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A BASELINE INVENTORY OF JUVENILE SALMONID POPULATIONS AND HABITATS IN STREAMS IN CAPITOL FOREST, WASHINGTON 1981-1982

by

Randy E. Carman, Carl J. Cederholm, and Ernest O. Salo

Progress Report for Sampling During 1981 and 1982

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R. E. Carman[1], C. J. Cederholm[2], and E. O. Salo[1]

ABSTRACT

During the summers of 1981 and 1982, juvenile salmonid populations were censused at stream study sites within the five drainage basins in Capitol Forest, Washington. Physical features within each 50 to 70 meter long study section were measured to define the types of habitat available and their relationship to salmonid biomass.

Relative biomass (g/m^2) estimates within study sections for 1981 and 1982 respectively ranged: coho salmon (Oncorhynchus kisutch) 0.00-1.18 and 0.00-1.49; yearling and older steelhead-rainbow trout (Salmo gairdneri) 0.00-1.52 and 0.00-1.96; yearling and older cutthroat trout (Salmo clarki) 0.10-2.51 and 0.30-2.39; subyearling trout (both steelhead and cutthroat) 0.00-0.86 and 0.00-0.44; total salmonids 0.54-3.49 and 0.90-3.34. The relative biomass values for Capitol Forest streams are substanially below the average for Pacific Northwest streams for all salmonid species present except steelhead-rainbow trout.

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Between the summers of 1981 and 1982, total salmonid relative-biomass increased at ten stations and decreased at seven. Biomass increases ranged from 10-82 percent ($\bar{X}$=24%, SD=22.8) while decreases ranged from 10-70 percent ($\bar{X}$=31%, SD=21.0). The overall mean change in relative biomass, without including the direction of change, was 30.2 percent (SD=21.5).

Physical habitat measurements showed significant correlations with biomass estimates during both years. For 1981, coho were positively correlated with percent pool area and negatively correlated with gradient. Subyearling 'trout' and yearling and older steelhead-rainbow trout were both negatively correlated with percent pool area. During 1982, coho relative biomass was positively correlated with percent pool area and mean depth but negatively correlated with gradient. Subyearling trout were positively correlated with mid-September discharge and a significant negative correlation was found between steelhead-rainbow trout and percent pool area. Cutthroat trout showed a positive correlation with percent total water surface area with instream cover. Significant positive correlations were also found between total salmonid relative biomass and both mean depth and instream cover area.

In 1982, sampling of six 100 m-long study sections during mid-July and mid-September showed a 26 percent average decline in coho abundance. During this same time cutthroat trout abundance declined an average of 22 percent at three stations, increased an average of 56 percent at two stations, and remained stationary at one site.

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A BASELINE INVENTORY OF JUVENILE SALMONID POPULATIONS AND HABITATS IN STREAMS IN CAPITOL FOREST, WASHINGTON 1981-1982

INTRODUCTION

The Capitol Forest is a 311 km^2 (120 mi^2) block of State trust land managed by the Washington State Department of Natural Resources (DNR). The forest is 24 km (15 mi) southwest of Olympia in Thurston and Grays Harbor Counties (Fig. 1). Originally logged in the 1920's and 1930's, the forest is now approaching the time for second growth harvest to begin. The DNR plans to convert the Capitol Forest management plan to an "evenflow harvest" during the next rotation, harvesting approximately 4.1 km^2 (1.6 mi^2) per year.

The DNR is also developing a multiple-use approach to management of these lands with emphasis on timber, recreation, water, wildlife, and fisheries. This multiple-use approach involves identification of a primary use, timber production, while providing other compatible uses. Guidelines in land management are therefore being established with the intention of minimizing conflicts among resource uses. The Capitol Forest management plan, then, represents the foundation for monitoring of current forest management practices upon which will be built the DNR's future statewide forest management activities.

An integral part of any management strategy is an inventory of the natural resources that actually or potentially exist on the lands. The DNR has developed information on the timber within the forest, but is only now beginning surveys of the nontimber resources. During the summer and winter of 1981 and 1982 the DNR initiated two parallel studies on the Captiol Forest,

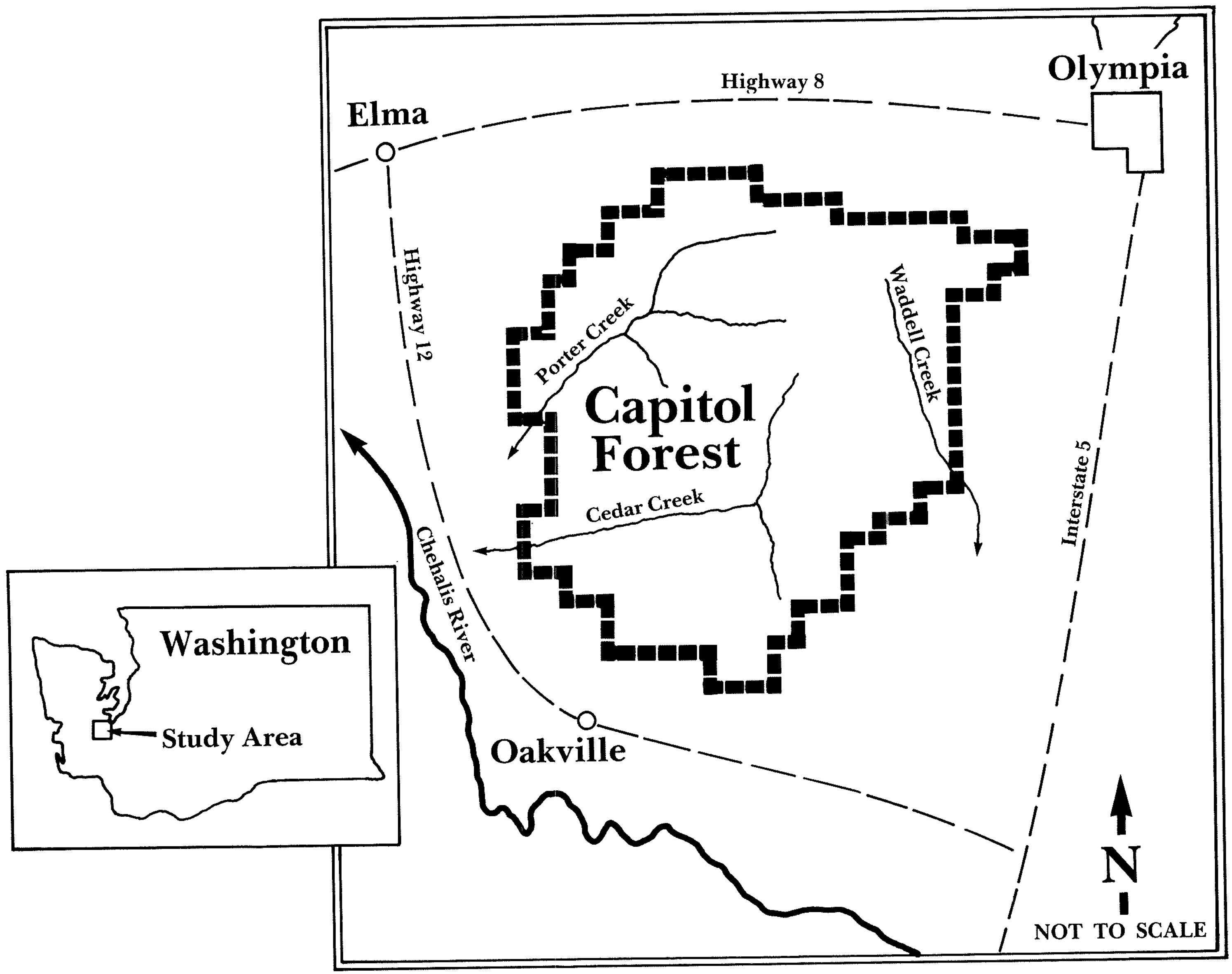


Fig. 1. Location map of Capitol Forest study area.

inventorying the water resources and the fisheries habitats and populations within the forest. This report concerns the fisheries aspect of these investigations.

Some factors previously assumed to be limiting salmonid production in Capitol Forest streams (Phinney and Bucknell 1975) were:

1. barriers to anadromous migration,
2. high summer water temperatures,
3. low summer stream-flows,
4. siltation of spawning and rearing environments,
5. limited amounts of rearing area.

Future forest management activities could have either positive or negative impacts on these streams and their fisheries resources. The purpose of the 1981-82 Capitol Forest baseline inventory was to provide knowledge of the juvenile fisheries resources in the forest. Therefore, during the 1981 and 1982 field seasons we developed an inventory on each of the major drainages within the forest. The objectives were to determine the relative abundance of juvenile salmonids, and the abundance and quality of rearing habitats in Cedar-Sherman, Porter, Waddell, Gibson, and Mima Creeks.

DESCRIPTION OF STUDY AREA

The Capitol Forest is located approximately 24 km southwest of Olympia and covers an area of nearly 311 km^2. The forest was initially logged in the 1920's and 1930's and is now almost exclusively a second growth forest.

Climate

The climate in Capitol Forest is characterized by warm, dry summers with cool, wet weather during the fall, winter, and spring. Annual precipitation for the Capitol Forest area varies from 127 to 178 cm (50 to 70 in.) and occurs predominantly in the form of rain (McMurphy and Anderson 1968). During the winter, however, snow may accumulate in the foothills and remain for several weeks. Summer and winter temperature extremes are moderated by marine air flows from both Puget Sound and the Pacific Ocean. The annual mean temperature for the area is 10.4°C (50.8°F) with extremes ranging from -18.3°C (-1°F) to 39.4°C (103°F) (Phillips 1964).

Geology and Soils

Bedrock within the Capitol Forest mainly consists of basalt flows termed the Crescent Formation (McMurphy and Anderson 1968). Deposited by volcanoes during the early and middle Eocene epoch, the Crescent Formation has formed deep, well-drained silt and clay loams in areas of gentle topography, while steeper terrains exhibit more shallow soils with a higher gravel content. In the western and southwestern portion of Capitol Forest sedimentary deposits of siltstone and sandstone from the Oligocene and Miocene epochs have formed residual soils of well-drained silt and clay loams, similar to the Crescent Formation soils. In areas of steeper slope, these residual soils formed from siltstone and sandstone have a high potential for mass-wasting following disturbance (Ken Schlichte, DNR, personal communication).

Soils within Capitol Forest were formed over mostly unglaciated terrain with the exception of the lower elevations near the eastern and northern boundaries. These lower elevation areas are covered with deposits of till, outwash, and lacustrine material from glacial activity. Soils within these areas show considerably less weathering and soil profile development than is present in soils formed on nearby unglaciated terrain (Ken Schlichte, DNR, personal communication).

Soil conditions within the riparian areas of Capitol Forest exhibit a wide range of variability thereby precluding a concise characterization. Riparian area soil types are also frequently different than those found in adjacent upland areas.

Vegetation

The overstory vegetation at the lower elevations of the Capitol Forest consists predominantly of Douglas Fir (Psuedotsuga menziesii) associated with western hemlock (Tsuga heterophylla) and western red cedar (Thuja plicata), along with such hardwood species as red alder (Alnus rubra), big-leaf maple (Acer macrophyllum), vine maple (Acer circinatum), cottonwood (Populus sp.), and willow (Salix sp.). The higher terrain supports a sparse, mixed overstory of Douglas fir, western hemlock, silver fir (Abies amabilis), and Noble fir (Abies procera). Much of the area above 457 m (1,500 ft.) supports little or no natural coniferous species because of past logging, repeated burns, and shallow droughty soils (McMurphy and Anderson 1968). Pure stands of red alder can be found in very wet areas and as a mixture with Douglas fir, hemlock, and western red cedar in the less wet areas.

Drainages

There are five major stream drainages in Capitol Forest, all flowing either directly or indirectly into the Chehalis River. The Cedar-Sherman

Creek drainage covers an area of 102 km^2 with approximately 72 km of stream accessible to anadromous fishes and a drainage density of 3.48. The Porter Creek drainage covers an area of 127 km^2 with approximately 64 km of stream accessible to anadromous fishes and a drainage density of 2.55. Waddell Creek drainage covers an area of 42 km^2 with approximately 26 km of stream accessible to anadromous fishes and a drainage density of 3.47. The Gibson Creek drainage covers an area of 18 km^2 with approximately 18 km of stream accessible to anadromous fishes and a drainage density of 2.90. Mima Creek drainage covers an area of 14 km^2 with approximately 11 km of stream accessible to anadromous fishes and a drainage density of 4.31.

Fish Species

There are five species of salmonids which utilize the major streams and their tributaries in Capitol Forest. These species are: chinook salmon (*Oncorhynchus tshawytscha*) and chum salmon (*O. keta*), both of which mainly reside outside the Capitol Forest boundaries; and coho salmon (*O. kisutch*), steelhead-rainbow trout (*Salmo gairdneri*), and cutthroat trout (*S. clarki*), each present within the forest boundaries. There are also at least seven non-salmonid species of fish in streams within the forest boundaries: the torrent (*Cottus rhotheus*), prickly (*C. asper*), and coastrange sculpin (*C. aleuticus*), western speckled dace (*Rhinichthys osculus*), longnose dace (*R. cataractae*), western brook lamprey (*Lampetra richardsoni*), and Pacific lamprey (*Entosphenus tridentatus*).

METHODS

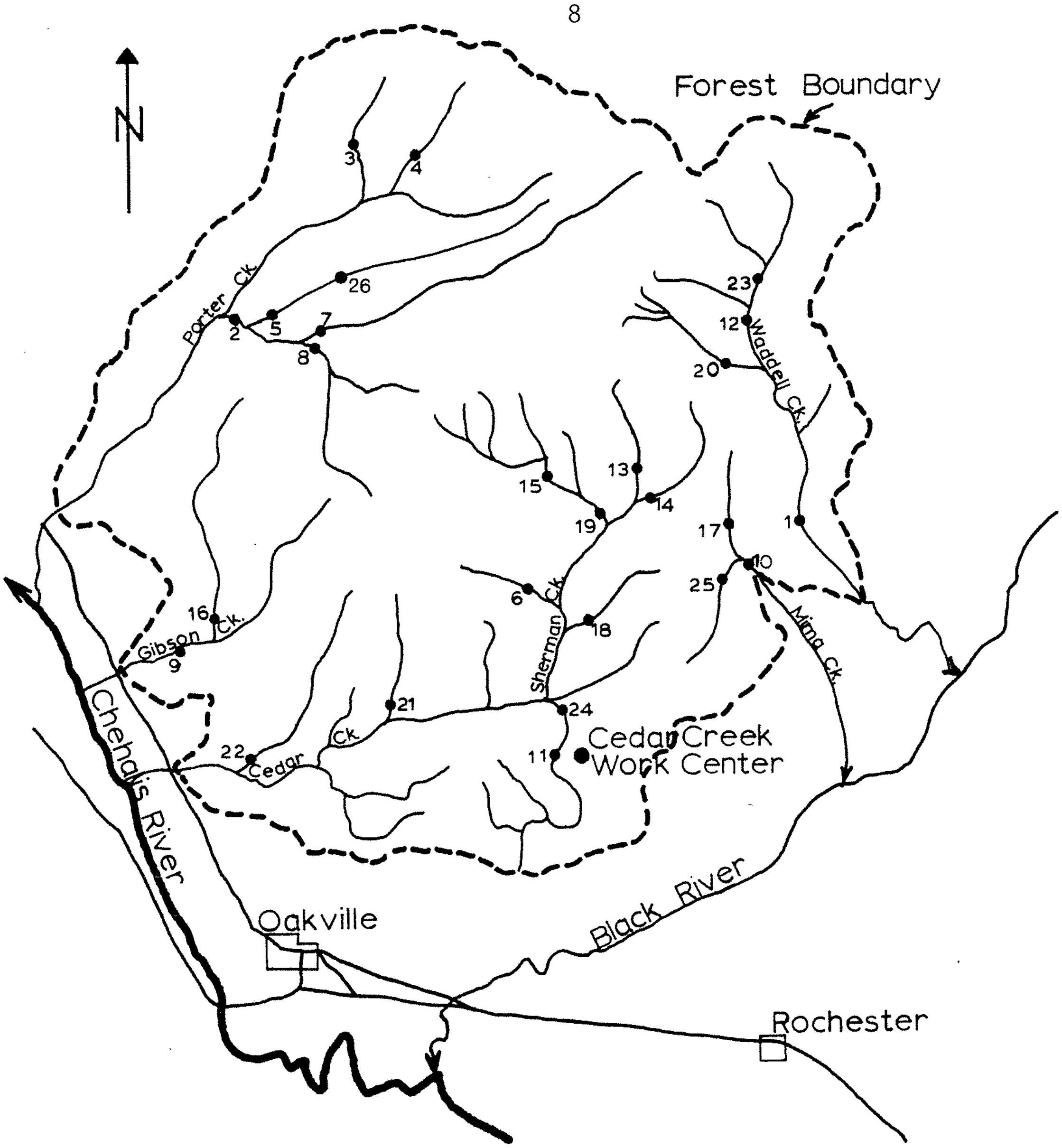
Watershed Surveys

In June, 1981, foot surveys were made for suitable study sections in the five watersheds. Beginning at the mouth of the tributary, or in some cases an easily accessible reference point, streams were measured along the thalweg using a cloth tape. Flaggings were placed at the beginning and at intervals of 152 meters (500 feet) along the stream. Physical characteristics (width, substrate, bank material, canopy and debris jams) of the streams were referenced as the survey progressed upstream. About twenty km (14 miles) of streams were surveyed in this manner.

Fish Population and Biomass Estimates

Based on the watershed surveys, 25 representative study sections were chosen for sampling in 1981. In 1982, six sections were removed and a new one added. Most streams contained one study section although some had two (Cedar, Gibson, Monroe, and Mima Creeks), and one contained three (Waddell Creek) (Fig. 2). Sections were 45.7 m (150 feet) in length (with a few longer due to pools at the upstream end) measured along the thalweg of the stream. Wooden stakes were placed on both stream banks above the high water mark at 9.1 m (30 feet) intervals.

To determine fish abundance, each study section was sampled once during mid-August to mid-September. During 1982, six study sections were extended to approximately 100 m in length and sampled once in July and again in September. Stop nets were placed at the downstream and upstream ends of each section during electrofishing with a Smith-Root Type V backpack electrofisher. A pass was made upstream followed by a pass downstream. Fish were held in buckets placed at 9.1 m (30 feet) intervals. Salmonids were anesthetized using MS-



1 Lower Waddell Creek	14 Sherman Creek
2 Main Porter Creek	15 Upper Monroe Creek[2]
3 Bozy Creek[1]	16 Upper Gibson Creek[1]
4 West Fork Porter Creek[1]	17 Upper Mima Creek
5 Lower North Fork Porter Creek	18 Lost Valley Creek
6 Fuzzy Top Creek	19 Lower Monroe Creek
7 South Fork Porter Creek	20 Noski Creek
8 Hell Creek[1]	21 North Creek
9 Lower Gibson Creek	22 Shelton Creek
10 Lower Mima Creek	23 Upper Waddell Creek
11 Upper Cedar Creek	24 Lower Cedar Creek
12 Middle Waddell Creek	25 Mill Creek[1]
13 Fall Creek tributary[1]	26 Upper North Fork Porter Creek[3]

[1]Sampled in 1981 only.

[2]1982 sampling location approximately 670 m downstream from 1981 station.

[3]Sampled in 1982 only.

Fig. 2. Locations of study sites in Capitol Forest streams.

222, measured to the nearest millimeter (fork length), weighed to the nearest 0.1 g using an Ohaus dial-gram balance, and the dorsal lobe of the caudal fin was nipped. Population estimates of non-salmonid species (i.e., dace, sculpins or lampreys), were not attempted. After processing and recovery the fish were returned to their location of capture. Following a one-hour recovery period to allow redistribution of marked fish the shocking procedure was repeated (Peterson and Cederholm 1984). During the recapture, only the unmarked fish were weighed while both marked and unmarked fish were measured for length.

Population estimates were calculated using the Chapman modification of the Petersen equation (Chapman 1951):

$$\hat{N} = \frac{(m+1)(c+1)}{(r+1)} - 1$$

where $\hat{N}$ = population estimate

m = total number of marked fish

c = total number of fish in recapture sample

r = number of recaptured marked fish

Confidence limits (95%) were calculated for each population point estimate using the standard error of estimate formula from Robson and Regier (1971):

$$\text{S.E.}\ (\hat{N}) = \hat{N}\sqrt{\frac{(\hat{N}-m)(\hat{N}-c)}{mc(\hat{N}-1)}}$$

95% confidence limits = $\hat{N} \pm 2$ (standard error)

Age groups were determined using length-frequency distributions and scales. Cutthroat and steelhead-rainbow trout were divided into two groups, subyearling and yearling and older. Due to the difficulty in field recognition of 0-age steelhead-rainbow and 0-age cutthroat trout, these fish were collectively classified as "young-of-the-year trout".

Length and weight data pairs covering the size range of each species were used to determine predictive length-weight relationships for each species or subgroup. Linear regression of the natural logarithm of weight on the natural logarithm of length was used to determine (a) and (b) in the allometric equation $W = aL^b$ (Ricker 1975):

$$\ln W = \ln a + b (\ln L)$$

where W = fish weight in grams and L = length in mm.

Average weights corresponding to average lengths were then used to calculate biomass. The product of the mean weight of a fish in an age group and the population estimate of that age group was the computed biomass (Ricker 1975):

$$\hat{B} = \hat{\bar{W}} \hat{N}$$

where $\hat{B}$ = biomass estimate in grams

$\hat{\bar{W}}$ = mean weight estimate in grams

$\hat{N}$ = population estimate

Biomass estimates (both absolute and relative) were computed for each species by age group. The summation of these estimates equaled the total salmonid biomass.

