Fish Commission of Oregon
Final Report

GNAT CREEK WEIR STUDIES

December 1962

Contract:
Operational Studies 14-17-0001-469

FINAL REPORT

GNAT CREEK WEIR STUDIES

by

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Fish Commission of Oregon
Research Division
Clackamas, Oregon

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ABSTRACT

Gnat Creek Weir, constructed with federal funds, was completed in October 1955. Primary objectives were to quantitatively study fall chinook and silver salmon to: (1) determine the survival, timing, and size of juvenile salmonids resulting from natural spawning; (2) measure the survival of hatchery-reared fingerlings and yearlings; (3) determine if a relationship between varying stream flows and adult production existed; and (4) study the juvenile production resulting from various numbers of adults above the weir. The source of Gnat Creek is at 2,500 feet altitude and the stream system drains 22 square miles. Falls and other obstructions limit the production area above the weir to the central part of the main stream and parts of two small tributaries. Counts of juveniles, although not complete due to spill over the dam above 150 c.f.s., are considered accurate and complete during times of no spill. Survival rates for silver salmon smolts (yearlings) were 0.5 and 2.0% of the maximum calculated egg deposition in the two years with no spill during April and May and averaged 1.5% for all years. Seventy-one per cent of the smolts migrated during May and 90% during April and May. The average size of 7,878 smolts from 6 brood years was 114.9 mm fork length with 95% confidence limits of 87.8-142.0 mm. Silver salmon survival rates of adults only (jacks excluded) returning to the weir averaged 2.5% of the smolts counted downstream. An excellent correlation existed between the numbers of silver salmon jacks in one year and the numbers of adults in the following year at Gnat Creek. Counts of steelhead adults and juveniles are presented and a manuscript concerning a test of spaghetti and Petersen tags on steelhead was prepared.

INTRODUCTION

Project Plans

As a part of the Columbia River Fishery Development Program (CRFDP) between the Oregon Fish Commission (OFC) and U.S. Fish and Wildlife Service (USFWS) 1/ it was desired to learn more about the fresh-water phase of anadromous salmonid life history in general, and lower Columbia River fall chinook salmon in particular.

After numerous stream surveys had been conducted on Oregon tributaries below the Willamette River, it was apparent that only one or possibly two streams would be at all suitable for a two-way weir on a stream having an appreciable minimum flow. Gnat Creek was chosen when preliminary engineering and biological data indicated maximum flows would not likely exceed 2,000 c.f.s and minimum flows would be about 10 c.f.s. Two species of salmon, chinook (Oncorhynchus tshawytscha) and silver (O. kisutch) or coho, were present in addition to steelhead (Salmo gairdneri) and sea-run cutthroat trout (Salmo clarki). Construction was completed in 1955.

The Gnat Creek project was initiated prior to the publication of two extensive papers dealing with weir studies on silver salmon and steelhead (Salo and Bayliff, 1958, and Shapavalov and Taft, 1954).

Objectives

Objectives of the study were: (1) determine the survival, timing, and size of juvenile salmonids resulting from natural spawning; (2) measure the survival of hatchery-reared fingerlings and yearlings liberated into Gnat Creek; (3) determine if a relationship between varying stream flows and adult production existed; and (4) study the juvenile production resulting from various numbers of adults above the weir. Although uncounted numbers of juveniles

1/ Later the Bureau of Commercial Fisheries of the USFWS.

would migrate over the dam when flows exceeded 150 c.f.s., it was hoped that a sampling technique could be developed for obtaining a reliable estimate of those fish that by-passed the counting facilities. Corrosion of the heavy-gaged screens later caused water in excess of about 135 c.f.s. to spill over the dam and the use of suitable gear for sampling on the crest of the dam during storms, especially at night, was only partially solved by June 1962 when the field project terminated.

DESCRIPTION OF STREAM AND FACILITIES

Gnat Creek Watershed

The Gnat Creek system is in Clatsop County, Oregon, and drains the northern slopes of Nicolai Mountain in the Coast Range. It originates at an altitude of 2,500 feet and flows northerly into Blind Slough which joins the Columbia River 28 miles above its mouth (Figure 1). Climate of the 22-square-mile stream system is generally similar to that of other coastal foothill areas with abundant rainfall in the fall, winter, and spring months. A maximum flow of 1,300 c.f.s. occurred at the weir for a short duration on November 22, 1959, as a result of 3.8 inches of rain in 12 hours. Minimum flows, on the other hand, of 7 c.f.s. were often encountered in the summer after a prolonged period of dry weather.

The mouth of Gnat Creek at high water of the Columbia River is located approximately between Supply Creek and Rock Creek. The weir with the dam on the north side (Figure 2) and the screens on the south side (Figures 2 and 3) is located 100 yards upstream from the mouth of Rock Creek. The photographs were taken on December 11, 1961 when the flow was 180 c.f.s. Three miles of stream are accessible to anadromous fish between the weir and a 6-8 foot cascade (Figure 4) which is located about 100 yards above the U. S. 30 highway bridge. At low flows this cascade appears to be impassable and

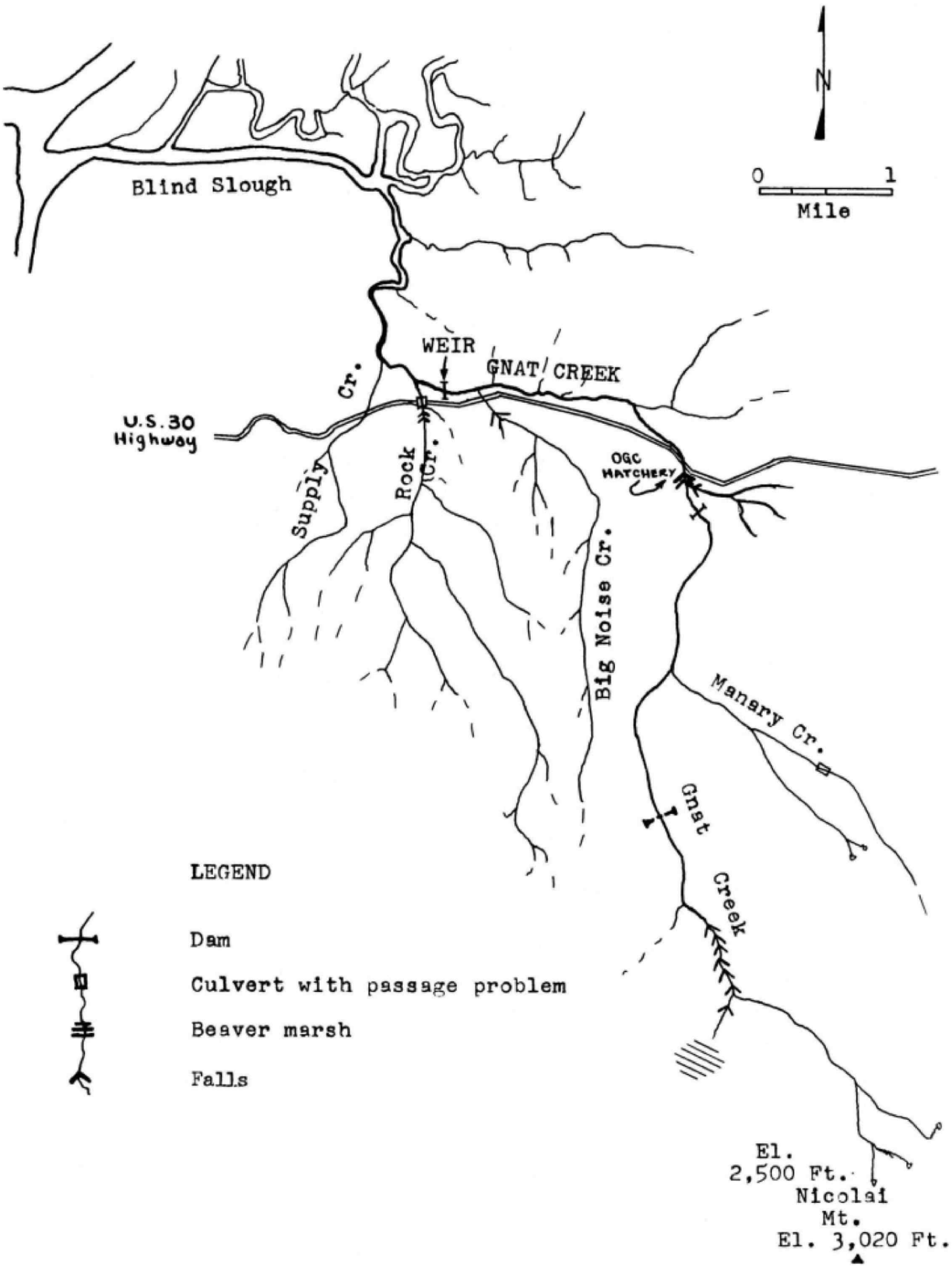

Figure 1. Gnat Creek and Tributaries.

Figure 2. Gnat Creek Weir at 180 c.f.s.

Figure 3. Sampling Traps on Dam (180 c.f.s.).

Figure 4. Partially-Passable Cascades Located on Gnat Creek 3 Miles above Weir.

Figure 5. First of 7 Impassable Falls Located 1 Mile above Manary Creek.

usually represents the upstream limit of chinook salmon migration. However silver salmon and steelhead trout are able to pass. The gradient in the 3-mile section of stream below this cascade is moderate with several fair riffles of coarse gravel. Occasional channel changes with scouring of the stream bottom have been observed.

A new hatchery operated by the Oregon Game Commission (OGC) was constructed under the federal program in 1960 at the highway bridge. Its water-supply dam is about 400 yards above the cascades and is equipped with a fishway of modern design. Water for hatchery use flows over a heavy-duty, fine-meshed, inclined-plane screen. Occasional low flows at the dam present a problem to upstream-migrating adults such as steelhead in May of some years.

The remains of an old dam are located about 3 miles above the hatchery water-supply dam. This wooden crib dam was considered to be an impassable barrier to fish migration during its use in the logging operations of 1920-30. One mile above Manary Creek, the stream drops about 800 feet within one-half mile over 7 falls. A photograph of the lower most of this series of falls is shown in Figure 5.

Most of the Gnat Creek tributaries above the weir are non-producers of anadromous fish because of impassable barriers. Although the mouth of Rock Creek is below the weir, this steep-gradient stream has an impassable culvert at most flows under Highway 30. Big Noise Creek has a steep cascade which is located 1/4 mile above the highway and is impassable at most flows. An unnamed tributary located opposite the OGC Hatchery at Highway 30 has an impassable falls at its mouth (photo in Figure 6). Manary Creek has a road culvert (Figure 7) about 1-1/4 miles above its mouth that is impassable at most times although an occasional steelhead is able to pass through it.

Gnat Creek Weir

The two-way fish counting facility, commonly called a weir, was pri-

Figure 6. Impassable Falls at Mouth of Unnamed Tributary Near U.S. 30 Bridge.

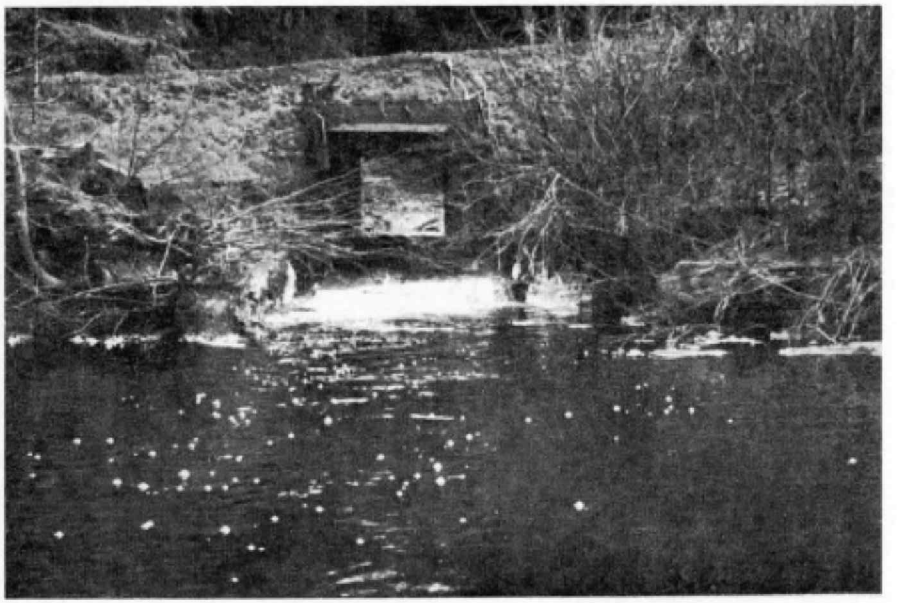

Figure 7. Partially-Passable Culvert Located on Manary Creek.

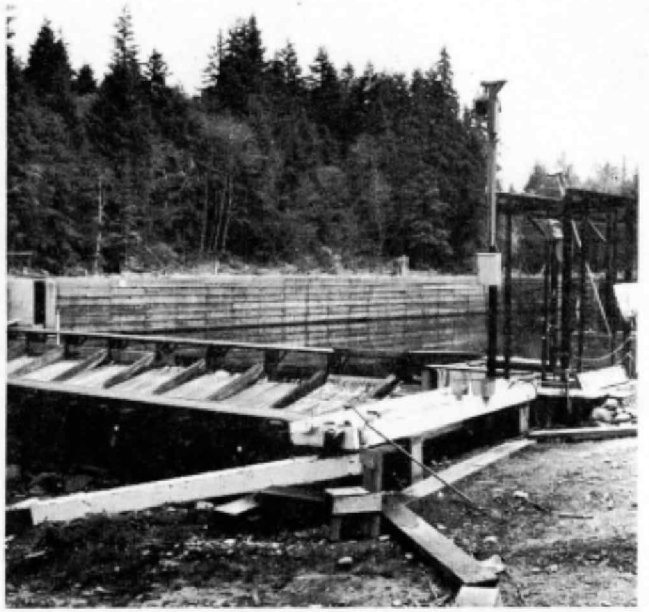

Figure 8. Screened Section (left center), Bulkhead (in background), and Traps (at right).

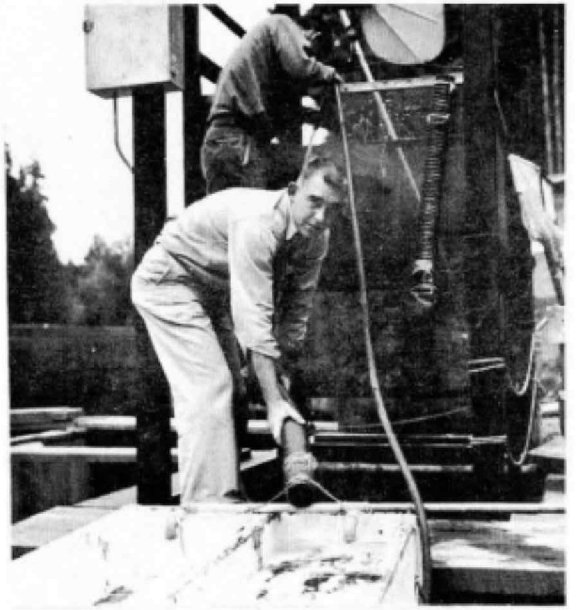

Figure 9. Downstream Trap Basket in Raised Position for Draining.

marily in two parts, viz., the 100-foot-long dam 10 feet high, and 9 inclined-plane screens leading to a holding box in a trap (Figure 2). The two parts were separated by a rock-filled, crib bulkhead running parallel to the stream upstream about 100 feet to the wooden water-control structure which allowed a maximum of 135 c.f.s. to the screened part. Two gates and stop logs controlled the amount of water to the screens and the excess over 135 c.f.s. was diverted over the spillway. Two additional stop logs (shown in Figure 8) at the head of each screen provided additional water control depth adjustments over the screens. Each of the nine 1/8-inch mesh screens passed up to 15 c.f.s. in such a manner that fish of various sizes were collected into a continuous trough under the lower ends of the screens. A longitudinal screen of 1/2-inch mesh provided a separate section of trough for the smaller fish. The trough carried the fish in water to the downstream trap (shown in the raised and drained position in Figure 9). Excessive water from the trough by-passed the downstream trap (to prevent turbulence for the fish being held) and fish were separated by a rotary screen driven by a paddle wheel. When emptying the trap the entrance was closed, the trap basket with fish and water was lifted by an electric hoist and drained by two hoses into two standard hatchery troughs for inspection of the day's catch. After inspection the fish were returned to the stream below the weir via a chute with water.

The upstream trap was located between the downstream trap and the first inclined-plane screen and utilized the flow from the downstream screening and trapping facilities for added attraction to the small ladder and trap entrance. Fish occasionally appeared at the base of the dam (shown in Figure 10) but most soon located the ladder leading to the upstream trap. In 1961, a floating compartment was installed so the adult fish would be lifted in water as shown in Figure 11 (lowered position) and Figure 12 (raised position).

Figure 10. Several Sea-Run Cutthroat Trout at Base of Dam.

Figure 11. Upstream Adult Trap with Easily-Opened Gates, in Lowered Position.

