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Factors affecting the natural rearing of juvenile coho salmon during the summer low flow season.

Factors Affecting the Natural Rearing of Juvenile Coho Salmon During the Summer Low Flow Season

Lincoln S. Pearson, Kelly R. Conover, and Roy E. Sams

INTRODUCTION

Demands for surface water resources in Oregon have been increasing rapidly and will continue to do so. This is creating serious problems for anadromous fish in many streams. Excessive appropriation of summer streamflows often results in reductions in fish populations.

Present knowledge concerning the summer rearing requirements of juvenile salmonids is limited. Also, little is known about the extent of losses in salmon and steelhead resources due to diminished flows. Additional information is needed to promote more efficient and enlightened use of available water supplies for both fisheries and other uses.

This paper examines factors which affect the production of juvenile coho salmon (Oncorhynchus Kusutch) during the summer stream rearing period. Study objectives were: (1) to obtain criteria for use in developing field methods to determine adequate rearing flows; (2) to provide data for use in predicting juvenile coho production at various summer flow levels; and (3) to provide additional biological justification for setting minimum summer streamflows and for requesting flow releases from storage reservoirs.

Coho were selected for study in preference to chinook salmon (R. Tshaurytscha) or steelhead trout (Salmo gairdnerii) because coho are the easiest to study. Coho rear in small easily worked streams. They are concentrated in pools rather than in swift turbulent areas. The study was carried out with limited funds from 1962 through 1966.

STUDY AREAS

Nineteen streams were studied in four river systems. These systems are the Nehalem and Wilson, coastal rivers, and the Tualatin and Yamhill, tributaries of the Willamette River.

The streams originate in the coast range of northwest Oregon. They flow through mixed stands of mainly alder and second-growth fir. The watersheds are of similar character. Precipitation varies from 40 to 100 inches a year, falling primarily as rain. There is much seasonal fluctuation of flow in each stream. High water and floods occur in the winter and spring. The low summer flow period persists from about mid-July until October.

All study streams contain runs of coho. Fish other than coho occurring in one or more of the study streams are: fall chinook salmon (*Oncorhynchus tshawytshaw*), steelhead trout (*Salmo gairdneri*), coastal cutthroat trout (*Salmo clarki clarki*), redside shiner (*Richarsonius balteatus balteatus*), largescale sucker (*Catostomus macrocheilus*), Pacific lamprey (*Lampetra tridentata*), brook lamprey (*Lampetra planeri*), and *Cottus* species.

Coho spawn in the study streams during the period November-January. Fry emergence takes place from March through May. Downstream movement of postemergent coho occurs into August. Smolts migrate to sea mainly in April and May of the year following emergence.

All study sections meet the following criteria: (1) a staricase of pools and riffles, (2) no significant tributary entering the stream within the boundaries of the study section, and (3) pools easily seinable. However, on some study sections population estimates were not made and only stream measurements taken. In these instances, the last criterion was disregarded.

Study sections used for population estimates were about 2,000 feet in length except for the Nehalen study sections in 1965 and 1966. The Nehalem study areas in 1965 and 1966 consisted of five pools per stream on five similar sized streams. On McKay Creek some measurements were taken on a one-mile section which included the 2,000 foot section on which population estimates were made. Also, stream measurements were made on North Fork of Gales and Willamina Creeks on a section of less than 2,000 feet. No population estimate was made on these streams. Table I gives the length and locations of study sections.

METHODS

Field studies were conducted over a five-year period, August 1962 to October 1966. Data was collected for two to five years on eight streams and for one year on eleven others. Investigations were confined largely to the effects of streamflow and physical stream dimensions on fish production. However, attempts were made to evaluate some of the many other ecological factors that might affect fish production.

Population Estimates and Fish Measurements

Population estimates were made on 17 streams in one or more of the years. Coho populations were estimated by the Peterson single census method as described by Ricker (1958). The formula is:

$$N = \frac{MC}{R},$$

Where:

Table I. Length and Location of Study Sections on Streams of the Nehalem, Tualatin, Wilson and Yamhill River Systems

Stream	Location	Downstream Boundary of Study Section	Section Length in Feet
Nehalem River System			
Beneke Creek	S25,T6N,R7W	Bridge	4,000
East Humbug Creek	S25,T5N,R8W	Highway 26 bridge	2,030
Fishhawk Creek	S6,T6N,R5W	1,200 Feet below section line 5-6	950
Hamilton Creek	S32,T6N,R7W	Highway 202 bridge	4,000
Humbug Creek	S25,T5N,R8W	150 feet above mouth of East Humbug Creek	2,000
Nehalem River	S15,T3N,R5W	200 feet above mouth of Castor Creek	2,600
North Fork Wolf Creek	S31,T4N,R5W	200 feet above mouth	2,600
Oak Ranch Creek	S1,T5N,R4W	Third highway bridge above mouth	2,500
Rock Creek	S5,T4N,R5W	800 feet below Selder Creek	2,100
South Fork Rock	S29,T4N,R6W	1,700 feet below Highway 26 bridge	2,000
Tualatin River System			
East Fork Dairy Creek	S21,T3N,R3W	1,800 feet below Denny Creek	11,000
Gales Creek	S19&20,T2N R5W	0.8 mile above Beaver Creek	16,000
McKay Creek	S13&24,T2N R3W	Collins Road bridge	5,280
North Fork Gales Creek	S18,T2N,R5W	3,500 feet above mouth	300
Beaver Creek	S3,T2N,R5W	1.2 miles above second highway bridge upstream from mouth	2,000
South Fork Gales Creek	S20,T2N,R5W	Highway bridge at mouth	2,000

Wilson River System

Cedar Creek	SI,TIN,R8W	100 feet above unnamed tributary on right bank	2,000
Devils Lake Fork	S35,T2N,R6W	1,000 feet below Highway 6 bridge	2,000

Yamhill River System

Willamina Creek	S24,T5S,R7W	2.5 miles downstream from from the Coast Creek	100

N = population estimate

M - number of marked fish released

C = total catch during mark sampling

R = number of marked fish recaptured

Fishing was done with a 20-foot seine. All pools were seined twice, initially for marking and subsequently for mark sampling. Some large pools were seined by sections to improve fishing success.

Mark sampling was performed within four days after marking. During mark sampling, some of the coho were measured. Fish were taken at random from the seine, measured for fork length to the nearest millimeter, and for volume to the nearest milliliter. Fish were measured for volume by displacement of water in a graduated cylinder. The number of fish measured in each stream is shown in Table 7, page

Trout populations were estimated by the Peterson single census method on six streams in 1964. On other streams only the number of trout captured was recorded. On these streams the trout population was obtained by using the ratio of coho marked to coho marked recaptured and applying a ratio of the trout's greater escape ability and multiplying these ratios by the trout captured.

Overpopulating Study Areas

Severe flooding causing stream bed damage occurred in some study streams in December 1964 and January 1965.

Because of this, in mid-July pools in four of the five streams between which coho production would be compared were overpopulated with resident coho seined from nearby pools. The number of fish transported and the number marked is shown in Table 4 on page

On March 11, 1966, 90,000 unfed coho fry from the Oregon Fish Commission's Sandy River Salmon Hatchery were distributed in the 2,000-foot study section on McKay Creek. In contrast, the largest recorded population estimate in the section prior to this was 2,284 fish on October 17, 1963.

There were three reasons for this plant: first, to eliminate any doubt that the study section was well seeded; second, to see if a large fry plant would result in greater fingerling production through the summer than would be indicated from previous production rates in the section from natural sources; and third, to see if an abnormally large fry population would result in smaller fish than usual in late summer.

Streamflow Measurement

Streamflow measurements were taken within the boundaries of each study section with a Gurley Pygmy current meter. Stream-gauging procedures described by Corbett (1962) were followed:

The streamflows used for fish production comparisons were measured during low flow periods either in late August or September. This is believed to be the critical period for coho rearing.

Stream Size Measurements

All stream measurements used for fish production comparisons were made during the low flow period. Measurements were made of pool widths, riffle widths, pool and riffle depths, pool and riffle lengths. Data calculated from stream size measurements are given in Table 3 and page

Rearing Velocity Measurements

Measurements were taken to find the highest water velocities at which individual fish were rearing in 1965. The measurements were made in two streams, East Fork Dairy Creek and South Fork Rock Creek. These two streams were chosen because their streamflows were higher per stream width than any of the other study streams. Velocities were measured only at the points where fish were observed rearing in the areas of highest velocities of the rearing areas observed.

Insect Velocity Measurements

Water velocities over riffles as related to numbers of aquatic insects (coho food organisms) were studied as a possible criterion for determining optimum flows for coho rearing. Riffles with uniformed-sized gravel were sampled for numbers of aquatic insects at selected water velocities across the riffle. Insect samples were taken with a Sauber square foot sampler. In each sample the total number of insects as well as the numbers in each of the main orders were recorded. Water velocity readings were taken over each sampling site with a current meter.

Temperature

Instantaneous water and air temperatures in five streams were recorded on July 29, 1966. Temperatures were taken from 3 p.m. to 6 p.m. with a standard hand thermometer.

Cover, Shad and Bottom Composition

Observations were made on cover, shade and bottom composition. Cover in each pool was placed in a category of either good or poor. Shade over each pool or riffle was recorded as a percent opening in the canopy of the total sky area. Bottom composition was recorded as the type of bottom present (gravel, bedrock, silt or sand) and the size of gravel (large, medium or small).

RESULTS

Population Estimates

Population estimates were made on 18 stream sections from 1962 throgh 1966 mainly in late September and October. Table 2 shows coho population estimates and confidence limits for the 17 sections. Trout population estimates for 1963 and 1964 are also shown in Table 2.

Stream Size

Data on stream size is included in Table 3.

Carrying capacity. Since severe floods occurred in the winter of 1965, it was decided to determine if the streams were at their carrying capacity. This was done by overpopulating the study pools with 1,415 fish seined from nearby pools. Chapman (1962) found that fry planted in an area that contained rearing area not used by other fish would take up residence.

Table 2. Population Estimates for Juvenile Coho Salmon and Trout in Study Sections, September and October 1962 to 1966.

Stream	Year	Coho Population Estimate: Study Section	Five Pools	Confidence Limits	Trout Population Estimates
Nehalem River System					
Beneke Creek	1965	--	298	251-345	--
	1966	--	310	---	--
East Humbug Creek	1964	664	--	765-1392	118
Fishhawk Creek	1964	466	--	---	36
Hamilton Creek	1965	--	249	207-294	--
	1966	--	220	---	--
Humbug Creek	1964	1,080	--	966-1193	334
Nehalem River	1964	1,673	--	1511-1836	470
North Fork Wolf Creek	1964	940	--	841-1040	73
	1965	--	265	203-310	--
	1966	--	452	---	--
Oak Ranch Creek	1964	780	--	694-868	209
	1965	--	296	248-344	--
	1966	--	355	---	--
Rock Creek	1964	1,429	--	1257-1602	294
South Fork Rock Creek	1964	2,319	--	2130-2508	933
	1965	--	915	823-[illegible]99	--
	1966	--	1,033	---	--
Tualatin River System					
Beaver Creek	1963	515	--	404-625	6
East Fork Dairy Creek (upper)	1963	1,706	--	1574-1838	541
	1964	664	--	379-489	676
East Fork Dairy Creek (lower)	1963	1,360	--	1216-1496	294
	1964	580	--	---	406
Gales Creek	1963	405	--	343-468	908
	1964	0	--	---	890
McKay Creek	1962	1,076	--	765-1392	--
	1963	2,284	--	2238-2330	79
	1964	2,210	--	2043-2380	93
	1965	739	--	564-915	--
	1966	3,921	--	3417-4426	--
South Fork Gales Creek	1963	286	--	263-307	166
Wilson River System					
Cedar Creek	1964	--	--	---	1,138
Devils Lake Fork	1964	2,044	--	1839-2249	106

Table 3. Stream Size Data for 18 Study Stream Sections - 1962-1966.

Stream		Pools						
Nehalem River System	Year	No.	Average Width in feet	% Pool	Total Area sq ft	Average Depth in feet	Average Length in feet	Total Stream Area sq ft
Beneke Creek	1965	5	--	--	6,000	--	--	--
	1966	5	--	--	5,500	--	--	--
East Humbug Creek	1964	18	21	75	26,500	1.6	70	35,800
Fishhawk Creek	1964	11	20	80	15,100	1.3	68	19,200
Hamilton Creek	1965	5	--	--	4,500	--	--	--
	1966	5	--	--	4,400	--	--	--
Humbug Creek	1964	13	22	60	26,600	1.6	93	45,600
Nehalem River	1964	17	27	70	45,000	1.4	102	57,800
North Fork Wolf Creek	1964	27	16	70	23,400	0.9	55	30,000
	1965	5	--	--	6,100	--	--	--
	1966	5	--	--	5,500	--	--	--
Oak Ranch Creek	1964	30	12	55	13,700	0.9	36	22,700
	1965	5	--	--	37,000	--	--	--
	1966	5	--	--	3,100	--	--	--
Rock Creek	1964	12	37	65	44,100	155	115	75,900
South Fork Rock Creek	1964	27	15	50	15,500	0.9	39	26,500
	1965	5	--	--	5,100	--	--	--
	1966	5	--	--	4,800	--	--	--
Tualatin River System								
Beaver Creek	1963	35	9	67	12,000	--	38	17,900
East Fork Dairy Creek (upper)	1963	11	22	30	12,500	--	53	42,900
	1964	14	21	43	17,200	1.4	61	38,900
East Fork Dairy Creek (lower)	1963	15	24	39	16,100	--	52	44,600
	1964	11	--	45	20,300	1.5	78	47,900
Gales Creek	1963	15	16	31	9,600	--	41	31,700
	1964	15	18	42	15,000	1.1	56	38,200
McKay Creek	1962	--	28	--	26,900	--	--	--
	1963	13	25	54	22,700	--	83	49,900
	1964	14	24	75	34,100	1.3	107	46,800
	1965	--	--	--	32,500	--	--	--
	1966	--	--	--	31,200	--	--	--
South Fork Gales Creek	1963	26	9	37	6,200	--	28	16,900
Wilson River System								
Cedar Creek	1964	24	14	33	9,100	1.0	28	27,700
Devils Lake Fork	1964	15	19	58	22,500	1.5	77	38,600

From a total of 249 marked fish released into the study pools, only three were subsequently recaptured there in September (Table 4). In addition, 10 marked fish were recovered from eight donor pools in September.

