Habitat and juvenile salmonid populations in streams in logged and unlogged areas of southeastern Alaska
by Peter Joseph Cardinal

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Fish and Wildlife Management
Montana State University

Abstract:
Relationships between fish populations and stream habitat features in logged and unlogged areas on Prince of Wales Island, southeastern Alaska, were studied in 1977 and 1978. Principal components analysis of fifteen habitat features showed that the majority of variation in habitat data (40,3%) was accounted for by fine debris features. Principal component ordination indicated differences in fine debris concentrations between Tye-One-Ohn and Little Toad creeks in logged areas and Three-Tenths Mile Creek in unlogged forest. Measurements of fine and coarse debris were 165-467% greater on Tye-One-Ohn and Little Toad creeks in logged areas than on Three-Tenths Mile Creek in an unlogged area. Debris in the streams in logged areas often extended completely across the stream channel increasing mid-channel cover for fish and creating dams that increased pool area and average depth. Multiple regression analysis indicated that age 1+ coho salmon (Oncorhynchus kisutch) in Tye-One-Ohn Creek preferred submerged coarse debris in mid-channel areas. Age group 2-3+ Dolly Varden (Salvelinus malma) seemed to use pools formed by debris dams and undercut banks when age 1+ coho salmon were not associated with this feature, Riffles with debris were important to age group 0-1+ Dolly Varden in this stream. In Three-Tenths Mile Greek age 1+ coho salmon preferred undercut banks and seemed to make use of debris at stream edges in September. Dolly Varden of both age groups in this stream were primarily associated with debris in July. Undercut banks and features of debris not associated with age 1+ coho salmon in September became important to age groups 2-3+ and 0-1+ Dolly Varden respectively. Age 0 coho salmon used fine debris when it was not associated with age 1+ coho salmon and age group 2-3+ Dolly Varden but were forced to use cover free areas if these age groups were present. Logging debris in Tye-One-Ohn Creek apparently provided fish with suitable habitat over a greater area of the stream and resulted in separation of age groups into distinct habitats. The riparian vegetation along Little Toad Creek appeared to mask the relationships between measured habitat features and fish populations. It may have provided additional cover for age 1+ coho salmon and both age groups of Dolly Varden, It was predicted that removal of the debris associated with logging from the streams in logged areas may have negative impacts on fish populations, particularly on Dolly Varden.

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STREAMS IN LOGGED AND UNLOGGED AREAS OF SOUTHEASTERN ALASKA

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

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ABSTRACT

Relationships between fish populations and stream habitat features in logged and unlogged areas on Prince of Wales Island, southeastern Alaska, were studied in 1977 and 1978. Principal components analysis of fifteen habitat features showed that the majority of variation in habitat data (40.3%) was accounted for by fine debris features. Principal component ordination indicated differences in fine debris concentrations between Tye-One-Ohn and Little Toad creeks in logged areas and Three-Tenths Mile Creek in unlogged forest. Measurements of fine and coarse debris were 165-467% greater on Tye-One-Ohn and Little Toad creeks in logged areas than on Three-Tenths Mile Creek in an unlogged area. Debris in the streams in logged areas often extended completely across the stream channel increasing mid-channel cover for fish and creating dams that increased pool area and average depth. Multiple regression analysis indicated that age 1+ coho salmon (Oncorhynchus kisutch) in Tye-One-Ohn Creek preferred submerged coarse debris in mid-channel areas. Age group 2-3+ Dolly Varden (Salvelinus malma) seemed to use pools formed by debris dams and undercut banks when age 1+ coho salmon were not associated with this feature. Riffles with debris were important to age group 0-1+ Dolly Varden in this stream. In Three-Tenths Mile Creek age 1+ coho salmon preferred undercut banks and seemed to make use of debris at stream edges in September. Dolly Varden of both age groups in this stream were primarily associated with debris in July. Undercut banks and features of debris not associated with age 1+ coho salmon in September became important to age groups 2-3+ and 0-1+ Dolly Varden respectively. Age 0 coho salmon used fine debris when it was not associated with age 1+ coho salmon and age group 2-3+ Dolly Varden but were forced to use cover free areas if these age groups were present. Logging debris in Tye-One-Ohn Creek apparently provided fish with suitable habitat over a greater area of the stream and resulted in separation of age groups into distinct habitats. The riparian vegetation along Little Toad Creek appeared to mask the relationships between measured habitat features and fish populations. It may have provided additional cover for age 1+ coho salmon and both age groups of Dolly Varden. It was predicted that removal of the debris associated with logging from the streams in logged areas may have negative impacts on fish populations, particularly on Dolly Varden.

INTRODUCTION

Logging in southeastern Alaska has resulted in the deposition of large quantities of debris and slash in many small streams. Excessive debris has been shown to increase biochemical oxygen demand and decrease surface and intragravel dissolved oxygen (Hall and Lantz 1969, Moring 1975). Debris can fill interstices in gravel and rubble substrates reducing living space for invertebrates (Hynes 1960) and refuges for young salmonids (McCrimmon 1954). Channel instability can result from the movement of debris at high flows (Bishop and Shapley 1963, Helmers 1966). Fish populations have been shown to change in watersheds that have been logged (Narver 1972, Moring and Lantz 1974, Moring 1975). However, few studies have been made to evaluate changes in fish populations as a result of instream debris removal.

Logging operations began on Prince of Wales Island in 1951 when the United States Forest Service (U.S.F.S.) awarded a 50 year timber sale contract to the Ketchikan Pulp Company (now Louisiana Pacific Ketchikan). Prior to 1974, the U.S.F.S. required the company to remove debris only from streams used for spawning. During 1974 they required debris be removed from streams used for rearing, and began a program of debris removal on rearing streams in previously logged areas (Fred Ziegler, personal communication). The U.S.F.S. Pacific Northwest Forest and Range Experiment Station initiated studies in 1977 on fish, aquatic macroinvertebrates, stream morphology and hydrology in streams on Prince of Wales Island to document the effects of debris removal. The present study was undertaken to provide information prior to debris removal on:

1. Habitat in streams in logged and unlogged areas.
2. Fish population numbers, age composition, biomass and movements.
3. Distribution of fish within habitats in streams in logged and unlogged areas.

Field work was conducted between June and September in 1977 and 1978.

DESCRIPTION OF STUDY AREA

The study area was located on Prince of Wales Island in southeastern Alaska. Records of the U.S. Weather Bureau on Annette Island, 20 miles east of Prince Wales, show precipitation averaged 290.3 cm per year from 1941-1970. Average precipitation for July, August, and September for these years was 13.7, 18.2 and 25.5 cm respectively. In 1977 precipitation was 67, 16, and 43% below normal for July, August, and September respectively. In 1978 precipitation was 66 and 16% below normal for July and August and 16% above normal for September. The annual air temperature averaged 7.6°C from 1941 through 1970.

Prince of Wales Island supported a rain forest composed largely of Sitka spruce (Picea sitchensis) and western hemlock (Tsuga heterophylla). Alaska yellow cedar (Chamaecyparis nootkatensis), mountain hemlock (Tsuga mertensiana), western red cedar (Thuja plicata), red alder (Alnus rubra), and American devils club (Oplapanax horridus), were also present. Logging operations on the island have produced clearcut areas in the forest ranging from several hundred to several thousand hectares in size. Salmonberry (Rubus spectabilis), blueberry (Vaccinium spp), and spruce and hemlock seedlings dominated in clearcut areas.

Three-Tenths Mile, Tye-One-Ohn and Little Toad creeks on the northwestern corner of Prince of Wales Island were selected for study (Figure 1). All three streams were (1) tributaries to Staney Creek, (2) less than 2m wide, and (3) used as rearing areas by salmonids. The study section on Three-Tenths Mile Creek was 80m in length and lay in unlogged forest between Twin Spur Road and Staney Creek. It contained coho salmon (Oncorhynchus kisutch) and Dolly Varden (Salvelinus malma). The study section on Tye-One-Ohn Creek lay between Road FDR 5400 and Staney Creek. It was 110m in length and was situated in a clearcut created in 1967. Coho salmon, Dolly Varden, coastrange sculpin (Cottus aleuticus), and cutthroat trout (Salmo clarki) were found in this stream. The study section on Little Toad Creek was located between Road FDR 5410 and Road FDR 5414. It was 170m long and lay in a clearcut created in 1971. Coho salmon, Dolly Varden, and cutthroat trout were present in this study section.

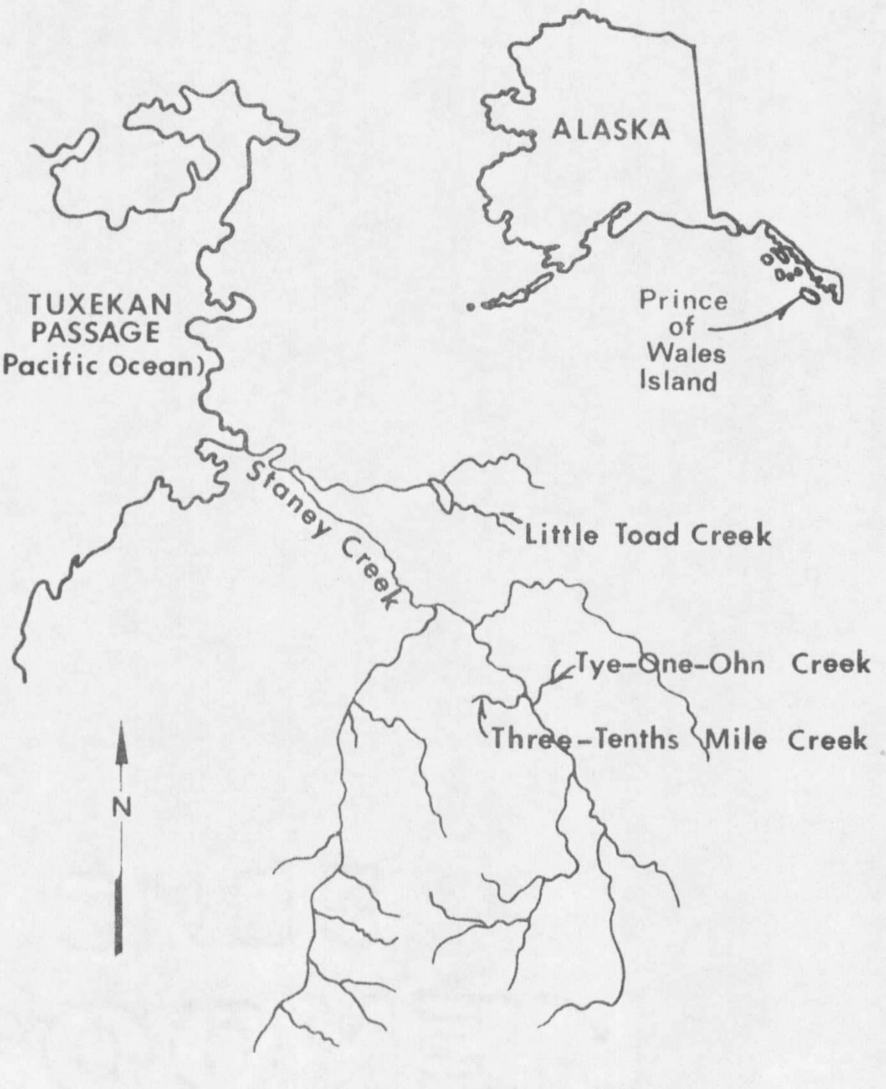

Figure 1. Map showing the location of the study streams in the Staney Creek drainage on Prince of Wales Island.

METHODS

Sampling Stations

Eleven stations of 10m length were established on Tye-One-Ohn Creek and used during 1977 and 1978. Eleven stations of 20m length were established on Little Toad Creek in 1977. In 1978 four of these were retained, three were shortened by 10m, and four were shortened by 5m. Eight stations of 10m length were established on Three-Tenths Mile Creek in 1978. All stations on a given stream comprised the study section. Stations were selected to provide a range of habitats on all streams.

Measurement of Habitat

Each station was mapped in 1978 to show undercut banks, riffles, pools, areas with fine debris (1cm to 10cm in diameter), and individual pieces of coarse debris (greater than 10cm in diameter and 30cm in length). Shallow, fast moving portions of the stream were mapped as riffles and areas that appeared to have slower currents and greater depth were recorded as pools. Mapping was done with a steel tape and compass on a 1:48 scale.

Six to eight line transects were established perpendicular to the stream channel at each station. Intervals between the transects were equal and dependant on the length of the station. Depth was measured to the nearest 0.5cm at 15cm intervals along each transect. Fine debris was sampled by the line intersect method of Froelich et al. (1972). Individual pieces of fine debris were counted along the entire wetted portion of each transect and classified as submerged or elevated.

The following habitat features were derived from measurements taken at each station.

1. Fine debris as percent of surface area (submerged and elevated).
2. Submerged fine debris as percent of surface area.
3. Elevated fine debris as percent of surface area.
4. Density of fine debris (submerged and elevated).
5. Density of submerged fine debris.
6. Density of elevated fine debris.
7. Coarse debris as percent of surface area (submerged and elevated).
8. Density of coarse debris (submerged and elevated).
9. Density of submerged coarse debris.
10. Stream gradient
11. Pools as percent of surface area.
12. Average depth.
13. Water surface area.
14. Undercut bank as percent of surface area.
15. Length of undercut bank as percent of total bank.

Measurements of undercut bank, coarse debris, fine debris, and stream surface areas were made from station maps with a planimeter. Stream gradients were determined with a stadia rod and hand level. Volume of fine debris per unit area (V) was calculated by:

$$V= \frac{\pi^2 d^2}{8L}$$

where d= count of intersections of all pieces in diameter class times mean diameter (2.42 cm), and L = length of transect line (Froelich et al. 1972). Pieces of coarse debris were measured individually and submerged pieces were counted. Specific weight of organic material was assumed to be 0.5 (Swanson et al. 1977) and density of debris was described as kg/m^2 water.

Fish Populations

Fish populations were censused on Little Toad Creek during July 13-27 and August 10-24 and on Tye-One-Creek during August 10-24 and September 9-21, 1977. In 1978 fish populations were censused during July 10-21 and September 1-4 on all streams. Fish were captured in minnow traps baited with salmon eggs placed at three trap sites per station on Three-Tenths Mile and Tye-One-Ohn creeks. Traps were used at three or four sites per station on Little Toad Creek. Traps were spaced as evenly apart as depth and channel characteristics permitted. Captured fish were anesthetized with MS 222 (Tricane Methanesulfonate), measured to the nearest mm (Total length) and marked with a station-specific combination of caudal and/or anal fin punches which were identifiable for up to two weeks.

Estimates of fish numbers on each study section of Tye-One-Ohn and Little Toad creeks in 1977 and July 1978 were made using the Chapman modification of the Schnabel formula (Ricker 1975). Estimates on the study section of Three-Tenths Mile Creek during July and on the study sections of all streams in September, 1978 were made with the Chapman modification of the Peterson formula (Ricker 1975). Confidence limits for Schnabel and Peterson estimates were obtained following the procedures of Ricker (1975). Population densities were estimated by dividing population estimates by stream volumes.

The lengths and weights of 20-25 live coho salmon and 20-25 living Dolly Varden were obtained at the end of each census period in 1978 to determine size-age and length-weight relationships. The ages of these fish were determined from examination of otoliths following the procedures of Williams and Bedford (1973). Size ranges were determined for each age or age group and these were compared to length-frequency distributions. The Fire 1 computer program (Hesse 1977) was used to sort length-frequencies from the population census data.

Biomass estimates on each stream were calculated using the population estimates and predicted weights from the length-weight relationships calculated by the Fire 1 computer program. The estimates of densities and biomass of each species for stations within each study section were obtained by proportioning the estimates from a given section to its individual stations based on the percentage of fish marked at each station during the censuses.

Fish Movement

Fish movements were monitored by one way box traps. Two one way box traps were located upstream and downstream from the study sections on Tye-One-Ohn and Little Toad creeks. The numbers, species, and direction of movement of fish captured at these sites were recorded. Traps were checked daily between July 17 and September 21 in 1977 and between May 12 and August 16 in 1978.

Statistical Analyses

Principal component (PC) analysis (Nie et al. 1975) was used to identify linear combinations of habitat features which described levels of variation in the habitat data from the three study streams. The first combination of habitat features (PC-1) explained the greatest amount of variation in the habitat data. Each subsequent PC was the combination of habitat features that explained the greatest amount of the variation that was not accounted for by preceeding components. Each PC was independant of the others. Within each PC habitat features having a correlation coefficient of 0.8 or more with other features were identified.

A stepwise multiple regression procedure (Nie et al. 1975) was used to determine the variation in fish population estimates attributable to specific habitat features or combinations of features in each stream. Population densities for each age group of coho salmon and Dolly Varden at each station served as dependant variables. Measurements of habitat features at each station having low (0.8 or less) correlation to other habitat features were used as independent variables. The use of low-correlated habitat features from each PC allowed a reduction in the number of variables considered in the same regression and reduced bias due to multicollinearity (Nie et al. 1975). The amount of variation in fish population estimates attributable to habitat features was described by the statistic $R^{2'}$. This statistic was the coefficient of determination (R^2) adjusted for the number of independant variables and the number of cases (stations per stream) in the analysis (Nie et al. 1975). It was a more conservative estimate of the variation explained than was R^2, especially when the number of cases was small. All statistical analyses were performed with the Sigma 7 computer at Montana State University.

RESULTS

Habitat

Maps of the sampling stations showing the location of fine debris, coarse debris, pools, riffles, and undercut banks are presented in Appendix Figures 3-33. Measurements of the habitat features at each station are given in Appendix Tables 16-18. Mean values for the measured habitat features in each study section are given in Table 1. Fine debris covered approximately 60% of the channel on Tye-One-Ohn and Little Toad creeks. It often extended completely across the channel on these streams. Fine debris covered 22.2% of the channel on Three-Tenths Mile Creek and was concentrated at the stream edges. The submerged component of fine debris comprised 62-67% of total fine debris on all streams. Tye-One-Ohn Creek had the highest density and coverage measurements of coarse debris. Submerged coarse debris comprised 36,37, and 12% of the total density of coarse debris on Tye-One-Ohn, Little Toad, and Three-Tenths Mile creeks respectively. Coarse debris, particularly small pieces, was often distributed throughout the channels of Tye-One-Ohn and Little Toad creeks and concentrated at stream edges in Three-Tenths Mile Creek. Measurements of gradient, pool area, and depth were greatest on Little Toad Creek. Debris dams (Appendix Figures 15-25) appeared to have increased the pool area and depth on this stream.

Table 1. Mean values of habitat features measured on the study section of each stream in 1978.

Habitat Features	Tye-One-Ohn Creek	Little Toad Creek	Three-Tenths Mile Creek
Fine debris as percent of surface area (submerged & elevated)	60.7	57.1	22.2
Submerged fine debris as percent of surface area	37.6	38.1	14.4
Elevated fine debris as percent of surface area	23.1	18.9	7.8
Density of fine debris-submerged & elevated (kg/m^2 water)	37.0	27.8	10.8
Density of submerged fine debris (kg/m^2 water)	23.7	18.3	6.9
Density of elevated fine debris (kg/m^2 water)	13.3	9.5	3.9
Coarse debris as percent of surface area (submerged & elevated)	24.4	20.8	17.0
Density of coarse debris-submerged & elevated (kg/m^2 water)	37.4	32.1	20.1
Density of submerged coarse debris (kg/m^2 water)	13.6	11.9	2.4
Stream gradient (m/10m of stream)	0.41	0.62	0.22
Pools as percent of surface area	69.7	78.1	70.7
Average depth (cm)	8.5	9.3	8.5
Water surface area (m^2)	20.7	22.7	18.0
Undercut bank as percent of surface area	10.8	12.3	13.6
Length of undercut bank as percent of total bank	20.5	28.9	30.8

The first five linear combinations of the habitat features constructed by the PC analysis are given in Table 2. Together these accounted for 80.7% of the variation in the habitat data. PC-1 accounted for 40.3% of the variation and showed high loading values (correlations between the feature and the PC they appear in) for fine debris features. Pool area and depth, coarse debris features, surface area and stream gradient, and undercut bank features had high loading values in PC-1 through 5. Features having correlation coefficients of 0.8 or greater with other features in the same PC are identified in Table 3.

Fish Populations

The numbers of fish collected in 1977 and 1978 are given in Appendix Table 19. Coho salmon was the most abundant species collected followed by Dolly Varden. Cutthroat trout and coastrange sculpin together represented less than 5% of the number of fish collected.

The estimated densities of fish in each study section in 1977 are presented in Table 4. Coho salmon was the dominant fish species and appeared to decline from July through September on both streams. Densities of Dolly Varden on each stream in September were greater than densities for July and August. No estimates of population numbers were made for cutthroat trout and coastrange sculpin because

Table 2. Results of the principal component (PC) analysis for the habitat features measured on Tye-One-Ohn, Little Toad, and Three-Tenths Mile creeks during 1978. The percent of total variance in the habitat data accounted for by each PC is in parenthesis. High loading values are underlined.

Habitat Features	PC-1 (40.3)	PC-2 (16.3)	PC-3 (10.1)	PC-4 (8.0)	PC-5 (6.1)
Fine debris as percent of surface area (submerged & elevated)	.927	.142	.258	.095	-.053
Submerged fine debris as percent of surface area	.828	.398	.219	-.007	.009
Elevated fine debris as percent of surface area	.794	-.278	.237	.218	-.129
Density of fine debris (submerged & elevated)	.946	-.069	.222	.073	-.085
Density of submerged fine debris	.924	.109	.196	-.024	-.043
Density of elevated fine debris	.817	-.331	.225	.209	-.135
Coarse debris as percent of surface area (submerged & elevated)	.343	.121	.431	.208	.118
Density of coarse debris (submerged & elevated)	.407	.011	.826	.017	-.080
Density of submerged coarse debris	.329	.056	.886	-.001	.048
Stream gradient (m/10m of stream)	.079	.149	-.194	.868	.044
Pools as percent of surface area	.068	.753	-.026	-.006	.169
Average depth	-.061	.859	.097	.111	-.147
Water surface area	.095	-.115	.367	.594	-.183
Undercut bank as percent of surface area	-.136	.014	-.013	-.069	.909
Length of undercut bank as percent of total bank	-.530	-.042	.028	.415	.431

[1] Each loading value indicates the correlation between the individual habitat feature and the entire PC in which it appears.

Table 3. Habitat features having correlation coefficients of 0.8 or greater with other habitat features in the same principal component (PC).

PC			
1	Fine debris as percent of surface area	with	Submerged and elevated fine debris as percent of surface area, density of fine debris, and density of submerged and elevated fine debris
	Submerged and elevated fine debris as percent of surface area	with	Fine debris as percent of surface area, density of fine debris, and density of submerged and elevated fine debris
	Density of fine debris	with	Fine debris as percent of surface area, submerged and elevated fine debris as percent of surface area, and density of submerged and elevated fine debris
	Density of submerged and elevated fine debris	with	Fine debris as percent of surface area, submerged and elevated fine debris as percent of surface area, density of fine debris
3	Density of coarse debris	with	Density of submerged coarse debris
	Density of submerged coarse debris	with	Density of coarse debris
5	Undercut bank as percent of surface area	with	Length of undercut bank as percent of total bank
	Length of undercut bank as percent of total bank	with	Undercut bank as percent of surface area

Table 4. Population densities (numbers/m of stream) of the major fish species on each study section of Tye-One-Ohn and Little Toad creeks in 1977. The 95% confidence limits are in parenthesis.

Location	Sampling Date	Coho Salmon	Dolly Varden
Tye-One-Ohn Creek	August	2.92 (2.61-3.28)	2.41 (2.09-2.77)
	September	2.77 (2.46-3.12)	2.54 (2.34-2.76)
Little Toad Creek	July	2.95 (2.51-3.48)	1.83 (1.59-2.11)
	August	2.44 (2.13-2.80)	1.73 (1.43-2.09)
	September	2.35 (2.01-2.74)	1.98 (1.83-2.14)

they were present in only small numbers throughout the study.

The estimated densities of fish in each study section in 1978 are given in Table 5. Coho salmon was the dominant species and showed declines on all streams from July through September. Densities of Dolly Varden showed an increase of 25% in September on Three-Tenths Mile Creek.

The length-frequencies of coho salmon and Dolly Varden collected in each study section in 1978 are given in Appendix Figures 34-39.

Table 5. Population densities (numbers/m of stream) of the major fish species on each study section in 1978. Population densities (numbers m^3 water) are in parenthesis.

Location	Sampling Date	Coho Salmon	Dolly Varden
Tye-One-Ohn Creek	July	4.80 (25.3)	2.16 (11.3)
	September	3.29 (17.4)	1.67 (8.8)
Little Toad Creek	July	3.39 (24.7)	2.39 (17.4)
	September	1.79 (13.0)	1.86 (13.7)
Three-Tenths Mile Creek	July	- (21.0)	- (10.3)
	September	- (15.5)	- (12.9)

Ages were assigned to the length-frequencies by application of the length-age relationship obtained from the specimens in which otoliths were examined. The estimated densities for each age group of these species at each station of the study sections in 1978 are given in Appendix Tables 20-25.

The densities for each age group of coho salmon and Dolly Varden in each study section in 1978 are presented in Table 6. Populations of coho salmon contained age 0 and 1+ fish. Age 0 fish

Table 6. The densities (numbers/m water) of the age groups of the major fish species on each study section in 1978. The 95% confidence limits are in parenthesis.

Location	Sampling Date	Coho Salmon Age 0	Coho Salmon Age 1+	Dolly Varden Age 0-1+	Dolly Varden Age 2-3+
Tye-One-Ohn Creek	July	20.7 (16.8-25.4)	4.6 (4.1-5.4)	6.9 (6.0-8.1)	4.4 (3.9-5.1)
	September	13.3 (10.4-16.9)	4.1 (3.1-5.5)	6.1 (4.6-8.3)	2.7 (2.0-3.7)
Little Toad Creek	July	17.4 (13.6-22.1)	7.3 (6.1-8.8)	9.4 (7.4-12.0)	8.0 (6.6-9.8)
	September	7.6 (5.6-10.7)	5.4 (4.2-6.9)	9.1 (6.8-12.4)	4.6 (3.5-5.8)
Three-Tenths Mile Creek	July	17.6 (14.0-22.2)	3.4 (2.3-5.4)	6.0 (3.8-9.9)	4.3 (2.9-6.4)
	September	12.1 (9.4-15.7)	3.4 (2.4-5.0)	9.7 (6.8-14.4)	3.2 (2.2-4.7)

comprised 59-84% of the coho salmon populations and experienced a 31-57% mortality from July through September. Estimates of mortality for age 1+ fish in this species ranged from 0 to 26%. Populations of Dolly Varden contained individuals ranging from age 0 to 3+. Age 0 and 1+ together comprised 54% of the population. Estimates of mortality for Dolly Varden were in contrast to those for coho salmon as the older age group (2-3+) declined more than the younger age group (0-1+). The density of age group 0-1+ Dolly Varden increased by 63% from July to September in Three-Tenths Mile Creek. This increase in estimated density may have been caused by recruitment into the sampled population as a result of growth of these fish. This probably resulted in low estimates of mortality for the 0-1+ age group.

