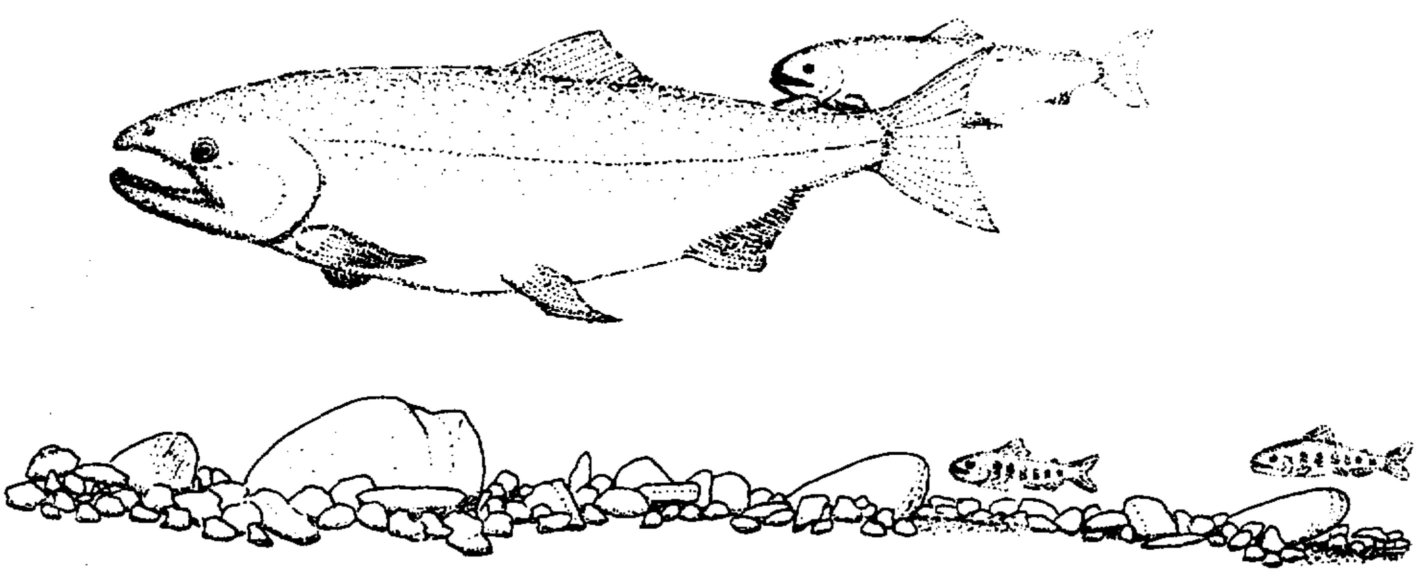
U.S. Fish and Wildlife Service
Fisheries Assistance Office
Olympia, Washington

National Park Service
Olympic National Park
Port Angeles, Washington

Hatchery Winter Steelhead Contribution to the Hoh River Fisheries and Potential Impacts on the Native Stock

Final Report

May 1986



HATCHERY WINTER STEELHEAD CONTRIBUTION TO THE HOH RIVER FISHERIES AND POTENTIAL IMPACTS ON THE NATIVE STOCK

FINAL REPORT

May 1986

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ABSTRACT

Creel census with concurrent recovery of coded wire tags was conducted in the 1983-84 and 1984-85 winter steelhead fisheries on the Hoh River, Jefferson County, Washington. The objective was to evaluate the contribution of outplants from the Quinault National Fish Hatchery (QNFH) located on the nearby but separate Quinault River system, and to assess the potential for impact of hatchery releases on the native stock.

The contribution rate of QNFH stock was within the range of other hatchery releases on the Hoh. Timing of QNFH stock in the Hoh sport catch reflected the early return timing characteristic of releases of this stock in the Quinault River system. The distribution of adult returns to the 1984-85 sport fishery revealed higher concentration of this group upstream of the Highway 101 Bridge than in the area downstream from this point. Adult returns to the 1983-84 sport fishery were concentrated between the bridge and the release site, which was about four miles upstream. However, the data from both years suggest some straying into the headwaters of the Hoh.

Hatchery releases from all sources combined dominated the sport catch in all areas of the river, making up 87% of the 1984-85 sport catch and 77% of the 1983-84 catch. The percent hatchery fish remained relatively high April (63% in 1984-85 and 65% in 1983-84), when most of the wild run also enters the catch. Hatchery fish were dispersed over all sport fishing areas. This combination of temporal and geographical overlap warrants management concern over their impact on the native stock in the headwaters. The greatest part of the later-timed hatchery fish could not be attributed to releases made on the Hoh. This suggests that straying from other watersheds must be addressed in connection with hatchery impact on wild stocks.

Management options for minimizing impact of hatchery releases on native stock are presented and discussed. Investigation of straying between coastal watersheds is also recommended, with a view to better control the stock composition within individual rivers. Finally, continued electrophoretic monitoring of Hoh steelhead would provide information on genetic trends in the wild segment of this stock.

IN MEMORIAM

Donald Cole, a co-author of this report, passed away on May 10, 1986. He will be remembered for his enthusiastic pursuit of resource investigation and conservation. Integrity, clarity of thought and expression, and an exemplary singleness of purpose were characteristic of his life and work. This report is dedicated to his memory.

ACKNOWLEDGEMENTS

This report is the work of many hands. Bob Leland of the Washington Department of Game analyzed the scale samples. Jeff McKee of FAO Olympia cheerfully read the fish tags and mounted a number of the scales. Richard Comstock provided extensive help with the statistical analysis. Bill Freymond of the Washington Department of Game (WDG) carefully reviewed the catch estimation techniques. Planting records and catch data from other fisheries were provided by Jim Gearheard of the WDG, Jim Jorgensen of the Hoh Tribe, and Marge McBride of the Quinault Department of Natural Resources. The rangers and staff of the Hoh and Kalaloch Ranger Stations cooperated in providing housing, and occasionally a boat or vehicle as needed. Special thanks are due to the field crew--Kurt Nelson, Phil Bischof, and Bryan Houtkooper--for their thorough and efficient work. Dave Zajac and Bryan Kenworthy of this office provided helpful criticism of the manuscript. Finally, our thanks to the the anglers and fishing guides on the Hoh, whose cooperation was essential to this study.

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INTRODUCTION

The U.S. Fish and Wildlife Service (FWS) and Olympic National Park (ONP) jointly conducted a creel census of winter steelhead on the Hoh River, located on the Pacific Coast of the Olympic Peninsula. The FWS participated in the census to evaluate the success of its hatchery outplant program into the Hoh River. The ONP collaborated to estimate the extent to which hatchery stocks were migrating into the Park. Another objective of the study was to provide catch data on the sport fishery to improve both in-season and post-season management. An incidental analysis was performed to evaluate the distribution and contribution of Hoh Tribal releases into Chalaat Creek, an on-reservation tributary of the Hoh.

A fundamental goal of the FWS is evaluating the contribution of its hatchery programs and their effect on native stocks of salmon and steelhead. This report concerns Quinault National Fish Hatchery (QNFH) releases of steelhead off-station into the Hoh River. This river is of special interest because the sport and commercial harvest rates are established to maintain optimum natural production. The impact of large scale releases of hatchery smolts on this objective may be significant. During the 1983-84 winter season FWS and ONP conducted a creel census (Hiss et al 1984) and found a high percentage of hatchery fish in the catch. ONP managers are particularly interested in the level of interaction between hatchery and wild stocks because of their management objective of maintaining native stocks. The cooperative creel census was conducted again during the 1984-85 season to provide complete contribution data for QNFH releases and additional information on potential hatchery/wild interactions.

The Hoh River originates in the Olympic Mountain Range and flows westward into the Pacific Ocean (Figure 1). A sport fishery operates from the mouth of the river up to Mount Tom Creek at River Mile (RM) 38.0 from December through February. In March the river closes to fishing above the Park boundary (RM 29.6) while the remainder of the river downstream remains open until April 15. The bag limit is two adult steelhead throughout the season. The Hoh Tribe fishes steelhead commercially with gillnets from the mouth of the river to the U.S. Highway 101 Bridge, one or two days a week from November to the end of March.

Hatchery releases have been made to supplement the river's viable wild run since the 1950's (Table 1). The objective of the hatchery programs has generally been to enhance the harvest with early-returning stocks from outside the Hoh, because such stocks

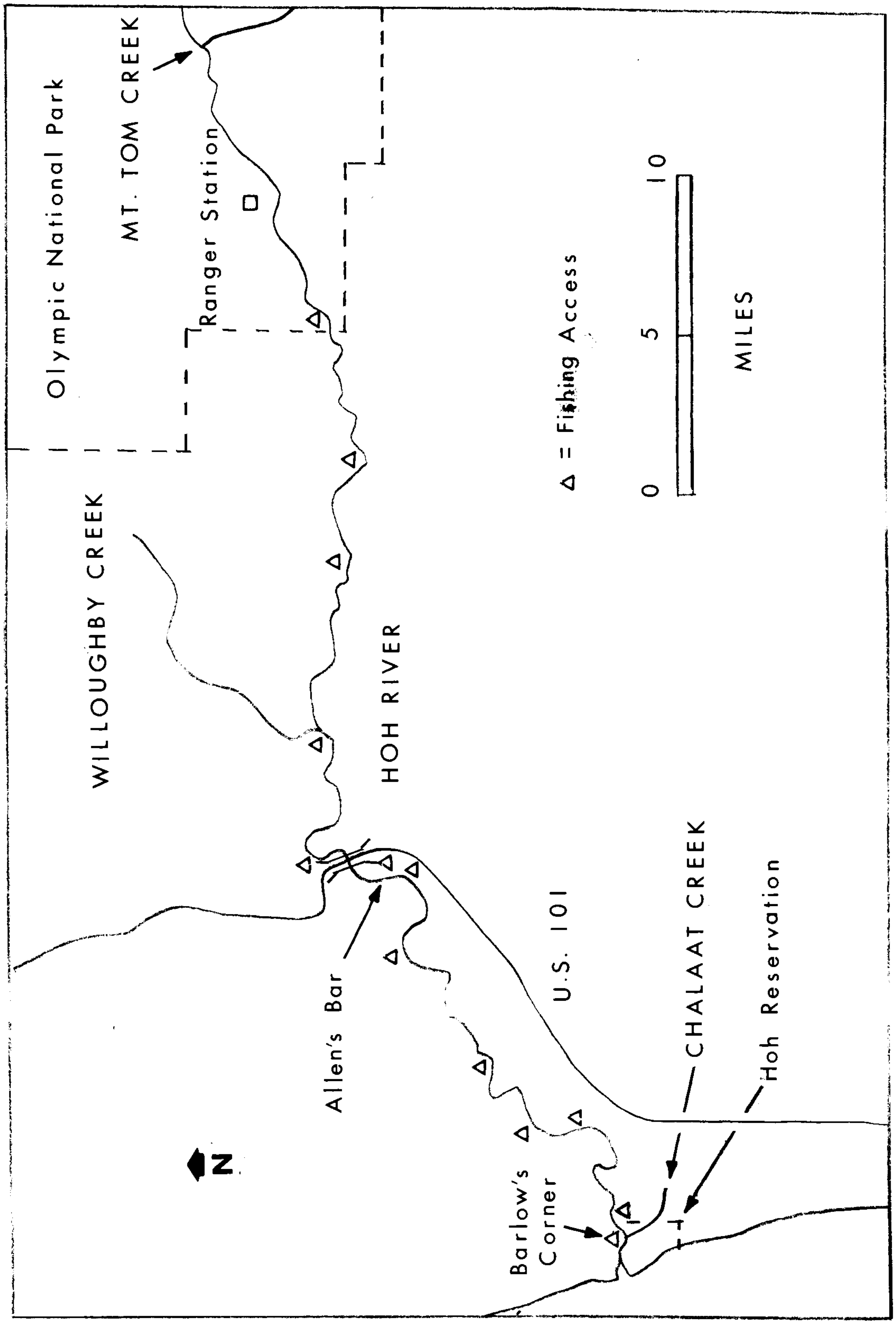

Figure 1. Hoh River, Jefferson County, Washington.

Table 1. Hatchery releases of early and late timed smolts, catch, and wild escapement on the Hoh, 1973-1985 Source: WDG and Hoh Tribe.

