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OBSERVATIONS OF THE EFFECTS OF LOGGING ON SALMON-PRODUCING TRIBUTARIES OF THE STANEY CREEK WATERSHED AND THE THORNE RIVER WATERSHED AND OF LOGGING IN THE SITKA DISTRICT

by

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OBSERVATIONS OF THE EFFECTS OF LOGGING ON SALMON-PRODUCING TRIBUTARIES OF THE STANEY CREEK WATERSHED AND THE THORNE RIVER WATERSHED AND OF LOGGING IN THE SITKA DISTRICT[1]

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Richard W. Tyler and Dave R. Gibbons

INTRODUCTION

The principal objectives of this study were to gather data on the effects of clear cutting on the summer temperatures and insect production in small streams of Southeast Alaska which provide rearing habitat for juvenile salmon, trout, and char. Additional data were collected on the populations of salmonids, concentrations of organic leachates, and on the composition of stream gravel. Subjective observations also were made of the effects of past and present logging operations on salmon-producing streams in the Sitka area. The report is divided into two parts: Studies in the Thorne River and Staney Creek watersheds (Fig. 1); surveys of logged watersheds in the Sitka district (Fig. 2).

The work fulfills part of a one-year contract between the Fisheries Research Institute and the Alaska Loggers Association.

STUDIES IN THE THORNE RIVER AND STANEY CREEK WATERSHEDS

The decline in salmon runs in Southeast Alaska has been attributed by some to the destruction of spawning and nursery areas by logging operations. Extreme weather conditions such as excessive rain, drought, wind, heat, and cold limit the production of salmon in streams. In undisturbed watersheds, a natural buffer is provided against extremes of weather by vegetation. Thus, any reduction in the buffering effect of vegetation by logging will probably lower the production of salmon.

Research in the past on the effects of logging on salmon in Southeast Alaskan streams concentrated primarily on pink and chum salmon (*Oncorhynchus gorbuscha* and *O. keta*) (Salo, 1966; McNeil, 1968; Sheridan and McNeil, 1968; and Meehan, Farr, Bishop, and Patric, 1969). This research revealed subtle changes in streamflow, sedimentation, and water temperatures but was inconclusive concerning the effects on the spawning habitat and early life histories of pink and chum salmon. Coho salmon (*O. kisutch*), trout (*Salmo gairdneri* and *S. clarki*), and char (*Salvelinus malma*) received little attention despite their longer period of stream residence. Subsequent studies have

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[1] This work was supported by the Alaska Loggers Association.

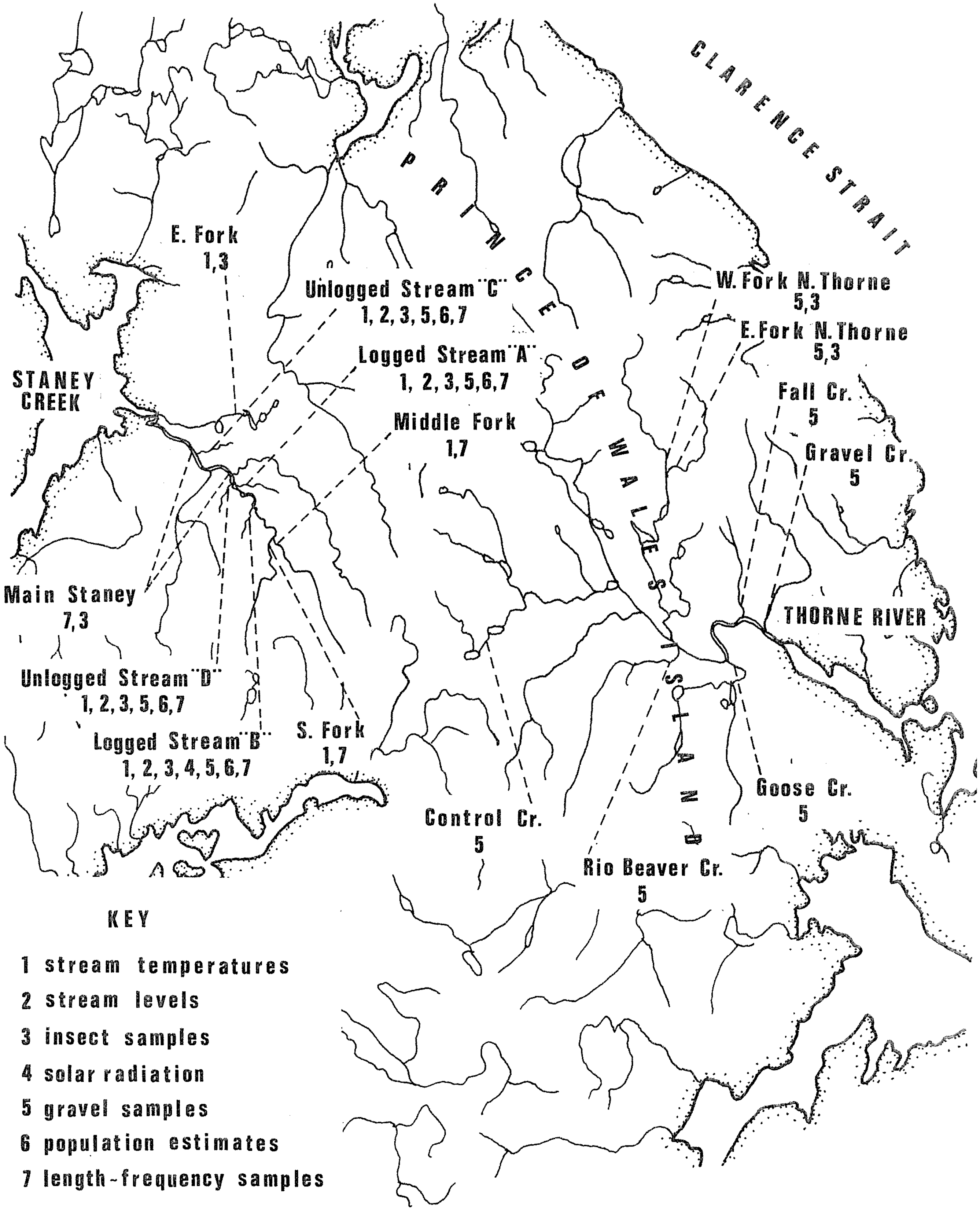

Fig. 1. Sampling locations and parameters measured in the Thorne River and Staney Creek watersheds of Prince of Wales Island during July and August, 1972.

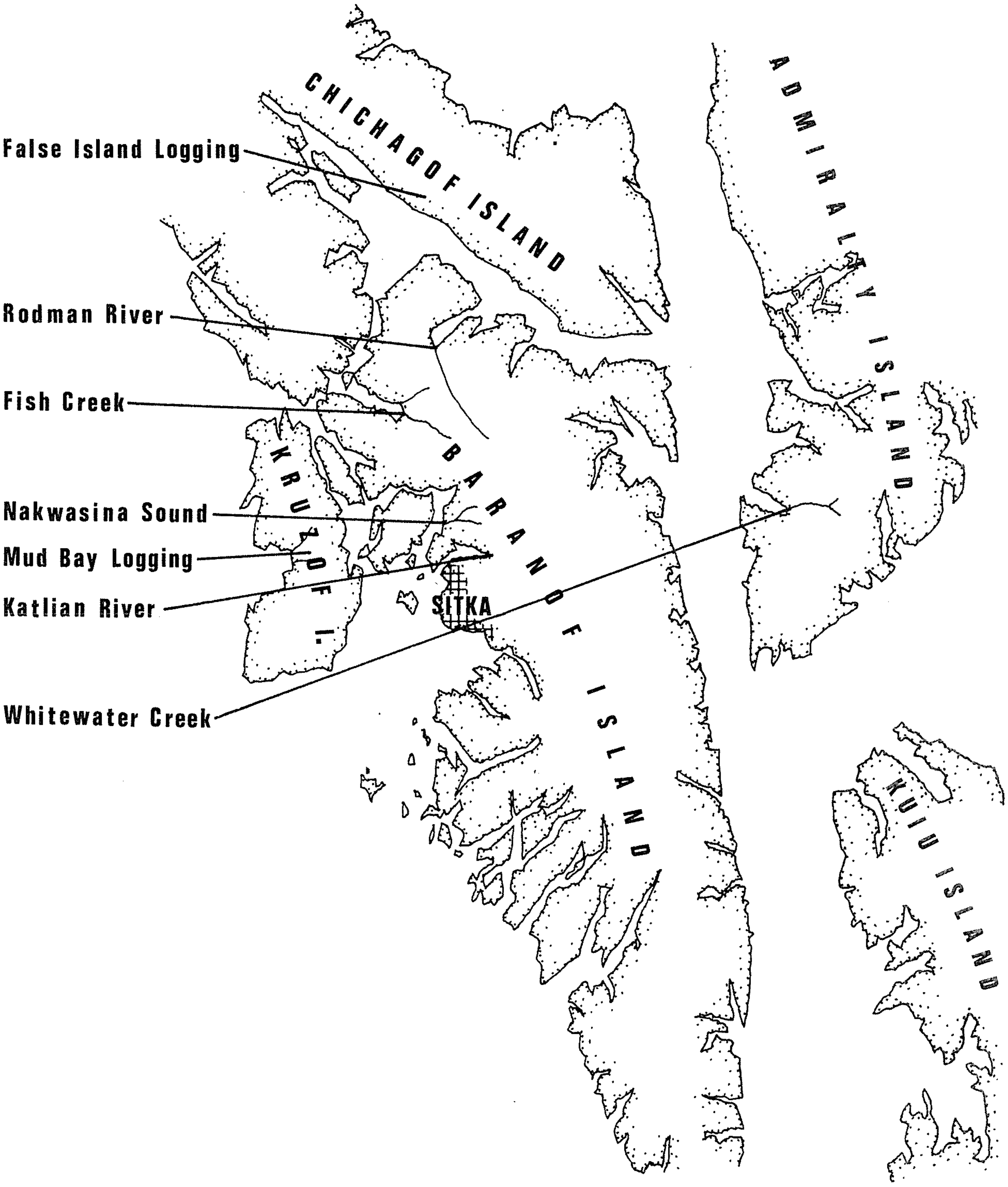

Fig. 2. Sites of past and present logging operations visited in the Sitka area during August, 1972.

shown increased water temperatures due to the removal of streamside vegetation (Meehan, 1970) and a further study by Sheridan et al. (1972) found juvenile salmonids under thermal stress or dead due to temperature ranges from 80-85 F. Subsequent stream temperature data were obtained by the U.S. Forest Service in 1971 and 1972.[2] In more southerly latitudes, clear-cut logging has substantially increased stream temperatures, the magnitude of the effect varying directly with the degree of stream exposure. Levno and Rothacher (1967) have reported on the effects of clear-cut logging on two watersheds in the Oregon Cascades and have shown mean monthly maximum stream temperatures to increase by 7-12 F. After slash burning, Levno and Rothacher (1969), found maximum monthly stream temperature increases of 12-14 F and a maximum stream temperature of 75 F. Green (1950) compared stream temperatures of farmed and forested watersheds and found differences as high as 13 F. Brown, Swank, and Rothacher (1971) showed that removing shade from a stream can increase water temperature 10 F or more and one stream in a large clear-cut in the Steamboat Watershed had a maximum water temperature of 83 F. In California, Burns (1972) found stream temperature increases up to 13 F due to logging road construction. The greatest reported change in stream temperature was recorded in the Alsea watershed, where stream temperatures increased 14 F and the annual temperatures ranged from 57-85 F (Brown and Krygier, 1970).

The energy-food relationship of salmon and trout in streams is complex but, as in all ecosystems, depends on sunlight. Light energy reaching the stream and its borders is fixed by terrestrial vegetation and algae; the algae and terrestrial plant detritus dropping into the stream are eaten by aquatic insects, and the latter are eaten by fish. Thus, an increase in the amount of light energy reaching a stream as a result of logging could affect the abundance and/or diversity of insects.

Studies on the effects of logging practices on stream ecology have shown increases in algal production and changes in both terrestrial and aquatic insect populations. Allen (1960) reported that in small streams increased illumination due to stream clearance enabled attached algae and the fauna feeding on them to increase but qualitatively produced little change. Chapman and Demory (1963) found insect food habits to differ according to the group examined and that any changes in the sources of fixed plant energy would certainly result in shifts in abundance of populations adjusting to these changes. Brode, Burns, and Smith (1973) found road construction and right-of-way logging immediately detrimental to most aquatic invertebrates, although conditions favored Diptera and Plecoptera whose increases offset the losses of other invertebrates. Terrestrial insects dropping into a logged stream in California have been shown to increase up to five and one-half times in number and three times in weight over control streams (Hess, 1969). It is not known whether young salmon can derive the same nutrient value from given amounts of ingested insects, the species composition of which has been altered by logging; however, it is conceivable

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[2] Personal communication with Mr. William L. Sheridan, U.S. Forest Service, Juneau, Alaska.

that fish populations could be increased after removal of streamside vegetation providing that other variables remain favorable. Increased water temperatures due to solar radiation should result in increased stream productivity provided the temperature increases are more optimal for growth and not lethal.

Much rearing habitat has been given partial protection by the U.S. Forest Service in recent timber sales of Southeast Alaska by identifying and marking the habitat before logging, by restricting falling and yarding practices in the vicinity, by requiring the removal of logging debris, by controlling road location, culvert construction and type of road bed material.

The summer weather of Southeast Alaska differs greatly from most coastal forests of Washington, Oregon, and California to the extent that long periods of fair weather are uncommon. Predominantly cool, wet weather precludes the need for slash burning and lessens the effect of solar radiation on stream temperature.

Present forest management principles pertaining to rearing habitat in Southeast Alaska are based largely on the results of studies conducted in more southerly coastal forests. But because of differences in climate and logging practices, their strict application in Southeast Alaska may be invalid. The following report summarizes our efforts to increase the scope of information primarily with respect to tributary streams which are too small to provide extensive spawning facilities but which serve as rearing habitat for coho, char, and trout.

METHODS

The Staney watershed was selected for the temperature and insect production studies because it has been extensively logged and offers a variety of logged and unlogged streams for comparison.

The streams chosen for study are typical of many thousands of small coho rearing streams throughout Southeast Alaska, i.e., of moderate gradient, summer flow less that 1 cfs, suitable rearing habitat for juvenile coho salmon, Dolly Varden char, and trout. Four streams of approximately equal size were selected for study: two which were partially logged in 1969 and subsequently hand-cleared were designated logged streams "A" and "B;" two others which had not been logged were designated unlogged streams "C" and "D." Streams "A" and "C" offered the best logged-to-unlogged comparison because their physical characteristics were very similar. Observations were also made on other, larger tributary streams in the Staney Creek watershed.

Description of Logged Stream "A"

Stream "A" is a small, partially logged tributary 1.5 miles long which enters from the right bank of Staney Creek 6.6 miles above tide water (Fig. 3), has a minimum water flow during the summer of approximately 0.175 cfs, a

Fig. 3. Logged stream A.

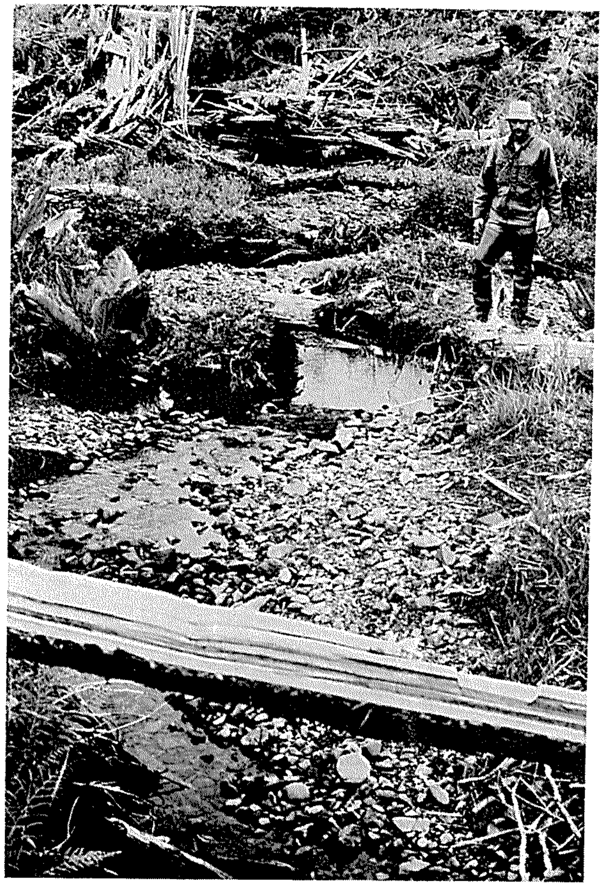

Fig. 4. Logged stream B.

moderate gradient of approximately 1%, is utilized for spawning by small numbers of pink and coho salmon and for rearing by juvenile coho salmon and Dolly Varden char, and has a gravel substrate except for a small section of bedrock outcropping near the mouth.

