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EFFECTS OF SUSPENDED VOLCANIC SEDIMENT ON COHO AND CHINOOK SALMON IN THE TOUTLE AND COWLITZ RIVERS

by

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ABSTRACT

The tolerance of coho (Oncorhynchus kisutch) and chinook (O. tshawytscha) salmon to suspended volcanic sediment was determined by live-box and static laboratory bioassays. The 96-hr LC50 suspended sediment concentrations determined by live-box bioassay were 1,217, 509, and 488 mg/l for presmolt coho, coho smolts, and fall chinook smolts, respectively. The 96-hr LC50 comparative static bioassays were 18,672, 28,184, and 19,364 mg/l in volcanic ash for presmolts coho, coho smolts, and fall chinook smolts. Static 96-hr LC50's for coho and fall chinook smolts in mudflow sediment were 29,580 and 11,000 mg/l. Live-box bioassays integrate numerous water quality parameters (i.e., temperature, velocity, organic compounds, etc.), while only suspended sediment is tested in the laboratory. Additional tests were conducted in artificial streams with known water velocity (0.5-1.5 l/sec) and suspended sediment concentrations (0-16 percent of 96-hr LC50) to determine the sublethal effects on coho and chinook salmon smolts. Sublethal effects were evaluated by swim chamber performace and seawater entry testing with no consistent significant effect found. Histological analysis of the gill tissue from both field and laboratory-tested salmon did not show a suspended sediment effect. Complete and partial mortality occurred consistently with coho presmolts in the Toutle and lower Cowlitz Rivers, respectively, during the summer following the May 18 eruption. Tests during the spring of 1981 showed partial mortality only in the lower Toutle, north fork Toutle, and Green Rivers. Survival was unaffected in the south fork Toutle and lower Cowlitz Rivers due to the decline in suspended sediment. Suspended sediment in portions of the Toutle

River watershed had returned to tolerable levels after one winter season.

KEYWORDS: Volcano; suspended sediment; coho and chinook salmon; survival; live-box, static, sublethal bioassays; swimming performance; artificial streams; seawater entry test; gill histology; water quality.

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Dr. Marsha Landolt, U. of W. School of Fisheries, conducted the histological analyses of the gill tissues. Messrs. Mark Hunter and Craig Olds carried out a portion of these field studies, while Gary Tamas and Donald Plebuch participated in the analysis of water samples and data. Ms. Betsy Day assisted in the operation of the artificial streams and associated testing. Personnel of the U. of W. Big Beef Creek Fisheries Research Station, including Bruce Snyder, Lynn McComas, Gary Maxwell, Thomas Thornhill and Clifford Whitmus, assisted in the construction and periodic operation of the stream channel laboratory. Messrs. Sam Felton and Ray McClain in the FRI Water Quality Laboratory assisted in some of the water quality measurements. Katie Swanson assisted on problems associated with computer programming and data analysis.

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INTRODUCTION

The May 18, 1980 eruption of Mount St. Helens caused a major loss of fish and aquatic life in the streams and rivers draining the western side of the volcano. The survival of juvenile and adult salmon was severely reduced by the runoff of mud, blast debris and volcanic ash in mudflows. Since the eruption occurred during the coho and chinook salmon smolt emigration season the best possible release strategy had to be determined to ensure smolt survival from the remaining hatcheries in the area. The survival of smolts released from the undamaged Cowlitz hatchery during passage through the silt- and ash-laden lower Cowlitz River to the ocean was of immediate concern. The rate of recovery of natural salmon production in the streams and rivers in the devastated watershed was an important long-range consideration in the recovery of the salmon resource in the area.

Reviews of the voluminous literature on the effects of suspended sediment on freshwater organisms have been conducted by Cordone and Kelly (1961), Ellinger and Snyder (1979), Sorenson et al. (1977) and Iwamoto et al. (1978). These reviews are related to particular suspended sediment effects; however, little information was found regarding the high suspended sediment impacts following volcanic eruptions. Poe (1980) reviewed the effects of volcanic ashfalls on the productivity of lakes. Ball (1914, in Eicher and Rounsefell 1957) observed a reduction in the numbers of sockeye salmon and food organisms following the eruption of Mt. Katmai in Alaska. Kurenkov (1957) observed similar effects on river fauna following volcanic eruptions of Mt. Bezyianna on the Kamchatka Peninsula. However, he suspected mortalities were more related to ash leachates than to suffocation from high suspended sediment concentrations.

This study was designed to determine the acute and sublethal tolerance of juvenile (presmolt and smolt) and adult coho salmon (*Oncorhynchus kisutch*) and chinook salmon smolts (*O. tshawytscha*) to suspended sediment concentrations in the Toutle, Cowlitz and Columbia Rivers; to monitor the water quality at each bioassay location; determine the 96-hr LC50 suspended sediment concentrations for presmolt and smolt coho and chinook salmon in static laboratory bioassays and test the responses to sublethal exposure to suspended sediment and water velocity in artificial streams. Testing was conducted over a 13-month period. Geological studies of the sediment stabilization rates and tolerance of salmon to suspended volcanic sediment can be utilized to determine management strategies for the recovery of the salmon resource.

STUDY AREA

The aquatic habitat and associated aquatic life in the north and south forks of the Toutle River (Fig. 1), and the lower 35.4 km of the Cowlitz River were destroyed by mudflows which severely scoured and buried the river channel. The upper north fork Toutle channel was buried to depths of 137 m while the lower Cowlitz River channel was filled with 4.6 m of mud and debris (Cummans 1980). The south fork Toutle River was affected by mudflow immediately after the eruption and by a subsequent mudslide in July 1981.

The Green River drainage (Fig. 1) on the edge of the blast zone was affected by heavy accumulations of airfall ash. The timber over large areas of the valley was scorched or blown down. The loss of vegetation increased runoff and erosion of the ash. Both infall and runoff of volcanic ash into the Green River destroyed fish and other aquatic life throughout this drainage basin.

The Kalama River was impacted with lesser amounts of airfall ash from eruptions subsequent to the May 18 blast while the Coweman and upper Cowlitz Rivers received light dustings of ash and were the least affected rivers draining the western side of the volcano.

The mud and debris in the Lewis River which flowed into Swift Reservoir originated in the mudflows travelling down the Smith Creek, Pine Creek and Muddy River tributaries. The lower Lewis River remained relatively unaffected due to Swift, Yale and Merwin reservoirs, which acted as catch basins and removed most of the suspended particles.

In an effort to control further runoff of sediment and debris and to control potential future flooding, the Army Corps of Engineers constructed two debris dams, one on each fork of the Toutle River (Fig. 1). Extensive

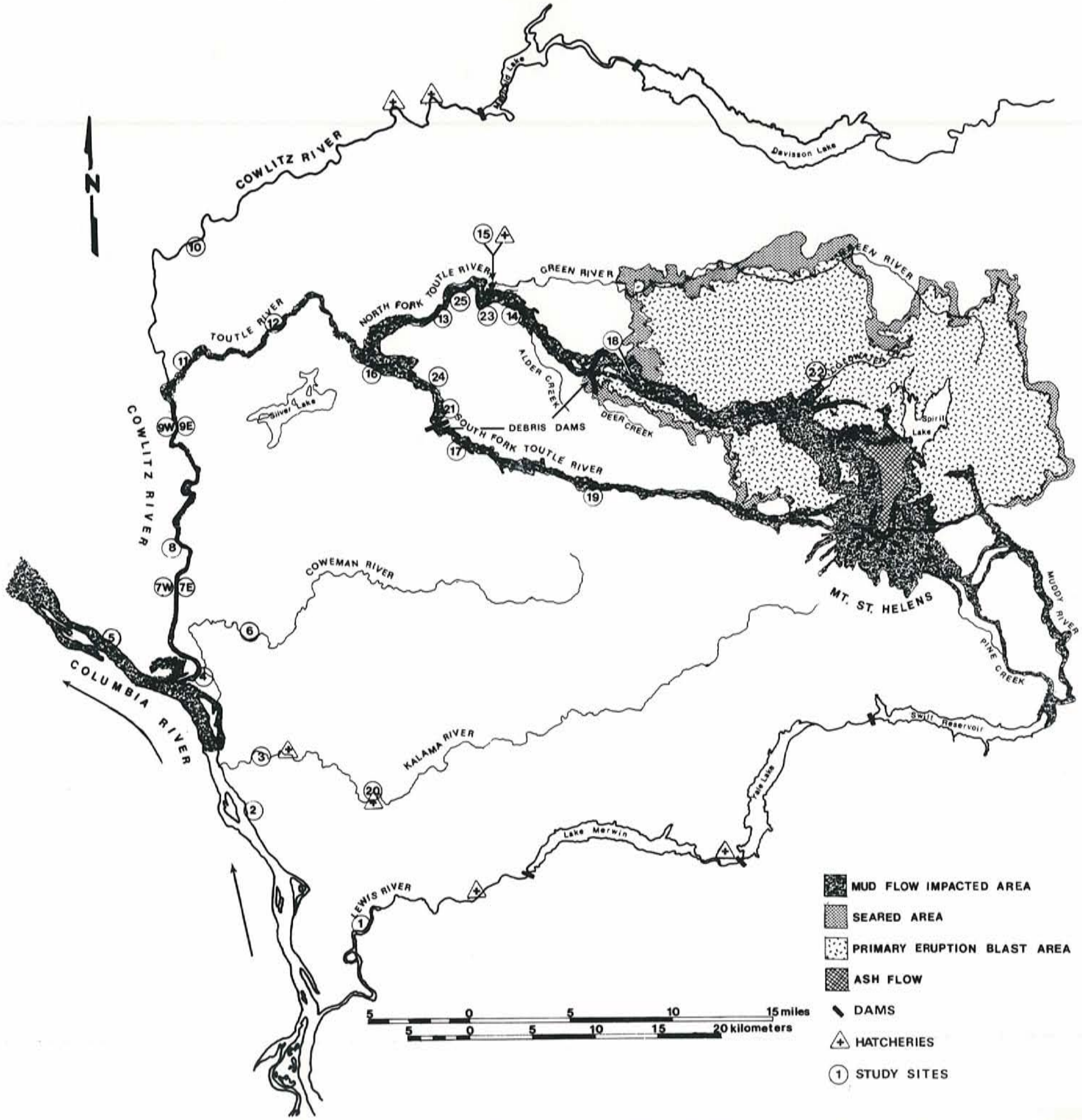

Fig. 1. Mount St. Helens showing the areas and types of impact. The study sites are located on the tributaries draining the west side of the volcano.

channel clearance and dredging was conducted on the main Toutle River, lower Cowlitz River and affected portion of the Columbia River (U.S.A.C.E. 1980a).

Twenty-five water quality stations were sampled on the north and south fork Toutle, Cowlitz, Coweman, Columbia, Kalama and Lewis Rivers in order to assess the damage and recovery to these rivers (Fig. 1). The site location descriptions are given in Table 1. Live boxes were placed at stations 2 (control), 3, 5, 7E and W, 8, 9E and W, 10 (control), 11, 13, 15, 16, 23 and 24 to monitor salmon presmolt and smolt survival. In addition, adult salmon survival was monitored at the Cowlitz Salmon Hatchery and station 7W (Cowlitz at Kelso, west).

Laboratory studies of suspended sediment were conducted at the University of Washington Big Beef Creek Fisheries Research Station near Seabeck, Washington on Hood Canal (Fig. 2).

Table 1. Water sampling and live-box bioassay sites.

Site No.	Location/description
1	Lewis River — on Route 503, N.E. of Woodland, Washington.
2*	Columbia River — at Kalama City boat basin (control).
3*	Kalama River — at Wash. Dept. of Game public boat launch.
4	Lower Cowlitz — at railroad bridge south of Kelso.
5*	Columbia River — at Longview, Weyerhaeuser pulp gate.
6	Coweman River — off Allen Street out of downtown Kelso.
7 E*	Cowlitz River — downtown Kelso, east bank.
7 W*	Cowlitz River — downtown Kelso, west bank.
8*	Cowlitz River — Lexington City Park.
9 E*	Cowlitz River — Castle Rock fairgrounds, east bank.
9 W*	Cowlitz River — Castle Rock fairgrounds, west bank.
10*	Cowlitz River — Jackson Highway under I-5 bridge (control).
11*	Lower Main Toutle River — near mouth of Toutle at Highway 99 bridge
12	Middle Main Toutle River — at Tower Road.
13*	Lower N. Fork Toutle River — 2 miles east of intersection of Routes 504 and 505.
14	Middle N. Fork Toutle River — 1½ miles upstream from confluence of Green River.
15	Green River — at hatchery intake, just above Toutle Hatchery.
16*	Lower S. Fork Toutle River — at bridge just east of Four Corners.
17	Middle S. Fork Toutle River — above USACE dam location.
18	Upper N. Fork Toutle River — 1 mile above USACE dam.
19	Upper S. Fork Toutle River — end of logging road 4100.
20	Kalama Falls Hatchery — spillways.
21	Middle S. Fork Toutle River — just below USACE dam.
22	Coldwater Lake.
23*	N. Fork Toutle River at Green River confluence.
24*	S. Fork Toutle River at Weyerhaeuser railroad bridge.
25	N. Fork Toutle River at Kid Valley

* Live-box bioassays

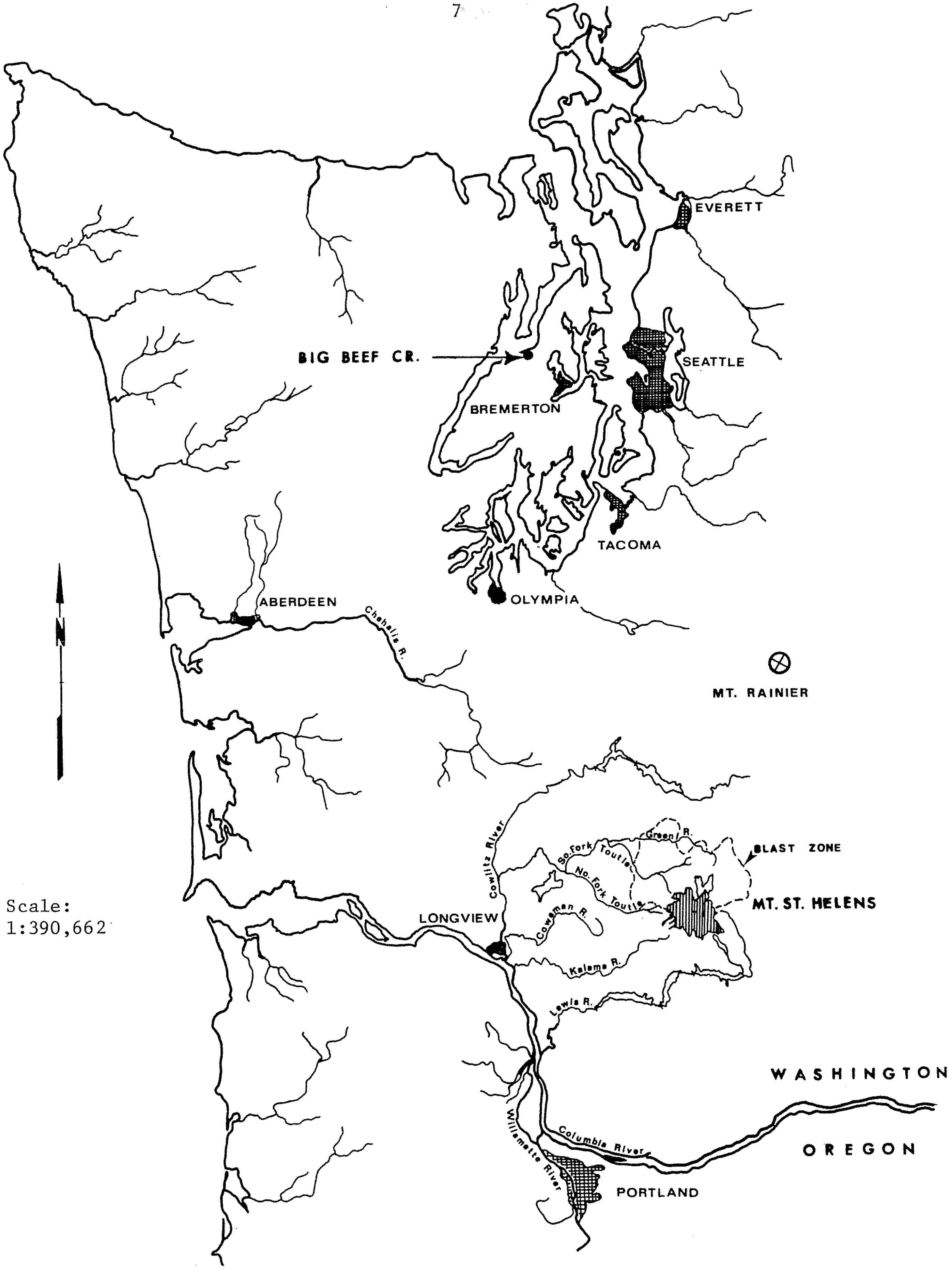

Fig. 2. Map of western Washington State showing Mount St. Helens and the location of the U. of W. Big Beef Creek Fisheries Research Station.

MATERIALS AND METHODS

Water Quality

Water quality was monitored intermittently at twenty-five sites from July 12 to November 14, 1980, and from March 16 to August 20, 1981. Temperature, pH, dissolved oxygen and conductivity were measured in-situ with a Model 4041 Hydrolab which was calibrated in the laboratory before and after each field trip. Water velocity was measured with a Marsh-McBirney Model 201 current meter at each suspended sediment sampling site and near each live box location. Integrated suspended sediment samples were taken with a USGS DH-48 sampler, lowered and raised through the water column at constant intervals at each water quality and live box site. Water samples stored in polyethylene containers were transported to the laboratory for determination of settleable solids, total non-filterable residues (TNFR) (APHA 1980) and organic and inorganic components of the sediment.

Settleable solids (ml/l) were determined by placing a thoroughly mixed one-liter sample into a graduated Imhoff cone, allowed to settle for 45 min, stirred gently, allowed to settle for an additional 15 min, prior to taking a volumetric reading of the settleable solids. Total non-filterable residues (TNFR) in mg/l were determined by filtering a 200-ml sample through a pre-weighed 4.25-cm-diameter glass microfiber filter. The filter was dried and weighed again and the difference was multiplied by 5 to obtain the concentration in mg/l. The organic versus inorganic component of the suspended residue was measured. Thirty-percent hydrogen peroxide (3-5 ml) was added to the dried residues. The samples were heated to 50°C for 45 min in order to digest all the organic components. This method was utilized to minimize breakdown of sediment particles to facilitate further analysis of particle sizes. The filters were weighed again and the differences in weight multiplied by 5 to give the value of the organic component of the sample in mg/l. The turbidity (JTU) of each suspended sediment sample was determined with a Hach DR-EL turbidimeter.

Nutrient samples were taken and filtered through glass fiber into polyethylene bottles and immediately frozen. The samples were analyzed for PO_4, SiO_4, NO_3 and NH_4 (all in μg at/l) by the U. of W. Oceanography water analysis laboratory. These results were converted to mg/l by multiplying the concentration (μg at/l) by the molecular weight.

Water samples collected for dissolved organic carbon and total phenol content were filtered through Gelman Glass Fiber Filters (47 mm) previously burned at 450° in a Lindberg Laboratory Box Furnace Model 51848 into acid prewashed and burned glass containers. Ten mg/l of 1 percent $CuSO_4$ was added to each sample as a preservative. The samples were stored and shipped on ice in an insulated container to USGS Water Quality Laboratory, Denver, Colorado, for analysis.

Trace Metals

On June 24-28, 1981 an additional set of water samples were taken in 200 ml polyethylene bottles and stored on ice for subsequent trace metal analysis. Zinc, cadmium, lead, copper and nickel were determined by atomic absorption spectrometry. The samples were further analyzed for specific metal binding capacity (EPA 1979) and labile metal fraction determined by subtraction.

Sediments Tested

Airfall ash was initially obtained from the banks of the Green River above the influence of the north fork Toutle River mudflow. Later tests utilized airfall ash washed into a rearing pond near the Toutle Salmon Hatchery from the Green River immediately following the eruption. The pond was subsequently drained. In utilizing these sources for airfall ash, the greatest range in particle size that would stay in suspension was maintained. Mudflow sediment was obtained from the banks of the south fork Toutle River during the summer of 1980. The hydraulically sorted mudflow deposits provided a wide range of particle sizes and associated debris which varied with location. A more uniform mudflow deposit was obtained from the sediment trapped on the floor of the Toutle River hatchery. This sediment was the top 30 cm of the mudflow which backed up the Green River from the north fork of the Toutle River. This sediment was not contaminated by later ashfalls or erosion because it was protected inside a building. Airfall ash and mudflow sediments used in bioassays were screened through a 0.105 mm mesh screen to remove larger particles and organic detritus.

A commercially prepared bentonite clay (Volclay 200) was purchased for use as a control sediment for comparative purposes. The Volclay was comprised primarily of silica (60 percent), alumina (21 percent) and other components (Table 2). The total recoverable metals by acid digestion of the solid sediment samples of mudflow, ash and bentonite are presented in Table 3. These samples were dried at 103-105°C before weighing and digestion for "total recoverable metals" (USGS 1979). A lower available Si and Fe and a higher available Ca, Mg, Na and K were found in the bentonite than in the mudflow and ash. The bentonite clay was prepared in a thick slurry with several additions of water

Table 2. Chemical analysis of "Volclay 200" bentonite (moisture-free) (supplied by Western Foundry Sand Co.).

Compound	% by weight
Silica (SiO_2)	60.00-62.00
Alumina (Al_2O_3)	21.00-23.00
Ferric oxide (Fe_2O_3)	3.00- 4.00
Sodium oxide (Na_2O)	2.50- 2.70
Magnesium oxide (MgO)	2.00- 3.00
Calcium oxide (CaO)	0.50- 1.50
Potassium oxide (K_2O)	0.40- 0.45
H_2O as shipped	5.00- 9.00

Table 3. Total recoverable metals in solid sediment samples (mg/kg dry wt.) by acid digestion.

	(Si)	(Ca)	(Mg)	(Fe)	(Na)	(K)
Volclay 200	277	1190	3150	553	5300	1610
Mudflow sediment	1760	734	5330	2350	764	945
Volcanic ash	1200	400	5100	1620	324	496

over a period of time to allow expansion due to water uptake prior to introduction into the bioassay system.

Particle Size Analysis

Particle size distribution of each sediment type used was analyzed by the sieve-pipette method (APHA 1980). Representative samples of airfall ash, Volclay and mudflow were first digested in 30 percent H_2O_2 at 60°C for 3 hrs and then "wet sieved" through a 62 μ mesh sieve. The coarse fraction (> 62 μ in diameter) was then dried and placed into a nest of sieves declining from a mesh size of 1000, 500, 250, 125 and 62 μ from top to bottom, respectively, and then shaken for 15 min on a "Ro-Tap" mechanical shaker. Each size fraction was then weighed on a Mettler H10 balance. Material passing through the 62 μ mesh sieve was saved for pipette analysis of the silt and clay fractions.

For the pipette analysis, particles finer than 62 μ in diameter from both the wet and dry sieve procedures were added to cylinders with approximately 1 gram of dispersing agent (sodium hexametaphosphate). The volume of each cylinder was then brought to 1000 ml with distilled water, capped, shaken manually for 5 minutes, and allowed to sit overnight. Pipette analysis was carried out using a sampling schedule based on a sedimentation velocity of $3.898 \times 10^4 \ r^2$, which was calculated by Stokes Law for particles of density 2.65 and the viscosity of water determined at 23.5°C. Pipetted aliquots were evaporated overnight in an oven maintained at 60°C. Sediment weight of the 62, 31, 16, 8, 4, 2 and 1 μ size classes was determined for the fine fraction, and combined with the coarse fraction analysis to construct a cumulative frequency plot of particle size for each sediment type analyzed (Figs. 3 and 4).

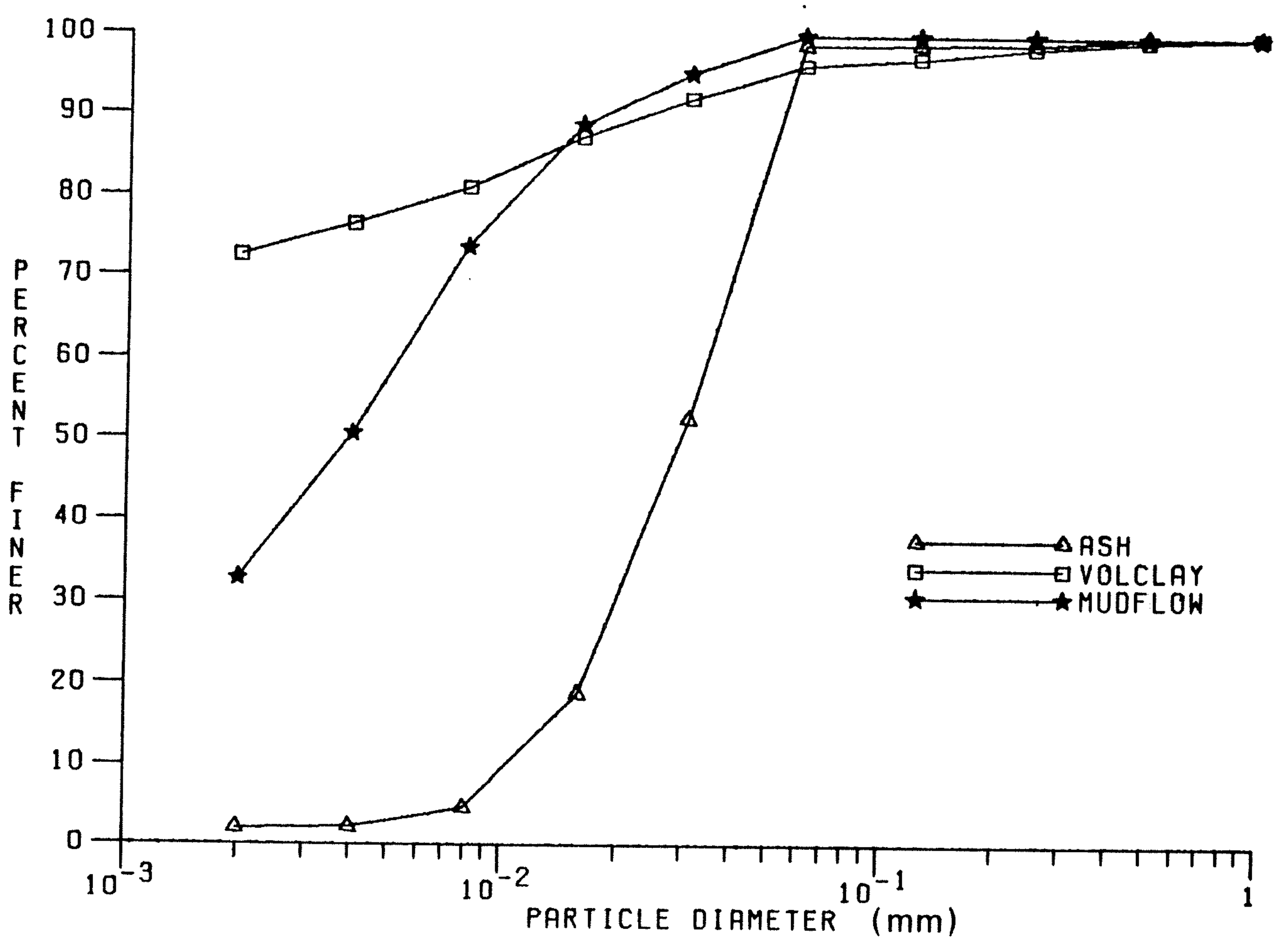

Fig. 3. Particle diameter (mm) vs percent finer for volcanic ash, Volclay 200 bentonite and mudflow sediment.

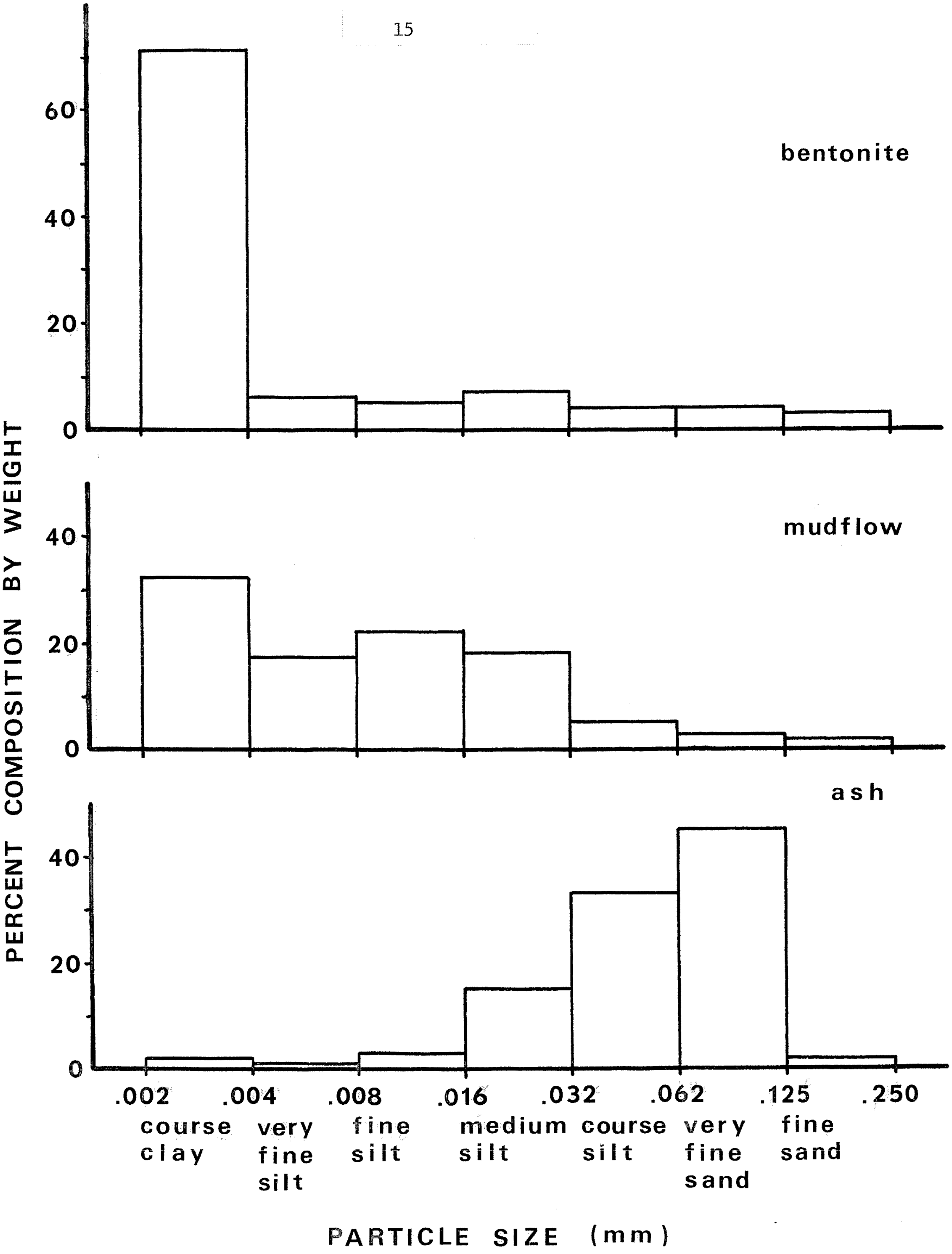

Fig. 4. Percent composition by weight of particle size classes for "Volclay 200" bentonite, mudflow sediment and unsieved volcanic ash.

Suspended sediment samples were taken at various times for scanning electron microscope (SEM) study. The samples were oven-dried, mounted, and Au/Pd plated for observation with a scanning JOEL model JSM-U3 SEM.

An analysis of the quality of Big Beef Creek water was conducted on a sample taken September 21, 1981. The results of these tests are presented in Table 4. A comparative trace metal analysis was conducted on Big Beef Creek water and on suspensions of Volclay 200, mudflow and airfall volcanic ash in Big Beef Creek water for Ni, Zn, Cd, Pb and Cu. The sediment water mixtures were filtered through an acid rinse, 0.45 μ filter before analysis by atomic absorption. Copper, cadmium, lead and nickel were done by graphite furnace AA and zinc was atomized by flame AA (USEPA 1979). The trace metal concentrations in Volclay were much higher than found in Big Beef Creek or in suspensions of mudflow or volcanic ash (Table 5). The high levels of toxic metals leached from Volclay reduced the utility of this sediment as a control due to high levels of zinc and copper and the possibility of synergistic effects.

Live-Box Bioassays

Presmolt and Smolt

Between July 8 and October 11, 1980, five 96-hr live-box bioassays were conducted at twelve locations in the Toutle, Cowlitz, Columbia and Kalama Rivers. The sampling schedule and locations were altered for the 1981 field season, March 16-July 17, to include six locations in the Toutle, Green and Cowlitz Rivers with an increased number of live boxes per location. A summary of the dates, locations, species tested and fish source for the live-box tests conducted during both years is given in Table 6.

Table 4. Quality of Big Beef Creek stream water (sample collected 21 September 1981). Samples acidified for trace metal analysis with ULTREX Nitric Acid.

Test parameter	Result
pH, glass electrode at 25°C	6.9
Specific conductance, micromhos at 25°C	35
Total dissolved solids	32.9 mg/l
Hardness	25.3 mg/l
Magnesium	3.0 mg/l
Calcium	5.2 mg/l
Ammonia as N	15 μg/l
Cadmium	< 0.5 μg/l
Copper	11 μg/l
Lead	< 2 μg/l
Zinc	12 μg/l

Table 5. Trace metal analysis by atomic absorption spectrometry for Ni, Zn, Cd, Pb, Cu (ppb).

Sample	(Ni)	(Zn)	(Cd)	(Pb)	(Cu)
Big Beef Cr. stream water	< 2.5	20	0.2	< 2.0	< 2.5
Volclay 200 in BBC stream water	22	197	1.6	15	17
Mudflow sediment in BBC water	< 2.5	22	1.1	< 2.0	8
Volcanic ash in BBC water	6.0	36	1.0	< 2.0	3

Table 6. Dates, locations, species tested and fish source for each bioassay.

Bioassay No.	Date	Site No. (No. of live boxes if > 1)	Species tested	Fish source
	<u>1980</u>			
1	July 8-12	2, 4, 7W, 10, 11	Coho presmolts	Lewis River Hatchery
2	July 22-26	2, 3, 5, 7E, 7W, 8, 9E, 9W, 10, 11, 13, 16	Coho presmolts	Lewis River Hatchery
3	Aug 12-16	2, 3, 5, 7E, 7W, 8, 9E, 9W, 10, 11, 16	Coho presmolts	Lewis River Hatchery
4	Sept 9-13	2, 3, 5, 7E, 7W, 8, 9E, 10, 11(2), 13, 16	Coho presmolts	Lewis River Hatchery
5	Oct 7-11	2, 3, 5, 7E, 7W, 9E, 10, 11, 13, 16	Coho presmolts	Grays River Hatchery
	<u>1981</u>			
6	Mar 16-20	7W(2), 9E(2), 10(2), 11(2), 15(2), 23(2)	Coho smolts	Cowlitz Salmon Hatchery
7	Mar 30-Apr 3	7W(2), 9E(2), 10(2), 11(2), 15, 23(2)	Coho smolts	Cowlitz Salmon Hatchery
8	Apr 13-17	7W(2), 8(2), 10, 11, 15, 23, 25	Coho smolts	Cowlitz Salmon Hatchery
9	Apr 27-May 1	7W(2), 8(2), 10, 11(3), 15(2), 23	Coho smolts	Cowlitz Salmon Hatchery
10	May 11-15	7W(2), 8(2), 10, 11(6), 15(3), 23(3), 24(3)	Coho smolts	Cowlitz Salmon Hatchery
11	May 28	Test aborted. High control mortality.	Fall chinook smolts	Cowlitz Salmon Hatchery
12	June 24-28	7W(2), 10(2), 11(7), 15(2), 23(4), 24(2)	Fall chinook smolts	Cowlitz Salmon Hatchery
13	July 13-17	7W(2), 10(5), 11(2), 15(4), 23(4), 24(2)	Coho presmolts	Cowlitz Salmon Hatchery

Coho salmon presmolts were tested in live boxes from July 8 - October 11, 1980, and again during July 13-17, 1981. Coho smolts were tested in live boxes from March 16 to May 15, 1981. Fall chinook smolts were tested from June 24 to 28, 1981. The source of test fish in 1980 was the Lewis and Grays River salmon hatcheries, while in 1981 all test fish used in the live boxes were from the Cowlitz River salmon hatchery.

In general, the number of presmolt coho and fall chinook smolts and coho smolts placed in individual live boxes were 25, 25 and 15, respectively. From one to seven cylindrical live boxes (45.7 cm long x 30.5 cm diameter) were suspended in the river at each station, perpendicular to the current (Fig. 5). The bottom side of each live box was perforated to reduce silt accumulation. Water quality and velocity measurements were taken each day at each site.

Mortalities were noted at approximately 24-hr intervals. Upstream sites, where mortalities occurred rapidly during the early part of the study, were checked at approximately hourly intervals until 100 percent mortality had occurred. The 96-hr LC50 concentrations of suspended sediment were calculated using the BMD03S computer program for probit analysis.

Adults

Two instream live-box bioassays were conducted from October 1 through 9 and October 12 through 31, 1980 with adult coho salmon. A large wire mesh pen was placed in the Cowlitz River at Kelso (site 7W) and at the Cowlitz salmon hatchery as a control. Four adult coho salmon from the Cowlitz hatchery were held in each pen during the first bioassay. During the second bioassay four adult coho salmon were held in the control and two steelhead trout (*Salmo*

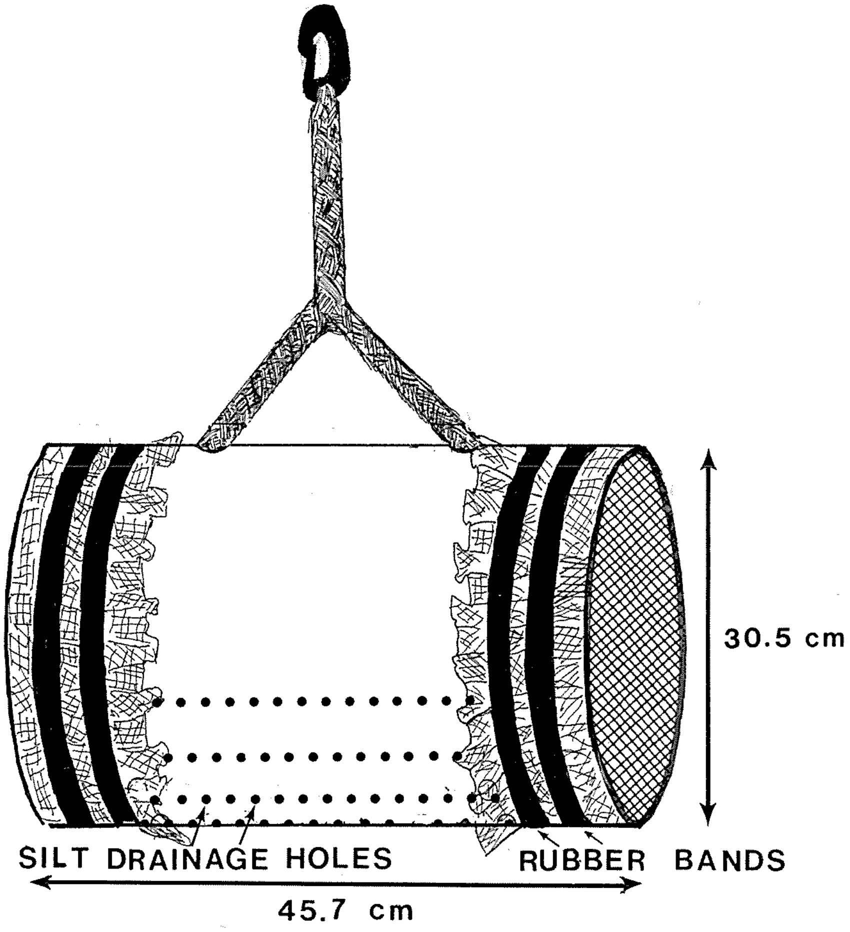

Fig. 5. Live-box used for instream bioassays of juvenile salmon.

gairdneri), two chinook salmon (jacks) and four coho salmon in the test pen. Pens were checked daily for mortality.

Static Bioassays

Static 96-hr bioassays were conducted in 60-liter polyurethane tanks (Fig. 6) with a 1/16-inch (3.2 mm) thick PVC concave bottom (50° slope) modified from the 28° slope used by Smith (1978). The concave bottoms were needed to help keep the sediment in circulation. The 45 l of water in each tank was recirculated by a 20-25 l/min submersible pump to keep the sediment in suspension. The pump intake was positioned at the center of the concave bottom and the recirculated water was directed in a slow circular motion in each tank. The test fish in each tank were contained in a 6.4 mm mesh Vexar pen to aid observation and recovery. Depending on the bioassay from 4 to 16 tanks were used. All tanks were placed in large flowing water baths which kept the temperature within 2.3°C of ambient. Airstones were added to all tanks after the third test in 1980 to ensure saturation of dissolved oxygen. All static tanks were screened from other activities with black plastic sheeting.

The initial bioassay utilized presmolt coho salmon from Minter Creek hatchery (average weight ∿ 8 grams) while presmolt coho from the Lewis River hatchery (average weight 3.5-6.5 grams) were used during the remainder of 1980. During 1981 coho smolts (average weight 15.4 to 28.6 g) from Minter Creek and Skykomish hatcheries were tested. Fall chinook salmon smolts (average weight 3.0 to 4.6 g) from the George Adams hatchery were tested. The loading rates varied from 18 to 25 fish per tank for presmolt coho, 10 fish per tank for

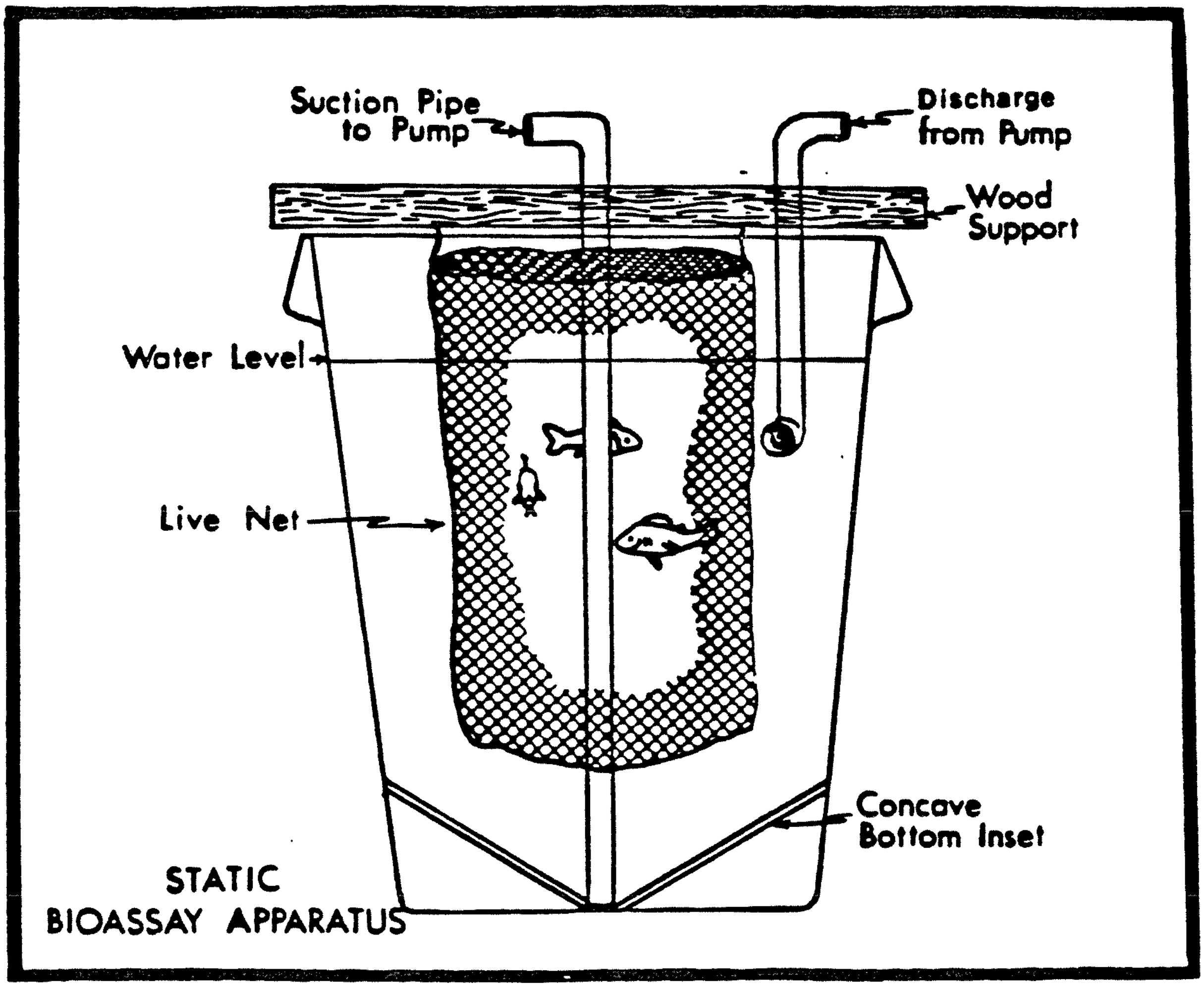

Fig. 6. Laboratory bioassay apparatus (after Smith 1978).

coho smolts, and 19-23 fish per tank for fall chinook smolts. The loading rates did not exceed 2.8 g fish/liter in 1980 or 6.4 g/l in 1981.

Mortality and water quality monitoring schedules varied among the bioassays. The typical schedule was to check the tanks at 0, 3, 6, 12, 24, 48, 72 and 96-hr intervals. Mortalities were measured (fork length) and smolts were staged by the visual method (Prentice et al. 1981). Survivors were counted, measured and staged and gill tissue samples removed at the end of each test. The 24-, 48- and 96-hr LC50 concentrations of suspended sediments were calculated using the BMD03S computer program for probit analysis. Water quality measurements were taken on temperature, pH, dissolved oxygen and conductivity. Turbidity (JTU) was determined with a Hach turbidimeter and water samples were taken for settleable and suspended solids. Samples were withdrawn with a siphon placed inside the fish cage at about 5 cm below the surface (Smith 1978) where most fish concentrated.

Six static tests were conducted on presmolt coho using airfall volcanic ash. One test of south fork Toutle River mudflow sediment was made. Coho smolts were exposed in five bentonite, one north fork Toutle River mudflow and one volcanic ash test, while chinook smolts were exposed in 4 volcanic ash and one north fork Toutle River mudflow test.

Artificial Streams

Suspended sediment testing was conducted in a 15.2 m by 6.1 m laboratory constructed at the University of Washington Big Beef Creek Fisheries Research Station near Seabeck, Washington, on Hood Canal, to house two artificial streams and the static bioassay tanks. Water from Big Beef Creek was supplied to the laboratory with an 8 hp cast iron centrifugal pump.

Test fish were held outside the laboratory in six (1.2 x 1.2 x 1.8 m) net pens suspended in two water tanks (5,700 and 12,700 1 capacity) to keep test groups separated and to aid capture and removal. The holding tanks were supplied with 57-76 1/min of Big Beef Creek water.

Two artificial streams 9.1 m long by 1.22 m wide by 0.46 m deep described by Noggle (1978) were modified to test suspended sediment concentrations in a range of water velocities. The streams were modified by reducing the channel width to 25 cm by the placement of plywood walls lined with a double layer of black plastic sheeting to achieve a water-tight fit. The headbox spillways were modified with corrugated fiberglass to direct the gravity flow of water into the narrow channel and the downstream spillway to the sump was lowered to about 15 cm to achieve a water depth of 18-30 cm. A 5 hp cast iron electric pump was utilized to recirculate the water from the sump through a 7.6 cm diameter PVC pipe to the head box in each channel. Water velocity in the streams was controlled by placing a 5.1 cm diameter PVC pipe and ball valve on the discharge side of the pump to bleed excess water back to the sump.

A 1.9 cm diameter pipe perforated with 3.18 mm holes on 15.2 cm centers was installed on the bottom the length of each stream channel to aid the resuspension of the sediment. Water was circulated with a 1.5 hp cast iron centrifugal pump from the head box of each stream to the perforated pipe. The velocity of the water jets along the perforated pipe was controlled by a 1.9 cm diameter ball valve installed at the proximal end of the pipe. Sediment accumulation in the perforated pipe was flushed periodically by removal of a threaded cap.

Ambient Big Beef Creek water was continually pumped to a fiberglass head tank from which both artificial streams were supplied by gravity flow. Once each stream was filled to capacity (∿ 2000 1) only about 1 percent (20 1/min or less) of the volume was added continuously (renewed 3 times per day) to make up for splash and evaporation loss. The small amount of water added allowed the maintenance of consistent suspended sediment concentrations in the test stream. During late spring and summer when the water temperature exceeded optimum levels two 1 hp Minocoolers were installed in the test stream to control the temperature. A larger volume of cool make-up water was added to the control stream for the same purpose.

Following each test the stream systems were drained and the residual sediment removed. The systems were disinfected with Wescodyn (TM) between tests of each sediment type, rinsed and refilled with fresh water.

Upper and lower fish containment screens of 0.64 cm mesh Vexar were placed in each channel approximately 30 cm upstream from the sump spillway and 1.8 m downstream from the head box. This placement held the fish in the 7 m long area of most uniform water velocity. The edges of the screen frames were covered with polyurethane foam to reduce wear on the plastic channel liner and to provide a fish-tight seal. The screens were held in place by weights placed on top. Both channels were covered with removable translucent corrugated fiberglass sheeting.

The suspended sediment concentration in the test channel was controlled with a continuously monitoring Hach Model 2100 turbidimeter with an attached chart recorder (Rustrak Model 288/F204B) equipped with a set-point alarm. A continuous flow (4 1/min) of water was pumped from mid-depth at the downstream end of the test channel through the turbidimeter with a submersible pump. Sampling from this location selected the minimum turbidity in the test channel. The turbidity level desired was selected as the set point below which an electrical relay activated submersible dosing pumps (20-25 l/min) suspended in four 60-l slurry tanks. The chart recording provided a continuous record of the turbidity throughout each test.

The slurry was mixed to a concentration of 100 g/l or greater and the slurry was dosed into the downstream sump where water turbulence mixed the sediment prior to recirculation to the head of the channel. Since there was a lag time between slurry addition and the detection of an increase by the turbidimeter to discontinue dosing, the discharge from the slurry pumps was restricted to add sediment at a slower rate which avoided a sharp change in concentration. The turbidity desired in the initiation of each test was rapidly achieved by adding sufficient quantities of sediment by hand followed by activation of the automatic monitoring and dosing equipment.

Depending on the test, 250 to 300 coho salmon smolts and 175 to 500 fall chinook salmon smolts were placed in each trough for each test. This corresponded to loading densities of no greater than 3 g fish/l. The fish were placed in clean flow-through Big Beef Creek water at ∿ 60 l/min for at least 48 hrs acclimation prior to introduction of sediment or increase in water velocity. Water quality was monitored at the beginning and end of this period. Prior to addition of sediment the recirculating pumps were activated, the flow-through of fresh stream water reduced to 20 l/min or less, and the channel velocity adjusted for the test. The initial addition of sediment began the 96-hr test period. A total of 14 96-hr sediment/velocity exposures was conducted in the artificial streams, 10 utilized coho smolts and 4 utilized fall chinook smolts. The mean water velocities and sediment concentrations and sediment types are given in Table 7. The mean maximum velocity of 1.5 l/sec was selected because higher velocities have been found to cause stress

Table 7. Sediment velocity exposure tests in chronological order.

