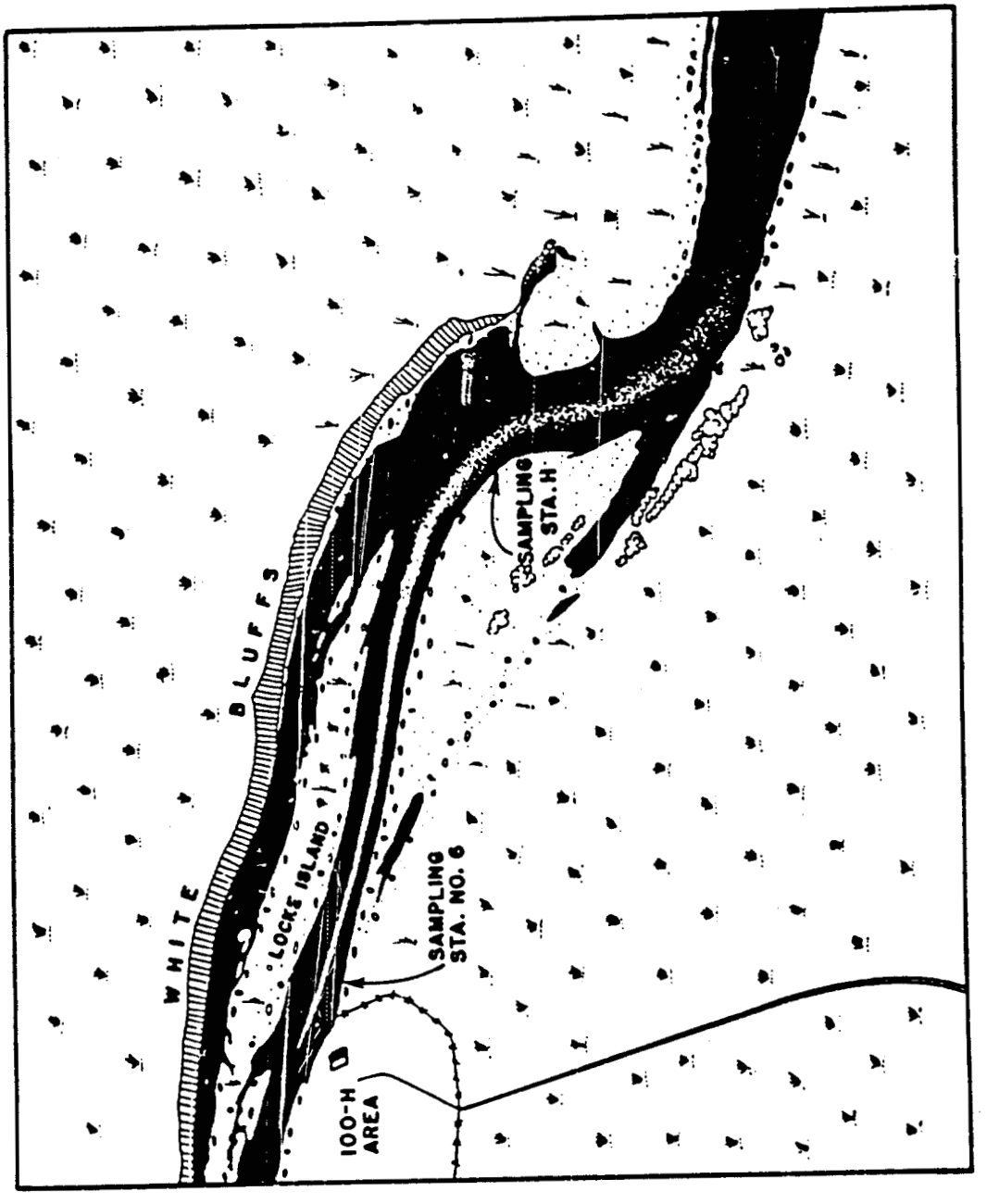

FIGURE 7. DISTRIBUTION OF EFFLUENT FROM 100-H AREA

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FIGURE 8. DISTRIBUTION OF EFFLUENT FROM 100-F AREA

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demonstrated repeatedly. Herde (2) reported that during 1947-1948 the average activity density of three types of fish caught below pile areas was about 100 times that of the water, Coopey (3) reported bottom algae collected during approximately the same period contained about 1,000 times as much activity, and recent studies by Herde, et al (5) have shown certain tissues of pekin ducks to contain activity densities hundreds of times that of the river water. Similar concentrations occur among the invertebrate animals. The average and maximum activity densities found in various organisms collected at the Hanford Station during the peak months (August through October) of 1949, are presented in Figure 9. From these data the following conservative gross concentration factors may be tabulated for some of the most commonly sampled forms:

ORGANISM	GROSS CONCENTRATION FACTOR*
Hydrobaeninae larvae	2300
Tendipedinae larvae	1700
Hydroptila argosa larvae	1700
Perlodes americana nymphs	1600
Spongilla lacustris	1500
Paraleptophlebia bicornuta nymphs	1300
Hydropsyche cockerelli larvae	1100
Brachycentrus occidentalis larvae	900
Fisherola nuttallii	400
Stagnicola apicina	300

Decay studies of water from Hanford have shown only approximately one per cent of the activity to be due to isotopes with half lives of 14 or more days. Radiochemical analyses of typical pile effluent water have shown that P^{32} is responsible for about 10 per cent of the activity from the longer lived (more than 14 days half life) radioisotopes. Seventy to eighty-five per cent of the activity in some organisms

* The concentration factor is the number of times the activity density of the organism exceeds that of the water.

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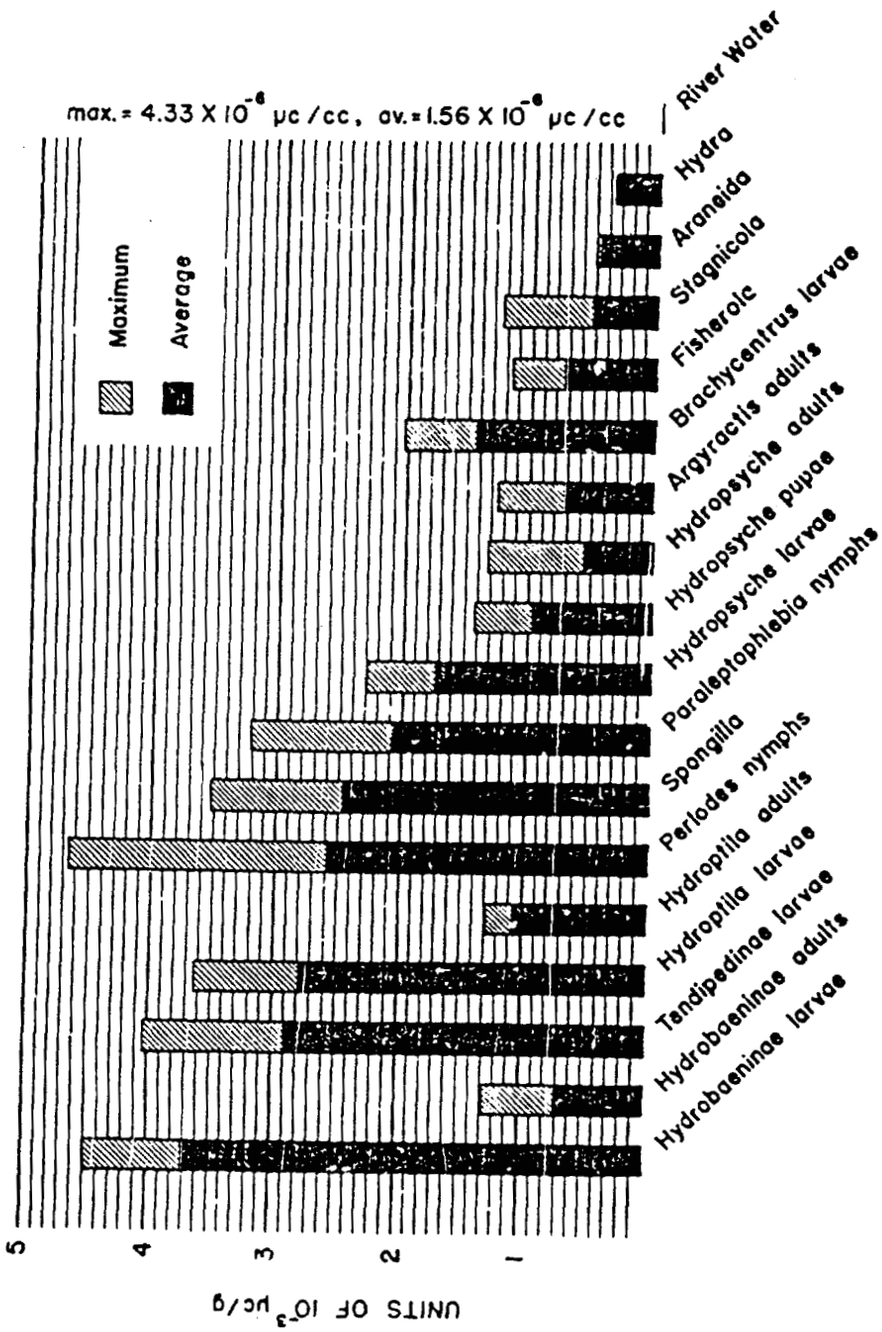

FIGURE 9. AVERAGE AND MAXIMUM RADIOACTIVITY IN ORGANISMS FROM HANFORD (STATION 4) DURING AUG.-OCT. 1949

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has been found to be due to P^{32}; consequently, the actual specific concentration factor for P^{32} may be well over one million for some organisms at Hanford.

