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No. 1300

Interactive Ecology of Juvenile Salmon and Trout in Streams. I. Progress during 1973.

by
Gordon J. Glova and J. C. Mason

Pacific Biological Station, Nanaimo, B.C.

March 1974

E R R A T A S H E E T

FOR: "IDB-supported GAIL BERNICE groundfish cruises 73-10 to 73-14 to Hecate Strait and Queen Charlotte Sound, August 3-December 16, 1973 (Data Record)"

by D. Chilton, D. Lovely and C. R. Forrester

Fisheries Research Board of Canada
Manuscript Report No. 1299, 1974

APPENDIX TABLE 1 - page 35:

Haul No. 26 - Catch for S. reedi (under Rockfish) should read 62000

APPENDIX TABLE 3 - page 51:

Haul No. 15 - Catch for S. alutus (under Rockfish) should read 35000

Haul No. 17 - Catch for S. alutus (under Rockfish) should read 40000

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INTRODUCTION

Small coastal streams in British Columbia are highly productive nursery systems for juvenile coho salmon, cutthroat and steelhead trouts. In such streams, these salmonids frequently occur in sympatry, the coho usually being numerically dominant. Due to their systematic affinity and generally similar ecological requirements during the juvenile rearing phase, coexisting populations of these species are likely to compete for stream resources, particularly in summer and early fall when stream flows are low. Sufficient understanding of the interspecific relationships, especially during the rearing phase of their life histories are therefore essential to developing sound management strategies.

Earlier studies documenting interaction among stream salmonids (Gerking 1959; Kalleberg 1958; Newman 1956; Lindroth 1955) have more recently stimulated works in a variety of cohabiting salmon and trout populations (Griffiths 1972; Everest and Chapman 1972; Lister and Genoe 1970: Chapman and Bjornn 1969; Jenkins 1969; Edmundson et al. 1968; Hartman 1965). However, the interactive aspects of sympatric coho and cutthroat trout have not been reported on, although Mason (1968) has documented growth, survival and behavioural responses to interaction in stream pens. Cutthroat and steelhead trouts often occur in sympatry but it remains unlikely that they occupy the same niche. Cutthroat trout cannot be managed by inference from studies directed at steelhead trout, nor can streams supporting sympatric salmon and trout be managed on a rational basis unless the species requirements, particularly of the young stages, are better defined and understood.

The general strategy adopted in this study was to investigate first the possibility of interaction between juvenile coho and cutthroat trout in natural populations cohabiting several small coastal streams, primarily by documenting their microhabitat distribution and abundance. These comparative field data would then serve as a first understanding for generating hypotheses for later experimentation testing and evaluation in stream aquaria.

METHODS

Field sampling

Following an early summer survey of small coastal streams on the east side of Vancouver Island between Saanich and Courtenay, Bush and Holland Creeks, situated in the vicinity of Ladysmith, were selected for detailed study (Fig. 1). Bush is a second-order stream (Horton 1945) with a watershed of 27 km^2; Holland is a third-order stream with a watershed of 31.6 km^2. Both streams possess impassable falls approximately 2,000 metres from their mouths and are physiographically similar throughout most of their lengths. However, Holland lacks a natural upper estuary due to a large culvert underlying the Island highway/railroad overpass but this structure presents no barrier to upstream movements of fish during high tide.

Initially, we established stream profiles with transit and level. Each stream was then stratified longitudinally into lower-, mid- and upper zones (Fig. 1) based on major changes in stream physiography. Within each zone, pool, glide and riffle habitats were then sampled with a direct current electrofisher to obtain distribution and abundance of fish species present and also size relations of juvenile coho and trout. The number of samples from each habitat type within each stream-section ranged from 3-13, with pools predominating due to prevailing low summer flows. The sampling period extended from 20 July-24 September 1973. During this period, stream water temperatures in either stream ranged from 11.5 C-15.5 C.

The fish populations were progressively sampled in an upstream direction in stream sections of fairly uniform velocity, selected if the local physiography appeared to allow isolation of its resident fish. Fine mesh minnow seines were then stretched across downstream and upstream limits of the test section and where necessary, held snug to the bottom with small rocks. The blocked off section was then electrofished intensively to obtain reliable estimates of actual fish densities. The stunned fish were collected with dip nets and held in plastic buckets until sampling was completed. To facilitate handling, all salmonids captured were anaesthetized in MS-222, fork length and species identification recorded for each fish and scale samples from those obviously exceeding the length range of age 0. Numbers but not lengths of sculpins were recorded. Upon complete recovery, the fish were returned to their section and the blocking nets were removed.

Underyearling coho and trout were subsampled during sampling of selected pool, glide and riffle habitats in the mid-section of both streams and preserved in 10% formalin for dietary analysis. Since fish densities were highest in mid-sections, we postulated that species microhabitat segregation would be accentuated in such areas andthat interspecific differences in food preferences, if present, would be more clearly defined.

Physical data gathered for each sampling site included stream velocity (pool <5 cm/sec; glide 5-20 cm/sec; riffle >20 cm/sec), area sampled, water depth (cm) and velocity (cm/sec) transects at mid-length of stream segment, and substrate composition (%). In the last instance, a square aluminum grid (0.25 m^2) divided into quadrats was placed on the stream bed along the longitudinal mid-line of the sampling area at down-, mid- and upstream points and the estimated percent of silt, sand, gravel (2-10 cm), rock (>10 cm) and bedrock recorded.

General water chemistry is being monitored in several streams and the results to date of three streams are compiled in Appendix I, Table IV.

Dietary analysis

Each preserved fish was weighed to the nearest 0.01 gm, the stomach then extracted and placed in a labelled vial containing 10% formalin. Each stomach was weighed to within 0.1 mgm, with and without food contents, and the identifiable food items separated to taxa and counted within several size categories.

RESULTS AND DISCUSSION

Physiographic features

During summer and early fall, overall stream discharge was slightly higher and more stable in Holland Creek. In Bush, immediately upstream of the barrier falls, flow was sporadically subsurface, forming isolated shallow pools. Below these falls, flow was comparable to that of Holland Creek, due to increased groundwater sources.

Unlike Bush, the canyon of Holland Creek is somewhat precipitous and largely of coniferous growth, resulting in a more shaded streambed. Bush meanders considerably and undercut banks are fairly common. Stream gradients, at least up to the barrier falls, are slightly higher in Holland than in Bush Creek, with average maximum slopes of 1.34 and 0.92%, respectively, in the mid-region of stream (Fig. 1). Accordingly, the streambed in Holland Creek is more deeply eroded, contains less gravel (Table 1) and provides a more open microhabitat between the rubble-boulder substrate. Bedrock formations and silt deposits (particularly in pools) were more common in Holland Creek.

Distribution and abundance

Upstream effects on the longitudinal distribution of the fish populations varied considerably between streams (Table 1). Unlike Holland, salmonids were least abundant in the lower section of Bush Creek. Stream physiography is fairly uniform in this region due to the shallow relief (0.58%). In Holland, coho abundance in pools declined with distance upstream (0.92-0.31 fish/m^2), whereas in glides and riffles, densities were more or less comparable throughout the system. In contrast, trout densities were highest in glides and riffles of the mid-region (1.09 and 1.21 fish/m^2), while in pools, their densities were fairly uniform throughout (0.45-0.60 fish/m^2). In both streams, sculpins attained peak densities in riffles of the lowermost region, due to the preponderance of young fish. In pools and glides, their densities were variable although usually higher in the mid-region of stream.

The relative abundance of coho and trout was quite different in the two streams. In Bush, coho outnumbered trout by a ratio of 4.7:1.0; in Holland, trout predominated by a ratio of 1.4:1.0 (Fig. 2, 3). In both streams, salmonid populations were primarily of underyearling fish, with the exception that age I+ trout were relatively abundant in lower Bush (Table 1). Young steelhead were rarely encountered and did not exceed 1% of the trout sampled. It was unlikely that the trout were incorrectly identified to species.

Estimated abundances of cottids (Cottus aleuticus and C. asper) are no doubt conservative, largely reflecting the difficulty encountered in adequately sampling age 0 fish. Similar problems have confronted others (Krohn 1967; Goodnight and Bjornn 1971). Using the present data for general comparison only, cottids were more than twice as dense in Bush Creek than in Holland. Pooling salmonid and cottid densities, indicates fish carrying capacity of Bush is approximately twice that of Holland.