Species	Dates	Sediment type	Average velocity (body lengths/second)	Average sediment concentration (mg/l)
Coho	3/09/81	Volcanic ash	0.529	647
	3/17/81		0.997	2174
	3/29/81		1.479	3775
	4/13/81	Bentonite clay	0.504	993
	4/20/81		0.948	1249
	4/27/81		1.545	1686
	5/04/81	Mudflow sediment	1.455	2967
	5/11/81	Volcanic ash (replicate)	0.586	757
	5/18/81		0.969	2019
	5/25/81		1.463	4515
Fall chinook	6/15/81	Volcanic ash	1.497	2565
	6/22/81	Mudflow sediment	1.406	4349
	6/29/81	Volcanic ash	1.369	3109
	7/06/81		0.996	943

(Besner 1980).

Water quality sampling including suspended sediment samples and the removal of mortalities were conducted at 0, 3, 6, 12, 24, 48, 72, and 96-hr intervals. Mortalities were easily collected on the downstream containment screen. Samples of gill tissue were removed from five randomly selected fish from each stream prior to the start and at 24-hr intervals during each test. All sampled fish were measured for fork length and maximum girth and weighed and evaluated for smolt stage.

Artificial Stream Water Quality

Water quality parameters measured during the stream exposures were temperature (°C), dissolved oxygen (mg/l), pH, conductivity (μmhos/cm^2) turbidity (JTU), settleable solids (ml/l), total nonfilterable residue (mg/l) or total residue (mg/l) and velocity (cm/sec). Temperature, dissolved oxygen, pH and conductivity were measured using a Hydrolab Surveyor Model 6D In-Situ Water Quality Analyzer.

Settleable solids were determined as previously described. Water samples in polyethylene containers were transported to the University of Washington campus for determination of total nonfilterable residue and/or total residue (depending upon sediment type). Total nonfilterable residues were determined by filtering a 200 ml sample through a pre-weighed 4.25 cm diameter glass microfiber filter. The filter was dried and weighed again, and the difference multiplied by 5 to obtain the sediment concentration in mg/l.

Filtration of bentonite (Volclay 200) and mudflow samples was not effective because all particles could not be retained on the filters. When this occurred both the TNFR and total residue were measured. Total residue was measured by placing a 200 ml sample in a pre-weighed aluminum dish and evaporated to dryness at 103-105°C. The aluminum dish was then re-weighed, and the weight difference multiplied by 5 in order to obtain results in mg/l (EPA 1979).

Continuous monitoring of turbidity (JTU) in the test stream was utilized to indicate the suspended sediment concentration. The average concentration and its standard deviation, as well as the concentration at any point, could be predicted from the chart recording and the relationship between JTU and sediment weight established for that sediment type. JTU vs $\log_{10}$ sediment weight produced a linear relationship with very high r values for every sediment type tested (Figs. 7 and 8). A separate relationship was established for each of the 3 sets of ash exposures (3 concentrations per set) in case any difference existed between batches of ash collected (the 3 exposure runs in a set used the same batch of ash). A weighted least-squares linear regression was used in the relationship between JTU and sediment weight for the tests using "Volclay 200", because back-calculation from another regression was made necessary by the fact that two types of weights were determined, TNFR and total residue (Kleinbaum and Kupper 1978).

Water velocity was measured in the stream channels with the floating chip method. An orange was released and timed over measured distances of 682 and 700 cm in the control and test streams, respectively. This method gave an average linear velocity over the length of each section. The high velocity jets arrayed along each channel caused the water to spiral. The floating orange traveled along one side of the channel. Additional tests with a Marsh McBirney current meter indicated that the water velocities were consistently higher along the side traversed by the orange. Velocities measured near the

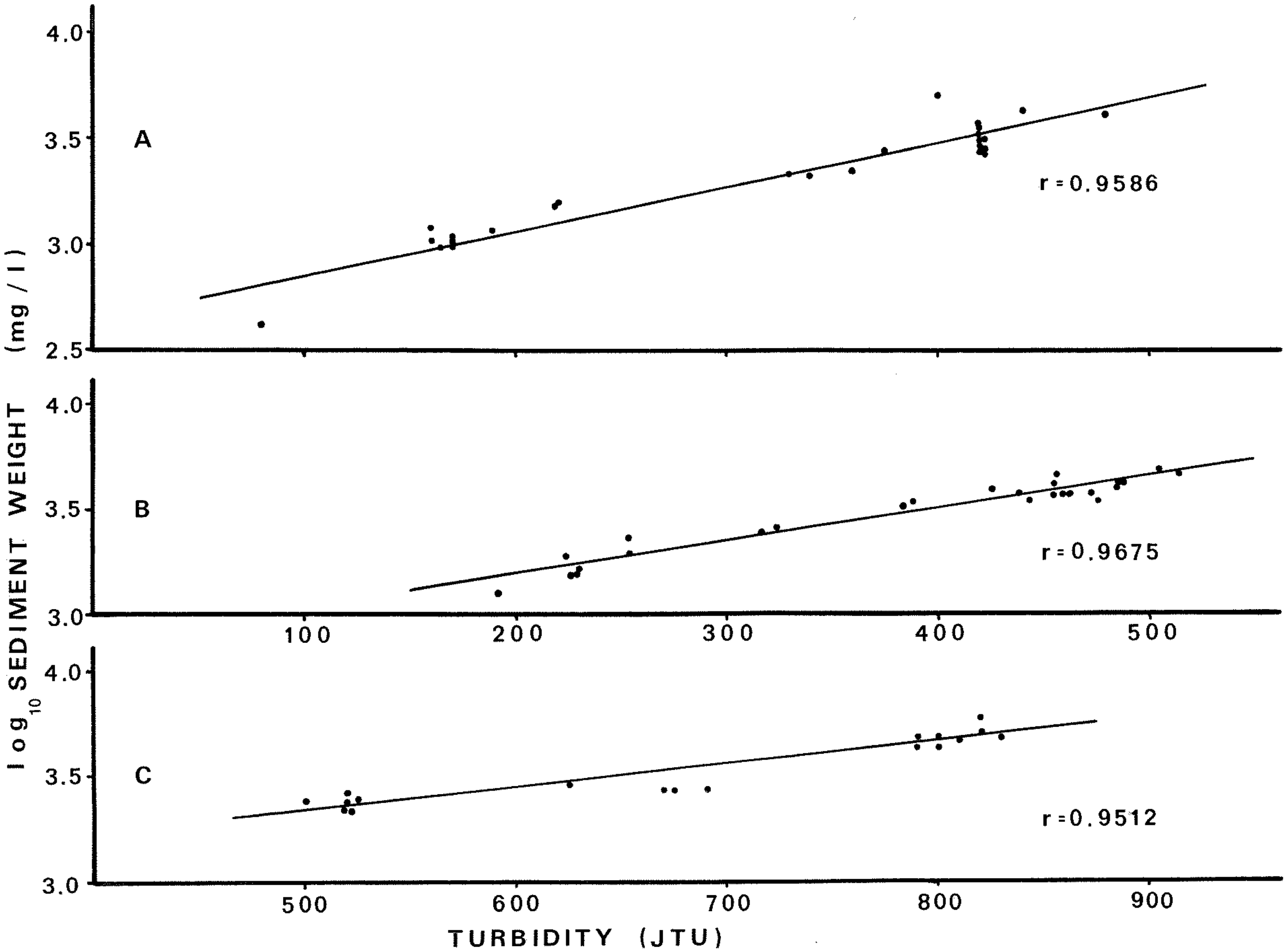

Fig. 7. Regression of $\log_{10}$ sediment weight (mg/1) on turbidity (JTU) for three sediment exposure tests (A) with volcanic ash (June 15, 29 and July 3, 1981); (B) with Volclay 200 (TM) bentonite clay (April 13, 20 and 27, 1981); and (C) two exposure tests with mudflow sediment (May 4 and June 22, 1981). The regression in B was weighted.

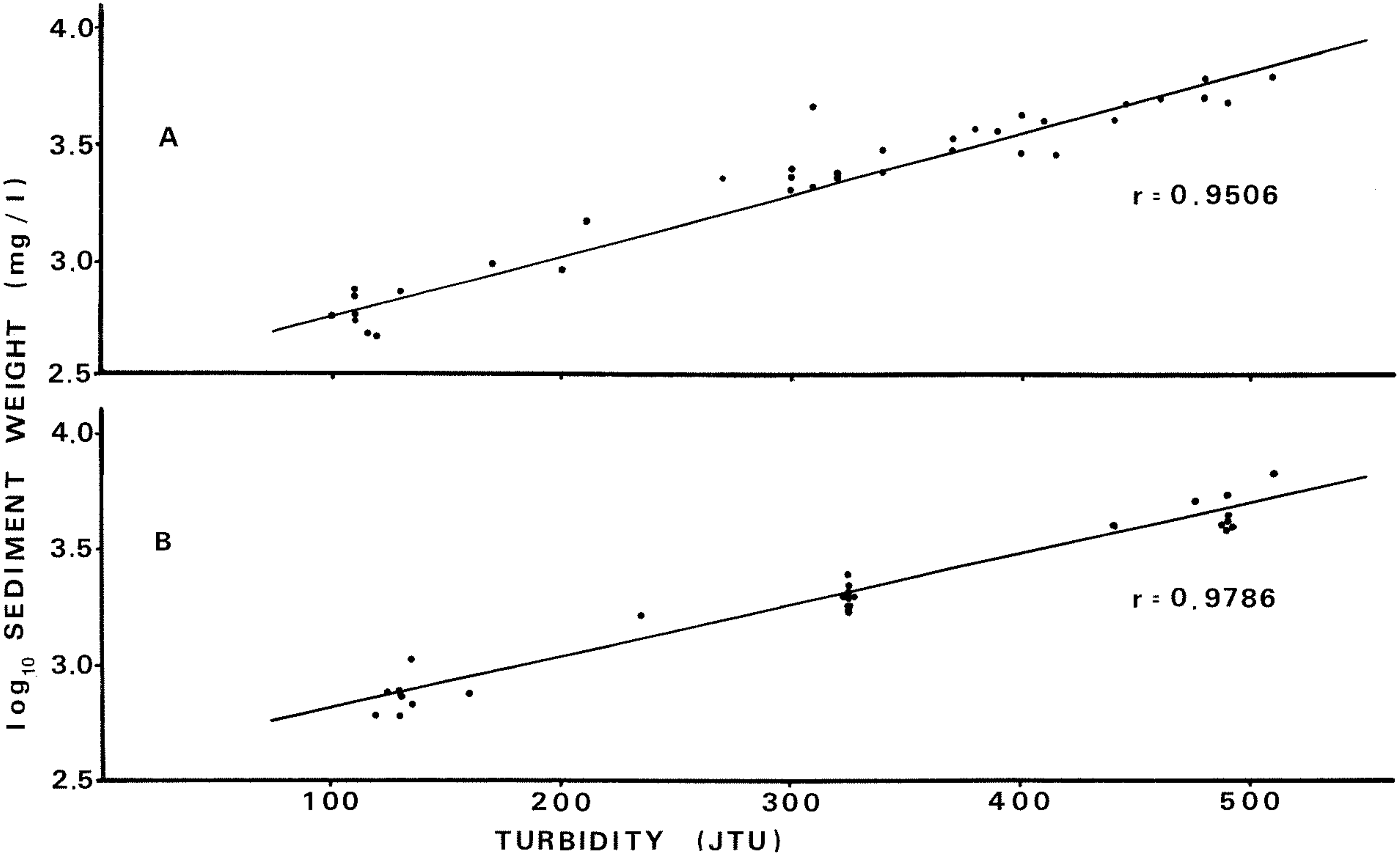

Fig. 8. Regression of $\log_{10}$ sediment weight (mg/l) on turbidity (JTU) for three sediment exposure tests with volcanic ash (A — March 9, 17 and 29, 1981) and (B — May 11, 18 and 25, 1981).

surface on the side opposite that along which the orange floated averaged 15.24 cm/sec, measured approximately every 50 cm down the length of the test channel. Measured mid-stream, the average velocity was 17.07 cm/sec, and measured along the path of the orange was 17.68 cm/sec. The orange estimated 18.30 cm/sec, while the velocity at the axis of spiralling water averaged 16.50 cm/sec. It should be pointed out that fish generally seemed to stay near the center of the water column, avoiding the somewhat faster water in the spiral. The floating chip velocity measurements represent the maximum velocities during each test.

For the static LC50 bioassays water quality determinations were similar to those made for the artificial streams, with a few exceptions. Turbidity values were point measurements taken on a Hach DR-EL turbidimeter at the University of Washington laboratory at the time of TNFR or total residue determination. Temperature and dissolved oxygen were measured with a Garcia Model 8500 oxygen-temperature probe. pH was measured with a Photovolt 12 pH meter.

During the seawater entry tests, temperature, dissolved oxygen, and pH were monitored with the Hydrolab and salinity was measured with salinity hydrometers.

Swimming Performance

The swimming performance of test and control fish was determined at 24 and 72-hr intervals during each of the 14 96-hr sediment/velocity exposure periods. A modified Blazka respirometer-stamina chamber described by Smith and Newcomb (1970) and Flagg (1981) was used. A maximum of eight fish was tested simultaneously by dividing the chamber with an x-shaped plexiglas divider separated into eight compartments with 0.64 cm Vexar screens. Initial testing utilized two sets of four controls and four sediment exposed fish in replicate tests at each time period (24 and 72 hrs). However, since only four fish could be electrically stimulated to swim consistently until fatigued the number tested was reduced to two sets of 2 exposed and 2 control fish per time period.

Prior to placement into the stamina chamber, fish were anesthetized with MS 222 to determine fork length, maximum height, maximum width and smolt stage. Each fish was placed in a compartment, the chamber sealed and a small amount of water allowed to continuously overflow. The fish were allowed a one-hour recovery period before testing. Testing began by setting the initial water velocity at 1.5 lengths per second (as determined from the average length of all fish in the chamber). The velocity was increased by 0.5 length/second intervals every 15 minutes until all fish fatigued (Flagg 1981). Fatigue was defined as the point at which a fish could no longer swim against the current and became impinged on the electric screen. A calibration curve for the stamina chamber which correlated propeller revolutions with water velocity was determined (Fig. 9).

All but the very earliest swimming performance tests were videotaped by a camera hung from the rafters above the chamber. The middle 5 minutes of each velocity were recorded for each test, and these tapes were later analyzed in slow motion for the most accurate tailbeat counts possible. During testing, respiration rate (opercular beats/minute) was timed for each fish at each velocity. This and the tailbeat rate data were adjusted for fish

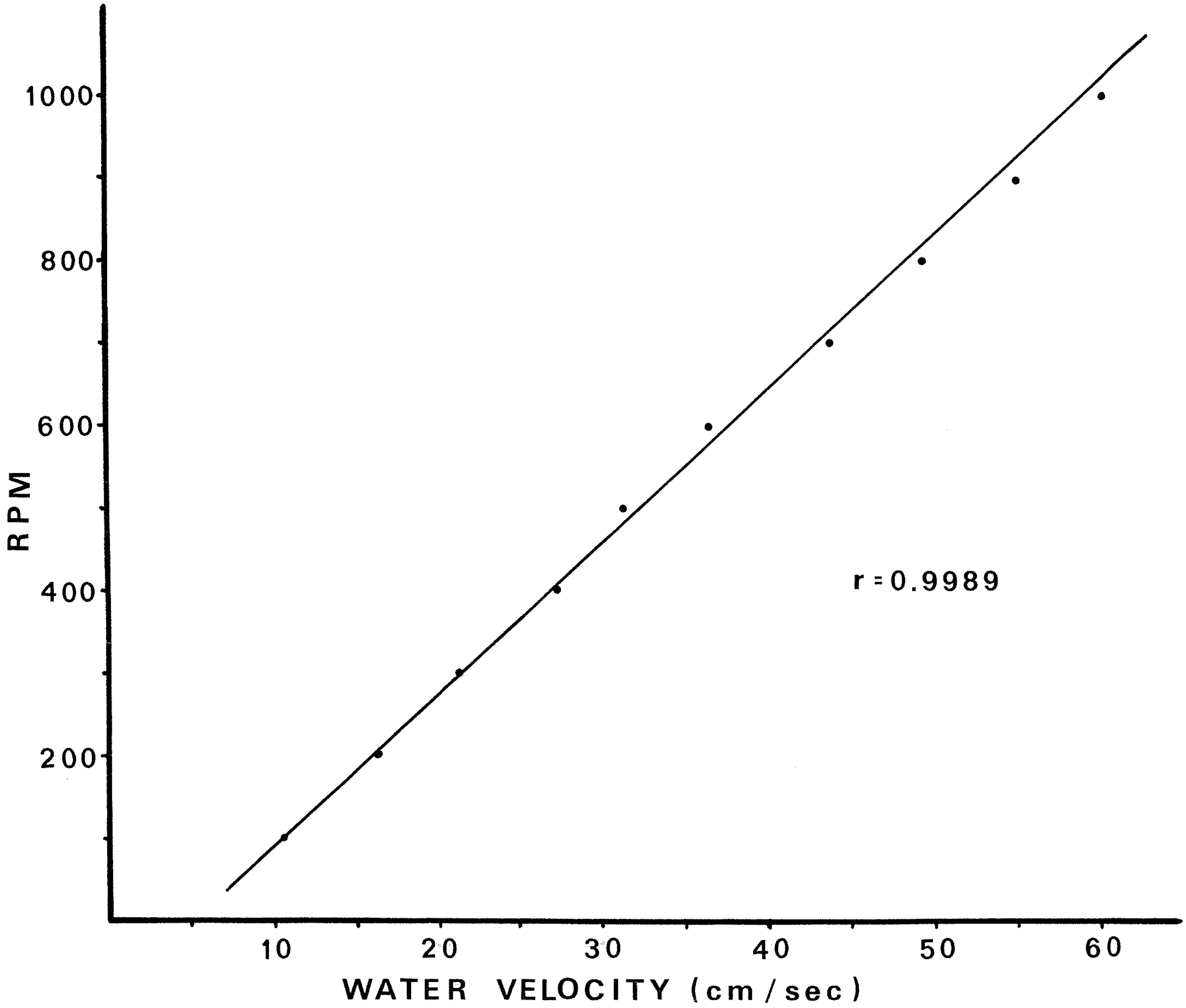

Fig. 9. Standard calibration curve for the swimming performance chamber.

length and solid blocking effects as described below.

Adjustments for differences in fish length and girth were made following the methods of Flagg 1981). The swimming speed of each fish (in body lengths per second) was first calculated by the formula:

$$S_p = (1_i/1_{ii}) \times V$$

where

S_p = swimming speed of the individual fish (1/s)
1_i = mean length of all the fish tested (mm)
1_{ii} = length of the individual fish
V = water velocity (1/s, on mean fish length)

These individual swimming speeds were then corrected for the effects of solid blocking using the formula described by Bell and Terhune (1970, in Flagg 1981):

$$V_f = V_t \cdot 1 + \left(\frac{A_o / A_t}{1 - A_o / A_t}\right)$$

where

V_f = effective velocity (1/s)
V_t = average velocity through the empty chamber (1/s)
A_o = maximum cross-sectional area of the fish in the compartment (mm^2)
A_t = test section area (per compartment) (mm^2)

The test section area (A_t) was taken as the total cross-sectional area of the inner 12.7 cm diameter cylinder, less the cross-sectional area of the 1.3 cm plexiglass (X) compartment assembly, divided by 4 (4 compartments in any cross-section). This value was constant for all tests at 2,492.6 mm^2.

The maximum cross-sectional area of individual fish was estimated from the measures of maximum height and width taken just anterior to the dorsal fin. Cross-section shape was best estimated by considering it as a half-circle above a triangle. Shape was not considered to be an ellipse due to the fact that at the time of testing the fish had not been fed for 4 to 6 days and were therefore less robust than fish tested in other studies (Flagg 1981). Cross-sectional area was determined by the formula

$$A_o = [\frac{\pi(w)^2}{2} + \frac{w(H - \frac{w}{2})}{2}]$$

where

A_o = maximum cross-sectional area (mm^2)
w = maximum width of the fish (mm^2)
H = maximum height of the fish (mm^2)

Swimming stamina or critical fatigue velocity in body lengths/second (U-CRITICAL) was determined for each fish by modifying the formula of Beamish (1978, in Flagg 1981) to

$$\text{U-CRITICAL} = U_i + [\, t_i/t_{ii} \times (U_{ii} - U_i) \,]$$

where

U-CRITICAL = critical swimming speed (1/s)

U_i = highest adjusted velocity maintained for an entire interval (1/s)

U_{ii} = adjusted velocity during which the fish fatigued (1/s)

t_i = time that the fish swam at the fatigue velocity U_{ii} (minutes)

t_{ii} = prescribed period of swimming (minutes: always = 15 for these tests).

This formula takes into account the fact that for an individual fish, the velocity increments would not be exactly 0.5 lengths per second unless the fish were exactly the same length as the mean of all fish tested.

Seawater Entry Tests

The fish surviving each 96-hr sediment/velocity exposure period were placed in seawater entry tests for a subsequent 96-hr exposure period. Fresh seawater was collected from Hood Canal where salinity ranged from 23.6 to 27.7 ppt ($\bar{x}$ = 25.9 ppt). Approximately 757 l were pumped or bucketed into a stainless steel tank for transport to the laboratory. An array of salinities were obtained for each test by dilution with fresh Big Beef Creek water. Tests were conducted in 60 l polyurethane tanks placed in flowing water baths and equipped with airstones for oxygenation and mixing. The loading densities per tank were 20 for coho smolts and 35 for fall chinook smolts. The number of tanks per test varied from six to ten.

Initial testing allowed the fish a 48-hr acclimation period in clean freshwater prior to introduction into seawater concentrations for 96-hr periods. In later tests fish were placed directly into salinity arrays with no acclimation.

Histopathology

One to five fish were sacrified at periodic intervals or at the termination of each live-box, static or sublethal exposure bioassay for samples of gill tissue. The first right gill arch was excised and placed into Bouin's fixative. During the March 16-20 and March 30 - April 3, 1981 live-box bioassays, an extra live box was placed in the Cowlitz River to provide gill samples at 24, 48, 72 and 96-hr intervals. Gill tissues were held in Bouin's fixative for 24 hr followed by a rinse and storage in 70 percent ethanol. Tissues were further dehydrated with ethanol, cleared in xylene, embedded in paraffin, cut on a microtome to a thickness of 4 µm, mounted on glass slides and stained with hematoxoylin and eosin for evaluation. The gill tissues were analyzed for any structural abnormality as well as the presence of parasites or other obstructions.

Tissues from regularly scheduled samples (randomly selected every 24 hours during the stream sediment exposures and at the end of static bioassays and seawater entry tests) were mounted and read together. Putting 3 to 5 gill arches on one slide allowed quick assessment of the variability in damage between fish, and controlled for the possibility of randomly selecting one fish showing more or less damage than usual. In all cases of gill tissue samples, the first or outer gill arch on the right side of the fish was taken. This controlled for variability in damage between gill arches, assuring that evaluation between slides could be directly compared. In a few cases, entire gill series were removed and analyzed separately to assess whether consistent difference in amount of damage existed between first, second, third and fourth gill arches. None was found.

During the April 27 - May 1, 1981 bioassay, an extra live box was placed in the Cowlitz River at Lexington (Station 8) to provide gill tissue samples for electron microscopy. Fish were sacrificed at 24-hr intervals. The first right gill arch was removed, rinsed with water and stored in 10 ml of 2-4 percent gluteraldehyde fixative in phosphate buffer, pH 7.1. In the laboratory, gills were rinsed in three changes of the buffered gluteraldehyde and then dehydrated in a series of ethanol and freon solutions (from 20 percent ethanol to 100 percent freon). The tissues were critical point dried with freon, mounted on stubs, and plated with Au/Pd.

RESULTS AND DISCUSSION

River Discharge

The post-eruption daily discharge of the Toutle River at Hwy 99 (Fig. 10) and Cowlitz River at Castle Rock (Fig. 11) show the low flow (late May to October) and storm-related runoff which occurred during the November 1980 to February 1981 period. The Toutle River contributes between 8.5 and 27 percent of the discharge of the Cowlitz River at Castle Rock.

Water Quality

Suspended Sediment

The May 18 eruption resulted in major increases in the suspended sediment concentrations in the rivers draining the western side of the volcano. Suspended sediment concentrations at each live-box bioassay and water quality site are listed in Appendix Table 1. The north fork of the Toutle River was most affected by both mudflow and blast debris (Fig. 12). Suspended sediment concentrations exceeded 300,000 mg/l in the upper north fork during fall rainfall events. Concentrations observed in the lower north fork ranged to 12,522 mg/l. The Green River drainage was covered by several centimeters of airfall ash which fell directly or eroded into the river. Suspended sediment concentrations ranged to 15,891 mg/l. A general decline was evident from the concentrations observed in the fall of 1980 to those during the spring of 1981.

The south fork of the Toutle River was only affected by mudflow. Suspended sediment concentrations ranged to 11,880 mg/l during summer-fall 1980 (Fig. 13). During the early spring of 1981 suspended sediment concentrations had declined

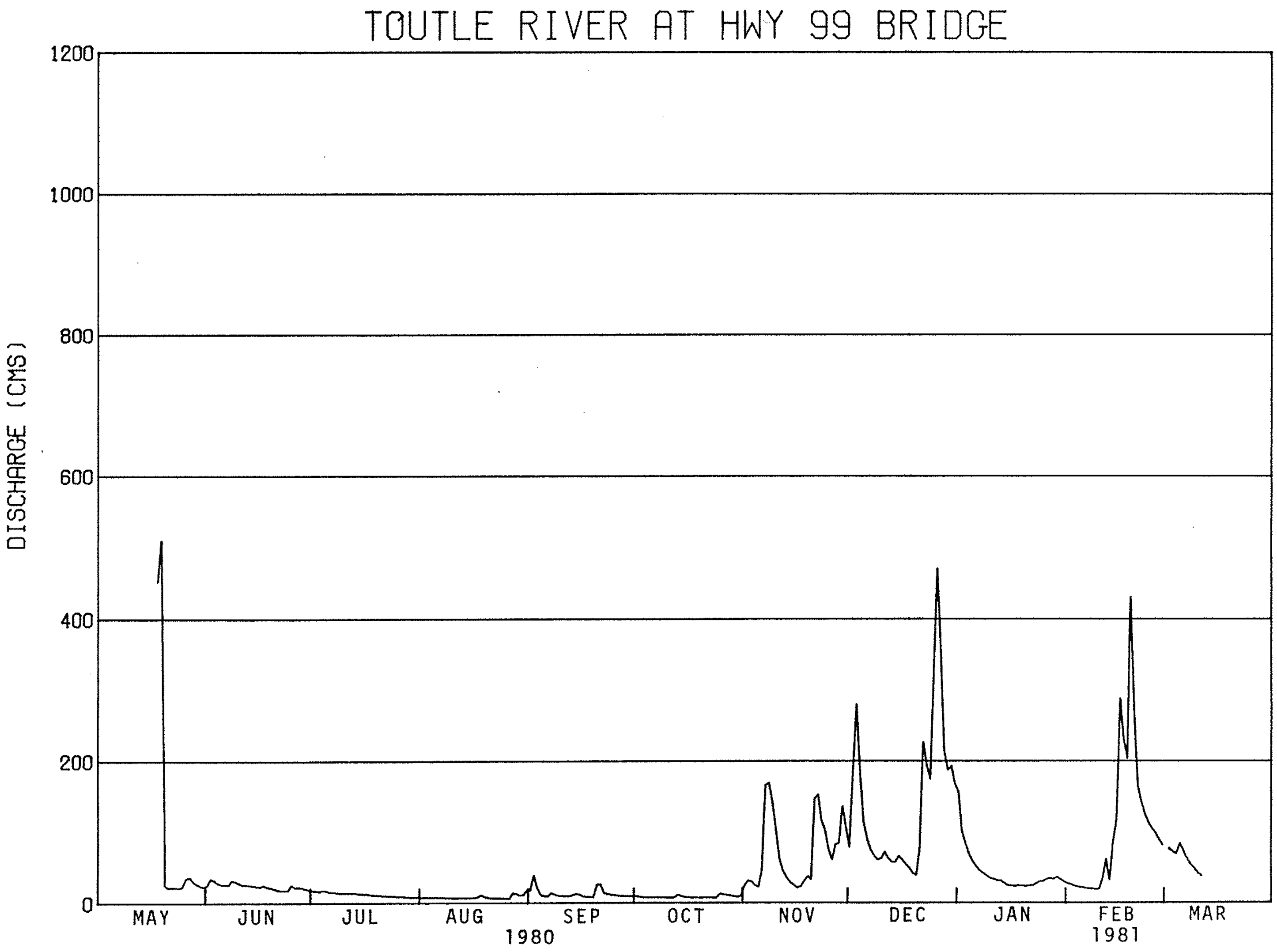

Fig. 10. Post-eruption daily discharge, cms, for the Toutle River at Hwy 99 (USGS Provisional Data).

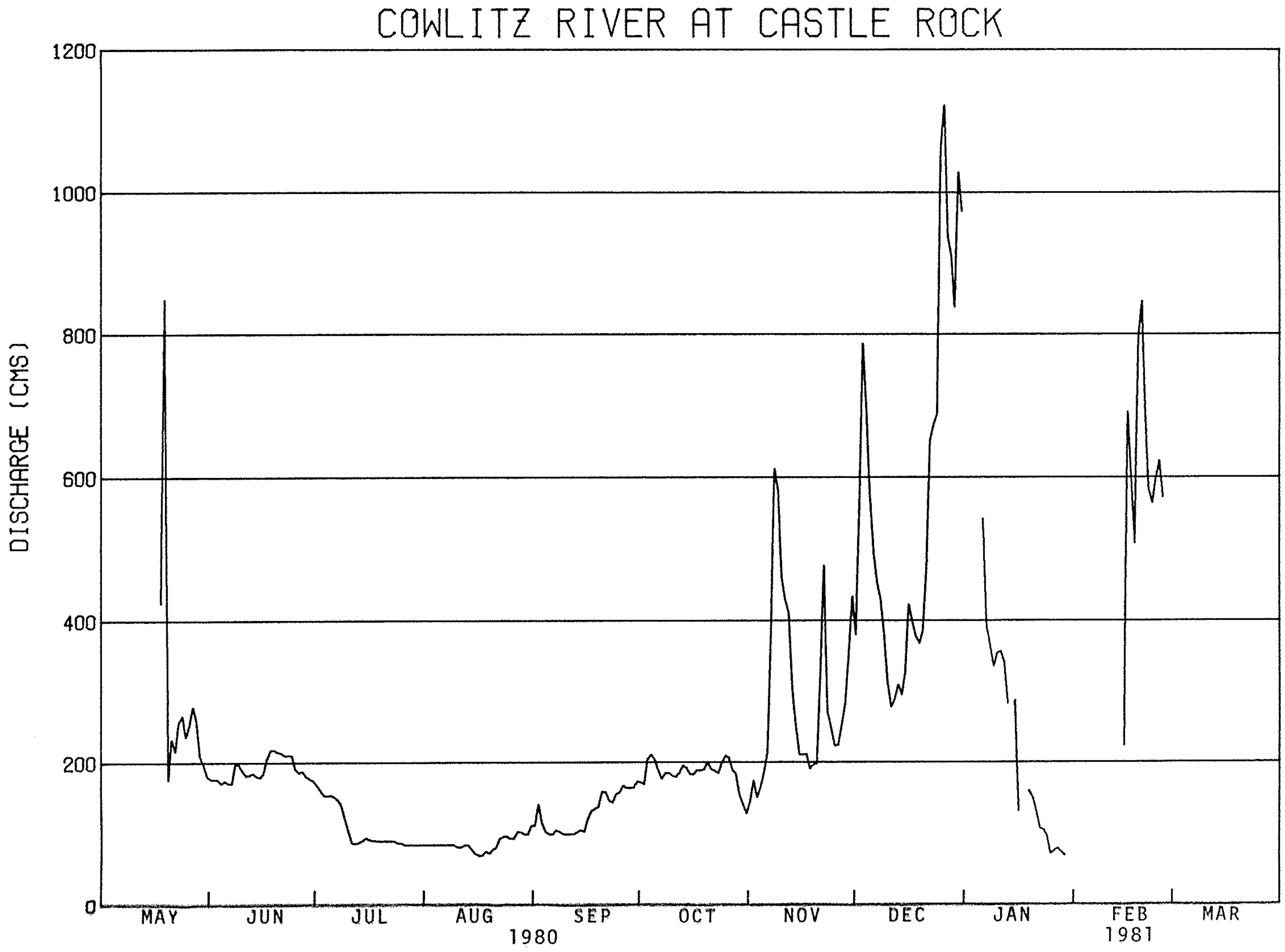

Fig. 11. Post-eruption daily discharge, cms, for the Cowlitz River at Castle Rock (USGS Provisional Data).

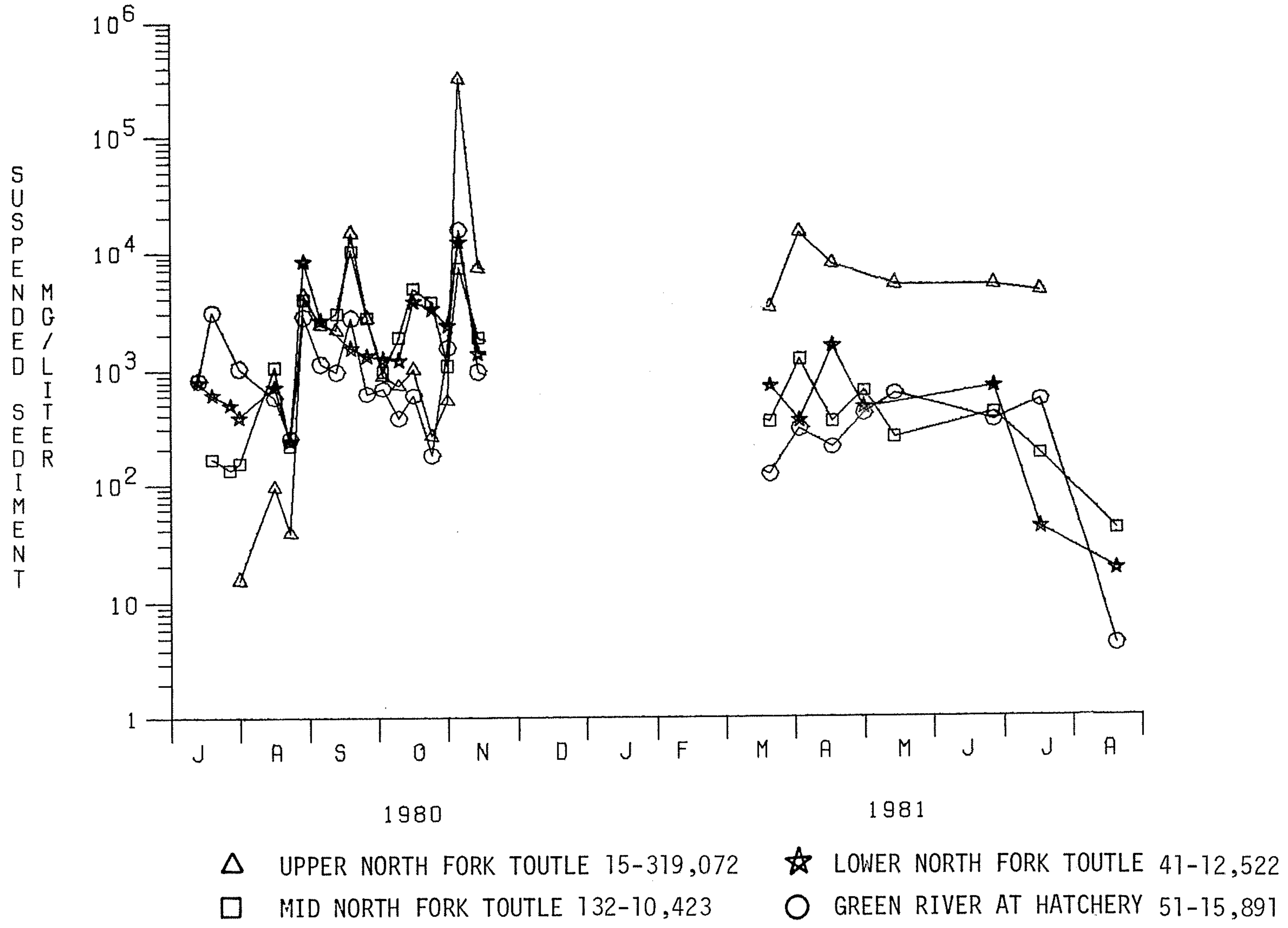

Fig. 12. Suspended sediment concentrations (mg/l) in upper (Station 18), middle (Station 14) and lower (Station 13) north fork Toutle River and the Green River (Station 15) during live-box testing.

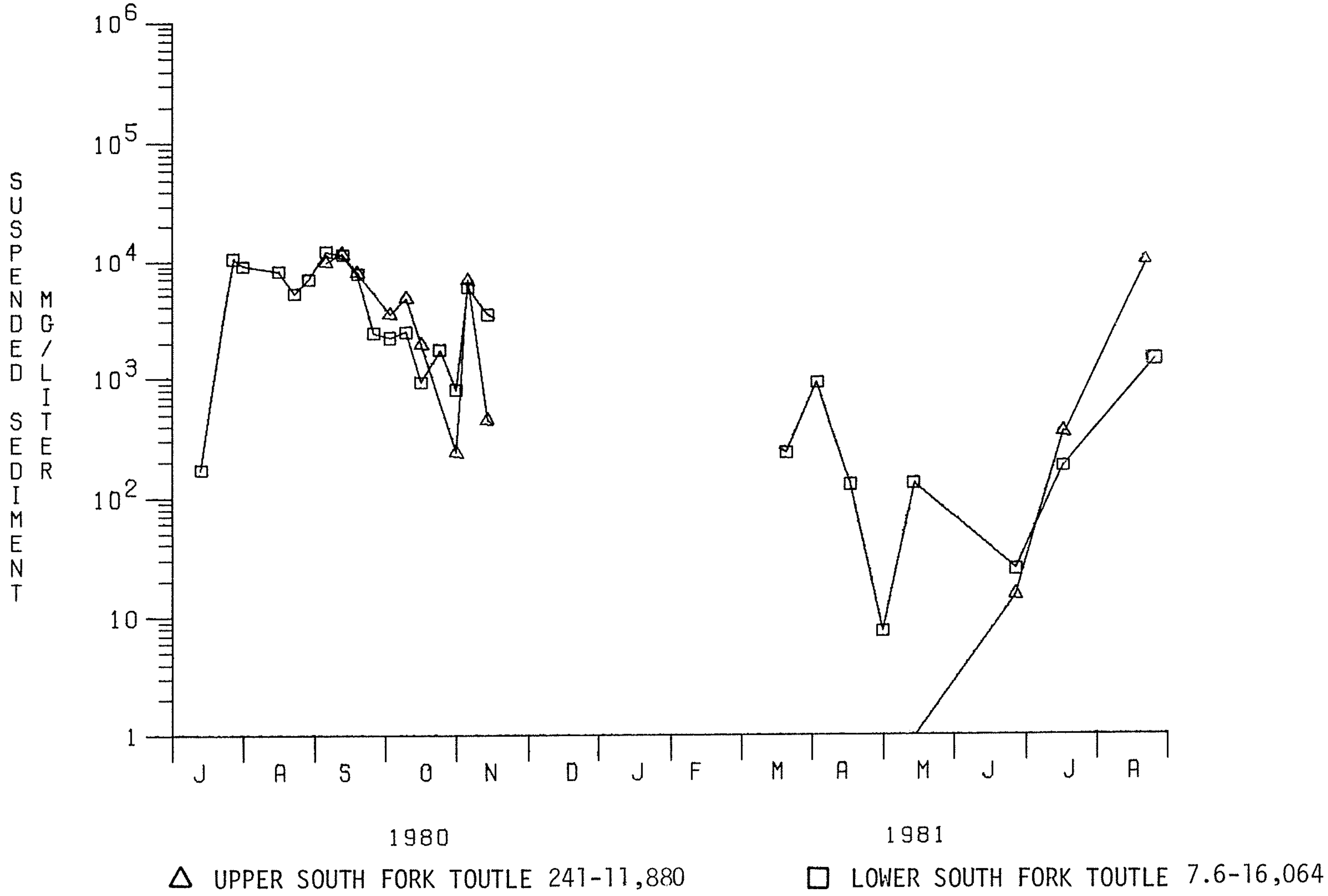

Fig. 13. Suspended sediment concentrations (mg/l) in the upper (Station 19) and lower (Station 16) south fork Toutle River during live-box testing.

to less than 1 mg/l immediately above the south fork debris dam. Concentrations increased abruptly again in June 1981. Suspended sediment remained high on the lower south fork below the debris dam due to dredging. During the beginning of the rainy season the debris dams constructed by the Corps of Engineers reduced the initial suspended sediment loads in both forks of the Toutle River; however, later storms in December 1980 breached the north fork dam. The continual dredging in the pool of both structures resulted in some artificially higher suspended sediment concentrations downstream.

Comparative suspended sediment concentrations for the sample periods are plotted for the upper Cowlitz River at Castle Rock and the lower Toutle River (Fig. 14). The upper Cowlitz River control site was unaffected by mudflow or blast debris; however, eruptions subsequent to May 18 contributed some airfall ash which washed in during initial rainfall events. Concentrations in the lower Toutle ranged from 93 to 12,135 mg/l in the samples taken near the edge of the river. Dinehart (1981) calculated concentrations in cross-sectional samples at greater than 400,000 mg/l during flood events at this site. The concentrations observed at Castle Rock (31 to 3,314 mg/l), 1 mile downstream from the confluence of the Toutle River with the Cowlitz River, indicated a general reduction of about four times due to the dilution by the upper Cowlitz River. The decline in suspended sediment concentrations from summer-fall 1980 to spring-summer 1981 is evident with the data.

Suspended sediment concentrations in the lower Cowlitz River at Lexington, Kelso and RR bridge were generally consistent (Fig. 15). Extensive channel clearance and dredging was the predominant factor influencing these concentrations from July 1980 until May 1981. The Coweman River was utilized as a local

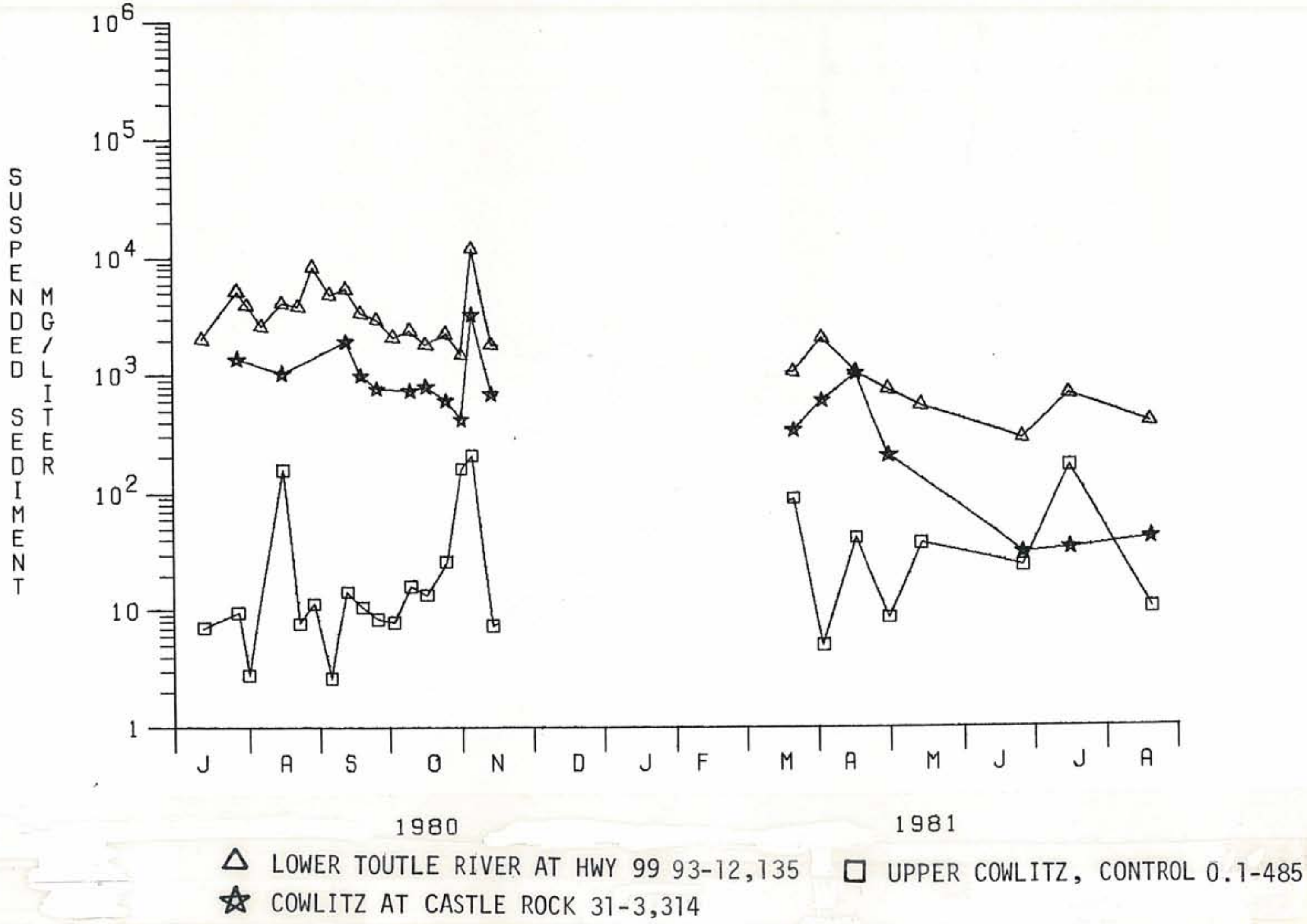

Fig. 14. Suspended sediment concentrations (mg/l) in the lower Toutle River (Station 11), Cowlitz River at Castle Rock (Stations 9E and W) and upper Cowlitz River control (Station 10) during live-box testing.

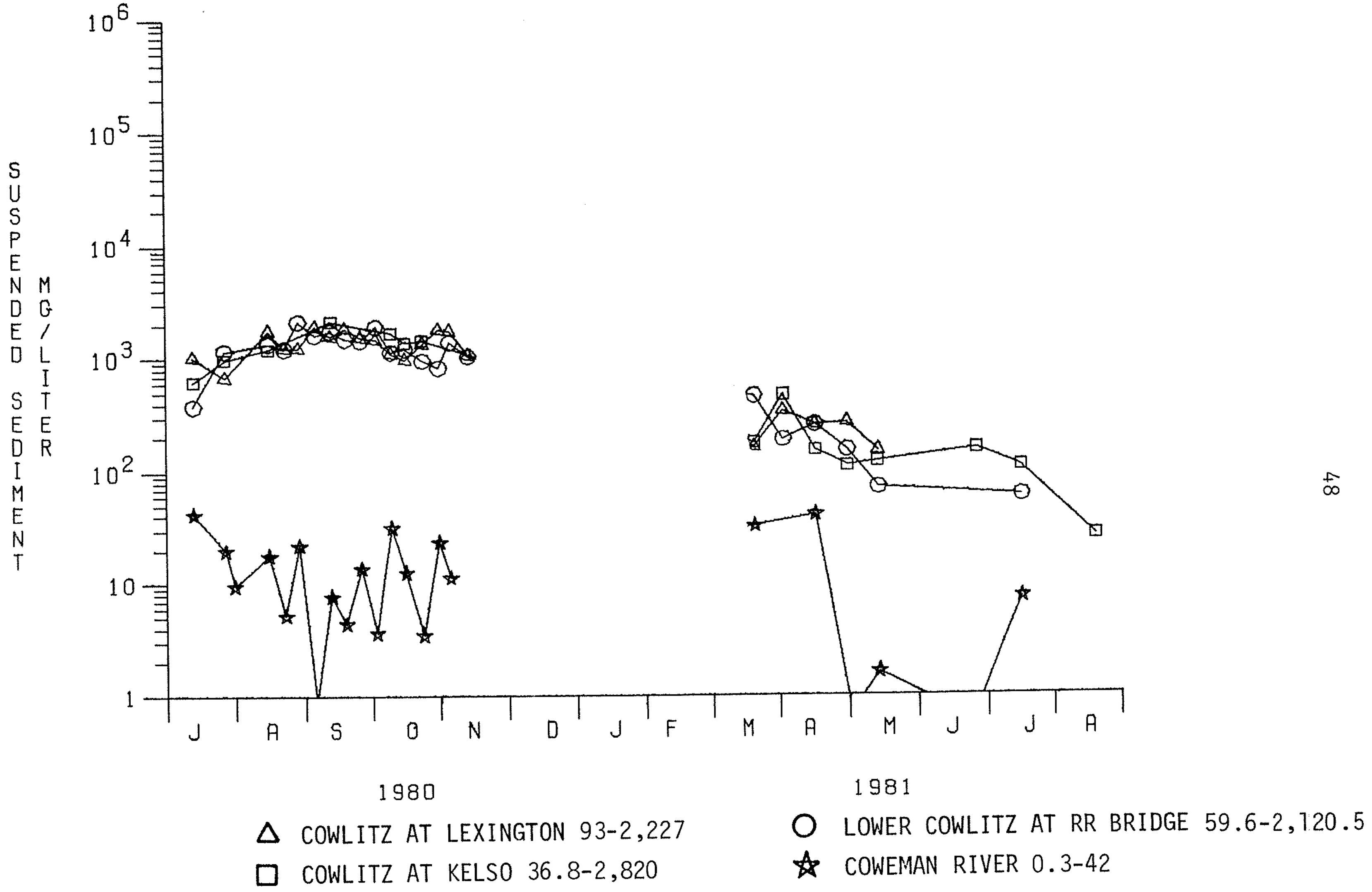

Fig. 15. Suspended sediment concentrations (mg/l) in the Cowlitz River at Lexington (Station 8), Kelso (Stations 7E and W) and lower Cowlitz (Station 4) and in the Coweman River (Station 6) during live-box testing.

control stream. The general decline from 1980 to 1981 is indicative of the decrease in sediment input from the Toutle River. Concentrations of suspended sediment observed in the Columbia River above and below the Cowlitz River and those in the Lewis and Kalama Rivers were generally much lower (Fig. 16).

The turbidity (JTU) and settleable solids (ml/l) values corresponding to the suspended sediment concentrations are presented in Appendix Table 1.

Water Temperature

Water temperatures in the devastated north fork Toutle and Green Rivers during the live-box testing periods are presented in Fig. 17. Due to the loss of most of the riparian vegetation along most of the channels upstream of these sites the temperatures probably exceeded normal pre-eruption ambient. The Green river exhibited a slightly lower thermal regime due to passage through an unlogged canyon section outside the blast zone upstream of the hatchery. Water temperatures in the south fork were similar to north fork temperatures (Fig. 18). Both forks were affected by the complete loss of riparian vegetation. The higher thermal regime of the lower Toutle River is evident in Figure 19 when compared to the Cowlitz River at I-5 and Castle Rock. Temperature differences of 8-9°C occurred between the two rivers. Water temperatures at lower Cowlitz stations remained relatively uniform (Fig. 20). The comparative temperatures in the Columbia River with those in the Lewis and Kalama Rivers indicate lower thermal regimes in the latter two (Fig. 21). Water temperatures in the Kalama and Lewis Rivers were probably similar to those which occurred in the Toutle River before the May 18 eruption. The 5 to 10°C increase in the water temperatures in the Toutle River system was probably a result of the loss of riparian vegetation and increased suspended sediment concentrations.

