Fishery Data Series No. 92-55

An Evaluation of Juvenile Hatchery Steelhead in the Ward Creek System, Ketchikan, Alaska, 1991

by

Glenn M. Freeman

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[1] This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-7, Job No. E-1-1, and the United States Forest Service Sykes Act, December 12, 1975, Public Law 93-452 (16 U.S.C. 565 A-1 to A-3 and 670 G, 670 H, and 670 O).

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ABSTRACT

Approximately 12,000 one-year-old steelhead *Oncorhynchus mykiss* from the Klawock Lake Hatchery were planted into Ward Creek, near Ketchikan, Alaska, on May 28, 1991. Prior to stocking, a sample of these steelhead had a mean length of 160 millimeters fork length (SD = 14 millimeters), and a mean weight of 46 grams. The fish were reared to this size so that most fish would smolt and leave Ward Creek, without overwintering.

A mark-recapture experiment was used to estimate that 1,318 (SE = 114) juvenile hatchery steelhead ≥110 millimeters remained in the Ward Creek system in August, 1991.

Mean length of hatchery fish captured between July 22 and August 5 was 146 millimeters fork length (SD = 14 millimeters), and the mean length of hatchery fish captured between August 7 and August 21 was 153 millimeters fork length (SD = 16 millimeters). Given the 2^+ month period for growth between stocking and early August, fish that remained in the Ward Creek system were well below the mean size of the fish when stocking occurred.

Approximately the same number of different hatchery steelhead were captured in Ward Lake and Ward Creek. An estimated 3,169 (SE = 343) wild steelhead ≥110 millimeters also occupied the habitats sampled in Ward Lake and Ward Creek during the experiment. However, most wild juvenile steelhead were captured in Ward Creek.

KEY WORDS: Steelhead, enhancement, smolt, residualize, Ward Creek, Ketchikan, Southeast Alaska, *Oncorhynchus mykiss*, hatchery, mark-recapture experiment.

INTRODUCTION

Steelhead *Oncorhynchus mykiss* sport fishing effort and harvests have increased in southern Southeast Alaska since 1977 (Mills 1991). Strong public support for steelhead enhancement near urban communities in Southeast Alaska prompted the Alaska Department of Fish and Game (ADF&G) to enhance steelhead populations in several waterways. The program usually began as small, "experimental" projects conducted by interested hatchery managers, and were expanded later to satisfy growing public demand for increased steelhead harvest.

Evaluations of these stocking programs have indicated success levels ranging from good to very poor. A requirement of the Division of Sport Fish is to hatchery rear steelhead to smolt of optimum size for planting which will emigrate to sea in one year. Information presented during the Alaska Steelhead Workshop in 1985 by fisheries scientists from other West Coast agencies indicated their best successes were achieved when steelhead smolt were between 170-180 mm at the time of release (Van Hulle 1985). No studies have been conducted to determine the optimum size of release for steelhead smolt in Southeast Alaska. In lieu of appropriate research data, the Division of Sport Fish has strived to attain one-year-old smolt of about 170 mm fork length (FL) or about 45 g each.

The Ward Creek system has been stocked a number of times since 1980. A summary of numbers of steelhead planted in Ward Creek from ADF&G's Fisheries Rehabilitation, Enhancement, and Development (F.R.E.D.) Division hatcheries at Klawock and Deer Mountain in Ketchikan appears in Table 1. Prior to 1991, steelhead were last planted in Ward Creek in 1989. Coho salmon (*O. kisutch*) have also been stocked in Ward Creek, using Reflection Lake and Ketchikan Creek broodstocks (Table 1). Other salmonids which inhabit the Ward Creek system include sockeye (*O. nerka*), pink (*O. gorbuscha*), and chum salmon (*O. keta*), cutthroat trout (*O. clarki*), and Dolly Varden char (*Salvelinus malma*).

Ward Creek flows into Ward Cove, 6.4 km northwest of Ketchikan along the Tongass Highway (Figure 1). The Ward Creek watershed contains four lakes, in descending elevation as follows: Perseverance, Talbot, Connell, and Ward. Ward Creek (upper and lower) and Signal Creek are the primary anadromous streams in the watershed. Ward Creek averages 15 to 20 m in width, and flows 4.0 km from Connell Lake to Ward Lake, and 0.6 km from Ward Lake to salt water at Ward Cove. The base of a concrete dam at the outlet of Connell Lake marks the upstream extent of anadromous fish habitat. The dam was constructed in the early 1950's to provide water for the Ketchikan Pulp Company log mill at Ward Cove.

Ward Creek is the most heavily fished stream along the Ketchikan road system. An estimated 3,288 angler-trips occurred at Ward Creek in 1990, with steelhead catch and harvest estimates of 606 and 319 fish, respectively (Mills 1991). Fall- and spring-run steelhead provide angling opportunities in Ward Creek from October through early June, but the number of fish returning annually is unknown.

On May 28, 1991, approximately 12,000 one-year-old steelhead smolt from the Klawock Lake Hatchery were planted into Ward Creek, 100 m upstream from Ward Lake. Twelve days prior to planting (May 16), a random sample of 501 steelhead destined for Ward Creek were measured. Those fish ranged from 112 to 195 mm FL, had a mean length of 160 mm FL (SE = 0.6 mm), and a mean weight of 46 g.

One measure of steelhead smolt planting success is the proportion of stocked fish that smolt in the year of planting. Studies documenting this measure of success in Southeast Alaska waters are lacking.

Table 1. History of fisheries enhancement by the Alaska Department of Fish and Game at Ward Creek.

Species (stock)	Release year	Stage	Number released	Average size (gm)
Steelhead (Klawock)	1991	smolt	12,047	46.0[a]
	1989	smolt	38,667	14.7
	1988	smolt	39,607	45.0
	1987	smolt	28,687	39.7
	1986	smolt	11,613	30.5
	1985	smolt	21,918	25.0
Steelhead (Ketchikan Cr.)	1983	smolt	12,036	--
	1982	smolt	1,479	--
	1981	smolt	2,816	--
	1980	smolt	1,723	--
		Total	170,593	
Summer coho salmon (Reflection Lake)	1990	pre-smolt	38,453	--
	1989	pre-smolt	84,567	--
	1988	pre-smolt	55,700	--
	1987	pre-smolt	21,200	--
Coho salmon (Ketchikan Cr.)	1984	fry	38,444	--
	1983	pre-smolt	80,993	--
	1982	pre-smolt	99,578	--
	1981	pre-smolt	52,536	--
		Total	471,471	

[a] Average length of steelhead was 160.4 mm on May 16, 1991. Steelhead were stocked into Ward Creek on May 28, 1991.

