AMCHITKA BIOENVIRONMENTAL PROGRAM
LIMNOLOGY OF AMCHITKA ISLAND, ALASKA

FINAL SUMMARY REPORT

and

PROGRESS REPORT

July 1, 1972 - September 30, 1973

by

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March, 1974

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LIMNOLOGY OF AMCHITKA ISLAND, ALASKA

by

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March, 1974

ABSTRACT

Limnological investigations have been an integral component of Battelle's Amchitka Bioenvironmental Program since inception of the program in 1967. Initial field effort was aimed at characterizing Amchitka's aquatic ecosystems to provide baseline information necessary to identify and evaluate any perturbations to the biota and aquatic habitats resulting from the underground nuclear testing program and the support activities required for successful execution of the tests. Test-related effects were sought in terms of unnatural changes in chemical, physical, and biological attributes of the freshwater lentic and lotic environments surveyed.

Changes observed in lakes following Milrow were slight, most being attributed to manifestations of seasonal fluctuation and not to Milrow results. Natural shifts in physical and chemical parameters plus changes in rates of metabolic parameters (heterotrophy and primary productivity) were not altered observably by Milrow. No elimination of planktonic species or drastic change in plankton community structure was observed. Three lakes were partially drained due to ground-surface displacement following Milrow, and one of these, Heart Lake, had gross morphological changes.

Detonation of Cannikin resulted in: (1) gross morphological changes to several lakes near SZ, (2) rupture of a dike in a drill-mud containment pond with subsequent contamination of an adjacent creek, and (3) formation of a new lake, Cannikin Lake, in the Cannikin subsidence crater. Cannikin Lake reached maximum size during autumn 1972 and is now the largest volumed lake on Amchitka Island.

Observations of potential short-term effects to chemical and biological parameters in Amchitka lakes as a result of Cannikin were masked by the separate effects of a severe storm immediately preceding detonation, and by the effects wrought from unusually low amounts of rainfall the following spring. Longer term post-Cannikin reconnaissance has not produced evidence to indicate that any significant changes in chemical and biological parameters occurred due to the Cannikin ground shock wave.

Several aquatic habitats were seriously altered as a result of drilling operations and general support activities. These waterbodies might recover their predisturbance status following evacuation of the Island. Streams perturbed by drill-mud influx appear to be recovering slowly.

INTRODUCTION

Battelle's Columbus Laboratories has been conducting for the United States Atomic Energy Commission a Bioenvironmental Program on Amchitka Island, Alaska. Since 1967 data from this program have been used to predict and evaluate the effects of AEC operations on the Amchitka environment. AEC activities on Amchitka have included the execution of two underground nuclear tests and the support services required for the performance and evaluation of these tests. The first test, designated by code name Milrow (about 1-megaton yield), was conducted on October 2, 1969, and the second, Cannikin (a little less than 5-megaton yield), on November 6, 1971. Prior to these tests, Project Long Shot (an 80-kiloton yield) was conducted by the U.S. Department of Defense with the assistance of the USAEC in October, 1965.

Effects analysis of the impact of AEC activities on the freshwater ecosystems of Amchitka have been an integral component of the Amchitka Bioenvironmental Program since 1967. Limnological investigations represent a portion of the total freshwater ecology program and have been conducted by investigators from The Ohio State University and Battelle's Columbus Laboratories. Additional freshwater ecology programs have been conducted by Utah State University scientists.*

Part of this report constitutes a summarization of research conducted on the limnology of Amchitka Island by Drs. Derry D. Koob and Thomas J. Birch from 1967 to 1972, and is adapted from their annual progress reports. Results and interpretations of FY 1973 research are detailed within the text. Research conducted during autumn of 1973 is discussed in Appendix B.

PROGRAM APPROACH

The AEC attempted to conduct its activities on Amchitka without detrimental effects on the biota and environs while allowing for successful execution of the nuclear testing programs. Problems attendant to the underground tests and support requirements were: (1) prevention of organic pollution via human waste entering lakes of the region, (2) minimization of inorganic pollution of lakes from construction activities, and (3) prediction, documentation, and evaluation of perturbation rendered to freshwater ecosystems due to shock wave effects arising from underground tests.

Initial or preevent limnological surveys were conducted to establish a basis for predicting the character and magnitude of effects from the proposed testing program and for determining whether or not the program could be conducted without producing unacceptable hazards to indigenous biota and associated habitats. Also, baseline data characterizing Amchitka's lakes and streams were needed for assessing detonation effects after the tests had occurred. The general approach was to acquire information pertaining to physical, chemical, and biological attributes (Table 1) of the freshwater systems prior to testtime, immediately afterward (short-term), and following the lapse of longer time intervals after the detonation.

*Their reports include: Neuhold 1971; Neuhold and Helm, 1968, 1970, 1971; Neuhold, Helm and Valdez 1971; Palmisano 1970; Palmisano and Helm, 1971; Valdez 1971; and Valdez and Helm 1971

TABLE 1. ATTRIBUTES SAMPLED SINCE INITIATION OF THE LIMNOLOGY STUDIES IN 1967

	Fall 1967	Spring 1968	Fall 1968	Spring 1969	Fall 1969 Milrow		Spring 1970	Fall 1970	Spring 1971	Fall 1971 Cannikin		Spring 1972	Fall 1972	Spring 1973
					Pre	Post				Pre	Post			
pH	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Alkalinity	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Temperature					X	X		X	X	X	X	X	X	X
Conductivity								X	X	X	X	X	X	X
Chloride										X		X	X	X
Hardness												X	X	X
Trace elements	X	X										X	X	X
Solids												X	X	
Suspended sediment					X	X	X							
Organic matter			X	X			X	X	X	X	X	X		
Heterotrophy			X	X			X							
Primary productivity	X	X	X	X			X		X	X	X	X	X	X
Phytoplankton (quant.)	X	X					X							
Phytoplankton (qual.)	X	X	X	X	X	X	X					X		X
Zooplankton (quant.)	X	X			X	X	X	X				X	X	X
Zooplankton (qual.)	X	X	X	X	X	X	X	X				X	X	X
Acidity													X	

Postevent surveillance included detection of changes in phyto- and zooplankton genera, and the monitoring of any gross chemical, physical, and/or morphometric change incurred by the waterbody. Koob (1971) established criteria for evaluating short-term seismic disturbance to aquatic ecosystems on the Island: (1) partial or complete drainage of a lake due to fracture of the bottom seal or to a breach of the peat retaining dam, (2) increase in alkalinity due to rupture of the peat mat in the watershed with resulting exposure of surface drainage water to alkaline subsurface rock deposits, (3) decrease in primary productivity as detected by a reduction in pH, (4) reduction in plankton populations due to direct or indirect ground shock wave, and (5) increase in suspended silt load due to disturbance of sediments. Posttest investigations were directed at detecting changes in chemical and/or biological parameters outside the range of natural variation exhibited for these parameters.

Objectives

The original objectives of the limnological studies on Amchitka were to collect and interpret data necessary to classify the major lakes on Amchitka according to their physical, chemical, and biological features. Following the initial survey, more intensive limnological studies were planned for selected lakes. These investigative efforts, which continued through FY 1973, had the objectives of collecting and interpreting limnological data pertinent to physical, chemical, and biological features in

sufficient detail to assist in: (1) evaluation of the effects of AEC operations, including underground nuclear tests, support requirements, and roll-up activities, and (2) following Cannikin, assessment of the new lake found in the subsidence crater resulting from the Cannikin detonation.

Methodology

The field and laboratory techniques employed for measurement of attributes sampled were standard procedures used commonly by practicing limnologists. Details concerning procedural methodologies have been discussed by Birch (1972) and Koob (1968, 1969, 1971).

Preliminary investigations were conducted on a broad areal basis to determine if similarities and differences existed in lakes and ponds representing various Island locales. Thereafter, study lakes were chosen with respect to (1) morphology and relative permanence, (2) proximity to SZ, (3) accessibility, (4) existence of prior sampling data, and (5) coordination of limnological sampling with the freshwater fisheries investigations. The principal lakes serving as sampling stations for test-related effects analyses are identified in Table 2. The location of each intensive study lake is shown in Figure 1.

OBSERVATIONS AND EVALUATION

General

The freshwater habitats of Amchitka include a few rapidly flowing streams, numerous small seasonal rivulets, a few cirque lakes, and many shallow lakes and ponds. Some of the larger lakes are situated in fault zones; in such lakes maximum water depth is from 3 to 5 meters. The majority of lakes and ponds are small, less than 1 hectare and less than 1 meter deep. These waterbodies are distributed throughout the southeastern two-thirds of the Island. Although the origin of these lakes is conjectural, many may have been formed as a result of differential thaw of ground ice during a period when permafrost was present; others probably originated in bedrock depressions (Everett, 1971).

Many of the lakes are increasing in surface area. This process results from bank erosion due to extensive wave action during much of the year. Concurrently, sedimentation is slowly decreasing the depth of the lakes. Dry lake beds with various stages of plant revegetation can be found throughout the southeastern two-thirds of the Island.

Many of the ponds and lakes are of the seepage type, receiving surface runoff from the surrounding region. These bodies of water have no definite inlet or outlet. However, most lakes have a well-formed outlet although water flow through it may be seasonal.