Decay curve analysis of invertebrates collected from Hanford and sites of similar proximity downstream from reactor areas indicated the dominant radioisotopes to be present in approximate proportions as follows:

Hydrobaeninae larvae *Hydropsyche cockerelli* larvae *Paraleptophlebia bicornuta* nymphs *Fisherola nuttallii* (minus shells)	15-30% Na^{24} 70-85% P^{32} 1% or less undetermined long-lived elements
Spongilla lacustris	50% Na^{24} 50% P^{32} 1% undetermined long-lived elements
Hydrobaeninae pupal exuviae	96% Na^{24} 3% P^{32} <1% undetermined long-lived elements
Hydropsyche cockerelli adults *Diamesa* (Hydrobaeninae)	99% P^{32} 1% undetermined long-lived elements

Radiochemical analysis of *Hydropsyche* and Hydrobaeninae larvae substantiated the presence of Na^{24} and P^{32} and detected Fe, Al, Cr, Ti, and rare earths as components of the long-lived element group.

The proportional occurrences of Na^{24}, P^{32} and long-lived elements in various life stages and parts of Hydrobaeninae is summarized as follows:

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	Na^{24}	P^{32}	undetermined long-lived elements
larvae	15-30%	70-85%	1% or less
pupal exuviae	96%	3%	1% or less
adults	none	99%	1% or less

The affinity for specific elements by definite parts of the insect, such as Na by the exoskeleton, is indicated. The absence of certain isotopes in adult insects may be due, in part, to the shedding of the chitinous pupal exuviae as well as from radiodecay and the large amount of Na associated with the pupal exuviae may be partly due to direct adsorption of Na from the water.

A comparison of the intraspecific levels of activity densities throughout the year is given in Table 13 which shows the activity for the more common forms expressed as a coefficient of the activity of Hydropsyche cockerelli larvae. The coefficient factors were obtained by dividing all determinations available for each by the activities of Hydropsyche cockerelli larvae that were collected from the same location and at the same time. The coefficient represents the mean value and the numbers enclosed in parenthesis indicate the number of samples compared. Hydropsyche cockerelli larvae were chosen as a standard because they are the most easily and commonly collected organism. The seasonal arrangement of Table 13 coincides with availablility of the organisms by shore sampling techniques. There was no significant difference in the coefficients at different collecting sites but there were pronounced seasonal variations.

The variations in activity may be attributed to combinations of at least five possible causes:

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TABLE 13

COMPARATIVE CONCENTRATION FACTORS REPRESENTED AS COEFFICIENTS OF THE ACTIVITY OF HYDROPSYCHE COCKERELLI LARVAE

(Hydropsyche cockerelli larvae = 1)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Hydracarina		← (3) 2.0 →			(2) 0.7	(1) 0.4			
Hydrobaeninae larvae	(5) 1.1	(15) 1.5	(12) 2.1	← (36) 2.3 →		(13) 2.5	(15) 3.1	(17) 4.0	(12) 3.3
Tendipedinae larvae		(4) 1.3	← (4) 0.6 →			(2) 0.5			
Tendipedidae exuviae								(2) 5.6	
Simulium larvae	(1) 7.0					← (4) 4.0 →			
Argyractis larvae			← (11) 1.1 →				← (4) 4.0 →		
Argyractis adults		← (16) 0.5 →							
Brachycentrus larvae (plus cases)		← (72) 1.0 →					(8) 1.5	(4) 2.1	(2) 2.2
Hydroptila larvae (plus cases)		(5) 1.3			(9) 1.7	(4) 1.9	(5) 2.2	(3) 2.3	(2) 1.8
Hydroptila adults		(2) 0.6							
Hydropsyche pupae		← (3) 0.5 →							
Hydropsyche adults	← (40) 0.4 →								

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TABLE 13 (Continued)

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Psychomyia larvae	← (2) 1.2 →					(1) 0.5			
Glossosoma larvae		(1) 1.0	(1) 0.5			(1) 0.8			(1)
Perlodes nymphs		← (5) 1.0 →		(7) 1.5	← (3) 1.3 →				
Baetis nymphs					(2) 1.4	(1) 1.8			(2) 2.8
Paraleptophlebia nymphs		← (28) 1.1 →							
Corixa		← (3) 0.6 →			(2) 0.2				
Fisherola (minus shells)							← (12) 0.5 →		
Planaria				(1) 0.3	(1) 0.9	(1) 1.4			
Spongilla		(5) 0.9	(14) 1.7	(27) 1.3	(21) 1.6	(9) 0.8	(12) 1.2	(8) 1.7	(3) 2.8

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1. Different types of organisms have different food habits and the decay time becomes progressively greater farther down the food chain series. Autotrophic forms, those capable of photosynthesis, obtain all of their required elements directly from the water and thus accumulate the radioelements before appreciable radioactive decay has occurred. Radioactive isotopes deposited in the tissues of herbivores and of those omnivores which feed upon the dominantly algal plankton are obtained principally from their food. Isotopes obtained from such food organisms have undergone more decay, eliminating a significant amount of the short-lived isotopes. There is still a greater decay time for elements which have entered the bodies of carnivores by way of food organisms.

2. Element requirements of the manifold forms of life differ. The quantities of required and nonessential elements that are metabolized among various kinds of organisms and variations in activity densities may be influenced to a lesser extent by different interspecific requirements for certain elements.

3. Rate of growth, metabolism and life span are important factors. Organisms having a very short life span grow rapidly and tend to have a higher metabolic rate. The uptake of isotopes presumably is directly proportional to the metabolic rate.

4. The different types of invertebrate animals have different life cycles and go through a variety of life stages. There is a definite correlation between the stage of development and activity density. Some forms spend their entire life in the water, others leave the aquatic environment during certain stages; some remain physiologically active throughout their life cycle, whereas many other forms undergo resting periods during which no food is consumed. Such resting periods may be for the purpose of preservation of the species during periods of unfavorable environmental conditions, or merely a transitional period or a definite life stage of a maturing organism. All of

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the arthropods undergo a series of molts which are associated with growth. Molts of active stages are preceded by and usually include a fasting period of varied duration which would have definite effects upon the radioactivity density. A considerable amount of radioactive material is cast off with the exuviae (molted skins).

5. The morphology of the animals undoubtedly plays a role of considerable but as yet undetermined importance in relation to absorption and adsorption of radioisotopes by aquatic organisms and by substances they produce. Such absorption and adsorption has been observed in laboratory experiments carried out by the authors and by E. C. Berry (6) in living and dead duckweed. The high activity of sponge may well be related to the great surface area of these animals. The very low activity found in the shells of snails and clams may be partly attributed to their impermeability and density, while the gelatinous substances excreted by many aquatic organisms can be expected to have higher activity. Examples of such gelatinous substances include the coverings of the egg masses of snails and many aquatic insects, sheaths or capsules excreted by the larvae of some midges, and the large gelatinous balls formed by Pectinatella colonies.

During the period of July 20, 1949 to January, 1950, Hydropsyche cockerelli larvae and water were sampled at a near-daily frequency at Hanford (Station 4) in an effort to detect the pattern of daily activity fluctuations, the influence of variations in pile operation, and to substantiate seasonal trends more explicitly. Activity densities of the caddis fly larvae and water are shown in Figure 10 both as daily values and as a smooth curve representing a moving average of five. Pile shutdowns are indicated as variously thatched bars, the width of the bars corresponding to the duration of the shutdowns.