Despite the mentioned upstream effects on the distribution of the fish populations, the densities of each habitat type throughout the system was pooled to investigate the overall pattern of habitat segregation, if any (Fig. 4, 5). In both streams, segregation was more clearly demonstrated by coho; their relative abundance was highest in pools and lowest in riffles, suggesting that at least in part, water velocity and depth influence their microdistribution (see Table 1). Habitat segregation among trout and sculpins between streams was inconsistent. In Bush, both species showed comparable microdistribution patterns; their relative abundance was highest in riffles and lowest in pools. However, in Holland, segregation was not distinct and near equal densities was observed in pool, glide and riffle habitats by both trout and sculpins (Fig. 4, 5).

Habitat responses of trout appears to be less discrete than that of coho as attested by their microdistribution in Holland Creek. Their tendency to occupy stations near the substrate may in part explain their relatively high densities in pools and glides. In these areas, trout commonly occupied marginal water less than 8 cm deep, whereas coho occupied deeper mid-stream areas.

Salmonid size relationships

Underyearling coho in Holland, but not in Bush, showed a considerable size advantage over trout of the same year class throughout the stream (Fig. 6, 7). This more pronounced size discrepancy was largely the result of faster growth of coho in Holland, resulting in minimal overlap in fork length ranges. In both streams, the numerically dominant species had a lower mean length relative to conspecifics in the other system. For example, in Bush, the numerically dominant coho had a mean length 5.3 mm less than did coho in Holland, which is predominantly a trout stream.

No significant upstream effects on size of coho and trout was noted in Holland. However, in Bush, both species were of significantly ($P < 0.05$) larger size in the lowermost region (Fig. 6, 7).

No significant size differences in either coho or trout could be attributed to habitat types in either stream (Fig. 6, 7). Trout in riffles and coho in pools may have been slightly larger than those fish in alternative habitats. However, the data suffer from certain inconsistencies which might be improved by more intensive sampling in 1974.

Comparison of size of salmonids in our study streams with other coastal drainages on the east side of Vancouver Island (see table below) indicates (1) that growth of Bush Creek coho was relatively low despite one month time lag in sampling and that growth of Holland Creek coho more closely resembles other stocks, and (2) growth of Holland Creek trout was relatively low compared to Bush, more typical of other stocks.

Stream	Date	Coho age 0 N	Coho age 0 x̄ FL	Coho age 0 Range (mm)	Cutthroat age 0 N	Cutthroat age 0 x̄ FL	Cutthroat age 0 Range (mm)
Bush Creek	29 Aug.	128	50.3	36-72	12	47.7	42-52
Holland Creek	21 Sept.	34	62.3	54-76	44	45.1	37-54
Chemainus River	26 Sept.	43	63.7	54-77	26	55.4	48-59
Haslam Creek	26 Sept.	20	66.7	58-78	41	53.4	44-59
Chase River	26 Sept.	30	67.8	47-77	-	-	-
Englishman River	1 Oct.	5	70.8	65-75	24	47.6	36-58
French Creek	1 Oct.	-	-	-	34	54.6	45-59

Salmonid biomass comparisons

With the exception of lower Bush, the observed differences in salmonid biomass throughout either stream (Fig. 8, 9) was largely the result of fish density and not fish size. The uppermost regions supported considerably less biomass per unit area primarily due to reduced coho abundance in pools and fewer age I+ fish. Relative to downstream areas, pools in the upper zone had lower mean maximum water depths (range 26.1-30.0 cm), and in Bush but not Holland, greater percentage of boulders (58.7%). In both streams, coho comprised more of the biomass in pools (53.1-90.8%) than did trout (9.2-46.9%), while in riffles, trout dominated the biomass, particularly in Holland (63.4-88.0%). Glides were intermediate but inconsistent between streams; throughout Holland, coho and trout constituted near comparable portions of the biomass (51.8-56.8% and 43.2-48.2%, respectively), whereas in Bush, coho contributed the greater portion of salmonid tissue (62.1-80.8%).

Food habits

Food selection was not clearly evident in the underyearling coho and trout dietary analysis (Appendix I, Tables I-III). The food items eaten appeared to be largely the result of food availability and fish microdistribution, although considerable overlap occurred. Chironomid larvae were numerically the most important food item in coho (43.9-76.4%) and trout (63.5-89.7%) in all habitat types in Bush Creek. In Holland, food habits of both salmonids were more variable, although chironomids predominated in trout stomachs (28.3-37.7%) but not in coho (5.7-24.4%). Other benthic forms of some importance to salmonids were dipteran and trichopteran larvae. Plecopteran and ephemeropteran nymphs were relatively infrequent in the diets of coho (0.4-5.7%) and trout (0.3-7.1%).

Terrestrial food items, particularly Diptera and Hemiptera, were more common in the diet of coho than trout, indicating greater surface feeding by coho. However, the degree of surface feeding appears to be influenced by water velocity. In either stream, coho ate more chironomids and less terrestrial items while in riffles than in pools, whereas in trout the converse was observed. These results suggest that coho forage more effectively on bottom and mid-water sources of food at higher water velocities.

General summary

1. Physiographically, both streams are reasonably similar downstream of the barrier falls with few minor differences. Unlike Bush, Holland has (1) no natural upper estuary, (2) slightly steeper stream gradient particularly in mid-region, (3) coarser substrate in certain regions, and (4) higher canyon walls dominated by coniferous rather than deciduous vegetation. Chemically, the outstanding differences between streams were the relatively high total dissolved solids and slightly greater concentrations of salts and nitrates in Bush, particularly during low flow conditions. These differences may, in part, reflect the higher proportion of deciduous species in the Bush Creek watershed.

2. Overall differences in relative and absolute densities of young coho and cutthroat trout varies between streams. Bush was more productive on an area basis but was numerically dominated by coho, while Holland was dominated by trout. Overall salmonid population density was very similar in the riffles of both streams but density was 50% higher in pools and glides in Bush than in Holland. In the pools and glides, there were more than 8 coho per trout in Bush, but near similar numbers in Holland. In the riffles, however, there were 4 times as many trout as coho in Holland, but less than twice as many in Bush. Since cottid densities were approximately twice as high in Bush in all habitats, this stream had a much greater relative rearing capacity than did Holland.

3. Growth of salmonids was related primarily to intraspecific densities. In Holland, coho showed relatively high growth at low densities, while in Bush their growth was markedly less at high densities. Trout showed a similar growth response to density, thus being opposite to that of coho in either stream.

4. Microhabitat utilization by both species was also related to intraspecific densities. At high densities trout exploited a wider range of habitats but at low densities they were found primarily in riffles and associated with high velocity areas. Similarly, at high densities coho showed wider habitat use but not as extensive as trout, but at low densities they were found predominantly in pools and associated with low velocity areas. Thus underyearling trout appear to have more flexible response to velocity than do coho. Since age 1 trout primarily occupy pools, this habitat is prematurely exploited by subyearlings at high population densities. Greatest interspecific interaction would most likely occur at intermediate velocities and water depths, e.g. glides and heads of pools.

5. Salmonid biomass in either stream was mostly a function of absolute densities and not fish size, with the exception of lower Bush, which contained a greater proportion of age 1+ fish. In either stream, coho dominated the relative biomass in pools and glides, while trout dominated in riffles. Total salmonid biomass was higher in the lower 2/3 of either stream.

6. Salmonid feeding habits were influenced by water velocity. Trout fed more on the surface at higher velocities and only near or on bottom and at margins in pools. Conversely, coho fed more on surface in pools and more in mid-water and bottom at higher velocities. Therefore, spatial separation of species is largely vertical; coho feed near the surface or towards stream centre at lower velocities, while trout feed nearer the surface or towards stream centre at higher velocities.

ACKNOWLEDGEMENTS

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Table 1. Summary of fish sampling data and physical data of pool, glide and riffle habitats in lower-, mid- and upper-stream sections, respectively, of Bush and Holland Creeks.