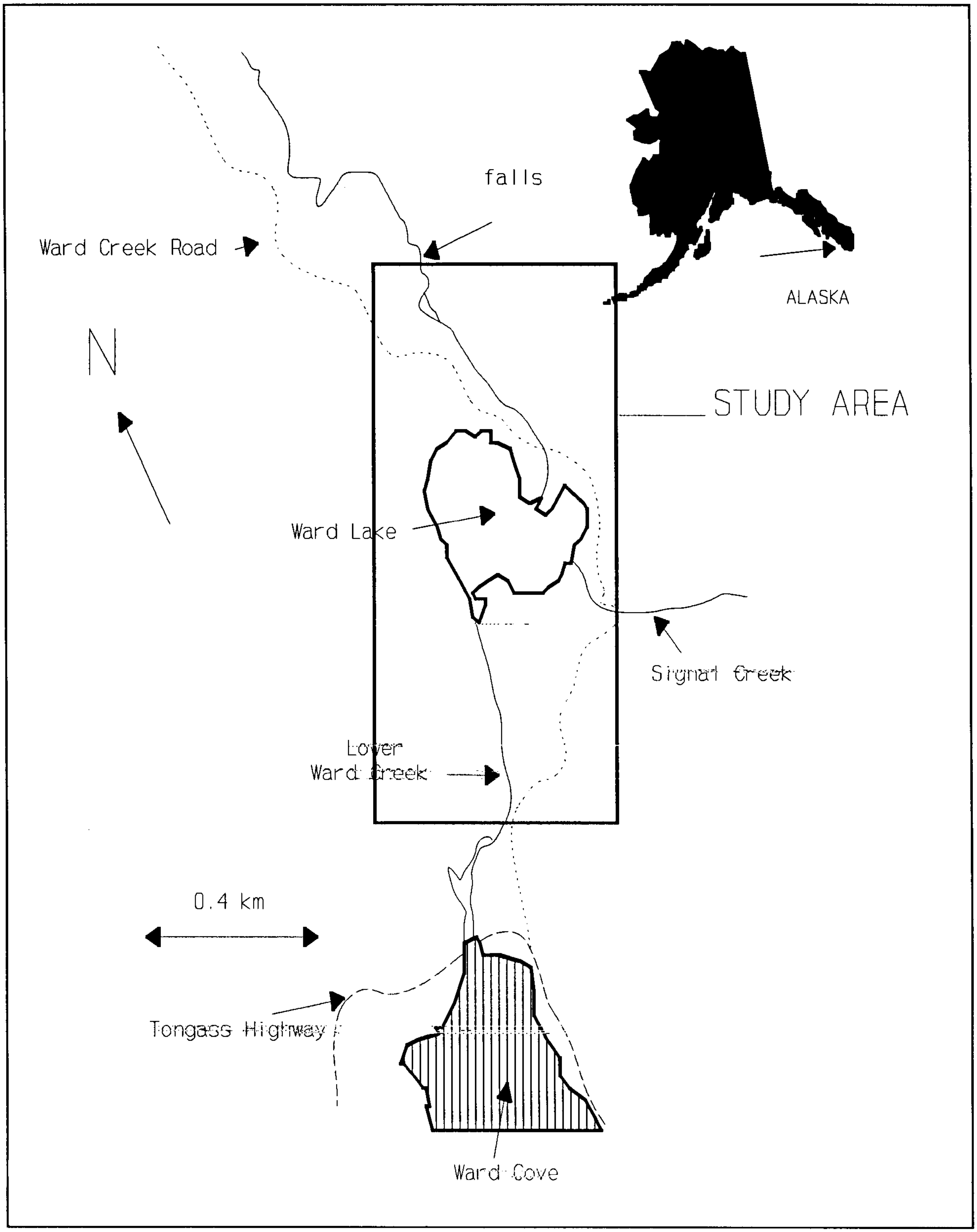


Figure 1. 1991 Ward Creek juvenile steelhead study area.

The emigration timing of steelhead smolt at Ward Creek is unknown. Studies conducted in 1983 and 1984 at Hugh Smith Lake, 75 km southeast of Ward Creek, found that most steelhead smolt emigrate from mid-May to early June (Zadina *unpublished*).

The specific objective of our study was to estimate that number of hatchery steelhead planted in Ward Creek in May 1991 which remained in the Ward Creek system on July 1991 [such that the estimate was within ±25% of the true value 95% of the time]. This information will provide managers with additional tools for evaluating steelhead stocking success.

METHODS

A mark-recapture experiment was used to estimate the abundance of stocked juvenile steelhead in the Ward Creek system. The first sampling event was July 22 to August 5, and the second event was August 7 to August 21. During each event, stream habitats were sampled for 5 to 7 days, then Ward Lake was sampled for 5 days, not counting rest days and holidays.

Since all hatchery steelhead planted into Ward Creek had their adipose fin removed prior to release, they could be distinguished from other ("wild") juvenile steelhead, which had adipose fins. It was assumed that steelhead planted into Ward Creek prior to this study (Table 1) had already emigrated to salt water, or that they could be easily distinguished from smaller steelhead planted in 1991.

Habitat available to juvenile hatchery steelhead within the Ward Creek system was defined as all fresh water downstream from a 2-meter falls in upper Ward Creek (Figure 1). The falls appears to be a velocity barrier to upstream movement. To confirm this, baited funnel traps were fished in three areas above the falls, to look for juvenile fish with adipose clips. Approximately 3.2 km of stream habitat upstream of the falls is available to wild steelhead, coho salmon, and other fishes.

Sampling gear was set so that all juveniles in the study area would experience a significant probability of capture. Stream habitats were sampled using small funnel traps and sport fishing gear (hook-and-line). Ward Lake was sampled with large and small funnel traps, beach seine, sport fishing gear, and fyke nets. Roughly equal effort was spent sampling in Ward Lake and in Ward Creek. Roughly twice the effort was expended in upper Ward Creek (above the lake) compared to lower Ward Creek (below the lake). Traps were baited and set around the perimeter of Ward Lake, and (usually) 9 traps were set at varied depths toward the center of the lake. Traps in Ward Lake were generally set overnight, while traps in Ward Creek were set overnight and checked during the day they were set.