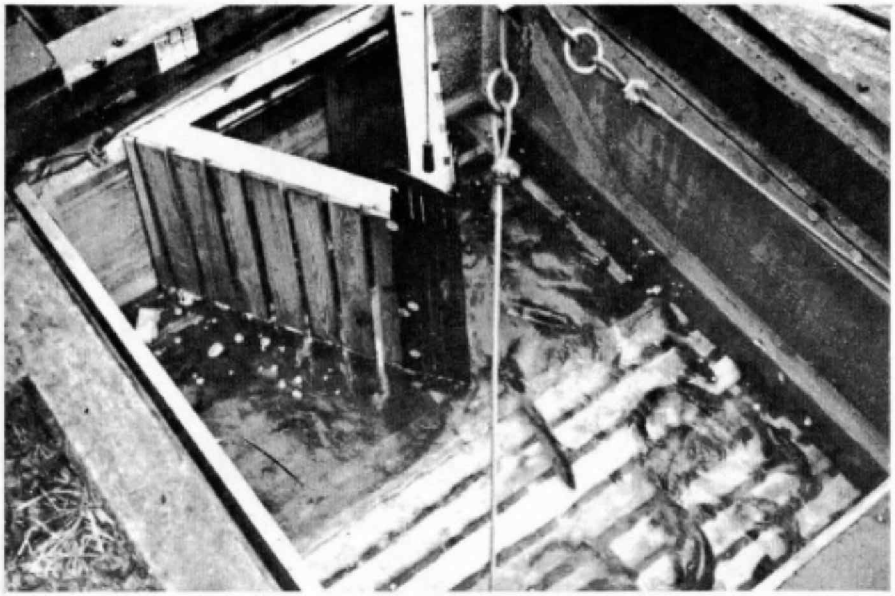

Figure 12. Upstream Adult Trap in a Raised Position.

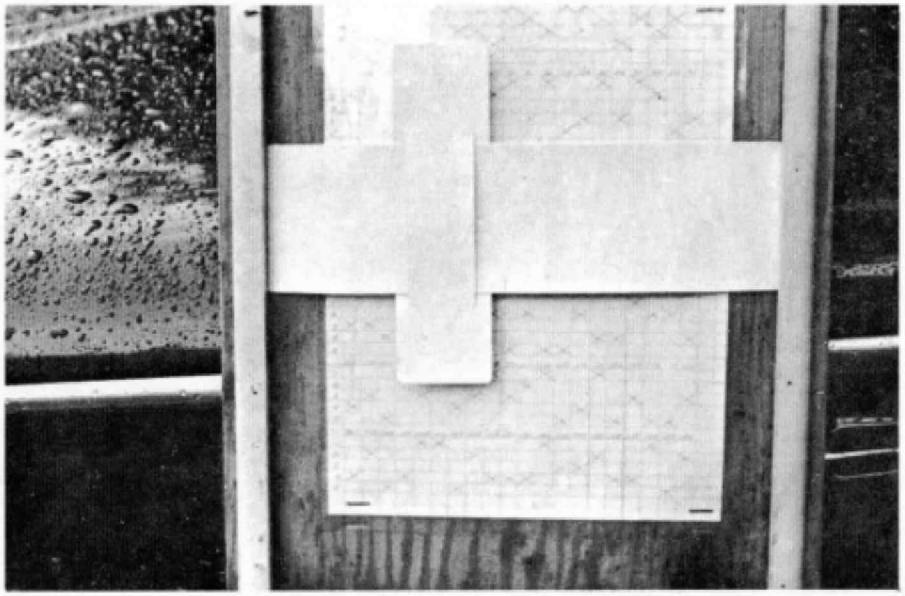

Figure 13. Waterproof Random Number Table for Sampling Downstream Migrants.

METHODS OF COLLECTING DATA

Air and water temperatures were obtained by a Weksler recording thermometer. Stream flows were obtained from gage height to flow conversion tables prepared by the OFC Engineering Division. An index for each annual average runoff in inches per acre, similar to that developed in Washington by Smoker (1953), was calculated by the formula:

$$\text{Index} = \frac{(A)\ (12C)}{(22)(640)}$$

where A is the yearly total flow in c.f.s.; C is the constant 1.9835 that converts c.f.s. to acre-feet and converts the numerator to inches; and the denominator is the area of the Gnat Creek watershed in acres.

Juvenile salmonids were separated by species and individually counted. Fall chinook juveniles were all 0+ except where noted. Silver juveniles were tabulated arbitrarily as 0+ through November 15 and as 1+ yearlings or smolts from that date until the end of the following spring. Two-year-old smolts were identified among the latter group but in insignificant numbers. Rainbow-steelhead trout are noted as steelhead for the sake of brevity.

Lengths of juvenile fish were recorded in both millimeters and inches but are standardized in this report as fork length in millimeters. Lengths of adults were recorded to the nearest one-half inch (fork length) and subsequently rounded to the nearest lower inch in keeping with length measurements obtained in the commercial fishery. With minor exceptions, no anesthetics were used while handling the fish. Random samples of juvenile silver salmon and steelhead were collected with the aid of a random numbers table. Appropriate information was put on a water-proof table for reference in collecting the samples (Figure 13).

Examinations of all silver salmon scales collected were made with a Bausch and Lomb Tri-Simplex projector at 150 X which was calibrated with an

American Optical stage micrometer. Circuli were counted along a 20° line on either side of the anterior-posterior axis through the end of the fresh-water growth. Distances were measured in units of 1/40 inch from a Bruning precision ruler from the center of the focus to the last circulus counted.

RESULTS

Physical Data

Stream flow data were recorded each day the weir was attended; the averages for 5-day periods from January 1956 through June 1962 are presented in Table 1. Conversion of runoff into average depths (in inches per acre) have been calculated for later use in studying silver salmon production in relation to flows. Dates associated with possible incomplete counts of juvenile fish during times of spill over the dam are shown graphically in Figure 14. Closer examination of the duration and magnitude of these spills is possible with the listing of water volumes by day during the major downstream-migration period in April and May (Table 2).

Voluminous records of stream temperatures have been recorded but are not presented.

Fish Migrations

Fall Chinook Salmon

From inspection of the fall chinook adult counts in Table 3, it is readily apparent that runs are sporadic in Gnat Creek. The adult counts to the weir are quite accurate in contrast to the fry and fingerling outmigrants.

Since nearly all of the Gnat Creek fall chinook juveniles migrate downstream in the month of February, and reference to Figure 14 indicates considerable spill in February of each year, substantial enumeration errors for these fry are suggested. Additional error may have been introduced into counts of

Table 1. Average Flows in Cubic Feet Per Second by 5-Day Periods, Gnat Creek, January 1956-June 30, 1962.1/

Date Ending		1956	1957	1958	1959	1960	1961	1962
January	5	401	58	103	161	47	100	142
	10	321	62	78	352	55	190	164
	15	200	88	186	244	49	168	92
	20	262	54	209	150	59	151	77
	25	191	45	192	227	68	77	70
	31	105	45	249	239	168	88	96
February	5	68	104	173	160	204	140	62
	10	67	118	142	138	288	161	77
	15	103	98	205	135	265	317	122
	20	79	68	224	186	166	301	95
	25	98	167	231	147	101	438	71
	28-29	184	212	220	132	64	255	55
March	5	333	111	125	111	62	246	75
	10	247	250	149	84	121	254	107
	15	120	171	84	87	160	350	74
	20	121	116	74	85	161	216	64
	25	317	105	67	93	96	168	147
	31	195	98	70	198	175	141	124
April	5	141	94	117	217	119	98	71
	10	107	93	98	95	78	73	158
	15	86	131	73	70	81	67	78
	20	64	93	213	54	144	69	54
	25	55	63	232	47	158	110	49
	30	49	49	117	100	110	81	141
May	5	36	42	59	86	74	92	90
	10	35	33	52	68	59	77	66
	15	33	29	44	66	55	58	51
	20	28	30	45	45	111	45	40
	25	27	38	32	57	155	40	40
	31	29	26	34	47	92	33	34
June	5	28	24	32	45	56	24	41
	10	39	23	81	73	39	24	35
	15	29	25	38	54	39	19	24
	20	29	23	29	39	41	14	21
	25	25	20	25	27	33	12	18
	30	23	20	27	29	25	12	20
July	5	21	14	25	25	24	12	
	10	16	11	22	26	20	12	
	15	14	13	15	24	14	11	
	20	11	10	13	16	11	11	
	25	10	9	13	12	11	9	
	31	9	9	10	11	10	9	
August	5	15	8	9	10	10	8	
	10	10	10	8	9	7	8	
	15	9	10	8	9	10	8	
	20	9	8	8	10	10	8	
	25	9	8	8	14	12	7	
	31	12	8	9	11	10	8	

Table 1. (Cont'd)

Date Ending		1956	1957	1958	1959	1960	1961
September	5	8	8	8	30	9	19
	10	14	7	8	27	9	8
	15	10	7	9	12	8	8
	20	9	8	10	42	9	8
	25	10	9	10	40	9	7
	30	19	9	9	93	10	9
October	5	10	10	8	43	10	7
	10	10	10	17	76	17	12
	15	13	10	10	119	12	17
	20	71	10	56	61	9	9
	25	130	20	32	152	35	29
	31	92	10	17	89	80	55
November	5	93	10	26	69	49	35
	10	48	28	253	50	52	31
	15	45	159	354	44	152	42
	20	145	59	338	133	333	28
	25	49	50	227	506	411	195
	30	34	71	101	126	187	109
December	5	35	107	138	85	93	122
	10	153	205	113	64	65	80
	15	258	65	122	162	72	57
	20	175	294	122	137	137	262
	25	135	291	188	91	86	220
	31	72	239	173	71	91	180
Total Runoff (c.f.s./24 hrs.)		40,070	23,200	33,130	48,415	29,360	31,845
Average Annual Flow (c.f.s.)		111.31	64.44	92.03	134.49	81.56	88.46
Runoff Index		67.72	39.21	56.10	81.82	49.62	53.82

1/ The last interval of the month is 6 days in 31-day months. Flows over the dam are included during times of spill.

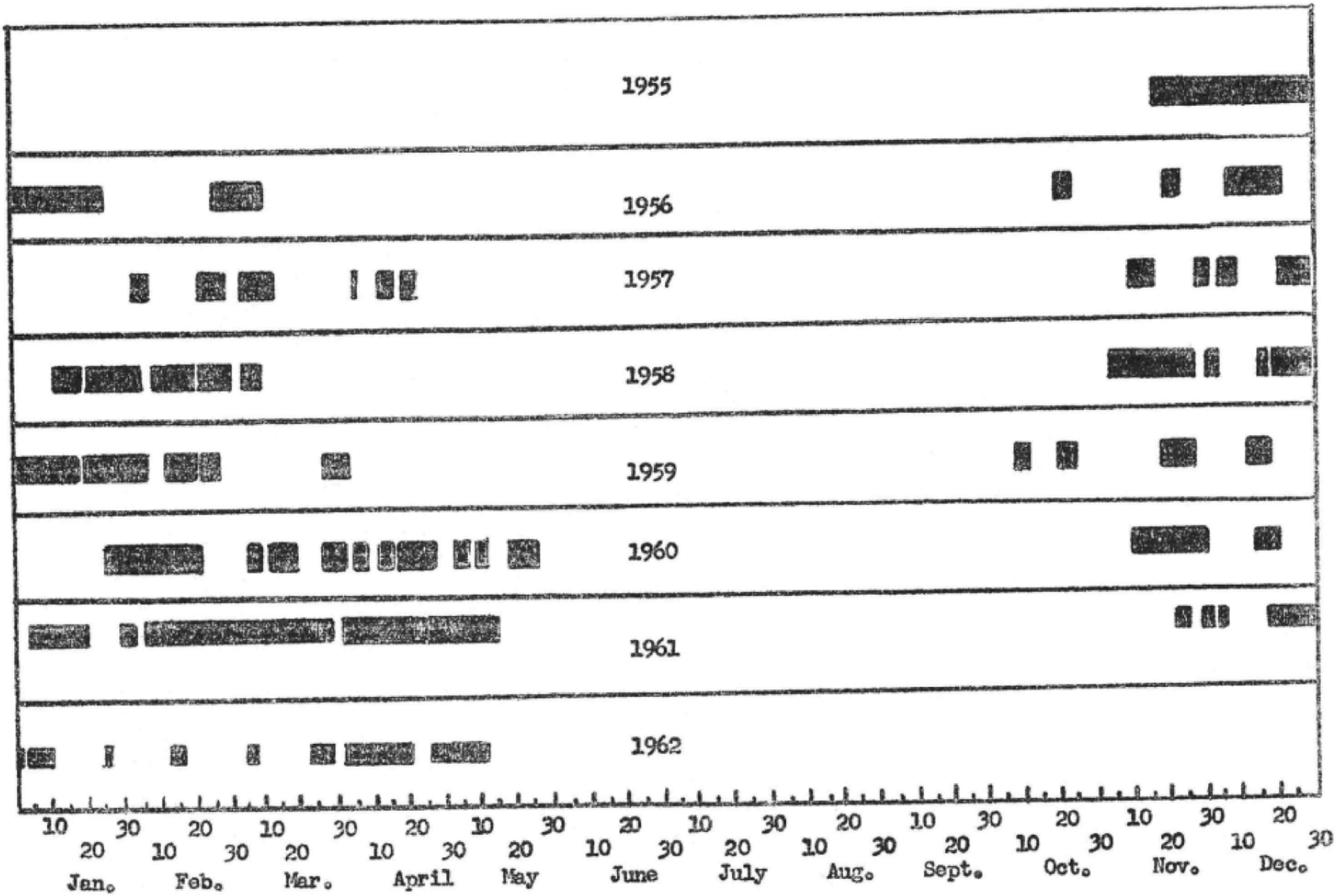

Figure 14. Periods of Overflow at the Gnat Creek Dam When Juvenile Salmonids Could Migrate, 1955-62.

Table 2. Flows Over the Dam by Day During the Months of April and May, 1957-62. 1/

Calendar Year	Month	Day	Flow c.f.s.
1957	April	1	78
		2	69
		3	69
		4	110
		5	143
		6	115
		7	98
		8	90
		9	90
		10	72
		11	65
		12	62
		13	81
		14	156
		15	130
		16	100
		17	100
		18	86
		19	90
		20	0
		21	67
		22	60
		23	65
		24	58
		25	0
		26	54
		27	50
		28	48
		29	47
		30	46
	May	1	46
		2	44
		3	42
		4	39
		5	38
		6	32
		7	31
		8	31
		9	39
		10	32
		11	31
		12	27
		13	28
		14	29
		15	28
		16	26
		17	26
1957	May	18	36
		19	29
		20	32
		21	30
		22	43
		23	42
		24	38
		25	36
		26	28
		27	25
		28	27
		29	26
		30	26
		31	23
1960	April	1	128
		2	128
		3	0
		4	105
		5	97
		6	86
		7	80
		8	77
		9	0
		10	70
		11	61
		12	70
		13	63
		14	95
		15	116
		16	0
		17	0
		18	94
		19	123
		20	106
		21	106
		22	111
		23	111
		24	106
		25	106
		26	109
		27	118
		28	112
		29	88
		30	87

Table 2. (Cont'd.)

Calendar Year	Month	Day	Flow c.f.s.	Calendar Year	Month	Day	Flow c.f.s.
1960	May	1	0	1961	April	14	65
		2	84			15	62
		3	75			16	60
		4	72			17	61
		5	63			18	66
		6	63			19	81
		7	0			20	75
		8	0			21	97
		9	56			22	117
		10	57			23	116
		11	57			24	112
		12	54			25	99
		13	55			26	88
		14	0			27	83
		15	0			28	76
		16	67			29	78
		17	87			30	80
		18	106				
		19	120				
		20	93		May	1	91
		21	101			2	87
		22	106			3	92
		23	101			4	99
		24	106			5	89
		25	111			6	84
		26	114			7	77
		27	95			8	73
		28	80			9	79
		29	0			10	70
		30	0			11	58
		31	65			12	52
						13	56
						14	67
						15	56
						16	52
1961	April	1	106			17	47
		2	108			18	45
		3	103			19	42
		4	89			20	40
		5	82			21	42
		6	77			22	43
		7	72			23	40
		8	74			24	38
		9	75			25	36
		10	66			26	36
		11	65			27	40
		12	69			28	35
		13	76			29	31

Table 2. (Cont'd.)

Calendar Year	Month	Day	Flow c.f.s.
1961	May	30	29
		31	28
1962	April	1	74
		2	71
		3	67
		4	74
		5	67
		6	98
		7	106
		8	111
		9	108
		10	108
		11	95
		12	85
		13	78
		14	72
		15	62
		16	55
		17	54
		18	54
		19	51
		20	55
		21	54
		22	49
		23	45
		24	45
		25	51
		26	51
		27	84
		28	81
		29	81
		30	98
	May	1	103
		2	92
		3	100
		4	83
		5	74
		6	77
		7	66
		8	65
		9	67
		10	57
		11	56
1962	May	12	56
		13	51
		14	48
		15	45
		16	42
		17	40
		18	40
		19	39
		20	37
		21	36
		22	43
		23	43
		24	38
		25	39
		26	37
		27	35
		28	36
		29	35
		30	34
		31	30

1/ The total Gnat Creek flow on a particular day is the sum of the flow over the dam plus the flow over the screens. This table shows the magnitude of the flows over the dam during the periods indicated in Figure 14. No migration over the dam was apparent when the spill was less than 50 c.f.s.

Table 3. Comparison of Annual Escapements of Adult Fall Chinook and Resulting Outmigration of Wild Juveniles at Gnat Creek Weir, 1955-62.