Stream	Total coho and trout	% trout	% age 1+ Coho	% age 1+ Trout	Fish/m^3 Coho	Fish/m^3 Trout	Fish/m^3 Sculpins	Mean water depth (cm) Minimum	Mean water depth (cm) Maximum	Mean water velocity cm/sec	Average % composition of stream bottom Silt	Sand	Gravel	Rock	Bedrock
HOLLAND CREEK															
Pools	384	32.8	0.8	4.0	0.92	0.45	0.73	7.5	36.9	2.7	7.0	20.0	58.8	18.5	0.0
	503	40.7	1.3	5.9	0.81	0.56	1.08	8.2	34.0	2.6	2.8	9.8	24.1	56.1	6.5
	420	66.0	0.0	4.3	0.31	0.60	0.43	7.6	26.1	4.4	1.9	7.8	35.0	45.7	9.9
	1307	46.5	0.9	4.8	0.63	0.55	0.71	7.8	32.3	3.2	3.9	12.5	39.3	40.3	5.5
Glides	149	64.4	0.0	2.1	0.33	0.59	0.59	4.2	17.5	15.8	0.0	21.7	47.7	30.6	0.0
	162	69.8	0.0	0.0	0.47	1.09	1.00	4.4	20.6	11.3	0.0	8.3	24.6	58.8	8.3
	91	69.2	0.0	0.0	0.32	0.73	0.31	5.3	26.7	11.8	0.5	9.4	50.2	31.5	8.4
	402	67.7	0.0	0.7	0.37	0.77	0.64	4.6	21.6	13.0	0.2	13.1	40.8	40.3	5.6
Riffles	67	86.6	0.0	5.1	0.07	0.46	1.33	6.1	13.8	33.3	0.0	1.3	53.4	35.3	10.0
	83	91.6	0.0	0.0	0.11	1.21	0.79	3.6	12.3	23.5	0.3	4.0	34.3	61.3	0.0
	80	80.0	0.0	0.0	0.18	0.74	0.60	3.7	13.8	27.9	0.0	11.0	42.5	46.4	0.0
	230	86.1	0.0	1.5	0.12	0.72	0.98	4.5	13.3	28.2	0.1	5.5	14.2	47.7	3.3
BUSH CREEK															
Pools	229	6.6	1.9	93.3	1.47	0.10	1.18	4.6	31.2	4.1	1.0	15.5	51.1	32.3	0.0
	566	5.6	0.2	19.4	2.57	0.15	1.37	3.8	28.0	3.1	0.3	10.0	42.7	47.0	0.0
	269	10.4	2.5	10.7	1.04	0.12	0.87	4.8	30.0	2.8	0.0	10.0	31.3	58.7	0.0
	1064	7.0	1.1	31.1	1.71	.13	1.13	4.4	29.7	3.3	0.4	11.8	41.7	46.0	0.0
Glides	141	14.2	0.0	35.0	0.89	0.15	2.32	4.9	19.6	14.3	4.0	8.0	42.7	45.3	0.0
	278	16.2	0.4	20.0	2.27	0.45	1.94	4.6	18.0	14.3	0.9	15.8	62.5	20.8	0.0
	212	17.5	2.3	16.2	2.48	0.54	2.50	3.8	13.3	12.7	0.0	8.4	36.2	55.4	0.0
	631	16.2	0.9	21.6	1.72	0.33	2.29	4.4	17.0	13.8	1.6	10.7	47.1	40.5	0.0
Riffles	25	84.0	0.0	47.6	0.04	0.20	3.20	2.7	9.7	29.6	1.3	3.8	51.6	43.3	0.0
	101	64.4	0.0	3.1	0.36	0.66	1.64	3.2	11.1	33.1	0.0	11.0	48.8	40.2	0.0
	73	50.7	0.0	8.1	0.37	0.38	1.52	3.5	9.4	26.4	0.0	8.1	44.3	47.6	0.0
	199	61.8	0.0	12.2	0.25	0.41	2.15	3.1	10.1	29.7	0.4	7.6	48.3	43.7	0.0

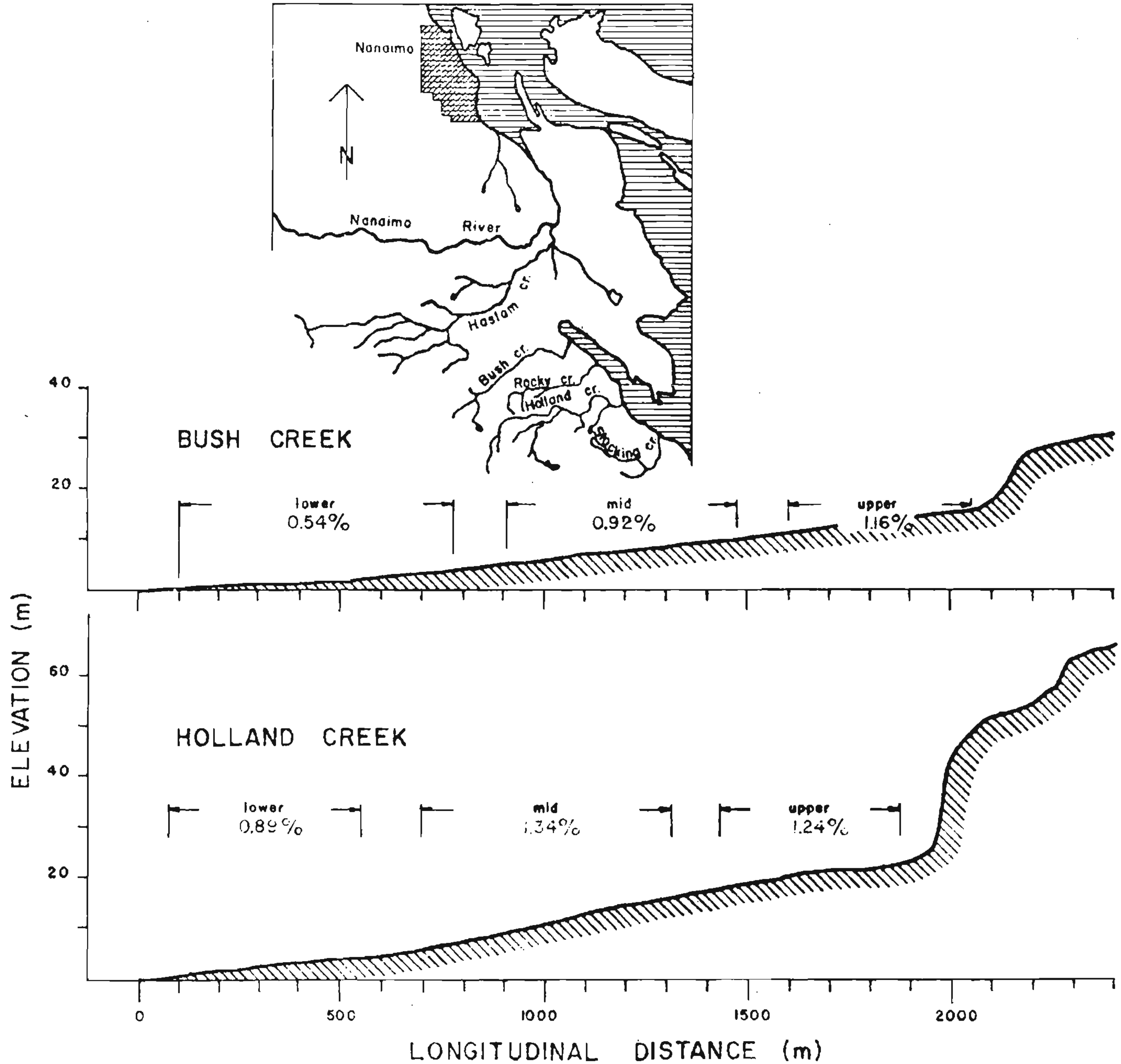

Fig. 1. Key map of study area (insert) and profiles of Bush and Holland Creeks up to the barrier falls. Average % slope for each stream section is indicated.