The large funnel traps were 1.2 m long and 0.5 m in diameter, with a 6-cm opening at each end of the trap. The small funnel traps were 44 cm long and 23 cm wide, with 4-cm openings. Fyke nets had a 1.2- by 1.2-m opening, 6.1- by 1-m wings off each side, a 12.1- by 1-m center lead, and three hoop entrances leading to the cod end. Funnel traps and fyke nets were constructed with 0.6- by 0.6-cm mesh materials. Salmon eggs treated with Betadine were used for bait, though herring and shelled shrimp were also tried. The beach seine used was 15.2 m by 1.2 m. Sport fishing tackle was small hooks baited with salmon eggs, small floating and wet flies, and small spoons.

Captured juvenile steelhead over ≈100 mm FL were anesthetized with a solution of 2-phenoxyethanol and examined for missing adipose fins. Steelhead ≥110 mm FL were measured to the nearest mm fork length, given a distinct fin mark to identify the area and time of marking, allowed to recover in a tub of water, and released where captured. Fish were marked during the second sampling event, in case a multiple-capture experiment was adopted. Loss of these marks during the study was assumed to be negligible. Marks used in the experiment were:

Event	Habitat location	Fin punch
1	Ward Creek above lake	dorsal
1	Ward Creek below lake	left pelvic
1	Ward Lake	upper caudal
2	Ward Creek above lake	anal fin
2	Ward Creek below lake	right pelvic
2	Ward Lake	lower caudal

If assumptions of a simple Peterson experiment were met (including that every fish has an equal probability of being marked, or of being recaptured, or that complete mixing occurs between events) abundance was estimated:

$$\hat{N} = \frac{(n_1+1)(n_2+1)}{(m_2+1)} - 1 \tag{1}$$

$$V[\hat{N}] = \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)} \tag{2}$$

where $\hat{N}$ = abundance,
n_1 = number of juvenile steelhead marked in event 1,
n_2 = number of juvenile steelhead examined for marks in event 2, and
m_2 = number of marked juvenile steelhead recaptured in event 2.

If the sampling/mixing assumptions of the Peterson model were not met, a Darroch estimator (Seber 1982, Chapter 11), which accommodates partial mixing of the marked fish, was used to estimate abundance:

$$\underline{U} = \mathbf{D_u}\mathbf{M}^{-1}\underline{a} \tag{3}$$

where $\underline{U}$ = vector of the estimated number of *unmarked* fish in each area during the second sampling event,
$\mathbf{D_u}$ = diagonal matrix of the number of *unmarked* fish captured in each area during the second sampling event,
$\mathbf{M}$ = matrix (m_{ij}) of the number of tagged fish recovered in area (j) which were released in area i, and
$\underline{a}$ = vector of the number of tagged fish released in area i.

Abundance is then $\hat{\underline{N}} = \underline{U} + \underline{a}$ and the variance-covariance matrix is estimated:

$$E[(\hat{\underline{U}}-\underline{U})(\hat{\underline{U}}-\underline{U})^T] \approx \mathbf{D}_U\boldsymbol{\Theta}^{-1}\mathbf{D}_\mu\mathbf{D}_\alpha^{-1}\boldsymbol{\Theta}^{T^{-1}}\mathbf{D}_U + \mathbf{D}_U(\mathbf{D}_\rho - \mathbf{I}) \tag{4}$$

as described in Seber (1982, p.433) and Darroch (1961). Statistical bias and variance of the estimate was also investigated using the bootstrap technique (Efron 1982). Tag histories were resampled 1,000 times, and abundance was estimated for each sample. Bias was estimated as the difference between the mean of the bootstrap estimates and the Darroch estimate.

The probability that fish of different sizes were captured with equal probability in the second sampling event was investigated by visually comparing the cumulative distributions of lengths of fish tagged and then recaptured, and calculating a Kolmogorov-Smirnov (K-S) statistic for similarity in the two distributions.

Steelhead <110 mm FL, and other species, were counted by area and gear type, then released where captured.

RESULTS

Sampling for juvenile steelhead was somewhat more difficult than expected; hook and line capture and beach seining proved more effective, and small traps less effective, than desired. Additionally, excess water above Connell Lake Dam (above the study area) was spilled between sampling events, causing high flows in the Ward Creek study area for several days. At our request, Ketchikan Pulp Company, the operators of the dam, reduced the flow and our experiment was completed nearly as planned.

Hatchery steelhead

A total of 636 different hatchery steelhead ≥110 mm FL was captured in the first sampling event. Six hundred thirty-two (632 or 99%) hatchery steelhead between 110 mm FL and 204 mm FL were marked and released alive (Table 2), and four fish died during handling. Two hatchery steelhead captured were shorter than 110 mm FL. Their mean fork length was 145.9 mm FL (SD = 14 mm). The mean length of hatchery fish captured in event 2 was 152.7 mm FL (SD = 16 mm). These means were significantly different (t-test, P>0.001).

Approximately the same number of different hatchery steelhead were captured and marked in Ward Creek (313) and Ward Lake (319) (Table 2); 234 (75%) of the stream-caught fish were captured in upper Ward Creek.

Most hatchery steelhead were captured using small traps (in streams) or with beach seines (in Ward Lake). Hook-and-line yielded the highest catch-per-unit-of-effort (CPUE) in streams and the second highest CPUE in Ward Lake (Table 3). Small traps were not an effective gear type in Ward Lake, and large traps were eight times as effective as small traps.

Individual sampling gear was selective for fish of different sizes (Figure 2). Overall, selectivity was hard to quantify, because significant growth occurred between sampling events; for example, cumulative length distributions of fish recaptured in event 2 (n = 99) to fish marked in event 1 (n = 339) suggests the second sampling event was selective for fish of different sizes (Kolmogorov-Smirnov [K-S] test, d_{max} = 0.15, P = 0.06, Figure 3). However, subtracting a constant 7 mm from the length of all fish capture in event 2 leads to similar, overlapping distribution functions, and a nonsignificant KS-statistic (P = 0.78). Seven (7) mm is the difference in mean lengths of hatchery fish captured in the lake during the first and second sampling events.

Nine of 99 hatchery steelhead marked and recaptured were recovered in an area different from the area of marking (Table 4), showing that partial mixing of fish

Table 2. Summary of juvenile hatchery and wild steelhead (≥110 mm) mark-recapture data collected in the Ward Creek system, 1991.