<u>Pool area</u>. The amount of pool area in any given stream is an important factor in determining the number of juvenile coho the stream will produce. A relationship between numbers of fish per pool and pool size for Devils Lake Fork in 1964 is shown in Figure 1. This relationship can also be seen for the rest of the 1964, 1965 and 1966 streams in a general way. Figure 2 shows that without exception the large pools average many more fish than the small pools. If other factors are enough alike, even stream sections from different streams will show this relationship. Figure 3 shows a significant relationship between pool area per stream section and the population estimates of the Tualatin study sections in 1963.

<u>Individual pool habitat</u>. For the 1965 and 1966 study sections, the habitat of the individual pools seemed to have controlled the population in the pools. This is shown by a comparison of ranking of pools by coho per area in each stream (Table 5) in 1965 and 1966. Only minor changes in ranking occurred. This showed that whatever factors were controlling the population for the individual pools in 1965 were controlling the populations in 1966 in a similar manner.

<u>Rearing efficiency</u>. Although pool area is related to numbers of juvenile coho, smaller pools hold more fish per unit area than larger pools, providing the pools have enough depth. The 1964 study sections were divided into a group of large pools and small pools for each section. Figure 4 shows

Table 4. Coho Juvenile Transplants and Mark Recoveries in Study Pools on Four Streams, 1965.

Stream	Pool No.	Date: Marking and Transplanting	Date: Mark Recovery	No. Fish Transplanted	No. Fish Marked	No. Marked Fish Recovered
Beneke Creek	1	7/14	9/21	100	0	0
	2	"	"	65	0	0
	3	"	"	50	0	0
	4	"	"	69	0	0
	5	"	"	55	55	0
Total				339	55	0
Hamilton Creek	1	7/15	9/21	82	0	0
	2	"	"	57	0	0
	3	"	"	53	0	0
	4	"	"	70	0	1
	5	"	"	57	57	0
Total				319	57	1
North Fork Wolf Creek	1	7/9	9/24	110	0	0
	2	"	"	65	0	0
	3	"	"	88	0	0
	4	"	"	125	0	0
	5	"	"	77	77	0
Total				465	77	0
Oak Ranch Creek	1	7/14	8/16	59	0	0
	2	"	"	54	0	0
	3	"	"	63	0	0
	4	"	"	55	0	0
	5	"	"	60	60	2
Total				291	60	2
GRAND TOTAL				1,414	249	3

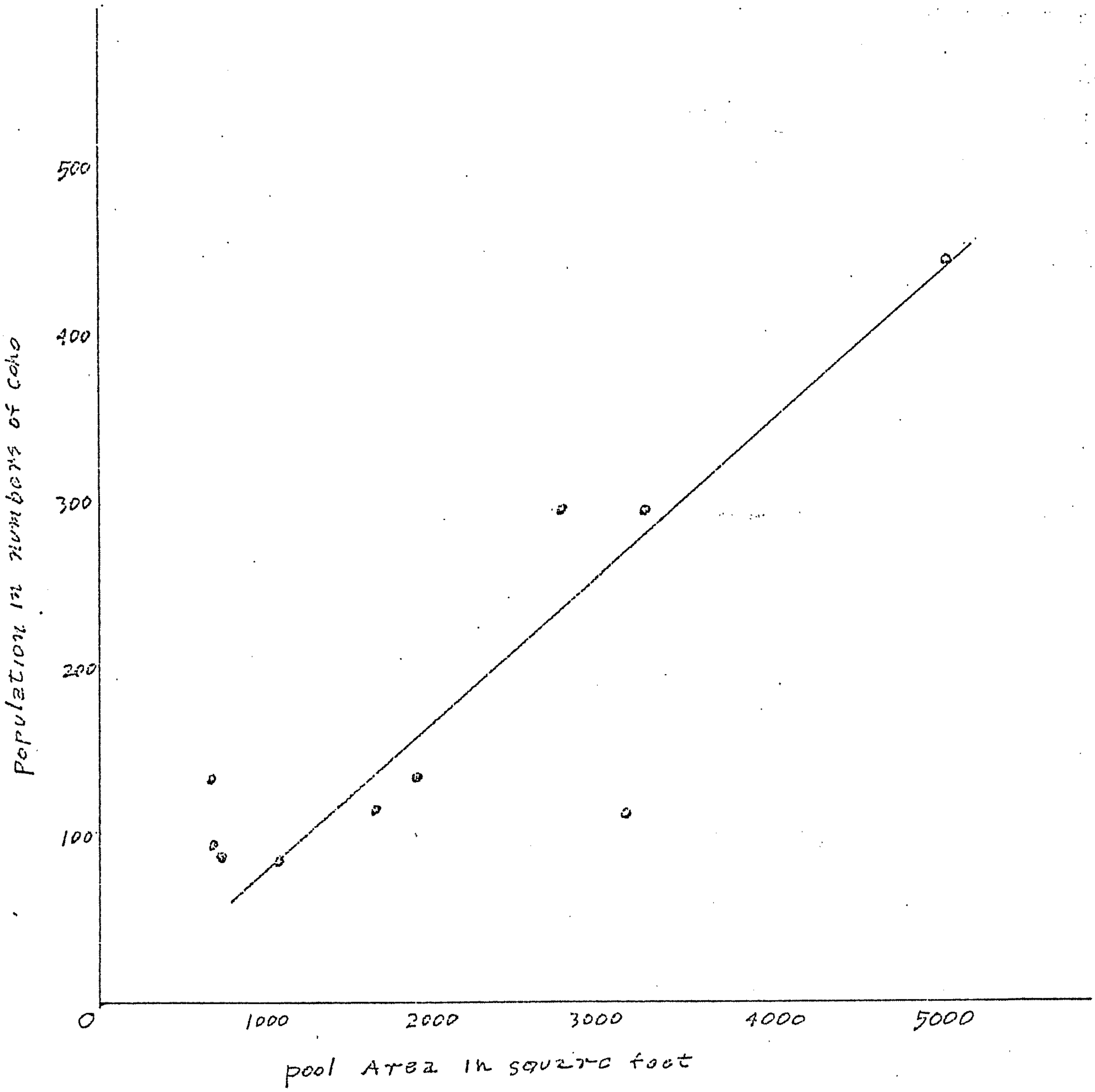

Figure 1. The relationship between juvenile coho population per pool and pool area in the study section on Devils Lake Fork, 1964. Line fitted by eye.

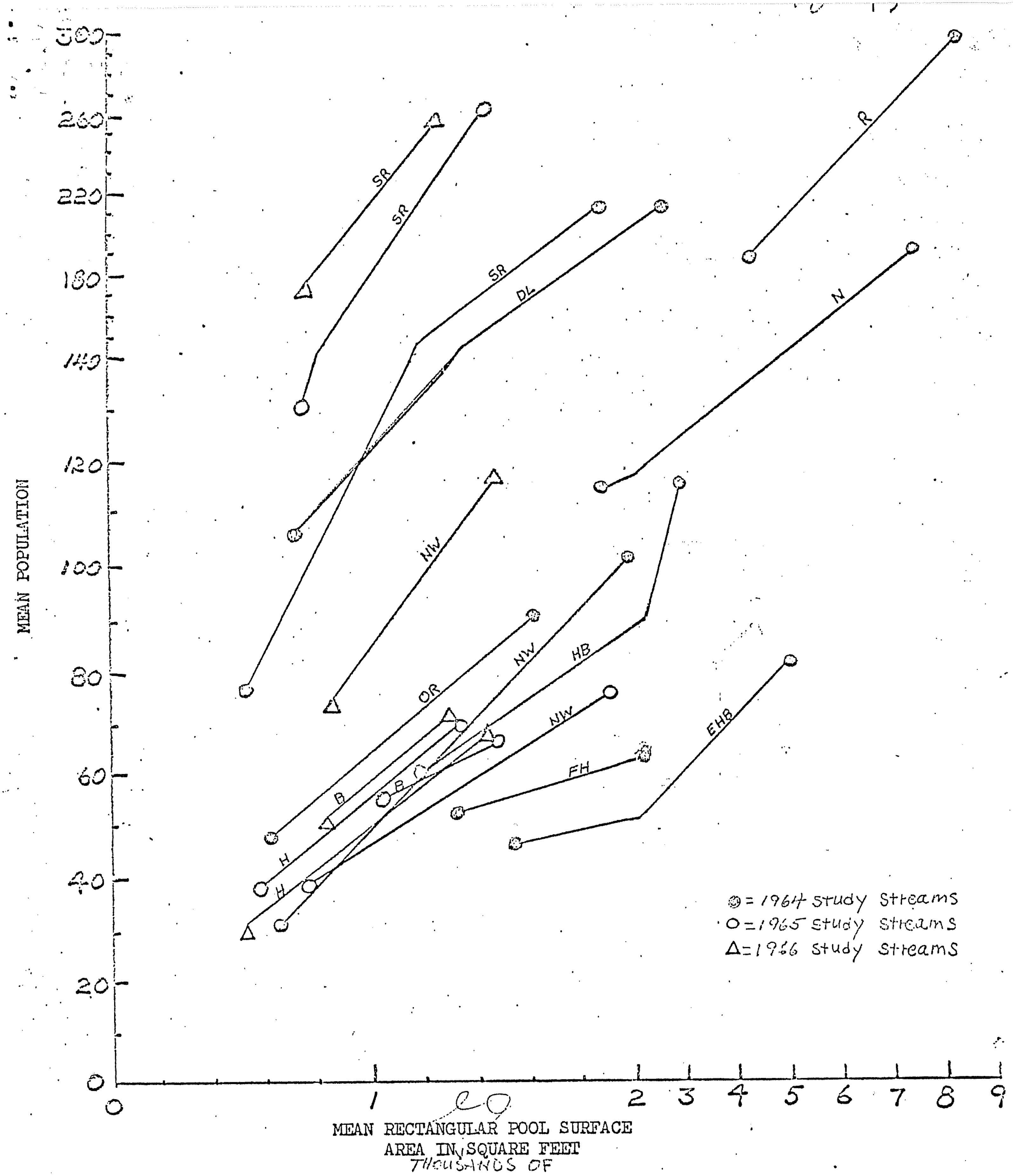

Figure 2 . Mean coho population for groups of large and small pools on 11 streams in early fall 1964-1966. Each point on the graph represents mean values for 2 - 13 pools.

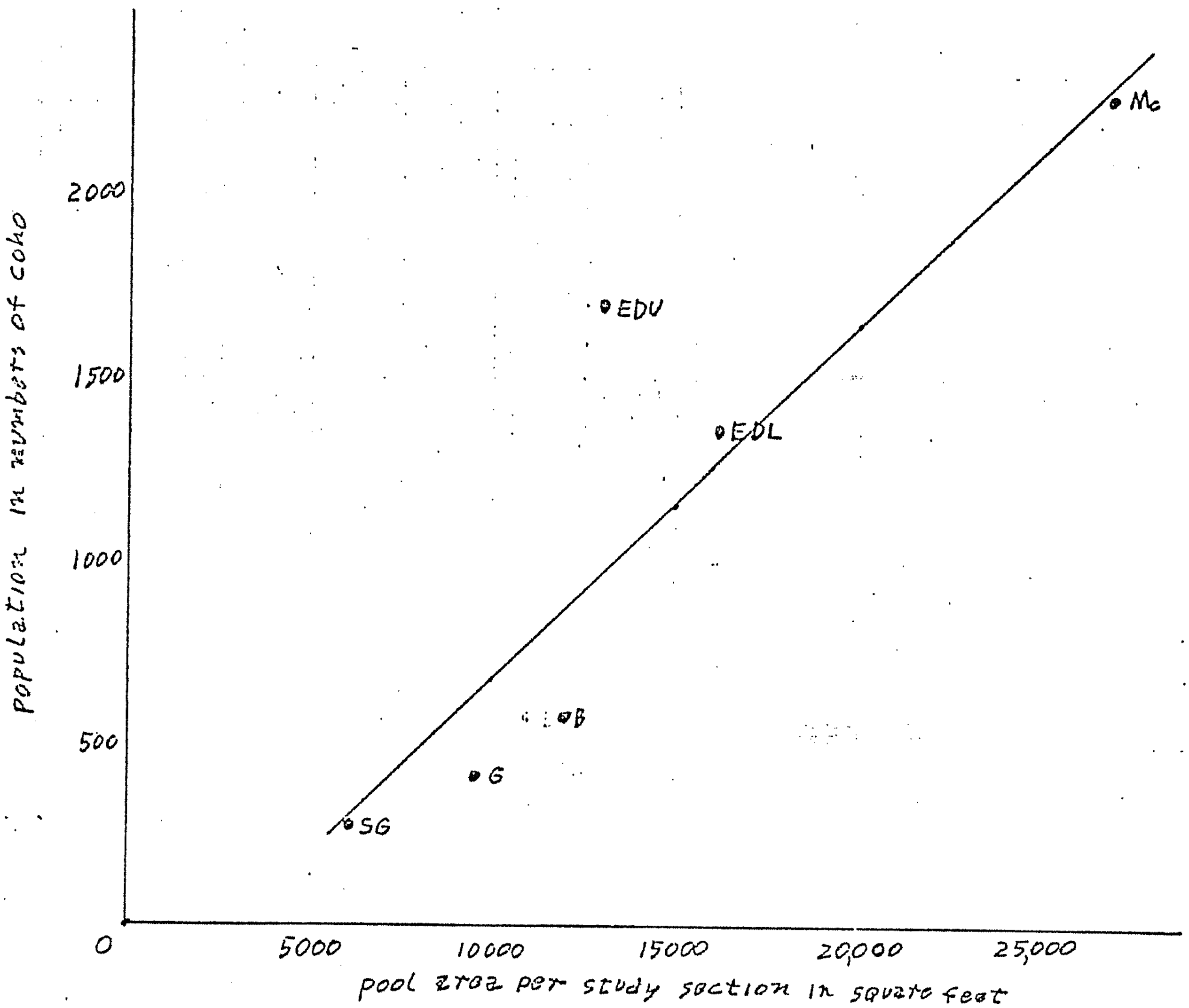

Figure 3. The relationship between juvinile coho population per section and pool area in the 1963 tualatin study sections.

Table 5. A Comparison of the Ranking of Coho Per Area for Pools of Each Stream of Five STreams between the Years 1965-1966.