Greater daily fluctuations occurred in the water than in the insect larvae. This may be attributed to several factors.

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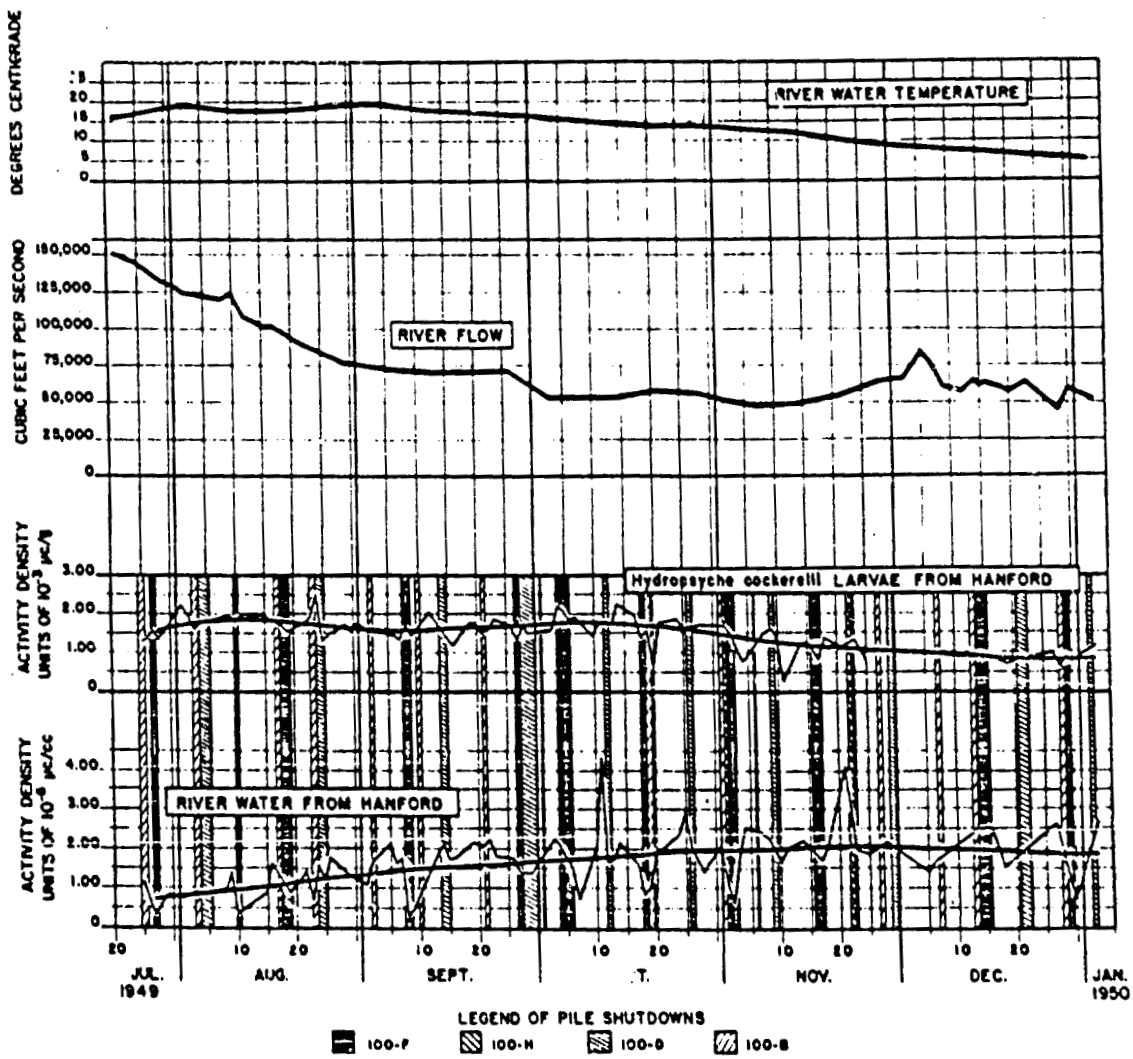
FIGURE 10

ACTIVITY DENSITY IN CADDIS FLY LARVAE AT HANFORD
AS AFFECTED BY PILE OPERATIONS AND HYDROGRAPHIC CONDITIONS



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1. Activity density levels of the larvae are much higher than activity of the water, consequently, counter variations are less obvious for the larvae.

2. Brief variations in radioactive waste discharges resulting from changes in pile operations may be detectable in the water as soon as the effects reach the sampling area. Shutdowns of the nearest influencing pile, 100-F, cause a direct sharp decline in the water activity, while immediate effects from more distant piles are less pronounced. On the other hand, activity densities of the insects, resulting from the deposition of the longer-lived isotopes within their bodies, are not noticeably changed by moderate variations of short duration in the activity density of the water.

3. As previously mentioned, the dispersion of pile effluent water is not uniform throughout the river at Hanford. Variations in river currents could, therefore, be responsible for some of the sporadic fluctuations in the activity density of the water. As with variations resulting from pile operation, such fluctuations tend to be subdued in larvae due to deposition of the longer-lived isotopes.

Seasonal activity trends are best illustrated by the moving average curves. The activity of the river shows a gradual rise from July until November and then a very slight decline. Since pile operations were uniform throughout this period, the rise may be attributed to reduced dilution, activity being inversely related to volume of flow. The seasonal trend for the Hydropsyche cockerelli larvae is quite different, however, since the activity reached a maximum about the middle of August. There was then a gradual decline until the first week of September when a slight rise occurred and this was followed by a steady decrease after the first third of October. This pattern is related to the metabolic rate of the larvae. During periods when the water is warm the larvae have a high metabolic rate and are undergoing rapid growth. This required the consumption of large quantities

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of food to supply the needs of growth and results in rapid accumulation of larger quantities of required elements. Likewise, the metabolic rate decreases with the lowering of the water temperature. Such is apparent from a comparison of the radioactivity density curve of the larvae to that of the river water temperature plotted against time. The cause of the slight secondary rise in the activity of the larvae cannot be explained with certainty at the present time. It is considered likely, however, that it may be related to the life cycle of the insects. The August maximum may correspond to the rapid growth of one brood, the decline may be related to the period when the majority of the larvae have reached larval maturity and are not feeding just prior to ecdysis, and the second maximum may then correspond to the growth period of the next large brood.

Ecological Studies

An ecological study of the benthonic fauna of a large river is a complicated and difficult task. This is evident by the paucity of such surveys as compared to the number of limnological studies that have been made of quiet bodies of water. Such an ecological study of the section of the Columbia River within the confines and downstream from the Hanford Works is essential, however, to determine whether or not the effluent being discharged from the plutonium-producing piles is causing any direct or indirect effects upon the natural aquatic inhabitants of the river. Direct effects could result in population abnormalities which would disturb the natural biological balance existing between the animal and plant populace. Such changes, though they may initially affect only the most minute and seemingly insignificant organisms, might produce indirect effects of considerable magnitude which could reflect upon man's economic interests. For example, the annihilation of certain small insect larvae could directly or indirectly cause the area to be barren of desirable fish because of a deficient food supply.

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A knowledge of the biology of all the common forms and their interrelationships is necessary to determine the importance of each form and to determine what total effects would occur with its removal from the habitat. A knowledge of the food habits of the animals will help to explain variations in radioactivity densities among the different types of organisms. Food chain studies are necessary for determining the avenues of radioactive contamination that may ultimately lead to concentrations of radioisotopes in organisms that will directly affect the welfare of man.

Up to this time the available manpower and facilities have been directed toward the most pertinent question as to whether pile effluents are producing any deleterious effects upon the invertebrate populations.

It was infeasible to make gravimetric determinations on all of the many samples involved in this study. The more important forms collected during October 1948 through January 1950 for determination of radioactivity were counted and weighed, however, and the average weights of the various individuals are shown in Table 14. Since the largest individuals were sorted out for radioassay, only the mature or near mature forms are represented by the values shown.