Year of Parent Run	Size of Parent Run				Year of Outmigration	Weir Count of Resultant Outmigration
	Male	Female	Unknown	Total		
1955	0 (0)	2	-	2 (0) 1/	1956	0
1956	35 (0)	23	-	58 (0)	1957	1,279
1957	1 (0)	3	-	4 (0)	1958	0
1958	51 (33)	16	-	67 (33)	1959	432
1959	56 (4)	23	-	79 (4)	1960	45
1960	33 (0)	53	2	88 (0)	1961	174
1961	6 (0)	3	-	9 (0)	1962	0
1962	-	-	-	7 (0)	-	-

1/ Numbers in parentheses list jacks which are included in the total.

juvenile fall chinook due to occasional fish passing over the rotating screen during flooding conditions. A larger and more efficient screen was installed in 1960. The most successful operation of the 5 scoop traps on the dam was accomplished in the winter and spring of 1961 and these sampling data are included in Table 4. The total weir trap count of the 1960 brood was 174 (in Table 3) and 164 of these were caught between January 16 and April 25, 1961. Since all 5 scoop traps fished 10 lineal feet of the 100-foot dam, a total of 1,000 was estimated to have passed over the dam during that time interval. No statistical treatment of these data appeared warranted because of the small numbers involved. Additional details concerning fall chinook adult and juvenile counting were presented in each annual Gnat Creek progress report from the start of the project in 1955 through June 1962.

A summary of all past chinook marking experiments at Gnat Creek including liberation data and all actual recoveries is presented in Table 5. Less than 50,000 fish are involved in each of 8 experiments. The purpose of four of the experiments was to compare the returns from fingerling vs. yearling

Table 4. Catches of Fall Chinook Salmon Fry and Flows Over Gnat Creek Weir and Dam by 5-Day Periods, January 16-April 25, 1961.

5-Day 1/ Period Ending	Sampling Traps on Dam						Weir Trap Catch	Sampling Trap Catch + Weir Trap Catch (Jan.-Apr.)	Sampling Catch as % of Total Catch	Flow in c.f.s.			
	A	B	C	D	E	Total				Weir Av.	Weir Max.	Dam Av.	Dam Max.
January													
20	0	2	0	0	0	2	0	2	100	118	121	33	55
25	0	0	0	0	0	0	-	-	-	77	87	0	0
30	0	0	0	0	0	0	23	23	0	84	135	4	26
February													
5	0	0	0	0	2	2	7	9	22	129	145	11	30
10	1	4	1	1	1	8	19	27	30	128	140	33	85
15	19	2	7	9	6	43	26	69	62	114	125	203	337
20	2	6	3	4	0	15	25	40	38	110	121	191	347
25	0	0	0	0	0	0	24	24	-	107	121	331	607
28	0	0	0	0	0	0	0	0	-	112	125	143	189
March													
5	1	0	0	0	3	4	1	5	80	119	125	127	215
10	1	0	0	0	0	1	2	3	33	119	125	135	223
15	0	0	3	5	4	12	16	28	43	112	121	238	337
20	3	5	4	0	0	12	15	27	44	118	130	98	181
25	0	1	0	0	0	1	0	1	100	124	130	44	79
30	0	0	0	0	0	0	0	0	-	119	130	22	79
April													
5	0	0	0	0	0	0	3	3	-	98	111	0	0
10	0	0	0	0	0	0	2	2	-	73	78	0	0
15	0	0	0	0	0	0	0	0	-	67	78	0	0
20	0	0	0	0	0	0	1	1	-	69	87	0	0
25	0	0	0	0	0	0	0	0	-	108	121	2	22
Total	27	20	18	19	16	100	164	264	38				

Approximation of Total Migration Jan. 16-April 25 Over dam: 1,000 In Weir Trap: 164 Estimated Total: 1,164

Per Cent of Est. Total: 86

1/ Six-day period in last group of 31-day months; 3 days at end of February.

Table 5. Summary of Chinook Salmon Marking Experiments at Gnat Creek.

Marking Information					Release and Juvenile Recovery Information						
Brood Year	Mark	Purpose of Experiment		Origin of Eggs	Date	Number	Release Site 2/	Average Size	Weir Recovery Number	% Survival	FW Residence 4/
1953	Ad	To Augment Runs of Fall Chinook	H 1/	Bonneville to Sandy	6/24-25/54	49,641	Br.	180/lb at marking (F) 3/	(Migrated prior to weir construction)		
1954	D	and to Appraise Results of Returns	H	Bonneville	7/1/55	49,851	Br.	64 mm (F)			
1955	LP	Time of Liberation	H	Bonneville	6/20/56	25,997	Br.	278/lb at marking (F)	19,436	75	3 days
1955	RP	Time of Liberation	H	Bonneville	4/3/57	23,938	Br.	3.6" at release (Y) 3/	21,007	88	2 days
1956	D-RM	Time of Liberation	H	Bonneville	6/12/57	26,221	Br.	2.2" or 262/lb at marking (F)	16,466	63	3 days
1956	D-LM	Time of Liberation	H	Bonneville	4/15/58	24,600	Br.	4-5" at release (Y)	12,264	50	5 days
1956	Ad	Identify Natural Stock	W 1/	Gnat Creek	3/1-10/24/57	1,022	BW	40 mm on 3/20/57 (F)	--	--	--
1959	Ad	Identify Natural Stock	W	Gnat Creek	2-4/60	45	BW	1½-2" (F)	--	--	--

Table 5. (Continued)

Brood Year	Mark	Adult Mark Recovery Information (Actual) 5/ Ocean Comm. (2 3 4 5) 7/	Ocean Sport (2 3 4 5)	River Comm. (2 3 4 5)	River Sport (2 3 4 5)	Other 6/ (2 3 4 5)	Gnat Creek (2 3 4 5)	Total Actual Recoveries for Experiment
1953	Ad			1 5			2,2	10
1954	D	1	2	1			1	5
1955	LP	1,3,1		1 4,1	1	1 1	0	14
1955	RP	1,1	1	1		1 1	0	6
1956	D-RM						3	3
1956	D-LM		1	3	1	1	32 24 36	98
1956	Ad						0	0
1959	Ad						-	

1/ H = hatchery; W = wild.
2/ Br. = released at highway bridge located 3 miles above weir; BW = below weir.
3/ F = fingerling; Y = yearling.
4/ FW Residence = Number of days that elapsed until 50% of the survivors of a particular group migrated past the weir. For example, 50% of the 19,436 migrants marked LP were recaptured at the weir within 3 days after liberation.
5/ Single fin recoveries in the fisheries have little or no significance.
6/ Little White, Spring Creek, and Big Creek hatcheries.
7/ Numbers in paretheses indicate age at recovery.

liberations of hatchery fish into Gnat Creek. The 1955-brood experiments used two nearly-equal groups of fish from the Bonneville Hatchery. One group was marked LP, reared until June 20, 1956, and released when about 2-1/4 inches in length at the Highway 30 bridge. The second group, marked RP, was reared 8 months longer at the hatchery and was liberated from the same location when 3.6 inches in length. The same type of experiment was repeated using 1956 brood; the yearling group (D-LM) was somewhat larger than the yearling group (RP) of the 1955 brood. A consistency in all four groups is that one-half of all fish surviving to reach the weir on the outward migration were counted within 2 to 5 days of the time they were liberated. The reason for the consistency of the rapid movement downstream immediately after each liberation is suggested by the results of Miller's (1957a and b) studies with cutthroat trout in Gorge Creek, Alberta, Canada. He demonstrated that native resident fish had established home territories where they would spend their entire life. After liberating hatchery-reared fish into the stream and measuring the blood lactate levels of both groups, he found the hatchery groups had significantly higher amounts of lactic acid and concluded that in competing for space and food, the introduced group encountered higher mortalities. Higher lactic acid amounts were also found in the hatchery groups liberated into areas devoid of resident trout. Total stream survival of all chinook between the time of liberation and their migration to the Columbia River varied from 50 to 88% with the lowest fresh-water survival from the 1956-brood yearling group. Subsequent actual returns (98) of adult fish, however, showed the best marine survival from this group. However only 6 fish from this experiment were recovered in all of the various fisheries. Table 6 contains length measurements of 92 of the 98 adult chinook salmon that returned to the Gnat Creek Weir at 2, 3, and 4 years of age. No 5-year-old chinook were recovered in the fall of 1961. The recoveries from the other chinook marking

Table 6. Length-Frequency Distributions of 1956-Brood Adult Fall Chinook Marked D-LM that Returned to Gnat Creek in 1958-60.

Fork Length (in Inches)	1958	1959	1960	Total
11	7			7
12	7			7
13	12			12
14	6			6
15				0
16		1		1
17		1		1
18		0		0
19		2		2
20		4		4
21		3		3
22		3	1	4
23		8	0	8
24		8	0	8
25		4	0	4
26		0	0	0
27		0	1	1
28		0	0	0
29		1	0	1
30		1	3	4
31			0	0
32			3	3
33			6	6
34			3	3
35			3	3
36			3	3
37			1	1
Total	32	36	24	92

experiments appear to be too few in number to warrant any further analysis.

Silver Salmon

Adult Silver Salmon

Table 7 summarizes the timing of adult and jack silver salmon by sex to the Gnat Creek Weir for each year from the start of the project in October 1955 to its end in June 1962. From the 7-year totals of the counts, it is apparent that the fish have entered Gnat Creek as early as the third week in September and as late as the second week in February. Peak jack counts were both earlier and later than peak adult counts, although none of the peaks were sharp and well defined. Most of the adult fish were not ripe upon arrival at the weir prior to November 20 but became progressively riper after that date. From information at Spring Creek, a 1-10 c.f.s. rivulet of the Wilson River of Tillamook Bay, females took about 12 days and males 10 days to spawn and die after reaching their spawning sites (Willis, 1954). The average run at Gnat Creek was 150 nature silvers composed of 32 males (over 20 inches in length), 84 jacks (precocious males less than 20 inches), and 33 females. In per cent this is 22, 56, and 22, respectively. From the cumulative totals an average of 57% of all adults and jacks arrived at the weir by November 20 and 95% arrived prior to January 10. The cumulative totals (in per cent) of females is just slightly lower for the same time periods.

All adult fish were measured (with minor exceptions) and length-frequency histograms of fish for each run are graphed in previous processed progress reports (Kruse, 1959[1]; Haas and Kruse, 1961; and Hreha and Willis, 1962).

General consistency of escapement abundance for Oregon tributaries of the lower Columbia River (6.1 miles), Oregon coastal streams (Oakley, 1961), and Gnat Creek counts are shown in Figure 15. Divergence in 1961 is readily apparent when both the Gnat Creek counts and lower Columbia River index counts

1/ Kruse, Thomas E., 1959. Summary of Gnat Creek Weir Operations, 1958-59 (Typewritten report).

Table 7. Time of Migration for Mature Silver Salmon at Gnat Creek by 5-Day Periods, 1955-62.

5-Day Period Ending Month	Day 1/	1955-56 M 2/	J 2/	F	Total	1956-57 M	J	F	Total	1957-58 M	J	F	Total
Sept.	15	0	0	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0	1	0	1
	25	0	0	0	0	0	0	0	0	0	0	0	0
	30	0	0	0	0	0	0	0	0	0	1	0	1
Oct.	5	0	0	0	0	0	2	0	2	0	4	0	4
	10	0	4	0	4	0	0	0	0	0	0	1	1
	15	0	3	0	3	0	5	0	5	1	12	1	14
	20	0	19	0	19	1	24	0	25	0	0	0	0
	25	6	9	0	15	0	8	0	8	6	25	9	40
	30	15	6	3	24	2	9	1	12	5	12	9	26
Nov.	5	2	1	3	6	3	17	2	22	0	0	0	0
	10	12	2	7	21	1	11	4	16	0	1	1	2
	15	2	0	0	2	0	5	1	6	22	22	34	78
	20	0	1	0	1	5	4	2	11	5	2	3	10
	25	1	6	1	8	1	0	0	1	0	0	0	0
	30	10	11	2	23	0	1	0	1	0	1	0	1
Dec.	5	1	4	2	7	2	4	1	7	6	3	3	12
	10	4	2	2	8	0	8	0	8	1	0	1	2
	15	2	4	1	7	10	29	8	47	0	1	1	2
	20	0	0	0	0	10	12	5	27	3	1	2	6
	25	0	0	0	0	1	4	0	5	0	0	0	0
	30	1	4	1	6	0	0	0	0	0	0	0	0
Jan.	5	2	1	1	4	0	0	0	0	0	0	0	0
	10	1	0	1	2	0	0	1	1	0	0	0	0
	15	4	2	1	7	3	3	2	8	4	1	2	7
	20	1	2	0	3	0	0	0	0	0	2	0	2
	25	2	0	0	2	0	0	0	0	0	0	0	0
	30	0	0	0	0	0	0	0	0	0	0	0	0
Feb.	5	0	0	0	0	6	1	1	8	0	0	0	0
	10	1	0	1	2	1	2	1	4	0	0	0	0
	15	0	0	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0	0	0	0
Total		67	81	26	174	46	149	29	224	53	89	67	209

1/ Six days are included in last period of a 31-day month.
2/ M = adult males 20" and over. J = jacks less than 20" in length.

Table 7. Time of Migration for Mature Silver Salmon at Gnat Creek by 5-Day Periods, 1955-62. (Cont'd.)

5-Day Period Ending 1/		1958-59				1959-60				1960-61			
Month	Day	M	J	F	Total	M	J	F	Total	M	J	F	Total
Sept.	15	0	0	0	0	0	0	0	0	0	0	0	0
	20	0	1	0	1	0	0	0	0	0	0	0	0
	25	0	0	0	0	1	2	2	5	0	1	0	1
	30	0	0	0	0	0	0	0	0	0	0	0	0
Oct.	5	0	0	0	0	0	0	0	0	0	1	0	1
	10	3	17	4	24	0	0	0	0	0	2	0	2
	15	0	4	1	5	0	7	0	7	0	0	0	0
	20	9	5	6	20	0	3	1	4	0	2	0	2
	25	2	5	2	9	0	5	2	7	4	28	1	33
	30	2	5	1	8	1	6	2	9	1	22	2	25
Nov.	5	5	6	5	16	0	0	0	0	0	0	0	0
	10	5	12	13	30	0	1	0	1	0	0	0	0
	15	2	9	4	15	0	0	0	0	0	0	1	1
	20	0	5	1	6	3	8	5	16	3	1	3	7
	25	1	7	1	9	1	4	6	11	0	6	1	7
	30	0	3	0	3	0	1	1	2	0	1	0	1
Dec.	5	0	5	2	7	1	0	1	2	0	2	0	2
	10	0	3	0	3	0	0	0	0	0	0	0	0
	15	0	3	0	3	4	4	15	23	0	1	0	1
	20	0	6	0	6	1	1	3	5	1	1	0	2
	25	0	3	0	3	0	0	0	0	0	0	0	0
	30	1	1	0	2	0	2	1	3	0	0	0	0
Jan.	5	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	1	0	1
	15	0	0	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	1	1	0	0	0	0
	25	0	0	0	0	0	0	2	2	0	0	0	0
	30	0	0	0	0	0	0	3	3	0	1	0	1
Feb.	5	0	0	0	0	1	0	0	1	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0
	15	0	0	0	0	1	0	0	1	0	0	0	0
	20	0	0	0	0	0	0	0	0	0	0	0	0
Total		30	100	40	170	14	44	45	103	9	70	8	87

Table 7. Time of Migration for Mature Silver Salmon at Gnat Creek by 5-Day Periods, 1955-62. (Cont'd.)