Stream	Pool No.	1965	Pool No.	1966
	Coho Per Area Ranked from Highest to Lowest in Each Stream			
South Fork Rock Creek	5	0.38	5	0.34
	2	0.20	3	0.22
	1	0.15	2	0.21
	4	0.14	1	0.19
	3	0.13	4	0.17
North Fork Wolf Creek	3	0.065	5	0.11
	5	0.055	1	0.087
	1	0.049	2	0.085
	2	0.043	3	0.075
	4	0.028	4	0.057
Oak Ranch Creek	3&5	0.10	3	0.15
	3&5	0.10	5	0.13
	4	0.074	4	0.11
	2	0.063	2	0.10
	1	0.051	1	0.091
Hamilton Creek	5	0.12	5	0.094
	2	0.067	1	0.054
	3	0.052	3	0.049
	4	0.047	4	0.046
	1	0.038	2	0.046
Beneke Creek	1	0.068	1	0.083
	5	0.057	2	0.068
	4	0.054	3	0.049
	2	0.043	4	0.048
	3	0.037	5	0.033

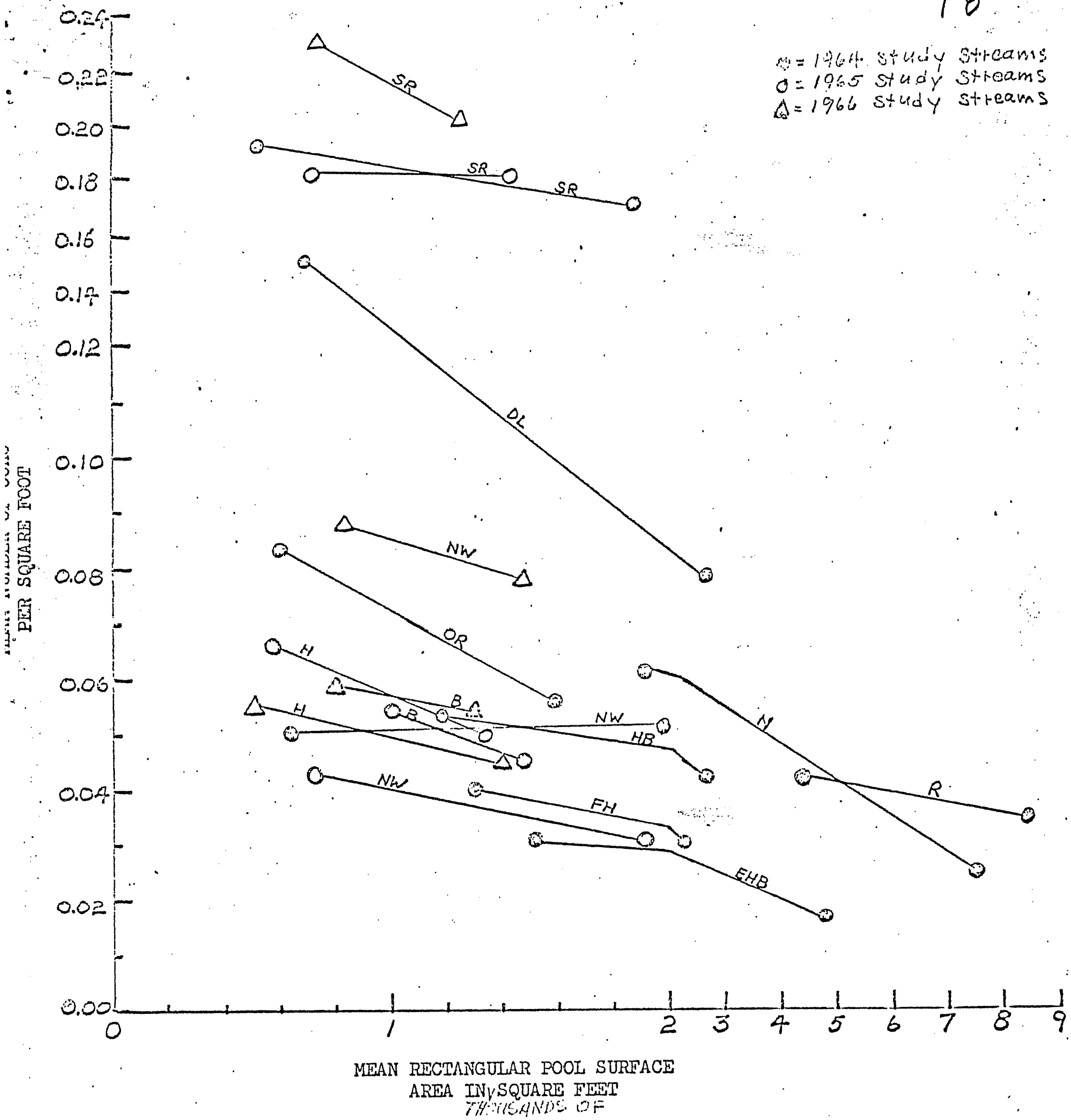

Figure 4. Mean number of coho per square foot of rectangular pool surface area for groups of large and small pools on 11 streams in early fall. 1964-1966.[1] Each point on the graph represents mean values for 2 - 13 pools.

1/ ~~These pool groups are the same as those shown in Figure~~

the number of coho per square foot of pool surface area was greater with two exceptions in the small pools. This may be explained by the fact that coho do not space themselves uniformly throughout the total rearing area of a pool. Observation on McKay and North Fork Gales Creeks in August, 1965, shows that a higher concentration of fish occurs in the upper end of the pool. Therefore, in large pools there is more pool area with low concentrations of juvenile coho. Also observed was the fact that fish residing near the front of the pools appeared to be larger than those farther back.

Pool depth. Adequate pool depth is an important factor in determining the number of young coho a pool will rear. Table 6 shows that on McKay Creek marginal depth pools rear fewer fish than the main deep pools. This was also true on the other study streams. However, the depth at which fish did not rear in an area appeared to depend upon the size of the fish.

Fish Size

Coho length, volume and coefficient of variation of coho from each stream section is shown in Table 7.

Fish size and stream size. Coho size seems to be related to stream size. Figure 5 shows for the 1964 sections mean coho size (length and volume) in each study section is significantly related to pool size. It was also observed in 1963 that the fish rearing in Beaver and South Fork Gales Creeks, the two smallest streams, were much smaller than the fish rearing in McKay, Gales and Dairy Creeks, the largest streams studied that year.

Table 6. Numbers of Juvenile Coho Captured in Main Pools and Marginal Pools 1962 through 1966 in McKay Creek.

Location Above Collins Road Bridge in Feet	Numbers Captured				
	1962	1963	1964	1965	1966
Main Deep Pools (Much area over 2 feet deep)					
2,800	40	85	80	13	144
3,400	98	185	136	61	135
3,600	77	130	232	107	220
4,100	9	56	31	10	21
4,300	16	57	121	44	244
4,700	107	133	81	62	153
Total	347	646	681	297	917
Marginal Depth Pools (Much area under 2 feet deep)					
3,100	0	0	2	1	1
3,200	0	30	12	5	14
3,800	0	14	0	0	4
3,900	2	32	2	1	35
4,000	36	29	7	5	72
4,150	0	35	0	0	49
4,200	4	49	4	0	0
4,550	0	0	0	0	16
4,800	7	11	1	0	15
Total	49	200	28	12	209

Table 7. Mean Coho Length, Volume, and Variability of Size in Study Streams in which Population Estimates were made.

Stream	Year	No. Meas. for Vol.	Mean Vol. (cc)	No. Meas. for Lgth.	Mean Fork Lgth (cm)	Coefficient of Variation for Lgth Meas. in percent
Nehalem River System						
Beneke Creek	1965	187	3.9	100	6.8	16.4
	1966	100	5.5	50	7.7	12.8
East Humbug Creek	1964	50	5.4	25	7.7	16.9
Fishhawk Creek	1964	50	5.0	25	7.7	18.9
Hamilton Creek	1965	158	4.2	100	7.1	14.2
	1966	96	5.9	50	7.7	12.9
Humbug Creek	1964	50	5.1	25	7.7	9.6
Nehalem River	1964	49	5.7	25	8.2	12.1
North Fork Wolf Creek	1964	50	4.5	25	7.2	17.2
	1965	100	2.5	100	6.1	18.9
	1966	100	3.6	50	6.7	14.9
Oak Ranch Creek	1964	50	4.5	25	7.0	17.2
	1965	155	3.9	95	6.6	20.8
	1966	100	3.7	51	6.8	16.5
Rock Creek	1964	50	6.7	25	8.1	10.0
South Fork Rock Creek	1964	50	4.2	25	7.1	17.3
	1965	200	4.0	100	6.6	24.8
	1966	100	4.3	51	7.0	21.5
Tualatin River System						
East Fork Dairy Creek (upper)	1964 1/	50	6.3	25	8.3	---
East Fork Dairy Creek (lower)	1964	50	8.2	25	8.9	---
McKay Creek	1964	50	5.9	25	7.9	7.3
	1966	140	3.6	50	6.6	11.0
Wilson River System						
Devils Lake Fork	1964	50	4.6	25	7.3	10.5

1/ Samples taken from only two pools instead of the usual five pools.

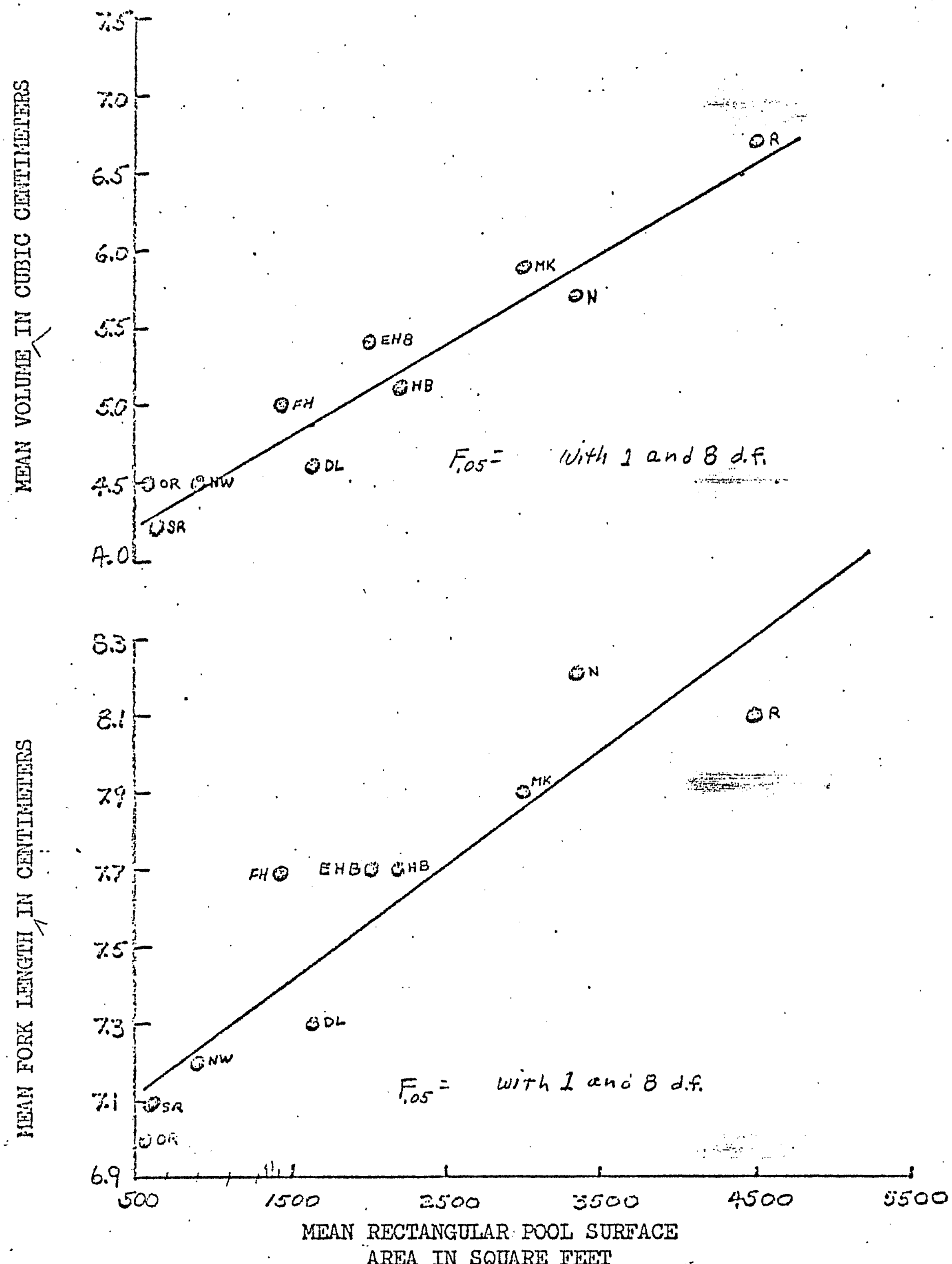

Figure 5. ~~Correlation~~ Relationship between mean ~~coho~~ size of coho juveniles and mean pool size on ten study streams in early fall 1964.

Observations were made that indicate that larger fish require more rearing area.

Figure 6 gives evidence to support this by showing a significant relationship between mean coho length and the mean maximum depth of unused and little used pools in eight streams.

Fish size and streamflows. The size of young coho may also be influenced by streamflows. In all three study streams in which fish were measured in 1964, 1965 and 1966, the fish were largest in 1964. The summer flows of 1964 were considerably better than 1965 and 1966. Also in 1964, the streams that had the best flows in most cases had the largest fish.

Fish size variations seem to be greater in streams that have higher flows. Figure 7 shows a significant relationship between mean pool velocity between streams and the coefficient of variation for fish lengths in five streams for 1965 and 1966.

Fish size and fry production. Coho juvenile size may also be influenced by fry production. On the lower section of East Fork Dairy Creek in 1964 the coho were much larger than in 1963. The average volume per fish was 8.2 ml. in 1964. Although no lengths were taken in 1963, for visual observation, the fish were believed to be near the size of the McKay Creek fish, 5.9 ml. There was a lack of fish in this section in 1964 indicated by very few fish caught in suitable easily seinable pools. Therefore, it is reasonable to assume that because of poor fry survival and lack of fish the ones that did survive were larger.