Smolt Releases X 1,000				Total Catch				Wild Escapement	
Year	Early (a)	Late (b)	Total	Year	Sport (est.)	Tribe	Total.	Year	Est. esc.
73	65	0	65	74-75	897	2,816	3,713	75	--
74	30	0	30	75-76	692	3,240	3,932	76	--
75	25	0	25	76-77	837	4,251	5,088	77	982
76	20	0	20	77-78	1,199	4,144	5,343	78	2,164
77	52	0	52	78-79	1,185	4,008	5,193	79	2,149
78	40	35	75	79-80	1,526	2,998	4,524	80	1,348
79	44	30	74	80-81	1,930	3,711	5,641	81	2,606
80	36	50	86	81-82	1,159	3,440	4,599	82	2,606
81	32	43	75	82-83	916	2,710	3,626	83	4,076
82	160	20	180	83-84	2,811	5,452	8,131	84	3,667
83	139	15	154	84-85	4,454	8,030	12,484	85	3,110
84	92	0	92	--	--	--	--	--	--
85	90	0	90	--	--	--	--	--	--

(a) Cook Creek, Lake Quinault, and Bogachiel stocks have early return timing.
(b) Hoh native stock has late timing.

have generally been readily available and relatively easy to raise to smolt size. Early-returning stocks are considered those which enter the sport fishery primarily from December through February. The wild run currently has a relatively late return timing in the sport and tribal fisheries, based on recent data from the Hoh Tribe and the FWS (Hiss et al 1984). The sport catch of wild fish occurs primarily in March and April. The late timing of the wild run may itself be an artifact of the generally early run timing of the hatchery releases, and not an inherent characteristic of the native stock (Houston and Contor 1984). The relatively high harvest rates corresponding to the harvest of a hatchery run may have resulted in over-harvest of the early component of the wild run and a shift of the run to a later timing pattern. That the return timing could be genetically manipulated was proposed by Royal (1973) based on observations of increasingly early returns of Chambers Creek hatchery fish attributable to selective breeding of early broodstock. Artificial selection against early wild returns on the Hoh may have occurred as a result of higher early fishing effort in some years to harvest the early hatchery segment of the run. In contrast, in recent years both the Tribe and the Washington State Department of Game (WDG) have attempted to keep the fishing effort more even throughout the run. The main motive is not so much the conservation of the early wild run as it is the desire by both parties for a long period of fishing opportunity.

Table 2. Steelhead smolt releases into the Hoh River, 1981 to 1983.

Release Year	Brood Year	Agency	Tag Code	Stock (a)	Release Site	Tagged Releases	Total Release
81	79-80	Hoh	5-7-55	Hoh	Chalaat	17,568	18,000
81	78-79	Hoh	5-7-56	Hoh	Chalaat	24,694	24,868
81	79-80	WDG	None	Bog.	Scatter(b)	0	32,200
82	80-81	FWS	5-10-42	CC	Will'by(c)	17,272	50,000
82	80-81	Hoh	5-9-61	LQ	Chalaat	14,078	69,427
82	80-81	Hoh	5-10-43	LQ	Chalaat	20,231	35,330
82	80-81	Hoh	5-10-44	Hoh	Chalaat	14,175	20,237
82	80-81	WDG	None	Bog.	Allen's	0	5,000
83	81-82	FWS	5-11-49	CC	Will'by	42,790	54,888
83	81-82	Hoh	5-13-56	LQ	Chalaat	27,807	72,180
83	81-82	Hoh	None	LQ	Allen's	0	11,459
83	81-82	Hoh	5-13-40	Hoh	Allen's	6,763	10,807
83	80-81	Hoh	5-10-44/ 5-11-32	Hoh	Allen's	3,589	4,222

(a) Bog. = Bogachiel Rearing Ponds; CC = Cook Creek; LQ = Lake Quinault.
(b) Allen's Bar to ONP boundary
(c) Mainstem Hoh near mouth of Willoughby Creek

Support for the long fishing season is based on the assumption that the escapement of the late wild run is adequate to support the current levels of harvest.

Steelhead have been released into the Hoh River by the FWS, Hoh Tribe, and WDG (Table 2). The FWS has released Cook Creek stock as smolts in the Hoh near Willoughby Creek annually since 1982. This stock actually originated from the Quinault River, but is now designated the Cook Creek stock to distinguish them from steelhead reared in Lake Quinault by the Quinault Tribe.

The Hoh Tribe releases Lake Quinault stock, which was originally drawn from Cook Creek but is now based on returns to the Quinault Lake Pens. This stock will be considered separately from the Cook Creek stock in this report because of differences in broodstock selection and rearing conditions. Smolts of this group are held at Chalaat Creek (near RM 0.0) for about one month before release for the purpose of imprinting to the Hoh system. All releases of this stock were made at Chalaat Creek in 1982, but some were also released at Allen's Bar in 1983. In both years a portion of each of the Willoughby and Chalaat Creek release groups were coded wire tagged (CWT). The WDG released unmarked smolts of Bogachiel stock at various locations in 1981 and at Allen's Bar in 1982.

An exception to the early-run hatchery program has been the Hoh Tribe's wild-brood steelhead program. Very late adults were captured, and the progeny reared at Lake Quinault, QNFH (1981 releases), or at Chalaat Creek (1982 and 1983 releases). All releases were made at the tribal hatchery on Chalaat Creek. The program was discontinued after the 1983 releases, when it was decided that summer water conditions at Chalaat Creek were unsuitable for further rearing of steelhead.

Hatchery steelhead typically return as two-salt fish after about a year and a half at sea. A smaller portion, but still of interest for management, return as three-salt fish after about 2 1/2 years at sea. Thus, for the 1983-84 season we expect two-salt returns from the 1982 releases and three-salt returns from the 1981 releases. For the 1984-85 season we expect two-salt returns from the 1983 releases and three-salt returns from the 1982 releases.

Creel census, combined with mark sampling, is useful in assessing the success of tagged hatchery release groups in terms of contribution, timing, and distribution in the sport fishery. This technique is also useful in assessing the possible effect of hatchery programs on natural production and the native stock, but only as suggested by the relative abundance, distribution and timing of hatchery versus wild fish and of certain tag groups in the sport catch. Creel census cannot be used to directly determine the genetic impact of such hatchery releases on the native stock because the composition of the spawning population is not directly observed.

This report will present the methods used in the 1984-85 creel census only. Results will include estimates of :

1) total and monthly sport catch;
2) hatchery/wild composition, timing, and relative distribution of the sport catch;
3) age, length, and sex composition of hatchery and wild fish; and
4) tag group contribution to the sport and Tribal fisheries, timing, and relative distribution by river section.

These results will be evaluated in light of the previous season's creel census (Hiss et al 1984) and the Hoh Tribal fishery data. Management options will be presented based on this discussion.

METHODS

Sport Catch Estimation

Sport catch was estimated by a creel census procedure similar to that used to estimate the 1983-84 catch (Hiss et al 1984). That is, estimated catch = (catch per effort) X (total instantaneous effort within a given stratum) X (time available for fishing). Catch-per-effort estimates were usually based on interviews of fishing parties that had completed their fishing trip for the day. We ordinarily discarded data from incomplete trips because such trips would have given a negative bias to the estimate unless anglers were catching their fish at random times throughout the fishing trip (see Robson 1961). In fact, anglers caught about 20% of their catch in the last 10% of the trip, as shown by our interviews this season. This was determined by asking each successful bank fishing party that had completed their trip, at what hour they caught each fish. Details on this pattern are presented in Appendix I.

Instantaneous effort in the index areas in the 1984-85 season was counted directly, in contrast to the 1983-84 season when bank anglers were estimated from the number of vehicles parked in the index areas. Instantaneous boat fishing effort, as represented by the number of anglers who used the index areas to launch or retrieve their boats was estimated from the number of boat trailers and the number of anglers per boat.

Total instantaneous effort was estimated by expanding the index effort by a factor derived from periodic counts of total bank anglers and fishing boats on the river, as in last season's survey. However, this season we were able to make all the counts of total effort from a helicopter, whereas during the previous season a combination of methods had to be used. Time available for fishing was calculated as previously, being equal to the daylight hours during which the river was fishable.

We stratified the catch estimate by variables that were likely to affect effort and catch per effort. First we divided the data into months. Then we divided each month into three categories: 1) weekdays when the Hoh Tribe was fishing at least part of the day, 2) weekdays when the Tribe was not fishing, and 3) weekends and holidays. No tribal fishery occurred in this last category. In contrast, last season's analysis combined all weekdays of each month regardless of tribal fishing. Finally, we separated the data from the boat fishery and the bank fishery. We did not distinguish between the two types of bank fishery (plunk or drift) because not all strata had enough angler hours of each type to allow a reasonable estimate of catch per effort. Determination of sufficient angler hours for catch-per-effort estimates is described in Appendix I.

We began our creel census on December 1, 1984 and continued until the end of the winter steelhead season on April 15, 1985. We attempted to sample 75 percent of the weekends and 70 percent of the weekdays, which we chose in an unbiased, systematic manner over each month. These are the sampling rates used by WDG for estimating catch per effort in their annual creel census of winter steelhead in several coastal and Puget Sound rivers. We counted bank anglers and boat trailers at 15 index areas twice a day. We began interviewing anglers after the first index count, conducted the second index count, then continued interviewing until dark. Details of the catch calculation method appear in Appendix I.

Catch Composition

Adults were separated from jacks on the basis of length, as defined by WDG fishing regulations (fish longer than 20 inches are considered adults). Hatchery/wild origin was determined by inspection for stubbed dorsal or clipped adipose fins, and by scale analysis. We defined fish as hatchery or wild based on combinations of freshwater growth (from scale analysis) and fin condition (Appendix II Table 1). This is in contrast to 1983-84, when freshwater age was the sole criterion.

For tag recovery, heads were taken from fish missing an adipose fin when anglers permitted. Heads were dissected and the first tag encountered was kept and read. The remaining tissue was discarded. This procedure resulted in the loss of some information, because a few of the returning fish were expected to carry two tags. This was the case for the 1983 release of 1980-81 brood smolts (that is, two-year-old smolts) of Hoh native stock. These fish had already received tag numbered "5-10-44" but some of this group had to be reared an extra year in fresh water. These fish did not reach the size considered necessary for acceptable marine survival after only one year in the hatchery. This group was then given another tag, "5-11-32", the following year. Thus, recovery of the tag "5-10-44" could represent either the 1982 or the 1983 releases of the same brood year. For this reason, the fish from which the tag "5-10-44" was dissected had to be identified as to release year by freshwater age, as indicated by scale analysis.

To estimate the contribution of the tag groups to the catch and their timing, we expanded the observed tag recoveries from the sport catch to account for 1) the snouts taken as a percentage of adipose-clipped fish observed in the catch and 2) the fish checked for adipose clips as a percentage of the estimated catch per month. In the previous season virtually all snouts of adipose-clipped fish were taken, so no expansion was necessary in this regard. Tag expansion can thus be summarized as:

expanded recoveries =(observed recoveries) X (C/M) X (A/S)

where C = estimated total catch
M = mark sample size
A = adipose clips observed, and
S = snouts taken for dissection

Appendix II Table 2 lists the values used in calculating the monthly tag expansion factors.

We calculated the total contribution of tagged and untagged steelhead for the 1982 and 1983 Hoh River releases to the 1984-85 season's sport and tribal catch by dividing the expanded tag recoveries by the percent marked in each release group. This method assumes total post-release tag retention for each tag group.

We studied the distribution of hatchery fish and specific tag groups in relation to Olympic National Park boundaries and in relation to their release sites by dividing the river into the four sections used in last year's study plus a fifth section representing the South Fork Hoh. These were designated as the "South Fork", "Park", "Upper", "Willoughby", and "Lower" sections of the river. The "Park" section began at the Park boundary at RM 29.5 and extended upstream to Mount Tom Creek. The "Upper" section began at the Park boundary and extended downstream to RM 20.3, about a mile above Willoughby Creek. The Willoughby section began at RM 20.3 and extended down to the 101 Bridge (RM 15.3). The "Lower" section went from the bridge to the mouth of the river.

The relative occurrence of various stocks in the river sections was described, combining the "Park", "Upper", and "South Fork" sections to obtain adequate mark sample size. Thus, comparison was made among three sections: "Above Willoughby Creek", "Willoughby Creek to 101 Bridge", and "101 Bridge to Mouth of River". Observed recoveries of stocks represented by tagged groups were adjusted upward to compensate for the difference between adipose-clipped fish observed and snouts obtained for dissection from each of the three sections. These calculations are presented in Appendix II Table 3.

The statistical significance of each stock's deviation from random distribution was determined by chi-squared analysis. The null hypothesis was that the particular stock was distributed over the three river sections in the same way as the total number of fish examined for marks. Thus the "observed distribution" was represented by the adjusted recoveries as calculated above, and the "expected distribution" was that of the total mark sample.

An indication of spawning activity was obtained by asking each fishing party how many kelts and ripe spawners they had hooked that day. This number included both the fish that were kept and those that were released. Collection of this information began on February 15 and continued until April 15. The timing pattern of kelts and ripe spawners in the catch was expected to reflect the timing of hatchery-origin fish spawning in the wild.

RESULTS AND DISCUSSION

Total Catch

An estimated total of 4,454 winter steelhead (4,415 adults) were caught in the 1984-85 sport fishery (Table 3; supporting data in Appendix III Tables 1-3). This represented a definite increase over last season's sport catch, which was 2,811, (2,619 adults).

This increase in catch is probably due to increased relative abundance of fish, increased angler effort, and more favorable fishing conditions. Relative abundance of fish, expressed by catch per angler hour, increased in comparison to 1983-84 for both early and late segments of the run (Table 4). Angler success for the two study years was above average compared to the Quillayute system for the early part of the run, and about average for the late segment (Table 5).

The increase in both sport effort and combined sport and tribal catch over the last several years (Table 1) is probably attributable to increased hatchery releases. Level of enhancement in the early-timed stocks had a rough but positive relation to the total early hatchery catch (Table 6). The number of early-timed releases at or above Allen's Bar and the early sport fishery were even more closely related, in terms of catch, effort, and catch per effort. Increased angler effort in response to increased hatchery releases was also thought to have occurred on the Soleduck following release of Chambers Creek stock in the late 1960's (Cederholm 1984). Increased angler effort in 1984-85, in comparison to the previous season, is also partly attributable to the absence of usual winter floods that make the river periodically unfishable for sport anglers.