TABLE 2. IDENTIFICATION OF STUDY LAKES, AMCHITKA ISLAND, ALASKA

Lake Designation	Lake Name	Map Coordinate(a)	Cannikin Intensive Study Lake	Distance, km ^(b) And Bearing(c)	Milrow Intensive Study Lake	Distance, km ^(b) And Bearing(c)
1	Pumphouse Lake	585932			X	8.41 - 129
1a		562927				
2	Clevenger Lake	556945			X	5.31 - 130
5	Jones Lake	576955			X	6.44 - 108
7	Range Pond	515965	X	9.35 - 148	X	1.77 - 192
9	Rifle Pond	516963	X	9.50 - 148	X	1.93 - 189
10	Duck Pond	515962	X	9.65 - 149	X	2.10 - 190
19b	Silver Salmon Lake	541990	X	9.38 - 126		
23	Upper Twin Lake	518986			X	0.48 - 10
24	Lower Twin Lake	517985			X	0.32 - 360
25	Heart Lake	515982			X	0.0 - 290
26	Weed Lake	527994	X	7.93 - 123	X	1.61 - 37
28	Quonset Lake	519000	X	6.92 - 128	X	1.77 - 5
29	Long Shot Lake	512002	X	6.26 - 130	X	2.10 - 345
30	Long Shot Pond	514006	X	6.26 - 127	X	2.41 - 354
31b	Round Lake	521016	X	6.39 - 116	X	5.54 - 7
33	Strange Pond	493030	X	3.19 - 113	X	5.31 - 334
35	Mud Pond	494034			X	5.80 - 338
36	Clear Pond	493034			X	7.80 - 350
41b		484033	X	2.17 - 114		
41c		481036	X	1.87 - 111		
42c		473039	X	0.98 - 112		
42d		471041	X	0.82 - 102		
42e		471036	X	0.92 - 124		
42f		467048	X	0.74 - 40		
42g		481045	X	1.80 - 83		
42h		472039	X	0.92 - 112		
42i		474033	X	1.17 - 106		
43a		465029	X	1.32 - 171		
43b		466027	X	1.43 - 168		
43c		465025	X	1.58 - 174		
43d		467026	X	1.60 - 172		
43e		472016	X	2.59 - 161		
43f		461016	X	2.49 - 184		
43h		447018	X	2.38 - 215		
44a		451037	X	1.22 - 245		
44b		457033	X	2.70 - 254		
45		457054	X	1.27 - 310		
46		453051	X	1.43 - 315		
48		451052	X	1.53 - 313		
49		447049	X	1.56 - 298		
50a		445053	X	2.11 - 304		
50c		424047	X	3.31 - 279		
51	Emerald Lake	431066	X	3.47 - 309	X	12.06 - 316
52a		415086	X	6.39 - 315		
52c		396078	X	7.56 - 200		
53		403041	X	7.42 - 314		
58a	Fault Lake	395110	X	4.43 - 316	X	13.68 - 317
	Cannikin Lake	467040				
	14-Mile Lake	435063				
	D-Site Sump	405088				

(a) Coordinates refer to approximate center of lakes (U. S. Army Corps of Engineers map of Rat Islands, Amchitka, Series Q-801).

(b) Distance from SZ to the nearest lake shore.

(c) In degrees true

The bottom composition of the lakes and ponds varies from compacted peat and organic detritus to rock embedded in fine clays. Many of the shallower bodies of water support rich populations of rooted aquatic plants and associated periphyton communities. Hippurus vulgaris, Myriophyllum sp. and Ranunculus sp. form extensive beds in some lakes. Others contain no populations of rooted tracheophytes.

Due to seasonal distribution of rainfall, periods of water-level fluctuation occur in spring and again in the fall. Flushing of the lakes with snow-melt in the spring may be an important factor in altering the concentrations of nutrients and organisms at a time when phytoplankton population growth potential is high.

An important feature of the Amchitka environment is its relatively strong winds. With respect to physical and chemical characteristics of the aquatic ecosystems, these winds are extremely important. Water and air temperatures are usually nearly equilibrated; a differential exceeding 2 C rarely exists. Constant turbulence results in oxygen saturation in lake waters during the ice-free portion of the year. Freeze-over during winter is intermittent and periods of ice cover are of short duration. Koob (1968) found 100 percent oxygen saturation of water below ice in lakes that he sampled. Therefore, winterkill of organisms due to oxygen depletion would be unlikely to occur.

Values for pH in the small tundra pools and shallow lakes on Amchitka range between 5.0 and 6.5. In large lakes, and lakes and ponds in areas disturbed by road construction, pH values from 6.0 to 9.5 were recorded. Amchitka's freshwater systems possess low buffering capacity; generally, alkalinity ranges from 10 to 20 mg CaCO_3/l but occasionally reaches higher values. On Amchitka, wind-blown dust and drainage water enriched with inorganic material arising from construction activities can increase alkalinity tenfold in affected ponds (Koob, 1968).

Rate of primary productivity common to the freshwater lentic habitats on Amchitka ranges from 0.6 to 9.7 mg C/m³/hr, although higher values have been observed. Low levels of phosphate appear to limit carbon fixation in the unproductive acid lakes, but not in the most productive lakes. Experiments showed that trace-element fortification of both acidic and alkaline waters was inhibitory to phytoplankton production (Gordon, 1969). Several lakes in the vicinity of the main camp on Amchitka exhibit relatively high primary productivity rates; high concentrations of orthophosphate occurred in these waters. This region contains geologic fault lines bearing springs rich in phosphate. No evidence was found indicating organic pollution as the phosphate source. Nonphotosynthetic inorganic carbon fixation by bacteria was investigated by Koob (1971). Heterotroph activity appears to be positively correlated with total organic matter present in the water. With few exceptions, autochthonous production is the principal source of organic matter within the lakes and ponds studied.

The most productive lakes contain large populations of Cyanophyta, especially Anabaena flos-aquae, and the Chrysophyte, Asterionella formosa. Acidic, undisturbed lakes contain Kephriopsis and Eunotia. Many lakes support a diverse phytoplankton composition, with Dinobryon usually dominating in the spring. Koob (1968) classified the lakes into three general types according to the dominant phytoplankters present during summer: those that supported predominantly members of the Chrysophyta; those that maintained populations of numerous diatom and Chlorophytan species, including desmids and filamentous Zygnematales; and those containing high densities of filamentous and colonial Cyanophyta.

Rotifers, especially Polyarthra and Keratella, dominate the zooplankton communities. Calanoid copepods and cladocerans comprise the remainder of the zooplankton constituents. Although distributional patterns were evident, no distinct correlations between dominant zooplankton and physicochemical features of the lakes were discerned.

Pre- and Post-Milrow

A monitoring survey of 16 lakes (Table 2: Lakes 23, 24, 25 were included later) preceded the Milrow experiment for a short time and continued after the detonation. Pretest sampling proceeded through September 17-27, 1969, and the posttest sampling extended from October 7-12, 1969. This research effort was conducted to detect any changes in population trends of phytoplankton and zooplankton genera, and any gross chemical and physical changes that might have occurred as a result of Milrow.

Versus data gathered during previous sampling missions, preevent observations revealed high water levels in all intensive study lakes, a decrease in pH in all lakes except Clear Pond, and significant changes in alkalinity in Strange Pond and Pump-house Lake. Observed decreases in pH were attributed to reduction in primary productivity due to one or a combination of factors: lower water temperature, decreased light intensity, flushing of phytoplankton organisms from the lake by increased water flow, or by the onset of nutrient limitation. The alkalinity of Strange Pond had increased from 4 ppm to 14 ppm, presumably due to influx of high-alkalinity runoff water from the bare slopes of the edges of Infantry Road. The reduction in the alkalinity of Pump-house Lake was due primarily to change in the spring water supplying the lake (Koob, 1971). During this preevent sampling period, phytoplankton blooms were present in the productive lakes. Shortly before Milrow, heavy rainfall and strong winds accompanied by decreasing water temperature caused dramatic reductions in phytoplankton standing crops. Zooplankton communities in all 16 lakes were dominated by rotifers. Round Lake, Mud, Clear, and Strange Ponds supported copepod populations. Cladocerans were found only in Pump-house, Jones, Clevenger, and Fault Lakes.

Posttest analysis commenced 5 days after the execution of Milrow and ended 6 days later, October 12, 1969. Two lakes (not included as Milrow intensive study lakes) within 1200 feet of S₂ were partially drained due to the tipping of their basins during the formation of the subsidence crater. The water level in Round Lake fell about 25 cm due to increased flow of water through a hole in the base of the peat dike at the outlet. For most lakes and ponds no structural disturbance to the basin, banks, or surrounding vegetation mat was detected.

Chemical parameters measured before and after Milrow were very similar in all lakes sampled except for Round Lake. In this lake the alkalinity fell from 23 ppm preceding the event to 19.5 ppm after the event. Also, zooplankton abundance decreased and suspended inorganic sediments increased in Round Lake. In the other lakes sampled, no effects on pH, alkalinity, and zooplankton community structure or absolute abundance could be attributed to Milrow.

Reexamination studies conducted 7, 12, 18, 24, and 30 months following Milrow indicated that no discernable long-term detrimental effects occurred in any of the selected study lakes as a result of the underground shock wave produced by Milrow. Alkalinity values in the Milrow intensive study lakes remained relatively stable, indicating that alkaline subsurface bedrock had not been exposed to any degree by rupture of overlying peat mat in the drainage basins of these lakes. Observations made by Birch (1972) on Round Lake suggested that short-term post-Milrow changes in water chemistry and zooplankton populations were probably manifestations of seasonal fluctuation and not the result of Milrow. Elevated alkalinity and pH in Strange Pond at testtime later decreased toward normal background levels for these parameters in this lake. Fluctuations in phytoplankton and zooplankton distribution and abundance occurred, but were within the bounds of normal variations associated with environmental vagaries. In summary, the changes observed in the freshwater lentic ecosystems following Milrow were changes in degree only, not in kind. Natural shifts in concentrations of various materials and the changes in rates of measured metabolic parameters (heterotrophy and primary productivity) were not significantly altered. No elimination of species or drastic change in plankton community structures were detected.