	Event 1 July 22-August 5	Event 2 August 7-21
Newly marked **hatchery** steelhead ≥110 mm released alive (total), including:	339	293
number marked in lower Ward Creek	19	59
number marked in upper Ward Creek	132	102
number marked in Signal Creek	1	
number marked in Ward Lake	187	132
Recaptured **hatchery** fish marked in Event 1 (total), including:		99
lower Ward Creek		6
upper Ward Creek		31
Ward Lake		62
Newly marked **wild** (unclipped) steelhead ≥110 mm released alive (total), including:	467	358
number marked in lower Ward Creek	163	102
number marked in upper Ward Creek	204	180
number marked in Signal Creek	4	
number marked in Ward Lake	96	76
Recaptured **wild** fish marked in Event 1 (total), including:		61
lower Ward Creek		13
upper Ward Creek		21
Ward Lake		27

Table 3. Effort, catch, and catch-per-unit-effort (CPUE, fish per hour) by sampling period and gear for juvenile steelhead, 1991 Ward Creek system sampling.

				Juvenile steelhead					
			Unit effort	Hatchery ≥110 mm		Wild ≥110 mm		Wild <110 mm	
Event	Area	Gear	(hours)	Catch	CPUE	Catch	CPUE	Catch	CPUE
1[a]	Lower Ward Creek	Small trap	500	19	0.04	162	0.32	95	0.19
	Upper Ward Creek[b]	Small trap	1,120	134	0.12	207	0.18	815	0.73
		Subtotal	1,620	153		369		910	
1[c]	Ward Lake	Beach seine	8	84	10.50	81	10.13	18	2.25
		Hook & line	17	50	2.94	12	0.71	0	.00
		Large trap	1,760	67	0.04	7	0.00	1	.00
		Small trap	3,520	24	0.01	16	0.00	0	.00
		Subtotal	5,305	225		116		19	
1	Total		6,925	378		485		929	
2[d]	Lower Ward Creek	Hook & line	19	54	2.84	46	2.42	4	0.21
		Small trap	1,439	13	0.01	75	0.05	60	0.04
		Subtotal	1,458	67	0.05	121	0.08	64	0.04
	Upper Ward Creek	Hook & line	15	68	4.53	37	2.47	11	0.73
		Small trap	2,630	83	0.03	174	0.07	396	0.15
		Subtotal	2,645	151		211		407	
2[e]	Ward Lake	Beach seine	6	143	23.83	107	17.83	15	2.50
		Fyke net	164	27	0.16	5	0.03	5	0.03
		Hook & line	5	9	1.80	1	0.20	0	0.00
		Large trap	1,222	46	0.04	6	0.00	1	0.00
		Small trap	2,539	3	0.00	1	0.00	3	0.00
		Subtotal	3,936	228		120		24	
2	Total		8,039	446		452		495	
1+2	Total (Streams)	Small trap	5,689	249		618		1,366	
		Hook & line	34	122		83		15	
1+2	Total (Lake)	Beach seine	14	227		188		33	
		Fyke net	164	27		5		5	
		Hook & line	22	59		13		0	
		Large trap	2,982	113		13		2	
		Small trap	6,059	27		17		3	
1+2	Total		14,964	824		937		1,424	

[a] July 22-26.

[b] Includes Signal Creek and a small unnamed tributary stream to Ward Lake.

[c] July 29-August 5.

[d] August 7-13.

[e] August 14-21.

