Downstream Migration of Juvenile Rainbow/Steelhead Trout in the Nisqually River and Muck Creek

1980 - 1981

Final Report

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TABLE OF CONTENTS

INTRODUCTION

The U.S. Fish and Wildlife Service (USFWS) monitored the downstream migration of juvenile rainbow/steelhead trout (*Salmo gairdneri*) on Muck Creek, a tributary of the Nisqually River, in the spring of 1980. The USFWS also monitored the juvenile outmigration on the mainstem Nisqually River in the spring of 1981 in cooperation with the Nisqually Indian Tribe.

The Nisqually has both winter and summer-run steelhead. The winter run consists of both native fish and hatchery fish of outside origin, but it is managed for natural production. This run contributes to both the Nisqually Indian commercial and non-Indian sport fisheries on the river. The summer run consists of hatchery fish of outside origin and contributes to a small non-Indian sport fishery on the river.

The population dynamics of naturally-produced steelhead are not well known in most western Washington streams. Only the Washington Department of Game (WDG) Snow Creek station monitors escapement, hatching survival, rearing density, outmigration, and adult return on the same population. Outmigration has been widely studied elsewhere (Table 1), but parr and fry migration patterns have been studied less frequently than smolt migration.

Knowledge of population size and survival of life stages on the Nisqually would help refine pre-season run size prediction and help establish escapement goals.

An index of escapement has been calculated from aerial surveys (Nisqually Tribe 1979), and escapement to Muck Creek was counted with a weir in 1978-79, 1979-80, and 1980-81 (Hiss 1981). Life history of winter-run fish has been obtained from scale analysis of lower mainstem commercial catch and Muck Creek weir returns (USFWS 1981; Eric Knudsen, Fisheries Research Services, personal communication). Distribution and relative abundance of juveniles has also been studied (Tyler 1979; Svoboda 1978; Harrington-Tweit and Svoboda 1980), but numbers and characteristics of outmigrants have not been studied until now.

The objectives of this study were:

(1) to investigate rainbow/steelhead life history on Muck Creek to complement WDG studies on Snow Creek and previous adult trapping on Muck Creek, and specifically to define smolt emigration. Secondary objectives were to evaluate productivity of escapement and to estimate the timing and length-age composition of the outmigration;
and

(2) to investigate, in cooperation with the Nisqually Tribe, steelhead outmigration on the Nisqually River. Secondary objectives were to estimate the length-age composition of the natural smolt run and evaluate the contribution of hatchery plants.

Table 1. Juvenile rainbow/steelhead migration studies.

Main River	Tributary	Reference (s)
Chehalis		Brix and Seiler 1977
Kalama	Gobar Creek	Chilcote *et al*. 1980; Crawford *et al*. 1979
Wynoochee		Larson and Ward 1954
Skagit	Alder Creek	Phillips *et al*. 1980
Snow Creek	Andrews Creek	USFWS and WDG 1980, 1979
Salmon Creek		"
Lemhi[a]	Big Springs Creek	Chrisp and Bjornn 1978
Trinity[b]		Healey 1970
Quinsam[c]		Reinhardt 1977, 1978
Various Washington streams		Royal 1973

a. Snake River drainage, Idaho.
b. Klamath River drainage, California.
c. Campbell River drainage, Vancouver Island, B.C.

STUDY AREA

Muck Creek

Muck Creek rises in Patterson Springs, Pierce County, Washington, and flows generally to the west for 15 miles, mainly through the Fort Lewis Military Reservation, before joining the Nisqually at River Mile (RM) 11 (Figure 1). The stream is largely spring-fed and flows through large subterranean gravel deposits (Pearson and Dion 1979). A dam on Chambers Lake maintains water level for a warmwater sport fishery there. These factors account for rather steady flows whose onset is delayed until mid-December and for slow decline in flows until fall, when the stream flow often becomes intermittent (Figure 2). During the study period flow increased until late April and then declined (Table 2).

Spring water also probably accounts for higher late winter and early spring temperatures than in the Nisqually River (Figure 3). During the study period temperatures increased until early May and then declined (Table 2) probably because most of the flow was then underground for several miles upstream from the site.

The creek supports extensive chum salmon (*Oncorhynchus keta*) and natural winter steelhead spawning in the lower 5 miles. Smaller numbers of coho salmon (*O. kisutch*) and cutthroat trout (*S. clarki*) also occur (USFWS 1981). Chum spawning density has been calculated (Phil Wampler, USFWS, unpublished data).

A number of catchable rainbow trout were planted in the Muck Creek system in February, April, and May 1980 (Table 3). Many were over 145 mm fork length (FL).

Nisqually River

The Nisqually River originates from a glacier on Mt. Rainier and flows generally northwesterly for about 80 miles before entering Puget Sound at Nisqually Reach (Figure 1). Discharge regulation at Alder and La Grande Dams usually keeps springtime flow at about 1500 cubic feet per second (cfs) at Nisqually, Washington. Releases in 1981 were as high as 5000 cfs (Figure 4).

The river supports a native winter steelhead run in the lower 40 miles enhanced by Washington Department of Game (WDG) outside hatchery plants. A total of 64,685 summer and winter run hatchery steelhead were planted at RM 39 on seven dates from April 17 to May 7, 1981 (Table 4). The river also has viable runs of fall chinook, pink, and chum, and coho salmon as well as searun cutthroat trout.

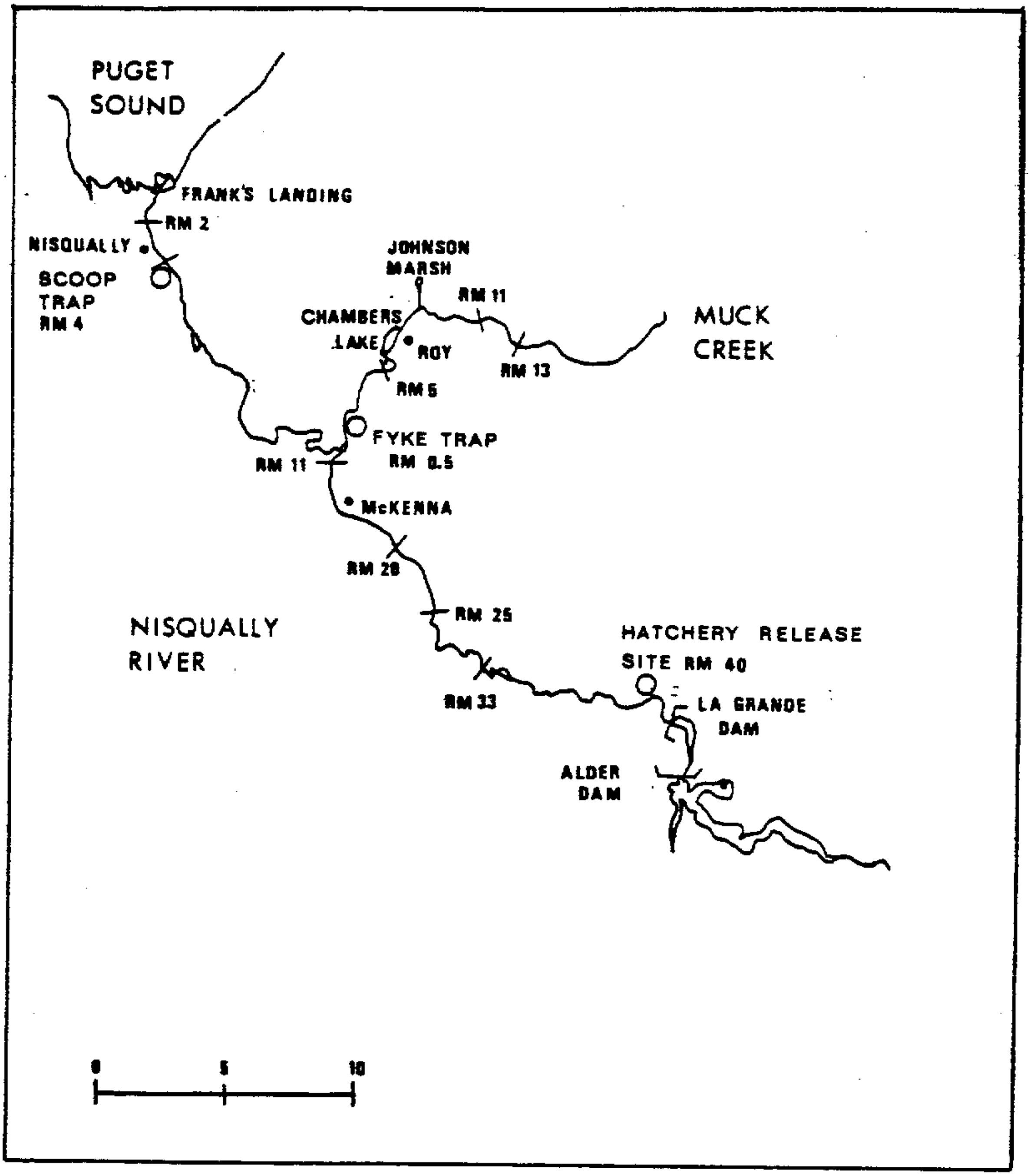

FIGURE 1.

NISQUALLY RIVER, PIERCE AND THURSTON COUNTIES, WASHINGTON.

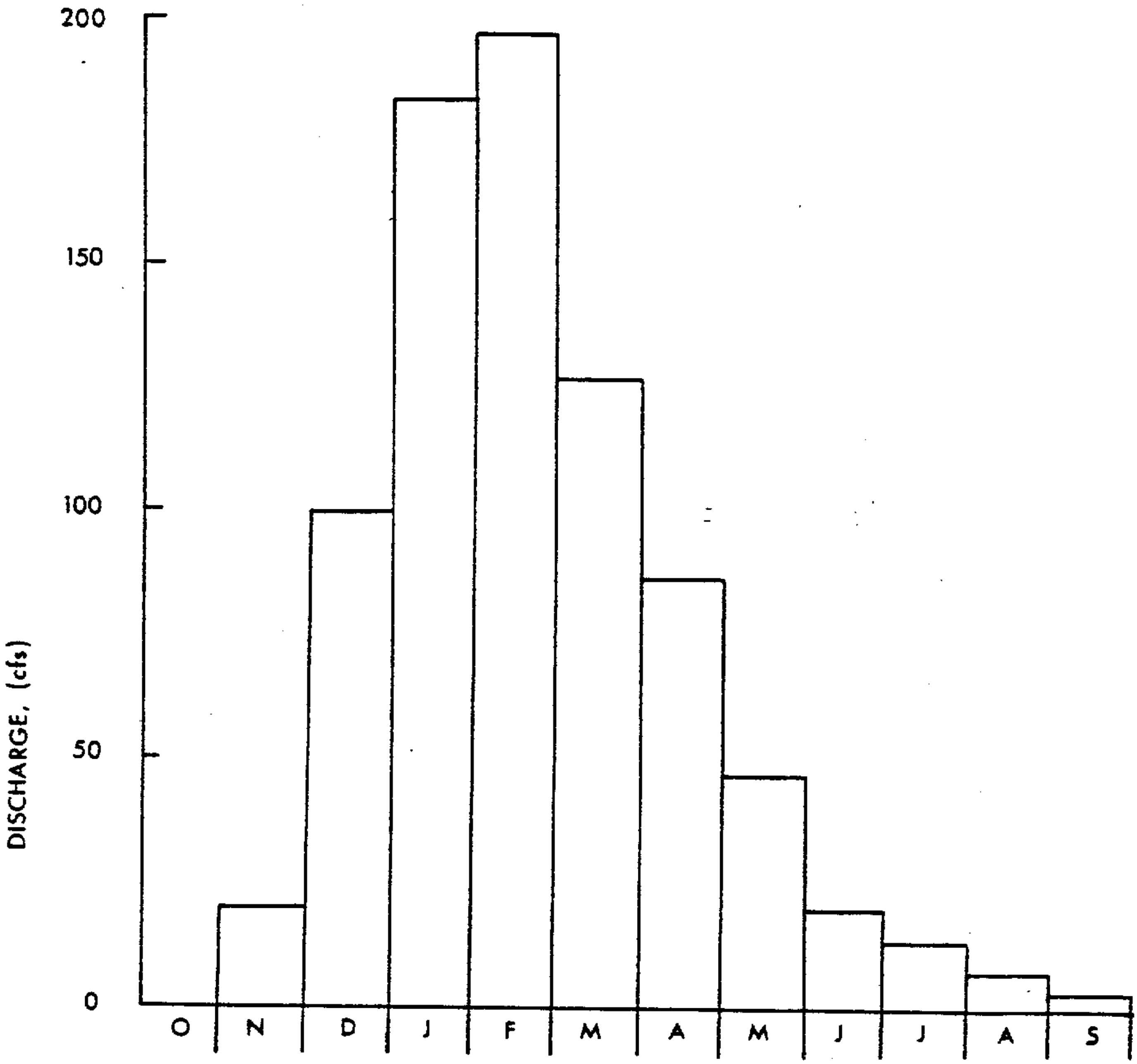

FIGURE 2.