Pre- and Post-Cannikin

Thirty-nine lakes were sampled during the autumn 1970 and spring 1971 field programs to acquire baseline information in preparation for Cannikin (see Table 2 for lake designations). During the autumn survey period, alkalinity in these lakes tended to increase; zooplankton communities were dominated by rotifers, and standing crop biomass tended to decrease. Periphyton production and primary productivity appeared comparatively low in lakes sampled near the Cannikin SZ area relative to other lentic habitats elsewhere on the Island (Birch, 1972).

The short-term pre- and postevent sampling was conducted from October 13, 1971 to November 17, 1971. Twenty-seven lakes from the 39 general survey lakes were selected for intensive investigation.

Gross morphological changes occurred in several lakes as a result of the Cannikin detonation, November 6, 1971 (Table 3). These changes were the result of ground motion produced by the shock wave, and by the formation of the Cannikin subsidence crater. Within a few days after the test small ponds formed in the Cannikin subsidence crater. Other ground disturbances included (1) channel blockage of White Alice Creek tributaries and (2) dike fracture in a drill-mud holding pond with release of drilling mud and wastes to Falls Creek. Although water quality in Clevenger Creek was markedly altered following the Cannikin event, water characteristics were greatly improved when this creek was resampled on June 3, 1972.

Water chemistry of the Cannikin intensive study lakes after the event was, in general, similar in the preevent period to that of previous autumn sampling periods. Just prior to Cannikin, pH values either decreased slightly or remained stable in most study lakes. With the onset of autumn weather, decreases in rates of primary productivity accounted for decreasing pH of the lake water. Preevent alkalinity values tended to remain stable or to increase.

TABLE 3. SUMMARY OF TEST-RELATED MORPHOLOGICAL CHANGES OBSERVED ON STUDY LAKES FOLLOWING CANNIKIN

Lake	Coordinate	Distance From Cannikin SZ		Bearing ^(a) From SZ	Drainage
		Miles	Kilometers		
<u>Completely Drained</u>					
42d	471041	0.51	0.82	102	Bering
42e	471036	0.57	0.92	124	Bering
42h	472039	0.57	0.92	112	Bering
42c	473039	0.62	0.99	112	Bering
<u>Partially Drained</u>					
44a	451037	0.76	1.22	245	Pacific
43e	472016	1.65	2.64	161	Pacific
<u>Extensive Shoreline Slumping</u>					
42f	467048	0.46	0.74	40	Bering
45	457054	0.79	1.2	340	Bering

(a) In degrees true.

As for the Milrow event, test effects were sought in terms of reduction in pH values due to reduced primary productivity and/or increased alkalinities due to exposure of subsurface alkaline bedrock. Any such subtle effects, however, would have been masked by the severe storm which swept Amchitka on D-1 (1 day preceding Cannikin). Postevent pH and alkalinity data gathered from 19 intensive study lakes were compared with all available preevent data from autumn sampling periods. Of the 19 lakes sampled, 13 had alkalinity values within the range of values obtained previously for this parameter. Only four lakes had postevent pH values outside previously recorded autumn ranges.

Of the intensive study lakes 26 were sampled for organic matter prior to Cannikin during autumn 1971. Of these 15 were resampled in mid-November following the event. Allochthonous organic inputs to Amchitka lakes and ponds enter from inlet streams, from bank erosion due to wave action, and from waterfowl excreta. Wind-blown matter is probably an additional extrinsic source. Autochthonous organic matter arises from intrinsic biotic production, from decomposition processes, from resuspension of precipitated organic materials in surficial sediment, and from release of excretory organics by indigenous aquatic biota. Organic matter analysis of the surveyed lakes revealed no general patterned effects associated with the Cannikin test. Pre- and posttest means for both total and particulate organic matter were similar. However, when the lakes sampled posttest were grouped according to Cannikin SZ proximity, as "close-in" or "control" (those lakes farthest removed from SZ), the

mean particulate organic matter content of the close-in group had increased from 3.4 mg/l preevent to 9.9 mg/l postevent. The mean particulates in the control group decreased from 14.0 mg/l to 6.5 mg/l. Organic particulates entering the lakes from the watershed, from bank slumping, and from agitation of bottom sediments by ground motion accounted for the increase in the posttest parameter value obtained from the close-in lakes. Decrease in particulate organisms in the control lakes was due to normal seasonal decline in plankton populations. Zooplankton populations were generally decreasing in abundance throughout the period of the Cannikin short-term effects survey. Analysis of postevent zooplankton samples showed reduced densities compared with preevent concentrations. No correlation existed between changes in density of zooplankton populations and proximity to Cannikin SZ. Primary productivity investigations were conducted on 13 lakes during the autumn of 1971 and were repeated on 3 of these lakes following the test. Carbon fixation rates decreased 50 to 77 percent in Lakes 31b, 43b, and 43c in the postevent analysis. Experience would indicate this change as attributable to the severe weather differences between analysis dates.

Water chemistry analyses were repeated for the Cannikin intensive study lakes during May and June, 1972. Again, an unfortunate weather factor confounded interpretation of results. A lack of normal quantities of precipitation during the interim period, resulting in generally increased concentrations of chemical constituents in the lakes, tended to obliterate any long-term subtle effects on water chemistry which might have occurred as a result of Cannikin.

Data on dissolved and particulate organic matter acquired during the spring of 1972 indicated that there was little change in the magnitude of these parameters in most study lakes when compared to pre-Cannikin data. Correspondingly, results of primary productivity estimates conducted on 18 Cannikin intensive study lakes during spring 1972, compared with preevent data revealed no discernable effects attributable to Cannikin.

Disturbances Due to Support Activities

Several lentic and lotic freshwater habitats on Amchitka were altered by activities associated with drilling test holes and support requirements necessitated by occupation of the Island. The influx of drilling mud and associated materials into three lakes seriously altered their chemical, physical and biological characteristics. In one instance, drill-mud was pumped into 14-Mile Lake for storage. This lake was eliminated as a freshwater aquatic habitat. Additionally, contaminated water from 14-Mile Lake entered Emerald Lake causing deterioration in water quality and loss of aquatic life. However, since the drilling materials were somewhat diluted prior to entering Emerald Lake, Birch (1973) predicted that the system might recover within a few years. A small pond at D-site received outfalls of drill-mud wastes from adjacent holding ponds and was rendered useless as an aquatic habitat. Moreover, the pond drained into an adjacent creek producing attendant adverse effects there, too.

Lake 1a has received considerable nutrient loads from the effluent of a sewage-treatment aeration pond serving the main camp area. The principal effect has been dramatic increases in rates of primary productivity, illustrating the dependence of

carbon fixation rates on nutrient availability. The rate at which this pond will return to its pre-1967 level is linked to the rapidity by which nutrients will be flushed from the lake following evacuation of the Island.

FY 1973 INVESTIGATIONS

The objectives of the limnology studies on Amchitka Island during FY 1973 were to collect and interpret data on the physical, chemical, and biological characteristics of selected freshwater habitats in sufficient detail to assist in: (1) the continued assessment of effects of the AEC underground nuclear tests, Long Shot, Milrow, and Cannikin on the freshwater ecosystems of the Island, (2) the continued evaluation of AEC test-related activities, including support facilities and the "roll-up" operations, and (3) the characterization of the new lake, Cannikin Lake, formed in the Cannikin subsidence crater. Documentation and evaluation of any effects possibly due to Cannikin received major effort. Additional attention was directed toward observing and evaluating the recovery status of lakes, ponds, and streams known to have been adversely perturbed by AEC test-related activities required for execution of the tests. Approach and field methodologies employed were the same as those utilized during previous limnological investigations on Amchitka Island.

During the autumn 1972 and spring 1973 field study periods, 45 lake stations and 26 stream stations were sampled for chemical analyses. The types of water chemistry analyses performed varied between stations according to the sampling design but the following analyses were conducted for all or some of the stations: acidity, alkalinity, chloride, hardness, pH, solids, and specific conductance. Mass spectrographic element analysis was conducted on 5 lakes; trace-element data are now available for 8 lakes. Primary productivity estimates using the carbon-14 technique were conducted for 18 lakes. Plankton samples were collected from the study lakes and analyzed with respect to composition and frequency of occurrence.