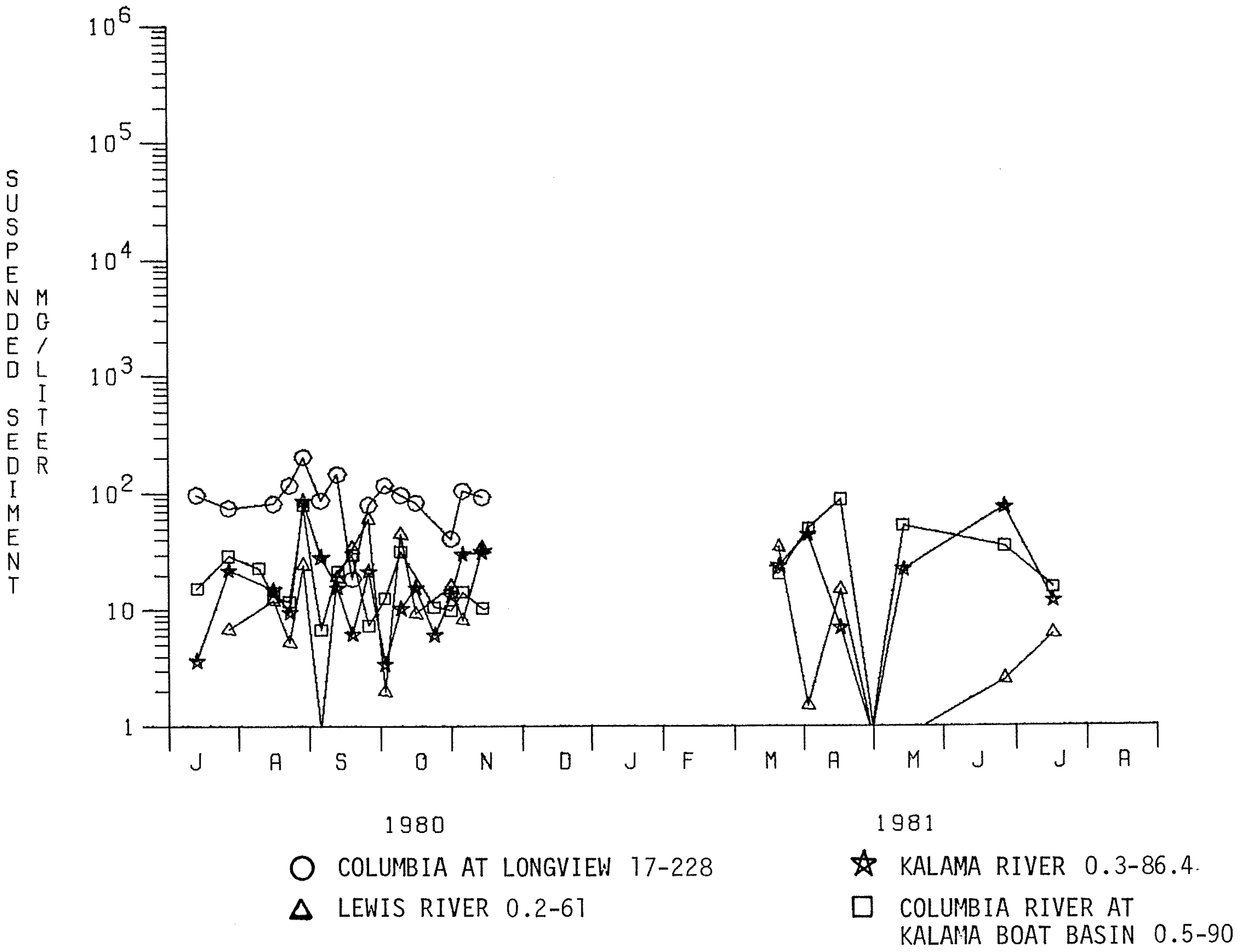

Fig. 16. Suspended sediment concentrations (mg/l) in the Columbia River at Longview (Station 5) and Kalama Boat Basin (Station 2), the Lewis River (Station 1) and the Kalama River (Station 3) during live-box testing.

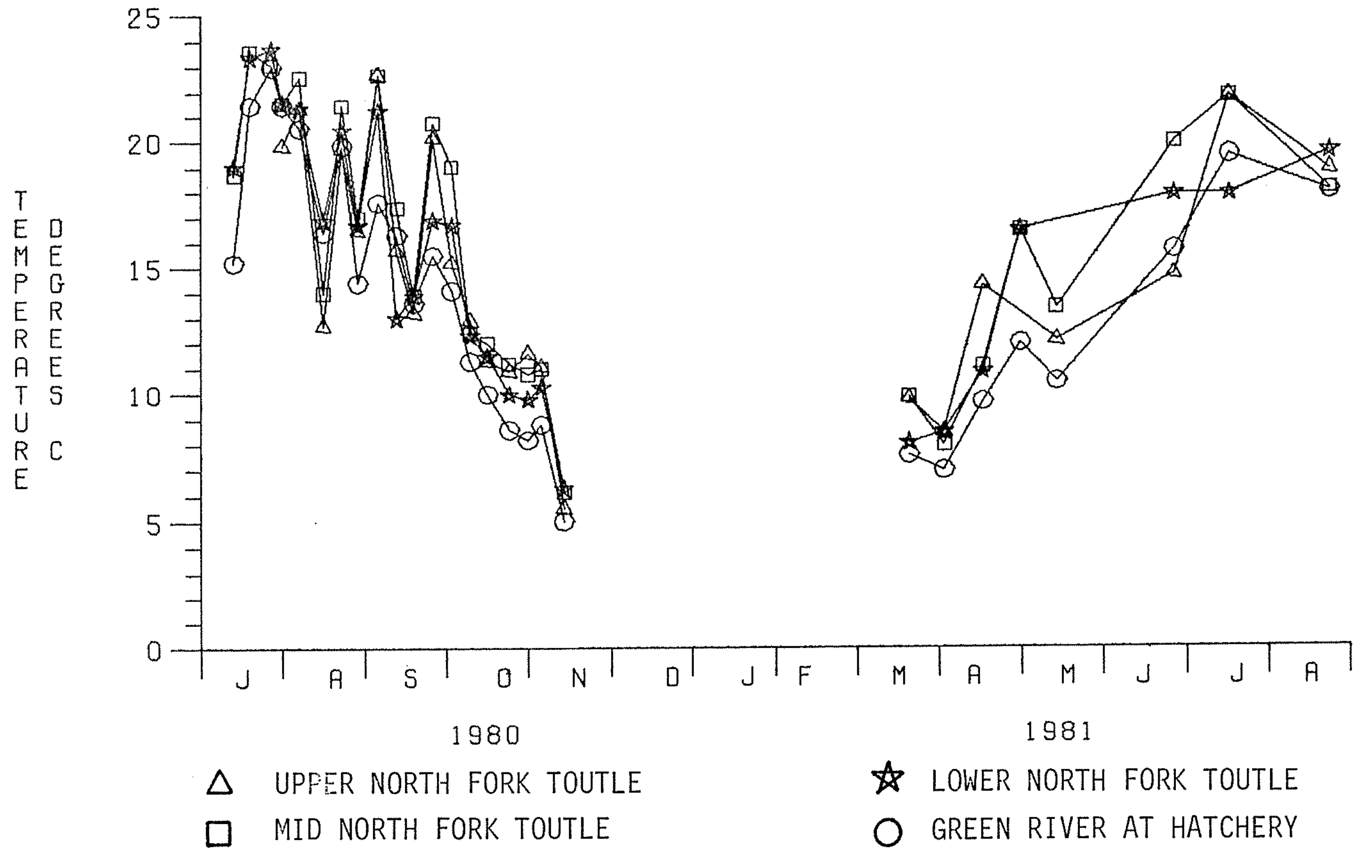

Fig. 17. Water temperatures in the upper (Station 18), middle (Station 14) and lower (Station 13) north fork Toutle River and the Green River (Station 15) during live-box testing.

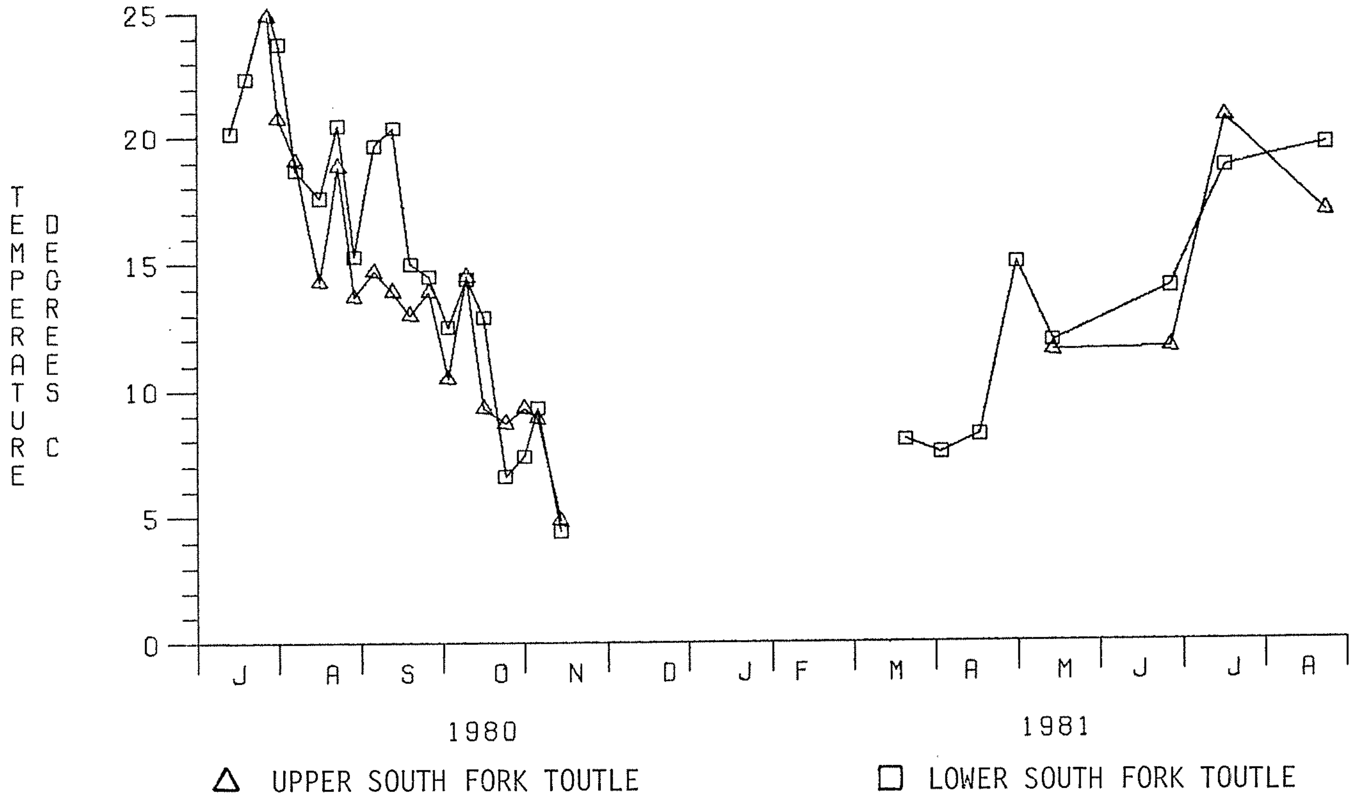

Fig. 18. Water temperatures in the upper (Station 19) and lower (Station 16) south fork Toutle River during live-box testing.

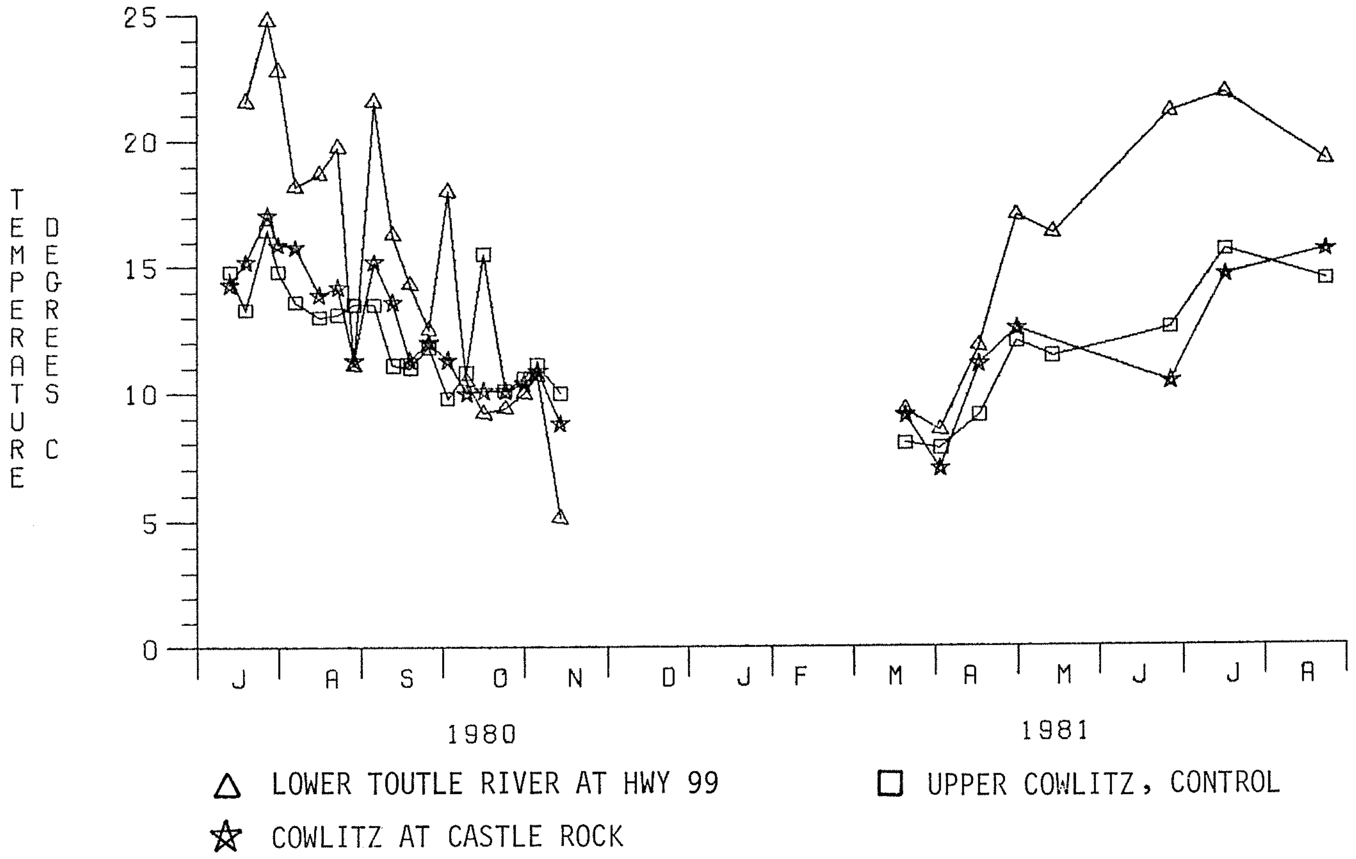

Fig. 19. Water temperatures in the lower Toutle River (Station 11), Cowlitz River at Castle Rock (Stations 9E and W) and upper Cowlitz River (Station 10) control during live-box testing.

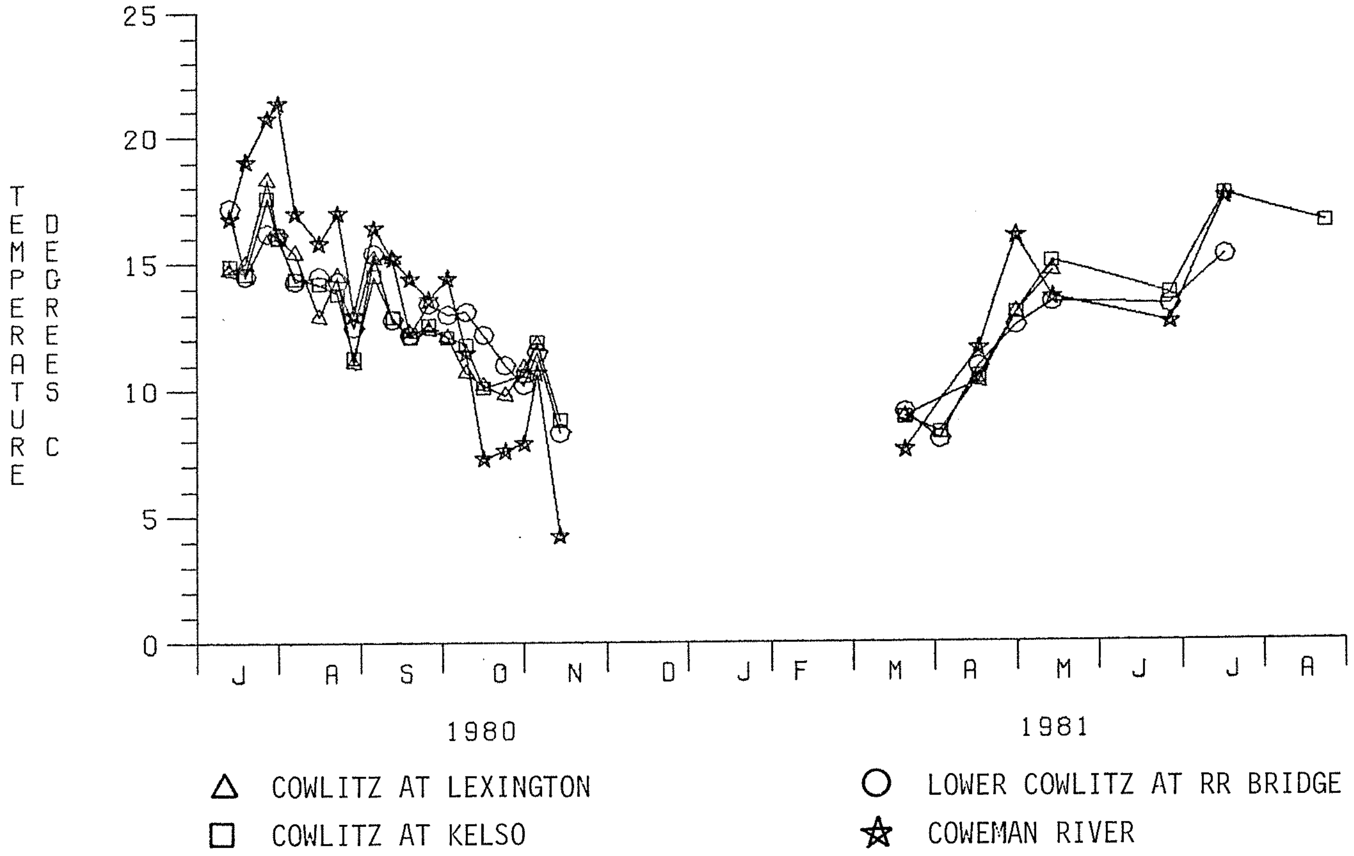

Fig. 20. Water temperatures in the Cowlitz River at Lexington (Station 8), Kelso (Stations 7E and W) and lower Cowlitz (Station 4) and the Coweman River (Station 6) during live-box testing.

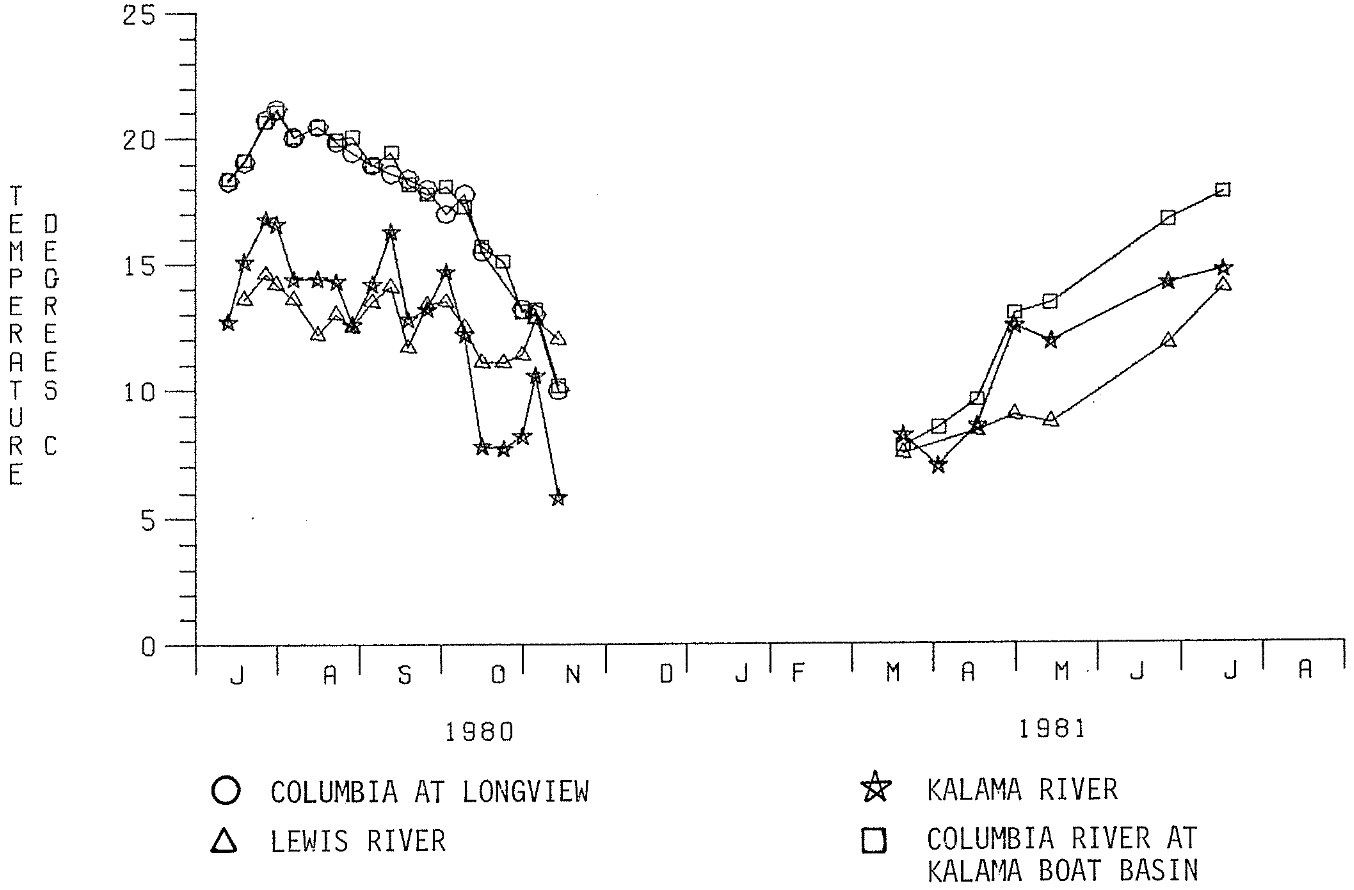

Fig. 21. Water temperatures in the Columbia River at Longview (Station 5) and Kalama Boat Basin (Station 2), the Lewis River (Station 1) and the Kalama River (Station 3) during live-box testing.

Other Parameters

Dissolved oxygen, pH and conductivity are summarized for the field sampling period by station and river in Table 8. There is little evidence that low dissolved oxygen concentrations persisted at any of the stations sampled. A temporary minimum of 4.5 mg/l occurred at the upper north fork Toutle River station immediately downstream of the massive avalanche debris. The pH was circumneutral at all the stations monitored and the eruption did not appear to cause major changes. The conductivity of the water in the north fork Toutle River was increased substantially above other stations with a mean of 674 μmhos/cm^2. This probably resulted from the leaching through the debris material in the upper valley.

Water samples were taken during the 1981 spring field season to determine the presence of dissolved organic carbon and phenols. Six stations were sampled on four dates and the water was analyzed by the USGS Water Quality laboratory in Denver, Colorado (Table 9). The concentrations of dissolved organic carbon were consistently low and did not exceed 2.0 mgC/1. The acceptable range for dissolved organic carbon is 0 to 7 mg/l, and the levels remained near the lower end of this range. In all cases the measurement of total phenols was < 1.0 μg/l.

Concentrations of phenolic compounds as high as 200 μg/l are non-toxic to fish and aquatic life (McKee and Wolf 1963), although 1 μg/l will taint fish flesh and is considered the maximum acceptable level for total phenols (EPA 1976). It was concluded that these rivers were not significantly contaminated in the spring of 1981 with organic compounds leached from pyrolized organic matter entering upstream from the blast zone. Unfortunately water was not analyzed for phenolic content throughout the 1980 field season and the potential

Table 8. Summary of water quality data by station in the rivers draining the west side of Mount St. Helens during the July-November 1980 and March-August 1981 field sampling periods.

	Filterable solids mg/1			Dissolved oxygen mg/1			pH			Conductivity µmhos/cm^2		
Site	$\bar{x}$	Min.	Max.	$\bar{x}$	Min.	Max.	$\bar{x}$	Min.	Max.	$\bar{x}$	Min.	Max.
North Fk. Toutle River												
Upper (18)	18,124.8	15.2	319,072.0	9.0	4.5	11.1	7.1	6.2	7.7	674	451	1271
Middle (14)	2,696.1	132.0	10,423.2	9.3	5.9	11.4	7.4	6.3	7.6	290	180	376
Lower (13)	1,686.2	17.7	12,521.6	9.4	4.8	11.6	7.2	6.6	7.6	236	17	573
Green River (15)	915.8	4.3	15,891.2	9.6	6.8	11.7	7.1	6.5	7.8	116	32	177
South Fk. Toutle River												
Upper (19)	5,270.5	240.8	11,879.7	10.4	9.8	11.7	7.0	6.7	7.2	61	38	72
Middle (17)	7,742.8	502.0	31,145.5	9.9	8.3	11.9	7.2	6.6	7.7	61	40	76
Lower (16)	5,218.0	7.6	16,064.2	9.6	6.1	12.0	7.1	6.6	7.7	68	39	214
Toutle River												
Tower Road (12)	3,429.2	465.0	11,148.0	9.6	7.6	11.4	7.2	6.6	7.6	148	55	194
Mouth (11)	2,513.4	92.9	12,134.8	9.9	7.2	19.0	7.0	6.7	7.6	184	44	417
Cowlitz River												
I-5 Bridge (10)	49.1	0.1	485.0	10.8	8.7	15.7	7.0	6.3	7.7	48	27	195
Castle Rock (9)	911.4	31.1	3,314.0	10.1	6.4	18.0	6.8	6.1	7.3	70	12	124
Lexington (8)	956.7	93.0	2,227.0	9.9	6.8	16.2	6.9	6.1	9.1	68	34	100
Kelso (7)	705.0	25.8	2,820.0	9.9	6.6	17.9	6.9	6.2	7.7	71	29	120
Longview (4)	1,007.9	59.6	2,120.5	9.6	8.3	11.9	6.9	6.1	7.4	70	55	89
Columbia River												
Kalama (2)	23.3	0.5	89.5	9.5	5.7	12.6	7.4	6.9	8.1	145	103	168
Longview (5)	91.4	17.3	227.9	9.3	6.7	12.1	7.3	7.0	7.9	165	132	226
Kalama River												
WDF boat launch (3)	20.0	0.3	86.4	10.2	8.7	12.1	7.0	6.4	7.5	39	24	50
WDF hatchery (20)	32.2	4.1	99.4	9.0	7.4	12.0	6.5	6.2	6.9	41	28	55
Coweman River (6)	14.1	0.3	42.1	9.6	5.2	11.9	7.0	6.5	7.4	58	35	104
Lewis River (1)	16.0	0.2	60.8	9.9	8.6	11.5	6.7	5.8	7.2	29	21	40

Table 9. Dissolved organic carbon and total phenolic content in water samples from 6 locations.

Sample location	Date	Dissolved organic carbon (mgC/l)	Total phenols (μg/l)
Cowlitz River at Kelso	18 Mar 81	0.5	<1.0
Castle Rock	1 Apr 81	1.4	
Castle Rock	29 Apr 81	0.9	
Castle Rock	16 Jul 81	1.3	
Main Toutle near mouth	18 Mar 81	1.1	<1.0
	1 Apr 81	1.1	
	29 Apr 81	1.1	
Lower South Fork Toutle	18 Mar 81	1.5	<1.0
	1 Apr 81	0.8	
	29 Apr 81	1.6	
	16 Jul 81	1.2	
Middle North Fork Toutle	18 Mar 81	2.0	<1.0
	1 Apr 81	1.5	
	29 Apr 81	1.1	
	10 Jul 81	3.5	
Green River	18 Mar 81	0.7	<1.0
	29 Apr 81	1.0	
	16 Jul 81	1.9	
Coldwater Lake effluent	16 Jul 81	5.2	

presence of phenols cannot be completely discounted as an influence on fish mortality.

Phenol concentrations as high as 140 µg/l in the north fork Toutle River and 134 µg/l in the south fork Toutle River were reported on November 25, 1980 (Larson and U'ren 1981). However, these values are within the normal background range, 100-200 µg/l associated with the Pacific Northwest and its logging industry. These concentrations exceeded the 1976 EPA guidelines of 1 µg/l and are on the low end of the range currently recommended for a variety of phenolics (i.e., 0.03-500 mg/l, EPA 1980). The most toxic of these substances are anthropogenic, chlorinated phenols which would probably not occur in the Toutle River. Phenol concentrations in the lower Columbia, Cowlitz and Toutle Rivers were 3, 3 and 1 µg/l, respectively, on October 6, 1980, and 3, 4 and 3 µg/l, respectively, on November 12, 1980 (U.S.A.C.E. 1980b).

The mean concentration of plant nutrients (PO_4, SiO_4, NO_3, NO_2 and NH_4) are presented by station in Table 10. The eruption appears to have increased the available PO_4 and SiO_4 in the north and south forks of the Toutle River.

Live-Box Bioassays

Presmolt and Smolt

The instream live-box bioassays on coho salmon presmolts and smolts and fall chinook salmon smolts conducted during 1980 and 1981 are summarized in Table 11. The 96-hr LC50 for the combined tests of coho presmolts in 1980 following the May 18 eruption was 1,217 mg/l (Fig. 22). The partial mortalities during this period (July-October 1980) occurred in the lower Cowlitz River where the suspended sediment concentrations ranged from 500 to 2,000 mg/l.

Table 10. Mean nutrient values by station (ppm).

Location (Site No.)	PO_4	SiO_4	NO_3	NO_2	NH_4
Lewis River (1)	.020	12.67	2.10	0.02	0.04
Coweman River (6)	.052	17.54	2.99	0.04	0.06
Kalama River					
WDF Boat Launch (3)	.050	23.88	1.68	0.02	0.04
WDF Hatchery (20)	.089	16.67	1.26	0.03	0.27
Columbia River					
Longview (5)	.156	11.59	2.30	0.05	0.16
Kalama (2)	.060	10.93	2.40	0.04	0.03
Cowlitz River					
Longview (4)	.222	11.51	2.75	0.05	0.10
Kelso (7)	.512	12.11	2.60	0.06	0.15
Lexington (8)	.352	8.84	2.84	0.07	0.09
Castle Rock (9)	.288	10.78	2.59	0.06	0.10
Control (10)	.197	11.17	1.71	0.05	0.17
Toutle River					
Mouth (11)	.335	28.65	2.60	0.07	0.17
Tower Road (12)	.409	26.85	2.27	0.06	0.09
North Fork Toutle River					
Lower (13)	.120	23.71	1.89	0.06	0.04
Middle (14)	.143	36.91	2.62	0.04	0.08
Green River confluence (23)	.228	17.90	0.00	0.00	0.01
Upper (18)	.105	45.42	1.37	0.03	0.07
South Fork Toutle River					
Lower (16)	.162	25.63	2.92	0.05	0.11
Weyerhaeuser RRB (24)	.513	11.60	0.10	0.01	0.01
Middle (17)	.165	14.97	2.16	0.04	0.06
Upper (19)	.124	20.24	1.61	0.03	0.04
Green River (15)	.255	13.54	1.37	0.03	0.08

Table 11. Instream 96-hr live-box bioassays conducted in 1980 and 1981. The 96-hr LC50 values were 1980 coho presmolts 1,217 mg/l; 1981 coho smolts 509 mg/l; 1981 fall chinook smolts 488 mg/l. Mortality was insufficient to calculate LC50 values for spring chinook or for 1981 presmolt coho.

Dates	Species	No. of sites	Concentration range (mg/l)	No. of tanks/ site	No. of fish/ tank	Range of average temps. (°C)	Fish information			Hatchery source
							Average length (mm)	Average weight (g)	Average condition factor	
7/08- 7/12/1980	Coho presmolts	6	8-2352	1	25-27	12.3-18.7	64.70	2.82	1.041	Lewis River
7/22- 7/26/1980	Coho presmolts	11	1-15320	1	24-25	14.5-23.5	72.21	3.85	1.023	Lewis River
8/12- 8/16/1980	Coho presmolts	11	6-11900	1	21-25	12.6-20.9	60.59	2.32	1.043	Lewis River
9/09- 9/13/1980	Coho presmolts	11	3-16064	1-2 (1)	19-25	12.6-19.5	65.38	3.35	1.199	Lewis River
10/07-10/11/1980	Coho presmolts	10	5-3137	1	9-25	10.7-17.3	82.75	6.74	1.189	Grays River
3/16- 3/20/1981	Coho smolts and spring chinook smolts	6	0-2280	2	Coho: 8-10 Chinook: 5	7.6-9.4	Coho: 113.8 Chinook: 198.8	Coho: 16.1 Chinook: 92.2	Coho: 1.095 Chinook: 1.274	Cowlitz Salmon Hatchery
3/30- 4/03/1981	Coho smolts and spring chinook smolts	6	0-4104	2	Coho: 10-15 Chinook: 5	6.6-8.7	Coho: 117.2 Chinook: 203.6	*	*	Cowlitz Salmon Hatchery
4/13-4/17/1981	Coho smolts	7	19-1120	1-2 (1)	14-15	9.1-11.4	121.6	*	*	Cowlitz Salmon Hatchery
4/27- 5/01/1981	Coho smolts	6	1-951	1-3 (2)	12-15	10.2-14.3	125.9	*	*	Cowlitz Salmon Hatchery
5/11- 5/15/1981	Coho smolts	7	3-1458	1-6 (3)	14-17	10.5-15.4	126.8	18.9	0.919	Cowlitz Salmon Hatchery
6/27- 7/01/1981	Fall chinook smolts	6	10-1129	2-7 (2)	20-25	12.9-19.4	76.6	4.0	0.931	Cowlitz Salmon Hatchery
7/12- 7/16/1981	Coho presmolts	6	8-2700	2-5 (2)	24-26	13.3-20.5	58.9	*	*	Cowlitz Salmon Hatchery

* Weights were not taken during this bioassay, and therefore condition factors could not be calculated.

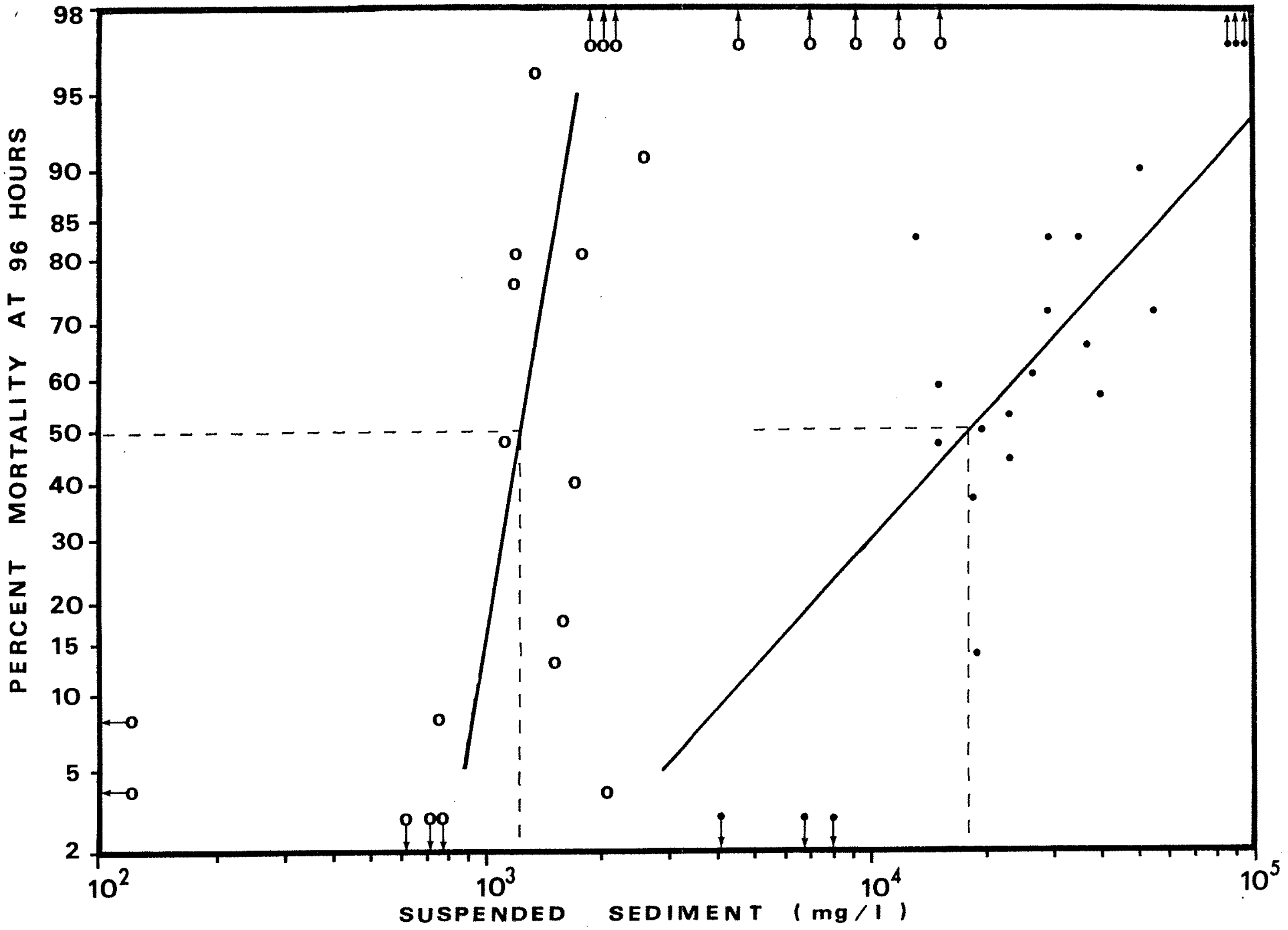

Fig. 22. Plots of 1980 instream live-box (O) and static laboratory (●) bioassays on presmolt coho salmon, indicating LC50 values (1217 and 18672 mg/1, respectively). (Instream live-box curve by probit analysis, static laboratory curve is eyefit).

Mortality was greater than 90 percent in the Toutle River during the summer following the eruption where suspended sediment concentrations ranged well above 2,500 mg/l. Mortality was less than 10 percent at the unaffected and control sites with suspended sediment less than 500 mg/l. Tests on coho presmolts in July 1981 did not result in sufficient partial mortalities to calculate an LC50 due to the natural reduction in the suspended sediment concentrations which did not exceed 2,700 mg/l.

The sensitivity of coho smolts increased in the spring of 1981. A 96-hr LC50 of 509 mg/l was determined from combined tests (Fig. 23). The suspended sediment concentrations had declined from the preceding summer and fall and did not exceed 4,104 mg/l during the live-box tests. Partial mortalities only occurred at the Toutle River sites and were infrequent. No mortalities occurred in the lower Cowlitz River. The increase in sensitivity of the coho smolts may indicate that the smolt stage is less tolerant to suspended sediment. Tests of fall chinook salmon smolts in 1981 resulted in a 96-hr LC50 of 488 mg/l (Fig. 24). The line was eyefit due to the clustering of these data below 50 percent. The smolt stage of this species was least tolerant in live-box testing. Live-box testing of spring chinook salmon was conducted during March 1981; however, due to the great difficulty in handling this species no useful tolerance data were obtained.

Adult Coho

One adult coho mortality occurred during the October 1-9, 1980 live-box test after four days exposure and another died after six days in the Cowlitz River at Kelso (Station 7W). Two remaining fish died on the eighth day. The suspended sediment concentrations averaged about 1,600 mg/l. The last individuals

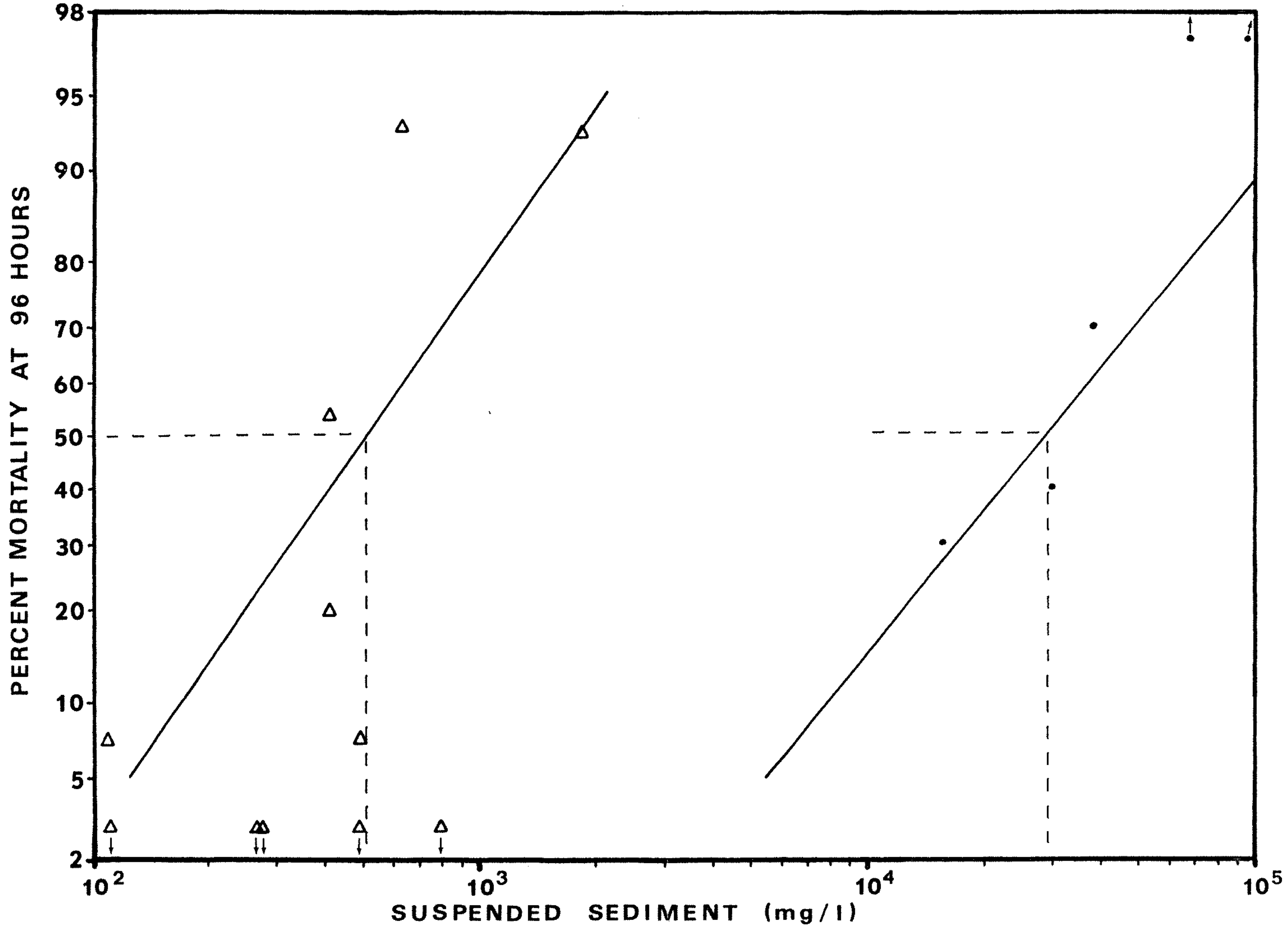

Fig. 23. Log-probit (percent) plots of 96 hr LC50 values for instream live-box (Δ) [509 mg/1] and static (●) [28,184 mg/1] laboratory bioassays in volcanic ash with coho salmon smolts.

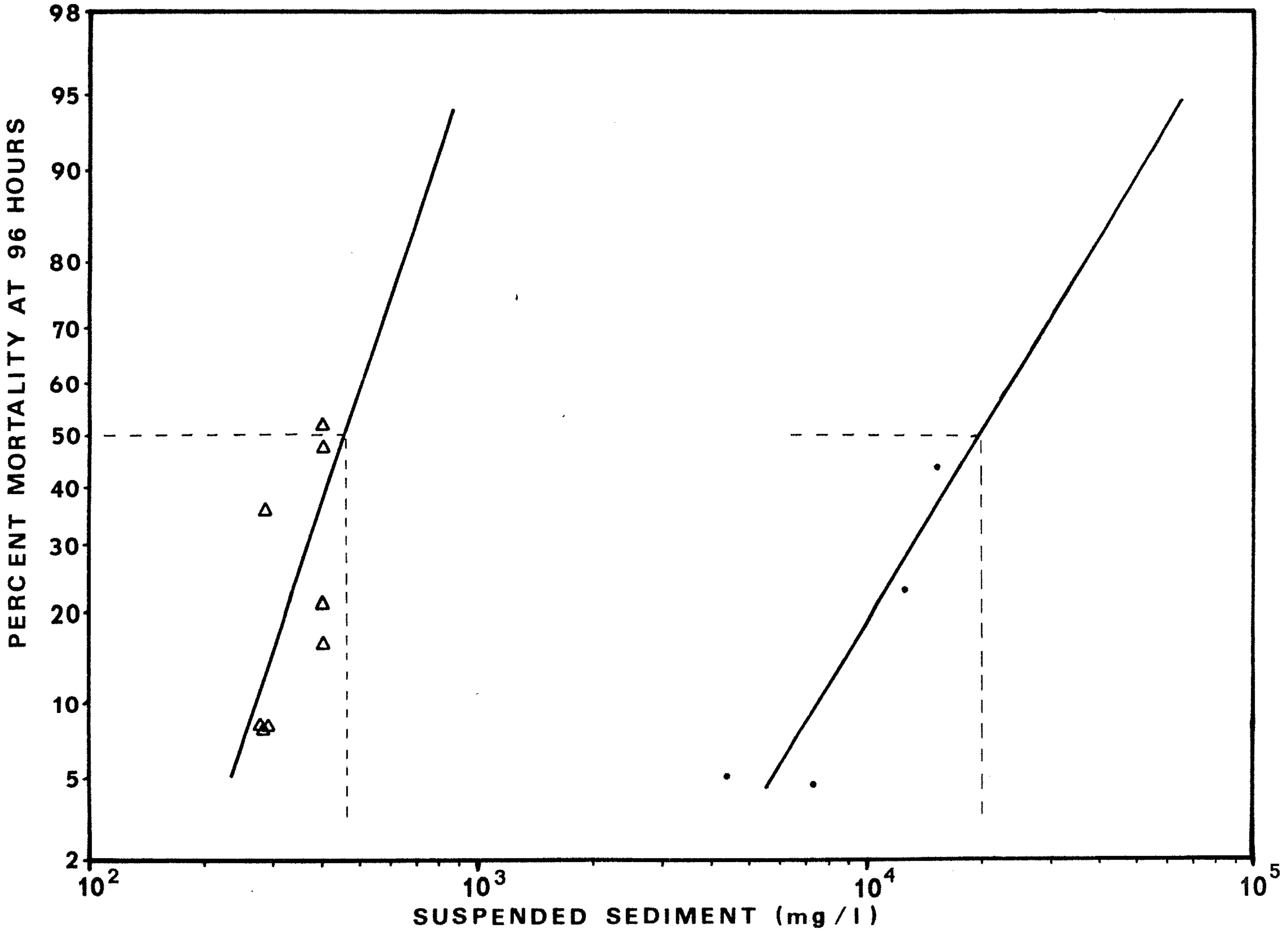

Fig. 24. Plot of 96-hr LC50 values for live-box bioassays (△) [488 mg/l] and static laboratory bioassays (•) [19,364 mg/l] in volcanic ash with fall chinook salmon smolts. (Live-box curve is eyefit, static laboratory curve is by probit analysis).

showed evidence of scale loss and abrasion from battering the sides of the live box. In the October 21-31 bioassay with four adult coho salmon, two chinook (jacks) and two steelhead, one ripe coho female died on the second day and another succumbed after the ninth day. Suspended sediment concentrations averaged 1,429 mg/l. Control fish did not die in either experiment. Bioassays of adult fish indicated a somewhat higher tolerance to suspended sediment; however, due to the difficulties of testing large maturing fish, an LC50 could not be determined.

Observations made on adult chinook and coho salmon in the field indicated a variety of responses. Some adult salmon may have avoided the affected rivers and migrated to hatcheries on adjacent streams. Based on 48 tag returns of marked 1976 and 1977 brood chinook from the Toutle hatchery, 38, 56 and 6 percent returned to the Cowlitz, Kalama and Lewis Rivers, respectively. The percentage for the Cowlitz was altered by a special terminal fishery in the lower Cowlitz River during 1980. Returns of 145 1977-brood coho salmon tagged at the Toutle hatchery returned to the upper Cowlitz (85 percent), Kalama (4 percent), Lewis (5.5 percent) and Toutle (5.5 percent) Rivers. Some straying of the Toutle River salmon may have occurred; however, the actual amount is unknown because the normal pre-eruption straying is unknown.

Returning adult salmon were found dead in the lower Cowlitz River during fall 1980. These individuals presumably could not tolerate the suspended sediment concentrations encountered in the lower Cowlitz River and did not elect to avoid the high suspended sediment concentrations encountered. Small numbers of both live and dead coho and chinook adults were observed in the north and south forks of the Toutle River. Natural production from any fish which did spawn in the Toutle River was very unlikely; most individuals observed had died unspawned, while some reached unaffected tributaries and spawned successfully.

Static Bioassays

The 96-hr static bioassays conducted in the laboratory on pre-smolt coho salmon in 1980 are summarized in Table 12. The combined 96-hr LC50 was 18,672 mg/l (Fig. 22). The static laboratory curve combines only the last three bioassays of volcanic ash because low dissolved oxygen concentrations confounded the first three tests. Due to the clustering of the data the curve was eyefit to approximate the LC50. The static bioassays indicated an LC50 concentration nearly 15 times higher than the live-box bioassays. A test conducted on south fork Toutle River mudflow silt did not result in sufficient partial mortality to determine an LC50.

The 96-hr static bioassays conducted in 1981 on coho and fall chinook salmon smolts are summarized in Table 13. The 96-hr LC50 for coho smolts in volcanic ash was 28,184 mg/l (Fig. 23). The great increase in tolerance observed in laboratory tests suggests coho smolts are as tolerant as other species and stages. A similar test in mudflow sediment resulted in a 96-hr LC50 of 29,580 mg/l (Fig. 25). Combined tests of coho salmon smolts in "Volclay 200" bentonite resulted in a 96-hr LC50 of 2,118 mg/l (Fig. 25). The low tolerance to bentonite was confounded by the high concentrations of trace metals leached from this material and therefore it was not an acceptable control sediment for comparison to volcanic sediments.

Three bioassays of fall chinook salmon were conducted in volcanic ash (Table 13). LC50's were determined in the first two tests but the third had

Table 12. Static 96-hr laboratory bioassays on presmolt coho salmon in 1980.

Dates	Sediment type	No. of tanks (concentrations)	Concentration range (mg/l)	No. of fish/tank	Loading density (g/l)	Mean temp. (°C)	LC50's				Fish information (averages)			
							24-hr	48-hr	72-hr	96-hr	Length (mm)	Weight (g)	Condition factor	Hatchery source
8/28- 9/01	Volcanic ash	8	0-38648	7-10	1.2-1.7	15.05	**				87.50	7.56	1.190	Minter Creek
9/02- 9/06	Volcanic ash	9	0-54197	19-21	1.1-1.3	14.53	**				65.03	2.69	1.053	Lewis River
9/23- 9/27	Volcanic ash	12	0-45142*	14-17	1.2-1.4	12.03	**				70.52	3.70	1.049	Lewis River
9/30-10/03	Volcanic ash	12	0-49588	17-20	1.5-1.8	12.41	***				72.61	4.00	1.165	Lewis River
10/23-10/27	Volcanic ash	5	0-23706	16-20	1.9-2.4	11.25	21528	17989	17989	17418	78.23	5.33	1.140	Lewis River
10/23-10/27	South Fork Toutle River mudflow silt	5	0-84239	16-20			***							
11/04-11/08	Volcanic ash	16	0-177800	17-19	2.5-2.8	13.00	***				83.47	6.54	1.060	Lewis River
							Bioassays 4-6 combined ****							
							***	19109	17023	18672				

* mg/l concentration by linear regression analysis of settleable matter on sediment weight.