Numerical counts of all quantitative samples are given in Tables 15 through 23. These figures readily indicate the vast variability in numbers of the specific organisms. This diversity occurs not only between stations but between samples taken at the same locations. Even greater variations in kind and abundance occur in the river than is indicated in these tables because collection sites of similar hydrographic conditions were purposely chosen for this study. Different hydrographic conditions produce environmental factors that are favorable to specific population types. Consequently, there are a multitude of population types which differ radically in both species and abundance; each type is indigenous to definite areas restricted by

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TABLE 14

AVERAGE WEIGHTS OF ORGANISMS SAMPLED FOR RADIOACTIVITY DETERMINATIONS

Organism	No. of Organisms Weighed	Av. Wt. g/1000 Organisms
TRUE FLIES		
Hydrobaeninae larvae	24,881	1.1
Tanytarsus spp. adult	1,350	0.22
Diamesa spp. adult	2,103	0.85
Tendipedinae larvae	1,029	2.5
Simulium sp. larvae	743	0.65
AQUATIC MOTHS		
Argyractis angulatalis larvae	309	6.3
A. angulatalis pupae	5	22.
A. angulatalis adults	1,190	1.1
CADDIS FLIES		
Glossosoma velona larvae	128	4.9
G. velona pupae	28	8.6
Psychomyia flavida larvae	60	4.6
P. flavida adults	82	1.7
Hydropsyche cockerelli larvae	5,535	21.
H. cockerelli pupae	26	22.
H. cockerelli adults	2,231	13.1
Cheumatopsyche campyla larvae	859	12.
C. campyla adults	100	6.1
Hydroptila argosa larvae	4,269	1.3
H. argosa adults	400	0.30
Athripsodes annulicornis larvae	71	2.6
A. annulicornis adults	70	5.3
Brachycentrus occidentalis larvae minus cases	33	18.
B. occidentalis adults	176	8.8
STONE FLIES		
Perlodes americana nymphs	50	38.
MAYFLIES		
Paraleptophlebia bicornuta nymphs	720	12
P. bicornuta adults	30	4.3
Baetis sp. nymphs	138	4.2
TRUE BUGS		
Corixa sp.	841	4.9
WATER MITES		
Hydracarina	1,076	0.30
SNAILS		
Stagnicola spp.	700	73.
Fisherola nuttallii	914	68.
F. nuttallii minus shells	35	43.
LEECHES		
Hirudnea	8	21.1
FLATWORMS		
Planaria sp.	105	5.9
HYDRA		
Hydra sp.	100	0.30

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TABLE 15
POPULATION COUNTS PER SQUARE FOOT CONTROL STATION

	Jan. 20, 1949	Feb. 3	July 12	July 26	Aug. 18	Sept. 15	Sept. 29	Oct. 13	Oct. 27	Nov. 10	Av No/sq ft
TRUE FLIES											
Tendipedidae larvae	1842	1146	318	1174	695	1200	891	475	128	28	789.7 - 1.1
Tendipedidae pupae	8	14	11	62	35	52	17	28	8	1	23.6 - 0.0
Simulium pupae			2			1					.3 - 0.0
AQUATIC MOTHS											
Argyractis angulatalis larvae							22	12	11	19	.65 - 0.0
Argyractis angulatalis pupae					1						
CADDIS FLIES											
Glossosoma velona larvae						1					.1 - 0.0
Glossosoma velona pupae						1	1				.2 - 0.0
Pyschomyia flavida larvae	9	8	1			2	137	230	40		42.1 - 0.14
Hydropsyche cockerelli larvae	74	62	20	88	75	1	146	631	41	37	117.5 - 0.2
Hydropsyche cockerelli pupae					15		11	3	1		3.0 - 0.0
Cheumatopsyche spp. larvae	37	6	2			1	20	6		3	7.5 - 0.0
Hydroptila argosa larvae	57	57	7	12			7	99	421	523	119.5 - 0.1
Albripsodes annulicornis larvae	1	6				2		7			1.7 - 0.0
Brachycentrus occidentalis larvae		21				2	5	67	8	25	12.8 - 0.2
Unidentified caddis fly larvae			2	4	1	1	149	169		9	33.5
STONE FLIES											
Perlodes americana					2					1	.3 - 0.0
MAY FLIES											
Paraleptophlebia bicornuta nymphs				1	5	8		1			1.5 - 0.0
Stenonema sp. nymphs				1					1		.2 - 0.0
Ephemerella sp. (needhami group) nymphs	38	22		1						2	6.3 - 0.0
Ephemerella sp. (serrata group) nymphs						2	11	1		2	1.6 - 0.0
Baetis sp. nymphs	1	7	3	9		1	2				2.3 - 0.0
WATER MITES											
Hydracarina	22	8	4	12	23	14	19	32	25	24	18.3 - 0.0
Hydracarina eggs					21			6			2.7
SNAILS											
Physa nuttallii										1	.1 - 0.0
Stagnicola sp.		3			1	11	10	18	1	2	4.6 - 0.0
Gyraulus vermicularis	1					2					
Fisherola nuttallii	9	5					5	10	14	9	5.2 - 0.0
Gastropods too young to identify					1						.1
WORMS											
Naididae					8	9	47	22	40	13	14.0
Gordius sp.	7	10		3	8	3	3		3	1	3.9
Planaria sp.						1			6		.7 - 0.0
HYDRA											
Hydra sp.				1	1	1			1	2	.6 - 0.0

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TABLE 16

POPULATION COUNTS PER SQUARE FOOT AT STATION 8

	Nov. 10, 1948	Dec. 8	Dec. 23	Jan. 6, 1949	Aug. 8	Aug. 13
TRUE FLIES						
Tendipedidae larvae	8	13	20	154	352	105
Tendipedidae pupae					31	
AQUATIC MOTHS						
Argyractis angulatalis larvae		1		1		
CADDIS FLIES						
Psychomyia flavida larvae				5		
Hydropsyche cockerelli larvae				14	4	6
Hydropsyche cockerelli pupae					1	
Cheumatopsyche spp. larvae	1	3	3	5		
Hydroptila argosa larvae		4	5	24		
Athripsodes annulicornis larvae		1	2	3		
Brachycentrus occidentalis larvae				1		
Caddis fly larvae too young to identify						2
MAYFLIES						
Baetis sp. nymphs				1		
WATER MITES						
Hydracarina		1	4	4	10	21
SNAILS AND CLAMS						
Stagnicola spp.		1		1	38	
Gyraulus vermicularis					5	
Fisherola nuttallii	4	2	1	2		
Pisidium spp.				1		
WORMS						
Lumbriculidae				1		
Naididae					2	
Gordius sp.		2	1	2	16	
Planaria sp.					1	

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TABLE 17
POPULATION COUNTS PER SQUARE FOOT AT STATION 7

	July 18, 1949	July 19	Aug. 3	Aug. 22	Sept. 9	Sept. 22	Oct. 6	Oct. 2	Nov. 3	Nov. 10
TRUE FLIES										
Tendipedididae larvae	1370	1358	2463	726	1110	545	447	236	459	363
Tendipedidae larvae	58	26	108	23	82	29	18	11	12	8
Simulium larvae										4
AQUATIC MOTHS										
Argyractis angulatalis larvae				1		1		11	8	23
CADDIS FLIES										
Glossosoma velona larvae								1		
Neureclipsis flavida larvae	1				3					
Hydropsyche cockerelli larvae	67	84	107	62	6	43	9	135	348	202
Hydropsyche cockerelli pupae				9	3	8	1	2		1
Cheumatopsyche spp. larvae	3		1			1			1	
Hydroptila argosa larvae	4		23	39	8	4	94	770	584	645
Athripsodes annulicornis larvae	2	1				1	2	3		
Brachycentrus occidentalis larv.			1	3		1		7	102	99
Caddis fly larvae to young to identify					2	58	396	178	23	3
STONE FLIES										
Perlodes americana nymphs		1			1					
Stone fly nymphs too young to identify					1					
MAY FLIES										
Paraleptophlebia bicornuta nymphs	16		48	28	9	7				
Stenonema sp. nymphs	2									
Ephemerella sp. (needhami group) nymphs	2	2	1			1		2	3	3
Baetis sp. nymphs		15	20	4	1	1			19	10
WATER MITE										
Hydracarina	8	46	22	16	31	39	38	37	12	13
Hydracarina eggs		38	2			7				
SNAILS										
Physa nuttalli					1					
Stagnicola spp.		7		19	1	1				
Gyraulus vermicularis	1	1		2	1	1				
Fisherola nuttallii				2		11	23	9	25	55
Gastropod eggs		113								
WORMS										
Lumbriculidae						2			1	2
Naididae					18	132	22	67	5	9
Gordius sp.	26	1	27	54	13	13	2	23	11	12
Planaria sp.				1					28	
HYDRA										
Hydra sp.	14	11		11						