Chemical Parameters

Alkalinity, pH, and Acidity

Comparison of pH data obtained during consecutive autumn samplings, 1971 (Birch, 1973) and 1972 (Table 4), showed little change in this parameter for respective lakes. For many intensive study lakes, pH values were very similar during these autumn periods. Eleven lakes exhibited slight pH increases between autumns. However, no pH differentials of unusual magnitude were recorded. Slight variations in pH between autumn sampling periods are not peculiar, and have been observed previously. Alkalinity values were fairly similar during both autumn sampling periods (Birch, 1973 and Table 4), only six lakes having undergone marked changes in buffering capacity. In Lakes 2, 5, 51, and 52a, alkalinity was very noticeably lower during autumn 1972 than during autumn 1971. These data might have been manifestations of different intensity of human activity pre- and post-Cannikin as compared with 1 year later. Wind-blown road dust can alter alkalinity in affected

TABLE 4. CHEMICAL PARAMETERS OF ANCHITFA LAKES

Station	Date	pH	Alkalinity, mg/l	Acidity mg/l	Hardness, mg/l	Chloride mg/l	Specific conductance, micromhos/cm	Solids, mg/l		
								Total	Suspended	Dissolved
1	9-24-72	7.99	53.5	1.7	8.3	35.3	250			
	5-18-73	7.80	43.5	--	8.3	40.3	323			170.0
1a	5-18-73	8.30	31.0	--	31.0	55.8	230			150.0
2	9-14-72	7.89	48.0	1.6	22.0	33.1	210	12.3	11.3	100.0
	3-26-72	7.77	47.3	2.0	22.3	33.3	225			156.0
	5-27-73	9.08	60.0	--	23.0	46.8	310			
5	1-25-72	7.99	64.3	1.5	15.3	44.5	283	103.3	16.3	154.3
	5-20-73	8.5	71.5	--	13.8	49.3	315			165.3
7	1-20-72	5.87	1.3	3.3	17.3	13.3	210			
8	1-31-72	7.33	3.3	2.5	13.3	5.5	225	83.5	14.5	74.0
	5-20-73	7.11	5.5	--	3.3	10.3	310			
10	9-30-72	6.84	6.1	3.2	24.3	14.3	303	123.3	7.5	121.5
	5-20-73	6.98	5.5	--	43.3	113.3	463			253.0
10b	10-1-72	7.59	28.3	--	22.0	27.3	125			
13	3-20-72	7.26	10.3	1.3	14.3	6.5	143			
14	4-21-72	7.85	5.7	1.3	4.3	25.2	153	14.5	17.0	8.5
	4-21-72	7.38	21.8	--	2.0	25.7	155			
	5-20-73	7.10	22.0	--	23.0	42.5	20			
15	4-21-72	7.36	23.0	1.5	2.3	20.3	153			
	5-23-73	7.13	21.0	--	23.3	8.3	203			
16	4-27-72	7.9	15.5	1.3	23.3	24.5	163	56.3	8.3	48.3
	5-20-73	7.05	11.0	--	3.0	36.8	170			
17	9-20-72	5.84	1.3	1.3	9.3	25.3	113	50.3	26.3	33.3
	5-20-73	6.23	1.0	--	15.3	34.6	153			
18	4-28-72	7.29	17.6	2.1	16.3	7.4	153	113.3	52.0	67.3
	5-20-73	7.31	16.0	--	24.3	45.3	216			135.3
19	4-22-72	7.48	16.6	1.5	18.3	25.3	143			
	10-1-72	7.07	3.8	--	7.3	21.3	133			
20	10-2-72	5.76	3.3	--	8.3	4.5	113			
11b	10-2-72	6.3	1.1	1.1	3.3	18.3	83			
11c	10-1-72	5.78	3.3	--	8.3	28.5	63			
11d	11-1-72	7.53	24.3	--	24.3	4.1	23			
13b	4-10-72	7.7	3.7	3.3	11.3	28.7	13	23.3	1.3	13.3
	5-13-73	7.93	1.0	--	13.3	33.3	143			
40c	4-24-72	7.15	14.3	2.3	21.3	3.3	15	43.3	21.3	22.5
	5-13-73	7.33	3.5	--	24.3	25.3	173			
40d	3-23-72	7.83	1.3	1.3	12.3	7.1	13	78.5	22.0	54.3
	5-13-73	7.33	3.3	--	13.3	3.3	153			
40e	10-1-72	7.07	16.3	--	18.3	8.3	133			
40f	10-1-72	7.3	2.3	--	3.3	22.5	133			
40g	10-1-72	7.73	3.3	--	7.3	22.5	213			
40a	4-20-72	7.3	1.3	1.3	2.3	23.5	133			
40b	10-1-72	7.3	3.3	--	4.3	22.5	133			
4	4-1-72	7.3	13.3	1.3	17.3	4.3	133			
40f	4-20-72	7.3	3.3	--	13.3	22.5	118			
50a	4-20-72	7.3	17.3	1.3	22.3	7.1	145	74.3	13.3	1.5
	5-19-73	7.53	1.3	--	3.3	33.5	165			
50c	11-1-72	7.77	3.3	--	31.3	7.5	180			
50	4-20-72	7.3	3.3	1.3	12.3	22.5	145	13.3	1.5	1.3
	5-14-73	7.0	1.3	--	14.3	32.5	183			
50a	4-20-72	7.7	3.3	1.3	4.3	13.4	96			
	5-1-73	7.82	4.3	1.3	11.3	6.3	120			
50a	4-21-72	7.41	3.3	1.3	4.3	8.3	133			
	5-19-73	6.8	3.3	--	13.3	33.3	14			
60	10-1-72	7.83	4.3	--	3.3	22.3	93			
60 Lake	5-17-73	7.77	1.3	--	3.3	30.3	183			201.3
60	4-20-72	7.33	42.3	3.5	50.3	42.3	330			
60 Site Sump	9-20-72	7.46	3.3	--	23.3	--	133			
60 Site Lake	4-23-72	8.13	21.3	--	13.3	--	33			
60 Lake	5-19-73	7.43	3.3	--	25.3	--	59			

lakes and ponds (Koob, 1968). Too, these data might reflect perturbations to the drainage basins of these lakes as a result of the Cannikin ground shock wave. Neither suggestion is solidly tenable, especially since no general pattern in lake location and alkalinity decrease was discernible.

Noticeable differences occurred in pH values recorded from Lakes 1a, 2, and 5, sampled spring and autumn 1972; pH decreased in these lakes with the onset of autumn. Such changes, no doubt, reflect the influence of primary productivity on pH in these relatively productive lakes. For most of the study lakes, pH was similar during spring and autumn samplings.

Values recorded for spring 1973 indicated a considerable pH decrease in Lake 1a, compared with data collected the previous spring; pH reduction was not observed for other lakes. Also, alkalinity tended to be the same or only slightly altered in Lake 1a.

Measurement of acidity in a selected number of study lakes was initiated during the 1972 autumn fieldwork. The capacity of water to donate protons is designated the "acidity" of that water (A.P.H.A., 1965). Mineral and organic acids contribute to the acidity of a water. On Amchitka, acidity ranged from 1-4 mg CaCO_3/l in those lakes sampled.

Hardness

Total water hardness determinations were first conducted during the spring of 1972 (Birch, 1973). In the lakes investigated, hardness tended to be higher in spring than in autumn, but comparison of spring 1972 (Birch, 1973) and 1973 (Table 4) data revealed little difference in hardness for most lakes. Hardness decreased by approximately one-half in 14-Mile Lake between autumn 1972, and spring 1973. Alkalinity and specific conductance also decreased in this lake, indicating, perhaps, a settling-out of drill-mud suspensoids. Most Amchitka lakes and ponds possess hardness of the noncarbonate type. Six lakes have hardness levels less than the equivalent alkalinity level (both measured in mg CaCO_3/l , i.e., carbonate hardness).

Specific Conductance, Chlorides And Solids

Due to the absence of typical amounts of precipitation during spring 1972, dissolved solids concentrations, specific conductance, and chloride levels reached record highs in many of the study lakes (Birch, 1973). The following autumn, chloride concentration and specific conductance was much lower in all lakes surveyed, except Lake 50a and Cannikin Lake. Lake 50a remained stable in these characteristics, and both chloride and specific conductance continued to increase in Cannikin Lake. Dissolved solids concentrations in lakes sampled during both spring and autumn 1972, decreased. Resumption of normal amounts of freshwater inputs to these aquatic systems accounted, probably, for the reductions observed in these parameters during autumn sampling. Why Lake 50a was apparently unaffected is unknown. Specific conductance and chloride concentration continued to increase in Cannikin Lake through spring 1973. Here, continued water runoff from adjacent test-pad areas and solubilization of inundated drill-mud materials probably accounted for these increases.

Stream Surveys

Chemical analyses were performed on water samples collected from 26 stream sites during FY 1973 (Table 5 and Figure 2). Inlet and outlet streams for 5 lakes were included. Clevenger and Falls Creeks, both subjected to drill-mud influx in the past, were scrutinized closely.

FIGURE 2. GENERAL LOCATION OF AMCHITKA STREAMS SAMPLED DURING FY 1973

For the streams investigated, pH varied from 6.83 to 7.97; alkalinity ranged between 13.5 and 69.5 mg CaCO_3/l ; and specific conductance values ranged from 135 to 280 micromhos/ cm^2 , excluding Clevenger Creek which had a specific conductance of 420 micromhos/ cm^2 . Inflow and outflow streams for Lakes 5, 19b, 26, 33, and 42g did not exhibit any general pattern of variation in water chemistry characteristics. Comparison of FY 1972 (Birch, 1973) and FY 1973 data for Clevenger and Falls Creeks indicates that disturbances rendered by drill-mud spillage, as reflected in water chemistry characteristics, are being ameliorated, suggesting that both streams will possibly recover their predisturbance status. This judgment is, however, not