Highest estimated catch for the 1984-85 season was in January (Table 3), in contrast to February in 1983-84. Virtually all the 1984-85 catch appears to have been taken below the boundary of Olympic National Park, based on mark sample distribution (Appendix IV Table 3). The same was observed in 1983-84.

Hatchery/Wild Composition

Hatchery fish made up 87.7 % of the catch over the season (Table 7), up from the 77.4% for 1983-84 (Hiss et al 1984). Hatchery fish made up about 85% of the catch from December through March. However, as late as April hatchery fish still constituted 63% of the catch, about the same as the 65% reported for 1983-84. Most of the wild run entered the sport fishery in March and April (Figure 2). The wild timing was similar to that of the previous season (Figure 3). The low numbers of the early part of the wild run may be due to either historically heavy fishing pressure early in the season or to a naturally late peak in catch timing. The predominance of hatchery fish throughout the season raises the possibility of more hatchery fish being present than can be

Table 3. Estimated adult and jack sport catch on the Hoh by month, 1984-85 season. Adult/jack determination based on fork length.

Month	Adult	Jack	Total
Dec.	936	0	936
Jan.	1,924	8	1,932
Feb.	580	11	591
Mar.	727	13	740
Apr.	248	7	255
Total	4,415	39	4,454

Table 4. Estimated Hoh sport catch per angler hour and corresponding smolt releases, for years when creel census was conducted.

Early Run (Dec-Feb)				Late Run (Mar-Apr)			
Release		Return		Release		Return	
Year	No.	Year	CPUE	Year	No.	Year	CPUE
78(a)	40,000	79-80	0.0718	78	35,000	79-80(b)	0.0394
82	180,000	83-84	0.0684	82	20,000	83-84	0.0518
83	141,000	84-85	0.0810	83	15,000	84-85	0.0663

(a) Source: WDG 1980.
(b) Fishery limited to Rm 0.0 to 15.5 and closed at end of March.

efficiently harvested under the present constraint of ensuring sufficient wild escapement. It also increases the likelihood of biological impact on the native population. This impact could theoretically take the form of either interbreeding or competition, and will be discussed later in this report. Future hatchery/wild ratio might be lower than those reported here due to decreased hatchery releases in 1984 and 1985 (Table 1). This may somewhat alleviate the potential impact on the native stock.

Hatchery fish dominated the catch in each section of the river (Table 8), although they were distributed randomly over the three areas sampled for marks (Figure 4). The probability of mistakenly rejecting the null hypothesis (that the distribution of hatchery fish was the same as that of the total number of fish sampled for marks in each section of the river) was 0.4. A similar situation existed the previous season (Figure 5), with a probability of 0.3. The hatchery influence was especially strong upstream of Willoughby Creek. This was indicated by the relatively small contribution of the wild run in this area in both years of the study. The probability level was 0.1 in the 1984-85 season and 0.05 in 1983-84. This indicates the

Table 5. Estimated catch per effort in the Quillayute River system. Source: WDG.

River	Season	Catch per angler hour: Dec. thru Feb.	Catch per angler hour: Mar. thru April
Bogachiel	1984-85	0.0729	0.0419
	1983-84	0.0513	0.0547
	1982-83	0.0436	0.0244
	1981-82	0.0662	0.0298
	Mean	0.0585	0.0377
Calawah	1984-85	0.0867	0.0513
	1983-84	0.0994	0.2018
	1982-83	0.0392	0.0257
	1981-82	0.0792	0.0563
	Mean	0.0761	0.0838
Soleduck	1984-85	0.0683	0.0543
	1983-83	0.0559	0.0498
	1982-83	0.0454	0.0410
	1981-82	0.0620	0.0512
	Mean	0.0579	0.0491
Quillayute System	Mean	0.0642	0.0572
	Range	0.0392-0.0994	0.0244-0.2018

Table 6. Early-timed hatchery releases, estimated catch, and angler effort on the Hoh for years when creel census was conducted.

Releases X 1,000: Year	Total	Upriver (a)	Early-timed Catch: Year	Tribal Catch(b) (Nov.-June)	Sport (Dec.-Feb.): Catch	Angler Hours	Catch per Angler Hr.
1978	40	40	79-80	1,355	810(c)	19,237(c)	0.0421
1982	160	55	83-84	3,467	1,683	26,900	0.0626
1983	141	67	84-85	5,885	3,459	42,582	0.0812

(a) Allen's Bar or Willoughby Creek.
(b) Source: Hoh Tribe.
(c) Source: WDG 1980.

possibility of hatchery stocks spawning in the same areas used by the native run. This issue will be discussed more thoroughly in the section on hatchery impacts on wild stocks.

Table 7. Estimated hatchery and wild sport catch of steelhead on the Hoh River by month, 1984-85 season. See "Methods" section for hatchery/wild determination.

Month	Hatchery	Percent	Wild	Percent
Dec.	859	91.8	77	8.2
Jan.	1,810	93.7	122	6.3
Feb.	482	81.6	109	18.4
Mar.	596	80.5	144	19.5
Apr.	161	63.3	94	36.7
Total	3,908	87.7	546	12.3

Age, Length, and Sex Composition

Age structure of the wild and FWS hatchery-origin catch was characterized by a larger proportion of three-salt fish in comparison to the catch of other hatchery fish (Table 9). Repeat spawners may have also made up a higher percentage of the wild catch, but small numbers recovered prevent a definite conclusion. A similar hatchery/wild difference was observed for the previous season, and is consistent with the difference in age structure observed on the Kalama River (Leider et al. 1985). The emphasis on several years of return from one broodyear, characteristic of the wild runs, is thought to ensure greater survival over a wider range of environmental conditions.

Wild adult fish in the 1984-85 sport catch had a slightly greater mean fork length by age than their hatchery counterparts. A similar condition was observed in the previous season. Small differences in length measured that year were associated with large differences in weight. Thus the 1983-84 wild run was characterized by a much larger proportion of large, highly-prized sport fish than the hatchery run. In that season, 12% of the wild fish examined weighed 15 pounds or over, while no hatchery fish achieved this size. About half the wild fish weighed 9 pounds or over, whereas only 9% of the hatchery fish reached this weight.

Abundance of females, especially of older age classes, is thought to be an adaptive advantage characteristic of particular stocks. Hatchery fish in the 1984-85 sport catch exhibited a higher ratio of females to males than the wild fish, especially in the two-salt returns. In contrast, the wild repeat spawners had a much higher proportion of females than did the hatchery repeat spawners. Such differences were absent in the 1983-84 sport catch, when each age class had essentially the same sex ratio regardless of hatchery or wild origin.

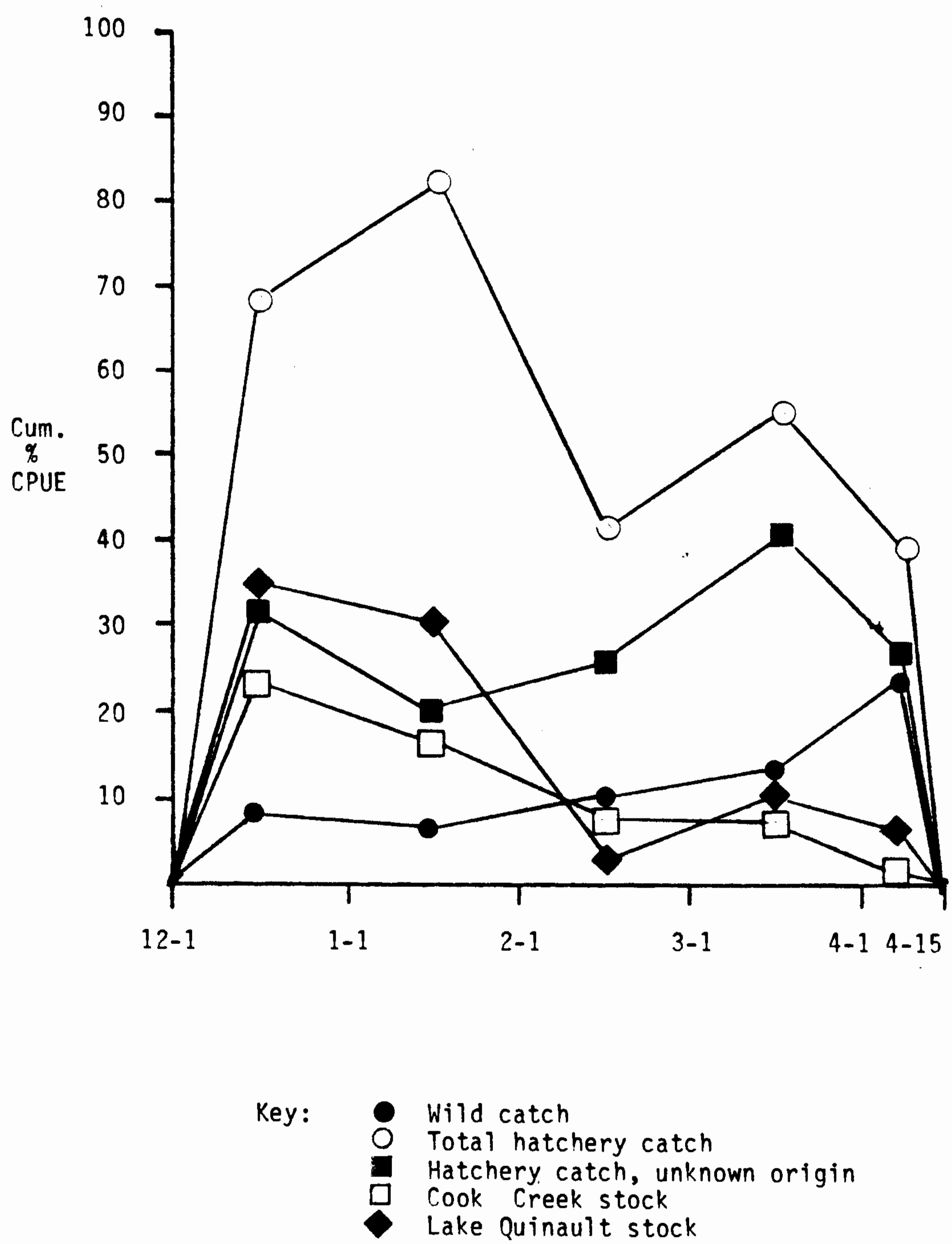

Figure 2. Timing of total sport catch and major subgroups, 1984-85 season.

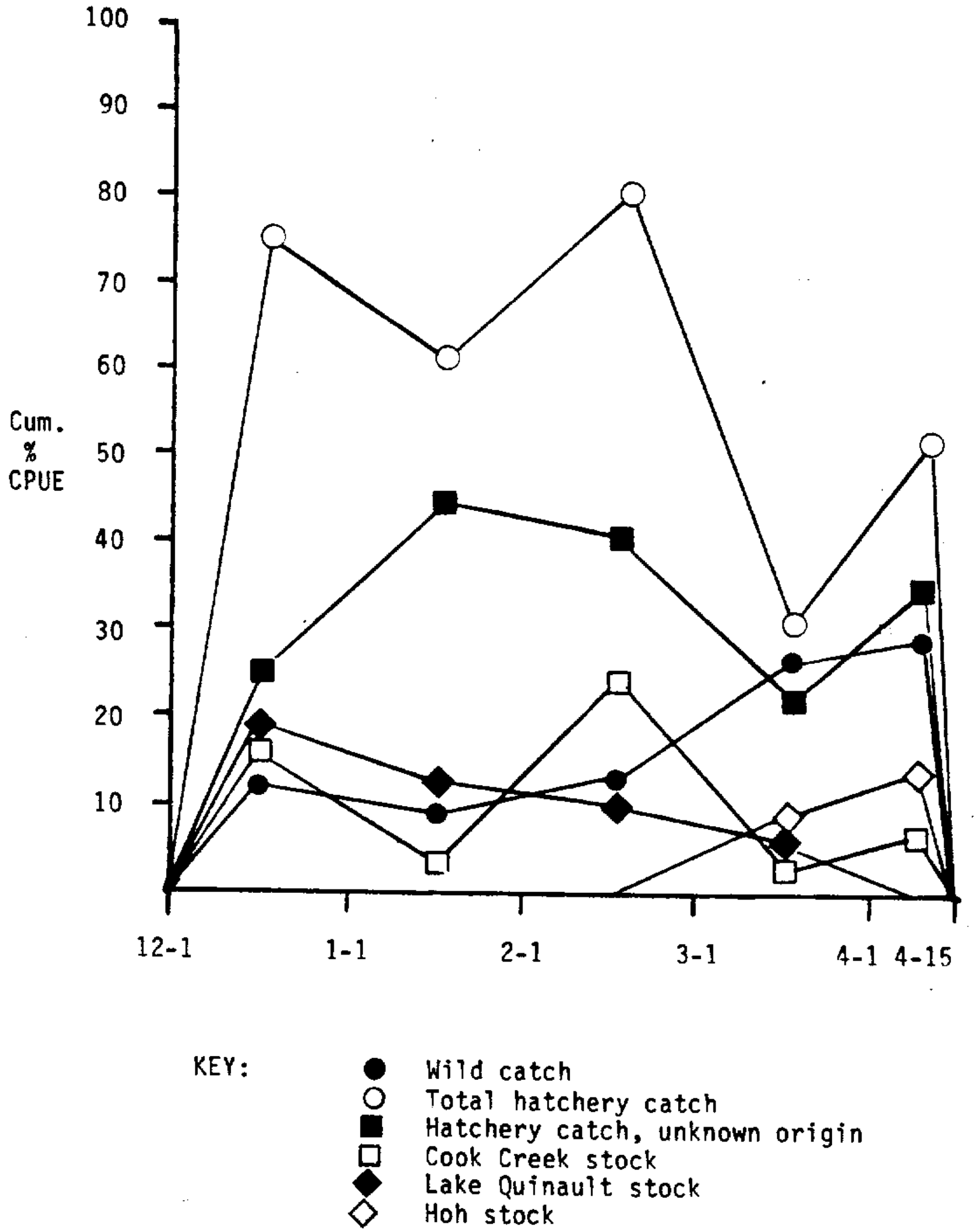

Figure 3. Timing of total sport catch and major subgroups, 1983-84 season.