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TABLE 18

[illegible] FOOT OF STATIONS 6 AND 8

	STATION 6														STATION 8			
	NOV. 18, 1949	NOV. 23	DEC. 6	DEC. 20	JAN. 3, 1950	JAN. 18	JAN. 30	FEB. 16	JULY 20	AUG. 10	AUG. 16	SEPT. 10	SEPT. 27	OCT. 4	OCT. 28	NOV. 8	JAN. 24, 1950	
TRUE FLIES																		
Tendipedidae larvae	96	201	67	108	208	306	325	195	908	1560	667	815	783	501	559	193	736	510
Tendipedidae pupae				1		1	2	4	227	175	76	26	63	14	14	8	4	35
Dexiidae larvae							3			1								0.2
AQUATIC MOTHS																		
Incurvatis annulistalis larvae	2	2	4	2	5	2	4	4				2	3	7	17	12	16	5
[illegible] FLIES																		
Glossosoma velona larvae								1	2	1	27					3		2
Glossosoma velona pupae									5		7							0.1
Psychoglys florida larvae	1	2	2	1		1	3	7							9	6	6	2
Psychoglys florida pupae										1			5	6				0.7
Hydropsyche cockerelli larvae	4	51				2	12	6	41	53	25	7	10	9	98	91	47	27
Hydropsyche cockerelli pupae					1			1			3	3						0.5
Cheumatopsyche spp. larvae		7	6	17	6	9		8		2		1		3		7		3
Hydroptila irgosa larvae	206	179	216	117	107	117	92	187	3	141	50	7	1	105	51	37	13	95
Hydroptila irgosa pupae									14		83	1	2					6
Leptocella albida larvae							1											
Athripodes annulicornis larvae	4	3	4	6		7	9	7				6	22	9	19	6	5	6
Brachycentrus occidentalis larvae	1	1	2	2	9	1	9	10							11	11	2	3
Caddis fly larvae too young to identify	1								1	69	19	2	208	498	64	10		51
STONE FLIES																		
Pteronarcys californica nymphs				1														
Perlodes americana nymphs									1	1	1		1					0.2
MAY FLIES																		
Paraleptophlebia bicornuta nymphs									2	1	3	3	10	2				1.2
Ephemerella sp. (needhami group) nymphs						1	8	2	2								9	1.3
Baetis sp. nymphs		11	2	1	1		3	1	9	32	2				2		2	4
WATER MITES																		
Hydrachnina	2	4		2	6	3	9	4	43	43	52	41	76	35	55	7	8	24
Hydrachnina eggs												7						.5
SNAILS																		
Physa nuttallii												1						
Stagnicola spp.	1	1	2	4	2	1	2					32	6	3	3	2	1	4
Fluminicola nuttalliana									5				6		5	4	11	2
Gyraulus vermicularis	3	2	2	1			2				3	17	6		2		4	2
Fisherola nuttallii	1			3	1	1	6	8						8	1	1		
Gastropod eggs												1	7					.5
WORMS																		
Lumbriculidae									6	8	21		14					3
Naididae											17	39	12			1		4
Oligochaeta sp.	7	23	7	11	22	9	6	4		13	3	9		2	11	20	5	7
Planaria sp.									1									
HYDRA																		
Hydra									3		16	34	4	1	1		1	4

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TABLE 19

POPULATION COUNTS PER SQUARE FOOT AT STATION 5

	NOV. 2, 1948	NOV. 18	DEC. 13	DEC. 29	JAN. 11, 1949	JAN. 27	AUG. 1	AUG. 20	SEPT. 8	SEPT. 18	OCT. 3	OCT. 17	OCT. 31	NOV. 14	JAN. 9, 1950
TRUE FLIES															
Tendipedidae larvae	355	675	1498	2183	2069	1424	1244	2629	3343	2336	1021	557	429	3517	927
Tendipedidae pupae					13	14	96	87	277	58	63	22	11	7	31
Simulium Sp. larvae		2	5	1	36	90	4	1			54			29	74
Simulium Sp. pupae							3				6				
AQUATIC MOTHS															
Argyractis angulatalis larvae	5	3	3	3	2	1			2	1	9	13	14	33	49
CADDIS FLIES															
Glossosoma velona larvae					4	3		3	1						37
Glossosoma velona pupae						1		1	2						1
Psychomyia flavida larvae		3	2			1			1		66	18	120	115	55
Hydropsyche cockerelli larvae	181	386	377	102	221	256	162	55	44	241	3186	164	274	1806	611
Hydropsyche cockerelli pupae	1	1						36	7	12	11	2	4	2	
Cheumatopsyche spp. larvae		10		3	3	1		1			58		7	5	
Hydroptila argosa larvae	44	86	34	38	25	29	7	10	5		11	171	494	620	127
Hydroptila argosa pupae								2			1				
Athripsodes annulicornis larvae	6	2	5	3	15	5					3	2	5	4	7
Brachycentrus occidentalis larvae	22	21	13	9	9	13			3	6	24		13	31	16
Caddis fly larvae - too young to identify		9							7	5	101	158	12	9	1
STONE FLIES															
Pteronarcys californica nymphs							1								
Perlodes americana nymphs								2	1						
Stone fly nymphs - too young to identify								2	2						
MAYFLIES															
Paraleptophlebia bicornuta nymphs									2	1					
Stenonema sp. nymphs								3							
Ephemerella sp. (needhami group) nymphs					22				2		1		2	67	45
Ephemerella sp. (serrata group) nymphs								3		2			1		
Baetis sp. nymphs	16	76	132	40	185	179	58	25	3	17	69	3	1	236	135
WATER MITES															
Hydracarina	19	21	25	83		4	60		80	50	83	108	50	475	15
Hydracarina eggs								10	13						
SNAILS AND CLAMS															
Physa nuttallii									1						
Stagnicola spp.	44	21	3	5	2	2	11	101	71	133	9	10	4		16
Gyraulus vermicularis	1							9		10				8	1
Fisherola nuttallii	1	1	1	1	1	12					145	2	3	2	32
Gastropods - too young to identify							21	109	45	4					
Pisidium spp.															1
WORMS															
Lumbriculidae										2	1	1			12
Naididae							2	12	182	40	2	22	27	65	1
Gordius sp.	4	8	36	37	115	15	4	60	138	60	17	8	33	69	17
Planaria sp.		1						2			1			4	
HYDRA															
Hydra sp.									14	5					

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TABLE 20

[illegible] STATIONS OCTOBER [illegible] 1 SEPTEMBER [illegible] 1 OCTOBER [illegible]

	OCT. 25,[illegible]	NOV. 9	NOV. 23	DEC. 7	DEC. 20	JAN. 18,[illegible]	FEB. 1	FEB. 17	MAR. 18	APR. 11	APR. 30	MAY. 9	MAY. 23	JUN. 20	SEPT. 12	SEPT. 26	OCT. 10	OCT. 24	NOV. 7	NOV. 21	Inv. 20
TRUE FLIES																					
Tendipedidae larvae	354	12[illegible]	75	177	1044	1673	1157	567	1076	512	1658	1086	1770	1661	2307	2018	814	623	441	379	963
Tendipedidae pupae		8				7	5		15	4	336	131	68	77	143	110	47	9	11	8	47
Empididae larvae																				1	
Simulium sp. larvae										1									1		
AQUATIC MOTHS																					
Nymphalis antiopalis larvae	1		4	5	7	3	5	1	3						8	2	71	27	15	44	7
CADDIS FLIES																					
Glossosoma velona larvae							1		5				7	8		3			3	7	1
Glossosoma velona pupae									5				3	16	5					1	1
Psychomyia flavida larvae		1			7	2	5	5	13			1		12	3	6	7	44	25	60	9
Hydropsyche cockerelli larvae	17	4	25	8	8	57	28	18	20	72	180	115	261	73	149	262	147	371	188	220	140
Hydropsyche cockerelli pupae			1									4	7	6	9	12	4				3
Cheumatopsyche spp. larvae	25	8	11	8	12	25	10	12	15			7	1	7	6			9		9	8
Hydroptila argosa larvae	150	21		118	466	312	843	395	592	8	16	539	259	125	30	5	787	1836	1447	1569	491
Hydroptila argosa pupae														62	3						3
Ithrypsodes annulicornus larvae	5	4	11	5	7	4	5	1	2							7		13	5	22	2
Brachycentrus occidentalis larvae	1		10	1		2	3	7	2				1		19	15	13	38		7	6
Brachycentrus occidentalis pupae									1												
Unidentified early instar caddis fly larvae								17		3	12	60	13	3	5	96	144	788	57	45	104
STONE FLIES																					
Perlodes americana nymphs													1	1	1						
Unidentified early instar Plecoptera											1										
MAY FLIES																					
Paraleptophlebia bicornuta nymphs										3		27	40	35	9	5	12				6
Stenonema sp. nymphs	4									1	1			1			1				
Ephemerella sp. (needham group) nymphs								4	7		7	1		1			1			4	1
Ephemerella sp. (serrata group) nymphs														1							
Baetis sp. nymphs			7	9		37			1	1	18	3	7	7	1	5	1	1	15	5	6
WATER MITES																					
Hydrozarina	12	1	1	10	4	1	7	8	1	11	34	27	9	29	87	12	79	17	8	18	13
Hydrozarina eggs											7				9						0.5
SNAILS AND CLAMS																					
Physa gyrinalis										1											
Stagnicola spp.	2	2	7	1	2	1	1	2	1	1		8	5			3			1		1.5
Fluminicola gyrinalisna										1		1		1	18		3	2		7	1.5
Gyraulus vermicularis	1		2	1					1		1	1	1						1		0.5
Fisherola gyrinalis			4	1	3	7	15	4	14							18	14	19	9	27	7
Gastropods too small to identify												14		4	1						2.5
Gastropod eggs												14									0.5
Pisidium spp.																				1	
WORMS																					
Lumbriculidae																1		1			
Naididae										1	2	32	8	6	17	10	8	1	7		5
Gordius sp.	5	10	8	14	20	14	15	3	5	5	12	41	83	31	179	16	1[illegible]	36	17	8	22
HYDRA																					
Hydra sp.										1		6	3	1	7						0.5