Salmonid Biomass Comparisons

Differences between relative biomass estimates from Capitol Forest and those from other areas of the Pacific Northwest were intially tested using a nonparametric Kruskal-Wallis single factor analysis of variance by ranks (Zar 1974). To determine specifically which groups had relative biomass estimates significantly higher than Capitol Forest a nonparametric test paralleling a

Dunnett test but using group rank sums instead of group means was employed (Zar 1974). Nonparametric statistics were applied to these data primarily because of the large variance differences between tested groups and non-random selection of study sites. A major underlying assumption of parametric analysis of variance is homogeneity of variances. Whereas severe deviations from this assumption can increase the probability of a Type I error (rejection of the null hypothesis when it is true) in parametric analysis, they will not affect the nonparametric procedures used (Siegel 1956).

Habitat Measurements and Classification

To determine the physical characteristics of study sections, several habitat measurements and classifications were employed. Width and depth measurements were taken every 4.6 m (15.0 feet) to quantify the living space available in each section. Depths were taken at stream center and at one-quarter of the stream width from either bank. The water surface area was divided into pool and riffle categories with measurements taken only on the less abundant area. The total water surface area minus this value equaled the area of the remaining category. Gradient within a section was measured using two equal length staffs and a hand sighting level. Staffs were placed at the water surface 9.1 m (30 feet) apart and the difference in elevations was recorded working upstream. Water temperatures were taken upon arrival (morning) and just prior to leaving (afternoon) a sampling site. Discharge measurements were taken at all study sections between 14-16 September 1982 (except M. Porter-Sept. 8 and L. Waddell-Sept. 9) using a Marsh-McBirney Model 201 flowmeter.

During 1981, instream cover was measured within each section as the linear distance of the cover actually extending into the water. Generally, this included root wads, logs, undercut banks with vegetation or roots in the stream, and various types of woody debris. During 1982, instream cover was divided into categories of undercut banks, logs, and debris piles, with measurements made on the total area at the water surface of each cover type. No attempt was made to quantify cover that was not directly in the stream (i.e., overhead cover or streamside riparian vegetation).

Stream order was determined using 2-1/2 inch-to-the-mile State Water Typing Maps with the smallest visible unbranched tributaries being considered as first order (Strahler 1957).

The dominant substrate was visually categorized according to a classification of channel materials from Platts (1979): boulders, 304.8 mm (12 inches) or over; rubble, 76.1 to 304.7 mm (3 to 11.9 inches); gravel 4.7 to 76.0 mm (0.18 to 2.9 inches); and silt, less than 4.7 mm (0.17 inch or less). Dominant substrate was defined as that channel material which covered the largest portion of the wetted streambed within a section.

The largest pool within each section was selected for classification of its quality as fish habitat based on its relative width, depth, and amount of cover (Table 1).

A classification system was developed during 1981 to allow a quick visual assessment of the major physical characteristics within a section of stream selected as a study site. The general approach was to visually assess the stream characteristics within a study section and then assign a numerical rating from zero to five (with a plus or minus for fine tuning if necessary) to that section of stream. Prior to classification of actual study sites,

Table 1. Pool quality designations used in Capitol Forest study sections during 1981 (from Platts 1979).

Description	Class
Maximum pool diameter exceeds average stream width, depth is over 1 m or over 0.6 m with abundant fish cover.	5
Maximum pool diameter exceeds average stream width, depth is less than 0.6 m or, if between 0.6 m and 1 m, lacks fish cover.	4
Maximum pool diameter less than average stream width, depth over 0.6 m with intermediate to abundant cover.	3
Maximum pool diameter less than average stream width, depth less than 0.6 m with intermediate to abundant cover.	2
Maximum pool diameter less than average stream width, depth less than 0.6 m, no fish cover.	1

field personnel independently rated sample stream sections and compared results in order to standardize methods. Classifications were made only on those sections of stream designated as electrofishing stations and were meant only to apply to that section of stream during summer low-flow.

The physical characteristics used to classify a stream section included the pool-riffle composition, water velocity, gradient, and substrate (Table 2). Physical measurements of these variables were not made until after a classification had been decided upon. The purpose of this was to test the reliability of a visual judgement of these characteristics in relation to the classification scheme. Also of interest was whether the visual classification could provide a reasonably accurate indication of the physical characteristics in a study section. This was tested by correlation analysis between the various physical parameters measured and the stream class designation for each section. Stream class was also tested against the relative biomass estimates for each salmonid species to determine significant correlations.

Habitat Use

To identify which physical variables in the stream environment relate to fish abundance in Capitol Forest, correlation analysis was run between the relative biomass estimates for each species or subgroup and the various habitat measurements: (1) percent pool area, (2) percent riffle area, (3) percent gradient, (4) mean depth, and (5) linear distance of instream cover. Additional habitat variables tested in 1982 included: area of instream cover (m^2) (replacing linear distance), percent of total water surface area with instream cover, and mid-September discharge. Percent pool, percent riffle, and percent of total water surface area with instream cover were all

Table 2. Physical characteristics used to visually classify stream study sections in Capitol Forest during 1981.

Description	Class[1]
Undetectable water velocity, extremely low gradient, no riffles, heavily silted bottom; usually a pond.	0
Slow water velocity, low gradient, relatively large pools with high percentage pool area, riffles small and infrequent, bottom mostly small gravel with silted pools.	1
Slow to moderate water velocity, low gradient, moderate percent pool area with few large pools, more frequent moderate-sized riffles, mostly gravel bottom.	2
Moderate to rapid velocity, moderate gradient, low percent pool area, no large pools, many large riffles, gravel and rubble bottom.	3
Rapid water velocity, high gradient, pool area lacking or absent, frequent riffles with cascades, rubble substrate with boulders usually present.	4
Rapid water velocity, no pool area, bedrock substrate with boulders sometimes present.	5

[1] A plus (+) or minus (-) was sometimes added for study sections in between the descriptions used.

transformed with an arcsine function (Zar 1974).

Statistical significance is referred to throughout this study as a probability level equal to or less than 0.05.

RESULTS

Age Structure

Coho Salmon

Length-frequency analysis of coho salmon indicates that both the 1981 and 1982 late-summer populations consist predominantly of a single age group (Figs. 3 and 4). Two separate modes with a gap in the 93 to 95 mm range indicate that most coho are age zero fish. Scale analysis further supported a division between age groups at this point. Using a break off point of 93 mm for age zero, only 9 (1.8%) of the 1981 coho and 19 (2.4%) of the 1982 coho captured during electrofishing would be age one fish. Due to the low number of yearling fish present, all coho were considered as age zero for further analyses.

Young-of-the-Year Trout

Histograms of the 1981 and 1982 trout populations indicate a distinct mode of sub-yearling fish from 38 to 83 mm (Figs. 5 and 6). Three trout above this size range, which were not identifiable to species in the field during 1981 sampling, were grouped with young-of-the-year trout for population and biomass estimates.

Steelhead-Rainbow Trout

The majority of the 100 steelhead-rainbow trout (>83 mm) captured during 1981 were between 92 and 149 mm in length (Fig. 7). Although this distribution is somewhat uneven, the 1982 steelhead-rainbow (n=104) provided a more normally distributed sample within this range (Fig. 8). Therefore, based on length-frequency distributions, the 1981 and 1982 steelhead-rainbow captured in study sections appear to be primarily yearling fish. A limited amount of scale analysis on steelhead-rainbow captured during 1982 indicated

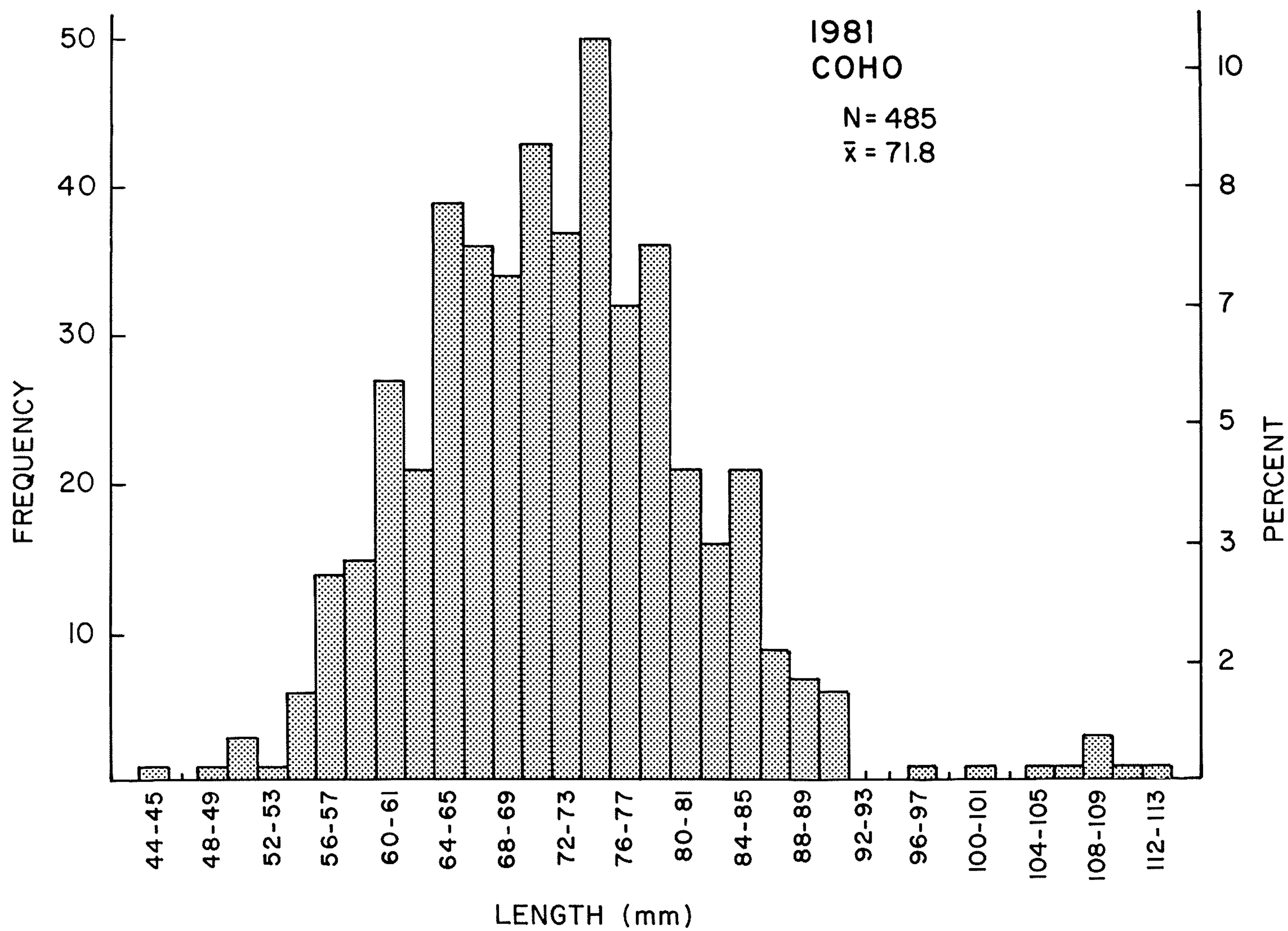


Fig. 3. Length-frequency distribution of coho salmon captured in Capitol Forest study sites during August and September, 1981.

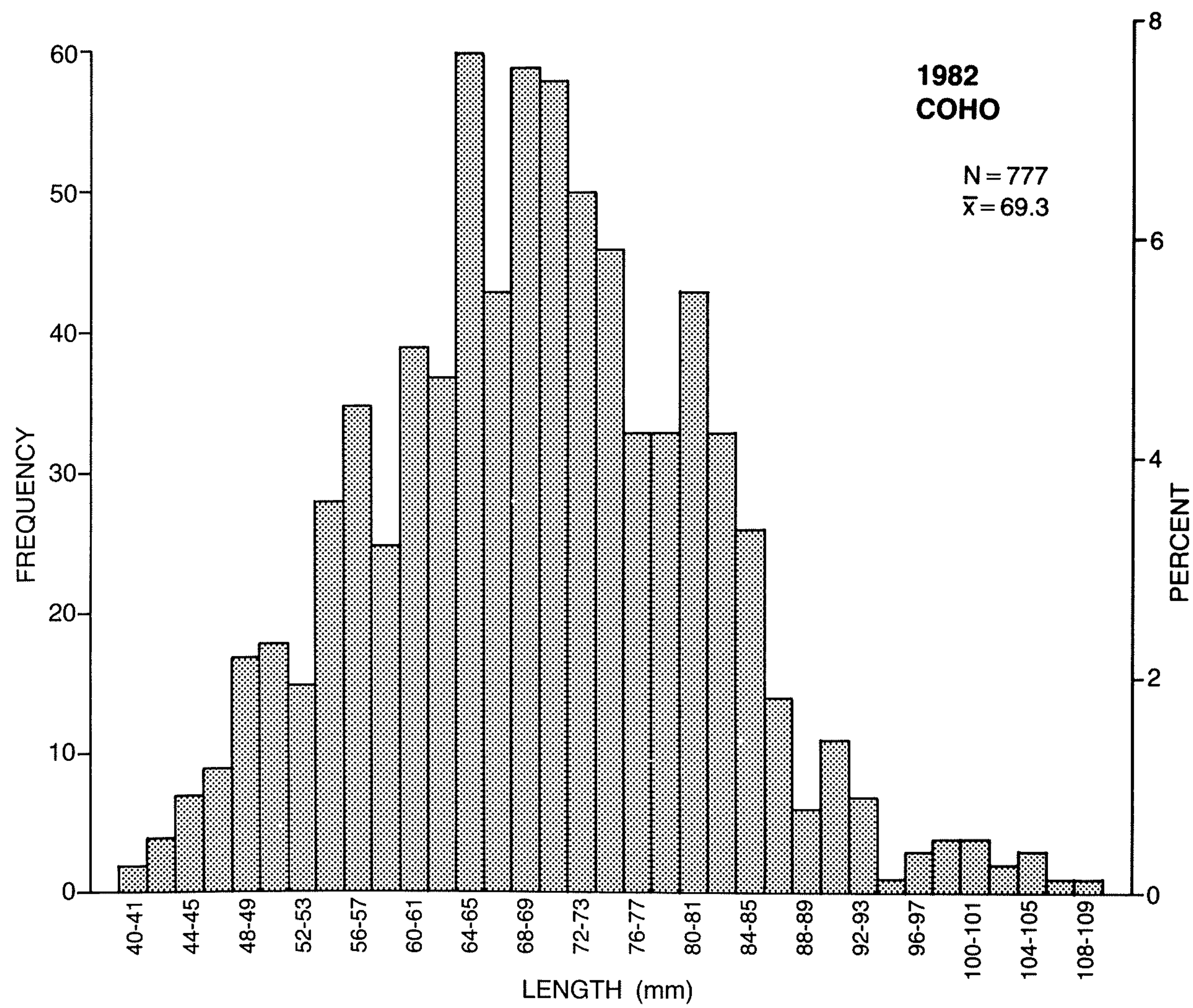


Fig. 4. Length-frequency distribution of coho salmon captured in Capitol Forest study sites during July through September, 1982.

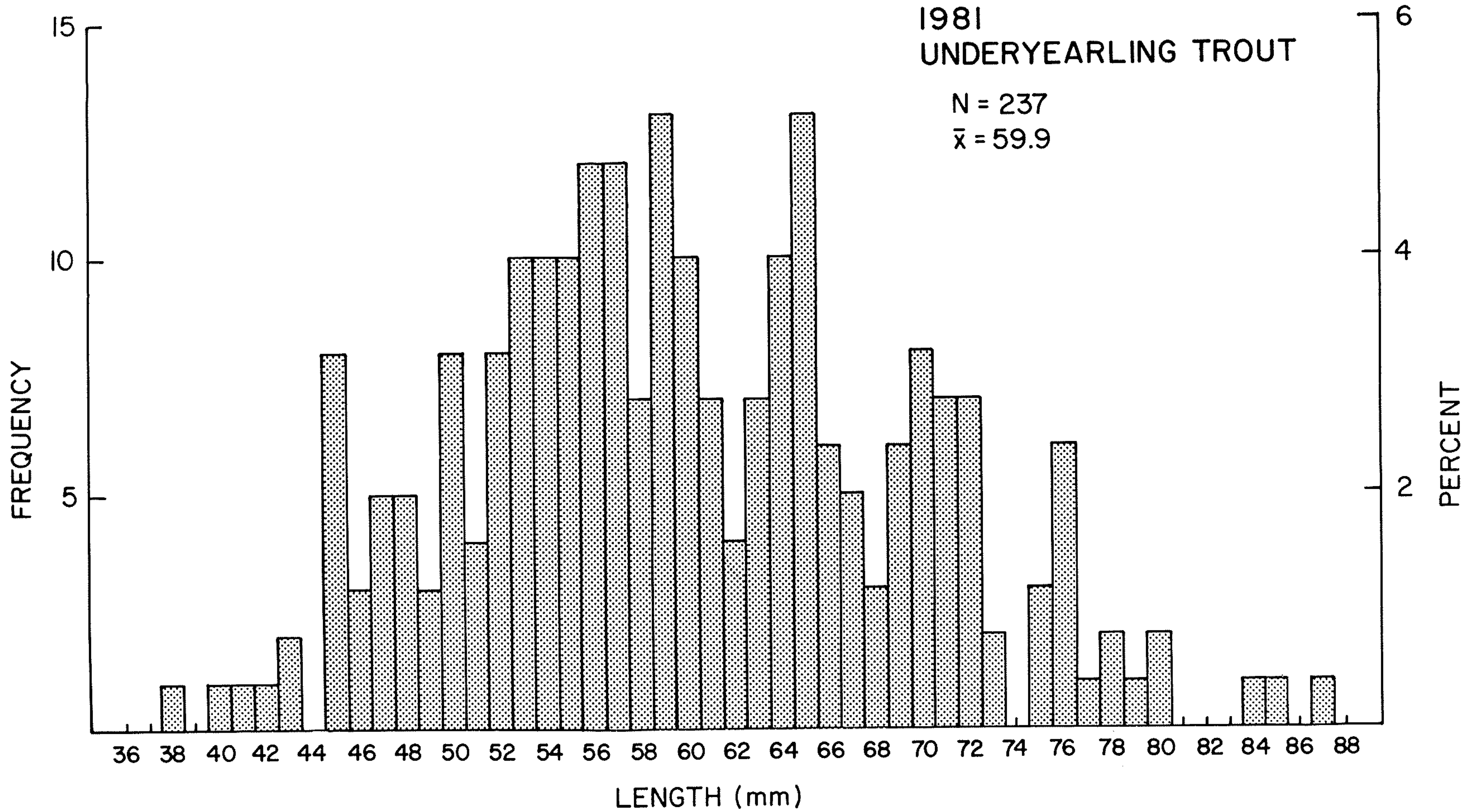


Fig. 5. Length-frequency distribution of young-of-the-year trout (unidentified to species) captured in Capitol Forest study sites during August and September 1981.

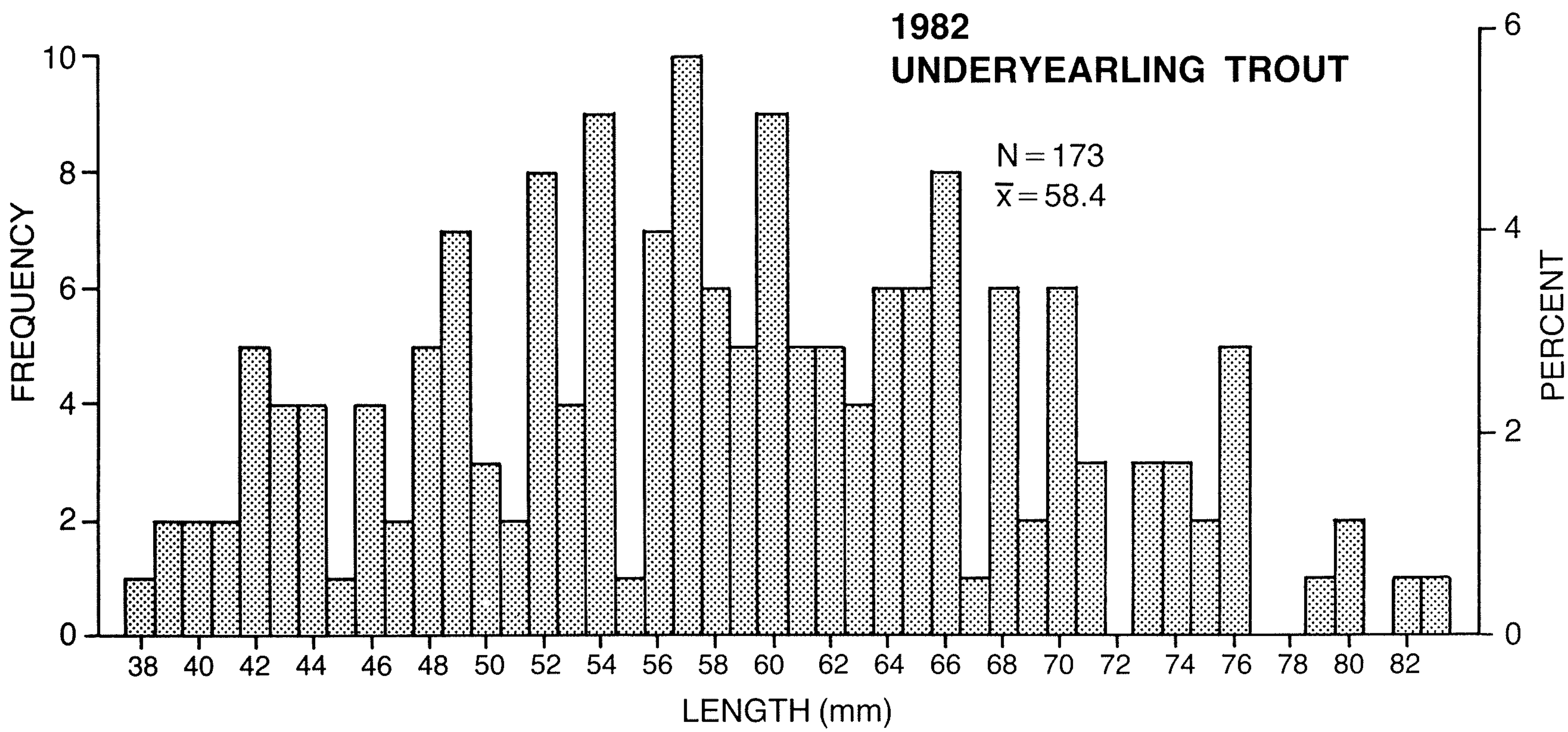


Fig 6. Length-frequency distribution of young-of-the-year trout (unidentified to species) captured in Capitol Forest study sites during July through September, 1982.