Estimates of Fish Biomass

The length-weight relationships for coho salmon and Dolly Varden in each study section are presented in Appendix Table 26. Estimates of biomass for coho salmon and Dolly Varden at each sampling station of the study sections are given in Appendix Tables 27-32. The estimates of biomass for fish in each study section are presented in Table 7. Dolly Varden comprised 60-68% of the total fish biomass in each sampling period. Their biomass was dominated by age group 2-3+. The biomass for age groups 2-3+ and 0-1+ decreased 11-36% and increased 2-98% respectively from July through September on all streams. Age 1+ coho salmon comprised 52-73% of the biomass of that species. Biomass estimates for this age increased by 14-15% from July through September on Tye-One-Ohn and Three-Tenths Mile creeks and declined by 8% on Little Toad Creek. Biomass of age 0 coho salmon declined by 19-51% on Little Toad and Three-Tenths Mile creeks but increased by 7% on Tye-One-Ohn Creek between the sampling periods.

Table 7. Estimates of biomass (g/m^3 water) for the major fish species on study sections in 1978. The 95% confidence limits are in parenthesis.

Location	Sampling Date	Coho Salmon			Dolly Varden		
		Age 0	Age 1+	Totals	Age 0-1+	Age 2-3+	Totals
Tye-One-Ohn Creek	July	11.5 (9.3-14.1)	13.2 (11.8-15.5)	24.7	14.8 (12.8-17.3)	31.5 (27.9-36.5)	46.3
	September	12.3 (9.6)-15.5)	15.0 (11.3-20.1)	27.3	16.2 (12.2-22.1)	23.2 (17.2-31.8)	39.4
Little Toad Creek	July	13.6 (10.6-17.3)	26.9 (22.4-32.4)	40.5	27.1 (21.3-34.6)	57.6 (47.5-69.8)	84.7
	September	9.0 (6.6-12.6)	24.7 19.2-31.5)	33.7	27.4 (20.5-37.3)	37.0 (28.1-46.6)	64.4
Three-Tenths Mile Creek	July	13.4 (10.6-16.9)	14.2 (9.6-22.6)	27.6	11.9 (7.5-19.6)	29.2 (19.7-43.4)	41.1
	September	11.3 (8.7-14.6)	16.4 (11.6-24.1)	27.7	23.6 (16.5-34.9)	25.9 (17.8-38.0)	49.5

Fish Movement

Coho salmon appeared to move into box traps more than Dolly Varden from July through August on Little Toad and Tye-One-Ohn creeks (Table 8). The majority of movements by coho salmon were made by age 0 fish (36-60mm) resident to the pool where the traps were located (Appendix Tables 33 and 34). Net movement of coho salmon over all sampling periods was less than 10 fish into the study areas on Tye-One-Ohn and Little Toad creeks. The greatest movements of Dolly Varden occurred in September on both streams and were probably associated with higher stream flows. At this time Dolly Varden fry (26-50mm) and spawning adults (up to 290mm) moved into the study area on Little Toad creek through the upstream and downstream traps respectively (Appendix Table 34). Movements of Dolly Varden showed a net decline of 16 and a net gain of 85 fish over the sampling periods on the study areas of Tye-One-Ohn and Little Toad creeks respectively.

In 1978 coho salmon moved more than Dolly Varden in late May and early June (Table 9) because of the downstream dispersal of their 31-50mm emergent fry (Appendix Tables 35 and 36). By the end of June dispersal had ceased. Movement of coho salmon was negligible during the remainder of trap operations and was primarily due to resident fish. Movements of coho salmon showed a net gain of 2270 and 10 fish for the study areas on Tye-One-Ohn and Little Toad

Table 8. Movements of fish of the major species through box traps on Tye-One-Ohn and Little Toad creeks in 1977.

Location	Species	Movements	Sampling Dates and Direction Moved[1]									
			7-17 to 7-31		8-1 to 8-15		8-16 to 8-31		9-1 to 9-15		9-16 to 9-21	
			U	D	U	D	U	D	U	D	U	D
Tye-One-Ohn Creek	coho salmon	Into study area	3	24	0	51	0	30	10	28	3	5
		Out of study area	25	4	33	10	32	0	24	2	5	2
	Dolly Varden	Into study area	7	7	0	1	0	6	10	52	2	26
		Out of study area	11	1	8	1	19	0	49	6	22	10
Little Toad Creek	coho salmon	Into study area	67	8	55	5	104	4	47	3	14	3
		Out of study area	1	78	0	54	0	92	0	56	1	19
	Dolly Varden	Into study area	17	6	12	0	14	2	51	76	16	23
		Out of study area	10	16	2	10	0	10	25	46	5	8

[1] U = upstream, D = downstream.

Table 9. Movements of fish of the major species through box traps on Tye-One-Ohn and Little Toad creeks in 1978.

			Sampling Dates and Direction[1] Moved													
			5-12/5-15		5-16/5-31		6-1/6-15		6-16/6-30		7-1/7-15		7-16/7-31		8-1/8-16	
Location	Species	Movements	U	D	U	D	U	D	U	D	U	D	U	D	U	D
Tye-One-Ohn Creek	coho salmon	Into study area	0	5	0	642	14	3082	5	41	5	6	3	10	0	2
		Out of study area	1	0	41	782	155	532	10	0	12	0	6	4	1	0
	Dolly Varden	Into study area	0	0	0	2	2	0	0	0	0	0	1	3	0	0
		Out of study area	1	1	9	11	3	3	1	0	2	2	2	8	0	0
Little Toad Creek	coho salmon	Into study area	3	4	7	15	33	3	10	3	6	3	9	7	0	4
		Out of study area	2	10	0	39	0	14	1	4	0	5	0	19	3	0
	Dolly Varden	Into study area	2	0	6	30	13	0	3	10	6	14	16	13	0	4
		Out of study area	0	10	0	10	0	5	0	2	1	5	1	22	0	1

[1] U = upstream, D = downstream.

creeks respectively. Movements of Dolly Varden were greatest in late May and late July. Dolly Varden fry moving into the study area through the upstream trap comprised the majority of movements on Little Toad Creek (Appendix Table 36). Net movement over all sampling periods was 55 Dolly Varden out of the study area on Tye-One-Ohn Creek and 60 into the study area on Little Toad Creek.

Most of the above movements of coho salmon and Dolly Varden occurred before and after the time period when population estimates were conducted. In addition, movements of Dolly Varden were by fish too small or too large to be successfully trapped, therefore movements did not affect population estimates.

A greater percent of the recaptured Dolly Varden than coho salmon had moved among stations during population censuses in 1978 (Appendix Table 37). In both species a greater percent of the recaptured fish of the older age groups than younger age groups had moved among stations. The numbers of fish moving and the distances moved during population census in 1978 are given in Appendix Tables 38-40. Age 1+ coho salmon comprised 62-100% of fish in that species moving among stations. Age group 2-3+ comprised 54-84% of the Dolly Varden that moved. The distances traveled by age groups 1+ coho salmon and 2-3+ Dolly Varden averaged 27.7 and 25.7m respectively and were 102 and 32% farther than fish in the younger age groups in these species. Fish in each age group did not appear to move consistently in any direction. Only two marked coho salmon and one marked Dolly Varden were captured in box traps outside of the study sections during the censuses on Tye-One-Ohn and Little Toad creeks respectively, indicating declines in population numbers were not due to movements.

Multiple Regression Analysis

Three-Tenths Mile Creek - July 1978

Multiple regression analysis (Table 10) showed density of submerged coarse debris, water surface area, and density of elevated fine debris together accounted for 93% of the variation in the density of age 0 coho salmon ($P < .01$). Density of submerged coarse debris was the most important single habitat feature and was negatively related to these fish.

Undercut bank as percent of surface area accounted for 76% of the variation in the density of age 1+ coho salmon. This feature was directly related to these fish ($P < .01$).

Two features of submerged debris, water surface area, stream gradient, and undercut bank together accounted for 98% of the variation in the density of age group 0-1+ Dolly Varden ($P < .01$). Submerged fine debris as percent of surface area, density of submerged coarse debris, and water surface area were the most important features. All features, except submerged fine debris as percent of surface area,

Table 10. Statistically significant results of the multiple regression analysis of fish population densities and measured habitat features on Three-Tenths Mile Creek in July 1978. The signs of the simple correlation coefficients of fish densities and individual habitat features are in parenthesis.

Age and species	Habitat Features	$R^{2'+}$	Increments of $R^{2'}$
0 coho salmon	Density of submerged coarse debris (-)	.73	.73
	Water surface area (+)	.82	.09
	Density of elevated fine debris (-)	.93**	.11
1+ coho salmon	Undercut bank as percent of surface area (+)	.76**	.76
0-1+ Dolly Varden	Submerged fine debris as percent of surface area (-)	.09	.09
	Density of submerged coarse debris (+)	.40	.31
	Water surface area (+)	.79	.39
	Stream gradient (+)	.92	.13
	Undercut bank as percent of total bank (+)	.98*	.06
2-3+ Dolly Varden	Density of submerged coarse debris (+)	.77	.77
	Stream gradient (+)	.78	.01
	Undercut bank as percent of total bank (+)	.81	.03
	Density of elevated fine debris (+)	.87	.06
	Coarse debris as percent of surface area - submerged & elevated (+)	.93**	.06

+ The $R^{2'}$ value represents the amount of variation accounted for by features at and above the value.

* All features at and above the single asterisk are significant at $P < .05$.

**All features at and above the double asterisk are significant at $P < .01$.

were directly related to age group 0-1+ Dolly Varden.

Two features of coarse debris, stream gradient, undercut bank and one feature of fine debris accounted for 93% of the variation in the density of age group 2-3+ Dolly Varden ($P < .01$). Density of submerged coarse debris alone accounted for 77% of the variation. All five features had a positive relationship with age group 2-3+ Dolly Varden.

Three-Tenths Mile Creek - September 1978

The relationships between habitat features and age 0 coho salmon in September were similar to those in July. Density of submerged coarse debris, density of elevated fine debris, and water surface area accounted for 91% of the variation in the density of age 0 coho salmon and were significant at $P < .01$ (Table 11). Density of submerged coarse debris was again the most important single feature and was negatively related to these fish.

Features of the undercut bank, density of fine and coarse debris, water surface area, and average depth accounted for 99% of the variation in the density of age 1+ coho salmon ($P < .01$). As in July, undercut bank as percent of surface area was the most important single feature explaining 84% of the variation in these fish and was directly related to their density.

Four features of the density of debris, pool area, and undercut bank accounted for 99% of the variation in the density of age group

Table 11. Statistically significant results of the multiple regression analysis of fish population densities and measured habitat features on Three-Tenths Mile Creek in September 1978. The signs of the simple correlation coefficients of fish densities and individual habitat features are in parenthesis.

Age and Species	Habitat Features	$R^{2'}$ +	Increments of $R^{2'}$
0 coho salmon	Density of submerged coarse debris (-)	.79	.79
	Density of elevated fine debris (-)	.80	.01
	Water surface area (+)	.91**	.11
1+ coho salmon	Undercut bank as percent of surface area (+)	.84	.84
	Density of elevated fine debris (+)	.91	.07
	Water surface area (-)	.95	.04
	Density of submerged coarse debris (+)	.98	.03
	Average depth (+)	.99**	.01
0-1+ Dolly Varden	Density of submerged fine debris (+)	.56	.56
	Pools as percent of surface area (-)	.75	.19
	Density of coarse debris - submerged & elevated (-)	.87	.12
	Density of elevated fine debris (+)	.95	.08
	Undercut bank as percent of total bank (+)	.96	.01
	Density of submerged coarse debris (+)	.99**	.03
2-3+ Dolly Varden	Undercut bank as percent of total bank (+)	.33	.33
	Average depth (+)	.43	.10
	Pools as percent of surface area (-)	.88**	.45

+ The $R^{2'}$ value represents the amount of variation accounted for by features at and above the value.

**All features at and above the double asterisk are significant at $P < .01$.

0-1+ Dolly Varden ($P < .01$). Density of submerged fine debris was the most important single feature. It accounted for 56% of the variation and was directly related to these fish.

Undercut bank as percent of total bank, average depth, and pool area explained 88% of the variation in the density of age group 2-3+ Dolly Varden ($P < .01$). Pool area was the only feature with a negative relationship.

Tye-One-Ohn Creek - July 1978

Multiple regression analysis (Table 12) showed stream gradient, coarse and submerged fine debris as percent of surface area together accounted for 72% of the variation in the density of age 0 coho salmon ($P < .01$). The above features together with water surface area and average depth accounted for 78% of the variation ($P < .05$). The features of stream gradient and coarse debris were negatively related while submerged fine debris was directly related to age 0 coho salmon.

Average depth and density of elevated fine debris accounted for 61% of the variation in the density of age 1+ coho salmon ($P < .01$). With the addition of the features of pool area, water surface area, submerged coarse debris, and undercut banks 78% of the variation was accounted for ($P < .05$). The features of average depth and density of fine debris were negatively related to these fish.

Average depth, three features of density of debris, pool area, and stream gradient accounted for 91% of the variation in the density

Table 12. Statistically significant results of the multiple regression analysis of fish population densities and measured habitat features on Tye-One-Ohn Creek in July 1978. The signs of the simple correlation coefficients of fish densities and individual habitat features are in parenthesis.

Age and Species	Habitat Features	$R^{2'+}$	Increments of $R^{2'}$
0 coho salmon	Stream gradient (-)	.23	.23
	Coarse debris as percent of surface area - submerged & elevated (-)	.37	.14
	Submerged fine debris as percent of surface area (+)	.72**	.35
	Water surface area (-)	.75	.03
	Average depth (+)	.78*	.03
1+ coho salmon	Average depth (-)	.21	.21
	Density of elevated fine debris (-)	.61**	.40
	Pools as percent of surface area (+)	.62	.02
	Water surface area (-)	.64	.02
	Density of submerged coarse debris (+)	.67	.03
	Undercut bank as percent of surface area (+)	.78*	.11
0-1+ Dolly Varden	Average depth (-)	.50	.50
	Density of coarse debris - submerged & elevated (+)	.54	.04
	Density of submerged coarse debris (+)	.70	.16
	Pools as percent of surface area (-)	.83	.13
	Density of elevated fine debris (+)	.85	.02
	Stream gradient (+)	.91**	.06
2-3+ Dolly Varden	Stream gradient (+)	.25	.25
	Density of submerged fine debris (-)	.35	.10
	Average depth (-)	.43	.08
	Density of elevated fine debris (-)	.47	.04
	Pools as percent of surface area (+)	.64	.17
	Water surface area (-)	.76**	.12

+ The $R^{2'}$ value represents the amount of variation accounted for by features at and above the value.

* All features at and above the single asterisk are significant at $P < .05$.

**All features at and above the double asterisk are significant at $P < .01$.

of age group 0-1+ Dolly Varden ($P < .01$). Average depth was the most important single feature and accounted for almost 50% of the variation. This feature had a negative relationship to age 0-1+ Dolly Varden.

Stream gradient, two features of fine debris, average depth, pool area, and water surface area combined to explain 76% of the variation in the density of age group 2-3+ Dolly Varden ($P < .01$). Stream gradient and pool area were the only features directly related to these fish.

Tye-One-Ohn Creek - September 1978

Three features of the density of debris and the water surface area accounted for 84% of the variation in the density of age 0 coho salmon at the $P < .01$ level (Table 13). Density of elevated and submerged fine debris were the most important features and together accounted for 63% of the variation. As in July, the features of debris and water surface area were directly and negatively associated respectively.

Two features of coarse debris, water surface area, and a feature of fine debris together accounted for 64% of the variation in the density of age 1+ coho salmon ($P < .05$). The features of coarse debris and water surface area were directly and negatively related to these fish respectively, as they were in July.

Average depth, two features of fine debris, and pool area

Table 13. Statisically significant result of the multiple regression analysis of fish population densities and measured habitat features on Tye-One-Ohn Creek in September 1978. The signs of the simple correlation coefficients of fish densities and individual habitat features are in parenthesis.

Age and Species	Habitat Features	$R^{2'}$+	Increments of $R^{2'}$
0 coho salmon	Density of submerged fine debris (+)	.40	.40
	Density of elevated fine debris (+)	.63	.23
	Water surface area (-)	.75	.12
	Density of coarse debris - submerged & elevated (-)	.84**	.09
1+ coho salmon	Density of submerged coarse debris (+)	.11	.11
	Water surface area (-)	.30	.19
	Density of fine debris - submerged & elevated (-)	.60	.30
	Density of coarse debris - submerged & elevated (+)	.64*	.04
0-1+ Dolly Varden	Average depth (-)	.46	.46
	Density of submerged fine debris (+)	.68	.22
	Density of elevated fine debris (+)	.72	.04
	Pools as percent of surface area (-)	.79**	.07
2-3+ Dolly Varden	Undercut bank as percent of surface area (+)	.25	.25
	Water surface area (+)	.45	.20
	Density of coarse debris (-)	.55*	.10

+ The $R^{2'}$ value represents the amount of variance explained by features at and above the value.

* All features at and above the single asterisk are significant at $P < .05$.

**All features at and above the double asterisk are significant at $P < .01$.

accounted for 79% of the variation in the density of age group 0-1+ Dolly Varden ($P < .01$). As in July, average depth was the most important single feature accounting for 46% of the variation and was negatively related to these fish.

Features of undercut bank, water surface area, and coarse debris combined to account for 55% of the variation in the density of age group 2-3+ Dolly Varden ($P < .05$). The features of undercut bank and water surface area were directly related to these fish.

Little Toad Creek - July 1978

Multiple regression analysis (Table 14) showed two features of the density of debris, undercut bank, pool area, and water surface area together accounted for 85% of the variation in the density of age 0 coho salmon ($P < .01$). Density of elevated fine debris was the most important single feature explaining 41% of the variation and was negatively related to these fish.

Stream gradient, two features of debris, and water surface area accounted for 85% of the variation in the density of age 1+ coho salmon ($P < .01$). Stream gradient and density of submerged coarse debris were the most important features and were both negatively related to these fish.

Average depth and submerged fine debris as percent of surface area accounted for 63% of the variation in the density of age group 0-1+ Dolly Varden ($P < .01$). Both features had a negative relationship

Table 14. Statistically significant results of the multiple regression analysis of fish population densities and measured habitat features on Little Toad Creek in July 1978. The signs of the simple correlation coefficients of fish densities and individual habitat features are in parenthesis.

Age and Species	Habitat Features	$R^{2'}$+	Increments of $R^{2'}$
0 coho salmon	Density of elevated fine debris (-)	.41	.41
	Density of submerged coarse debris (+)	.58	.17
	Undercut bank as percent of surface area (-)	.70	.12
	Pools as percent of surface area (-)	.78	.09
	Water surface area (-)	.85**	.07
1+ coho salmon	Stream gradient (-)	.54	.54
	Density of submerged coarse debris (-)	.78	.24
	Water surface area (+)	.84	.06
	Elevated fine debris as percent of surface area (+)	.85**	.01
0-1+ Dolly Varden	Average depth (-)	.61	.61
	Submerged fine debris as percent of surface area (-)	.63**	.02
2-3+ Dolly Varden	Average depth (-)	.25	.25
	Water surface area (-)	.46	.21
	Density of submerged fine debris (-)	.54	.07
	Coarse debris as percent of surface area - submerged & elevated (-)	.59*	.05

+ The $R^{2'}$ value represents the amount of variance explained by features at and above the value.

* All features at and above the single asterisk are significant at $P < .05$.

**All features at and above the double asterisk are significant at $P < .01$.

with these fish.

Average depth combined with water surface area and two features of debris accounted for 59% of the variation in the density of age group 2-3+ Dolly Varden. Average depth and water surface area were the most important features and were negatively related to these fish.

Little Toad Creek - September 1978

Density of elevated fine and submerged coarse debris, pool area and water surface area accounted for 81% of the variation in the density of age 0 coho salmon at the $P < .01$ level (Table 15). As in July, density of elevated fine debris was the most important feature and was negatively related to these fish.

Stream gradient and four features of fine and coarse debris, accounted for 99% of the variation in the density of age 1+ coho salmon ($P < .01$). As in July, stream gradient and density of submerged coarse debris were the most important features and were negatively related to age 1+ coho salmon.

Average depth and two features of debris combined to explain 51% of the variation in the density of age group 0-1+ Dolly Varden ($P < .05$). As in July, all features had a negative relationship with these fish.

Features of average depth and undercut bank accounted for 44% of the variation in the density of age group 2-3+ Dolly Varden

Table 15. Statistically significant results of the multiple regression analysis of fish population densities and measured habitat features on Little Toad Creek in September 1978. The signs of the simple correlation coefficients of fish densities and individual habitat features are in parenthesis.

Age and Species	Habitat Features	$R^{2'}$+	Increments of $R^{2'}$
0 coho salmon	Density of elevated fine debris (-)	.34	.34
	Pools as percent of surface area (-)	.62	.28
	Density of submerged coarse debris (+)	.78	.16
	Water surface area (-)	.81**	.03
1+ coho salmon	Stream gradient (-)	.59	.59
	Density of submerged coarse debris (-)	.89	.30
	Submerged fine debris as percent of surface area (+)	.97	.08
	Elevated fine debris as percent of surface area (+)	.98	.01
	Coarse debris as percent of surface area - submerged & elevated (-)	.99**	.01
0-1+ Dolly Varden	Average depth (-)	.32	.32
	Density of submerged coarse debris (-)	.45	.13
	Fine debris as percent of surface area - submerged & elevated (-)	.51*	.06
2-3+ Dolly Varden	Average depth (-)	.16	.16
	Undercut bank as percent of total bank (-)	.44*	.28

+ The $R^{2'}$ value represents the amount of variance explained by features at and above the value.

* All features at and above the single asterisk are significant at $P < .05$.

**All features at and above the double asterisk are significant at $P < .01$.

($P < .05$). Both features were negatively related to these fish.

The measured habitat features of debris and undercut bank that were important to fish on Three-Tenths Mile and Tye-One-Ohn creeks generally accounted for lower levels of variation and did not have direct relationships to fish on Little Toad Creek. Riparian vegetation was very abundant along many stations and often extended completely across the channel on this stream. The influence of this feature may have masked the response of fish to the measured habitat features.

DISCUSSION

Habitat and Fish Populations - 1978

Differences in habitat between Tye-One-Ohn and Little Toad creeks in logged areas and Three-Tenths Mile Creek in unlogged forest were identified by constructing a plot diagram using the two principal components that accounted for the greatest amount of variation in the habitat data. Two distinct clusters were apparent from this PC ordination (Figure 2). Stream stations having similar habitats formed each cluster. All stations on Three-Tenths Mile Creek and 7 stations from Tye-One-Ohn and Little Toad creeks comprised cluster I. Twelve stations from the streams in logged areas comprised cluster II. These clusters were separated along the PC - 1 axis indicating that differences in habitat were largely attributable to fine debris. The deliberate selection of stations with low quantities of debris on the streams in logged areas accounted for the 30% overlap of these stations in cluster I. Had a more random selection of stations been conducted it is likely that the overlap of stations from logged and unlogged areas in cluster I would have been even less. Three stations from Tye-One-Ohn and Little Toad creeks were not included in clusters I and II because they were characterized by extremely high concentrations of debris.

Measurements of fine debris were 165-242% greater on Tye-One-Ohn and Little Toad creeks than Three-Tenths Mile Creek (Table 1).

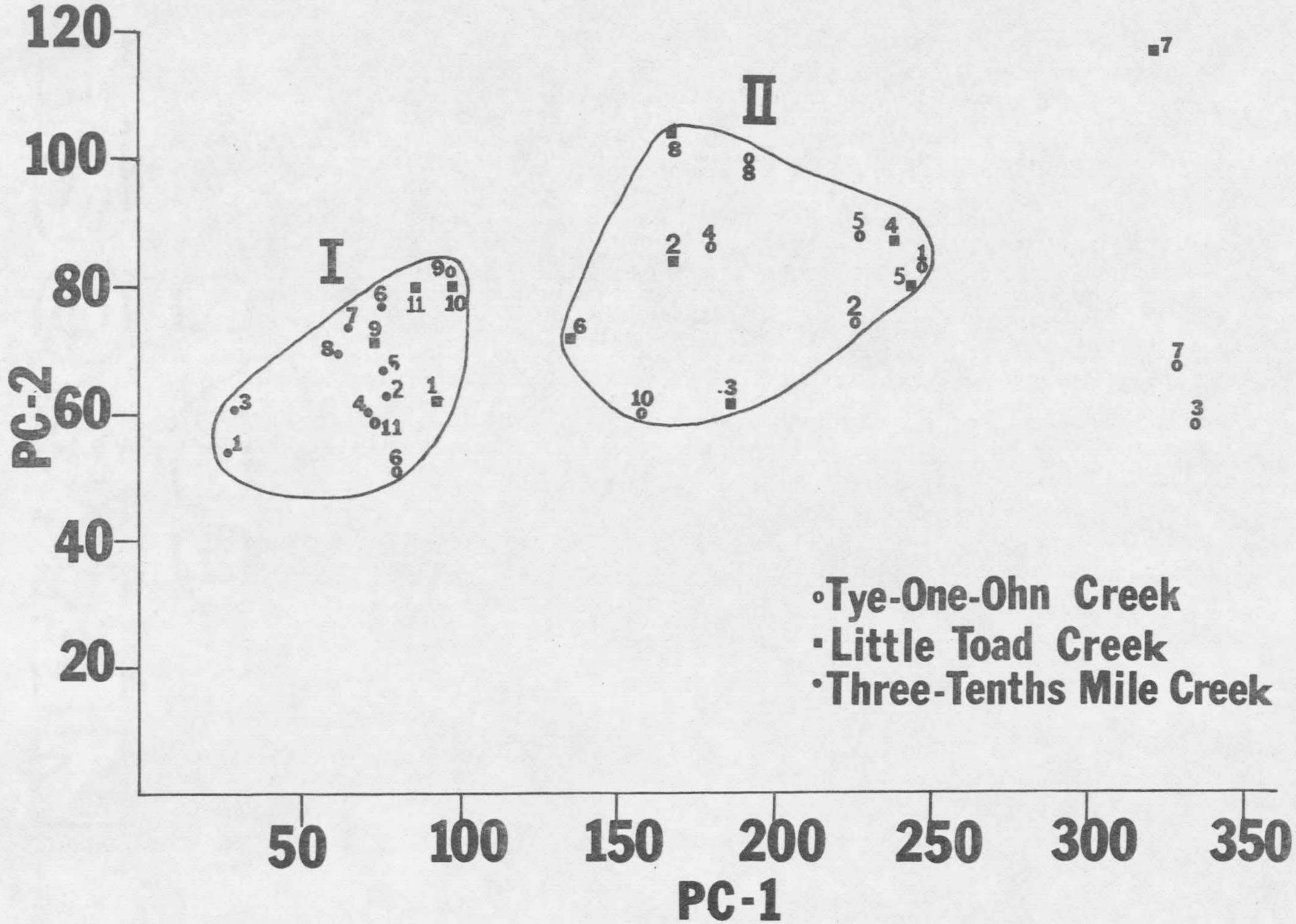

Figure 2. Principle components ordination of habitat data from Tye-One-Ohn, Little Toad, and Three-Tenths Mile creeks. Large circles represent clusters formed by principal component ordination. Numbers associated with stream symbols indicate the specific stream stations.