5-Day Period Ending Month	Day	1961-62 M	J	F	Total	7-Year Totals M	J	F	Total	Cum. Total	Cum. Total (%)	Cum. Females No.	Cum. Females (%)
Sept.	15	0	0	0	0	0	0	0	0	0	0.0	-	0.0
	20	0	0	0	0	0	2	0	2	2	0.2	-	0.0
	25	0	0	0	0	1	3	2	6	8	0.8	2	0.9
	30	0	0	0	0	0	1	0	1	9	0.9	0	0.9
Oct.	5	0	0	0	0	0	7	0	7	16	1.5	0	0.9
	10	0	1	0	1	3	24	5	32	48	4.6	7	3.0
	15	0	0	0	0	1	31	2	34	82	7.8	9	3.9
	20	0	0	0	0	10	53	7	70	152	14.5	16	6.9
	25	0	1	1	2	18	81	15	114	266	25.4	31	13.4
	30	0	1	0	1	26	61	18	105	371	35.5	49	21.2
Nov.	5	0	0	1	1	10	24	11	45	416	39.8	60	25.9
	10	0	0	0	0	18	27	25	70	486	46.5	85	36.8
	15	0	2	2	4	26	38	42	106	592	56.6	127	55.0
	20	0	0	0	0	16	21	14	51	643	61.5	141	61.0
	25	1	3	5	9	5	26	14	45	688	65.8	155	67.1
	30	3	15	1	19	13	33	4	50	738	70.6	159	68.8
Dec.	5	2	18	3	23	12	36	12	60	798	76.3	171	74.0
	10	0	0	0	0	5	13	3	21	819	78.3	174	75.3
	15	0	0	0	0	16	42	25	83	902	86.3	199	86.1
	20	2	8	3	13	17	29	13	59	961	92.0	212	91.8
	25	0	3	0	3	1	10	0	11	972	93.0	212	91.8
	30	0	2	0	2	2	9	2	13	985	94.3	214	92.6
Jan.	5	0	1	0	1	2	2	1	5	990	94.6	215	93.1
	10	0	0	0	0	1	1	2	4	994	95.0	217	93.9
	15	0	0	0	0	11	6	5	22	1,016	97.1	222	96.1
	20	0	0	0	0	1	4	1	6	1,022	97.7	223	96.5
	25	0	0	0	0	2	0	2	4	1,026	98.1	225	97.4
	30	0	0	0	0	0	1	3	4	1,030	98.5	228	98.7
Feb.	5	0	0	0	0	7	1	1	9	1,039	99.3	229	99.1
	10	0	0	0	0	2	2	2	6	1,045	99.9	231	100.0
	15	0	0	0	0	1	0	0	1	1,046	100.0		
	20	0	0	0	0	0	0	0	0				
Total		8	55	16	79	227	588	231	1,046				
7-Year Average						32	84	33	149				
7-Year Average in Per Cent						22	56	22					

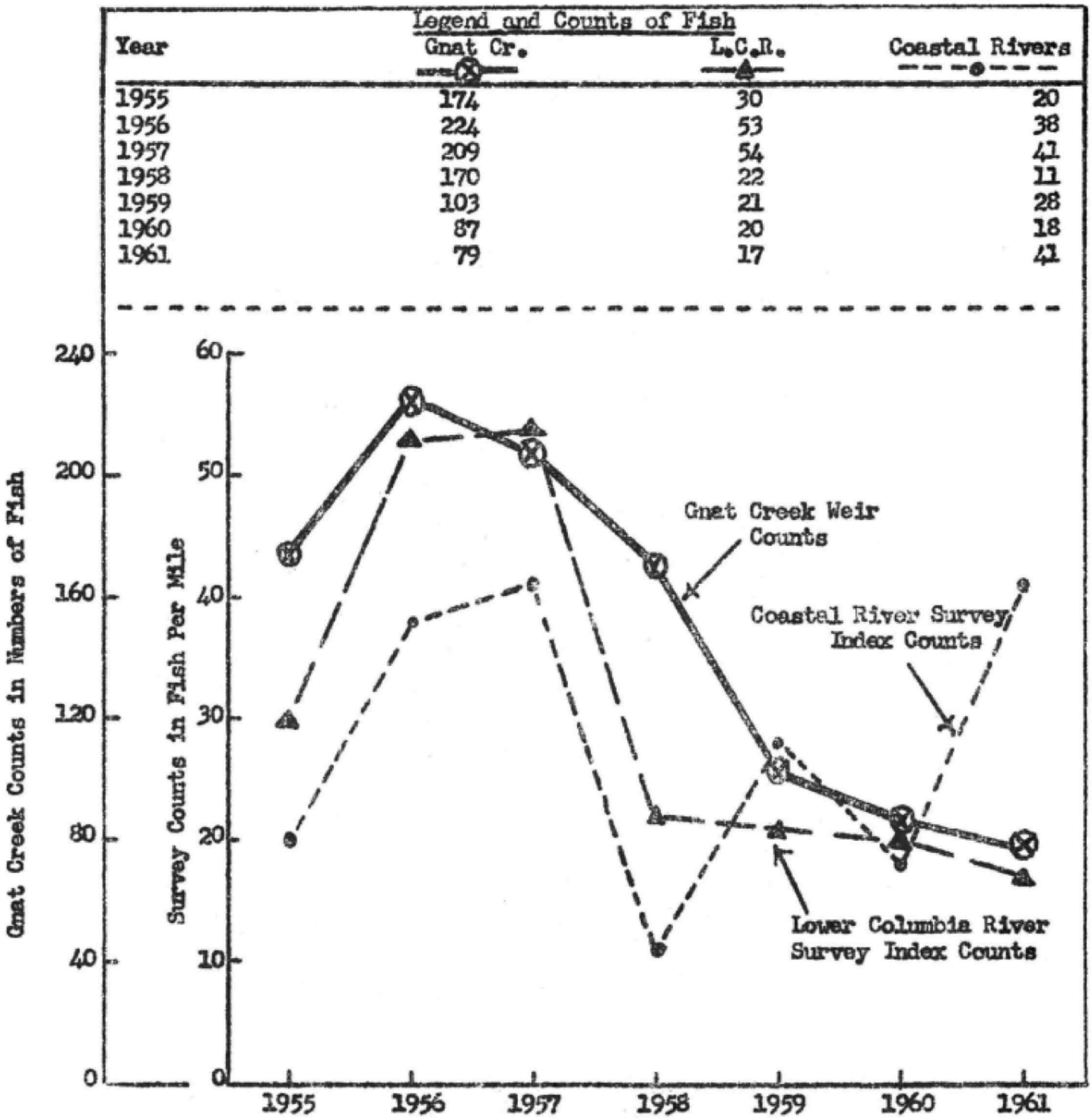

Figure 15. A Comparison of Silver Salmon (Adult and Jack) Counts at Gnat Creek with Oregon Lower Columbia River and Coastal River Index Counts, 1955-61.

were down while the coastal river index was up substantially. A good correlation exists ($r = 0.87$ with 5 degrees of freedom) between the Gnat Creek counts and the lower Columbia River spawning ground counts (jacks included). Correlation coefficients were also computed for adults only from 1957 through 1961 (lower Columbia River survey counts for 1955-56 were not used because jacks were not always listed separately). When the abundance of adults is compared at Gnat Creek with the lower Columbia standard survey units, the correlation coefficient obtained is quite high ($r = 0.90$) and significant at the 5% level. The correlation coefficient (0.78) between the Gnat Creek and the coastal river counts is not significant at the 5% level ($r_{.05} = .878$ for 3 degrees of freedom).

The relationship between the numbers of jacks in one year and the numbers of adults the following year for Gnat Creek is shown in Figure 16. A very good correlation ($r = 0.922$) resulted which is significant at the 5% level with 4 degrees of freedom.

The percentage sex composition of jacks, adult males, and females in the silver salmon runs each year at Gnat Creek are compared in Table 8 with similar data from Minter Creek (Salo and Bayliff, 1958), Waddell Creek (Shapavalov and Taft, 1954), and Spring Creek (Willis, unpub. manuscript). The average percentage of females was similar at Gnat (22%) and Spring (25%) creeks but only half of that for Minter (45%) and Waddell (44%) creeks. The proportion of adult males in the runs at Spring, Minter, and Waddell creeks was generally similar but Gnat Creek had a much lower percentage of adult males and a consistently higher percentage of jacks (average of 56% and range from 43 to 80%). Since the years involved at each stream are not the same, and each run was subjected to different kinds of fisheries, no reason for these gross

Year of Run	No. of Jacks	No. of Adults
1955-56	81	75
1956-57	149	120
1957-58	89	70
1958-59	100	59
1959-60	44	17
1960-61	70	24
Total	533	365
Average	88.8	60.8

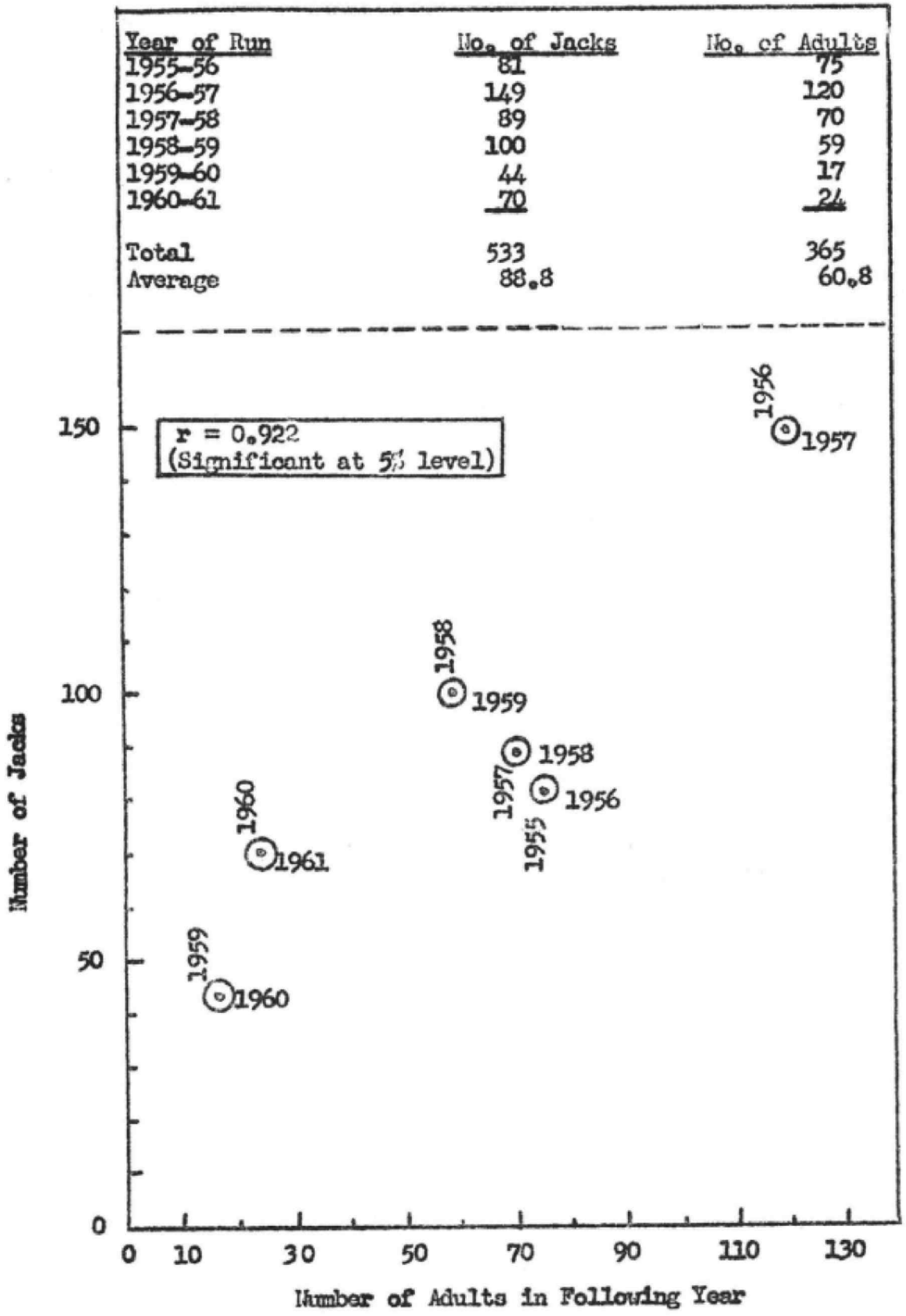

Figure 16. Relationship of Numbers of Silver Salmon Jacks in One Year to Adults in the Following Year at Gnat Creek, October 1956 - January 1961.

Table 8. Total Silver Salmon Counts and Sex Composition of Returning Runs to Gnat, Spring, Minter, and Waddell Creeks.

Location	Year	Adult Males		Jacks		Females		Total
		No.	Per Cent	No.	Per Cent	No.	Per Cent	No.
Gnat Cr.	1955	67	38	81	47	26	15	174
	1956	46	20	149	67	29	13	224
	1957	53	25	89	43	67	32	209
	1958	30	17	100	59	40	24	170
	1959	14	13	44	43	45	44	103
	1960	9	11	70	80	8	9	87
	1961	8	10	55	70	16	20	79
	Total	227	22	588	56	231	22	1,046
	Average	32		84		33		149
Spring Cr.	1950	39	40	38	39	21	21	98
	1951	83	41	63	31	57	28	203
	1952	44	49	24	27	22	24	90
	1953	40	60	12	18	15	22	67
	1954	15	58	5	19	6	23	26
	1955	38	51	20	27	17	23	75
	1956	26	39	19	29	21	32	66
	Total	285	46	181	29	159	25	625
	Average	41		26		23		90
Minter Cr.	1938	795	32	679	28	996	40	2,470
	1939	673	33	433	12	915	45	2,021
	1940	1,314	35	860	23	1,574	42	3,748
	1941	921	36	502	19	1,160	45	2,583
	1942	759	34	662	29	821	37	2,242
	1943	978	42	349	15	1,015	43	2,342
	1944	1,787	46	166	4	1,959	50	3,912
	1945	1,922	51	134	4	1,681	45	3,737
	1946	719	37	179	9	1,034	54	1,932
	1947	872	58	39	2	604	40	1,515
	1948	357	52	44	6	291	42	692
	1949	1,181	47	178	7	1,140	46	2,499
	1950	964	52	68	4	807	44	1,839
	1951	637	42	290	9	598	39	1,525
	1952	1,282	45	55	2	1,536	53	2,873
	1953	943	54	75	4	737	42	1,755
	1954	593	55	51	4	441	41	1,085
	Total	16,697	43	4,764	12	17,309	45	38,770
	Average	982		280		1,018		2,280
Waddell Cr.	1933	151	34	119	26	177	40	447
	1934	265	45	35	6	283	49	583
	1935	33	26	56	44	39	30	128
	1936	104	49	4	1	106	50	214

Table 8. (Cont'd).

Location	Year	Adult Males		Jacks		Females		Total
		No.	Per Cent	No.	Per Cent	No.	Per Cent	No.
Waddell Cr. (Cont'd)	1937	42	50	20	24	22	26	84
	1938	29	33	17	20	40	47	86
	1939	88	33	52	20	126	47	266
	1940	95	36	65	25	103	39	263
	1941	61	41	11	7	75	51	147
	Total	868	39	379	17	971	44	2,218
	Average	96		42		108		246

differences is offered. An attempt was made by scale analysis to determine if the larger-sized downstream migrants contributed to the production of jacks. Circuli counts and measurements from the focus through first annulus were made for nearly all silver salmon returning to Gnat Creek from the 1958 brood and were separated into two groups---jacks and adults. These 1960-61 data are presented in Figure 17; the overlapping dispersion of the jacks (dots) and adults (crosses) suggests that jacks resulting from natural rearing were produced from a mixture of sizes at the time of downstream migration.

A non-significant correlation coefficient of 0.20 resulted between the average fork lengths of the smolts for the 1954-through 1959-brood years and the resulting numbers of jacks returning to the weir in the fall and winter of the same year. Likewise, no significant correlation existed between the average sizes of the smolts and the percentage of the run returning as jacks. This lack of correlation may be due to the lack of any large variation in the annual average lengths of the smolts.

A summary of all silver salmon marking experiments at Gnat Creek is contained in Tables 9 and 10. The purposes of each experiment are included in Table 9 and all experiments utilized wild fish except for one small group of 631 hatchery yearlings. The actual recoveries are shown in Table 10; due to the small numbers involved it is doubtful if any extrapolations involving total calculated recoveries in the commercial fisheries are justified. The total actual recovery of 1955-brood wild yearlings marked LV was 77 while those of the hatchery yearlings marked RV was 14. Since about five times as many wild migrants were originally marked the survival rates of the two groups were similar.

Survival rates of various yearling groups (where over 1,000 were released) returning to the weir as jacks and adults combined are: 1954 brood - 3.0%, 1955 brood - 2.3%, 1956 brood - 1.3%, and 1958 brood - 3.2%. The over-all average survival rate was 2.5%.

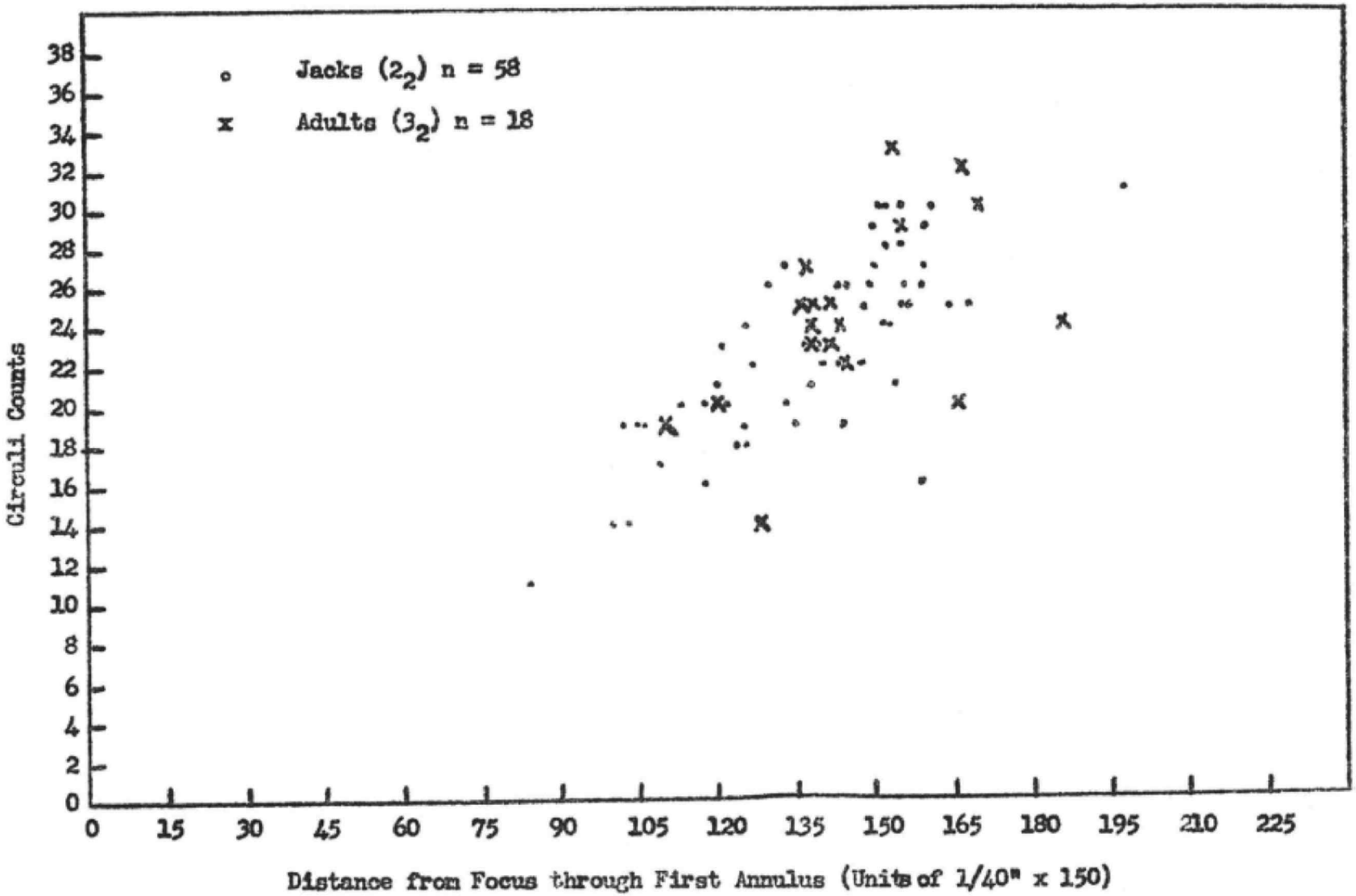

Figure 17. A Scatter Diagram Showing the Relationship Between Circuli Counts and Distances from Focus through First Annulus, 1958 Brood.