** These bioassays suffered high control mortalities, so no LC50's were computed.

*** No LC50's could be computed for this bioassay.

**** These LC50 values calculated by linear regression analysis of the partial mortality points.

Table 13. Static 96-hr laboratory bioassays on coho and fall chinook salmon smolts in 1981.

								LC50's (mg/l)				Fish information (std. dev.)				
Species	Sediment type	Dates tested	No. of tanks (concentrations)	Concentration range (mg/l)	No. of fish/tank	Loading density (g/l)	Mean temp. °C (range)	24 hr	48 hr	72 hr	96 hr	Length (mm)	Ave. wt. (g)	Condition[1] factor	Smolt stage	Hatchery source
Coho	Bentonite	4/16-20	4	0-5338	10	4.1	13.0 (11.1-14.4)	3750	2642	*	*	115.92 (8.8359)	18.4	.986 (.0389)	2.855 (.6153)	Minter Cr.
Coho	Bentonite	4/20-24	4	0-3621	10	3.4	13.8 (9.7-15.4)	*	*	*	*	114.87 (6.8647	15.4	.991 (.0595)	2.909 (.7093)	Minter Cr.
Coho	Bentonite	5/4-8	4	0-4273	10	5.2	13.0 (10.2-16.5)	*	*	*	*	125.74 (9.8047)	23.5	.984 (.0528)	3.122 (.8071)	Skykomish
Coho	Bentonite	5/18-22	4	0-3722	10	6.4	13.5 (12.2-15.4)	*	*	*	*	130.72 (12.6855)	28.6	1.041 (.0533)	3.087 (.6263)	Skykomish
Coho	Bentonite	5/25-29	3	0-2075	10	5.2	15.6 (13.0-16.8)	*	*	*	*	130.00 (8.9007)	23.6	.981 (.0355)	3.225 (.5109)	Skykomish
								All 5 bentonite bioassays combined: (fiducial limits)								
								2642 (1977-3570)	2460 (1312-4876)	2193 (1376-3602)	2118 (1401-3280)					
Coho	Mudflow	6/1-5	6	0-47665	10	5.7	13.6 (11.3-17.2)	33884	31550	30549	29580	132.38 (7.3533)	21.6	.981 (.0355)*	3.225† (.5109)	Skykomish
Coho	Volcanic ash	6/5-9	6	0-119499	10	4.8	13.9 (13.3-16.1)	28379	28510	28314	28184	137.30 (6.3171)	25.9	.898 (.0586)*	3.225† (.5109)	Skykomish
Fall chinook	Volcanic ash	6/15-19	9	0-68138	20-22	1.3-1.4	15.0 (12.8-15.6)	16982	62661	16672	16558	70.13 (9.2184)	3.0	.898 (.0586)	2.575 (.8439)	George Adams
Fall chinook	Volcanic ash	6/29-7/3	5	0-14999	19-23	1.5-1.8	13.3 (12.2-16.1)	23878	21928	21928	19364	72.35 (13.4525)	3.6	.875 (.1747)	2.911 (.7306)	George Adams
Fall chinook	Volcanic ash	7/7-11	6	0-22662	20-21	2.0-2.1	12.8 (11.1-14.4)	*	*	*	*	80.39 (8.8379)	4.6	.992 (.0524)	3.581 (.8517)	George Adams
Fall chinook	Mudflow	6/22-26	8	0-67939	19-23	1.3-1.6	14.7 (12.2-16.1)	11298	66834	134,896	28708	75.61 (8.4264)	3.15	.891 (.0886)	3.217 (.8409)	George Adams

* A separate LC50 could not be calculated for this period.

[1] Condition factor at beginning of test.

insufficient mortality to calculate an LC50. The 96-hr LC50's were 16,558 and 19,364 mg/l in volcanic ash. The difference may have been due to insufficient feeding of the test fish in the first test. This condition did not persist into the second test, and the latter LC50 is considered most accurate, although based on fewer partial mortalities. The data for the second test are plotted in Figure 24. A substantial increase in tolerance to suspended volcanic ash was apparent in the static laboratory tests. The difference in tolerance to suspended sediment between live-box and static testing was consistent in all bioassays of volcanic ash and mudflow. Fall chinook salmon smolts were tested in mudflow sediment. The 96-hr LC50 was approximately 11,000 mg/l (Fig. 25).

The lower tolerance in live-box tests than found in static tests was consistent with each life stage and species. The increased sensitivity of coho smolts in live-box tests may have been an artifact resulting from the use of Cowlitz hatchery stock because the tolerance in static tests increased from the presmolt testing of coho salmon. The coho smolts utilized in the static tests were obtained from the Skykomish hatchery. More than an order of magnitude difference remained between live-box and static tests in volcanic ash. Little substantial change was evident between suspended sediment type and species or smolt stage except for the test in bentonite which was confounded by toxic concentrations of leached trace materials (Table 13).

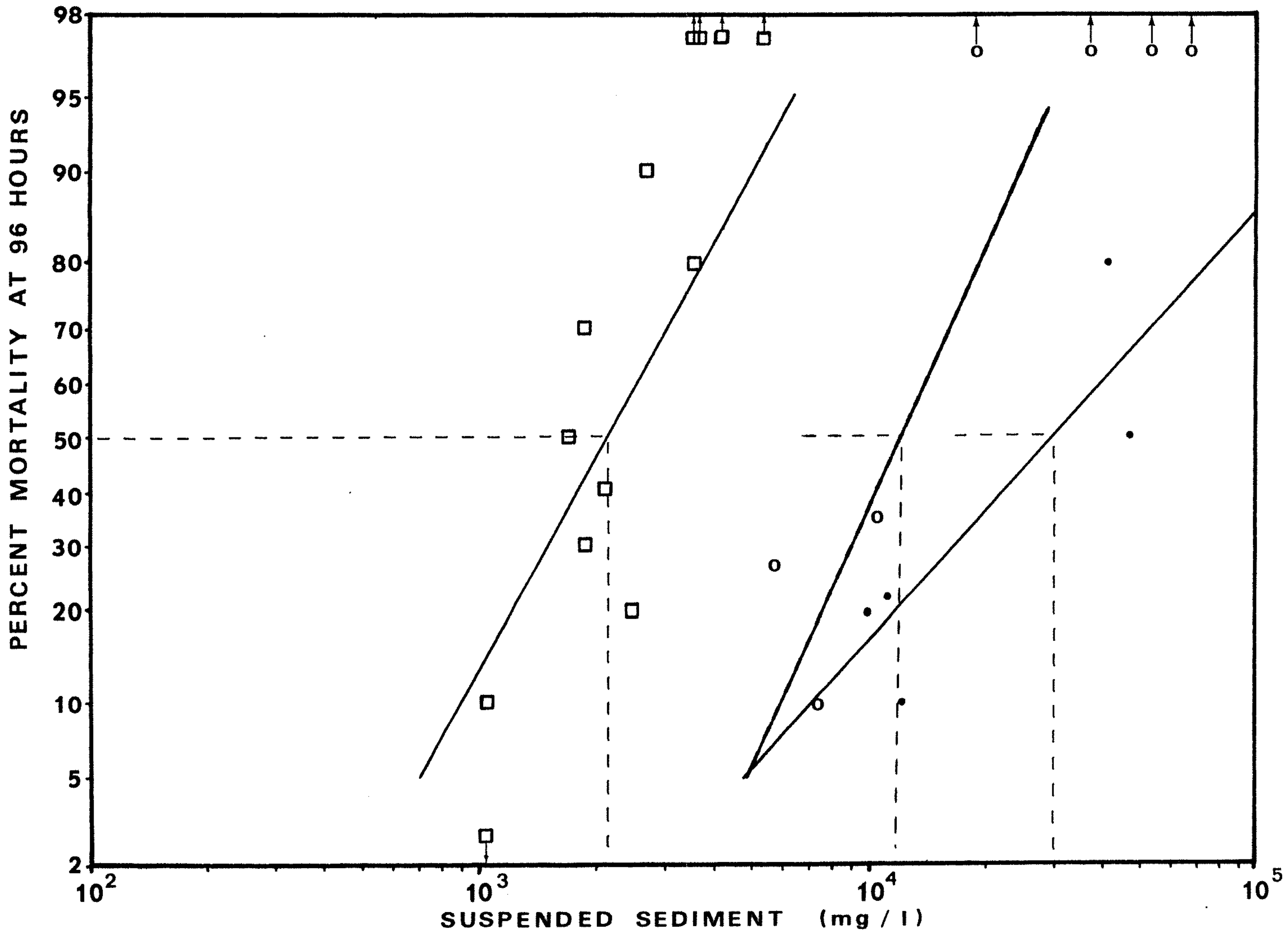

Fig. 25. Log-probit (percent) plots of 96-hr LC50 values for laboratory static bioassays in "Volclay 200" (TM) bentonite (□) [2118 mg/l], mudflow sediment (•) [29,580 mg/l] with coho salmon smolts and eyefit plot of static bioassay of mudflow sediment [11,000 mg/l] with fall chinook salmon smolts (○).

Gill Histology

Live-Box Tests

No significant difference in gill condition between fish in affected vs. unaffected rivers was observed for presmolt coho or coho, fall and spring chinook salmon smolts. Analysis of gills taken from live fish at various time intervals reflected only minor abnormal conditions (Table 14). Abnormalities were mostly limited to mild hypertrophy, inflammation, parasites, and vascular aneurysms. Two isolated cases of epithelial hydropic degeneration were observed in coho smolts (Cowlitz at Lexington and Main Toutle, 17 April 1981). Hemorrhage of gill tissue may have occurred in many instances, but whether or not this abnormality was an artifact of preservation was not determined.

Suspended sediment has previously been shown to directly damage gill tissue by causing inflammation (Eschner and Larmoyeux 1963). Herbert and Merkens (1961) found thickening and fusion of gill lamelli cells in a fish tested with 810 ppm diatomaceous earth after 16 days.

In this study, a positive correlation between gill damage and suspended sediment was expected. The absence of this relationship may be due to the short exposure time; however, Peddicord et al. (1975) found that mortality after four days was nearly the same as after ten days. Very little mortality occurred in this study during the final 24 hr of each 96-hr test. In most instances the control fish gills were characterized by the same abnormalities as those of fish in affected streams. This may indicate that the fish were in an unhealthly condition at the onset of the experiment or were adversely affected by the handling involved in selection and transport of test animals to the site. It should be emphasized that all abnormalities in gill structure were minor.

Table 14. Histological effects of suspended sediment on gill tissue of presmolt and smolt coho salmon and spring and fall chinook salmon smolts exposed in live boxes in the Toutle and Cowlitz Rivers during 1980 and 1981.

Species	Location	Date	Hour	Mean suspended sediment (mg/1)	Comments*
Coho yearlings 1980					
	Cowlitz River at Kelso	12 Jul 80	96	629.00	HP
		26 Jul 80	96	981.26	HP (mild)
		16 Aug 80	96	1,200.36	HP
		16 Aug 80	96	1,200.36	NR; artifacts
		16 Aug 80	96	1,200.36	NR
	Cowlitz River at Castle Rock	12 Jul 80	96	88.20	NR
	North Fork Toutle River	13 Sep 80	96	1,539.43	NR
	South Fork Toutle River	22 Jul 80	<.5 hr	10,588.33	HP (mild); A
		22 Jul 80	<.5 hr	10,588.33	I; abundant particulate matter in gill lamelli
	North Fork Toutle River	13 Sep 80	96	1,539.43	NR
	Main Toutle River	22 Jul 80	0	5,236.38	HP (mild)
	Kalama Hatchery	11 Sep 80	—	18.48	NR
	Kalama River	26 Jul 80	96	21.76	NR
		16 Aug 80	96	14.90	NR
	Columbia River at Kalama	12 Jul 80	96		NR

Table 14. (Continued).

Species	Location	Date	Hour	Mean suspended sediment (mg/1)	Comments*
Coho smolts	Cowlitz River at Kelso	17 Mar 81	24	180.96	HP (mild); I
		19 Mar 81	72	180.96	HP (mild); A
		20 Mar 81	96	180.96	HP (mild); P; A; I
		20 Mar 81	96	180.96	HP (mild); P
		31 Mar 81	24	467.00	HP (mild)
		1 May 81	96	105.00	HP (mild); P; I
	Cowlitz River at Lexington	17 Apr 81	72	337.02	HP; HD; edema and separation
		28 Apr 81	24	272.74	HP (mild); H(?)
		29 Apr 81	48	272.74	HP; H(?)
		30 Apr 81	72	272.74	P; I
		1 May 81	96	272.74	HP (mild); H(?); I
	Green River	20 Mar 81	96	120.46	HP (mild)
		14 Mar 81	0	203.05	HP (mild)
		17 Apr 81	72	203.05	HP (mild)
		1 May 81	96	400.34	HP (mild)
		15 May 81	96	605.72	HP (mild); I
		17 Jul 81	96	617.66	HP (mild); A
	No. Fork Toutle	20 Mar 81	96	278.00	HP (mild)
		15 May 81	96	262.80	HP (mild); P; I
	So. Fork Toutle	15 May 81	96	85.48	HP (mild); edema; I
	Main Toutle	17 Apr 81	96	97.90	HP; HD; H(?)
	Cowlitz at I-5 (control)	16 Mar 81	0	109.88	HP; P; H(?); I
		20 Mar 81	96	109.88	HP (mild); A; I
		17 Apr 81	72	41.86	HP (mild); I
		27 Apr 81	0	8.64	HP; P; A; H(?); I
		30 Apr 81	72	8.64	HP (mild); A
		1 May 81	96	8.64	HP (mild); I
		11 May 81	96	35.80	HP (mild); A; H(?); I

Table 14. (Continued).

Species	Location	Date	Hour	Mean suspended sediment (mg/1)	Comments*
Spring chinook smolts	Cowlitz at Kelso	20 Mar 81	96	180.96	HP (mild); H(?)
		20 Mar 81	96	180.96	HP (mild); P
		20 Mar 81	96	180.96	HP (mild)
	Cowlitz at I-5 (control)	16 Mar 81	0	109.88	HP (mild); H(?)
		20 Mar 81	96	109.88	HP
		20 Mar 81	96	109.88	HP (mild); P
		3 Apr 81	0	5.00	HP (mild); P
		3 Apr 81	0	5.00	HP (mild); P
Fall chinook smolts	Green River	3 Jul 81	96	347.64	NR
	So. Fork Toutle	3 Jul 81	96	36.18	HP (mild)
	Cowlitz River at I-5 (control)	13 Jul 81	0	22.90	HP
		17 Jul 81	96	22.90	HP

* Key to comments

A = vascular aneurysms
H = hemorrhage
HD = epithelial hydropic degeneration
HP = epithelial hypertrophy
I = inflammation
NR = unremarkable — no gross lesions
P = parasites

The conditions other than remarkable described in this column reflect only <u>minor</u> changes for the most part — <u>not gross lesions</u>.

Static Tests

The results of histological analysis of gill tissues taken from coho salmon presmolts used in static 96-hr LC50 testing during 1980 are summarized in Table 15. Histological damage to exposed fish was minimal and appeared to be no different from the control.

The results of histological analysis of gill tissues taken from fish used in static 96-hr LC50 testing during 1981 are summarized in Table 16. In most cases, damage to control samples was comparable to that seen in fish exposed to suspended sediments, indicating that, in the absence of high water velocities, gill damage is mild even at very high sediment concentrations. Exceptions include the tissues from coho smolts tested in volcanic ash at 119,499 mg/l (the highest level tested), and in mudflow sediment at 40,084 mg/l. Both showed more intensive effects than almost any other tissue samples. The ash-exposed fish had been exposed for one hour when found dead. Histological analysis of gill tissue taken from dead specimens is as likely to produce artifacts as actual sediment effects. The mudflow-exposed fish were survivors of 96-hr exposure, so the interpretation of damages to these tissues is not confounded by the possibility of post-mortem degeneration.

Fall chinook smolts in volcanic ash showing the worst histological damage were control fish. This appears to have been the result of multiple parasites in the gills, but it underlies the fact that the effects noted on exposed fish were very minor.

Table 15. Histological effects of volcanic ash on coho presmolts in 96-hr static bioassays in 1980.

Test date (average concentration)	Control/ exposed	Hours	D	HPL	HP	HD	P	A	H	C	VC	NR
Sept. 2-6, 1980 (15,937 mg/1)	Exposed	96	+		+	+	+					
Sept. 2-6, 1980 (262 mg/1)	Exposed	96					+		?			
Sept. 2-6, 1980 (22,128 mg/1)	Exposed	96	+		+	+		+				
Sept. 2-6, 1980 (475 mg/1)	Exposed	96			+	+					+	
Sept. 2-6, 1980 (10 mg/1)	Control	96	+		+	+						
Sept. 2-6, 1980 (19,903 mg/1)	Exposed	96										+
Sept. 2-6, 1980 (30,874 mg/1)	Exposed	96			+	+						

Where:

D = debris in interlamellar space

HPL = epithelial hyperplasia

HP = epithelial hypertrophy

HD = epithelial hydropic degeneration

P = parasites

A = vascular aneurysms

H = hemorrhage

C = changes in chloride cell size or number

VC = vascular congestion

NR = unremarkable, no visible lesions

Table 16. Histological effects of suspended sediments on gill tissue of coho salmon and fall chinook smolts exposed in static (no-velocity) 96-hr LC50 bioassays during 1981.

Sediment type	Species	Test dates	Average concentration (mg/l)	Control/ exposed	Hours	D	HPL	HP	HD	P	A	H	C	VC	NR	Comments
"Volclay 200" bentonite	Coho	4/16-20	2,321	Exposed	39[1]			+ (mild)								
		5/4-8	3,557	Exposed	39[1]			+ (focal)								
			3,574	Exposed	96			+	+			?				
		5/18-22	1,809	Exposed	48			+ (mild)	+							
			0	Control	96			+	+							
			1,696	Exposed	96			+	+			?				
			2,749	Exposed	96			+	+							
		5/25-29	1,877	Exposed	96							?			+	
			0	Control	96		?	+	+			?				
			1,857	Exposed	96		?	+	+			?				
Volcanic ash	Coho	6/5-9	0	Control	96		+ (focal)									Focal inflammation
			37,505	Exposed	96										+	
			29,101	Exposed	24	+										Some artifact
			119,499	Exposed	1		+ (focal)									Mult. inflammation[2]
			119,499	Exposed	1		+ (extensive)									Inflammation, necrosis[2]
Mudflow sediment	Coho	6/1-5	0	Control	95		+ (focal)	+ (mild)								Inflammation
			11,493	Exposed	12[1]	++	+ (focal)									Inflammation
			40,084	Exposed	95	+	+ (focal)	+ (mild)		+						Inflammation[2]
			46,788	Exposed	95	+	+ (focal)									Inflammation
Volcanic ash	Fall chinook	6/15-20	0	Control[2]	96		+ (focal)			+ (mult.)						2
			10,027	Exposed	96		+ (mild)									
			14,464	Exposed	96		+ (focal)									Focal inflammation
			8,801	Exposed	96											Focal inflammation
			15,370	Exposed	96										+	
Mudflow sediment	Fall chinook	6/22-27	0	Control	96		+ (mild, focal)									
			10,703	Exposed	96		+ (mild)									

D = debris in interlamellar spaces
HPL = epithelial hyperplasia
HP = epithelial hypertrophy
HD = epithelial hydropic degeneration
P = parasites

A = vascular aneurysm
H = hemorrhage
C = changes in chloride cell size or number
VC = vascular congestion
NR = unremarkable, no visible lesions

[1] Moribund when sampled.

[2] Much more major effects on this sample than on most.

Artificial Stream Exposure Tests

Coho Smolts in Volcanic Ash

Coho smolts were exposed to sublethal concentrations of volcanic ash in March and again in May 1981. During each month, three directly related exposure combinations of suspended sediment ranging from 0 to 16 percent of the static 96-hr LC50 concentration and water velocity were tested. Table 17 summarizes the test conditions for each exposure. Concentrations of ash averaging as high as 4,515 mg/l produced no appreciable direct mortality, even in combination with water velocities of up to an average of 1.5 fish lengths/second.

Swimming performance profiles for coho salmon smolts tested in volcanic ash during March after 24 and 72-hr exposures at sublethal concentrations of 647, 2,174 and 3,775 mg/l are presented in Figures 26, 27 and 28, respectively. No statistically significant differences were found between exposed and control fish at 24 and 72 hr. Swimming performance profiles for coho salmon smolts tested during May after 24 and 72-hr exposures at sublethal concentrations of 757, 2,019 and 4,515 mg/l are presented in Figures 29, 30 and 31, respectively. Several differences were exhibited in swimming performance after exposure to both low and medium velocity-sediment combinations beginning on May 11 and 18, respectively. The slopes of the regression lines of tailbeats per minute vs swimming speed of both the control and the exposed fish were greater after 24 hr in the artificial streams than after 72 hr. The intercepts of both the control and the exposed fish were greater after 72 than after 24 hr. There were, however, no statistically significant differences between the control and exposed fish after 24 or 72 hr in either case. No statistically significant

Table 17. Artificial stream suspended sediment exposure of coho salmon smolts in volcanic ash.

	Dates tested					
	March 9-13, 1981		March 17-21, 1981		March 29 - April 2, 1981	
Stream	Test	Control	Test	Control	Test	Control
Actual sediment concentration (mg/l) (std. dev.)	647 (62)	13 (9)	2174 (335)	39 (22)	3775 (980)	0 (0)
95% confidence interval on mean concentration (mg/l)	524-770	0-31	1509-2839	0-83	1829-5721	–
% of LC50[1]	2.3	0	7.7	0	13.4	0
Average velocity (L/sec)	0.519	0.538	1.024	0.970	1.517	1.440
95% confidence interval on velocity (L/sec)	0.449-0.613	0.466-0.636	0.882-1.219	0.836-1.155	1.328-1.770	1.261-1.680
% mortality in stream	0	0	0	0	0.7	0
No. fish/stream	300		300		300	
Loading density (g/l)	2.0		2.3		2.2	
Fish information (std. dev.)						
Length (mm)	107.4 (8.278)		107.6 (8.652)		110.5 (7.872)	
Average weight (g)	12.77		14.28		13.72	
Condition factor[2]	1.009 (.0947)		1.009 (.0500)		.977 (.1118)	
Smolt stage[3]	2.342 (.9113)		2.300 (.8228)		2.306 (1.004)	
Hatchery source	Minter Creek		Minter Creek		Minter Creek	
Water quality						
Mean temperature (°C) (range)	14.4 (12.5-18.4)	16.0 (12.7-19.5)	16.0 (12.8-17.8)	14.4 (11.4-16.1)	12.9 (12.0-14.4)	12.5 (11.5-14.4)
pH	6.9	6.9	6.9	6.9	7.0	7.1
Mean dissolved oxygen (mg/l) (range)	8.95 (8.5-9.9)	8.76 (8.3-9.8)	9.6 (8.9-11.9)	9.8 (9.0-11.9)	9.3 (7.2-11.0)	9.2 (7.1-10.9)
Conductivity (μmhos/cm^2)	–	–	–	–	25	27
Saltwater LC50 (96 hr) (^{o}/oo)	*[4]	*	*	*	*	*

[1] 96 hr LC50 for coho smolts in volcanic ash = 28183.83 mg/l as determined from probit analysis of results from the static LC50 bioassay of June 5-9, 1981.

[2] Condition factor at beginning of test.

[3] Average smolt stage as determined by the visual methods of Prentice et al. (1981) where stage:
1 = full parr
2 = between parr and transitional
3 = transitional
4 = between transitional and smolt
5 = full smolt.

[4] No significant saltwater mortalities occurred within 96 hr in these tests.

Table 17. (Continued).

	Dates tested					
	May 11-15, 1981		May 18-22, 1981		May 25-29, 1981	
Stream	Test	Control	Test	Control	Test	Control
Actual sediment concentration (mg/l) (std. dev.)	757 (93)	40 (26)	2019 (28)	37 (49)	4515 (367)	36 (16)
95% confidence interval on mean concentration (mg/l)	572-942	0-92	1963-2075	0-135	3787-5243	4-68
% of LC50[1]	2.7	0	7.2	0	16.0	0
Average velocity (L/sec)	0.589	0.582	0.972	0.965	1.396	1.530
95% confidence interval on velocity (L/sec)	0.518-0.681	0.512-0.673	0.875-1.093	0.869-1.085	1.251-1.579	1.371-1.730
% mortality in stream	0	0	0	0	0	0
No. fish/stream	250		250		250	
Loading density (g/l)	2.7		3.0		2.8	
Fish information (std. dev.)						
Length (mm)	125.4 (8.500)		130.2 (7.199)		129.3 (7.475)	
Average weight (g)	20.35		23.08		21.39	
Condition factor[2]	1.016 (.0311)		1.041 (.0533)		.981 (.0355)	
Smolt stage[3]	2.958 (.6174)		3.273 (.5505)	2.917 (.6539)	3.391 (.6564)	3.077 (.2717)
Hatchery source	Skykomish		Skykomish		Skykomish	
Water quality						
Mean temperature (°C) (range)	15.2 (12.9-17.6)	12.9 (10.4-15.5)	15.2 (12.7-16.2)	13.0 (12.5-13.9)	16.4 (14.3-17.6)	14.7 (12.9-17.0)
pH	7.6	7.4	7.7	7.6	7.5	7.4
Mean dissolved oxygen (mg/l) (range)	9.9 (9.3-10.4)	9.8 (9.2-10.3)	10.0 (9.6-10.2)	10.0 (9.7-10/2)	10.0 (9.6-10.3)	9.9 (9.9-10.1)
Conductivity (μmhos/cm^2)	57	43	49	45	44	42
Saltwater LC50 (96 hr) (^{o}/oo)	*[4]	*	*	*	*	*

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[1] 96 hr LC50 for coho smolts in volcanic ash = 28183.83 mg/l as determined from probit analysis of results from the static LC50 bioassay of June 5-9, 1981.

[2] Condition factor at beginning of test.

[3] Average smolt stage as determined by the visual methods of Prentice et al. (1981) where stage:
1 = full parr
2 = between parr and transitional
3 = transitional
4 = between transitional and smolt
5 = full smolt.

[4] No significant saltwater mortalities occurred within 96 hr in these tests.

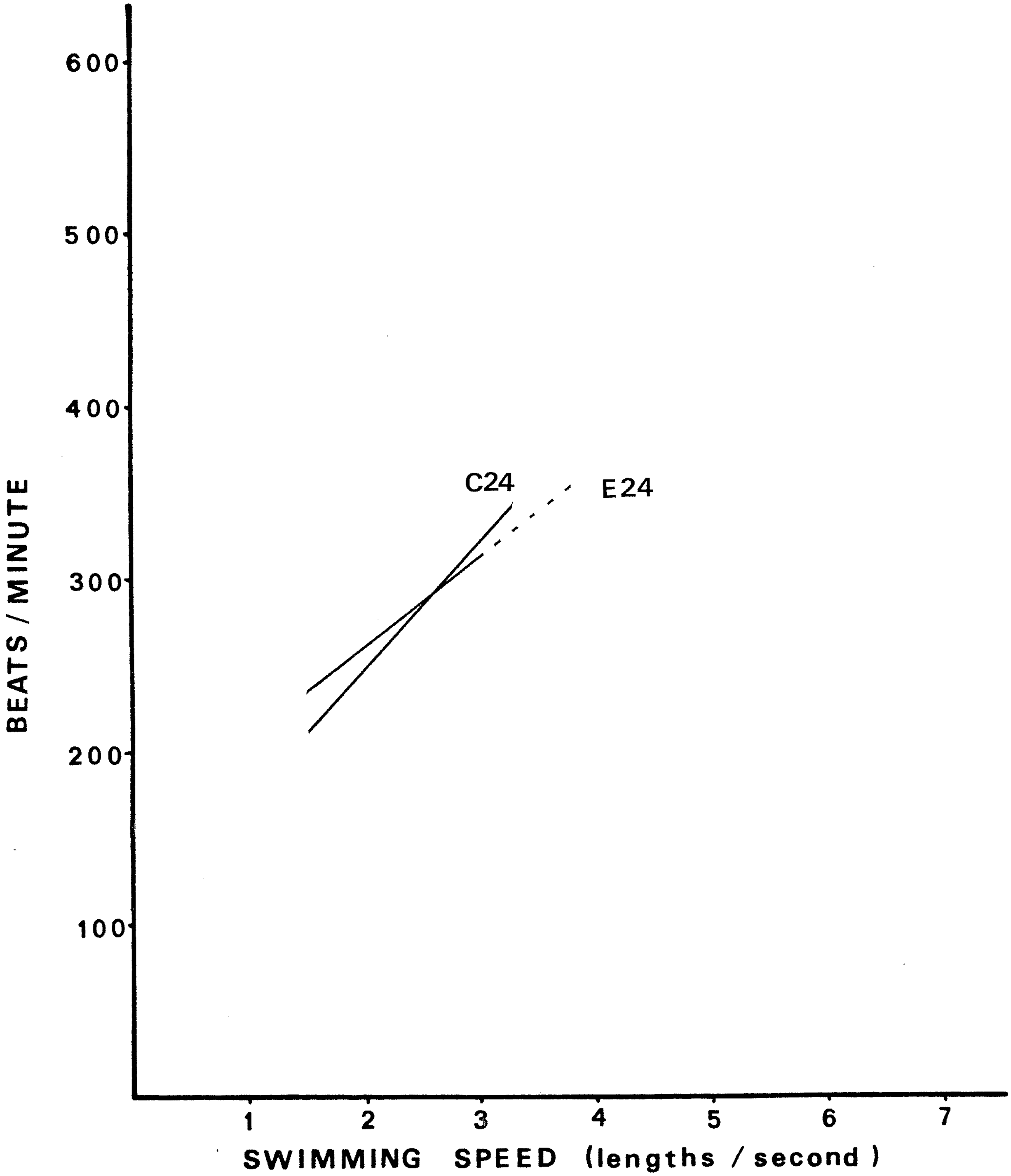

Fig. 26. Regression of swimming performance (tail beats/minute) on speed (lengths/second) for coho salmon smolts after 24-hr exposure to volcanic ash averaging 647 mg/l. (Test began 9 March 1981, C = control, E = exposed).

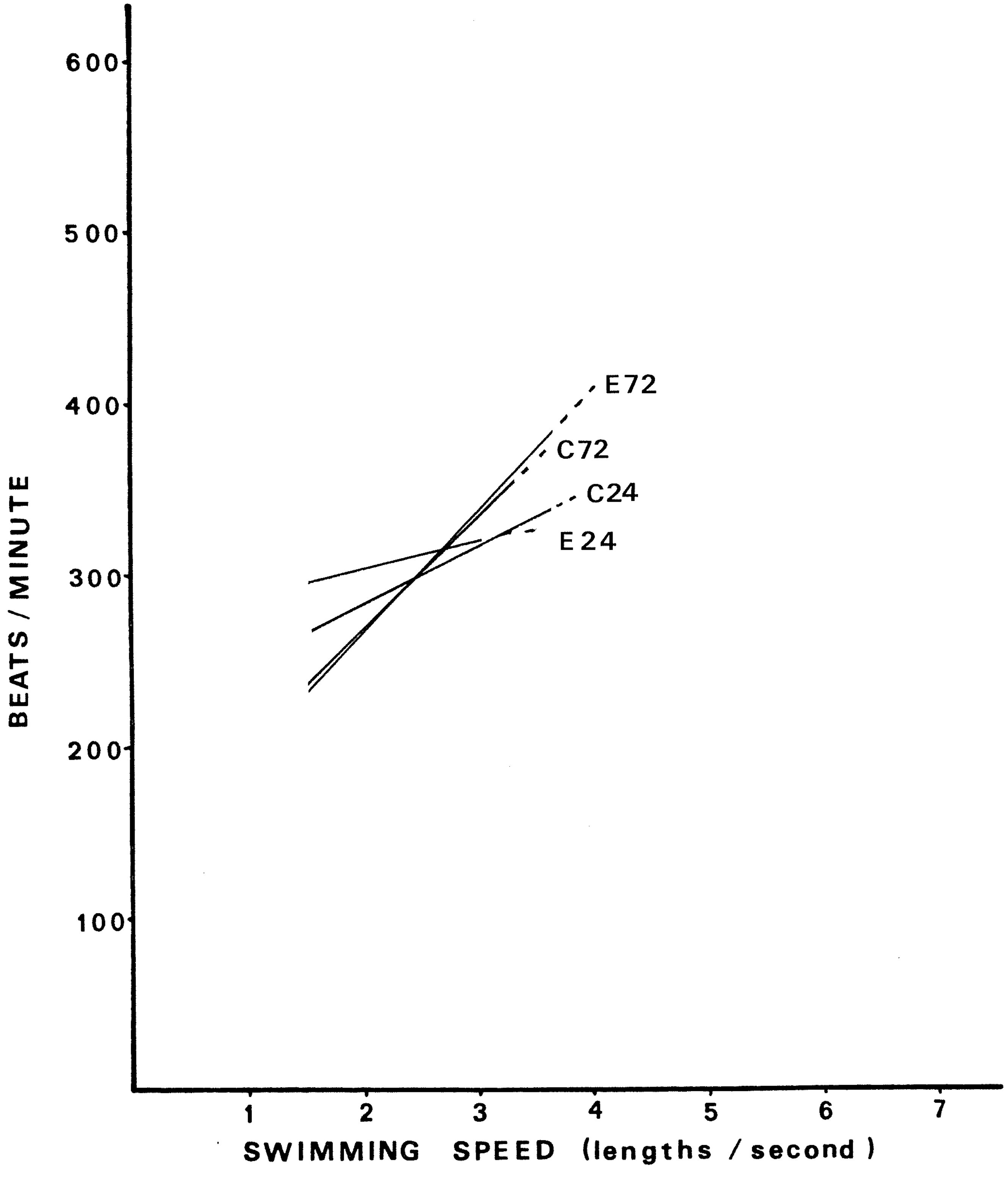

Fig. 27. Regression of swimming performance (tail beats/minute) on speed (lengths/second) for coho salmon smolts after 24 and 72 hr exposure to volcanic ash averaging 2,174 mg/l. (Test began 17 March 1981, C = control, E = exposed).

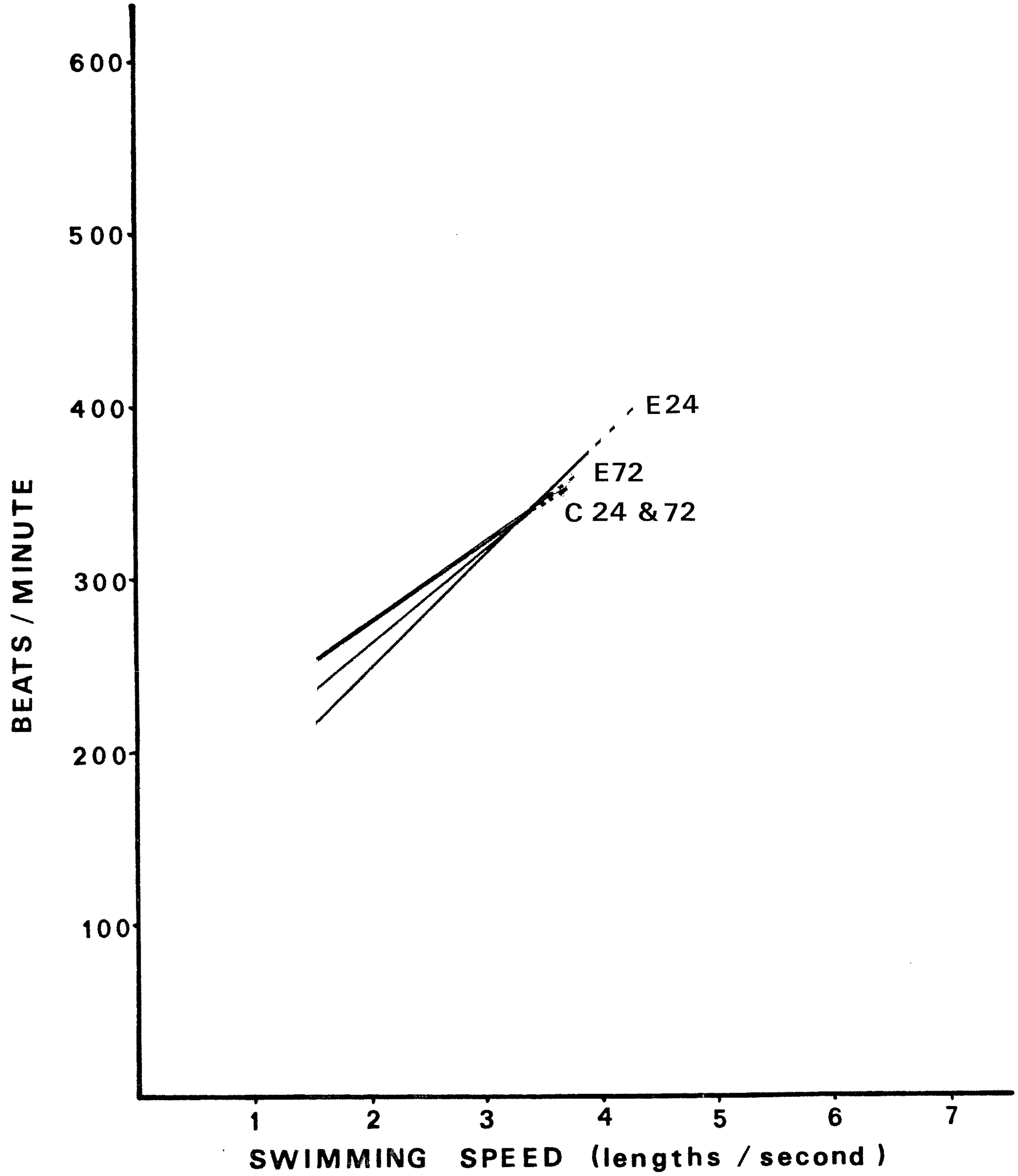

Fig. 28. Regression of swimming performance (tail beats/minute) on speed (lengths/second) for coho salmon smolts after 24 and 72 hr exposure to volcanic ash averaging 3,775 mg/l. (Test began 29 March 1981, C = control, E = exposed).

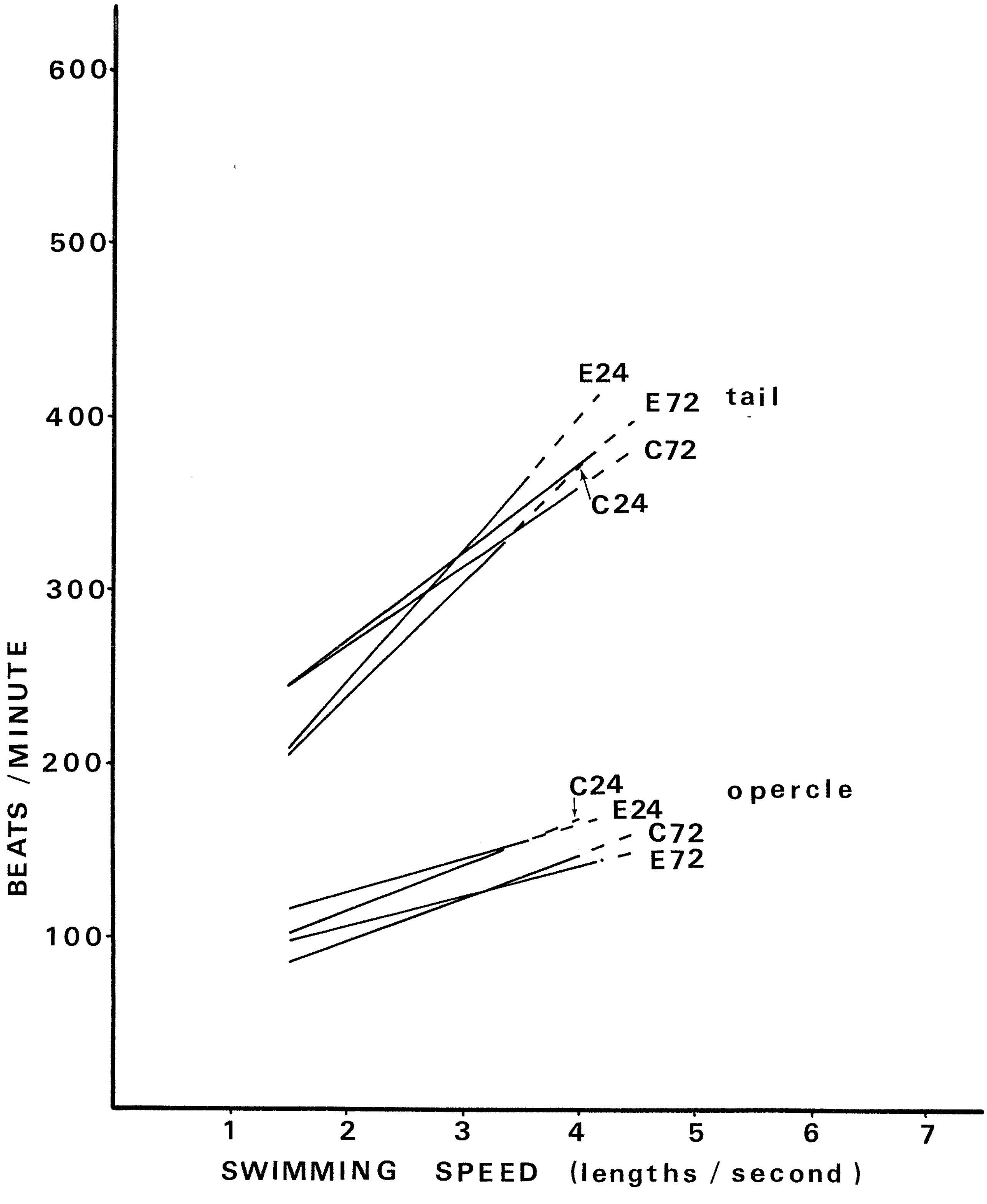

Fig. 29. Regression of swimming performance (tail and opercle beats/minute) on speed (lengths/second) for coho salmon smolts after 24 and 72 hr exposure to volcanic ash averaging 757 mg/l. Fatigue interval indicated by dashes. (Test began May 11, 1981, C = control, E = exposed).

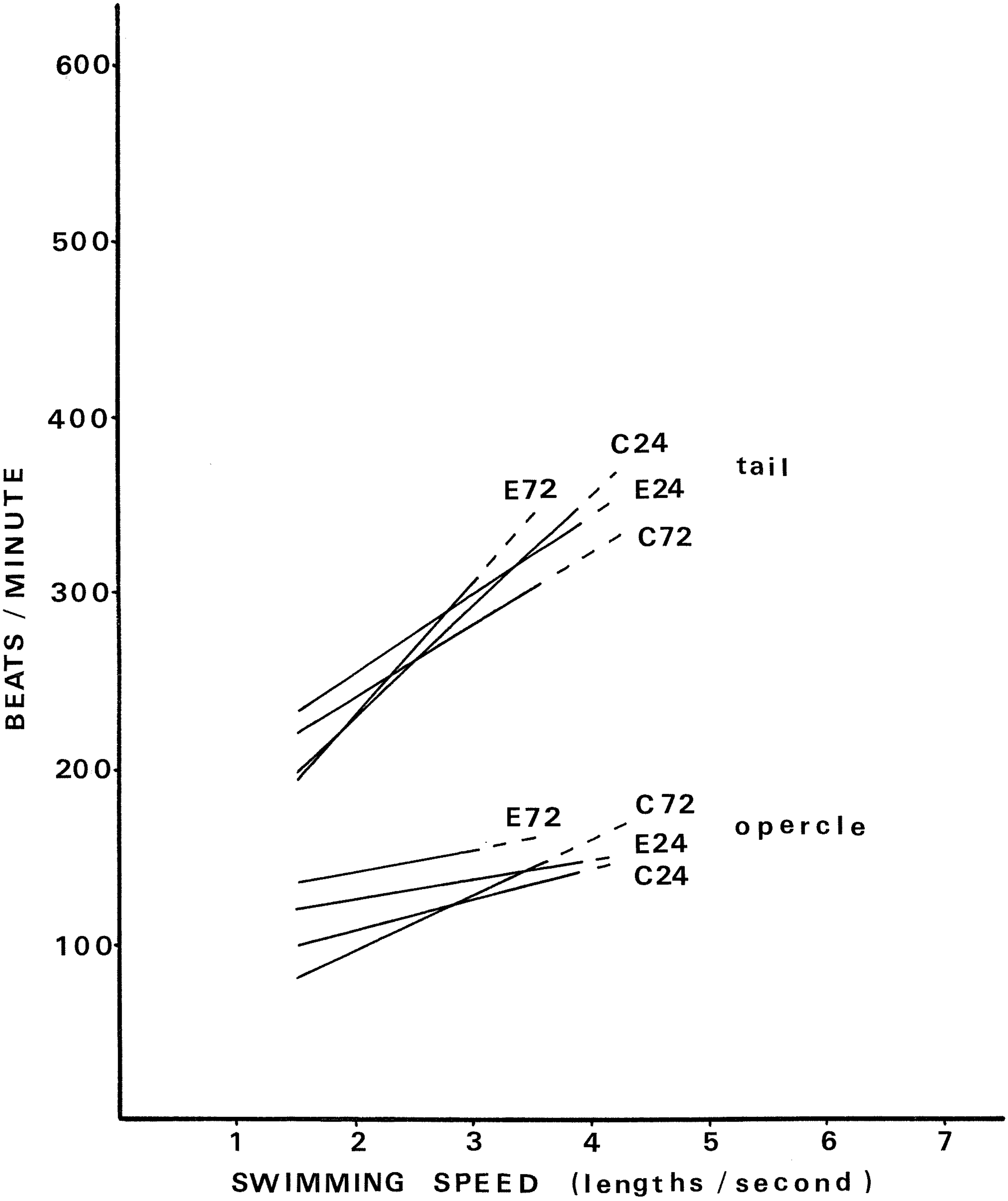

Fig. 30. Regression of swimming performance (tail and opercle beats/minute) on speed (lengths/second) for coho salmon smolts after 24 and 72 hr exposure to volcanic ash averaging 2019 mg/l. Fatigue interval indicated by dashes. (Test began May 18, 1981, C = control, E = exposed).

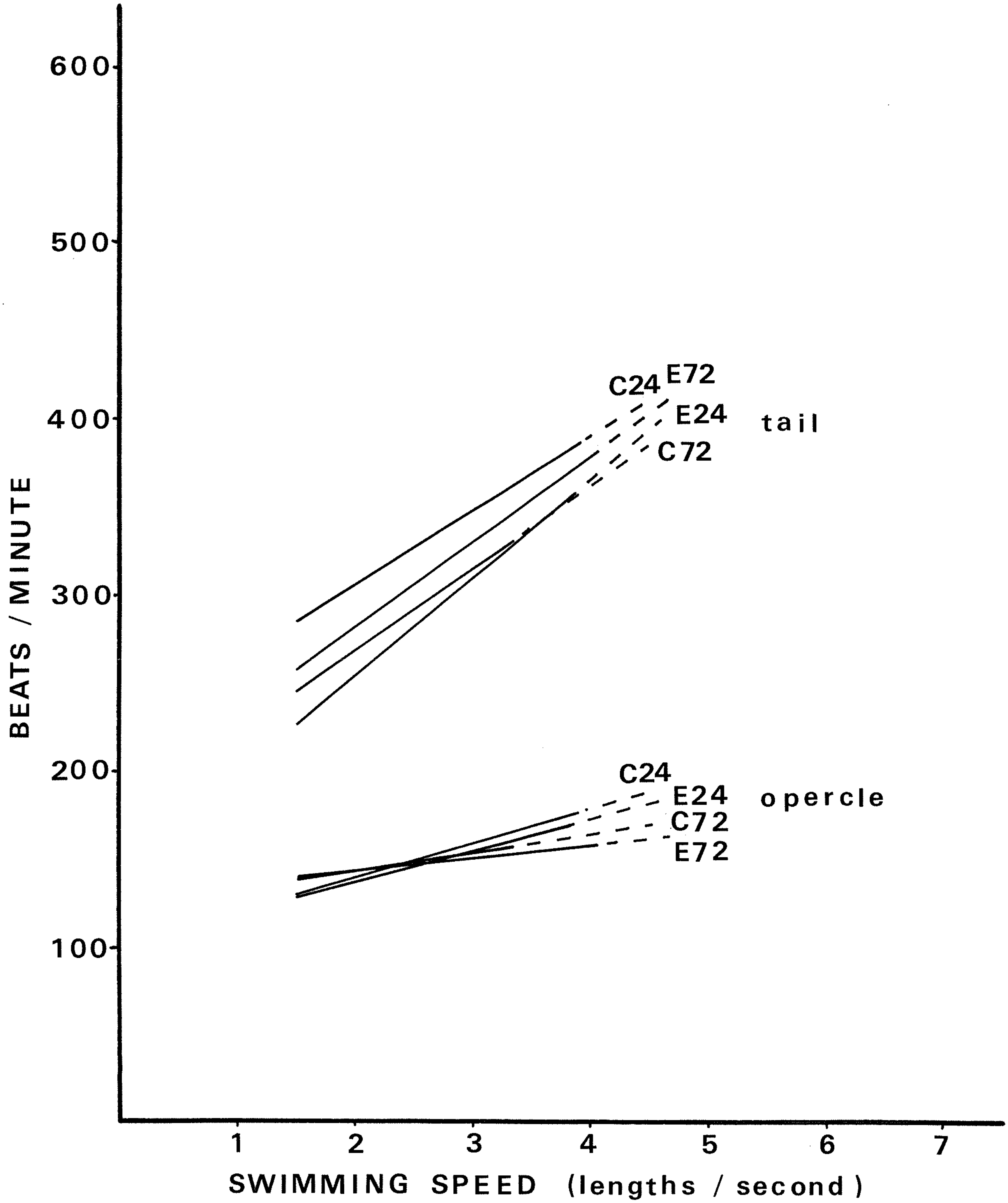

Fig. 31. Regression of swimming performance (tail and opercle beats/minute) on speed (lengths/second) for coho salmon smolts after 24 and 72 hr exposure to volcanic ash averaging 4515 mg/l. Fatigue interval indicated by dashes. (Test began May 25, 1981, C = control, E = exposed).

differences were found in swimming performance during the high velocity-sediment combination exposure which began on May 25. Exposures after 24 and 72 hr to volcanic ash averaging 757 mg/l at 0.5 lengths/second velocity, 2,019 mg/l at 1.0 lengths/second, and 4,515 mg/l at 1.5 lengths/second had no effect on the swimming performance of coho smolts.

An additional swimming performance test was conducted on coho salmon smolts exposed for 96 hr at 4,515 mg/l at 1.5 lengths/second on May 25-29 followed by 115 hr in sea water (27.3 ppt). The regression of swimming performance (Fig. 32) on tail beats per minute for sediment-exposed and control fish showed no statistically significant differences. Like the performance tests during the ash exposure of May 25-29, there were no statistical differences between control or exposed fish.

The results of the histological analyses of specimens from these tests are presented in Table 18. This table shows that essentially no more damage occurred during sediment exposure than was detected in the control fish. Histological changes found were minor, and the epithelial hypertrophy was probably an artifact of the osmolarity of the fixative or alcohol used, as it was seen in almost all of the nearly 200 specimens analyzed.