Density of submerged coarse debris was 396-467% greater on the two streams in logged areas. Coarse debris as percent of surface area and density were only 22-86% greater on these streams because numerous logs lay across the channel of Three-Tenths Mile Creek. Blowdown attributable to the presence of Twin Spur Road may have contributed to the coarse debris in this stream.

Logging undoubtedly increased the levels of debris in the streams in logged areas. Swanson et al. (1977) observed that clearcutting increased the debris in the streams in the Staney Creek area by five to ten times. Debris was more widely distributed across the channels of Tye-One-Ohn and Little Toad creeks than Three-Tenths Mile Creek (Appendix Figures 3-33). This appeared to reduce water velocities and increase stream widths, pools, and depths in these streams. Marzolf (1978), Hall and Lantz (1969), and Swanson et al. (1976) also reported logging debris produced these effects.

Multiple regression analysis was used to identify the relationships between fish densities and specific habitat features within each stream. It showed that debris was an important component of habitat for fish in Tye-One-Ohn and Three-Tenths Mile creeks (Tables 10-13).

Densities of age 1+ coho salmon in Tye-One-Ohn Creek in July were positively associated with undercut banks, submerged coarse debris, and pools in shallow areas (Table 12). Submerged coarse debris was particularly important to these fish in September (Table 13). The coarse debris in mid-channel areas was observed to receive the greatest use by these fish, while fine debris (Tables 12-13) was apparently avoided. On Three-Tenths Mile Creek age 1+ coho salmon were positively associated with undercut banks and in September showed increased association with submerged coarse and elevated fine debris (Tables 10-11) that was limited to the stream edge (Appendix Figures 26-33). The coarse debris in mid-channel areas of Tye-One-Ohn Creek and the stream edge of both streams appeared to provide areas of low velocity necessary for these fish to maintain a low activity level (Carline 1968) and feed on drifting organisms (Mundie 1969).

Age group 2-3+ Dolly Varden in Tye-One-Ohn Creek in July appeared to be most abundant in the shallower pools in areas of higher stream gradient (Table 12). Observations indicated that these pools were created by debris dams. This age group of fish was primarily associated with submerged coarse debris, elevated fine debris, and undercut banks in July on Three-Tenths Mile Creek (Table 10). Undercut banks became more important to these fish in both streams in September (Tables 11 and 13).

On Tye-One-Ohn Creek in July undercut banks were important to age 1+ coho salmon but not age group 2-3+ Dolly Varden. The inverse of this relationship existed in September, suggesting that coho salmon were competitively excluding Dolly Varden from undercut banks. A decline in the association of debris features to age group 2-3+

Dolly Varden on Three-Tenths Mile Creek from July to September corresponded to an increase in association of the same features to age 1+ coho salmon, indicating competitive exclusion from debris habitats on this stream. However, the areas of undercut bank were larger on Three-Tenths Mile Creek than Tye-One-Ohn Creek (Appendix Figures 4-14 and 26-33) and seemed to provide space for both age groups.

Age 0 coho salmon were positively associated with submerged and elevated fine debris and negatively with areas of high stream gradient and coarse debris on Tye-One-Ohn Creek (Tables 12-13). This same age group was negatively associated with submerged coarse debris (Tables 10-11) and were mostly observed in cover-free, mid-channel and edge areas on Three-Tenths Mile Creeks. Scott and Crossman (1973), Ruggles (1966), and Mundie (1969) also reported the use of stream edge and backwater areas by age 0 coho salmon. Fine debris habitats and cover-free areas not utilized by the older age groups of the major species seemed to be occupied by age 0 coho salmon. This distribution may be due to the territorial aggression and predation from these older age groups. Areas with debris were used when they were available and appeared to provide age 0 coho salmon protection and visual isolation from other fish.

Age group 0-1+ Dolly Varden in Tye-One-Ohn Creek seemed to use shallow riffle areas where cover was provided by coarse and fine debris (Tables 12-13). On Three-Tenths Mile Creek this age group was linked with coarse and fine debris at the stream edge and undercut banks (Tables 10-11). The debris features associated with age group 0-1+ Dolly Varden on Tye-One-Ohn Creek probably provided these fish with areas of low velocity and cover that were not preferred by the older age groups of both major species. However, the associations of debris features to these fish declined from July to September corresponding to an increased association of the same features to age 1+ coho salmon on Three-Tenths Mile Creek, suggesting the possibility of competitive exclusion on this stream. Observations indicated that age group 2-3+ Dolly Varden used faster and deeper water than the smaller, age group 0-1+ fish on Three-Tenths Mile Creek. Everest and Chapman (1972) McCrimmon (1954), and Saunders and Gee (1964) have shown this size-velocity distribution for steelhead trout, chinook salmon, and Atlantic salmon.

The larger quantity and wider distribution of debris in Tye-One-Ohn Creek obviously provided fish with suitable habitat over a greater area of the channel and allowed separation of age groups into distinct habitats. The importance of debris in providing fish shelter, escape cover, and feeding stations is well documented (Chapman 1962, Marzolf 1978, Bustard and Narver 1975). The debris in Tye-One-Ohn Creek may have allowed for increased numbers of fish by providing additional habitat, but this cannot be assessed by the present study due to lack of prelogging data.

Riparian vegetation on Little Toad Creek seemed to mask the relationships between fish densities and habitat features. It may have affected fish distribution by providing additional cover, particularly in areas lacking debris and undercut banks. This type of cover would have greatest impact on age 1+ coho salmon and both age groups of Dolly Varden, perhaps allowing greater densities of these fish to be supported. Meehan et al. (1977) has indicated the importance of overhanging riparian vegetation in providing escape cover for salmonids.

Possible Effects of Debris Removal

A removal of all debris associated with logging from Tye-One-Ohn and Little Toad creeks would probably result in a reduction in pool areas, loss of mid-channel cover, higher water velocities, and a reduction in channel widths. The loss of debris may force fish, particularly age 1+ coho salmon and both age groups of Dolly Varden, to use stream edges more extensively than when debris was present. If suitable habitat is not provided for displaced fish by stream edges or riparian vegetation overcrowding may occur resulting in increased interactions, stress, and perhaps a lower carrying capacity. Brown (1957) reported that stress from overcrowding can increase mortality. Emigration must also be considered as a source for potential loss of fish if removal of debris results in a severe reduction in habitat.

Dolly Varden would probably show the greatest decline with the removal of debris because age 1+ coho salmon can apparently use the edge areas on streams in logged areas more effectively. Age 0 coho salmon should be least affected because they would be able to utilize the cleared areas without conflict from the older age groups. Coho salmon are considered to be a resilient fish able to compensate for adverse conditions (Hall and Lantz 1969). Populations of coho salmon in two watersheds in Oregon remained stable or even showed increases after logging and debris removal while cutthroat trout populations became severely depressed (Moring and Lantz 1975).

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APPENDIX

Table 16. Measurements of the habitat features at each station of Tye-One-Ohn Creek in 1978.

Habitat Features	Stations										
	1	2	3	4	5	6	7	8	9	10	11
Fine debris as percent of surface area (submerged & elevated)	79.6	62.9	88.8	55.0	77.6	33.7	93.6	70.8	33.1	49.2	23.3
Submerged fine debris as percent of surface area	47.4	38.5	52.7	44.4	54.4	9.6	45.8	54.3	25.4	25.5	15.7
Elevated fine debris as percent of surface area	32.3	24.5	36.1	10.7	23.2	24.0	47.8	16.5	7.7	23.7	7.6
Density of fine debris (kg/m^2 water)	53.2	49.9	77.2	30.6	37.6	9.6	59.6	31.6	14.1	31.2	12.4
Density of submerged fine debris (kg/m^2 water)	31.6	34.7	49.2	24.7	27.9	2.7	29.2	25.4	10.8	16.0	8.3
Density of elevated fine debris (kg/m^2 water)	21.6	15.2	28.0	5.9	9.6	6.8	30.4	6.2	3.3	15.2	4.1
Coarse debris as percent of surface area (submerged & elevated)	24.7	26.7	32.4	30.1	25.6	7.5	35.0	11.6	22.2	28.1	14.5
Density of coarse debris-submerged and elevated (kg/m^2 water)	22.9	23.4	67.8	45.8	31.7	30.2	88.8	7.7	41.4	33.8	18.6
Density of submerged coarse debris (kg/m^2 water)	22.9	14.9	12.7	12.3	22.9	1.3	18.2	7.7	15.7	6.4	14.3
Stream gradient (m/10m of stream)	0.37	0.24	0.49	0.06	0.39	0.61	0.64	0.18	0.61	0.58	0.31
Pools as percent of surface area	81.3	68.2	49.7	71.4	77.1	63.7	67.7	85.8	84.3	59.1	58.7
Average depth (cm)	9.8	9.0	4.5	9.4	5.4	6.0	5.9	12.6	8.1	11.2	11.4
Water surface area (m^2)	27.2	17.3	19.2	21.8	16.8	17.1	19.7	19.9	23.3	20.6	25.1
Undercut bank as percent of surface area	5.6	2.1	6.8	55.6	6.2	12.8	2.7	1.5	13.3	6.5	5.4
Length of undercut bank as percent of total bank	38.5	9.1	12.5	11.0	20.0	27.3	6.7	13.7	37.2	26.6	23.2

Table 17. Measurements of the habitat features at each station of Little Toad Creek in 1978.

Habitat Features	Stations										
	1	2	3	4	5	6	7	8	9	10	11
Fine debris as percent of surface area (submerged & elevated)	38.7	66.1	64.7	73.6	74.6	50.9	97.9	64.6	27.0	31.1	38.5
Submerged fine debris as percent of surface area	21.5	38.3	31.8	47.1	39.7	34.4	78.9	50.3	23.9	23.6	30.0
Elevated fine debris as percent of surface area	17.2	27.8	32.9	26.6	34.9	16.4	18.9	14.3	3.1	7.4	8.5
Density of fine debris-submerged & elevated (kg/m^2 water)	19.6	24.9	36.0	48.4	38.3	26.1	51.3	27.3	6.9	14.8	12.5
Density of submerged fine debris (kg/m^2 water)	10.9	14.4	17.7	30.9	20.3	17.7	41.4	21.3	6.1	11.2	9.8
Density of elevated fine debris (kg/m^2 water)	8.7	10.5	18.3	17.5	17.9	8.4	9.9	6.0	0.8	3.5	2.7
Coarse debris as percent of surface area (submerged & elevated)	4.8	22.5	16.1	24.8	34.4	3.9	43.9	17.9	19.1	29.5	12.3
Density of coarse debris-submerged & elevated (kg/m^2 water)	3.1	34.9	13.9	36.8	78.2	3.1	91.3	17.3	33.3	28.9	12.8
Density of submerged coarse debris (kg/m^2 water)	3.1	4.6	2.8	12.9	39.3	3.0	6.7	10.1	14.9	27.6	5.6
Stream gradient (m/10m of stream)	0.61	0.37	0.61	0.88	0.61	0.46	0.64	0.37	0.85	0.55	0.85
Pools as percent of surface area	70.5	83.8	64.0	80.3	77.2	78.0	84.9	93.9	68.2	81.8	77.2
Average depth (cm)	5.9	8.8	8.3	11.1	10.7	6.2	12.6	10.8	8.0	7.8	11.6
Water surface area (m^2)	22.5	20.6	20.1	22.7	30.9	28.9	17.5	15.7	15.1	26.4	29.5
Undercut bank as percent of surface area	19.9	20.6	7.33	11.9	12.5	9.9	2.6	14.6	11.3	12.1	12.6
Length of undercut bank as percent of total bank	32.9	38.0	15.5	20.6	32.0	25.6	12.3	32.7	31.0	38.5	39.3

Table 18. Measurements of the habitat features at each station of Three-Tenths Mile Creek in 1978.

Habitat Features	Stations							
	1	2	3	4	5	6	7	8
Fine debris as percent of surface area (submerged & elevated)	16.8	24.5	10.9	25.2	29.5	23.5	21.6	25.5
Submerged fine debris as percent of surface area	14.2	17.5	9.5	10.0	15.6	14.4	17.1	17.2
Elevated fine debris as percent of surface area	2.6	7.0	1.4	15.2	13.9	9.1	4.5	8.3
Density of fine debris (kg/m^2 water)	7.0	13.9	4.7	14.1	19.7	4.9	10.2	12.2
Density of submerged fine debris (kg/m^2 water)	5.9	9.9	4.1	5.6	10.4	3.0	8.1	8.2
Density of elevated fine debris (kg/m^2 water)	1.1	4.0	0.6	8.5	9.3	1.9	2.1	4.0
Coarse debris as percent of surface area (submerged & elevated)	7.4	20.3	0.5	41.3	5.3	22.4	20.2	18.5
Density of coarse debris-submerged and elevated (kg/m^2 water)	7.1	32.2	0.1	28.2	3.1	38.1	35.5	16.9
Density of submerged coarse debris (kg/m^2 water)	1.1	2.3	0.1	3.8	3.1	1.5	3.4	4.0
Stream gradient (m/10m of stream)	0.21	0.31	0.03	0.34	0.12	0.09	0.15	0.49
Pools as percent of surface area	59.3	63.5	70.6	65.4	75.2	83.5	74.3	73.7
Average depth (cm)	6.2	8.2	6.9	7.5	9.8	8.6	11.4	9.1
Water surface area (m^2)	20.0	20.7	22.4	15.8	11.6	16.1	16.7	20.3
Undercut bank as percent of surface area	17.2	8.0	3.2	17.1	22.5	1.5	14.5	24.8
Length of undercut bank as percent of total bank	45.7	28.4	10.2	48.1	33.3	6.8	32.1	41.9

Table 19. Numbers of fish in each species collected during 1977 and 1978. The species composition of each collection is given as a percent in parenthesis.

Location	Sampling Date	Coho Salmon	Dolly Varden	Cutthroat Trout	Coastrange Sculpin
Tye-One-Ohn Creek	July 1978	323 (59.0)	219 (40.0)	2 (0.4)	3 (0.6)
	August 1977	271 (55.0)	215 (43.0)	3 (0.6)	7 (1.4)
	September 1977	260 (48.0)	268 (49.0)	4 (1.0)	10 (2.0)
	September 1978	268 (68.2)	122 (31.0)	1 (0.3)	2 (0.5)
Little Toad Creek	July 1977	351 (53.5)	281 (42.8)	24 (3.7)	0
	July 1978	329 (51.9)	281 (44.3)	24 (3.8)	0
	August 1978	369 (60.7)	220 (36.2)	19 (3.1)	0
	September 1977	338 (44.5)	393 (51.8)	28 (3.7)	0
	September 1978	240 (47.5)	245 (48.5)	20 (4.0)	0
Three-Tenths Mile Creek	July 1978	209 (68.0)	99 (32.0)	0	0
	September 1978	168 (57.9)	122 (42.1)	0	0

Table 20. The densities (numbers/m^3 water) for each age of coho salmon at stations on Tye-One-Ohn Creek in 1978.

Station	Age 0 July	Age 0 September	Age 1+ July	Age 1+ September
1	11.9	9.7	3.0	2.8
2	28.5	27.9	5.2	9.0
3	20.5	23.6	3.5	2.5
4	13.3	12.9	3.5	5.9
5	25.4	16.5	16.6	8.3
6	5.2	7.9	11.7	3.1
7	1.5	7.0	3.5	3.7
8	60.4	23.2	3.6	2.6
9	18.0	7.9	6.9	7.4
10	8.4	8.8	1.3	0.9
11	18.5	7.6	3.5	2.6

Table 21. The densities (numbers/m^3 water) for each age of coho salmon at stations on Little Toad Creek in 1978.

Station	Age 0		Age 1+	
	July	September	July	September
1	3.1	6.3	10.9	5.7
2	6.9	5.4	10.8	8.4
3	6.3	7.5	8.8	6.5
4	2.5	2.2	4.4	3.9
5	13.4	3.4	5.5	3.6
6	15.3	7.8	11.0	8.0
7	21.9	8.2	8.9	6.9
8	11.1	3.3	9.3	8.4
9	59.2	27.8	2.0	2.7
10	45.0	14.9	5.9	3.7
11	19.0	7.7	6.1	4.1

Table 22. The densities (numbers/m^3 water) for each age of coho salmon at stations on Three-Tenths Mile Creek in 1978.

Station	Age 0		Age 1+	
	July	September	July	September
1	24.6	16.3	3.6	5.9
2	21.6	14.5	1.9	0.6
3	39.1	30.0	2.9	0.7
4	13.4	7.6	4.6	2.6
5	10.7	9.8	4.8	6.4
6	16.7	12.1	0.8	0
7	8.4	4.1	4.1	4.4
8	8.6	4.8	4.8	6.7

Table 23. The densities (numbers/m^3 water) for each age group of Dolly Varden at stations on Tye-One-Ohn Creek in 1978.

Station	Age Group 0-1+		Age Group 2-3+	
	July	September	July	September
1	5.1	4.0	4.6	4.0
2	11.4	8.3	3.9	2.7
3	21.7	24.5	0	0
4	2.6	5.8	2.5	4.7
5	14.9	19.4	7.8	2.3
6	12.1	3.4	9.8	2.0
7	5.4	8.1	8.7	0.9
8	3.7	2.3	2.0	0.8
9	7.7	4.3	5.4	3.3
10	2.3	2.5	4.8	2.7
11	7.3	4.9	3.9	3.3

Table 24. The densities (numbers/m^3 water) for each age group of Dolly Varden at stations on Little Toad Creek in 1978.

Station	Age Group 0-1+		Age Group 2-3+	
	July	September	July	September
1	23.5	27.4	16.2	9.5
2	9.6	8.6	8.5	3.5
3	9.5	16.2	9.3	8.3
4	2.5	5.6	6.1	3.4
5	6.2	5.2	5.4	2.9
6	17.8	15.1	11.5	5.4
7	9.4	9.7	9.9	6.3
8	6.5	8.3	11.3	5.7
9	9.2	4.7	9.6	4.4
10	13.1	6.2	6.2	4.7
11	6.9	5.0	3.7	1.6

Table 25. The densities (numbers/m^3 water) for each age group of Dolly Varden at stations on Three-Tenths Mile Creek in 1978.

Station	Age Group 0-1+		Age Group 2-3+	
	July	September	July	September
1	4.4	11.9	0	4.2
2	4.8	11.9	5.2	4.9
3	7.9	7.9	0.7	0
4	10.3	10.2	6.5	3.5
5	3.6	14.2	5.8	3.6
6	1.9	3.9	1.6	0
7	7.1	8.5	4.1	6.0
8	7.3	10.2	8.9	2.2

Table 26. Length-weight relationships of coho salmon and Dolly Varden sampled from the study sections during population censuses in 1978.

Location	Sampling Date	Coho Salmon	Dolly Varden
Tye-One-Ohn Creek	July	LogW = -5.14 + 3.04 LogTL	LogW = -4.77 + 2.84 LogTL
	September	LogW = -5.03 + 2.99 LogTL	LogW = -4.77 + 2.83 LogTL
Little Toad Creek	July	LogW = -4.89 + 2.90 LogTL	LogW = -4.79 + 2.84 LogTL
	September	LogW = -4.95 + 2.94 LogTL	LogW = -4.68 + 2.78 LogTL
Three-Tenths Mile Creek	July	LogW = -4.76 + 2.84 LogTL	LogW = -4.72 + 2.81 LogTL
	September	LogW = -4.87 + 2.90 LogTL	LogW = -4.96 + 2.78 LogTL

Table 27. Estimates of biomass (g/m^3 water) for each age of coho salmon at stations on Tye-One-Ohn Creek in 1978.

Station	Age 0		Age 1+	
	July	September	July	September
1	7.8	11.4	10.5	12.2
2	14.7	23.9	11.5	33.0
3	10.6	20.1	8.3	7.9
4	7.4	12.3	9.8	18.1
5	14.9	17.2	36.1	21.8
6	3.3	8.9	30.9	9.8
7	0.9	5.6	9.0	13.1
8	31.3	17.8	9.7	11.1
9	11.7	8.5	21.8	26.2
10	5.4	9.3	4.1	4.1
11	10.1	6.8	13.3	13.4

Table 28. Estimates of biomass (g/m^3 water) for each age of coho salmon at stations on Little Toad Creek in 1978.

Station	Age 0		Age 1+	
	July	September	July	September
1	2.9	8.2	41.5	23.1
2	5.6	6.0	40.1	41.3
3	5.0	9.9	32.6	28.6
4	1.7	2.1	15.1	18.6
5	9.0	3.6	19.5	14.6
6	11.5	9.5	39.5	36.5
7	14.9	8.5	32.6	31.3
8	8.3	3.9	31.8	34.6
9	51.3	35.4	9.9	14.8
10	35.9	18.6	20.9	17.0
11	15.5	8.1	24.1	22.0

Table 29. Estimates of biomass (g/m^3 water) for each age of coho salmon at stations on Three-Tenths Mile Creek in 1978.

Station	Age 0		Age 1+	
	July	September	July	September
1	17.4	15.8	13.5	29.8
2	17.7	14.6	4.4	3.8
3	28.6	23.9	12.2	2.2
4	11.3	10.2	20.4	7.4
5	7.6	8.5	20.4	34.0
6	12.4	11.3	5.6	0
7	5.7	4.5	21.5	24.9
8	7.5	4.0	16.4	29.2

Table 30. Estimates of biomass (g/m^3 water) for each age group of Dolly Varden at stations on Tye-One-Ohn Creek in 1978.

Station	Age Group 0-1+		Age Group 2-3+	
	July	September	July	September
1	11.6	12.2	37.1	32.8
2	23.5	24.0	30.6	18.6
3	36.8	54.3	0	0
4	7.0	16.9	16.7	40.7
5	34.2	40.0	58.5	17.4
6	22.6	7.2	67.1	21.5
7	9.6	22.3	48.4	7.0
8	8.0	6.4	11.0	6.4
9	17.4	11.9	41.6	29.7
10	4.3	8.6	35.2	23.5
11	17.6	14.9	26.8	31.0

Table 31. Estimates of biomass (g/m^3 water) for each age group of Dolly Varden at stations on Little Toad Creek in 1978.

Station	Age Group 0-1+		Age Group 2-3+	
	July	September	July	September
1	67.7	79.6	102.6	80.7
2	30.4	27.0	53.3	27.3
3	29.8	46.5	71.7	63.1
4	7.8	18.6	47.5	29.4
5	19.1	18.0	37.5	23.0
6	51.7	45.0	76.9	46.2
7	30.8	31.9	86.8	46.1
8	21.1	24.1	73.6	49.4
9	23.4	13.4	75.9	36.2
10	28.2	17.7	47.5	42.2
11	17.9	13.3	25.0	11.8

Table 32. Estimates of biomass (g/m^3 water) for each age group of Dolly Varden at stations on Three-Tenths Mile Creek in 1978.

Station	Age Group 0-1+		Age Group 2-3+	
	July	September	July	September
1	10.7	27.8	0	29.2
2	10.9	34.0	40.8	48.7
3	12.8	11.8	7.2	0
4	21.8	22.5	42.2	28.7
5	6.3	27.7	34.2	30.6
6	3.3	4.8	9.9	0
7	15.0	25.8	30.4	49.3
8	13.1	31.2	57.9	15.0

Table 33. Number of fish per 5 mm size group captured in box traps on Tye-One-Ohn Creek during 1977.

Sampling Period / Species / Size (mm)	7-17 to 7-31		8-1 to 8-15		8-16 to 8-31		9-1 to 9-15		9-16 to 9-21	
	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden
31-35		2		1		2		2		
36-40	3		1			2		2		
41-45	19		36		27	1	15	1	1	
46-50	13	1	10		15		15	2	5	2
51-55	10	1	13		14		12	8	3	1
56-60	2	3	2	3		5	6	8	1	
61-65		2		1		5	3	19	2	9
66-70		2		3		3	1	16		6
71-75	5		12		3		5	9	1	4
76-80	1	3		1	3	2	3	[illegible]	1	3
81-85	3	1						8		4
86-90	2	2		1				20		9
91-95		1				6	1	11		10
96-100		2						2		10
101-105		4					2			2
106-110									1	
111-115							1			
116-120		1								
171-175								1		
326-330								1		

Table 34. Number of fish per 5 mm size group captured in box traps on Little Toad Creek during 1977.