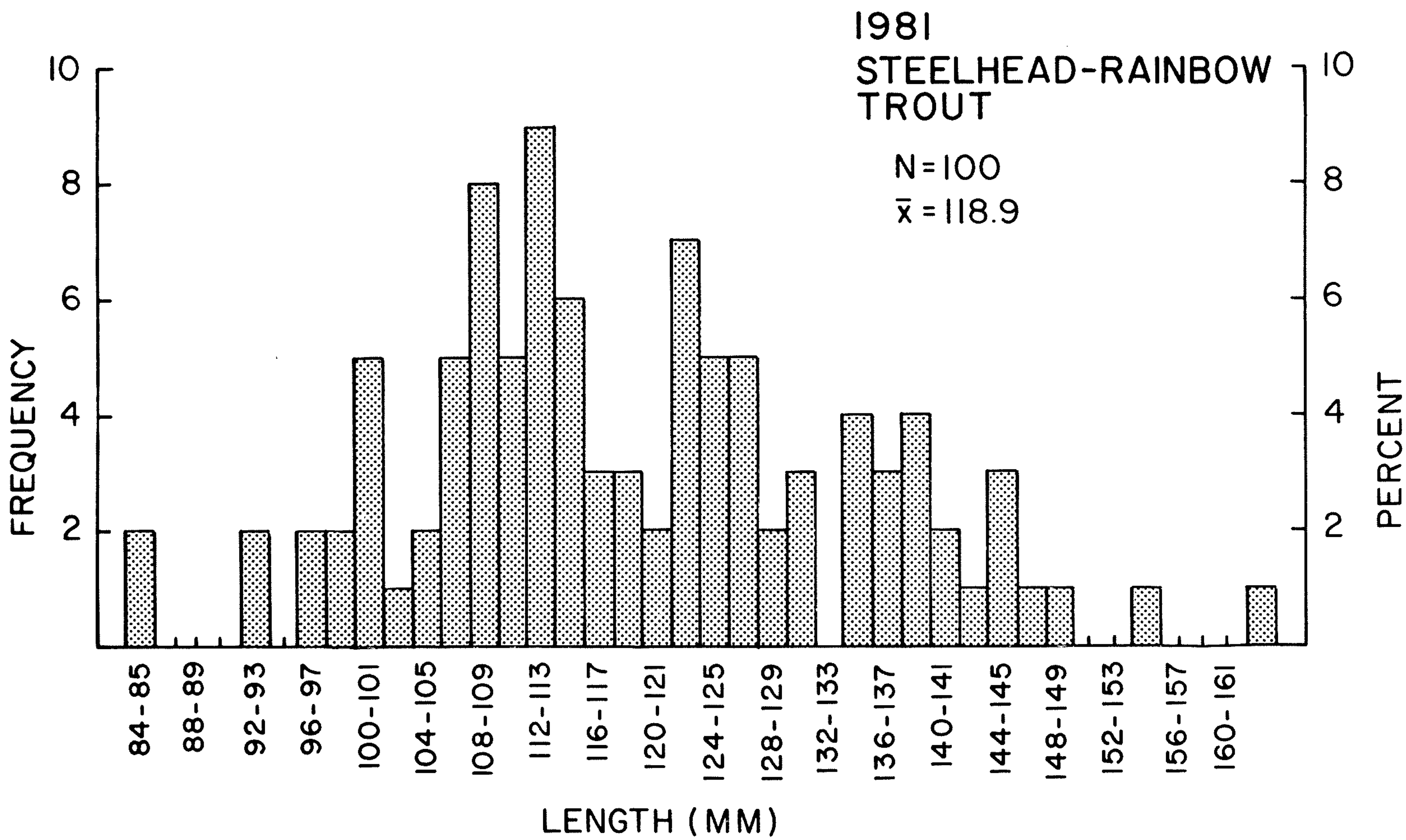


Fig. 7. Length-frequency distribution of steelhead-rainbow trout (>83 mm) captured in Capitol Forest study sites during August and September, 1981.

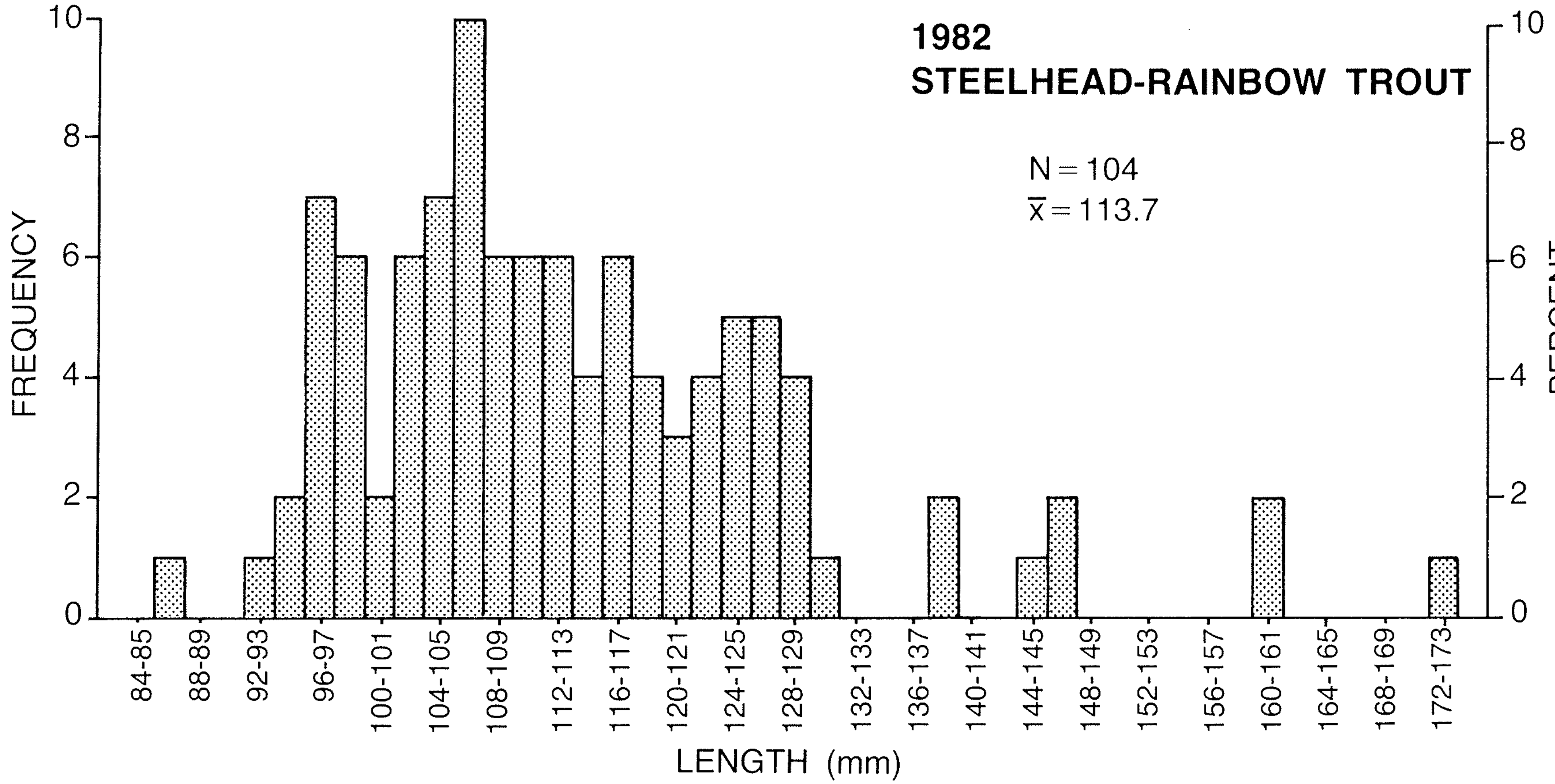


Fig. 8. Length-frequency distribution of steelhead-rainbow trout (>83 mm) captured in Capitol Forest study sites during July through September, 1982.

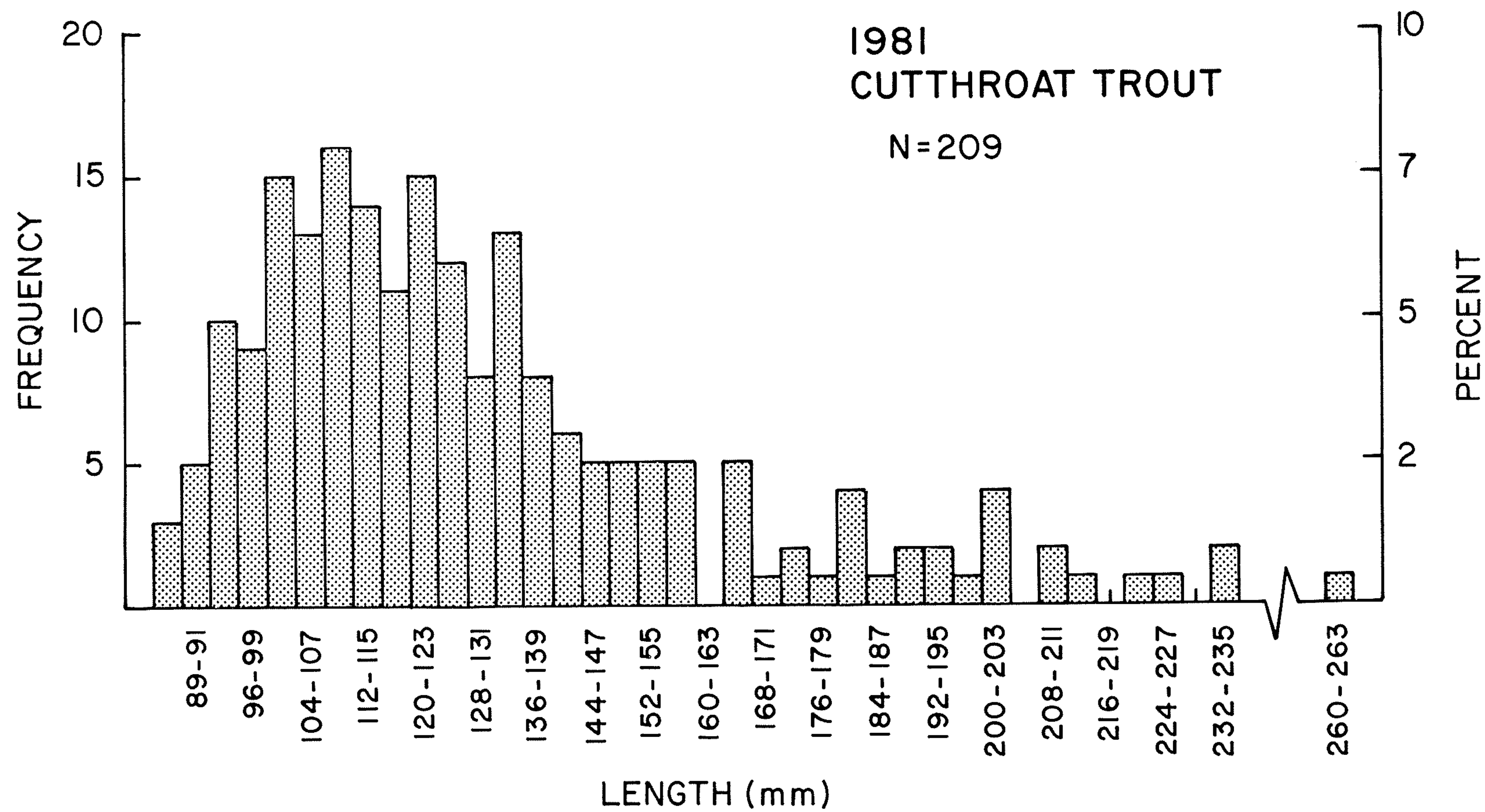


Fig. 9. Length-frequency distribution of cutthroat trout (>83 mm) captured in Capitol Forest study sites during August and September, 1981.

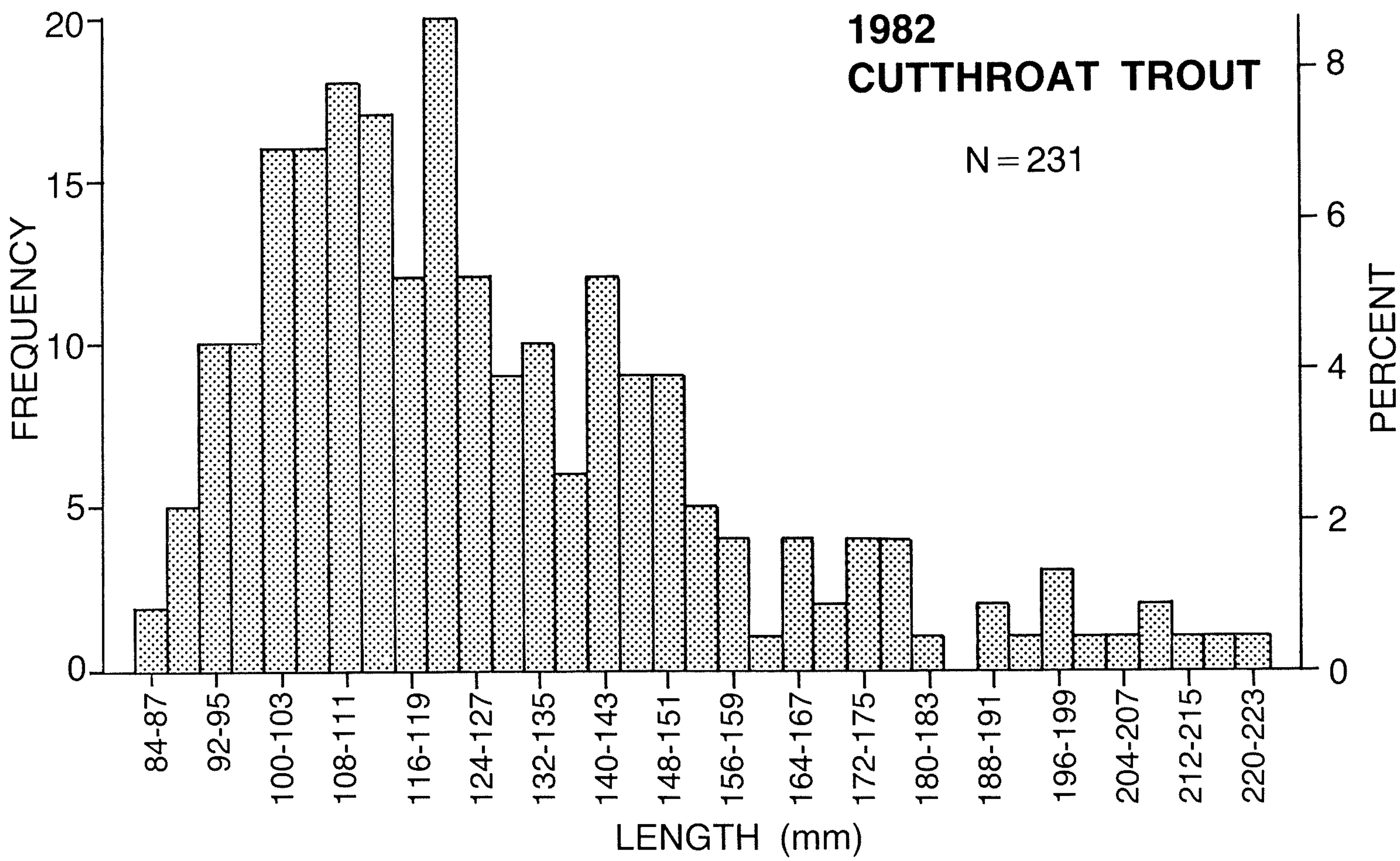


Fig. 10. Length-frequency distribution of cutthroat trout (>83 mm) captured in Capitol Forest study sites during July through September, 1982.

Table 3. Population, density, and biomass estimates for juvenile coho salmon during August and September in streams in Capitol Forest, Washington.

Station number	Station name	Sample year	Population estimate[1]	95% Confidence interval	Absolute biomass (g)	Density (No./m^2)	Relative biomass (g/m^2)
1	Lower Waddell Ck	1981	82	64-103	389.0	0.15	0.71
		1982	152	127-177	859.2	0.25	1.41
2	Main Porter Ck	1981	5	5-10	31.8	0.01	0.08
		1982	17	16-23	103.3	0.04	0.27
3	Bozy Ck	1981	0				
4	W. Fork Porter Ck	1981	0				
5	Lower N. Fork Porter Ck	1981	27	23-35	145.6	0.06	0.34
		1982	69	38-108	321.5	0.18	0.84
6	Fuzzy Top Ck	1981	27	27-30	98.6	0.16	0.57
		1982	78	69-90	221.1	0.45	1.29
7	S. Fork Porter Ck	1981	0				
		1982	13	12-16	52.6	0.07	0.28
8	Hell Ck	1981	0				
9	Lower Gibson Ck	1981	11	5-35	62.0	0.05	0.31
		1982	32	24-47	144.0	0.16	0.70
10	Lower Mima Ck[2]	1981	25	19-38	129.1	0.14	0.72
		1982	69	56-85	245.1	0.38	1.37
11	Upper Cedar Ck	1981	77	57-97	262.0	0.28	0.94
		1982	57	36-85	211.2	0.29	1.09

Table 3. Population, density, and biomass estimates for juvenile coho salmon during August and September in streams in Capitol Forest, Washington--continued

Station number	Station name	Sample year	Population estimate[1]	95% Confidence interval	Absolute biomass (g)	Density (No./m^2)	Relative biomass (g/m^2)
12	Middle Waddell Ck	1981	42	31-56	154.2	0.24	0.88
		1982	33	31-38	147.8	0.17	0.77
13	Fall Ck trib.	1981	8	7-13	40.0	0.08	0.42
14	Sherman Ck	1981	53	45-63	196.5	0.19	0.71
		1982	37	32-46	132.9	0.19	0.69
15	Upper Monroe Ck[3]	1981	25	22-30	99.1	0.15	0.59
		1982	54	36-81	185.9	0.27	0.94
16	Upper Gibson Ck	1981	0				
17	Upper Mima Ck	1981	0				
		1982	0				
18	Lost Valley Ck	1981	15	15-18	74.3	0.15	0.73
		1982	18	18-19	94.0	0.20	1.07
19	Lower Monroe Ck	1981	47	34-65	196.5	0.22	0.92
		1982	78	61-96	232.7	0.38	1.14
20	Noski Ck	1981	35	25-56	146.7	0.22	0.93
		1982	23	20-34	98.2	0.16	0.69
21	North Ck	1981	8	6-14	42.9	0.05	0.26
		1982	0				
22	Shelton Ck	1981	44	43-46	190.2	0.27	1.18
		1982	3	±0	22.1	0.02	0.16

Table 3. Population, density, and biomass estimates for juvenile coho salmon during August and September in streams in Capitol Forest, Washington--continued

Station number	Station name	Sample year	Population estimate[1]	95% Confidence interval	Absolute biomass (g)	Density (No./m^2)	Relative biomass (g/m^2)
23	Upper Waddell Ck	1981	25	23-31	132.9	0.18	0.94
		1982	17	16-21	80.9	0.14	0.66
24	Lower Cedar Ck	1981	39	33-49	151.8	0.22	0.86
		1982	96	73-119	297.7	0.48	1.49
25	Mill Ck	1981	1	±0	4.3	< 0.01	0.04
26	Upper N. Fork Porter Ck	1982	34	32-39	167.2	0.14	0.71

[1]For 50- to 70-m-long study section only.

[2]Coho fry planted above this section by WDF in spring 1982.

[3]Location of study section moved downstream approximately 670 m for 1982 sampling.

estimate, its coho density was equal to the average 1981 value (0.15 fish/m^2) due to its relatively large water surface area.

Relative biomass estimates for stations with coho present ranged from 0.04 (Mill) to 1.18 g/m^2 (Shelton). All three Waddell Creek stations had comparatively high relative biomass estimates (0.71, 0.88 and 0.94 g/m^2) as did the two Cedar Creek stations (0.86 and 0.94 g/m^2).

Grouping the results from stations within a drainage reveals that the Waddell and Cedar-Sherman stations generally exhibited a greater abundance of coho (both absolute and relative) than the Porter, Gibson, and Mima stations.

Coho Salmon - 1982

Of the twenty study sections sampled in 1982, eighteen had juvenile coho. Population estimates for these eighteen stations with coho present ranged from $\hat{N} = 3$ (Shelton) to $\hat{N} = 152$ (Lower Waddell). Stations in the Cedar-Sherman drainage produced a majority of the higher population estimates in 1982 while most of the lower values were from the Porter Creek stations. An exception to the general lack of coho in the Porter study sections was apparent at both the Upper and Lower North Fork stations. Although the large 95% confidence interval weakens the point estimate at the lower station, the Upper North Fork study section had a relatively narrow confidence interval.