The upper and lower thirds of this stream were logged in 1967 and 1970; the middle third is scheduled for logging by 1974. The lower logged section, which was selected for study, measures 2,250 ft along the stream, was logged during 1969 and 1970, and is the principal section used by spawning and rearing fish.

Considerable direct solar radiation reaches the stream surface due to the lack of timber and large shade plants at the water's edge. Despite the fact that logging occurred 3 years ago and streamside plants are established, effective shade cover is not present.

Description of Logged Stream "B"

Stream "B" is a small, partially logged tributary one-half mile long which enters from the left bank of Staney Creek 7.2 miles above tide water (Fig. 4), has a minimum water flow during the summer of approximately 0.15 cfs, variable gradient from moderate in the lower half to fairly steep (approximately 3%) in the upper half, is utilized for spawning by Dolly Varden char but not by salmon, and has a gravel substrate throughout. The middle 2/3 of this stream was logged in 1969; the lower part is scheduled for logging by 1974. The logged section, which was selected for study, measures 1,750 ft along the stream, is used for rearing by juvenile coho in approximately the lower 1,000 ft and by juvenile Dolly Varden char over the entire distance.

As with logged stream "A" the stream surface is largely exposed to solar radiation because of logging. Streamside plants are established but most are not large enough to overhang the water, consequently they provide little protection.

Description of Unlogged Stream "C"

Stream "C" is a small, unlogged tributary of undetermined length which enters from the right bank of Staney Creek four miles above tide water (Fig. 5), has a minimum water flow during the summer of approximately 0.175 cfs, moderate gradient, is utilized by juvenile coho and Dolly Varden char for rearing and perhaps also by these species for spawning, and has a gravel substrate throughout. The stream is scheduled to be logged by 1974.

Little direct sunlight reaches the stream because of the dense forest canopy formed by mature spruce and hemlock trees. Additional shading results from abundant streamside growth of skunk cabbage, devil's club, ferns, blueberry, and salmonberry shrubs.

Fig. 5. Unlogged stream C.

Fig. 6. Modified Neill insect sampler.

Description of Unlogged Stream "D"

Stream "D" is a small unlogged tributary one mile long which enters from the left bank of Staney Creek, 6.4 miles above tide water, has a minimum water flow during the summer of approximately 0.175 cfs and moderate gradient except for a 12-ft falls 1,750 ft upstream. The stream is utilized by juvenile coho and Dolly Varden below the falls, has numerous bedrock outcroppings in the upper half and gravel substrate elsewhere. It is scheduled to be logged by 1974.

The amount of forest cover in the study area is less than on unlogged stream "C" because logging in an adjacent setting has partially opened up the forest canopy and because the mature timber is smaller and less dense due to shallow soils.

This stream differs from the other study streams in that it originates partially from a muskeg above the falls and traverses bedrock.

Description of Sampling Apparatus

The daily ranges of water temperatures in study streams were monitored by submerging maximum-minimum thermometers above and below the study sections. Maximum-minimum thermometers also were placed for varying periods of time at seven other locations in the Staney Creek watershed (Fig. 1). All thermometers previously had been standardized at 15 C against two chemical thermometers so that deviations exceeding 0.5 C were eliminated. The accuracies of temperatures taken by means of the maximum-minimum thermometers and chemical thermometers were ± 0.5 C and ± 0.1 C, respectively.

Fluctuations in water levels were determined daily by noting water levels on sections of measuring tape affixed to boards mounted vertically at streamside.

The minimum time of water transport through the study area was determined by marking the water with fluorescein dye. Approximately 1/8 teaspoon of powdered dye was placed in mid-stream at the head of the study section and its time of first appearance was determined visually at the foot of the study section. The intensity of the leading edge of the dye was boosted midway through the study section by the addition of another 1/8 teaspoon of fluorescein. The transport time thus obtained was minimal; the mode was estimated to be 40% longer.

Solar radiation was measured during a 9-day period from July 16-24 by means of a recording pyrheliometer mounted atop a stump near logged stream "B." Total daily radiation received was determined from planimetric measurements of areas under the curves expressed in g cal/cm^2/day.

The numbers of juvenile salmonids in the study sections were estimated at 2-day intervals by foot survey. Two or three surveyors walking downstream at

50-yd intervals visually counted all fish seen without reference to species. Coho and Dolly Varden were positively identified in all study streams and cutthroat were identified only in logged stream "A." Coho comprised about 95% of all species.

The amounts and periods of precipitation and the daily ranges of air temperatures were obtained from the Coffman Cove weather station which is located 15 miles north of Staney Creek on the east coast of Prince of Wales Island. Due to local variation these data are useful only to indicate the general weather conditions prevalent during the study.

Relative humidity was measured daily at 1200 hr during the fair weather period using a sling psychrometer.

A modified Neill insect sampler was used to collect the aquatic insects (Fig. 6). The sampler was pushed into the gravel with the attached net trailing downstream, thus isolating 1,000 cm^2 of streambed. The area was then examined; large stones were lifted and stripped underwater within the cylinder and thrown out, the whole substratum was loosened and grubbed with a probe to a depth of 5 cm (regulated by the sampler flange), and allowed to flush into the downstream collecting net. This process was repeated twice, the net was then removed and its contents preserved in vials. Three samples each were collected from a pool and a riffle on each study stream once during the study.

A modified Miller plankton sampler of 6-inch diameter was used to collect drifting aquatic insects (Fig. 7). The sampler was anchored in the streams by metal or wooden posts driven into the gravel and was positioned half immersed so that its fishing area was 92 cm^2 and included 15.2 cm of the surface film. The contents of the sampler were removed daily and preserved in vials.

A trap to sample the rate of insect drop was devised and tested briefly. The trap consisted of a No. 10 food can nearly filled with water, over which a 1/8-inch layer of mineral oil was superimposed. A drain pipe with vertical elbow extending nearly to the lip of the can was installed to release rain water without loss of the oil (Fig. 8). These traps were placed partially submerged in each of the four study streams. Insects contacting the liquid surface were held there by the oil.

All insects were separated from the detritus the day of collection and preserved in 70%-80% alcohol for later identification to family.

A small number of gravel samples was taken from logged stream "A" and unlogged stream "C" to provide descriptive information on gravel composition. Additional gravel samples were taken from logged and unlogged tributaries of the Thorne River and from Mud Bay Creek to provide information on composition with particular reference to the amount of sediment (particles <4 mm). The samples were taken from typical spawning gravel to a standard depth of 20 cm using the McNeil sampler with a 15-cm corer, were sieved through a series of Tyler screens, residues from which were measured volumetrically. In some samples the pan silts (<0.10 mm) were settled and measured as well.

Fig. 7. Miller plankton sampler.

Fig. 8. Trap designed to sample insect drop.

Samples of 100 or more coho fry were taken from each study stream and from six other locations in the Staney Creek watershed, anesthetized, and measured for length-frequency determinations. Fish from the four study streams were captured by hand dip nets and from the larger tributaries by 12-ft by 4-ft beach seines.

Tests of Gee's wire fish traps were made using commercially prepared salmon roe as bait but proved unsuccessful for two reasons: the bait was not sufficiently attractive; catches were not representative of age classes because fry could escape through the mesh.

Adult coho returning to the Thorne River in July were sampled from the sport fishery in the lower Thorne River and at the head of Thorne Bay. Total lengths and scale samples were taken for determinations of fresh and salt water age.

The concentrations of tannins and lignins in tributaries of Staney Creek and Thorne River were measured to determine relative levels and variability in concentration within and between streams. Water samples of 100 ml were tested colorimetrically using a kit from Hach Chemical Company, which ostensibly measures dissolved tannins and lignins in mg/liter on a scale of 0-15.

RESULTS

The Effect of Solar Radiation on Stream Temperatures

The study was conducted during the period July 15-26, 1972. Additional observations were made on August 12, 1972. The weather during this period began as cloudy and rainy, became partly cloudy on July 17, changed to fair for 6 days until July 24, and then resumed cloudy and rainy broken occasionally by half- or one-day periods of fair weather. The Coffman Cove weather records approximate the weather at Staney watershed during this period (Appendix Table 1). Complete stream temperature data appear in Appendix Table 2.

Solar radiation varied threefold between cloudy days (225 g cal/cm^2/day) and clear days (777 g cal/cm^2/days) and closely influenced stream temperatures as shown in Fig. 9. The temperature data are summarized in Table 1.

Table 1. Comparison of the ranges and averages of stream temperatures of the four study streams

Stream	Maxima		Minima		Averages	
"A"-logged	24.2 C	(75.5 F)	10.7 C	(51.2 F)	16.4 C	(55.2 F)
"B"-logged	19.2 C	(66.5 F)	10.5 C	(50.9 F)	12.5 C	(54.5 F)
"C"-unlogged	14.2 C	(57.5 F)	10.0 C	(50.0 F)	10.6 C	(51.0 F)
"D"-unlogged	20.5 C	(68.9 F)	11.0 C	(51.8 F)	13.5 C	(56.3 F)

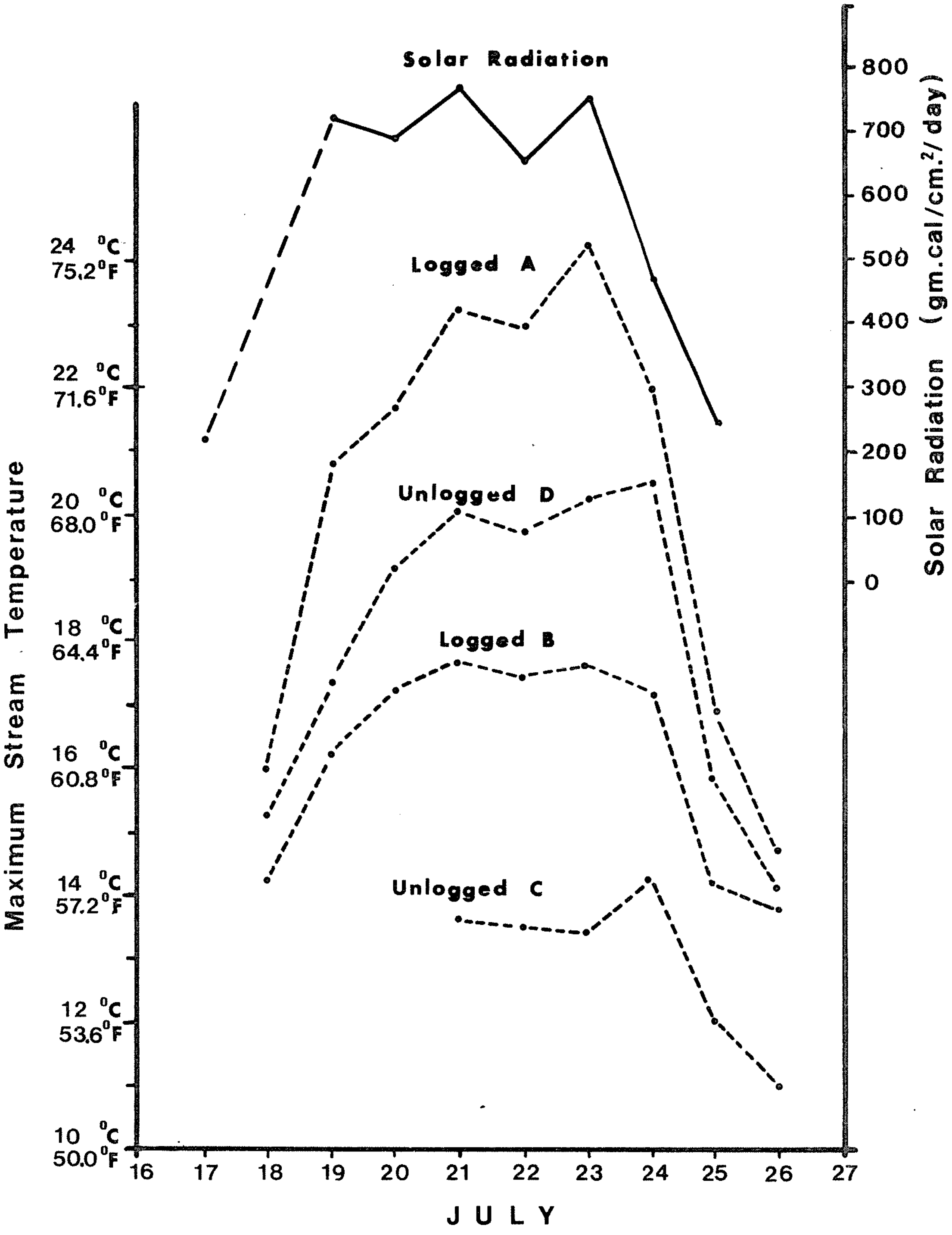

Fig. 9. Solar radiation and maximum daily temperatures of study streams.

The temperatures of logged streams "A" and "B" were high as expected due to rapid temperature increases through the logged areas, but the high temperatures in unlogged "D," which were unexpected, were due to its drainage from unforested muskeg containing several small ponds.

The two streams which appeared most similar in physical characteristics, logged "A" and unlogged "C," exhibited the greatest differences in temperature. That the difference was due primarily to the removal of streamside vegetation by logging is indicated by the rates of temperature increase in the study areas; 0.28 C/100 ft (0.50 F) through the study area of logged "A;" 0.02 C/100 ft (0.04 F) through the area of unlogged "C."

During several of the warm days detailed observations were made of water and air temperatures on streams "A," "B," and "D" to define the temperature curves and the relationships between solar radiation, water temperature, and air temperature (Appendix Tables 2 and 3).

Temperature Regimen of Logged Stream "A"

On July 20 water temperatures below the logged area were taken approximately every 15 min for 3 hr (Fig. 10). Temperatures increased during the morning from an over-night low of 12.5 C until 1530 hr, then stabilized at 23.0 C (73.4 F) except for a brief increase to 23.2 C (73.7 F) at 1645 hr, and then began to decline. Solar radiation was first detected at 0615 hr, increased to a peak at 1400 hr, then declined to zero at 2215 hr. The time lag between peak solar radiation and peak stream temperature was 2-3/4 hr.

Temperature Regimen of Logged Stream "B"

On July 18 the following hourly observations were taken: stream temperatures above and below the logged area; streamside air temperatures from undisturbed forest above the logged area (Fig. 11).

Solar radiation which was slightly reduced by intermittent, high cirrus clouds was first detected at 0600 hr, peaked at 1400 hr and became zero at 2230 hr. Air temperatures in the logged and unlogged areas were similar until 1500 hr at which time the air temperature in the logged area became substantially warmer: 6.0 C (10.8 F). Temperature curves of the stream water above and below the logged area were similar at 0915 hr but gradually diverged because of more rapid warming in the logged area. The maximum stream temperature below the logged area was 3.0 C (5.4 F) higher and occurred 1-1/4 hr later than above the logged area. The peak stream temperature below the logged area lagged 2-1/2 hr behind the peak of solar radiation.

Temperature Regimen of Unlogged Stream "D"

On July 19 the following observations were made at unlogged stream "D;" streamside air temperature; stream temperature above and below the study area (Fig. 12).