Coho juvenile size in September, 1966, on McKay Creek seems to have been depressed by large fry plants. The Fish Commission released 90,000 unfed

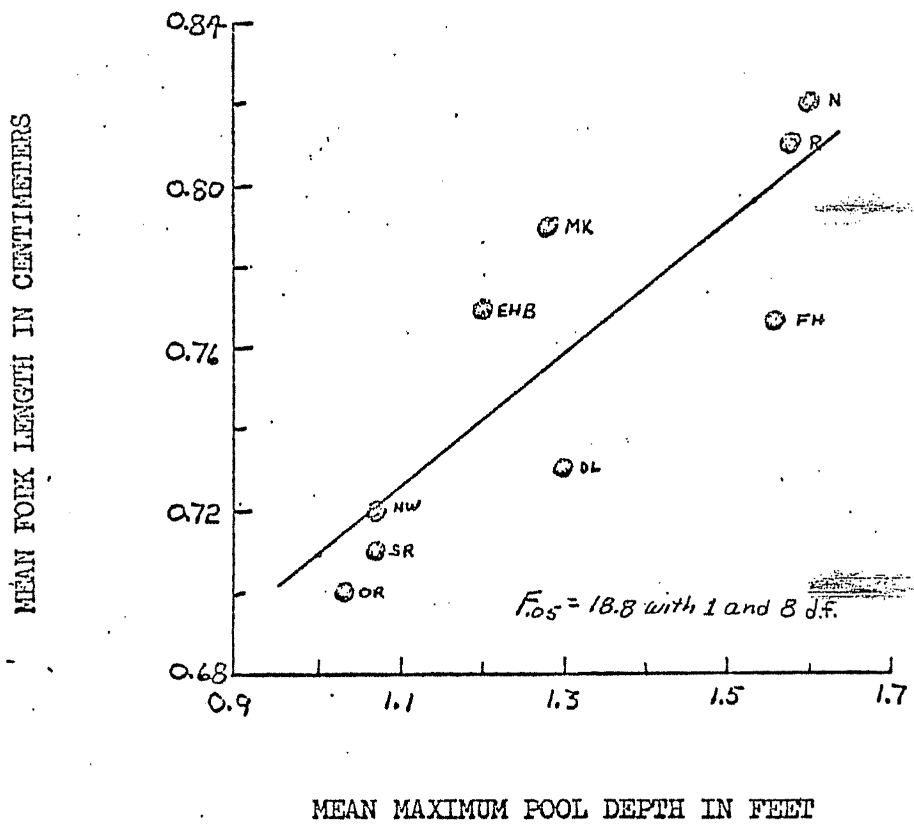

Figure 6. ~~Correlation~~ Relationship between mean ~~coho~~ size of coho juveniles and mean maximum depth of pools containing few or no ~~fish~~ coho on nine streams in early fall, 1964.

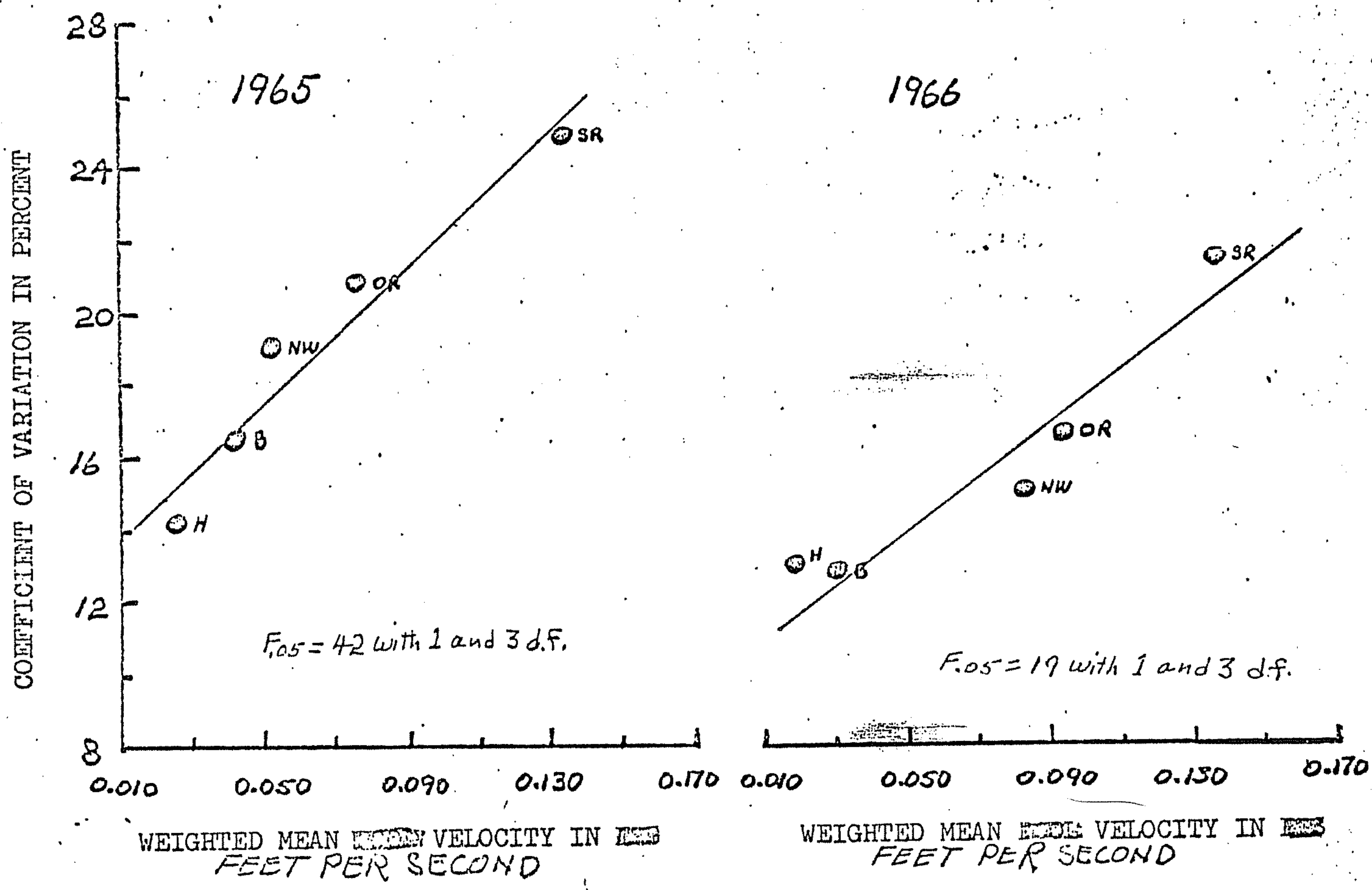

Figure 7. Relationship between coefficient of variation and weighted mean water velocity for pool groups on five streams, 1965-1966. Velocity was weighted by pool surface area.

fry in the study section on March 11, 1966. When measured in September, the fish were much smaller than in other years. Mean coho length was 66 mm; substantially less than the 74 mm. coho length of the 1964 McKay Creek fish and smaller than was visually apparent for 1962, 1963 and 1965.

<u>Fish size, population size and condition</u>. Apparently because of the small fish size of 1966 population on McKay Creek was much higher than in any other year the stream was studied. The 1966 population estimate was 3,921 compared to 2,284 in 1963, the highest of the other years. The 1966 fish were rearing more in marginal depth pools than in any other year except 1963, which was the best year for streamflow in McKay Creek. Table 6 on page ___ shows numbers of coho juveniles captured in main and marginal pools in 1962-66.

The condition of the 1966 McKay Creek fish appeared to be poor. The fish were heavily infected with a Tremalode Metacercani. Although disease was present to some degree in all years, infected fish were most numerous in 1966 when the high population of fish was present. The two worst years for disease were 1965 and 1966, when flows were at their lowest for an extended period of time during August and September.

Another indication that condition of the fish was very poor in 1966 is the low recapture rate. Table 8 shows for 16 study sections the percent of marks recaptured in easily seinable pools. It can be seen from the table that the percent marked recapture for McKap Creek in 1966 is far below the other years on McKay Creek and all other streams. This may indicate that fish were dying from handling and not available for recapture.

Table 8. The Precent Marks Recovered in Easily Seinable Pools in which Good Numbers of Fish Were Marked in 16 Study Streams.

Stream Section	Year	No. of Pools	Percent Marks Recovered Range	Mean
McKay Creek	1962	3	46-89	67
	1963	9	23-69	43
	1964	4	23-65	39
	1965	2	28-85	56
	1966	9	10-74	23
Upper East Fork Dairy	1963	11	43-100	69
	1964	6	52-92	75
Lower East Fork Dairy	1963	10	25-100	59
	1964	7	28-100	67
Beaver Creek	1963	4	15-100	53
Gales Creek	1963	6	29-78	50
Devils Lake Fork	1964	10	30-79	52
East Humbug Creek	1964	7	40-90	62
Fishhawk Creek	1964	7	32-80	53
Humbug Creek	1964	9	45-91	68
Nehalem River	1964	7	38-74	56
North Fork Wolf Creek	1964	7	58-96	78
	1965	5	40-66	56
	1966	5	52-84	68
Oak Ranch Creek	1964	8	62-93	78
	1965	5	41-71	62
	1966	5	67-96	80
Rock Creek	1964	3	41-80	56
South Fork Rock Creek	1964	9	31-74	50
	1965	4	59-79	71
	1966	5	43-68	56
Beneke Creek	1965	5	56-87	70
	1966	5	50-85	75
Hamilton Creek	1965	5	53-89	71
	1966	5	69-92	79

Streamflow

Streamflows taken in the study sections are shown in Table 9.

Our work showed a relationship between streamflow and coho production. Variations in population estimates between years on McKay Creek other than 1966 may be related to low summer flows. Figure 8 shows a significant relationship between coho production and low summer flows for the years 1962-65. Data for 1966 was not included in the regression analysis. The 1966 McKay Creek data cannot be used because of the great difference in fish sizes between 1966 and other years. As explained earlier, smaller fish require less rearing area.

From the Nehalem streams studied in 1964, South Fork Rock Creek had the best streamflow for its size. South Fork Rock Creek also had the highest coho per unit of pool value of the 1964 streams.

Of the Tualatin streams studies in 1963, East Fork Dairy Creek had the best flow and also had the highest coho per unit area of pool value of these streams.

Water velocity in pools. Pool velocities are an index to the suitability of a particular flow with respect to coho production for individual pools. Our Nehalem study pools of 1965 and 1966 show a definite relationship between flow as expressed by pool velocity and numbers of coho.

In Figure 9, the 50 pools represented by the 10 pool groups have been graphed separately. The relationship remains significant. Analysis

Table 9. Minimum Summer Streamflows for Study Sections on Streams of the Nehalem, Tualatin and Wilson River Systems.

Stream	Minimum Summer Flows (cfs)				
	1962	1963	1964	1965	1966
Nehalem River System					
Beneke Creek	--	--	--	0.8	0.9
East Humbug Creek	--	--	3.5	--	--
Fishhawk Creek	--	--	4.8	--	--
Hamilton Creek	--	--	--	0.4	0.3
Humbug Creek	--	--	6.5	--	--
Nehalem River	--	--	3.7	--	--
North Fork Wolf Creek	--	--	1.7	0.7	0.9
Oak Ranch Creek	--	--	1.5	1.2	1.2
Rock Creek	--	--	15.0	--	--
South Fork Rock Creek	--	--	3.0	2.4	2.3
Tualatin River System					
East Fork Dairy Creek (upper)	--	6.7	6.2	--	--
East Fork Dairy Creek (lower)	--	10.0	7.8	--	--
Gales Creek	--	4.5	--	--	--
McKay Creek	1.9	4.0	3.1	2.0	1.7
North Fork Gales Creek	--	--	--	0.7	--
Beaver Creek	--	0.3	--	--	--
South Fork Gales Creek	--	0.9	--	--	--
Wilson River System					
Cedar Creek	--	--	3.5	--	--
Devils Lake Fork	--	--	2.6	--	--

1/ These flow measurements were taken a few days after a heavy local rainstorm and probably do not represent the minimum summer flow.

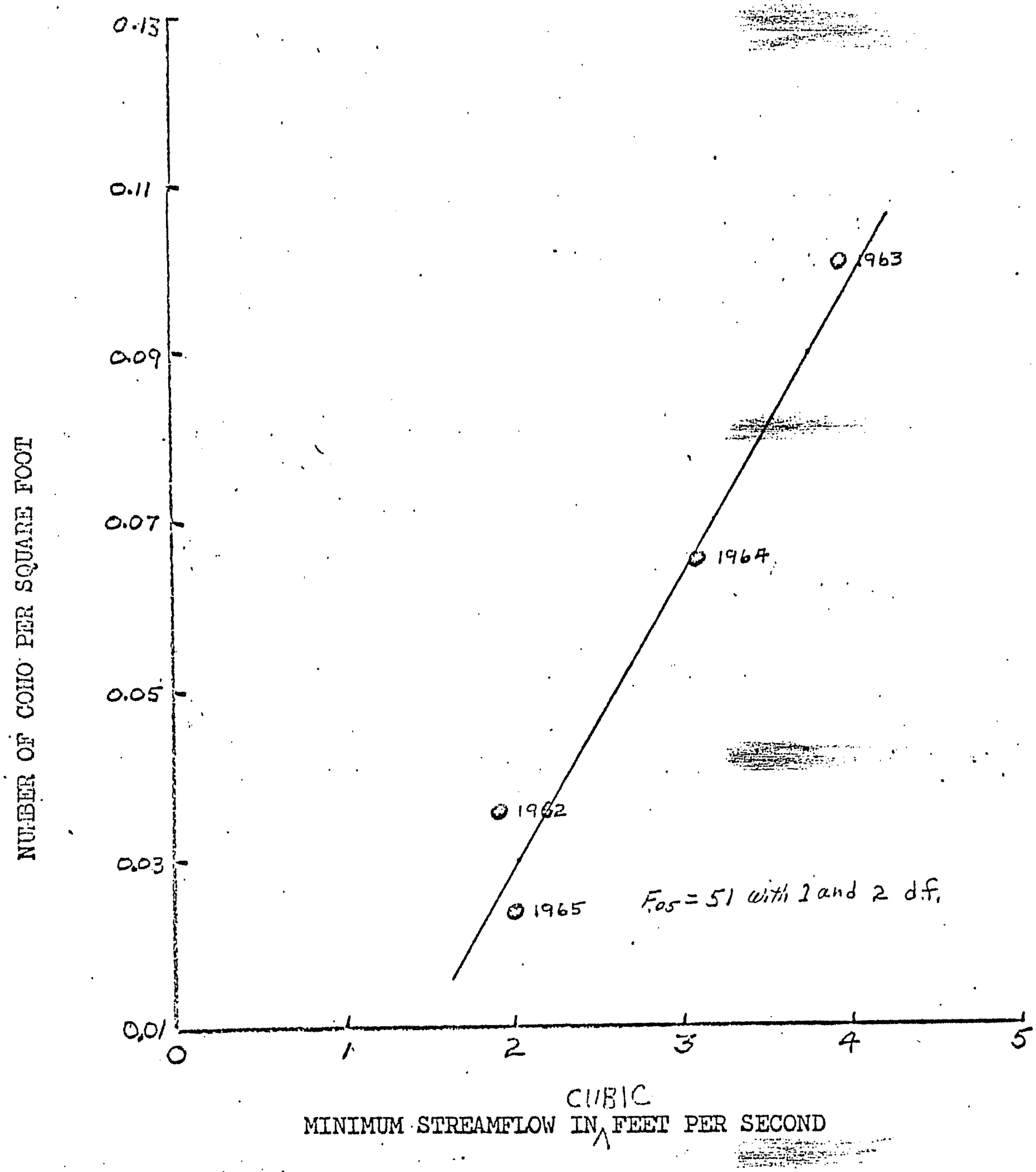

Figure 8. Relationship between number of coho per square foot of rectangular pool surface area and minimum summer streamflow in a 2,000-foot study section on McKay Creek in early fall--1962-1965.