Table 9. Summary of Marking Experiments for Silver Salmon at Gnat Creek.

Expt. No.	Brood Year	Marking Information					Release Information		
		Mark	Purpose of Experiment	H or W 1/	Origin of Eggs	Age (0 or 1+)	Date	Number	Ave. Length
1.	1954	RP	Survival of Natural Yearlings	W	Gnat Creek	1+	1/1/56-6/17/56	3,112	92 mm 119 mm
2.	1955	Ad	Compare Fingerling and Yearling	W	Gnat Creek	0	8/3/56 11/15/56	116	76 mm 94 mm
2.	1955	LV	Returns	W	Gnat Creek	1+	11/16/56-6/15/57	2,995	92 mm 112 mm
3.	1955	RV	Compare Natural & Hatch. Yearlings	H	Big Creek	1+	12/56-4/57	631	141 mm
4.	1956	LP-LM	Survival of Natural Yearlings	W	Gnat Creek	1+	11/28/57-6/13/58	1,806	2.0-5.8 in
5.	1957	RP-LM	Compare Survival of Fingerlings and	W	Gnat Creek	0 1+	10/9/58-1/29/59	113	3.4 in
5.	1957	LP-RM	Yearlings	W	Gnat Creek	1+	2/5/59-6/15/59	934	3.2-5.9 in
6.	1958	An	Compare Returns of 3 Segments of 1958-Brood	W	Gnat Creek	0	2/6-6/29/59	264	1.3-3.5 in
6.	1958	LP	Natural Migrants	W	Gnat Creek	0 1+	9/27/59-1/15/60	156	4.0 in
6.	1958	RP		W	Gnat Creek	1+	1/18-6/10/60	1,013	4.6 in
7.	1959	LP	Compare Returns of 3 Segments	W	Gnat Creek	0	4/12-6/27/60	118	3.0 in
7.	1959	RP	of 1958-Brood	W	Gnat Creek	0 1+	8/29/60-1/15/61	311	3.5 in
7.	1959	RV	Natural Migrants	W	Gnat Creek	1+	1/16-6/16/61	2,974	4.6 in

1/ H = Hatchery; W = Wild.

Table 10. Summary of Recovery Data for Silver Salmon Marking Experiments at Gnat Creek.

Expt. No.			Jacks										Adults										Brood Year Total
			Ocean 1/				River				Other	Gnat Creek	Total	Ocean				River				Other	Gnat Creek	Total	
			Cm.		Sp.		Cm.		Sp.					Cm.		Sp.		Cm.		Sp.					
			R	S	R	S	R	S	R	S				R	S	R	S	R	S	R	S				
1.	1954	RP	0	0	0	0	0	0	0	0	0	57	57	0	0	0	6	14	0	0	0	5 2/	37	62	119
2.	1955	Ad	0	0	0	0	0	0	0	0	1 2/	1	2	0	0	0	0	0	0	0	0	2 2/	0	2	4
2.	1955	LV	0	0	0	0	0	0	0	2	5 2/	43	50	0	0	0	0	0	0	0	0	0	27	27	77
3.	1955	RV	0	0	0	0	0	0	0	0	2 2/	6	8	0	0	0	0	0	0	0	0	3 2/	3	6	14
4.	1956	LP-LM	0	0	0	0	0	0	0	0	0	10	10	0	1	0	0	0	0	0	0	0	13	14	24
5.	1957	RP-LM	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1
5.	1957	LP-RM	0	0	0	0	0	0	0	0	0	8	8	1	0	0	0	0	1	0	0	0	3	5	13
6.	1958	An	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.	1958	LP	0	2	0	0	0	0	0	0	0	1	3	0	0	0	1	2	0	0	0	0	0	3	6
6.	1958	RP	0	0	0	0	1	0	0	0	0	26	27	0	1	0	0	2	0	0	0	0	6	9	36
7.	1959	LP										1													
7.	1959	RP										7													
7.	1959	RV										25											21 3/		

1/ Cm.= Commercial, Sp.= Sport, R = Random, S = Selected.
2/ BC = Big Creek Hatchery.
3/ Partial count of adults at time of writing in 1962.

Nearly all jacks and adults that returned to Gnat Creek were measured. Appendix Tables I - VI show length-frequency tabulations by sex and mark for each inch interval from 1956-61. Data from 5 years, 1957-61, were then combined into two separate groups, viz., marked and unmarked. The mean length of the marked fish was 20.34 inches (number = 227; variance = 31.719; and standard deviation = 5.632). The mean length of the unmarked group was 21.50 inches ($n = 412$; $s^2 = 31.472$; $s = 5.610$). In making a comparison of the two means with unpaired observations and nearly equal variances, the null hypothesis was made that the means of the two groups were equal and a t-test was used (Steel and Torie, p. 73). Since the computed t-value was 2.505 and the table value for $t_{.05}$ (637 d.f.) = 1.960, the hypothesis was rejected. These results suggest that something affected the growth of marked fish to make their average size smaller than that of the unmarked group.

An effort to refine the estimates of potential egg deposition was undertaken in 1961. Since it was inadvisable to kill any Gnat Creek fish in order to count the eggs, a sample of 2 females from each inch interval from 22 to 31 inches was taken from the lower Columbia River commercial gill-net fishery in late September. Details of the collection of fish, the hand-counting of all eggs by ovary, and the analyses of these fecundity data compared with data from other areas, are presented in a separate paper 1/. The relationship of fecundity to length was found to be linear for the Columbia River sample; the summary of the regression analysis is presented in Figure 18. The regression equation is $\hat{Y} = 239.433\ (x) - 3,345.033$. The increase in egg content is about 240 eggs for each inch increase in length of fish. The potential egg deposition for each year of operation at Gnat Creek was based on fish length and the above linear equation and the subsequent computed numbers of eggs spawned above the weir are included in Table 11.

1/ Fecundity of silver salmon (Oncorhynchus kisutch) in northwestern North America. R. A. Willis (in preparation)

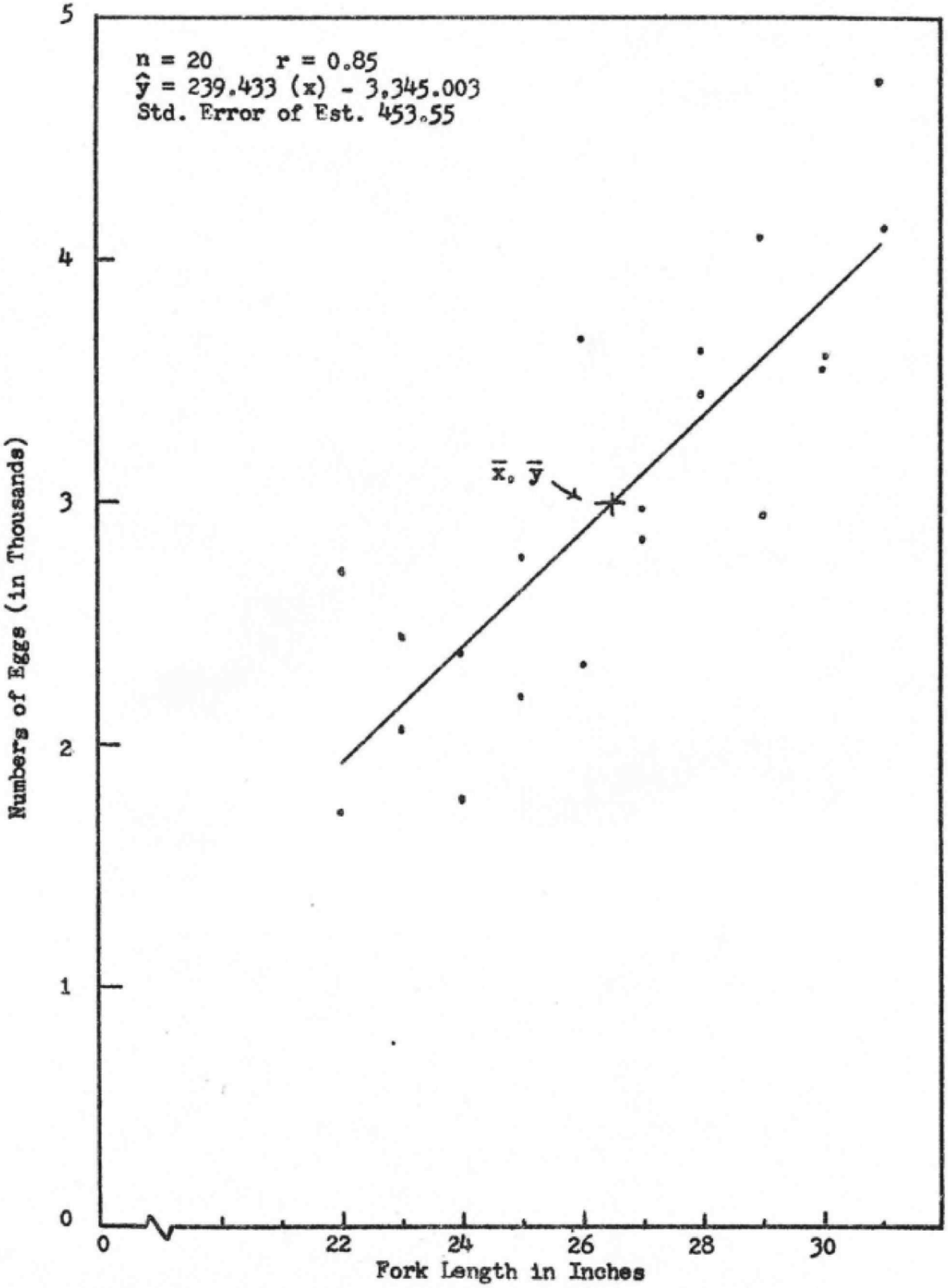

Figure 18. The Relationship of Fecundity to Length for Columbia River Silver Salmon Sample, 1961.

Table 11. Computations for Deriving the Potential Egg Deposition for Silver Salmon at Gnat Creek from 1955-61 Runs.

Computed Ova Counts (from Length-Fecundity Equation)	Fork Length in Inches	1955		1956		1957		1958		1959		1960		1961	
		No. Females	Calc. No. Eggs	No. Females	Calc. No. Eggs	No. Females	Calc. No. Eggs	No. Females	Calc. No. Eggs	No. Females	Calc. No. Eggs	No. Females	Calc. No. Eggs	No. Females	Calc. No. Eggs
1,683	21	0	--	0	--	0	--	1	1,683	2	3,366	0	--	0	--
1,922	22	0	--	2	3,844	0	--	2	3,844	1	1,922	0	--	0	--
2,162	23	0	--	0	--	0	--	1	2,162	1	2,162	0	--	0	--
2,401	24	0	--	1	2,401	2	4,802	2	4,802	3	7,203	1	2,401	0	--
2,641	25	1	2,641	2	5,282	3	7,923	4	10,564	4	10,564	0	--	1	2,641
2,880	26	3	8,640	7	20,160	16	46,080	6	17,280	11	31,680	0	--	0	--
3,120	27	3	9,360	0	--	9	28,080	9	28,080	4	12,480	3	9,360	4	12,480
3,359	28	7	23,513	10	33,590	16	53,744	6	20,154	9	30,231	0	--	6	20,154
3,599	29	5	17,995	3	10,797	11	39,589	5	17,995	4	14,396	0	--	3	10,797
3,838	30	6	23,028	2	7,676	8	30,704	4	15,352	4	15,352	2	7,676	1	3,838
4,077	31	1	4,077	1	4,077	2	8,154	0	--	2	8,154	2	8,154	1	4,077
4,317	32	0	--	1	4,317	0	--	0	--	0	--	0	--	0	--
Total No. Females		26		29		67		40		45		8		16	
Total Calc. No. Eggs			89,254		92,144		219,076		121,916		137,510		27,591		53,987

Juvenile Silver Salmon

Silver salmon juveniles are separated into two groups possessing different habits, characteristics, and mortality rates. One group consists of fish-of-the-year and are often referred to as 0+, fry, or fingerlings. They are less than one year of age and do not appear to contribute to the adult population if they migrate to sea at this age. Hunter at Port John, British Columbia, counted 20,000 fry per year (Hoar, 1951) and Wickett (1951) counted varying numbers between 700 and 2,800 into the intertidal zones and concluded that the majority perished. Marr (1944) examined the scales from 885 Columbia River silver salmon from the 1914 run and found no fish of the 0+ group. The time of migration for the second group, called yearlings, 1+, or smolts, occurs mostly at 12-14 months of age. Counts of these fish for each brood year while the weir was in operation from November 16 of one year through the end of migration the following summer are summarized in Table 12. It is readily apparent that most smolts counted at the weir migrated in the spring and that of those counted only 4% of the 6-year average migrated in the latter half of November. Of the 2,217 (6-year average) counted, 71% migrated into brackish water during the month of May and 90% migrated in April and May combined. By referring to Table 2 and Figure 14 it can be seen that no water spilled over the dam during these two spring months in 3 (1956, 1958, and 1959) of the 6 years. The time of migration at Gnat Creek is generally similar to that at Minter Creek, Waddell Creek, and Taku River (Meehan and Siniff, 1962). When spawning grounds are located on small headwater tributaries which are also farther from salt water, the time of yearling migration appears to be earlier. At Spring Creek this peak occurred regularly in late March and early April and was closely associated with increased flows (Willis, 1955 typed manuscript)1/. At Deer Creek, Alsea River, OGC personnel found a sharp peak of smolts in March (Chapman, Corliss, Phillips, and Demory, 1961). A graph

1/ Willis, R. A., 1955. Downstream migration studies of silver and chinook salmon in certain Oregon coastal areas. Oreg. Fish Comm. Typewritten manuscript. 28 p.

Table 12. Counts of Wild Juvenile Silver Salmon Migrants at Gnat Creek Weir by 5-Day Periods from November 16 to End of Migration Year, 1954-59 Brood Years.

5-Day Period Ending 1/ Mo.	Day	Brood Year 1954	1955	1956	1957	1958	1959	Total	6-Year Average
Nov.	20	0	170	29	3	10	101	313	52
	25	2	62	9	11	3	33	120	20
	30	5	64	5	2	6	33	115	19
Dec.	5	4	4	23	5	6	9	51	9
	10	3	5	17	4	2	12	43	7
	15	2/	27	8	0	3	4	42	7
	20	2/	6	10	3	4	1	24	4
	25	1	3	9	0	1	5	19	3
	30	3	3	5	1	0	3	15	3
Jan.	5	11	0	2	0	0	0	13	2
	10	4	0	2	0	2	0	8	1
	15	13	0	18	3	11	3	48	8
	20	5	0	13	0	13	0	31	5
	25	6	0	5	0	11	1	23	4
	30	0	0	2	8	6	1	17	3
Feb.	5	7	0	4	1	2	1	15	3
	10	0	7	5	0	1	3	16	3
	15	9	5	6	16	0	8	44	7
	20	0	2	11	0	0	5	18	3
	25	7	9	3	0	3	2	24	4
	30	26	17	2	0	24	0	69	12
Mar.	5	16	6	6	2	3	2	35	6
	10	2	22	0	1	5	2	32	5
	15	10	3	1	1	3	4	22	4
	20	19	5	3	1	3	2	33	5
	25	7	10	9	1	1	14	42	7
	30	8	46	8	2	9	11	84	14
Apr.	5	14	41	16	3	13	43	130	22
	10	18	31	13	2	6	129	199	33
	15	43	4	40	4	26	72	189	32
	20	28	62	54	47	30	91	312	52
	25	60	92	17	36	40	185	430	72
	30	168	221	12	216	72	69	758	126
May	5	245	295	20	37	75	355	1,027	171
	10	509	544	312	48	155	487	2,055	343
	15	351	320	235	188	181	396	1,671	279
	20	542	515	399	128	271	442	2,297	383
	25	516	216	341	108	3	256	1,440	240
	30	332	124	143	81	34	257	971	162
June	5	106	45	22	46	15	150	384	64
	10	33	9	5	2	8	29	86	14
	15	11	1	2	2	0	4	20	3
	20	2	0	0	0	0	1	3	1
	25	0	0	0	0	0	0	0	
	30	0	0	0	0	0	0	0	
July	5	0	0	0	0	0	0	0	
	10	0	0	1	0	0	0	1	
	15	0	0	0	0	0	0	0	
	20								(2,217)
		3,146	2,995	1,847	1,013	1,061	3,226	13,289	

1/ Six days are included in last period for 31-day months; three days (four-, leap year) for February.