Sampling Period	7-17 to 7-31		8-1 to 8-15		8-16 to 8-31		9-1 to 9-15		9-16 to 9-21	
Species / Size (mm)	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden
26-30		3		1				1		
31-35		13		6		13		25		9
36-40		11		10		5		23		14
41-45	37		43		58	6	32	7		5
46-50	77		62	1	123		36	2	13	1
51-55	27		7		14		12	4	4	1
56-60	3	1	2	5	5		6	7	9	
61-65	6	6					3	11	2	1
66-70		1					6	3	2	1
71-75	3	2					4	5	5	1
76-80								12		2
81-85		1						7		2
86-90	1	2		1		2	4	14		
91-95		2						11		2
96-100		2					1	6		2
101-105		3					2	10		2
106-110		2						11		
111-115								1		1
116-120										
121-125								4		1
126-130										
136-140								2		
141-145								1		
146-150								2		
151-155								2		
166-170								2		
181-185								2		
186-190								2		1
191-195								7		
196-200								4		
201-205								2		
206-210										
216-220								2		
221-225								2		
226-230										
246-250								2		
286-290								2		

Table 35. Number of fish per 5 mm size group captured in box traps on Tye-One-Ohn Creek during 1978.

Sampling Period	5-12 to 5-15		5-16 to 5-31		6-1 to 6-15		6-16 to 6-30		7-1 to 7-15		7-16 to 7-31		8-1 to 8-16	
Species Size (mm)	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden
26-30	1													
31-35												1		
36-40			1437		3771		45	1	14		3			
41-45									1		9			
46-50									1		6	1		
51-55			2	1							1			
56-60	2		5	2	5				1					
61-65			5	3	2							1		
66-70			3	2	3	2			1					
71-75		1	3	2		3					1			
76-80			3	2					2			2		
81-85	1		2	2	1	1	1		1		1			
86-90			2	3	1				1	1		3		
91-95			2	1					1					
96-100	1			1						1	1			
101-105		1	1	1										
106-110											1	2		
111-115						1								
116-120				1								1		
121-125						1								
126-130				1								1		
145-150										1		1		
161-165										1		1		

Table 36. Number of fish per 5mm size group captured in box traps on Little Toad Creek During 1978.

Sampling Period	5-12 to 5-15		5-16 to 5-31		6-1 to 6-15		6-16 to 6-30		7-1 to 7-15		7-16 to 7-31		8-1 to 8-16	
Species / Size (mm)	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden	Coho Salmon	Dolly Varden
21-25			4	8		3		9		1				
26-30			1	3		14				4		3		
31-35			8		1					4		6		
36-40					28		12		3	1		1		
41-45									1					
46-50						1	1							
51-55	3		1		1	2						1		
56-60			3	1	4							4		
61-65	2		4		1		1				2	2	2	
66-70	1		9	1	6	1		1	2	1	7	2		
71-75	3		11	3	3	1		2		3	9	3		
76-80	3	2	6	4	3				2	2	10	5	2	1
81-85	3	1	6	1	2	1	3	1	1	3	2	5		2
86-90	3		6	2		1	1	2	5		3	3		1
91-95	1	1	1	1		3						6	3	
96-100					1					1	2	7		
101-105				1		1				1				
106-110		1	1	1								4		
111-115		2		1										
116-120		2		1		1				2				
121-125		1		4		1								
126-130				4						1				
131-135				2										
136-140		1		2										
141-145				2										
146-150		1		1										
151-155				1						2				1
171-175				1										

Table 37. The percent of the recaptured fish of age groups of the major species that had moved among stations during population censuses in 1978.

Location	Sampling Date	Coho Salmon Age 0	Coho Salmon Age 1+	Dolly Varden Age 0-1+	Dolly Varden Age 2-3+
Tye-One-Ohn Creek	July	1.1	38.3	34.0	49.0
	September	6.5	22.2	32.6	44.7
Little Toad Creek	July	4.9	5.2	3.2	7.4
	September	0	7.7	7.1	16.9
Three-Tenths Mile Creek	July	2.9	10.0	6.3	21.7
	September	10.9	24.1	21.4	22.2

Table 38. Movements of coho salmon and Dolly Varden among stations during population censuses on Tye-One-Ohn Creek in 1978.

	Coho Salmon					Dolly Varden				
Month	Age Group	Length (mm)	Average Distance Moved (m)[1]	Numbers of Movements[2] U	D	Age Group	Length (mm)	Average Distance Moved (m)[1]	Numbers of Movements[2] U	D
July	0	47	10	1		0-1+	50	10	1	
							53	20		1
	1+	54	10	1			54	10		1
		55	20	2			55	10		1
		56	10		1		56	10		1
		57	10	2			58	20		1
		58	20	2			60	10	1	3
		60	10	1	2		61	10	1	1
		62	15	3	1		64	10	2	1
		63	21.7	4	2		65	20	1	
		64	20	1	1		66	10	1	1
		65	10	1			67	10	1	
		66	15.7	5	2		68	10	4	
		67	12.5	2	2		69	40	2	
		68	10	1			70	21	5	5
		69	33.3	2	1		71	15		4
		70	21.7	4	2		72	12.5	3	1
		71	42.5	4			73	12.5	3	1
		72	26.7	3			74	10	1	
		73	12.5	6	2		75	15	3	1
		74	13.3	1	2		76	10	3	
		75	20	2						
		76	30	1	1	2-3+	77	17.1	7	
		77	20	1			78	12	3	2
		80	20	1			79	13.3	2	1
		81	20	1			80	10	4	
		82	10	1			81	12.5	2	2
		83	40	1			82	10	1	
		86	90	1			83	23.3	3	
							84	18	2	3
							85	10	2	
							86	34	3	2
							87	40		1
							88	15	2	
							89	16.7	4	2

Table 38. (Continued)

Month	Coho Salmon: Age Group	Coho Salmon: Length (mm)	Coho Salmon: Average Distance Moved (m)[1]	Coho Salmon: Numbers of Movements[2] U	Coho Salmon: Numbers of Movements[2] D	Dolly Varden: Age Group	Dolly Varden: Length (mm)	Dolly Varden: Average Distance Moved (m)[1]	Dolly Varden: Numbers of Movements[2] U	Dolly Varden: Numbers of Movements[2] D
July						2-3+	90	22	5	
							91	12.8	5	2
							92	10	2	
							93	10	2	
							94	10	3	
							95	10	4	
							96	10	1	
							98	10		1
							99	13.3	2	1
							100	20		3
							101	10	2	
							102	10	2	
							106	10	1	
							107	15.7	5	2
							108	10	1	
							109	10		1
							110	23.3	2	1
							111	16.7	6	
							118	20	1	
							133	60	1	
September	0	43	10		1	0-1+	59	10	1	
		44	10		1		63	10	1	
		45	10	1			72	10		1
		52	10		1		73	10		1
							74	10	1	1
	1+	60	30	1			75	20	1	
		63	10		1		76	10		1
		55	10		1		77	10	1	1
		66	10		1		81	10		1
		68	20	1			82	20		1
		73	10		1		85	13.3	2	1

Table 38. (Continued)

	Coho Salmon					Dolly Varden				
Month	Age Group	Length (mm)	Average Distance Moved (m)[1]	Numbers of Movements[2] U	D	Age Group	Length (mm)	Average Distance Moved (m)[1]	Numbers of Movements[2] U	D
September	1+	77	45	2		2-3+	88	10		1
		78	20	1			90	45	2	
		84	10		1		93	80	1	
							95	60	1	
							97	10		1
							100	30		1
							103	10	1	
							105	50	1	
							108	30	1	
							109	10	1	
							113	10		1
							117	25	2	
							120	60	1	
							125	10	1	
							126	10		1

1 Distance moved is measured between the midpoints of the stations where the fish was marked and subsequently recaptured.

2 U = upstream, D = downstream.

Table 39. Movements of coho salmon and Dolly Varden among stations during poulation censuses on Little Toad Creek in 1978.

	Coho Salmon					Dolly Varden				
Month	Age Group	Length (mm)	Average Distance Moved (m)[1]	Numbers of Movements[2] U	D	Age Group	Length (mm)	Average Distance Moved (m)[1]	Numbers of Movements[2] U	D
July	0	40	20		1	0-1+	69	20	1	
		43	22.5		1					
		44	20		1	2-3+	84	20	1	
							95	20	1	
	1+	70	20	1			97	57.5		1
		78	20	1			98	22.5		1
		86	40	1			99	15	1	
		88	31.3	1	1		101	22.5		1
		89	22.5		1		102	22.5		1
							103	22.5		1
September	1+	72	22.5	1		0-1+	69	15		1
		80	20	1	2		84	15		1
							86	20		1
							87	20	1	
						2-3+	91	42.5	1	
							95	22.5		1
							97	17.5		2
							99	15		1
							100	17.5	2	
							103	42.5	1	
							105	20	1	
							106	20		1
							144	57.5	1	

1 Distance moved is measured between the midpoints of the stations where the fish was marked and subsequently recaptured.

2 U = upstream, D = downstream.

Table 40. Movements of coho salmon and Dolly Varden among stations during population censuses on Three-Tenths Mile Creek in 1978.

	Coho Salmon					Dolly Varden				
Month	Age Group	Length (mm)	Average Distance Moved (m)[1]	Numbers of Movements[2] U	D	Age Group	Length (mm)	Average Distance Moved (m)[1]	Numbers of Movements[2] U	D
July	0	43	10		1	0-1+	59	10		1
		45	20		1		60	10		1
		46	10	1	1		70	35	1	
		52	20		1	2-3+	76	10		1
	1+	57	15		1		77	10	1	
		65	45	1			78	10		1
		73	20	1			87	10		1
		80	10		1		92	10		1
		84	10		1		102	15		1
		90	10	1			103	30		1
		96	10		1		108	20		1
		117	10		1		111	60		1
September	0	41	10	1		0-1+	48	35	1	
		45	10	1		2-3+	76	60		1
		55	20		1		86	35		1
	1+	96	60		1		95	25		1
							100	35		1
							105	35		1

1 Distance moved is measured between the midpoints of the stations where the fish was marked and subsequently recaptured.

2 U = upstream, D = downstream.

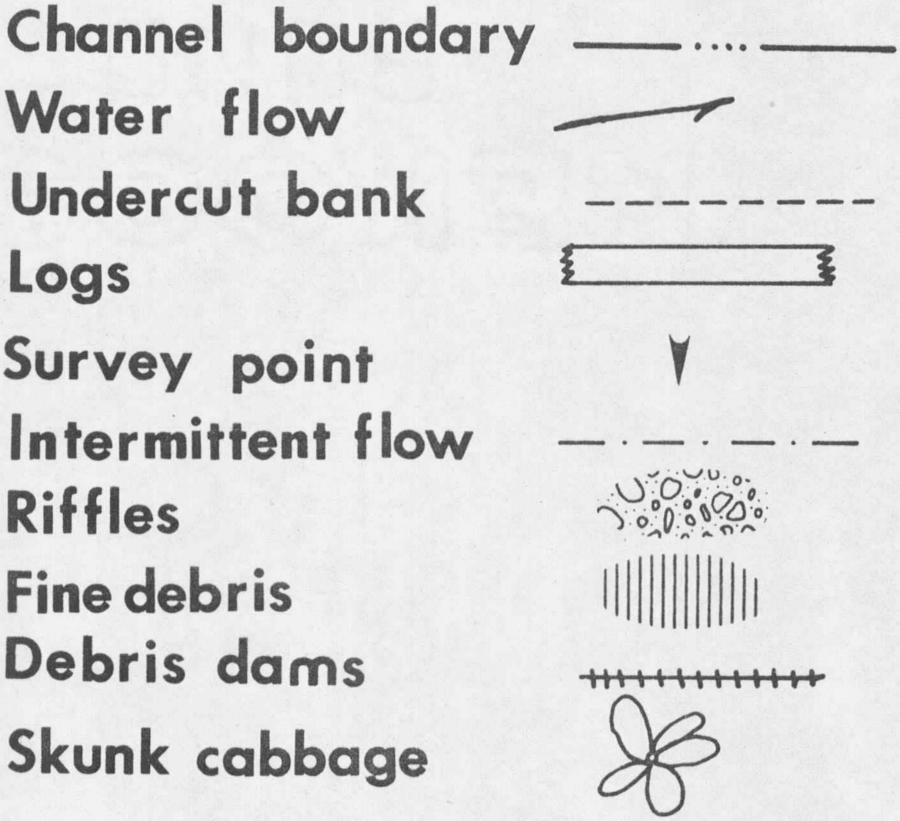

Figure 3. Key to the features on the maps of the study stations on Three-Tenths Mile, Tye-One-Ohn and Little Toad Creeks.

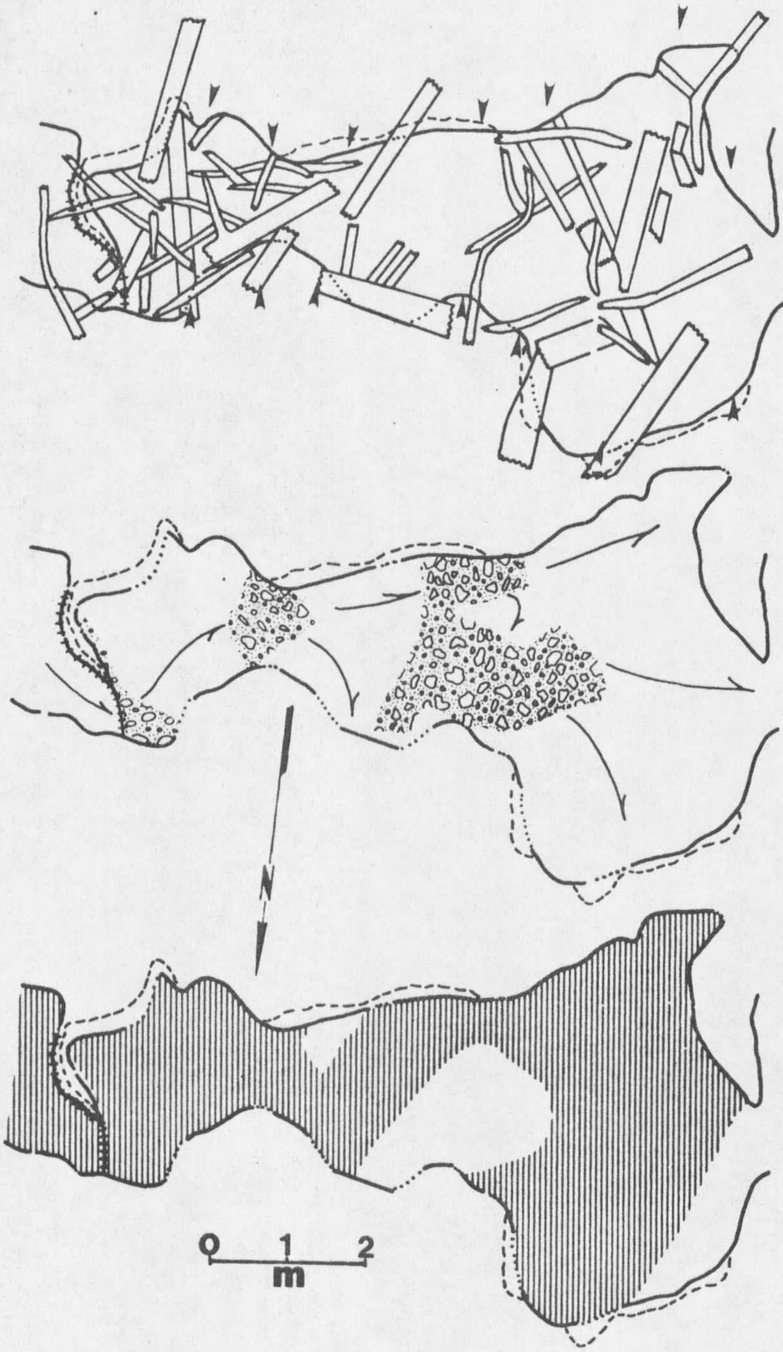

Figure 4. Map of station 1 on Tye-One-Ohn Creek in 1978.

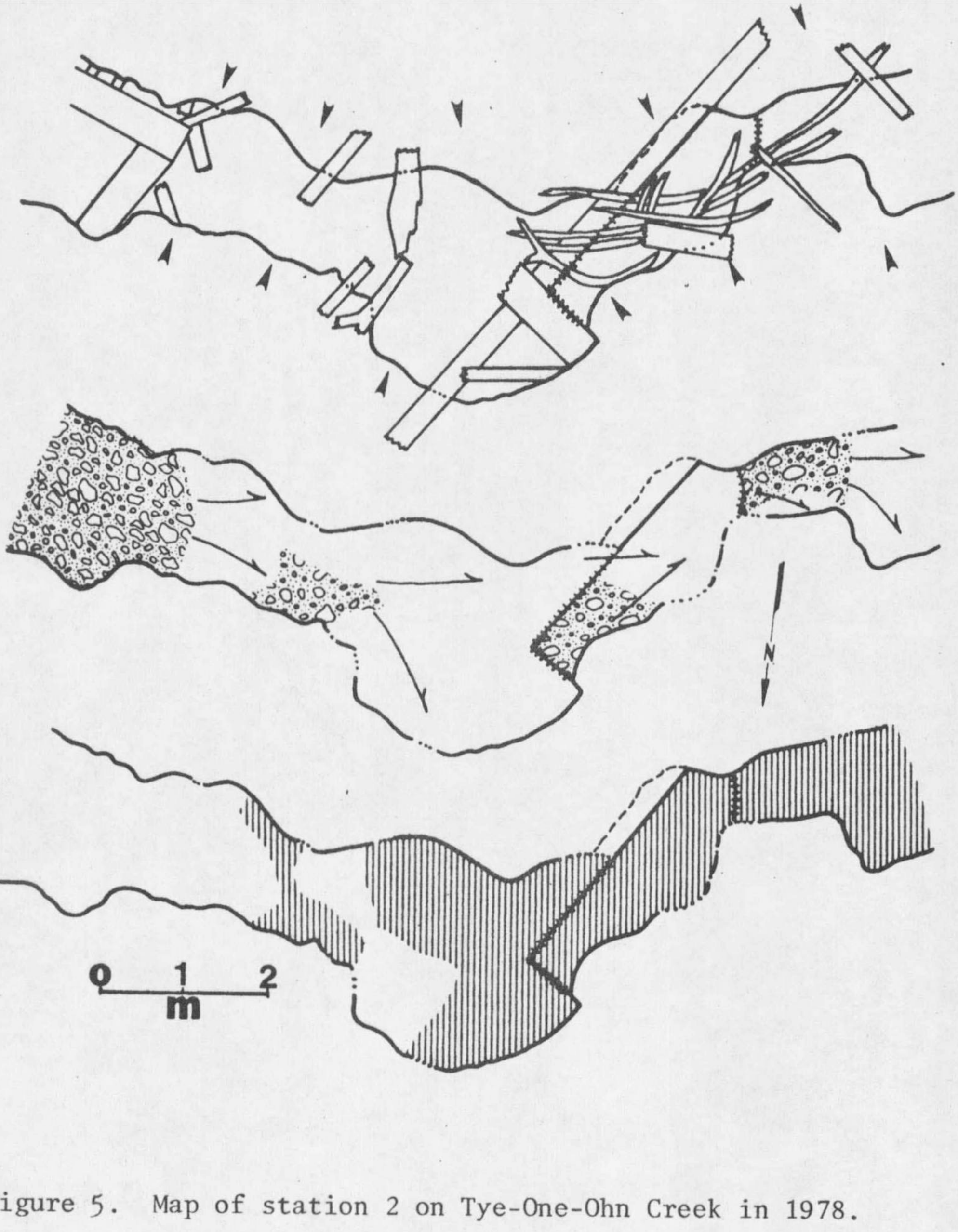

Figure 5. Map of station 2 on Tye-One-Ohn Creek in 1978.

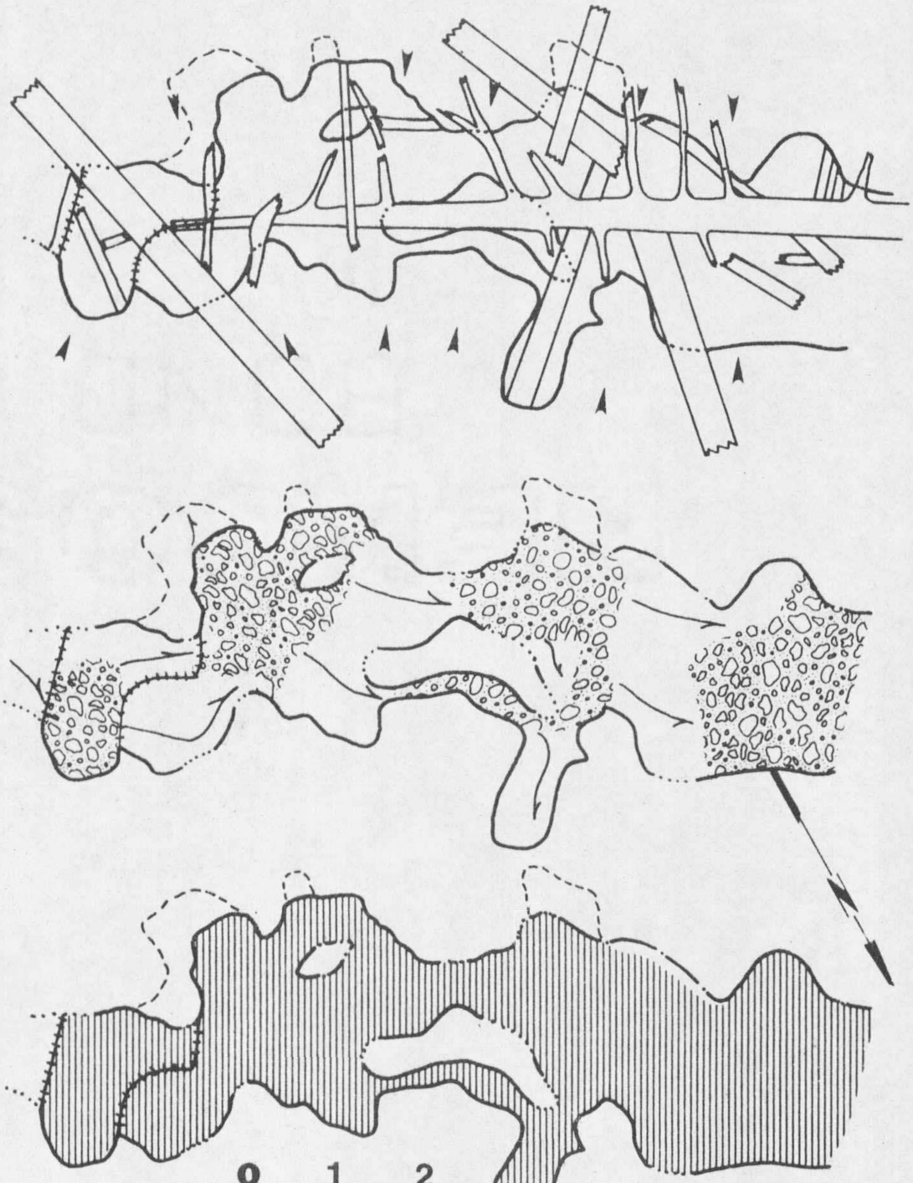

Figure 6. Map of station 3 on Tye-One-Ohn Creek in 1978.

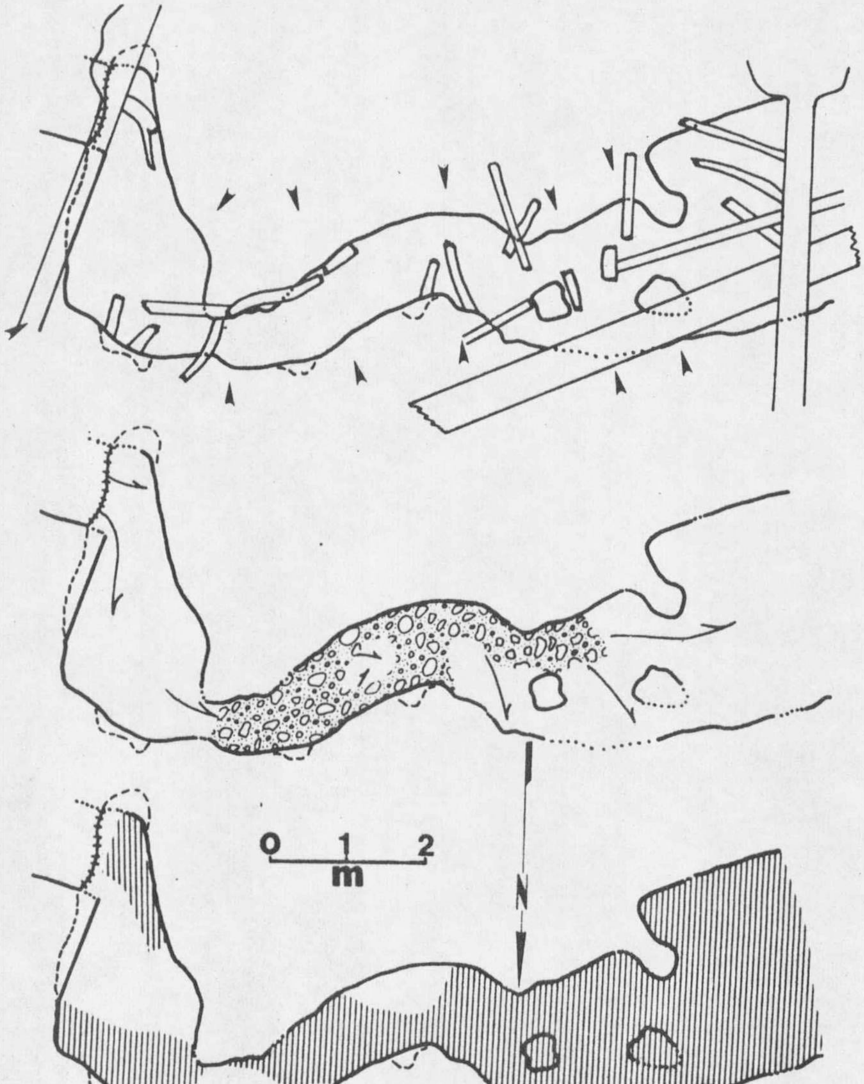

Figure 7. Map of station 4 on Tye-One-Ohn Creek in 1978.