None of the six separate ash exposures in March and May caused any mortality to fish placed in salt water, either after a 48-hr acclimation period in fresh water as in March testing, or after being introduced directly into the seawater entry tests (Table 19) as was done in May, even after exposure to concentrations averaging as high as 4,515 mg/l. It is possible that delayed mortality may occur in salt water after many days, as has been reported with coho smolts (Mahnken et al. 1981). However, the lack of

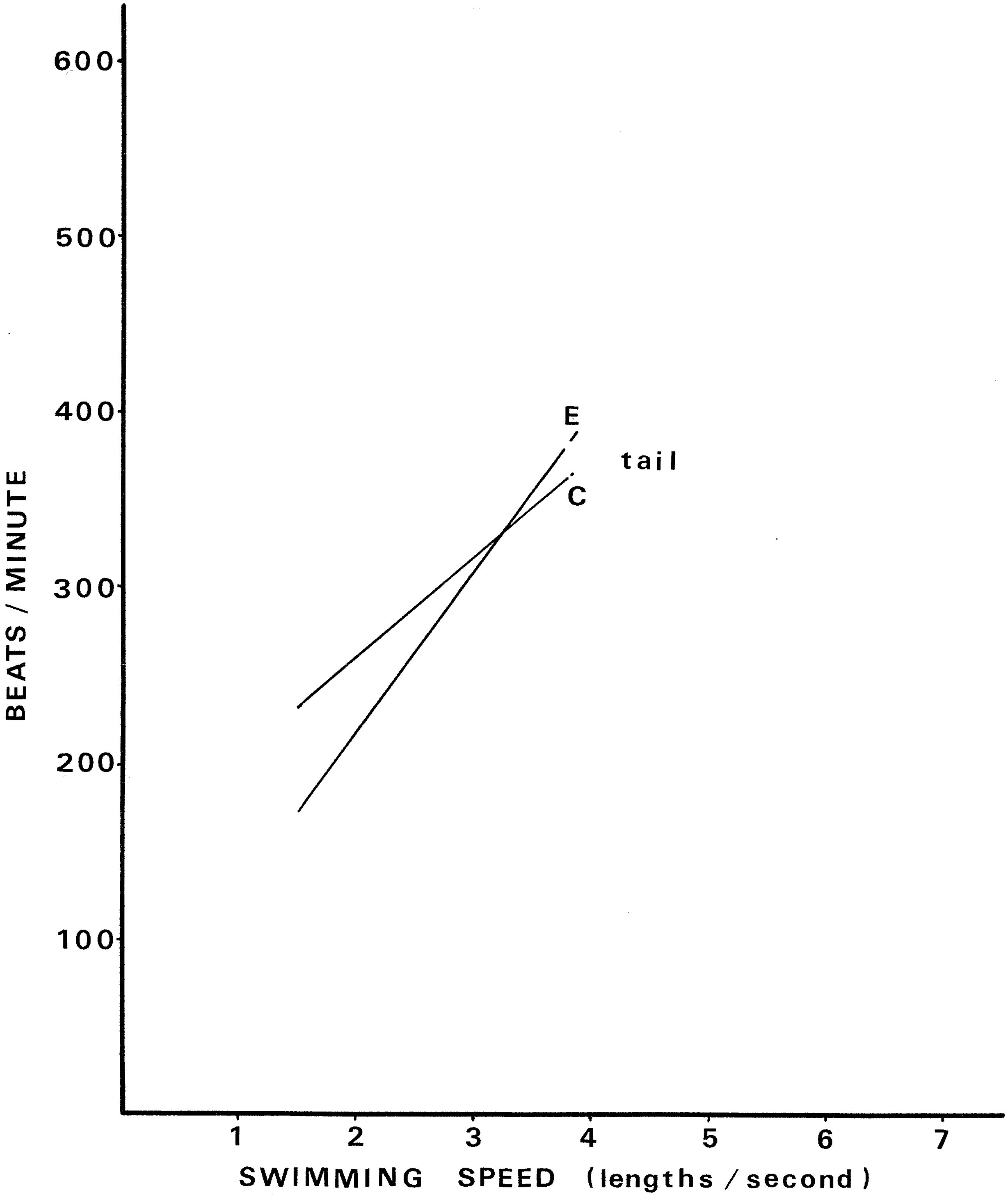

Fig. 32. Regression of swimming performance (tail beats/minute) on speed (lengths/second) for coho salmon smolts after 96 hr exposure to volcanic ash averaging 4515 mg/l followed by 115 hr exposure in seawater (26.3 ppt). Fatigue interval indicated by dashes. (Sediment exposure began May 25, 1981, C = control, E = exposed).

Table 18. Histological effects of volcanic ash on coho smolts as determined by Dr. Landolt.

Test date (average concentration)	Control/ exposed	Hours	D	HPL	HP	HD	P	A	H	C	VC	NR	Comments
Mar 9-13 (647 mg/l)	Control	0		+	+ (mild)				?				
	Exposed	96		+	+		+		?				Edema
Mar 17-21 (2174 mg/l)	Control	24		+	+	+		+	?				
	Exposed	96			+ (mild)				?				
Mar 29-Apr 2	Control	0			+ (mild)				?				
	Control	96		+	+	+							
	Exposed	96			+ (mild)								
May 11-15 (757 mg/l)	Control	0			+ (mild)								
	Control	96			+ (mild)		+						
	Exposed	96			+								
May 18-22 (2019 mg/l)	Control	0		+	+	+	+	+	?				
	Control	96			+	+	+		?				
	Exposed	96	+ (small)	?	+	+			?				
May 25-29 (4515 mg/l)	Control	0		+	+	+	+	+	?				
	Control	96		?	+	+			?				
	Exposed	72.5	+		+	+	+						
	Exposed	96		?	+	+			?				

Where:

D = debris in interlamellar spaces
HPL = epithelial hyperplasia
HP = epithelial hypertrophy
HD = epithelial hydropic degeneration
P = parasites
A = vascular aneurysm
H = hemorrhage
C = changes in chloride cell size or number
VC = vascular congestion
NR = unremarkable, no visible lesions

Table 19. Summary of seawater entry tests conducted on coho and chinook salmon smolts exposed to three types of suspended sediment.

Date sediment exposure began	Species	Sediment type, concentration (% of 96 hr LC50)	Average length (mm)	Average smolt stage	Mortality in 100% seawater (96 hrs)
3/09/81	Coho	Ash, 647 mg/l (2.3)	107.4	2.342	*
3/17/81	Coho	Ash, 2174 mg/l (7.7)	107.6	2.300	*
3/29/81	Coho	Ash, 3775 mg/l (13.4)	110.5	2.306	*
4/13/81	Coho	Volclay, 993 mg/l (46.9)	114.5	2.800	*
4/20/81	Coho	Volclay, 1249 mg/l (59.0)	115.3	2.909	*
4/27/81	Coho	Volclay, 1686 mg/l (79.6)	120.9	3.167	40%, test 5%, control
5/04/81	Coho	Mudflow, 2967 mg/l (10.0)	127.9	3.122	*
5/11/81	Coho	Ash, 757 mg/l (2.7)	125.4	2.958	*
5/18/81	Coho	Ash, 2019 mg/l (7.2)	130.2	3.095	*
5/25/81	Coho	Ash, 4515 mg/l (16.0)	129.3	3.234	*
6/15/81	F. chinook	Ash, 2565 mg/l (15.5)	68.1	2.575**	94.1%, test 95.1%, control
6/22/81	F. chinook	Mudflow, 4349 mg/l (15.1)	70.1	3.217	75%, test 25%, control
6/29/81	F. chinook	Ash, 3109 mg/l (16.1)	72.2	2.911	84.6%, test 32%, control
7/06/91	F. chinook	Ash, 943 mg/l (4.5)	78.4	3.518	*

* No mortality.

** Underfed prior to testing.

other indicators of substantial damage by histological analyses, swimming performance testing or significant mortality in the artificial streams indicate that delayed mortality is unlikely following exposure to suspended volcanic ash.

Coho Smolts in Mudflow Sediment

Coho salmon smolts were exposed to sublethal concentrations of suspended mudflow sediment at 10 percent of the static 96-hr LC50 (Table 20). No mortalities occurred after 96 hr of exposure to suspended mudflow sediment averaging 2,967 mg/l at approximately 1.4 lengths/second velocity. The results of swimming performance testing are presented in Figure 33. The tailbeat intercept of the 24 hr control fish was greater than that for the 72 hr control fish, but no other statistical differences existed between any of the tailbeat regression lines. The seawater entry tests did not produce a response in either test or control groups (Table 19) after 96-hr exposure. Possible delayed saltwater mortality beyond a 96-hr exposure bioassay is unknown.

The results of histological analysis after mudflow exposure on coho smolts are given in Table 21. Very little could be seen histologically, although the exposed specimens exhibited multiple aneurysms while the control fish did not. It should be pointed out, however, that over all tests, aneurysms were seen as often in control fish as in exposed fish, so any correlation between sediment exposure and the presence of aneurysms is tenuous.

Coho Smolts in Bentonite

Table 22 summarizes the conditions for the three artificial stream exposures of coho salmon smolts in "Volclay 200" bentonite during April 1981. The lowest

Table 20. Artificial stream sediment exposure summary: coho and fall chinook smolts in mudflow sediment.

	Dates tested			
	May 4-8, 1981 (coho)		June 22-26, 1981 (fall chinook)	
Stream	Test	Control	Test	Control
Actual sediment concentration (mg/l) (std. dev.)	2967 (492)	1	4349 (649)	2
95% confidence interval on mean concentration (mg/l)	1990-3944	0 - 2	3061-5637	0 - 13
% of LC50	10.0[1]	0	39.5[2]	0
Average velocity (L/sec)	1.394	1.516	1.419	1.392
95% confidence interval on velocity (L/sec)	1.263-1.555	1.374-1.692	1.130-1.907	1.108-1.871
% mortality in stream	0	0	7.2	0.8
No. fish/stream	150		250	
Loading density (g/l)	1.6		0.4	
Fish information (std. dev.)				
Length (mm)	127.86 (6.6364)		70.09 (8.9736)	
Average weight (g)	20.32		3.15	
Condition factor[3]	.984 (.0528)		.891 (.0886)	
Smolt stage[4]	3.122 (.8071)		3.217 (.8409)	
Hatchery source	Skykomish		George Adams	
Water quality				
Mean temperature (°C) (range)	13.5 (12.2-13.9)	12.1 (10.4-13.5)	16.9 (14.0-19.8)	15.7 (12.8-17.8)
pH	7.6	7.5	7.2	7.4
Mean dissolved oxygen (mg/l) (range)	10.3 (10.0-11.2)	10.2 (10.0-10.8)	9.5 (8.8-10.5)	9.7 (9.0-11.0)
Conductivity (μmhos/cm^2)	50	40	60	49
Saltwater LC50 (96 hr) (°/oo)	*[5]	*	74.3	65.8

[1] 96 hr LC50 for coho smolts in mudflow sediment = 29580 mg/l as determined from probit analysis of results from the static bioassays of June 1-5, 1981.

[2] 96 hr LC50 for fall chinook smolts in mudflow sediment = 11,000 mg/l as determined from the static bioassays of June 22-27, 1981.

[3] Condition factor at beginning of test.

[4] Average smolt stage as determined by the visual methods of Prentice et al. (1981) where stage:
1 = full parr
2 = between parr and transitional
3 = transitional
4 = between transitional and smolt
5 = full smolt.

[5] No significant saltwater mortality occurred at 96 hr in the tests.

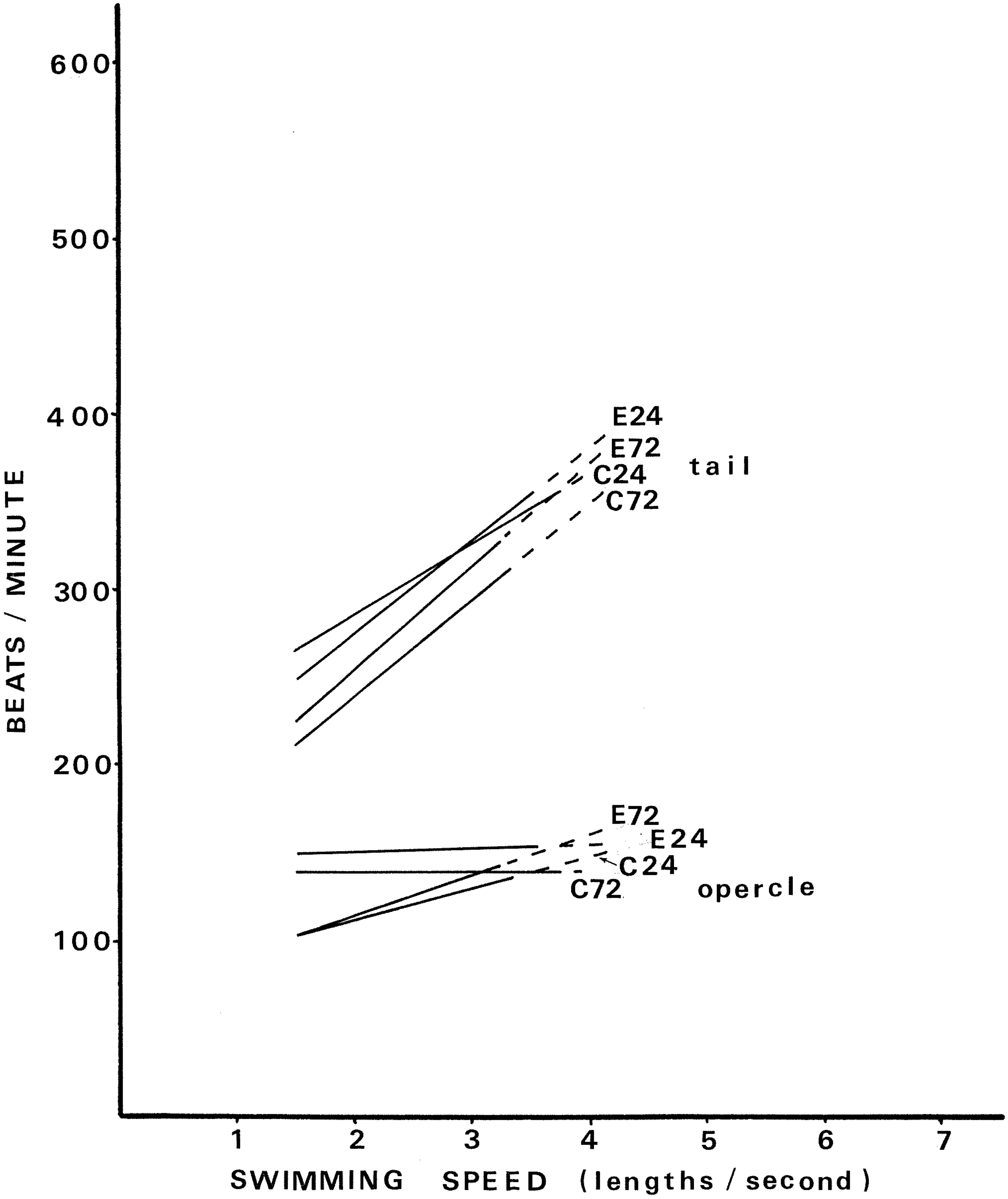

Fig. 33. Regression of swimming performance (tail and opercle beats/minute) on speed (lengths/second) for coho salmon smolts after 24 and 72 hr exposure to mudflow sediment averaging 2967 mg/l. Fatigue interval indicated by dashes. (Test began May 4, 1981, C = control, E = exposed).

Table 21. Histological effects of mudflow sediment on (A) coho smolts and (B) fall chinook smolts.

Test date (Average) concentration)	Control/ exposed	Hours	D	HPL	HP	HD	P	A	H	C	VC	NR	Comments
A. Coho smolts													
May 4-8 (2967 mg/l)	Control	96			+ (mild)								Inflammation
	Exposed	96			+ (mild)			+ (mult.)					Inflammation
B. Fall chinook smolts													
June 22-26 (4349 mg/l)	Control	0		+ (focal)									
	Control	96		+ (focal)				+ (focal)					Focal inflammation
	Exposed	96						+					

Where:

D = debris in interlamellar space
HPL = epithelial hyperplasia
HP = epithelial hypertrophy
HD = epithelial hydropic degeneration
P = parasites
A = vascular aneurysm
H = hemorrhage
C = changes in chloride cell size or number
VC = vascular congestion
NR = unremarkable, no visible lesions

Table 22. Artificial stream sediment exposure summary: coho smolts in "Volclay 200" bentonite.

	Dates tested						
	April 13-17, 1981		April 20-24, 1981		April 27 - May 1, 1981		
Stream	Test	Control	Test	Control	Test	(Test[4])	Control
Actual sediment concentration (mg/l) (std. dev.)	993 (49)	1	1249 (82)	61	1686 (157)	[2206 (49)]	1
95% confidence interval on mean concentration (mg/l)	897-1089	0-1	1086-1411	5-192	1375-1998	(2085-2327)	0-5
% of LC50[1]	46.9	0	59.0	0	79.6	(104.1)	0
Average velocity (L/sec)	.518	.490	.942	.951	1.524		1.565
95% confidence interval on velocity (L/sec)	.444-.622	.420-.588	.826-1.096	.834-1.106	1.328-1.789		1.363-1.837
% mortality in stream	2.7	0	6.3	0	22.0	(7.3)	0
No. fish/stream	300		300		300		
Loading density (g/l)	2.5		2.4		2.9		
Fish information (std. dev.)							
Length (mm)	114.52 (9.5564)		115.30 (8.0827)		120.94 (8.9564)		
Average weight (g)	15.86		15.35		18.18		
Condition factor[2]	.981 (.0284)		.991 (.0595)		1.071 (.1445)		
Smolt stage[3]	2.800 (.5231)		2.909 (.7093)		3.167 (.5746)		
Hatchery source	Minter Creek		Minter Creek and Skykomish		Skykomish		
Water quality							
Mean temperature (°C) (range)	14.6 (10.9-16.7)	11.5 (7.2-14.1)	15.7 (12.4-19.0)	13.3 (11.1-16.8)	15.7 (12.6-18.0		15.3 (10.9-17.0)
pH	7.6	7.4	7.5	7.4	7.6		7.3
Mean dissolved oxygen (mg/l) (range)	10.0 (9.7-11.4)	10.0 (9.5-11.4)	8.8 (7.8-10.7)	9.3 (8.4-10.8)	10.0 (9.4-11.8)		9.7 (9.3-11.4)
Conductivity (µmhos/cm^2)	38	32	83	49	72		42
Saltwater LC50 (96 hr) (°/oo)	*[5]	*	*	*	37.15		*

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[1] 96 hr LC50 for coho smolts in "Volclay 200" bentonite = 2118.36 mg/l as determined by probit analysis of the combined results from the static bioassays conducted from April 15 to May 29, 1981.

[2] Condition factor at beginning of test.

[3] Average smolt stages as determined by the visual methods of Prentice et al. (1981), where stage:
1 = full parr
2 = between parr and transitional
3 = transitional
4 = between transitional and smolt
5 = full smolt

[4] Mean sediment concentration with 95% confidence interval and percent of static LC50 during first 6 hours of test, before concentration was lowered.

[5] No significant saltwater mortalities occurred within 96 hr in these tests.

concentration tested (April 13-17) was run at a higher percentage of the 96-hr static LC50 value (46.9 percent) than the highest concentration of any of the other sediment types tested. High mortality in the stream did not occur until the high concentration/high velocity test (April 27 - May 1), which averaged 79.6 percent of the static 96-hr LC50 value, and resulted in 22 percent mortality. In the low and medium concentration tests, only 2.7 and 6.3 percent mortality occurred, respectively (8 and 19 fish out of 300).

Swimming performance test results are given in Figures 34, 35 and 36. No statistically significant differences were found between exposed and control fish at the three concentrations tested. For the high concentration exposure, the tailbeat intercept for the 72 hr controls was greater than that for the 24-hr controls ($p = .0008$), but there were no statistical differences between control and exposed fish.

Mortality in salt water was observed only after exposure to the highest concentration of bentonite (Table 22) averaging 1,686 mg/l (79.6 percent of the static 96-hr LC50). In this bioassay there was only one control mortality (5 percent), in 100 percent sea water (27.7 $^{o}/oo$), but mortalities among sediment-exposed fish were sufficient to produce a saltwater mortality of 40 percent.

Histological examination of gill tissues from these tests (Table 23) showed exposed fish being somewhat more affected than control fish, especially in the case of the high concentration run of April 27 - May 1. Even so, all the effects noted were relatively minor, even among the moribund fish.

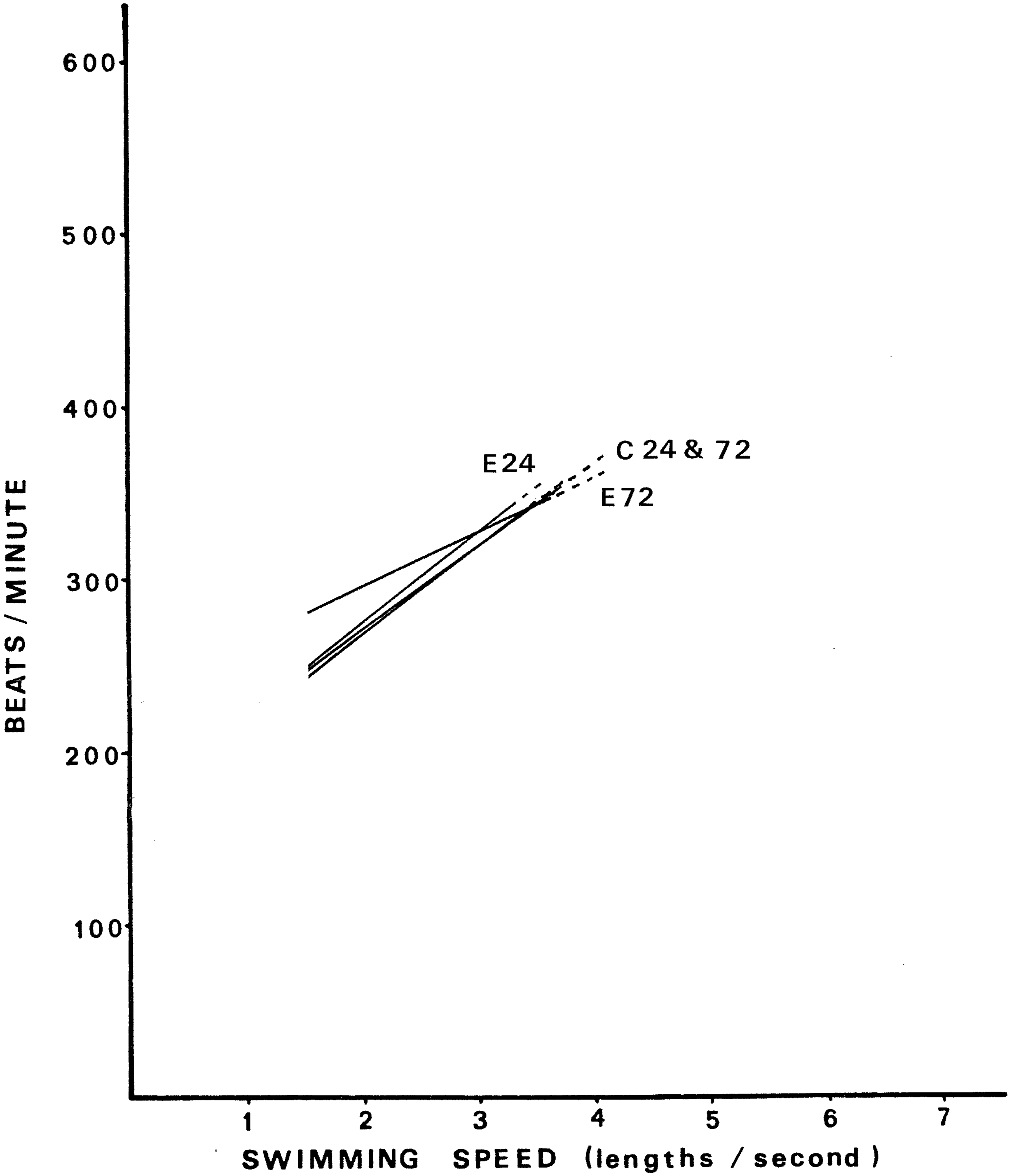

Fig. 34. Regression of swimming performance (tail beats/minute) on speed (lengths/second) for coho salmon smolts after 24 and 72-hr exposure to bentonite clay averaging 993 mg/l. (Test began 13 April 1981, C = control, E = exposed).

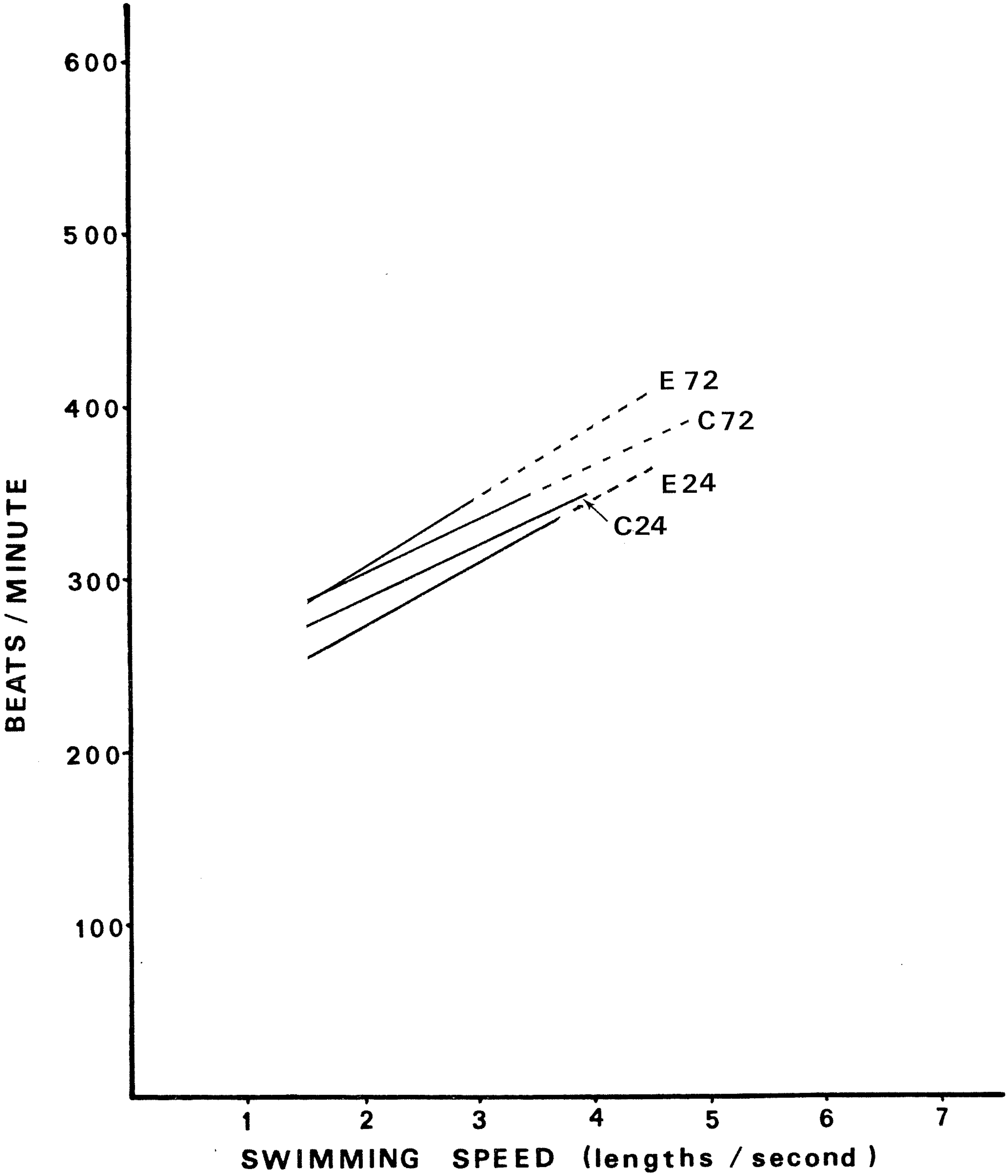

Fig. 35. Regression of swimming performance (tail beats/minute) on speed (lengths/second) for coho salmon smolts after 24 and 72-hr exposure to bentonite clay average 1,249 mg/l. (Test began 20 April 1981, C = control, E = exposed).

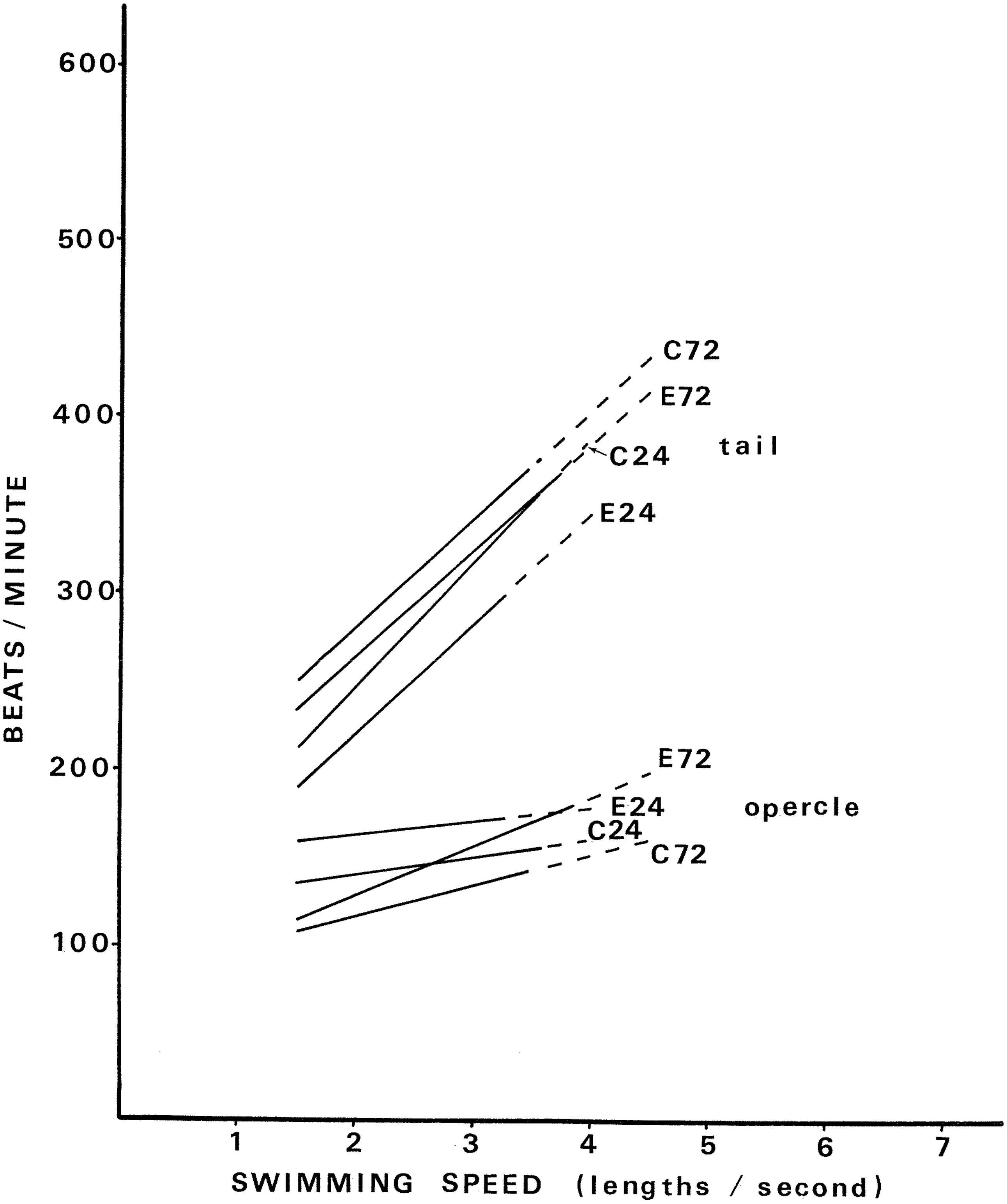

Fig. 36. Regression of swimming performance (tail and opercle beats/minute) on speed (lengths/second) for coho salmon smolts after 24 and 72 hr exposure to bentonite clay averaging 1686 mg/l. Fatigue interval indicated by dashes. (Test began April 27, 1981, C = control, E = exposed).

Table 23. Histological effects of bentonite exposure on coho smolts.

Test date (average concentration)	Control/ exposed	Hours	D	HPL	HP	HD	P	A	H	C	VC	NR	Comments
Apr 13-17 (993 mg/1)	Control	0			+								
	Control	96			+	+							Inflammation
	Exposed	3*	+		+								
	Exposed	96			+ (mild)								
Apr 20-24 (1249 mg/1)	Control	0					+		?				
	Control	96										+	
	Exposed	96							?				
Apr 27-May 1 (1686 mg/1)	Control	96			+	+			?				
	Exposed	13*	+		+	+							
	Exposed	24	+		+	+		+					
	Exposed	96			+	+					+		

Where:

D = debris in interlamellar spaces
HPL = epithelial hyperplasia
HP = epithelial hypertrophy
HD = epithelial hydropic degeneration
P = parasites
A = vascular aneurysm
H = hemorrhage
C = changes in chloride cell size or number
VC = vascular congestion
NR = unremarkable, no visible lesions

* Moribund when sampled.

Fall Chinook Smolts in Volcanic Ash

Fall chinook smolts were exposed to volcanic ash in June and July 1981 (Table 24). During the first exposure (2,656 mg/l average at ∿ 1.5 lengths/second, June 15-19) the fish were suffering from insufficient feeding during the two-week period prior to testing. Although the average condition factor (0.898, n = 11) at the beginning of testing was low, it declined to 0.780 (n = 8) after 96 hr in the artificial streams, and 0.733 (n = 10) after an additional 96 hr in saltwater challenge bioassays. Because the fish were obviously starving, the entire sediment exposure test was repeated two weeks later. In this replicate test, there was 8 percent mortality in the artificial stream as opposed to 24 percent in the first test, even though the second test was at a somewhat higher average concentration than the first (3,109 mg/l vs 2,565 mg/l). The average condition factor for fish sampled at the start of testing was only 0.875 (n = 8). After the 96 hr exposure in suspended volcanic ash a similar average condition factor of 0.880 (n = 12) was found. Clearly the fish in this test, while not overly robust, had sufficient bodily reserves that 96 hr without feeding did not leave them emaciated. Length and weight measurements (for condition factor) were not taken following the second saltwater challenge bioassay because the fish appeared healthy.

Swimming performance test results are shown in Figures 37, 38, and 39 following 24 and 72 hr exposures to volcanic ash concentrations of 2,565, 3,019 and 943 mg/l, respectively. The exposure to 2,565 mg/l concentration when the fish were starving showed the tailbeat slope of the control fish after 72 hr was greater than that for the controls at 24 hr (p = .048). No statistical differences were found between control and exposed fish, and no statistical

Table 24. Artificial stream sediment exposure on fall chinook salmon smolts in volcanic ash.

	Dates tested					
	June 15-19, 1981		June 29-July 3, 1981		July 6-10, 1981	
Stream	Test	Control	Test	Control	Test	Control
Actual sediment concentration (mg/l) (std. dev.)	2565 (470)	6	3109 (511)	15	943 (160)	7
95% confidence interval on mean concentration (mg/l)	1632-3498	0-15	2095-4123	0-30	625-1261	0-19
% of LC50[1,2]	15.5	0	16.1[2]	0	4.9[2]	0
Average velocity (L/sec)	1.520	1.474	1.345	1.392	1.011	0.981
95% confidence interval on velocity (L/sec)	1.178-2.143	1.142-2.077	1.062-1.834	1.099-1.898	0.838-1.274	0.813-1.237
% mortality in stream	24.0	7.4	8.0	0.8	3.4	0
No. fish/stream	500		250		175	
Loading density (g/l)	0.8		0.5		0.4	
Fish information (std. dev.)						
Length (mm)	68.13 (9.8940)		72.24 (9.6250)		78.40 (8.1010)	
Average weight (g)	3.07		3.60		4.58	
Condition factor[3]	.898 (.0586)		.875 (.1747)		.992 (.0524)	
Smolt stage[4]	3.000 (.6489)	2.150 (.8127)	2.911 (.7306)		3.581 (.8517)	
Hatchery source	George Adams		George Adams		George Adams	
Water quality						
Mean temperature (°C) (range)	15.8 (13.6-17.5)	15.8 (13.6-19.2)	17.6 (14.0-19.0)	15.3 (11.7-18.5)	16.5 (12.8-19.7)	15.6 (13.1-18.3)
pH	7.3	7.3	7.4	7.4	7.7	7.6
Mean dissolved oxygen (mg/l) (range)	9.3 (9.0-10.2)	9.3 (9.0-10.1)	9.6 (9.2-10.3)	9.8 (9.1-10.6)	9.9 (9.0-10.8)	10.1 (9.0-10.9)
Conductivity (μmhos/cm^2)	50	45	43	43	45	46
Saltwater LC50 (96 hr) (°/oo)	13.305	16.943	22.3	16.9	*[5]	*

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[1] 96 hr LC50 for fall chinook smolts in volcanic ash = 16557.7 mg/l as determined from probit analysis of results from the static bioassays of June 15 through June 20, 1980. This is compared to test of June 15-19, 1980 only.

[2] 96 hr LC50 for fall chinook smolts in volcanic ash = 19364.22 mg/l as determined from the static bioassay of June 29-July 3, 1980. This is compared to the tests beginning June 29 and July 6.

[3] Condition factor at beginning of test.

[4] Average smolt stage as determined by the visual methods of Prentice et al. (1981) where stage:
1 = full parr
2 = between parr and transitional
3 = transitional
4 = between transitional and smolt
5 = full smolt.
A separate average value is given if a statistical difference existed between the average stages in the two streams.

[5] No significant saltwater mortality occurred in 96 hr in these tests.

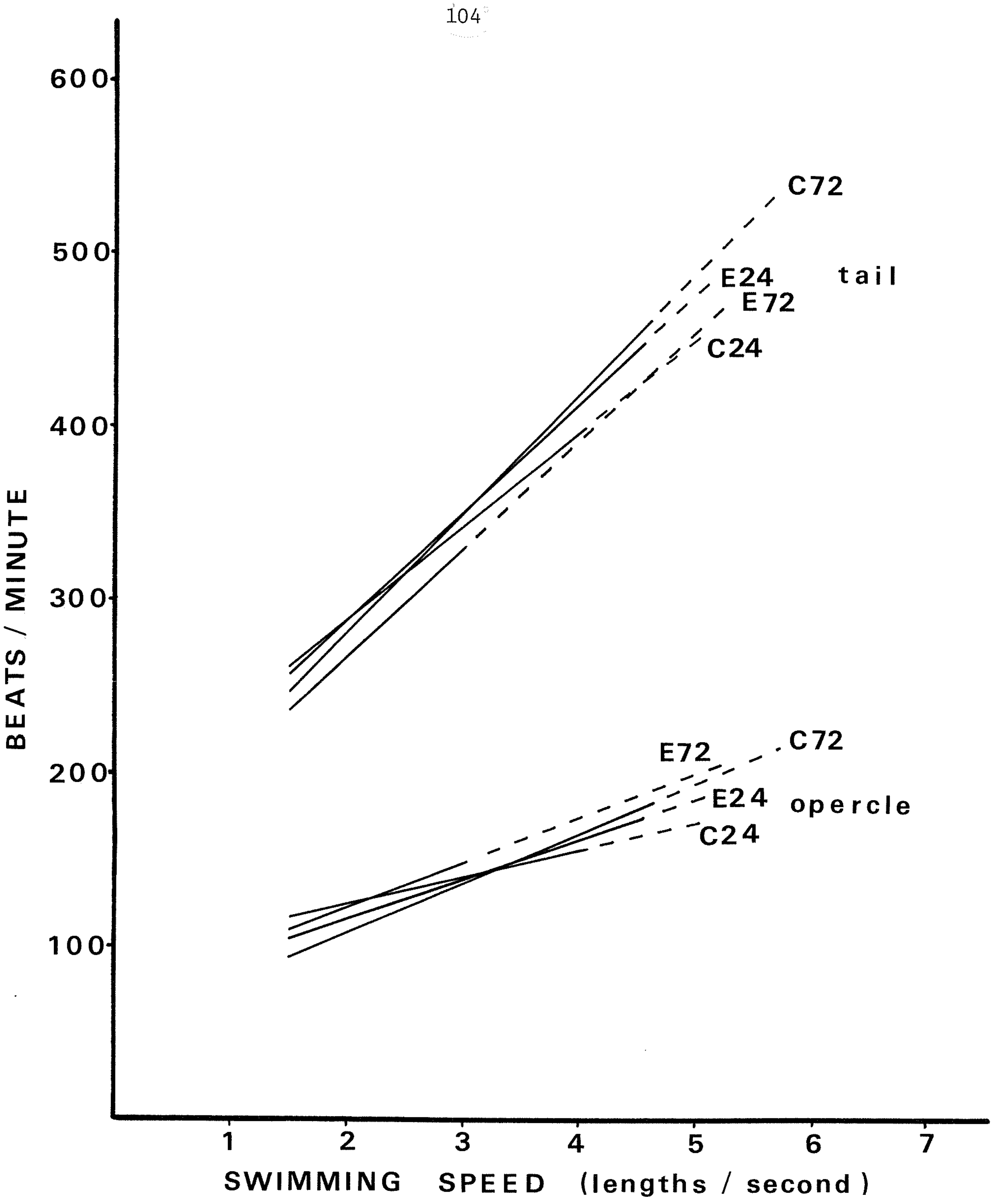

Fig. 37. Regression of swimming performance (tail and opercle beats/minute) on speed (lengths/second) for fall chinook salmon smolts after 24 and 72 hr exposure to volcanic ash averaging 2565 mg/l. Fatigue interval indicated by dashes. (Test began June 15, 1981, C = control, E = exposed).

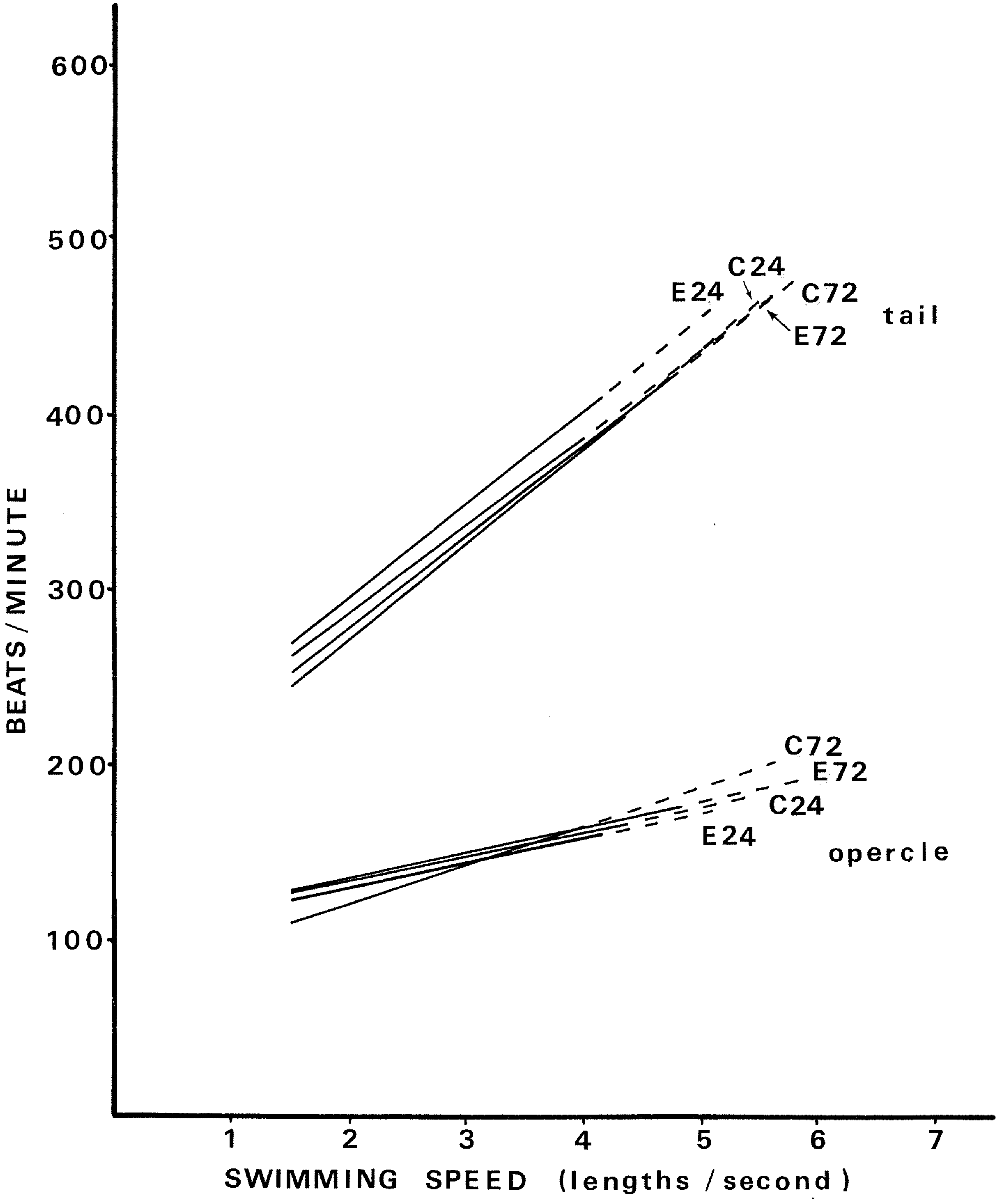

Fig. 38. Regression of swimming performance (tail and opercle beats/minute) on speed (lengths/second) for fall chinook salmon smolts after 24 and 72 hr exposure to volcanic ash averaging 3019 mg/l. Fatigue interval indicated by dashes. (Test began June 29, 1981, C = control, E = exposed).

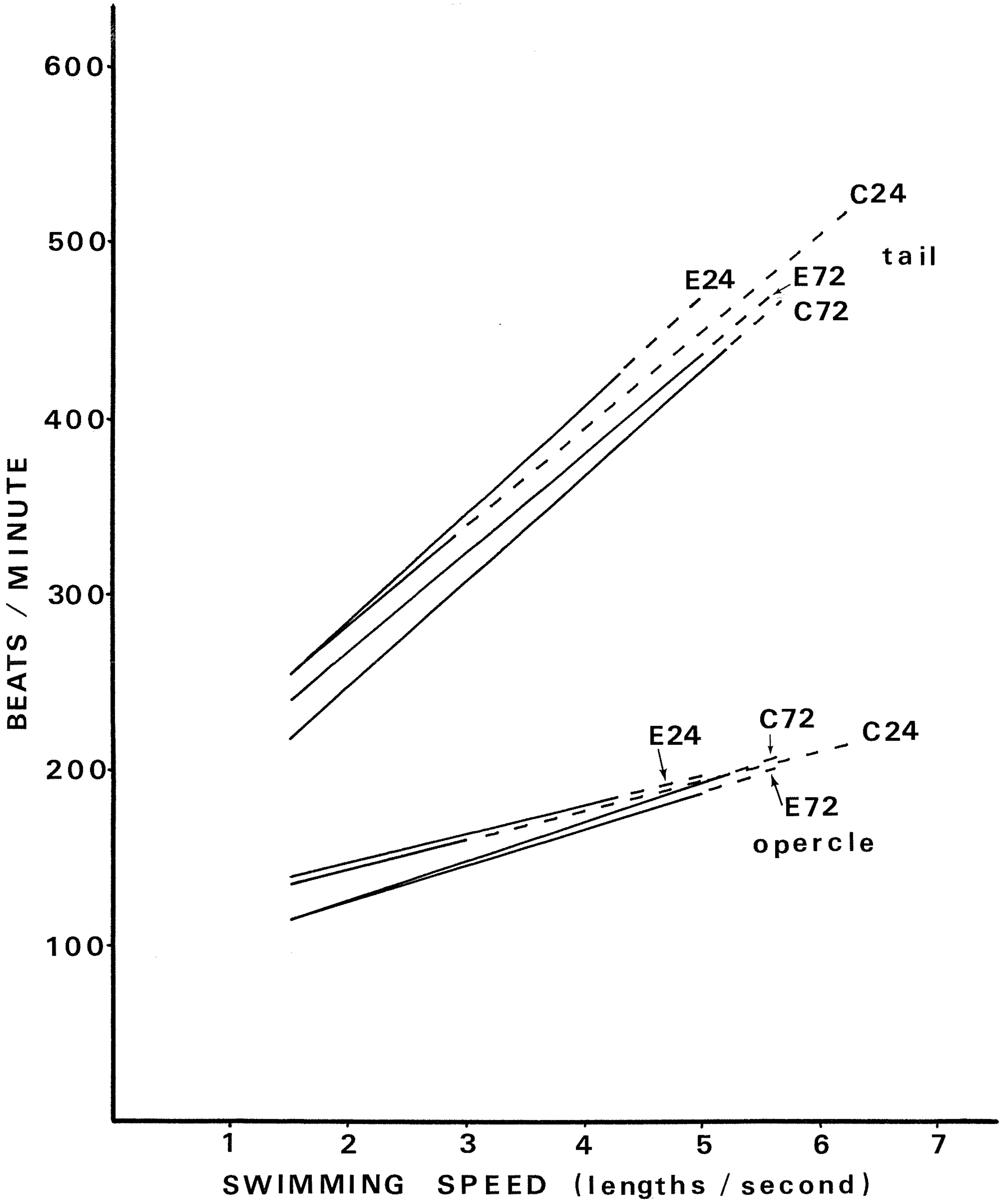

Fig. 39. Regression of swimming performance (tail and opercle beats/minute) on speed (lengths/second) for fall chinook salmon smolts after 24 and 72 hr exposure to volcanic ash averaging 943 mg/l. Fatigue interval indicated by dashes. (Test began July 6, 1981, C = control, E = exposed).

differences resulted from the second, high concentration exposure or the third ash exposure (July 6-10), of medium concentration and velocity (943 mg/l at 1.0 lengths per second).

Although swimming performance was not affected, the high exposures of chinook smolts to ash did affect saltwater tolerance. The seawater entry test on the starving fish of the first exposure yielded a control mortality of 95.1 percent and an exposed fish mortality of 94.1 percent in 96 hours. (Table 19). The subsequent high concentration of ash tested on well-fed test specimens gave a calculated control mortality of 32 percent, and a test mortality of ash-exposed fish of 84.6 percent. The mortality for controls indicated little effect because only 8 of 25 control fish in 100 percent Hood Canal salt water died in 96 hr. Other concentrations of 0, 25, 50, and 75 percent Hood Canal salt water resulted in no mortalities. For ash-exposed fish, however, mortalities occurred at all salinities (22 of 26 died in 100 percent salt water, 8 of 33 died in 75 percent, 2 of 23 in 50 percent, and 1 of 28 in 25 percent). This large difference in saltwater tolerance occurred in the absence of a significant rate of direct mortality in the artificial streams, without an effect on swimming performance, and without significant gill damage.

Histological effects of ash exposure on fall chinook smolts are presented in Table 25. Analysis of the histological changes in test and control fish at all exposure concentrations showed only minor changes and no apparent difference between exposed and control.

Table 25. Histological effects of volcanic ash on gill tissue of fall chinook salmon smolts.

Test date (average concentration)	Control/ exposed	Hours	D	HPL	HP	HD	P	A	H	C	VC	NR	Comments
Jun 15-19 (2565 mg/1)	Control	0						+ (mult.)					
	Control	72*									+		
	Exposed	72*	+		+ (mild)								Focal inflammation
	Exposed	96										+	
Jun 29-Jul 3 (3109 mg/1)	Control	96										+	
	Control	96			+ (mild, focal)								Focal inflammation
	Exposed	24*			+								
	Exposed	96			+ (mild)								
Jul 6-10 (943 mg/1)	Control	0	+										Focal inflammation
	Control	96			+ (mild)								Focal inflammation
	Exposed	96						+ (mult.)					

Where:

D = debris in interlamellar spaces

HPL = epithelial hyperplasia

HP = epithelial hypertrophy

HD = epithelial hydropic degeneration

P = parasites

A = vascular aneurysm

H = hemorrhage

C = changes in chloride cell size or number

VC = vascular congestion

NR = unremarkable, no visible lesions

* Moribund when sampled.

Fall Chinook Smolts in Mudflow Sediment

Fall chinook salmon smolts were exposed to sublethal concentrations of suspended mudflow sediment at 15.1 percent of the static 96-hr LC50 (Table 20). A mortality of 7.2 percent (18 fish) occurred in the test stream, while 0.8 percent (2 fish) died in the control stream.

The swimming performance of these fish is shown in Figure 40. The tailbeat slope of the 24 hr exposed fish was greater than that of the 72 hr exposed fish ($p = .0033$). The 72 hr tailbeat intercept for the exposed fish was greater than that of the 24 hr exposed fish ($p = .0035$). There were also statistical differences between the exposed and control fish. The tailbeat slope for fish exposed to mudflow for 24 hr was greater than that for 24 hr controls ($p < .0005$). The intercept of the tailbeat line for 24 hr control fish was greater than the intercept for 24 hr exposed fish ($p < .0005$).