MEAN MONTHLY DISCHARGE OF MUCK CREEK AT ROY, DURING 1957—71 WATER YEARS.

Table 2. Mean weekly discharge and temperature of Muck Creek at RM 0.5 taken between 1800 and 2000 hours, April to July 1980.

Week	Flow (cfs)	Temperature (°C)
3/30-4/5	95	12
4/6-12	115	11
4/13-19	127	12
4/20-26	175	11
4/27-5/3	146	14
5/4-10	80	14
5/11-17	66	13
5/18-24	54	12
5/25-31	52	12
6/1-7	48	11
6/8-14	a	a-
6/15-21	35	12
6/22-28	32	10
6/28-7/4	28	10
7/5-11	28	11
7/12-18	28	11

a. Not taken.

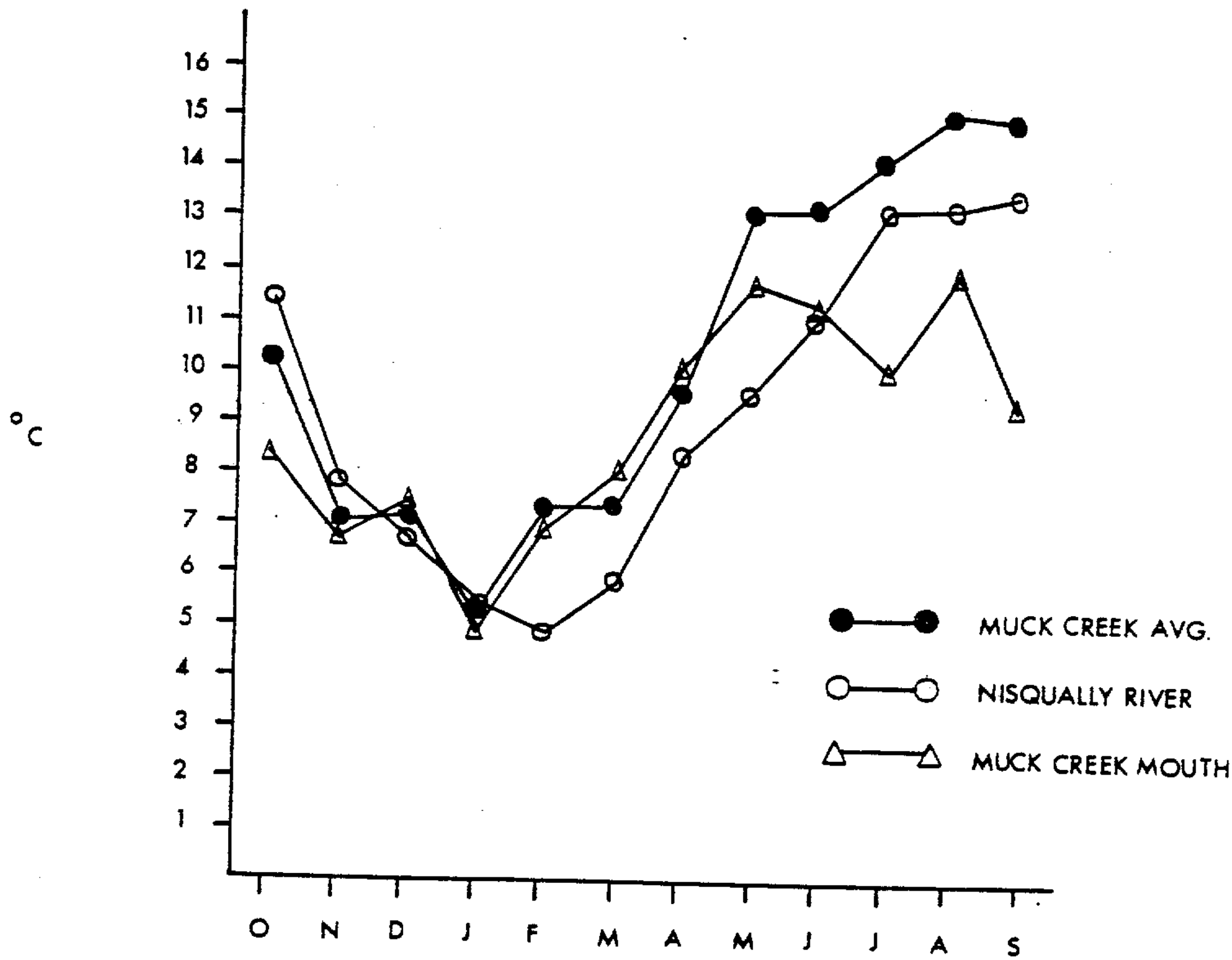

FIGURE 3.

MEAN MONTHLY TEMPERATURES BETWEEN 0800 AND 1300 HOURS(1) ON THE NISQUALLY RIVER, AVERAGE BETWEEN McKENNA AND NISQUALLY DURING 1974–78 WATER YEARS (USGS 1977, 1978, 1979),(2) ON MUCK CREEK, AVERAGE BETWEEN THREE POINTS (AT ROY, AT RM 5, AND AT MOUTH), AND(3) AT MOUTH ONLY, DURING 1978–79 WATER YEARS (PEARSON AND DION 1979).

Table 3. Rainbow trout plants in Muck Creek system, 1980.

Date	Number	Total length (mm) Mean	Range	Location
Feb 24	8,000	137		Johnson Marsh
Apr	3,000		178-229	Chambers Lake
Apr	400	305		Chambers Lake
May	3,500		178-229	Chambers Lake
	500	305		Chambers Lake

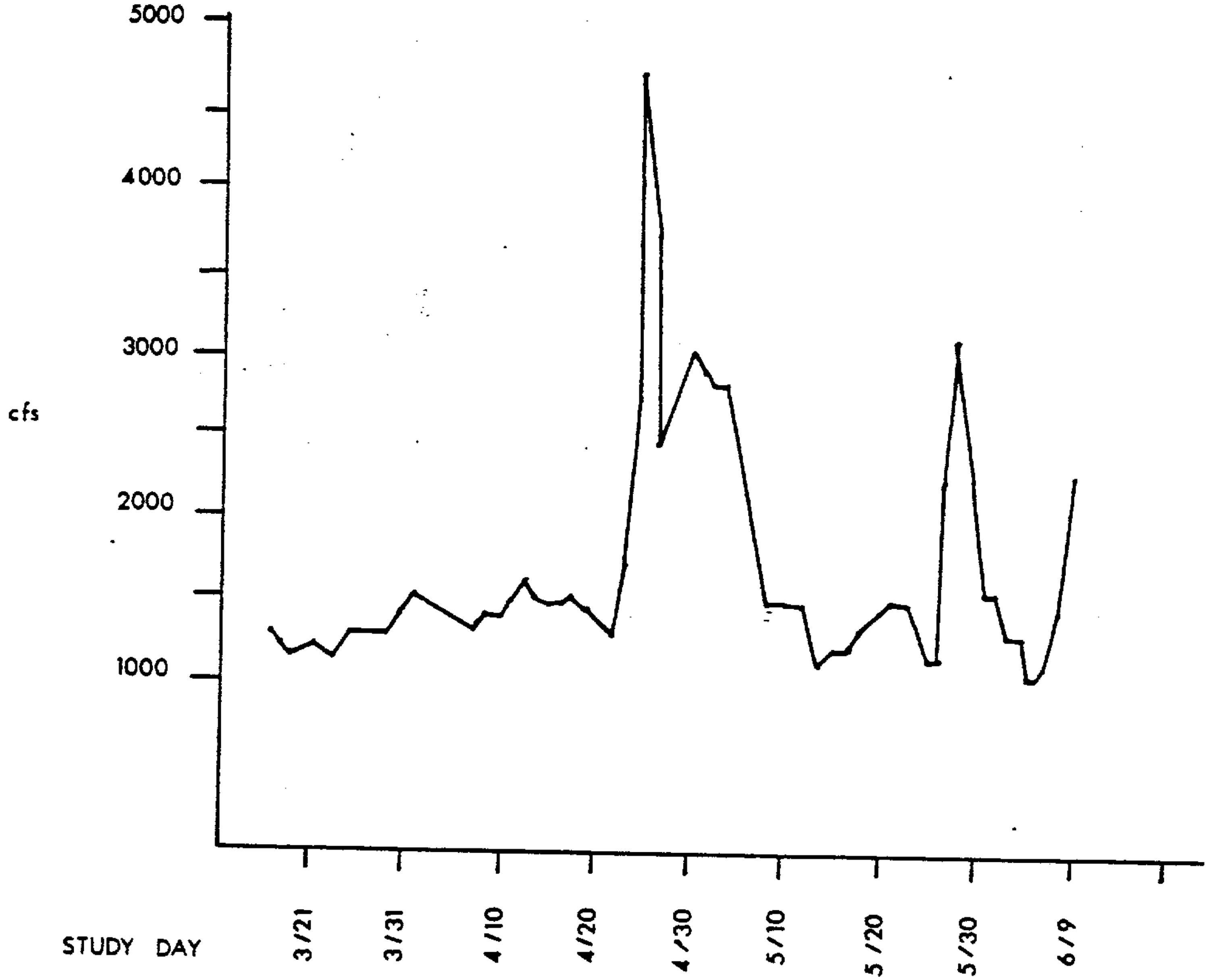

FIGURE 4.

NISQUALLY RIVER FLOW AT NISQUALLY, WASHINGTON, 1981.

Table 4. WDG hatchery steelhead smolt releases into Nisqually River 1981. All releases made at RM 39.

Date	Hatchery	Timing	Number	Stock
4/17	South Tacoma	Winter	15,394	Chambers Creek
4/22	Shelton	Winter	5,555	Bogachiel
4/23	Shelton	Winter	5,126	Bogachiel
4/28	South Tacoma	Summer	11,250	Skamania
4/28	South Tacoma	Winter	10,010	Chambers Creek
4/29	Shelton	Winter	4,950	Bogachiel
4/30	Shelton	Winter	4,400	Bogachiel
5/7	South Tacoma	Summer	8,000	Skamania
Total			64,685	

MUCK CREEK

Methods

Downstream migrant fish were captured by a fyke trap suspended under a bridge across the stream, following the design of Dlugokenski et al. (1981), with a 1.83 square mouth and a net of 1 cm stretched mesh nylon web. The live box followed the dimensions of Dlugokenski but was made of perforated plywood as described by Craddock (1961) and lined with 9.5mm mesh Vexar.

The trap initially sampled about 30% of the cross-section of the creek, but wings were later installed, increasing the area to about 80%. Water velocity at the mouth ranged from 3 to 4ft/second.

The trap was operated a total of 42 nights between April 2 and July 16, 1980, and checked twice a night or as often as needed to assure fish survival. Fish of each species were counted. The diurnal periodicity of rainbow/steelhead migration was examined on one occasion by trapping for 24 hours and checking the trap every two hours.