TABLE 5. CHEMICAL PARAMETERS OF AMCHITKA STREAMS

Station	Date	pH	Alkalinity, mg/l	Hardness, mg/l	Chloride, mg/l	Specific Conductance, micromhos/cm ²	Solids, mg/l		
							Total	Suspended	Dissolved
Roller Coaster 636972	9-30-72	7.61	36.1	20.8	32.5	210	88.5	13.0	75.5
Lake 5 Inlet 572965	9-25-72	7.56	25.0	20.0	27.5	170	--	--	--
Lake 5 Outlet 578968	9-25-72	7.97	69.5	15.0	34.5	280	--	--	--
Lake 2 Inlet 560946	9-25-72	7.33	46.7	25.0	--	240	--	--	--
Lake 19b Inlet 539987	10-1-72	7.93	43.5	31.0	33.2	225	--	--	--
Lake 19b Outlet 546992	10-1-72	7.59	28.5	22.0	27.1	170	--	--	--
Lake 26 Inlet 526996	9-26-72	7.10	20.0	23.0	--	160	--	--	--
Lake 26 Outlet 526995	9-26-72	7.37	22.1	22.0	--	155	--	--	--
Bridge Creek 517018	9-23-72	7.13	25.5	25.0	27.0	165	--	--	--
	5-18-73	6.95	13.5	22.0	38.0	180	--	--	--
Clevenger Creek 510968	9-23-72	7.32	64.3	24.0	39.0	--	169.5	21.0	148.5
	5-20-73	7.75	95.0	31.0	59.3	420	--	--	--
Duck Cove 506980	9-23-72	7.10	25.5	25.0	29.5	178	--	--	--
Lake 33 Inlet 493028	9-22-72	7.42	16.4	18.0	25.0	135	--	--	--
Lake 33 Outlet 495031	9-22-72	7.42	16.7	18.0	25.0	135	--	--	--
Lake 42g Inlet 480045	10-1-72	7.48	35.3	33.0	35.5	218	--	--	--
Lake 42g Outlet 483045	10-1-72	7.56	28.8	29.0	34.5	200	--	--	--
C-Site Area Cr-S 477034	9-23-72	6.97	25.5	27.0	29.0	175	--	--	--
C-Site Area Cr-W 476035	9-23-72	6.83	29.0	28.0	26.7	170	--	--	--
Ultra Creek 465001	10-3-72	7.93	48.2	35.0	35.5	230	--	--	--
Falls Creek 499072	10-3-72	7.93	33.7	32.0	39.0	230	140.5	32.0	108.5
	5-19-73	7.28	28.0	30.0	38.3	220	--	--	--
Fumarole Cove 316136	10-3-72	7.95	30.9	42.0	32.0	205	--	--	--
Chapel Cove 281200	10-1-72	7.54	19.6	24.0	24.0	110	--	--	--
Pop Side Creek 273159	10-3-72	7.60	21.4	25.0	27.5	160	--	--	--
Midden Cove 231208	10-1-72	7.48	14.3	23.0	24.0	150	--	--	--
Signal Cove 222168	10-3-72	7.45	14.9	24.0	34.0	160	66.0	14.5	51.5
Burr House Cove-N 206218	10-1-72	7.52	22.5	27.0	26.5	160	--	--	--
Burr House Cove-S 200216	10-1-72	7.39	21.6	23.0	26.5	170	--	--	--

completely bias free, since sample collection sites were well below the points of drill-mud outfall to both streams. Moreover, the extreme upper reaches of Falls Creek were receiving seepage from a drill-mud holding pond during spring 1973.

Element Analysis

To date, mass spectrographic element analysis has been conducted on water samples from 8 Amchitka lakes (Table 6). These lakes, 5, 10, 29, 30, 31b, 45, 58a, and Cannikin Lake, differ considerably in their physical, chemical, and biological characteristics. Element analysis is of particular importance in the study of aquatic ecosystems because certain elements constitute nutrients essential to algal metabolism. According to Nicholas (1963) sixteen elements are needed for growth of various algal species: N, P, Ca, Mg, Na, K, S, Fe, Mn, Cu, Zn, Mo, B, Cl, Co, and V.

In none of the lakes sampled was any of the above elements absent. Ca, K, Cl, Na, and Mg were present at "high" levels (exceeding the upper detection limits of mass spectrographic analysis). Iron concentrations ranged from 10 to 1000 ppb; manganese was recorded at concentrations varying from 6 to 50 ppb. Concentration of boron was lowest, 4 ppb, in Lake 45 and highest, 60 ppb, in Cannikin Lake. Lakes 5, 29, 30, and 31b had relatively high copper concentrations, while Cannikin Lake and Lakes 58a, 45, and 10, contained the element at levels less than 10 ppb. With few exceptions Zn, P, Mo, Co, and V occurred in all lakes at levels less than 10 ppb.

In freshwater lakes the sulfate ion is usually the second or third most abundant anion, exceeded only by bicarbonate and occasionally by silicate (Hutchinson, 1957). On Amchitka aquatic habitats are exposed to wind-carried sea spray constituting an important extrinsic source of chloride ion. Consequently, chlorine exceeded sulfur in all of the lakes examined, and exceeded silicon in five lakes. Sulfur levels were greater than those recorded for silicon in Lakes 5, 29, 30, and 31b. Both sulfur and silicon concentrations were markedly higher in the bottom waters of Cannikin Lake than in the surface waters. These elements follow a depth distribution determined by their source, in this instance probably exposed bedrock materials at the lake bottom. Specifically, silicon is derived from decomposition of aluminosilicate minerals. Aluminum also occurred at greater concentrations in the bottom waters of Cannikin Lake. Sulfur commonly originates from two sources: rainwater (probably not applicable due to the remoteness of the Island from industrialization), and sedimentary rock bearing calcium sulfate, which is moderately water soluble.

The quantity of manganese present in the surface waters of the earth is generally less than the quantity of iron. However, in Lake 30, manganese concentration exceeded that for iron. The Fe:Mn ratio in surface waters is normally well below the geochemical ratio of 50:1. An anomalous condition was observed in Lake 45 where the ratio was 167:1. Excluding the above rarities, the Fe:Mn ratios in the lakes sampled were equal to or considerably below 10:1.

Concentrations of copper did not follow any discernable pattern with regard to hardness of lake water. In "hard" water, copper is in large part precipitated as copper carbonate (Hutchinson, 1957). That the variability in hardness amongst the 8 study lakes is not great could have accounted for the lack of trend in the occurrence of

TABLE 6. MASS SPECTROGRAPHIC ANALYSIS OF LAKE WATER SAMPLES

(ppb, weight)

Element	Lake							Cannikin	
	5	29	30	31b	58a	45	10	Surface	Bottom
Li	1	1	1	1	1.	1.	0.6	0.1	0.06
Be	0.6	0.2	0.1	0.1	<0.005	<0.002	<0.003	<0.006	<0.006
B	30	20	10	10.	10.	4.	10.	60	60
F	30	15	6	6	50.	20.	30.	60	30
Na	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Mg	2000	~5000(b)	1000	~5000	~10000	~3000	~10000	1000	1000
Al	5	30	30	10	500.	1000	50.	60	100
Si	300	300	60	400	1000	~10000	300	1500	6000
P	10	10	6	10	5.	30.	6.	10	10
S	1000	1500	1000	600	1000.	2000.	1500.	1000	3000
Cl	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
K	~5000	~5000	~1000	~1000	~2000	~5000	~3000	3000	3000
Ca	500	~10000	~2000	~1000	~2000	~5000	~3000	1000	1000
Sc	<0.3	<0.3	<0.2	<0.2	<0.2	<0.6	<3.	<0.6	<0.6
Ti	<2	<2	<1	<1	3.	30.	<20.	10	30
V	1	0.6	1	1	0.5	6.	3.	10	50
Cr	1	1	<0.6	<0.6	1.	1.	1.	<2	<2
Mn	10	10	30	6	15.	6.	20.	10	50
Fe	15	15	10	30	25.	1000.	50.	200	600
Co	<0.6	0.6	0.4	0.4	<3.	<1.	<2.	<2	<2
Ni	<0.6	1	0.6	0.4	<2.	≤3.	<1.	<2	<5
Cu	100	500	150	300	3.	2.	<10.	<2	<5
Zn	<3	10	20	10	≤2.	6.	≤5.	<10	<10
Ga	<0.2	<0.2	<0.1	<0.1	<0.4	<0.4	<6.	<1	<1
Ge	<0.1	<0.1	<0.1	<0.1	<2.	<1.	<3.	3	3
As	1	1	1	1	≤0.5	≤2.	≤3.	3	10
Se	<2	<2	<2	<2	<1.	<1.	<3.	<3	<3
Br	100	100	100	50	400.	400.	600.	30	30
Rb	2	5	1	3	2.	10.	10.	1	3
Sr	5	50	20	20	20.	100.	100.	3	6
Y	<0.2	<0.2	<0.1	<0.1	<1.	<0.4	<0.6	<0.2	<0.3
Zr	<0.3	<1	<1	<0.2	<0.6	<0.6	<0.6	<0.3	<0.3
Nb	<0.2	<0.2	<0.1	<0.1	<0.3	<0.1	<0.2	<0.5	<0.5
Mo	≤0.6	≤1	≤1	≤0.4	<2.	<2.	<3.	0.6	0.6
Rh	<0.2	<0.1	<0.1	<0.1	<0.2	<0.1	<0.2	<0.2	<0.2
Pd	<0.3	<0.6	<0.4	<0.2	<0.3	<0.1	<0.2	<0.3	<0.3
Ag	0.3	1	2	0.4	<0.2	<0.1	<0.1	<0.1	<0.3
Cd	≤0.1	0.6	0.4	≤0.1	<0.3	≤0.4	≤0.6	<0.2	<0.2
In	<0.2	<0.2	<0.1	<0.1	<0.3	<0.1	<0.6	<0.2	<0.2
Sn	≤0.6	1	1	≤0.2	<1.	<0.4	<0.6	<0.3	<0.2
Sb	<0.3	<0.3	<0.2	<0.2	<0.5	<0.2	<1.	<0.6	<0.6
Te	<0.1	<0.1	<0.06	<0.06	<0.2	<0.06	<0.2	<0.3	<0.6
I	2	5	4	4	10.	1.	10.	2	4
Ru	<1	<0.3	<0.4	<0.4	<0.3	<1.	<2.	<0.6	<1
Cs	<0.2	<0.2	<0.1	<0.1	<0.5	<0.2	<1.	<0.3	<0.6
Ba	0.6	2	1	1	7.	7.	3.	0.3	1
La	<0.2	<0.2	<0.1	<0.1	<0.5	<0.2	<0.3	<1	<1
Ce	<0.3	<0.3	<0.2	<0.2	<0.5	<0.2	<0.3	<0.1	<0.1
Pr	<0.2	<0.2	<0.1	<0.1	<0.1	<0.06	<0.1	<0.3	<0.3
Nd	<0.1	<0.1	<0.06	<0.06	<0.5	<0.2	<0.3	<0.2	<0.2