When the population estimates are adjusted for the amount of water surface area within a section the highest coho density values are still found at stations in the Cedar-Sherman drainage (e.g., Lower Cedar, Fuzzy Top, Lower Monroe). The lowest density values (with the exception of Shelton) are from the Porter Creek stations. Relative biomass estimates ranged from 0.16 (Shelton) to 1.49 g/m^2 (Lower Cedar) during 1982. Stations with the highest values included Lower Waddell, Lower Mima (planted with hatchery coho by WDF), and Fuzzy Top. Comparatively low values for coho were recorded at Main

Porter, South Fork Porter, and Upper Waddell.

Coho Salmon - Changes in Abundance Between 1981 and 1982

Population estimates for study sections during 1981 and 1982 indicate that considerable variation occurs between years for a given area in Capitol Forest. Estimates show eleven stations had increased coho abundance in 1982 (range 20-204%) and seven had reduced coho populations (range 21-93%). For stations sampled both years, population estimate totals were 562 ($\overline{X}$ = 31.2) and 792 ($\overline{X}$ = 44.0) for 1981 and 1982, respectively.

Although some variation in population size may be due to slightly shorter sections at two locations in 1982 (Upper Cedar and Sherman) and one of greater length (Lower Gibson), considerable changes in coho abundance did occur at several other stations which were of equal length both years. Moreover, comparison of density and relative biomass estimates between the two years, which alleviates the section size problem, indicates substantial abundance differences.

The four study sections in the Waddell Creek drainage varied in their direction of population change between years. Middle Waddell, Upper Waddell, and Noski all had reduced coho abundance in 1982 (-21%, -32%, and -34%, respectively) whereas Lower Waddell coho populations increased by 85 percent (1981 $\hat{N}$ = 82, 1982 $\hat{N}$ = 152). Three Porter Creek stations sampled both years had larger populations in 1982. Substantial increases in coho abundance also occurred in the Lower Cedar (1981 $\hat{N}$ = 39, 1982 $\hat{N}$ = 96) and Lower Mima stations (1981 $\hat{N}$ = 25, 1982 $\hat{N}$ = 69). Recall that the Lower Mima section is located approximately 200 m downstream of an area heavily planted with coho fry in the spring of 1982.

The most dramatic change in coho abundance was the extreme reduction between years at the Shelton Creek station. Population estimates for 1982 showed a 93 percent decline in coho (1981 $\hat{N}$ = 44, 1982 $\hat{N}$ = 3).

Density and relative biomass estimates generally fluctuated in a pattern similar to that shown by the population estimates. Annual variation in coho relative biomass was highest at Shelton Creek (1981 = 1.18 g/m^2, 1982 = 0.16 g/m^2) and lowest at Sherman Creek (1981 = 0.71 g/m^2, 1982 = 0.69 g/m^2).

Young-of-the-Year Trout

Subyearling trout (steelhead-rainbow and cutthroat) were present at twenty of the 1981 sampling locations and twelve of the 1982 locations. Of those stations sampled both years, six contained young-of-the-year trout in 1981 but not 1982 and two (Sherman and Lost Valley) had no subyearling trout either year. Study sections which supported subyearling trout populations in 1981, but not 1982, generally had very low levels of abundance of these fish during the first year.

Population estimates for young-of-the-year trout ranged from $\hat{N}$ = 0-140 during 1981 and $\hat{N}$ = 0-83 for 1982 (Table 4). Mean values for these estimates were 13.9 and 11.3 for 1981 and 1982, respectively.

These mean values are somewhat misleading due to the large range in abundance between study sections. In 1982, only five locations had underyearling trout populations greater than 25, while seventeen locations contained fewer than 5 fish. In 1982, only two locations supported more than 25 underyearling trout and fourteen study sections had less than 5 fish. The mean abundance value, therefore, is substantially increased by a small percentage of the study sections which support comparatively high subyearling trout populations.

Stations with the largest populations of underyearling trout were almost exclusively from the Porter Creek drainage for 1981 and 1982. Notable exceptions to this are the relatively high population estimates for Lower

Table 4. Population, density, and biomass estimates for young-of-the-year trout (unidentified to species) during August and September in streams in Capitol Forest, Washington.

Station number	Station name	Sample year	Population estimate[1]	95% Confidence interval	Absolute biomass (g)	Density (No./m^2)	Relative biomass (g/m^2)
1	Lower Waddell Ck	1981	37	17-82	93.4	0.07	0.17
		1982	83	46-127	190.8	0.14	0.31
2	Main Porter Ck	1981	140	79-197	324.5	0.34	0.86
		1982	65	54-79	169.2	0.17	0.44
3	Bozy Ck	1981	0				
4	W. Fork Porter Ck	1981	2	±0	4.6	0.01	0.03
5	Lower N. Fork Porter Ck	1981	51	39-69	98.3	0.12	0.23
		1982	21	16-33	37.1	0.05	0.10
6	Fuzzy Top Ck	1981	1	±0	3.4	< 0.01	0.02
		1982	1	±0	1.1	< 0.01	< 0.01
7	S. Fork Porter Ck	1981	30	24-40	54.1	0.15	0.26
		1982	15	14-19	18.9	0.08	0.10
8	Hell Ck	1981	37	28-50	82.1	0.15	0.34
9	Lower Gibson Ck	1981	3	±0	12.9	0.01	0.06
		1982	4	3-9	15.4	0.02	0.07
10	Lower Mima Ck	1981	0				
		1982	3	±0	4.1	0.02	0.02
11	Upper Cedar Ck	1981	0				
		1982	1	±0	1.7	< 0.01	< 0.01

Table 4. Population, density, and biomass estimates for young-of-the-year trout (unidentified to species) during August and September in streams in Capitol Forest, Washington--continued

Station number	Station name	Sample year	Population estimate[1]	95% Confidence interval	Absolute biomass (g)	Density (No./m^2)	Relative biomass (g/m^2)
12	Middle Waddell Ck	1981	2	±0	3.7	0.01	0.02
		1982	0				
13	Fall Ck trib.	1981	1	±0	3.5	0.01	0.04
14	Sherman Ck	1981	0				
		1982	0				
15	Upper Monroe Ck[2]	1981	1	±0	1.6	< 0.01	< 0.01
		1982	0				
16	Upper Gibson Ck	1981	10	7-15	40.3	0.07	0.29
17	Upper Mima Ck	1981	18	13-29	46.4	0.10	0.27
		1982	10	10-11	30.0	0.07	0.22
18	Lost Valley Ck	1981	0				
		1982	0				
19	Lower Monroe Ck	1981	1	±0	2.0	< 0.01	< 0.01
		1982	1	±0	2.8	< 0.01	0.01
20	Noski Ck	1981	1	±0	1.7	< 0.01	0.01
		1982	0				
21	North Ck	1981	2	±0	6.1	0.01	0.04
		1982	4	±0	16.7	0.02	0.10
22	Shelton Ck	1981	1	±0	3.0	< 0.01	0.02
		1982	0				

Table 4. Population, density, and biomass estimates for young-of-the-year trout (unidentified to species) during August and September in streams in Capitol Forest, Washington--continued

Station number	Station name	Sample year	Population estimate[1]	95% Confidence interval	Absolute biomass (g)	Density (No./m^2)	Relative biomass (g/m^2)
23	Upper Waddell Ck	1981	2	±0	4.9	0.01	0.04
		1982	0				
24	Lower Cedar Ck	1981	1	±0	2.4	< 0.01	0.01
		1982	0				
25	Mill Ck	1981	7	±0	22.9	0.06	0.19
26	Upper N. Fork Porter Ck	1982	18	15-24	36.1	0.08	0.15

[1]For 50- to 70-m-long study section only.

[2]Location of study section moved downstream approximately 670 m for 1982 sampling.

Waddell and Upper Mima.

Densities ranged from 0.0 to 0.34 fish/m^2 ($\overline{X}$ = 0.05) in 1981, and from 0.0 to 0.17 fish/m^2 ($\overline{X}$ = 0.06) for 1982. General trends are similar to those shown by the population estimates with the highest density value occurring at Main Porter for both years.

Relative biomass estimates ranged from 0.0 to 0.86 g/m^2 ($\overline{X}$ = 0.12) for 1981, and from 0.0 to 0.44 g/m^2 ($\overline{X}$ = 0.02) in 1982. Main Porter again had the highest value for both years. Other stations in the Porter Creek drainage and Lower Waddell also had comparatively high relative biomass values for underyearling trout.

Nearly all stations that were sampled both years had fewer subyearling trout in 1982. This trend was especially noticeable at stations which supported relatively large populations in 1981. Most of these stations had a greater than 50 percent reduction in subyearling trout population size between 1981 and 1982. One exception to this was Lower Waddell, which increased its standing stock estimate by 124 percent (1981 $\hat{N}$ = 37, 1982 $\hat{N}$ = 83).

Cutthroat Trout

Yearling and older cutthroat trout (>83 mm) were present at every study site within the forest during 1981 and 1982. These populations are most likely a mixture of anadromous and resident fish.

Population estimates for cutthroat ranged from $\hat{N}$ = 1-22 ($\overline{X}$ = 9.2) for 1981, and from $\hat{N}$ = 3-23 ($\overline{X}$ = 9.1) for 1982 (Table 5). Stations in Waddell Creek supported the largest populations of cutthroat in 1981 while Fuzzy Top, Upper Waddell, and Upper Mima had the highest levels of abundance in 1982. Relatively small populations of cutthroat were found at Main Porter, Lower Cedar, and Hell Creek.

Density estimates ranged from less than 0.01 to 0.13 fish/m^2 in 1981, and

Table 5. Population, density, and biomass estimates for yearling and older cutthroat trout during August and September in streams in Capitol Forest, Washington.

Station number	Station name	Sample year	Population estimate[1]	95% Confidence interval	Absolute biomass (g)	Density (No./m^2)	Relative biomass (g/m^2)
1	Lower Waddell Ck	1981	14	12-20	627.4	0.03	1.14
		1982	7	±0	371.8	0.01	0.61
2	Main Porter Ck	1981	1	±0	49.3	< 0.01	0.13
		1982	3	±0	108.3	< 0.01	0.30
3	Bozy Ck	1981	7	±0	89.1	0.04	0.54
4	W. Fork Porter Ck	1981	11	±0	231.6	0.08	1.69
5	Lower N. Fork Porter Ck	1981	1	±0	42.9	< 0.01	0.10
		1982	10	±0	250.8	0.03	0.66
6	Fuzzy Top Ck	1981	15	±0	273.2	0.09	1.58
		1982	23	22-26	351.5	0.13	2.05
7	S. Fork Porter Ck	1981	9	7-15	263.4	0.04	1.28
		1982	6	±0	130.7	0.03	0.71
8	Hell Ck	1981	2	±0	38.9	< 0.01	0.16
9	Lower Gibson Ck	1981	7	5-15	137.4	0.04	0.68
		1982	6	5-10	202.6	0.03	0.98
10	Lower Mima Ck	1981	8	7-11	93.1	0.05	0.52
		1982	8	±0	172.1	0.04	0.96
11	Upper Cedar Ck	1981	7	5-15	211.3	0.03	0.75
		1982	10	9-14	275.8	0.05	1.42
12	Middle Waddell Ck	1981	22	14-37	358.8	0.13	2.04
		1982	10	9-13	145.9	0.05	0.76

Table 5. Population, density, and biomass estimates for yearling and older cutthroat trout during August and September in streams in Capitol Forest, Washington--continued

Station number	Station name	Sample year	Population estimate[1]	95% Confidence interval	Absolute biomass (g)	Density (No./m^2)	Relative biomass (g/m^2)
13	Fall Ck trib.	1981	7	±0	105.4	0.07	1.11
14	Sherman Ck	1981	5	5-6	84.7	0.02	0.30
		1982	5	5-6	80.3	0.03	0.42
15	Upper Monroe Ck[2]	1981	11	10-14	195.6	0.07	1.16
		1982	16	11-28	438.0	0.08	2.21
16	Upper Gibson Ck	1981	8	7-11	189.3	0.06	1.34
17	Upper Mima Ck	1981	13	±0	178.8	0.08	1.04
		1982	17	16-20	177.8	0.13	1.32
18	Lost Valley Ck	1981	8	±0	179.3	0.08	1.76
		1982	5	5-7	160.4	0.06	1.82
19	Lower Monroe Ck	1981	8	8-9	308.4	0.04	1.44
		1982	3	±0	95.1	0.01	0.47
20	Noski Ck	1981	14	13-18	187.2	0.09	1.18
		1982	11	11-16	172.1	0.08	1.21
21	North Ck	1981	12	12-13	211.1	0.07	1.30
		1982	9	9-10	180.3	0.06	1.14
22	Shelton Ck	1981	9	8-13	295.4	0.06	1.84
		1982	6	±0	102.3	0.04	0.74
23	Upper Waddell Ck	1981	16	14-21	353.3	0.11	2.51
		1982	18	18-20	294.4	0.15	2.39

Table 5. Population, density, and biomass estimates for yearling and older cutthroat trout during August and September in streams in Capitol Forest, Washington--continued

Station number	Station name	Sample year	Population estimate[1]	95% Confidence interval	Absolute biomass (g)	Density (No./m^2)	Relative biomass (g/m^2)
24	Lower Cedar Ck	1981	5	±0	117.5	0.03	0.66
		1982	4	±0	97.4	0.02	0.49
25	Mill Ck	1981	11	±0	225.9	0.09	1.85
26	Upper N. Fork Porter Ck	1982	5	4-10	225.3	0.02	0.95

[1] For 50- to 70-m-long study section only.

[2] Location of study section moved downstream approximately 670 m for 1982 sampling.

from less than 0.01 to 0.13 fish/m^2 in 1981, and from less than 0.01 to 0.15 fish/m^2 in 1982. Trends in these estimates were similar to the population level patterns. An obvious exception, however, is Lower Waddell which has a large water surface area, thus reducing its relative density. Densities less than 0.01 fish/m^2 were present at Main Porter (1981 and 1982), Lower North Fork Porter (1981), and Hell Creek (1981).

Relative biomass estimates ranged from 0.10-2.51 g/m^2 for 1981, and from 0.30-2.39 g/m^2 for 1982. The highest estimate for both years occurred at the Upper Waddell station. Middle Waddell and Shelton also supported high cutthroat biomass in 1981, but had substantially reduced relative biomass in 1982. Fuzzy Top and Upper Monroe were among the highest biomass values for 1982. Those stations with the lowest values for cutthroat relative biomass included Main Porter, Sherman, Lower Cedar and Hell Creek.

Changes in abundance levels of cutthroat between 1981 and 1982 were generally smaller than those which occurred for coho salmon or subyearling trout. Variation between years was less than 50 percent at most stations although some sections with small populations in 1981 had relatively large increases for 1982. Stations with 10 or more cutthroat in 1981 ($n = 7$) exhibited changes in abundance between 1981 and 1982 ranging from -54 to +53 percent ($\overline{X} = -7.7\%$).

Steelhead-Rainbow Trout

Yearling and older steelhead-rainbow trout (>83 mm) were only present at eight stations in 1981 and 1982. As with subyearling trout, their abundance was concentrated at stations within the Porter Creek drainage for both years.

Population estimates for steelhead-rainbow at these eight stations ranged from $\hat{N}$ = 1-28 ($\overline{X}$ = 12.9) for 1981, and from $\hat{N}$ = 1-51 ($\overline{X}$ = 13.9) for 1982 (Table 6). During both years the highest abundance was recorded at the Main

Table 6. Population, density, and biomass estimates for yearling and older steelhead-rainbow trout during August and September in streams in Capitol Forest, Washington.[1]

Station number	Station name	Sample year	Population estimate[2]	95% Confidence interval	Absolute biomass (g)	Density (No./m²)	Relative biomass (g/m²)
1	Lower Waddell Ck	1981	6	6-7	152.8	0.01	0.28
		1982	11	8-19	212.7	0.02	0.35
2	Main Porter Ck	1981	28	26-32	555.5	0.07	1.48
		1982	51	49-53	760.8	0.13	1.96
5	Lower N. Fork Porter Ck	1981	27	26-30	475.2	0.06	1.12
		1982	12	11-15	163.4	0.03	0.66
6	Fuzzy Top Ck	1981	1	±0	21.4	< 0.01	0.12
		1982	0				
7	S. Fork Porter Ck	1981	19	18-22	314.0	0.09	1.52
		1982	15	15-16	221.7	0.08	1.20
8	Hell Ck	1981	20	±0	303.2	0.08	1.24
9	Lower Gibson Ck	1981	1	±0	31.8	< 0.01	0.16
		1982	3	±0	87.4	0.01	0.42
15	Upper Monroe Ck	1982	2	±0	23.5	0.01	0.12
19	Lower Monroe Ck	1981	0				
		1982	1	±0	20.9	< 0.01	0.10
21	North Ck	1981	1	±0	13.2	< 0.01	0.08
		1982	0				
26	Upper N. Fork Porter Ck	1982	16	16-18	225.5	0.07	0.95

[1]Yearling and older steelhead-rainbow trout absent from stations not listed.
[2]For 50- to 70-m-long study section only.

Porter station. While additional stations within the Porter Creek drainage supported moderate populations of steelhead-rainbow, very low levels of abundance were found at study sections in the other four drainages.

Densities ranged from less than 0.01-0.09 fish/m^2 for 1981, and from less than 0.01-0.13 fish/m^2 for 1982. Stations in the Porter Creek drainage had densities ranging from 0.06-0.09 fish/m^2 for 1981 and 0.03-0.13 fish/m^2 for 1982, while stations in other drainages had densities of 0.02 fish/m^2 or less.

Relative biomass estimates ranged from 0.08-1.52 g/m^2 in 1981, and from 0.10-1.96 g/m^2 in 1982. South Fork Porter and Main Porter had the highest estimates for 1981 and 1982, respectively. As with the population and density estimates, the relative biomass values for stations outside Porter Creek were quite low.

Of the eight stations sampled both years, four had population increases and four had reductions in abundance between 1981 and 1982. Four of these stations, with very small populations of steelhead-rainbow in 1981, exhibited changes in abundance of only one or two fish. The three stations in the Porter Creek drainage however had substantial population changes ranging from -21 to +82 percent ($\overline{X}$ = +1.7%). Main Porter was the only study section of these three to show an increased abundance in 1982 (1981 $\hat{N}$ = 28, 1982 $\hat{N}$ = 51).

Total Salmonids

Absolute biomass estimates for all salmonids combined at each station ranged from 89.1 - 1262.6 g ($\overline{X}$ = 412.1) for 1981, and from 124.4 - 1634.5 g ($\overline{X}$ = 494.5) for 1982 (Table 7). Stations with the greatest total salmonid biomass for 1981 and 1982 were Lower Waddell, Main Porter, and Lower North Fork Porter. The major portion of this biomass consisted of cutthroat trout (1981) and coho salmon (1982) at Lower Waddell, steelhead-rainbow trout (1981 and 1982) at Main Porter, and steelhead-rainbow trout (1981) and coho salmon

Table 7. Biomass estimates for all salmonids combined during August and September in streams in Capitol Forest, Washington. Dashes mean not sampled.

Station number	Station name	Absolute biomass (g)[1]		Relative biomass (g/m²)[1]	
		1981	1982	1981	1982
1	Lower Waddell Ck	1262.6	1634.5	2.29	2.69
2	Main Porter Ck	961.1	1141.6	2.55	2.95
3	Bozy Ck	89.1	--	0.54	--
4	W. Fork Porter Ck	236.2	--	1.72	--
5	Lower N. Fork Porter Ck	762.0	772.8	1.79	2.02
6	Fuzzy Top Ck	396.6	573.7	2.29	3.34
7	S. Fork Porter Ck	631.5	423.9	3.06	2.29
8	Hell Ck	424.2	--	1.74	--
9	Lower Gibson Ck	244.1	449.4	1.20	2.19
10	Lower Mima Ck	222.2	421.3	1.24	2.35
11	Upper Cedar Ck	473.3	488.7	1.69	2.51
12	Middle Waddell Ck	516.7	293.7	2.94	1.54
13	Fall Ck trib.	148.9	--	1.56	--
14	Sherman Ck	281.2	213.2	1.01	1.11
15	Upper Monroe Ck	296.3	647.4	1.76	3.27
16	Upper Gibson Ck	229.6	--	1.63	--
17	Upper Mima Ck	225.2	207.8	1.31	1.54
18	Lost Valley Ck	253.6	254.4	2.49	2.89
19	Lower Monroe Ck	506.9	351.5	2.36	1.73
20	Noski Ck	335.6	270.3	2.12	1.90
21	North Ck	273.3	197.0	1.68	1.24
22	Shelton Ck	488.6	124.4	3.04	0.90
23	Upper Waddell Ck	491.1	375.3	3.49	3.04
24	Lower Cedar Ck	271.7	395.1	1.53	1.97
25	Mill Ck	253.1	--	2.07	--
26	Upper N. Fork Porter Ck	--	654.1	--	2.76
	Mean	412.1	494.5	1.99	2.21
	Range	89.1-1262.6	124.4-1634.5	0.54-3.49	0.90-3.34

[1]For 50- to 70-m-long study section only.

(1982) at Lower North Fork Porter (Appendix Tables 1 and 2). The lowest total-biomass estimates were present at the Bozy and Fall Creek tributary stations in 1981 and at Shelton and North Creek in 1982. Cutthroat trout represented the major portion of the total salmonid biomass at all four of these stations.

When the absolute biomass estimates are adjusted for the amount of water surface area within a section, the stations exhibiting the highest values are changed considerably. For example, in 1981 stations with the highest relative biomass for all salmonids were Upper Waddell, South Fork Porter, and Shelton (Table 7). In 1982, Fuzzy Top, Upper Monroe, and Upper Waddell had the highest relative-biomass estimates. Cutthroat trout comprised the majority of the biomass at all of these stations except South Fork Porter which contained predominantly steelhead-rainbow trout. While stations with the highest total salmonid absolute-biomass were different from those with the highest relative estimates, a comparatively large absolute biomass generally resulted in a high relative biomass at most stations.