Trap Efficiency

Catch efficiency of the trap for rainbow/steelhead capture was tested on six occasions. Fish were captured from sunset to 2400 and approximately 50 were clipped on the upper or lower lobe of the tail and released approximately 50m upstream. Recapture was monitored until sunrise and again on some subsequent nights. The May 11 and 16 efficiencies were assigned to all dates between April 16 and May 16.

The May 20 and 25 efficiencies were assigned to all dates from May 20 until June 12. The last three tests were averaged and applied to the study nights after June 13.

To calculate trap efficiency the actual catch was adjusted to account for the hours of darkness actually fished after release and then adjusted to account for fish which apparently did not migrate back to the trap site on the same night, to get the proportion of marked fish available for recapture the night of release.

To adjust for hours fished it was assumed that migration was constant during hours of darkness and nil during daylight. The number recovered was corrected by the factor

$$\frac{\text{hours from release to sunrise}}{\text{hours fished from release to sunrise}}$$

Then the recovery data was adjusted by linear regression to account for delayed migration from the release point. The catch was examined for marked fish the 4th to 6th night after release. There is no delay from the last efficiency test because it was performed on the last study day. It was assumed that a recovery represented the most recent release of that mark.

The number of fish recaptured in each test was standardized by expressing recapture on each night as percent of total recaptured for that test. This was regressed against nights since release, transforming percent catch to log (Y + 1) and days to X to best approximate a straight line. The sum of positive percents was adjusted to add to 100%, thus accounting for nights on which we did not look for marks. The resulting Y-intercept was the percent of released fish available for recapture on the night of the test.

Population Estimate

The population migrating out of Muck Creek between April 23 and July 17 was estimated by expanding the actual catch to account for trap efficiency, diurnal periodicity, and the number of nights fished by week, and then summing the weekly estimates. The recorded catch for each night was first adjusted to account for periodicity by the factor

$$\frac{1}{\frac{NF \times PN}{HN \times 100} \quad \frac{DF \times PD}{HD \times 100}}$$

NF = night hours fished
PN = percent of fish captured at night in periodicity study
HN = hours in night
DF = day hours fished
PD = percent of fish captured during day in periodicity study
HD = hours in day

and then adjusted upward to account for the efficiency on that night. Weekly catch was averaged and multiplied by 7 to account for nights not fished, and added for the whole period.

Biological Data

All salmonids 85mm forklength were measured, as well as a random sample below this length. Fish were classified as subyearling, parr, or smolt on the basis of length, with cutoff points at 85 and 145mm respectively. Subyearlings were separated from parr at an apparent gap in the length frequency distribution. The parr/smolt boundary was established based on Chrisp and Bjornn (1978) and Scarlett and Cederholm (Washington Department of Natural Resources (WDNR), in preparation).

Length frequency was calculated to avoid bias toward nights when a larger proportion of fish were measured. For each of the three length groups, the actual length distribution for each week was multiplied by a correction factor equal to

$$\frac{(\text{number captured})\ (\text{estimated total population, all lengths})}{(\text{number measured})\ (\text{total captured, all lengths})}$$

percent composition was then calculated from these adjusted figures. The effect of fish size on seasonal timing of migration was examined. Each week the total number of each size class was adjusted by the correction factor.

$$\frac{\text{Total estimated weekly population}}{\text{Total actual weekly count}}$$

Timing for each length class was calculated as the weekly cumulative percent of total estimated outmigrants. Fish were weighed on various dates throughout the run. Those less than 85mm were weighed as a group and those greater individually. Scales were taken from all sizes of juvenile trout and coho.

Scales were examined to determine the age composition of each group. Scales with no winter annulus were reported as 0+, those with one winter annulus as I+, and those with two as II+.

Results

A total of 16, 375 juvenile rainbow/steelhead trout were captured in 51 nights of trapping between April 2 and July 17, 1980. Nearly all (96.7%) were below 85mm FL, 2.4% were between 85 and 145mm and 0.9% were over 145mm (Table 5). Almost all migration (92%) took place between sunset and sunrise (Table 6, Appendix Table 1). No fish could be identified as cutthroat trout. A total of 401 fish in seven efficiency tests were captured and released. A total of 117 fish were recaptured on the same test nights (Table 7, Appendix Table 2), and six more were recaptured several days after marking.

Recapture of marked fish regressed the number of nights since release resulted in the equation

$$\log\ (Y+1) = -0.558\sqrt{X} + 1.916$$

with a coefficient of regression of -0.798 (Appendix Tables 4,5). The X-intercept corresponds to 12 nights, implying that all fish had left the release site after this time. The sum of positive Y-values was 139.4% so the correction factor was 100/139.4, and the corrected Y-intercept was 58.6%, indicating the percent of released fish available for recapture the same night. Trap efficiency ranged from 18 to 64% (Table 8), and total juvenile outmigration was approximately 150,000 fish (Table 9, Appendix Table 6), of which 899 were smolts, 2,547 were parr, and 146,000 subyearlings, based on size.

Table 5. Rainbow/steelhead and coho catch at fyke trap, Muck Creek, 1980.

Date	Time		Rainbow-Steelhead			Coho	
	In	Out	< 85mm	85-144mm	≥ 145mm	≤ 79mm	≥ 95mm
4/2-3	1900	0600	17	1	2	0	0
4/4-5	"	"	11	0	0	0	0
4/7-8	"	"	7	0	0	0	0
4/9-10	1800	0200	4	0	0	0	0
4/11-12	1900	0600	1	0	0	0	0
4/14-15	1900	0700	2	1	0	0	0
4/15-16	1900	0600	1	0	0	0	0
4/16-17	"	"	2	0	0	0	0
4/23-24	"	0200	3	0	10	0	0
4/24-25	1800	"	2	2	2	0	6
4/25-26	"	"	3	2	6	0	4
4/26-27	"	"	0	12	6	0	6
4/27-28	1900	0300	0	2	5	0	12
4/28-29	"	"	1	6	5	0	11
4/29-30	"	"	0	8	3	0	4
4/30-5/1	"	"	0	7	8	0	11
5/2-3	"	"	1	10	11	0	8
5/3-4	"	"	8	13	9	0	6
5/4-5	"	"	2	9	6	0	2
5/5-6	"	"	3	7	5	0	5
5/7-8	1900	0300	3	12	5	0	3
5/8-9	1900	0300	1	10	2	0	6
5/9-10	"	"	1	8	3	0	4
5/10-11	"	"	16	14	4	0	3
5/11-12	2000	0500	37	28	4	0	3
5/12-13	1900	0300	1	6	4	0	14
5/13-14	2100	"	12	19	1	0	3
5/14-15	1900	"	33	15	4	0	0
5/16-17	2000	0400	110	50	5	3	0
5/18-19	"	0300	19	11	2	1	0
5/20-21	1900	0200	521	5	1	0	0
5/22-23	1900	0300	568	24	8	1	0
5/25-26	"	"	585	3	0	4	0
5/28-29	"	0700	256	31	3	0	0
5/30-31	"	0300	539	10	0	0	0
6/1-2	2000	0200	450	0	1	0	0
6/3-4	"	0400	804	16	3	0	0
6/4-5	1900	0300	678	11	2	0	0
6/8-8	"	0100	903	1	1	0	0
6/9-10	2100	0200	700	10	3	0	0
6/12-13	1900	0200	475	3	2	0	0

Table 5. continued

Date	Time		Rainbow-steelhead			Coho	
	In	Out	<85mm	85-144mm	≥ 145mm	< 79mm	≥ 95mm
6/13-14	"	0300	1318	22	3	0	0
6/15-16	"	0200	1862	7	0	0	0
6/17-18	"	"	1125	0	0	0	0
6/19-20	"	"	855	4	0	0	0
6/23-24	2000	0300	1622	1	0	0	0
6/27-28	"	0200	553	4	0	0	0
7/1-2	"	"	974	0	0	0	0
7/7-8	1200	0600	442	0	0	0	0
7/11-12	1000	1000	178	0	0	0	0
7/16-17	2000	0600	130	1	0	0	0
Total			15,839	396	139	9	71

Table 6. Periodicity of juvenile rainbow/steelhead catch in fyke trap at Muck Creek, May 28-29, 1980.

Time	Catch				
	<85mm	85-144mm	≥145mm	Total	Percent
2100-0500	237	28	3	268	92.4
0500-2100	19	3	0	22	7.6

Table 7. Recovery of marked fish from efficiency tests at fyke trap, Muck Creek, 1980.

Marking			Immediate recovery	Delayed recovery		
Date	Caudal clip	Number	Number	Days from release	Number	Total
5/11	Upper	39	6	5	1	7
5/16	Lower	99	25	6	2	27
5/22	Upper	-	16	-	-	16
5/25	Upper	53	9	4	1	10
5/28	Lower	56	6	6	2	8
6/13	Upper	53	15	-	-	15
6/23	Lower	48	10	-	-	10
7/16	Upper	53	20	-	-	20
Total			117		6	

Table 8. Trapping efficiency adjusted for residualism in released fish at fyke trap, Muck Creek, 1980.

Date	Actual release from Table 6	Available for recapture (X 58.4/100)	Adjusted recapture from App. Table 3	% Efficiency	Flow (cfs)	Mean % Efficiency
5/11	39	23	7	30.4	64	
5/16	99	58	31	53.4	64	41.9
5/25	53	31	12	38.7	55	
5/28	56	33	6	18.2	48	28.5
6/13	53	31	20	64.5	38	
6/23	48	28	18	64.3	32	
7/16	53	31	20	64.5	28	64.4

Table 9. Weekly and total population estimate of rainbow/steelhead downstream migrants at fyke trap, Muck Creek, 1980.

Week	Adjusted total catch	# days fished	Expanded total for week
4/23-26	178	4	312
4/27-5/3	335	6	391
5/4-10	411	6	480
5/11-16	1,109	5	1,553
5/18-22	6,246	3	14,574
5/25-30	6,687	3	15,603
6/1-4	9,701	3	22,636
6/8-13	16,824	4	29,442
6/15-19	10,152	3	23,688
6/23-27	5,083	2	17,791
7/1	2,596	1	18,172
7/7-11	981	2	3,434
7/16	251	1	1,757
Total			149,833

The 35-84mm length class predominated, but there was a minor peak at 110-114mm (Figure 5). Although the largest fish measured 250mm, individuals over 175mm were captured very infrequently.

Age-0+ fish averaged 67mm FL and ranged up to 86mm for one individual (Table 10). Age-I+ fish averaged 153mm and ranged from 85 to 210mm. Over half or 63% were smolt-sized. Age-II+ fish averaged 184mm and ranged from 155 to 200mm. Age-I+ fish outnumbered Age-II+ by about 4 to 1 among the smolt-sized fish.

Length-weight relationship was somewhat variable, condition factors being generally higher early and late in the season and lower midway through the study (Table 11). The mean condition factor of smolt-sized fish was slightly lower than that of parr-sized individuals.

Timing of migration varied with fish length. Smolt-sized fish left first, followed by parr, and then subyearling-sized fish (Figure 6, Appendix Table 7). Smolt-sized fish migration had already begun by April 2. For the period of population estimates, median time was the first week of May, although weekly abundance was fairly even from April 23 to May 18. The last individuals were collected during the second week in June.

Parr-sized fish were also already present by April 2, and for the period of population estimates, median time was the second week of May, but weekly abundance was fairly even from May 4 to the 25th. The last parr-sized individuals were collected in the last week of June.

Fry first occurred in the last week of April but their presence was infrequent until mid-May. Median migration time was the first week in June and fry were very abundant from mid-May to the first week of July. Many were still being captured at the end of trapping in mid-July.

A total of 71 coho smolts and nine fry were captured. Smolts ranged from 95 to 250mm FL, with the most common length range being 110 to 125mm. Migration began April 24 and lasted until May 13. Fry ranged from 40 to 65mm, and were captured between May 16 and 25.