Table 12. Counts of Wild Juvenile Silver Salmon Migrants at Gnat Creek Weir by 5-Day Periods from November 16 to End of Migration Year, 1954-59 Brood Years.

5-Day Period Ending 1/ Mo.	Day	Brood Year 1954	1955	1956	1957	1958	1959	Total	6-Year Average
Nov.	20	0	170	29	3	10	101	313	52
	25	2	62	9	11	3	33	120	20
	30	5	64	5	2	6	33	115	19
Dec.	5	4	4	23	5	6	9	51	9
	10	3	5	17	4	2	12	43	7
	15	2/	27	8	0	3	4	42	7
	20	2/	6	10	3	4	1	24	4
	25	1	3	9	0	1	5	19	3
	30	3	3	5	1	0	3	15	3
Jan.	5	11	0	2	0	0	0	13	2
	10	4	0	2	0	2	0	8	1
	15	13	0	18	3	11	3	48	8
	20	5	0	13	0	13	0	31	5
	25	6	0	5	0	11	1	23	4
	30	0	0	2	8	6	1	17	3
Feb.	5	7	0	4	1	2	1	15	3
	10	0	7	5	0	1	3	16	3
	15	9	5	6	16	0	8	44	7
	20	0	2	11	0	0	5	18	3
	25	7	9	3	0	3	2	24	4
	30	26	17	2	0	24	0	69	12
Mar.	5	16	6	6	2	3	2	35	6
	10	2	22	0	1	5	2	32	5
	15	10	3	1	1	3	4	22	4
	20	19	5	3	1	3	2	33	5
	25	7	10	9	1	1	14	42	7
	30	8	46	8	2	9	11	84	14
Apr.	5	14	41	16	3	13	43	130	22
	10	18	31	13	2	6	129	199	33
	15	43	4	40	4	26	72	189	32
	20	28	62	54	47	30	91	312	52
	25	60	92	17	36	40	185	430	72
	30	168	221	12	216	72	69	758	126
May	5	245	295	20	37	75	355	1,027	171
	10	509	544	312	48	155	487	2,055	343
	15	351	320	235	188	181	396	1,671	279
	20	542	515	399	128	271	442	2,297	383
	25	516	216	341	108	3	256	1,440	240
	30	332	124	143	81	34	257	971	162
June	5	106	45	22	46	15	150	384	64
	10	33	9	5	2	8	29	86	14
	15	11	1	2	2	0	4	20	3
	20	2	0	0	0	0	1	3	1
	25	0	0	0	0	0	0	0	
	30	0	0	0	0	0	0	0	
July	5	0	0	0	0	0	0	0	
	10	0	0	1	0	0	0	1	
	15	0	0	0	0	0	0	0	
	20								(2,217)
		3,146	2,995	1,847	1,013	1,061	3,226	13,289	

1/ Six days are included in last period for 31-day months; three days (four-, leap year) for February.

showing the numbers of migrants and average flows by 5-day intervals for the 1958-brood fish that migrated downstream at Gnat Creek in 1959 and 1960 is included as Figure 19. This figure and Figure 18 in Salo and Bayliff (1958) appear somewhat similar in that no close relationship exists between flows and juvenile silver migration. However, at Spring Creek an increase in smolt migrants accompanied an increase in flow during days with freshets in late March or April.

During May 9 and 10, 1962, 3- and 6-hour counts of downstream migrants were made at Gnat Creek. A total of 180 silver yearlings were captured in the following time periods: 30 (17%) from noon-6 p.m.; 96 (53%) from 6 p.m.-midnight; 38 (21%) from midnight to 6 a.m.; and 16 (9%) from 6 a.m. to noon.

A total of 7,878 smolts was measured during the Gnat Creek study. The characteristics of the length-frequency distributions in 5-mm groups are presented in Table 13 for each brood year. It was desired to compute confidence limits to qualify the average lengths since not all migrants were measured. The numbers measured exceeded 500 except for the 1956 brood and it was assumed that confidence intervals based on a normal distribution would be suitable. This assumption was tested in the following manner: (1) the cumulative frequency of the 6-year average was tabulated in per cent as shown in Table 13; (2) the mean and standard deviations were computed; (3) the cumulative frequency in per cent was determined for $\bar{X} \pm 1$, 1.96, and 3 standard deviations, which were then plotted (as ⊗ points) on normal probability paper in Figure 20. It was also desired to compare the sample distribution (Table 14) composed of 2,212 May migrants (as 0 in Figure 20) with both the 6-year average and a true normal distribution which is shown as the straight line. With the minor exception of each extreme, both length distributions are similar to a normal distribution. Confidence limits at the 95% level were then computed and added to the bottom of Table 13 and enclosed in parentheses in the following sentences. The average length of all 7,878 smolts measured

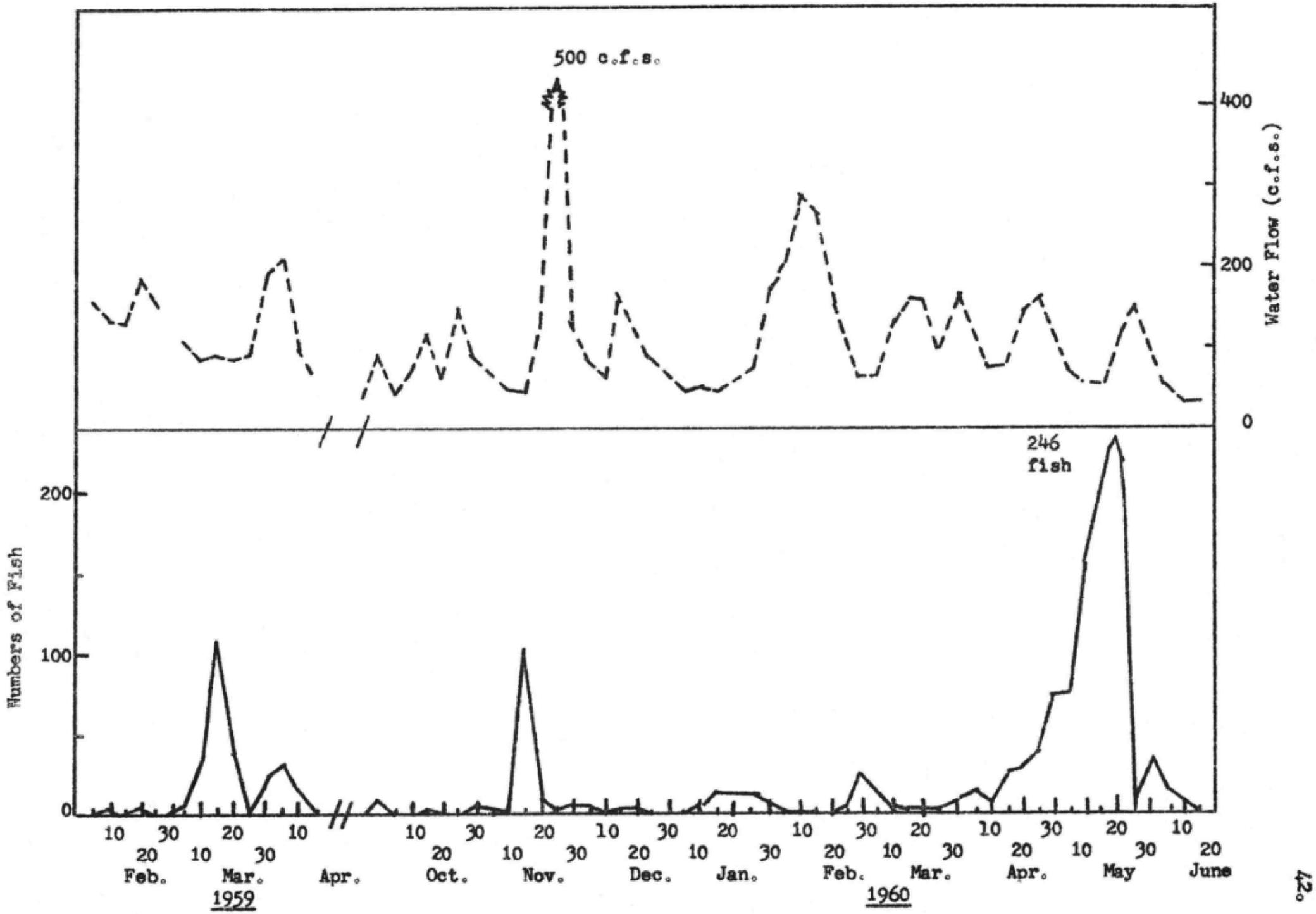

Figure 19. Time of Outmigration of Juvenile Silver Salmon of the 1958 Brood and Average Daily Discharge, by 5-Day Periods, Gnat Creek Weir, 1959-60.

Table 13. Characteristics of the Length-Frequency Distributions in 5-mm Groups of Wild Silver Salmon Smolts that Migrated out of Gnat Creek by Brood Year Between November 15, 1956 and June 30, 1961.

Fork Lengths Millimeters Interval	Mid Point	Inches Mid Point	Frequencies Brood Year 1954	1955	1956	1957	1958	1959	Total	6-Yr. Av.	C.F. 1/ for 6-Yr. Av.	C.F. in Per Cent
51-55	53	2.1	0	1	0	0	0	0	1	0.2	.2	-
56-60	58	2.3	1	1	9	0	0	0	11	1.8	2.0	0.002
61-65	63	2.5	4	0	8	0	0	0	12	2.0	4.0	0.003
66-70	68	2.7	8	0	15	0	1	2	26	4.3	8.3	0.006
71-75	73	2.9	21	5	36	2	0	5	69	11.5	19.8	1.505
76-80	78	3.1	13	6	27	1	3	17	67	11.5	31.3	2.379
81-85	83	3.3	37	21	31	6	2	33	130	21.7	53.0	4.028
86-90	88	3.5	27	40	25	4	8	28	132	22.0	75.0	5.700
91-95	93	3.7	25	37	19	10	16	42	149	24.9	99.9	7.592
96-100	98	3.9	50	70	33	20	25	79	277	46.3	146.2	11.111
101-105	103	4.1	77	97	30	44	55	233	536	89.5	235.7	17.913
106-110	108	4.3	116	123	44	102	114	460	959	160.2	395.9	30.088
111-115	113	4.5	329	100	41	173	172	695	1,510	252.2	648.1	49.255
116-120	118	4.7	417	130	26	151	171	661	1,556	259.9	908.0	69.007
121-125	123	4.8	186	104	38	138	128	453	1,047	174.8	1,082.8	82.292
126-130	128	5.0	59	76	28	125	69	268	625	104.4	1,187.2	90.226
131-135	133	5.2	14	37	22	87	82	101	343	57.3	1,244.5	94.581
136-140	138	5.4	2	10	8	55	70	45	190	31.7	1,276.2	96.990
141-145	143	5.6	2	5	3	23	68	23	124	20.7	1,296.9	98.564
146-150	148	5.8	2	4	1	7	40	13	67	11.2	1,308.1	99.415
151-155	153	6.0	0	1	0	1	17	8	27	4.5	1,312.6	99.757
156-160	158	6.2	0	0	0	0	6	6	12	2.0	1,314.6	99.909
161-165	163	6.4	1	0	0	0	3	2	6	0.8	1,315.4	99.970
166-170	168	6.6	0	0	0	0	0	1	1	0.2	1,315.6	99.985
171-175	173	6.8	0	0	0	0	0	1	1	0.2	1,315.8	100.000
Total (n)			1,391	868	444	949	1,050	3,176	7,878	1,315.8		
Average Length in mm.			112	111	101	120	121	115		114.9		
Variance in mm.			155.40	177.66	423.99	133.95	218.42	103.70		190.90		
Standard deviation in mm.			12.5	13.3	20.6	11.6	14.8	10.2		13.8		
95% Confidence limits of Av. Length (for Normal Dist.)			88-136	85-137	61-141	97-143	92-150	95-135		87.8-142.0		

1/ C.F. = Cumulative frequency.

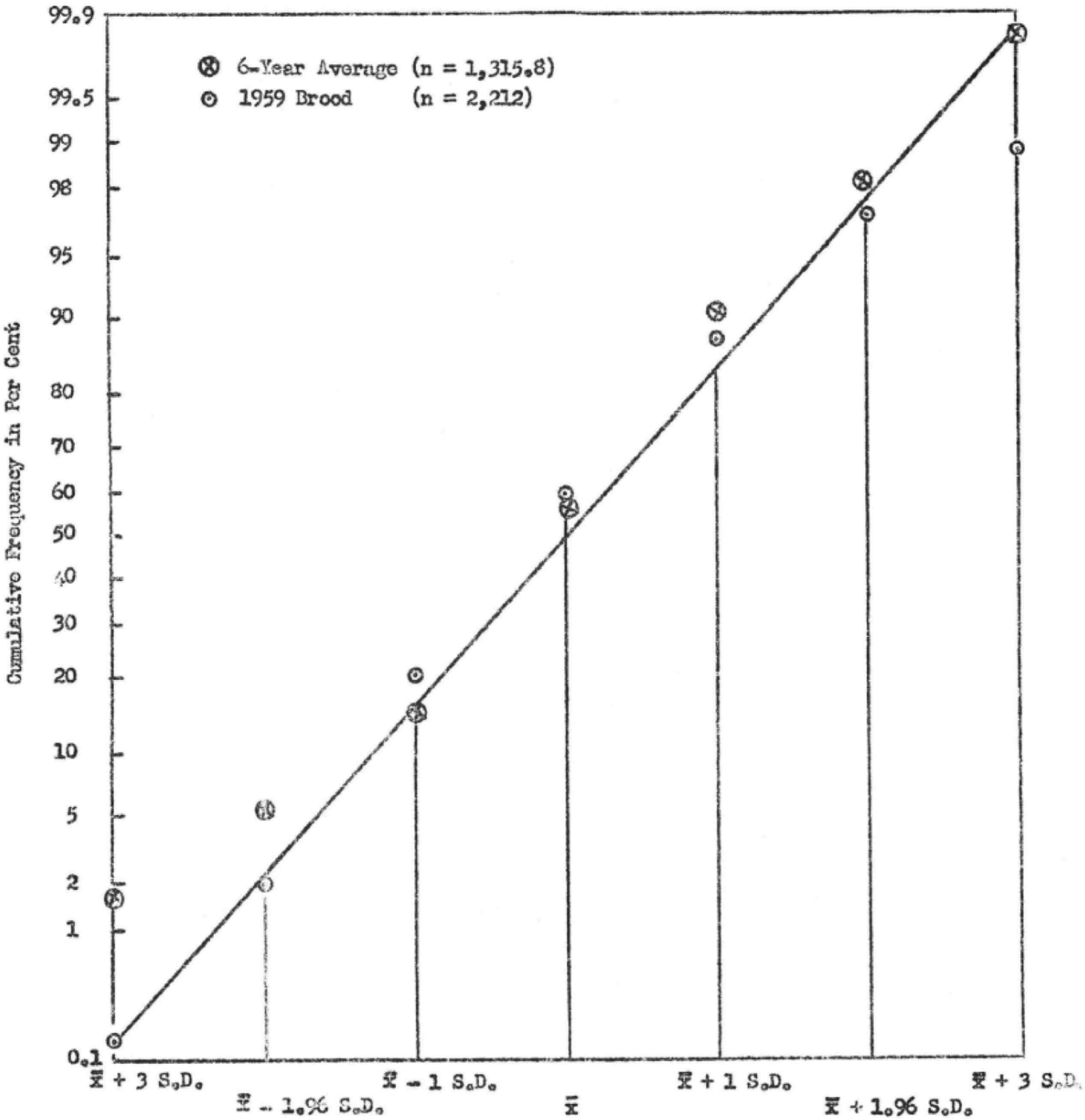

Figure 20. A Comparison of Points on Two Length-Frequency Distributions with a Normal Distribution (shown as a straight line).

Table 14. Length-Frequency Distribution of 2,212 1959-Brood Yearling Silver Salmon, Gnat Creek, May 1961.