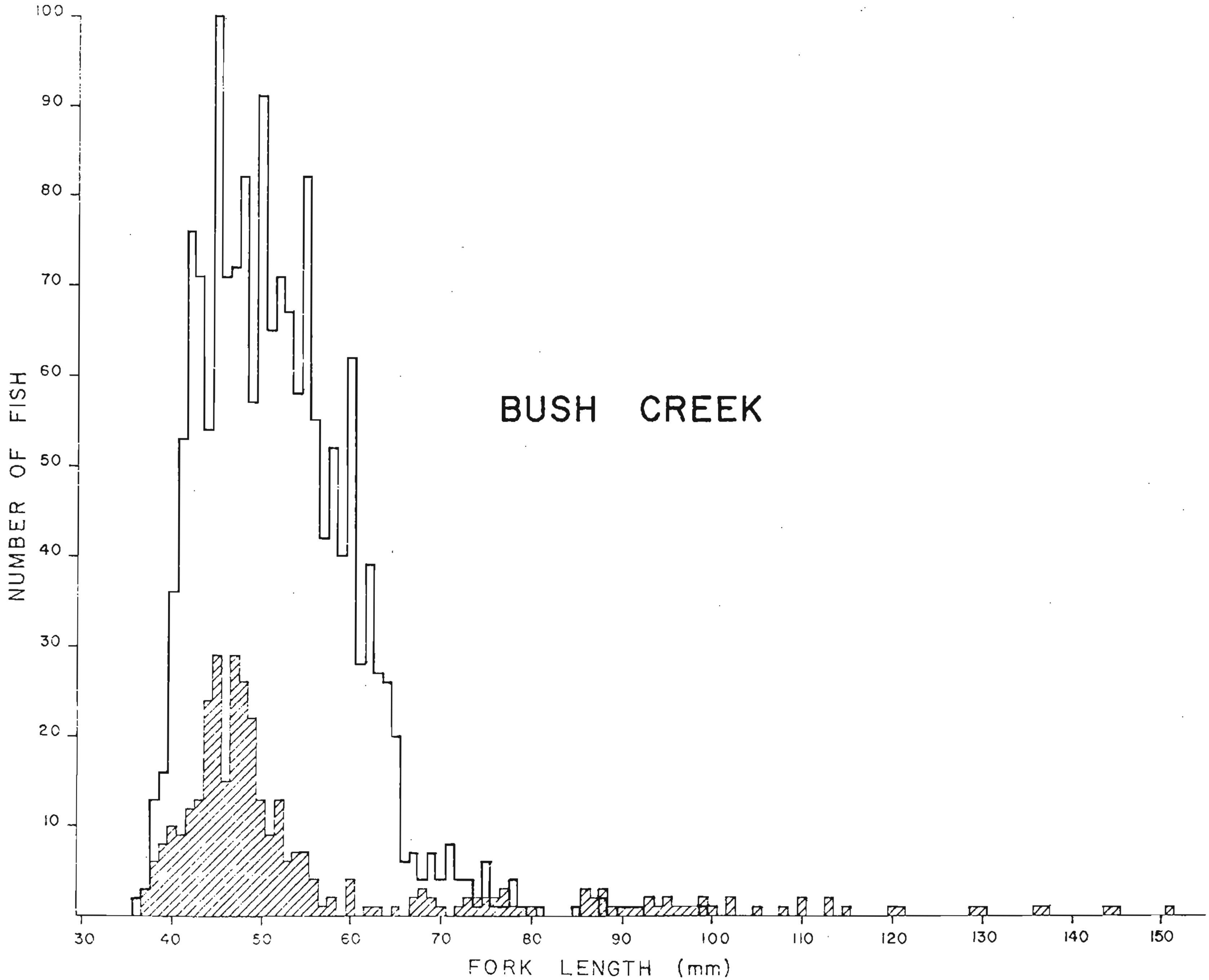

Fig. 2. Length-frequency histogram of coho (opened) and cutthroat trout (hatched), pooling all samples from the different habitat types.

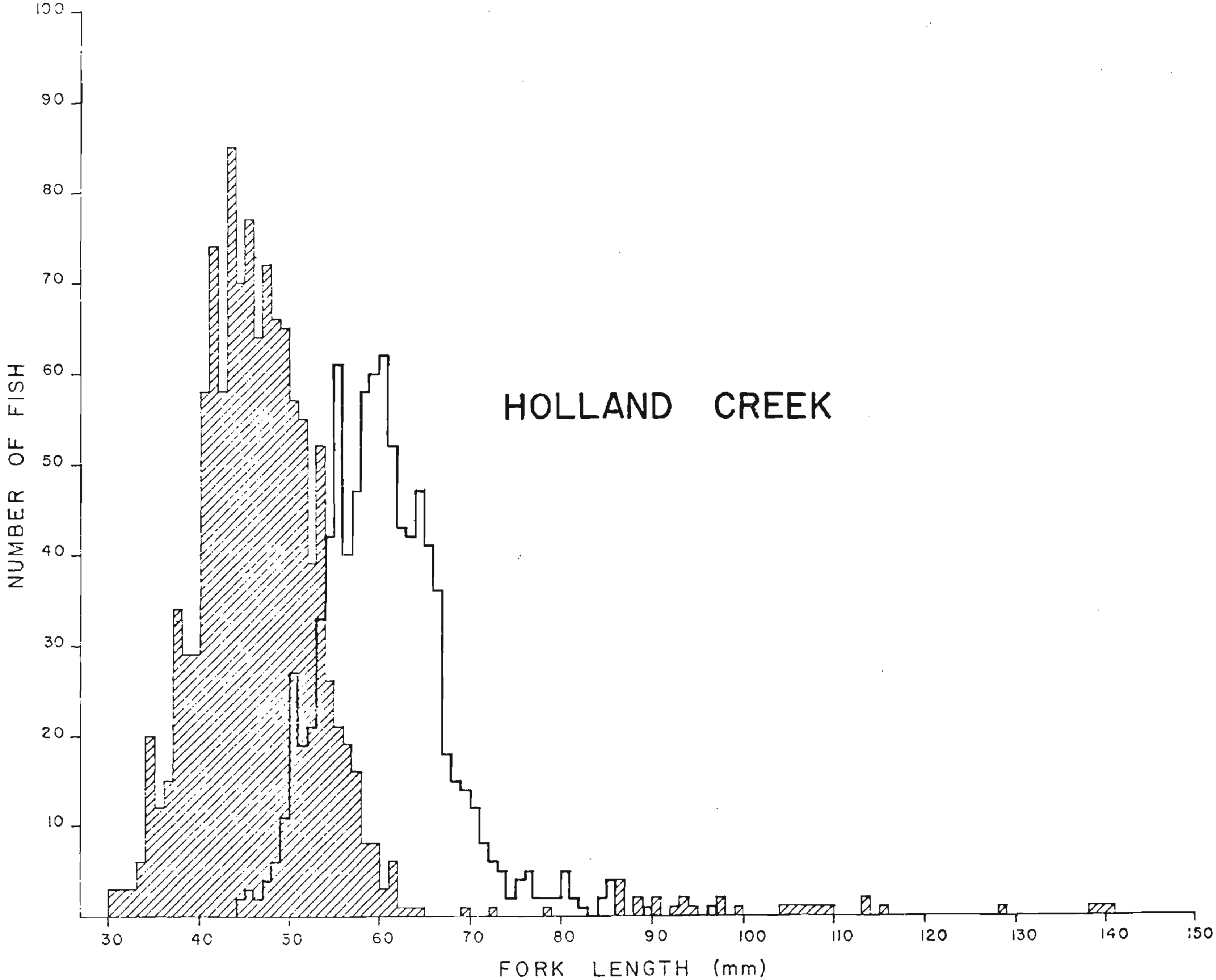

Fig. 3. Length-frequency histogram of coho (opened) and cutthroat trout (hatched), pooling all samples from the different habitat types.