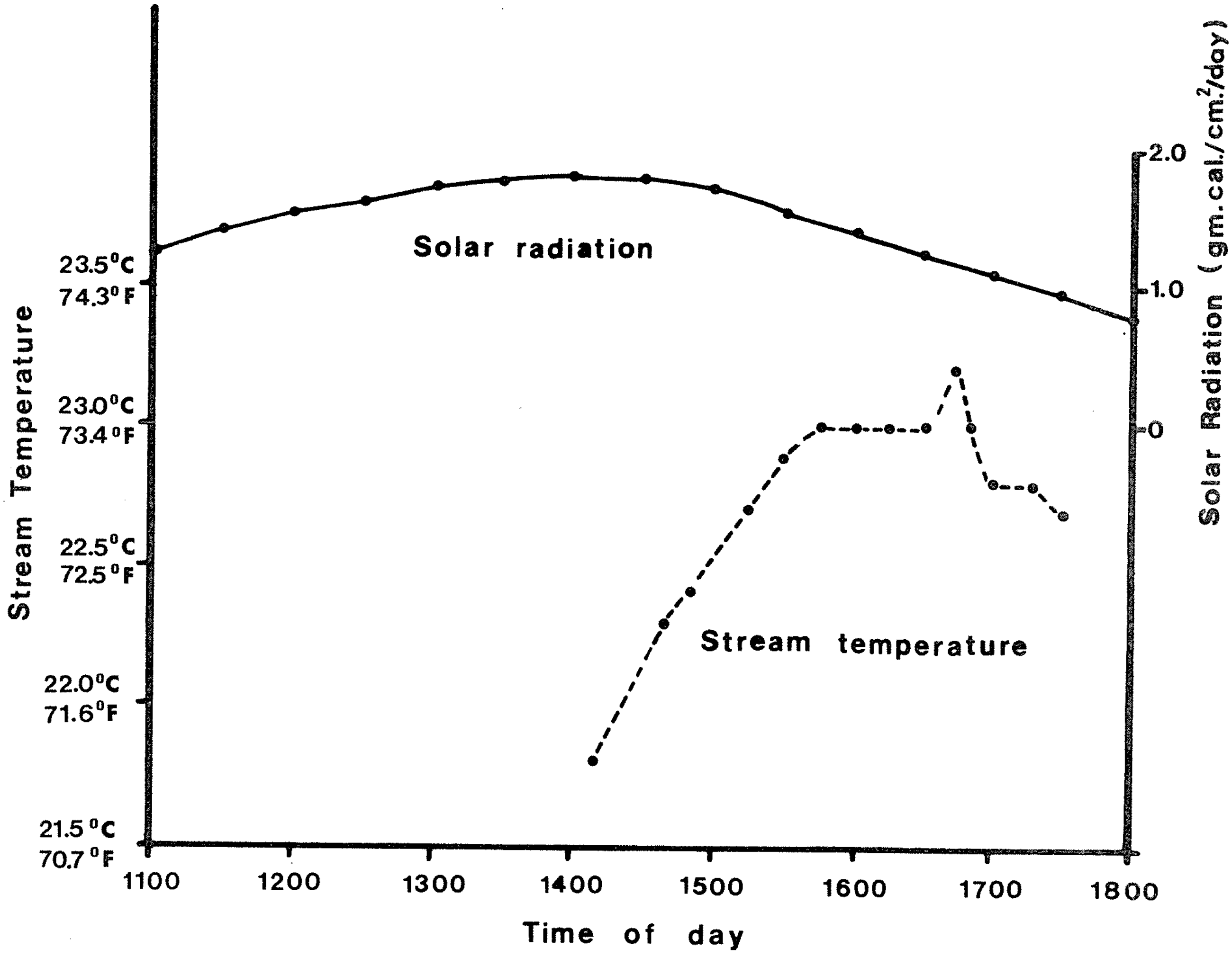

Fig. 10. Comparison between solar radiation and stream temperature below the logged area of logged stream "A," July 20, 1972.

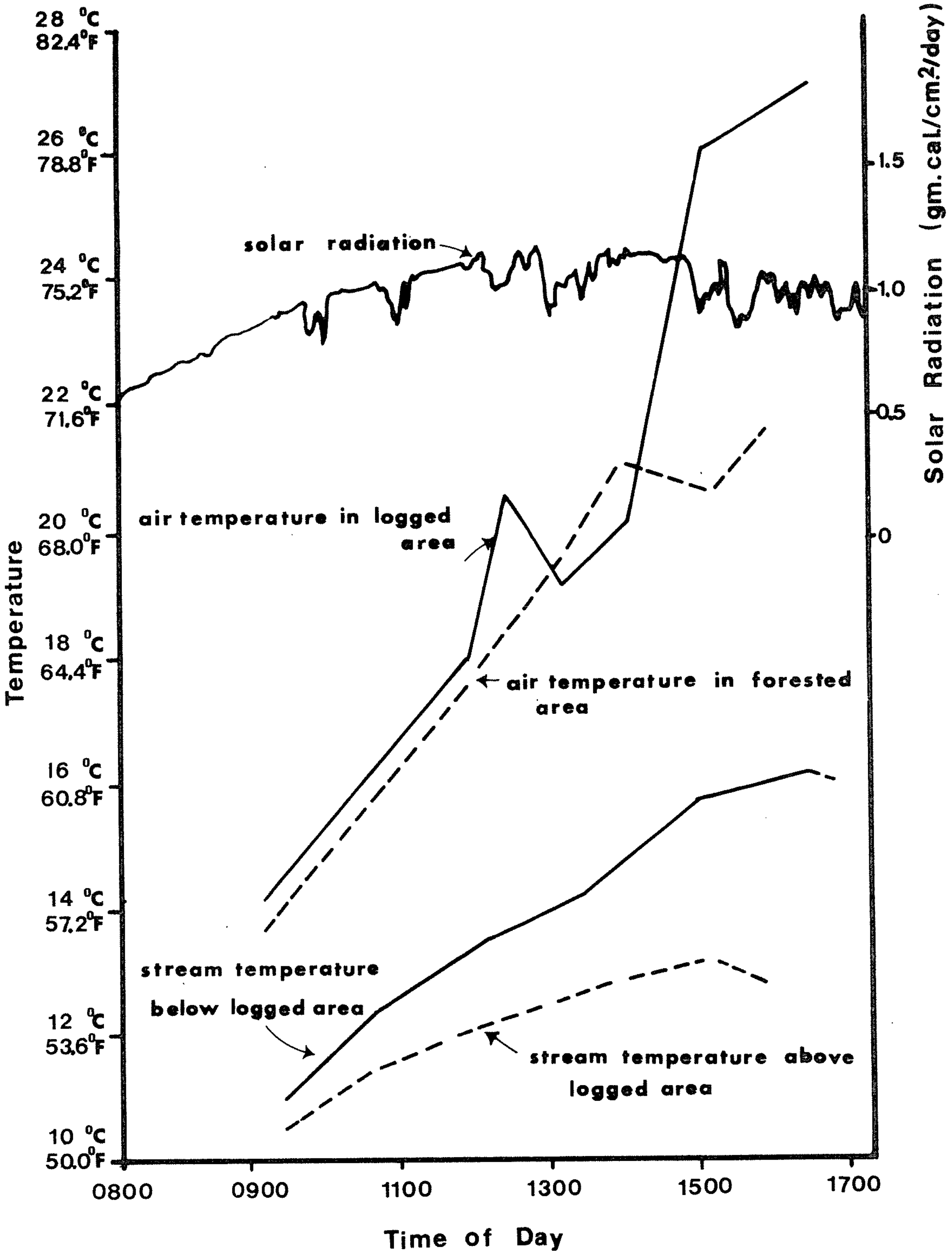

Fig. 11. Comparison between solar radiation, stream temperatures above and below the logged area, air temperatures in logged and unlogged areas of logged stream "B," July 18, 1972.

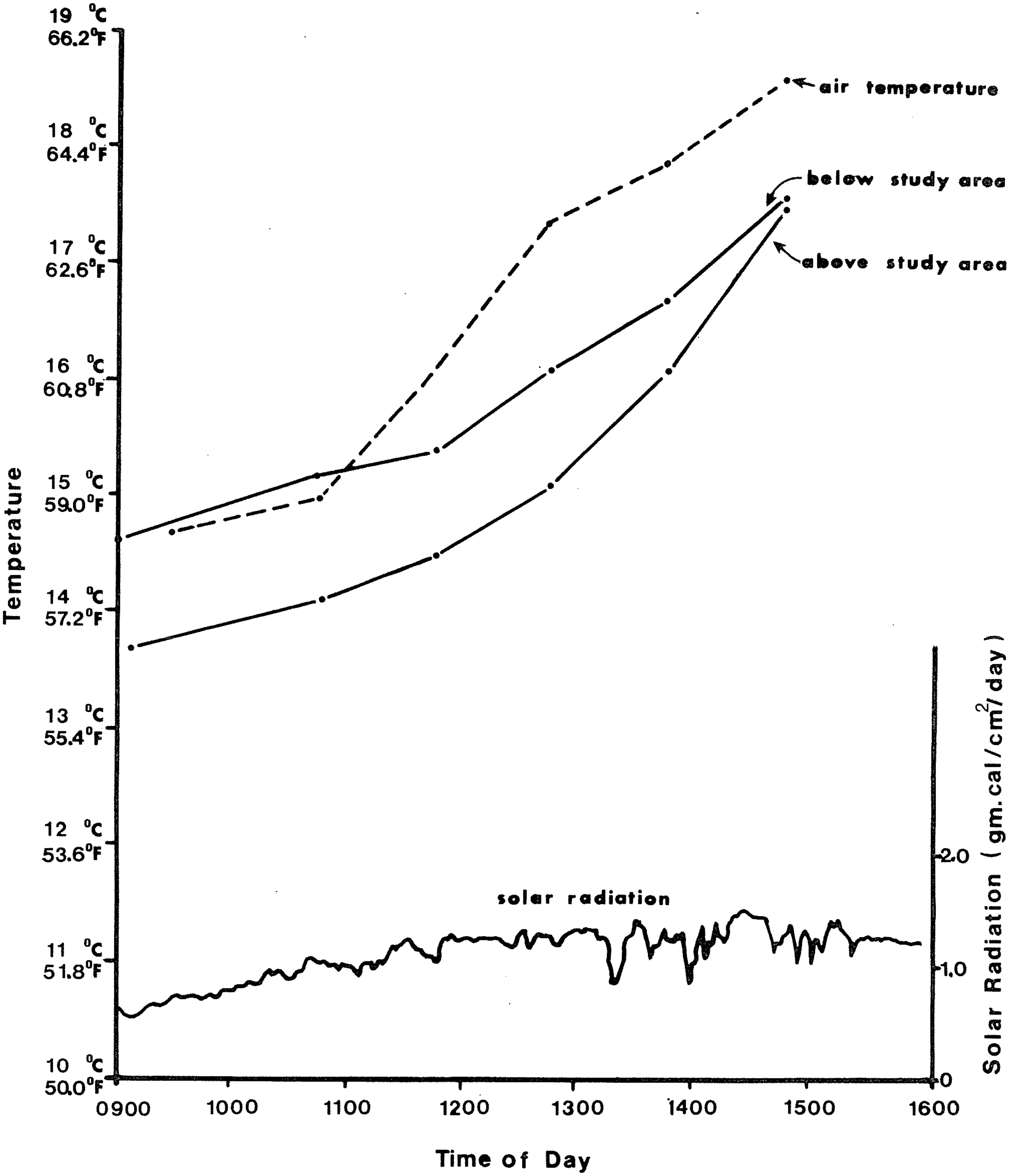

Fig. 12. Comparison between solar radiation, stream temperatures above and below the study area and air temperature of unlogged stream "D," July 19, 1972.

The water temperature curves are unusual in that the upstream and downstream temperatures were most widely separated during midmorning and gradually converged during the afternoon. This pattern is due to a large fluctuation in stream temperatures resulting from muskeg drainage above the study area which remained relatively cool during the morning but which warmed rapidly during the afternoon, and by approximately 1500 hr controlled the temperature of the lower stream.

Temperature Regimen of Larger Tributaries

The daily maximum-minimum temperatures of several larger tributaries of Staney Creek (East, Middle, and South Forks) also were monitored during the period of warm weather to enable comparisons with the small study streams (Fig. 13). The temperatures of the three forks varied considerably due to natural influences in the source waters; East Fork emanates from a 40 acre lake, which because of thermal stratification, supplies unusually warm water; Middle Fork, which has an intermediate temperature regime, drains largely from elevations between 500 and 1,500 ft; the South Fork drainage includes four precipitous, snow-fed streams which caused this stream to be coldest. All three were partially logged and had flows estimated at 5, 20, 20 cfs, respectively on July 26.

The water of all three streams warmed and cooled in direct response to variations in solar radiation, particularly East Fork which exhibited almost the same daily fluctuations as did solar radiation. East Fork reached a peak temperature of 23.2 C (73.8 F) on July 21.

Reactions of Juvenile Coho During Warm Stream Temperatures

The reactions of coho fry (0-1 year class) and fingerling (1+ year class) were observed for several hours during the period of warmer stream temperatures on logged stream "A" (from 1415 hr to 1730 hr on July 20). During this time no attempts by the coho were made to move from established territories on riffles and in pools. Motions such as hand waving and movement along the stream bank produced the normal, quick retreat into deeper water or to concealment under brush and logs. The fish fed actively throughout and gave no visual sign of being distressed.

Stream Flow

Stream gauges were established July 20 and 21 on study streams "A," "B," "C," and "D" to measure fluctuations in water levels during the period of warm weather (Fig. 14, Appendix Table 4). The gauges were established too late to document the entire lowering of stream levels which began several days earlier. Flows in the four study streams were measured only once on July 23 but were estimated to have decreased by about half during the previous week.

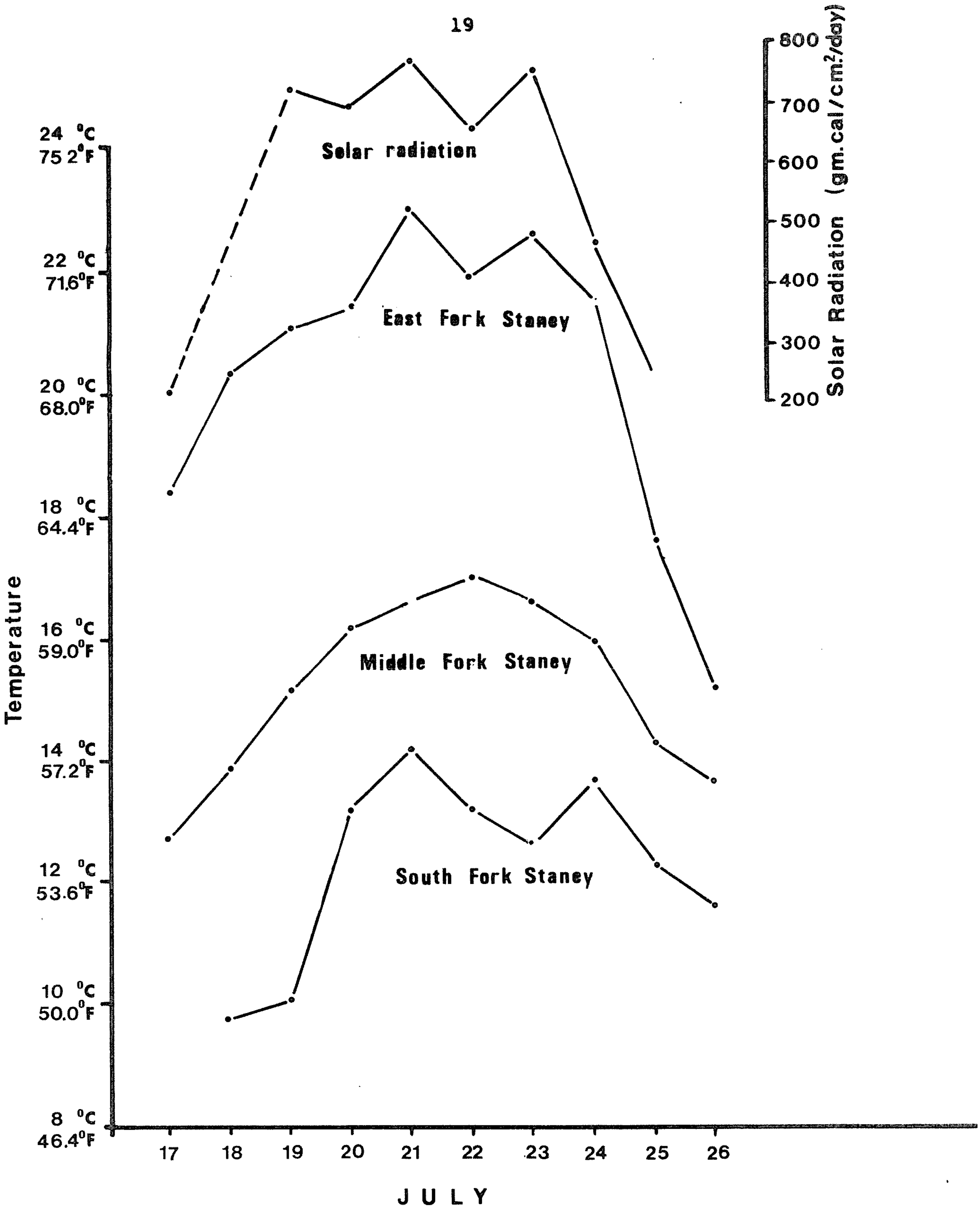

Fig. 13. Comparison between solar radiation and the maximum daily water temperatures of three larger tributaries to Staney Creek.