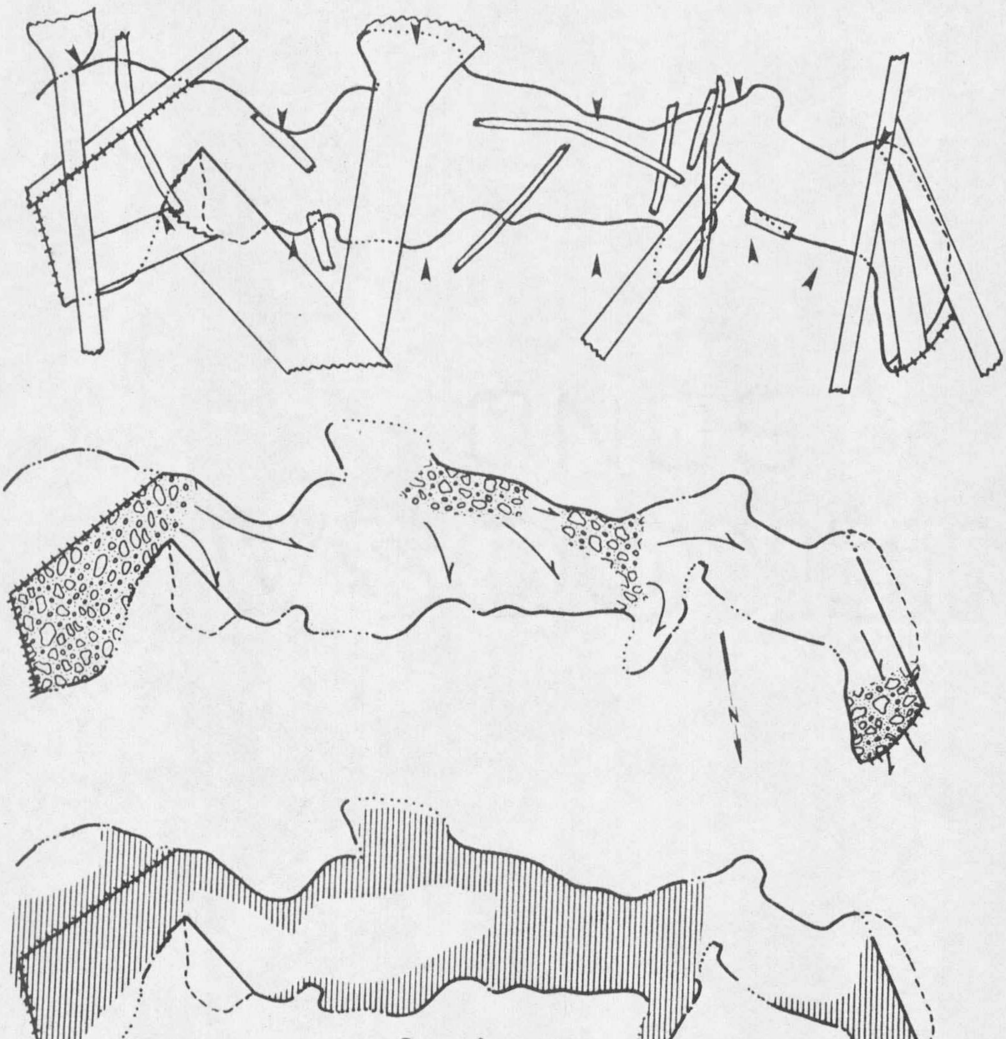

Figure 8. Map of station 5 on Tye-One-Ohn Creek in 1978.

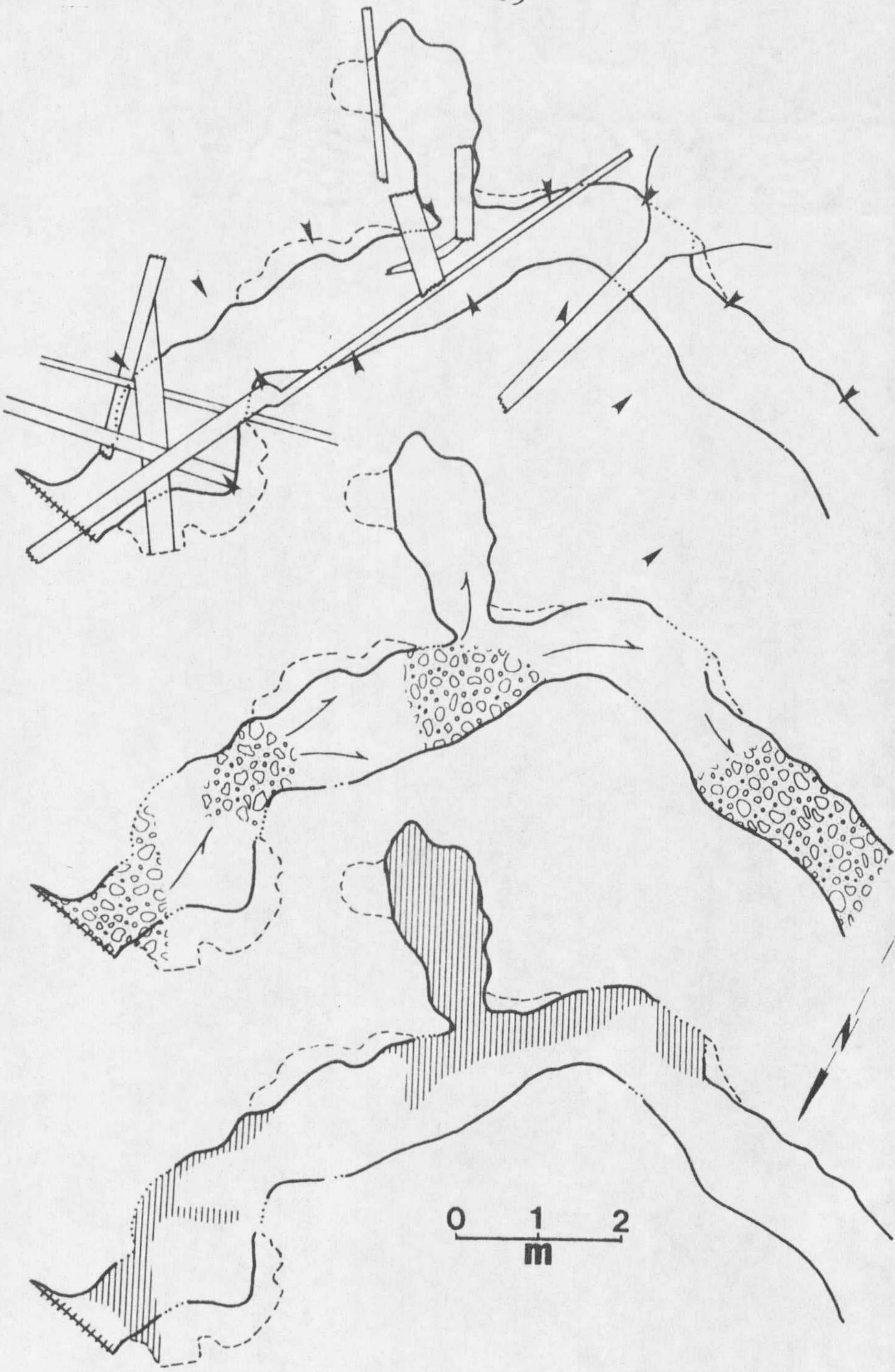

Figure 9. Map of station 6 on Tye-One-Ohn Creek in 1978.

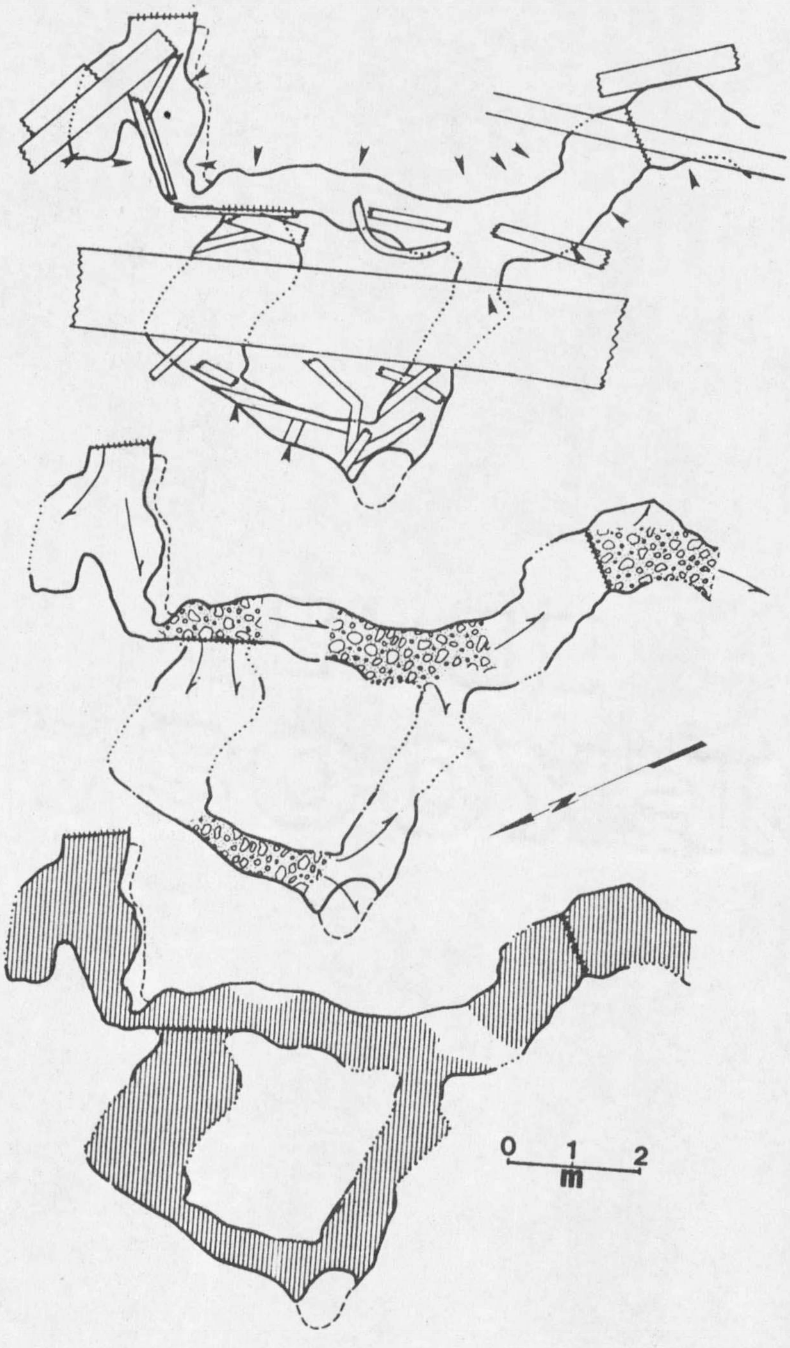

Figure 10. Map of station 7 on Tye-One-Ohn Creek in 1978.

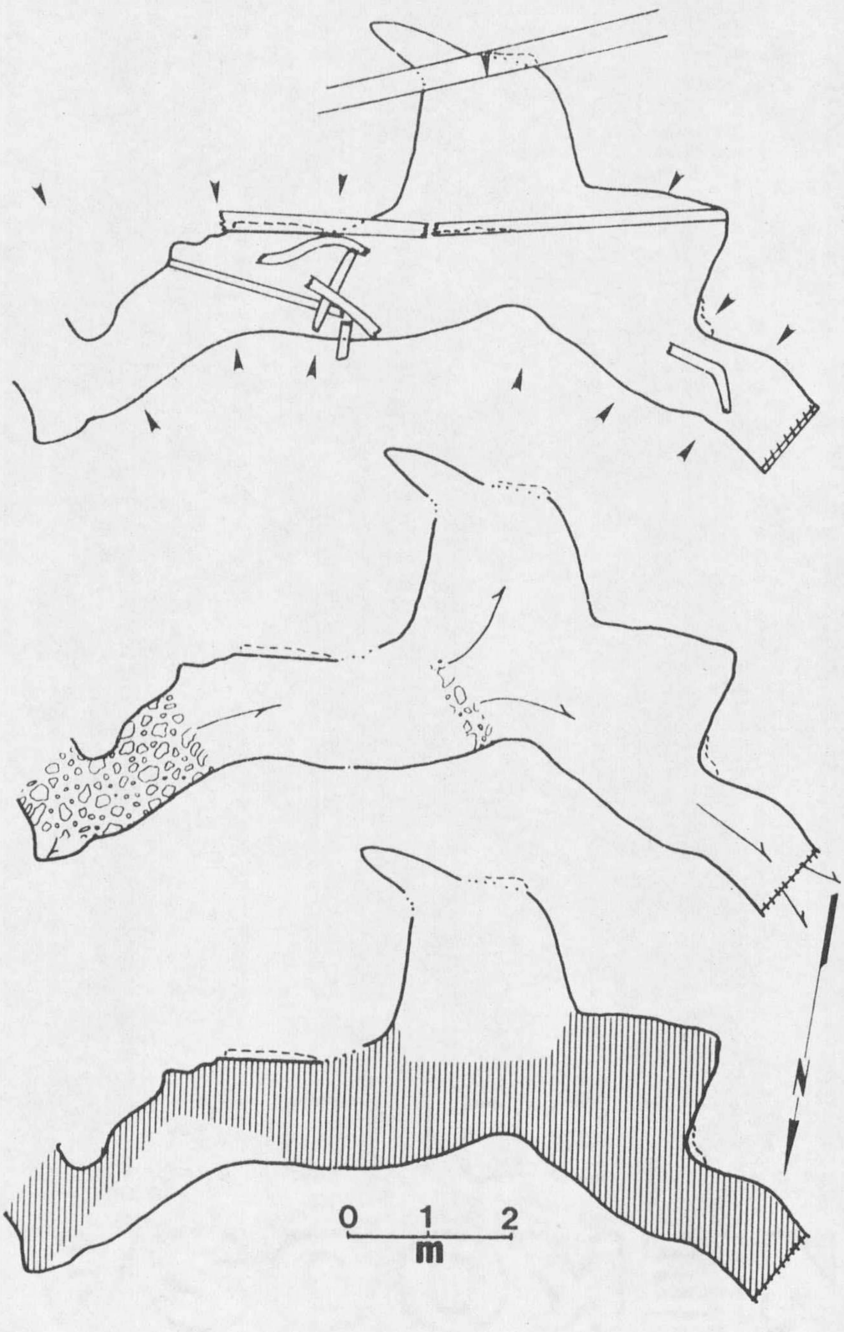

Figure 11. Map of station 8 on Tye-One-Ohn Creek in 1978.

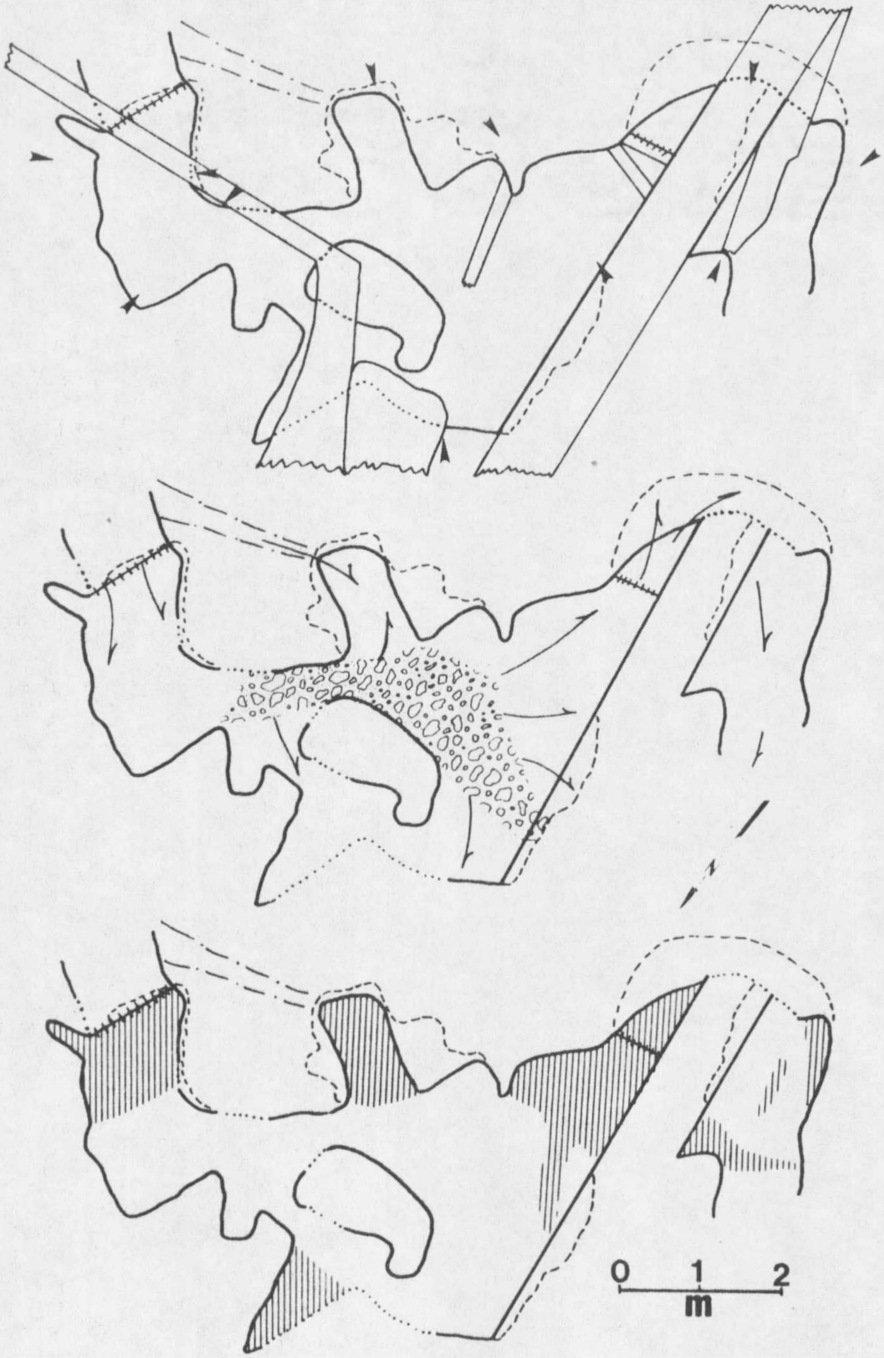

Figure 12. Map of station 9 on Tye-One-Ohn Creek in 1978.

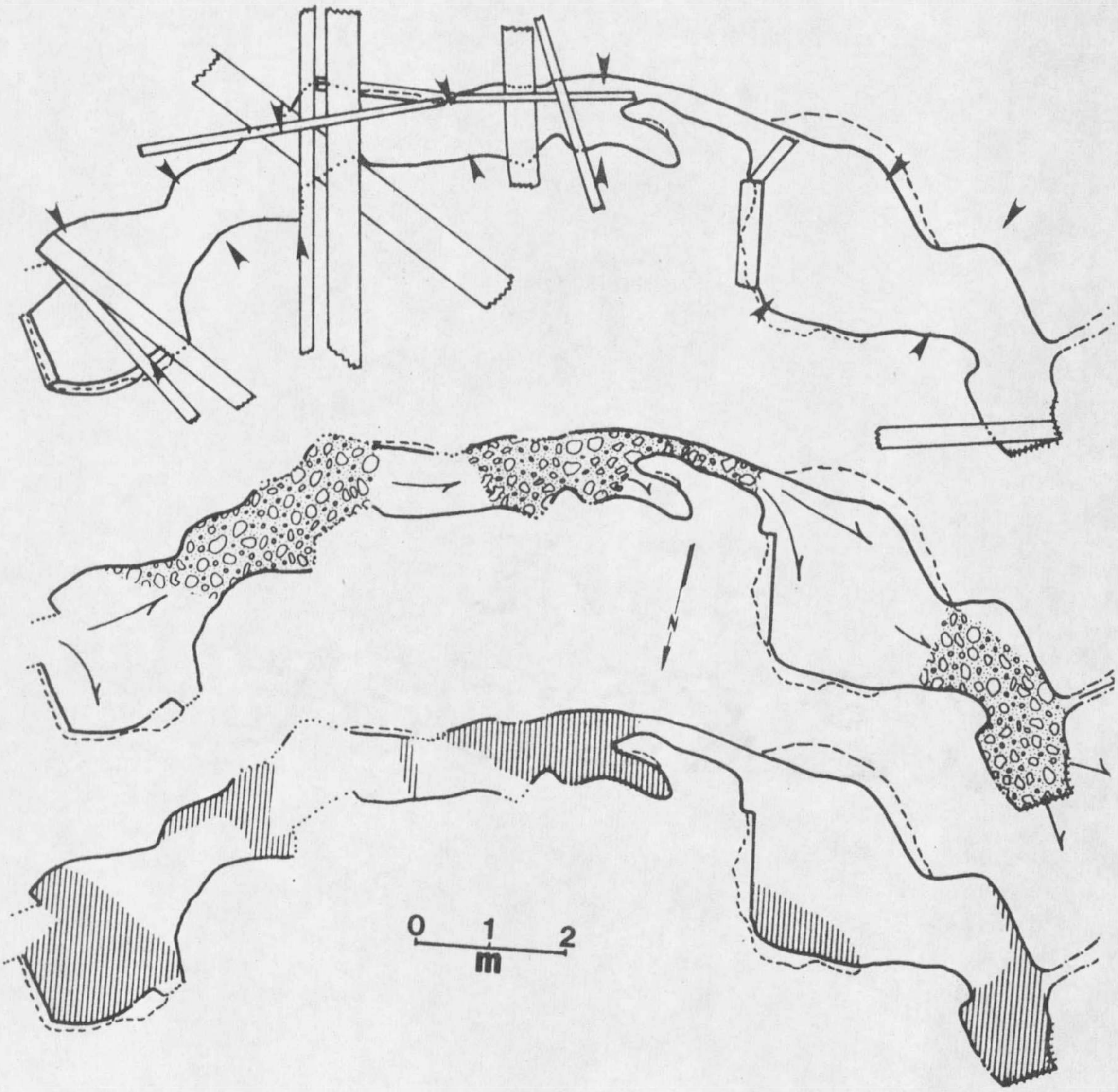

Figure 13. Map of station 10 on Tye-One-Ohn Creek in 1978.

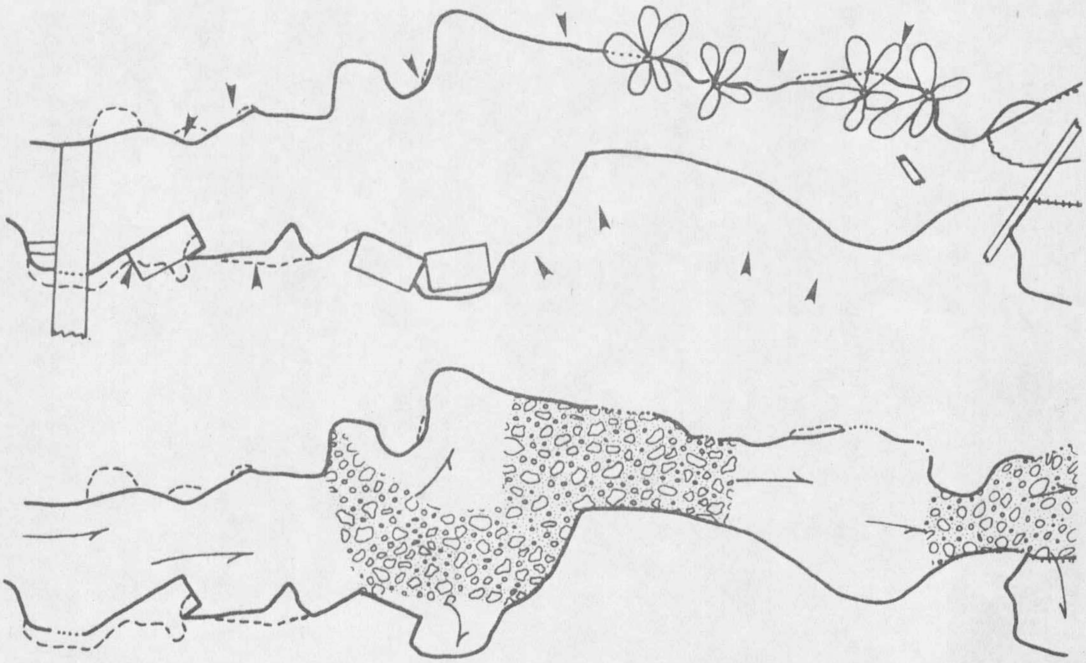

Figure 14. Map of station 11 on Tye-One-Ohn Creek in 1978.

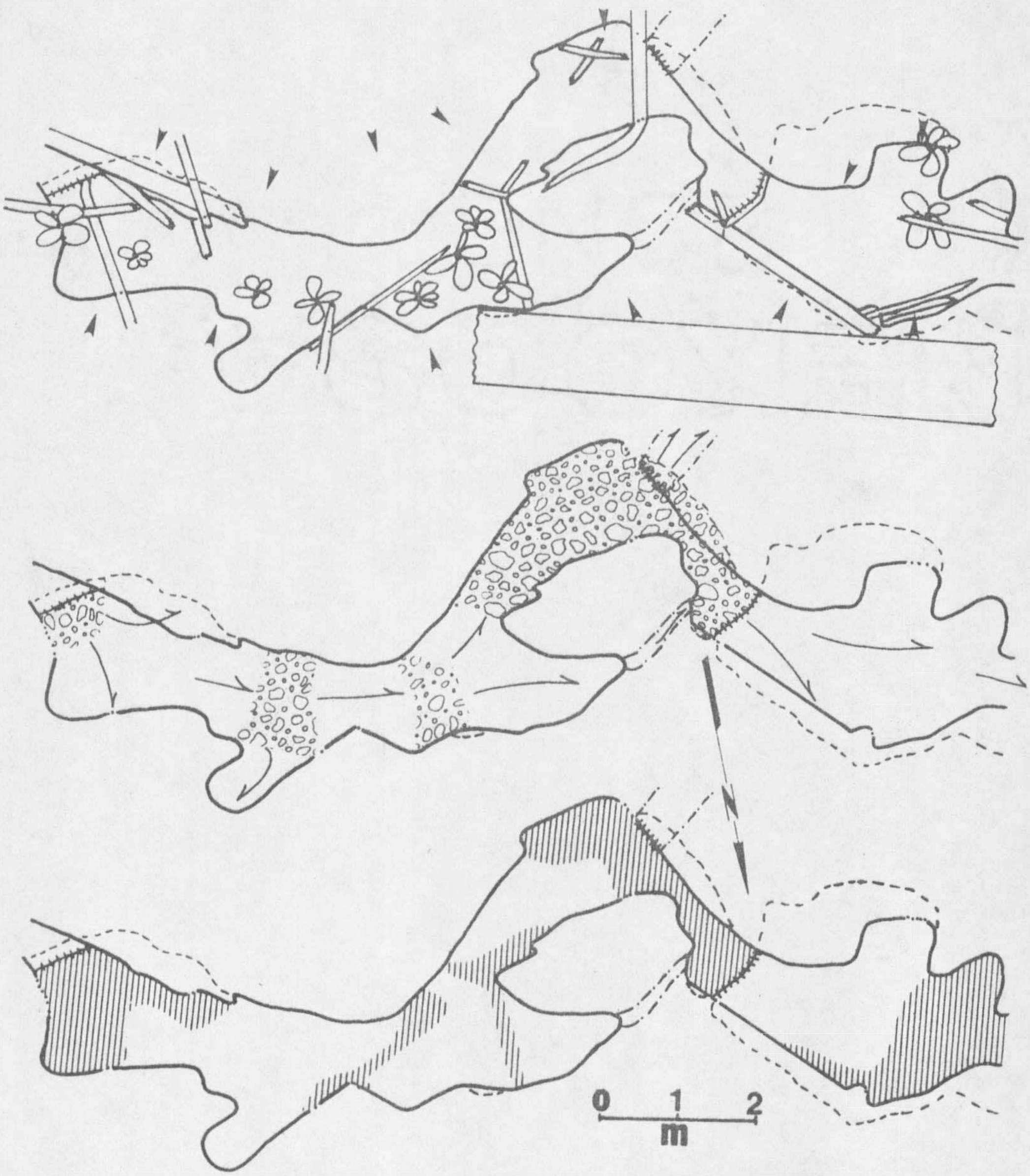

Figure 15. Map of station 1 on Little Toad Creek in 1978.