Chum fry were numerous even though the mesh of the trap undoubtedly allowed many smaller fry to pass through. A total of 1,530 were captured, ranging from 40 to 80mm. Migration apparently began on April 15 and lasted at least until the last day of the study on July 17. Peak abundance occurred on June 1, when 780 were captured.

Other species included lamprey ammocetes (Petromyzontidae), three-spine stickleback (*Gasterosteus aculeatus*), longnose dace (*Rhinichthys cataractae*), largescale sucker (*Catostomus macrocheilus*), brown bullhead (*Ictalurus nebulosus*) yellow perch (*Perca flavescens*), largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus*), pumpkinseed (*Lepomis gibbosus*), torrent sculpin (*Cottus rhotheus*), and coast range sculpin (*C. aleuticus*).

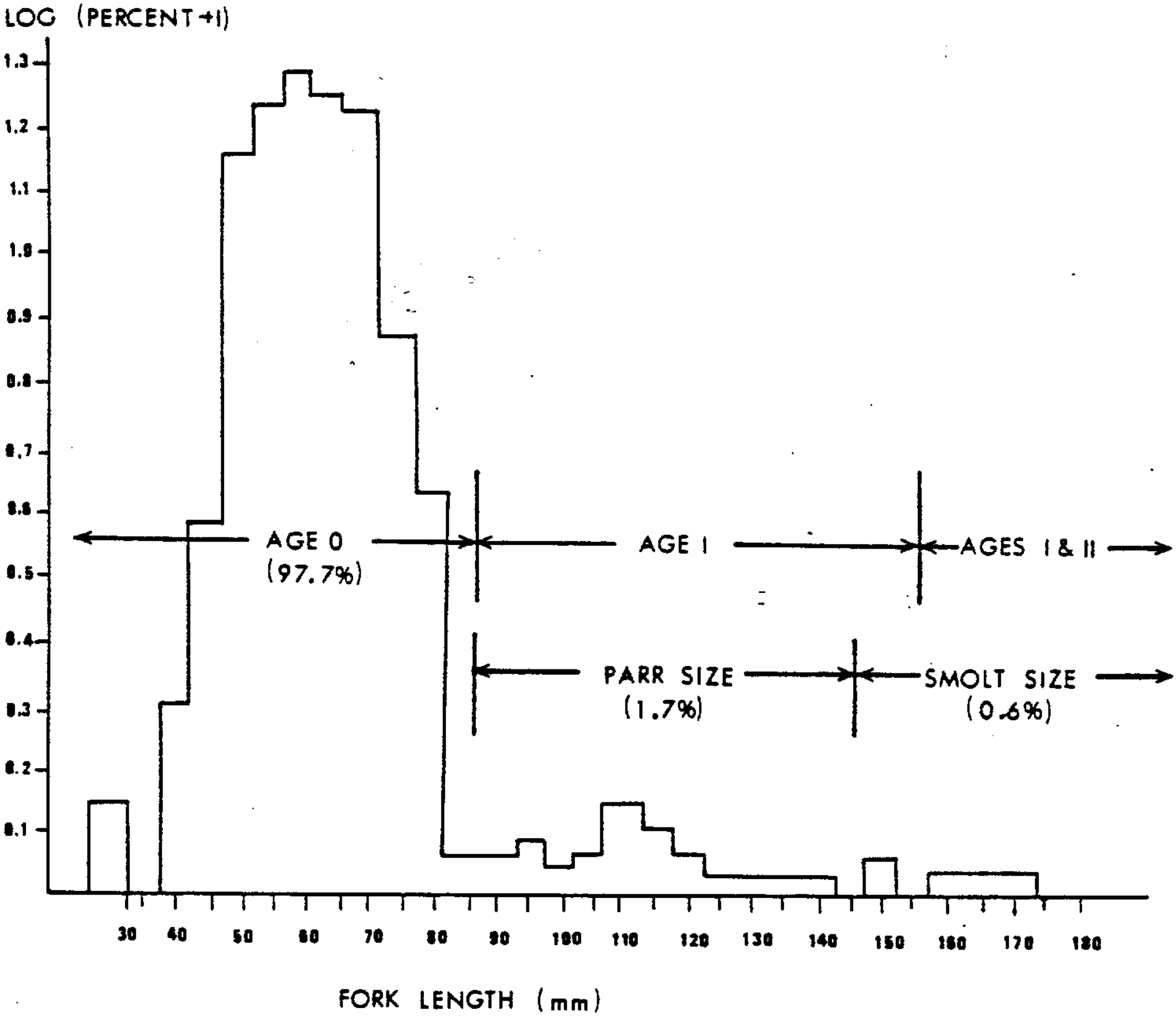

FIGURE 5.

LENGTH FREQUENCY, MUCK CREEK OUTMIGRANT STEELHEAD/RAINBOW TROUT APRIL 24—JULY 17, 1980.

Table 10. Scale analysis and length of Muck Creek outmigrant rainbow/steelhead, 1980.

	Age			
	0 +	I +	II +	Total
N	71	43	6	120
Range	50-86	85-210	155-200	
$\bar{X}$	67	153	184	
Smolt-sized (≥ 145)	0	27	6	33
Percent smolt-sized	0	62.8	100.0	
Percent of smolt-sized fish	0	81.8	18.2	

Table 11. Length and relation to weight for juvenile rainbow/steelhead Muck Creek fyke trap, 1980.

<85mm FL

Period	N	Length(mm) X̄	Length(mm) Range	Weight (g) X̄	Condition factor
5/11-24	86	60	47-80	3.0	1.39
5/25-6/7	77	67	45-84	3.4	1.13
mean					1.26

85-144mm FL

Period	N	Length (mm) X̄	Length (mm) Range	Weight (g) X̄	Weight (g) Range	Condition factor
4/27-5/10	45	120	90-144	25	9-62	1.45
5/11-24	96	113	88-140	16	5-60	1.11
5/25-6/7	16	119	87-143	19	12-32	1.13
6/8-21	18	118	85-144	22	10-40	1.34
mean						1.26

≥145mm FL

Period	N	Length(mm) X̄	Length(mm) Range	Weight(g) X̄	Weight(g) Range	Condition factor
4/27-5/10	51	180	145-231	68	26-120	1.17
5/11-24	24	167	150-220	44	18-75	0.94
6/8-21	8	175	150-230	64	40-150	1.19
mean						1.10

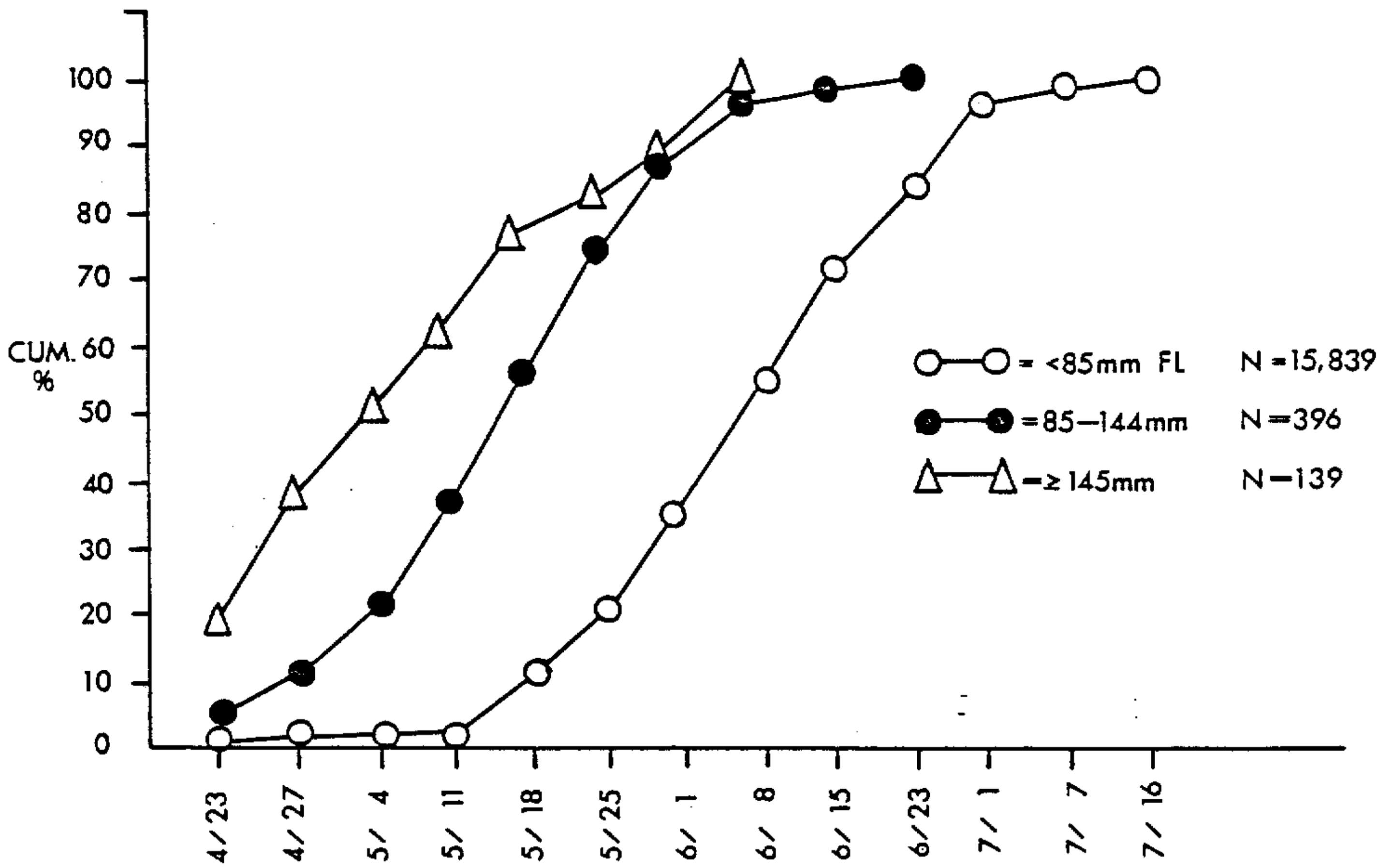

FIGURE 6.

OUTMIGRATION TIMING OF THREE LENGTH GROUPS OF RAINBOW / STEELHEAD TROUT, MUCK CREEK, 1980.

Discussion

All trout fry were considered rainbow/steelhead and not cutthroat because steelhead predominate in Muck Creek. All trout below 85mm appeared very similar in color and markings, and a sample of trout fry examined in the laboratory all had less than 150 lateral line scales, a reliable characteristic of rainbow/steelhead (Jim Johnston, WDG, personal communication). Moreover, steelhead, rainbow outnumbered cutthroat 216:2 in the weir escapement, and 48:1 in June electroshocking at Muck Creek RM 0.8.

Catchable rainbow trout were not considered separately from wild catch because there was no distinct difference in body form or coloring. A similar difficulty occurred in Snow Creek (WDG 1980). Howevever, scale analysis showed no hatchery trout, so these fish were probably not numerous in the catch.

Combining size classes in efficiency tests and in population estimates was justified by chi-square analysis. The recovery rate for length groups above and below 85mm was tested for the first five test dates, when both groups were available. Difference in recovery rate between the groups was not significant at the 95% confidence level (Table 12).

The fyke trap did not catch all of the smallest trout and chum salmon fry, because these fish could pass through the mesh of the net of the live box. Also, late June electroshocking revealed many fry of about 30mm FL in the vicinity of the trap (Appendix Figure 1). However, some of these fish may have been residing in the area, as was the case with Lemhi River fry (Chrisp and Bjornn 1978). These smaller fish probably were destined to outmigrate since the creek flow near the mouth is very low later in the year (Figure 2), so that very little, if any, rearing area remains. Larson and Ward (1954) also reported extensive movement of age-0+ steelhead in the Wynoochee River. Migration there began as early as mid-May and lasted until mid-August. Peak abundance was between late June and mid-July.