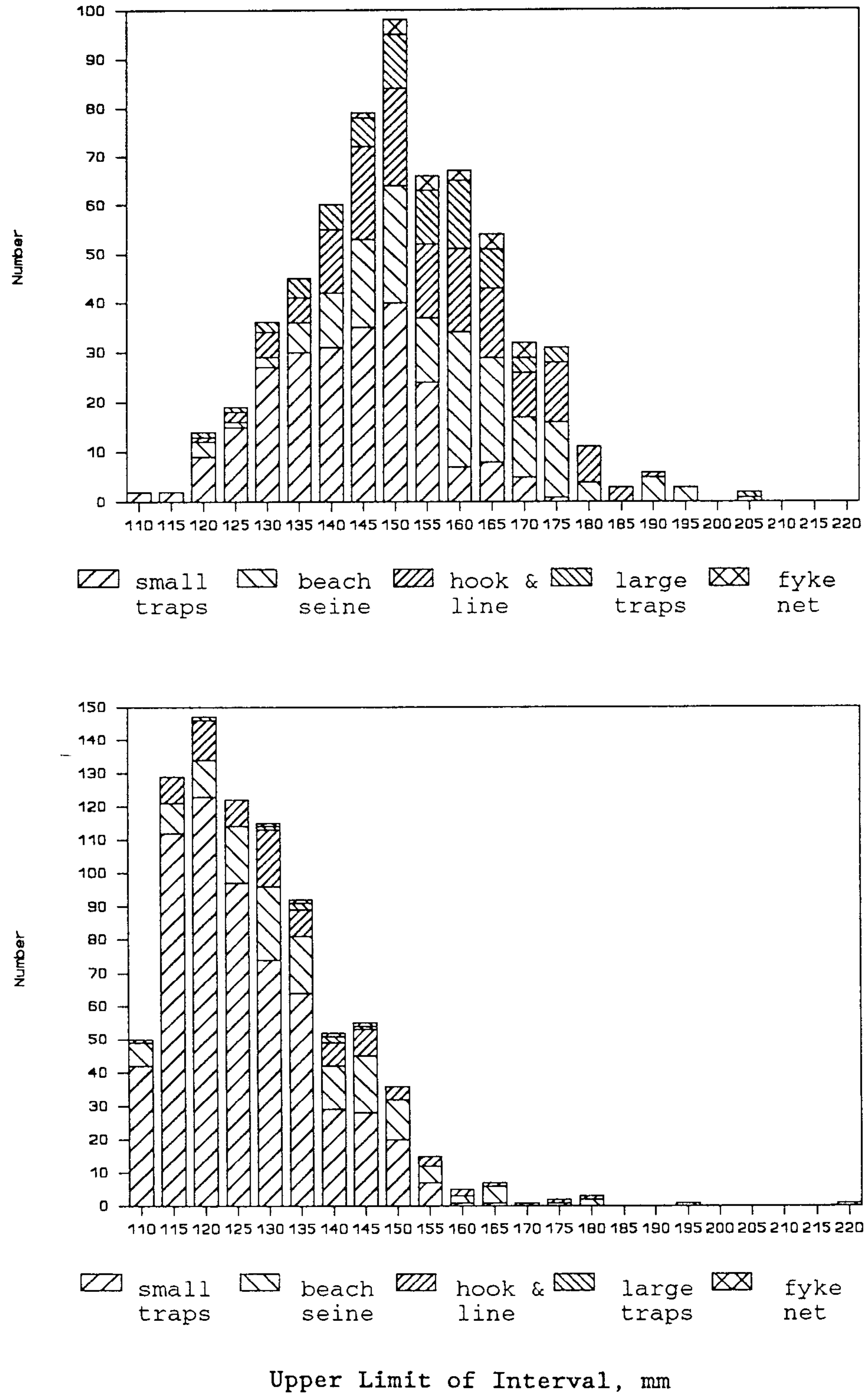
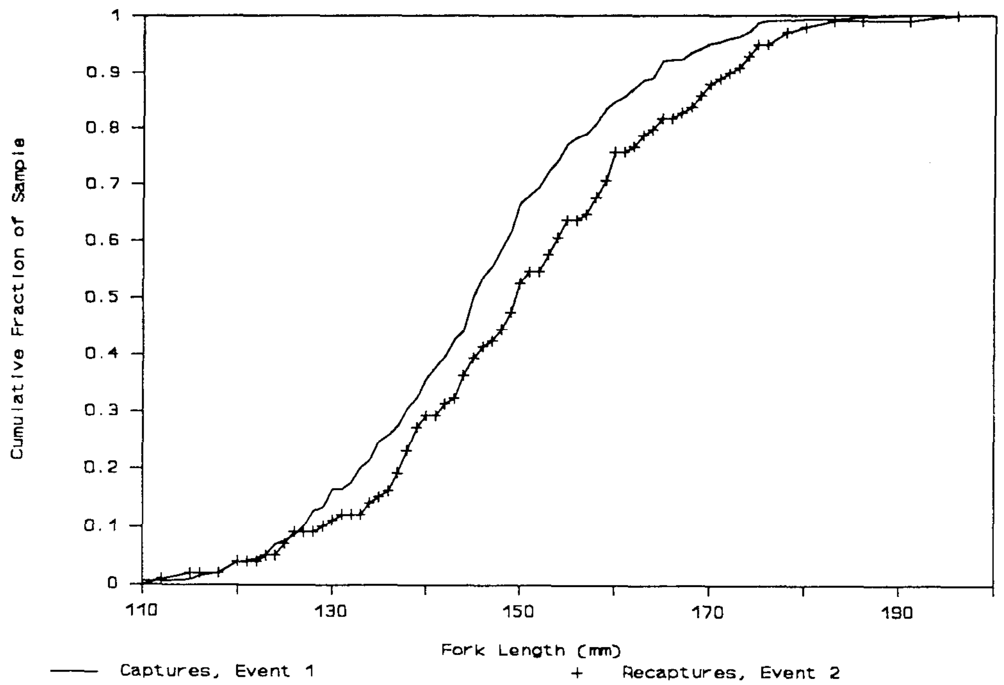


Figure 2. Length frequency of hatchery (above) and wild (below) steelhead caught at Ward Creek in 1991, by gear type.



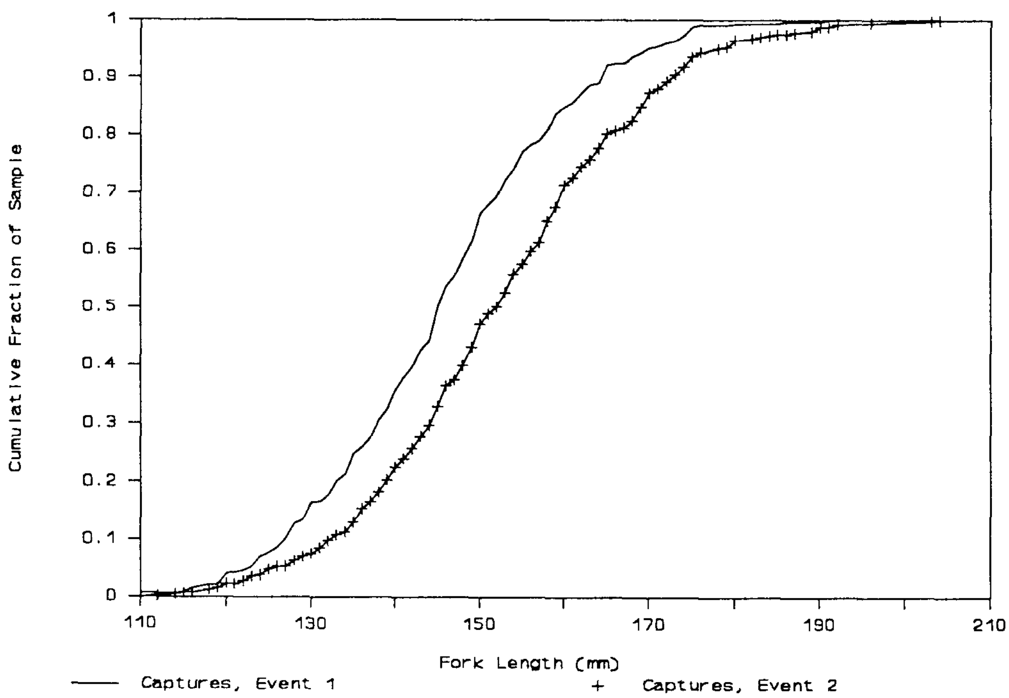


Figure 3. Cumulative length distribution of juvenile hatchery steelhead marked versus lengths of hatchery steelhead recaptured (above) and versus lengths of hatchery steelhead examined for marks (below), Ward Creek system, 1991.

Table 4. Numbers of juvenile steelhead ≥110 mm FL recovered (m_{ij}), marked by area in sampling event 1 (a_i), and unmarked captures by area in sampling event 2 (u_j), Ward Creek system, 1991.

HATCHERY STEELHEAD

Mark area	Recovery area: LWC[a]	UWC[b]	WL[c]	a_i
LWC	5	0	1	19
UWC	0	30	1	133
WL	2	5	55	187
u_j	59	102	132	

WILD STEELHEAD

Mark area	Recovery area: LWC	UWC	WL	a_i
LWC	12	0	1	163
UWC	0	19	2	208
WL	0	10	17	96
u_j	102	180	76	

[a] LWC = lower Ward Creek.