Saltwater tolerance did not appear to be affected by exposure to mudflow sediments (Table 19). Mortality in 100 percent seawater after 96 hr was 25 percent in control and 75 percent in sediment-exposed fish. The fact that the LC50 for exposed fish was actually a bit higher than that for unexposed fish suggests that the mortalities seen were more related to smoltification stage at the time, rather than an effect of the sediment.

Histologically, exposed fish exhibited no more effect than did control fish (see Table 21).

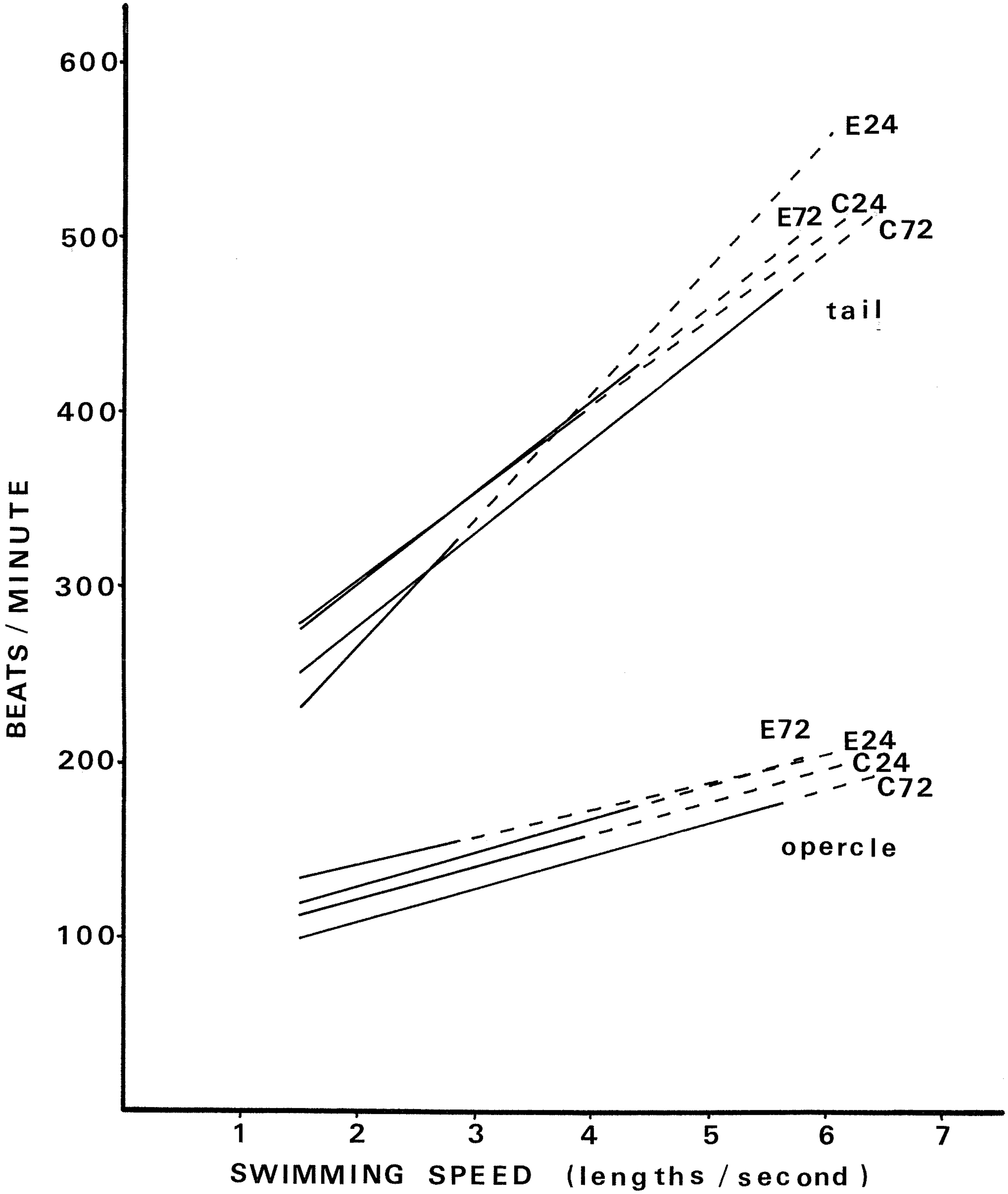

Fig. 40. Regression of swimming performance (tail and opercle beats/minute) on speed (lengths/second) for fall chinook salmon smolts after 24 and 72 hr exposure to mudflow sediment averaging 4349 mg/l. Fatigue interval indicated by dashes. (Test began June 22, 1981, C = control, E = exposed).

Swimming Performance Testing

The interpretation of swimming performance tests requires consideration of several factors. The first and most obvious is the difference in length and girth of the individual fish being tested at any one time. Adjustments for these differences have been made in all cases. A less obvious difference between individuals that can affect swimming performance is smolt stage, reported by Flagg and Smith (unpubl.) to cause a consistent shift in performance with advancing smoltification (i.e. the slope of the swimming performance regression line increased for each more advanced stage of smoltification, up to the peak before reversion back toward parr).

In order to compare groups of fish tested as experiments continued through the spring and into the summer, it was necessary to assess the background effects of smolt stage on swimming performance for this project. Swimming performance was analyzed for all tests combined, using control (non-sediment-exposed) fish separated by smolt stage only. The results are shown in Figure 41 for coho smolts. The fatigue intervals (dashes) are much longer than shown for individual tests because all tests are combined. The tailbeat regression lines for coho smolts are statistically identical with no significant differences between stages. When control fall chinook smolts were analyzed by stage only (Figs. 42 and 43), the results were similar. The tailbeat regression lines were all statistically identical, except that in this case the intercept for the stage 5 fish was greater than the intercept for stage 4 ($p = .0046$). When stages 1 - 4 (statistically identical) were grouped and compared with stage 5 (Fig. 43), there was no significant statistical difference between stages.

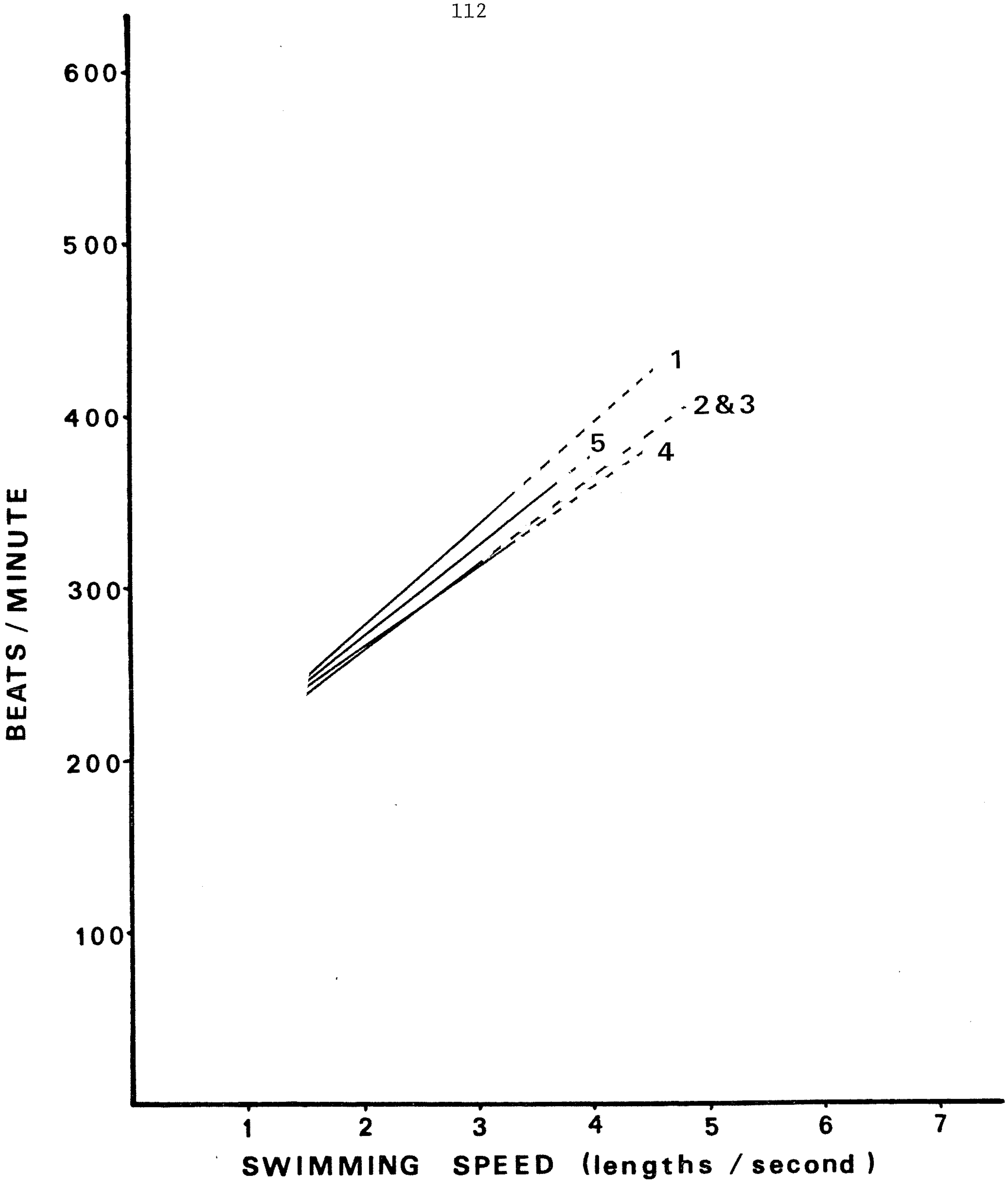

Fig. 41. Regression of swimming performance (tail beats/minute) on speed (lengths/second) for control coho salmon in 24 and 72-hr tests combined by smolt stages 1-5. There are no statistically significant differences between stages.

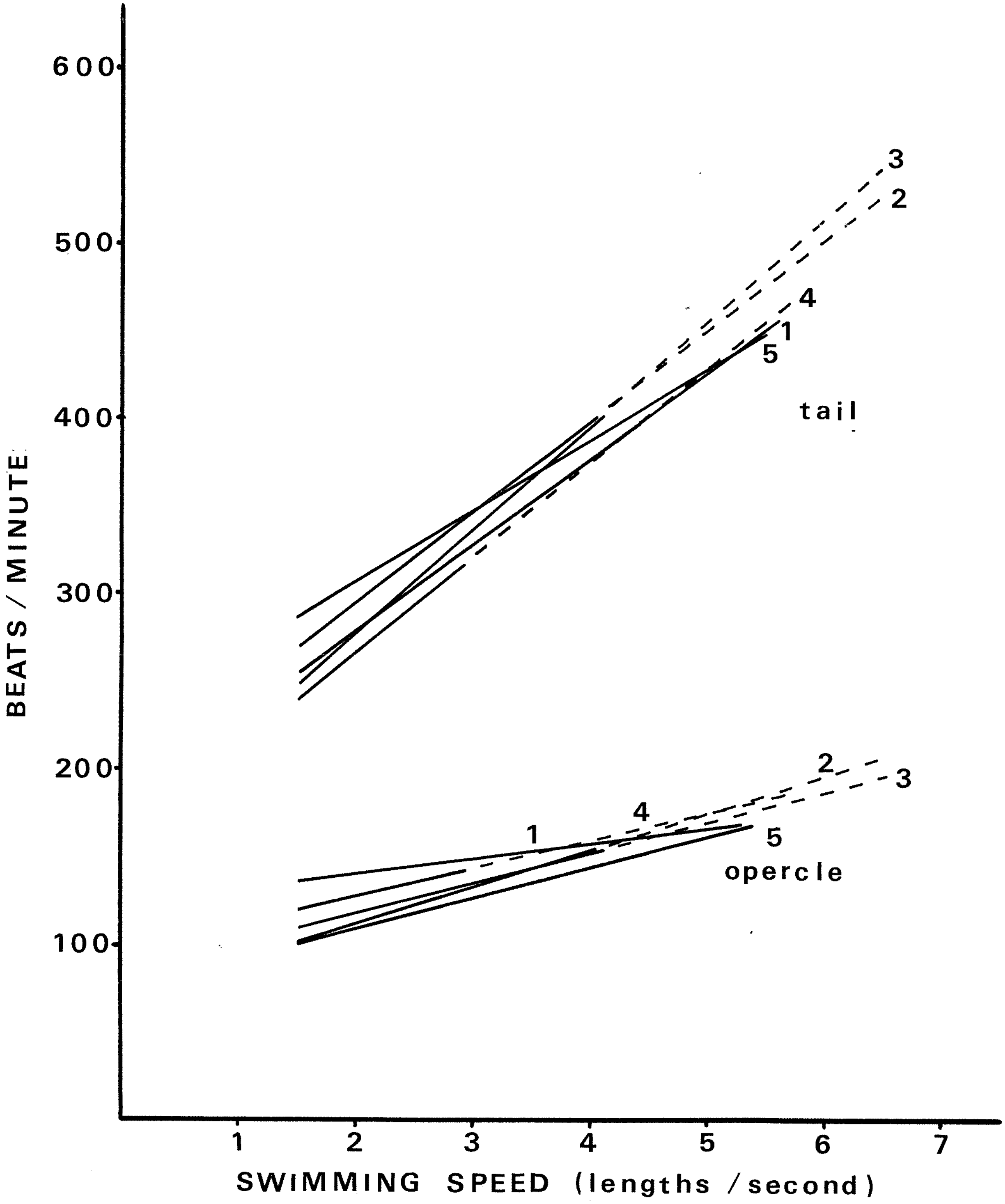

Fig. 42. Regression of swimming performance (tail and opercle beats/minute) on speed (lengths/second) for control fall chinook salmon by smolt stages 1-5. Fatigue interval indicated by dashes. (Intercept of stage 5 > stage 4, p = .0046).

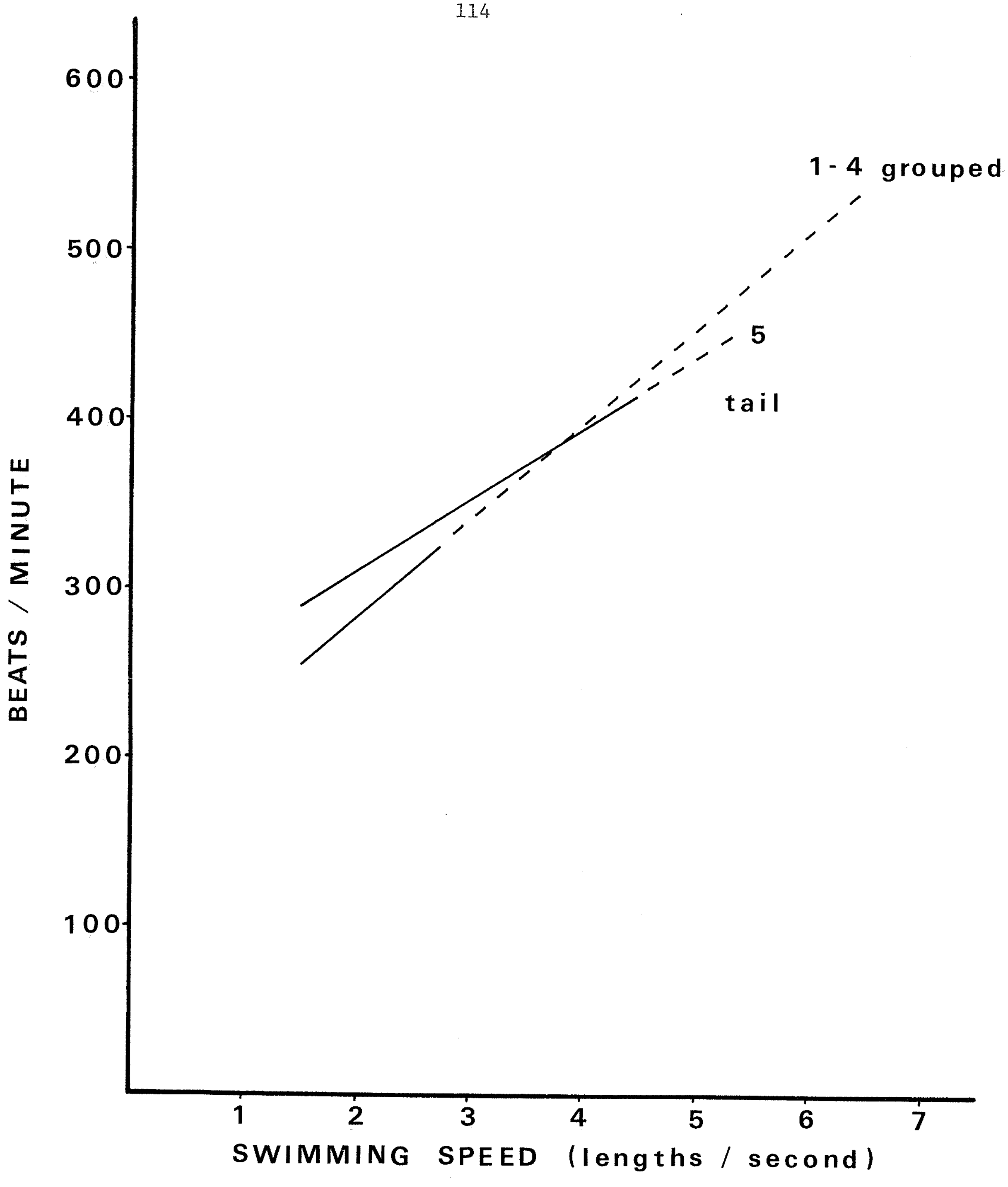

Fig. 43. Regression of swimming performance (tail beats/minute) on speed (lengths/second) for control fall chinook salmon by smolt stages 1-5 (1-4 combined). Fatigue interval indicated by dashes. (No significant differences at .05 level).

Not only were there no statistically significant differences between the smolt stages for the coho or fall chinook controls used in these experiments, there was also no consistent trend in performance with smolt stage. For both fish species, the slopes of the stages were essentially randomly scattered. Because no differences could be detected in the control fish by smolt stage, individual tests were not separately analyzed by this parameter, and any differences between exposed and control fish in those tests can be considered test effect.

Tests of the swimming performance regressions by smolt stages for coho salmon smolts exposed to volcanic ash (Fig. 44) show that the slope of stage 2 exposed was greater than all exposed groups combined. The slope of stage 2 exposed was greater than stage 2 control (Fig. 41). A similar analysis for coho salmon smolts in bentonite (Fig. 45) showed that the slope of stage 2 exposed was greater than stage 2 control. This indicates that earlier coho smolt stages were more sensitive to volcanic ash and bentonite exposure than later stages.

Interpretation of the regression lines is such that fish performance which follows a regression line with a greater slope are displaying a more rapid tailbeat to maintain the same speed than fish whose regression line is less steep. Whether the amplitude of those tailbeats is constant or comparable between the two, however, is difficult to determine. Videotape analysis in these studies was no help because the curvature of the test chamber distorted the view, making accurate amplitude measurements impossible even in slow motion. Whether a greater tailbeat regression line slope always means that a fish is actually working harder to swim the same speed remains an unknown.

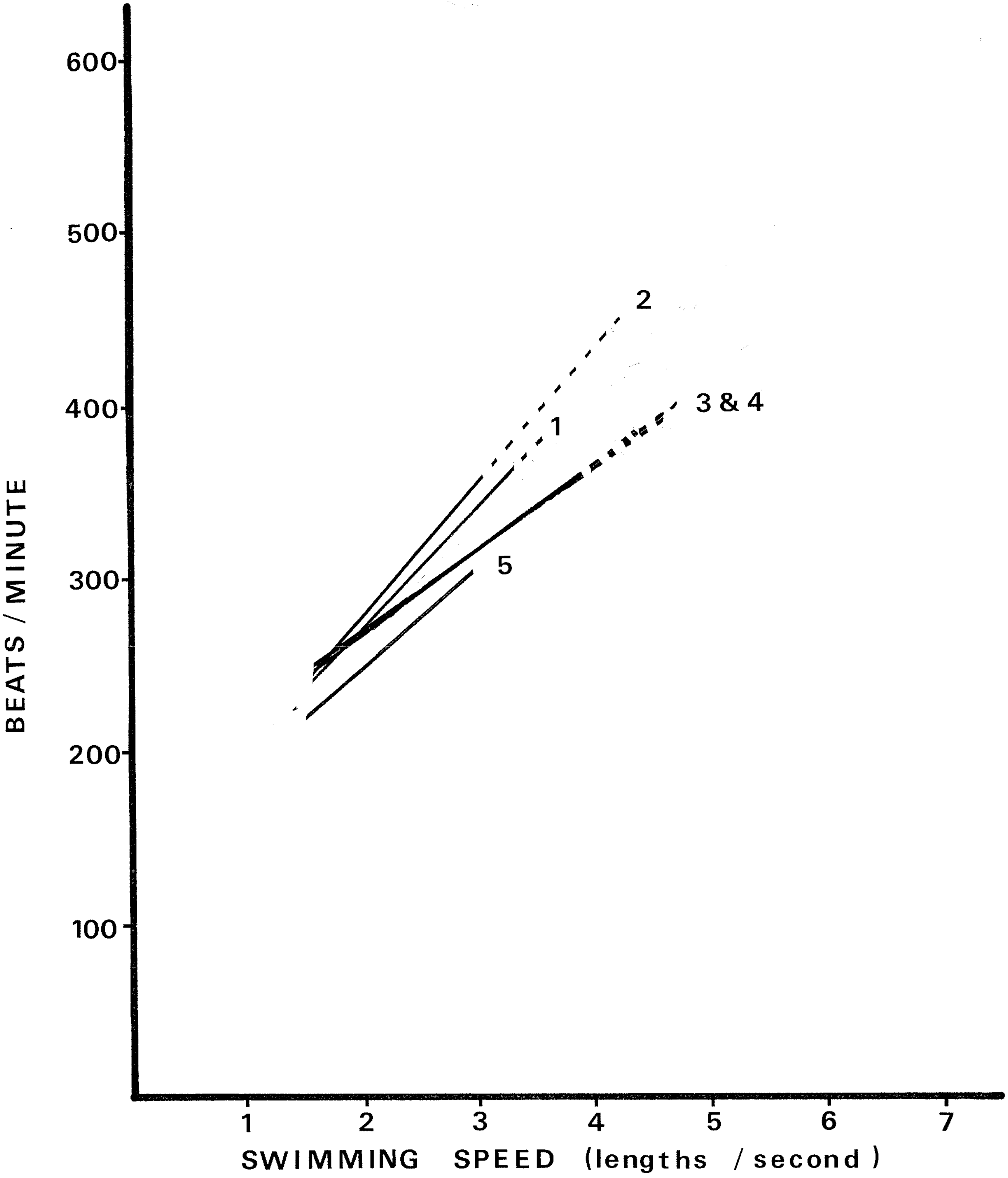

Fig. 44. Regression of swimming performance (tail beats/minute) on speed (lengths/second) for volcanic ash exposed coho salmon smolts by smolt stages 1-5. All concentrations and 24 and 72-hr tests combined. (Slope of stage 2 exposed > slope of all exposed stages grouped; slope of stage 2 exposed > slope of stage 2 control).

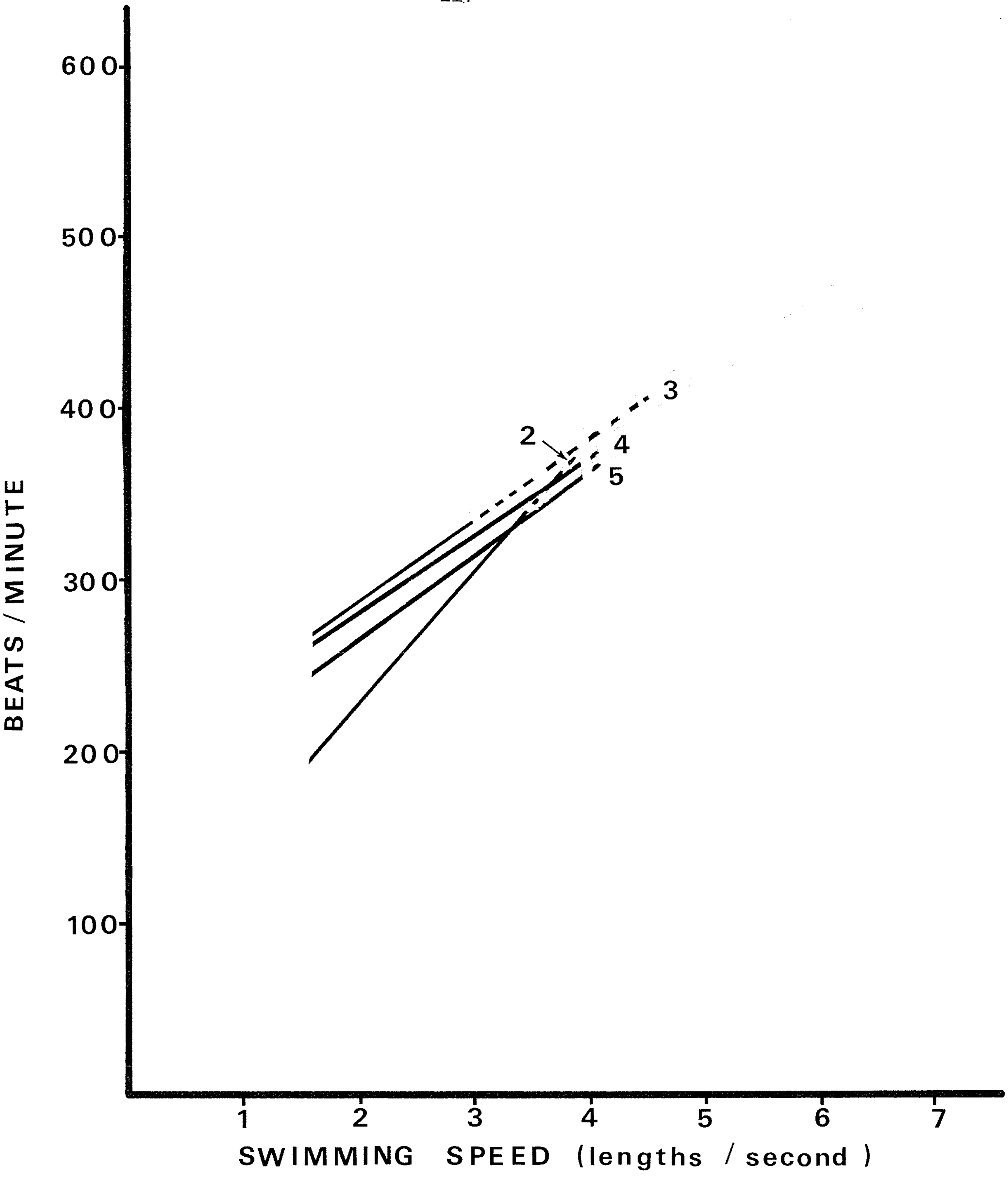

Fig. 45. Regression of swimming performance (tail beats/minute) on speed (lengths/second) for bentonite exposed coho salmon smolts by smolt stages 1-5. All concentrations and 24 and 72-hr tests combined. (Slope of stage 2 exposed > slope of stage 2 control).

The interpretation of intercept differences is even more difficult. A statistical difference on the y-intercept is really an artifact, because the regression line does not begin there but rather at approximately 1.5 lengths per second swimming speed. Assuming linearity all the way to the intercept is unreasonable in any case (fish "swimming" at 0 lengths per second do not have to beat their tails 150 to 200 times per minute). Lines which have statistically different y-intercepts usually converge as they increase and in most cases would not be statistically different at an x value near 1.5 lengths per second.

The most meaningful variable calculated from swimming performance testing is U-critical (Fig. 46) the fatigue level represented by dashes on all swimming performance regression lines. The difference in the velocities at which fish fatigue in standardized testing is a measure of whether damage or stress is enough to affect competitive or predator-avoidance abilities. In no individual performance test was a statistically significant difference observed between the mean fatigue levels of control and exposed fish. Since fatigue level is overall the most significant measure involved with performance testing, it can be said that none of the sediment exposures conducted significantly affected the swimming performances of coho or fall chinook salmon smolts, differences in slope or intercept of individual regression lines notwithstanding.

Since no consistent pattern existed in the differences that were seen in the swimming performance regression lines of individual tests, the data were combined by species for all exposed fish vs all control fish, regardless of sediment type or exposure concentration and are presented in Figures 47 and 48.

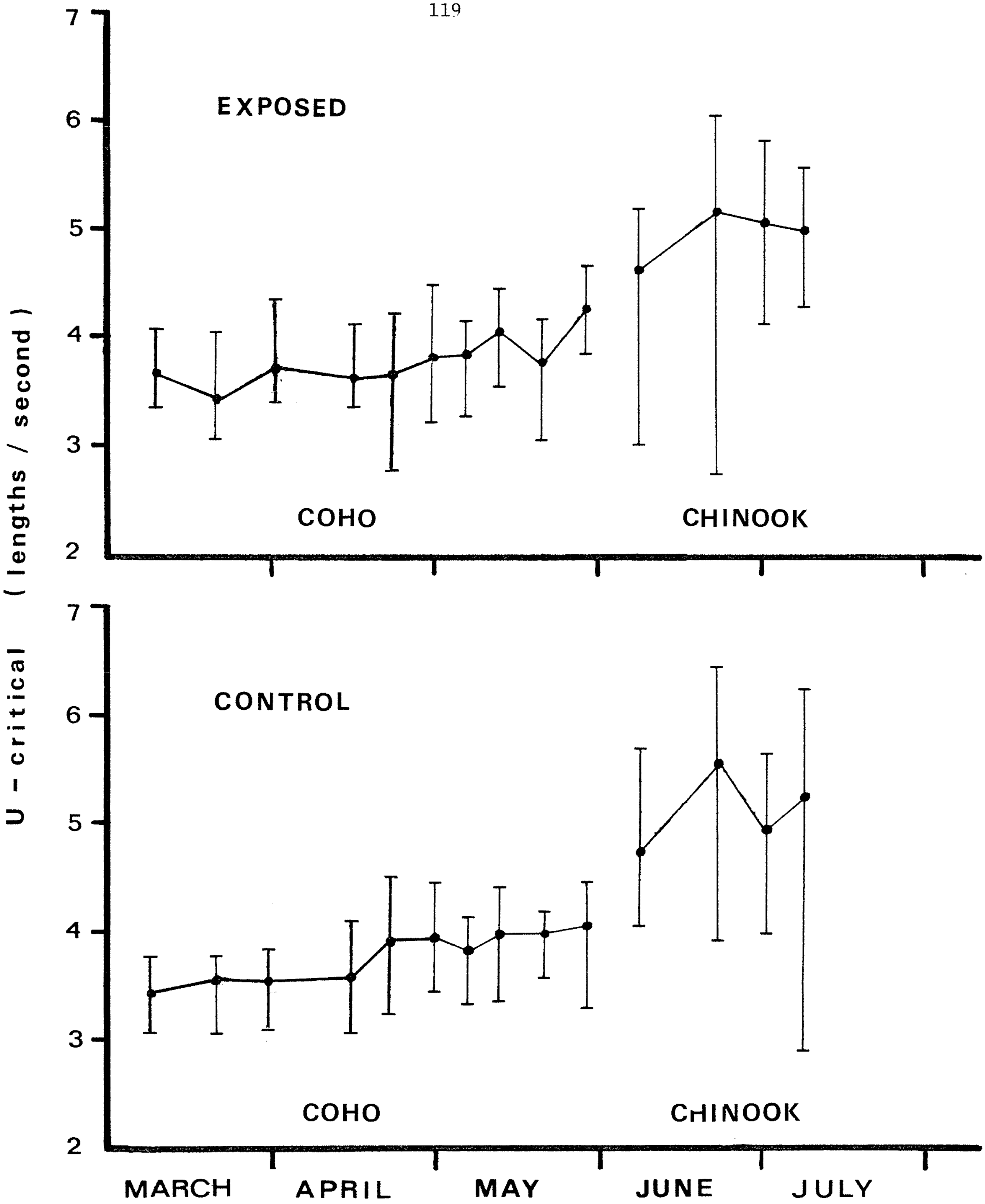

Fig. 46. Fatigue velocity (U-critical, body lengths per second) throughout 1981 swimming performance testing (24 and 72-hr tests combined).

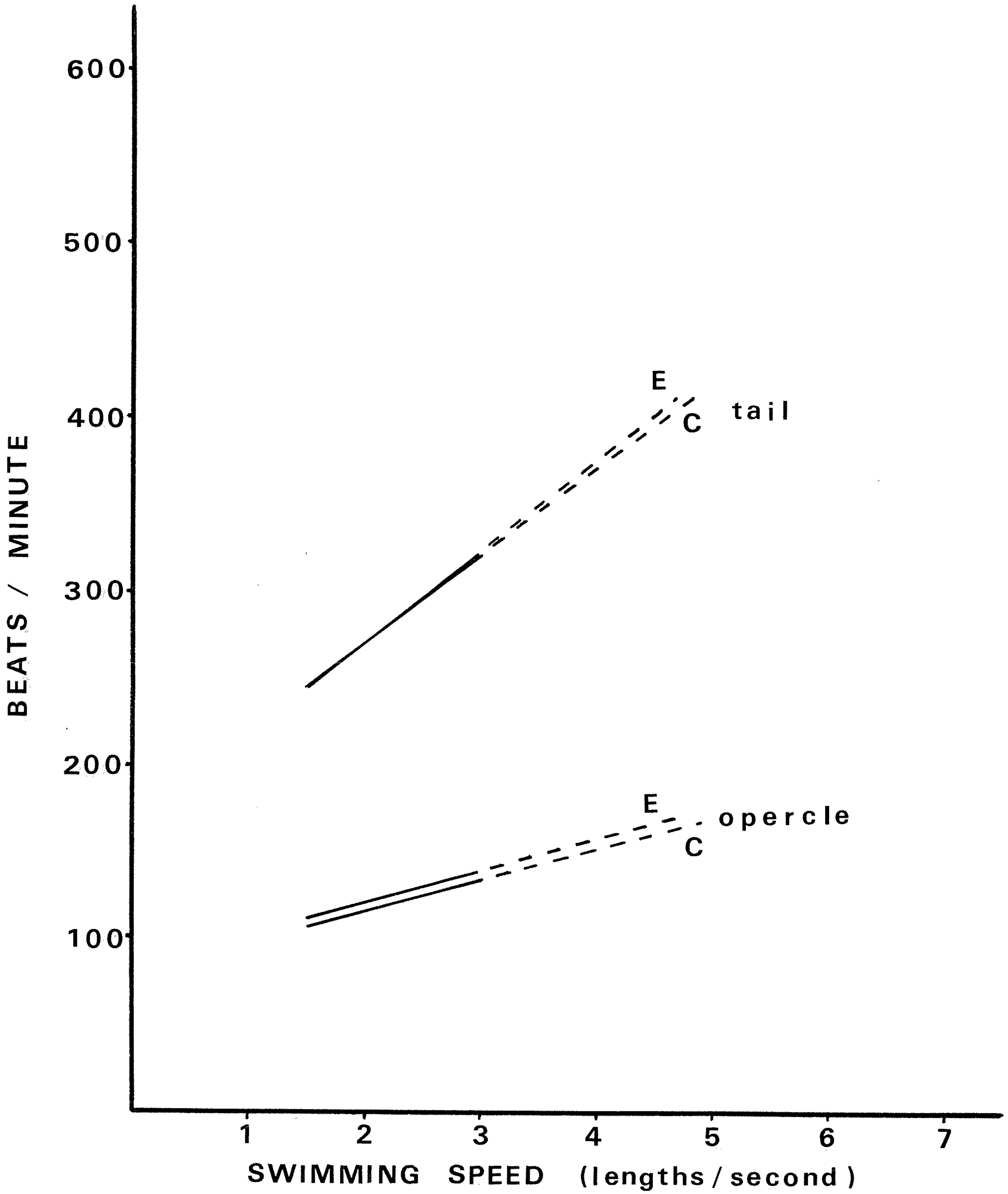

Fig. 47. Regression of swimming performance (tail and opercle beats/minute) on speed (lengths/minute) for coho salmon smolts exposed to volcanic ash, mudflow and bentonite with average concentrations ranging from 643 to 4515 mg/l, all 24 and 72 hr tests combined. Fatigue interval indicated by dashes (C = control, E = exposed).

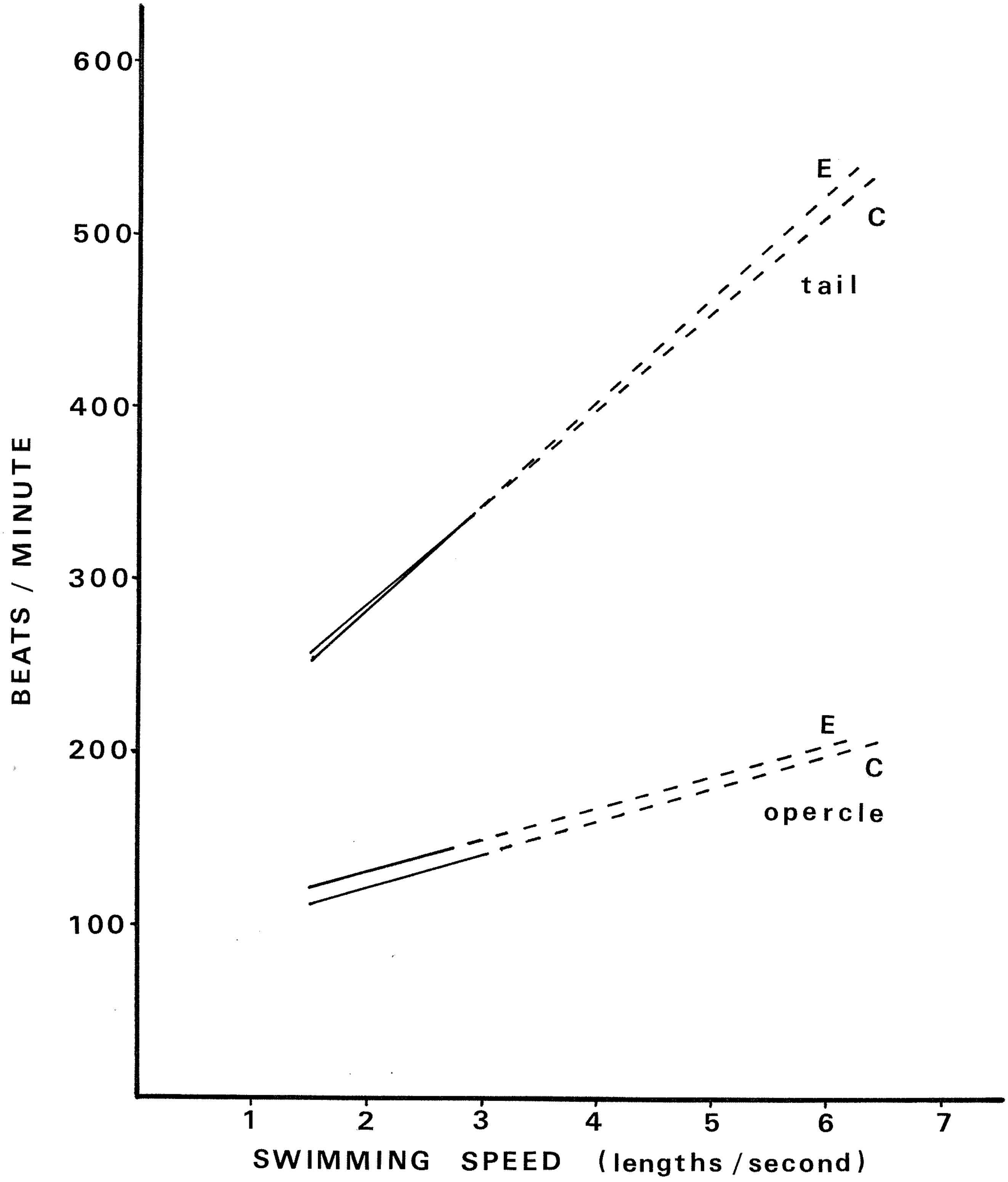

Fig. 48. Regression of swimming performance (tail and opercle beats/minute) on speed (lengths/second) for chinook salmon smolts exposed to volcanic ash and mudflow with average concentrations ranging from 943 to 4349 mg/l, all 24 and 72 hr tests combined. Fatigue interval indicated by dashes (C = control, E = exposed).

No significant statistical difference between the slopes or intercepts of any of the sets of regression lines occurred, nor were there significant differences in the means of the fatigue velocities (U-criticals, represented by the dashed portions of the lines). An interesting pattern emerged, however, that may be biologically significant. In combined results for both coho and fall chinook smolts, the tailbeat frequency and the respiration frequency were slightly higher among the fish exposed to sediments than among control fish. A slight overall difference was also seen in the fatigue intervals: the first and last exposed fish fatiguing a little sooner than the first and last controls. While these differences are not statistically significant, they tend to indicate that the fish exposed to suspended sediments were indeed somewhat stressed. Redding and Schreck (1981) noted increases in the levels of plasma corticosteroids and hematocrit, physiological responses correlated with sublethal stress in fishes, during exposures of juvenile steelhead trout to kaolin clay, topsoil and Mount St. Helens volcanic ash. These trends, however, were so small that the ability of exposed fish to compete for food or avoid predators and their abilities to grow and resist disease were probably not impaired. In the case of fall chinook, however, some aspect of their osmoregulatory process was evidently disrupted after exposure to high concentrations of volcanic ash without affecting their swimming performance.

Seawater Entry Test

Coho smolts exhibited significant saltwater mortality only after exposure to high levels of bentonite clay, but this was confounded by toxic effects of metals, as mentioned earlier, and therefore cannot simply be considered a sediment-related effect. Mudflow and volcanic ash exposures produced no significant seawater mortality on coho smolts in 96-hr testing. There is evidence to suggest, however, that coho often do not exhibit seawater mortality from smoltification or osmoregulatory problems until several months have passed (Mahnken et al. 1981). Since the saltwater tolerance of fall chinook smolts markedly decreased after high concentration exposure to volcanic ash, it is possible that whatever caused this decrease affected coho smolts as well, but that these seawater entry tests were simply of too short a duration to detect it. Mudflow sediment exposure did not seem to affect the fall chinook the way volcanic ash did, and perhaps its effects on the saltwater tolerance of coho smolts was likewise less severe than those of ash might be. In any case, it is not known by what mechanism the high concentrations of suspended ash may have affected saltwater tolerance, when mudflow exposure did not. More research is needed in this area.

Electron Micrographs

Sediments

Plates 1-8 are scanning electron micrographs of various sediments to which fish were exposed in 1980 and 1981.

Plate 1 shows a sample of the airfall volcanic ash collected at the Green River and used as the standard ash type for laboratory static and flow-through tests. Plate 2 is a higher magnification of ash from the same source, showing the typical characteristics of particles making up the sediment. Most of the particles are either solid glass or obsidian-like pieces, or are more porouslooking particles that appear to be the same high-silica material as the others, but that have been heated much more.

Plate 3 shows the North Fork mudflow sediment collected from the Toutle hatchery buildings that was used in 1981 laboratory testing. It is obvious from this picture (similar in magnification to Plate 1) that the average particle size is much smaller than that for standard ash (Plates 1 and 2). Plate 4 is a higher magnification of the mudflow sediment in which it can be seen that much of it is composed of what appear to be very fine ash particles.

Plates 5-7 are samples of sediments suspended in the Cowlitz River. Plate 5 shows particles that were in suspension just downstream from the mouth of the Toutle River on March 18, 1981. Plate 6 is a sample from the Cowlitz River at Kelso, Washington, approximately 12 river miles downstream from where the sample in Plate 5 was taken, collected on the same day and shown at the same magnification. It can be seen that most of the larger ash-like particles have fallen from suspension leaving mainly smaller, clay-like particles. Plate 7 is a higher magnification of material like that of Plate 6.

Plate 8 is a close-up of "Volclay 200" bentonite showing large conglomerations formed during evaporation of the sample. They would be broken down in solution. Greater than 70 percent of the particles of bentonite, when in solution, were less than 2 microns in diameter.

Gill Tissue

In most cases no consistent effect of the sediment exposures tested in this project could be detected histologically using standard tissue sections and light microscopy. With SEM, however, several interesting effects can be seen.

Plate 1. Airfall volcanic ash from the Green River. 100X.

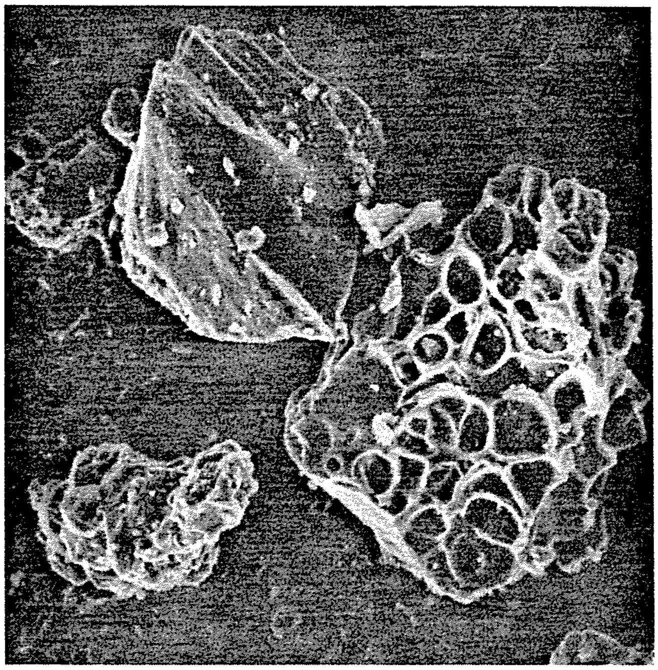

Plate 2. Airfall ash showing the two predominant particle types. 450X.

Plate 3. North Fork Toutle River mudflow sediment from the Toutle hatchery. 150X.

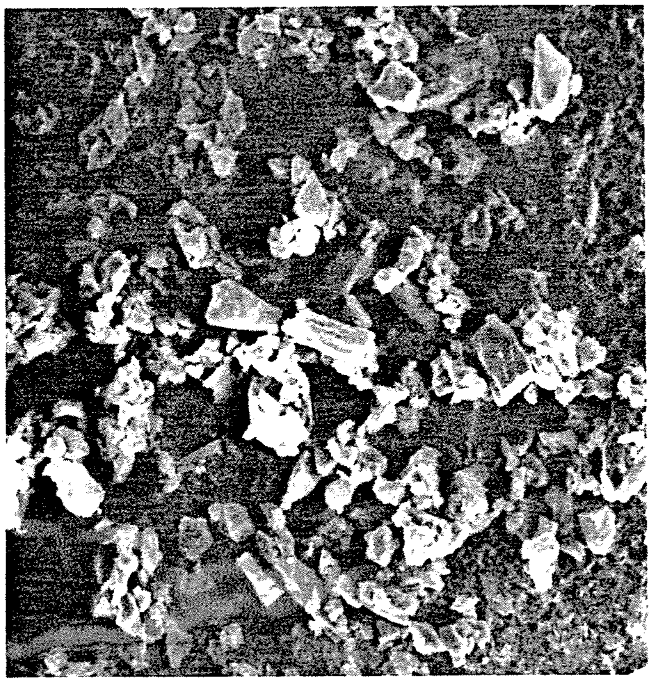

Plate 4. Mudflow sediment, 450X.

Plate 5. Suspended sediment from the Cowlitz River below the confluence of the Toutle River, 3/18/81. 150X.

Plate 6. Suspended sediment from the Cowlitz River at Kelso, 3/18/81. 150X.

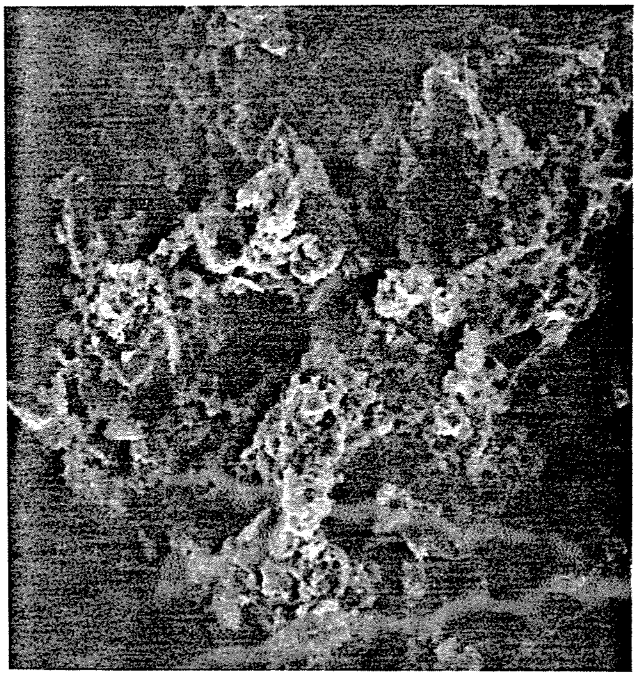

Plate 7. Cowlitz River suspended sediment, showing predominance of very fine clay particles, at Kelso. 500X.

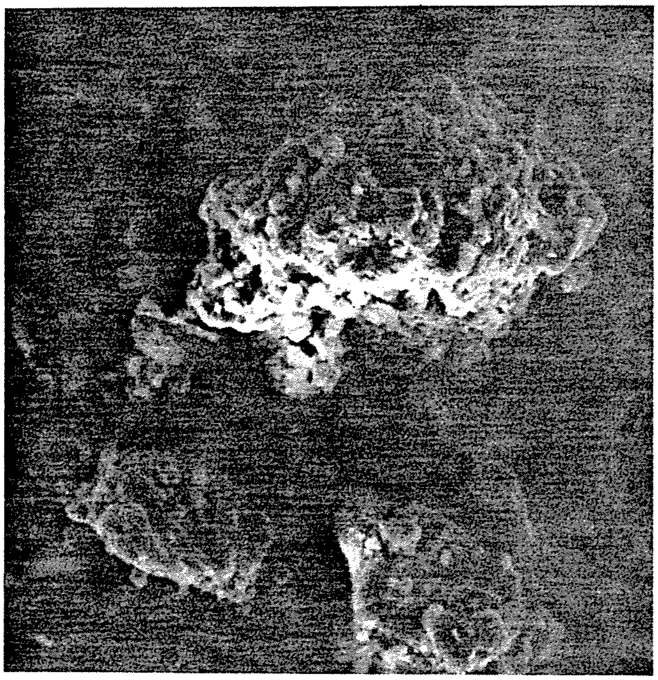

Plate 8. "Volclay 200" Ⓡ bentonite: conglomerations of clay particles, which break up in solution. 700X.

Plates 9 through 20 show several different aspects of the gill surface that are not visible by standard histological analysis. Plate 9 and 10 show some typical controls.

Plate 9 is a coho smolt control gill showing filaments, lamellae and filament tips. Plate 10 shows that same for fall chinook smolts at the same magnification. Plate 10 actually shows an exposed fish, but the view is typical of an unaffected tissue sample. Plate 12 is a much higher magnification of the same gill.

Minor coating of the gill lamellae is seen in Plate 11. This coho smolt was exposed to "Volclay 200" bentonite, the characteristics of which are quite different from the other sediments used, as has been previously discussed. Similar coating was never seen in gill specimens taken from any of the fish exposed to mudflow sediment or to volcanic ash. What was seen, but only very rarely, was single large particles (much larger than the average particle sizes of the sediments used) wedged between lamellae, as in Plate 12. In cases such as this it is interesting to note that even though the particles are at times very angular and have fairly sharp edges, there is no apparent damage to the immediately surrounding tissue: neither cutting nor abrasion of the epithelium or its micro-ridged surface, nor an obvious inflammatory response can be detected. If such particles were embedded for a long period of time and were not easily dislodged by the fish coughing, for example, then perhaps some abrasion and inflammation might occur. In fact, it was only extremely rare that sediment particles were found physically in conjunction with tissue damage. Plate 13 shows an area of coho gill in which a more or less typical-looking ash particle has become embedded in the tissue of the gill filament, evidently chunking-out and lifting a flap of epithelium. While it cannot be said with certainty that the particle actually caused the damage as opposed to becoming embedded after the fact, this was the only time that a particle was found remaining at a point of damage. Several mucin glands are seen to have discharged in the area of the damage.