TABLE 6. (Continued)

Element	Lake							Cannikin	
	5	29	30	31b	58a	45	10	Surface	Bottom
Sm	<0.1	<0.1	<0.06	<0.06	<0.1	<0.06	<0.1	<0.1	<0.1
Eu	<0.06	<0.06	<0.04	<0.04	<0.03	<0.2	<0.3	<0.2	<0.2
Gd	<0.1	<0.1	<0.06	<0.06	<0.1	<0.04	<0.06	<0.1	<0.1
Tb	<0.3	<0.3	<0.2	<0.2	<0.1	<0.2	<0.3	<0.3	<0.3
Dy	<0.1	<0.1	<0.06	<0.06	<0.1	<0.1	<0.1	<0.2	<0.2
Ho	<0.3	<0.1	<0.06	<0.06	<0.1	<2.	<0.3	<0.3	<0.3
Er	<0.1	<0.1	<0.06	<0.06	<0.1	<0.1	<0.2	<0.3	<0.3
Tm	<0.03	<0.03	<0.2	<0.02	<0.5	<0.06	<0.06	<0.1	<0.1
Yb	<0.1	<0.1	<0.06	<0.06	<0.4	<0.4	<0.6	<0.1	<0.1
Lu	<0.1	<0.1	<0.04	<0.1	<0.5	<0.2	<0.3	<0.2	<0.2
Hf	<0.1	<0.1	<0.06	<0.06	<0.2	<0.06	<0.3	<0.1	<0.1
Ta	<2	<3	<2	<1	<50.(c)	<2.	<6.	<0.6	<0.6
W	<0.1	<0.1	<0.06	<0.06	<0.1	<0.1	<0.1	<0.1	<0.1
Re	<0.06	<0.06	<0.04	<0.04	<0.1	<0.2	<0.3	<0.3	<0.6
Os	<0.1	<0.1	<0.06	<0.06	<0.4	<0.4	<0.4	<0.1	<0.1
Ir	<0.06	<0.1	<0.1	<0.1	<0.4	<1.	<2.	<0.2	<0.2
Pt	<0.1	<0.1	<0.06	<0.06	<0.2	<0.2	<0.2	<0.1	<0.1
Au	<0.3	<0.3	<0.2	<0.2	<0.5	<0.2	<0.3	<0.3	<0.3
Hg	<0.1	<0.1	<0.1	<0.1	<0.2	<0.2	<0.2	<0.3	<0.3
Tl	<0.06	<0.06	<0.06	<0.06	<0.1	<0.1	<0.1	<0.3	<0.3
Pb	0.2	0.6	0.6	0.6	2.	0.4	0.2	0.3	0.3
Bi	<0.03	<0.03	<0.02	<0.02	<0.04	<0.04	<0.04	<0.1	<0.1
Th	<0.03	<0.03	<0.02	<0.02	<0.05	0.5	0.5	<0.06	<0.06
U	<0.03	0.1	0.1	<0.02	<0.1	0.5	0.5	<0.06	<0.06

(a) Approximately 100,000 ppb.

(b) Approximations of element concentrations which exceeded the upper limits of detectability.

(c) Contamination from Ta electrode holders.

this element. Furthermore, although some hardness was present, these waters might also have been too "soft" for precipitation of ionic copper.

With one exception, total phosphorus levels were low. The value recorded for Lake 45, 30 ppb, is in the range normally reported for surface waters. No correlation between total phosphorus concentration and primary productivity was observed for these lakes.

Zn, Mo, Co, and V were found in trace amounts. Gordon (1969), working on four Amchitka ponds, conducted primary productivity experiments with trace-element (Fe, Mo, B, Zn, Mn, Co, Cu) fortification of pond water and reported that trace-element enrichment inhibited phytoplankton carbon fixation rates in each of his study ponds. Evidence suggests that certain essential elements found only in trace amounts are not limiting lake metabolism on Amchitka Island.

Little or no information pertaining to concentration or role in aquatic systems is available for many of the elements listed in Table 5. Nevertheless these data are extremely important because they will serve to augment the growing data base needed to elucidate element concentrations of the earth's surface waters.

Biological Parameters

Plankton

Although algal organisms were not enumerated, general observations were made pertaining to occurrence and to predominant forms present in the water samples. Phytoplankton densities were generally low in most study lakes during the FY 1973 investigations. In Lakes 5, 9, 10, and 43e large standing crops of algae were indicative of bloom conditions. The predominant algal forms in these lakes were the blue-greens, Aphanizomenon and Anabaena. Algae were blooming in Lakes 9 and 10 during both autumn and spring sampling periods. Phytoplankton populations in other lakes consisted of a few mixed green and diatom species. Few algal organisms were found in the Cannikin Lake samples. Although a small number of individuals of the family Palmellaceae were present, additional samples are required to adequately characterize the phytoplankton community in this lake.

Rotifers dominated the zooplankton community in most intensive study lakes (Tables 7 and 8). Cannikin Lake, because of its magnitude, was sampled at four different locations (Figure 3), helping to overcome any sampling bias introduced by uneven spatial distribution of zooplankton. Lakes 2, 5, 9, and 10, contained very large populations of rotifers, compared with other lakes. Keratella cochlearis and K. quadrata were the predominant rotifers in these lakes. Highest cladoceran densities were found in the samples from Lakes 5, 42f, and 43d, while moderate numbers were taken from Lakes 10, 26, 28, and 44a. In general, cladoceran abundance in the study lakes during the FY 1973 period agreed with observations reported by Birch (1973). Concentrations of adult copepods and/or nauplii were greatest in Lakes 1, 1a, 2, 7, 28, 35, 42f, 43b, and 43d. Copepods were the only zooplankters in Lake 1a.

TABLE 7. ZOOPLANKTON POPULATION CONCENTRATIONS OF
AMCHITKA LAKES

(Organisms/Liter)

Lake	Date	Adult Rotifers	Rotifer Eggs	Cladocerans	Adult Copepods	Copepod Nauplii	Total Zooplankton
1	9-24-72	84	23	18	5	3	133
	5-18-73	85	0	0	0	68	153
1a	5-18-73	0	0	0	0	303	306
2	9-24-72	360	220	0	3	3	586
	5-20-73	2425	25	0	0	27	2475
5	9-25-72	1299	405	230	7	0	1941
	5-20-73	1150	200	50	25	0	1425
7	9-20-72	3	3	0	7	60	73
9	9-30-72	495	165	10	0	0	670
	5-20-73	716	143	3	5	35	902
10	9-30-72	613	353	7	3	0	976
	5-20-73	9125	1125	63	0	0	10313
19b	10-1-72	11	0	0	0	0	11
23	9-20-72	59	3	8	13	10	93
26	9-24-72	288	40	30	0	0	331
28	9-24-72	41	5	0	3	0	49
	5-20-73	97	25	25	23	38	208
29	9-27-72	13	3	5	0	5	26
	5-17-73	41	0	5	0	35	81
30	9-27-72	180	15	5	5	15	220
	5-18-73	41	3	0	3	33	80
31b	9-28-72	6	7	10	15	7	45
	5-20-73	0	0	3	9	6	18
33	9-22-72	56	18	0	0	7	81
35	10-2-72	256	15	3	45	83	402
36	10-2-72	158	40	0	3	23	224
41b	9-22-72	341	33	3	5	45	427
42f	10-1-72	13	3	475	23	63	577
42g	10-1-72	33	5	0	3	0	41
43b	9-29-72	0	3	18	10	13	46
	5-18-73	6	5	40	25	15	85
43c	9-29-72	127	18	0	0	0	145
	5-19-73	0	0	25	0	25	50
43d	9-29-72	21	0	133	43	13	210
	5-19-73	0	0	23	13	25	61
43e	10-2-72	259	148	3	3	0	413
43f	10-2-72	71	50	0	0	0	121
43h	10-2-72	501	180	3	0	0	684
44a	9-22-72	65	10	40	0	0	115
44b	10-2-72	131	20	0	0	0	151
45	9-22-72	154	43	5	3	0	205
49	9-22-72	48	20	3	3	0	74
50a	9-22-72	6	3	0	5	7	21
	5-18-73	3	0	0	0	0	3
50c	10-2-72	92	40	3	3	0	138
51	9-22-72	21	0	0	10	25	56
	5-19-73	9	0	0	0	0	9
52a	9-22-72	3	0	3	0	0	6
53	9-22-72	19	3	3	0	5	30
58a	9-24-72	48	5	0	0	10	63
	5-18-73	8	0	3	0	0	11
Canni- kin lake	10-2-72	34	0	3	0	3	40
1	5-18-73	36	0	0	0	0	36
2	5-18-73	69	0	3	3	0	75
3	5-17-73	88	0	0	0	0	88
4	5-17-73	38	0	0	0	3	41

TABLE 8. ROTIFER POPULATIONS OF AMCHITKA LAKES

(Organisms/Liter)