Table 8. Observed hatchery/wild ratio in the Hoh sport fishery by river section, 1984-85 season. See "Methods" section for hatchery/wild determination and definitions of river sections.

River Section	Catch Sample Composition			
	Hatchery	Percent	Wild	Percent
South Fork, Park, and Upper Combined	158	88.3	21	11.7
Willoughby	55	79.7	14	20.3
Lower	389	86.1	63	13.9

Cook Creek Stock Contribution, Timing, and Distribution

The 1982 outplant of Cook Creek steelhead smolts contributed 894 fish to the combined 1983-84 and 1984-85 fisheries, or 1.79% of the release (Table 10). This contribution was about average for 1982 hatchery releases on the Hoh. The two-salt contribution of 1983 releases on the Hoh was also in the middle of the range for 1983 hatchery releases. The two-salt contribution of all 1983 releases was generally better than the two-salt contribution of 1982 releases (Table 10), the only exception being group 5-13-40, a release of yearling native hatchery smolts at Chalaat Creek. This release produced no returns at all in 1984-85. This suggests that the post-release environment influenced several groups regardless of their stock origin.

The percentage contribution to the sport and tribal fishery of Cook Creek steelhead released in the Hoh was less than the contribution of the same stock released on-station into the Quinault River. Contribution of Cook Creek releases was 3.82%, while Lake Quinault stock released on-station contributed at a 2.59% rate (Table 11). The difference in fishery contribution between on-station releases and the Hoh releases may be due to the fact that the Quinault River harvest is managed for hatchery production, whereas the Hoh is managed for wild escapement needs. Differential survival may be a factor. This question cannot be resolved because total survival is unavailable for the Hoh River and Lake Quinault outplants.

The relative contribution of Cook Creek fish (released near Willoughby Creek) to the Hoh sport fishery was much higher in both seasons than any of the Chalaat Creek groups (Table 12). A lesser degree of difference in contribution was observed in the 1983 Chalaat Creek release groups than the 1982 releases. This coincided with unusually good sport fishing conditions in the 1984-85 season.

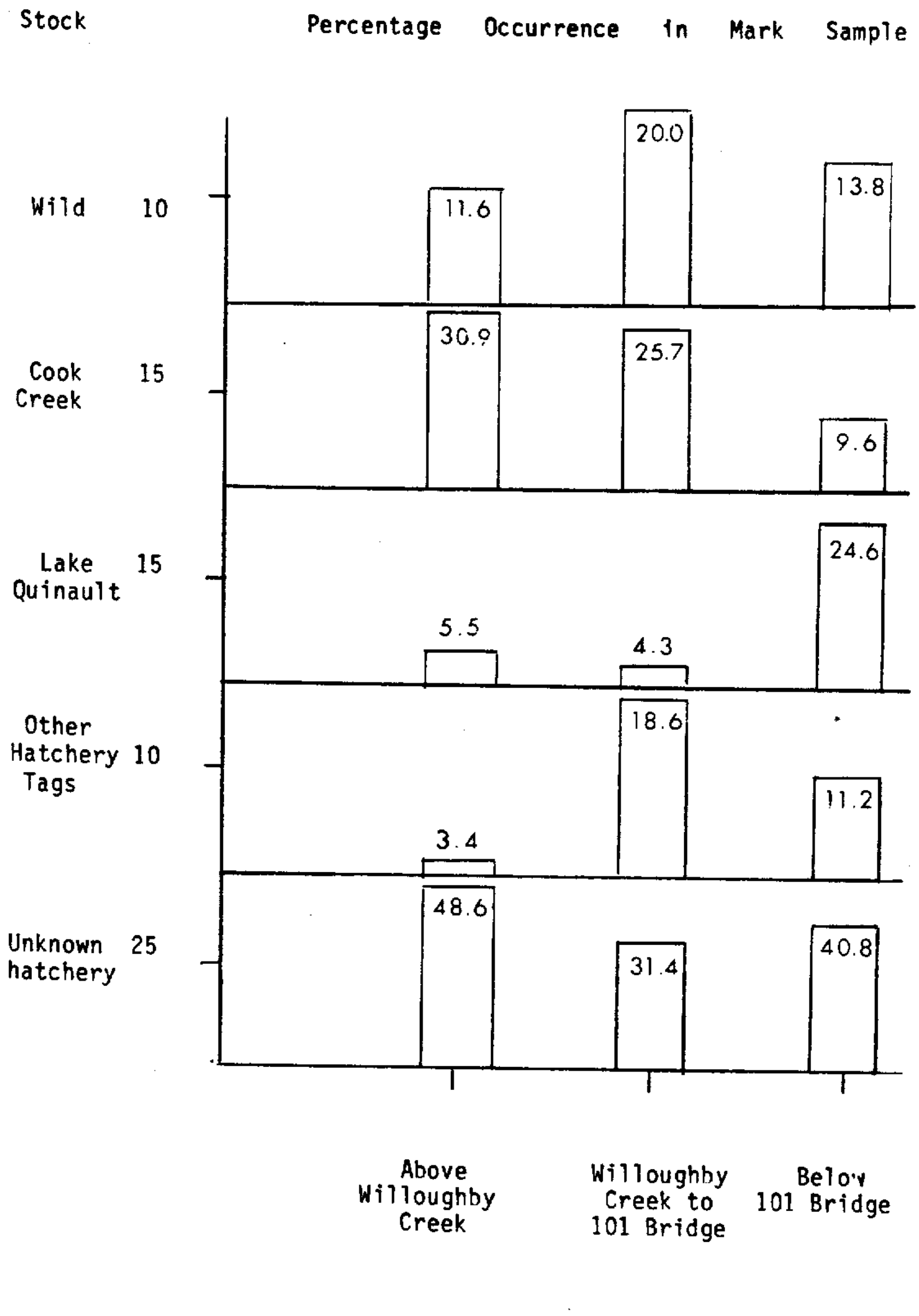

Figure 4. Geographical distribution of stocks in 1984-85 sport catch. Tag groups have been adjusted to account for differential percentage by river section of heads taken for dissection.

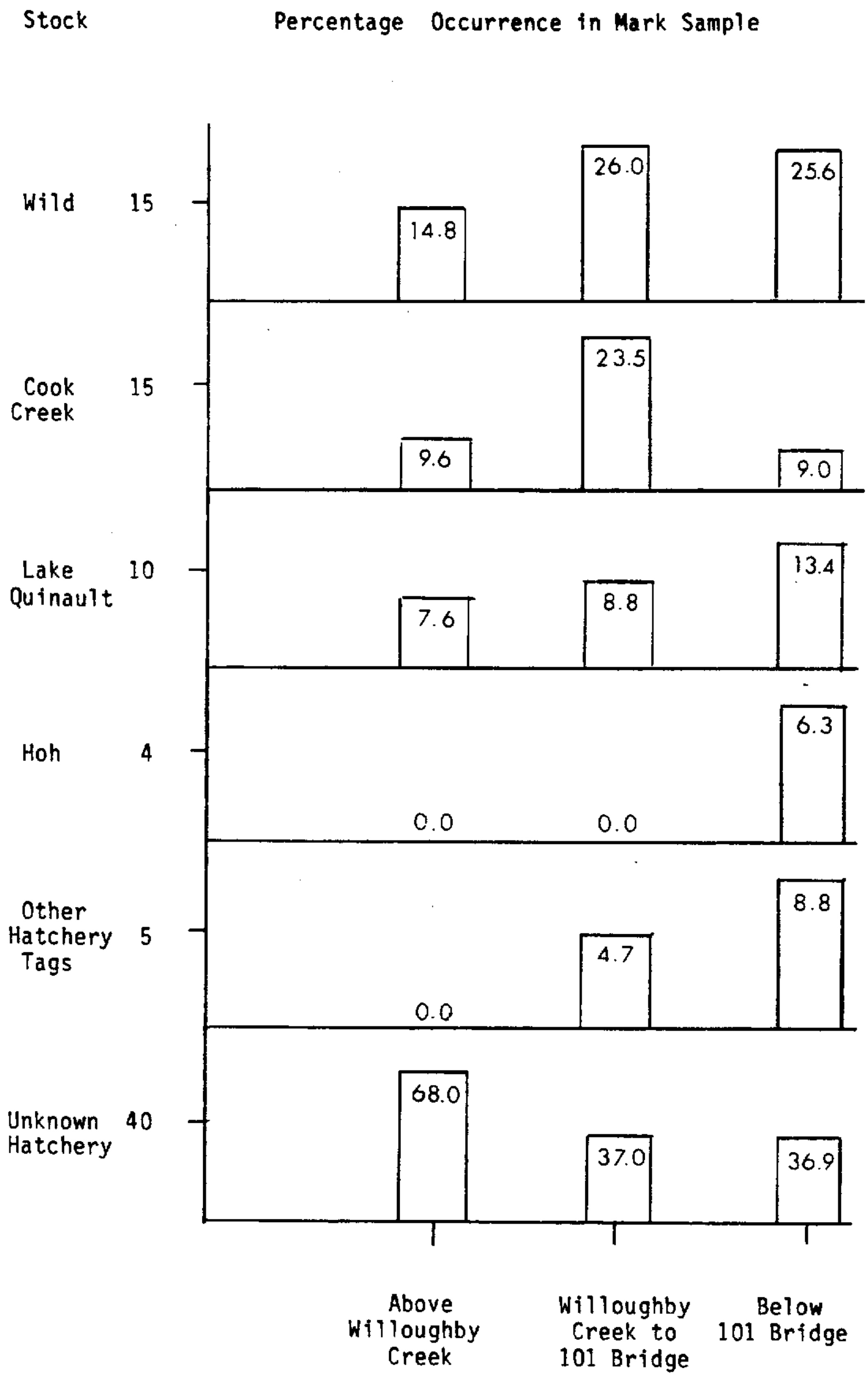

Figure 5. Geographical distribution of stocks in 1983-84 sport catch.

Table 9. Composition of Hoh sport catch sample by hatchery/wild origin, age, fork length, and sex, 1984-85 season.

Origin		Percent by Saltwater Age: Jack	Two-salt	Three-salt	Repeat Spawner	Sample size
Hatchery	Number	8	460	98	34	600
	Percentage	1.3	76.7	16.3	5.7	
Wild	Number	4	53	32	9	98
	Percentage	4.1	54.1	32.6	9.2	

		Fork Length (in.) by Saltwater Age: Jack	Two-	Three-	Repeat Spawner	Ages Combined
Hatchery	Mean	19.6	26.9	32.0	28.0	27.7
	SD	0.7	1.7	2.7	2.3	
Wild	Mean	19.0	28.2	32.8	29.7	29.5
	SD	0.0	2.1	3.0	3.9	

	Sex Ratio (M/F) by Saltwater Age: Jack	Two-salt	Three-salt	Repeat Spawner	Ages Combined
Hatchery	8/0	1.18/1	1/1.65	1/1.07	1.07/1
Wild	4/0	2.47/1	1/1.58	1/3.50	1.37/1

Table 10. Contribution of tagged release groups to sport and tribal fisheries on the Hoh River. Recovery information provided, in part, by Hoh Tribe.

Release Year	Tag Code	Total Release x 1,000	Stock	Estimated Contribution: Two-Salt Number	Two-Salt % of Rel.	Two- and Three-Salt Number	Two- and Three-Salt % of Rel.
1982	5-10-42	50.0	CC	471	0.94	894	1.79
	5-9-61	69.4	LQ	675	0.97	924	1.33
	5-10-43	35.5	LQ	319	0.90	666	1.89
	5-10-44	20.2	HOH	227	1.12	324	1.60
1983	5-11-49	54.9	CC	1,205	2.20	--	--
	5-13-56	83.6	LQ	2,425	2.90	--	--
	5-13-40	10.8	HOH	0	0.00	--	--
	5-10-44/ 5-11-32	4.2	HOH	87	2.06	--	--

Table 11. Contribution of tagged release groups to the tribal fishery on the Quinault system. Source: Quinault Department of Natural Resources (QDNR).

Release Year	Tag Code	Total Release x 1,000	Stock	Estimated Contribution: Two-salt Number	Two-salt % of Rel.	Two- and Three-Salt Number	Two- and Three-Salt % of Rel.
1982	5-10-31	211.4	CC	5,842	2.76	8,060	3.82
	5-9-55	34.3	LQ	600	1.75	867	2.53
	5-9-56	34.2	LQ	845	2.47	1,152	2.37
	5-9-57	34.3	LQ	778	2.27	1,216	3.55
1983	5-11-31	195.1	CC	5,329	2.73	--	--
	5-13-59	139.3	LQ	4,809	3.45	--	--

Table 12. Relative estimated contribution of marked release groups to Hoh sport and tribal fisheries, years combined when possible.