Fork Length Mm.	Fork Length Inches	Frequency	Cumulative Frequency	Cumulative Frequency in Per Cent
76	3.0	0	0	.00
79	3.1	1	1	.05
81	3.2	1	2	.09
84	3.3	0	2	.09
86	3.4	0	2	.09
89	3.5	0	2	.09
91	3.6	1	3	.14
94	3.7	3	6	.27
96	3.8	16	22	.99
99	3.9	15	37	1.67
101	4.0	54	91	4.11
104	4.1	97	188	8.50
107	4.2	138	326	14.74
109	4.3	192	518	23.41
112	4.4	227	745	33.67
114	4.5	261	1,006	45.47
117	4.6	293	1,299	58.71
119	4.7	228	1,527	69.02
122	4.8	187	1,714	77.47
124	4.9	160	1,874	84.70
127	5.0	131	2,005	90.63
129	5.1	80	2,085	94.24
132	5.2	39	2,124	96.00
135	5.3	25	2,149	97.13
137	5.4	11	2,160	97.63
140	5.5	19	2,179	98.49
142	5.6	7	2,186	98.81
145	5.7	7	2,193	99.12
147	5.8	3	2,196	99.26
150	5.9	5	2,201	99.49
152	6.0	2	2,203	99.58
155	6.1	3	2,206	99.71
157	6.2	0	2,206	99.71
160	6.3	1	2,207	99.76
162	6.4	1	2,208	99.80
165	6.5	2	2,210	99.89
168	6.6	1	2,211	99.94
170	6.7	1	2,212	99.99
Total		2,212		
Mean	117 mm.	4.61		
	8.687 mm.			
Standard Deviation		0.342		
95% Conf. Limits	100-134 mm.			

was 114.9 (87.8 to 142.0) mm and the average length of the large sample of May migrants of the 1959 brood was 117 (100-134) mm. The average lengths for other brood years did not vary a great deal from the 6-year average with the smallest being 101 (61-141) mm and the largest 121 (92-150) mm. The average lengths of smolts at Spring Creek were slightly under 100 mm.

A general indication of fresh-water growth as reflected by the fish leaving the stream is illustrated in Figure 21 for 3,414 juveniles of the 1959 brood. When alevins absorb the yolk sac, they are about 1.5 inches long as shown in April. By mid-winter (December) they were 4.1 inches long and the bulk of the fish migrated in May at an average length of 4.6 inches.

In May 1962, 10 weight measurements were obtained for each millimeter in length ranging from 101-135 mm. The individual weights are shown in Table 15 with averages for each 5-mm group. Since only 8 females were released above the weir in 1960, the majority of these 1962 migrants was believed to be from a liberation of 30,000 Big Creek Hatchery fingerlings released into Gnat Creek in June 1961 and reared naturally for about 10 months. The weight data and the condition factors included in Table 16 were obtained for comparison with naturally reared fish of hatchery origin on other CFC projects. The typical Gnat Creek smolt was 115 mm long, weighed 15.4 grams (27 fish/lb.), and had a condition factor of 1.01. The average size of silver salmon yearlings of the same brood naturally reared from May 1961 to February 1962 (8-1/2 months) in Wahkeena Pond was 102 mm in fork length and 10.2 grams in weight or 44 fish/lb. (Haas and Willis, 1962). The latter group probably would have been 12 mm (1/2 inch) longer--based on information in Figure 21--had they been released in May.

Productivity

Comparisons of the annual adult silver salmon runs and resulting progeny are shown in Table 17. A summary of the productivity of silver salmon in

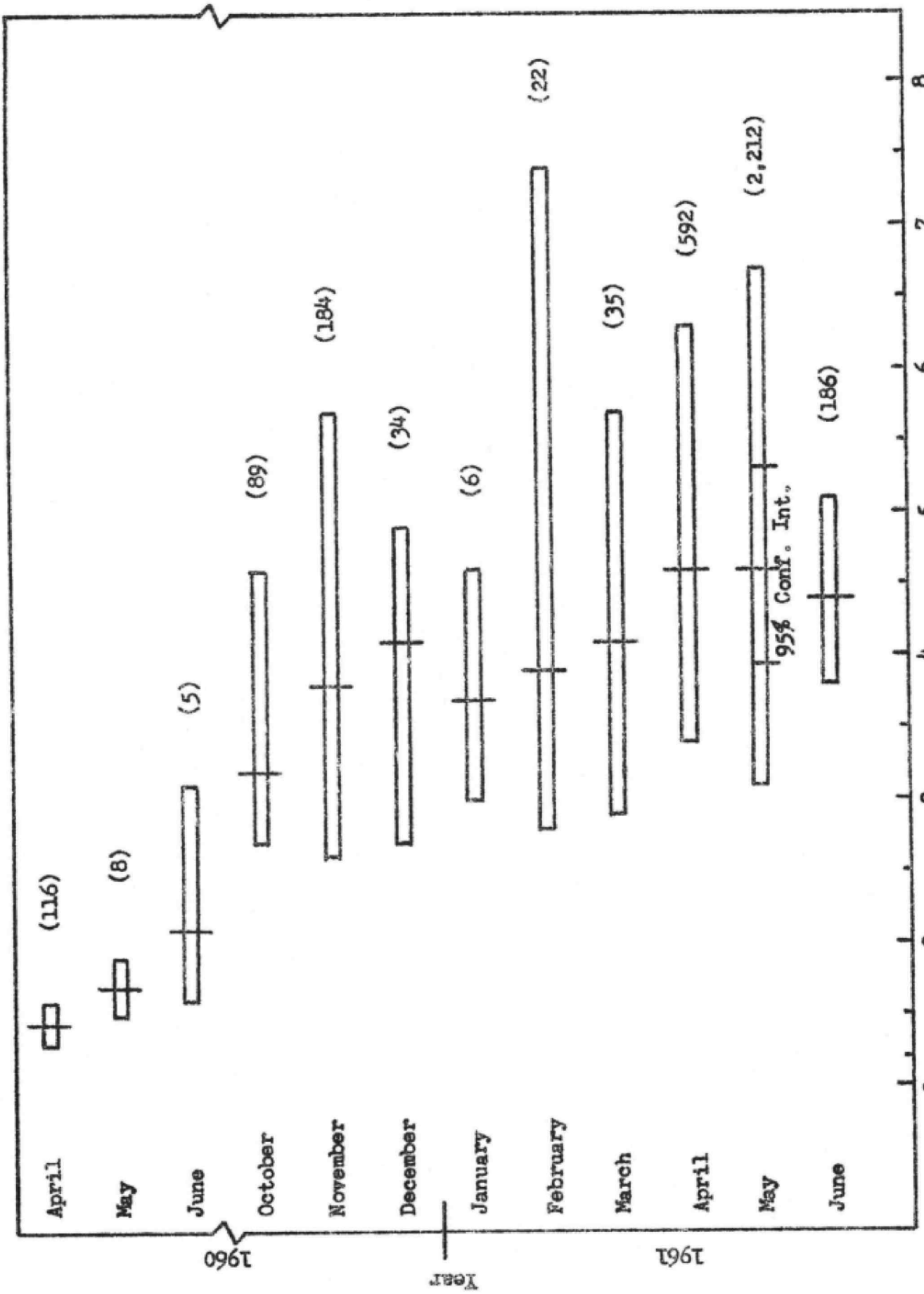

Figure 21. Average Lengths and Range in Size of 3,414 Downstream-Migrant Silver Salmon of the 1959 Brood at Gnat Creek Weir, April 1960-June 1961.

Table 15. Average Length-Weight Measurements for Yearling Silver Salmon per Millimeter of Fork Length, 1960 Brood.

Fork Length (mm)	5-mm Mid Point	Total Weight of Ten Fish (grams)	Average Weight for Each mm 1/	Average Weight Per 5-mm Interval 2/
101		118.9	11.9	
102		109.3	10.9	
103	103	112.5	11.3	11.4
104		113.6	11.4	
105		115.8	11.6	
106		121.0	12.1	
107		122.1	12.2	
108	108	129.2	12.9	12.8
109		132.1	13.2	
110		135.5	13.6	
111		140.4	14.0	
112		142.8	14.3	
113	113	146.1	14.6	14.6
114		149.3	14.9	
115		153.5	15.4	
116		157.2	15.7	
117		160.4	16.0	
118	118	166.7	16.7	16.6
119		172.0	17.2	
120		174.7	17.5	
121		179.6	18.0	
122		184.0	18.4	
123	123	184.7	18.5	18.7
124		187.9	18.8	
125		197.0	19.7	
126		196.8	19.7	
127		203.6	20.4	
128	128	207.3	20.7	20.8
129		215.3	21.5	
130		218.4	21.8	
131		220.9	22.1	
132		225.5	22.6	
133	133	229.5	23.0	23.0
134		237.3	23.7	
135		236.2	23.6	

1/ N = 10
2/ N = 50

Table 16. Average Condition Factors [1] for Yearling Silver Salmon per Millimeter of Fork Length, 1960 Brood.

Fork Length (mm)	5-mm Mid-Point	Average for [2] Each mm	Average Per 5-mm [3] Interval
101		1.04	
102		1.03	
103	103	1.03	1.03
104		1.01	
105		1.00	
106		1.02	
107		1.00	
108	108	1.03	1.02
109		1.02	
110		1.02	
111		1.03	
112		1.02	
113	113	1.01	1.02
114		1.01	
115		1.01	
116		1.01	
117		1.00	
118	118	1.02	1.01
119		1.02	
120		1.01	
121		1.01	
122		1.01	
123	123	0.99	1.01
124		0.99	
125		1.01	
126		0.98	
127		0.99	
128	128	0.99	0.99
129		1.00	
130		1.00	
131		0.98	
132		0.98	
133	133	0.98	0.98
134		0.99	
135		0.96	

1/ Condition Factor = $\frac{100,000\ W_o}{L^3}$ where W is weight in grams and L is fork length in millimeters.

2/ N = 10

3/ N = 50

Table 17. Comparisons of Annual Adult Silver Salmon Runs and Resulting Progeny at Gnat Creek, 1955-59 Brood Years.

Year of Parent Run (Brood Year)	Size of Parent Run (Numbers of Fish)				Resultant Outmigration (Numbers of Fish) 1/			Year of Outmigration
	Males	Jacks	Females	Total	Fingerlings	Smolts 2/	Total	
1955	67	81	26	174	219	2,996	3,215	1956-57
1956	46	149	29	224	1,964	1,847	3,811	1957-58
1957	53	89	67	209	975	1,013	1,993	1958-59
1958	30	100	40	170	398	1,061	1,459	1959-60
1959	14	44	45	103	236	3,226	3,494	1960-61
1960	9	70	8	87	13,148 3/	4,110	17,258	1961-62
1961	8	55	16	79				

1/ Counts represent minimum numbers since some fish are known to bypass counting facilities at the weir and escape over the dam when volumes exceed 150-200 c.f.s.

2/ November 15 arbitrarily selected as the date to separate fingerlings from smolts.

3/ Of the 13,148, 13,046 were of hatchery origin, being larger in size and different in coloration while 102 were wild.

Gnat Creek based on estimated egg deposition weir counts of juveniles and counts of returning jacks and adults is presented in Table 18. The counts of adult males, jacks, and females are believed to be accurate although some fish may have returned from the occasional spawners in the small area available below the weir or strays from other streams. The fingerling counts for zero-aged fish that migrated between emergence in the spring and November 15 of the same year are subject to errors of varying magnitude but probably not as great as that indicated in Table 4 for fall chinook fry and fingerlings. The smolt counts are accurate for the 1956 and 1957 brood years that migrated when there was no spill of consequence over the dam in April and May 1958 and 1959. In 1961 a liberation of 30,000 3-month-old, hatchery-reared fingerlings was made into the pond outlet at the newly-constructed OGC hatchery. The 30,000 stocking rate was derived by productivity and stream-size relationships by Wallis (1961). It was desired that these fish not be affected by any mark and the objective was to determine if any gross differences would result in the subsequent smolt count which had previously varied from about 1,000 to 3,200 with an average of about 2,000 or 1.5% of the average maximum egg deposition. From the results in Table 18 the number of fingerling migrants increased nearly 7-fold over the earlier maximum count, and the yearling smolt count was 1.27 times higher than the previous maximum count. The average survival of fingerlings (reared 3 months in a hatchery) to yearling migrants was determined to be approximately 10% at Minter Creek (Salo and Bayliff, 1958). The average smolt survival (1955-59) of 2,029 from 41 females indicates we might have expected $\frac{2,029\ (8)}{41}$ or less than 400 1960-brood smolts from the 8 females placed above. This suggests that 3,700 of the 4,100 counted might have been contributed from the hatchery liberation. Scales were collected from a random sample of migrants but were not analyzed for this report. From data in Table 18 the returning jacks and adults have averaged only 122% of

Table 18. Survival Rates of Silver Salmon Based on Calculated Egg Deposition, Juvenile-Migrant Counts, and Resultant Adults Returning to Gnat Creek Weir, 1955-60 Brood Years.

Year of Parent Run (Brood Year)	No. of Females Above Weir	Calculated Egg Deposition	Fingerling Survival		Smolt Survival 1/		Return as Adults (Jacks Excluded)			
			Number	Per Cent of Eggs	Number	Per Cent of Eggs	No. of Adult Males and Females	Per Cent of Parent Females	Per Cent of Eggs	Per Cent of Smolts
1955	26	89,254	219	0.2	2,996	3.3	70	269	0.08	2.3
1956	29	92,144	1,964	2.1	1,847	2.0	59	203	0.06	3.2
1957	67	219,076	975	0.4	1,013	0.5	17	25	0.01	1.7
1958	40	121,916	398	0.3	1,061	0.9	24	60	0.02	2.3
1959	45	137,510	236	0.2	3,226	2.3	81	180	0.06	2.5 2/
1960	8	27,591	13,148 3/	47.7	4,110 3/	14.9	—	—	—	—
Total (1955-59)	207	659,900	3,792		10,143		251			
Average (1955-59)	41	131,980	758	0.6	2,029	1.5	50	122	0.04	2.5

1/ Does not include fingerlings or smolts passing over spillway when flows exceeded 135-150.
2/ Partial count of adults in 1962.
3/ Primarily hatchery fish.

the parent females. In order to maintain the runs we should expect 200% or 1 male and 1 female to return to spawn for each parent female. The average return of adults only to Gnat Creek has been 50 or 2.5% of the average number (2,029) of smolts counted. The possibility of incomplete juvenile counts at the weir indicates that smolt survival may be somewhat higher than this, and the return of adults would be correspondingly lower.

An attempt was made to determine if any relationship existed between the Columbia River commercial gill-net catch, the number of Gnat Creek adults, and a runoff index--similar to that used by Smoker (1953)--two years earlier. The derivation of the index was given previously and is listed in Table 19 with estimates of the total catches in the lower Columbia River two years later. Although the data are insufficient for statistical analysis, a general relationship between the commercial catch and total water quantity is apparent since the highest catch is accompanied by the highest runoff index 2 years earlier and the lowest catch is accompanied by the lowest water quantity index 2 years earlier. No relationship was present between the number of Gnat Creek adults and the runoff index two years earlier.

Steelhead Trout

Although the study of steelhead was not included in the original Gnat Creek project objectives, some interesting information was obtained. The total numbers of adult steelhead returning to the weir from 1955-62 are listed in Table 20. The spawned-out adults that returned downstream were also counted; the percentage survival averaged 57.5% and varied between 11.5 and 81.3%. The adult run varied between 41 and 262 fish and averaged 123. An average of 1,467 migrants was produced of which 104 were zero-aged fish (Table 21).

A use of the random sampling device shown previously (Figure 13) was tested as to the accuracy of a 20% sample in portraying the size composition

Table 19. A Comparison of Columbia River Gill-Net Catches and Gnat Creek Adults with Runoff Index Two Years Earlier.

Year	Commercial Gill-Net Catch 1/			Gnat Creek Adults	Gnat Creek Runoff Index 2 Years Before
	Wash.	Oregon	Total		
1958	6,152	12,645	18,797	70	67.62
1959	3,770	11,039	14,809	59	39.21
1960	3,499	12,933	16,432	17	56.10
1961	11,900	28,996	40,896	24	81.82
1962	-	-	-	81 2/	49.62

1/ From Washington Department of Fisheries (1961) and IBM records.
2/ Nearly complete counts.

Table 20. Numbers of Adult Steelhead Counted at Gnat Creek Weir During Upstream Migration and Survival after Spawning, 1955-62.

Calendar Year	Numbers		Per Cent of Upstream Migrants Captured at Downstream Weir
	Upstream	Downstream	
1955-56	262	213	81.3
1956-57	234	154	65.8
1957-58	60	30	50.0
1958-59	114	53	46.5
1959-60	88	10	11.4
1960-61	41	6	14.6
1961-62	65	31	47.7
Total	864	497	
7-Year Average	123.4	71.0	57.5

Table 21. Numbers of Wild Juvenile Steelhead Outmigrants Trapped at Gnat Creek Weir, January 1, 1956-June 25, 1962.

Calendar Year	Age Group 0	Age Groups I, II, and III	Total
1956	286	1,203	1,489
1957	89	1,959	2,048
1958	18	1,219	1,237
1959	110	878	988
1960	209	1,032	1,241
1961	19	1,644	1,663
1962	0	1,602	1,602
Total	731	9,537	10,268
7-Year Average	104.4	1,362.4	1,466.9

of all steelhead juveniles that migrated during the spring of 1961. The results of the sample lengths are compared graphically in Figure 22 with the lengths for all fish caught of age groups I, II, and III combined. By using these sampling data and by further examination of the scales in the sample, the age composition of the downstream juveniles could have been determined. Although insufficient time was available for working up these data prior to preparing this report, steelhead age-length data and earlier material on chinook and silver salmon have been summarized in a summary report of Gnat Creek Weir Operations, June 1958-June 1959 by Thomas E. Kruse. It was shown that extent of overlapping lengths prevented separation of steelhead into brood years from length-frequency distributions.