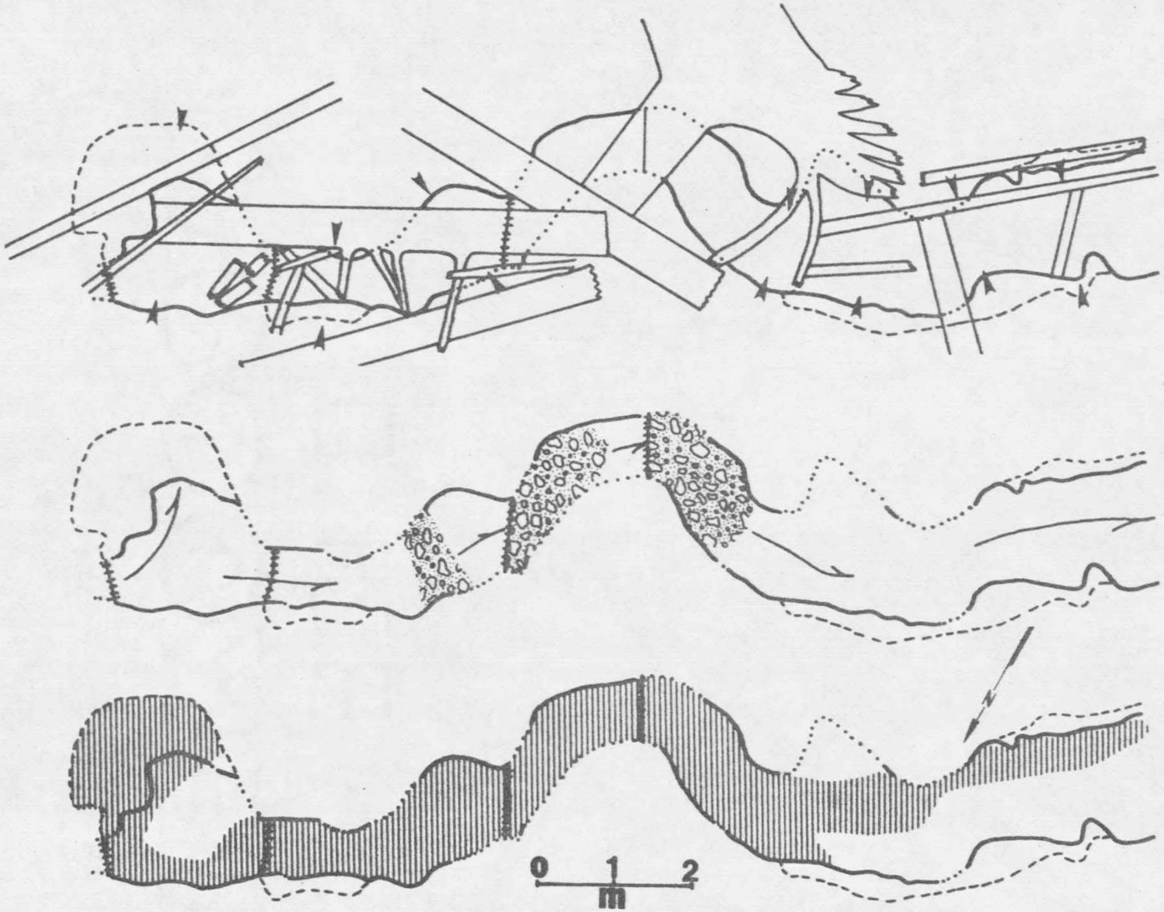

Figure 16. Map of station 2 on Little Toad Creek in 1978.

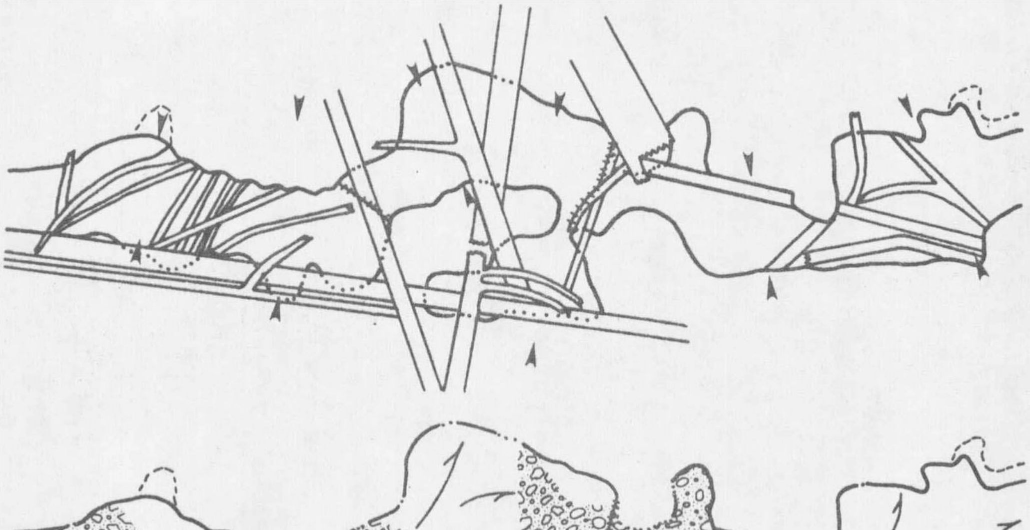

Figure 17. Map of station 3 on Little Toad Creek in 1978.

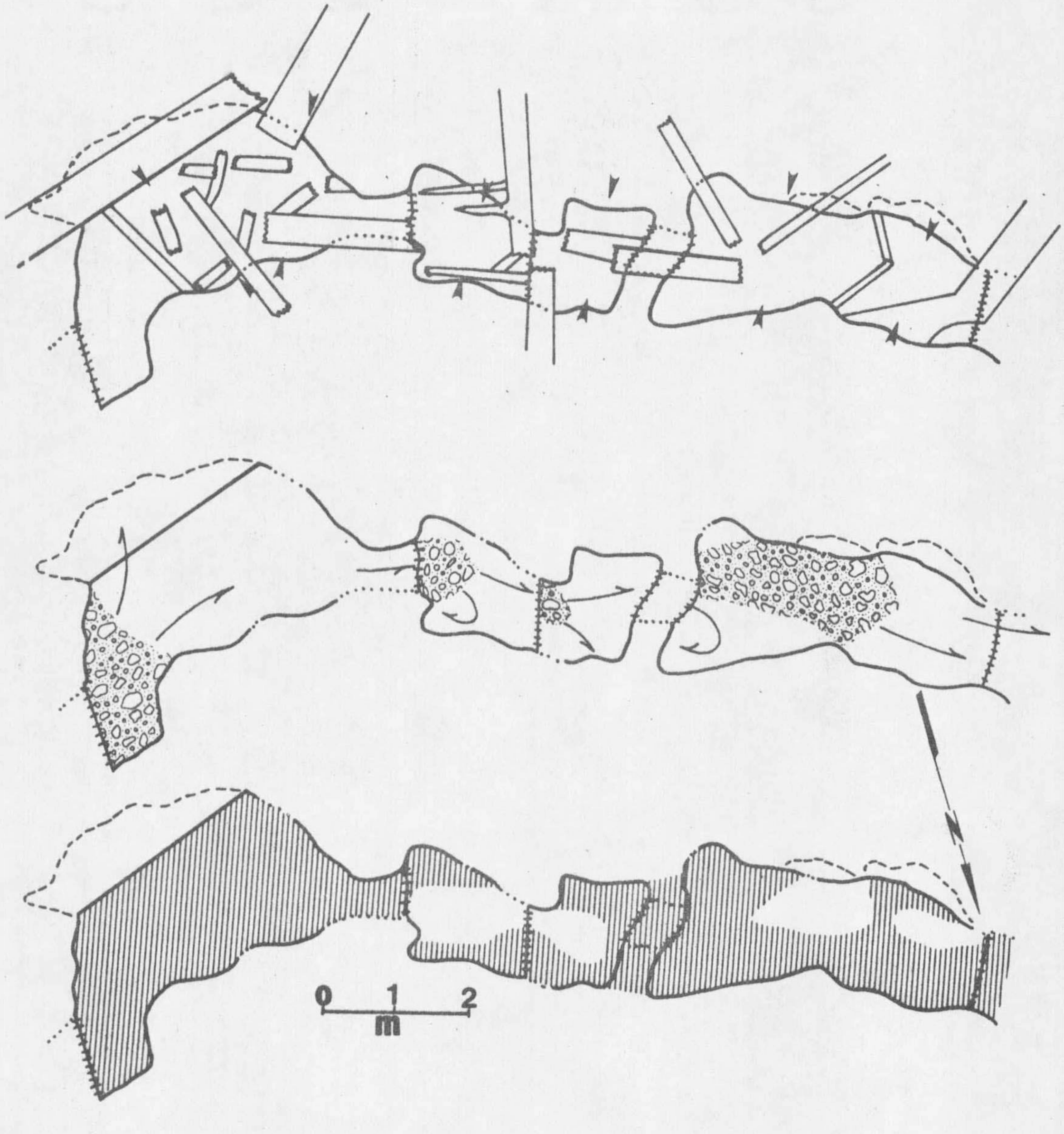

Figure 18. Map of station 4 on Little Toad Creek in 1978.

Figure 19. Map of station 5 on Little Toad Creek in 1978.

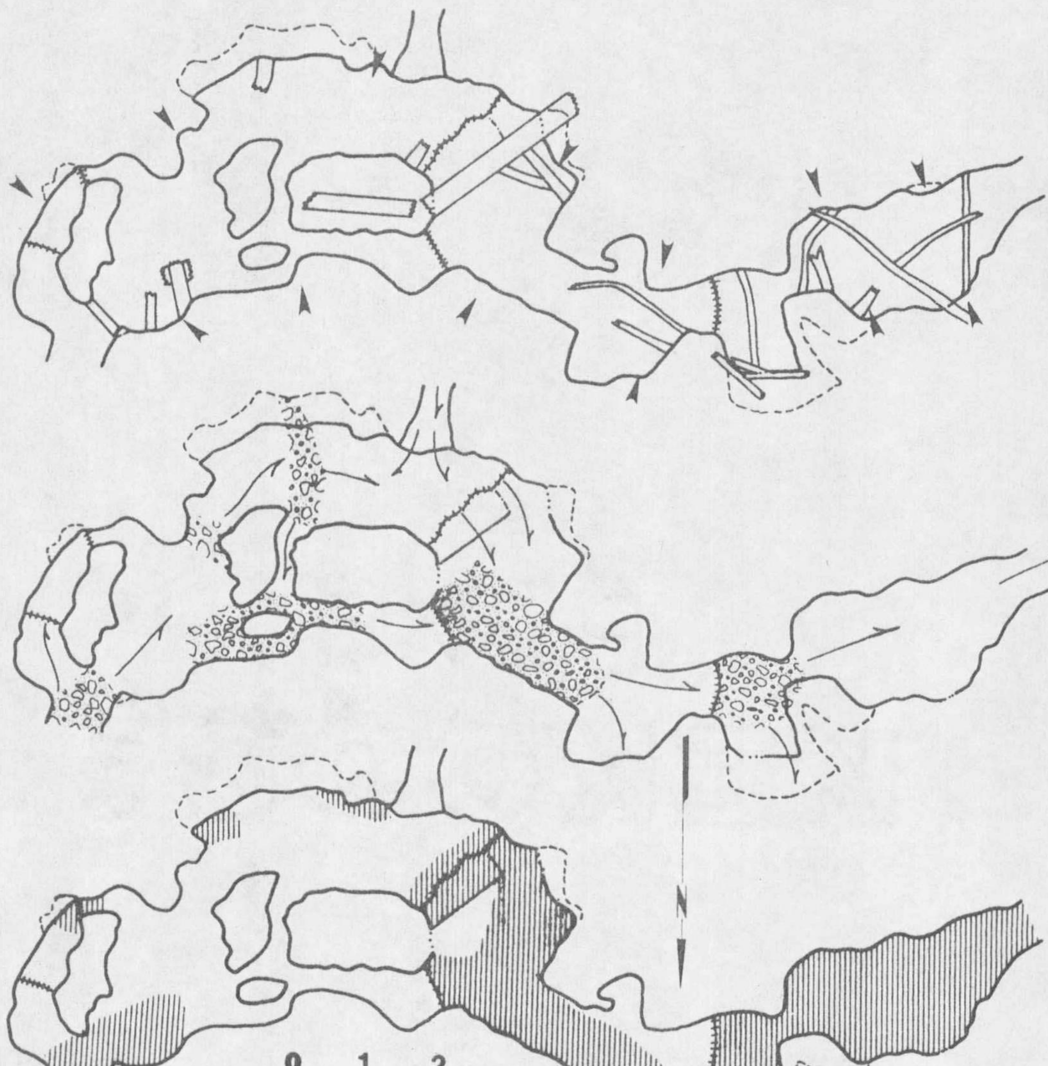

Figure 20. Map of station 6 on Little Toad Creek in 1978.

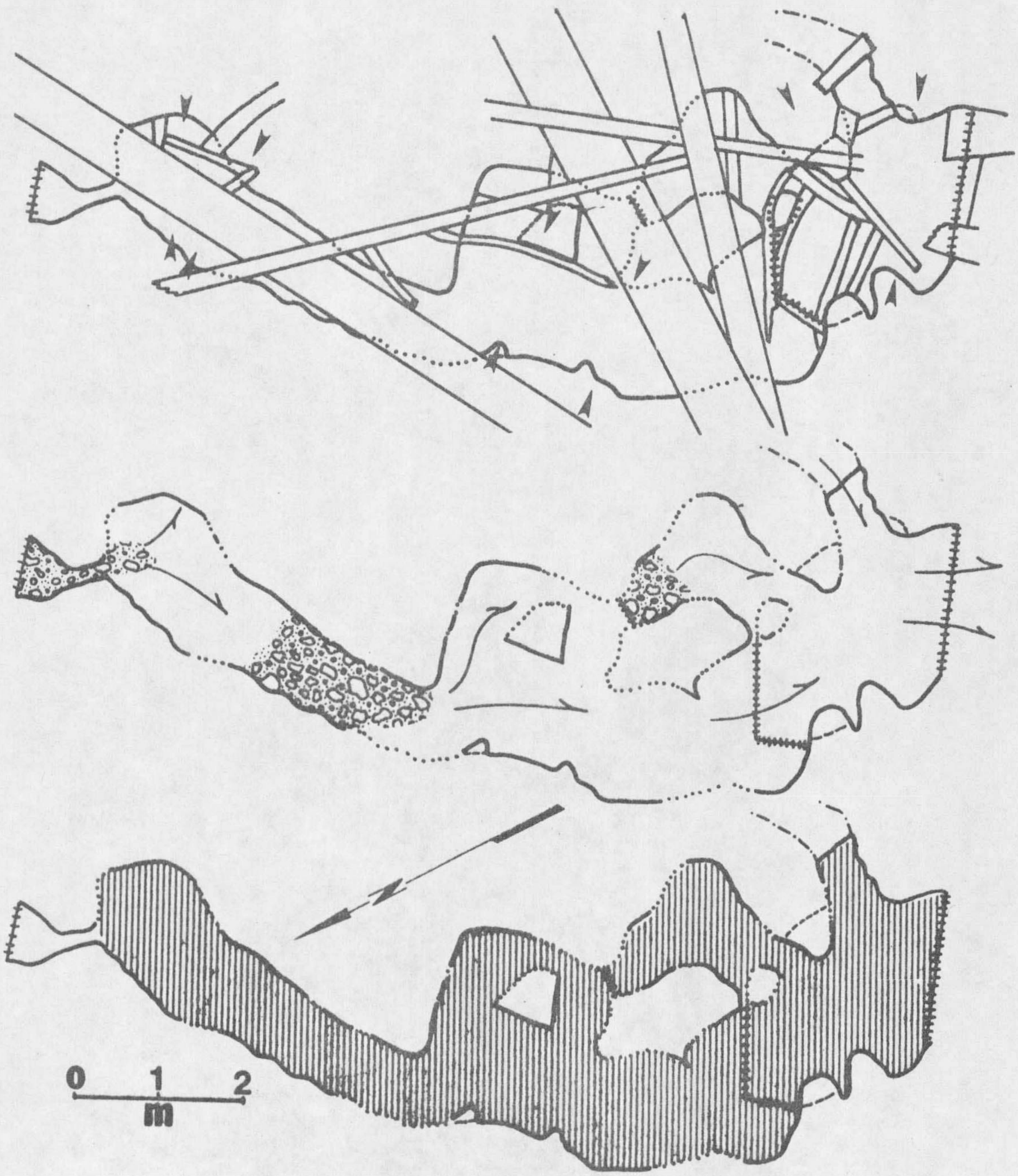

Figure 21. Map of station 7 on Little Toad Creek in 1978.

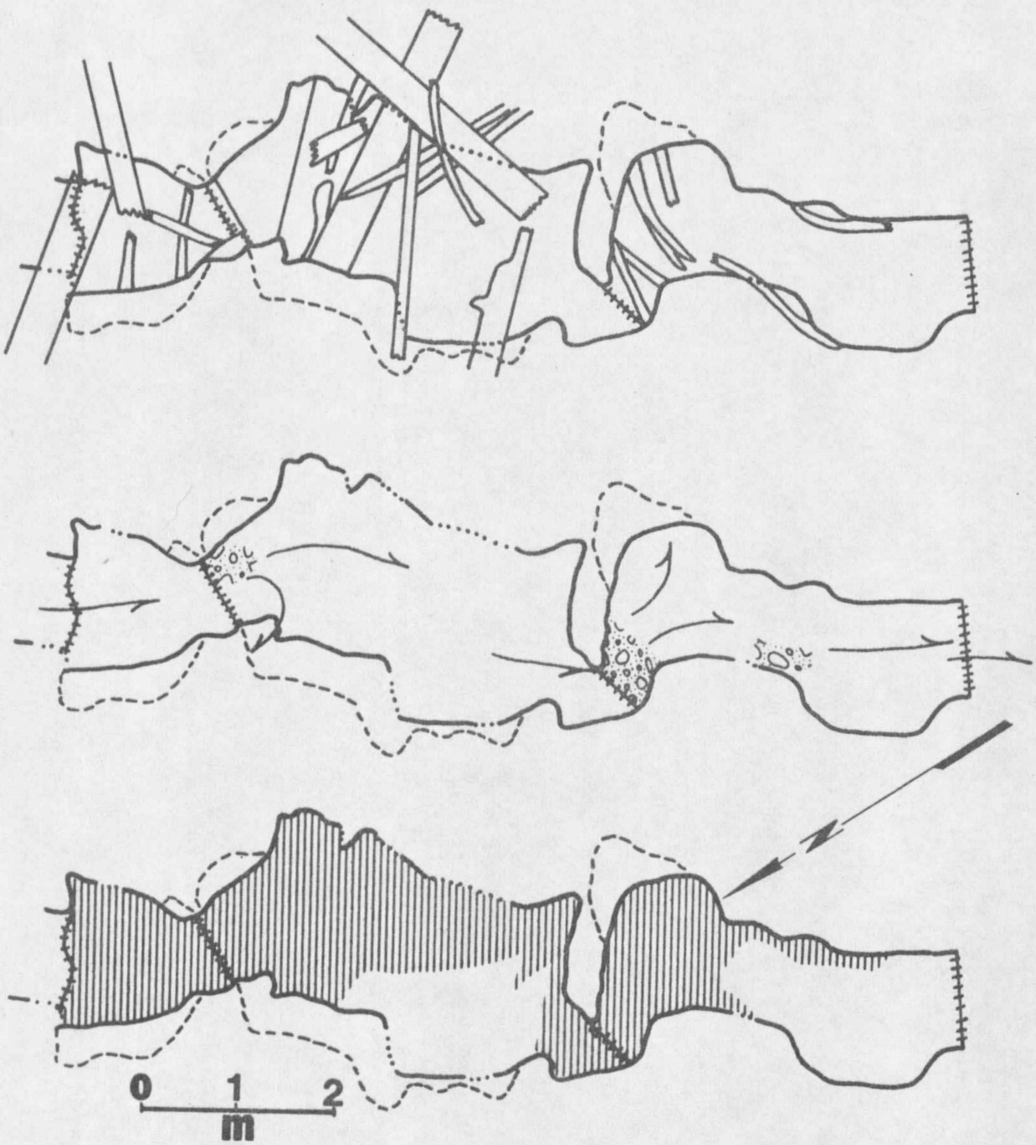

Figure 22. Map of station 8 on Little Toad Creek in 1978.

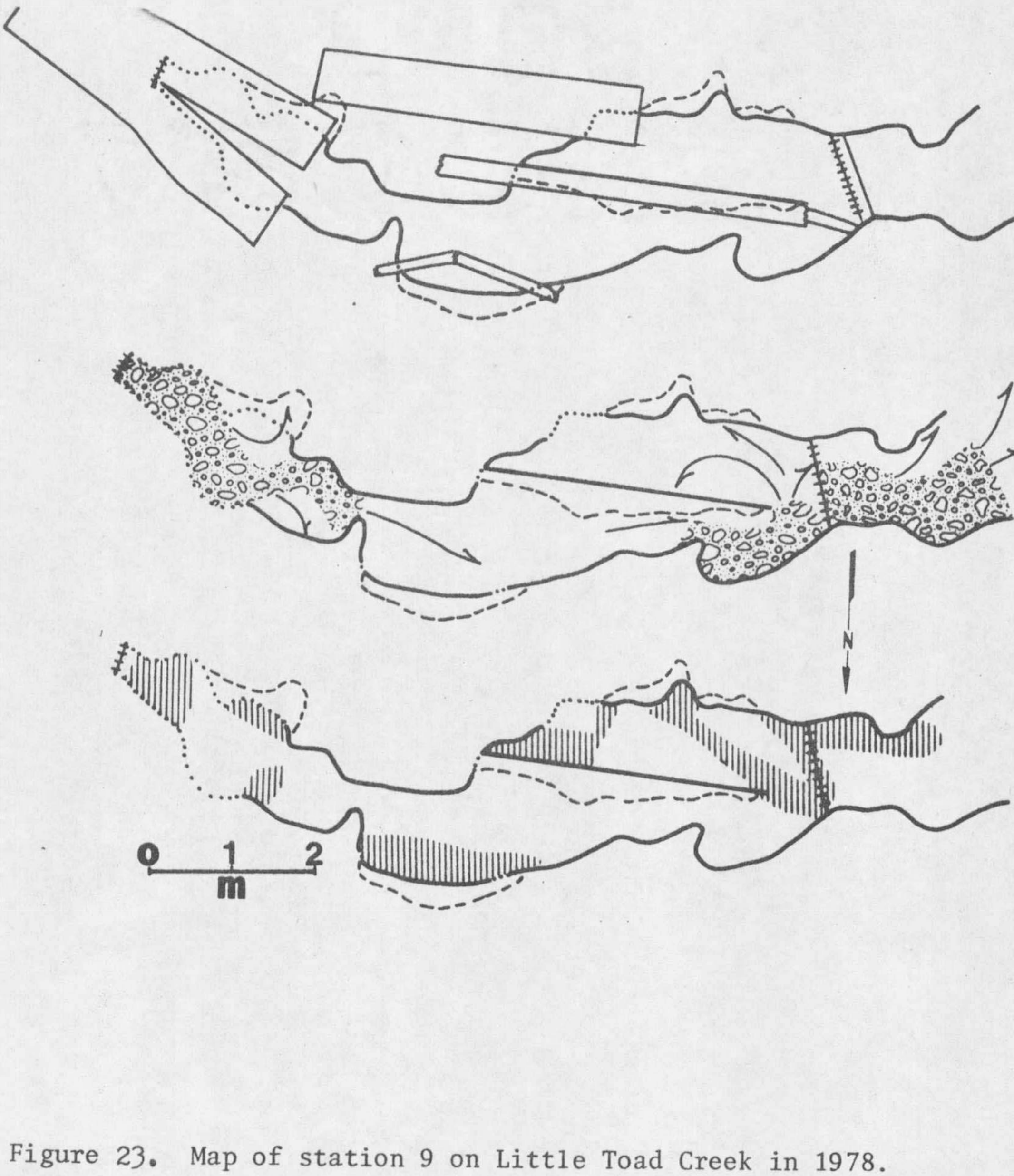

Figure 23. Map of station 9 on Little Toad Creek in 1978.