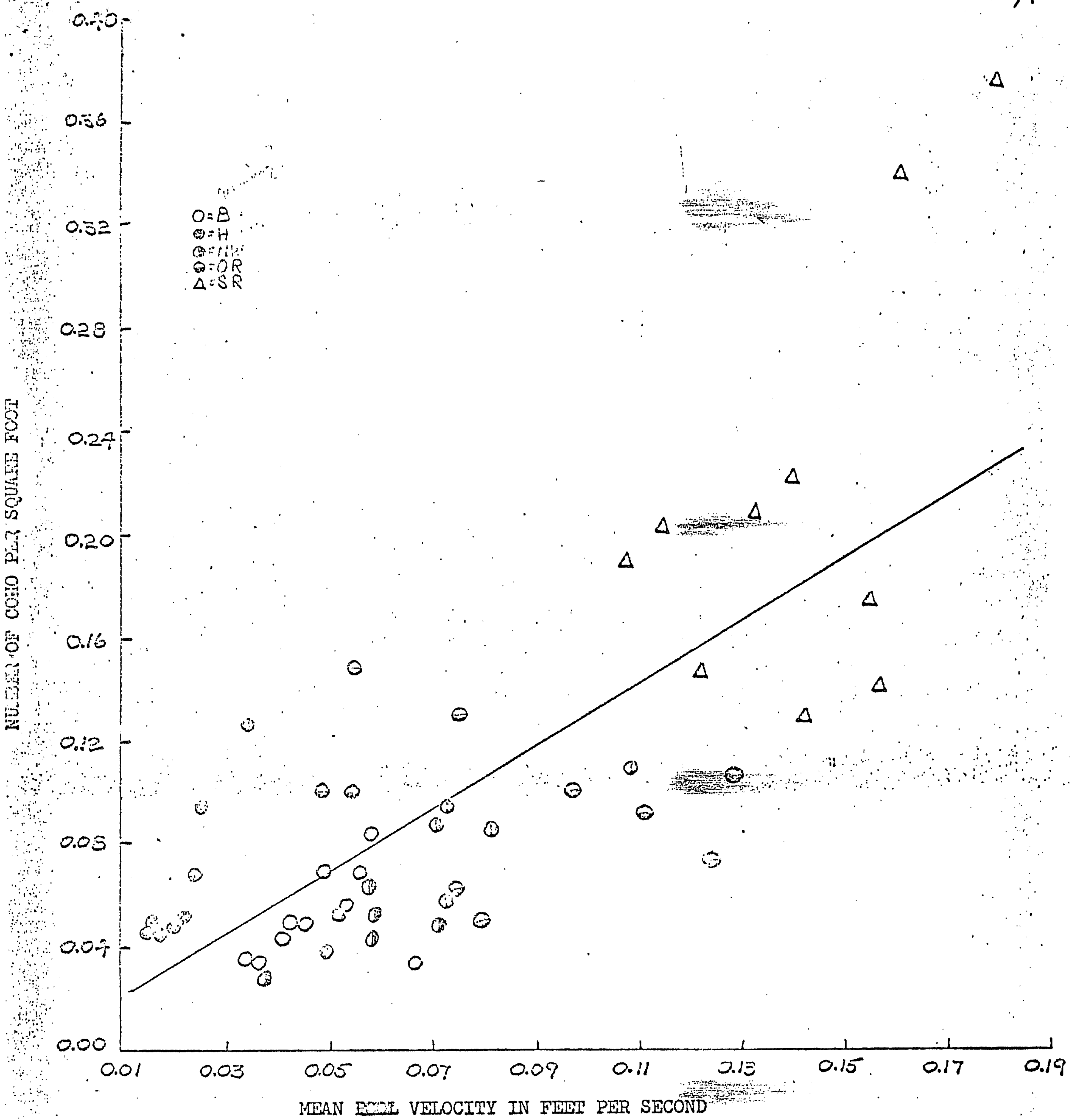

Figure 9. Relationship between number of coho per square foot of pool surface area and mean water velocity for 50 pools in early fall 1965-1966.

of production between groups of pools more uniform in size was accomplished by separating the pools into categories of 500 to 1,000 square feet and 1,000 and 2,000 square feet. Significant relationships between fish production and velocity for groups of pools in these two size ranges are shown in Figures 10 and 11.

The effect of flow changes on rearing area. Increases in fish production from increased flows are sometimes attributed to increases in rearing area. However, as shown in Figures 13 and 14, higher flows result primarily in greater pool velocities and to a limited extent only to increases in pool size. Therefore, improved fish production in a given pool with an increase in flows is probably primarily velocity related.

It is doubtful that moderate changes in summer flows would have much effect on the total pool area within a stream. Table 10 shows the effects of different flows on stream surface area in a one-mile reach on McKay Creek. An increase in flow from 3 to 45 cfs resulted in a decline in pool area while riffle area more than doubled. This resulted from a decrease in mean pool length and by the loss of some pools, shallow pools which become more rifflelike at higher flows.

Velocities at which fish were rearing. Measurements were taken to find the highest velocities at which fish were rearing. These velocity measurements are summarized in Table 11. About 90 percent of the observations occurred between velocities of 0.3 to 0.7 feet per second.

Food Production

Riffles are generally believed to be the food producing areas of streams.

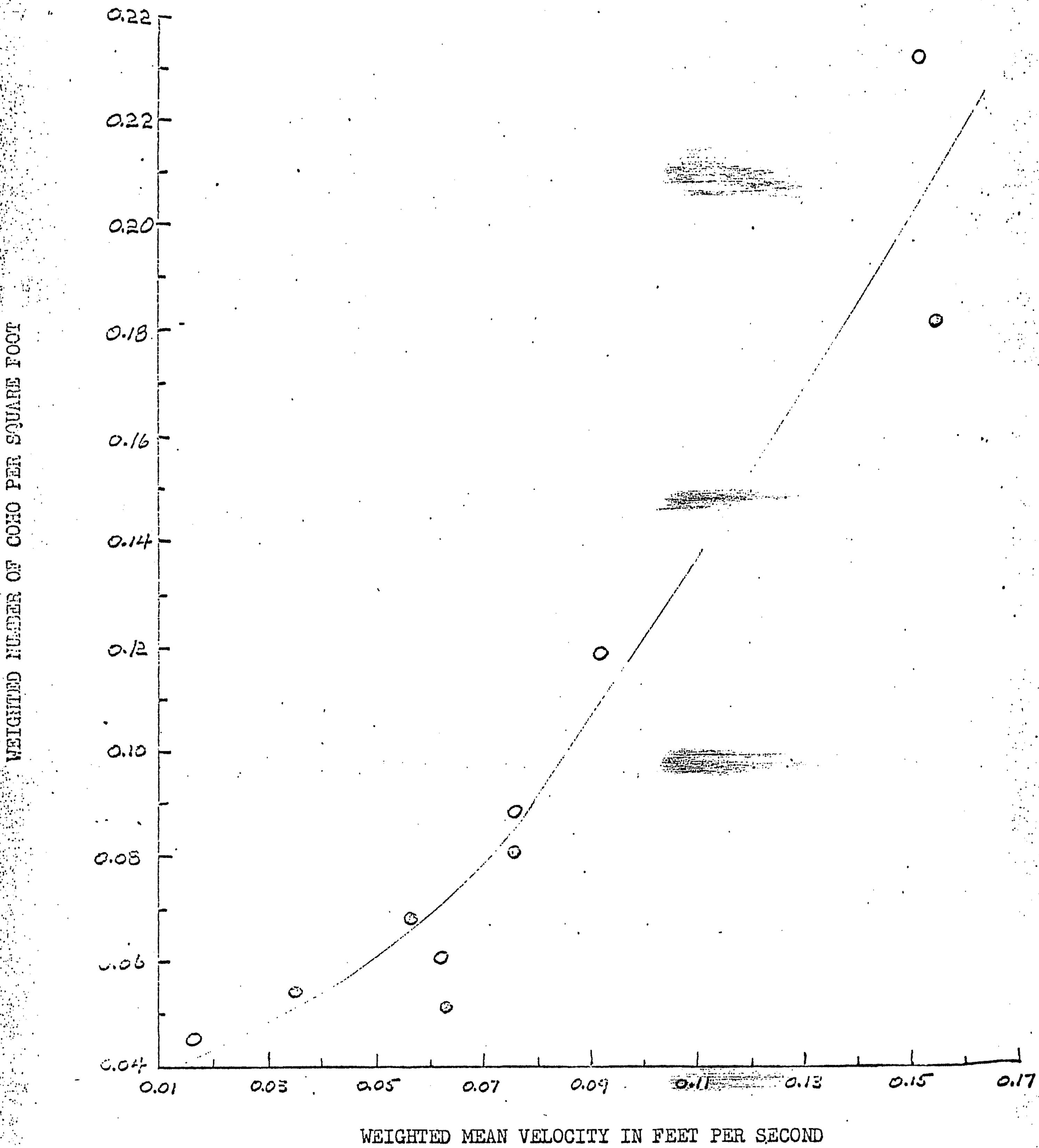

Figure ~~[illegible]~~ 10 ~~Correlation~~ Relationship between weighted number of coho per square foot of pool surface area and mean water velocity for ten groups of pools between 500 and 1000 square feet in area in early fall 1965-1966. ~~Both quantities were weighted by pool surface area. All pools are between 500 and 1,000 square feet in area.~~

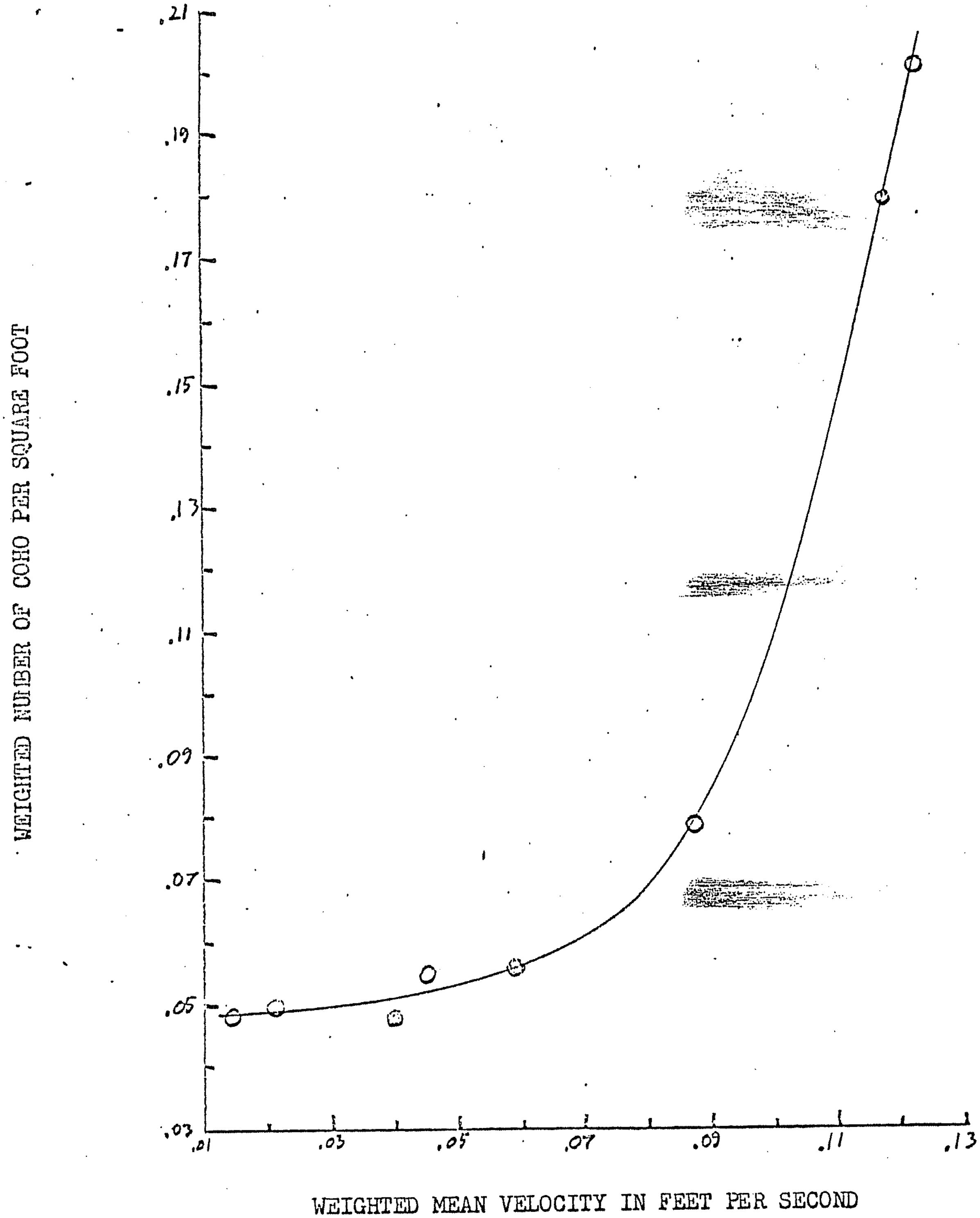

Figure ~~II~~ 11. ~~Correlation~~ Relationship between weighted number of coho per square foot of pool surface area and mean water velocity for eight groups of pools between 1000 and 2000 square feet in area in early fall 1965-1966. ~~Both quantities were weighted by pool surface area. All pools are between 1,000 and 2,000 square feet in area.~~