A summary of steelhead marking experiments is shown in Table 22. The primary objective of marking steelhead was to identify Gnat Creek fish and determine the numbers of subsequent returning adults. Marked OGC hatchery fish of the 1960 brood (as well as unmarked fish) escaped downstream from

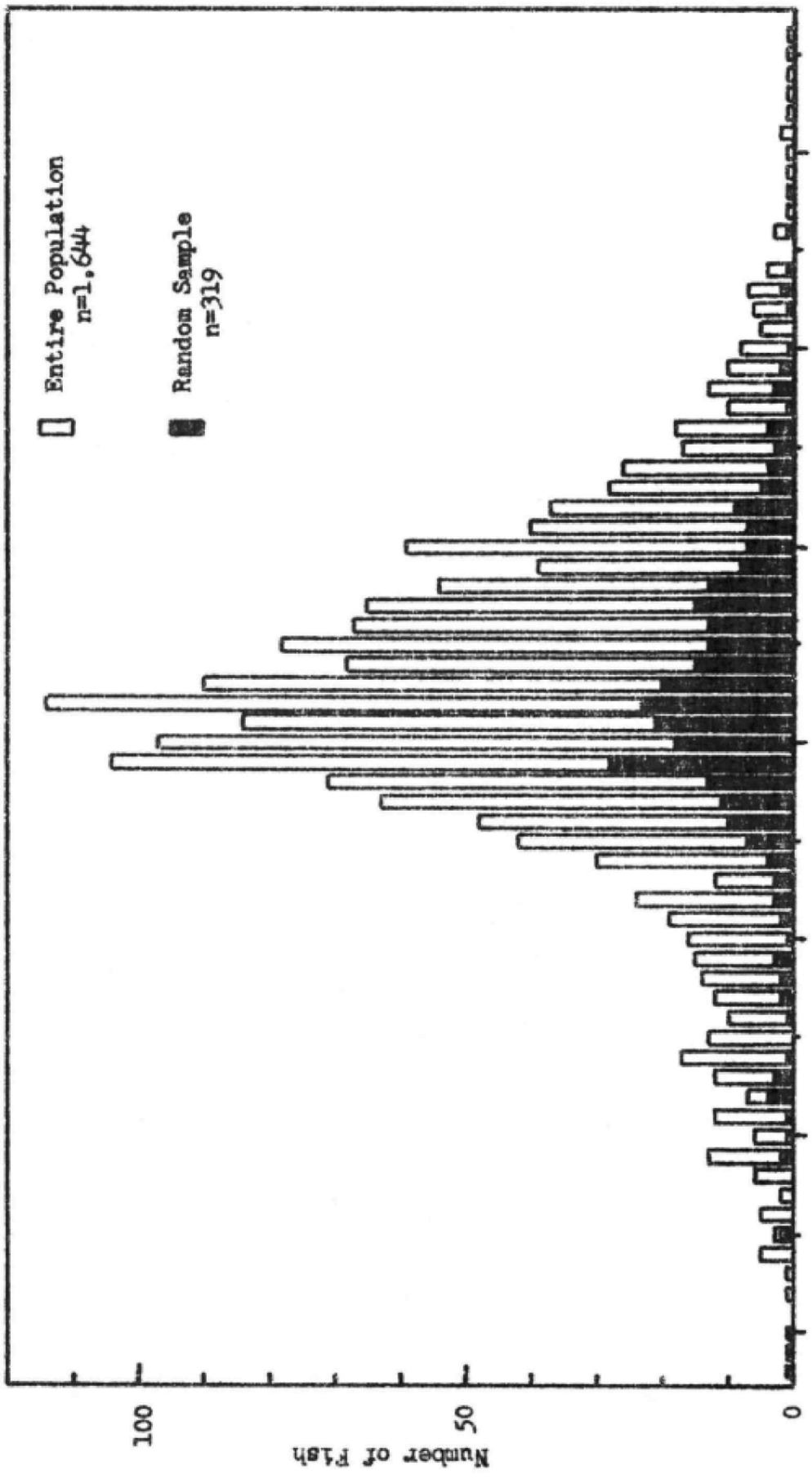

Figure 22. Comparison of Length-Frequency Distributions of Juvenile Steelhead Taken by a Sampling Technique with the Entire Population, 1961.

Table 22. Summary of Information Relating to Steelhead Mark Experiments at Gnat Creek, Through June 1962.

Brood Year 1/	Stock	Mark	Numbers Released	Date of Release	Returns to Gnat Creek	
					Numbers Recovered	Year of Recovery
1955	Natural	Ad	1,630	3/23-6/11/57	2	1958
					59	1959
					10	1960
					71	
1958	Natural	D-Ad	25	10/10/58-10/2/59	0	1959-62
1957-58		Ad-LP	64	10/20/59-3/30/60	1	1962
1957-58		Ad-RP	892	4/1-6/60-1/15/61	36	1961-62
1960	Gnat Creek Hatchery	BV	3			
		Ad-BV	18			
		Ad-LM	152			
		Ad-RM	27			
		LP-only	20			
		LM-only	1			
		Ad-only	1			
		Total	222	2/18-9/6/61	--	--
1960	Big Creek Hatchery	RV	1,015	5/24/61	--	--

1/ Brood year as determined by length-frequency data except for the hatchery fish.

other anticipated marking experiments. A Kray-Meekin scoop trap was tested at Gnat Creek with 1,015 hatchery-reared juveniles (6.5 inches long and about 9 fish/lb.) of the 1960 brood being marked RV and liberated 200 feet upstream from the trap on May 24, 1961. It was found that some of these fish could swim back out of the scoop trap at stream velocities of 3.0-3.5 feet per second. The best operating velocities are higher than this. Additional details of adult steelhead recoveries were presented in the Operational Studies annual progress report for 1962. Out of 65 adults that returned in the 1961 run, 42 had a variety of different marks, and 36 of these were Ad-RP.

Another side experiment using steelhead was conducted at Gnat Creek between December 1955 and June 1958 to compare the use of spaghetti with Petersen tags; the former were more satisfactory from the standpoint of tag loss. These data have been summarized in a typed manuscript (Kruse, 1959).

Miscellaneous Species

Counts of adult and juvenile cutthroat trout, lamprey (Entosphenus tridentatus), and cottids (Cottus sp.) are tabulated in Table 23. The numbers of adult cutthroat trout declined from 583 in 1955-56 to 115 in 1959-60, but increased to 254 in 1961-62. In some years more lamprey adults were counted going downstream than were counted going upstream. This was due to their ability to cling to the dam and pass over the weir without entering the upstream trap.

SUMMARY AND CONCLUSIONS

Gnat Creek drains a 22-square-mile area. Flows fluctuated between 1,300 and 7 c.f.s. between the start of the project in October 1955 and its termination in June 1962. A partially-passable cascade located 3 miles above the weir prevented passage of adult migrants during low flows. A modern

Table 23. Miscellaneous Species of Fish Enumerated at Gnat Creek Weir, October 1, 1955-June 30, 1962.

Species	1955-56		1956-57		1957-58		1958-59	
	Up	Down	Up	Down	Up	Down	Up	Down
Cutthroat								
Adults	583	96	554	87	355	15	142	13
Juveniles	34	2,329	14	2,706	5	1,694	8	1,631
Lamprey								
Adults	1,773	1,022	378	959	2,880	1,502	457	624
Juveniles	—	4,345	—	4,566	—	1,796	—	1,368
Cottids	—	1,231	—	477	—	330	—	135

Species	1959-60		1960-61		1961-62	
	Up	Down	Up	Down	Up	Down
Cutthroat						
Adults	115	1	186	24	254	49
Juveniles	—	1,405	3	1,592	—	1,546
Lamprey						
Adults	178	269	173	897	355	210
Juveniles	—	859	—	3,549	—	1,687
Cottids	—	180		363		233

hatchery was constructed near this location in the summer of 1960. The problem of adequately sampling the numbers of juvenile fish going over the dam during floods was not entirely solved although substantial effort was expended. Data from sampling traps on the dam during fall chinook migration suggest that 86% of the estimated total chinook migrants from January through April went over the spillway. Data are presented to show that in certain years no spill took place during the major migration period for juvenile silver salmon and steelhead trout in April and May. The adult counts are considered to be accurate and the average number and range of mature fish (jacks included) of each species was 39 (2-88) fall chinook, 149 (79-224) silvers, and 123 (41-262) steelhead.

Juvenile production was based on weir counts. Many of the chinook fry had visible yolk sacs and appeared to be dislodged. Based on a 6-year average, 71% of the yearling silvers migrated in the month of May and 90% migrated in April and May. Most smolts migrated between 6 p.m. and midnight when counted on May 9 and 10, 1962. The average lengths of 7,878 smolts from 6 brood years averaged 114.9 mm with 95% confidence limits of 87.8-142.0 mm. Yearlings from individual brood years had average lengths that ranged from 101-121 mm. Average weights and condition factors are presented for one group of migrants.

An estimate of the silver salmon potential egg deposition at Gnat Creek was based on the individual egg counts of 20 females caught in the lower Columbia River commercial fishery. This sample contained two fish from each inch in length from 22 to 31 inches. The regression of fecundity on length was linear and the equation for the calculated egg content was: $\hat{Y} = 239.433 (X) - 3,345.033$. The calculated egg deposition at Gnat Creek varied between 27,591 for 8 females to 219,076 for 67 females. The average estimated survival to yearling migrants was 1.5% of the computed egg deposition and varied between 0.5 and 3.3%. If complete counts of yearlings had been obtained these survival figures may have been somewhat higher. Survival rates of 0.5 and 2.0% for two brood years are from accurate counts. On the

average, 2.5% of the smolts counted returned to the weir as adults (jacks excluded). Complete enumeration of smolts would tend to lower this figure.

From accurate counts of hatchery-reared, marked chinook fingerlings liberated between April and June 3 miles upstream, fresh-water survivals of 50-88% were obtained with half the numbers reaching the weir within 2 to 5 days after liberation. Most of the surviving adults (98) returned to the stream from a yearling release. One marking experiment (631 silver salmon) was undertaken to make a comparison between hatchery and wild yearlings. The survival rates of these two groups were similar using total actual recoveries since about 5 times as many wild fish were originally marked.

A comparison of the average lengths of marked and unmarked silver salmon that returned to Gnat Creek Weir from 1956 through 1961 was made. Two-hundred twenty-seven marked fish averaged 20.34 inches and 412 unmarked fish averaged 21.50 inches. A t-test of the means indicated the difference was significant at the 5% level.

The total Columbia River commercial gill-net catches and a runoff index at Gnat Creek two years earlier (from the type of relationship established in western Washington by Dr. Smoker) suggests a possible relationship but insufficient data were available for a statistical test. No relationship between Gnat Creek adults and the index was apparent.

The production of juveniles from varying numbers of adults is presented for chinook and silver salmon and steelhead and cutthroat trout. Productivity and survival rates for silver salmon was related to the calculated egg deposition, 0+ and smolt counts, and adults in the progeny run from the numbers of smolts counted.

ACKNOWLEDGMENTS

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Appendix Table I. Length-Frequency Tabulation of Marked and Unmarked Wild Silver Salmon Adults at Gnat Creek, 1956-57.

Fork Length (in Inches)	Adult Males (20" and Over)		Jacks (Under 20")		Females		Total		Combined Total 2/
	M.	Unm. 1/	M.	Unm.	M.	Unm.	M.	Unm.	
12			2				2		2
13				1				1	1
14			7	2			7	2	9
15			18	6			18	6	24
16			14	16			14	16	30
17			10	34			10	34	44
18			5	26			5	26	31
19			2	5			2	5	7
20		3						3	3
21		1						1	1
22		3				2		5	5
23		1				0		1	1
24		3				1		4	4
25		5				2		7	7
26		5				6		11	11
27		6				1		7	7
28		9				11		20	20
29		2				4		6	6
30		3				3		6	6
31		1				1		2	2
32		1				1		2	2
Total		43	58	90		32	58	165	223(148) 3/

1/ M = Marked; Unm. = Unmarked.
2/ On 12/12/56 1 unmarked male, no length given; not listed in above tabulations.
On 12/12/56 1 unmarked fish, no sex given; not listed in above tabulations.
3/ Jacks, included in total, are listed separately in parentheses.

Appendix Table II. Length-Frequency Tabulation of Marked and Unmarked Wild Silver Salmon at Gnat Creek, 1957-58.

Fork Length (in Inches)	Adult Males (20" and Over)		Jacks (Under 20")		Females		Total		Combined Total
	M.	Unm.	M.	Unm.	M.	Unm.	M.	Unm.	
11			1				1		1
12			2				2		2
13			3	1			3	1	4
14			2				2	0	2
15			6	7			6	7	13
16			8	8			8	8	16
17			11	6			11	6	17
18			6	12			6	12	18
19			5	5			5	5	10
20	1					1	1	1	2
21								0	0
22	1	3					1	3	4
23		2						2	2
24	3					2	3	2	5
25	2	5			1	1	3	6	9
26	3	5			2	14	5	19	24
27		2			3	6	3	8	11
28	6	8			6	10	12	18	30
29		5			5	6	5	11	16
30	2	2			1	7	3	9	12
31		1				2		3	3
32	1	1					1	1	2
Total	19	34	44	39	18	49	81	122	203(83) 1/

1/ Jacks, included in total, are listed separately in parentheses.

Appendix Table III. Length-Frequency Tabulation of Marked and Unmarked Wild Silver Salmon Adults at Gnat Creek, 1958-59.

Fork Length (in Inches)	Adult Males (20" and Over)		Jacks (Under 20")		Females		Total		Combined Total 1/
	M.	Unm.	M.	Unm.	M.	Unm.	M.	Unm.	
12			2	1			2	1	3
13			1	3			1	3	4
14			3	3			3	3	6
15			2	16			2	16	18
16				21				21	21
17			2	23			2	23	25
18			1	8			1	8	9
19				6				6	6
20	2	2					2	2	4
21						1		1	1
22					0	1		1	1
23	4					1	4	1	5
24		1				2		3	3
25	1				1	3	2	3	5
26		3				6		9	9
27		4			10	2	10	6	16
28	4	1			0	3	4	4	6
29	3	2			1	4	4	6	10
30	1	1			1	1	2	2	4
31								0	0
32	1						1	0	1
Total	16	14	11	81	13	24	40	119	159(92) 2/

1/ Eight additional fish with no length, sex, or inspected for marks not included.

2/ Jacks, included in total, are listed separately in parentheses.

Appendix Table IV. Length-Frequency Tabulation of Marked and Unmarked Wild Silver Salmon Adults at Gnat Creek, 1959-60.

Fork Length (in Inches)	Adult Males (20" and Over)		Jacks (Under 20")		Females		Total		Combined Total
	M.	Unm.	M.	Unm.	M.	Unm.	M.	Unm.	
12									
13				1				1	1
14			3				3		3
15			1	4			1	4	5
16			4	9			4	9	13
17			1	10			1	10	11
18				5				5	5
19			2	3			2	3	5
20		1						1	1
21		2			1	1	1	3	4
22	1	1				1	1	2	3
23		1			1		1	1	2
24	1				1	2	2	2	4
25		1			1	3	1	4	5
26	1	1			4	7	5	8	13
27		1			1	3	1	4	5
28					2	7	2	7	9
29		2				4		6	6
30		1				5		6	6
31						1		1	1
32									
33									
Total	3	11	11	32	11	34	25	77	102

Appendix Table V. Length-Frequency Tabulation of Marked and Unmarked Wild Silver Salmon Adults at Gnat Creek, 1960-61.

Fork Length (in Inches)	Adult Males (20" and Over)		Jacks (Under 20")		Females		Total		Combined Total
	M.	Unm.	M.	Unm.	M.	Unm.	M.	Unm.	
11				1				1	1
12								0	0
13			2	1			2	1	3
14			2	1			2	1	3
15			5	3			5	3	8
16			6	7			6	7	13
17			4	9			4	9	13
18			4	9			4	9	13
19			3	12			3	12	15
20	1			1			1	1	2
21		1						1	1
22		1						1	1
23									0
24		1				1		2	2
25	1			1			1	1	2
26									0
27	1				1	2	2	2	4
28									0
29									0
30		1				2		3	3
31		1				2		3	3
Total	3	5	26	45	1	7	30	57	87

Appendix Table VI. Length-Frequency Tabulation of Marked and Unmarked Wild Silver Salmon Adults at Gnat Creek, 1961-62.

Fork Length (in Inches)	Adult Males (20" and Over)		Jacks (Under 20")		Females		Total		Combined Total
	M.	Unm.	M.	Unm.	M.	Unm.	M.	Unm.	
13			1				1		1
14			3	1			3	1	4
15			7	3			7	3	10
16			11	2			11	2	13
17			6	6			6	6	12
18			5	2			5	2	7
19			2	6			2	6	8
20		2						2	2
21									0
22									0
23		1						1	1
24									0
25	1				1		2		2
26									0
27		1			1	3	1	4	5
28	1	1			2	4	3	5	8
29		1			1	2	1	3	4
30						1		1	1
31						1		1	1
32									0
Total	2	6	35	20	5	11	42	37	79

Appendix Table VII. Length-Frequency Distribution of Adult Fall Chinook Salmon in the 1960 Run at Gnat Creek Weir by Sex and Mark.

Fork Length in Inches	Males					Females				Sex Unknown		Total
	D	D-LM	D-RM	RM	RV	D	D-LM	D-RM	RV	D	D-LM	
22						1				1	1	3
27					1		1					2
28												0
29												0
30		1					2					3
31												0
32		1					2					3
33	1	2				1	3					7
34		1					2					3
35	1	1					2		1			5
36		2	1			1	1	1				6
37		2		1								3
38												0
39			1					1				2
40	1											1
Total	3	10	2	1	1	3	13	2	1	1	1	38