[b] UWC = upper Ward Creek.

[c] WL = Ward Lake.

Table 5. Comparisons of the number of marked and unmarked juvenile steelhead ≥110 mm FL captured in sampling event 2, in the Ward Creek system, 1991.

HATCHERY STEELHEAD

	Recovery area			
	LWC[a]	UWC[b]	WL[c]	
Marked fish	7	35	57	99
Unmarked fish	59	102	132	293
	66	137	189	392

$\chi^2 = 9.92$, df = 2, P = 0.007

WILD STEELHEAD

	Recovery area			
	LWC	UWC	WL	
Marked fish	12	29	20	61
Unmarked fish	102	180	76	358
	114	209	96	419

$\chi^2 = 4.61$, df = 2, P = 0.100

[a] LWC = lower Ward Creek.

[b] UWC = upper Ward Creek.

[c] WL = Ward Lake.

occurred between events. However, contingency table analyses of fish rejects the hypothesis of equal probability of capture among sampling areas (P = 0.01) (Table 5), and, thus, Darroch's model was used to estimate abundance.

Estimated abundance of juvenile hatchery steelhead planted in 1991, which remained in fresh water through July, 1991, was an estimated 1,318 (SE = 114). The bootstrap procedure indicated that bias was less than 5% and that variance could be slightly higher than calculated. Bootstrap 95% confidence intervals [1159, 1841] were nonsymmetrical around the estimate.

Wild steelhead and other species

We captured a total of 825 wild steelhead between 110 mm FL and 219 mm FL. These were marked and released alive (Table 2). We also captured 1,422 wild steelhead <110 mm FL, 86% of which were captured in upper Ward Creek and 11% in lower Ward Creek (Table 3). Mean length of wild steelhead captured in event 1 was 124.1 mm FL (SD = 11 mm) and in event 2 was 130.6 mm FL (SD = 15 mm). These differences were highly significant (P>0.001).

Seventy-nine percent (79%) of the unique wild steelhead ≥110 mm FL sampled were captured in streams, and 59% of these fish were captured in upper Ward Creek.

Most wild fish were captured in creeks with small traps and beach seines. Since these wild fish were smaller than hatchery fish (Figure 2), small traps were more effective than they were for the hatchery fish, and other gear less effective (Table 3).

Comparing distributions of lengths of fish recaptured in event 2 (n = 61) to fish marked in event 1 (n = 462) suggests the second sampling event was selective for fish of different sizes (Kolmogorov-Smirnov [K-S] test, P = 0.002, Figure 4). Since growth might explain the difference between the distributions, the K-S test was repeated after the difference in mean lengths of wild fish captured in both sampling events was subtracted from the lengths measured in event 2. This procedure also yields a significant K-S statistic (P = 0.007). Thus, gear selectivity was probably important for wild fish.

This might occur because most wild steelhead were captured in streams with small funnel traps, which are probably more size selective than the large traps. In addition, the high stream flows between sampling events may have washed larger wild juvenile steelhead from above the falls into the upper study area and could also have moved smaller wild juveniles from the upper study area to Ward Lake (Table 4). Since growth was highly likely and individual juvenile fish were not uniquely marked, the experiment was not stratified by length classes.

Thirteen of 61 wild steelhead marked and recaptured were recovered in an area different from the area of marking (Table 4), indicating partial mixing of fish between events. A hypothesis of equal probability of capture by sampling area was accepted (P = 0.10, Table 5). Thus, a simple Peterson model was used to estimate abundance. Estimated abundance of juvenile wild steelhead ≥110 mm FL in the study area was 3,169 (SE = 343).

Ninety-eight (98) wild steelhead were captured above the falls in upper Ward Creek and released unmarked. Since juvenile hatchery fish were not caught above the falls, I accept the hypothesis that hatchery fish did not traverse the falls.