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TABLE 23

POPULATION COUNTS PER SQUARE FOOT OF SECTION 3

	OCT. 21, 1948	NOV. 4	DEC. 10	DEC. 28	JAN. 18, 1949	JAN. 28	JULY 28	AUG. 11	AUG. 24	SEPT. 7	SEPT. 21	OCT. 8	OCT. 20	NOV. 2	NOV. 17	
TRUE FLIES																
Tendipedidae larvae	197	151	1099	798	680	850	681	616	2654	1480	1285	1491	414	575	250	981
Tendipedidae pupae			4	4	6	5	120	44	78	88	45	39	30	8	1	33
Simulium sp. larvae					4											
AQUATIC MOTHS																
Argyractis angulatalis larvae		12	8	10		7				2	13	75	50	53	78	20
CADDIS FLIES																
Glossosoma velona larvae		1			1					1		1				
Glossosoma velona pupae										1						
Psychomyia flavida larvae			31	11	25	22	3	7	10	14	93	136	62	49	60	35
Hydropsyche cockerelli larvae	7	13	96	58	75	38	79	32	139	26	154	83	45	205	36	72
Hydropsyche cockerelli pupae		2	1				1	3	14	11	8	1			1	3
Cheumatopsyche spp. larvae	2	32	16	12	7	9		1	4	9	18		1	1		5
Hydroptila argosa larvae		38		81			40	342	54	6	8	31	304	677	783	155
Hydroptila argosa pupae					84	137		1	11	3						14
Leptocella albida larvae						1										
Athripsodes annulicornis larvae		10			17	10			3	12	32	12	9	1	17	8
Brachycentrus occidentalis larvae		2	2	14	1	2			2	1	10	1	4	17	1	4
Caddis fly larvae too young to identify		17					11	22	3	2	14	340	277	26	23	49
STONE FLIES																
Stone fly nymphs too young to identify								1		1						
MAYFLIES																
Paraleptophlebia bicornuta nymphs	1						27	11	11	22						5
Stenonema sp. nymphs			4			3				1		2		1		0.7
Ephemerella sp. (needham group) nymphs			23			6							1	2		1.6
Ephemerella sp. (serrata group) nymphs								1	16	14	4	1		4		2.7
Baetis sp. nymphs		9	5	5	12		2		4		6	3		1	1	3
WATER MITES																
Hydracarina	5	2	5	1	3	8	3	33	75	45	37	39	26	27	26	22
SNAILS AND CLAMS																
Stagnicola spp.	4	11	1	4		2		20	39	20	4	[illegible]		4	5	8
Fluminicola nuttallina										2	[illegible]	1				
Gyraulis vermicularis	7	2		1			3	7	17	16	3	1		12		6
Fisherola nuttallii		1	13	15	9	9					5	4	4		11	5
Gastropods too young to identify							1	18	1	1						1.5
Gastropod eggs							7	10	7							1.5
Pisidium spp.						1										
WORMS																
Naididae	1						20	162	16	55	7					18
Gordius spp.	[illegible]	5	14	28	9	5			[illegible]	73	17	[illegible]	1	3	[illegible]	16
Planaria spp.		1					8	[illegible]								.7
HYDRA																
Hydra sp.									7	[illegible]						1

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TABLE 22

POPULATION COUNTS PER SQUARE FOOT AT RICHLAND STATION

	Aug. 23, 1949	Sept. 8	Sept. 20	Oct. 4	Nov. 4	Nov. 17
TRUE FLIES						
Tendipedidae larvae	643	613	732	873	454	411
Tendipedidae pupae	47	45	63	59	12	8
Empididae larvae					3	13
AQUATIC MOTHS						
Argyractis angulatalis larvae	1	1	6	33	35	44
Argyractis angulatalis pupae	1					
Glossosoma velona larvae	8	7	2		3	
Glossosoma velona pupae	2	5	8			
Psychomyia flavida larvae		2	5	7		24
Hydropsyche cockerelli larvae	24	46	126	231	421	138
Hydropsyche cockerelli pupae	25	5	8			
Cheumatopsyche sp. larvae	2	2	4	3		
Hydroptila argosa larvae	23	14	3	4	176	110
Hydroptila argosa pupae	1	3				
Athripsodes annulicornis larvae	1	1	8	2	22	2
Brachycentrus occidentalis larvae		4	30	27	20	2
Caddis fly larvae too young to identify		12	27	77		
MAYFLIES						
Paraleptophlebia bicornuta nymphs	1					
Stenonema sp. nymphs		2	1	2		
Rhithrogena sp. nymphs			1			
Ephemerella yosemite nymphs						5
Ephemerella sp. (needhami group) nymphs					3	3
Ephemerella sp. (serrata group) nymphs	1	1				
Baetis sp. nymphs	4	6	5	3	21	80
WATER MITES						
Hydracarina	27	31	44	18	26	9
SNAILS						
Stagnicola sp.	1	2	1		3	1
Fluminicola nuttalliana		3	3		1	
Fisherola nuttallii						1
WORMS						
Lumbriculidae		12			1	
Naididae	1	4		3	17	3
Gordius sp.	13	9	6	19	33	15
Planaria sp.	1			1		
HYDRA						
Hydra sp.		2	1		1	

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TABLE 23
POPULATION COUNTS PER SQUARE FOOT AT STATION 1

	July 27, 1949	Aug. 11	Aug. 24	Sept. 7	Sept. 12	Oct. 5	Oct. 19	Nov. 2	Nov. 15	
TRUE FLIES										
Tendipedidae larvae	505	440	642	845	1057	691	732	690	418	659
Tendipedidae pupae	32	24	20	39	35	20	45	10	4	25
Simulium sp. larvae		1			1			1	3	
Simulium sp. pupae		1			1					
AQUATIC MOTHS										
Argyractis angulatalis larvae		1		1	2	25	12	8	9	6
CADDIS FLIES										
Glossosoma velona larvae	5	9	13	10	4	1	1	3	14	7
Glossosoma velona pupae	2	13	5	13	2				1	4
Psychomyia flavida larvae	1	5	3	3	13		51	28	34	35
Hydropsyche cockerelli larvae	28	77	35	3	125	164	112	72	34	72
Hydropsyche cockerelli pupae			5		3	2		1		1
Cheumatopsyche sp. larvae						16		23		11
Hydroptila argosa larvae	2	45	36	8	10	14	111	168	67	51
Hydroptila argosa pupae				4						
Athripsodes annulicornis larvae					1	12	4	1	3	2
Brachycentrus occidentalis larvae								1		
Caddis fly larvae too small to identify	7	11	6		49	17	59	18	3	19
STONE FLIES										
Perlodes americana nymphs	1				1					
MAYFLIES										
Paraleptophlebia bicornuta nymphs			4		1					
Stenonema sp. nymphs			1					1	1	
Rhithrogena sp. nymphs		1								
Ephemerella sp. (needhami group) numphs		1						4	1	.7
Ephemerella sp. (serrata group) nymphs				2		1		1		
Baetis sp. nymphs	4	58	22	52	25	7	21	38	21	29
WATER MITES										
Hydracarina	16	8	10	10	3	18	8	14	3	10
SNAILS										
Fluminicola nuttalliana					7	3				1
WORMS										
Naididae	2	3		3	3		1	7		2
Gordius sp.	5	11	19	31	10	19	11	53	19	2.0
Planaria sp.		2				2				
HYDRA										
Hydra sp.	1								1	

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environmental factors. Slack water areas, for example, support much smaller gross populations of macroscopic invertebrates than the swift water areas referred to here.