In several of the gill samples studied, what appear to be the external manifestations of vascular aneurysms were seen, as in Plate 14. The presence of vascular aneurysms was confirmed histologically in gill sections from different fish. No correlation could be made between sediment exposure and vascular aneurysms, however, because control fish exhibited them almost as often as did exposed fish.

Much more typically seen with the SEM and more easily correlated to exposure to suspended sediments because it was rare in control fish, is focal epithelial sloughing, as pictured in Plates 15, 16, and 17. Such damage has been correlated to toxicants in the water (Hawks 1976) and is considered to be a fairly typical response to irritants as well (Hawks, personal communication 1981). Plate 15 shows the typical dying and sloughing of a number of epithelial cells in a small area, the sort of focal damage that in many of the gills studied was fairly widespread. Plate 16 shows where only a single cell has died and fallen away — this was seen fairly often on some gills. Plate 17 catches the early stages of epithelial sloughing, just as several cells are dying. Note the lack of a distinct microvillar surface on the dying cells, a fairly common occurrence before cell death (Hawks, personal communication 1981). As these cells fall away, areas similar to those in Plate 15 and 16 will result. While not immediately life-threatening to the fish, unless the

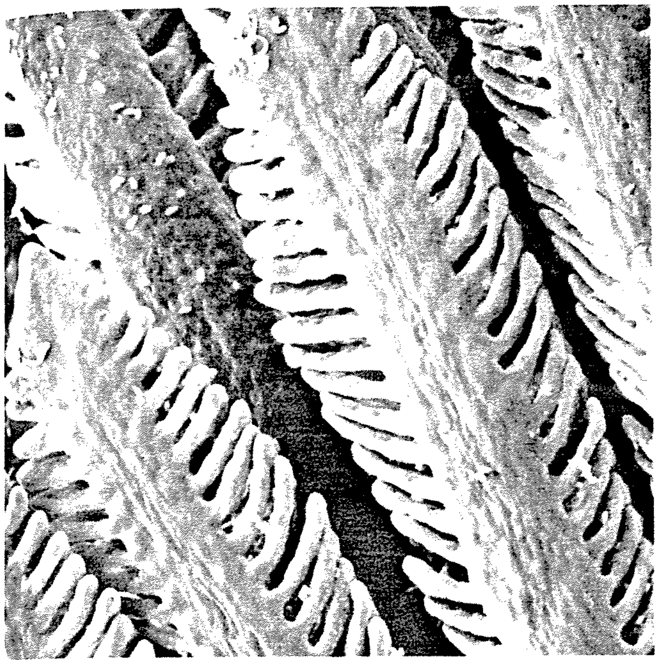

Plate 9. Normal coho gill filaments and lamellae. 150X.

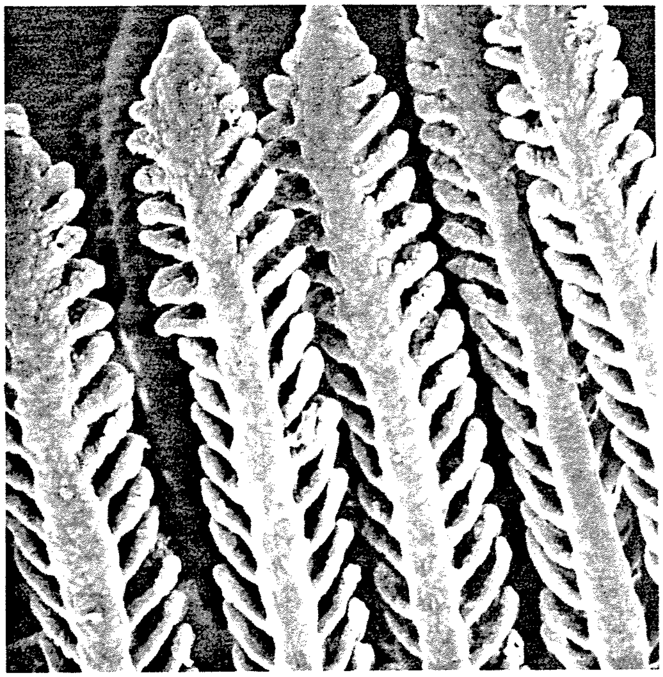

Plate 10. Normal fall chinook gill filaments and lamellae. 150X.

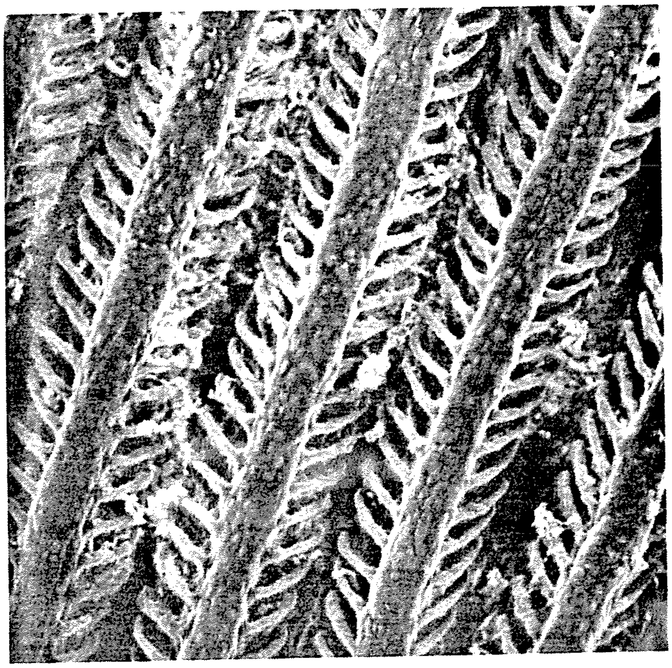

Plate 11. Minor clogging of coho gill lamellae with bentonite. 100X.

Plate 12. Volcanic ash particle lodged between chinook gill lamellae. Note lack of damage/inflammation. 1400X.

Plate 13. Sediment particle in conjunction with damage to coho gill filament. Note discharged mucin glands in area. 500X.

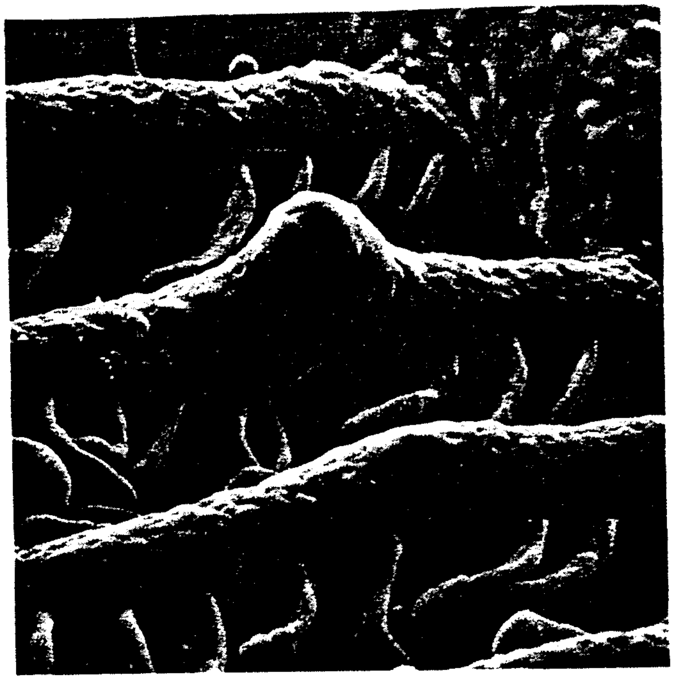

Plate 14. Probable vascular aneurysm on coho gill filament. 300X.

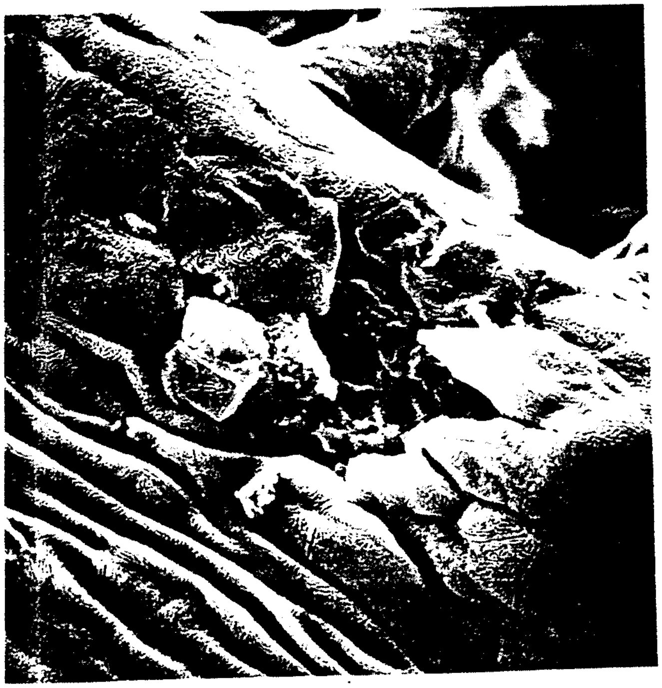

Plate 15. Sloughing of several epithelial cells on coho gill filament after suspended sediment exposure. 1200X.

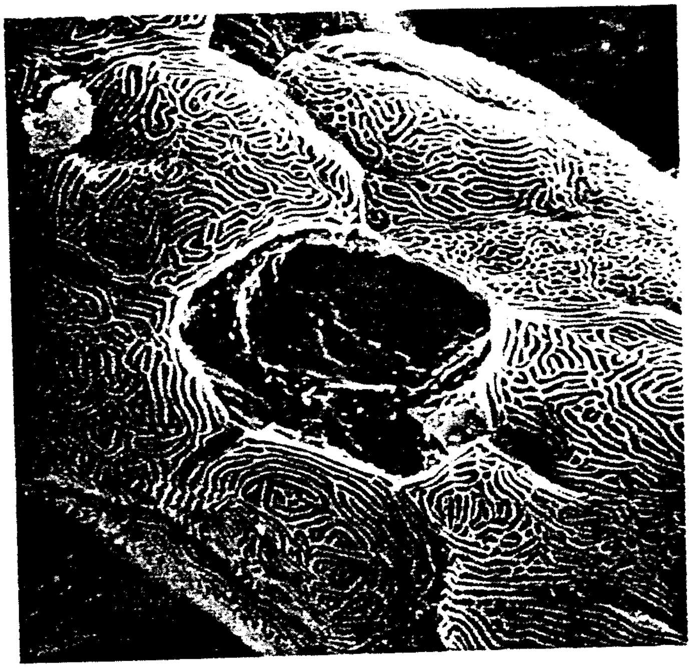

Plate 16. Coho gill filament after death and sloughing of a single epithelial cell. 2500X.

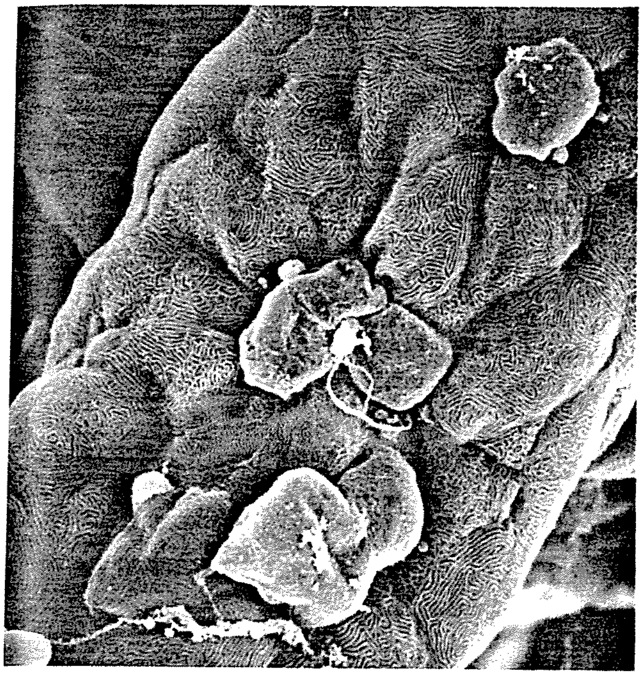

Plate 17. Dying epithelial cells on coho gill filament, prior to sloughing. Compare with Plates 15, 16. 1300X.

Plate 18. Microvillar structure on the surface of a normal coho gill. 2000X.

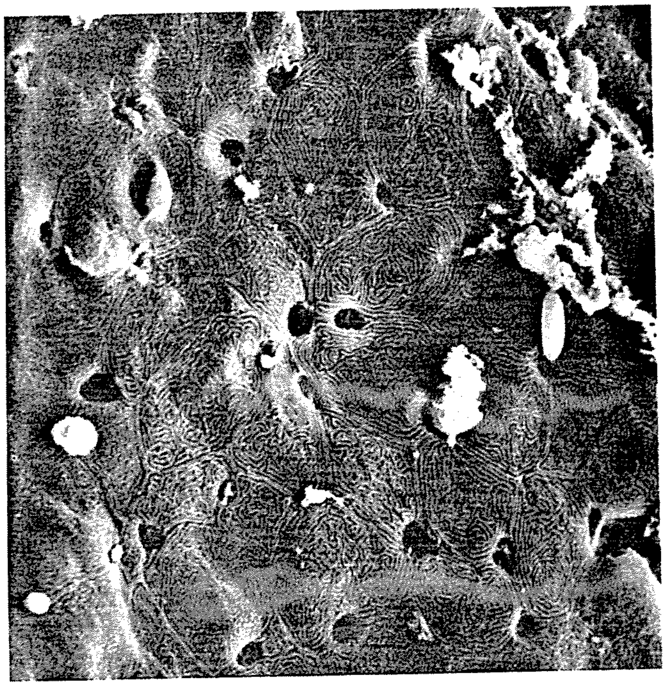

Plate 19. Discharged mucin glands on fall chinook gill surface following suspended sediment exposure. 1000X.

Plate 20. Fall chinook gill surface with discharged mucin glands following suspended sediment exposure. 2500X.

sloughing is so widespread that little surface area remains for gas exchange, all such areas are prime targets for the entrance of any pathogens present in the water. The chances of secondary infection are thus greatly increased.

Another fairly commonly seen condition, especially among fall chinook exposed to volcanic ash, was the presence of what appeared to be much greater numbers of dicharged mucin glands than on control gills. Plate 18 is a high magnification of the intricate microvillar structure on the surface of the gill epithelium of a control coho. Fall chinook look very similar. Comparing this with Plates 19 and 20, gills from ash-exposed fall chinook smolts, the qualitative difference is obvious. Quantitative analysis required more tissues from the same treatment group than were available. Also, variation between individuals and between different areas on the same individual gill can be quite large (Hawks, personal communication 1981). However, control fish were never seen to have nearly the number of discharged mucin glands as some of the exposed fish, examples of which are given in Plates 19 and 20. As with epithelial sloughing, discharged mucin glands have been correlated to toxicants in the water (Hawks 1976) and the discharging of extra mucus onto the gills is considered a standard response of fish to irritants in the water such as sediment particles in suspension. It should be noted, however, that never were thick coatings of mucus seen on the gills of fish that were samples for histological or SEM analysis, or on any other fish. So while more mucus may have been discharged onto the gill surface in some instances, the amount was probably never sufficient by itself to cause a significant impairment of gas exchange across the gills. In the very high sediment concentrations in the static LC50 testing, however, it may have helped contribute to any possible effects from the sediment in reducing the availability of oxygen to the fish, thus being a small part of the overall cause of death by hypoxia (Smith 1978).

SUMMARY AND CONCLUSIONS

The survival and passage of juvenile salmon in the streams and rivers affected by mud-flow and airfall volcanic ash presented management concerns for hatchery and wild fish not directly destroyed by the May 18, 1980 eruption of Mount St. Helens. The tolerance of coho and chinook salmon to suspended sediment was determined by live-box (in river) and static laboratory bioassays. The 96-hr LC50 suspended sediment concentrations determined by live-box bioassay were 1,217, 509 and 488 mg/l for presmolt coho, coho smolts and fall chinook smolts, respectively. The 96-hr LC50 comparative static bioassays were 18,672, 28,184 and 19,364 mg/l in volcanic ash for presmolt coho, coho smolts and fall chinook smolts. Live-box bioassays integrate numerous additional water quality parameters (i.e., temperature, velocity, organic compounds, trace metals, etc.), while only suspended sediment is tested in the laboratory. However, handling can also be an important factor in the conduct of live-box studies. The influence of handling was minimized as much as possible and the control fish were always exposed to the maximum (hauled farthest and placed last) in each experiment.

It is apparent that the smolt stage of both coho and chinook was less tolerant of suspended sediment than presmolt coho salmon in the field. However, coho smolts were found most tolerant in comparable static tests. This may have resulted from the unavoidable testing of coho smolts from the Cowlitz hatchery in the field and Skykomish hatchery smolts in the laboratory. Because these data were developed on two different hatchery stocks, it is unknown whether coho salmon smolts are actually more sensitive in the field. Noggle (1978) estimated LC50 values for wild coho presmolts to range from 1,200 mg/l in August to about 35,000 mg/l in November in static laboratory bioassays. He found the minimum LC50 was coincident with the maximum summer ambient temperature. This was consistent with live-box results obtained in the present study. Our static tests minimized the change in water temperature and consistently found high tolerance to suspended sediment. The high sensitivity of fall chinook salmon smolts in the field appears to be consistent with the smaller size of this species. The wide disparity in the live-box and static tests was consistent and indicates a low field tolerance when other parameters are uncontrolled. However, the tolerance to suspended sediments in static tests was consistently high. Static tests of coho and fall chinook smolts in mudflow sediment (96-hr LC50) were 29,580 and 11,000 mg/l. The static test with coho smolts in bentonite declined to a 96-hr LC50 of 2,118 mg/l, but this was confounded with high amounts of trace metals.

Complete and partial mortality occurred consistently with coho presmolts in the Toutle and lower Cowlitz Rivers, respectively, during the summer following the May 18, eruption. Live-box tests during the spring of 1981 showed partial mortality only in the lower Toutle, north fork Toutle and Green Rivers. Survival was not affected in the south fork Toutle and lower Cowlitz Rivers in 1981. The increase in survival of fish exposed in live-boxes in 1981 was directly related to the decline in suspended sediment concentration. Within one winter season the suspended sediment concentrations had declined to a level which no longer was expected to reduce survival during passage of emigrant smolts. The data of Dawley et al. (1981) estimated that the emigration rate of coho salmon smolts in the lower Columbia River marked upstream and recaptured at Jones Beach in the lower Columbia River was about 9 km/day. At this rate emigrant coho smolts would take 4 days to pass the lower 35.4 km of the lower Cowlitz River. Peddicord et al. (1975) found that mortality after four days was nearly the same as after ten days. Very little mortality occurred in this study during the final 24 hr of each 96-hr test. A similar observation was made by Noggle (1978). The 96-hr LC50 values reported here are probably close to the lethal threshold for acute exposure to the suspended sediment tested.

Sublethal effects were tested by exposing fish in artificial stream channels to suspended sediment concentrations of 0-16 percent of the 96-hr LC50. The velocity of water in each test was controlled at 0.5, 1.0, and 1.5 l/sec for low, medium, and high concentrations, respectively. Exposed and control fish were tested at 24 and 72-hr intervals in a 96-hr exposure period. Testing was conducted by a determination of swim chamber performance followed by a seawater entry test in a subsequent 96-hr period. No consistent statistically significant effects was found based on swimming performance for either coho or chinook smolts in volcanic ash or mudflow sediments. No effect was found which could be related to changes in smolt stage when the control fish were pooled by species. Pooled coho smolts which had been exposed to volcanic ash showed that the slope of stage 2 was greater than stages 3-5, indicating a greater sensitivity of fish less advanced in smoltification.

The seawater entry testing did not indicate a response with coho in volcanic ash or mudflow sediments; however, chinook smolts exposed to mudflow and ash sediments indicated a greater sensitivity. Seawater entry tests are not precise tests and do not simulate a salinity gradient during the time a smolt might make the transition into sea water. Results reflect the condition of the test animal and aid in predicting possible effects on emigrant smolts.

Extensive histological analysis of the gill tissue from both field and laboratory exposed salmon did not show effect when compared with controls. This was verified by numerous tissue scans with an electron microscope.

The laboratory testing has shown that juvenile chinook and coho salmon are very tolerant to high suspended sediment concentrations and low water velocities under controlled conditions. However, the tolerance may be reduced considerably when fish are exposed to suspended sediment in combination with other factors in the field. The rapid reduction in the suspended sediment concentrations over one winter season suggest that juvenile salmon may be able to survive passage through most of the system, although high suspended sediment loads may prevent salmonid reproduction for a considerable time due to excessive gravel sediments in the affected rivers. Tributaries unaffected by high sediment concentrations are expected to continue to produce where incubation and rearing can be successfully completed. Recovery of the rivers in the area is occurring and the passage and survival of anadromous salmonids should be managed so that this natural recovery is not impeded.

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Appendix Table 1 (pp. 1-23). Water quality data by river and sample site obtained during the live-box bioassay testing periods.

LOCATION	DATE	TIME	TURBIDITY JTU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER-ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC-TIVITY MOSM/L	VELOCITY FT/SEC
LEWIS RIVER										
	800718	900	5	0	-0	13.6	6.8	11.2	-0	-0
	800726	1015	4	0	6.8	14.6	6.8	11.5	-0	-0
	800730	1015	4	0	-0	14.2	-0	10.2	-0	-0
	800806	930	5	0	-0	13.6	-0	8.6	-0	-0
	800815	1000	6	0	12.0	12.2	6.7	10.2	-0	-0
	800822	1030	4	0	5.2	13.0	7.1	10.3	-0	-0
	800828	1530	4	0	24.4	12.5	7.1	10.1	-0	-0
	800904	900	5	0	.5	13.5	6.8	9.2	25	-0
	800911	1500	6	0	19.0	14.1	6.2	9.7	24	-0
	800919	900	5	0	33.7	11.7	5.8	9.5	26	.25
	800925	1845	5	0	60.8	13.4	6.2	9.2	28	.45
	801001	1620	-0	0	2.0	13.5	6.6	9.0	21	.20
	801009	1630	6	0	44.5	12.5	6.6	9.6	26	1.10
	801016	1520	-0	0	9.4	11.1	6.5	10.0	29	-0
	801023	1500	5	0	-0	11.1	6.2	9.2	25	.05
	801031	800	-0	0	15.9	11.4	6.3	9.1	29	-0
	801105	1630	12	0	8.2	12.8	6.4	9.1	29	-0
	801114	2030	14	0	33.6	12.0	6.7	8.9	36	-0
	810318	2100	17	0	34.3	7.5	7.1	10.6	40	.09
	810403	1015	15	.02	1.5	-0	6.9	-0	-0	1.40
	810416	930	7	.10	15.0	8.4	7.1	10.0	33	-0
	810501	1000	11	0	.2	9.0	7.0	-0	-0	2.60
	810514	945	5	.01	.6	8.7	6.4	11.1	34	-0
	810625	1100	32	0	2.5	11.8	7.1	11.4	30	2.30
	810715	1000	12	0	6.2	14.0	7.2	9.2	36	1.05
MIN			4	0	.2	7.5	5.8	8.6	21	.05
MAX			32	.10	60.8	14.6	7.2	11.5	40	2.60
VALIDN			22	25	21	24	23	23	16	10
COLUMBIA R AT KALAMA										
	800708	1130	12	-0	7.6	20.0	7.0	11.4	-0	-0
	800709	1345	17	-0	11.2	18.8	7.2	-0	-0	-0
	800710	815	17	-0	25.6	17.9	7.2	10.6	-0	-0
	800711	1000	11	-0	13.6	18.3	7.1	11.5	-0	-0
	800712	1000	9	0	19.0	18.4	7.2	11.6	-0	-0
	800718	930	13	0	-0	19.2	7.5	10.5	-0	-0
	800722	1100	3	-0	33.2	20.4	7.3	10.2	-0	-0
	800723	1300	6	-0	16.8	20.6	7.3	12.6	-0	.20
	800724	1045	20	-0	24.8	20.6	7.5	11.7	-0	.26
	800725	900	14	-0	41.6	20.2	7.6	12.3	-0	.37
	800726	1115	10	0	-0	20.7	7.6	10.2	-0	.46
	800730	1100	12	0	-0	21.1	-0	8.8	-0	-0
	800806	1000	13	0	-0	20.1	-0	5.7	-0	-0
	800812	1030	5	-0	12.7	21.4	7.4	8.8	-0	0
	800813	1420	30	-0	25.0	21.2	-0	9.0	-0	.20

LOCATION	DATE	TIME	TURBIDITY ITU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPERATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUCTIVITY MOSM/L	VELOCITY FT/SEC
COLUMBIA R. AT KALAMA, CONT.										
	800814	1330	37	-0	30.6	20.9	7.3	-0	-0	0
	800815	1100	22	0	15.8	20.5	7.2	8.9	-0	-0
	800816	1200	10	-0	10.4	20.4	7.6	9.2	-0	0
	800822	1130	12	0	11.8	20.0	7.7	9.1	-0	-0
	800828	1430	10	0	79.2	20.1	8.1	9.4	-0	-0
	800904	1000	5	0	3.8	19.0	7.4	8.2	138	-0
	800909	1200	1	-0	9.5	19.6	7.4	8.5	133	-0
	800910	1530	12	-0	-0	20.1	7.3	8.6	133	-0
	800911	1630	7	0	21.2	19.5	7.5	8.5	137	-0
	800912	1830	4	-0	21.2	19.4	7.4	8.5	143	-0
	800913	1200	13	-0	22.0	19.0	7.3	8.0	147	-0
	800919	945	2	0	29.4	18.2	6.9	8.5	148	.10
	800925	1750	5	0	7.4	17.8	7.4	8.1	140	.10
	801001	1705	12	0	4.7	18.1	7.6	8.3	145	.05
	801007	1400	12	-0	13.9	17.7	7.4	8.6	153	.30
	801008	1530	6	-0	19.2	17.7	7.3	8.8	155	.10
	801009	1700	4	0	11.1	17.3	7.4	8.6	155	-0
	801010	-0	32	-0	70.5	16.9	7.4	8.6	161	-0
	801011	1400	3	-0	12.3	16.9	7.4	8.5	168	-0
	801016	1555	-0	0	-0	15.7	7.3	8.9	161	-0
	801023	1545	6	0	10.7	15.1	7.3	8.3	157	.25
	801031	1030	-0	0	9.9	13.1	7.3	9.4	161	.20
	801105	1700	5	0	14.2	13.2	7.4	9.2	153	-0
	801114	1830	7	0	10.4	10.2	7.5	10.3	162	.50
	810319	1230	9	.10	20.6	7.8	6.9	10.6	155	0
	810403	1100	19	0	49.1	8.5	6.9	-0	-0	1.60
	810416	1030	6	0	89.5	9.6	7.6	10.0	111	-0
	810501	1030	14	.02	.5	13.0	6.9	-0	-0	1.10
	810514	1000	6	.04	53.1	13.4	7.4	10.5	143	-0
	810625	1130	13	0	35.1	16.7	7.5	10.8	103	.10
	810715	1030	29	.02	15.5	17.8	7.2	9.0	115	.80
MIN			1	0	.5	7.8	6.9	5.7	103	0
MAX			37	.10	89.5	21.4	8.1	12.6	168	1.60
VALIDN			44	26	40	46	43	42	24	21
KALAMA RIVER										
	800712	900	3	0	3.6	12.7	7.0	10.9	-0	-0
	800718	830	10	0	-0	15.1	7.1	10.8	-0	-0
	800722	1130	1	-0	11.4	17.9	7.0	11.6	-0	-0
	800723	1200	5	-0	18.0	17.1	7.3	12.1	-0	.80
	800724	1115	6	-0	44.0	16.2	6.9	12.0	-0	.94
	800725	930	3	-0	24.4	16.3	7.2	11.2	-0	.86
	800726	915	12	0	11.0	16.8	7.0	10.4	-0	.84
	800730	1000	3	0	-0	16.6	-0	9.1	-0	-0
	800806	830	6	0	-0	14.4	-0	-0	-0	-0
	800812	1100	8	-0	35.9	17.0	6.7	9.5	-0	.60
	800813	1515	15	-0	14.0	16.2	6.8	10.0	-0	.42
	800814	1430	8	-0	12.2	15.6	7.0	11.6	-0	1.10

LOCATION	DATE	TIME	TURBIDITY JTU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER- ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC- TIVITY MOSM/L	VELOCITY FT/SEC
KALAMA R., CONT.										
	800815	1130	2	0	6.8	14.4	7.0	9.9	-0	1.35
	800816	1300	6	-0	5.6	14.1	6.9	9.5	-0	.98
	800822	1000	21	0	9.5	14.3	7.3	9.6	-0	-0
	800828	1330	80	0	86.4	12.6	7.5	10.2	-0	-0
	800904	1030	12	0	14.0	14.2	6.8	9.2	39	-0
	800909	1230	18	-0	56.4	14.4	6.7	9.7	38	-0
	800910	1630	3	-0	15.5	16.0	7.1	9.6	37	-0
	800911	1600	2	0	21.2	16.3	7.1	9.5	40	-0
	800912	1900	12	-0	7.6	15.3	7.2	9.7	45	-0
	800913	1300	5	-0	18.4	13.6	7.2	9.5	46	-0
	800919	1025	3	0	6.2	12.8	6.4	10.1	46	.40
	800925	1720	6	0	21.4	13.2	7.0	9.6	35	1.00
	801001	1540	-0	0	3.4	14.7	7.3	9.2	37	.70
	801007	1430	0	-0	4.9	13.1	7.1	9.9	43	.50
	801008	1600	8	-0	15.1	13.9	7.1	9.9	44	.65
	801009	1730	2	0	12.4	12.2	7.2	9.8	44	-0
	801010	-0	5	-0	9.0	11.0	7.1	10.1	45	-0
	801011	1630	2	-0	10.1	11.2	7.2	10.0	50	-0
	801016	850	-0	0	15.5	7.8	6.7	10.8	47	-0
	801023	1700	10	0	6.1	7.7	7.3	10.9	41	.40
	801031	1100	-0	0	13.4	8.2	6.8	10.6	43	.60
	801105	1600	20	0	30.0	10.6	6.9	9.9	29	-0
	801114	2000	-0	0	31.4	5.8	-0	11.2	38	-0
	810319	1330	7	.20	23.9	8.2	7.0	10.5	30	1.80
	810403	1130	13	.01	44.6	7.0	6.9	-0	-0	1.70
	810416	1015	0	0	7.0	8.6	7.0	9.5	24	-0
	810501	1100	5	0	.3	12.5	7.0	-0	-0	.05
	810514	1030	10	.01	22.6	11.9	6.9	11.2	29	-0
	810625	1200	22	0	76.0	14.2	7.5	10.1	24	.10
	810715	1100	5	0	12.0	14.7	7.1	8.7	34	.22
MIN			0	0	.3	5.8	6.4	8.7	24	.05
MAX			80	.20	86.4	17.9	7.5	12.1	50	1.80
VALIDN			38	26	39	42	39	39	24	21
LOWER COWLITZ AT RRB										
	800712	1145	145	.30	379.0	17.2	7.3	-0	-0	-0
	800718	1015	251	.20	-0	14.5	7.0	11.6	-0	-0
	800726	1230	360	.15	1160.6	16.2	7.2	10.8	-0	-0
	800730	1130	460	.70	-0	16.1	-0	11.9	-0	-0
	800806	1100	575	.70	-0	14.3	-0	9.2	-0	-0
	800815	1200	740	.40	1360.2	14.5	7.0	9.9	-0	-0
	800822	1200	625	.37	1217.1	14.3	7.3	8.9	-0	-0
	800828	1300	1290	.40	2120.5	12.5	-0	9.4	-0	-0
	800904	1800	840	.25	1617.3	15.4	6.9	8.9	70	-0
	800913	1530	1150	.39	1753.0	12.8	7.3	9.0	81	-0
	800919	1200	950	.20	1478.6	12.2	6.5	9.7	68	0
	800925	1930	1000	.26	1435.8	13.4	6.3	9.1	63	.10
	801001	1755	1000	.57	1897.1	13.0	6.8	8.8	58	.10

LOCATION	DATE	TIME	TURBIDITY JTU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER-ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC-TIVITY MOSM/L	VELOCITY FT/SEC
LOWER COWLITZ AT R.R. BRIDGE, CONT.										
	801008	1630	740	.20	1131.1	13.1	6.6	9.6	59	0
	801016	1635	-0	.38	1219.3	12.2	7.1	9.7	64	-0
	801023	1430	450	.11	959.3	11.0	6.1	9.1	56	.10
	801031	1130	500	.35	817.7	10.2	6.6	10.2	72	.05
	801105	1730	825	.48	1373.2	11.5	6.7	9.6	55	-0
	801114	1800	-0	.36	1048.6	8.3	-0	10.1	69	.50
	810319	2030	118	-0	464.9	9.1	7.0	9.6	86	1.70
	810403	1200	105	.06	192.9	8.0	7.0	-0	-0	1.15
	810417	1900	115	.20	259.0	10.9	6.7	8.9	84	-0
	810501	1115	86	.05	156.2	12.5	7.0	-0	-0	.20
	810513	1100	47	.03	71.7	13.4	6.6	8.5	87	-0
	810625	1230	-0	.20	-0	13.3	7.4	11.0	57	0
	810715	1230	37	.05	59.6	15.2	6.9	8.3	89	.20
MIN			37	.03	59.6	8.0	6.1	8.3	55	0
MAX			1290	.70	2120.5	17.2	7.4	11.9	89	1.70
VALIDN			23	25	22	26	22	23	16	12
COLUMBIA AT PULPMILL										
	800708	1245	52	-0	60.2	19.1	7.0	10.5	-0	-0
	800709	1430	56	-0	67.4	18.1	7.0	7.6	-0	-0
	800710	1030	63	-0	80.6	17.1	7.0	9.5	-0	-0
	800711	1100	93	-0	98.8	17.9	7.1	9.8	-0	-0
	800712	1115	71	.10	171.0	18.3	7.3	10.6	-0	-0
	800718	1100	47	.50	-0	19.1	7.2	11.3	-0	-0
	800722	1230	34	-0	52.6	20.3	7.5	11.2	-0	-0
	800723	1400	36	-0	54.1	20.6	7.3	12.1	-0	.81
	800724	1200	55	-0	83.6	20.3	7.5	11.3	-0	.36
	800725	1015	58	-0	94.4	19.9	7.6	11.1	-0	1.23
	800726	1330	61	1.25	88.4	20.8	7.5	10.3	-0	.34
	800730	1200	47	0	-0	21.2	-0	9.2	-0	-0
	800806	1145	59	0	-0	20.1	-0	10.4	-0	-0
	800812	1230	80	-0	97.0	21.2	7.3	10.4	-0	.85
	800813	1700	58	-0	79.4	21.0	7.2	6.7	-0	.30
	800814	1500	60	-0	113.4	20.6	7.5	8.7	-0	.35
	800815	1245	53	.70	65.4	20.5	7.4	-0	-0	.22
	800816	1500	34	-0	51.9	20.2	7.5	10.5	-0	.20
	800822	1230	94	0	116.2	19.9	7.6	8.2	-0	-0
	800828	1215	88	0	205.4	19.5	7.9	8.5	-0	-0
	800904	1900	70	.10	103.2	19.0	7.3	8.5	136	-0
	800909	1345	122	-0	197.6	19.2	7.1	7.9	132	-0
	800910	1700	60	-0	36.4	19.9	7.4	8.6	137	-0
	800911	1730	25	0	38.0	19.6	7.4	8.5	138	-0
	800912	2000	50	-0	62.8	19.5	7.1	8.3	193	-0
	800913	1530	92	0	144.2	18.6	7.8	8.2	168	-0
	800919	1230	15	0	18.6	18.4	7.1	8.6	147	.15
	800925	1520	56	0	79.4	18.0	7.1	7.9	150	.20
	801001	1845	87	0	122.7	17.0	7.3	8.2	143	.10
	801007	1630	12	-0	111.1	17.3	7.3	8.8	152	.30

LOCATION	DATE	TIME	TURBIDITY ITU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER- ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC- TIVITY MOSM/L	VELOCITY FT/SEC
COLUMBIA R. AT PULPMILL, CONT.										
	801008	1730	60	0	227.9	17.8	7.1	8.8	209	0
	801009	1900	38	-0	90.1	17.1	7.2	8.7	176	-0
	801010	-0	4	-0	17.3	16.7	7.2	8.3	162	-0
	801011	2100	22	-0	47.9	16.4	7.3	8.8	175	-0
	801016	1905	-0	0	82.8	15.5	7.2	8.7	195	-0
	801031	1200	55	0	40.9	13.2	7.1	9.6	226	-0
	801105	1800	55	0	105.4	13.0	7.3	9.1	169	-0
	801114	1730	42	0	91.5	10.0	-0	9.8	170	.10
MIN			4	0	17.3	10.0	7.0	6.7	132	0
MAX			122	1.25	227.9	21.2	7.9	12.1	226	1.23
VALIDN			37	19	35	38	35	37	18	15
COWEMAN RIVER										
	800712	830	5	0	42.1	16.8	7.4	10.3	-0	-0
	800718	800	17	0	-0	19.1	7.0	8.8	-0	-0
	800726	830	13	.05	19.6	20.8	6.9	8.6	-0	-0
	800730	830	10	.01	9.6	21.4	7.0	8.0	-0	-0
	800806	800	7	0	-0	17.0	-0	5.2	-0	-0
	800815	845	28	0	17.6	15.8	7.0	9.4	-0	-0
	800822	930	8	0	5.2	17.0	7.4	9.3	-0	-0
	800828	800	6	0	21.8	13.0	7.4	9.6	-0	-0
	800904	1730	11	0	.4	16.4	7.3	10.0	51	-0
	800913	1100	11	0	7.6	15.2	6.6	9.1	70	-0
	800919	800	25	0	4.4	14.4	7.1	10.6	69	2.00
	800925	2000	5	0	13.8	13.6	6.7	9.1	58	1.70
	801001	1940	11	0	3.6	14.4	7.1	9.0	63	1.50
	801011	1300	3	0	31.3	11.5	7.4	11.1	70	-0
	801016	700	-0	0	12.7	7.3	6.8	8.4	104	-0
	801023	1830	35	0	3.5	7.6	7.1	10.7	66	.90
	801031	1230	10	0	23.3	7.9	7.0	11.1	69	.50
	801105	1500	18	0	11.3	10.7	7.1	9.8	57	-0
	801114	800	-0	0	-0	4.2	6.5	11.9	42	1.40
	810319	1345	5	0	32.4	7.6	7.0	10.8	42	1.60
	810402	1830	-0	.04	-0	-0	-0	-0	-0	.40
	810417	1830	0	.03	41.1	11.6	6.9	8.8	35	-0
	810429	2030	6	.01	.4	16.0	7.0	-0	-0	.20
	810513	1500	0	.01	1.6	13.6	6.9	9.8	38	-0
	810627	1000	61	-0	.3	12.6	6.8	11.7	41	0
	810717	1100	7	.03	7.3	17.5	7.2	9.5	55	1.10
MIN			0	0	.3	4.2	6.5	5.2	35	0
MAX			61	.05	42.1	21.4	7.4	11.9	104	2.00
VALIDN			23	25	22	25	24	24	16	11

LOCATION	DATE	TIME	TURBIDITY ITU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER-ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC-TIVITY MOSM/I	VELOCITY FT/SEC
COWLITZ. KELSO WEST										
	800708	1330	345	-0	637.6	16.2	6.8	11.2	-0	-0
	800709	1515	280	-0	421.4	14.0	6.8	8.7	-0	-0
	800710	1100	430	-0	538.8	12.3	6.8	10.4	-0	-0
	800711	1130	390	-0	1090.0	13.0	6.8	10.7	-0	-0
	800712	1215	350	.80	457.2	14.9	6.8	10.9	-0	-0
	800722	1300	235	-0	509.6	16.4	6.8	17.9	-0	-0
	800723	1445	575	-0	1243.0	16.8	6.8	10.6	-0	.14
	800724	1230	360	-0	1096.2	15.7	7.7	15.1	-0	.24
	800725	1045	280	-0	1003.4	14.9	6.9	12.3	-0	1.40
	800726	1430	375	-0	1054.1	17.5	7.3	10.4	-0	1.04
	800812	1400	600	-0	1065.9	15.7	-0	8.2	-0	.72
	800813	1810	605	-0	1151.8	15.8	7.2	6.6	-0	.55
	800814	1600	690	-0	1351.8	15.4	6.9	8.3	-0	.74
	800815	1445	445	.40	851.1	14.1	7.2	9.6	-0	.60
	800816	1700	980	-0	1581.2	15.3	7.0	9.0	-0	.40
	800909	1500	1200	-0	2372.5	14.9	6.7	9.1	69	-0
	800910	1730	1050	-0	2820.0	15.7	6.6	9.7	68	-0
	800911	1000	1005	1.00	2645.4	13.2	6.2	9.1	67	-0
	800912	2030	-0	-0	2519.6	14.9	6.5	8.9	81	-0
	800913	1545	1250	-0	2366.0	13.0	7.0	9.2	83	-0
	801007	1730	725	-0	1452.4	12.3	6.6	9.7	56	.40
	801008	1800	625	-0	1714.1	11.8	6.5	9.6	60	1.00
	801009	2000	800	-0	1615.5	10.8	6.6	9.5	60	-0
	801010	2000	860	-0	1790.0	11.1	6.7	9.7	61	-0
	801011	2130	710	-0	1747.9	10.9	6.6	9.7	62	-0
	801016	630	-0	.52	1385.4	10.1	6.6	10.7	63	-0
	801023	1900	535	.58	1429.1	9.9	6.4	9.1	60	-0
	810316	1430	103	-0	230.3	8.9	7.0	9.8	77	.80
	810317	1430	132	-0	211.4	8.7	7.0	10.1	-0	.55
	810318	1400	96	.90	222.8	8.9	6.8	9.9	82	.54
	810319	1430	92	-0	119.4	9.1	7.0	9.8	84	.50
	810320	1430	58	-0	120.9	8.5	6.8	9.9	90	.40
	810330	2030	144	-0	340.6	-0	6.9	-0	-0	.35
	810331	2030	262	-0	827.5	7.0	7.1	-0	-0	.60
	810401	2030	184	.45	446.7	8.3	6.7	-0	-0	1.10
	810402	2000	152	-0	423.3	-0	7.0	-0	-0	.40
	810403	2000	148	-0	296.9	8.5	6.9	-0	-0	-0
	810413	1730	95	-0	148.1	8.5	6.6	9.3	55	0
	810414	1730	84	-0	126.7	9.7	7.1	9.4	50	0
	810415	1730	57	-0	183.1	9.8	7.2	8.8	72	.10
	810416	1700	84	.60	142.7	10.5	6.8	8.8	80	-0
	810417	1815	129	-0	175.3	11.3	6.9	8.5	82	-0
	810427	1600	81	-0	138.2	11.0	7.0	-0	-0	.10
	810428	1600	95	-0	139.1	11.5	7.0	-0	-0	.10
	810429	1630	66	.05	99.6	13.0	7.0	-0	-0	.10
	810429	1630	66	.05	99.6	13.0	7.0	-0	-0	.10
	810430	1630	76	-0	84.6	14.5	7.0	-0	-0	.10

LOCATION	DATE	TIME	TURBIDITY ITU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER-ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC-TIVITY MOSM/L	VELOCITY FT/SEC
COWLITZ AT KELSO, WEST, CONT.										
	810501	1630	78	-0	68.0	11.5	7.0	-0	-0	.05
	810511	1600	51	-0	76.1	14.0	7.0	-0	-0	0
	810512	1600	65	-0	78.9	13.5	7.0	-0	-0	-0
	810513	1600	42	.01	36.8	15.0	6.3	8.6	87	-0
	810514	1600	45	-0	240.0	13.8	7.0	9.4	29	-0
	810515	1800	116	.01	177.2	-0	7.1	-0	-0	-0
	810624	1545	51	-0	147.5	14.6	-0	-0	-0	.30
	810625	1515	51	.10	112.8	13.7	7.5	10.9	55	0
	810626	1700	73	-0	96.3	12.6	7.0	10.1	57	.20
	810627	1500	80	-0	61.4	13.6	6.9	9.0	71	.30
	810628	1700	105	-0	366.3	14.3	7.1	10.0	64	.30
	810713	1700	118	-0	195.0	12.8	6.8	11.6	76	.10
	810714	1700	24	-0	75.8	14.6	7.3	8.8	79	.30
	810715	1700	48	.15	92.7	17.6	7.2	8.7	95	.10
	810717	1930	45	-0	74.9	17.1	-0	-0	-0	-0
	810820	1810	32	0	25.8	16.5	6.9	-0	120	-0
MIN			24	0	25.8	7.0	6.2	6.6	29	0
MAX			1250	1.00	2820.0	17.6	7.7	17.9	120	1.40
VALIDN			61	15	63	60	60	46	31	38
COWLITZ, LEXINGTON										
	800712	1300	152	1.70	1014.2	14.7	7.0	-0	-0	-0
	800718	1230	139	.30	-0	15.0	7.1	11.2	-0	-0
	800722	1500	270	-0	553.8	16.8	7.1	14.7	-0	-0
	800723	1600	255	-0	605.9	16.6	7.0	16.2	-0	2.12
	800724	1330	230	-0	649.8	15.5	6.9	11.8	-0	1.38
	800725	1145	188	-0	548.0	15.1	7.1	11.9	-0	1.30
	800726	1530	198	.40	1016.2	18.3	7.1	10.7	-0	2.23
	800730	1400	230	.40	-0	16.1	-0	9.7	-0	-0
	800806	1330	425	.50	-0	15.4	-0	8.7	-0	-0
	800812	1700	445	-0	1250.3	16.7	6.8	10.0	-0	1.30
	800813	1940	850	-0	2153.6	15.9	6.9	8.0	-0	1.45
	800814	1700	750	-0	2189.0	15.5	6.8	9.7	-0	1.10
	800815	2220	600	-0	-0	12.9	7.2	10.4	-0	.71
	800816	1800	675	-0	1338.7	14.0	7.2	9.0	-0	.60
	800822	1330	525	.55	1234.7	14.5	7.3	9.7	-0	-0
	800828	1030	1000	.80	1247.8	11.1	7.6	9.5	-0	-0
	800904	1500	870	.70	1656.8	15.2	6.8	8.9	65	-0
	800909	1600	850	-0	2227.4	15.7	6.7	9.3	64	-0
	800910	1830	800	-0	1798.6	16.0	6.4	9.2	65	-0
	800911	2230	675	-0	1882.8	15.0	6.8	9.3	68	-0
	800912	1800	700	.50	1538.3	15.2	6.5	8.8	70	-0
	800913	1630	675	-0	1574.0	13.0	7.1	9.8	76	-0
	800919	1440	700	.90	1830.2	12.3	6.5	9.9	64	1.25
	800925	1350	640	.61	1523.2	12.4	6.4	9.5	58	3.50
	801002	730	500	.88	1475.0	12.1	6.7	9.8	58	1.30
	801011	1400	500	.51	1111.1	10.7	6.7	9.9	61	-0
	801016	1830	-0	.19	983.0	10.2	6.8	9.4	59	-0

LOCATION	DATE	TIME	TURBIDITY ITU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER- ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC- TIVITY MOSM/L	VELOCITY FT/SEC
COWLITZ AT LEXINGTON, CONT.										
	801023	2030	540	.40	1342.7	9.8	6.2	9.7	58	-0
	801031	1400	575	.61	1801.5	10.9	6.6	9.8	83	.50
	801106	730	700	1.20	1747.6	11.8	6.6	9.1	61	-0
	801113	1600	310	.61	1076.2	-0	7.0	-0	-0	1.80
	810319	2115	62	3.00	163.8	8.9	7.0	9.8	34	.01
	810402	1830	148	.18	341.4	-0	7.0	-0	-0	.52
	810413	1530	100	-0	340.0	8.5	6.7	9.8	52	.41
	810414	1630	83	-0	199.3	9.7	7.1	9.5	51	.10
	810415	1800	111	-0	164.9	9.7	7.3	8.5	82	.30
	810416	1645	112	.07	275.3	10.3	9.1	6.8	79	-0
	810417	1730	128	-0	316.5	11.2	6.9	8.2	83	-0
	810427	1700	86	-0	278.0	11.0	7.0	-0	-0	-0
	810428	1730	111	-0	366.3	12.0	7.0	-0	-0	.45
	810429	1700	94	.12	254.3	13.0	7.0	-0	-0	1.00
	810430	1700	98	-0	306.7	13.5	7.0	-0	-0	.90
	810501	1700	88	-0	158.4	11.5	7.0	-0	-0	.30
	810511	1630	58	-0	200.7	13.0	-0	-0	-0	-0
	810512	1630	65	-0	93.0	13.5	-0	-0	-0	-0
	810513	1630	66	.02	101.2	14.6	6.1	9.7	100	-0
	810514	1630	56	-0	209.3	13.0	-0	9.1	93	-0
MIN			56	.02	93.0	8.5	6.1	6.8	34	.01
MAX			1000	3.00	2227.4	18.3	9.1	16.2	100	3.50
VALIDN			46	23	43	45	42	37	22	23
COWLITZ, CASTLE ROCK										
	800722	1630	695	-0	1859.4	19.6	7.2	6.4	-0	-0
	800723	1700	658	-0	1702.9	17.5	7.2	11.5	-0	1.02
	800724	1445	120	-0	1345.8	17.1	7.0	11.7	-0	.62
	800725	1300	345	-0	1003.0	16.9	7.3	11.2	-0	.47
	800726	1645	410	-0	1016.2	18.7	6.9	-0	-0	.43
	800813	1200	400	-0	911.4	14.2	7.0	8.6	-0	1.15
	800814	2145	910	-0	1862.2	14.7	7.0	10.4	-0	.20
	800815	2115	395	-0	763.4	13.6	6.7	10.0	-0	.25
	800816	1330	270	-0	658.0	14.3	7.1	10.4	-0	.90
	800909	1700	-0	-0	-0	13.8	6.1	9.2	59	-0
	800910	1930	435	-0	1998.8	13.5	6.4	9.2	60	-0
	800911	2130	305	-0	1999.5	13.6	6.6	9.3	63	-0
	800912	1730	1200	1.30	1794.8	13.6	6.6	9.5	66	-0
	800913	1700	-0	-0	1958.4	12.4	7.0	9.1	70	-0
	800919	1530	625	.61	998.4	11.3	6.6	10.1	60	.55
	800925	1300	240	.40	773.6	12.0	6.5	9.3	51	.65
	801002	815	240	-0	-0	11.3	6.7	9.6	57	.20
	801008	2030	220	-0	854.6	11.4	6.6	10.1	51	.10
	801009	945	215	.60	873.4	10.0	6.5	9.8	52	.50
	801010	900	181	-0	569.5	10.3	6.6	9.6	53	-0
	801011	2330	180	-0	638.2	10.9	6.8	10.4	56	-0
	801016	1800	-0	.48	802.9	10.1	6.8	10.0	54	-0
	801023	2100	166	.31	608.5	10.1	6.6	10.6	54	1.20