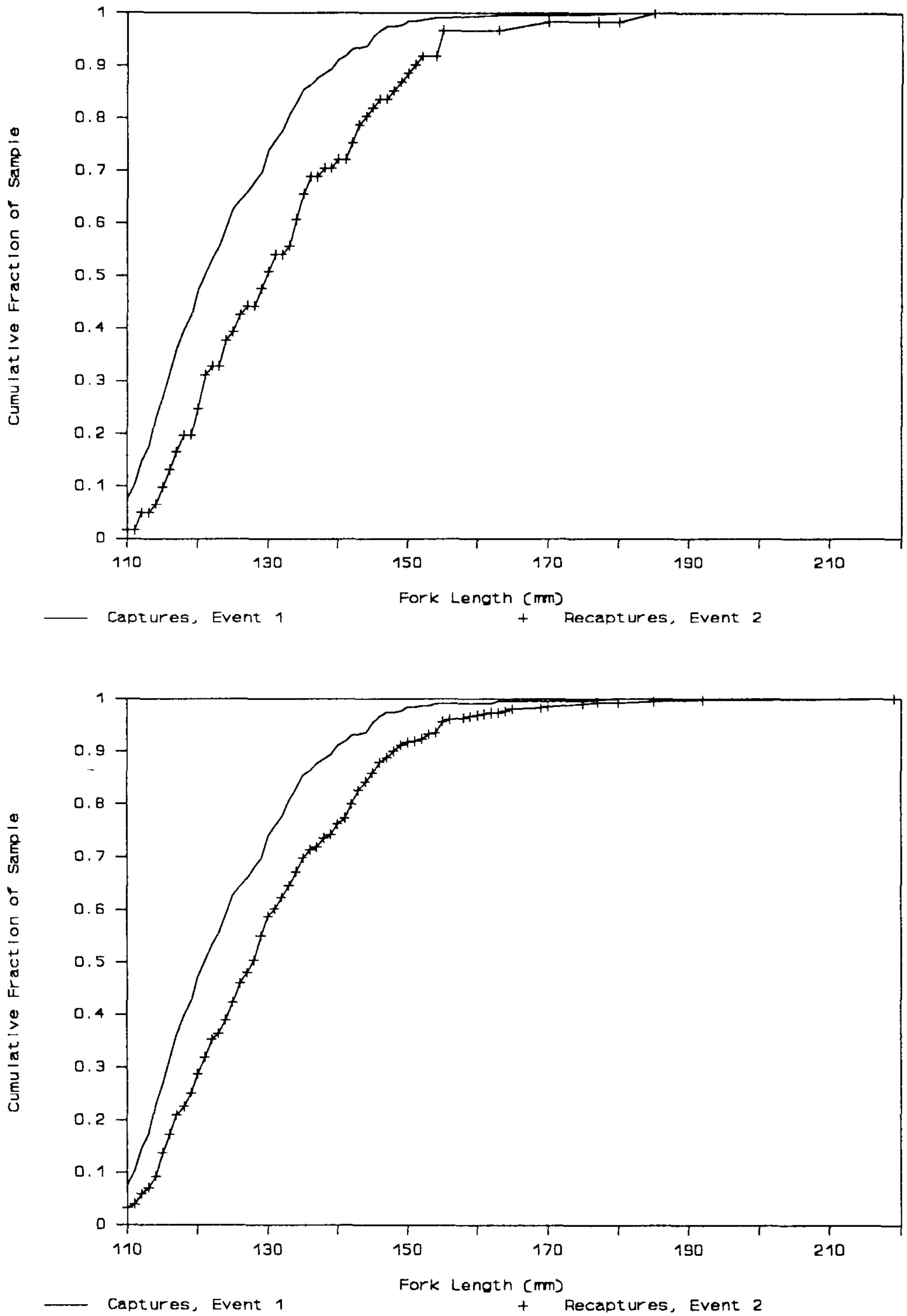


Figure 4. Cumulative length distribution of juvenile wild steelhead marked versus lengths of wild steelhead recaptured (above) and versus lengths of wild steelhead examined for marks (below), Ward Creek system, 1991.

Numbers of other salmonids captured in the study area included 84 cutthroat trout, 3,104 Dolly Varden, and 6,578 juvenile coho salmon (Appendix A).

The results of our trapping indicated that cutthroat trout populations within the study area may have been very low.

DISCUSSION

The estimate of 1,318 juvenile hatchery steelhead which remained in the Ward Creek system is 11% of the estimated 12,047 fish planted on May 28, 1991. These ("residualized") fish presumably will remain in fresh water and compete with other fishes for rearing habitat and food, until at least spring of 1992. These hatchery fish share habitat with an estimated 3,169 wild juvenile steelhead ≥110 mm FL. Hatchery fish were about equally abundant in stream and lake habitats in late July, whereas most wild steelhead ≥110 mm (79%) were caught in streams. Stream rearing was also indicated for wild steelhead <110 mm, since 97% of these fish were captured in Ward Creek (Table 3).

Estimation of the total number of juvenile wild steelhead in the Ward Creek system was beyond the scope of our study. The 3.2-km reach of upper Ward Creek upstream of the falls at the study boundary was also inhabited by wild steelhead. Also, the high stream flows which occurred between the two sampling events may have resulted in a downstream movement of wild fish into the study area. Indeed, both immigration and emigration of wild fish could have occurred during this event, and the estimate for wild fish could contain an unknown bias.

Assuming that juvenile hatchery steelhead in Ward Lake grew about 7 mm between sampling events (roughly 2 weeks in early August), and that size selective sampling was not significant in the experiment, the mean length of fish that residualized in the Ward Creek system in 1991 was significantly less than the mean length of fish stocked into the system (Figure 5). Although growth of individual steelhead was not measured, the mean length of fish sampled in Ward Lake increased by nearly 7 mm between August 2 and August 16, the (weighted) mean dates for the two samples taken. If hatchery fish that remained in Ward Lake experienced a growth rate that changed linearly from 0.0 mm/day on May 28 when stocking occurred to 0.46 mm/day on August 1, a back-calculation estimates that the mean size of the residualized fish on May 28 was about 131 mm.

Assuming the coefficient of variation (CV) for lengths of these fish on May 28 was equal to the CV on August 2, 90% of residualized fish would have been between about 110 mm and 150 mm on May 28. Although these growth calculations are *purely speculative*, they *illustrate a possible* result of growth and the sizes of fish during the experiment.

We assumed that mortality, loss of marks, and immigration of juvenile hatchery steelhead were minimized by the short duration (≈2 weeks) between sampling events. Hatchery fish were also assumed not to have traversed the falls in upper Ward Creek. No regeneration of clipped adipose fins or punched fins was observed during the experiment. Emigration of fish out of the Ward Creek system was not indicated by substantial recoveries of fish in lower Ward Creek that had been marked in upper Ward Creek or Ward Lake (Table 4). Also, considerable trapping upstream of the falls (which marked the upstream study area boundary) produced 98 wild steelhead and no hatchery steelhead.