Life cycles of the organisms often are responsible for quantitative fluctuations. Most aquatic organisms produce many offspring to offset the high mortality suffered during early life stages. Consequently, in many cases sudden large influxes of certain forms correspond to reproductive periods in the life cycle of the species involved. An example of this is illustrated by the larvae of Hydroptila argosa which show a pronounced peak of abundance during the latter half of October and during November. Most of the aquatic insects of the Columbia River spend only their immature stages in the water, and during periods of concentrated emergence the immature populations of some forms may become nearly depleted. If the eggs hatch soon after being layed there is an immediate quantitative increase. This is the case in Hydroptila argosa. Some other forms are known to have an extended egg incubation period, often including a resting state. In such cases the immature stages are absent from the riverbed for a period of corresponding duration. Apparently this occurs in the case of Paraleptophlebia bicornuta.

If the radioactivity or other properties of the pile effluents produced any adverse effects upon the aquatic communities, the abundance of some forms might be expected to diminish and because of shifts of natural balance certain other species might increase in proportion to the concentration of the effluent, providing other factors remain constant. Hydropsyche cockerelli larvae, water mites and limpets have been chosen for comparing abundance with activity densities. The caddis fly larvae were selected because of their abundance and ability to concentrate relatively large amounts of radioisotopes. To negate life cycle irregularities, samples collected during the periods of emergence and peak of egg hatching (June 1 through October 15) have

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been omitted in calculating these averages. Mites were selected since they are aquatic throughout their life and are relatively abundant at all stations. Their averages are based on samples taken throughout the year. The limpet, Fisherola nuttallii, was selected because it is abundant, concentrates only small amounts of radioisotopes and is an animal of pronounced physiological and morphological differences from the other two forms. Quantitative records of limpets for the inclusive period of July through September were omitted in calculating the averages since the water level of the river at the time was too high to permit collection from areas inhabited by these slow-moving gastropods. It was not necessary to make the same omission for the mites as they are much more active and migrate with the changing water level. In Figure 11 the average abundance of the three organisms is listed in a stationwise series of progressively greater activity density levels. The series ranges from the control station where only background activity occurs to Hanford where the highest levels of activity are usually found. There is no apparent correlation between activity levels and abundance. In fact, Station 5 which is a site immediately below the 100-F Area where submaximum radioactivity is found, produces the largest population of Hydropsyche cockerelli, mites and limpets as well as of other forms and in proportions not significantly different from communities sampled at other stations.

Interstation population variations, other than those caused by biological factors, can be attributed primarily to significant hydrographic differences between grossly similar collecting sites. Chemical differences can be eliminated as a possible cause of major population differences for all stations above the mouth of the Yakima River because the river does not receive any tributaries or other sources of possible chemical alterations within that region other than the pile effluent itself. Differences in water temperatures at the various stations were not significant in relation to the general scope of this

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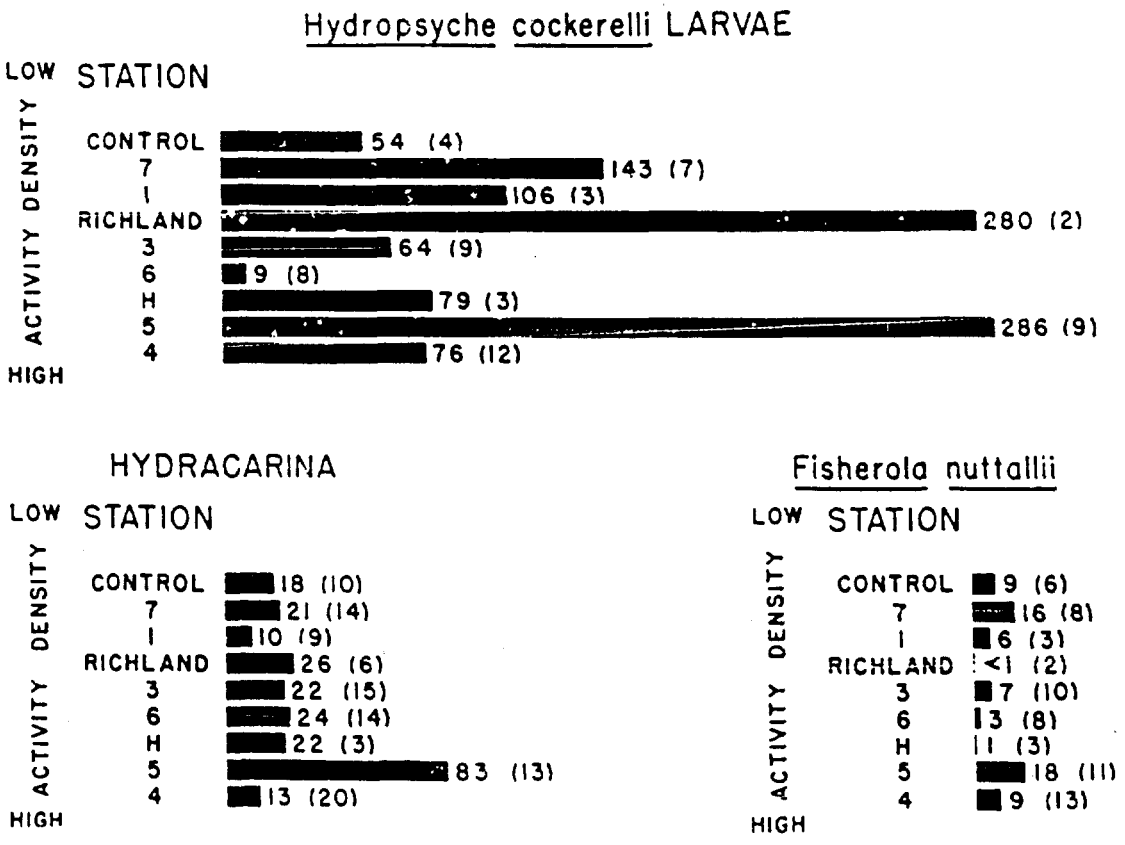
FIGURE 11

COMPARISON OF POPULATION ABUNDANCE TO ACTIVITY DENSITY

(AVERAGE NUMBER PER SQUARE FOOT)



( ) – NUMBER OF SAMPLES AVERAGED

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Even though the stations studied had similar hydrographic conditions there were variations sufficient to produce marked population differences. Current velocity and substratum composition were found to be factors intimately related to the abundance of organisms. Table 24 summarizes the current velocity readings which were taken during the 1949-1950 collecting season. The rate of flow on the bottom ranged from an average of 1.0 feet per second at four of the stations to an average of 2.6 feet per second at Station 5. The abundance data for the larvae of Hydropsyche cockerelli presented in Figure 11 are shown again in Figure 12 rearranged by stations with progressively greater water velocities. The pronounced affinity of this organism for swift water is evident. Maximum population density occurs at Station 5 which has the maximum water velocity; smaller population densities occur in the slower water areas. Explanations for irregularities may be found among other natural environmental factors. For example, the dense population at Station 7 is associated with large, rough-surfaced rocks which provide the most favorable anchorage for the nets of these non-case-building caddis larvae. Table 25, which summarizes the data on the composition of the riverbed at the sites selected for quantitative sampling, shows a maximum average rock size of 530 cubic centimeters (10 rocks per square foot) at Station 7 and a minimum average of 140 cubic centimeters (29 rocks per square foot) at Station H.

It should be emphasized that all organisms do not have the same affinity for swift water and large rough cobblestones. For example, the larvae of the caddis fly Mystacides alafimbriata are found only in the lagoon or slough areas where water currents are practically nonexistent.