The lowest values for total salmonid relative-biomass occurred at Bozy, Sherman, and Lower Gibson (1981) and Shelton, Sherman, and North Creek (1982). Absolute biomass estimates at these stations were also very low. The largest fraction of the total biomass was represented by cutthroat trout at all of these stations except Sherman Creek which contained mostly coho salmon.

Changes in absolute biomass of all salmonids between 1981 and 1982 ranged from -364.2 to +371.9 g (Shelton and Lower Waddell, respectively). A total of nine stations had increased biomass in 1982 while nine exhibited a decrease in total salmonid biomass. Excluding three stations which had different section lengths between years and one station planted with coho fry in the spring of 1982 (Lower Mima), the average increase in total salmonid biomass was 144.1 g at six stations while the average decrease was 153.1 g at eight stations. Expressed as percent change between years, the absolute estimates varied from -74 to +44 percent (excluding sections with changed lengths or supplemental stocking). Lower Mima, however, having received additional coho salmon fry from hatchery plantings during the spring of 1982, had an increase of 90 percent in total salmonid biomass. Interestingly, this increase was not due solely to greater coho biomass but resulted from a twofold increase in both cutthroat and coho biomass between years.

Differences in relative biomass for all salmonids between years ranged from -2.14 to +1.05 g/m^2 (excluding Lower Mima). Stations with a greater relative biomass in 1982 (n = 10) averaged a 24 percent increase (SD = 22.8) and those with reduced relative biomass (n = 7) averaged a 31.3 percent decrease (SD = 21.0). Combining all stations sampled during both years, the mean change in total salmonid relative biomass is +4.41 percent (SD = 37.5). Calculated without including the sign (i.e., without direction of change), the mean variation is 30.2 percent (SD = 21.5).

Stations with the largest increases in total salmonid relative-biomass included Lower Gibson (82%), Upper Cedar (48%), and Fuzzy Top (46%). Increases at Lower Gibson and Fuzzy Top were primarily due to greater coho biomass in 1982, although cutthroat biomass also increased at both stations. Greater salmonid biomass at Upper Cedar was largely the result of an increase in cutthroat biomass. The largest decreases between years were exhibited at Shelton (70%) and Middle Waddell (48%). The drastic reduction in biomass at Shelton Creek was predominantly the result of fewer coho although the cutthroat biomass also declined between years at this station. Reduced salmonid biomass at Middle Waddell was largely attributable to a decrease in cutthroat biomass.

Biomass Comparisons

Coho Salmon

Even though a large amount of variation is present, coho biomass values for Capitol Forest are well below average when compared to results from six studies conducted in the Pacific Northwest (Fig. 11). The relative biomass estimates for Capitol Forest coho exhibit a relatively contracted range which lies substantially below the combined mean for data from other studies. Nonparametric statistical tests show that the majority of the biomass values used for comparison are significantly higher than found in Capitol Forest during 1981 and 1982. Relative biomass values of juvenile coho were significantly greater in the Alsea Watershed (Moring and Lantz 1975), Puget Sound (Chapman and Knudsen 1980), Vancouver Island (Narver and Andersen 1974), and Puget Sound (Flint 1979, unpub.) (Table 8). The northern California (Burns 1971, 1972) and Clearwater River values (Edie 1975) were not significantly greater than Capitol Forest biomass estimates for 1981 or 1982. Although relative biomass estimates for coho are below average in Capitol Forest streams, density appears to be influencing the size of coho. Linear regression of mean fork length versus density produced significant negative relationships for 1981 and 1982 (Fig. 12). This indicates that stations with lower densities of coho generally supported coho of a larger size.

Differences between 1981 and 1982 relative biomass estimates for Capitol Forest coho were not statistically significant.

Young-of-the-Year Trout

A lack of available data on underyearling trout somewhat limited comparisons between studies. While three studies were used to illustrate differences in mean biomass values, only two (Puget Sound and Clearwater River) had sufficient sample sizes for nonparametric statistical testing. All

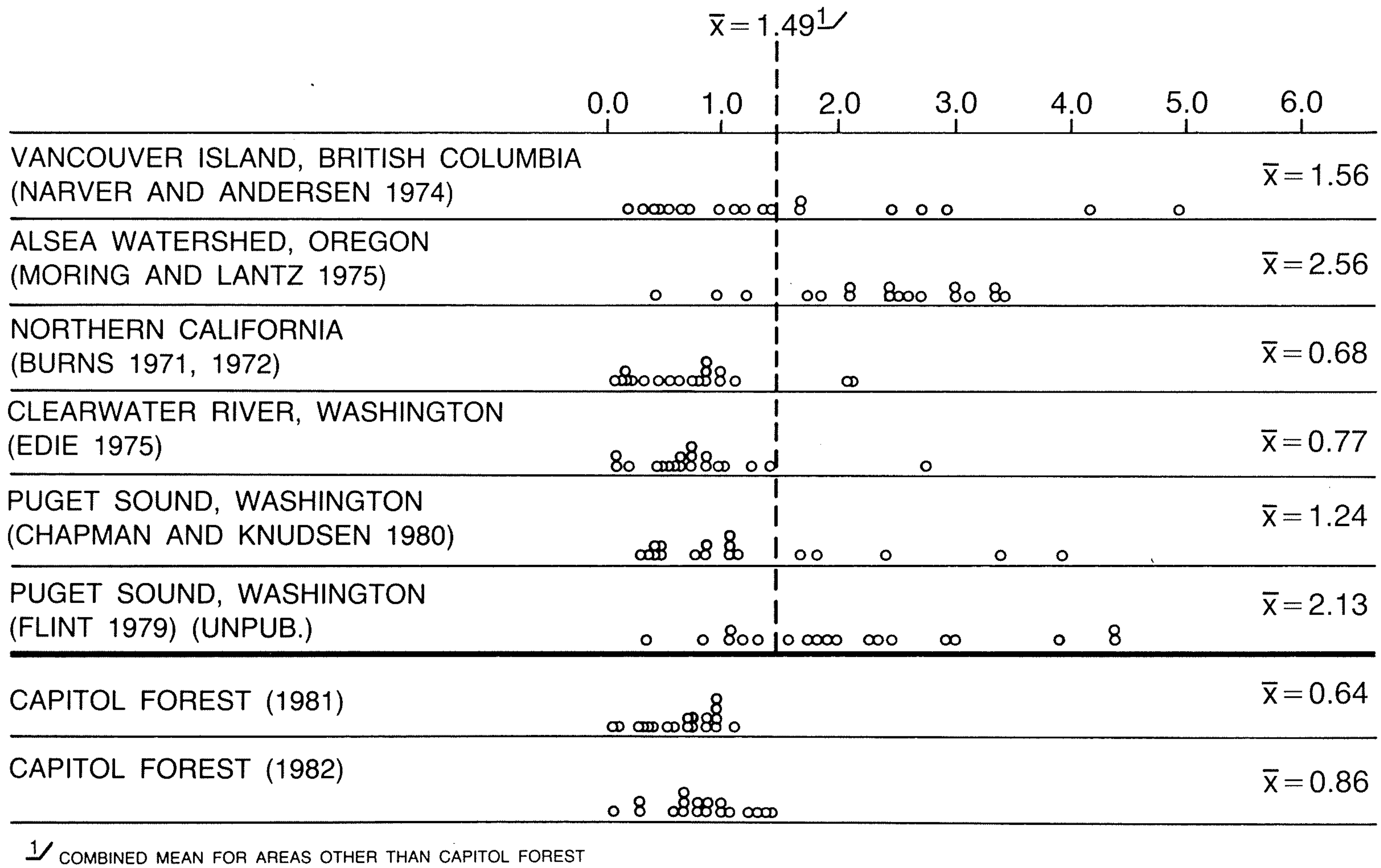


Fig. 11. Comparison of coho salmon late-summer relative biomass (g/m^2) reported for different areas of the Pacific Northwest. Each circle represents a relative biomass estimate for an individual stream study section.

Table 8. Results of nonparametric rank comparisons between relative biomass estimates of juvenile coho from Capitol Forest (group 2) and those from other areas in the Pacific Northwest.
H_0: Capitol Forest coho relative biomass (g/m^2) $\geq$ values reported in other studies.
H_A: Capitol Forest coho relative biomass (g/m^2) $<$ values reported in other studies.

Comparison (2 vs. A)	Difference ($R_2 - R_A$)	SE	$\lvert q' \rvert$	p	q' 0.05(1), ∞, p	Conclusion
2 vs. 1	805 - 784 = 21			2		Since $R_2 \geq R_1$, accept H_0: $B_2 \geq B_1$.
2 vs. 7	1986 - 805 = 1181	203.75	5.80	6	2.23	Reject H_0: $B_2 \geq B_7$
2 vs. 6	1823 - 805 = 1018	169.94	5.99	5	2.16	Reject H_0: $B_2 \geq B_6$
2 vs. 5	1375 - 805 = 570	136.13	4.19	4	2.06	Reject H_0: $B_2 \geq B_5$
2 vs. 4	1240 - 805 = 435	102.32	4.25	3	1.92	Reject H_0: $B_2 \geq B_4$
2 vs. 3	898 - 805 = 93	68.51	1.36	2	1.64	Accept H_0: $B_2 \geq B_3$

Group 1 California: Burns (1971, 1972).
Group 2 Washington — Capitol Forest.
Group 3 Washington — Clearwater River Basin: Edie (1975).
Group 4 Washington — Puget Sound streams: Chapman and Knudsen (1980).
Group 5 British Columbia — Carnation Creek: Narver and Andersen (1974).
Group 6 Washington: Flint (1979)(unpub.).
Group 7 Oregon — Alsea watershed: Moring and Lantz (1975).

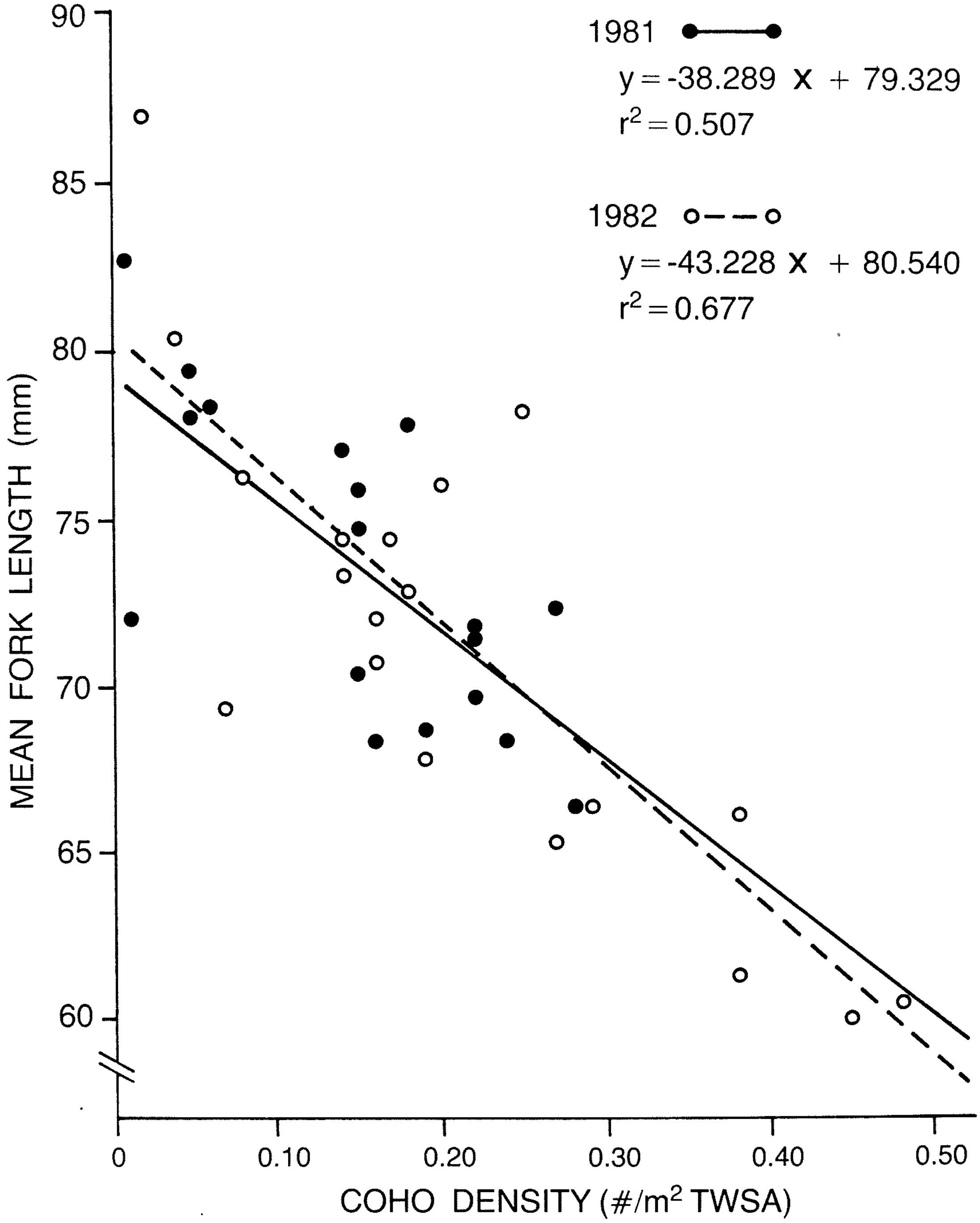


Fig. 12. Simple linear regression of juvenile coho mean fork length versus the number of juvenile coho per square meter of total water surface area during summer low-flow. Each dot (1981) or circle (1982) represents sampling results for an individual stream study section in Capitol Forest.

studies used comparable size limits for underyearling trout.

Relative biomass estimates for young-of-the-year trout from Capitol Forest in 1981 and 1982 are substantially below those reported in three other Washington State studies (Fig. 13). A comparison of mean values indicates Capitol Forest study sites supported underyearling trout biomass levels well below the average of comparison studies. Nonparametric statistical testing showed Capitol Forest values for both years to be significantly lower than those reported from Puget Sound (Chapman and Knudsen 1980) and Clearwater River tributaries (Edie 1975).

Relative biomass values for underyearling trout in Capitol Forest were not significantly different between 1981 and 1982.

Cutthroat Trout

Mean relative-biomass estimates for yearling and older cutthroat trout were lower in Capitol Forest during 1981 and 1982 than for any other study area used for comparison (Fig. 14). During both years the range of values for Capitol Forest sites were almost exclusively below the combined mean from comparison study sites. While the small sample size at Bear Creek (June 1981) again precluded use of this study for statistical comparison, nonparametric analysis of results from the three remaining studies and Capitol Forest indicates that Vancouver Island (Narver and Andersen 1974), Puget Sound (Chapman and Knudsen 1980), and Clearwater River tributaries (Osborn 1980) all supported significantly greater relative biomass of cutthroat trout than Capitol Forest study sections in 1981 and 1982.

Relative biomass values for yearling and older cutthroat trout in Capitol Forest were not significantly different between 1981 and 1982.

Steelhead-Rainbow Trout

Relative biomass values for steelhead-rainbow trout in Capitol Forest

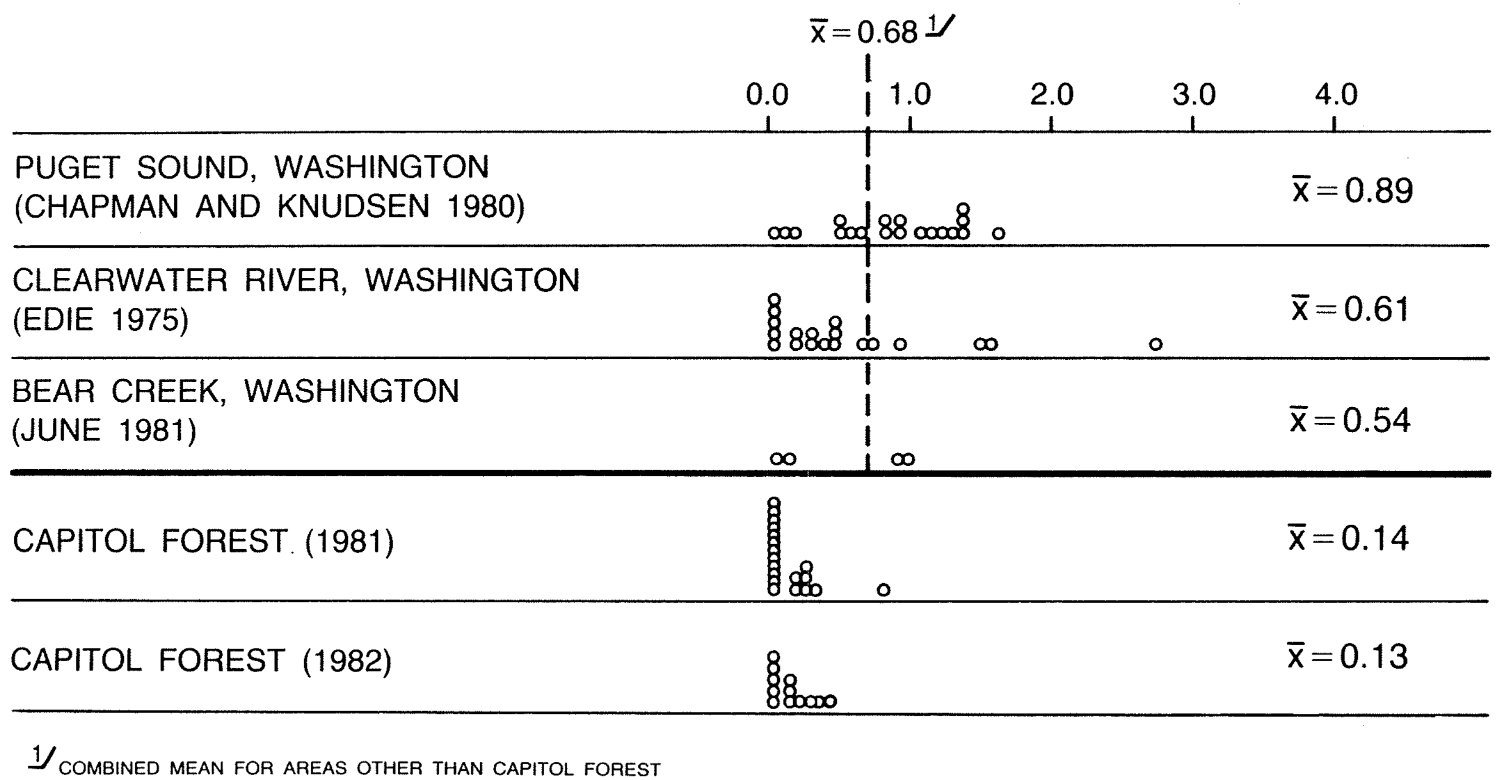


Fig. 13. Comparison of young-of-the-year trout late summer relative biomass (g/m^2) reported for different areas of the Pacific Northwest. Each circle represents a relative biomass estimate for an individual stream study section.

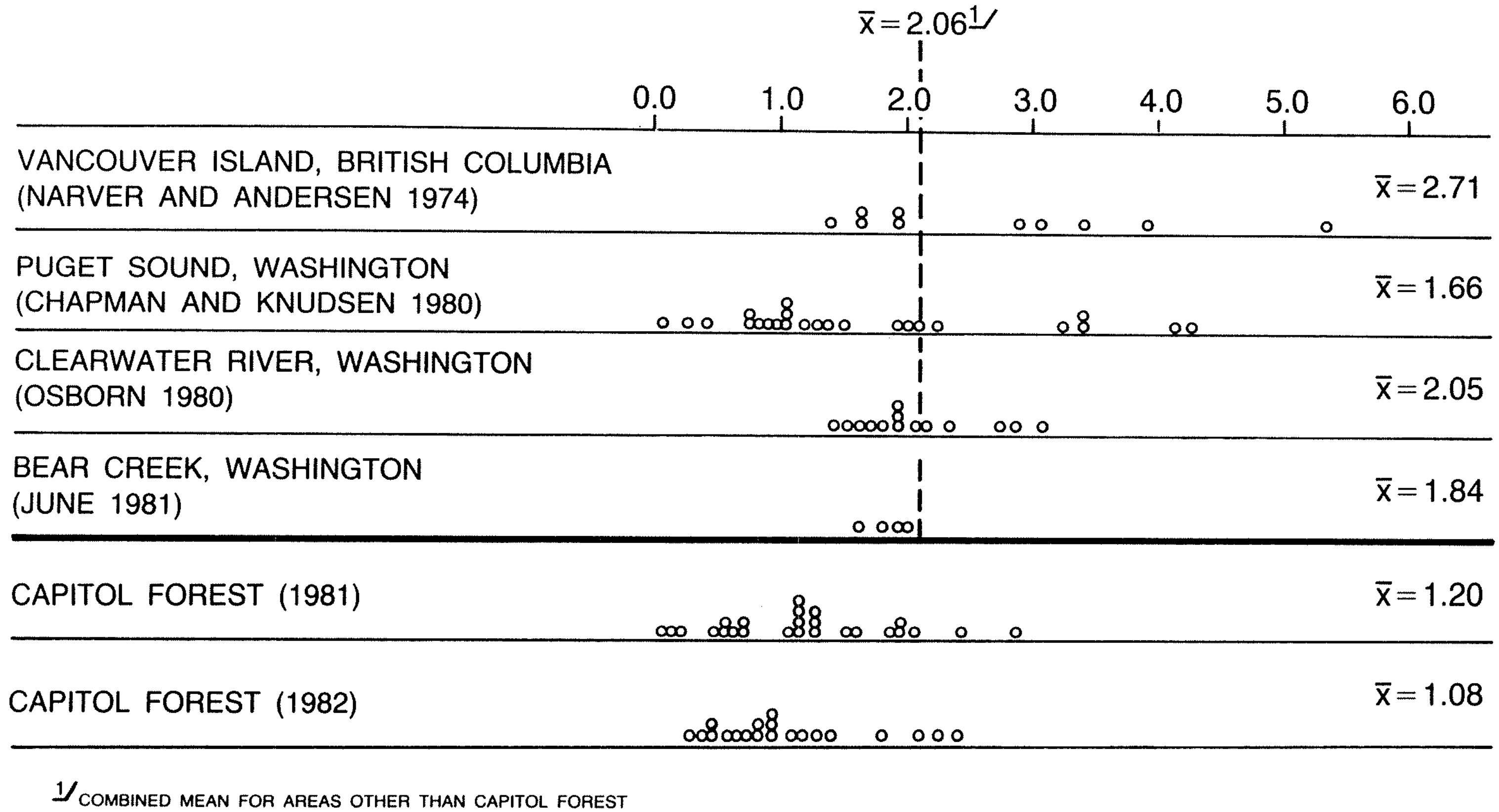


Fig. 14. Comparison of yearling and older cutthroat trout late-summer relative biomass (g/m^2) reported for different areas of the Pacific Northwest. Each circle represents a relative biomass estimate for an individual stream study section.

streams were more comparable to those reported in other Pacific Northwest studies than occurred for coho, cutthroat, or young-of-the-year trout. In fact, the mean relative biomass value for Capitol Forest steelhead-rainbow in 1981 and 1982 exceeded those reported in two other studies (Fig. 15). Nonparametric statistical tests concluded that Capitol Forest relative biomass estimates for both years were significantly lower than reported for northern California (Burns 1971, 1972); but not significantly less than Puget Sound (Chapman and Knudsen 1980) or Vancouver Island (Narver and Andersen 1974). The second Vancouver Island study (Narver 1972) was not included in the statistical comparisons due to the small samples size.