The appearance of large age-0+ trout in April signifies probable emergence in February, while the presence of newly-emerged fry in June shows emergence at least up to that point. Spawning must begin in December and continue through early May. This is possible because steelhead begin to enter Muck Creek in mid-December and continue until early or mid-March (USFWS 1981). Mean age of subyearlings was calculated to be 54 days (Table 13), assuming adults spawned immediately after ascending above the weir. Actual age could be less.

Table 12. Chi-Square tests for differences in release/recovery ratio among two length classes of rainbow/steelhead for efficiency tests at fyke trap, Muck Creek, 1980.

Date	$\overline{X}$	P
5/11	1.386	>0.1
5/16	0.902	>0.1
5/25	2.171	>0.1
5/28	1.064	>0.1
6/13	0.016	>0.5

Table 13. Calculation of peak steelhead emergence time on Muck Creek, 1980.

Peak adult entry: Feb. 15

Degree days to emergence:

Month	Mean monthly temperature (°C)	days	Cumulative degrees
Feb	7	15	105
Mar	8	31	353
Apr	10	15	150
		Total	608
		required for emergence	606 [a]

Calculated peak emergence: Apr 15

Peak juvenile migration : June 8

Calculated age at migration: 54 days

a. Thom Johnson, WDG, personal communication.

The 1979-80 steelhead escapement to Muck Creek included 134 females (USFWS 1981). If the total age-0+ steelhead production equalled the April 23 to July 17 outmigration, survival to outmigrant fry would be 1014/female. Actual survival is probably higher because a few fish emigrated before or after sampling. In contrast, survival at Snow Creek is calculated as 262 two-month-old fry per female, assuming mean fecundity of 4,000 eggs, 16.8% survival to emergence, and 30% survival from emergence to capture by electroshocking two months later (Thom Johnson, WDG, personal communication). Survival at Muck Creek was much higher than at Snow Creek, even though age at Muck Creek was only slightly less than at Snow Creek. Perhaps predators are fewer in an intermittent stream like Muck Creek than in a permanent stream like Snow Creek.

First-year growth was more rapid in Muck Creek than in other streams in western Washington (Pam Knudsen, Fishery Research Services, personal communication). This is probably due to early spawning and relatively high temperatures in late winter and early spring (Figure 3), due, in turn, to the fact that the stream is largely spring-fed. Parr-sized outmigrants, those between 85 and 144mm, were much larger at Muck Creek than yearlings at Big Springs Creek in the Snake River drainage, Idaho, where parr averaged 85-95mm (Chrisp and Bjornn 1978) and in Gobar Creek, where they averaged 95mm (Crawford et al. 1979), from March to June.

Age-I+ outmigrants were about the same size at Muck Creek and Gobar Creek, where they averaged 156mm, but Muck Creek smolt-sized outmigrants, those over 145mm, averaged 177mm, somewhat larger than Gobar Creek age-I+ smolts and closer to Peterson and Elkhorn Creek smolts, which averaged 170mm (Scarlett and Cederholm, WDNR, in preparation).

Spring outmigration of fry and parr is also probably temperature-influenced, because most of Muck Creek becomes warmer than the mainstem Nisqually during the summer. Low flows probably add to the pressure to outmigrate due to decreasing space. Low flows are probably more important than temperature in the lower part of the creek, because although this section is relatively cool, it is frequently dry in September and October (Pearson and Dion 1979).

Rapid spring growth and decreasing summer habitat suitability together cause a higher proportion of outmigrant fry than at any location yet reported on Puget Sound, to our knowledge. The fact that there are more parr than smolt in the outmigration, however, is similar to the composition on Andrews Creek and Alder Creek (WDG 1980, 1979), Gobar Creek (Crawford et al. 1979), and Peterson and Elkhorn Creeks (Scarlett and Cederholm, WDNR, in preparation), being tributaries of Snow Creek, the Skagit River, the Kalama River, and the Clearwater River, respectively.

Timing of migration generally fell within the ranges reported in the literature, except that fry migration was highly unusual, being very early. Parr outmigration in early May was within the range established at Alder Creek, where peak migration might occur from late April to late May (WDF 1980, 1979), and at Gobar Creek from mid-April to mid-May (Chilcote et al. 1980; Crawford et al. 1979). It was later than the late April peak emigration, however, on Andrews Creek (UWFWS and WDF 1980, 1979), the Quinsam River (Reinhardt 1978, 1977), and Peterson and Elkhorn Creeks (Scarlett and Cederholm, WDNR, in preparation).

Smolt outmigration peaked in late April. This was within the range of mid-April to mid-May peak migration reported for other Washington streams.

NISQUALLY RIVER

Methods

The inclined plane trap design was based upon the Washington Department of Fisheries (WDF) plans for a 1.83m^2 scoop trap. The trap has a 1.83m mouth facing upstream. The inclined plane (scoop) is 4.88m long and rises 1.57m in that length, and spills into a 1.83m X 1.83m X 1.04m live box (Figure 7). The inclined plane and the sides of the scoop are covered with wire screening, 16 gauge, 4 holes to the inch, and galvanized after weaving. The walls of the live box were covered with 1.59mm mesh vexar during much of the period, as the wire screening was not holding small salmonids (30-50mm) in the box.

The scoop trap was fished at RM 4.1 of the lower Nisqually River. This site is immediately above the highest extent of tidal influence (RM 3.8). The trap was moored immediately adjacent to the revetment of the left bank of the river, straddling the swiftest river current. The remainder of the river at this point is all back eddy over to the right bank. Current velocity at the mouth of the trap was measured throughout the study period. Surface velocity averaged 4 feet per second (fps); velocities 0.6m down were more constant at 6 fps from early March through the end of May. Surface velocities ranged greatly, due to water turbulence; the extremes of the surge were 2.5 to 4.5 fps. During June, the surface velocities stayed at 4 fps, and the surge lessened considerably; velocity 0.6m down decreased to 5 fps. No velocity measurements were taken during high water periods. The current is focused by the revetment at this location. Immediately upstream of the revetment, the river velocity is fairly uniform across the entire channel.

The trap fished 5-6 nights weekly from dusk to dawn. The trap was attended at all times while it was fishing, and the catch was generally removed two to five times nightly.

Removing the catch entailed lifting and cleaning the trap, transferring the catch into buckets and then lowering the trap into fishing position again.

All rainbow/steelhead in the catch were counted. Smolts were distinguished regardless of size by silvery color, lack of parr marks, and black on fin edges. Parr were defined as non-smolts from 70 to 145mm FL, fry as rainbow/steelhead under 70mm, and resident rainbow as non-smolts over 145mm. Parrs and smolts were measured; scales were taken and dorsal condition examined on smolts whenever possible. Flood conditions sometimes made this detailed sampling impractical without harming the fish, and in these cases, fish were counted or estimated and released as quickly as possible.

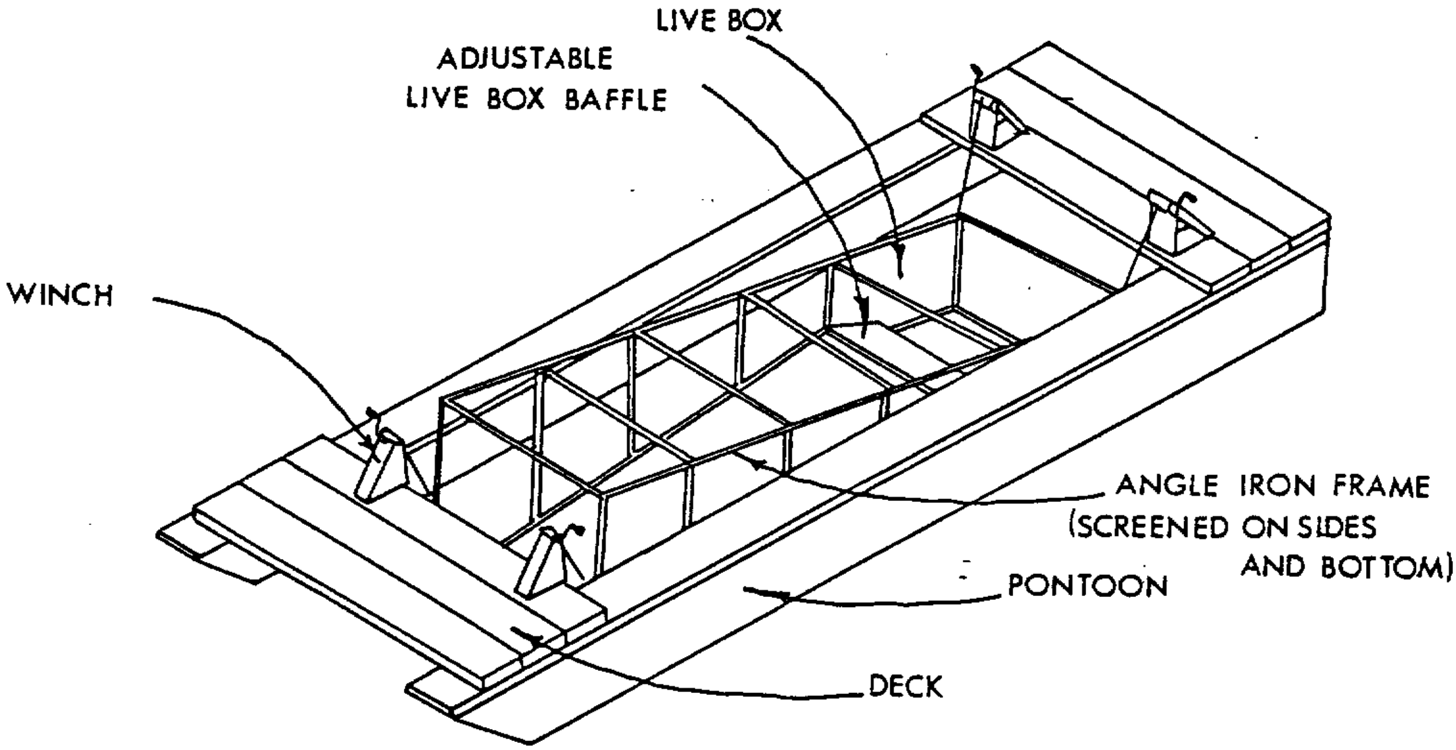

FIGURE 7.

INCLINED PLANE TRAP USED IN NISQUALLY RIVER.

(NOT TO SCALE)

Hatchery/wild determination was made for most periods of the run. All fish caught on or before April 17, when the first plant was made, were considered wild. The composition of the run on April 23 and 24 was not examined. From April 25 to July 8 the composition was determined from the ratio of hatchery scales to total scales read.

The periods of April 27 to May 5 and May 20 to June 8 were combined to get a larger sample size. For each group, mean percent hatchery fish, weighted by the total catch for each day examined, was calculated.

Results

The trap captured a total of 671 steelhead smolts in 68 nights of trapping between March 12 and July 2 (Table 14). A few parr were captured, but fry and resident rainbow were very infrequent.

All fish caught on or before April 17 were wild. Hatchery fish were predominant on April 25 and decreased in percent through the end of the study (Table 15, Appendix Table 8).

Hatchery smolts were slightly larger than wild smolts although there was considerable overlap (Figure 8).

Hatchery fish ranged in length from 120 to 250mm, with a mean of 208mm. Age-I+ wild fish ranged from 130 to 199mm with a mean of 171mm. Age-II+ wild fish ranged from 160 to 239mm with a mean of 201mm. The sample was evenly divided between the two age classes (Table 16, Figure 8), and mean wild length was 188mm. Parr averaged 108mm FL, with a range of 69 - 140mm. Smaller, younger wild smolts migrated later than larger, older ones (Table 17).

The natural smolt run began on March 16 and the last capture was on July 8. Hatchery smolts were planted from April 17 to May 7. Their migration was also apparently complete by June 8. The hatchery migration peaked earlier than the natural run. Parr were present the first night of trapping on March 12 and were occasionally captured until May 24. They were slightly more abundant in mid-April than at other times.