Lake	Date	<u>Keratella</u> <u>cochlearis</u>	<u>Keratella</u> <u>quadrata</u>	<u>Polyarthra</u>	<u>Asplanchna</u>	<u>Synchaeta</u>	<u>Filinia</u>	Other Species	Total Rotifers	Percent of Total Zooplankton
1	9-24-72	3	25	5	0	0	23	28	84	63
	5-18-73	0	0	25	35	0	25	0	85	55
1a	5-18-73	0	0	0	0	0	0	0	0	0
2	9-24-72	0	73	30	7	7	195	48	360	61
	5-20-73	0	2250	25	150	0	0	0	2425	97
5	9-25-72	3	593	138	13	7	500	45	1299	67
	5-20-73	25	0	0	1050	0	75	0	1150	80
7	9-20-72	0	0	3	0	0	0	0	3	4
9	9-30-72	325	100	7	13	0	0	50	495	74
	5-20-73	420	245	43	0	3	5	0	716	79
10	9-30-72	30	570	10	0	0	3	0	613	63
	5-20-73	2187	6438	313	0	0	500	0	9125	88
19b	10-1-72	3	0	0	3	0	0	5	11	100
23	9-20-72	0	0	33	0	0	8	18	59	64
26	9-24-72	7	0	3	20	30	215	13	288	86
28	9-24-72	0	13	5	3	0	0	20	41	86
	5-20-73	3	68	18	5	0	0	3	97	46
29	9-27-72	0	3	0	3	0	0	7	13	50
	5-17-73	3	0	38	0	0	0	0	41	50
30	9-27-72	55	3	18	93	3	0	8	180	83
	5-19-73	0	0	33	8	0	0	0	41	51
31b	9-28-72	0	3	0	0	3	0	0	6	14
	5-20-73	0	0	0	0	0	0	0	0	0
33	9-22-72	3	0	5	0	0	43	5	56	70
35	10-2-72	5	0	198	35	0	3	15	256	64
36	10-2-72	105	0	25	15	7	3	3	158	71
41b	9-22-72	45	25	35	188	3	0	45	341	80
42f	10-1-72	0	5	0	0	0	0	8	13	2
42g	10-1-72	0	18	0	0	3	7	5	33	81
43b	9-29-72	0	0	0	0	0	0	0	0	0
	5-18-73	3	0	3	0	0	0	0	6	7
43c	9-29-72	58	0	0	8	0	53	8	127	89
	5-19-73	0	0	0	0	0	0	0	0	0
43d	9-29-72	8	0	0	0	0	3	10	21	10
	5-19-73	0	0	0	0	0	0	0	0	0
43e	10-2-72	98	0	35	43	40	8	35	259	63
43f	10-2-72	33	0	0	10	0	5	23	71	59
43h	10-2-72	40	33	30	25	50	258	64	501	73
44a	9-22-72	18	35	0	0	5	0	7	65	57
44b	10-2-72	7	33	0	3	23	65	0	131	87
45	9-22-72	3	138	0	3	0	3	7	154	75
49	9-22-72	30	0	0	5	0	0	13	48	65
50a	9-22-72	0	0	0	0	0	3	3	6	30
	5-18-73	3	0	0	0	0	0	0	3	100
50c	10-2-72	18	28	5	0	8	20	13	92	68
51	9-22-72	0	0	0	8	0	8	5	21	38
	5-19-73	0	0	0	3	3	3	0	9	100
52a	9-22-72	0	0	0	0	0	3	0	3	50
53	9-22-72	0	0	13	3	0	0	3	19	66
58a	9-24-72	0	0	40	0	0	0	8	48	76
	5-18-73	0	0	8	0	0	0	0	8	72
Canni- kin Lake	10-2-72	5	0	5	3	13	3	5	34	87
1	5-18-73	0	0	33	0	0	0	3	36	100
2	5-18-73	13	0	50	3	0	3	0	69	92
3	5-17-73	0	0	83	5	0	0	0	88	100
4	5-17-73	0	0	38	0	0	0	0	38	92

FIGURE 3. CANNIKIN LAKE SAMPLING STATIONS

Primary Productivity

Rates of carbon fixation by phytoplankton were determined for 17 lakes during autumn, 1972, and for 5 lakes during spring, 1973 (Table 9). During autumn, 1972, in situ determinations were conducted on Lakes 5, 29, 30, and 31b. Productivity estimates for Cannikin Lake were conducted with water samples collected from depths of 0.2 m and 2.0 m at four lake stations.

Total carbon fixation values for the 17 autumn analyses ranged from a high of 16.93 mgC/m³/hr in Lake 5, to a low of 0.31 mgC/m³/hr in Lake 58a. Considering the in situ determinations, midafternoon incubations yielded highest productivity rates. Rate of carbon fixation during spring was highest in Lake 5, and lowest in Cannikin Lake.

No significant differences were found between productivity measurements conducted on water samples obtained from 0.2 m and 2.0 m depths in Cannikin Lake. Furthermore, values obtained from stations on Cannikin Lake sampled on the same day showed little variation. However, considerable variation occurred between values obtained on the two consecutive sampling days. Most of this difference was due, apparently, to increased heterotroph activity as evidenced by the difference shown in dark uptake.

TABLE 9. RATES OF CARBON FIXATION BY PHYTOPLANKTON

Lake	Date	pH	Alkalinity, mg/l	Carbon Fixation, mgC/m ³ /hr		
				Total	Dark	Net
1	9-24-72	7.99	53.5	4.89	0.37	4.52
2	9-24-72	7.89	46.6	9.50	0.26	9.24
	5-20-73	8.08	60.0	1.79	0.29	1.50
5	9-25-72(a)	7.99	69.3	8.15	0.49	7.66(0834-1235)(b)
				16.93	0.67	16.26(1230-1630)
				2.82	0.35	2.47(1630-2030)
	5-20-73	8.05	71.5	3.34	0.46	2.88
9	9-30-72	6.60	3.0	1.02	0.05	0.97
10	9-30-72	6.84	6.1	7.74	0.22	7.52
	5-20-73	6.98	5.5	2.54	0.09	2.45
19b	10-1-72	7.59	28.3	1.45	0.18	1.27
26	9-24-72	7.85	25.7	1.77	0.17	1.60
28	9-24-72	7.26	29.6	2.91	0.19	2.72
29	9-27-72(a)	7.39	15.5	0.51	0.10	0.41(0815-1230)
				0.51	0.10	0.41(1230-1620)
				0.39	0.12	0.27(1600-2000)
30	9-27-72(a)	5.89	1.3	0.70	0.04	0.66(0815-1215)
				2.20	0.11	2.09(1220-1620)
				0.66	0.13	0.53(1600-2000)
31b	9-28-72(a)	7.29	17.6	0.65	0.07	0.58(0800-1200)
				1.57	0.10	1.47(1200-1600)
				0.79	0.09	0.70(1555-1955)
	5-20-73	7.31	16.0	0.46	0.12	0.34
42f	10-1-72	5.78	0.9	4.85	0.14	4.71
42g	10-1-72	7.56	29.3	0.76	0.22	0.54
43b	9-29-72	5.87	1.7	2.24	0.05	2.19
43c	9-29-72	7.15	14.3	0.70	0.09	0.61
43d	9-29-72	5.89	1.0	1.44	0.03	1.41
58a	9-24-72	6.91	4.0	0.31	0.04	0.27
<u>Cannikin Lake Stations</u>						
1(0.2m)	5-18-73	7.80	62.0	0.54	0.20	0.34
(2.0m)	5-18-73	7.80	62.0	0.47	0.16	0.31
2(0.2m)	5-18-73	7.80	62.0	0.51	0.18	0.33
(2.0m)	5-18-73	7.80	62.0	0.51	0.21	0.30
3(0.2m)	5-17-73	7.70	61.5	0.32	0.10	0.22
(2.0m)	5-17-73	7.70	61.5	0.34	0.09	0.25
4(0.2m)	5-17-73	7.70	61.5	0.35	0.10	0.25
(2.0m)	5-17-73	7.70	61.5	0.35	0.10	0.25

(a) In situ determination.

(b) Incubation period.

On both sampling days, Cannikin Lake was isothermal at 6 C; saturated with oxygen, 11-12 ppm; and had a Secchi disc transparency ranging from 150 to 160 cm. Lake depths measured at the sampling stations ranged from 4 to 6 m.

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APPENDIX A

DESCRIPTION OF CANNIKIN LAKE

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DESCRIPTION OF CANNIKIN LAKE

On November 6, 1971, Cannikin, a nuclear device of a little less than 5 megatons, was detonated underground on Amchitka Island, Alaska. The collapse crater formed by this explosion subsequently filled with water forming what is now called Cannikin Lake. The following discussion of the formation and present character of Cannikin Lake is based largely upon a report* in preparation by the United States Geological Survey, Federal Center, Lakewood, Colorado.

The basin surrounding the area of the Cannikin detonation was drained by the north and south forks and main channel of White Alice Creek, which flowed in a northeasterly direction to the Bering Sea. The White Alice Creek drainage area encompassed approximately 207 ha (512 acres). Formation of the subsidence crater following Cannikin greatly altered this drainage pattern. Eighty-four percent of the original drainage area was transformed into a closed basin of 172 ha (475 acres) with the upper most part containing the collapse crater which intersected the north and south forks of White Alice Creek. Following ground collapse, flow in the lower reach of the main channel of White Alice Creek decreased to no flow 2 days after the collapse and remained so for about 2 weeks. Water from that portion of the drainage area downstream of the crater provided minimal flow in White Alice Creek thereafter until the crater filled with water.