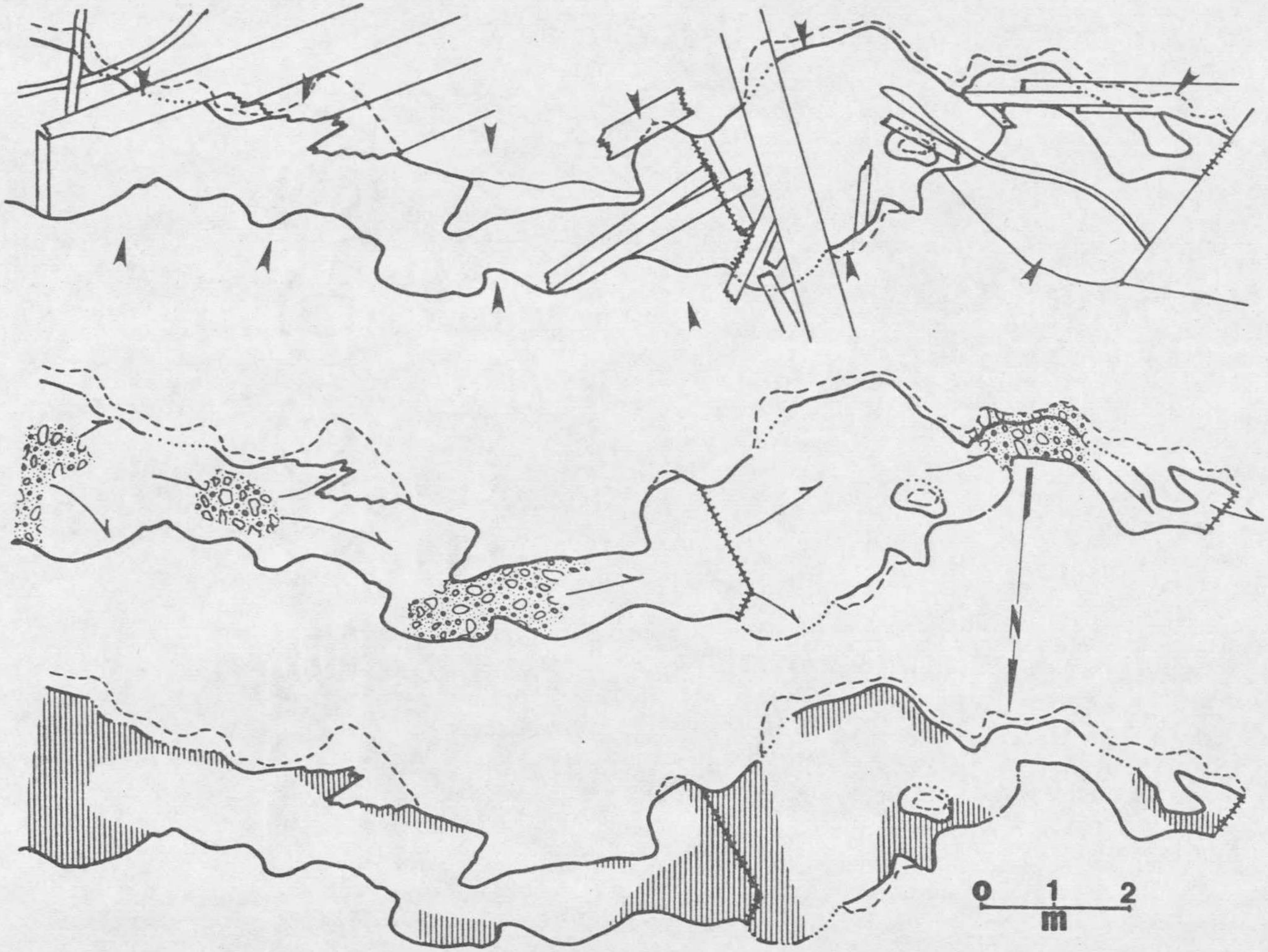

Figure 24. Map of station 10 on Little Toad Creek in 1978.

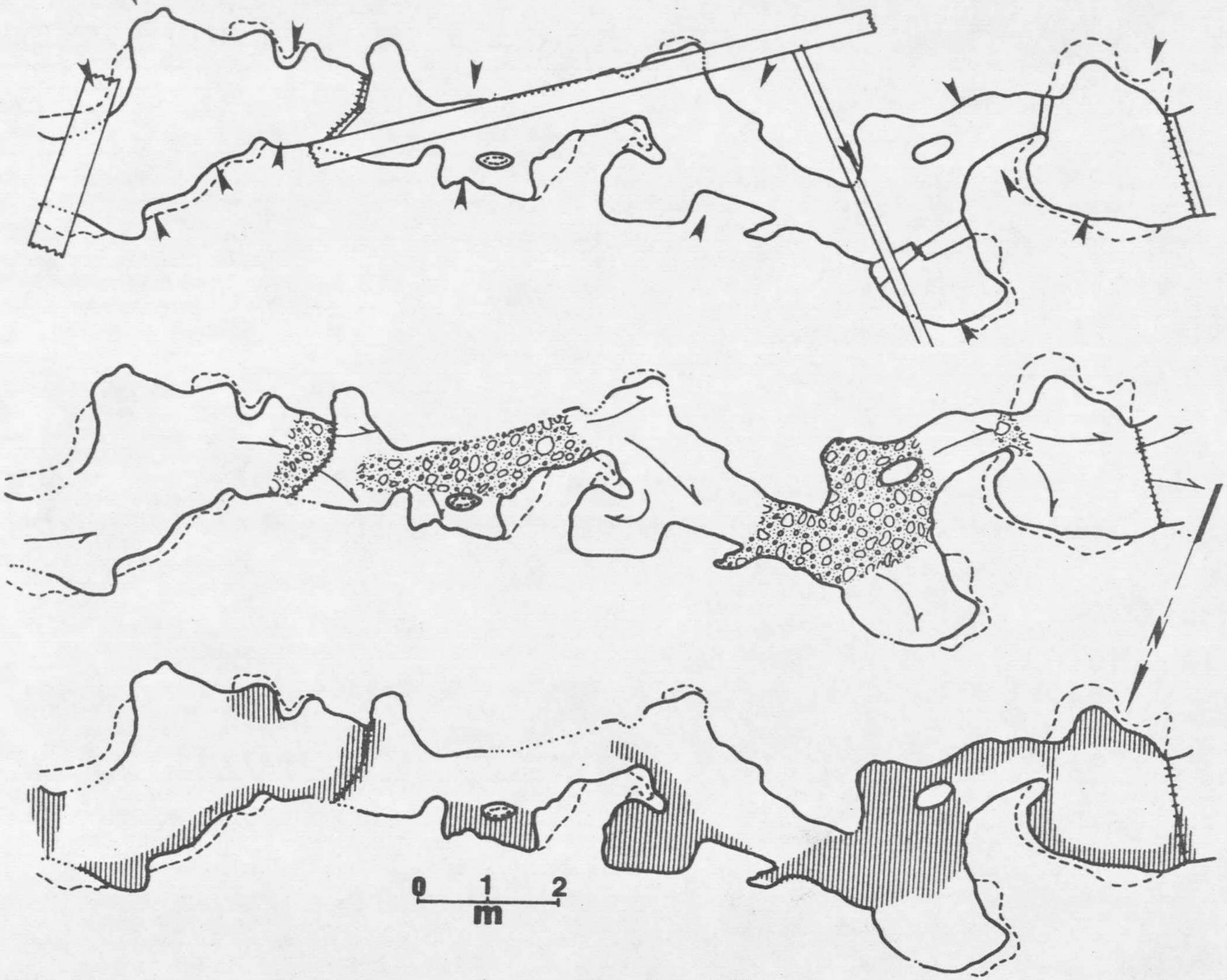

Figure 25. Map of station 11 on Little Toad Creek in 1978.

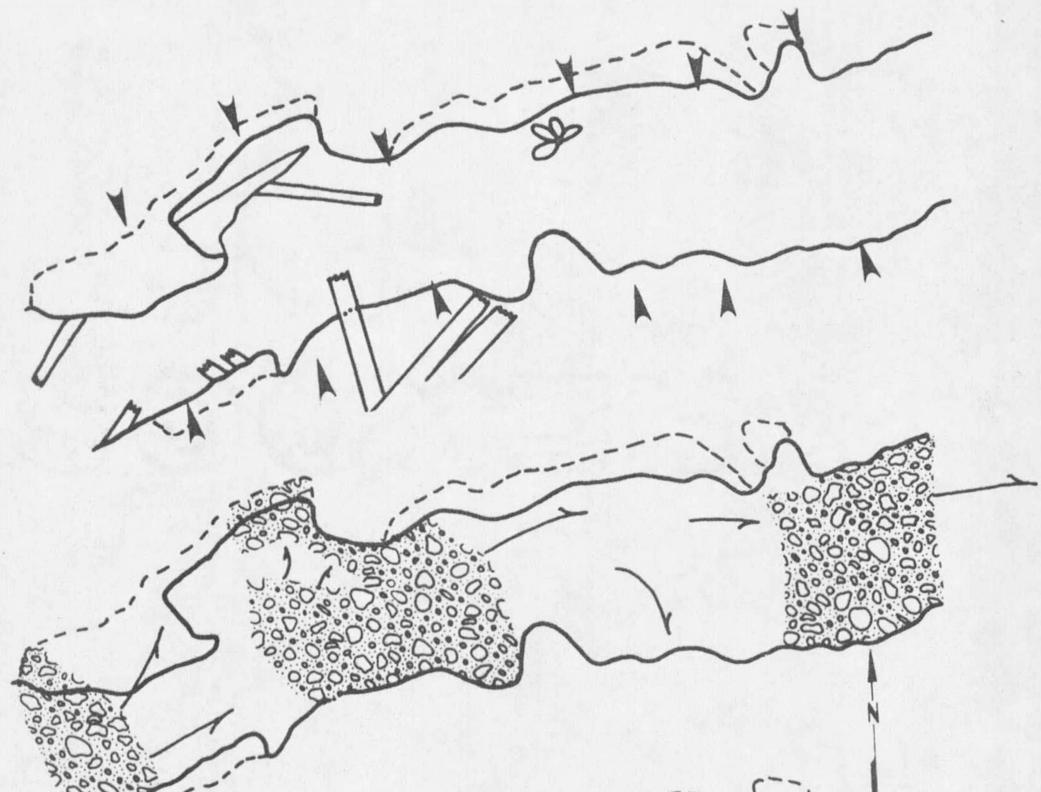

Figure 26. Map of station 1 on Three-Tenths Mile Creek in 1978.

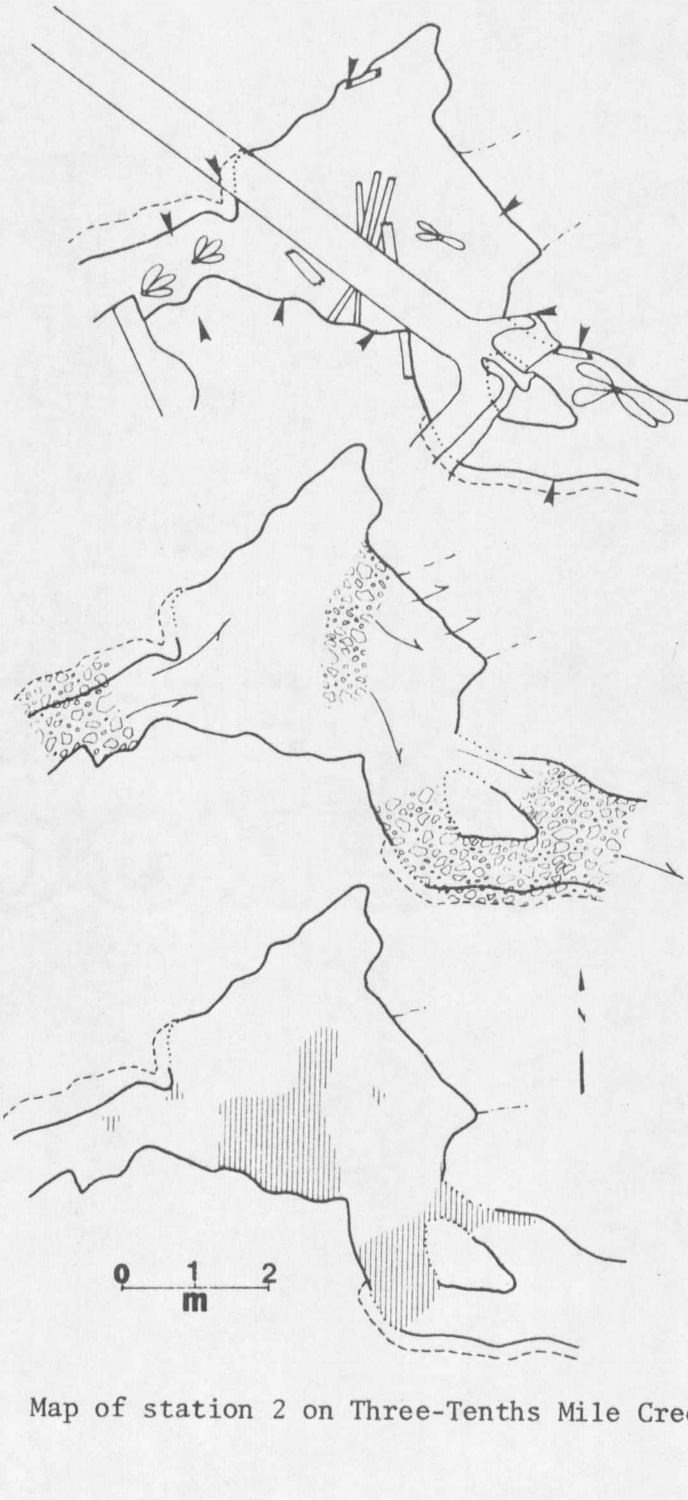

Figure 27. Map of station 2 on Three-Tenths Mile Creek in 1978.

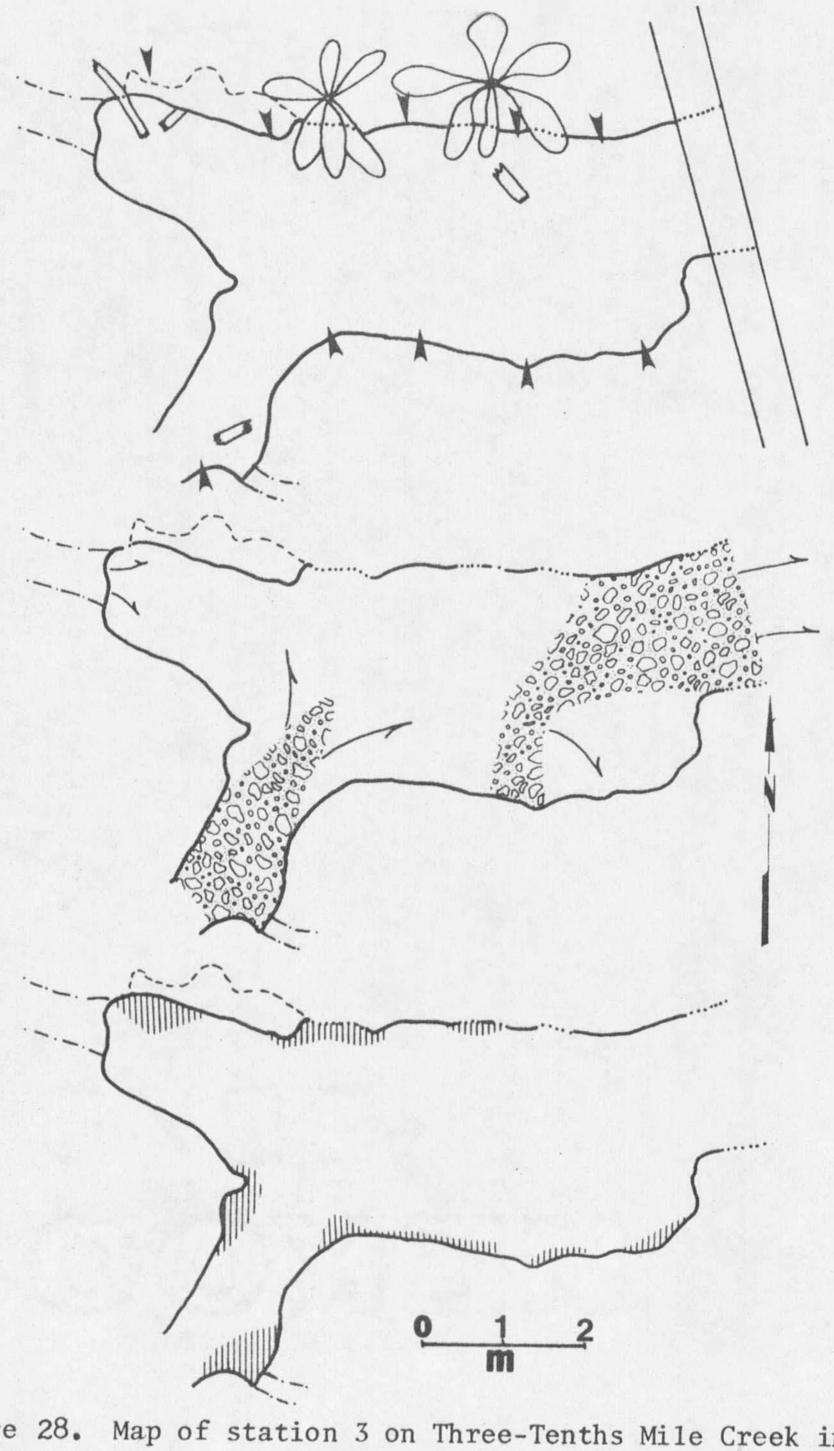

Figure 28. Map of station 3 on Three-Tenths Mile Creek in 1978.

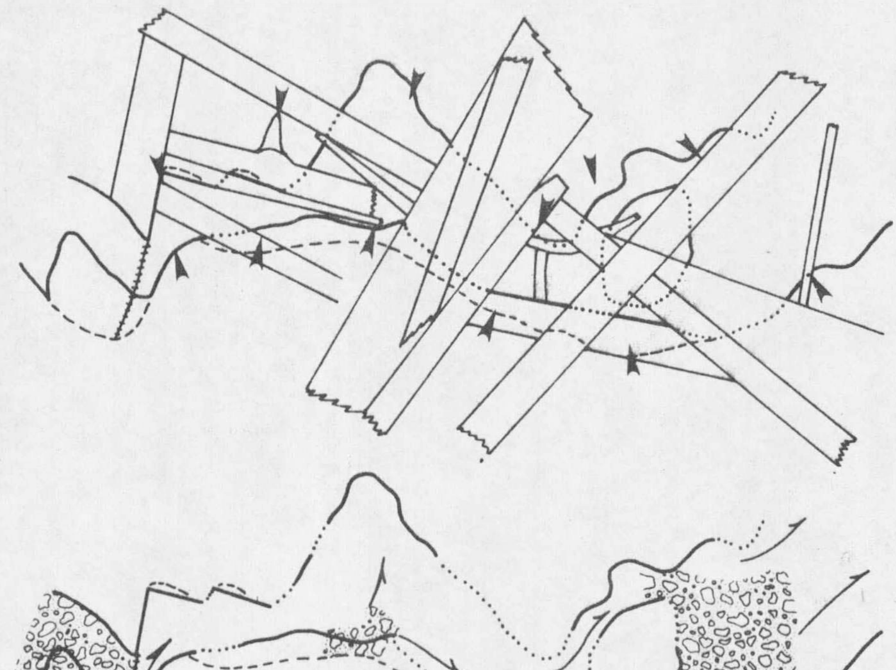

Figure 29. Map of station 4 on Three-Tenths Mile Creek in 1978.

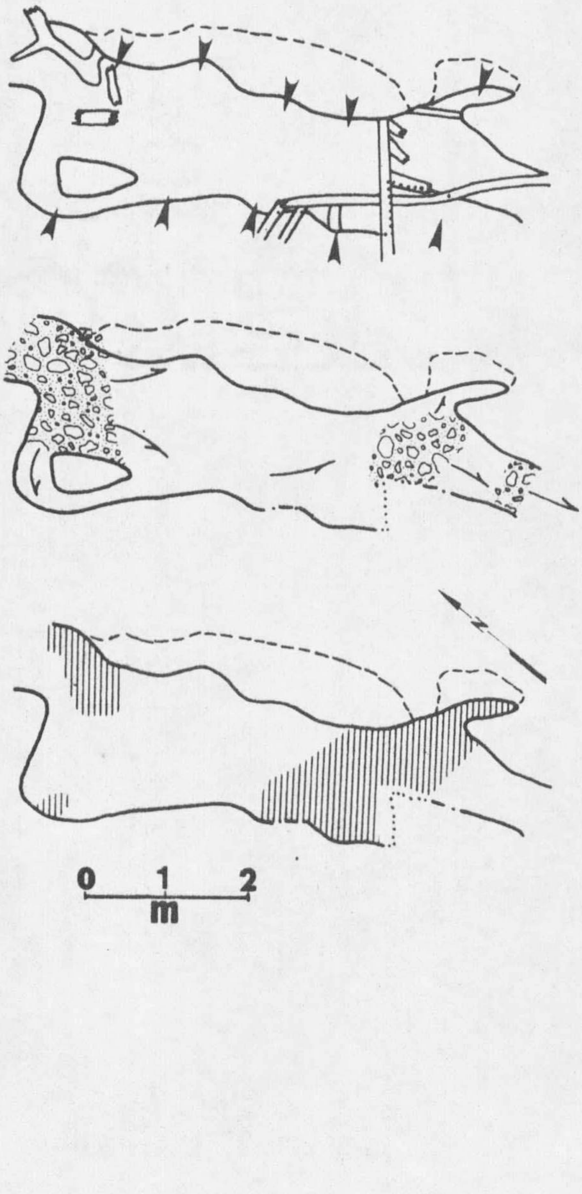

Figure 30. Map of station 5 on Three-Tenths Mile Creek in 1978.

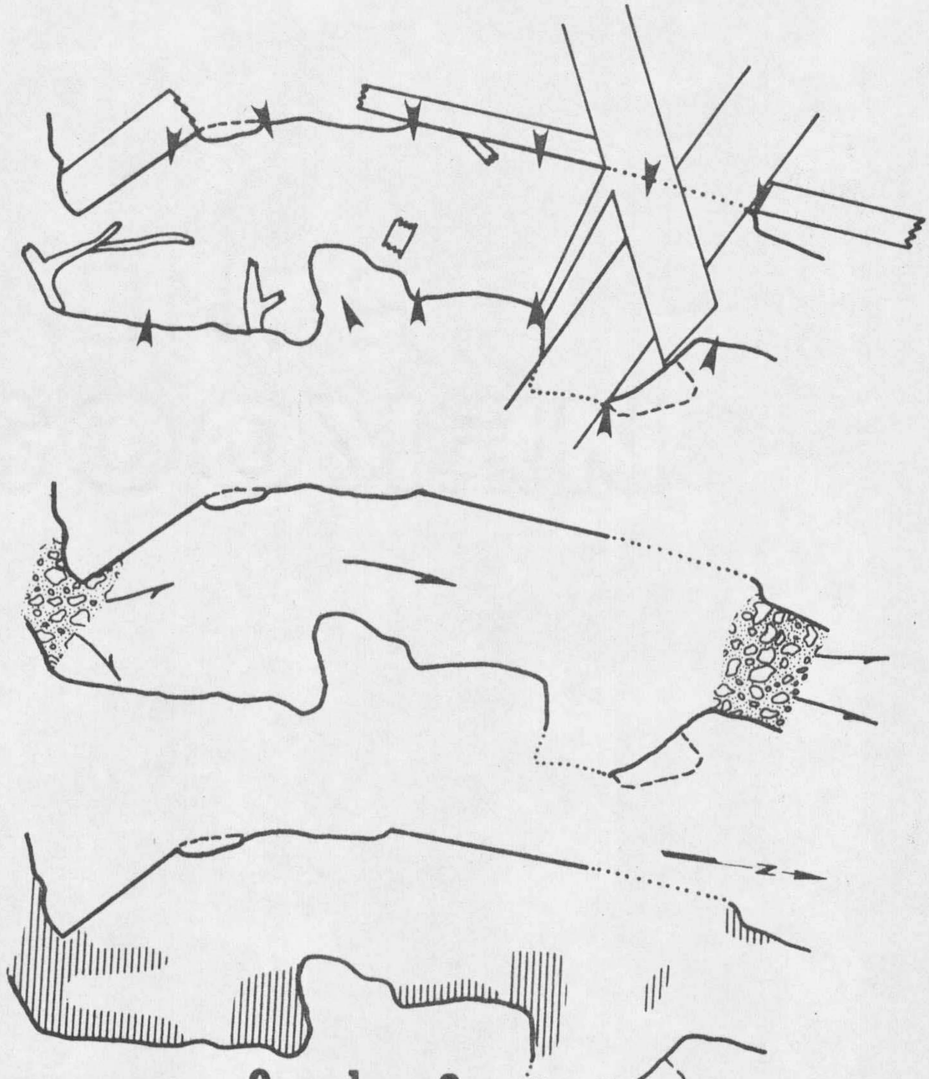

Figure 31. Map of station 6 on Three-Tenths Mile Creek in 1978.