Site	Release Year	Release Stock	Release Tag Code	Estimated Contribution: Sport	%	Tribal (a)	%	Total
Willoughby Creek	82	CC	5-10-42	589	65.9	305	34.1	894
	83	CC	5-11-49	704	63.4	441	36.6	1,205
	Mean				64.6		35.4	
Chalaat Cr.	82	LQ	5-9-61	246	26.6	678	73.4	924
	82	LQ	5-10-43	165	24.8	501	75.2	666
	82	Hoh	5-10-44	121	37.3	203	62.7	324
	Mean				29.6		70.4	
Chalaat Cr.	83	LQ	5-13-56	1,102	45.4	1,323	54.6	2,425
	83	Hoh	5-10-44/ 5-11-32	41	47.1	46	52.9	87
	Mean				46.3		53.8	

(a) Source: Hoh Tribe.

The FWS release on the Hoh in 1982 contributed about equal numbers in both age classes (Table 13), whereas other hatchery programs did not. The overall high proportion of three-salts is again, possibly due to higher sport fishing effort in 1984-85 than the previous season. However, the high variability of age at return among the various releases on the Hoh in 1982 suggests other factors are also operating. Incongrously, the greatest difference in contribution was between April and May releases of the same Lake Quinault stock.

Table 13. Estimated relative contribution of 1982 releases by age class to sport and tribal fisheries on the Hoh River, 1983-84 and 1984-85. Recovery data provided in part by Hoh Tribe.

Tag Code	Stock	Two-Salt Catch		Three-salt Catch		Total
		Number	% of Total	Number	% of Total	
5-10-42	CC	471	52.7	423	47.3	894
5-9-61	LQ	675	73.1	249	26.9	924
5-10-43	LQ	319	47.9	347	52.1	666
5-10-44	Hoh	227	70.1	97	29.9	324

Cook Creek stock timing in the catch exhibited less overlap with the wild Hoh run, in comparison to hatchery releases as a whole, and in comparison to hatchery fish of unknown origin (Table 14 and Figures 2 and 3). The catch of Cook Creek stock appeared slightly later than that of Lake Quinault stock, as evidenced by a higher percentage of the Cook Creek catch occurring in February (Appendix IV Tables 1 and 2). However, this apparent difference may be due to the catch of Cook Creek stock being concentrated further upriver than the catch of Lake Quinault stock, rather than to any inherent timing difference between the stocks.

Timing of the Cook Creek stock in the sport fishery was almost a month earlier in 1984-85 (early January) than in 1983-84 (early February). This may be attributable to different river conditions between the two years. The 1983-84 timing is probably the more typical because it was associated with a normal water year.

FWS releases homed to specific areas along the length of the river, tending in both years to return more to the area upstream from the 101 Bridge than to the area between the 101 bridge and the mouth of the river (Table 15, Figures 4 and 5). Chi-squared probability of incorrectly rejecting the hypothesis of random distribution (that is, the probability of Type I error) was low both years ($P = 0.005$ in 1984-85 and 0.025 in 1983-84). However, homing was more site-specific in 1983-84 than in the following season. In 1983-84 these fish returned preferentially to the area between the 101 Bridge and Willoughby Creek, while in 1984-85 the same release site produced age-3 returns equally preferring all points upstream of the 101 Bridge. One apparent explanation for the change is the difference in flow regimes between the two years. The low midwinter flows of the second year (1984-85) may have altered normal migratory behavior. In any case, it is clear that enough of these fish strayed upstream of their release sites in both study years to be of management concern.

Table 14. Summary of median catch timing in Hoh sport fishery. (Calculation in Appendix IV Table 1.)

Group	1983-84 Catch	1984-85 Catch
Wild	Mid-March	Mid-March
Total Hatchery	Early February	February 1
Unknown hatchery	Early February	March 1
Cook Creek stock	Early February	Early January
Lake Quinault stock	Early January-Feb. 1(a)	Early January
Hoh stock	Early April	

(a) Two tag groups differed in timing by almost one month.

Table 15. Summary of in-river distribution of adults in Hoh sport fishery.

Group	1983-84	1984-85
Wild	Concentrated from Willoughby Creek to mouth.	Random.
Total hatchery	Random.	Random.
Hatchery, unknown origin	Concentrated above Willoughby Creek.	Concentrated above Willoughby Creek.
Cook Creek stock released at Willoughby Creek	1982 release concentrated from Willoughby Creek to 101 Bridge but some straying upstream.	1983 release concentrated above 101 Bridge.
Lake Quinault stock released at Chalaat Creek	1982 release random.	1983 release concentrated below 101 Bridge but some straying upstream.
Hoh stock released at Chalaat Creek	1982 release all between mouth and 101 Bridge	Recoveries insufficient to establish distribution.

(a) Initial evaluation (Hiss et al. 1984) that fish concentrated around Chalaat Creek was based on questionable calculation. Relcalculation of chi-squared following the method for 1984-85 suggested randomness.

Upriver straying has been observed on other river systems as well. The pattern of significant concentration around the release site with some degree of straying upstream was consistent with the findings of Cramer (1981) who found this occurring in outplants of hatchery summer steelhead to the Clackamas River in Oregon, and Aho (1975) who looked at releases of summer steelhead on the Deschutes River, also in Oregon.

On the Rogue River in Oregon, Everest (1973) stated that "hatchery smolts liberated in the main stem establish no homing imprint which will guide them back to a specific tributary for spawning when they return as adults. Adults of hatchery origin home to the general area of release, then seek habitat suitable for spawning above that point".

On the Kalama, hatchery adults planted as smolts as far as 34 km downstream were capable of distributing themselves throughout the watershed for spawning (Leider et al. 1984). On the Big Qualicum River, British Columbia, hatchery fish made up 70-80% of the catch along the 6.2 miles of river available for fishing, although the hatchery apparently released all smolts on-station at about RM 1.0 (Hooton and Hay 1978). On the Chilliwack River in British Columbia, releasing hatchery-reared native steelhead smolts at RM 5, 11, 19, or 24 resulted in about the same percentage distribution of recoveries over three reaches of river ending at RM 6, 12, and 19, respectively (Bruce Ward, Fisheries and Oceans Branch, Vancouver, BC). Releases at a small number of sites produced widely scattered distribution of summer steelhead over about 100 miles of the Deschutes River in Oregon (Don Swartz, Oregon Department of Fish and Wildlife (ODFW), personal communication).

Steelhead released near one Snake River hatchery in Oregon generally returned to the release site, held for a time, and some individuals then proceeded up to 40 miles upstream (Emil Slatick, National Marine Fisheries Service, Pasco, Washington, personal communication).

The straying pattern of the Cook Creek stock upstream of the release site was roughly duplicated by the Lake Quinault stock (Figures 4 and 5). However, the proportion of these releases contributing to the upriver catch, in comparison to the QNFH releases, was apparently reduced due to the downriver location of the release site of the Lake Quinault stock. This downriver concentration of Lake Quinault stock in the sport catch was very distinct in the 1984-85 season ($P = 0.005$) but was barely distinguishable in the 1983-84 season ($P = 0.2$). This difference may be attributable to the unusually heavy fishing pressure in the lower river in the 1984-85 season, in response to abnormally low flows. If this is the case, the degree of upriver straying observed in the 1983-84 season may be expected in most years. Given this, the one-month acclimation period at Chalaat Creek may not be sufficient to reduce straying upriver relative to direct outplanting. (Appendix IV Tables 3 and 4 provide supporting data.)

The tendency to be caught well upriver from the release site exhibited by both the QNFH and Lake Quinault release groups was in contrast to the tendency to remain in the lower river characteristic of the Hoh native stock reared and released at Chalaat Creek (Figure 5). This was apparently related to on-station rearing, with its continuous exposure to water different from the mainstem Hoh. This suggests that sensitivity to imprinting is not necessarily restricted to a few hours at the time of smolt transformation. Rather, it is possible that at some time prior to one month before smolting, a predisposition toward stronger homing tendency is established. The theory of serial imprinting beginning early in freshwater life and continuing until the smolt stage has been supported by the review of Lister et al. (1981) and by the subsequent experiments of Slatick et al. (1983). In Lister's review, straying rates were presented from six releases of coho salmon and steelhead trout smolts released upstream of their rearing site. "Control releases at the rearing sites resulted in virtually no straying, whereas the test releases produced rates of straying ranging from 3.9% to 100%. In five of the six cases all straying was back to the rearing site."

Contribution of Releases Made Outside the Hoh

Tagged groups released on other river systems contributed relatively little to the sport and tribal catch on the Hoh River in both years of the study, based on expanded CWT recoveries (Table 16). For example, native-brood Bogachiel steelhead reared at Bear Springs and released into the Soleduck River in 1981 contributed only an estimated 8 fish to the 1983-84 sport catch. This is less than 1% of the hatchery fish of unaccountable origin for that season. This scarcity of tagged fish, however, does not negate the possibility of large-scale straying into the Hoh because most of the hatchery releases in neighboring rivers were not represented by tagged release groups. For example, none of the releases of early Bogachiel stock, either on-station or outplants, have been tagged in recent years. Extensive straying of hatchery fish released out-of-system has been observed in tributaries to the Georgia Straits in British Columbia (Lister et al. 1981). In a series of outplants to rivers 35 to 47 miles away from the hatchery stream, Lister et al. (1981) found 57 to 78% of the tag recoveries occurred outside the river of release. Of this group, between 0 and 59% strayed to a river other than where the hatchery was located. Extensive straying to a river other than that of release site was also observed on the Alsea and Deschutes rivers in Oregon (Don Swartz, ODFW, personal communication).

The percentage of release groups represented by tagged strays in the sport fishery was similar to that in the tribal fishery, suggesting that a high percentage of each of these groups were traveling upriver of the area fished by the Tribe. This makes it more likely than previously supposed that the out-of-system releases might have spawned in the Hoh, instead of milling near the mouth of the river before returning to their home stream.

Table 16. Estimated composition of Hoh winter steelhead catch, 1983-84 and 1984-85.

Stock	1983-84				1984-85			
	Sport		Tribal(a)		Sport		Tribal(a)	
	Number	%	Number	%	Number	%	Number	%
Cook Creek	375	13.3	96	1.8	978	22.0	650	8.1
Lake Quinault	341	12.1	653	12.0	1,172	26.3	1,849	23.0
Hoh	111	4.0	160	2.9	68	1.5	121	1.5
Strays(b)	110(c)	3.9	290	5.3	174	3.9	295	3.7
Unaccountable Hatchery(d)	1,253	44.6	3,074	56.4	1,516	34.0	3,315	41.3
Wild	621	22.1	1,219	21.6	546	12.3	1,800	22.4
Total	2,811	100.0	5,452	100.0	4,454	100.0	8,030	100.0

(a) Source: Hoh Tribe.
(b) Expanded recoveries of marks released in other river systems. See Appendix IV Table 2 for details.
(c) Includes an estimated 8 two-salt fish from 1981 tagged release group of native-brood Bogachiel stock at Bear Springs on the Soleduck River.
(d) Hatchery fish not accountable by expansion of tag recoveries.

Unaccountable Hatchery Fish

A large portion of both the sport and tribal catch each year was composed of hatchery fish that could not be accounted for by expansion of CWT returns from any releases, within or outside of the Hoh. The tribal fisheries have been affected more than the sport fishery (Table 16). This suggests that a part of this group may be true dip-ins, that were caught en route to other streams. However, the high contribution to the sport catch, in comparison to known stocks, implies that some part of the unaccountable fish were strays that would likely have remained in the Hoh and perhaps spawned there. This conclusion is strengthened by the geographical distribution of this group within the sport fishery (Figures 4 and 5). Their tendency to be caught in the upper river was significant (P less than 0.05) in the 1984-85 season and highly significant (P less than 0.005) in the 1983-84 season.

The unaccountable hatchery fish probably originated from several different sources, no single one of which adequately explains the numbers of unaccountable fish observed. One source must be the release of unmarked Bogachiel stock on the Hoh in 1981 and 1982. This could have contributed to the early portion of the run in both the 1983-84 and 1984-85 seasons. The 1983-84 season was expected to receive three-salt adults from the relatively large 1981 release and two-salt adults from the smaller 1982 release. Assuming an optimistic contribution to the sport and tribal fisheries of, for example, 6% to two-salt catch, 2% to three-salt catch and a sport catch of 33% of the run, one would expect 312 fish (213 from the 1981 release and 99 from the 1982 release) to the 1983-84 catch and 33 fish to the 1984-85 catch. Clearly, an optimistic estimate of contribution from this group to the 1983-84 catch of 4,327 unaccounted hatchery fish is insufficient to explain the large proportion of these fish in the catch.

A second possible source may be from greater post-release mortality of tagged versus untagged members of release groups on the Hoh. This phenomenon is thought by some to affect virtually all major stocks and release years, because unaccountable hatchery fish have consistently made up a large part of the coastal tribal catches (Bob Gibbons, WDG, personal communication).

On the other hand, it is possible that only a few release groups were so affected. A recent review by Zajac (1985) suggests that differential post-release mortality is only likely in stocks which have been diseased or otherwise unduly stressed. If such were the case, the Hoh native stock reared at Chalaat Creek could have been significantly affected. Poor condition was noted in this group by tagging crews in both release years, possibly due to adverse summer rearing conditions at Chalaat Creek. In contrast, all of the steelhead groups reared at Cook Creek and Lake Quinault were in good condition at tagging and, in the case of Lake Quinault releases, were not expected to deteriorate during the short acclimation period at Chalaat Creek. If tagged juveniles in the Hoh stock were stressed during tagging, there is more of a concern with the 1982 releases (represented by tag code 5-10-44) when 6,062 smolts were unmarked. In contrast, the 1983 releases (represented by fish tagged with a combination of tag codes 5-10-44 and 5-11-32) of only 633 smolts were unmarked.