LOCATION	DATE	TIME	TURBIDITY ITU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/l	TEMPER-ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC-TIVITY MOSM/L	VELOCITY FT/SEC
COWLITZ AT CASTLE ROCK, CONT.										
	801031	1430	185	1.40	422.6	10.4	6.5	9.7	75	.10
	801106	800	1050	2.30	3314.0	10.9	6.6	9.2	71	-0
	801113	1530	-0	.39	691.0	8.8	6.8	18.0	12	0
	810316	2230	156	-0	383.0	8.6	6.9	10.8	90	2.60
	810317	2200	144	-0	446.4	8.6	6.8	10.5	96	3.30
	810318	2200	106	1.30	285.2	9.1	6.8	10.5	93	1.90
	810319	2200	82	-0	214.2	8.7	6.9	10.2	94	3.70
	810320	2200	93	-0	377.8	8.4	7.0	10.6	90	1.00
	810330	1800	125	-0	301.0	8.0	7.0	-0	-0	1.08
	810331	1800	442	-0	1695.0	7.0	7.0	-0	-0	3.10
	810401	1900	154	.25	390.7	7.0	6.8	-0	-0	3.10
	810402	1800	117	-0	347.7	-0	7.0	-0	-0	2.70
	810403	1800	140	-0	326.7	9.0	7.2	-0	-0	-0
	810417	2100	120	.12	1043.2	11.1	6.8	9.3	83	-0
	810429	1530	91	.10	208.9	12.5	7.0	-0	-0	3.40
	810626	1015	30	.05	31.1	10.4	7.0	10.4	62	3.80
	810716	900	24	.20	33.4	14.6	6.8	8.9	124	1.40
	810820	1900	28	.05	41.2	15.6	6.9	8.8	115	-0
MIN			24	.05	31.1	7.0	6.1	6.4	12	0
MAX			1200	2.30	3314.0	19.6	7.3	18.0	124	3.80
VALIDN			37	16	39	40	41	34	26	28
COWLITZ, I-5										
	800708	1830	3	-0	3.6	13.9	6.9	9.9	-0	-0
	800709	1930	0	-0	17.7	10.3	6.7	11.1	-0	-0
	800710	1345	0	-0	9.2	10.8	6.9	12.2	-0	-0
	800711	1430	2	-0	3.7	11.9	7.1	12.9	-0	-0
	800712	1800	8	0	.6	14.8	7.0	11.9	-0	-0
	800718	1500	0	0	-0	13.3	7.2	12.1	-0	-0
	800722	1730	2	-0	4.7	14.0	7.1	15.7	-0	-0
	800723	1900	3	-0	16.7	13.3	7.3	14.4	-0	.30
	800724	1515	10	-0	9.6	13.9	7.0	12.6	-0	.75
	800725	1830	2	-0	7.0	15.0	7.2	12.6	-0	.54
	800726	2015	0	0	-0	16.5	6.9	-0	-0	.38
	800730	1900	2	.01	2.8	14.8	7.1	10.1	-0	-0
	800806	1530	1	0	-0	13.6	-0	8.7	-0	-0
	800812	2200	12	-0	78.0	13.2	6.9	10.0	-0	-0
	800813	2325	4	-0	14.1	-0	7.1	10.6	-0	-0
	800814	2045	3	-0	15.8	12.3	7.1	11.1	-0	-0
	800815	1900	15	0	485.0	13.0	6.9	10.7	-0	-0
	800816	2330	16	-0	204.0	11.7	7.2	11.1	-0	-0
	800822	1530	7	0	7.7	13.1	7.4	11.2	-0	-0
	800828	1800	2	0	11.2	13.5	7.3	10.8	-0	-0
	800904	1530	3	0	2.6	13.5	6.9	10.2	44	-0
	800909	1930	2	-0	12.8	14.1	7.3	10.5	44	-0
	800910	1130	2	-0	32.3	11.6	6.5	10.3	45	-0
	800911	2030	2	-0	7.4	13.2	7.0	10.2	48	-0
	800912	1630	1	0	2.6	13.1	7.0	10.4	52	-0

LOCATION	DATE	TIME	TURBIDITY ITU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER- ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC- TIVITY MOSM/L	VELOCITY FT/SEC
COWLITZ AT I-5, CONT.										
	800913	2130	5	-0	17.1	11.1	7.2	10.1	53	-0
	800919	1815	2	0	10.6	11.0	6.3	11.0	48	-0
	800925	1220	5	0	8.4	11.8	6.6	9.8	42	.30
	801003	830	7	0	7.8	9.8	6.8	9.4	46	.48
	801008	1130	6	-0	7.5	10.8	6.7	10.2	44	.70
	801009	1200	2	-0	13.7	10.8	6.9	10.6	45	.10
	801010	930	5	-0	26.9	14.3	7.7	10.5	47	-0
	801012	400	6	-0	-0	10.2	6.7	10.2	48	-0
	801015	2000	-0	0	13.4	15.5	7.2	8.7	195	-0
	801023	2200	17	0	25.8	10.1	6.5	10.2	50	.30
	801031	1900	22	0	161.7	10.6	6.8	10.3	62	-0
	801106	1730	88	0	211.0	11.1	6.7	9.9	53	-0
	801113	1330	0	0	7.3	10.0	6.9	15.4	27	0
	810315	1930	8	-0	14.6	-0	7.1	-0	-0	-0
	810316	1130	10	-0	15.4	7.8	7.0	11.0	42	.70
	810317	1230	0	-0	.1	8.4	7.0	11.0	40	-0
	810319	900	19	0	46.2	8.0	7.0	10.6	44	.38
	810320	930	93	-0	377.8	7.8	7.0	10.5	47	0
	810330	1300	14	-0	2.3	7.7	6.9	-0	-0	-0
	810331	1300	5	-0	.3	7.5	7.0	-0	-0	.51
	810401	1230	8	.10	.9	7.8	7.0	-0	-0	.55
	810402	1300	13	-0	16.5	7.8	6.9	-0	-0	.22
	810403	1300	-0	-0	-0	8.5	7.0	-0	-0	1.14
	810413	1100	10	-0	48.3	7.9	6.9	11.0	38	3.10
	810414	1100	120	-0	79.5	8.5	7.1	10.5	35	1.60
	810415	1100	3	-0	36.0	-0	7.0	-0	-0	1.00
	810416	1145	5	0	26.6	9.1	7.1	10.2	42	-0
	810417	2130	2	-0	18.9	10.7	7.0	8.8	46	-0
	810427	1930	3	-0	.7	10.5	7.0	-0	-0	1.60
	810428	1900	11	-0	4.5	12.0	7.0	-0	-0	1.90
	810429	1930	9	.01	20.5	12.0	7.0	-0	-0	2.40
	810430	1930	9	-0	.6	10.0	7.0	-0	-0	1.70
	810501	1930	8	-0	16.5	10.0	7.0	-0	-0	1.20
	810511	1930	14	-0	8.4	11.5	7.1	-0	-0	-0
	810512	1800	9	-0	14.4	13.5	7.0	-0	-0	-0
	810513	1700	2	-0	12.5	12.6	6.9	10.9	42	-0
	810513	1900	2	.01	12.5	11.4	7.4	9.1	46	-0
	810514	1900	35	-0	141.4	11.4	7.4	9.1	46	-0
	810624	1800	29	-0	43.1	13.6	-0	-0	-0	.35
	810625	1800	28	.05	28.1	12.5	7.5	11.1	35	.40
	810626	1830	57	-0	10.8	12.1	7.4	10.8	40	.35
	810627	1715	60	-0	9.6	13.2	7.2	11.4	37	.05
	810628	1830	55	-0	-0	13.3	7.3	10.4	37	.10
	810713	2000	87	-0	477.2	11.0	7.2	10.8	40	0
	810714	1830	51	-0	69.9	13.6	7.6	10.0	43	0
	810715	1900	70	.08	259.0	15.6	7.5	9.7	47	0
	810717	2100	16	-0	7.6	13.1	-0	-0	-0	-0
	810820	1930	14	0	10.2	14.4	7.0	10.4	52	-0
MIN			0	0	.1	7.5	6.3	8.7	27	0
MAX			120	.10	485.0	16.5	7.7	15.7	195	3.10
VALIDN			71	26	67	70	70	56	37	33

LOCATION	DATE	TIME	TURBIDITY ITU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER-ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC-TIVITY MOSM/L	VELOCITY FT/SEC
MAIN TOUTLE, MOUTH										
	800708	1950	500	-0	-0	24.4	-0	-0	-0	-0
	800709	1900	621	-0	2094.5	16.4	7.3	10.7	-0	-0
	800710	1315	440	-0	1593.7	15.7	7.3	10.4	-0	-0
	800711	1400	750	-0	2351.6	15.9	7.2	10.5	-0	-0
	800712	1430	562	.30	2046.4	18.5	6.9	9.5	-0	-0
	800718	1415	583	1.50	-0	21.6	7.4	10.0	-0	-0
	800722	2130	2136	-0	6823.8	22.8	7.2	12.2	-0	-0
	800723	1930	1591	-0	5751.7	21.2	6.9	13.2	-0	2.20
	800724	1545	1450	-0	4845.4	22.7	7.4	12.8	-0	2.14
	800725	1900	1100	-0	3524.6	22.9	7.4	10.4	-0	1.98
	800726	1915	1100	-0	-0	24.8	7.5	-0	-0	2.06
	800730	1830	890	3.20	3922.8	22.8	7.4	8.2	-0	-0
	800806	1330	470	2.00	2647.0	18.2	-0	8.9	-0	-0
	800812	2100	885	-0	4445.2	20.0	7.1	10.8	-0	2.40
	800813	2240	960	-0	3702.6	-0	7.4	9.5	-0	2.00
	800814	2015	1225	-0	4249.0	17.8	7.2	10.4	-0	1.90
	800815	1930	-0	-0	4029.3	18.2	-0	9.3	-0	1.85
	800815	2230	715	2.40	4029.3	18.7	7.2	10.6	-0	-0
	800816	2230	715	-0	-0	18.7	7.2	9.6	-0	1.75
	800822	1430	1275	2.00	3894.4	19.8	7.6	8.8	-0	-0
	800828	830	1930	5.90	8451.4	11.1	7.5	9.7	-0	-0
	800904	1630	1230	3.40	4879.6	21.6	7.1	7.9	181	-0
	800909	1830	825	-0	4911.8	21.4	7.1	8.3	165	-0
	800910	1130	1050	-0	4466.3	17.1	7.0	9.2	165	-0
	800911	1115	1638	3.00	5321.2	16.3	7.3	9.5	166	-0
	800912	1700	1200	-0	6110.4	18.5	7.2	8.9	170	-0
	800913	1800	1000	-0	6359.4	13.5	7.2	9.7	164	-0
	800919	1745	750	2.50	3394.8	14.3	7.0	9.9	172	1.50
	800926	930	420	2.60	3015.1	12.5	6.9	9.6	160	2.90
	801002	1815	440	1.60	2125.2	18.0	7.2	8.3	153	2.80
	801008	800	550	-0	2718.6	14.4	7.1	9.2	157	2.10
	801009	1015	500	0	2582.2	10.5	7.2	10.5	159	2.20
	801010	930	555	-0	2159.7	9.1	7.2	10.5	158	-0
	801011	2400	460	-0	2128.3	12.1	7.2	10.1	167	-0
	801015	1030	-0	1.70	1811.2	9.2	7.1	10.5	148	-0
	801023	2130	455	1.70	2276.4	9.4	6.9	10.3	52	1.35
	801031	1830	375	.55	1518.3	10.0	7.1	10.4	131	.70
	801106	1700	3580	9.30	12134.8	10.7	6.7	10.3	132	-0
	801113	1430	550	2.00	1807.6	5.1	7.1	19.0	44	2.70
	810316	2000	315	-0	1334.3	9.1	6.8	10.4	169	2.70
	810317	2000	425	-0	2279.7	9.8	6.9	10.1	184	2.80
	810318	1230	-0	5.20	626.1	9.3	6.8	10.5	187	2.30
	810318	2000	258	-0	397.9	9.7	6.8	9.6	191	2.30
	810319	2000	228	-0	803.2	9.3	6.9	9.9	207	1.70
	810320	2100	271	-0	922.1	8.9	6.9	9.9	204	1.50
	810330	1715	250	-0	762.3	8.6	7.0	-0	-0	3.20
	810401	1300	418	-0	2284.2	-0	6.9	-0	-0	-0

LOCATION	DATE	TIME	TURBIDITY ITU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER-ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC-TIVITY MOSM/L	VELOCITY FT/SEC
MAIN TOUTLE MOUTH, CONT.										
	810401	1730	945	-0	4104.0	8.6	7.0	-0	-0	2.30
	810401	1830	295	1.70	2288.3	8.5	6.9	-0	-0	2.60
	810402	1715	273	-0	1021.0	-0	6.9	-0	-0	2.40
	810403	1715	-0	-0	-0	9.0	-0	-0	-0	-0
	810416	1800	342	.70	1065.9	11.8	6.9	8.7	156	-0
	810429	1830	227	.40	753.4	17.0	7.0	-0	-0	2.40
	810511	1800	192	-0	508.0	14.5	-0	-0	-0	-0
	810511	1800	192	-0	503.0	14.5	-0	-0	-0	-0
	810512	1800	176	-0	518.5	17.0	7.0	-0	-0	-0
	810513	1730	196	-0	656.7	16.3	7.0	-0	-0	-0
	810513	1730	196	.31	656.7	16.3	6.9	9.3	142	-0
	810514	1730	184	-0	487.9	13.6	7.0	9.3	142	-0
	810515	1830	224	-0	540.6	-0	7.0	9.5	189	-0
	810624	1700	162	-0	415.1	18.2	-0	-0	-0	1.70
	810625	1700	142	.20	237.8	21.1	7.4	8.6	70	2.70
	810626	1745	152	-0	270.2	18.5	7.1	9.2	181	.80
	810627	1700	158	-0	237.6	18.7	7.1	9.1	197	1.15
	810628	1730	118	-0	286.1	20.4	7.1	9.0	199	1.00
	810713	1830	1875	-0	2700.2	16.5	6.9	9.5	288	1.10
	810714	1800	153	-0	325.5	20.5	7.6	7.2	336	.62
	810715	1830	67	.20	177.7	21.8	7.4	7.6	343	1.18
	810716	2000	61	-0	92.9	23.1	7.5	7.7	349	.90
	810717	2000	77	-0	114.2	20.5	-0	-0	-0	-0
	810820	1915	245	.10	387.3	19.2	7.1	9.1	417	-0
MIN			61	0	92.9	5.1	6.7	7.2	44	.62
MAX			3580	9.30	12134.8	24.8	7.6	19.0	417	3.20
VALIDN			67	26	66	67	63	56	37	37
MAIN TOUTLE,TOWER RD										
	-0	-0	-0	.75	1045.4	11.5	7.1	10.2	148	-0
	800712	1515	345	1.00	-0	9.3	-0	-0	-0	-0
	800718	1600	479	2.00	-0	24.8	7.2	8.8	-0	-0
	800726	1730	750	-0	465.0	24.1	-0	10.1	-0	-0
	800730	1715	650	3.00	4160.0	25.6	7.4	8.6	-0	-0
	800806	1430	350	2.20	-0	20.0	-0	8.4	-0	-0
	800815	45	109	1.30	-0	14.5	7.6	11.4	-0	-0
	800822	730	1125	2.20	3306.7	13.3	7.5	9.9	-0	-0
	800828	1845	2250	7.50	8967.8	18.2	7.3	8.3	-0	-0
	800904	1600	980	2.70	3931.7	22.9	7.3	7.6	176	-0
	800913	2030	638	3.00	3756.4	13.6	7.4	9.8	166	-0
	800918	840	750	3.30	4754.0	14.3	7.3	10.1	194	1.90
	800926	2030	460	.82	1650.2	16.9	7.0	8.7	160	1.50
	801002	1735	330	.70	1023.5	18.8	7.2	8.3	154	2.00
	801009	1100	275	.31	1055.3	11.7	7.3	10.2	163	-0
	801024	1800	260	1.40	1487.0	9.2	7.2	10.5	55	-0
	801031	1630	37	1.10	1771.1	10.2	7.1	10.5	132	1.70
	801106	1630	3480	9.30	11148.0	10.8	6.6	10.1	136	-0
	801113	1545	420	2.80	2915.3	6.3	6.8	11.4	138	3.70

LOCATION	DATE	TIME	TURBIDITY ITU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER-ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC-TIVITY MOSM/L	VELOCITY FT/SEC
MAIN TOUTLE AT TOWER ROAD, CONT.										
MIN			37	.31	465.0	6.3	6.6	7.6	55	1.50
MAX			3480	9.30	11148.0	25.6	7.6	11.4	194	3.70
VALIDN			18	18	15	19	16	18	11	5
LOW NO FORK TOUTLE										
	800712	1630	170	1.00	814.8	19.1	7.4	9.3	-0	-0
	800718	1530	145	.70	607.8	23.4	7.1	9.5	-0	-0
	800722	2030	140	-0	773.2	22.4	7.2	10.9	-0	-0
	800723	1730	-0	-0	421.1	20.8	7.2	11.6	-0	2.59
	800724	1930	-0	-0	365.0	22.8	7.4	10.7	-0	2.13
	800725	2000	-0	-0	504.8	22.5	7.6	7.8	-0	1.50
	800726	1630	132	.60	374.2	23.7	7.3	9.9	-0	1.76
	800730	2100	90	.50	377.8	21.6	7.3	8.3	-0	-0
	800806	1900	132	.40	-0	21.4	-0	4.8	-0	-0
	800815	1730	47	.30	717.7	16.9	7.4	9.5	-0	-0
	800822	1830	92	.25	235.4	20.5	7.6	8.6	-0	-0
	800828	1815	3200	5.80	8303.1	16.7	7.1	6.9	-0	-0
	800904	1530	660	2.00	2610.6	21.3	7.4	7.9	240	-0
	800910	930	300	-0	1365.1	14.9	6.6	9.3	216	-0
	800911	1300	235	.63	837.8	19.0	7.0	8.6	212	-0
	800912	1530	1200	-0	1451.0	19.1	7.0	8.6	220	-0
	800913	1930	660	-0	2502.8	13.3	7.2	9.6	218	-0
	800918	740	750	1.60	2573.6	13.9	7.4	9.9	208	1.30
	800926	1945	305	.75	1312.6	16.9	7.3	8.6	206	2.00
	801002	1700	260	.81	1235.7	16.7	7.4	8.6	198	1.70
	801008	1000	178	-0	1437.0	18.8	7.1	9.7	205	3.40
	801009	1300	182	-0	1108.9	12.4	7.1	9.6	161	3.40
	801010	1100	152	-0	1111.3	13.4	7.1	9.5	220	-0
	801011	2000	185	1.00	1334.3	12.3	7.4	10.0	212	-0
	801012	20	201	-0	1072.6	11.7	7.1	10.1	85	-0
	801015	1835	-0	5.40	3741.6	11.5	7.6	11.1	302	-0
	801024	1730	925	2.20	3267.1	10.0	7.2	10.0	17	-0
	801031	1830	700	2.20	2373.9	9.8	7.2	10.5	158	1.50
	801106	1600	3180	9.60	12521.6	10.3	6.7	10.2	249	-0
	801113	1530	380	.91	1384.3	6.3	7.0	11.1	205	4.00
	810320	1830	132	2.90	727.6	8.1	6.9	10.1	332	1.70
	810403	1430	159	.80	348.4	8.5	7.1	-0	-0	1.45
	810416	1515	530	1.00	1570.9	10.9	7.1	9.2	239	-0
	810430	1430	166	.30	453.8	16.5	7.0	-0	-0	1.80
	810628	1500	100	.40	704.0	17.9	6.9	9.3	275	2.10
	810717	1230	51	.10	41.2	17.9	7.2	8.9	472	.78
	810820	1610	24	0	17.7	19.6	7.5	9.1	573	-0
MIN			24	0	17.7	6.3	6.6	4.8	17	.78
MAX			3200	9.60	12521.6	23.7	7.6	11.6	573	4.00
VALIDN			33	26	36	37	36	35	23	16

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LOCATION            DATE      TIME      TURBIDITY  SETTLEABLE  FILTERABLE  TEMPER-   PH   DISSOLVED  CONDUC-   VELOCITY
                                        ITU        SOLIDS      SOLIDS      ATURE          OXYGEN     TIVITY    FT/SEC
                                                   ML/L        MG/L         C             MG/L       MOSM/L


MID NO FORK TOUTLE


                    800712    1600         163        .90          -0      18.7    7.0       9.8        -0        -0
                    800718    1700          74        .20       164.8      23.6    7.4       9.2        -0        -0
                    800726    1515          58         -0       132.0      23.1    7.6      10.4        -0        -0
                    800730    1900          43        .35       153.0      21.6    7.4       8.6        -0        -0
                    800806    1730         112        .45          -0      22.6     -0       5.9        -0        -0
                    800815    1800         110       1.30      1066.6      14.0    7.6       9.4        -0        -0
                    800822    1700          88        .59       212.9      21.5    7.5       9.0        -0        -0
                    800828    1630        1320       2.90      3952.8      17.0    7.6       8.6        -0        -0
                    800904    1330         790       2.30      2467.6      22.7    7.6       7.8       342        -0
                    800912    1330         400       2.30      2962.0      17.4    7.4       9.1       308        -0
                    800918    1800        2000       6.00     10423.2      13.9    7.2       9.8       279      3.40
                    800926    1530         240       3.30      2721.0      20.8    7.4       7.9       202        -0
                    801002    1525         195        .65       975.0      19.1    7.5       8.3       265      1.85
                    801011    1900         148       1.40      1844.9      12.4    7.6       9.8       292        -0
                    801015    1640          -0        .31      4843.5      12.0    7.6      11.1       302        -0
                    801024    1430         700       2.30      3674.0      11.2    7.6       9.9       302      2.50
                    801030    1600          -0        .59      1088.8      10.8    6.3      10.2       180      2.45
                    801106    1500        1880       6.40      7286.8      11.0    6.9      10.2       344        -0
                    801114    1317         585       1.40      1864.0       6.1    7.2      11.4       376      2.30

MIN                                     43        .20       132.0       6.1    6.3       5.9       180      1.85
MAX                                   2000       6.40     10423.2      23.6    7.6      11.4       376      3.40
VALIDN                                  17         18          17        19     18        19        11         5


GREEN RIVER


                    800712    1615         180         -0       820.5      15.2    6.8        -0        -0        -0
                    800718    1930         521       3.00      3070.6      21.5    7.4       9.8        -0        -0
                    800726    1600         113        .50          -0      23.0    7.1       9.2        -0        -0
                    800730    2000         108       1.20      1039.2      21.5    7.3       8.5        -0        -0
                    800806    1830          49        .10          -0      20.6     -0       6.8        -0        -0
                    800815    1830          70        .40       569.6      16.4    7.3       9.5        -0        -0
                    800822    1730          77        .30       245.4      19.9    7.3       8.9        -0        -0
                    800828    1730        1600       1.90      2773.0      14.4    7.1       9.2        -0        -0
                    800904    1500         400       1.00      1135.6      17.6    7.3       8.5       175        -0
                    800912    1400          93       1.00       980.0      16.3    7.0       9.0       150        -0
                    800918    1900         150       1.20      2731.8      13.6    7.1       9.7       150      1.40
                    800926    1615         115        .80       627.0      15.5    7.0       8.6       152      2.30
                    801002    1620         169       1.80       698.4      14.1    7.3       9.1       143      2.70
                    801011    1930          55        .30       372.1      11.3    7.3       9.8       144        -0
                    801015    1745          -0        .50       591.3      10.0    7.1      10.2       148        -0
                    801024    1530          43          0       176.4       8.6    6.8      10.1       135      1.55
                    801030    1630          49       1.50      1551.6       8.2    7.3      10.2       144      1.80
                    801106    1200        4600      15.20     15891.2       8.8    6.5      10.5       177        -0
                    801114    1500         193        .70       989.0       5.0    6.7      11.6       142      2.40
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LOCATION	DATE	TIME	TURBIDITY ITU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER- ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC- TIVITY MOSM/L	VELOCITY FT/SEC
GREEN R., CONT.										
	810316	1730	41	-0	172.9	7.8	6.9	10.3	97	2.60
	810317	1730	40	-0	104.7	7.9	6.8	9.8	32	3.30
	810318	1700	25	1.00	50.9	7.6	7.0	9.6	106	3.50
	810319	1700	11	-0	54.7	7.8	7.0	10.1	109	2.90
	810320	1730	10	-0	219.1	6.9	6.8	10.5	113	3.10
	810331	1400	133	-0	599.0	6.0	7.0	-0	-0	1.30
	810401	1400	51	.10	176.7	7.0	7.0	-0	-0	1.50
	810402	1500	66	-0	231.6	6.0	6.8	-0	-0	1.10
	810403	1400	41	-0	161.9	7.5	6.7	-0	-0	1.10
	810414	1430	16	-0	104.0	10.3	7.2	9.2	87	-0
	810415	1600	43	-0	187.8	9.0	7.4	8.9	101	.60
	810416	1430	65	.04	317.7	9.7	6.9	8.8	86	-0
	810417	1430	56	-0	202.7	11.3	7.0	8.7	107	-0
	810427	1230	54	-0	221.1	7.5	7.0	-0	-0	1.20
	810428	1300	112	-0	633.5	11.0	7.0	-0	-0	.80
	810429	1230	75	.20	423.7	12.0	7.0	-0	-0	.80
	810430	1200	84	-0	378.1	12.5	7.0	-0	-0	.80
	810501	1230	72	-0	345.3	10.0	7.0	-0	-0	3.90
	810511	1200	119	-0	609.2	10.0	7.0	-0	-0	3.80
	810512	1300	35	-0	297.5	11.5	7.0	-0	-0	-0
	810513	1300	41	-0	252.4	12.0	7.0	-0	-0	-0
	810514	1300	448	-0	1457.9	10.5	7.0	10.9	91	-0
	810515	1200	81	-0	411.6	8.5	7.0	11.3	94	-0
	810624	1330	58	-0	419.2	12.6	-0	-0	-0	3.70
	810625	1300	36	.20	1129.2	15.7	7.4	9.7	92	4.50
	810626	1330	69	-0	46.4	13.2	6.9	11.2	95	4.50
	810627	1300	78	-0	73.4	12.0	6.8	11.5	98	4.50
	810628	1330	72	-0	70.0	14.5	6.8	9.9	97	4.60
	810713	1430	1565	-0	2504.3	12.0	6.5	11.7	84	5.10
	810714	1400	88	-0	242.9	15.9	7.5	9.0	104	3.50
	810715	1500	20	.04	60.2	19.5	7.8	7.7	109	4.60
	810716	1700	63	-0	261.4	21.6	7.3	8.4	116	4.00
	810717	1530	39	-0	19.5	18.0	7.3	-0	103	-0
	810820	1530	28	0	4.3	18.0	7.1	9.0	128	-0
MIN			10	0	4.3	5.0	6.5	6.8	32	.60
MAX			4600	15.20	15891.2	23.0	7.8	11.7	177	5.10
VALIDN			52	25	51	53	51	38	32	31
LOW SO FORK TOUTLE										
	800712	1745	440	1.25	171.0	20.2	7.5	9.7	-0	-0
	800718	1600	140	1.50	-0	22.4	7.2	9.2	-0	-0
	800722	1930	5456	-0	15320.2	25.0	7.0	11.5	-0	-0
	800723	1800	2450	-0	10054.0	22.2	6.9	11.9	-0	.65
	800724	1945	1200	-0	7418.0	22.1	7.1	10.2	-0	.73
	800725	2030	1360	-0	9561.1	22.4	7.4	8.0	-0	.43
	800726	1830	1250	-0	-0	25.6	7.3	-0	-0	.34
	800730	1730	1200	8.50	9067.3	23.8	7.2	8.0	-0	-0
	800806	2100	560	5.00	-0	18.7	-0	-0	-0	-0

LOCATION	DATE	TIME	TURBIDITY ITU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER-ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC-TIVITY MOSM/L	VELOCITY FT/SEC
LOWER S. FK. TOUTLE, CONT.										
	800812	2200	1200	-0	11900.4	20.0	7.2	8.8	-0	.25
	800813	2115	-0	-0	-0	-0	-0	10.9	-0	.10
	800814	1930	-0	-0	-0	18.3	-0	10.4	-0	.80
	800815	2015	1050	4.50	5841.0	17.6	7.4	8.6	-0	-0
	800815	2030	1125	-0	9288.7	16.8	7.4	9.2	-0	.10
	800816	2015	1050	4.50	5841.0	17.6	7.4	8.6	-0	1.00
	800822	1930	1050	4.75	5269.3	20.5	7.6	8.8	-0	-0
	800828	1945	1060	6.20	7084.4	15.3	7.7	8.9	-0	-0
	800904	1200	1610	9.90	12365.3	19.7	7.1	8.7	73	-0
	800910	830	1700	-0	9098.6	15.6	6.6	9.2	77	-0
	800911	1230	1825	5.80	9331.8	20.4	7.0	8.5	79	-0
	800912	900	2450	-0	16064.2	13.8	6.8	9.5	81	-0
	800913	1930	1064	-0	11221.4	13.2	7.0	9.7	81	-0
	800918	1400	350	4.30	7813.6	15.0	7.2	6.1	94	.65
	800926	2115	740	1.30	2434.6	14.5	6.7	8.7	75	1.20
	801002	915	750	3.20	2232.8	12.5	7.1	9.5	82	.90
	801007	2200	750	-0	3137.1	14.2	7.1	9.6	81	2.10
	801009	1330	625	1.50	2807.5	14.4	7.1	9.5	83	2.10
	801010	1030	600	-0	2385.2	13.9	7.1	9.6	87	-0
	801012	100	325	-0	1517.4	11.1	7.2	10.6	214	-0
	801015	1500	-0	.53	936.5	12.9	6.9	10.0	76	-0
	801024	930	67	1.60	1753.2	6.6	6.8	10.9	78	1.80
	801030	1030	65	.45	807.5	7.4	6.8	10.6	60	2.20
	801106	1100	2000	7.50	5881.2	9.3	6.7	10.4	48	-0
	801114	900	-0	2.80	3494.0	4.4	6.6	12.0	46	1.40
	810318	1200	158	2.00	240.9	8.0	6.9	10.6	49	4.40
	810401	1700	242	.55	938.4	7.5	7.0	-0	-0	3.70
	810417	1000	63	.05	130.0	8.2	6.8	9.6	39	-0
	810429	1500	76	.01	7.6	15.0	6.9	-0	-0	2.40
	810514	1500	80	0	132.0	11.9	6.8	10.1	47	-0
	810627	1130	93	.05	24.8	14.0	6.6	10.7	43	1.55
	810716	1030	141	.10	187.4	18.7	7.0	9.4	63	1.90
	810820	1715	1205	.10	1307.7	19.6	6.9	-0	78	-0
MIN			63	0	7.6	4.4	6.6	6.1	39	.10
MAX			5456	9.90	16064.2	25.6	7.7	12.0	214	4.40
VALIDN			38	27	37	41	39	37	23	22
MID SO FORK TOUTLE										
	800726	1730	720	2.90	-0	24.9	7.4	10.1	-0	-0
	800730	1630	635	6.90	7010.2	20.8	7.6	8.3	-0	-0
	800806	2000	320	3.50	-0	19.1	-0	9.5	-0	-0
	800815	2100	1527	6.50	7509.0	14.3	7.4	9.3	-0	-0
	800822	1900	625	2.75	5958.5	18.9	7.6	9.1	-0	-0
	800828	1930	500	2.10	3608.2	13.7	7.7	9.8	-0	-0
	800904	1130	1000	9.50	10221.1	14.7	7.1	9.7	58	-0
	800912	1100	1200	12.50	13776.4	13.9	7.1	9.8	67	-0
	800918	1440	700	6.80	6983.7	13.0	7.0	10.2	69	2.75
	800926	2230	2950	6.20	10803.5	13.9	7.0	9.1	68	3.00

LOCATION	DATE	TIME	TURBIDITY JTU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER-ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC-TIVITY MOSM/L	VELOCITY FT/SEC
MID S. FK. TOUTLE, CONT.										
	801002	1030	550	.90	2795.9	10.5	7.3	10.0	67	1.80
	801010	1530	655	6.40	13085.4	14.5	7.6	9.5	76	-0
	801015	1240	-0	6.70	31145.5	9.3	6.9	10.7	65	-0
	801024	1130	55	1.60	833.4	8.7	7.0	10.6	40	3.20
	801030	1315	45	.70	671.4	9.3	6.6	10.7	66	2.60
	801106	1000	1360	11.60	7381.6	8.9	6.9	10.6	44	-0
	801114	1030	148	.23	502.0	4.8	7.1	11.9	49	3.90
	810820	1635	1405	.02	1599.2	17.7	7.0	9.4	67	-0
MIN			45	.02	502.0	4.8	6.6	8.3	40	1.80
MAX			2950	12.50	31145.5	24.9	7.7	11.9	76	3.90
VALIDN			17	18	16	18	17	18	12	6
UP NO FORK TOUTLE										
	800730	1830	24	.03	15.2	19.9	7.3	9.1	-0	-0
	800806	1630	22	.30	-0	21.4	-0	4.5	-0	-0
	800815	1945	57	.10	95.2	12.7	7.0	9.5	-0	-0
	800822	1530	28	.10	37.2	19.8	7.5	8.9	-0	-0
	800828	1530	1470	3.80	4280.4	16.5	7.7	8.5	-0	-0
	800904	1300	980	2.30	2387.0	22.7	7.2	7.9	697	-0
	800912	1230	380	2.50	2147.8	15.7	7.3	9.0	553	-0
	800918	1715	1125	10.40	14848.1	13.2	7.2	9.7	480	3.80
	800926	1400	315	2.00	2734.3	20.2	7.1	7.8	451	4.00
	801002	1350	195	.90	901.9	15.2	6.9	8.6	459	2.60
	801010	1830	82	1.20	733.5	12.9	7.0	8.6	516	-0
	801015	1600	-0	.74	1023.2	11.3	7.2	9.6	495	-0
	801024	1400	74	.34	260.0	10.9	7.1	9.6	502	3.40
	801030	1500	52	-0	534.1	11.6	7.1	9.7	515	3.80
	801106	1400	78000	500.00	319072.0	11.1	6.2	9.3	754	-0
	801114	1221	1675	8.50	7366.0	5.5	7.3	11.1	493	3.80
	810320	1615	580	1.60	3336.1	9.8	6.9	9.5	1008	5.60
	810402	1400	335	12.80	14840.4	8.5	7.1	-0	-0	2.60
	810417	1145	1178	6.80	7826.0	14.3	7.0	8.2	664	-0
	810515	1330	1040	4.20	5239.8	12.1	6.9	9.9	970	-0
	810626	1130	1050	4.00	5236.0	14.7	7.4	9.8	576	3.80
	810717	1300	1520	4.50	4582.8	21.8	-0	-0	1057	.70
	810820	1430	208	1.00	1247.7	18.9	7.3	9.4	1271	-0
MIN			22	.03	15.2	5.5	6.2	4.5	451	.70
MAX			78000	500.00	319072.0	22.7	7.7	11.1	1271	5.60
VALIDN			22	22	22	23	21	21	17	10
UP SO FORK TOUTLE										
	800904	1030	650	7.40	9843.2	12.9	6.9	10.0	61	-0
	800912	1000	1025	9.80	11879.7	12.5	7.0	9.9	65	-0
	800918	1545	700	5.90	7940.0	12.5	7.1	10.3	68	4.80

LOCATION	DATE	TIME	TURBIDITY JTU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPERATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUCTIVITY MOSM/L	VELOCITY FT/SEC
UPPER S. FK. TOUTLE, CONT.										
	801002	1050	610	2.70	3457.2	11.0	7.1	10.0	67	2.50
	801010	1230	425	3.60	4738.5	13.0	7.2	9.8	72	-0
	801015	1150	-0	2.00	1931.4	9.1	7.0	10.6	65	-0
	801030	1230	28	.10	240.8	8.8	7.0	10.7	64	2.60
	801106	930	1360	9.50	6953.6	8.7	6.9	10.2	38	-0
	801114	1000	129	-0	450.4	4.8	6.7	11.7	49	1.70
MIN			28	.10	240.8	4.8	6.7	9.8	38	1.70
MAX			1360	9.80	11879.7	13.0	7.2	11.7	72	4.80
VALIDN			8	8	9	9	9	9	9	4
KALAMA HATCHERY										
	800904	1200	17	0	28.1	13.6	6.6	8.1	37	-0
	800911	1630	3	0	26.4	14.8	6.4	8.2	40	-0
	800919	1100	0	0	25.3	11.4	6.4	9.2	45	0
	800925	1630	4	0	15.0	13.7	6.3	7.4	28	.20
	801001	1500	7	0	10.4	13.0	6.9	8.3	37	.70
	801011	1530	5	0	8.9	10.3	6.8	9.6	44	-0
	801016	750	-0	0	99.4	7.5	-0	12.0	46	-0
	801023	1630	-0	0	4.1	7.6	6.2	8.3	42	.05
	801030	1000	-0	0	6.5	8.2	6.4	9.1	44	0
	801105	1530	30	0	53.3	10.0	6.4	8.5	55	-0
	801114	1900	-0	0	76.3	5.7	-0	10.3	34	0
MIN			0	0	4.1	5.7	6.2	7.4	28	0
MAX			30	0	99.4	14.8	6.9	12.0	55	.70
VALIDN			7	11	11	11	9	11	11	6
SFT BELOW DAM										
	800926	2300	700	.13	951.4	15.1	6.9	8.8	72	2.20
	801024	1100	54	0	69.4	6.9	6.9	10.9	64	2.10
	801030	1330	60	0	187.8	7.6	6.6	11.0	66	2.70
	810320	1230	89	.20	43.1	6.9	7.2	10.2	53	2.50
	810403	1730	117	.04	166.3	8.5	7.0	-0	-0	-0
	810417	1030	49	.02	66.2	7.8	6.8	10.3	38	-0
	810430	1230	125	.02	133.8	12.0	7.0	-0	-0	3.80
	810514	1430	111	.03	74.0	11.0	6.9	10.8	43	-0
	810627	1200	39	0	11.4	12.3	6.8	10.5	39	1.90
MIN			39	0	11.4	6.9	6.6	8.8	38	1.90
MAX			700	.20	951.4	15.1	7.2	11.0	72	3.80
VALIDN			9	9	9	9	9	7	7	6

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LOCATION             DATE       TIME     TURBIDITY  SETTLEABLE  FILTERABLE  TEMPER-   PH   DISSOLVED  CONDUC-  VELOCITY
                                          ITU       SOLIDS      SOLIDS      ATURE          OXYGEN     TIVITY   FT/SEC
                                                    ML/L        MG/L         C             MG/L       MOSM/L


DEER CREEK


                     800926     1500         7          0          15.4      14.8     6.6      8.6       36       1.80
                     801002       -0         9          0           9.4        -0      -0       -0       -0         -0
                     801015     1625        -0          0          30.6       9.8     6.7     10.1       44         -0
                     801030     1530        -0          0           4.8       9.1     6.8     10.1       45       1.50
                     801106       -0        69        .38         208.0       9.5     6.3     10.1       40         -0
                     801114     1300        15          0          18.5       5.8      -0     11.0       37       3.60
                     810320     1530        -0         -0            -0       7.6      -0     10.2       51         -0

MIN                                          7          0           4.8       5.8     6.3      8.6       36       1.50
MAX                                         69        .38         208.0      14.8     6.8     11.0       51       3.60
VALIDN                                       4          6             6         6       4        6        6          3

GRAYS R HATCHERY


                     801007      900         4          0           5.5      12.4     6.7      9.0       57         -0

MIN                                          4          0           5.5      12.4     6.7      9.0       57          M
MAX                                          4          0           5.5      12.4     6.7      9.0       57          M
VALIDN                                       1          1             1         1       1        1        1          0

WYANT CREEK


                     801015     1440        -0          0          17.8      11.7     6.8     11.7       49         -0
                     801030     1100        10          0           6.8       6.5     6.5     11.3       48        .75

MIN                                         10          0           6.8       6.5     6.5     11.3       48        .75
MAX                                         10          0          17.8      11.7     6.8     11.7       49        .75
VALIDN                                       1          2             2         2       2        2        2          1

ALDER CREEK


                     810320     1515        -0         -0            -0       7.6      -0     10.4       20         -0

MIN                                          M          M             M       7.6       M     10.4       20          M
MAX                                          M          M             M       7.6       M     10.4       20          M
VALIDN                                       0          0             0         1       0        1        1          0
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LOCATION	DATE	TIME	TURBIDITY ITU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER- ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC- TIVITY MOSM/L	VELOCITY FT/SEC
COLDWATER LAKE										
	810625	1500	83	.05	43.9	16.0	7.5	10.0	33	-0
	810716	1200	34	-0	69.6	17.4	7.2	7.6	343	7.80
	810820	1320	34	0	34.6	19.4	6.9	6.1	388	-0
MIN			34	0	34.6	16.0	6.9	6.1	33	7.80
MAX			83	.05	69.6	19.4	7.5	10.0	388	7.80
VALIDN			3	2	3	3	3	3	3	1
MNFT BIOASSAY										
	810316	1700	157	-0	278.0	8.8	6.9	10.3	450	.90
	810317	1700	96	-0	500.2	10.6	7.0	9.4	479	.72
	810318	1000	64	-0	245.3	8.1	6.6	10.4	492	1.25
	810318	1630	112	1.80	183.4	9.9	6.6	9.7	476	2.80
	810319	1630	59	-0	136.4	9.6	6.8	9.9	515	3.90
	810320	1700	185	-0	698.8	9.0	6.9	10.0	540	4.90
	810330	1500	136	-0	345.2	8.4	6.9	-0	-0	-0
	810331	1530	665	-0	4050.1	7.2	7.0	-0	-0	3.70
	810401	1530	197	.55	1046.5	8.0	6.9	-0	-0	4.80
	810402	1500	208	-0	257.7	8.5	6.9	-0	-0	3.90
	810403	1530	321	-0	321.8	8.5	6.9	-0	-0	-0
	810414	1330	101	-0	220.5	11.8	7.1	8.7	318	-0
	810415	1500	225	-0	413.1	10.3	7.2	8.9	371	3.80
	810416	1330	210	.03	347.2	11.1	7.1	9.1	284	-0
	810417	1230	200	.10	374.9	12.4	7.1	8.6	384	-0
	810427	1330	162	-0	482.7	11.0	7.0	-0	-0	5.20
	810428	1330	143	-0	693.6	13.0	7.0	-0	-0	2.60
	810429	1400	179	.50	716.9	16.5	6.9	-0	-0	4.00
	810430	1400	218	-0	636.8	17.0	6.9	-0	-0	5.20
	810511	1300	125	-0	291.6	14.0	7.0	-0	-0	3.80
	810512	1330	113	-0	246.0	16.0	7.0	-0	-0	-0
	810513	1330	84	-0	230.1	15.5	7.0	-0	-0	-0
	810514	1330	71	.08	226.1	13.4	6.9	10.4	502	-0
	810515	1330	124	-0	239.3	12.4	7.0	10.4	513	-0
	810624	1400	101	-0	386.3	18.1	-0	-0	-0	-0
	810625	1400	250	.10	417.9	20.0	7.6	8.5	444	2.10
	810626	1530	175	-0	901.2	18.9	7.1	9.5	451	2.10
	810627	1400	141	-0	250.8	16.2	7.0	9.8	487	4.00
	810628	1400	99	-0	67.9	19.1	7.3	9.3	495	5.85
	810713	1330	142	-0	194.1	14.6	7.3	10.9	731	1.50
	810714	1330	150	-0	383.4	19.4	7.8	7.8	730	.20
	810715	1400	95	.05	118.4	21.8	7.9	7.1	726	1.45
	810716	1600	61	-0	66.3	23.1	8.0	7.6	730	3.20
	810717	1400	114	-0	218.6	20.8	7.7	-0	728	-0
	810820	1500	30	.03	39.3	18.1	-0	8.8	795	-0

LOCATION	DATE	TIME	TURBIDITY JTU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER-ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC-TIVITY MOSM/L	VELOCITY FT/SEC
MID N. FK. TOUTLE, CONT.										
MIN			30	.03	39.3	7.2	6.6	7.1	284	.20
MAX			665	1.80	4050.1	23.1	8.0	10.9	795	5.85
VALIDN			35	9	35	35	33	21	22	23
MSFT BIOASSAY										
	810511	1400	59	-0	62.2	12.0	7.1	-0	-0	1.15
	810512	1400	89	-0	78.1	13.0	7.1	-0	-0	-0
	810513	1400	78	-0	88.6	13.0	7.1	-0	-0	-0
	810514	1400	88	.01	86.1	12.0	7.2	11.2	42	-0
	810515	1400	63	-0	62.4	-0	-0	-0	-0	-0
	810624	1500	42	-0	47.6	17.3	-0	-0	-0	2.30
	810625	1500	83	.05	43.9	16.0	7.5	10.0	33	.60
	810626	1600	105	-0	57.5	15.7	7.1	10.4	35	.34
	810627	1430	82	-0	15.6	14.9	7.0	9.8	39	2.10
	810628	1500	48	-0	16.3	15.6	7.1	10.2	38	.90
	810713	1530	60	-0	47.5	15.1	6.9	10.4	51	1.40
	810714	1530	198	-0	298.8	17.9	7.5	8.2	51	1.40
	810715	1500	175	.10	235.6	19.7	7.4	8.2	53	1.30
	810716	1745	101	-0	31.2	19.6	7.4	8.6	56	2.50
	810717	1630	149	-0	179.7	20.0	-0	-0	50	.60
MIN			42	.01	15.6	12.0	6.9	8.2	33	.34
MAX			198	.10	298.8	20.0	7.5	11.2	56	2.50
VALIDN			15	3	15	14	12	9	10	11
SFT ABOVE DAM										
	810514	1600	2	.07	.6	11.5	7.0	10.1	40	-0
	810627	1215	63	0	15.1	11.6	6.7	10.5	44	1.85
	810717	1330	56	.45	354.6	20.7	7.8	-0	54	2.00
	810820	1700	1295	11.50	8348.1	16.9	7.0	9.9	52	-0
MIN			2	0	.6	11.5	6.7	9.9	40	1.85
MAX			1295	11.50	8348.1	20.7	7.8	10.5	54	2.00
VALIDN			4	4	4	4	4	3	4	2
NFT AT KID VALLEY										
	810413	1200	96	-0	248.5	8.1	6.7	9.8	186	4.40
	810414	1200	84	-0	190.6	9.2	6.9	9.5	150	4.40
	810415	1330	132	-0	289.5	9.1	7.2	9.4	226	4.60
	810416	1230	137	.23	375.3	10.0	7.0	9.2	180	-0
	810417	1330	830	-0	3139.7	12.1	7.1	8.9	244	-0

LOCATION	DATE	TIME	TURBIDITY JTU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER-ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC-TIVITY MOSM/L	VELOCITY FT/SEC
N. FK. TOUTLE AT KID VALLEY, CONT.										
MIN			84	.23	190.6	8.1	6.7	8.9	150	4.40
MAX			830	.23	3139.7	12.1	7.2	9.8	244	4.60
VALIDN			5	1	5	5	5	5	5	3
COWLITZ.KELSO.EAST										
	800712	1215	350	.80	1798.8	14.9	6.8	7.8	-0	-0
	800718	1200	220	.40	-0	14.6	7.1	10.9	-0	-0
	800722	1330	255	-0	661.1	16.0	6.9	16.7	-0	-0
	800723	1500	285	-0	755.2	16.7	7.0	13.5	-0	1.38
	800724	1300	230	-0	824.5	15.7	7.0	12.7	-0	1.14
	800725	1100	280	-0	777.9	14.7	7.1	11.9	-0	1.80
	800726	1445	245	.40	-0	17.6	7.2	11.4	-0	2.02
	800730	1300	550	.75	1491.5	16.0	6.9	9.4	-0	-0
	800806	1230	420	-0	-0	14.4	-0	9.8	-0	-0
	800812	1330	490	-0	1051.7	15.8	7.0	8.5	-0	.65
	800813	1835	670	-0	1267.0	15.8	6.9	7.8	-0	1.08
	800814	1620	880	-0	1507.0	15.4	6.9	9.0	-0	.70
	800815	1530	430	.36	929.7	14.2	7.0	9.6	-0	.58
	800816	1430	305	-0	855.8	14.1	7.2	11.2	-0	.08
	800822	1300	280	.40	813.2	13.8	7.3	9.7	-0	-0
	800828	1130	1060	.70	1902.6	11.3	7.3	9.4	-0	-0
	800904	1400	960	.64	1593.4	14.5	6.7	8.9	65	-0
	800909	1530	1050	-0	2105.8	15.0	6.6	9.0	67	-0
	800910	1830	860	-0	2023.5	15.9	6.5	9.1	67	-0
	800911	1030	973	.90	2209.6	12.9	6.5	9.3	67	-0
	800912	2045	850	-0	-0	14.9	6.5	9.4	76	-0
	800913	1600	825	-0	1742.9	13.0	7.0	9.3	78	-0
	800919	1330	825	.81	1879.0	12.1	6.5	9.9	65	1.30
	800925	1420	750	.85	1656.0	12.6	6.6	9.2	59	.60
	801001	2015	930	.60	1483.2	12.1	6.7	9.4	58	.20
	801008	1230	610	-0	1765.4	11.8	6.8	10.1	57	1.70
	801009	2030	690	-0	1025.7	10.6	6.6	9.7	59	-0
	801010	2030	900	-0	1600.3	11.0	6.7	9.7	60	-0
	801011	2145	700	-0	1687.9	10.8	6.7	9.6	62	-0
	801030	730	400	.56	1299.7	10.6	6.4	10.0	61	.80
	801105	1430	8	1.20	223.6	11.9	6.8	9.2	64	-0
	801114	730	-0	.60	1211.9	8.8	6.4	10.1	67	.60
MIN			8	.36	223.6	8.8	6.4	7.8	57	.08
MAX			1060	1.20	2209.6	17.6	7.3	16.7	78	2.02
VALIDN			31	15	28	32	31	32	16	15
COW.CASTLE ROCK.W										
	800708	1515	32	-0	71.6	14.6	6.9	10.6	-0	-0
	800709	1815	32	-0	90.6	12.4	6.8	10.3	-0	-0
	800710	1130	41	-0	104.0	10.8	6.8	11.4	-0	-0

LOCATION	DATE	TIME	TURBIDITY ITU	SETTLEABLE SOLIDS ML/L	FILTERABLE SOLIDS MG/L	TEMPER-ATURE C	PH	DISSOLVED OXYGEN MG/L	CONDUC-TIVITY MOSM/L	VELOCITY FT/SEC
COWLITZ AT CASTLE ROCK, WEST, CONT.										
	800711	1300	44	-0	87.0	12.1	6.8	11.7	-0	-0
	800712	1345	40	.05	87.8	14.3	6.8	8.6	-0	-0
	800718	1315	42	.08	-0	15.2	7.0	13.2	-0	-0
	800722	1530	31	-0	54.6	17.5	6.9	12.3	-0	-0
	800723	1630	28	-0	55.0	15.9	7.1	12.8	-0	.36
	800724	1430	41	-0	126.9	15.3	6.9	10.2	-0	.26
	800725	1215	138	-0	345.0	15.5	7.2	11.5	-0	.38
	800726	1600	103	.15	-0	17.1	7.2	13.6	-0	.49
	800730	1500	173	.51	602.4	15.9	6.9	9.7	-0	-0
	800806	1430	265	.60	-0	15.8	-0	7.8	-0	-0
	800812	1720	410	-0	1005.3	16.0	6.9	10.2	-0	.54
	800813	2015	450	-0	1041.2	14.2	-0	10.2	-0	.50
	800814	1730	337	-0	782.6	14.4	7.0	-0	-0	.61
	800815	2145	170	-0	425.0	13.9	6.9	9.4	-0	.18
	800816	1830	345	.25	543.6	15.0	7.2	9.8	-0	.40
	800822	1400	310	.50	852.8	14.2	7.3	10.1	-0	-0
	800828	1000	420	.70	1129.2	11.3	7.4	10.5	-0	-0
	800904	1600	650	1.00	1740.8	15.2	6.8	8.9	59	-0
MIN			28	.05	54.6	10.8	6.8	7.8	59	.18
MAX			650	1.00	1740.8	17.5	7.4	13.6	59	.61
VALIDN			21	9	18	21	19	20	1	9
TOUTLE HWY99 XTRA										
	800919	1630	-0	.84	1245.0	11.4	6.6	10.1	68	1.58
	800926	1030	500	2.10	2748.4	12.8	6.8	9.5	162	1.35
	801002	-0	2800	2.10	5655.8	-0	-0	-0	-0	-0
	801015	3500	-0	.10	542.5	9.3	6.8	10.5	152	-0
MIN			500	.10	542.5	9.3	6.6	9.5	68	1.35
MAX			2800	2.10	5655.8	12.8	6.8	10.5	162	1.58
VALIDN			2	4	4	3	3	3	3	2