During the first few weeks after subsidence, several small ponds formed at or near the bottom of the crater. These ponds occurred along the empty stream bed of what previously was the south fork of White Alice Creek. In June, 1972, these ponds were little more than large puddles supporting luxuriant growths of algae. During this period the diverted discharge from the upper reaches of White Alice Creek was probably recharging the shallow groundwater reservoir through newly formed ground fissures or cracks and flowing into the Cannikin chimney. The subsidence crater began to store water during mid-September, 1972, and was full about late November, 1972. The water level in the lake fluctuates approximately 1.5 feet annually; the overflow is into the main channel of White Alice Creek, the outlet stream for Cannikin Lake.

Cannikin Lake (Figure A-1) has a surface area of 12 ha (30 acres) and a storage capacity of 325 acre-ft. The lake is about 655 m (2150 ft) long with an average width of 198 m (650 ft) and 2.1 km (1.3 mi) of shoreline. The maximum lake depth is 9.5 m (31 ft) and the average depth is less than 6 m (20 ft).

* USGS-474-203, Bathymetric Reconnaissance of Cannikin Lake, Amchitka Island, Alaska. D.D. Gonzalez, L.E. Wollitz, and G.E. Brethauer. (Publication Pending Director's Approval).

Universal Transverse Mercator Projection (UTM)
400-foot grid ticks, zone 60

FIGURE A-1. BATHYMETRIC CONTOUR MAP OF CANNIKIN LAKE

APPENDIX B

LIMNOLOGY OF AMCHITKA ISLAND, ALASKA

PROGRESS REPORT, FY 1974

APPENDIX B

LIMNOLOGY OF AMCHITKA ISLAND, ALASKAPROGRESS REPORT, FY 1974

September 24, 1973

INTRODUCTION

Since 1967, Amchitka Island, Alaska has been subjected to intensive ecosystem analysis for evaluation of possible impacts arising from AEC on-Island activities. Effects analysis on freshwater ecosystems is an integral component in the Amchitka Bioenvironmental Program. Limnological surveys and interpretations have been conducted on aquatic habitats by scientists from Battelle's Columbus Laboratories. Utah State University scientists have investigated the ecology of freshwater vertebrates and invertebrates on Amchitka.

Characterization of freshwater ecosystems has been conducted for documentation and evaluation of perturbations generated from underground nuclear tests and the support services required by AEC for the performance of such tests. This report summarizes work accomplished on the limnology program between July 1, 1973, and September 31, 1973.

Objectives

The objectives of the limnological studies on Amchitka during FY 1974 are to collect and interpret data pertaining to physical, chemical, and biological features of selected Amchitka lakes and streams. Investigative efforts are being performed in sufficient detail to assist in (1) continued evaluation of the effects evolved from AEC operations, including underground nuclear tests, support requirements, and roll-up activities, on the freshwater ecosystems of Amchitka Island, and (2) assessment of the new lake formed in the subsidence crater of the Cannikin detonation.

Field Efforts

The fall FY 1974 sampling mission on Amchitka was from August 21-28, 1973. It included reconnaissance of (1) study lakes near the Cannikin SZ, (2) Cannikin Lake, and (3) lakes and streams known to have been perturbed by AEC on-Island activities. During this investigative period, 10 lakes and two streams were surveyed. Plankton samples were collected from all lake stations and samples for water chemistry analyses

(alkalinity, chloride, hardness, pH, and specific conductance) were obtained from both lake and stream stations. Primary productivity experiments utilizing carbon-14 were conducted on water samples obtained from Cannikin Lake.

Observations and Comment

Data acquired during the fall sampling period are presented in Tables B-1 through B-4. The lake stations' (excluding Cannikin Lake) physicochemical and biological data revealed that no substantive or unusual fluctuations in these parameters have occurred in recent months. Lake 1a is still receiving inflow of effluent from the sewage-holding ponds serving the main camp. This lake will not return to predisturbance status until the input of nutrient materials ceases and the excess nutrients have been flushed from the lake.

Chemical values measured on Emerald Lake (Lake 51) indicate a slow return to its presumed predisturbance status. This statement is based upon a comparison between water chemistry following drill-mud inputs (Birch, 1973) with chemical characteristics obtained in more recent surveys. Fourteen-Mile Lake remains a biological sterile habitat and recovery appears doubtful.

Water contaminated with drill-mud wastes is still seeping from the sumps at D-site and continues to reach the upper portions of Falls Creek. However, the magnitude of present input is small and Falls Creek is recovering slowly from an earlier episode of drill-mud influx following Cannikin. Clevenger Creek appears to be in comparatively good condition, although alkalinity and specific conductance are relatively high (Table B-1). Why high alkalinity and specific conductance values were obtained for this station is unknown. Perhaps surface water runoff from exposed bedrock materials at Milrow SZ has sufficient influence to significantly elevate these parameters in this stream.

Dramatic changes have taken place with regard to the development of a biotic community in Cannikin Lake. When this lake was sampled during spring, 1973, very few animal and plant plankters were present. Latest observations show a marked establishment of planktonic species (Tables B-2 and B-3) and a dramatic increase in primary production (Table B-4), as compared with earlier observations. The delay in ecological development was probably linked to the rate of invasion and subsequent establishment of aquatic species, since all the chemical characteristics correlated with production in aquatic ecosystems were present during springtime, 1973.

Pelagic phytoplankton in Cannikin Lake during fall, 1973, was dominated by green algae, primarily Sphaerocystis. Numerous diatoms were present on Hester-Dende samplers placed in the lake during May, 1973, and recovered in August, 1973.

The zooplankton community in Cannikin Lake during this same period was dominated by Keratella quadrata. Also, a species of cyclopoid copepod was present. This copepod form has not been reported from lentic ecosystems on Amchitka.

Dolly Varden trout are presently found in Cannikin Lake and are expected to complete the trophic development of this aquatic system. These fishes have entered Cannikin Lake apparently from the outlet stream, White Alice Creek.

TABLE B-1. CHEMICAL PARAMETERS OF AMCHITKA LAKES AND STREAMS, FY 1974

Station	Date	pH	Alkalinity, mg/l	Hardness, mg/l	Chloride, mg/l	Specific Conductance, micromhos/ cm ²
1a	8-27-73	8.02	48.5	30.0	39.0	260
28	8-23-73	7.19	29.0	23.0	31.3	197
31b	8-23-73	7.24	21.5	18.0	16.5	162
43b	8-23-73	5.82	0.5	9.0	27.3	126
43c	8-23-73	7.10	17.0	21.0	28.0	155
43d	8-23-73	5.12	0.5	7.0	21.5	114
50a	8-22-73	6.99	19.0	25.0	29.4	165
51	8-22-73	6.90	10.0	16.0	29.0	160
Cannikin Lake	8-25-73	7.71	70.0	30.0	74.0	540
14-Mile Lake	8-22-73	7.70	90.5	51.0	32.8	345
Falls Cr.	8-27-73	6.70	38.5	38.0	31.8	218
Clevenger Cr.	8-27-73	7.52	92.5	28.0	47.5	392

TABLE B-2. ZOOPLANKTON POPULATION CONCENTRATIONS OF AMCHITKA LAKES

(Organisms/Liter)

Lake	Date	Adult Rotifers	Rotifer Eggs	Cladocerans	Adult Copepods	Copepod Nauplii	Total Zooplankton
1a	8-27-73	54	10	3	3	5	75
28	8-23-73	0	0	400	0	0	400
31b	8-23-73	0	0	0	25	0	25
43b	8-23-73	100	25	0	50	75	250
43c	8-23-73	85	13	10	18	0	126
43d	8-23-73	25	0	50	25	0	100
44a	8-23-73	14	0	18	8	0	40
50a	8-23-73	38	0	3	0	38	79
51	8-22-73	3	0	0	0	3	6
Cannikin Lake							
1	8-25-73	828	165	3	8	68	1072
2	8-25-73	699	128	0	18	55	900
3	8-25-73	2686	553	5	70	80	3394
4	8-25-73	1881	385	0	38	48	2352

TABLE B-3. ROTIFER POPULATIONS OF AMCHITKA LAKES
(Organisms/Liter)

Lake	Date	<u>Keratella</u> <u>cochlearis</u>	<u>Keratella</u> <u>quadrata</u>	<u>Polyarthra</u>	<u>Asplanchna</u>	<u>Synchaeta</u>	<u>Filinia</u>	Other Species	Total Rotifers	Percent of Total Zooplankton
1a	8-27-73	3	43	0	0	3	0	0	54	72
28	8-23-73	0	0	0	0	0	0	0	0	0
31b	8-23-73	0	0	0	0	0	0	0	0	0
43b	8-23-73	25	50	25	0	0	0	0	100	40
43c	8-23-73	28	0	3	25	13	3	13	85	67
43d	8-23-73	25	0	0	0	0	0	0	25	25
44a	8-23-73	3	0	5	3	3	0	0	14	35
50a	8-23-73	0	0	38	0	0	0	0	38	48
51	8-22-73	0	0	3	0	0	0	0	3	50
<u>Cannikin Lake</u>										
1	8-25-73	133	690	0	0	0	0	5	828	77
2	8-25-73	110	580	3	0	0	3	3	699	78
3	8-25-73	80	2580	5	3	0	13	5	2686	79
4	8-25-73	78	1785	3	0	0	15	0	1881	80

TABLE B-4. RATES OF CARBON FIXATION BY PHYTOPLANKTON

Cannikin Lake	Date	pH	Alkalinity, mg/l	Carbon Fixation, mgC/m ³ /hr		
				Total	Dark	Net
1	8-25-73	7.71	70.0	9.67	0.20	9.47
2	8-25-73	7.71	70.0	9.23	0.30	8.93
3	8-25-73	7.71	70.0	9.37	0.13	9.24
4	8-25-73	7.71	70.0	8.14	0.25	7.89