Differential mortality of tagged fish in the Hoh native program cannot be the only contributor to unaccountable hatchery fish. It has been argued (Jorgensen, personal communication) that the Chhalaat Creek fish suffered no adverse conditions not experienced by other stocks. He cites the lack of specific disease outbreaks to support this view. Further, the return rates of most of the Hoh stock tag groups were roughly similar to those of stocks originating elsewhere. By inference, the survival of unmarked individuals of Hoh and other stocks was also similar.

A third source of unaccountable fish resulted from the omission of the tag retention sample for the Hoh native stock releases at Allen's Bar in 1983 (tag code 5-13-40 and the double code 5-10-44/5-11-32). This undoubtedly caused underexpansion of tag recoveries and consequent unaccountability of some of the late-returning hatchery fish.

A fourth source may have arisen from inaccuracy in counting tagged and total releases. This is thought to have been a problem particularly in the Hoh native program.

A fifth probable source is the straying of unmarked hatchery fish from other watersheds. Principal contributors might include members of unmarked release groups from nearby areas such as the Quinault system, the Queets system, Goodman Creek, and the Quillayute system, which have either received large hatchery plants or are very close to the Hoh, or both (Table 17). The straying pattern from each river system can best be determined by tagging that represents the total production of each hatchery program, and by tag recoveries from all major fisheries on each coastal stream.

The timing of the unaccountable group was not similar to any known hatchery run on the Hoh, but rather was spread out over the whole season, with median catch timing between early February (1983-84) and early March (1984-85). It is this group, therefore, which is responsible for the largest degree of temporal overlap with the wild run. This implies that efforts to reduce the impact of hatchery programs on wild stocks by reducing the early-timed releases into the Hoh may not be as effective as desired.

The lack of a definite peak entry timing also supports the hypothesis that this group is composed of several stocks whose timing overlaps. The early-returning hatchery stocks on the Washington coast are Bogachiel, Cook Creek, and Lake Quinault. Large numbers of these have been planted in nearby drainages. The later-returning hatchery stocks are Soleduck, Humptulips, and Wynoochee. Programs utilizing these stocks have been much smaller and have not been as widely outplanted. Of the three, the Soleduck stock is the most likely contributor to the late segment of the unaccountable hatchery run because of the geographical proximity of the Soleduck River to the Hoh. The hatchery segment of the late Soleduck run has apparently been a large contributor to the sport catch on the Soleduck (Cederholm 1984). However, the contribution of Soleduck hatchery native-brood fish straying to the Hoh sport fishery was extremely low, based on coded wire tag recoveries (one tag recovered, and expanded contribution of 8 fish to the 1983-84 catch). In view of the many possible contributors outlined above, it is doubtful that any one stock is responsible for either the early or late portion of the unaccountable portion of the Hoh run.

Hatchery stock of unknown origin was more frequent in the mark sample above Willoughby Creek in both study years. This distribution in 1983-84 may be at least partially explained by unmarked 1981 scatter plants of Bogachiel stock between the Park and Allen's Bar, and a 1982 plant at Allen's Bar (Table 2). The 1984-85 distribution may also be partially explained by unmarked 1983 plants of Lake Quinault stock at Allen's Bar. It is impossible to accurately assess the degree to which Hoh in-system releases contributed to each reporting area, because the separate catches could not be estimated for these areas.

The coming years will not have large returns of Hoh native hatchery plants, whose influence cannot now be separated from

Table 17. Winter steelhead smolt releases outside the Hoh River. (Includes both marked and unmarked release groups. Source: WDG except where noted.)

Location	Release Year		
	1981	1982	1983
Straits of Juan de Fuca(a)	143,919	114,681	119,512
Quillayute System(b)			
Early Bogachiel Stock	114,619	98,477	77,444
Late Soleduck Stock	35,300	30,996	19,800
Goodman Creek	17,002	14,569	19,791
Queets System(c)	107,713	158,408	143,944
Quinault System(d)	350,435	383,187	334,419
Grays Harbor(e)	254,097	192,609	302,426

(a) Includes Hoko, Clallam, Pysht, Lyre, and Elwha rivers, Morse Creek, and Dungeness River.
(b) Includes Soleduck, Bogachiel, and Calawah rivers.
(c) Salmon River (Source: QDNR).
(d) Includes Lake Quinault and Cook Creek.
(e) Includes Johns River, Fuller and Workman creeks, Newaukum and Skookumchuck rivers, Bingham Creek, Satsop River, Sylvia Lake, Wynoochee River, Van Winkle Creek, and the Wishkah, Hoquiam, and Humptulips rivers.

that of strays from outside the Hoh. Therefore, in the 1986-87 catch, the relative abundance of the unaccountable hatchery fish will be expected to reflect, more clearly than at present, the influence of strays.

Potential Impact of Hatchery Fish on Native Stock

Presence of a hatchery-reared run can adversely affect the naturally-producing native stock either through overharvest or through biological mechanisms. Overharvest is not likely because harvest rates in the late-season fisheries (Table 18) reflected management to maintain natural production. These rates have apparently not led to a declining trend in the wild escapement (Table 1). The total harvest rates estimated in this study probably fell within the range of prior years. This is because tribal harvest rates were low to average in the two study years, and because the ratio of sport to tribal catch is fairly constant over the years. However, accurate estimation of total harvest rate for prior years is difficult because one would have to rely on punch card returns for the sport catch.

The validity of using harvest rates to assessing the status of the native stock depends on the degree to which wild escapement represents native stock and not late hatchery strays or hybrids

Table 18. Estimated harvest rates on Hoh wild run.

	1983-84				1984-85			
	Catch			Esc.	Catch			Esc.
	Tribal (a)	Sport	Total		Tribal (a)	Sport	Total	
Wild Run	1,219	621	1,840	3,667	1,800	546	2,346	3,110
Harvest Rate	0.221	0.113	0.334		0.330	0.100	0.430	

(a) Source: Hoh Tribe.

with non-native stock. It was possible to confuse unmarked hatchery fish released as two-year-old smolts with wild fish, especially in the 1983-84 catch where freshwater age was the sole criterion of hatchery/wild origin. Also, incidence of hybrids could not be detected by the methods in this study.

Biological mechanisms of hatchery/wild impact are of two kinds: competition and interbreeding. Competition may decrease survival to adulthood as the offspring of hatchery stock or of crosses between hatchery and wild stock displace the wild fish from their food or space resources. Early-spawning hatchery stocks presumably produce fry which emerge from the gravel, take up residence in the preferred areas, and begin growth before the native juveniles have emerged from the gravel. These fish theoretically could increase the density-dependent mortality of the native stock (McIntyre 1984). Despite the hatchery release's temporary theoretical advantage however, survival to adulthood may be diminished by the relative lack of genetic adaptation in the hatchery run, especially if the hatchery stock is of non-native origin.

Interbreeding may also decrease survival to adulthood. In the words of Leider et al. (1984) "If, through the domestication process (artificial selection), hatchery steelhead have undergone a reduction in reproductive fitness (ability to reproduce under wild conditions), then their successful interbreeding with wild populations may reduce the fitness of those wild populations." The degree of impact, regardless of the biological mechanism involved, would depend on the relative abundance, temporal separation, geographical isolation, and relative spawning success of the spawning populations of native versus outside stocks, in a given watershed.

The relative abundance of hatchery fish versus wild fish observed for the recent Hoh winter runs is potentially of management concern. A similar relative abundance of 85% hatchery fish was cited by Leider et al (1985) in the Kalama summer steelhead run as a cause for concern relative to the genetic integrity of the wild run. This overabundance, he suggested, tended to negate the potentially isolating effect of differences in spawning time between hatchery and wild components of the run.

The timing difference between early hatchery stocks released on the Hoh and the wild run would appear sufficient to provide some degree of temporal separation, were it not for the overriding effect of high relative abundance of hatchery fish. Unfortunately,the high percentage (63%) of hatchery fish in April indicates that temporal separation is not being achieved at the current high production levels. Although the peak timing of the wild and hatchery catches differed by as much as 2 1/2 months, hatchery fish still outnumbered wild stock during a peak wild stock spawning period (April) and at a time that is usually considered beyond the normal hatchery stock spawning period.

Relative spawning success of hatchery versus wild fish can be expected to parallel the situation described by Chilcote et al. (1984) on the Kalama River. Based on redd-trapping studies, it was concluded that "wild steelhead spawners were 270% more capable of contributing to the natural production of sub-yearling steelhead than were hatchery spawners. The observed differnce may be due to: (1) early, non-adaptive spawning of hatchery steelhead, and (2) frequency-dependent competitive interaction between fry from wild parents and fry from hatchery parents. Preliminary evidence from smolt marking and trapping data indicates that the reproductive fitness of wild steelhead may exceed the reproductive fitness of hatchery steelhead by 600%." It has further been suggested (for example, Jorgensen, personal communication) that some hatchery fish may migrate upstream but fail to spawn. However, the extent to which this occurrs has not been rigorously examined, as far as we are aware.

Management Issues

A recent study (Reisenbechler et al. 1985) indicates that for the major coastal watersheds, wild and hatchery stocks have maintained significant genetic differences. However, on the Hoh, sampling for this study was completed prior to the recent substantial increase in smolt planting levels. Maintaining this genetic separation and simultaneously continuing hatchery production at recent levels will be a major challenge of future fisheries management on the Hoh.

The basic management question will be to determine the level of enhancement compatible with protection of the native run assuming that some level of enhancement is compatible with natural production of the late wild run, the determination of a permissible level would be fundamental to any management program.

Related to the level of enhancement is the question of the ability of the sport fishery to harvest all the hatchery stock available to it. This problem stems from the Tribe's efforts to extend their fishery through the entire run and because of the highly variable water conditions usually experienced in December and January. If excessive hatchery fish are expected to be available to the sport fishery in a particular year, given the existing regulations, then consideration might be given to selective harvest to reduce the potential impact on the genetic integrity of the native run. This might be accomplished through an increase in the bag limit of adipose-clipped or stubbed-dorsal fish.

Another consideration is whether a hatchery program should use wild Hoh broodstock or continue to rely on outside stocks. The advantage of the former is that the potential genetic impact of outside stocks would be reduced. This reduction could be substantial, given the high contribution of hatchery outplants to the Hoh in recent years. However, some outside stock influence would remain, in the form of strays from other river systems.

A native brood program could either be taken over the entire season, or selected for early returns. Spreading out the returns would have the advantage of maximizing continued genetic similarity to the wild native run. Maintaining this timing pattern would also ensure the season-long fishery desired by the Hoh Tribe and the WDG but might necessitate lower harvest rates than at present. Concentrating the returns early in the season, on the other hand, would be expected to permit continuation of the present relatively-high harvest rates. This option would not necessarily preclude a season-long fishery, but expected catches would continue to be larger in the early months.

The rearing location would also have to be carefully chosen. Rearing native stock in the Hoh system is preferable from the standpoint of disease containment. Infectious hematopoietic necrosis (IHN) was isolated from Hoh native stock in May of 1981 (Ray Brunson, FWS Olympia Fish Health Center, personal communication). The current status of this disease in the Hoh watershed is not known because the last disease check on Hoh native steelhead was performed in July of 1981. IHN was detected at Lake Quinault in 1976 but has not occurred in examinations performed annually since that time. Were it not for the possibility of reintroduction of this disease into the Quinault system, the Quinault facilities would be the primary choice for rearing Hoh stock. However, since rearing facilities in the Hoh system suitable for oversummering steelhead and still ensuring good growth are not available at this time, rearing outside the Hoh watershed would be acceptable if adequate attention were given to disease containment.

If a wild brood program is not chosen, and non-native stocks continue to be released in the Hoh, an appropriate stock must be chosen and an outplanting procedure determined. Of the three winter steelhead stocks outplanted to the Hoh in recent years (Bogachiel, Cook Creek, and Lake Quinault), only the last two have been studied for their timing and contribution rates to the Hoh River fisheries. The characteristics of the Bogachiel stock must be inferred from the run on that river. Timing is about the same as Quinault system stocks (Table 19), and total contribution to in-system harvest is relatively high in comparison to other coastal hatchery stocks (Bill Freymond, WDF, personal communication).

Regarding an outplanting strategy, either the existing program can be continued, or outplanting can be modified to reduce the extent of hatchery influence on upriver spawning. The existing program consists of a combination of releases at Chalaat Creek and Allen's Bar, in an attempt to balance the objective of avoiding hatchery influence in the headwaters and providing sufficient fish to both the sport and tribal fisheries. However, it is not assured that the location of a release site at Allen's Bar will significantly reduce upriver straying, in comparison to releases at Willoughby Creek. The distance between the two sites may not be sufficient to significantly change adult distribution (Allan Scholz, University of Wisconsin, personal communication).

Some degree of straying may be inevitable in spite of all efforts to the contrary. The straying of hatchery steelhead between Columbia River tributaries has not been completely explained either by lack of imprinting to the hatchery or by transportation to distant outplanting sites (Slatick et al. 1984). In summary, the observation of Lister et al. (1981) that "there are no definitive guidelines regarding the amount and type of imprinting required to assure a high rate of homing to an off-station release site" apparently still holds true.