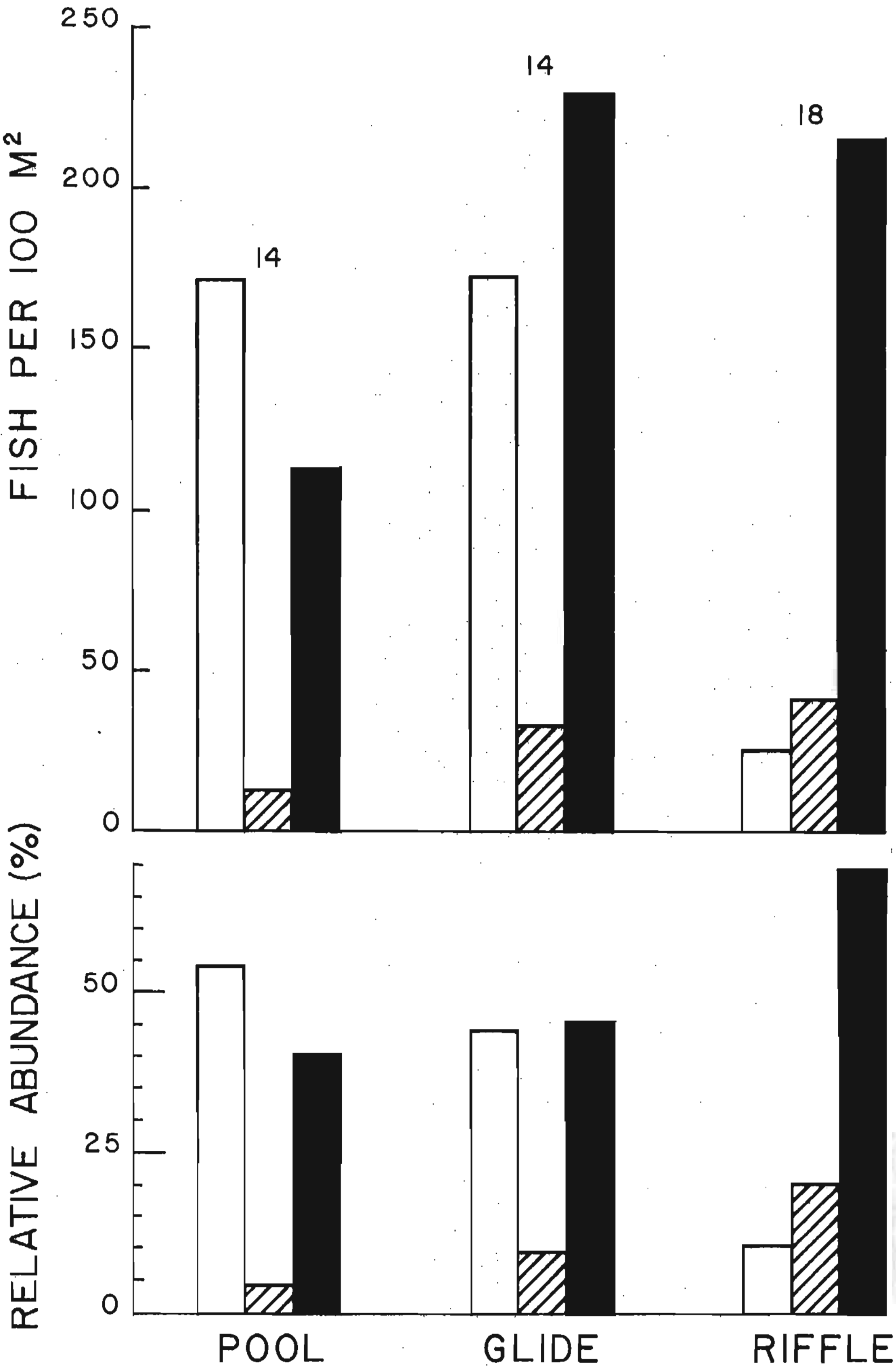

Fig. 4. Absolute densities (upper graph) and relative species abundance (lower graph) of coho (opened), trout (hatched) and sculpins (closed) in pools, glides and riffles of Bush Creek, pooling all samples of each habitat type. The total number of samples of each habitat type are shown (upper graph).

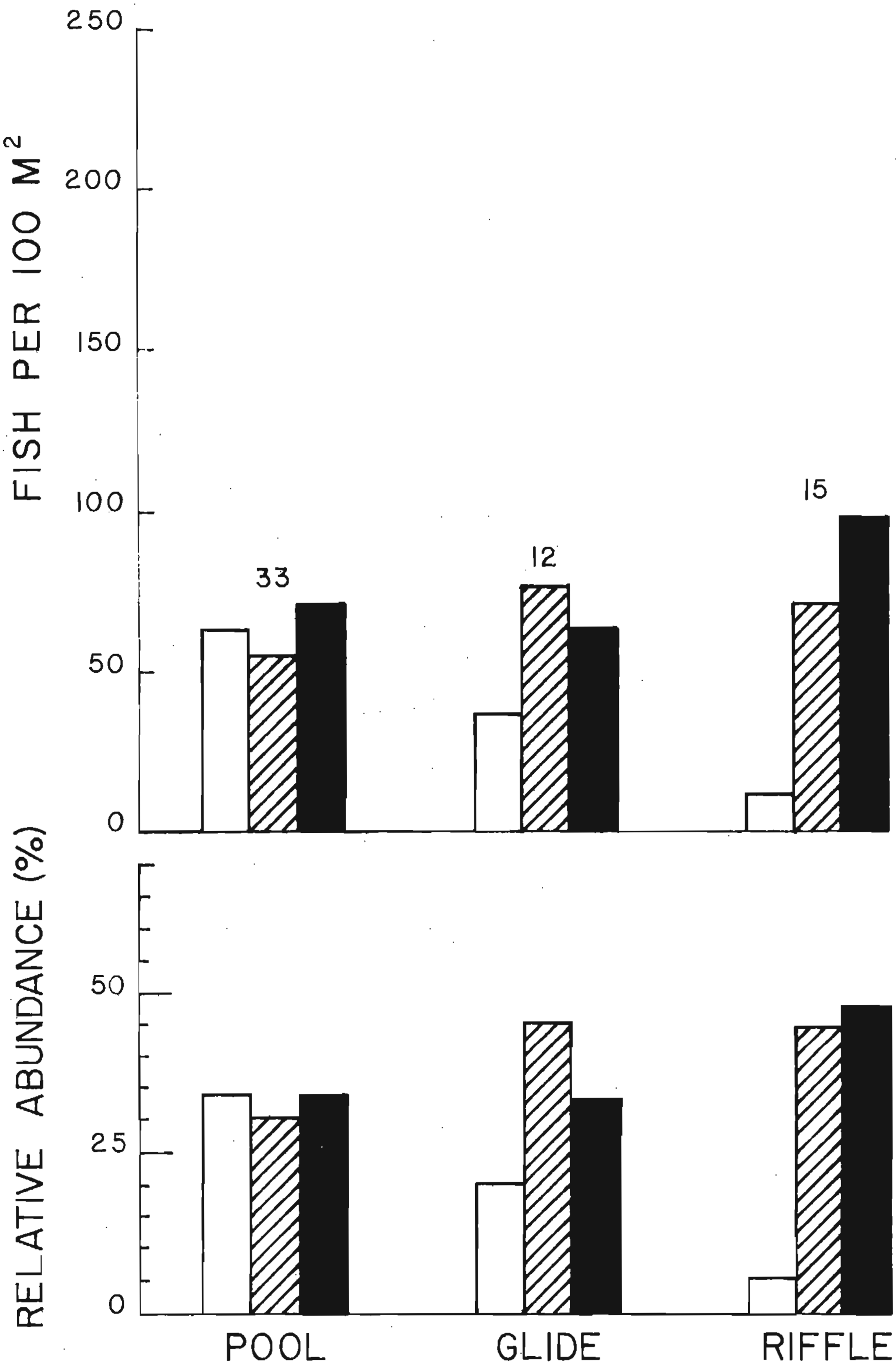

Fig. 5. Absolute densities (upper graph) and relative species abundance (lower graph) of coho (opened), trout (hatched) and sculpins (closed) in pools, glides and riffles of Holland Creek, pooling all samples of each habitat type. The total number of samples in each habitat type are shown (upper graph).