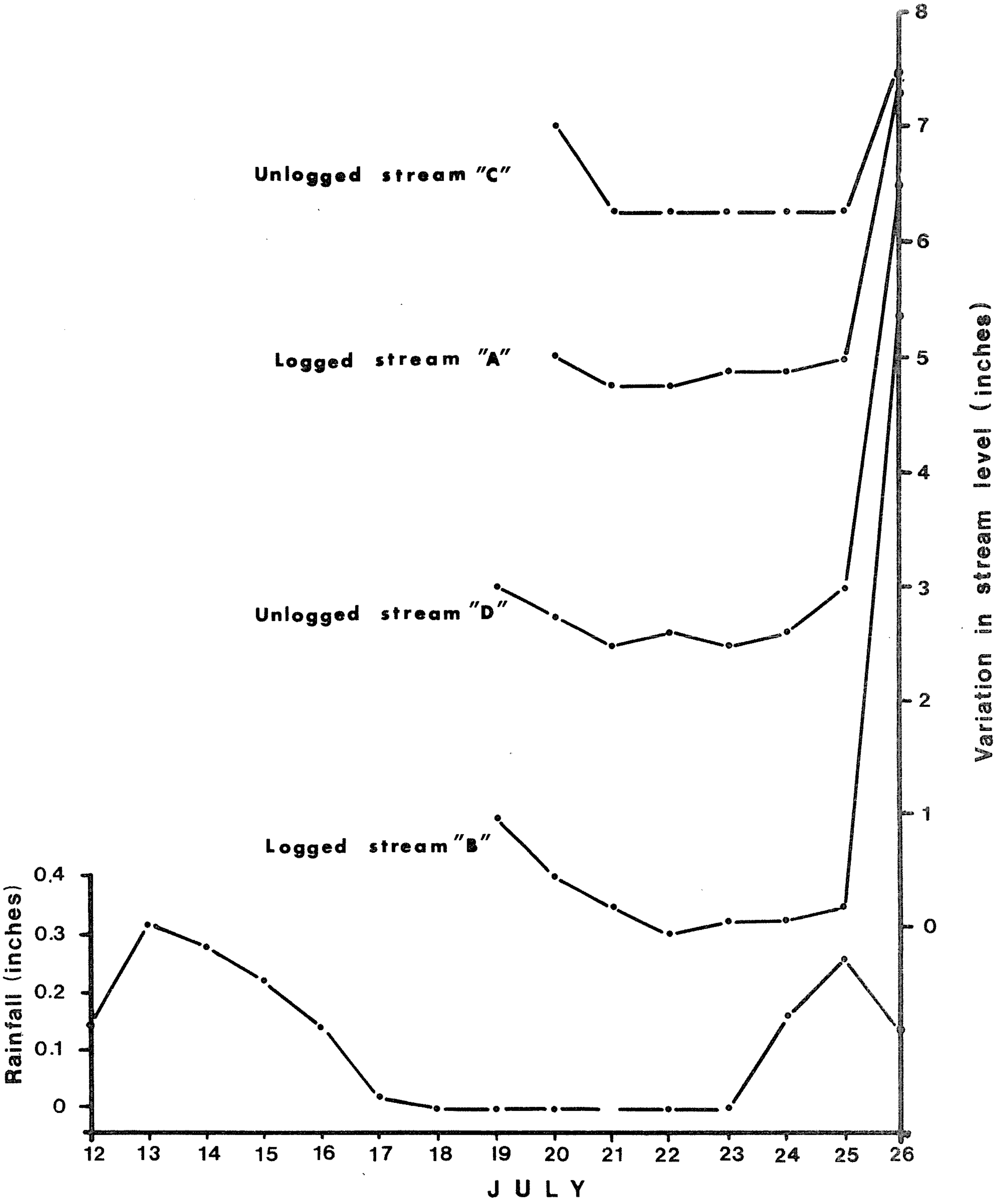

Fig. 14. Comparison between rainfall and stream levels.

Measurements of water transport rates through the study areas were made on several dates as summarized in Table 2.

Table 2. Comparison of water transport rates of four study streams

Stream	Date	Duration (min)	Distance (ft)	Rate (ft/min)
"A"-logged	7-15	70	2,250	32.1
	7-18	138		16.3
	7-23	290		7.8
"B"-logged	7-18	157	1,750	11.0
	7-23	307		5.7
"C"-unlogged	7-25	67	600	9.0
"D"-unlogged	7-19	65	1,980	30.5

Since the thermal effect of solar radiation on unshaded water depends largely on the period of exposure, stream velocity is an important factor in the amount of warming in logged areas. The estimated 50% decrease in stream flow in logged stream "A" quadrupled the water transport rate through the study area and consequently the exposure time as well.

Obstructions to water flow such as debris jams became more effective in slowing the water transport rates during low flow. This effect was particularly noticeable in logged stream "B" which contained considerable logging debris in a 30-yd section. During low flows this section became a series of pools through which the passage of the tracer dye was noticeable delayed.

Estimates of Juvenile Coho Abundance

The populations of salmonids in the four study streams were estimated from one to five times during the period July 16 to August 12 (Fig. 15). Unlogged stream "D" was surveyed only once because of poor visibility caused by abundant periphyton, dissolved tannins and lignins. The estimates are summarized in Appendix Table 5. The method of visually estimating salmonid populations was fairly successful in streams "A," "B," and "C" but the estimates were somewhat influenced by variable flows and light conditions. Visibility was best under full sunlight during low flows, conditions which prevailed from July 19-23 but not on other dates due to varying cloud cover. Estimation of abundance by species was impractical during the routine counts owing to the shyness of the yearling coho and larger Dolly Varden char which occupied the deeper pools together. The Dolly Varden population in logged stream "A"

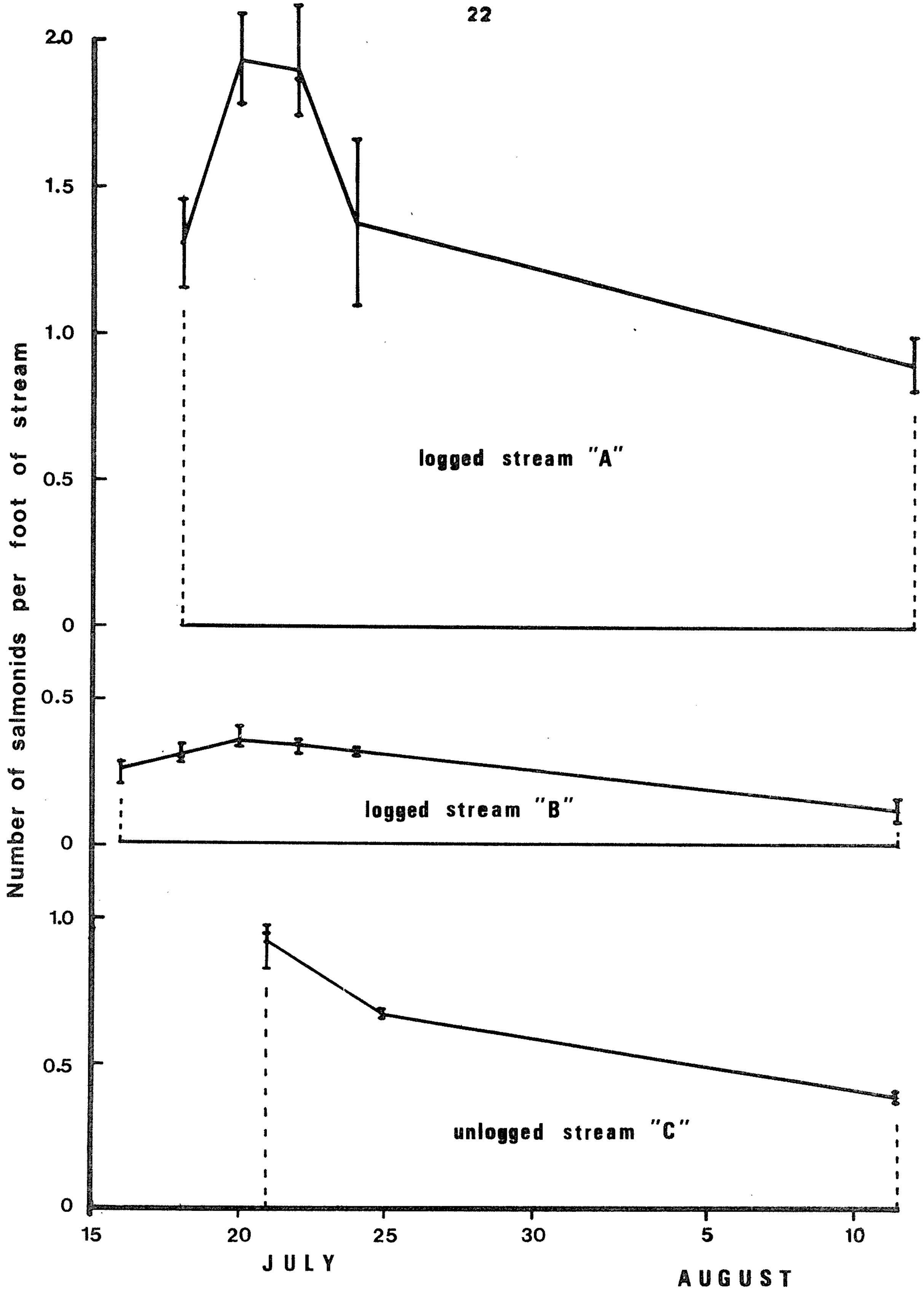

Fig. 15. Estimated densities of salmonids in three study streams. Individual counts and averages are shown.

was estimated singly on July 23 at 75; roughly 2% of the estimated total salmonids on that date. In the opinions of the observers, the relative abundance of Dolly Varden in the other study streams was similar or slightly less.

The fish densities apparently declined by about half during the period of observation and did so proportionately in all three streams. Fingerling coho were inadvertently caught at night in drift-insect nets in all study streams, thus demonstrating nocturnal activity which may have been a downstream movement out of the smaller tributary streams. However, July and August are not the usual months for seaward migration by fingerling cohos. We believe that predation of coho fry by fingerling coho and Dolly Varden was the most likely cause of decline.

The densities of salmonids varied considerably between the four study streams: logged stream "A" (1.93 per lineal foot); logged stream "B" (0.36 per lineal foot); unlogged stream "C" (0.92 per lineal foot); and unlogged stream "D" (0.07 per lineal foot). The fish counts are not expressed by area because stream surface areas were not determined. Because the study areas were of approximately equal width but of varied length, relative abundance is best described in fish per lineal foot, rather than in absolute numbers.

Length Frequencies of Juvenile Coho

Samples of approximately 100 coho were collected at each of eight locations in the Staney watershed: the four study streams, two places on the Middle Fork, main Staney Creek 4 miles above tidewater, the South Fork (Figs. 16 and 17). The samples were predominately age 0 coho (fry) but contained varying numbers of age 1+ coho (fingerlings). Although the sampling methods were biased against the larger age 1 coho the bias is minimized in our comparison of distributions by excluding all coho >54 mm.

The frequency distributions varied considerably between locations, particularly between the larger tributaries of Staney Creek. A comparison of the 95% confidence limits on sample means show that coho fry from logged stream "A," logged stream "B," and unlogged stream "C" were of nearly identical sizes but those from unlogged stream "D" were significantly larger (Fig. 18). Differences also were apparent among samples from the four larger streams but the differences cannot be explained by any parameters which were measured during the limited duration of the study.

Early-Run Coho of the Thorne River

The run of coho salmon to the Thorne River has never been accurately estimated, but judging from the numbers of early-run coho observed during July in the lower river and off the mouth, the run was substantial in 1972, far exceeding the few hundreds annually reported in past stream survey records.

In an effort to learn the life history of the July segment of the run we sampled coho from the sports fishery which was concentrated off the mouth

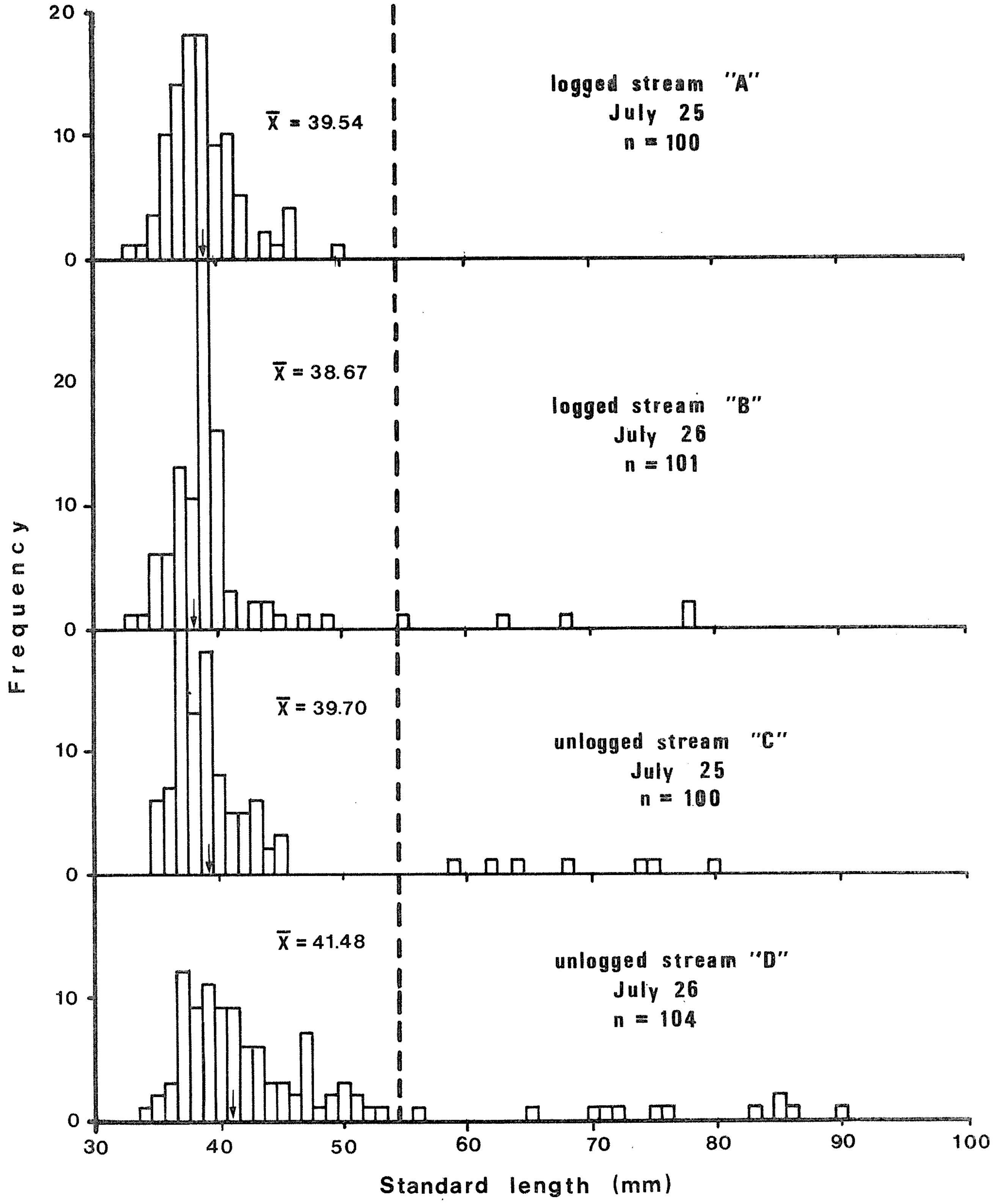

Fig. 16. Length frequencies of juvenile coho from 4 study streams. Arrows indicate means of distributions below 55 mm.