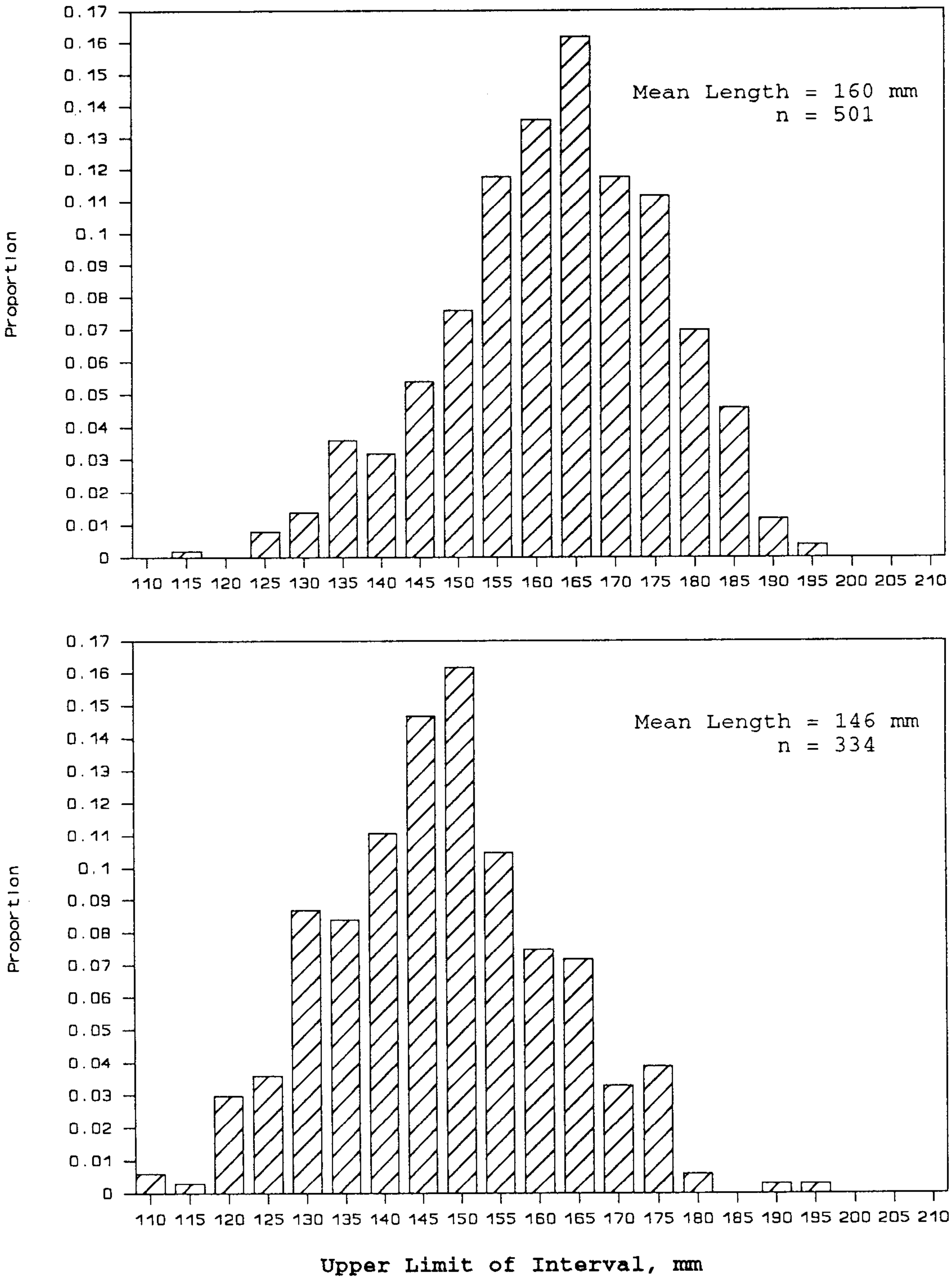


Figure 5. Length frequency of May 16, 1991 sample of hatchery steelhead destined for Ward Creek (above) and hatchery steelhead caught at Ward Creek from July 22 to August 5, 1991 (below).

Additional studies could be conducted to evaluate the success of the stocking in Ward Creek in 1991. On the basis of aging of adult hatchery steelhead harvested from the Klawock River (i.e., source of the 1991 Ward Creek planted steelhead) in 1987-1988, we determined that fish initially returned to spawn after two or three years' ocean residence (Freeman and Hoffman 1989). Hence, information on the adult returns from the 1991 enhancement could be obtained by operating a weir across Ward Creek during the spring of 1993 and the spring of 1994.

A study that concentrated only on returns of adults would ignore other important factors, though; e.g., the progeny of adult hatchery fish which return and spawn "become" "wild" fish, and may produce fewer and less resilient stocks (Chilcote et al. 1986).

If steelhead are planted into Ward Creek in the future, alternate release sites along lower Ward Creek should be considered. Reduced competition with native fishes would be an expected result. Ward and Slaney (1990) recommended utilizing a lower stream stocking site to reduce competition with wild fishes and increase adult returns. However, steep stream banks and distance from existing roads present logistical challenges for planting fish in lower Ward Creek. Also, testing for osmocompetency would probably be required several weeks prior to the planned stocking to ensure the fish had become smolts and would survive.

ACKNOWLEDGMENTS

We wish to thank the U.S. Forest Service, Ketchikan Ranger District, for providing a convenient campsite at Signal Creek Campground, which served as a base for our study. Bob Marshall helped with design and analysis of the experiment, and commented on the manuscript. Dennis Hubartt, also of the Division of Sport Fish, provided valuable computer assistance and drew the map.

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APPENDIX A

Appendix A. Effort, catch, and catch-per-unit-effort (CPUE, fish per hour) by sampling period for three salmonid species, 1991 Ward Creek system sampling.

Event	Area	Gear	Unit effort (hours)	Cutthroat trout Catch	Cutthroat trout CPUE	Dolly Varden Catch	Dolly Varden CPUE	Juvenile coho salmon Catch	Juvenile coho salmon CPUE
1[a]	Lower Ward Creek	Small trap	500	3	0.01	52	0.10	332	0.66
	Upper Ward Creek[e]	Small trap	1,120	5	0.00	897	0.80	2,092	1.87
		Subtotal	1,620	8		949		2,424	
1[b]	Ward Lake	Beach seine	8	0	0.00	49	6.13	128	16.00
		Hook & line	17	4	0.24	3	0.18	21	1.23
		Large trap	1,760	10	0.01	436	0.25	620	0.35
		Small trap	3,520	8	0.00	355	0.10	325	0.09
		Subtotal	5,305	22		843		1,094	
1	Total		6,925	30		1,792		3,518	
2[c]	Lower Ward Creek	Hook & line	19	0	0.00	0	0.00	0	0.00
		Small trap	1,439	8	0.01	56	0.04	86	0.06
		Subtotal	1,458	8	0.01	56	0.04	86	0.06
	Upper Ward Creek	Hook & line	15	1	0.07	11	0.73	0	0.00
		Small trap	2,630	1	0.00	483	0.18	1,912	0.73
		Subtotal	2,645	2		494		1,912	
2[d]	Ward Lake	Beach seine	6	4	0.67	30	5.00	55	9.17
		Fyke net	164	29	0.18	85	0.52	503	3.07
		Hook & line	5	0	0.00	0	0.00	0	0.00
		Large trap	1,222	10	0.01	442	0.36	411	0.34
		Small trap	2,539	1	0.00	205	0.08	93	0.04
		Subtotal	3,936	44		762		1,062	
2	Total		8,039	54		1,312		3,060	
1+2	Total (streams)	Small trap	5,689	17		1,488		4,422	
		Hook & line	34	1		11		0	
1+2	Total (lake)	Beach seine	14	4		79		183	
		Fyke net	164	29		85		503	
		Hook & line	22	4		3		21	
		Large trap	2,982	20		878		1,031	
		Small trap	6,059	9		560		418	
1+2	Total		14,964	84		3,104		6,578	

[a] July 22 to July 26; [b] July 29 to August 5; [c] August 7 to August 13; [d] August 14 to August 21; [e] Including Signal Creek and a small unnamed tributary stream to Ward Lake.