Other species captured included chum fry, coho smolts, chinook (*O. tshawytscha*) smolts, lamprey ammocetes, sculpins (*Cottus* spp), and yellow perch.

Discussion

The total population of hatchery plus wild steelhead smolts could not be estimated because the study did not fulfill the requirements of the Petersen method, which demands that either tagging or recovery be random over time (Youngs and Robson 1978). Release of hatchery fish is the equivalent of marking a sample of the total population. Release was clearly not random over time, so random recovery was required. Randomness could not be demonstrated because catch was positively correlated with flow (Figure 9). Therefore, recovery effort could have been biased toward times of high flow. This bias was not verified because efficiency tests were not performed.

Table 14. Scoop trap rainbow/steelhead catch, Nisqually River, 1981.

Date	Fry[a]	Parr[b]	Smolt[c]	Resident rainbow[d]
3/12	0	3	0	0
13	0	3	0	0
14	0	0	0	0
16	0	2	1	0
17	0	2	0	0
18	0	1	1	0
23	0	1	0	0
24	0	1	1	0
25	0	0	0	0
30	0	0	0	0
31	0	0	1	0
4/ 1	0	0	2	0
7	0	0	0	0
9	0	0	0	0
10	0	2	0	0
11	0	5	4	0
12	0	0	0	0
13	0	0	6	0
14	0	7	0	0
15	0	2	0	0
4/16	0	0	0	0
17	0	2	1	0
21	0	0	0	0
22	0	0	1	0
23	0	0	52	1
24	0	0	70	0
25	0	0	70	0
27	0	4	18	2
28	0	1	38	0
29	0	0	71	0
30	0	0	76	0
5/ 1	0	0	52	0
2	0	0	56	0
7	0	0	7	1
10	0	0	1	0
11	1	0	1	0
13	0	1	1	0
14	0	0	0	0
16	0	0	10	0
17	1	0	2	0
20	0	0	6	0
21	0	0	12	0
22	0	0	4	0

Table 14 continued

Date	Fry[a]	Parr[b]	Smolt[c]	Resident rainbow[d]
23	0	1	4	0
24	0	1	0	0
25	0	0	46	0
26	0	0	27	0
27	0	0	15	0
28	0	0	5	0
29	0	0	0	0
30	0	0	6	0
31	0	0	0	0
6/ 1	0	0	1	1
3	0	0	0	0
5	0	0	0	0
6	0	0	0	0
8	0	0	2	0
16	8	0	0	0
17	0	0	0	0
18	0	0	0	0
19	0	0	0	0
23	0	0	0	0
6/24	0	0	0	0
25	0	0	0	0
26	0	0	0	0
30	0	0	0	0
7/ 1	0	0	0	0
2	1	0	0	0
Total	11	39	671	5
Percent	1.5	5.4	92.4	0.7

a. Less than 65mm FL
b. From 65 to 140mm FL without smolt characteristics
c. Body silvery, fins dark on edges, scales deciduous
d. Over 140mm FL without smolt characteristics

Table 15. Hatchery-wild steelhead composition, Nisqually River, scoop trap catch, 1980. Percent hatchery is weighted by total daily catch.

Date	Percent hatchery	Number examined
3/12 -4/17	0.0	8
4/23-24	-	0
4/25	95.2	21
4/27 - 5/7	55.2	48
5/20 - 6/8	18.6	16

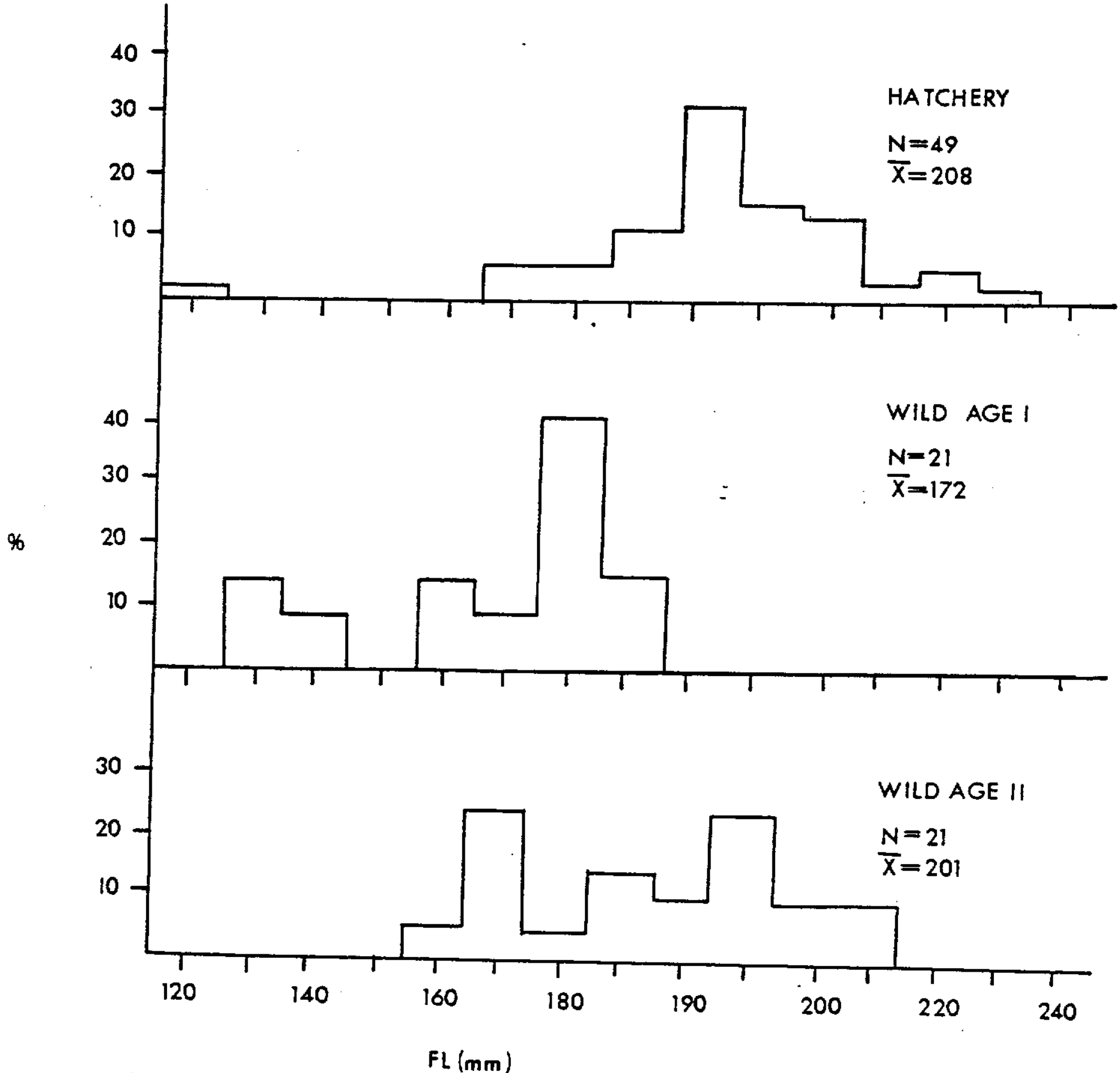

FIGURE 8.

LENGTH FREQUENCY OF HATCHERY AND WILD STEELHEAD SMOLTS AT SCOOP TRAP, NISQUALLY RIVER, 1981.

Table 16. Wild steelhead smolt timing by age and length, Nisqually River scoop trap, 1981

Period	Age I +	Age II +
4/1-13	3	4
4/25-5/7	9	13
5/20-6/8	10	4
	22	21

$\overline{X} = 30.751$ df=2 $P < 0.005$

Period	N	Length (mm) $\overline{X}$	Length (mm) Range
4/1-13	7	192	160-219
4/25-5/7	22	196	130-239
5/20-6/8	14	173	130-250

$F = 11.93$ df = 2,40 $P < 0.001$

Table 17. Age composition, of wild steelhead smolt captured at Nisqually River scoop trap, 1981.

Period		Age %		
	N	I +	II +	III +
4/1 - 5/7	29	41.4	58.6	0.0
5/20 - 6/8	15	66.7	26.7	6.7
Total	44	50.0	47.7	2.3

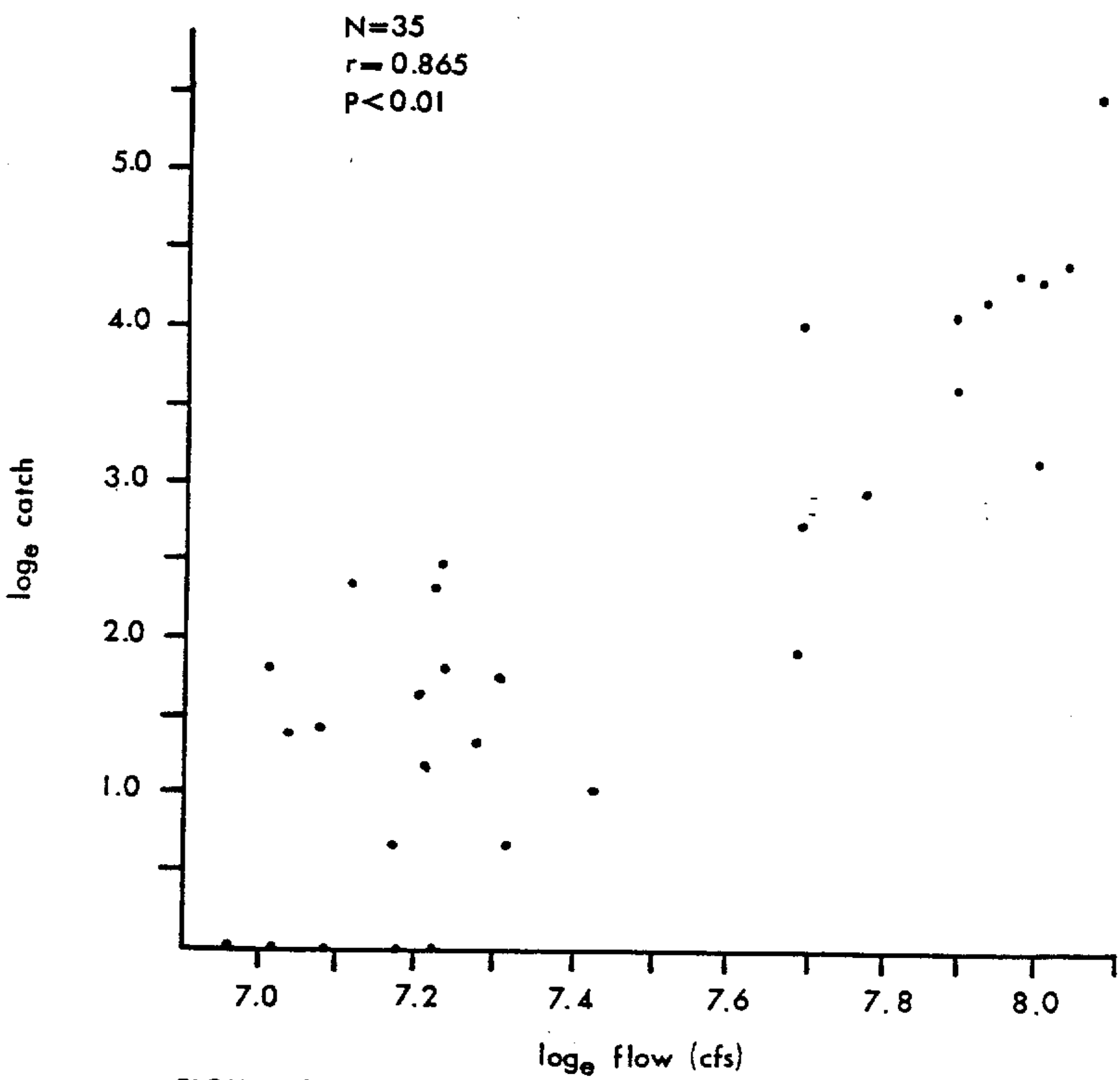

FIGURE 9.
STEELHEAD SMOLT CATCH AND STREAM FLOW
AT NISQUALLY SCOOP TRAP 1981.