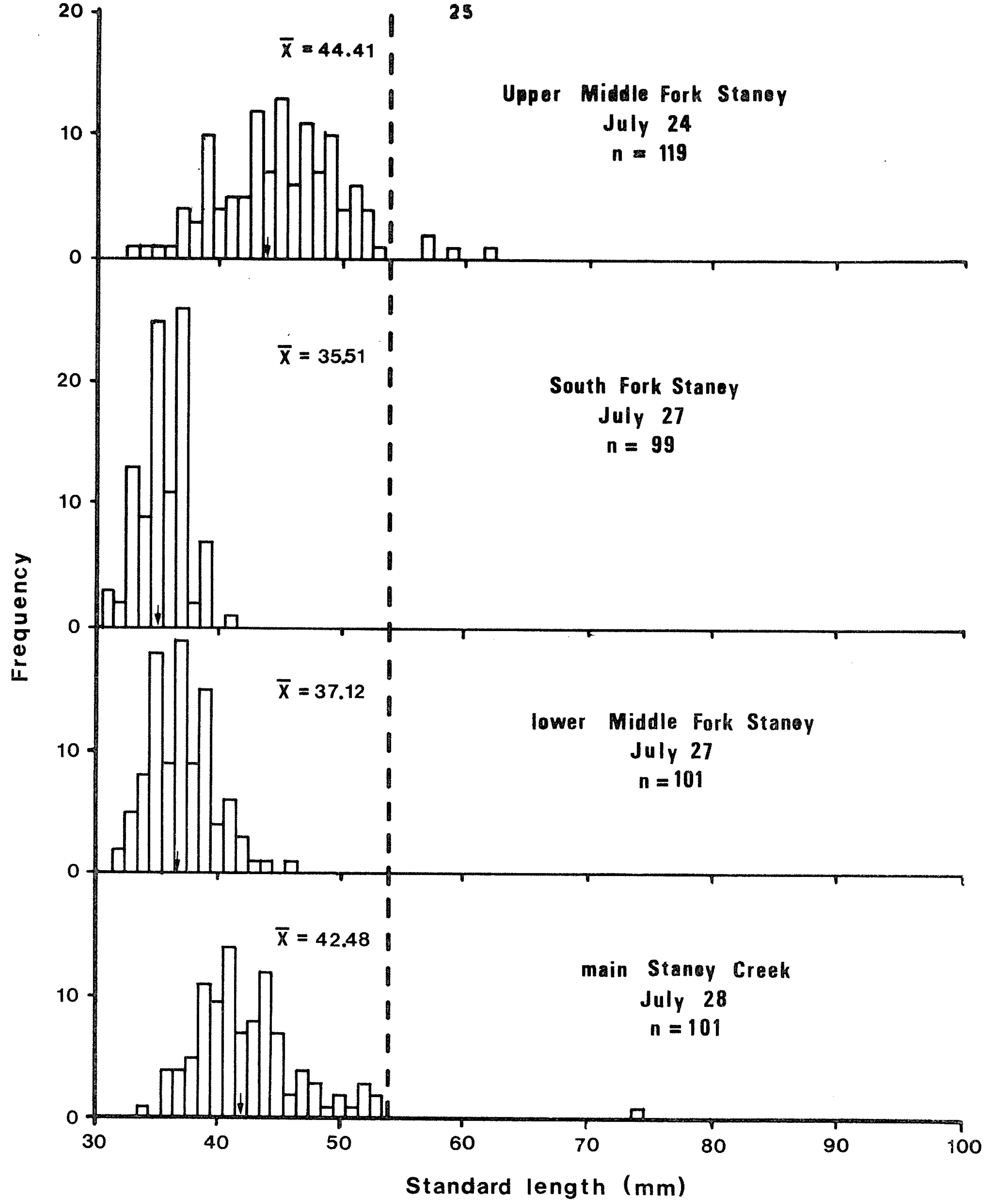

Fig. 17. Length frequencies of juvenile coho from main Staney Creek and three other locations with flow >20 cfs. Arrows indicate means of distributions below 55 mm.

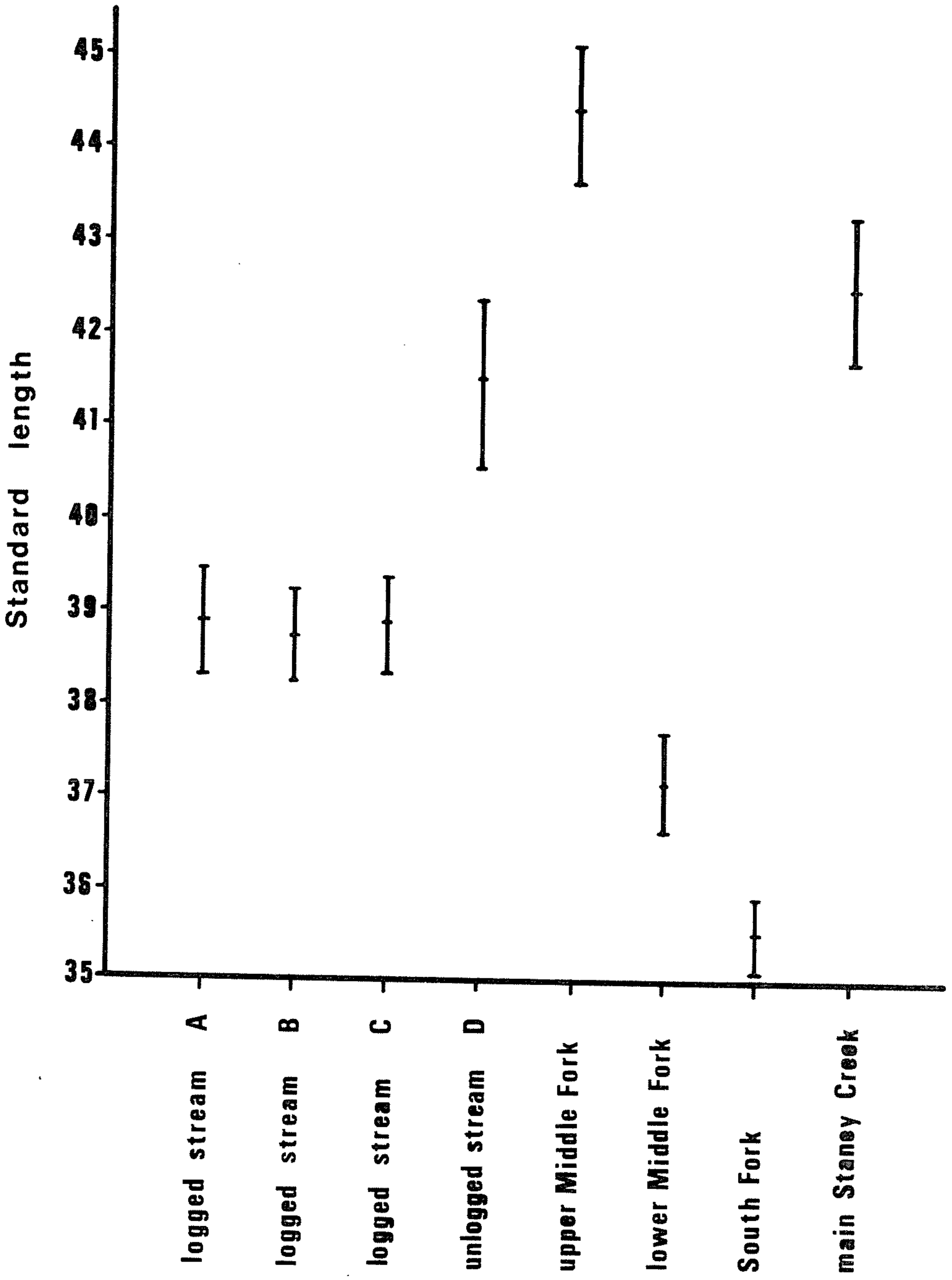

Fig. 18. Comparison of the means and 95 per cent confidence intervals of length frequencies of coho fry from eight locations in the Staney Creek watershed, July 24-28, 1972.

and in the lower river between 2 and 3 miles above high tide level. Standard lengths and scales were obtained from 50 coho as presented in Appendix Table 6 and summarized in Table 3 below.

Table 3. Age distribution of coho from the Thorne River sports fishery during July 1972

Annuli		Number of fish	Per cent of total	Mean length cm:inches
Fresh water	Salt water			
1	1	39	78	64.3:25.3
2	1	8	16	71.1:28.0
1	2	1	2	76.2:30.0
2	2	1	2	68.6:27.0
1	0	1	2	59.7:23.5

Most of the coho sampled (78%) migrated to salt water after one year of residence in the stream and spent only one year in salt water, which accounts for their small size (64.3 cm/25.3 inch: about 5 lb). A second group (16%) spent two years in the stream and one year in salt water. Only two coho sampled (4%) had spent two years in salt water and one returned apparently after having spent only a few months in salt water.

Local residents report that the July run consists principally of small coho (one year in salt water) and that the September run consists of 8-lb to 12-lb coho (probably two years in salt water). It is likely that the coho which returned after a single year in salt water did not enter the Gulf of Alaska but remained in the inner waters of Southeast Alaska.

Insects

The most prominent order of insects found in all streams sampled in the Staney Creek watershed was Ephemeroptera (mayflies) (Fig. 19). The greatest abundance of aquatic insects occurred in logged stream "A," with the most prominent orders being Ephemeroptera, Diptera (flies) and Trichoptera (caddisflies), respectively. This greater abundance occurred despite the higher sediment concentrations (~5%) observed (*see* Gravel Composition, p. 30).

The greater abundance of aquatic insects found in logged stream "A" corresponds with the greater density of coho fry and fingerlings present. The fact that aquatic insects constitute a significant portion of the diet of young coho salmon may account for the greater abundance of coho, however, the preliminary nature of these data are an inadequate basis for conclusions.

Family diversity between logged and unlogged streams appears to be negligible (Appendix Table 7).

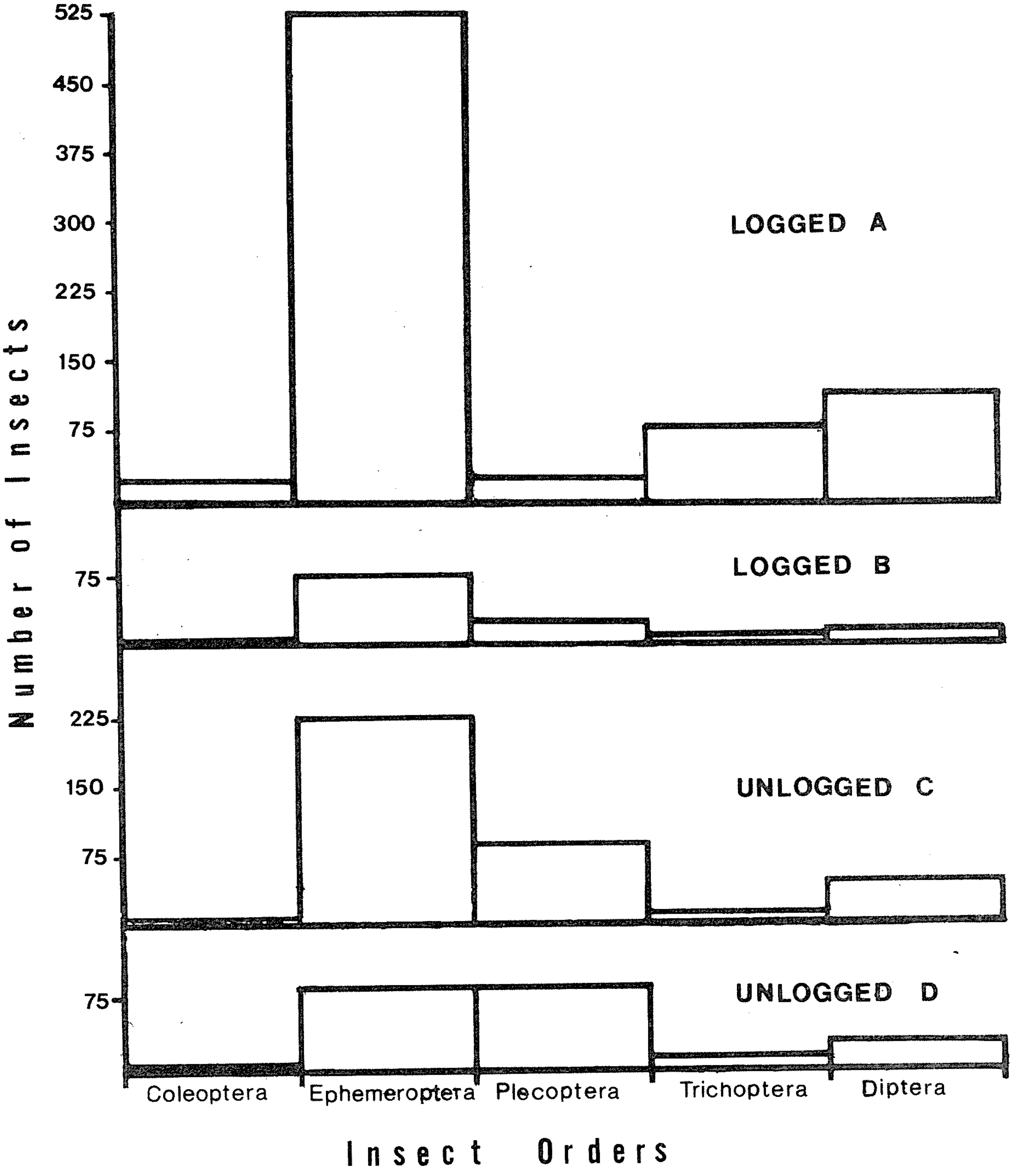

Fig. 19. Occurrence of insects in samples from four study streams.

Aquatic insects made up the major portion of the drifting insects in all streams; the most abundant was Ephemeroptera (Appendix Table 8). The drift rates of invertebrates, although highly variable, appear to correspond with stream discharge.

The east and west forks of the North Thorne River were also sampled for aquatic insect abundance and diversity to provide pre-logging information (Fig. 1, Appendix Table 7).

Tannins and Lignins

The concentrations of tannins and lignins were measured at 12 locations in the Staney and Thorne River watersheds. Samples were taken on August 3 following a week of light rain showers from which 1.56 inches of rainfall was accumulated at the Coffman Cove weather station and at which time stream flows were estimated to be near the normal summer levels. The results are summarized in Table 4.

Table 4. Concentrations of dissolved tannins and lignins in tributary streams of Staney Creek and Thorne River on August 3, 1972

Staney Creek trubutaries		Thorne River tributaries	
Stream	Concentration (mg/liter)	Stream	Concentration (mg/liter)
logged "A"	1.5	Thorne River	0.5
logged "B"	3.5	Gravelly Creek	1.8
unlogged "C"	1.6	Gravelly Creek (replicate)	2.0
unlogged "D"	3.0	Goose Creek	2.3
East Fork	1.6	Coho Creek	1.5
East Fork (replicate)	1.5		
North Fork	0.5		
Middle Fork	1.0		
South Fork	0.5		

The concentrations of tannins and lignins varied between 0.5 and 3.5 mg/l but with no apparent relation to logging or stream size. The concentrations are believed to be relatively moderate and without significance to the survival of salmonids as inferred from bioassay studies of the effects of wood leachates on pink salmon fry.[3]

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[3] Personal communication with Mr. Bruce M. Pease, College of Fisheries, University of Washington, Seattle, Washington.

Gravel Composition

Gravel samples were taken from two streams of the Staney watershed, seven streams in the Thorne River watershed and from Mud Creek, Kruzof Island (Appendix Table 9). The Staney Creek watershed samples were taken from logged stream "A" and unlogged stream "C" to compare gravel compositions of the two streams. Samples from Thorne River watershed were taken for two purposes: (1) as a measure of pre-logging sedimentation (percentage of particles <3.3 mm) in the unlogged streams; (2) as a preliminary comparison of sediment levels between logged and unlogged streams.