Differences in steelhead-rainbow trout relative biomass between 1981 and 1982 in Capitol Forest were not statistically significant.

Habitat Characteristics

Within the stream environment, numerous morphological features shape the habitat available for fishes and as there is habitat selectivity among species, it is important to determine the suitability of particular stream environments for the different fish species. The physical characteristics of Capitol Forest study streams are presented in Tables 9, 10, 11 and 12.

Porter Creek stations were relatively high gradient, had more riffle than pool area, and generally contained rubble and bedrock substrates. The four stations sampled in 1982 had an average of 28% pool area, 72% riffle area, and 2.3% gradient. Of the stations sampled in 1982, Main Porter had the second highest total water surface area (387.5 m^2), the largest total riffle area (345.4 m^2), the second highest discharge (4.98 cfs), and was the only fifth-order study site.

Waddell Creek stations were relatively low gradient with a high

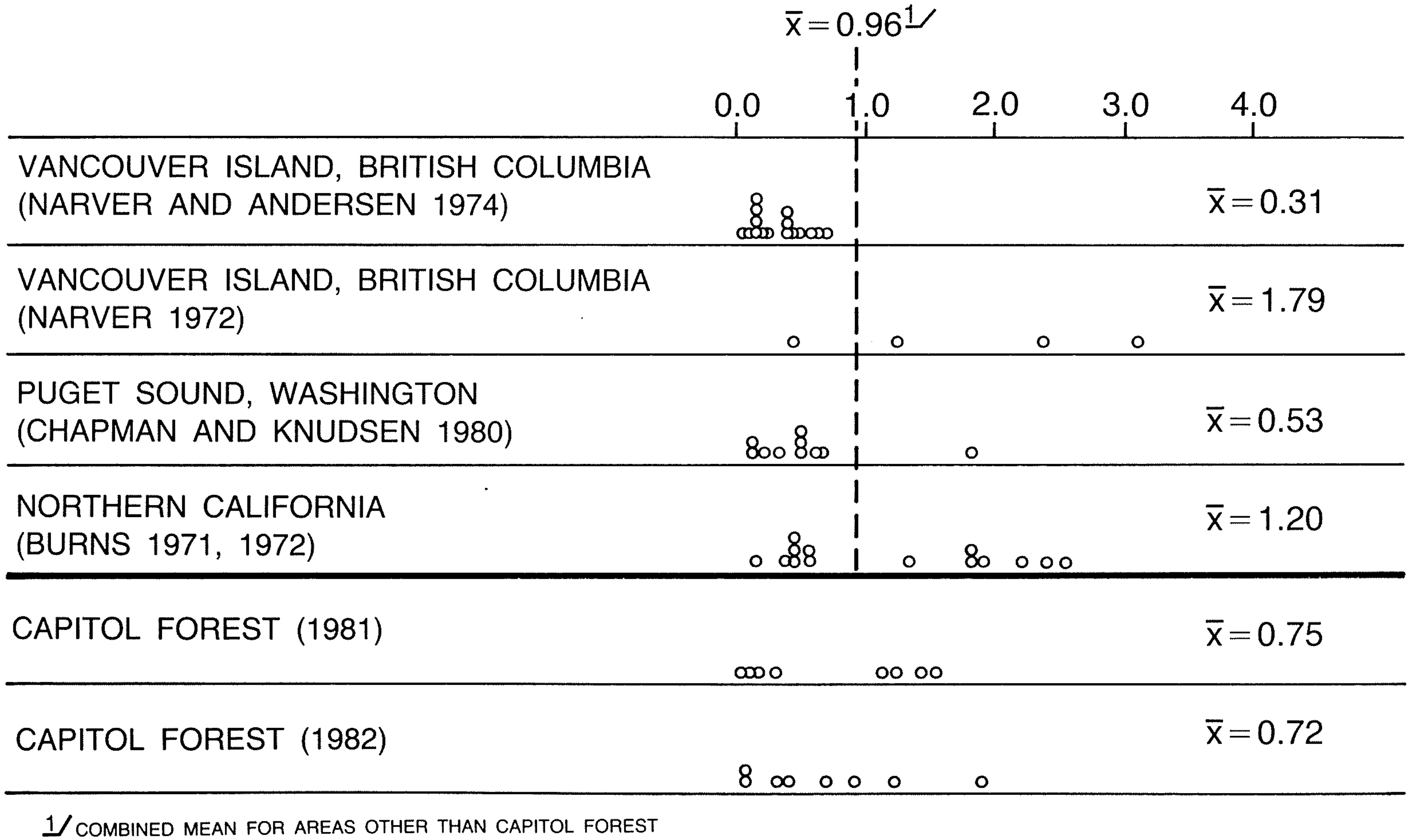


Fig. 15. Comparison of yearling and older steelhead-rainbow trout late-summer relative biomass (g/m^2) reported for different areas of the Pacific Northwest. Each circle represents a relative biomass estimate for an individual stream study section.

Table 9. Physical characteristics of electrofishing stations sampled in Capitol Forest during summer 1981.

Sta. No.	Station name	Total length (m)	Mean width (m)	Mean depth (cm)	Total surface area (m^2)	Pool area (m^2)	Pool area (%)	Riffle area (m^2)	Riffle area (%)	Gradient within section (%)
1	Lower Waddell Ck	71.6	7.3	16.9	551.5	394.3	72	157.2	28	0.7
2	Main Porter Ck	59.1	6.4	18.9	376.4	61.9	16	314.5	84	1.7
3	Bozy Ck	51.8	3.2	14.0	165.0	129.9	79	35.1	21	1.4
4	W. Fork Porter Ck	49.4	2.9	11.3	137.0	71.2	52	65.8	48	1.9
5	Lower N. Fork Porter Ck	62.2	6.9	12.2	424.9	159.5	38	265.4	62	1.8
6	Fuzzy Top Ck	58.2	2.9	11.8	173.4	43.2	25	130.2	75	2.1
7	S. Fork Porter Ck	45.7	4.6	10.5	206.3	9.4	5	196.9	95	3.2
8	Hell Ck	45.7	5.4	13.2	244.4	16.5	7	227.9	93	2.8
9	Lower Gibson Ck	45.7	4.0	10.6	202.8	151.1	75	51.7	25	1.7
10	Lower Mima Ck	45.7	4.4	15.9	179.0	142.3	80	36.7	20	0.8
11	Upper Cedar Ck	59.1	5.1	15.3	280.0	217.9	78	62.1	22	1.2
12	Middle Waddell Ck	45.7	3.8	13.7	175.9	105.8	60	70.1	40	1.7
13	Fall Ck trib.	45.7	2.1	8.5	95.3	52.6	55	42.7	45	2.8
14	Sherman Ck	61.0	4.6	17.9	278.7	227.6	82	51.1	18	1.1
15	Upper Monroe Ck	45.7	3.7	14.7	168.6	116.4	69	52.2	31	1.4
16	Upper Gibson Ck	45.7	3.1	10.5	141.2	36.0	25	105.2	75	4.9
17	Upper Mima Ck	53.9	3.1	12.1	172.0	132.8	77	39.2	23	1.9
18	Lost Valley Ck	45.7	2.2	11.0	101.7	38.7	38	63.0	62	1.9
19	Lower Monroe Ck	45.7	4.7	16.8	214.6	146.0	68	68.6	32	1.1
20	Noski Ck	52.4	3.1	11.8	158.1	100.7	64	57.4	36	1.8
21	North Ck	47.2	3.5	11.6	162.5	0	0	162.5	100	5.0
22	Shelton Ck	45.7	3.5	12.2	160.6	40.4	25	120.2	75	1.7
23	Upper Waddell Ck	45.7	3.1	17.4	140.8	108.1	77	32.7	23	1.3
24	Lower Cedar Ck	45.7	4.0	16.3	177.3	104.2	59	73.1	41	1.2
25	Mill Ck	50.3	2.6	9.7	122.4	12.4	10	110.0	90	4.0

Table 10. Physical characteristics measured or classified at electrofishing sites in Capitol Forest during summer 1981.

Station number	Station name	Stream order	Stream class[1]	Instream cover[2] (m)	Dominant substrate[3]	Class of dominant pool[3]	Temperature (°C) Morning	Temperature (°C) Afternoon
1	Lower Waddell Ck	4	1	21.9	Gravel	3	16.1	18.3
2	Main Porter Ck	5	3-	29.7	Rubble	3	15.5	17.8
3	Bozy Ck	3	2-	23.0	Gravel	4	15.5	16.7
4	W. Fork Porter Ck	3	2	14.1	Gravel	2	15.0	16.7
5	N. Fork Porter Ck	4	2+	16.1	Rubble	4	15.0	15.5
6	Fuzzy Top Ck	3	2+	38.8	Gravel	2	13.9	13.9
7	S. Fork Porter Ck	3	3	16.9	Rubble	2	12.8	14.4
8	Hell Ck	4	4	8.1	Rubble	2	12.8	13.9
9	Lower Gibson Ck	4	2-	23.9	Gravel	2	12.8	14.4
10	Lower Mima Ck	4	1	19.1	Gravel	3	13.3	14.4
11	Upper Cedar Ck	3	1	34.6	Gravel	4	12.8	13.9
12	Middle Waddell Ck	4	1+	9.8	Gravel	3	13.9	14.4
13	Fall Ck trib.	2	2	10.7	Gravel	2	12.2	12.2
14	Sherman Ck	3	1-	26.2	Silt	2	15.0	15.5
15	Upper Monroe Ck	4	2	0.3	Rubble	4	12.2	13.3
16	Upper Gibson Ck	3	3-	20.9	Gravel	4	12.2	12.8
17	Upper Mima Ck	3	1+	42.1	Gravel	4	13.3	13.3
18	Lost Valley Ck	2	2	17.6	Gravel	4	13.3	13.9
19	Lower Monroe Ck	4	1+	26.8	Gravel	5	13.9	14.4
20	Noski Ck	3	2	15.8	Gravel	4	14.4	15.0
21	North Ck	4	4	7.6	Boulder	*	12.8	13.3
22	Shelton Ck	3	2	16.3	Gravel	4	12.2	13.3
23	Upper Waddell Ck	4	1+	32.2	Gravel	4	13.3	13.9
24	Lower Cedar Ck	3	1+	14.0	Gravel	4	13.3	13.9
25	Mill Ck	3	3	11.2	Rubble	4	13.3	13.9

[1]According to proposed scheme (see Methods).
[2]Linear distance within stream.
[3]According to Platts (1979) (see Methods).
*No pool area at this station.

Table 11. Physical characteristics of electrofishing stations sampled in Capitol Forest during summer 1982.

Sta. No.	Station name	Total length (m)	Mean width (m)	Mean depth (cm)	Total surface area (m^2)	Pool area (m^2)	Pool area (%)	Riffle area (m^2)	Riffle area (%)	Gradient within section (%)
1	Lower Waddell Ck	70.4	8.4	20.4	607.5	331.3	55	276.2	45	1.0
2	Main Porter Ck	59.1	6.4	13.9	387.5	42.1	11	345.4	89	2.1
3	Bozy Ck	--	--	--	--	--	--	--	--	--
4	W. Fork Porter Ck	--	--	--	--	--	--	--	--	--
5	Lower N. Fork Porter Ck	60.4	6.3	12.7	381.6	105.8	28	275.8	72	2.1
6	Fuzzy Top Ck	57.9	2.9	10.0	171.8	103.2	60	68.6	40	2.3
7	S. Fork Porter Ck	45.7	4.1	9.0	185.2	24.3	13	160.9	87	3.4
8	Hell Ck	--	--	--	--	--	--	--	--	--
9	Lower Gibson Ck	52.4	3.9	11.4	205.6	62.7	30	142.9	70	2.4
10	Lower Mima Ck	45.7	3.8	15.7	179.1	139.7	78	39.3	22	0.9
11	Upper Cedar Ck	45.7	4.2	16.3	194.4	150.1	77	44.3	23	1.5
12	Middle Waddell Ck	45.7	3.7	13.3	190.9	119.3	62	71.6	38	1.8
13	Fall Ck trib.	--	--	--	--	--	--	--	--	--
14	Sherman Ck	45.7	4.1	10.5	191.8	131.0	68	60.8	32	1.4
15	Upper Monroe Ck	45.7	4.3	24.0	197.7	140.0	71	57.7	29	1.7
16	Upper Gibson Ck	--	--	--	--	--	--	--	--	--
17	Upper Mima Ck	53.9	2.4	9.2	134.5	99.9	74	34.6	26	1.8
18	Lost Valley Ck	45.7	2.0	9.4	88.1	51.9	59	36.2	41	2.2
19	Lower Monroe Ck	45.7	4.3	14.5	203.2	127.1	63	76.1	37	1.9
20	Noski Ck	54.6	2.5	12.4	142.2	86.5	61	55.7	39	2.0
21	North Ck	48.2	3.2	10.5	158.7	4.5	3	154.2	97	5.6
22	Shelton Ck	45.7	3.0	9.7	138.3	25.2	18	113.1	82	2.4
23	Upper Waddell Ck	45.7	2.6	16.4	123.3	101.6	82	21.7	18	1.8
24	Lower Cedar Ck	45.7	4.4	17.7	200.2	112.1	56	88.1	44	1.2
25	Mill Ck	--	--	--	--	--	--	--	--	--
26	Upper N. Fork Porter Ck	48.8	4.8	14.5	236.7	140.8	59	95.9	41	1.4

Table 12. Physical characteristics measured at electrofishing sites in Capitol Forest during summer 1982. Dashes mean not sampled.

Station number	Station name	Discharge (cfs)	Instream cover area (m^2) Undercut banks	Logs	Debris piles	Total*	Temperature (°C) Morning	Afternoon
1	Lower Waddell Ck	14.42	15.3	11.1	6.9	33.2	14.4	15.0
2	Main Porter Ck	4.98	5.9	7.2	2.0	15.0	14.4	16.1
3	Bozy Ck	--	--	--	--	--	--	--
4	W. Fork Porter Ck	--	--	--	--	--	--	--
5	Lower N.F. Porter Ck	2.14	5.6	1.5	0.4	7.5	12.8	14.4
6	Fuzzy Top Ck	1.20	16.5	2.6	0.7	19.8	11.7	12.8
7	S. Fork Porter Ck	1.46	6.0	0.4	3.7	10.1	11.1	12.8
8	Hell Ck	--	--	--	--	--	--	--
9	Lower Gibson Ck	1.40	1.7	2.3	12.9	17.0	12.2	15.0
10	Lower Mima Ck	1.89	8.1	1.2	0.0	9.3	13.3	14.4
11	Upper Cedar Ck	1.41	10.8	0.5	1.7	13.1	14.4	15.6
12	Middle Waddell Ck	1.06	6.6	0.0	3.0	9.6	11.1	12.2
13	Fall Ck trib.	--	--	--	--	--	--	--
14	Sherman Ck	0.90	0.9	3.3	7.5	11.6	15.6	17.2
15	Upper Monroe Ck	1.78	17.5	0.0	0.5	18.1	13.9	13.9
16	Upper Gibson Ck	--	--	--	--	--	--	--
17	Upper Mima Ck	0.64	8.1	5.7	7.9	21.6	13.3	13.9
18	Lost Valley Ck	0.44	4.3	0.2	0.5	4.9	13.3	13.3
19	Lower Monroe Ck	1.44	5.8	2.2	2.9	10.9	15.0	15.0
20	Noski Ck	0.38	6.3	0.6	0.0	6.9	14.4	17.8
21	North Ck	1.56	2.1	0.0	0.0	2.1	12.2	13.3
22	Shelton Ck	1.31	0.5	2.5	2.2	5.2	14.4	14.4
23	Upper Waddell Ck	0.42	10.5	3.0	6.2	19.6	11.1	12.8
24	Lower Cedar Ck	1.56	5.3	2.5	0.3	8.1	12.2	13.3
25	Mill Ck	--	--	--	--	--	--	--
26	Upper N.F. Porter Ck	2.13	4.4	0.9	3.4	8.8	13.3	13.9

*Sums not equal to totals due to rounding off.

percentage pool area and predominantly gravel substrate. During 1982, the four Waddell Creek stations averaged 65% pool area, 35% riffle area, and 1.6% gradient. Relative to all stations sampled in 1982, Lower Waddell had the largest total water surface area (607.5 m^2), the largest total pool area (331.3 m^2), the greatest mean width (8.4 m), the second largest mean depth (20.4 cm), the highest discharge (14.42 cfs), and the largest amount of total instream cover (33.2 m^2).

Study sections in the Cedar-Sherman drainage had more variability between sites than either Porter or Waddell Creek, but were predominantly low gradient, had nearly equal percent pool and riffle area, and contained mostly gravel substrates. Nine stations sampled in 1982 averaged 53% pool area, 47% riffle area, and 2.2% gradient. North Creek was atypical of stations in the Cedar-Sherman drainage and, relative to all stations in 1982, had the lowest percent pool area (3%), the highest percent riffle area (97%), the steepest gradient (5.6%), and the least amount of total instream cover (2.1 m^2).

The two Mima Creek stations were relatively low gradient, contained more pool than riffle area, and had predominantly gravel substrates. In 1982, these stations averaged 76% pool area, 24% riffle area, and 1.3% gradient. The Lower Mima station had the second highest percent pool area (78%), the second lowest percent riffle area (22%), and the lowest gradient (0.9%).

The Lower Gibson station, during 1982, had 30% pool area, 70% riffle area, 2.4% gradient, and the dominant substrate was gravel. This station contained the largest amount of instream cover in the debris pile category (12.9 m^2).

Physical Characteristics and Relative Biomass

One method used to assess how the physical characteristics of stream study sites affected fish distribution in Capitol Forest was to compile the habitat measurements for those stations which supported a relative biomass greater than the mean for a particular species or subgroup. While a number of habitat variables were compiled, only those which showed a trend among the species are presented (Table 13).

Average percent pool area was greatest at study sites with high coho relative-biomass, while average percent riffle area was greatest at stations with high relative-biomass of steelhead-rainbow. Stations with high coho relative-biomass also had the lowest average gradient (1981 = 1.3%, 1982 = 1.6%) and the greatest average mean depth (1981 = 15.0 cm, 1982 = 16.0 cm). In 1981, average gradient was highest (2.6%) at stations with above average relative-biomass of underyearling trout. During 1982, however, the highest average gradient (2.4%) was found at stations with high relative biomass of cutthroat. Although not included in the table due to a general lack of trends, total water surface area was lowest at stations with above average relative-biomass of cutthroat for 1981 and 1982.

Study Site Classification

The results of the visual stream-class rating system and the actual physical habitat measurements suggest that stream class is a good indicator of pool-riffle composition, gradient, and, to some extent, substrate. Although the class rating was visually determined prior to measurement of the habitat variables, values obtained from the subsequent measurements were fairly well stratified when compared with the stream classification results (Table 14).

Correlation analysis between study-site habitat parameters and stream-class ratings indicate that mean stream width, total water surface area, and stream order were not significantly correlated with stream class (Table 15). Significant positive correlations were, however, present between stream class and percent riffle area, stream gradient, and dominant substrate. In

Table 13. Physical characteristics of study sections with relative biomass estimates greater than the mean value for a particular species or subgroup.