Constant flow would facilitate determination of migration timing. Nisqually flow was relatively constant in May, June, and July of 1980 (Appendix Table 9). The smolt run declined during the trapping period, which began on May 9. The level of migration was relatively high through late June, and lasted until early July.

High flow is not always related to high catch. High flow was associated with low trap catch of hatchery smolts on the Trinity River, in contrast to low flows and higher catch in the previous year (Healey 1970). High flows also delayed peak hatchery smolt migration for about one month after release.

The hatchery/wild determination is probably valid for the periods for which it was calculated, despite the changes in flow, because there is evidence that the trap did not discriminate on the basis of fish length in varying flows (Table 18). We divided the catch into two time periods corresponding to higher and lower mean size of fish, which were caught earlier and later in the season. Each period had days of high and low flows. Analysis of variance showed no significant difference of length among different flows. Thus, the trap was not significantly selective for hatchery fish or age-II+ wild fish at the flows encountered. The observed age composition is probably representative because scale samples were taken randomly with respect to fish length (Table 19) and date (Table 20).

The Nisqually outmigration characteristics are best compared to those described in other mainstem outmigration studies as performed on Snow Creek, Salmon Creek, and the Skagit, Lemhi, and Kalma Rivers (Table 1). In all these cases, smolt occurrence predominated over that of parr. The high smolt/parr ratio (at Nisqually RM 4) suggests that the site represents production of the entire system and is suitable for obtaining an annual index of abundance. Nisqually parr outmigration began and ended earlier than at Snow Creek. Migration began at the same time as on the Kalama but ended much sooner. Smolt outmigration timing coincided with Snow and Salmon Creeks, but the Nisqually run ended earlier than that on Salmon Creek, but later than that on the Chehalis River. There is some evidence for a fall-winter smolt run in some locations (WDG 1980; Healey 1970). It is possible, therefore, that the entire outmigration was not sampled.

The high proportion of age-I+ wild smolts is unusual in western Washington. Only the Samish River has shown a similarly high proportion (Phillips et al. 1980, Appendix Table 10).

Smolts were generally larger than on other mainstem rivers, the mean FL being 188mm; on the Sauk and its tributaries it was 170mm (Muller 1981), and on the Kalama, 164mm (Crawford et al. 1979). Age-I+ smolts averaged 172mm, compared to 143 on the Kalama (Chilcote et al. 1980). Age-II+ smolts averaged 201mm, in comparison to 195 on the Lemhi (Chrisp and Bjornn 1978) and 159 on the Kalama (Chilcote et al. 1980).

Parr were also larger, averaging 108mm in comparison with 90-100mm on the Sauk (Muller 1981), 105mm on the Lemhi (Chrisp and Bjornn 1978), and 86 to 93mm on the Kalama (Chilcote et al. 1979). Growth is apparently faster in the Nisqually than in most rivers in the area.

Table 18. Size structure of Nisqually River scoop trap steelhead smolt catch versus flow, 1981.

April 27 - May 2

Length (mm)	Flow (cfs)				
	1500	2400	2700	2900	3000
$\bar{X}$	177	196	200	189	194
N	6	16	27	20	41

$F = 0.890$ df=4,60 $p > 0.25$

May 17 - June 8

Length (mm)	Flow (cfs)		
	1500	2200	3100
$\bar{X}$	161	172	177
N	16	13	12

$F = 1.989$ df=2,33 $P > 0.10$

Table 20. Timing of Nisqually River scoop trap 1981 steelhead smolt catch versus number of readable scales collected.

Period	Catch	Scales	Percent
3/16 - 4/17	17	7	41.2
4/21 - 25	193	22	11.4
4/27 - 5/2	311	46	14.8
5/7 - 16	20	2	10.0
5/17 - 23	28	5	17.9
5/24 - 6/8	102	11	10.8
Total	671	93	

$X^2 = 10.183$ df=5 $P > 0.05$

RELATION BETWEEN MUCK CREEK AND NISQUALLY STUDIES

Muck Creek steelhead life history differed from the Nisqually system as a whole. Muck Creek emergence was much earlier than reported for the mainstem, which was from May through September and peaked in July (Tyler 1979).

Smolt-sized outmigrants from Muck Creek were younger, on the average, than smolts representing the entire Nisqually system. Muck Creek smolt-sized fish were 82% age-I+ , but mainstem smolts were only 50% age-I+. Adult returns show a similar difference. Muck Creek returns had reared an average of 1.5 years in fresh water while fish representing the whole system reared 1.9 years (Table 21). The difference may be due to higher temperatures in Muck Creek (Figure 3). Symons (1978) showed that age of Atlantic salmon (S.salar) smolts depended largely on number of days the temperature of the rearing stream exceeded 7 C. A higher proportion of smolts than adults reared one year in fresh water both on Muck Creek and on the mainstem Nisqually This could be due to several factors. First, some parr may have been recorded as smolts, especially on Muck Creek where all fish over 145mm FL were classified as smolts. Second, smolts rearing only one year in fresh water may have poorer ocean survival than those rearing two years. Finally, rearing conditions that favored younger smolts in 1980 may not have been present in years when 1979 and 1980 adult returns were rearing.

A decrease in smolt length over the season was observed on the Nisqually River and might reflect a change in age composition as observed in the Kalama (Chilcote et al. 1980).

Muck Creek's high ratio of subyearlings and parr to smolt, and the Nisqually River's high ratio of smolt to parr is similar to the respective parr-smolt composition of Snow Creek and its tributary Andrews Creek, the Kalama River and Gobar Creek, the Skagit River and Alder Creek, and the Lemhi River and Big Springs Creek (Table 1). This implies that many subyearlings and parr rear in the mainstem. However, some fish may ascend Muck Creek to overwinter, as occurred in Peterson and Elkhorn Creeks, tributary to the Clearwater River (Scarlett and Cederholm, WDNR, in preparation), where age-0+ and age-I+ steelhead, in a 70-30 ratio, accounted for the entire steelhead population of the creeks, entering in October and November from the mainstem Clearwater apparently upstream of the tributaries. A similar upstream migration might be expected on Muck Creek, which is warmer than the mainstem during the winter. If so, outmigrant smolt and parr from Muck Creek would not necessarily represent Muck Creek spawners. In any case, numbers of these fish are not necessarily proportional to the number of Muck Creek spawners that produce them.

Table 21. Freshwater rearing time for wild adult steelhead at Muck Creek and mainstem Nisqually River.

Location Capture	Year	N	Percent years reared in FW[a] 1	2	3	Mean FW age
Muck Creek	1979-80	152	30.5	68.2	1.3	1.7
Muck Creek	1980-81	169	68.6	30.8	0.6	1.3
Muck Creek	Combined	321	49.5	49.5	1.0	1.5
Frank's Landing	1979-80	130	7.7	90.8	1.5	1.9

a. Eric Knudsen, Fisheries Research Service, personal communication, contracted by Nisqually Tribe.

SUMMARY

Conclusions

1. An estimated 796 smolt-sized (> 145mm FL) rainbow/steelhead trout, 2,470 parr-sized fish (85 - 144mm), and 138,000 subyearling-sized individuals (< 85mm) migrated down Muck Creek to the mainstem Nisqually River between April 23 and July 17, 1980. Approximately 1,010 subyearling sized fish were produced per spawning female.

2. Smolt-sized rainbow/steelhead trout migration on Muck Creek began before April 2, peaked in the first week of May, and was essentially complete by the first week of June. Parr-sized fish migration began before April 2, peaked in mid-May and continued until the third week of June. Subyearling-sized fish migration began before April 2, peaked in the first week of June, and was continuing when the project ended on July 17.

3. Smolt-sized fish were 82% age- I+ and 18% age- II+. Parr-sized fish were all age- I+.

4. The Muck Creek run is neither an independent population nor is it representative of the Nisqually drainage in general, in life history. Outmigrant smolt and parr do not necessarily represent the total survival from Muck Creek spawning, because emigration is mainly age- 0+ fish. Also, smolt and parr originating outside the creek could have entered in the winter. This makes it unlikely that Muck Creek can be used as an index of the entire Nisqually steelhead resource.

5. Steelhead emerge unusually early and grow extremely rapidly in Muck Creek, probably because the creek is warmer than the mainstem in late winter and early spring. Rapid growth leads to a large proportion of yearling smolts, which is reflected in Muck Creek returns, so that outmigrant population estimates cannot be relied on to predict mainstem returns.

6. The mainstem Nisqually outmigrant catch consisted of 92% smolts, 5% parr, 2% fry, and 1% resident rainbow trout, by numbers. Smolts were distinguished from parr and residents by color, not size in the Nisqually study. Hatchery smolts made up 95% of the run shortly after release, and decreased to 19% at the end of the run.

7. Wild smolt migration began on March 16. Hatchery plants were begun on April 17 and dominated the catch by April 25. Migration of both hatchery and wild fish was virtually complete by June 8. Parr migration began on March 12 and and was essentially over by May 24.

8. Hatchery smolts averaged 208mm FL. Wild smolts were 49% age- I+, 49% age- II+, and 2% age- III+. Age- I+ smolts averaged 172mm FL and age- II+, 201mm. Parr averaged 108mm FL.

9. Age-II+ wild smolts were most abundant in the first half of the run and age- I+ fish were more abundant in the second half of the run.

10. The Nisqually scoop trap catch consisted primarily of smolts, indicating site suitability for obtaining annual index of abundance, for eventual prediction of adult returns.

Implication for Study Area

The Muck Creek activities established that that area is important for steelhead spawning and early rearing. The Nisqually activities established the lower river just above tidewater mainly as a migration route. The presence of a few parr suggests some residence in the area. Population estimation of wild outmigrants by using hatchery smolts is theoretically possible, by marking a portion of hatchery fish to determine recovery rate for various times of release or hatchery of origin. Alternatively, wild smolts captured in the trap could be marked and released upstream to determine efficiency. In either case, the resulting population estimates will enable calculation of survival to adult and hatchery contribution to the catch. Even if population estimates are not made, scoop trapping can yield estimates of relative abundance useful in predicting adult returns. However, returns will have to be carefully monitored to make smolt trapping a useful predictive device.