The five gravel samples each from logged stream "A" and unlogged stream "C" were of similar composition except that 5.5% more sediment existed in logged stream "A" (16.6% and 11.1%, respectively). Since no point source of sediment due to logging or natural causes exists on this stream we assume the higher sediment level is due to variation in soils or gradient.

Statistical analysis of the gravel composition data was limited by the small number of samples, consequently, differences which were readily apparent during field sampling did not prove to be significantly different in the analysis. A graphical presentation of the 95% confidence limits on the percentage means of four gravel sizes from tributaries of Thorne River appears in Fig. 20. The east fork of the North Thorne River contained the greatest amount of sediment (32.9%) and the west fork was second highest (20.0%). Because no human disturbance had occurred in the upper North Thorne River watershed, the sediment has resulted from natural sources, most likely from the numerous earth slides which are visible on surrounding hillsides. Sediment levels in the other tributary streams generally were moderate and apparently were not related to logging or road building.

The samples from Mud Creek were significantly higher in sediment content than all other samples (45.0%), and are the probable cause for the low productivity of this stream (Appendix Table 7). The low productivity however, may not be due to reduced permeability caused by compaction of sediments, but rather to abrasion from movement of particles. The sediment of Mud Creek was largely composed of pumice granules, which appeared to be less compactible than usual stream sediment, but which shifted more readily when disturbed. Lack of pre-logging data precludes any determination of the amount of sediment resulting from logging; however, judging from the relatively large amounts of exposed mineral soils at bridges, road cuts, and resulting from numerous slides, the amount has been substantial.

Surveys of Logged Watersheds in the Sitka District

Active logging operations at Mud Bay and False Island were visited to familiarize project personnel with present logging practices. Previously logged watersheds of Katlian, Nakwasina, Whitewater, Fish, and Rodman Bays were surveyed by foot to observe the residual effects of logging on salmon-producing streams. The logged streams were chosen from a list of streams which, by general consensus of Messrs. Theno (ALP), Elliason (ALP), Parker (ADF&G), and Anklin (USGS), were suggested as examples of high-impact logging practices.

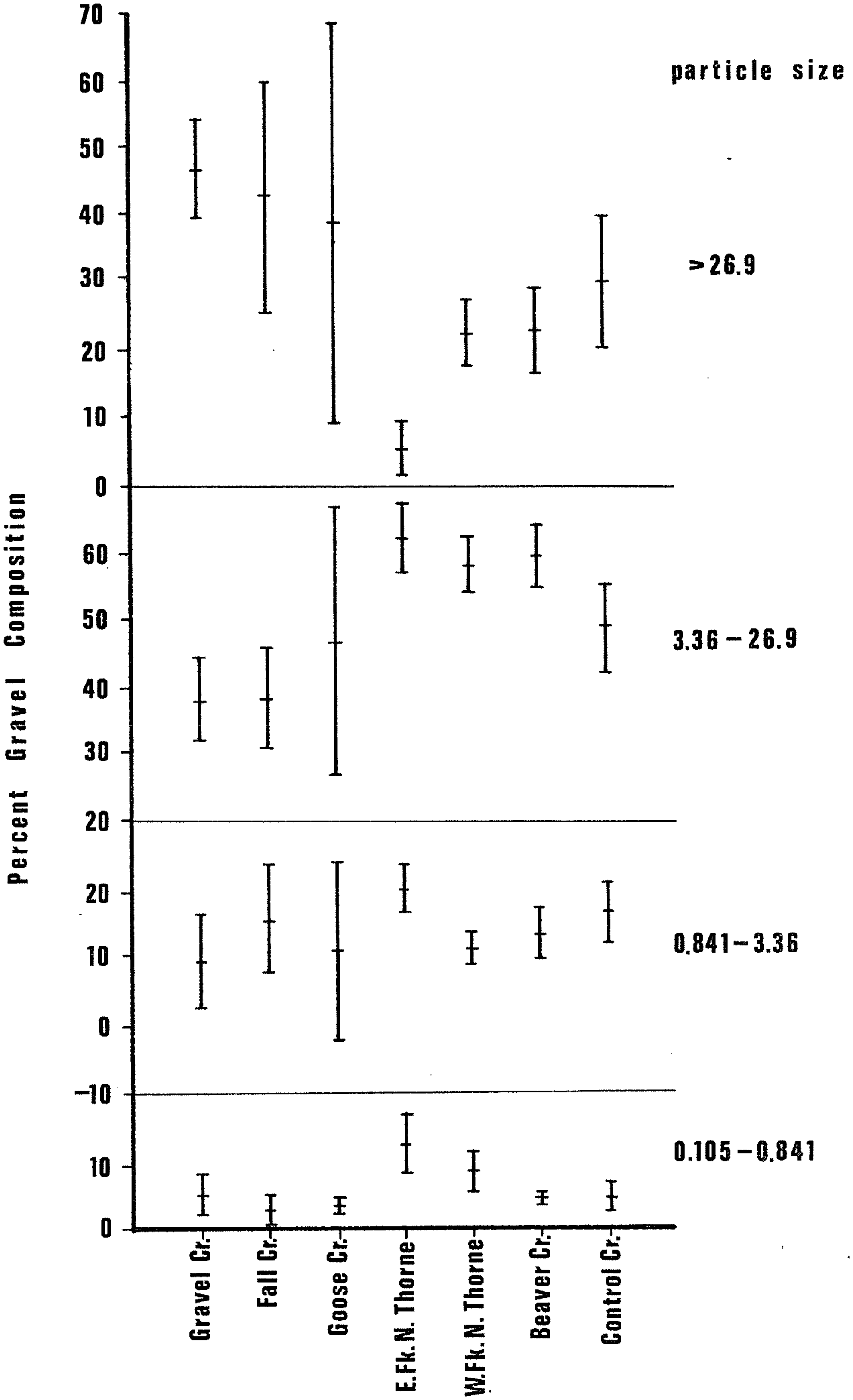

Fig. 20. Comparison of means and 95 per cent confidence limits of percentage gravel composition from Thorne River tributaries.

The logged watersheds were reached daily from Sitka by float plane. Foot surveys extended from 1 to 2 miles upstream usually via logging roads, and the return was made down the main stream channel.

Subjective observations were made of post-logging conditions which appeared to be obviously either beneficial or harmful to salmon production, such as the condition of logging roads and bridge abutments, regeneration of plants, stability of stream banks, and the effects of logging debris. Also, observations were made of adult and juvenile salmon and Dolly Varden char including counts of salmon where possible.

Visits to past and present logging operations and/or logged streams were made to the following seven locations during the period August 5-11:

Baranof Island - Katlian River, Nakwasina Sound, Fish Creek, Rodman River

Chichagof Island - False Island logging operation

Kruzof Island - Mud Bay logging operation

Admiralty Island - Whitewater Bay

The following commentary summarizes the subjective observations recorded by Tyler and Gibbons during visits to each area:

False Island Logging Operation - August 5

We observed several small tributaries to False Island Creek which had been hand-cleared following logging. The first stream (about 0.5 cfs) was providing excellent habitat for a fairly high density of coho fry. Some shading resulted from abundant skunk cabbage plants rooted along the banks and in the stream. No debris jams were observed and good current velocity was maintained throughout. A second hand-cleared stream (about 0.1 cfs) was providing poor rearing habitat due to insufficient flow and a heavy blanket of fine organic material on the stream bottom. Only one coho fingerling was seen in a 50-yd section examined. About half of the debris was recognizable as needles and twigs and appeared to have resulted from logging, however, the rest was well decomposed, organic material which probably formed the natural bottom prior to logging.

We also looked at a section of False Island Creek near the mouth which reportedly had been selectively logged for large spruce in 1941 and had been used by tractors as a roadbed for log hauling. The stream area immediately above and below the road bridge contained good spawning gravel and was being used by spawning pink salmon at an approximate density of one female per 5 yd^2 of stream bed. The banks of this stream appeared fairly stable but were nearly inaccessible to travel by foot due to numerous fallen trees, stumps, and slash, which was largely hidden beneath a thick growth of shrubs, small hardwoods, and a few spruce saplings. Numerous logs lay across the stream, and one large root ball was positioned in mid-stream near the bridge. This portion of the stream appears to have required nearly 30 years to stabilize following logging.

The regeneration of conifers throughout recently logged portions of the False Island area has been excellent.

A small tributary stream (estimated 0.5 cfs) in the upper watershed which had deposited a deep layer of gravel and boulders over the forest floor during recent flooding, was scheduled to be logged in 1972. We believe that logging the flood plain of this stream will greatly increase its potential as a source of sediment to the main stream.

The location and construction of roads, bridges, and culverts seemed well planned to minimize the impact of logging on fisheries resources in the area.

Mud Bay Logging Operation - August 7

Kruzof Island is widely recognized as a problem area due to the instability of its surface soils which are composed of volcanic ash. Streams in the area contained amounts of visible pumice varying from scattered pockets in some to others in which the substrate is entirely of pumice. Assessment of the amount of sediment contributed to the streams by logging is difficult because no pre-logging measurements of sediment are recorded.

Logging began at Mud Bay in 1966 and is scheduled for completion in 1973. Principal logged streams are Iris Creek (113-45-06) and Shelikof Creek (113-45-05). There are two named tributaries to Iris Creek: Mud Creek and Canyon Creek.

On the date of our survey Shelikof Creek contained a fairly high density of coho fry in the vicinity of the road crossing. Pools in the area each contained from 25 to 70 coho fry. The stream bottom was heavily silted with pumice sand to the extent that wading was difficult because of soft footing.

The bottom of Mud Creek was deeply covered with pumice sand. Samples taken immediately above and below the bridge crossing contained high percentages of small particles (Table 5).

Table 5. Percentage of gravel sizes from Mud Creek, Kruzof Island

Particle size	Percentage of sample Sample 1	Sample 2
726.7	0.0	2.8
3.3-26.7	62.3	44.9
0.8-3.3	32.5	37.3
0.1-3.3	5.2	15.0

Several small logged streams were observed from which logging debris had been removed. These offered excellent rearing habitat for juvenile coho salmon (Fig. 21) except for a 20-yd section of one stream which appeared to have been cleared excessively as evidenced by a complete absence of logs and other debris and sparse streamside vegetation.

A number of corrugated culvert pipes installed at road crossings of small streams created plunges at the lower end of from several inches to 2 ft which formed effective barriers to the upstream movement of small salmon and trout. Although no measurements of current velocities through the pipes were taken, the velocities appeared to greatly exceed the sustained swimming capability of small salmonids. Coho fry occurred above some impassable culverts reportedly resulting from upstream spawning by adult coho which negotiate the culverts during high water flows. Most of the culverts were near the natural limits of accessibility to coho fry.

Numerous, small earth slides were seen on hillsides throughout the logged settings. These appear to have resulted from logging and attest to the instability of surface soils. Most of the slides were not associated with surface run-off but some had occurred in gullies and undoubtedly contribute sediment to streams during heavy rainfall.

Sediment also is being introduced into streams from fill material used at several road crossings. To overcome gullied terrain at these crossings, the road was laid parallel to the stream for short distances by adding fill material along the stream banks. Sediment from one such fill on Mud Creek was seen to noticeably increase the turbidity of the stream during a period of moderate rainfall.

Katlian Bay - August 8

Our survey began at the log dump at north Katlian Bay, progressed along the main logging road past Coxe River (113-44-02) and ended approximately 1 mile upstream on Katlian River (113-44-03).

The regrowth of spruce and hemlock in clear-cut areas has been excellent except along the lower river channels and wherever mineral soils were exposed by logging activity, such as on roads, borrow-pits, and dragline furrows. In these places red alder has established in dense thickets to the exclusion of other species (Fig. 22).

The potential hazard to salmon spawning beds of bridges left in place after logging is demonstrated on two small streams which enter Katlian Bay just west of Coxe River. Bridge logs have dropped into the stream due to erosion of their abutments and thus form excellent dams because the logs are lashed together by cable. On one stream the entire flow was being diverted by the bridge logs from its channel to the road bed, which it followed for about 200 yd before joining the other stream (Fig. 23). The bridge at the other stream likewise had dropped, forcing a diversion which has caused considerable

Fig. 21. Hand-cleared rearing habitat in the Mud Bay area, Kruzof Island.

Fig. 22. Growth of red alder on mineral soils exposed by logging.

Fig. 23. Diversion of stream flow by bridge logs.

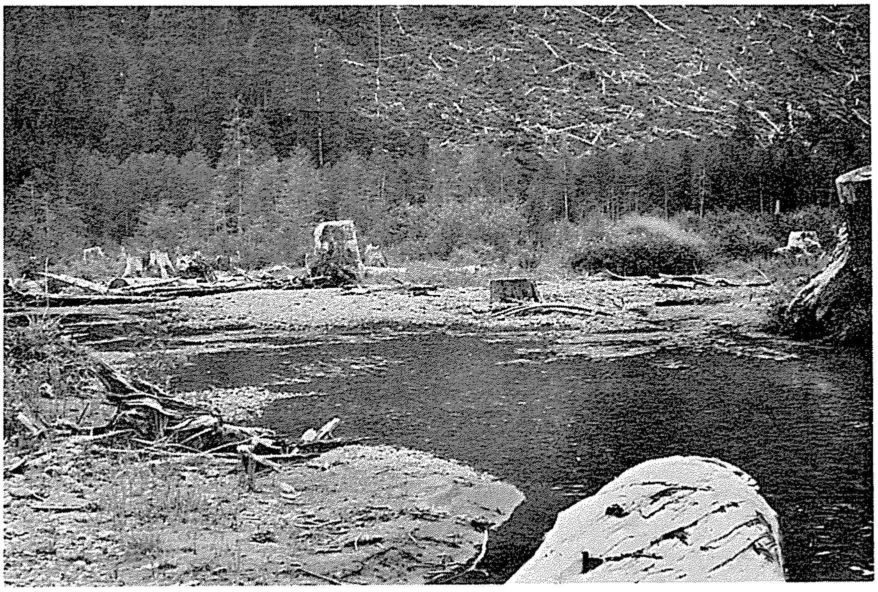

Fig. 24. Flood plain of upper Whitewater Creek.

erosion of the stream bank. A similar diversion of flow or erosion of stream banks above spawning beds of a salmon-producing stream would seriously reduce the survival of eggs and alevins.

Bridges also were left in place over Coxe River and a small tributary stream between Coxe River and Katlian River and eventually will drop into these streams.

No adult salmon were seen in any of the streams, however, the survey preceeded the normal peak of spawning by several weeks.

Nakwasina Sound - August 8

The scheduled survey of the Nakwasina River (113-43-02) was cancelled because of high water conditions. Instead, a smaller unnamed salmon stream (113-43-05) 3-1/2 miles to the south was surveyed. The survey route began at the stream mouth, progressed upstream for 1/2 mile, and then followed up a hillside logging road for 1/2 mile.

Regrowth of spruce and hemlock in clear-cut areas has been excellent except that red alder predominates along the lower stream banks and wherever mineral soils were exposed by logging.

The deposition of several root balls on probable spawning bars in the lower stream had caused scouring of the bars and consequently a reduction of spawning facility.

Whitewater Bay - August 9

The survey of Whitewater Creek (113-90-14) began at the mouth, progressed up the main logging road for approximately 2 miles, then down the main- and side-stream channels for approximately 1/4 mile.

The regrowth of spruce and hemlock has been excellent except where mineral soils were exposed by logging activity. Dense growths of red alder occur on all mineral soil.

Intensive spawning by chums and a few pinks was in progress throughout the upper stream. Numerous, small schools of pink and chum salmon were observed in the inner Whitewater Bay. An aerial survey of the escapement to Whitewater Creek made on August 10 by the Alaska Department of Fish and Game estimated 11,000 pink, 7,000 chum upstream and 10,000 pink, 2,000 chum off the mouth.[4] This abundance compares very favorably with historical escapement estimates dating as far back as 1940. A comparison of pre- and post-logging escapement estimates is valid with Whitewater Creek because ground rather than aerial surveys have been made most years, thereby voiding bias created by improved visibility resulting from the removal of streamside timber.