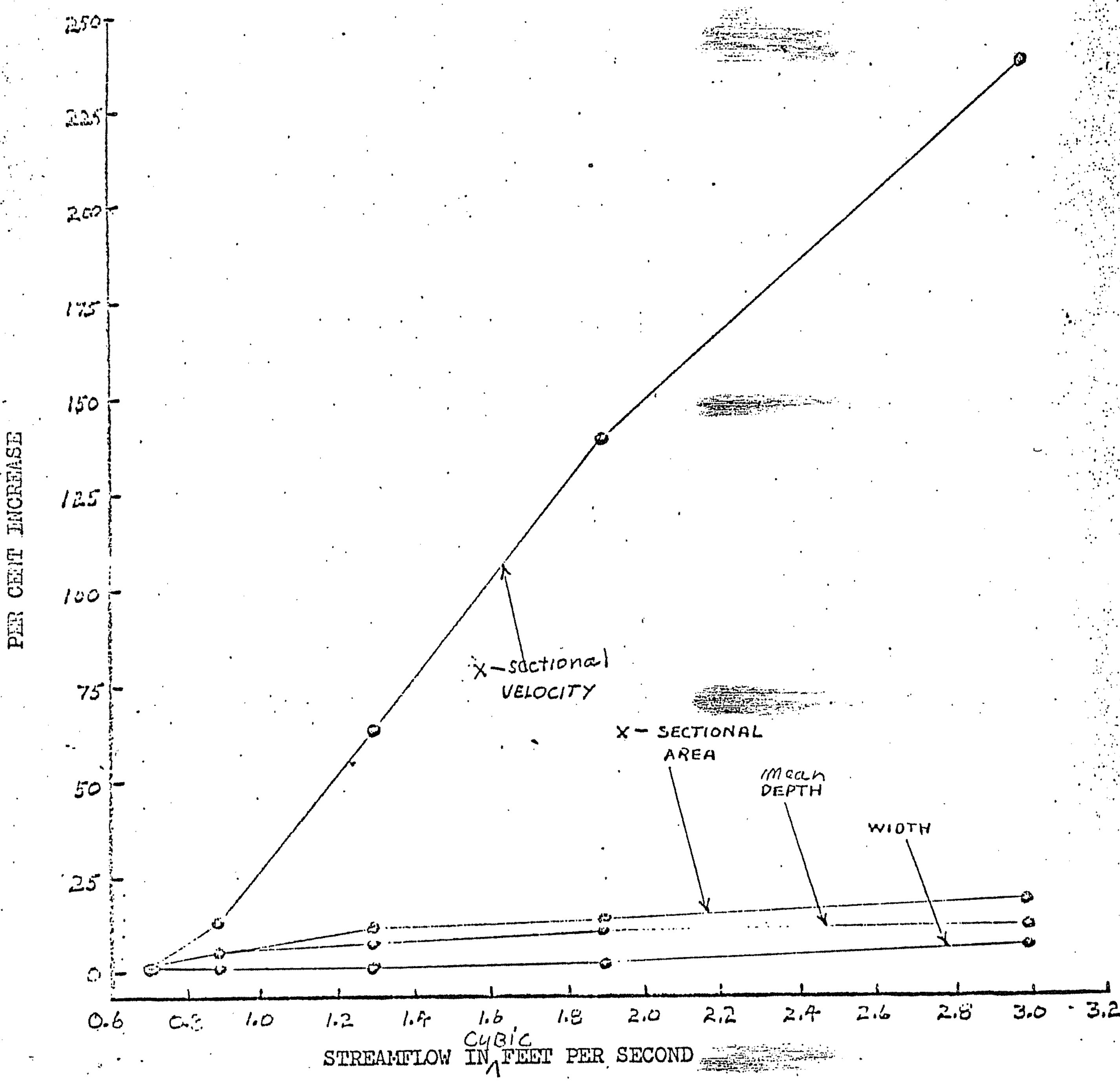

Figure 12. Mean per cent increase in measurements of four pool cross-sections on North Fork Gales Creek at four flow levels above base flow of 0.7 cubic feet per second, May 14 - August 2, 1965.

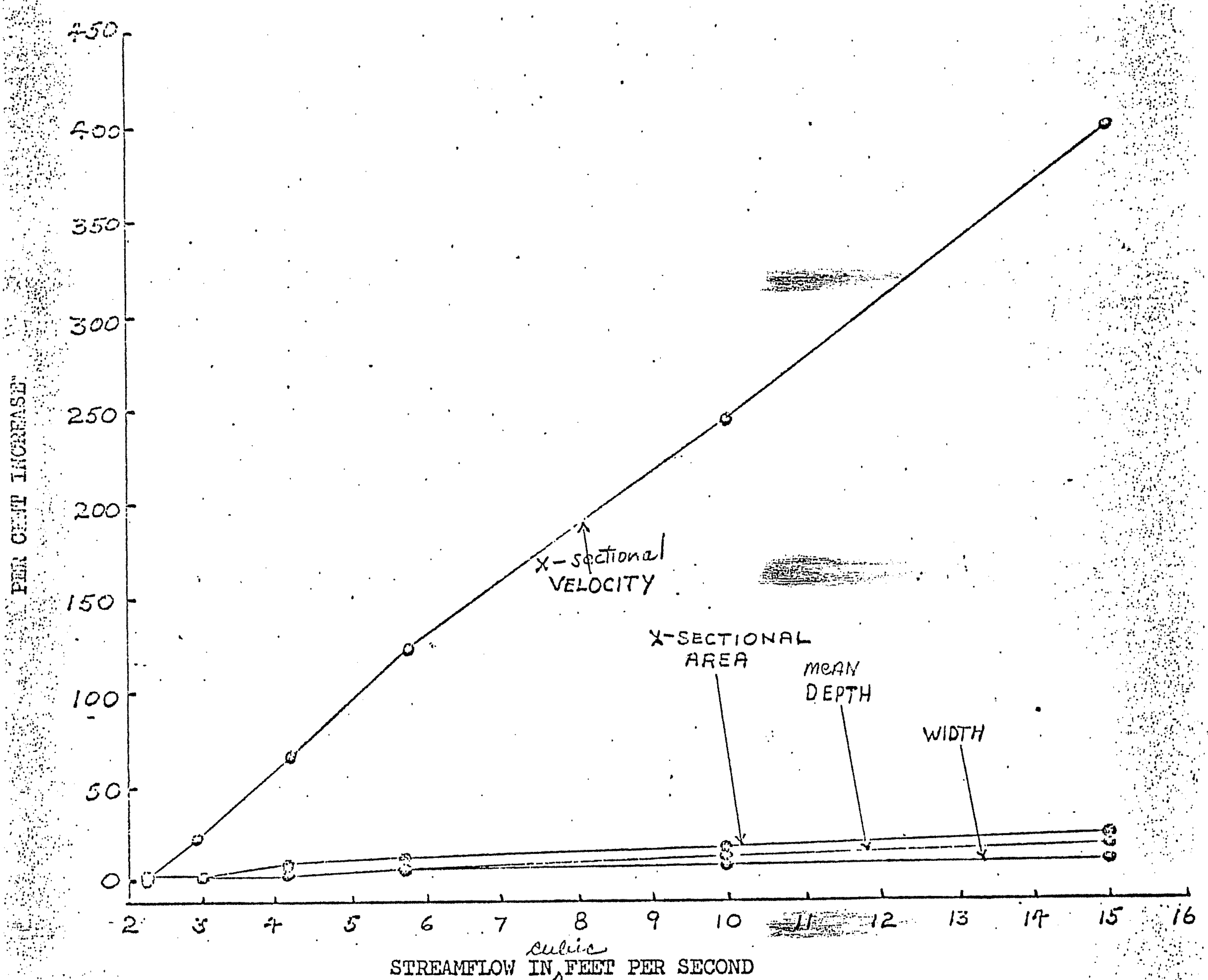

Figure 13. Mean per cent increase in measurements of ten pool cross-sections on McKay Creek at five flow levels above base flow of 2.2 cubic feet per second, April 7 - August 2, 1965.

Table 10. Changes in Stream Measurements with Changes in Stream Flow for a One-Mile Reach of McKay Creek, 1962-1963.

Flow in cfs	Date	Mean Pool Width-ft.	Number of Pools	Average Pool Length - ft.	Average Riffle Length - ft.	Total Pool Area - ft2	Total Stream Area - ft2
3	7-25-62	23.4	48	74	36	83,070	123,552
7	10-25-62	25.2	42	74	51	78,674	133,056
15	10- 9-62	27.9	38	78	61	82,724	147,313
25	1-21-63	29.2	35	76	75	77,176	154,176
45	5-14-62	30.9	28	81	108	69,803	163,152

Table II. Maximum velocities in which juvenile coho were rearing in East Fork Dairy and South Fork Rock Creeks, August 11, 1965.

Velocity in Feet Per Second	Observed Frequency	Percent
.13 - .19	1	3
.20 - .29	1	3
.30 - .39	6	19
.40 - .49	10	31
.50 - .59	9	28
.60 - .69	4	13
.70 - .77	1	3
TOTAL	32	100

In the 1964 study streams, pools with large riffles averaged higher in coho production per unit pool area than pools with small riffles (Tabel 12).

An indirect approach was also used to determine if riffles might affect production. The streams were divided into a large stream group and a small stream group. In each group an F test was run on numbers of coho captured and pool area, and numbers captured and stream area. In both the large and the small groups the F values were higher for the numbers captured and stream area (Table 13). This would indicate that the riffle areas are important in determining the coho rearing capacity of a stream.

Insect production and velocity. Riffles are the primary fish food producing areas of a stream. It seems reasonable to assume that the flow of water on the riffles influences this food production. We found on riffles with uniform sized gravel on four study streams that the velocity over the sampling site seemed to be related to the number of aquatic insects taken in each sample (Figure 15).

Cover

Our data indicates that cover defined as an area the fish can escape to for protection, may also be an important factor in the juvenile coho rearing capacity of a stream. Table 14 shows that in all ten 1964 streams evaluated, the pools in which cover was rated good or very good averaged better coho per unit area values than pools where cover was rated poor. Pool bottom roughness which was rated in the 1965-1966 study pools may also be a form of cover. In three out of four streams in both years, juvenile coho per unit of pool area values were higher in pools with large gravel bottoms than pools with other bottom types (Table 15).

Table 12. Numbers of coho per pool area in pools below large and small riffles.

Stream	Pools with a Large Riffle Upstream		Pools with a Small Riffle Upstream	
	No. of Pools	Average Coho Per Ft2	No. of Pools	Average Coho Per Ft2
Devils Lake Fork	3	0.073	3	0.068
East Humbug Creek	2	0.029	3	0.028
East Fork Dairy Creek	3	0.045	2	0.025
Fishhawk Creek	2	0.041	4	0.033
Humbug Creek	4	0.036	4	0.057
McKay Creek	3	0.083	2	0.064
Nehalem River	3	0.033	3	0.031
North Fork Wolf Creek	3	0.047	3	0.034
Oak Ranch Creek	4	0.066	5	0.078
South Fork Rock Creek	5	0.193	7	0.195
AVERAGE		0.065	7	0.061

No. of streams in which large riffle had a higher number of coho per area: 7.

No. of streams in which small riffle had a higher number of coho per area: 3.

Table 13. A comparison of the relationship of the number of coho captured to stream size and pool size for study section groups according to large and small fish.

Large Stream Group	No. Captured	Pool area	Test for Significance F	Stream Area	Test for Significance F
Gales Creek	291	9,647		31,680	
McKay Creek (1965)	314	32,501		46,600	
East Humbug Creek	319	26,460		45,719	
McKay Creek (1962)	405	34,005		49,000	
East Fork Dairy Creek	463	17,206		39,287	
Fishhawk Creek	503	30,130		40,794	
McKay Creek (Lower 1963)	539	37,572		48,492	
Humbug Creek	634	26,620		47,823	
McKay Creek (1964)	670	34,454		52,323	
McKay Creek (1963)	737	26,896		49,900	
Nehalem River	852	45,058	4.18	68,658	24.36
Small Stream Group					
South Fork Gales Creek	132	6,194		16,900	
Beaver Creek	215	11,980		17,900	
Oak Ranch Creek	573	13,700		21,831	
North Fork Wolf Creek	597	23,373		30,105	
Devils Lake Fork	1,030	22,542		36,731	
McKay Creek (1966)	1,126	31,211	17.98	46,600	38.89

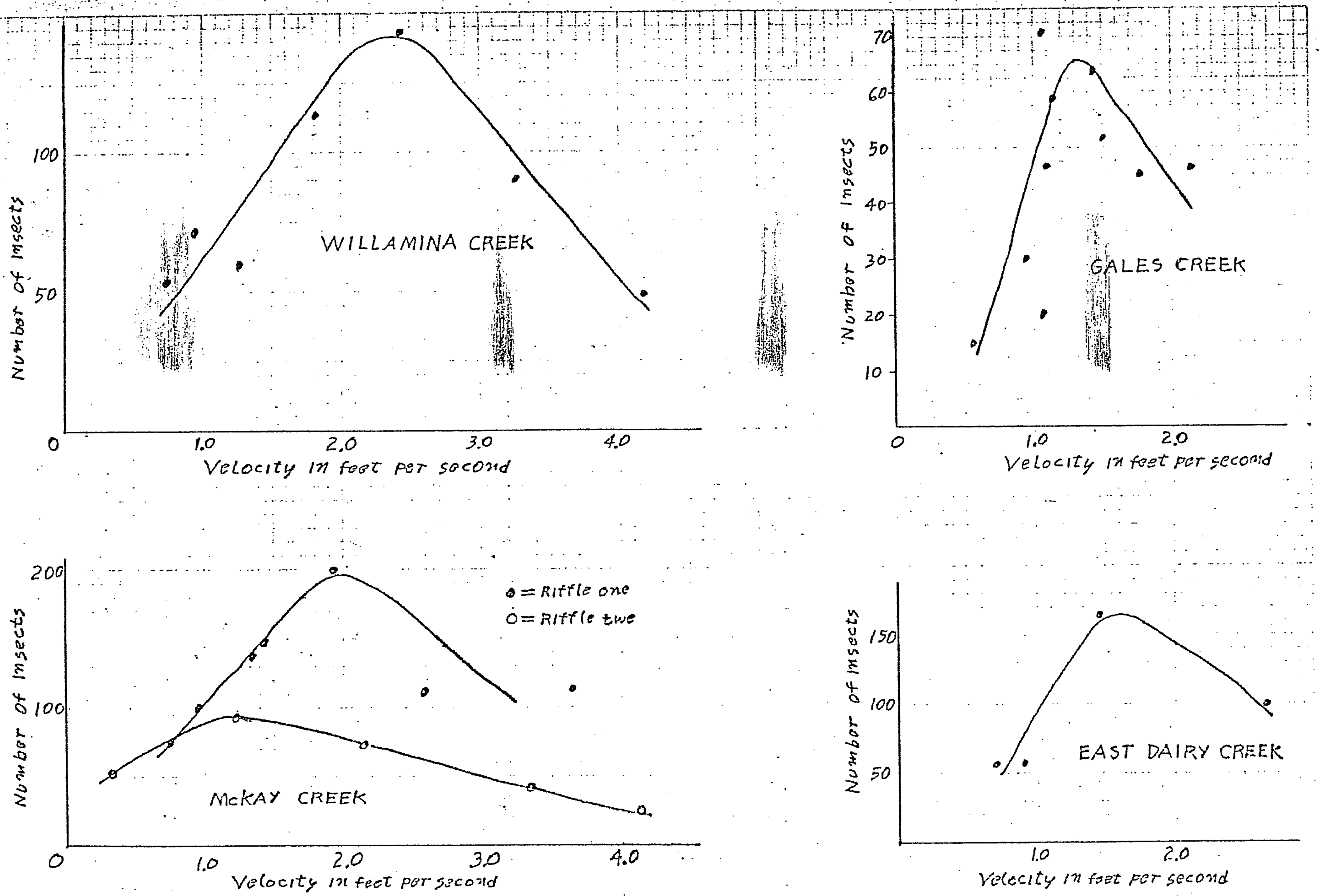

Figure 15. Relationship between the velocity over the sampling site and number of insects in the samples on study riffles on Mckay, Gales, East Dairy, and Willamina creeks.