ACKNOWLEDGEMENTS

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APPENDIX

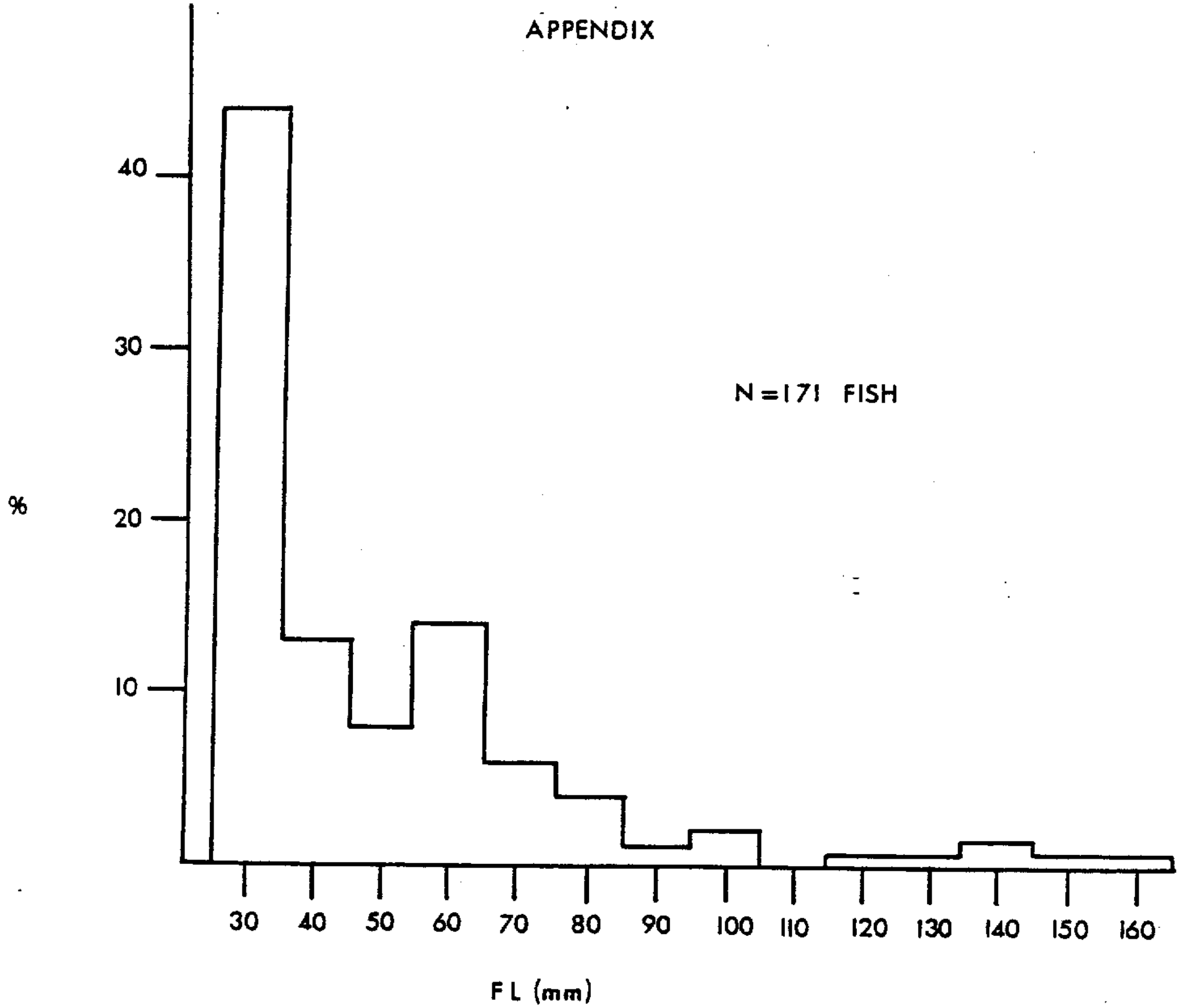

FIGURE I.
LENGTH OF JUVENILE RAINBOW/STEELHEAD TROUT FROM ELECTROSHOCKING IN VICINITY OF FYKE TRAP SITE AT MUCK CREEK ON JUNE 27, 1980.

Appendix Table 1. Periodicity of juvenile steelhead/rainbow catch in fyke trap at Muck Creek, May 28-29, 1980

Time	Catch				
	≤85mm	85-144mm	≥145mm	Total	Percent
1900-2100	2	3	0	5	1.7
2100-2300	51	4	1	56	19.3
2300-0100	67	0	0	67	23.1
0100-0300	60	9	0	69	23.8
0300-0500	59	15	2	76	26.2
0500-0700	6	0	0	6	2.1
0700-0900	3	0	0	3	1.0
0900-1200	5	0	0	5	1.7
1200-1300	2	0	0	2	0.7
1300-1500	0	0	0	0	
1500-1800	0	0	0	0	
1800-1900	0	0	1	0.3	

Appendix Table 2. Fyke trap efficiency for capture of steelhead/rainbow, Muck Creek, 1981. Fish released 50m upstream of trap.

Date	Release					Recapture				
	Time	Number				Time	Number			
		<85mm	85-144mm	≥145mm	Total		<85mm	85-144mm	≥145mm	Total
5/11-12	2400	23	13	3	39	0500	2	3	1	6
16-17	"	73	21	5	99	0400	16	8	1	25
25-26	2100	50	3	0	53	0300	7	2	0	9
28-29	2300	51	4	1	56	1900	6	0	0	6
6/13-14	2100	38	14	1	53	0300	11	4	0	15
23-24	2000	48	0	0	48	0200	10	0	0	10
7/16-17	2400	53	0	0	53	0600	20	0	0	20
Total		336	55	10	401		72	17	2	91

Appendix Table 3. Efficiency test recapture adjusted for diurnal periodicity of migration, Muck Creek fyke trap, 1980.

Date	Actual catch	Correction factor	Adjusted catch
5/11	6	1.20	7
5/16	25	1.25	31
5/25	9	1.33	12
5/28	6	1.00	6
6/13	15	1.33	20
6/23	10	1.75	18
7/16	20	1.00	20

Appendix Table 4. Data for regression analysis of percent recovery versus days after release of marked fish in Muck Creek fyke trap efficiency tests, 1980.

Marking				Delayed recapture			
Days after release		Percent recovered		Days after release		Percent recovered	
X	$\sqrt{X}$	Y	log (Y+1)	X	$\sqrt{X}$	Y	log (Y+1)
0	0	86	1.94	5	2.24	14	1.18
0	0	93	1.97	6	2.45	7	0.90
0	0	100	2.00	3	1.73	0	0
0	0	90	1.96	4	2.00	10	1.04
0	0	75	1.88	6	2.45	25	1.41
0	0	100	2.00	6	2.45	0	0
0	0	100	2.00	4	2.00	0	0

r = -0.798 $\log(Y+1) = -0.558\sqrt{X} + 1.916$

Appendix Table 5. Percent of marked fish recovered each night, with adjustment for actual nights fished at Muck Creek fyke trap. 1980.

Days after recovery		Percent of actual recovery		Percent of Total recovery
X	√X	log (Y+1)	Y	Y X 100/139.4
0	0.000	1.916	81.4	58.4
1	1.00	1.358	21.8	15.6
2	1.414	1.127	12.4	8.9
3	1.732	0.950	7.9	5.7
4	2.000	0.801	5.3	3.8
5	2.236	0.669	3.7	2.7
6	2.449	0.550	2.6	1.9
7	2.646	0.440	1.8	1.3
8	2.828	0.339	1.1	0.8
9	3.000	0.243	0.8	0.6
10	3.162	0.153	0.4	0.3
11	3.317	0.066	0.2	0.1
Total			139.4	100.0

Appendix Table 6. Estimated daily population of rainbow/steelhead downstream migrants at Muck Creek fyke trap at RM 0.5, 1980.

Date	Catch	Correction factor for periodicity	Corrected catch	Correction factor for efficiency	Estimated population
4/2	20	1.08	22	Not available	-
4	11	"	12	"	-
7	7	"	8	"	-
9	4	1.68	7	"	-
11	1	1.08	1	"	-
14	3	1.07	3	"	-
15	1	1.08	1	"	-
16	2	"	2	"	-
23	13	1.55	20	2.39	48
24	6	1.53	9	"	22
25	11	"	17	"	41
26	18	"	28	"	67
27	7	1.35	9	"	22
28	12	"	16	"	38
29	11	"	15	"	36
30	15	"	20	"	48
5/2	22	1.53	34	"	81
3	30	"	46	"	110
4	17	"	26	"	62
5	15	"	23	"	55
5/7	20	"	31	"	74
8	13	"	20	"	48
9	12	"	18	"	43
10	34	1.59	54	"	129
11	69	1.58	109	"	261
12	11	1.59	17	"	41
13	32	1.62	52	"	124
14	52	1.59	83	"	198
16	165	1.23	203	"	485
18	32	1.43	46	"	110
20	527	1.70	896	3.51	3,145
22	600	1.42	852	"	2,991
25	588	"	835	"	2,931
28	290	1.00	290	"	1,018
30	549	1.42	780	"	2,738
6/1	451	1.71	771	"	2,706
3	823	1.23	1012	"	3,552
4	691	1.42	981	"	3,443
8	905	2.12	1919	"	6,736
9	703	1.73	1216	"	4,268
12	480	1.70	816	"	2,864

Appendix Table 6 continued.

Date	Catch	Correction factor for periodicity	Corrected catch	Correction factor for efficiency	Estimated population
13	1343	1.42	1907	1.55	2,956
15	1869	1.70	3177	"	4,924
6/17	1125	"	1913	"	2,965
19	859	"	1460	"	2,263
23	1623	1.43	2321	"	3,598
27	557	1.72	958	"	1,485
7/1	974	"	1675	"	2,596
7	442	1.03	455	"	705
11	178	1.00	178	"	276
16	132	1.23	162	"	251

Appendix Table 7. Rainbow/steelhead outmigration timing by length class at Muck Creek fyke trap, 1980.

Week beginning	Length (mm)					
	<85		85 - 144		≥145	
	#	cum %	#	cum %	#	cum %
4/23	49	0.0	98	4.0	147	18.5
4/27	38	0.1	175	11.1	156	38.1
5/4	106	0.1	246	21.0	102	50.9
5/11	985	0.9	398	37.2	91	62.3
5/18	13,061	10.3	478	56.5	123	77.8
5/25	14,140	20.6	453	74.9	29	81.4
6/1	20,856	35.7	297	86.9	64	89.4
6/8	27,378	55.5	221	95.9	83	100.0
6/15	22,398	71.7	67	98.6	0	-
6/23	16,836	83.9	34	100.0	0	-
7/1	17,234	96.4	0	-	0	-
7/7	3,259	98.8	0	-	0	-
7/16	1,666	100.0	0	-	0	-
Total	138,007		2,468		796	

Appendix Table 6 continued.

Date	Catch	Correction factor for periodicity	Corrected catch	Correction factor for efficiency	Estimated population
13	1343	1.42	1907	1.55	2,956
15	1869	1.70	3177	"	4,924
6/17	1125	"	1913	"	2,965
19	859	"	1460	"	2,263
23	1623	1.43	2321	"	3,598
27	557	1.72	958	"	1,485
7/1	974	"	1675	"	2,596
7	442	1.03	455	"	705
11	178	1.00	178	"	276
16	132	1.23	162	"	251

Appendix Table 8. Hatchery-wild steelhead composition, Nisqually River. scoop trap, 1981.

Date	Total Catch	Scales			Dorsal fins		
		Hatchery	Total	% Hatchery	Hatchery	Total	% Hatchery
4/25	70	20	21	95.2	10	69	14.5
27	18	7	10	70.0	5	18	27.8
28	38	10	16	62.5	6	26	23.1
29	71	4	13	30.8	35	61	57.4
30	76	5	7	71.4	-	-	-
5/7	7	1	2	50.0	1	6	16.7
20	6	0	2	0.0	0	6	0.0
21	12	0	3	0.0	2	6	33.3
25	46	0	7	0.0	21	46	45.7
26	27	2	3	66.7	15	27	55.6
6/8	2	0	1	0.0	0	2	0.0

Appendix Table 9. 1980 steelhead smolt catches at the Nisqually River scoop trap.[a]

Calendar night	Study night	Total	Number per hour	Stub dorsal ratio
5/9	58	0	-	-
5/9-10	59	6	1.5	1/6
5/14-15	64	2	0.4	0/2
5/15-16	65	2	0.4	1/2
5/20-21[b]	70	7	2.2	1/7
5/21-22	71	12	2.4	1/12
5/22-23	72	10	2.4	0/10
5/23	73	6	4.5	-
6/3-4	84	2	0.5	0/2
6/4-5	85	3	0.6	3/3
6/5-6	86	4	0.9	1/4
6/10-11	91	3	0.4	0/3
6/11-12	92	3	0.4	1/3
6/17-18	98	6	0.9	0/6
6/18-19	99	4	0.5	2/4
6/24-25	105	1	0.1	0/1

a. Source: Nisqually Indian Tribe, personal communication.

b. Trap moved upstream approximately 5m into faster water.

Appendix Table 10. Samish River wild steelhead outmigrant age composition from 1979 adult sampling.[a]

Source	N	Age % at smolt I +	II +	III +
Trap	185	71.1	25.5	3.4
Creel census	32	52.3	43.0	4.8

a. Source: Phillips *et al*. 1980