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[4] Personal correspondence from John Edgeton, Alaska Department of Fish and Game.

The upper portion of Whitewater Creek above 2 miles bears evidence of severe flooding similar to that which has been observed in adjacent, unlogged watersheds of Chaik Creek (112-80-28), Hood Bay, South Arm Weir Creek (112-72-24), and Hood Bay, North Arm, South Head (112-72-12) (Tyler, 1970). Deposits of gravel and boulders were observed at several locations where small streams cascading from steep hillsides level-out at the sides of the valley floor. The deposition had not reached the main stream and did not appear to have harmed the spawning facilities.

Approximately 1/3 of the main stream flow is diverted into a separate channel at the site of a logged blowdown area 2 miles upstream. The flow into this channel braids into numerous small channels as it runs across a flood plain of about 20 acres. Most organic material other than tree stumps has either been washed away or covered with gravel (Fig. 24). Hardwoods will dominate the regrowth in this area and unless the stream rechannelizes, the diverted flow will probably remain unstable and braided for many years. Whether or not logging caused the original diversion was not determined but certainly the instability of the flood plain was increased by logging.

Bears were especially active in the upper watershed in response to heavy spawning by chums. Streamside foliage was well beaten down and the remains of partially-eaten salmon were scattered along the stream banks.

Fish Creek - August 10

Our survey began at the mouth of Fish Creek (113-65-04), progressed upstream for 1 mile, and returned along the same route.

Excellent spawning gravel exists in a 200-yd section immediately above the stream mouth. Very light spawning by chums (65 counted) was in progress beneath overhanging alder trees near the stream banks. For 1/4 mile above this section the channel has unstable banks and recently has split into a new channel which is choked with washed-out alder trees (Fig. 25).

The stream banks from 1/4 to 1 mile above the mouth are more stable, noticeably so in a few places where old-growth timber remains. Numerous root balls were stranded on gravel bars in the lower stream. Also present about 1/2 mile upstream was a single, large log jam which was mainly composed of cut logs. Gravel bars which appeared to be suitable for spawning occurred regularly in this section however, few salmon were present (30 chums, 5 pinks counted).

Rodman Creek - August 11

The survey followed the main logging road upstream for 2 miles then followed Rodman Creek (113-54-07) downstream to its mouth.

Several abandoned stream channels with openings into lower river have created excellent rearing habitat for young coho. Fry and fingerling coho

Fig. 25. Newly-formed channel of lower Fish Creek.

were abundant in all of these channels and also along the edges of the main stream. A small number of chum salmon were spawning in two of the abandoned channels and others were spawning in the main stream (count: 300 chum).

Adult pink salmon were sparsely distributed throughout the lower river except that a relatively high density occurred in the upper intertidal zone and the mouth (count: 4,600); an area which contains excellent spawning facilities.

Root balls were scattered throughout the stream in fashion typical of the streams in the Sitka district which have been logged along the stream banks.

Large schools of Dolly Varden were observed in many pools.

SUMMARY

Preliminary data were gathered towards determining the effect of clear-cut logging on small, coho-producing streams of Southeast Alaska. The parameters which were measured during July on logged and unlogged tributaries in the Staney Creek and Thorne River watersheds include water temperatures, abundance of juvenile coho salmon, insect abundance, concentrations of organic leachates, and gravel composition.

Subjective observations also were made of the effects of past and present logging operations on salmon-producing streams of the Sitka area.

Preliminary findings are:

1) Maximum stream temperatures occurred about 4:30 P.M.; 2-1/2 hr after the peak of solar radiation.
2) Stream temperatures increased much more rapidly in logged than in unlogged study areas.
3) Juvenile coho and Dolly Varden char apparently were unharmed by temperature peaks which reached as high as 24.2 C (75.5 F), but which were of short duration.
4) As the result of a 6-day drought during which stream flows decreased by 1/2 and current velocities decreased by 3/4, the exposure to solar radiation of stream waters flowing through unforested areas increased fourfold.
5) The removal of logging debris from rearing habitats, as is presently required, is important in maintaining adequate current velocity through clear-cut areas thereby minimizing exposure to solar radiation.
6) The abundance of salmonids apparently declined by about half in both the logged and unlogged streams during the period July 16 to August 12.

7) Mayflies (Ephemeroptera) were the most abundant aquatic insects found in all study streams. The production of mayflies, caddisflies (Trichoptera) and miscellaneous flies (Diptera) was greatest in logged stream "A."

8) The regrowth of spruce and hemlock in clear-cut areas has been excellent except wherever mineral soils were exposed by logging activity. Because exposed mineral soils promote the establishment of dense alder thickets in which evergreens are excluded, the regrowth of evergreens has been poor near the mouths of many streams where selective cat-logging has been done, on roads, borrow pits, and drag-line furrows.

9) The potential hazard to salmon spawning beds of log bridges not removed after logging was obvious on two streams into which road bridges had fallen causing erosion and diversion of flow.

10) Root balls cause substantial erosion in streams which have been logged along the stream banks. Because the balls decompose very slowly in the stream, move readily with high water, and often ground on spawning bars they effect the stability and productivity for decades after logging.

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Appendix Table 1. Weather observations at Coffman Cove, July 1972

Date	Temperature (F) Maximum	Minimum	At time of observation	Precipitation (inches)	Remarks
1	63	40	66	0.03	Little cloudy A.M., sunny day
2	69	40	70	0	Beautiful, warm day
3	72	50	70	0	Clear, warm
4	83	54	71	0	Clear, warm
5	75	52	71	0	Clear, warm
6	68	50	60	0	Clear, windy
7	65	52	66	0	Cloudy, sunny at times
8	70	55	72	0	Cloudy, sunny at times
9	62	50	65	0	Fog A.M., spots of sun
10	75	42	68	0.25	Fog A.M., sunny P.M.
11	68	50	69	0.22	Fog A.M., partly cloudy, misty P.M.
12	70	48	65	0.14	Cloudy misty A.M.
13	61	45	54	0.32	Drizzle A.M., rain 1 P.M.
14	60	52	55	0.28	Fog A.M., rain and drizzle
15	59	52	55	0.22	Fog and drizzle all day, rain P.M.
16	65	52	60	0.14	Fog A.M., misty
17	66	52	62	0.02	Overcast A.M.
18	74	58	72	0	Clouds A.M., later beautiful day
19	76	72	72	0	Overcast, high clouds A.M., sunny P.M.
20	75	52	72	0	Cloudy A.M., sunny day, little breeze
21	78	60	75	0	Cloudy A.M., beautiful P.M.
22	79	52	72	0	Sunny, beautiful, little breeze
23	76	54	67	0	Fog A.M., sunny periods
24	66	52	60	0.16	Cloudy, fire danger, went hoot-owl
25	62	50	56	0.26	Showers, cool breeze
26	58	45	65	0.13	Fog, showers, and drizzle
27	52	49	50	0.24	Overcast, showers, bright spots
28	60	52	58	0.23	Cloudy, showers
29	60	50	58	0.17	Cloudy, drizzle, sun out 1 P.M.
30	62	45	55	0.09	Fog A.M., sun 6:30 P.M.
31	62	40	68	0	Fog A.M., sun 12 noon, nice day

Appendix Table 2. Stream temperatures

Date, 1972	Location	Temperature (F) Maximum	Minimum	At time of observation	Averages
7-17	Logged "A" below clear cut	15.7	12.2		
7-18	"	16.0	10.7		
7-19	"	20.7	12.3		Max. = 19.9
7-20	"	21.6	12.5		Min. = 12.9
7-21	"	23.2	13.2		Total = 15.6
7-22	"	22.9	13.7		
7-23	"	24.2	14.2		
7-24	"	21.9	14.1		
7-25	"	16.9	14.1		
7-26	"	14.7	12.1		
7-22	Logged "A" above clear cut	15.6	12.9		
7-23	"	15.4	12.0		Max. = 14.9
7-24	"	15.7	12.2		Min. = 12.0
7-25	"	15.7	12.2		Total = 13.5
7-26	"	12.2	10.7		
7-17	Logged "B" below clear cut	13.2	12.6		
7-18	"	14.2	11.5		Max. = 15.8
7-19	"	13.2	10.5		Min. = 12.5
7-20	"	17.2	13.7		Total = 14.1
7-21	"	17.7	13.8	14.7	
7-22	"	17.4	12.7		
7-23	"	17.6	13.3		
7-24	"	17.2	13.0		
7-25	"	14.2	12.5	12.2	
7-26	"	13.8	11.2		
7-19	Logged "B" above clear cut	13.2	10.5		Max. = 13.5
7-20	"	13.7	10.2		Min. = 10.5
7-21	"	13.7	11.0		Total = 12.0
7-23	Unlogged "C" below study area	13.1	11.0		
7-24		13.6	11.3		Max. = 12.5
7-25	"	11.4	11.2	10.3	Min. = 11.0
7-26	"	11.2	10.7		Total = 11.75
7-21	Unlogged "C" above study area	13.6	11.3		
7-22		13.5	11.2		
7-23	"	13.4	11.0		Max. = 12.8
7-24	"	14.2	11.2	11.0	Min. = 11.0
7-25	"	12.0	11.2		Total = 12.0
7-26	"	11.2	10.7		
7-18	Unlogged "D" below study area	15.3	11.0		
7-19		17.3	13.7		
7-20	"	19.1	13.7		
7-21	"	20.0	14.2		Max. = 18.0
7-22	"	19.7	14.2		Min. = 13.5
7-23	"	20.2	14.5		Total = 15.7
7-24	"	20.5	13.9		
7-25	"	15.8	13.7		
7-26	"	14.1	12.9		

Appendix Table 2. Stream temperatures - continued

Date, 1972	Location	Temperature (F) Maximum	Minimum	At time of observation	Averages
7-17	Middle Fork Staney Creek	12.7	10.7		
7-18	"	13.9	11.2	11.0	
7-19	"	15.2	10.2		Max. = 15.2
7-20	"	16.2	12.2		Min. = 12.3
7-21	"	16.7	13.5		Total = 13.7
7-22	"	17.1	13.1		
7-23	"	16.7	13.8		
7-24	"	16.0	14.0	13.4	
7-25	"	14.3	13.2	12.7	
7-26	"	13.7	12.2		
7-18	South Fork Staney Creek	9.7	9.0		
7-19	"	10.2	10.0		
7-20	"	13.2	9.7		Max. = 12.5
7-21	"	14.2	10.3		Min. = 10.5
7-22	"	13.2	11.2		Total = 11.5
7-23	"	14.6	11.8		
7-24	"	13.7	11.6		
7-25	"	12.3	11.5		
7-26	"	11.6	10.1		

Appendix Table 3. Change in stream temperature through the study areas

Date, 1972	Top of study area		Bottom of study area		ΔT		
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	
			Logged "A"				
7-17			15.7	12.2			
7-18			16.0	10.7			
7-19			20.7	12.3			
7-20			21.6	12.5			
7-21			23.2	13.2			
7-22	15.6	12.9	22.9	13.7	7.3	0.8	
7-23	15.4	12.0	24.2	14.2	9.8	2.2	
7-24	15.7	12.2	21.9	14.1	6.2	1.9	
7-25	15.7	12.2	21.9	14.1	6.2	1.9	
7-26	12.2	10.7	14.7	12.1	2.5	1.4	
					320	82	= ΣX
X̄	14.9	12.0			6.4	1.6	= X̄
					0.28	0.07	= ΔT/100 ft
			Logged "B"				
7-17			13.2	12.6			
7-18			14.2	11.5			
7-19	13.2	10.5	13.2	10.5	0.0	0.0	
7-20	13.7	10.2	17.2	13.7	3.5	3.5	
7-21	13.7	11.0	17.7	13.8	4.0	2.8	
7-22			17.4	12.7	7.5	6.3	= ΣX
					2.5	2.1	= X̄
7-23			17.6	13.3	0.14	0.12	= ΔT/100 ft
7-24			17.2	13.0			
7-25			14.2	12.5			
7-26			13.8	11.2			
			Unlogged "C"				
7-21			13.6	11.3			
7-22			13.5	11.2			
7-23	13.1	11.0	13.4	11.0	0.3	0.0	
7-24	13.6	11.3	14.2	11.3	0.6	0.0	
7-25	11.4	11.2	12.0	11.2	0.6	0.0	
7-26	11.2	10.7	11.2	11.7	0.0	0.0	
X̄	12.3	11.05			1.5	0.0	= ΣX
					0.38	0.0	= X̄
					0.02	0.00	= ΔT/100 ft

Appendix Table 4. Stream levels

Date, 1972	Stream	Level	Change from beginning level (inches)	Cumulative change (inches)
7-21	Logged "A"	10'4-3/4"		
7-22	"	10'4-1/2"	-1/4	-1/4
7-23	"	10'4-1/2"	0	-1/4
7-24	"	10'4-5/8"	+1/8	-1/8
7-25	"	10'4-5/8"	0	-1/8
7-26	"	10'4-3/4"	+1/8	0
7-27	"	10'7-1/8"	+2-3/8	+2-3/8
7-20	Logged "B"	4'9-1/4"		
7-21	"	4'8-3/4"	-1/2	-1/2
7-22	"	4'8-1/2"	-1/4	-3/4
7-23	"	4'8-1/4"	-1/4	-1
7-24	"	4'8-3/8"	+1/8	-7/8
7-25	"	4'8-3/8"	0	-7/8
7-26	"	4'8-5/8"	+1/8	-3/4
7-27	"	5'1-3/4"	+5-1/8	+4-3/8
7-21	Unlogged "C"	19'3-1/2"		
7-22	"	19'2-3/4"	-3/4	-3/4
7-23	"	19'2-3/4"	0	-3/4
7-24	"	19'2-7/8"	0	-3/4
7-25	"	19'2-3/4"	0	-3/4
7-26	"	19'2-3/4"	0	-3/4
7-27	"	19'4"	+1-1/4	+1/2
7-20	Unlogged "D"	16'5"		
7-21	"	16'4-3/4"	-1/4	-1/4
7-22	"	16'4-1/2"	-1/4	-1/2
7-23	"	16'4-3/8"	+1/8	-3/8
7-24	"	16'4-1/4"	-1/8	-1/2
7-25	"	16'4-3/8"	+1/8	-3/8
7-26	"	16'4-3/4"	+3/8	0
7-27	"	16'8-1/4"	+3-1/2	+3-1/2

Appendix Table 5. Estimates of juvenile coho abundance in four study streams

Stream	Length of study area	Date, 1972	Time	Observer	Count	Average count	Fish per lineal ft	Remarks
Logged "A"	2,250 ft	7-18	1330	Gibbons	3,247	2942.0	1.31	
				Antipa	2,637			
		7-20	1300	Antipa	4,033	4336.5	1.93	
				Tyler	4,640			
		7-22		Antipa	4,170	4276.3	1.90	
				Tyler	4,700			
				Gibbons	3,959			
		7-24	1015	Tyler	2,550	3110.0	1.38	Poor visibility
				Antipa	3,670			
		8-12		Gibbons	2,223	2036.0	0.90	Poor visibility
				Tyler	1,850			
Logged "B"	1,750 ft	7-16	0930	Antipa	532	459.0	0.26	
				Gibbons	388			
				Tyler	457			
		7-18		Antipa	519	583.0	0.33	
				Gibbons	539			
				Tyler	642			
		7-20		Antipa	584	630.7	0.36	
				Gibbons	584			
				Tyler	724			
		7-22	1020	Antipa	637	600.0	0.34	
				Gibbons	616			
				Tyler	546			
		7-24	0750	Antipa	538	509.5	0.29	Poor visibility
				Tyler	481			
		8-12		Gibbons	456	384.5	0.22	Poor visibility
				Tyler	313			
Unlogged "C"	675 ft	7-21	1330	Pollock	747	621.0	0.92	
				Gibbons	679			
				Tyler	437			
		7-25	1215	Tyler	446	454.0	0.67	Poor visibility
				Antipa	461			
		8-12		Gibbons	304	255.0	0.38	Poor visibility
				Tyler	207			
Unlogged "D"	1,980 ft	7-19	0930	Antipa	134	140.0	0.07	
				Gibbons	135			
				Tyler	151			