Hatchery influence in upriver spawning areas may be reduced by releases in tributaries. One would expect preferential return to the release site or at least to the vicinity if the fish were still susceptible to imprinting at the time of release and remained in the tributary long enough for imprinting to occur. Holding ponds may be necessary to ensure sufficient residence time. Nevertheless, straying to the mainstem Hoh and other tributaries may still be expected in a sizeable percentage of the return (Allan Scholz, Univ. Wisc., personal communication).

Investigations of steelhead distribution manipulation have now begun at the Quinault Tribe's Salmon River acclimation pond in the Queets system. The objective is to support an intense hatchery-based sport fishery on the Salmon River (a tributary of the Queets) while maintaining natural production on the mainstem Queets (Larry Lestelle, Quinault Department of Fisheries, personal communication). Steelhead smolts are reared at Lake Quinault and held for approximately two weeks in an acclimation pond receiving water from the Salmon River. Volitional release is permitted. Imprinting to the pond is expected to occur because of the distinctive odor of the feed used there. Monitoring of returns in the coming years should shed some light on this method of stock separation.

Chemical imprinting should also be considered. This has had good success in drawing fish from the open waters of Lake Michigan into individual tributary rivers where availability to the sport

Table 19. Timing of Bogachiel hatchery steelhead to Quillayute River system sport fishery, 1984-85. Source: WDG.

	Dec.	Jan.	Feb.	Mar.	Apr.	Total
Catch/Angler Hour	0.0942	0.0511	0.0328	0.0167	0.0248	0.2196
Percent of Total	42.9	23.3	14.9	7.6	11.3	100.0
Cumulative Percent	42.9	66.2	81.1	88.7	100.0	

fishery was desired (Hasler and Scholz 1983). The ability of steelhead to locate an artificially scented stream has been demonstrated over a range of at least 13 km from the stream (Cooper and Scholz 1976). Experiments with coho established a maximum range of about 40 km on either side of their stocking site for successful location of a simulated home stream. (Scholz et al. 1975).

This technique has also been employed to concentrate adult steelhead at certain points within a river for better availability to the sport harvest. Scholz et al. (1978) state that "In one artificial imprinting experiment, when we metered the imprinting chemical into the Twin Rivers harbor, imprinted fish stopped their migration there and did not migrate up the Twin Rivers . The fish were concentrated in the harbor for harvest by sport fishermen." Upstream migration resumed as soon as the chemical stimulus was discontinued.

Better imprinting techniques may have the potential for achieving certain other management goals in an enhacement program regardless of the choice of stock. First of all, improved imprinting might decrease the incidence of straying resulting in higher and more predictable returns to the stream of release. Secondly, chemical imprinting in particular might give management agencies greater control over in-river migration rate, and hence influence over the distribution of the catch between the fishing groups.

CONCLUSIONS

1. The contribution rates of Cook Creek smolts reared at Quinault National Fish Hatchery and released on the Hoh near Willoughby Creek were within the range of other hatchery programs on the Hoh. The 1982 release of QNFH stock on the Hoh contributed to the combined Hoh River sport and tribal fisheries at a rate of 1.79% for the 1983-84 season. The 1983 release contributed to these fisheries at a rate of 2.20% in the 1984-85 season.

2. Nearly all marked groups released in 1983 contributed to the 1984-85 harvest at a higher rate than did the marked groups released in 1982 to the 1983-84 harvest.

3. The QNFH releases at Willoughby Creek contributed far more heavily to the sport fishery than did either stock released by the Hoh Tribe at Chalaat Creek. The contribution of QNFH releases averaged over the two years was 65% to the sport fishery and 35% to the tribal fishery. In contrast, the Hoh Tribal releases at Chalaat Creek contributed 30%/70% to the 1983-84 sport and tribal fisheries, respectively. This season is considered more representative of typical sport fishing opportunity than the 1984-85 season, when the Chalaat Creek contribution pattern was 46%/54%.

4. The timing of QNFH and Lake Quinault hatchery outplants in the sport catch reflected the early timing of those runs in the Quinault River system. The timing of hatchery-reared Hoh native stock was slightly later than naturally-produced wild stock.

5. Some adults returning from QNFH releases made at Willoughby Creek are likely to stray into the headwaters, based on the sport catch of marked adults. The upper limit of fish distribution could not be defined, however, because relatively little fishing occurrs upstream of the Olympic National Park boundary at RM 38.0. Some straying to the headwaters could be inferred for both seasons, but especially in 1984-85 when concentration of QNFH fish occurred in the catch from the 101 Bridge to the ONP. In 1983-84 the heaviest concentration of QNFH fish occurred between the 101 Bridge and Willoughby Creek. Lake Quinault smolts released at Chalaat Creek also tended to stray upstream, but less frequently than QNFH releases. In contrast, virtually all adults returning from Hoh native smolts reared and released at Chalaat Creek were caught between the 101 Bridge and the river mouth.

6. Increased releases of hatchery smolts in 1982 and 1983 appeared to greatly increase sport and tribal catches in the 1983-84 and 1984-85, in comparison to previous years.

7. Hatchery fish made up at least 70% of the catch in all sections of the river, even in that section which included the ONP. This, coupled with the observed distribution of hatchery and wild stocks, indicates potential negative impact on the genetic integrity of the native population.

8. Hatchery fish whose origin could not be accounted for by expansion of tagged groups caught on the Hoh made up 34% of the sport catch of hatchery origin and 41% of the Hoh tribal catch of hatchery origin in 1984-85. A large part of the unaccountable group is thought to originate from various releases on other river systems. This group is of concern to management for two reasons:

a. The timing of this group in the sport catch is very spread out, so that the unaccountables are responsible for much more overlap between hatchery and wild runs than are the early hatchery stocks planted in the Hoh from the Quinault river system.

b. The distribution of this group was concentrated above Willoughby Creek in both years, suggesting possible straying into the headwaters. No control over in-river distribution is now considered possible, to the degree that these fish originate from other river systems.

RECOMMENDATIONS

1. Evaluate the level of enhancement appropriate for natural production of the native run,taking into account the considerable temporal and spatial overlap of the stocks returning to the Hoh.

2. Consider a transition to all-native broodstock. If native broodstock is used, consider:

   a. capturing at least some brood from the wild each year, to maximize similarity to the native run;and

   b. selecting the hatchery component of the run for early timing. This would tend to to avoid harvest impacts on natural production while still permitting the current timing pattern of the fisheries.

3. Take stringent fish health precautions when rearing Hoh native stock outside the Hoh river system.

4. Examine long-term rearing on tributaries of the Hoh as a means of controlling distribution of adult returns within the river.

5. Vigorously examine the potential of chemical imprinting for minimizing straying from other north coastal river systems. Using this technique to manipulate the distribution of hatchery fish within the Hoh to achieve greater catch efficiency might also be investigated.

6. Conduct a comprehensive investigation on straying of hatchery steelhead from one Washington coastal watershed to another.

   a. Review existing data on CWT recoveries in all coastal tribal catches to discern straying patterns and possible differential mortality of tagged fish.

   b. If required, conduct a marking study to ideally represent all production groups and release locations for which the straying pattern is not well known. Mark sampling would be required in all coastal hatcheries and in all major coastal fisheries.

   c. Monitor the the Hoh Tribal and sport catches for hatchery/wild ratio, especially later in the season. Since late hatchery releases are no longer being made in the Hoh, the current timing pattern of hatchery fish would serve to clarify the origin of the late unmarked hatchery fish observed in the creel census.

7. Investigate by electrophoresis the genetic identity of steelhead associated with various spawning grounds within the Hoh, with an experimental design adequate to meet management needs. Monitor annually the long-term genetic changes in the wild stock attributable to introduction of foreign stocks.

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APPENDIX I: CATCH ESTIMATION METHOD

Estimating Catch per Effort

Catch per effort was calculated as total steelhead per angler hour reported in the interviews. The same method was used in our previous creel census. This method is an unbiased estimator of catch per effort because each angler hour from the sample has equal weight. Further justification was given by a regression of catch against angler hours, in the 1984-85 sport fishery, where each interview day was represented by a data point. The slope of the line was considered to be an unbiased estimator of the ratio of total catch to total effort because, on visual inspection, it fulfilled the criteria of Snedecor and Cochran (1967), that (1) the plot could be best fitted with a straight line, (2) the line passed through the origin, and (3) the standard deviation of the catch was proportional to the amount of effort. The second criterion was further supported by the nature of the data because as effort approaches zero, the catch is expected to approach zero. The third criterion was also further supported by the nature of the data, because as effort increases, the range of possible catches is expected to increase proportionally.

This method of determining the catch per effort was applied to each individual stratum because there was no reason to expect a sample from a stratum to behave differently than the sample taken as a whole. The percentage of effort sampled per strtatum reflects the accuracy of the catch per effort estimate. Percent sampled was calculated as the number of fish reported by anglers relative to the estimated catch, and presented in Appendix I Table 1.

Estimating Total Effort from Index Counts

Special procedures in estimating the 1984-85 effort were necessary because many bank anglers were observed fishing downstream of the index area, used in December and January, referred to as the "old index area." Reliance on the original index area would have led to a very large expansion factor based on relatively low numbers of anglers counted. Thus, the reliability of bank fishing effort would be less than optimum. To remedy this situation, we added a new index site known as "Barlow's Corner" on February 1, to represent the area around the mouth of the river. The total area used from then until the end of the study is referred to as the "new index area." Then we adjusted the December and January index counts to account for the effort expected to have occurred at Barlow's Corner in those months.

To make this adjustment we had to account for the effect of river stage, because it appeared that anglers were fishing at the mouth of the river mainly on days when the flow was very low. We also

Appendix I Table 1. Sampling effort: angler hours reported in fishing trips used for analysis as percentage of total estimated angler hours in the stratum.

		Percent of Effort Sampled
Month	Dec.	30.8
	Jan.	29.4
	Feb.	33.2
	Mar.	38.2
	Apr.	40.8
Fishery	Bank	16.2
	Boat	43.4
Day of Week	Weekday, tribal fishery	46.5
	Weekday, no tribal fishery	23.3
	Weekdays combined	31.8
	Weekends	34.1
Strata combined		32.8

initially considered total daily fishing pressure but found this had no significant effect on use of the new index area. We decided to make separate adjustments according to day of week, since Tribal fishing effort, which is also concentrated around the mouth of the river, might affect anglers' choice to fish there. Therefore, we regressed the percentage of effort occurring in the old index area against the stream gage height. We constructed separate lines for tribal fishing days, weekdays without tribal fishing, and weekends (Appendix I Table 2). Then, using the gauge height for each census day in December and January, we expanded the index count to include the effort at Barlow's Corner (Appendix I Table 3).

The next step was to determine whether the distribution of sport fishing was affected by the March 1 closure of Park waters from RM 29.5 upstream. Such a change would have affected the validity of the index expansion factors, or require adjustment for before or after the closure. Fortunately, closure of the Park did not reduce the ratio of park index anglers to anglers in downstream index areas in a statistically significant manner (Appendix I Table 4). In the case of the bank fishery, effort at the Park index area was nearly negligible even when the Park was open. In the case of the boat fishery, trailers at the Park boat launch were slightly more numerous after the closure. For these reasons we chose to use the same index expansion factor throughout the season.

The next step was to choose appropriate index expansion models. This was done by regressing the total effort, as obtained from

Appendix I Table 2. Adjustment of December and January bank angler counts to account for movement of effort outside old index area.

Stratum	Formula	Correlation N	Correlation r	Correlation P
Weekday, tribal fishery	Y = 37.4 X - 77.8	14	0.567	GT 0.05 (a)
Weekday, no tribal fishery	Y = 47.0 X - 121.9	18	0.858	LT 0.01
Weekend	Y = 26.3 X - 38.1	17	0.762	LT 0.01

Y = Old index area effort as percentage of new total index area effort

X = Gage height at 101 Bridge

(a) Chi-squared at 5% probability = 0.627, indicating marginal significance.

counts made from the helicopter, against the adjusted index effort, as obtained from simultaneous counts made on the ground. Four questions had to be answered: (1) Was a linear model appropriate, or should the data be transformed? (2) How was the variability of the total effort related to the index effort? (3) Did the line pass through the origin? and (4) Were there any outlying points that could be rejected on empirical or statistical grounds?

On the question of linearity, the bank fishery data appeared linear under visual observation (Appendix I Figure 1). This linearity was especially obvious after two outlying points were removed, by the procedure described below. The boat fishery data appeared linear except for the the point representing the highest index effort (Appendix I Figure 2). Here, the coresponding total effort was considerably higher than predicted by linear regression. Nonetheless, plots of log-10 total effort versus index effort, of log-10 total effort versus log-10 index effort, or of square root of total effort versus index effort, failed to yield any higher correlation coefficients than the linear model.

We eliminated two outlying points from the bank fishery regression based on both empirical and statistical reasons. The empirical argument is based on the fact that it takes longer to complete a count of anglers on the ground than from the air. If a count is made fairly early in the day, anglers can still be arriving in the index areas between the time the aerial count is finished and the time the ground count is finished. If a count is made fairly late in the day, anglers may already be leaving the index areas between the end of the aerial count and the end of the ground count. In the data, one outlying point corresponded to each of these two cases. Statistical testing of the

Appendix I Table 3. Hoh winter steelhead 1984-85 index effort in bank fishery.