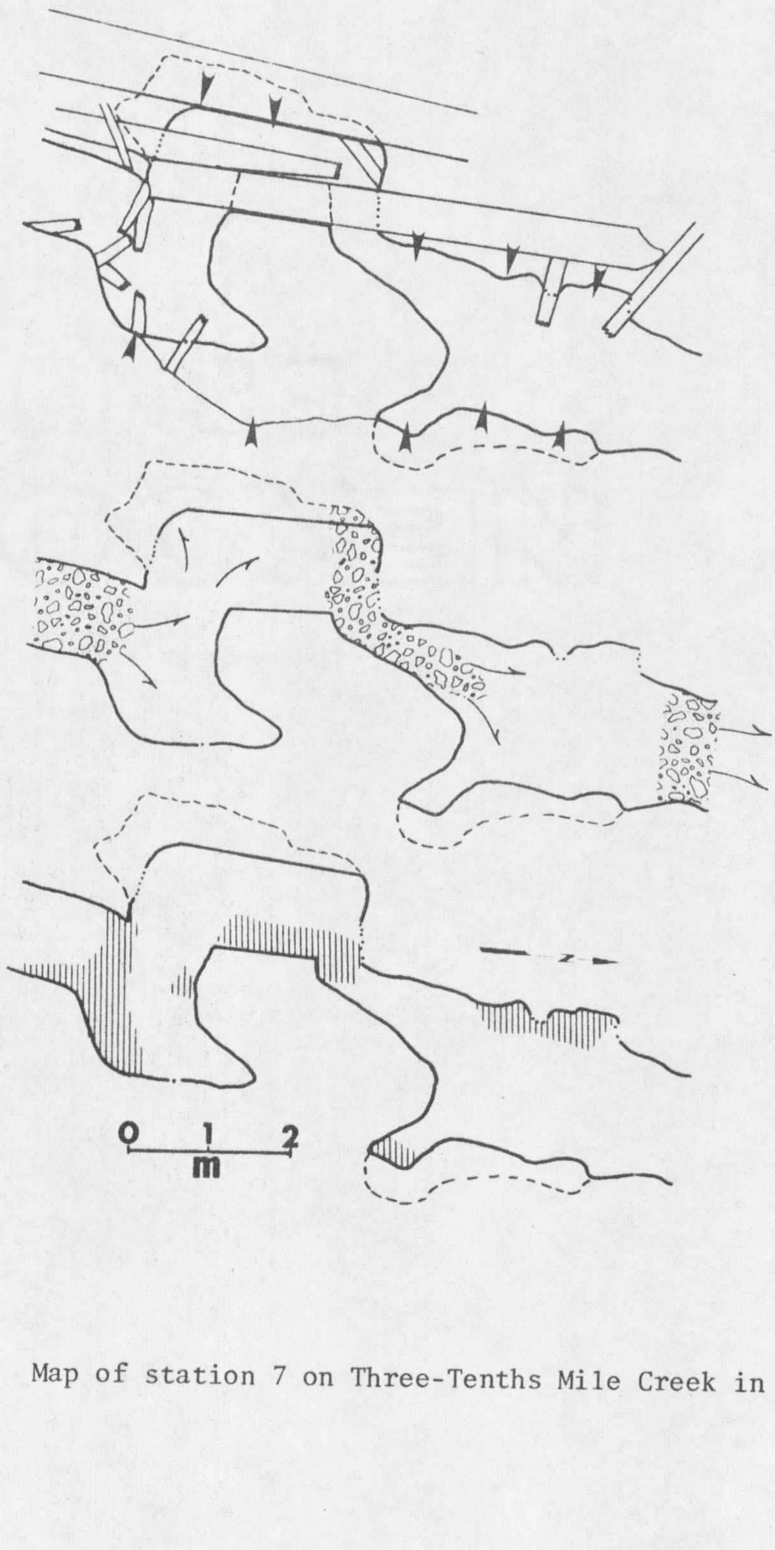

Figure 32. Map of station 7 on Three-Tenths Mile Creek in 1978.

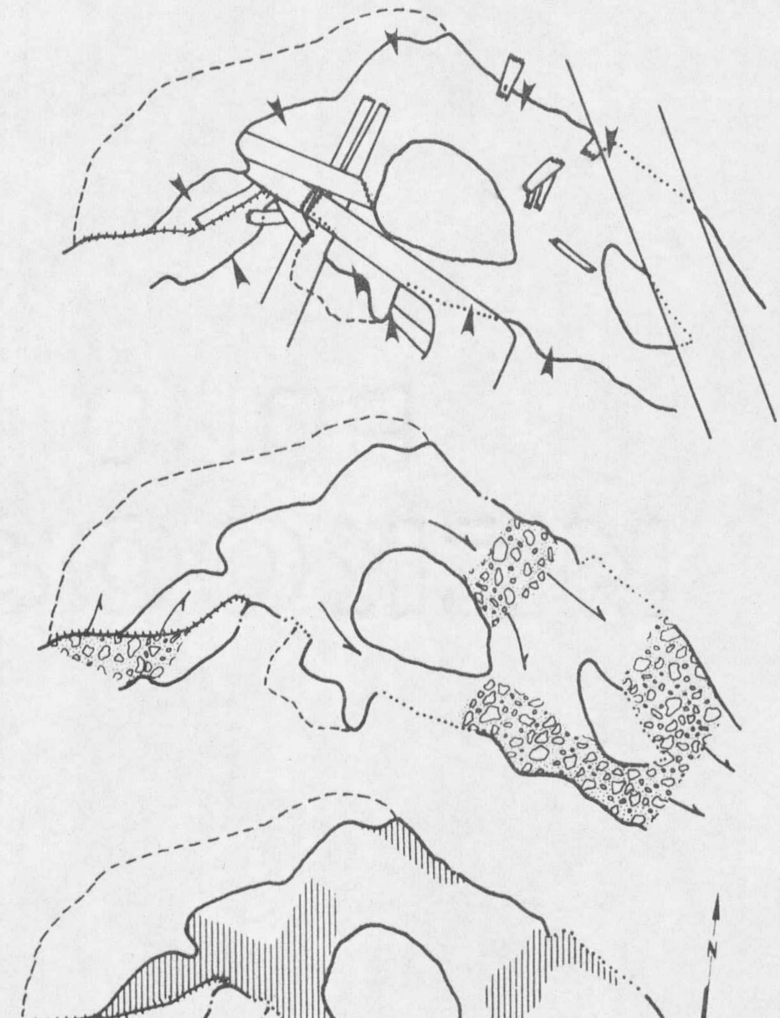

Figure 33. Map of station 8 on Three-Tenths Mile Creek in 1978.

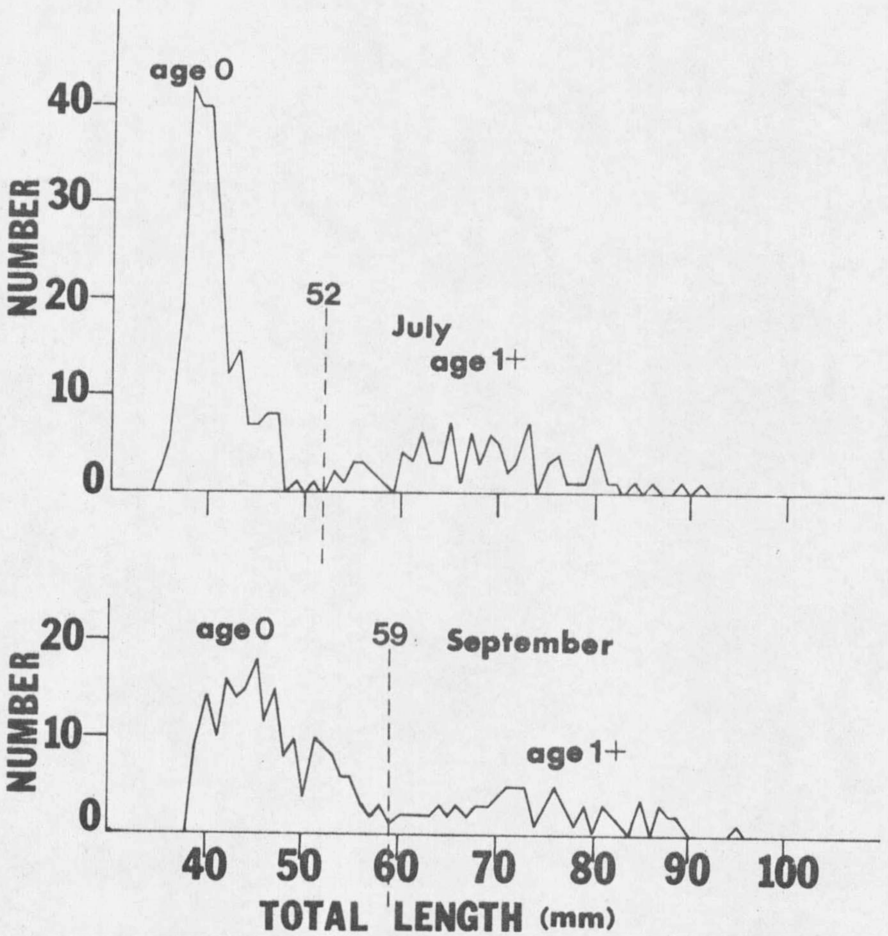

Figure 34. Length-frequencies of coho salmon captured on Tye-One-Ohn Creek during population censuses in 1978. Ages were determined from examination of otoliths.

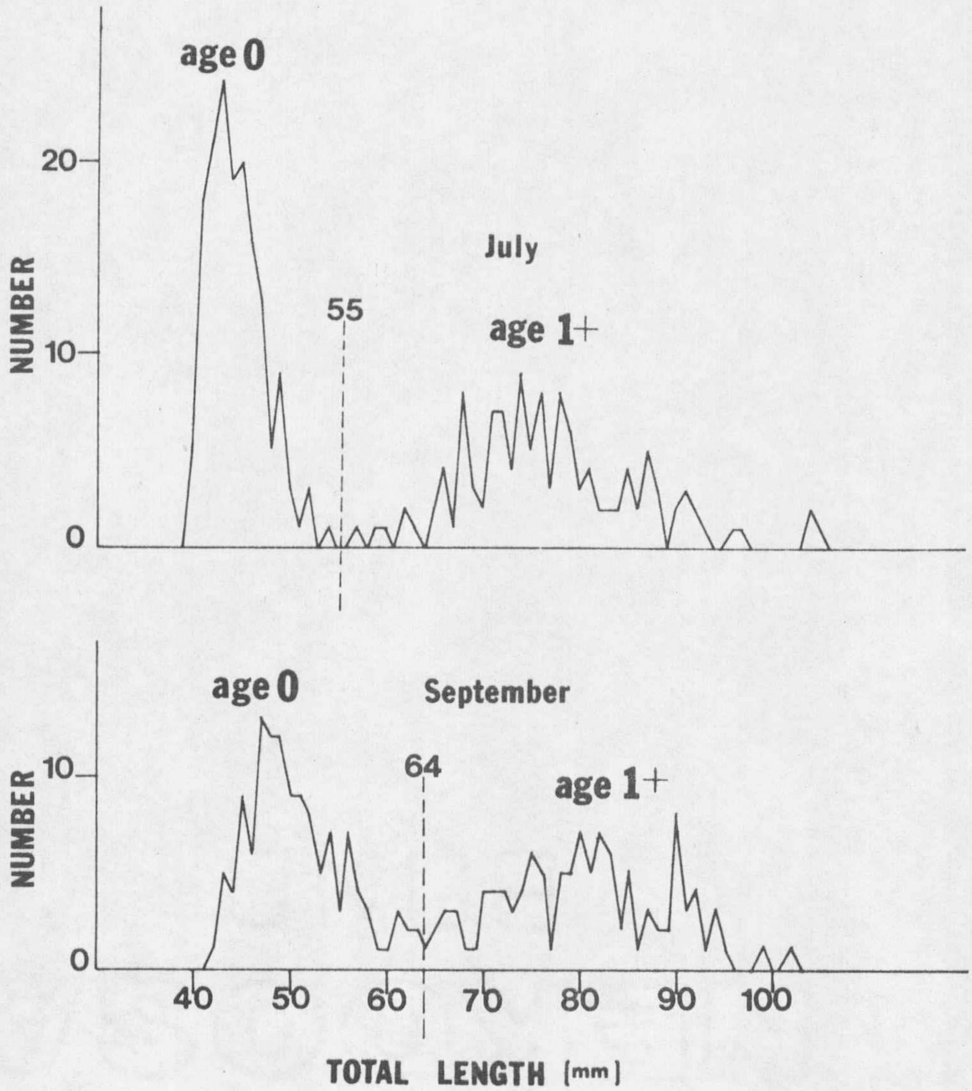

Figure 35. Length-frequencies of coho salmon captured on Little Toad Creek during population censuses in 1978. Ages were established from examination of otoliths.

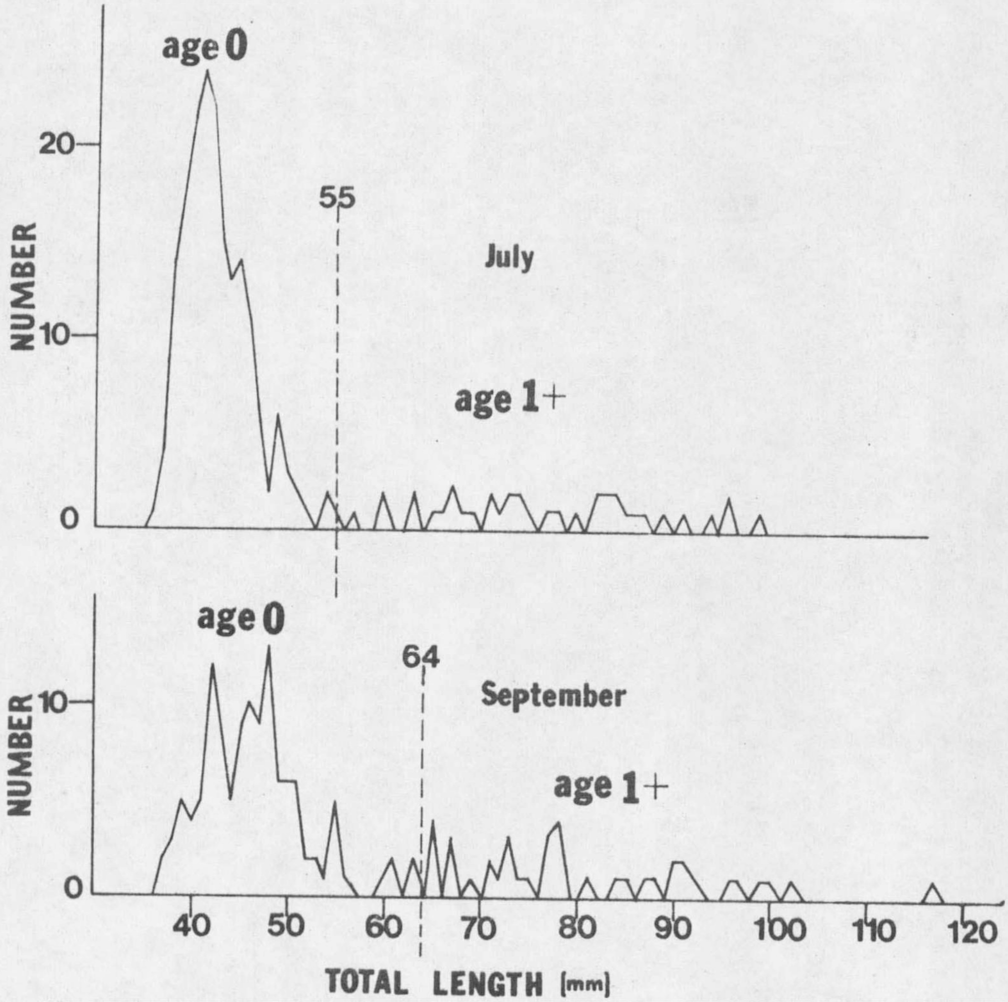

Figure 36. Length-frequencies of coho salmon captured on Three-Tenths Mile Creek during population censuses in 1978. Ages were established from examination of otoliths.

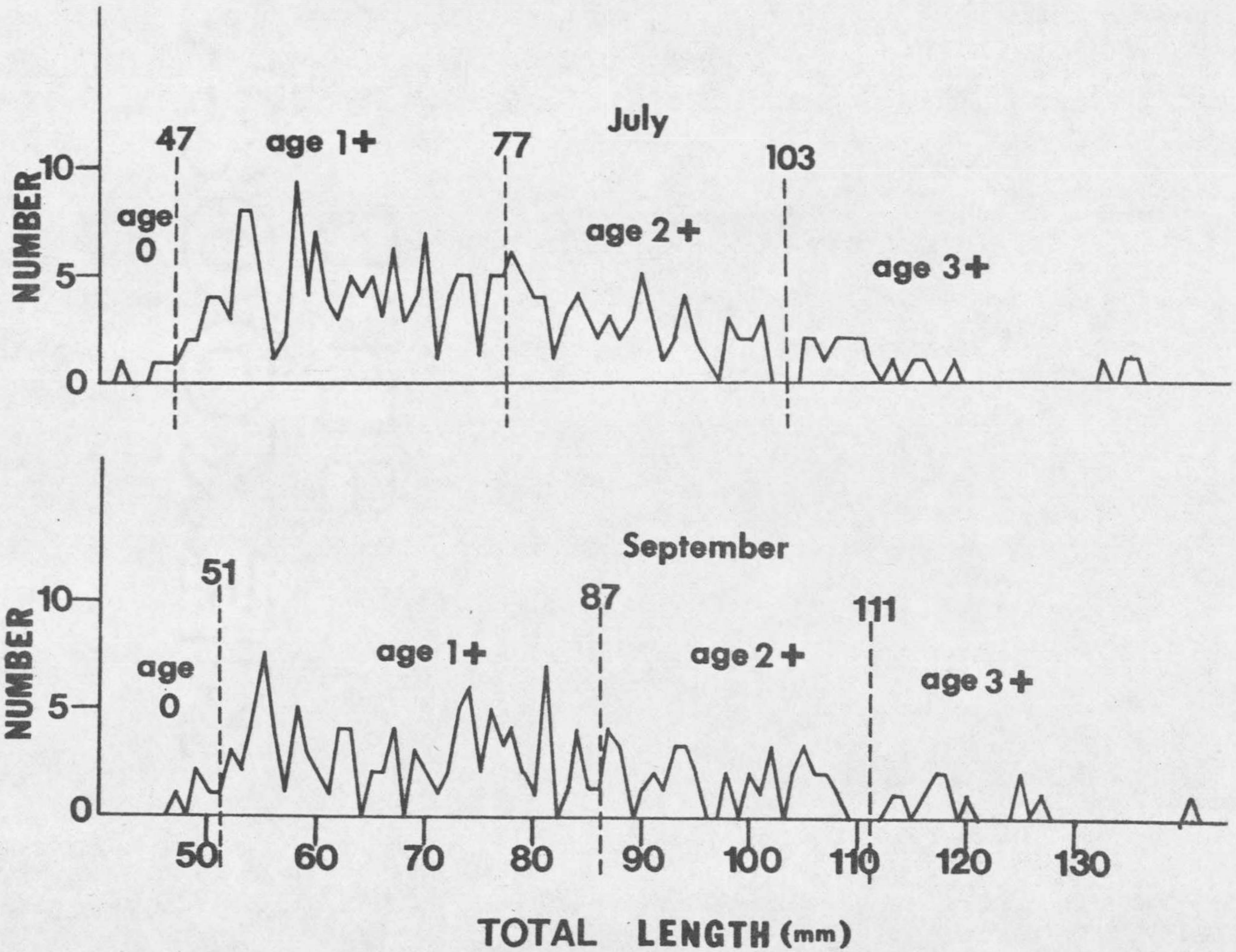

Figure 37. Length-frequencies of Dolly Varden captured on Tye-One-Ohn Creek during population censuses in 1978. Ages were established from examination of otoliths.

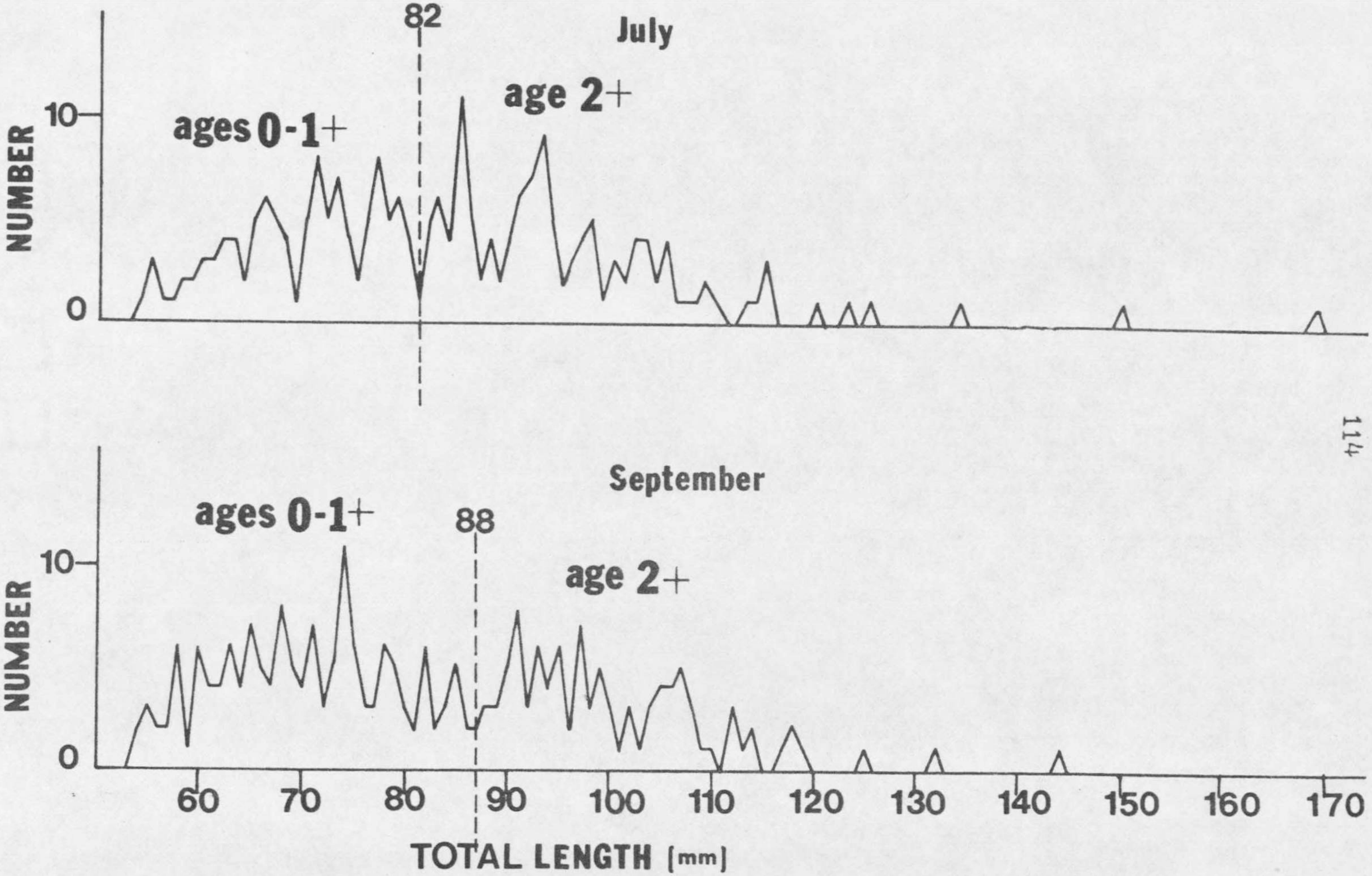

Figure 38. Length-frequencies of Dolly Varden captured on Little Toad Creek during population censuses in 1978. Ages were established from examination of otoliths.

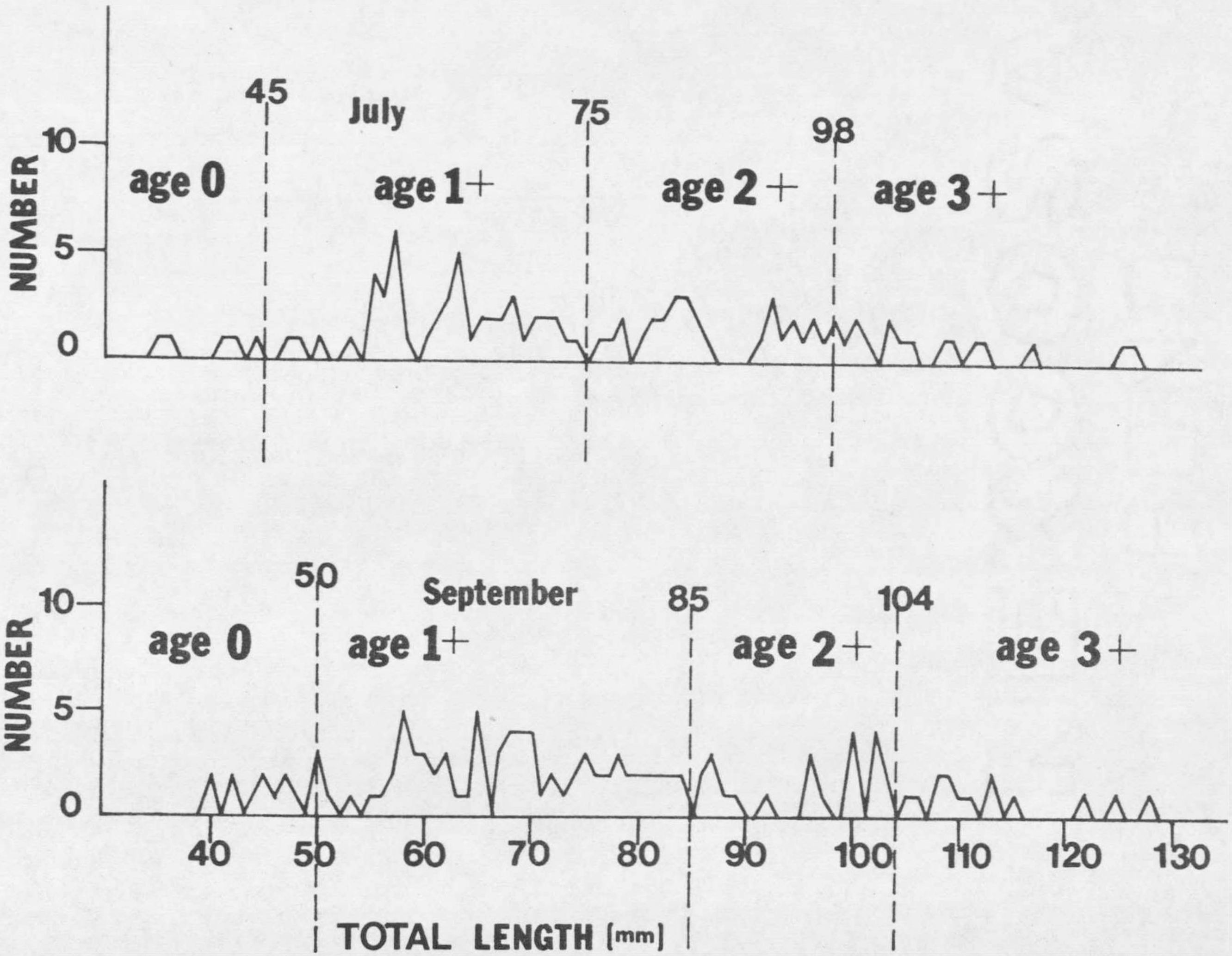

Figure 39. Length-frequencies of Dolly Varden captured on Three-Tenths Mile Creek during population censuses in 1978. Ages were established from examination of otoliths.