Table 14. Numbers of coho per pool area in pools with good and poor cover.

	Pools with Cover Rated Good		Pools with Cover Rated Poor	
Stream	No. of Pools	Average Coho Per Ft2	No. of Pools	Average Coho Per Ft2
Devils Lake Fork	3	0.099	3	0.059
East Humbug Creek	3	0.030	3	0.022
East Fork Dairy Creek	4	0.084	3	0.036
Humbug Creek	3	0.048	5	0.038
McKay Creek	2	0.094	3	0.063
Nehalem River	4	0.035	3	0.026
North Fork Wolf Creek	3	0.050	3	0.031
Oak Ranch Creek	6	0.075	3	0.067
South Fork Rock Creek	7	0.221	6	0.175
AVERAGE		0.082		0.057

No. of streams in which pools rated with good cover had a higher number of coho per area: 9.

No. of streams in which pools rated with poor cover had a higher number of coho per area: 0.

Table 15. Average coho per unit area in pools with bottoms of large gravel and other type bottoms in the 1965 and 1966 Nehalem study sections.

Year	Stream	Average Coho Per Ft2 of Pools with Bottoms of Large Gravel or Rubble		Average Coho Per Ft2 of Pools with Bottoms of Other Types*	
		No. of Pools	Average Coho Per Ft2	No. of Pools	Average Coho Per Ft2
1965	Beneke Creek	2	0.063	3	0.045
	Hamilton Creek	3	0.072	2	0.057
	Oak Ranch Creek	1	0.063	4	0.081
	South Rock Creek	1	0.0377	4	0.156
	AVERAGE		0.144		0.085
1966	Beneke Creek	2	0.058	3	0.055
	Hamilton Creek	3	0.066	2	0.046
	Oak Ranch Creek	1	0.100	4	0.119
	South Rock Creek	1	0.340	4	0.199
	AVERAGE		0.141		0.105

* Other bottom types include bedrock, sand, silt and small gravel.

Species Competition

Table 2 on page ___ gives trout population estimates. Coho salmon and steelhead trout use many of the same streams. Observations indicate young trout rear in somewhat different areas of the stream. Coho usually rear in the deeper pools, while trout generally rear in the faster water areas. This is born out by our data. Table 16 shows that coho numbers divided by trout numbers in both South Fork Rock Creek and East Dairy Creek were much higher in the large pools. These two streams only were evaluated because they contained large numbers of both trout and salmon. Again to show that trout favor areas of faster water, trout per stream area was plotted against percent pool. The lower the percent pool in a stream, the more trout were found per stream area (Figure 15).

Temperature and Shade

Hand temperature data for the 1966 Nehalem study streams for the period of maximum daily temperature for July 29, 1966 are shown in Table 17. Temperatures appear to be related to flows, and except for Beneke Creek with the productivity of each study section as measured by the population estimate in 1966.

In the 1964 study section pools which had openings in the overhead canopy of over 10 percent of the sky were compared with pools on the same stream that had less than 10 percent opening. In six of the seven streams where comaprisons could be made, more juvenile coho per unit area were rearing in the pools with over 10 percent canopy opening. This probably means that enough canopy opening to let in bright light gives better overall

Table 16. The ratio of coho to trout for large and small pools in South Fork Rock Creek and East Fork Dairy Creek.

	Large Pools					Small Pools				
Stream	Pool No.	Pool Volume in Ft3	Coho Caught	Trout Caught	Ratio Coho Trout	Pool No.	Pool Volume in Ft3	Coho Caught	Trout Caught	Ratio Coho Trout
South Fork Rock Creek	2	980	43	8	5.4	1	330	39	3	13.0
	8	490	75	3	25.0	3	380	42	3	14.0
	11	830	54	3	18.0	4	440	38	8	4.7
	13	1,850	220	14	15.7	5	330	32	4	8.0
	14	520	8	1	8.0	6	340	11	4	2.7
	15	4,200	34	3	11.3	7	230	3	2	1.5
	16	740	85	7	12.1	10	110	2	1	2.0
	17	1,750	166	5	33.2	12	190	14	4	3.5
	18	1,000	98	9	10.9	19	210	6	4	1.5
	21	1,250	34	7	4.9	20	450	35	1	35.0
	23	500	10	5	2.0	25	160	8	12	0.8
	27	690	110	35	3.4	26	190	19	37	0.5
	AVERAGE				12.5					4.6
East Fork Dairy Creek	1	5,540	111	70	1.6	3	530	4	6	0.7
	2	1,710	23	4	5.7	4	830	1	8	0.1
	8	2,730	52	22	2.4	6	1,100	2	5	0.4
	11	4,130	25	13	1.9	7	500	13	38	0.3
	12	1,840	54	20	2.7	9	880	11	13	0.8
	13	4,070	121	32	3.8	10	910	46	25	1.8
	AVERAGE				3.0					0.7

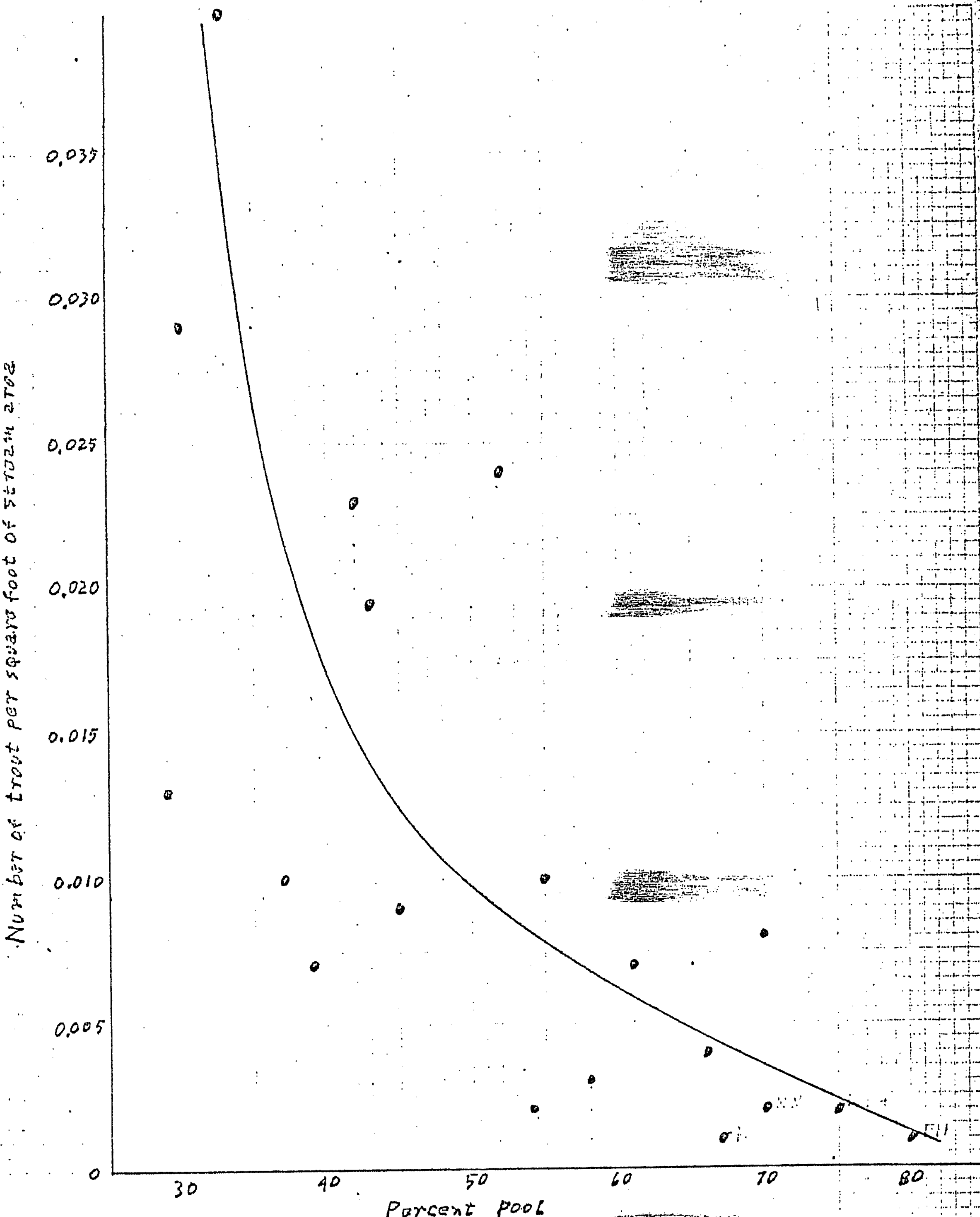

Figure 15. Trout per stream area with varying amounts of pool area in seventeen stream sections.

Table 17. Water temperatures taken in five Nehalem River system study streams on July 29, 1966.

Stream	Time	Air Temperature °F.	Water Temperature °F.
Hamilton Creek	3:25 p.m.	74	63
Beneke Creek	3:48 p.m.	76	60
South Fork Rock Creek	4:20 p.m.	77	55
North Fork Wolf Creek	4:37 p.m.	80	62
Oak Ranch Creek	5:20 p.m.	82	60

stream productivity. It does not mean that a stream is better off with no shade. In these study streams the canopy openings were not large enough to cause the stream to heat up more rapidly than normal.

DISCUSSION

As stated in the introduction, the objectives of the study were: (1) to obtain criteria for use in developing field methods to determine adequate rearing flows, (2) to provide data for use in predicting juvenile coho production at various summer flow levels, and (3) to provide additional justification for setting minimum streamflows and for requesting flow releases from storage reservoirs.

To achieve these objectives it was necessary to study some of the important factors that determine the numbers of fish a stream can rear. To study these factors, it was assumed that a stream has a definite carrying capacity determined by its physical dimensions. Results from severl weir studies and our work indicate that this assumption is valid. Chapman (1962) gives data from weir studies on Hooknose Creek, Spring Creek, and Minter Creek which shows that smolt production remains relatively constant from year to year and bears no relationship to females passed upstream or the out migration of fry. This would indicate the stream environment was controlling the number of smolts produced.

Results of this study show that a stream has a definite rearing capacity. Marked fish were added to the study pools in 1965 but only about one percent took up residence. This seems to show that the pools were already at their carrying capacity. Also the ranking of the study pools from highest to lowest in coho per area values stayed nearly the same in each stream section for two years in 1965 and 1966. This would indicate that not only the stream has a definite capacity but also each individual pool has a definite rearing capacity. Still another indication from our study that each stream has a definite carrying capacity was that the amount of pool area in each pool was directly related to the number of fish in each pool. This shows fish have spacial requirements. These spacial requirements probably limit the number of fish a stream can produce.

Factors Affecting Coho Rearing Capacity

As stated, a stream has a definite rearing capacity which is determined by the physical dimensions and environmental factors of the stream. Figure 18 illustrates some of the factors that affect the coho rearing capacity in streams.

Fish size seems to be an important factor which determines rearing capacity in numbers of fish. In fact, rearing capacity seems to be a function of both numbers and size of fish. For example, the rearing capacity of a given pool at a given time may be 50 large coho or 100 smaller coho. This is shown in data from a number of streams. The McKay Creek study section had a 1966 late September population estimate of 3,921 coho which averaged 66 mm. In 1964 the late September population estimate was 2,210 for the section and the coho averaged 74 mm long. In both cases we believe the stream may have been at its rearing capacity based on the good numbers of fish captured in all the suitable pools in both years.

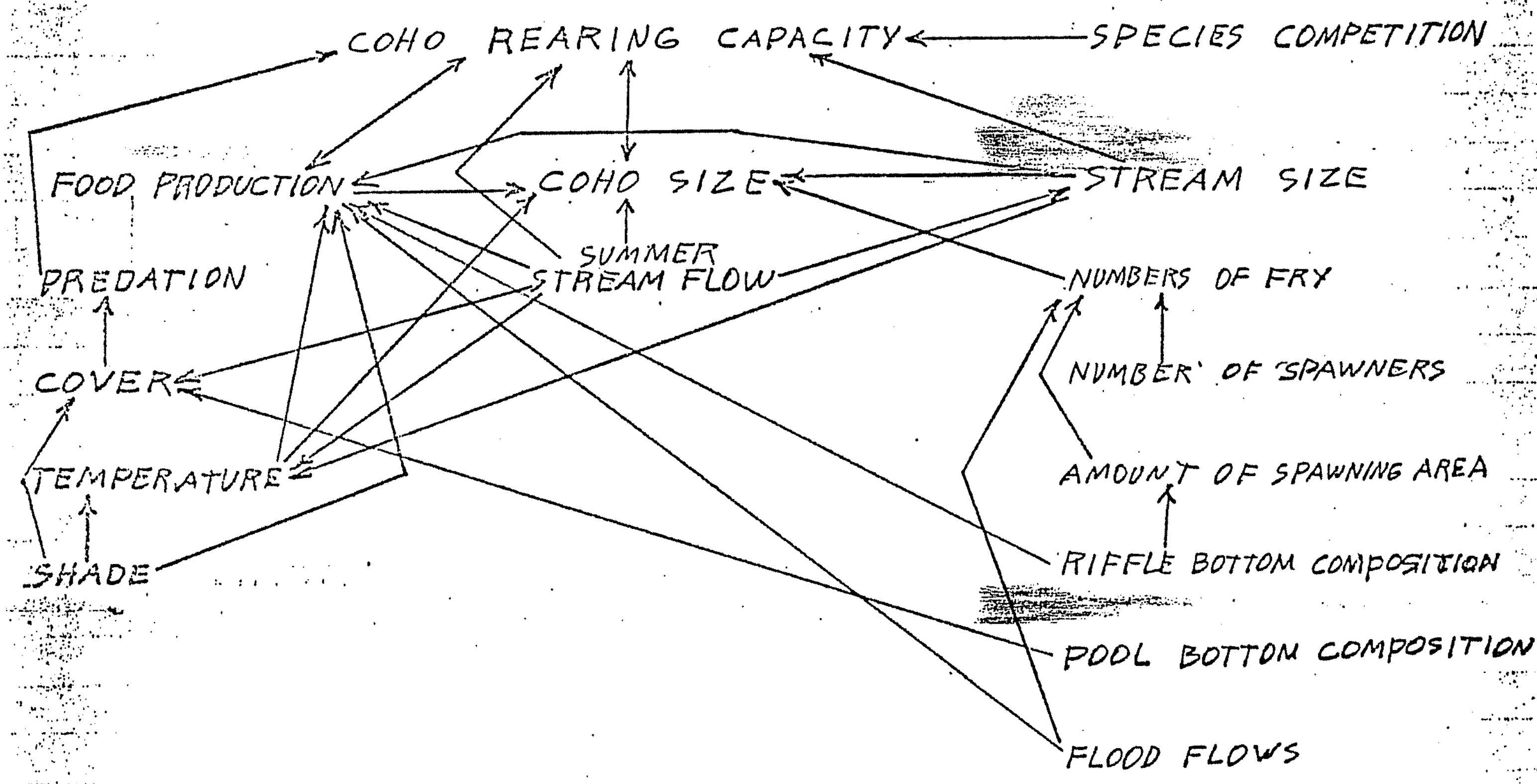

Figure 16. Some factors effecting coho rearing capacity

Shapovalov and Taft (1954) report that an inverse relationship existed between the total number of downstream migrant coho and their size in Waddell Creek. From graphs presented by Chapman (1965) it appears that on Deer Creek, Flynn Creek and Needle Branch the years in which the production of smolts was highest they were the smallest and the years in which the production of smolts was the lowest, they were the largest. Also in a Fish Commission weir study on Gnat Creek, the largest smolts were produced in years when their numbers were smallest.