Species or subgroup	Year	Mean relative biomass estimate* (g/m^2)	Average % pool area (range in parentheses)	Average % riffle area (range in parentheses)	Average % gradient (range in parentheses)	Average mean depth (cm) (range in parentheses)
Coho salmon	1981	0.64	63.9 (25-82)	36.1 (18-62)	1.3 (0.7-1.9)	15.0 (11.0-17.9)
	1982	0.86	64.9 (55-78)	35.1 (22-45)	1.6 (0.9-2.3)	16.0 (9.4-24.0)
Underyearling trout	1981	0.15	31.2 (5-77)	68.8 (23-95)	2.6 (0.7-4.9)	13.0 (9.7-18.9)
	1982	0.13	49.7 (11-74)	50.3 (26-89)	1.6 (1.0-2.1)	14.5 (9.2-20.4)
Steelhead-rainbow trout	1981	0.75	16.5 (5-38)	83.5 (62-95)	2.4 (1.7-3.2)	13.7 (10.5-18.9)
	1982	0.69	27.7 (11-59)	72.3 (41-89)	2.3 (1.4-3.4)	12.5 (9.0-14.5)
Cutthroat trout	1981	1.12	42.1 (0-77)	57.9 (23-100)	2.3 (0.7-5.0)	12.8 (9.7-17.4)
	1982	1.08	57.8 (3-77)	42.2 (23-97)	2.4 (1.5-5.6)	13.1 (9.2-24.0)
Total salmonids	1981	2.04	41.8 (10-77)	58.2 (23-90)	1.9 (0.7-4.0)	13.7 (9.7-18.9)
	1982	2.21	56.5 (11-82)	43.5 (18-89)	1.8 (0.9-3.4)	15.0 (9.0-24.0)

*For all stations with the species or subgroup present.

Table 14. Percent pool area, percent gradient, and dominant substrate for each stream class rating at the 25 study sections in 1981.

Stream class	Number of sections	Average pool area, % (range in parentheses)	Average gradient, % (range in parentheses)	Dominant substrate type and frequency
1	9	73 (59-82)	1.2 (0.7-1.9)	Silt-1 Gravel-8
2	10	52 (25-79)	1.9 (1.4-2.8)	Gravel-8 Rubble-2
3	4	14 (5-25)	3.5 (1.7-4.9)	Gravel-1 Rubble-3
4	2	4 (0-7)	3.9 (2.8-5.0)	Rubble-1 Boulder-1

Table 15. Correlation analysis of habitat parameters and some stream characteristics within Capitol Forest study sections in 1981 versus stream classification according to the proposed scheme.

Habitat variable	Correlation coefficient	Statistically significant at 5% level
Percent pool area	-0.9176	Yes ($p < 0.001$)
Percent riffle area	0.9174	Yes ($p < 0.001$)
Stream gradient	0.8218	Yes ($p < 0.001$)
Stream mean width	-0.0635	No ($p > 0.50$)
Stream mean depth	-0.5913	Yes ($p < 0.001$)
Stream surface area	-0.1498	No ($p > 0.50$)
Stream order	0.0981	No ($p > 0.50$)
Dominant substrate	0.8057	Yes ($p < 0.001$)

addition, significant negative correlations were present between stream class and percent pool area and mean stream depth.

Possible associations between relative biomass and stream class were also tested using correlation analysis. Each species and subgroup was tested separately, as well as total salmonid relative biomass. No significant correlations were found for steelhead-rainbow trout, cutthroat trout, subyearling trout or total salmonid relative biomass. A significant negative correlation was found between coho relative biomass and stream class (r^2 = 0.422).

Habitat Use

Correlation analysis was used to test relative biomass estimates of 1981 against the following physical parameters: 1) percent pool area, 2) percent riffle area, 3) percent gradient, 4) mean depth, and 5) linear distance of instream cover. Additional habitat variables tested for 1982 included: 1) area of instream cover (replacing linear distance of cover), 2) percent of total water surface area with instream cover, and 3) mid-September discharge.

1981

Coho relative biomass showed a significant positive correlation with percent pool area while subyearling and steelhead-rainbow trout were negatively correlated with percent pool area (Table 16). A significant negative correlation was also found between coho relative biomass and percent gradient. No other significant correlations were found between the habitat variables tested and relative biomass estimates for 1981 (Appendix Table 3).

1982

Coho relative biomass showed significant positive correlations with percent pool area and mean depth, but was negatively correlated with percent

Table 16. Correlation analysis of habitat parameters versus relative biomass of coho, cutthroat, steelhead-rainbow, subyearling trout, and total salmonids for 1981.[1]

Habitat variable	Biological variable	Correlation coefficient	Significance
Percent pool area[2]	Coho relative biomass	.652	.001
Percent pool area[2]	Subyearling trout relative biomass	-.436	.029
Percent pool area[2]	Steelhead-rainbow relative biomass	-.523	.015
Percent gradient	Coho relative biomass	-.641	.002

[1]Correlations with a significance greater than 0.10 not shown (see Appendix Table 3).

[2]Results are equivalent for percent riffle area with the correlation coefficient sign changed.

gradient (Table 17). Coho relative biomass also showed a strong positive association with instream cover, but this relationship was not significant at the 95 percent level. A significant positive correlation was found between subyearling trout relative biomass and mid-September discharge. Subyearling trout also showed a strong positive association with instream cover area and a strong negative association with percent pool area, but neither of these was significant at the 95 percent level. The only relationship found for relative biomass of steelhead-rainbow trout was a negative correlation with percent pool area. A significant positive correlation occurred between cutthroat trout relative biomass and the percent total water surface area with instream cover. A strong association was also found between cutthroat relative biomass and percent pool area, but this was not significant at the 95 percent level. Total salmonid relative-biomass showed significant positive correlations with both mean depth and area of instream cover. A complete list of the correlation analysis results for 1982 are shown in Appendix Table 4.

Summer Attrition

Changes in population size and density between mid-July and mid-September within six extended (100 m-long) study sections were evaluated as part of the 1982 summer sampling. Since these changes in population size and density can be the result of both emigration and death, and it was not possible to separate the two effects, the terms "apparent mortality" and "attrition" will be used in reference to decreases in abundance resulting from these two factors. Physical characteristics of the extended study sections are presented in Table 18.

Apparent mortality of coho salmon averaged 26 percent between the six stations sampled (Table 19). Without inclusion of the Shelton Creek station,

Table 17. Correlation analysis of habitat parameters versus relative biomass of coho, cutthroat, steelhead-rainbow, subyearling trout, and total salmonids for 1982.[1]

Habitat variable	Biological variable	Correlation coefficient	Significance
Percent pool area[2]	Coho relative biomass	.717	<.001
Percent pool area[2]	Subyearling trout relative biomass	-.387	.091
Percent pool area[2]	Steelhead-rainbow relative biomass	-.512	.025
Percent pool area[2]	Cutthroat relative biomass	.426	.061
Percent gradient	Coho relative biomass	-.698	<.001
Mean depth	Coho relative biomass	.489	.034
Mean depth	Total salmonid relative biomass	.454	.044
Instream cover area	Coho relative biomass	.399	.091
Instream cover area	Subyearling trout relative biomass	.437	.054
Instream cover area	Total salmonid relative biomass	.450	.046
Percent total water surface area with instream cover	Cutthroat relative biomass	.627	.003
Mid-September discharge	Subyearling trout relative biomass	.648	.002

[1]Correlations with a significance greater than 0.10 not shown (see Appendix Table 4).
[2]Results are equivalent for percent riffle area with the correlation coefficient sign changed.

Table 18. Physical characteristics of extended stream study sections in Capitol Forest sampled during July and September 1982.

Station number	Station name	Sampling date	Total length (m)	Total surface area (m^2)	Pool area (%)	Riffle area (%)	Gradient (%)	Instream cover area* (m^2)
11	Upper Cedar Ck	7-22-82	100.6	428.9	78	22	1.6	28.9
		9-7-82		408.0	78	22		
12	Middle Waddell Ck	7-20-82	106.7	489.5	65	35	1.8	20.0
		9-14-82		447.3	58	42		
14	Sherman Ck	7-28-82	100.6	385.7	88	12	0.9	20.6
		9-2-82	109.1	434.6	85	15		
22	Shelton Ck	7-23-82	86.3	277.8	13	87	3.2	12.5
		9-3-82		248.3	15	85		
23	Upper Waddell Ck	7-21-82	106.7	296.1	75	25	1.8	35.9
		9-13-82		283.8	71	29		
24	Lower Cedar Ck	7-29-82	106.7	431.3	32	68	1.5	21.4
		9-10-82		434.0**	33	67		

*Includes undercut banks, logs and debris piles.
**Rainfall occurred on the day prior to sampling.

Table 19. Juvenile coho salmon population estimates, apparent mortalities, instantaneous mortality rates, densities, and mean fork lengths for July and September samplings of extended stream study sections in Capitol Forest during 1982.

Station name	Sampling date	Population estimate (95% c.i.)	Apparent mortality (%)	Instant. mortality rate (z)	Density (#/m^2)	Mean fork length (mm)	Change in mean fork length (mm/day)
Lower Cedar	7-29-82	128(97-162)	25	0.00669	0.30	57.6	0.126
	9-10-82	96(73-119)			0.22	63.0	
Upper Cedar	7-22-82	154(123-185)	33	0.00856	0.36	58.3	0.189
	9-7-82	103(67-139)			0.25	67.2	
Middle Waddell	7-20-82	88(68-108)	42	0.00974	0.18	63.8	0.145
	9-14-82	51(46-59)			0.11	71.9	
Upper Waddell	7-21-82	54(50-61)	17	0.00338	0.18	65.3	0.150
	9-13-82	45(38-55)			0.16	73.4	
Sherman	7-28-82	110(94-126)	38	0.01336	0.29	61.7	0.131
	9-2-82	68(57-82)			0.16	66.4	
Shelton	7-23-82	5(4-7)	0	0	0.02	75.3	0.255
	9-3-82	5(5-8)			0.02	86.0	

which had such low numbers of coho that its attrition value may not be realistic, the mean apparent mortality was 31 percent. The greatest reductions in coho abundance occurred at Middle Waddell (42%) and Sherman Creek (38%). These stations also had the highest instantaneous mortality rates.

Reductions in coho density ranged from 0 to 0.13 fish/m^2 at Shelton and Sherman Creek, respectively. A relatively large decrease in density occurred at the Upper Cedar Creek station (0.11 fish/m^2).

Increases in mean fork length of coho captured during sampling were interpreted as growth. It should be mentioned, however, that displacement of small fish by larger cohorts as living spaces decreases during the summer may have accounted for some of this size differential.

Greater increases in coho mean fork length generally occurred at stations with lower mean densities (mean density = July + September density/2), suggesting the occurrence of density dependent growth factors. Correlation analysis between the change in mean fork length and mean density, however, resulted in a non-significant relationship (Fig. 16). Although this association is not statistically significant ($.05 < p < .10$), it does indicate a trend for greater apparent growth at sites with lower mean densities.

Plotting of apparent mortality of coho versus density and change in mean fork length failed to show a relationship between these variables. Instream cover area, however, did show an inverse association with percent apparent mortality ($r = -0.761$) and instantaneous mortality ($r = -0.749$) when the Shelton Creek station, which had only 5 coho present, was not included. Although not statistically significant at the 95% level ($.05 < p < .10$ in both cases), these trends suggest lower attrition at study sites with larger amounts of instream cover.

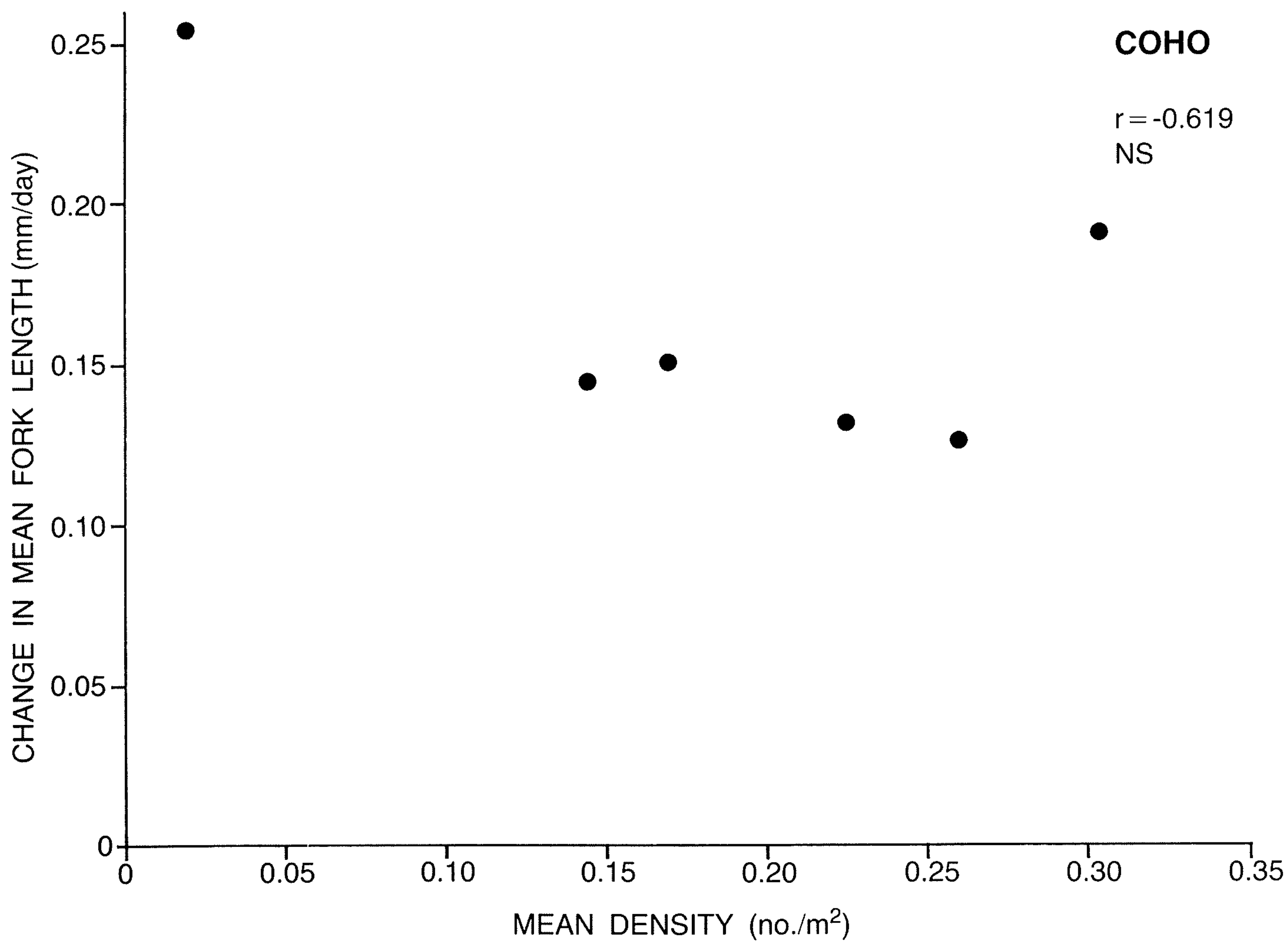


Fig. 16. Correlation between juvenile coho salmon change in mean fork length between July and September and mean density for the six extended sections in Capitol Forest during 1982.

Population changes during the summer for subyearling trout were not very well documented by this study due to the small number of these fish present within the sampling sites. During July, four stations were void of age zero trout and the highest abundance was three fish at Upper Waddell (Table 20). September populations of subyearling trout were likewise sparse, ranging from zero to three fish. Obviously, such small numbers of fish precludes any meaningful analysis of changes in abundance.

Cutthroat trout were present at all six stations during July and September. Population sizes ranged from $\hat{N}$ = 10-41 for July and from $\hat{N}$ = 12-31 for September (Table 20). Changes in population size during the summer failed to show a discernable trend as three stations had reduced cutthroat abundance in September, two had larger populations, and one remained the same. Differences in cutthroat abundance ranged from a 71 percent increase to a 33 percent decrease during this time. Changes in abundance of cutthroat failed to show any meaningful association with percent pool area, percent gradient, or area of instream cover.

Table 20. Population estimates and percent population change for July and September samplings of extended stream study sections in Capitol Forest during 1982.

Station name	Sampling date	Population estimate (95% c.i.)		Population change (%)	
		Age zero trout	Cutthroat trout	Age zero trout	Cutthroat trout
Lower Cedar	7-29-82	0	17 (14-23)	--	0
	9-10-82	3 (2-11)	17 (15-21)		
Upper Cedar	7-22-82	0	14 (11-18)	--	+ 71
	9-7-82	1 ± 0	24 (18-35)		
Middle Waddell	7-20-82	1 ± 0	31 (29-35)	+ 200	- 10
	9-14-82	3 (2-11)	28 (26-30)		
Upper Waddell	7-21-82	3 (2-11)	41 (38-44)	0	- 24
	9-13-82	3 (2-11)	31 (30-34)		
Sherman	7-28-82	0	18 (17-20)	0	- 33
	9-2-82	0	12 (10-18)		
Shelton	7-23-82	0	10 ± 0	0	+ 40
	9-3-82	0	14 (13-16)		

DISCUSSION

Low Biomass Values

The large annual variation in salmonid populations found on the West Coast of the United States (Hall and Knight 1981; Burns 1971) coupled with the different climatic and geomorphic characteristics of watersheds, make comparisons between studies on salmonid abundance somewhat tentative. These comparisons, however, can be useful in providing some perspective on the relative abundance found within a given watershed. The fact that the relative biomass values for Capitol Forest were substantially below those reported in other Pacific Northwest studies suggests that conditions are less than optimal for salmonid production in streams in Capitol Forest. These low biomass values may be related to habitat quality or, in the case of coho, lack of an adequate spawning escapement. Phinney and Bucknell (1975) reported that numerous sport and commercial fisheries intercepting coho originating in Capitol Forest streams may have a signficant impact on the spawning populations. In addition, water quality problems in the Grays Harbor estuarine areas caused by domestic and industrial effluents have previously been reported (McCall 1970).

In addition to showing substantially lower relative biomass values, comparisons between Capitol Forest coho and results from other Pacific Coast studies reveal that Capitol Forest coho are larger than average (Table 21). Mean fork lengths of late-summer coho salmon were substantially lower in all other studies with the exception of the Clearwater River Basin. Edie (1975) hypothesized that tributaries of the Clearwater River were generally underseeded for coho and that their large average size was likely due to these low densities. In Capitol Forest, a comparison of coho mean length versus

Table 21. Comparison of late-summer mean fork lengths of coho salmon in Capitol Forest streams with those reported from other areas.

Location	Authors	Mean fork length (mm)
Oregon		
Alsea watershed	Chapman (1965)	58.1
Alsea watershed	Moring and Lantz (1974)	65.3
California		
Northern coast	Burns (1971, 1972)	60.4
British Columbia		
Carnation Creek	Narver and Andersen (1974)	52.4
Eastern Vancouver Island	Narver (1972)	54.2
Washington		
Clearwater River basin	Edie (1975)	74.8
Puget Sound streams	Flint (1979) (unpubl.)	60.2
Capitol Forest streams	1981	71.8
	1982	69.3

density showed that stations with lower coho densities generally contained larger fish (Fig. 12). Correlation analysis of these variables showed a significant negative relationship for both years, implying density dependent growth is occurring. Burns (1971) reported that young-of-the-year salmonids in North Fork Caspar Creek in June were larger at low densities, but found no trend in growth from June to October to support a density dependent growth hypothesis. Capitol Forest streams sampled twice during the summer did indicate a trend of greater apparent growth at sites with lower mean densities although this relationship was not statistically significant. Reduced densities similarly resulted in accelerated growth in the Alsea watershed. In this study, lower coho smolt yields resulted in a significant increase in mean fork length (Knight 1979). Sufficient data is not presently available to determine the relationship between coho smolt size and density in Capitol Forest. However, the inverse relationship between summer density and size for both years and the negative trend between density and summer growth indicate that large sized coho are likely the result of sparse populations in Capitol Forest streams. Similarly, because underyearling coho typically exhibit a size frequency distribution skewed to the right (Mason 1976), a lack of skewness in the size frequency distributions of Capitol Forest coho suggests that low densities have allowed smaller fish to compete more effectively for food and ultimately attain a larger average size.

Some insight into whether Capitol Forest streams can sustain higher densities of rearing salmonids and what effect these higher densities may have on fish size was gained by way of supplemental stocking of hatchery reared coho. On 19 April 1982, the Washington Department of Fisheries planted 33.1 kg (73 lbs.) of coho fry at 1160 fish per kg (526/lb.) 200 m upstream of the Lower Mima study section (Rick Brix, WDF, personal communication). Subsequent late-summer sampling of this section showed that both the abundance and biomass of coho in this section had been significantly increased (176% and 90%, respectively) relative to the 1981 values. While this increased abundance is most likely the result of the supplemental stocking, it should be noted that similar population increases did occur between years at several stations which received only natural recruitment of juvenile coho (e.g., Fuzzy Top +189%, Lower North Fork Porter +156%, and Lower Cedar +146%). Interestingly, this increased density at Lower Mima coincided with a significant ($p < .001$) reduction in coho mean length between years (1981 $\overline{X}$ = 77 mm, 1982 $\overline{X}$ = 66 mm). This reduction in fish size is most likely the result of increased density and may be indicative of large coho being the result of underseeded conditions not only at the Lower Mima station but in other Capitol Forest streams as well.

An expected result of increased coho biomass at this station, if the site was near carrying capacity for fish production, would be a reduction in biomass of the other species present. What occurred, however, was a large increase in both the absolute and relative biomass of cutthroat trout for 1982 (+85% in both cases) accompanied by a small increase in the biomass of subyearling trout. The ability of this section to support substantially greater coho biomass concurrent with increased cutthroat and subyearling trout biomass strongly suggests that salmonid population levels during summer at this site, and possibly others, were well below carrying capacity. This contention is further supported by the fact that large increases in coho abundance and biomass at Fuzzy Top, Lower North Fork Porter, and Lower Cedar were also associated with greater cutthroat abundance and biomass resulting in higher levels of total salmonid biomass at these stations in 1982.

Therefore, the evidence suggests that low levels of salmonid biomass in some Capitol Forest streams are not due to habitat restrictions on the summer rearing populations. Greater salmonid biomass can be supported during the summer months. It does appear, however, that rearing capacity may be generally lower in Capitol Forest streams than other areas of the Pacific Northwest. The fact that even the highest coho biomass values in Capitol Forest (including the hatchery stocked section) were almost entirely below the combined mean from other studies suggests this to be the case.