The data presented indicate that observed fluctuations in populations are the result of normal life cycles and hydrographic conditions.

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FIGURE 12

COMPARISON OF POPULATION ABUNDANCE
TO WATER VELOCITY
(AVERAGE NUMBER PER SQUARE FOOT)

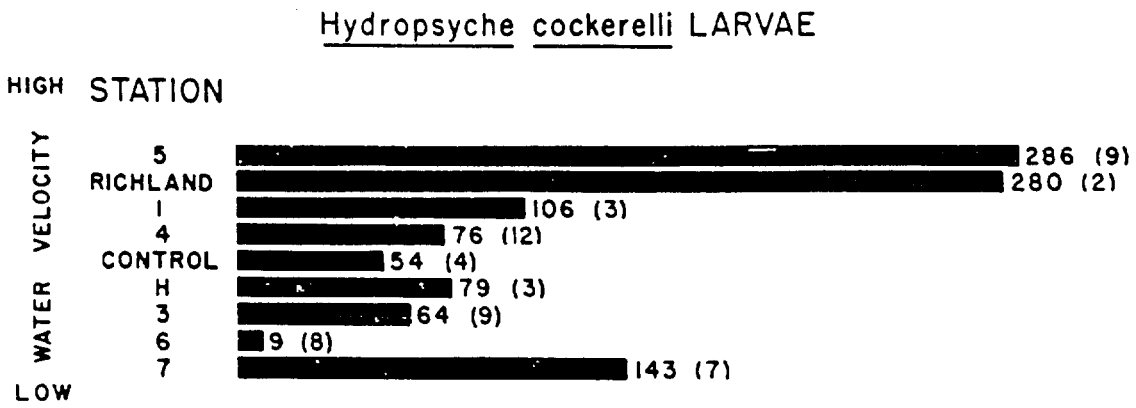

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TABLE 24

CURRENT VELOCITIES AT COLLECTING SITES

Location	Surface		Bottom		
	Number of Measurements	Average Velocity (ft./sec.)	Number of Measurements	Average Velocity (ft./sec.)	Combined Average Velocity (ft./sec.)
Sta. 1	48	2.4	48	1.5	1.9
Richland	42	2.4	36	1.5	2.0
Sta. 3	50	1.5	50	1.0	1.3
Sta. 4	49	1.9	49	1.5	1.7
Sta. 5	46	2.7	7*	2.6	2.6
Sta. 6	36	1.4	36	1.0	1.2
Sta. H	21	1.6	12	1.0	1.3
Sta. 7	37	1.2	37	1.0	1.1
Sta. 9	44	1.6	44	1.2	1.4
McNary	33	2.7	33	1.7	2.2

* Small number of measurements taken because water was too shallow at sampling points to take readings at two levels.

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TABLE 25

COMPOSITION OF RIVERBED AT COLLECTING SITES

Location	Number Of Samples	Average Number of Rocks Per Square Ft.	Average Volume Of Rocks In Cubic Centimeters Per Square Foot
Sta. 1	6	15	280
Richland	6	19	200
Sta. 3	6	18	260
Sta. 4	8	19	310
Sta. 5	6	30	250
Sta. 6	2	15	250
Sta. H	6	29	140
Sta. 7	6	10	530
Sta. 9	6	13	460
McNary	8	21	190

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They do not reveal any inhibiting or otherwise detrimental effects on the normal macroscopic invertebrate fauna of the Columbia River caused by liquid wastes from the Hanford piles.

SUMMARY

1. A preliminary radiobiological-ecological survey of the bottom-dwelling invertebrate fauna was made of that section of the Columbia River extending from the western boundary of the Hanford Works downstream to the site of McNary Dam to detect possible effects of effluents being discharged into the river from the pile areas. Samples were collected from 10 sites every second week. The survey was carried out during the period of October 1948 through February 1950.

2. Activity densities of both the water and the aquatic organisms increased as the river received additional effluent from each reactor area. Maximum activity levels were detected in the vicinity of Hanford; activity then decreased as the distance from the sources increased.

3. Decreases in activity density levels downstream from Hanford are attributed to more complete mixing of effluents with the river water, radioactive decay, sedimentation and filtration, and assimilation by living organisms. Below Richland additional dilution by the Yakima, Snake, Walla Walla and other rivers is an important factor.

4. All aquatic invertebrates studied were found to concentrate radioisotopes to many times the levels detected in the river water.

5. Different kinds of animals concentrate the activity to different but definite levels. The activity densities in specimens collected at Hanford ranged from approximately 300 times that of water for snails (Stagnicola apicina) to 2,300 times for midge larvae (Hydrobaeninae). Interspecific variation in activity densities have been attributed to at least five possible causes: (a) food habits of the organisms; (b) physiological requirements for specific elements; (c) rate of growth, metabolism, and life span; (d) life cycles; and (e) morphology. A table of coefficients is given comparing the activity density of all

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organisms to caddis fly larvae (Hydropsyche cockerelli).

6. Samples of caddis fly larvae and water from Hanford were analyzed daily for a period of approximately six months to study daily fluctuations as influenced by variations in pile operation and seasonal trends. The larvae were less effected by the changes in operation than was the water. Variations in operation of the 100-F pile produced a greater effect than similar variations for piles located further upstream.

7. The activity density of the water is inversely related to flow while the activity density of the insect larvae is related to the metabolic rate as controlled by temperature and possibly life cycle, as well as to the activity density of the water.

8. Decay curve and radiochemical analyses of various organisms show Na^{24} and P^{32} to be the dominant beta-emitting isotopes. Usually less than one per cent of the activity density was found to originate from longer-lived elements.

9. Population variations resulted from variations in biological and hydrographic conditions. The radioactive wastes from reactor areas did not appear to be producing any effects upon the natural invertebrate fauna, within the scope of methods of this study.

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ADDENDUM

PHYLOGENETIC LIST OF INVERTEBRATES STUDIED

PHYLUM PORIFERA "Sponge"

Spongilla lacustris (Linnaeus)

PHYLUM COELENTERATA

Hydra sp.

PHYLUM PLATYHELMINTHES "Flat Worms"

Planaria sp.

PHYLUM BRYOZOA "Moss Animalcules"

Plumatella sp.
Pectinatella sp.

PHYLUM ANNELIDA

Hirudinea "Leeches"

PHYLUM MOLLUSCA

Class Pelecyopoda "Clams"

Anodonta nuttalliana Lea "Freshwater mussel"
Pisidium columbianum Sterki "Pea Clam"
Pisidium compressum Prime "Pea Clam"
Cyclas fluminea (Muller)

Class Gastropoda "Snails"

Stagnicola nuttalliana (Lea)
Stagnicola apicina (Lea)
Radix japonica (Jay)
Physa nuttallii (Lea)
Fluminicola nuttalliana (Lea)
Goniobasis plicifera (Lea)
Gyraulus vermicularis (Gould)
Parapholyx effusa costata (Hemphill)
Parapholyx effusa neritoides (Hemphill)
Fisherola nuttallii (Haldeman) "Limpet"

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PHYLUM ARTHROPODA

Class Crustacea

Corophium spinicorne Stimpson "Amphipod"

Astacus trowbridgii Stimpson "Crayfish"

Class Insecta

"True Bugs"

Corixida "Water Boatmen"

"Mayflies"

Ephoron album Say

Paraleptophlebia bicornuta McDunnough

Ephemerella yosemite Trauer

Ephemerella sp.

Hexagina sp.

Stenonema sp.

Baetis sp.

"Stoneflies"

Pteronarcys californica Newport

Perlodes americana (Klapalek)

Isogenus sp.

"Caddis flies"

Rhyacophila coloradensis Banks

Glossosoma velona Ross

Psychomyia flavida Hagen

Hydropsyche cockerelli Banks

Hydropsyche californica Banks

Cheumatopsyche enomis Ross

Brachycentrus occidentalis Banks

Cheumatopsyche campyla Ross

Hydroptila argosa Ross

Leucotrichia pictipes Banks

Leptocella sp.

Athripsodes annulicornis (Stephens)

Mystacides alafimbriata Griffin

Lepidostoma strophis Ross

"Moths"

Argyractis angulatalis Lederer "Aquatic Moth"

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"True Flies"

Simulium spp. "Blackflies"
Tendipedinae "Bloodworm Midges"
Hydrobaeninae "Midges other than from Bloodworms"

Class Arachnida

Hydracarina "Water Mites"
Aranedia "Spiders"

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