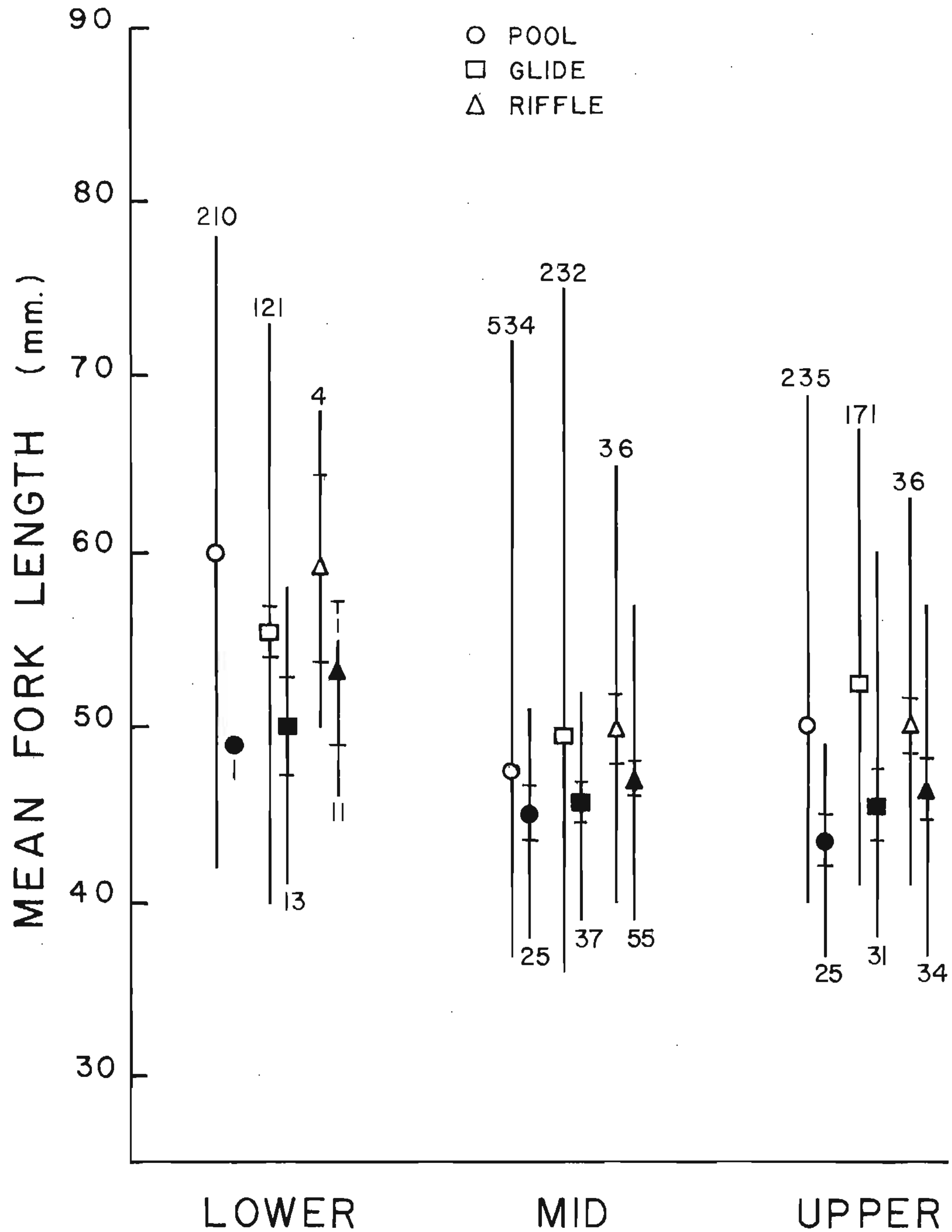

Fig. 6. Mean fork lengths of age 0 coho (opened) and cutthroat trout (closed) ± 2 S.E. (horizontal bars) and range (vertical lines) in Bush Creek. 2 S.E. <1.0 mm are not shown. Numbers indicate total fish sampled in each habitat type.

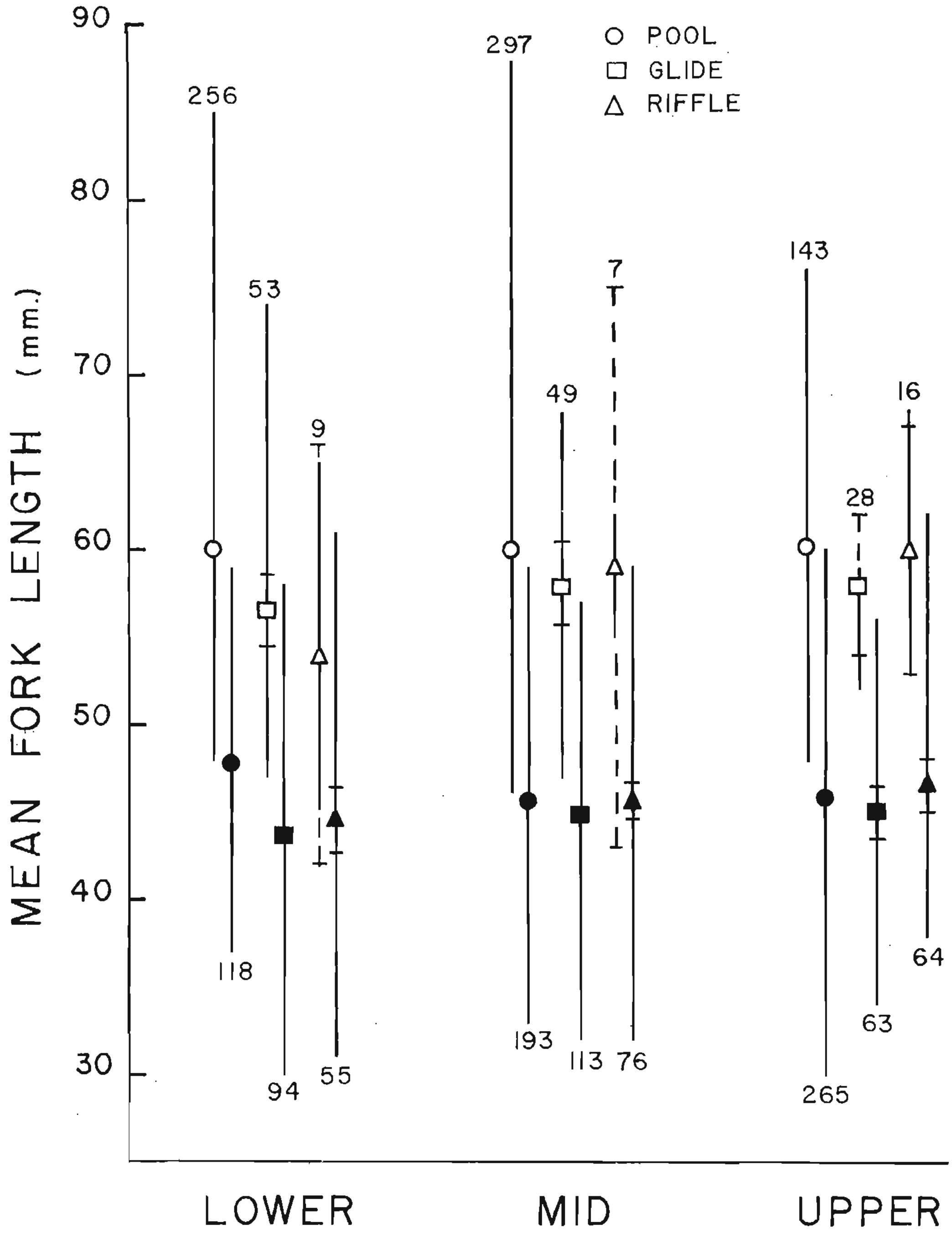

Fig. 7. Mean fork lengths of age 0 coho (opened) and cutthroat trout (closed) $\pm$ 2 S.E. (horizontal bars) and range (vertical lines) in Holland Creek. 2 S.E. <1.0 mm are not shown. Numbers indicate total fish sampled in each habitat type.

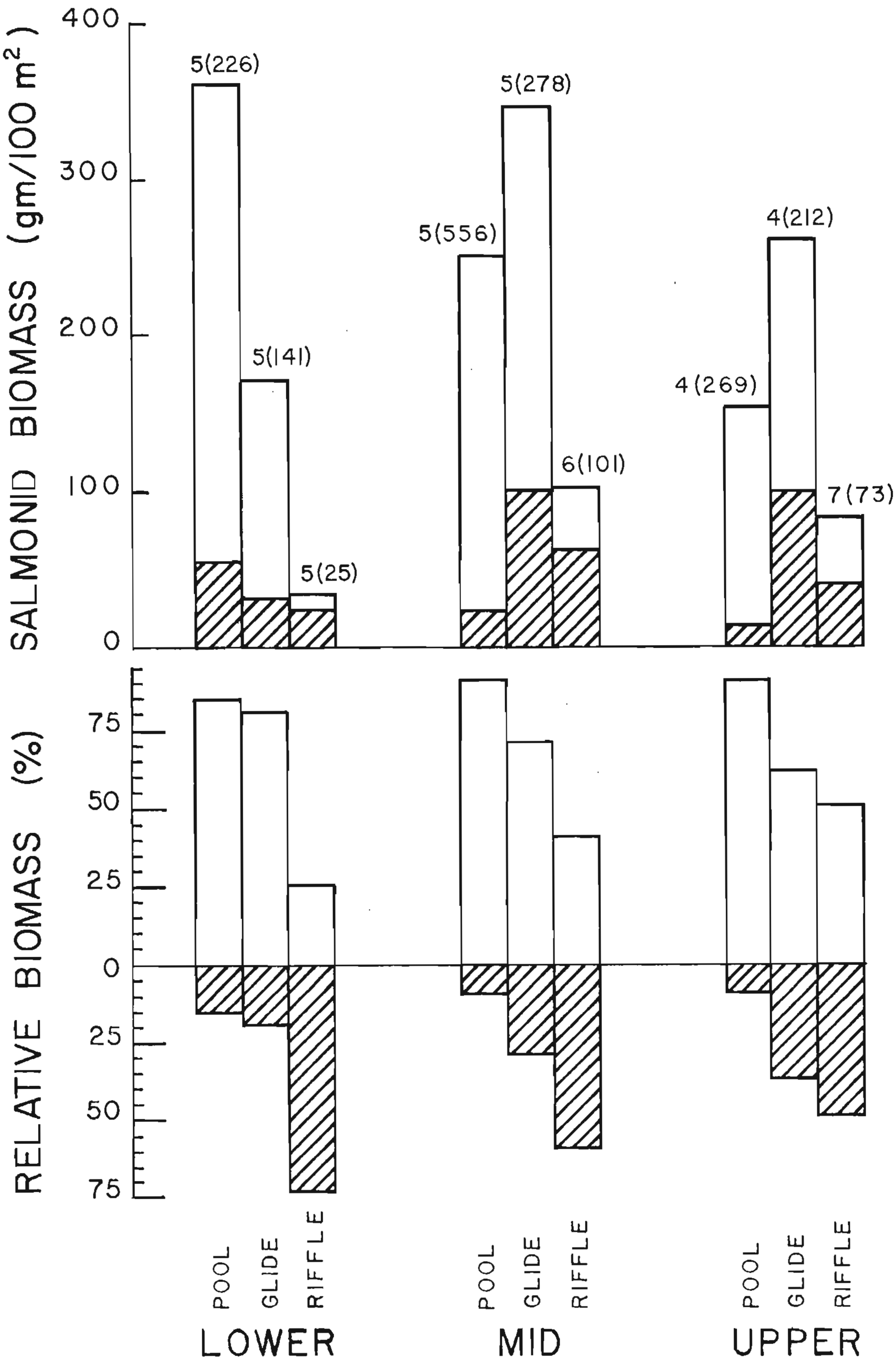

Fig. 8. Absolute (upper graph) and relative biomass (lower graph) of coho (opened) and cutthroat trout (hatched) in Bush Creek. The numbers of samples are indicated and those in parenthtses indicate number of fish sampled.