The implications of the above are that such things as number of spawners, amount of good spawning area, winter streamflows and water quality, and the summer environment all affect the fish production of a stream. Shapovalov and Taft (1954) found that the number of smolts were in direct proportion to the number of females put over the weir. Yet Chapman (1962) presents data which shows that for three other weir studies, Hooknose Creek, Minter Creek and Spring Creek, the years of stream residence undergone by coho tends to stabilize the fluctuations caused by varying parent egg potential. The apparent contradiction may be ude to differences in the character of the individual streams. Apparently in Waddell Creek the effect of the stream environment was not strong enough to observe the relationship of smolts to parent egg potential.

If the proposition is true that carrying capacity is a function of both size and numbers of coho, then a stream with more good spawning area and fewer high winter flows will likely have better fry survival which will result in smaller fish and more fish per area than a stream that has less spawning area and more high winter flows. Most small coho streams have more spawning area per stream area and less severe winter flows than the normal larger coho inhabited streams. Therefore, the fish in thylarge streams would usually be larger and number fewer per area than the fish of the samller streams. The results of this study showed that fish size was significantly related to stream size; the smaller streams producing smaller fish but more fish per unit area. This also could mean that our larger study streams did not have enough spawners to provide the number of smolts at a size to produce the optimum number of harvestable adults. Our hatchery operations have shown that fish released at a larger size survive better than smaller smolts. This probably also applies to stream-reared fish. Therefore, some optimum balalce in the carrying capacity of each stream section undoubtedly exists between size and numbers to provide the highest number of harvestable adult fish.

<u>Summer streamflow</u>. Probably the most important factor determining the juvenile coho carrying capacity of a stream is the summer streamflow. The results of this study indicated that summer streamflows were directly related to production of juvenile coho. That streamflow is an important factor in coho production has been shown in other work.

Wickett (1951) found that for the period 1947-1950 the number of coho yearlings counted out of Nile Creek each spring was closely associated with the minimum monthly rainfall at Parksville the previous years.

Neave and Wickett (1949) showed that a marked correlation exists between summer flows in a representative stream and the annual catch of coho two years later by traps located at Sooke (southest end of Vancouver Island).

Neave (1949) indicates that angler success for coho in Cowichan Bay, British Columbia, for the years 1940-1947 is closely related to the level of summer flows two years previously.

McKernan, et all (1950), found a significant relationship between the trend deviation of silver salmon landings near the Siletz River, 1924-1945 and the July-to-September minimum flows of the river two years earlier. However, a similar analysis of the Coquille River showed no correlation.

Smoker (1953) demonstarted a relationship between coho salmon yield to the Puget Sound commercial fishery and total stream runoff two years previously.

Flow is important because much of the stream environment changes with changes in flow. For example, study results show the amount of cover may be directly related to the number of coho a pool can hold. When flow changes the surface distrubance, a form of cover, changes. Thus a change in the flow could affect the numbers of coho in a pool by changing the cover.

Although there are many factors that may cause flow to be related to production, two stand out as probably the most important. These two factors are space and food supply.

Chapman (1962) described aggressive behavior in coho and suggested space could be a factor determining the population size. The results of this study also show space to be important. Pool area was shown to be directly related to numbers of fish in the pool. Kallenberg (1958) studying territories of Atlantic salmon (S. salar) and brown trout (S. trutta) in a stream tank concluded that the larger the fish the greater the size of the territory required. Not only area but depth was shown to have an effect. In this study the length of fish was directly related to the depth of unused or little used pools. Chapman (1962) also found depth of rearing area to have an effect on the population. He stated that fry ceased to emigrate from the channel when the water depth was increased. Ruggles (1966) found in experiments at Roberton Creek that more fish were raised in his deeper pools than the shallow pools.

Although space is an important factor in determining the coho carrying capacity of a stream, indications from this study show that increases in population that result from increased flow are also velocity related. Kallenberg (1958) found that higher velocities increased the carrying capacity of his stream tank. He found that with higher velocities fish moved closer to the bottom which reduced their vision, allowing the fish to move closer together without increasing aggressive behavior.

Another effect of increasing flow may be to increase the food supply and thereby increase the carrying capacity for juvenile coho. Food supply may be an important factor in determining the carrying capacity of a stream. In this study, pools with larger riffles above averaged more coho per area than pools wtih smaller riffles above them. Also stream area seemed to be more related to the number of fish than the pool area indicating that riffles were important in determining numbers of fish. Ruggles (1966) found more fish could be reared in the channel that had 50 percent riffle than the channel which was all pool. Chapman (1965) states that the available food supply may be a primary factor among those determining the holding, rearing capacity in artificial stream channels with controlled flows.

It has been shown that fish food supply is affected by changes in flows.

Needham and Usinger (1956) found that for one riffle on Prosser Creek in California the number of aquatic insects produced was related to water velocity. In this study on four study streams, insect production seemed to be related to water velocity.

Although as discussed in the previous section carrying capacity can be manifest in either numbers or size, another factor exists which is connected to flow that undoubtedly is important in the survival to harvestable adulthood. This factor is the condition of the juvenile fish. On McKay Creek it was definitely seen that in years of low flow the condition of the fish was poorer. Therefore, if the summer flow is reduced in a stream, the survival to harvestable adults will probably be significantly less even if there were only a small reduction in size or numbers of juvenile coho.

Species competition. A factor which may affect the coho rearing capacity of some streams is the competition with trout. Little published work has been done on competition between juvenile salmon and trout in streams. Results of this study indicate that steelhead, young in general, rear in faster water than juvenile coho.

Since coho and trout have slightly different environmental preferences, it is probable that they do not directly compete in much of the stream. For example, if all coho were removed from a stream, the trout population would not increase to equal the previous population of trout plus coho. This is shown by data from three study sections in 1963 and 1964. On Gales Creek in 1963 the population estimates were trout 908, coho 405.

Probably due to floods in the winter, no young coho were found in this Gales Creek section in 1964 while 890 trout were present. Thus, when the coho were eliminated no increase in trout occurred although a large part of the trout population were young-of-the-year fish. However, there were some changes in the physical makeup of this section of stream which may have held down the trout population. On the upper section of East Fork Dairy Creek, the population estimates for 1963 were trout 541 and coho 1,706. During the winter floods some major changes occurred in the section. Also during the early summer much silt was deposited in the section from culvert replacements upstream. Some pools were eliminated and others were made shallower. In 1964 the population estimates were trout 676, coho 664. It seems likely that these changes were due mostly to physical changes in the section and species competition was not too important in determining the populations. Even though the environment in the section changed to favor trout more than coho, the increase in the trout population was not nearly as great as the decrease in the coho population.

In the lower section of East Dairy Creek the 1963 population estimates were trout 294, coho 1,360. There were only minor changes in the section in the winter of 1963-64. In 1964 the population estimates were trout 406, coho 543. In this case it appears that when coho were not taking up all the environment suitable to them, the numbers of trout increased about 35 percent. However, these comparisons may mean that competition between trout and coho has a small effect on thepopulations of the two species but that a stream can support many more fish with both species than it would with a single species.

Methods of Determining Rearing Flow Requirements

The number one objective of the study was to obtain criteria for use in developing field methods to determine adequate rearing flows. From the work of this study, two approaches appear workable to determine optimum streamflows for rearing coho salmon. These two approaches are the use of pool velocity and the use of riffle velocity and area as criteria.

Pool velocity method. This method is based on the fact that pool velocity seems to be an index of the factors that control the population of juvenile coho in a pool. The average velocity through the pools was found to be related to the numbers of fish per pool area.

With this method the assumption is made that conditions for rearing would improve with higher velocities in the pools. These conditins would improve until the current in parts of the pools becomes too fast and reduces the pool area available for coho rearing. Maximum velocities of about 0.7 feet per second at which coho were found in rearing could be used as the criterion for th optimum velocity in the pools.

The method cosists of getting measurements in the pools of the study stream that would enable the average pool velocity to be calculated for several streamflow levels. The optimum flow would be that flow in which the average velocity of the study pools matched the velocity carterion of 0.7 feet per second.

The riffle method. Food supply has been shown to be an important ingredient in the coho production of a stream. Therefore an optimum flow for coho juvenile rearing would be that flow which provided the maximum amount of fish food while velocities through the pools are not excessive.

A large portion of the food supply originates on the riffles. The maximum amount of fish food is controlled by at least two factors related to flow. These two factors are water velocity through the riffle and the amount of riffle area. Results from our work indicate that peak insect production on the riffles occurred at velocities of about 2.0 feet per second. Therefore an optimum flow based on fish food production would be that flow which covered the greatest amount of the riffle and still provided large sections of the riffle with water velocities of about 2.0 feet per second.

This method would entail measuring the areas and velocities of an adequate sample of the riffles of the study stream. From the results of these measurements, it could be determined what was the best riffle area-velocity combination.

Water quality. Another factor that must be considered when de ermining optimum rearing flows for anadromous salmonids is water quality. When an optimum flow is to be recommended for a long reach of stream, the above two methods may not be adequate because of the heating of the water throughout the reach. The water temperature at the lower end of the reach may be too high for salmonid production even though the flows are optimum for production at the upper end of the reach.

In these instances, a flow has to be calculated that will provide good water temperature throughout the reach.

Predicting Juvenile Coho Production

One of the stated objectives of the study was to obtain data for use in predicting juvenile production for a given stream reach. An estimate of the potential fish production in streams above barriers or problem areas is needed when evaluating the costs and benefits of providing fish passage or correcting the problem.

It has been determined that the amount of pool area is directly related to the number of juvenile coho. Therefore, an estimate of coho production on a given section of stream can be obtained by determining the pool area of the section and applying data on known numbers of coho per area from a similar stream section.

Table 19 gives information on the production per square food of pool area in early fall of 17 study streams and information on the size and character of the sections.

Justification for Minimum Streamflows

The third objective of the study was to provide additional biological justification for setting minimum summer streamflows.

Work of other investigators referred to earlier in the text shows that the yield of coho smolts can be positively correlated with summer streamflows. The mechanism by which increased streamflows increases fish production seems to be a combination of many interrelated factors which vary with the individual stream. Some of these factors are space, velocity, food supply, fish size, cover and temperature.

In one stream, one of the factors will be more important, while in another stream one of the other factors may be more important. However, based on results of this study and others on streamflow and fish production,

Table 18. Production per square foot of area, stream size and character for 17 study sections.

Stream	Coho/ft²	Average Pool Width	Percent Marginal Pools	Flow Rating Per Stream Size	Stream Bank Vegetation	Remarks
Nehalem River System						
East Humbug Creek	0.020	21	28	Low	2nd growth fir, alder and brush	Stream had a very low flow, less than normal riffle area & was silty.
Fishhawk Creek	0.030	20	9	Medium Low	Pasture w/ cut banks & some alder	Stream somewhat silty.
Humbug Creek	0.041	22	15	Low	2nd growth fir, alder and brush	Good section of stream; however logging upstream caused slightly silty condition.
Nehalem River	0.030	27	41	Low	Alder w/ some brush	Section of bedrock in study section cut down coho/ft2 rate.
North Fork Wolf Creek	0.043	16	56	Low	Mostly alder & willow, trees quite bushy	Section has long reach of marginal pools.
Oak Ranch Creek	0.051	12	64	Medium Low	"	Good Stream except for bedrock section in study area.
Rock Creek	0.020	37	42	Medium	Alder w/ some brush	Somewhat silty & has bedrock reach in study section.
South Rock Creek	0.119	15	37	High	Mostly alder and willow trees quite brushy	Very good stream; good pools with good cover and good flows.

Stream	Coho/ft2	Average Pool Width	Percent Marginal Pools	Flow Rating Per Stream Size	Stream Rank Vegetation	Remarks
Tualatin River System						
Beaver Creek	0.043	9	45	Low	Alder, Willow trees; very brushy	Good low gradient stream although somewhat silty.
East Dairy Creek (upper 1963)	0.136	22	39	High	Alder with some brush	Very good stream.
East Dairy Creek (upper 1964)	0.039	21	64	High	"	Flood during winter changed section: more marginal pools and silty.
East Dairy Creek (lower 1963)	0.074	24	20	High	"	Good stream.
Gales Creek	0.042	16	50	Medium	"	Large bottom materials; section better for steelhead.
McKay Creek (1963)	0.100	25	46	Medium	Some pasture with alder, willow & brush.	Good low gradient stream.
McKay Creek (1964)	0.061	24	50	Low	"	"
South Gales Creek	0.046	9	77	Medium Low	Alder, willow; not much brush	Fairly steep section.
Wilson River System						
Devils Lake Fork	0.083	19	33	Low	Alder with some brush	Good coho section.

It seems clear that whichever mechanism increases production, almost all streams would increase fish production with an increase in summertime streamflows; and also if water is taken from a stream in the summer, production as measured by adult returnees will be reduced.

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