Appendix Table 6. Adult coho scale data

Fish number	Location of capture	Date of capture, 1972	F.W. annuli	S.W. annuli	Fork length (inches)	Weights (lb)	Comments
1	Thorne	7-19	1	1	25	5	
2	River	7-19	1	2	30	10	
3	mouth	7-20	2	1	27	7	Nucleus indistinct
4	"	7-22	1	1	25		
5	"	7-22	1	1	25		
6	"	7-22	1	1	29		Regenerated?
7	"	7-22	1	1	28		
8	"	7-22	1	1	24		
9	"	7-22	1	1	25		
10	"	7-22	1	1	25		
11	"	7-22	2	1	27		
12	"	7-22	1	1	25		
13	"	7-22	1	1	28		
14	"	7-22	2	2	29		Regenerated
15	"	7-23	1	1	27½		
16	"	7-23	1	1	26		
17	"	7-23	1	1	23½		Regenerated
18	"	7-23	1	1	27½		Regenerated
19	"	7-23	1	1	23½		
20	"	7-23	1	1	27		
21	"	7-23	1	1	24		
22	"	7-23	1	1	25		
23	"	7-23	1	1	27		
24	"	7-23	1	0	23½		Probably 1.1
25	"	7-23	1	1	25½		
26	"	7-23	2	1	27½		
27	"	7-23	1	1	24½		
28	"	7-23	1	1	21½		
29	"	7-24	1	1	29½		
30	"	7-24	2	1	28½		
31	"	7-24	1	1	26½		
32	"	7-24	1	1	29		Probably 2.1
33	"	7-24	1	1	24		
34	Thorne	7-24	1	1	22½		
35	River	7-24	1	1	25		
36	"	7-24	1	1	25		
37	"	7-25	1	1	22		
38	"	7-25	1	1	25		
39	"	7-25	1	1	25		
40	"	7-28	2	1	28		
41	"	7-28	1	1	27		
42	"	7-30	1	1	23		
43	"	7-30	1	1	27		
44	"	7-30	1	1	27		
45	"	7-30	2	1	32		
46	"	7-30	1	1	22		
47	"	7-30	2	1	25		
48	"	7-30	2	1	28		
49	"	7-30	1	1	28		
50	"	7-30	1	1	24		
					1272	$=\Sigma$	
					25.4	$= \bar{X}$	

Appendix Table 7. Abundance of aquatic insects in tributaries of the Staney Creek and Thorne River watersheds

		Ephemeroptera					Diptera					
Streams	Date	Heptageniidae	Baetidae	Coleoptera	Plecoptera (chloroperlinae)	Trichoptera	Tendipedidae	Tipulidae	Simuliidae	Oligochaetes	Other misc. invertebrates	Mean number insects/m^2
Expt. A$^{(8)}$	7/24/72											
pools$^{(4)}$		--	79	18	14	67	14	29	--	68	25	
riffles$^{(4)}$		130	312	14	16	13	26	48	--	17	8	
Total	898	130	391	32	30	80	40	77	--	85	33	975
Control C$^{(8)}$	7/25/72											
pools$^{(4)}$		39	39	4	48	3	30	1	--	29	--	
riffles$^{(4)}$		54	92	1	44	3	13	--	1	2	2	
Total	405	93	131	5	92	6	43	1	1	31	2	465
Expt. B$^{(6)}$	7/26/72											
pools$^{(3)}$		3	13	2	15	3	2	1	--	24	--	
riffles$^{(3)}$		20	42	2	5	2	--	3	--	3	3	
Total	143	23	55	4	20	5	2	4	--	27	3	188
Control D$^{(6)}$	7/26/72											
pools$^{(3)}$		3	43	1	26	9	--	1	--	5		
riffles$^{(3)}$		6	42	4	64	3	28	2	--	3		
Total	240	9	85	5	90	12	28	3	--	8		386

Appendix Table 7. Abundance of aquatic insects in tributaries of the Staney Creek and Thorne River watersheds - continued

Streams	Date	Ephemeroptera		Coleoptera	Plecoptera (chloroperlinae)	Trichoptera	Diptera			Oligochaetes	Other misc. invertebrates	Mean number insects/m^2
		Heptageniidae	Baetidae				Tendipedidae	Tipulidae	Simuliidae			
Middle Fork, Staney Creek(6)	7/24/72											
pools(3)		16	22	1	16	3	108	--	--	6	1	
riffles(3)		18	39	2	73	--	21	4	1	5	3	
Total	339	34	61	3	89	3	129	4	1	11	4	540
East Fork, Staney Creek(6)	7/27/72											
pools(3)		1	38	1	2	14	32	5	--	50	7	
riffles(3)		37	43	5	5	8	30	4	1	1	2	
Total	286	38	81	6	7	22	62	9	1	51	9	376
Left Arm, North Thorne River(6)	7/31/72											
pool(3)		14	25	2	7	--	2	3	--	137	1	
riffles(3)		15	12	2	2	--	1	1	--	13	2	
Total	239	29	37	4	9	--	3	4	--	150	3	143
Right Arm, North Thorne River(6)	7/31/72											
pools(3)		74	5	--	4	--	--	2	--	5	--	
riffles(3)		46	2	1	4	--	--	2	--	1	--	
Total	146	120	7	1	8	--	--	4	--	6	--	233

(Number) = number of samples.

Appendix Table 8. Abundance of drifting insects in tributaries of Staney Creek

Streams	Aquatic Coleoptera	Terrestrial Coleoptera	Ephmeroptera	Plecoptera	Trichoptera	Diptera	Other insects	Total
Expt. A								
7/17/72			5	1	1			7
7/18/72			5	1	1	1		8
7/19/72			4				1	5
7/20/72			2	2	2	7		13
7/21/72	1		4	1	4	3		13
7/22/72	1	1	4		1			7
7/23/72			3			1		4
7/24/72			2		1	2		5
7/25/72		1	2			1		4
Total	2	2	31	5	10	15	1	7.3
Stream discharge								.116
Expt. B								
7/17/72		2						2
7/18/72	1	1			9	1		12
7/19/72			2		2	1		5
7/20/72			1		1			2
7/21/72					1			1
7/22/72			1		2			3
7/23/72					1			1
7/24/72					2			2
7/25/72			1		1			2
Total	1	1	7	--	19	2	--	3.3
Stream discharge								.116
Control C								
7/24/72	7	1	7		1			16
7/25/72	4	1	4	1		1		11
7/26/72	2	1	4		1	1		9
7/27/72	2	2	12	3	1			20
Total	15	5	27	4	3	2	--	14.0
Stream discharge								.116

Appendix Table 8. Abundance of drifting insects in tributaries of Staney Creek - continued

Streams	Aquatic Coleoptera	Terrestrial Coleoptera	Ephmeroptera	Plecoptera	Trichoptera	Diptera	Other insects	Total
Control D								
7/18/72			3			1		4
7/19/72		1			1			2
7/20/72	1	2	4			6		13
7/21/72			6			6		12
7/22/72	3		16		1	4		24
7/23/72	2		32		2	3		39
7/24/72	1	1	17			3		22
7/25/72			14		1	5	6	26
7/26/72	Lost →							
Total	7	4	92	--	5	28	6	17.8
Stream discharge								.175
East Fork, Staney Creek								
7/17/72			3		1	2		6
7/18/72			3		3	2	1	9
7/19/72			4					4
7/20/72			4		2	1		7
7/21/72			3		1			4
7/22/72			10					10
7/23/72		1	4	1	1	4		11
7/24/72	1	2	1			1		5
7/25/72			4		2	1		7
Total	1	3	36	1	10	11	1	7.0
Stream discharge								5.0
Middle Fork, Staney Creek								
7/17/72	2		29	2		3		36
7/18/72			30		1	6	1	38
7/19/72	1		51			5		57
7/20/72			11			3		14
7/21/72			33			3	1	37
7/22/72			32				2	34
7/23/72			36				4	40
7/24/72			17			2	1	20
7/25/72			4			4		8
Total	3	--	241	2	1	26	9	31.6
Stream discharge								20.0

Appendix Table 9. Analysis of gravel samples from Staney Creek, Thorne River, and Mud Creek

		Percentage of total volume							
Stream	Sample No.	26.7	13.5	7.9	3.3	1.6	0.83	0.1	<1.6
Unlogged "C"	001		53.918	12.401	25.521	4.493			3.666
	002		55.190	15.190	23.291	4.557			1.772
	003		51.079	15.192	17.834	12.770			3.126
	004		59.211	9.649	15.789	7.456			7.895
	005		72.196	6.044	12.089	3.526			6.145
	MEAN		58.319	11.695	18.905	6.560			4.521
	S2		68.737	15.264	30.082	14.213			6.063
	STDEV		8.291	3.907	5.485	3.770			2.462
	SEMN		3.708	1.747	2.453	1.686			1.101
	95CON		10.308	4.857	6.819	4.687			3.061
	MEAN-95CON		48.011	6.838	12.086	1.873			1.460
	MEAN+95CON		68.626	16.552	25.724	11.248			7.582
Logged "A"	001		58.161	10.694	12.946	8.068			10.131
	002		78.838	7.884	6.639	2.490			4.149
	003		60.452	13.363	10.818	8.750			6.618
	004		41.979	13.868	19.115	17.616			7.421
	005		53.966	14.105	14.718	9.608			7.604
	MEAN		58.679	11.983	12.847	9.306			7.185
	S2		177.727	7.106	21.365	29.364			4.612
	STDEV		13.331	2.666	4.622	5.419			2.148
	SEMN		5.962	1.192	2.067	2.423			.960
	95CON		16.574	3.314	5.747	6.737			2.670
	MEAN-95CON		42.105	8.669	7.100	2.569			4.515
	MEAN+95CON		75.254	15.297	18.594	16.043			9.855
Gravel Creek	001	50.822			36.678		8.717	3.783	
	002	41.667			41.228		11.842	5.263	
	003	44.118			33.640		14.338	7.904	
	004	50.613			42.032		4.028	3.327	
	MEAN	46.805			38.394		9.731	5.069	
	S2	21.421			15.604		19.745	4.255	

Appendix Table 9. Analysis of gravel samples from Staney Creek, Thorne River, and Mud Creek - continued

		Percentage of total volume							
Stream	Sample No.	26.7	13.5	7.9	3.3	1.6	0.83	0.1	<1.6
Gravel Creek (cont'd)	STDEV	4.628			3.950		4.444	2.063	
	SEMN	2.314			1.975		2.222	1.031	
	95CON	7.359			6.281		7.065	3.280	
	MEAN-95CON	39.446			32.113		2.666	1.790	
	MEAN+95CON	54.164			44.675		16.797	8.349	
Fall Creek	001	28.302			44.340		22.642	4.717	
	002	44.885			38.622		13.570	2.923	
	003	54.264			32.946		10.853	1.938	
	004	43.384			37.961		16.920	1.735	
	MEAN	42.709			38.467		15.996	2.828	
	S2	115.421			21.751		25.785	1.854	
	STDEV	10.743			4.664		5.078	1.362	
	SEMN	5.372			2.332		2.539	.681	
	95CON	17.082			7.415		8.074	2.165	
	MEAN-95CON	25.627			31.052		7.922	.663	
	MEAN+95CON	59.791			45.883		24.070	4.993	
Goose Creek	001	65.653			29.787		2.128	2.432	
	002	33.419			57.326		5.398	3.856	
	003	33.766			45.455		17.811	2.968	
	004	21.634			55.188		18.764	4.415	
	MEAN	38.618			46.939		11.025	3.418	
	S2	356.653			157.442		72.252	.787	
	STDEV	18.885			12.548		8.500	.887	
	SEMN	9.443			6.274		4.250	.444	
	95CON	30.028			19.951		13.515	1.411	
	MEAN-95CON	8.591			26.988		-2.490	2.007	
	MEAN+95CON	68.646			66.890		24.540	4.828	

Appendix Table 9. Analysis of gravel samples from Staney Creek, Thorne River, and Mud Creek - continued

Stream	Sample No.	Percentage of total volume							
		26.7	13.5	7.9	3.3	1.6	0.83	0.1	<1.6
East Fork, North Thorne River	001	13.718			57.762		18.051	10.469	
	002	.946			64.984		16.404	17.666	
	003	5.137			56.507		19.521	18.836	
	004	3.774			70.755		16.352	9.119	
	005	2.834			67.611		24.291	5.263	
	006	4.049			60.729		22.672	12.551	
	007	4.120			56.554		25.468	13.858	
	MEAN	4.940			62.129		20.394	12.537	
	S2	16.719			32.722		14.107	22.764	
	STDEV	4.089			5.720		3.756	4.771	
	SEMN	1.545			2.162		1.420	1.803	
	95CON	3.786			5.297		3.478	4.418	
	MEAN-95CON	1.153			56.832		16.916	8.119	
	MEAN+95CON	8.726			67.426		23.872	16.955	
West Fork, North Thorne River	001	19.243			59.306		11.987	9.464	
	002	17.049			59.016		13.115	10.820	
	003	22.297			51.689		14.865	11.149	
	004	26.070			54.475		12.451	7.004	
	005	29.278			55.133		11.787	3.802	
	006	26.007			61.172		7.326	5.495	
	007	14.815			64.310		8.081	12.795	
	MEAN	22.108			57.872		11.373	8.647	
	S2	28.222			18.829		7.359	10.826	
	STDEV	5.312			4.339		2.713	3.290	
	SEMN	2.008			1.640		1.025	1.244	
	95CON	4.919			4.018		2.512	3.047	
	MEAN-95CON	17.189			53.853		8.861	5.600	
	MEAN+95CON	27.028			61.890		13.885	11.694	

Appendix Table 9. Analysis of gravel samples from Staney Creek, Thorne River, and Mud Creek - continued

Stream	Sample No.	Percentage of total volume							
		26.7	13.5	7.9	3.3	1.6	0.83	0.1	<1.6
Beaver Creek	001	12.780			60.064		22.684	4.473	
	002	17.578			67.969		10.938	3.516	
	003	30.660			55.660		8.491	5.189	
	004	37.815			45.798		13.445	2.941	
	005	27.039			63.948		6.438	2.575	
	006	8.150			65.831		18.809	7.210	
	007	24.016			59.055		13.386	3.543	
	008	21.488			56.198		17.769	4.545	
	009	28.629			55.645		8.468	7.258	
	010	16.207			62.759		15.517	5.517	
	MEAN	22.436			59.293		13.594	4.677	
	S2	80.757			41.170		26.844	2.686	
	STDEV	8.987			6.416		5.181	1.639	
	SEMN	2.842			2.029		1.638	.518	
	95CON	6.422			4.586		3.703	1.171	
	MEAN-95CON	16.014			54.707		9.891	3.506	
	MEAN+95CON	28.859			63.878		17.297	5.848	
Control Creek	001	44.398			37.344		15.353	2.905	
	002	30.580			54.482		10.545	4.394	
	003	30.794			45.705		17.828	5.673	
	004	20.359			52.096		21.557	5.988	
	005	18.519			51.852		22.222	7.407	
	006	32.721			50.735		13.787	2.757	
	MEAN	29.562			48.702		16.882	4.854	
	S2	87.859			39.391		20.669	3.377	
	STDEV	9.373			6.276		4.546	1.838	
	SEMN	3.827			2.562		1.856	.750	
	95CON	9.834			6.585		4.770	1.928	
	MEAN-95CON	19.727			42.117		12.112	2.926	
	MEAN+95CON	39.396			55.287		21.652	6.782	

Appendix Table 9. Analysis of gravel samples from Staney Creek, Thorne River, and Mud Creek - continued

Stream	Sample No.	Percentage of total volume							
		26.7	13.5	7.9	3.3	1.6	0.83	0.1	<1.6
Mud Creek	001	0.000			62.298		32.460	5.242	
	002	2.804			44.860		37.383	14.953	
	MEAN	1.402			53.579		34.921	10.098	
	S2	3.930			152.052		12.120	47.155	
	STDEV	1.983			12.331		3.481	6.867	
	SEMN	1.402			8.719		2.462	4.856	
	95CON	17.818			110.822		31.289	61.716	
	MEAN-95CON	-16.416			-57.243		3.633	-51.618	
	MEAN+95CON	19.220			164.401		66.210	71.813	