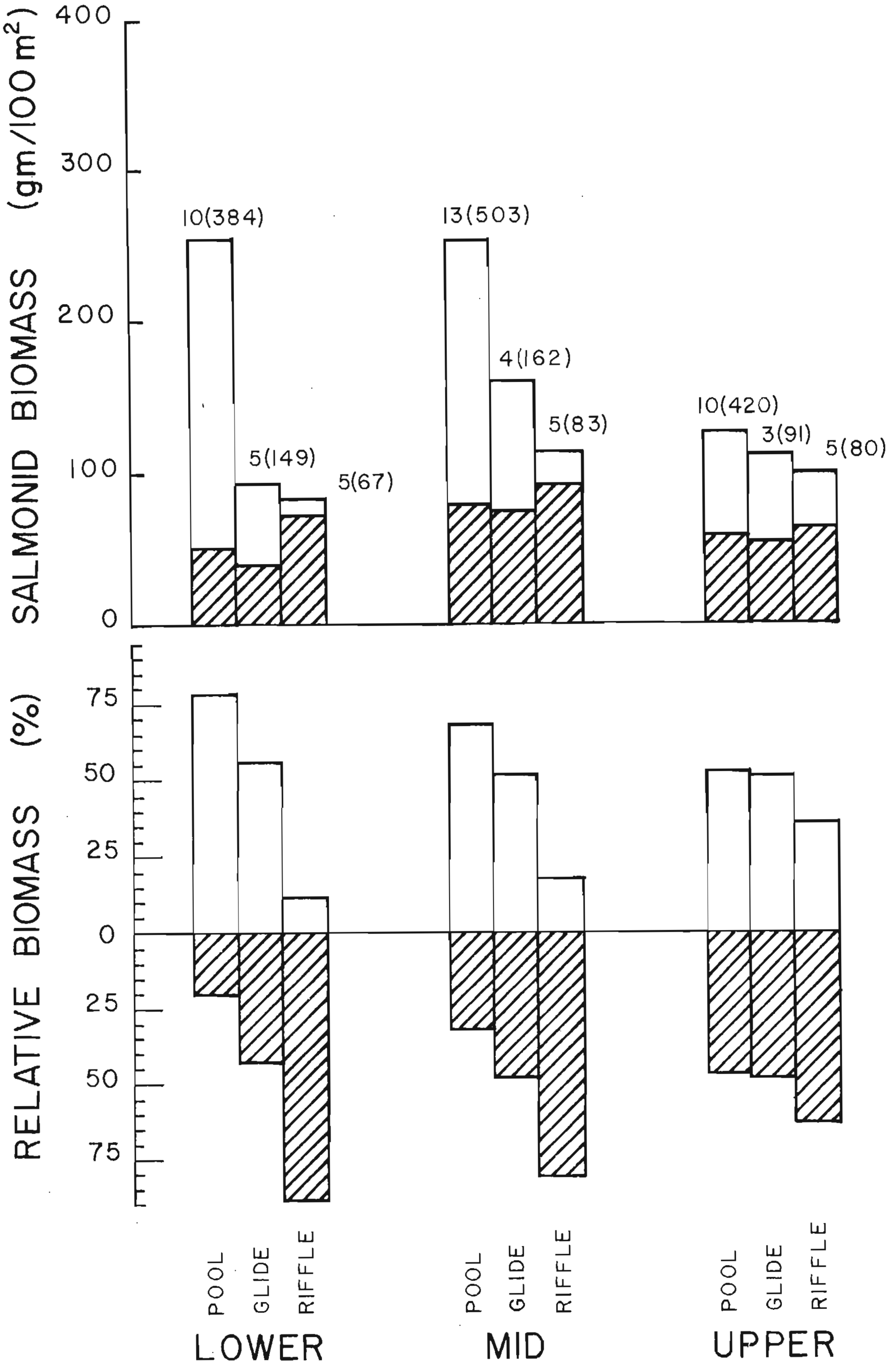

Fig. 9. Absolute (upper graph) and relative biomass (lower graph) of coho (opened) and cutthroat trout (hatched) in Holland Creek. The numbers of samples are indicated and those in parentheses indicate number of fish sampled.

APPENDIX I

Table I. Dietary analysis of salmonids in pools.

Food categories	Bush Creek: 9 coho (No. food items = 157; No. categories = 14) % of total food items	% freq. of occurrence	Bush Creek: 10 trout (No. food items = 224; No. categories = 9) % of total food items	% freq. of occurrence	Holland Creek: 11 coho (No. food items = 87; No. categories = 16) % of total food items	% freq. of occurrence	Holland Creek: 11 trout (No. food items = 138; No. categories = 13) % of total food items	% freq. of occurrence
Trichoptera								
Larvae					10.3	27.3		
Pupae					1.1	18.2		
Adults					1.1	9.1		
Plecoptera								
Nymphs			0.8	10.0	3.4	9.1		
Adults					5.7	18.2	1.4	13.6
Ephemeroptera								
Nymphs	5.7	55.6	4.0	40.0				
Adults	0.6	11.1						
Diptera								
Larvae	1.9	22.2	0.8	20.0	5.7	27.3	5.1	27.3
Pupae	2.5	22.2	0.4	10.0	1.1	9.1	2.9	31.8
Adults	18.5	88.9	1.8	40.0	25.3	72.7	9.4	63.7
Chironomidae								
Larvae	43.9	77.7	89.7	100	5.7	36.4	37.7	72.7
Pupae					2.3	9.1	0.7	13.6
Adults							0.7	4.5
Hemiptera								
Nymphs	0.6	11.1			4.6	36.4		
Adults	0.6	11.1					2.1	13.6
Aphids	3.2	22.2			8.0	18.2	4.3	22.7

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APPENDIX I

Table I. (cont'd)

	Bush Creek				Holland Creek			
	9 coho		10 trout		11 coho		11 trout	
	No. food items = 157		No. food items = 224		No. food items = 87		No. food items = 138	
	No. categories = 14		No. categories = 9		No. categories = 16		No. categories = 13	
Food categories	% of total food items	% freq. of occurrence	% of total food items	% freq. of occurrence	% of total food items	% freq. of occurrence	% of total food items	% freq. of occurrence
Hymenoptera								
Adults	0.6	11.1			5.7	27.3		
Coleoptera								
Larvae							1.4	13.6
Adults							2.9	22.7
Odonata								
Nymphs	3.2	11.1						
Melgoloptera								
Larvae								
Arachnida	5.1	44.4			3.4	27.3	10.9	27.3
Collembola	1.9	22.2					20.3	13.6
Cladocera	11.5	22.2						
Slugs					4.6	9.1		

APPENDIX I

Table II. Dietary analysis of salmonids in glides.