Unfortunately, more complete utilization of summer rearing space by coho in Capitol Forest will not necessarily result in a larger smolt output. Because these summer populations need to endure winter stream conditions prior to smolt outmigration, appropriate refuge habitat must be available during winter or increased summer population size may be negated during winter (Mason 1976).

Another condition previously indicated (Phinney and Bucknell 1975) as a major factor limiting fish production in Capitol Forest streams is the occurrence of high water temperatures during the summer. Water temperatures in the Porter Creek watershed were reported to often exceed 21°C for prolonged periods during summer months. Such conditions would undoubtedly be stressful to stream dwelling salmonids.

The upper lethal temperature for salmon has been reported as 25.1°C (Brett 1952). DeHart (1975) concluded that, for temperatures up to 28°C, the total time the water exceeded 25°C was the crucial factor rather than the maximum temperature attained. In general, mean summer water temperatures between 10° and 15°C are considered optimal for rearing salmonids (Reiser and Bjornn 1979).

Afternoon water temperatures taken at Capitol Forest study sites during fish and habitat sampling show maximums to be well below lethal levels and generally within the optimum range (Tables 10 and 12). The maximum afternoon temperature observed at a site was 18.3°C (1981). Two other sites had afternoon temperatures of 17.8°C, but the general range occurred between 12° and 15°C ($\overline{X}$ = 14.4°C for 1981 and 1982 combined). Continuous monitoring of water temperatures in the lower reach of Waddell, Mima, Cedar, and Porter Creeks during 1982 indicated the maximum daily temperature at any of these sites to be 17.2°C (Jim Ryan, DNR, unpublished data). This temperature occurred at the Waddell Creek station for three consecutive days in late August. The range of maximum water temperatures during the summer of 1982 generally fell between 10° and 16°C.

Comparisons of these data with critical temperature values reported in the literature indicate that high summer water temperatures are unlikely to presently be a major factor limiting fish production in Capitol Forest streams. It appears that the second growth forest canopy as well as the abundant streamside riparian vegetation are currently providing sufficient shading to prevent adversely high summer water temperatures. However, to avoid the high water temperatures reported in the past (Phinney and Bucknell 1975), maintenance of this streamside vegetation should be considered an important goal of future land management plans for Capitol Forest.

Summer Attrition

During summer, coho fry have been shown to exhibit a downstream drift as the result of a reduction in available rearing space and consequent aggressive behavior (Chapman 1962). Both the territorial demands of juvenile coho and the stream carrying capacity are important factors in regulating these emigrations (Chapman 1966). In addition, reductions in summer abundance can be expected as a result of mortality caused by predation or stress. In

Alaska, Crone and Bond (1976) reported juvenile coho suffered the greatest mortality during their first summer of life as a result of predation and emigration into the estuary.

Sampling of salmonid populations during mid-July and mid-September of 1982 in Capitol Forest showed an average reduction of 26 percent in coho populations at six study sites. Flint (1977) showed late summer coho mortality to be about 11 percent at four sites in Puget Sound streams; while Murphy et al. (1982) reported that coho densities in an old growth stream in southeastern Alaska had stabilized by mid-to-late summer resulting in minimal mortality during this time.

Since factors regulating summer emigration of coho have been shown to be largely density dependent (Chapman 1966), fairly low levels of movement from Capitol Forest study sections would be expected as a result of the relatively low densities existing in early summer. Substantial attrition, however, did occur within the study sections regardless of these initial low densities. The exception to this being the Shelton Creek station which maintained its coho population of five fish throughout the summer. The relatively high summer attrition in the Capitol Forest study sections, in light of the low densities, suggests two possibilities. First, the carrying capacity of these streams, and possibly others in Capitol Forest, may be generally lower than other Northwest streams that were used for comparison. Food could be the limiting factor in this situation. As shown by Mason (1976), summer emigration from a stream can be substantially reduced and standing crop increased by supplemental feeding. Second, attrition may be largely the result of mortality caused by predation. Avian predators, including both herons and kingfishers, have been seen frequenting Capitol Forest streams. In addition, cutthroat trout populations within these study sections were substantial enough to present some predation pressure.

The apparent association between summer attrition and instream cover indicates that fewer coho emigrated from or suffered mortality in those sections with greater amounts of instream cover, with the exception of the Shelton Creek station. This trend may be due to the environmental heterogeneity provided by instream cover. Kalleberg (1958) showed that visual isolation resulted in reduced territory size among Atlantic salmon (*Salmo salar*) and brown trout (*S. trutta*). Instream logs and rootwads likely provide a similar type of isolation for coho and may allow more efficient use of space during summer as water area and volume decrease. Better opportunities for predator avoidance would also be afforded coho residing in sections with greater amounts of instream cover and would likely result in reduced mortality.

Because coho densities were greater in 1981 than in 1982 at most of the six expanded study sites, it seems unlikely that high densities would have been a major factor in causing population reductions at these sites during the summer of 1982. It may be that mortality caused by predation is largely responsible for population reductions at these sites. However, at present, no studies have been conducted to evaluate predation levels on coho in Capitol Forest streams. Therefore, while it is recognized that both downstream migration and mortality are responsible for reductions in coho populations during the summer, the degree to which each is responsible for these reductions in Capitol Forest streams remains unresolved.

Habitat Use

According to Hall and Knight (1981), assessment of the physical characteristics of stream habitats is the most promising method for determining causes of variability among salmonid populations. Several studies have related physical perturbations in the aquatic environment to salmonid population changes (Wasserman 1984; Cederholm et al. 1982; Murphy and Hall 1981; Osborn 1980; Chapman and Knudsen 1980; Baker 1979; Lestelle 1978; Moring and Lantz 1975; Gibbons and Salo 1973; Burns 1972; Narver 1972; Hall and Lantz 1969; Gunderson 1968). Therefore, we measured physical stream characteristics previously shown to be important to salmonids in order to identify their relationship to Capitol Forest fish populations.

Juvenile coho salmon have probably been studied more frequently than any other juvenile salmonid due to their relatively long and dependable stream residence. Coho were the only salmon species present in Capitol Forest streams and, with few exceptions, were considerably more abundant at more stations than juvenile trout. A number of interesting, yet somewhat predictable, correlations were found between coho and their physical habitat.

Coho in Capitol Forest showed a strong preference for study sites with a high percentage pool area, low gradient, and relatively high mean depth. Both Hartman (1965) and Allee (1974) found coho preferred pools, while Ruggles (1966) reported coho preferred a pool-like environment with low velocity flows. Edie (1975) reported capturing approximately 75 percent of the coho in Clearwater River tributary study sites in pools, but subsequently failed to find any statistical correlations between coho and pool environments. This apparent anomaly was hypothesized to be the result of low densities of coho in study sections. Edie's relative biomass values for coho were nearly equivalent to those found in Capitol Forest during 1981 and 1982. Even though one might expect differing relationships between coho and their habitat in geographically separate areas, the fairly consistent findings between coho and pool area or volume, velocity, and gradient throughout the Northwest suggests a fairly strong tie to this type of habitat.

Both subyearling trout and steelhead-rainbow trout differed from coho in preference of habitat. Negative correlations were found between percent pool area and subyearling (not significant) and steelhead-rainbow trout, indicating a preference for sections with more riffle habitat. Similar habitat preferences for steelhead-rainbow were also found by Hartman (1965) and Allee (1974). Bisson et al. (1982) reported that steelhead trout in western Washington streams favored riffle areas over pool or glide habitats. In southeastern Alaska, steelhead heavily utilized riffles, but were found to specifically prefer riffle margins with undercut banks and debris while avoiding the centers of riffles (Murphy et al. 1982). For subyearling trout, a similar positive correlation with riffle area also occurred in tributaries of the Clearwater River, Washington (Edie 1975). June (1981) found a negative correlation between cutthroat fry density and pool area, and suggested this was likely due to fry avoiding larger, older trout residing in pool areas. Older-age cutthroat trout occupying pools in Capitol Forest streams may also result in a similar segregation of space between year classes. The significant positive association found between subyearling trout and mid-September discharge in Capitol Forest was also similar to results reported for Clearwater River tributaries (Edie 1975).

Although the relationship was not significant, age one and older cutthroat trout in Capitol Forest showed a trend towards preferring pools as their favored habitat. Life history studies have shown that cutthroat will generally reside in shallow, small tributaries as fry and gradually shift downstream as they become larger (Lowry 1965). At age II and older, cutthroat prefer deeper waters along the current margins where cover is abundant (Chapman and Bjornn 1969). Age one and older cutthroat in Capitol Forest streams showed similar predilections to areas with more cover as indicated by a significant positive correlation with percent total water surface area with instream cover. Pools and low velocity areas were also preferred by adult cutthroat in Bear Creek, Washington while fry were found in shallower, faster waters (June 1981).

The importance of cover to both juvenile and adult salmonids has been reported in relation to protection from predation (Meehan et al. 1977), significance to winter survival (Chapman and Bjornn 1969; Bustard and Narver 1975b), importance to habitat differentiation (Chapman 1966), and variation in population densities (June 1981; Lewis 1969; Gunderson 1968). Cover is also considered an important variable necessary for optimal rearing of smolts (Mundie 1974).

While low densities of fish can severely mask relationships with habitat variables, it is likely that the lack of any significant correlations between cover and fish density or biomass in Capitol Forest study sites in 1981 was largely due to the method used to measure and express the amount of instream cover that year. Only the linear distance of instream cover was measured in 1981. This method provides some accounting of cover, but fails to adequately represent the total area provided by overhanging banks or debris piles. In retrospect, it now seems obvious that such a measurement technique did not realistically assess the amount of cover present for use by fish. During 1982, however, use of the surface area measurement of instream cover provided a more accurate assessment of this habitat variable. Although only total salmonid relative biomass was significantly correlated with instream cover area in 1982, both coho and subyearling trout relative biomass showed strong positive associations with instream cover, further suggesting the importance of cover to salmonids in Capitol Forest streams. When instream cover was expressed as the percent of total water surface area within a study section, it correlated significantly with cutthroat relative biomass.

While Lestelle (1978) suggested that debris was not a significant cover item for cutthroat during the summer, Bisson et al. (1982) found debris to be the preferred type of cover during summer for age 1+ steelhead and age 1+ and 2+ cutthroat. Osborn (1980) and June (1981) also determined that older cutthroat largely utilize debris for cover. The general lack of correlations between cover items, including debris, and either fish biomass or density in Capitol Forest streams during summer may be the result of several factors. First, low fish abundance levels may have resulted in incomplete utilization of cover items by fish. This condition was also suggested to be responsible for a general lack of correlations between habitat variables and fish biomass in Clearwater River tributaries (Edie 1975). Second, cover items which were not measured, including boulders and cobble, may be preferred by certain species. Also, use of cover items to avoid predation may not be as frequent in summer as occurs during other seasons due to the importance of feeding at this time.

It may be, then, that fish in Capitol Forest streams utilize cover more frequently during the winter when food is presumably less abundant and increased stream flows combined with decreased temperatures present a more rigorous physical environment. On Vancouver Island, British Columbia, both Bustard and Narver (1975a, 1975b) and Tschaplinski and Hartman (1983) found that protection from high flows during winter was provided by woody debris, especially large logs and rootwads. Similarly, recent studies on the Olympic Peninsula coast of Washington indicate that large organic debris is particularly important to juvenile salmonids during winter (Grette, in press). Therefore, while certain cover items are extremely important to stream rearing salmonids, utilization of these items may be more prominent on a seasonal basis. Use of cover may also vary between species and can be affected by fish density. Consequently, the importance of cover may not be adequately represented by assessment of only summer conditions in areas of low fish density. Also, varying levels of predator occurrence combined with different hydrologic characteristics between study sites could largely influence cover utilization by salmonids in Capitol Forest streams.

Conclusions

In conclusion, we feel that future management of the riparian areas in Capitol Forest will be crucial to the vitality of salmonid populations within the forest. The goals of future land use plans should necessarily include consideration of possible impacts to the riparian zone which may result from forest activities. Specifically, the previously cited problem of high water temperatures (Phinney and Bucknell 1975) deserves special attention. To prevent a recurrence of such problems, it is recommended that maintenance of streamside vegetation be considered of paramount importance.

An effective management strategy to serve this end may be the implementation of a selective harvest within the riparian zone. This approach could potentially reserve enough trees from harvest to provide both adequate stream shading and a source area for future recruitment of wood debris to the stream. Future recruitment of wood debris will be especially important in providing fish cover and stream channel stability as older decaying wood, presently in the stream, breaks down and becomes dislodged.

Lastly, it is recommended that numerous streams in Capitol Forest be reevaluated in terms of their State Water Type designation. This review will be necessary to assure future protection of those stream habitats which are important to salmonid fish production.

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APPENDIX TABLES

Appendix Table 1. Percentage of total estimated late-summer population represented by each species or subgroup at sampling stations in Capitol Forest, Washington.

Station number	Station name	Sample year	Percentage of total estimated population: Coho salmon	Underyearling trout	Yearling & older steelhead-rainbow trout	Yearling & older cutthroat trout
1	Lower Waddell Ck.	1981	59	27	4	10
		1982	60	33	4	3
2	Main Porter Ck.	1981	3	80	16	<1
		1982	12.5	48	37.5	2
3	Bozy Ck.	1981	0	0	0	100
4	W. Fork Porter Ck.	1981	0	15	0	85
5	Lower N.F. Porter Ck	1981	25.5	48	25.5	1
		1982	61	19	11	9
6	Fuzzy Top Ck.	1981	62	2	2	34
		1982	76	1	0	23
7	S. Fork Porter Ck.	1981	0	52	33	15
		1982	26	31	31	12
8	Hell Ck.	1981	0	63	34	3
9	Lower Gibson Ck.	1981	50	14	4	32
		1982	71	9	7	13
10	Lower Mima Ck.[1]	1981	76	0	0	24
		1982	86	4	0	10
11	Upper Cedar Ck.	1981	92	0	0	8
		1982	84	1	0	15

Appendix Table 1 (continued)

Station number	Station name	Sample year	Percentage of total estimated population: Coho salmon	Underyearling trout	Yearling & older steelhead-rainbow trout	Yearling & older cutthroat trout
12	Middle Waddell Ck.	1981	64	3	0	33
		1982	77	0	0	23
13	Fall Ck. Trib.	1981	50	6	0	44
14	Sherman Ck.	1981	91	0	0	9
		1982	88	0	0	12
15	Upper Monroe Ck.[2]	1981	67	3	0	30
		1982	75	0	3	22
16	Upper Gibson	1981	0	56	0	44
17	Upper Mima Ck.	1981	0	58	0	42
		1982	0	37	0	63
18	Lost Valley Ck.	1981	65	0	0	35
		1982	78	0	0	22
19	Lower Monroe Ck.	1981	84	2	0	14
		1982	94	1	1	4
20	Noski	1981	70	2	0	28
		1982	68	0	0	32
21	North Ck.	1981	35	9	4	52
		1982	0	31	0	69
22	Shelton Ck.	1981	81	2	0	17
		1982	33	0	0	67
23	Upper Waddell Ck.	1981	58	5	0	37
		1982	49	0	0	51

Appendix Table 1 (continued)

			Percentage of total estimated population			
Station number	Station name	Sample year	Coho salmon	Underyearling trout	Yearling & older steelhead-rainbow trout	Yearling & older cutthroat trout
24	Lower Cedar Ck.	1981	87	2	0	11
		1982	96	0	0	4
25	Mill Ck.	1981	5	37	0	58
26	Upper N. Fork Porter Ck.	1982	46	25	22	7

[1] Coho fry planted above this station by WDF in spring 1982.

[2] Location of study section moved downstream approximately 670 meters for 1982 sampling.

Appendix Table 2. Percentage of total estimated late-summer biomass represented by each species or subgroup at sampling stations in Capitol Forest, Washington.

			Percentage of total estimated biomass			
Station number	Station name	Sample year	Coho salmon	Underyearling trout	Yearling & older steelhead-rainbow trout	Yearling & older cutthroat trout
1	Lower Waddell Ck.	1981	31	7	12	50
		1982	52	12	13	23
2	Main Porter Ck.	1981	3	34	58	5
		1982	9	15	67	9
3	Bozy Ck.	1981	0	0	0	100
4	W. Fork Porter Ck.	1981	0	2	0	98
5	Lower N. Fork Porter Ck.	1981	19	13	62	6
		1982	42	5	21	32
6	Fuzzy Top Ck.	1981	25	1	5	69
		1982	38	<1	0	61
7	S. Fork Porter Ck.	1981	0	8	50	42
		1982	12	5	52	31
8	Hell Ck.	1981	0	19	72	9
9	Lower Gibson Ck.	1981	26	5	13	56
		1982	32	3	20	45
10	Lower Mima Ck.[1]	1981	58	0	0	42
		1982	58	1	0	41
11	Upper Cedar Ck.	1981	55	0	0	45
		1982	43	<1	0	56

Appendix Table 2 (continued)

Station number	Station name	Sample year	Percentage of total estimated biomass: Coho salmon	Underyearling trout	Yearling & older steelhead-rainbow trout	Yearling & older cutthroat trout
12	Middle Waddell Ck.	1981	30	1	0	69
		1982	50	0	0	50
13	Fall Ck. Trib.	1981	27	2	0	71
14	Sherman Ck.	1981	70	0	0	30
		1982	62	0	0	38
15	Upper Monroe Ck.[2]	1981	33	<1	0	66
		1982	29	0	4	67
16	Upper Gibson Ck.	1981	0	18	0	82
17	Upper Mima Ck.	1981	0	21	0	79
		1982	0	14	0	86
18	Lost Valley Ck.	1981	29	0	0	71
		1982	37	0	0	63
19	Lower Monroe Ck.	1981	39	<1	0	61
		1982	66	1	6	27
20	Noski Ck.	1981	44	<1	0	56
		1982	36	0	0	64
21	North Ck.	1981	16	2	5	77
		1982	0	8	0	92
22	Shelton Ck.	1981	39	1	0	60
		1982	18	0	0	82

Appendix Table 2 (continued)

Station number	Station name	Sample year	Percentage of total estimated biomass: Coho salmon	Underyearling trout	Yearling & older steelhead-rainbow trout	Yearling & older cutthroat trout
23	Upper Waddell Ck.	1981	27	1	0	72
		1982	22	0	0	78
24	Lower Cedar Ck.	1981	56	1	0	43
		1982	75	0	0	25
25	Mill Ck.	1981	2	9	0	89
26	Upper N. Fork Porter Ck.	1982	26	6	34	34

[1] Coho fry planted above this station by WDF in spring 1982.

[2] Location of study section moved downstream approximately 670 meters for 1982 sampling.

Appendix Table 3. Correlation analysis of habitat parameters versus relative biomass (g/m^2) of coho salmon, cutthroat, steelhead-rainbow, and subyearling trout, and total salmonids for 1981.

Habitat variable	Biological variable (g/m^2)	Correlation coefficient	Significance
Percent pool area[1]	Coho salmon	0.652	0.001
	Subyearling trout	-0.436	0.029
	Steelhead-rainbow	-0.523	0.015
	Cutthroat	-0.077	0.715
	Total salmonids	-0.308	0.135
Percent gradient	Coho salmon	-0.641	0.002
	Subyearling trout	0.227	0.275
	Steelhead-rainbow	0.198	0.388
	Cutthroat	0.185	0.376
	Total salmonids	0.007	0.975
Mean depth	Coho salmon	0.345	0.126
	Subyearling trout	0.155	0.458
	Steelhead-rainbow	0.024	0.918
	Cutthroat	-0.267	0.197
	Total salmonids	0.076	0.717
Instream cover	Coho salmon	0.249	0.276
	Subyearling trout	0.157	0.455
	Steelhead-rainbow	-0.006	0.978
	Cutthroat	-0.036	0.865
	Total salmonids	-0.012	0.955

[1]Results are equivalent for percent riffle area with the correlation coefficient sign changed.

Appendix Table 4. Correlation analysis of habitat parameters versus relative biomass (g/m^2) of coho salmon, cutthroat, steelhead-rainbow, and subyearling trout, and total salmonids for 1982.

Habitat variable	Biological variable (g/m^2)	Correlation coefficient	Significance
Percent pool area[1]	Coho salmon	0.717	<0.001
	Subyearling trout	-0.387	0.091
	Steelhead-rainbow	-0.512	0.025
	Cutthroat	0.426	0.061
	Total salmonids	0.278	0.236
Percent gradient	Coho salmon	0.698	<0.001
	Subyearling trout	0.019	0.937
	Steelhead-rainbow	0.081	0.742
	Cutthroat	0.059	0.806
	Total salmonids	-0.275	0.241
Mean depth	Coho salmon	0.489	0.034
	Subyearling trout	0.051	0.829
	Steelhead-rainbow	-0.074	0.764
	Cutthroat	0.156	0.511
	Total salmonids	0.454	0.044
Instream cover area	Coho salmon	0.399	0.091
	Subyearling trout	0.437	0.054
	Steelhead-rainbow	0.116	0.636
	Cutthroat	0.204	0.389
	Total salmonids	0.450	0.046
Percent total water surface area with instream cover	Coho salmon	0.301	0.211
	Subyearling trout	-0.104	0.663
	Steelhead-rainbow	-0.215	0.376
	Cutthroat	0.627	0.003
	Total salmonids	0.361	0.118
Mid-September discharge	Coho salmon	0.249	0.305
	Subyearling trout	0.648	0.002
	Steelhead-rainbow	0.279	0.247
	Cutthroat	-0.312	0.181
	Total salmonids	0.226	0.339

[1]Results are equivalent for percent riffle area with the correlation coefficient sign changed.