Food categories	Bush Creek				Holland Creek			
	10 coho No. food items = 276 No. categories = 13		10 trout No. food items = 312 No. categories = 12		7 coho No. food items = 98 No. categories = 12		7 trout No. food items = 56 No. categories = 11	
	% of total food items	% freq. of occurrence	% of total food items	% freq. of occurrence	% of total food items	% freq. of occurrence	% of total food items	% freq. of occurrence
<u>Trichoptera</u>								
Larvae	0.4	10	1.3	20			14.3	23.1
<u>Plecoptera</u>								
Nymphs	0.4	20	0.3	10			1.8	7.7
Adults	0.4	10						
<u>Ephemeroptera</u>								
Nymphs	1.0	20	2.2	40			7.1	53.8
<u>Diptera</u>								
Larvae	4.0	70	6.1	50	9.2	57.1	1.8	15.4
Pupae	3.6	40	2.9	50	1.0	14.3		
Adults	12.7	90	2.2	50	24.5	100	17.9	38.5
<u>Chironomidae</u>								
Larvae	64.9	100	76.6	90	13.3	100	32.1	84.6
<u>Hemiptera</u>								
Nymphs	0.4	20	1.6	40	2.0	14.3		
Adults	0.7	10	1.0	20	2.0	28.6	1.8	7.7
Aphids	4.0	50	1.3	40	4.1	28.6		
<u>Hymenoptera</u>								
Adults	1.8	40	0.3	10				

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APPENDIX I

Table II. (cont'd)

Food categories	Bush Creek: 10 coho, No. food items = 276, No. categories = 13		Bush Creek: 10 trout, No. food items = 312, No. categories = 12		Holland Creek: 7 coho, No. food items = 98, No. categories = 12		Holland Creek: 7 trout, No. food items = 56, No. categories = 11	
	% of total food items	% freq. of occurrence	% of total food items	% freq. of occurrence	% of total food items	% freq. of occurrence	% of total food items	% freq. of occurrence
<u>Coleoptera</u>								
Adults	5.4	60			11.2	57.1	5.3	7.7
<u>Odonata</u>								
Nymphs							1.8	7.7
Adults			4.2	20				
<u>Arachnida</u>					20.4	71.4	1.8	23.1
<u>Amphipoda</u>								
Gammarids					1.0	14.3		
<u>Collembola</u>					10.2	71.4	10.7	30.8
<u>Slugs</u>								
Juveniles					1.0	14.3	1.	

APPENDIX I

Table III. Dietary analysis of salmonids in riffles.

Food categories	Bush Creek: 10 coho, No. food items = 394, No. categories = 15: % of total food items	% freq. of occurrence	Bush Creek: 10 trout, No. food items = 241, No. categories = 18: % of total food items	% freq. of occurrence	Holland Creek: 7 coho, No. food items = 119, No. categories = 15: % of total food items	% freq. of occurrence	Holland Creek: 7 trout, No. food items = 60, No. categories = 17: % of total food items	% freq. of occurrence
Trichoptera								
Larvae					0.8	14.3		
Plecoptera								
Nymphs					2.5	28.6	6.7	42.9
Ephemeroptera								
Nymphs	1.3	10	2.5	30	2.5	42.9	1.7	21.4
Adults			0.8	20	0.8	14.3	1.7	14.3
Diptera								
Larvae	4.1	60	5.0	80	10.1	85.7	18.3	78.6
Pupae	1.0	20	2.5	20				
Adults	5.3	80	4.1	60	12.6	71.4	5.0	57.1
Chironomidae								
Larvae	76.4	100	63.5	100	24.4	71.4	28.3	78.6
Pupae	2.5	40	0.4	10			5.0	7.1
Tipulidae								
Larvae							1.7	7.1
Hemiptera								
Nymphs	0.5	20	2.5	50	5.9	57.1	1.7	7.1
Adults	0.5	20						
Aphids	2.3	30	4.1	50	6.7	57.1	1.7	7.1

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APPENDIX I

Table III. (cont'd)

	Bush Creek				Holland Creek			
	10 coho No. food items = 394 No. categories = 15		10 trout No. food items = 241 No. categories = 18		7 coho No. food items = 119 No. categories = 15		7 trout No. food items = 60 No. categories = 17	
Food categories	% of total food items	% freq. of occurrence	% of total food items	% freq. of occurrence	% of total food items	% freq. of occurrence	% of total food items	% freq. of occurrence
Hymenoptera								
Adults			0.8	20	2.5	42.9	1.7	7.1
Coleoptera								
Larvae			0.4	20	0.8	14.3	3.3	7.1
Adults	1.3	40			7.6	71.4	3.3	21.4
Odonata								
Nymphs	0.3	10	1.2	10				
Adults	0.3	10	0.8	30	1.7	14.3		
Arachnida	1.8	30	0.8	20	4.2	57.1	5.0	14.3
Collembola	2.3	60	8.7	40	16.8	57.1	11.7	21.4
Thysanoptera							1.7	7.1
Lepidoptera								
Larvae							1.7	7.1

APPENDIX I

Table IV. Water chemistry analysis of three streams (Fig. 1), each arranged in chronological order for the four sampling dates shown.

	Sampling date	Bush Creek Lower	Bush Creek Mid	Bush Creek Upper	Holland Creek Lower	Holland Creek Mid	Holland Creek Upper	Haslam Creek*
Chlorides (ppm)	15 Oct/73	210.0	65.0	35.0	40.0	12.0	10.0	
	13 Nov/73	3.6	3.4	3.6	2.6	2.7	2.6	
	10 Dec/73	1.9	1.9	1.8	1.5	1.0	4.2	1.1
	11 Jan/74	13.6	12.4	11.6	5.4	5.4	5.0	4.8
Calcium (ppm)		-	22.0	20.5	9.1	5.7	6.0	-
		2.1	2.1	2.1	2.0	1.6	1.8	-
		1.8	1.3	1.7	-	1.3	1.3	2.4
		5.6	5.2	5.0	3.8	3.1	2.8	5.2
Magnesium (ppm)		-	3.8	2.9	1.3	0.7	0.6	-
		0.4	0.4	0.4	0.4	0.3	0.4	-
		0.4	0.4	0.4	-	0.3	0.5	0.5
		1.0	0.9	0.8	0.6	0.6	0.6	1.0
Sodium (ppm)		97.0	40.0	28.0	8.0	5.3	5.0	-
		1.7	-	1.5	1.1	1.0	1.2	-
		1.6	1.6	1.5	-	0.9	2.6	1.1
		5.6	5.2	5.0	2.6	3.0	2.7	2.4
Potassium (ppm)		3.4	0.5	0.5	0.3	0.2	0.3	-
		0.1	-	0.1	0.1	0.1	0.1	-
		0.2	0.2	0.2	-	0.1	0.2	0.2
		0.1	0.1	0.1	0.2	0.1	0.1	0.1
Dissol. iron (ppm)		0.02	0.01	0.01	<0.01	0.03	0.03	-
		-	-	-	-	-	-	-
		0.1	0.1	0.1	0.1	0.1	0.1	0.04
		0.03	0.03	0.03	0.02	0.03	0.02	0.01
T.D.S. (ppm)		523.4	234.6	227.3	99.5	62.0	43.7	-
		28.2	28.5	28.3	13.7	9.7	12.6	-
		37.5	31.1	34.7	28.1	31.0	37.8	23.0
		59.0	54.8	55.4	40.6	36.0	31.3	41.9
Nitrates (µg-at No$_3$-N/l)		11.2	11.4	14.4	11.1	7.2	6.8	-
		9.0	9.5	8.7	9.4	9.6	8.6	-
		7.5	9.0	4.5	4.1	2.7	2.6	2.6
		9.2	8.7	8.1	7.1	5.9	5.9	5.4
Phosphates (µg-at P/l)		0.8	0.6	0.6	0.9	0.5	0.4	-
		0.3	0.3	0.2	0.3	0.3	0.3	-
		0.2	0.2	0.1	0.2	0.2	0.1	0.4
		0.2	0.1	0.1	0.1	0.1	0.1	0.1
Ammonia (µg-at NH$_4$-N/l)		7.1	<0.1	<0.1	5.9	0.5	0.1	-
		0.5	0.4	0.3	0.3	0.3	0.2	-
		0.5	0.2	0.4	0.3	0.2	<0.1	0.1
		1.8	0.8	1.2	1.2	0.9	0.7	0.3

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APPENDIX I

Table IV. (cont'd)

	Sampling date	Bush Creek Lower	Bush Creek Mid	Bush Creek Upper	Holland Creek Lower	Holland Creek Mid	Holland Creek Upper	Haslam Creek*
Silicates (µg-at Si/l)		107.9	187.9	154.3	112.9	76.5	79.9	-
		30.0	31.0	30.0	22.8	24.8	23.8	-
		34.1	20.9	15.7	14.1	11.1	8.6	17.1
		142.6	147.6	138.6	110.6	89.6	78.6	135.6
Sulphates (ppm)		27.0	15.0	5.0	7.0	6.0	7.0	-
		4.1	4.6	4.0	4.1	5.4	5.2	-
		2.8	2.8	3.3	2.7	2.7	3.9	3.2
		5.1	6.7	5.3	5.2	5.4	5.0	6.6

*Water samples taken just upstream of Island highway crossing.