Month	Week Day	Day	Gage Ht.	Obs. Effort	Adjusted Effort
Dec.	WDT	3	4.5	10	11.0
		4	4.4	18	20.7
		5	4.2	12	15.1
		10	5.0	8	8.0
		11	4.7	8	8.2
		17	4.9	8	8.0
		18	4.6	17	18.0
		19	4.4	23	26.5
		26	4.2	67	84.5
		27	4.2	63	79.4
		28	4.0	58	80.8
	WDNT	6	4.1	23	32.5
		7	4.5	9	10.0
	WE	9	5.3	18	18.0
		16	5.3	11	11.0
		22	4.8	39	44.3
		23	4.8	66	74.9
		29	4.0	50	74.5
		30	4.8	36	40.9
Jan.	WDT	2	3.9	18	26.4
		3	3.9	19	27.9
		4	4.0	21	29.2
		8	3.8	22	34.2
		14	3.6	7	12.3
		21	3.9	33	48.5
		22	3.9	24	35.2
		23	3.8	35	54.4
		28	3.4	10	20.2
		29	3.4	10	20.2
	WDNT	9	3.8	48	84.7
		10	3.7	46	88.5
		11	3.6	33	69.8
		17	3.9	25	40.7
		18	4.0	41	62.0
	WE	5	4.0	75	111.8
		12	3.6	54	95.4
		13	3.6	58	102.5
		19	3.9	66	102.3
		20	3.9	46	71.3
		26	3.6	46	81.3
		27	3.5	19	35.2

Appendix I Table 4. Angler counts inside and outside Olympic National Park before and after March 1st closure of Park.

Type	Location (a)	Period Dec.-Feb.	Mar.-Apr.	X-squared	P
Bank	Park	22	0		
	Below Park	1,590	145	2.028	GT 0.1
Boat	Park	29	20(b)		
	Below Park	1,273	348	17.367	LT 0.005

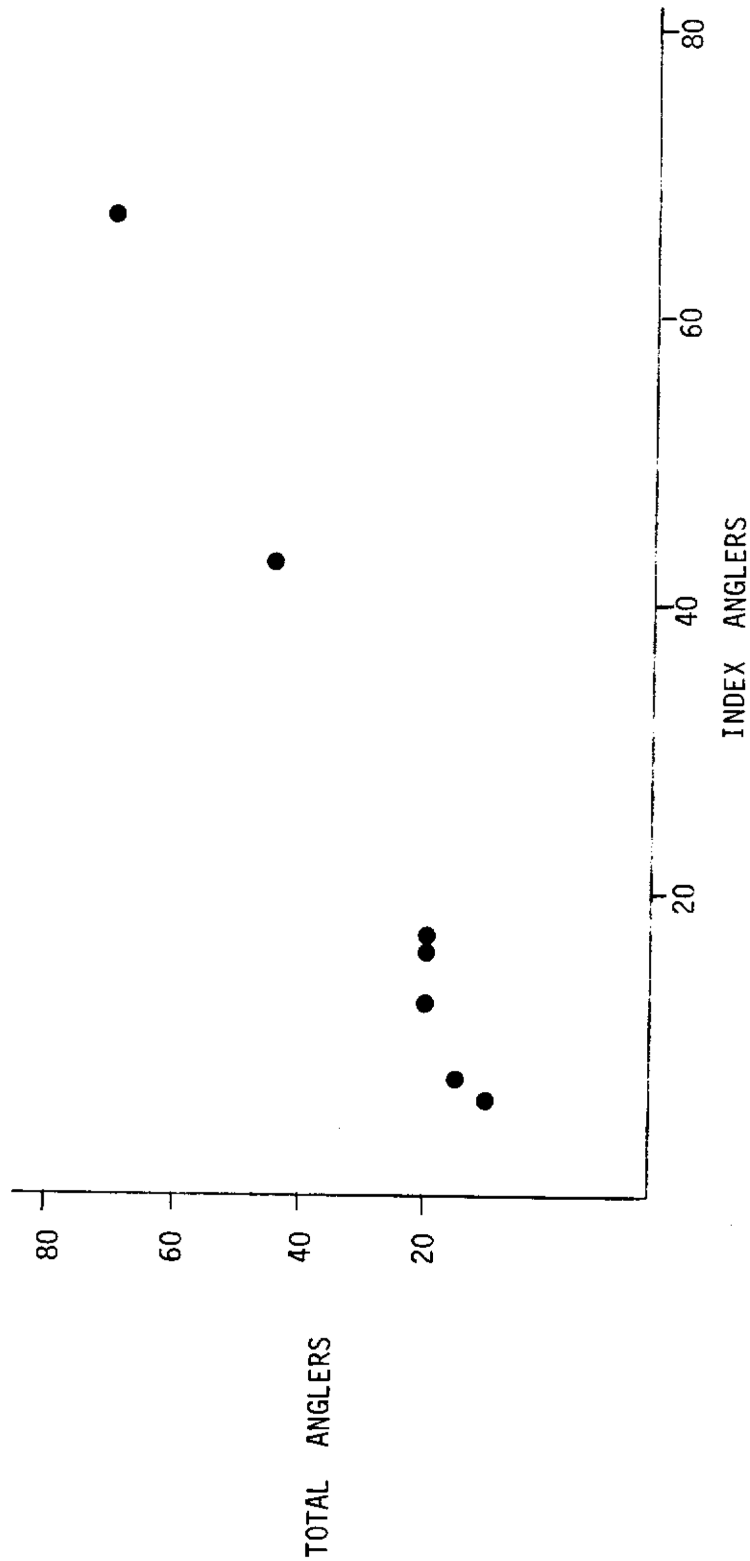
(a) Park = RM 30 and upstream. Below Park = RM 0 to 30.
(b) Anglers continued to leave boat trailers at Park boat launch but began fishing below Park boundary at RM 29.5.

respective differences between these outliers and the regression line showed significant differences and thus confirmed our discarding these points.

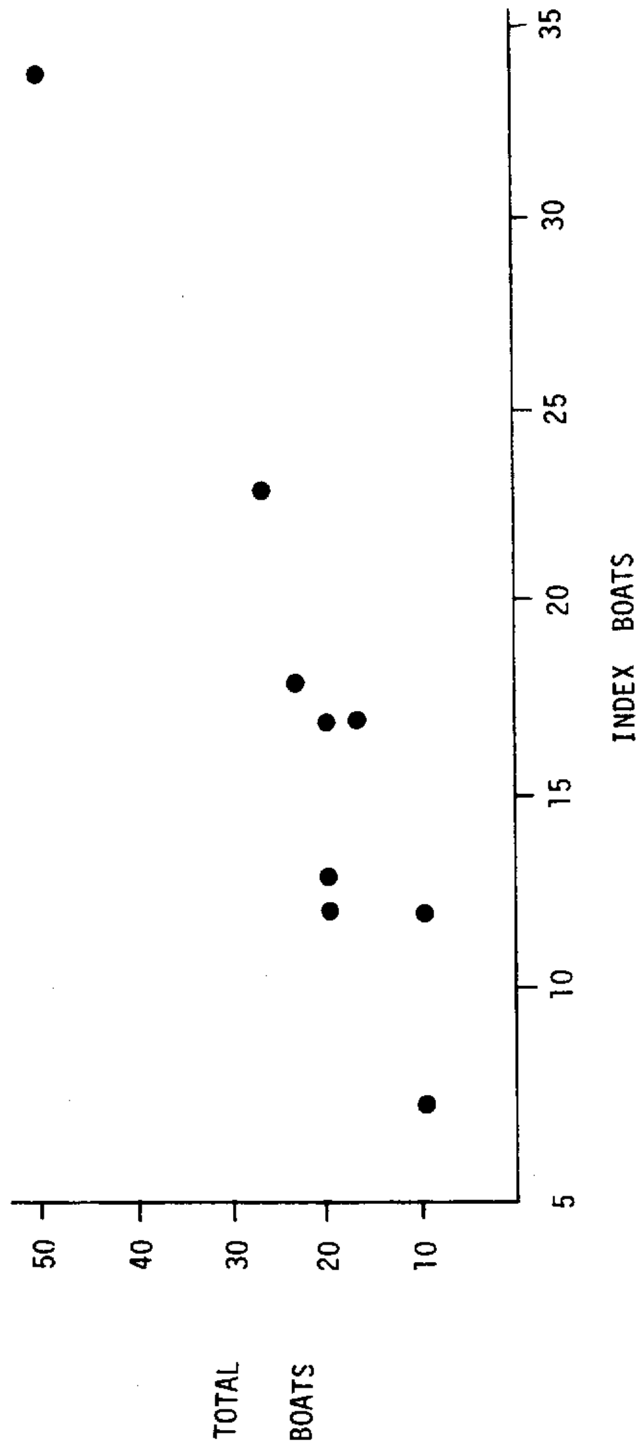
On the question of variability, we expected the range of total effort to increase in proportion to the index effort due to the larger number of anglers arriving or leaving during the more heavily-fished days. However, statistical confirmation was not possible due to the low number of data points.

We expected the regression lines to pass through the origin because there were no major fishing areas not included in the index area. If there were such fishing areas, we would have expected a positive intercept. Statistical testing confirmed that both the boat and bank regression lines could indeed be considered to pass through the origin.

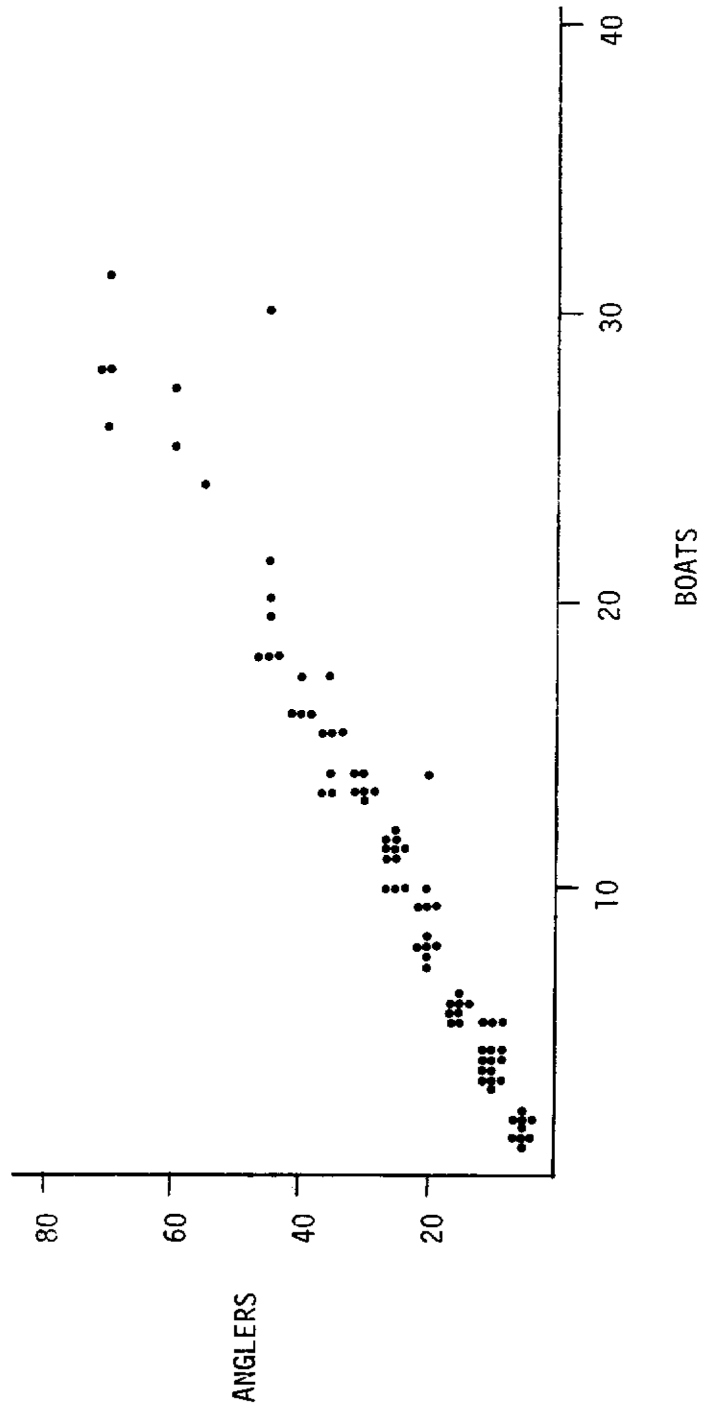
The final step in estimating the instantaneous angler effort was to convert our expanded counts of boat trailers into counts of boat anglers. To do this we relied on the number of anglers per boat reported in the interviews. To calculate a ratio we regressed the number of anglers versus the number of boats, with each interview day constituting a data point. The data supported calculating the ratio of anglers per boat as total anglers per total boats. That is, the model appeared to be linear, to pass through the origin, and to increase slightly in variability in proportion to the number of anglers interviewed on a given day, based on visual inspection (Appendix I Figure 3). We then calculated anglers per boat separately for each stratum.



Appendix I Figure 1. Total observed bank effort versus index effort in the bank fishery. Outlying points have been removed.



Appendix I Figure 2. Total observed boat effort versus index effort.



Appendix I Figure 3. Daily counts of anglers interviewed in boat fishery versus boats used by these anglers.

Determining Fishable Days per Stratum

To estimate the total effort per stratum we had to expand the census days to account for the total fishable days in the stratum. Fishability depends almost entirely on turbidity of the river. Turbidity on the Hoh was found to be closely related to gage height in the 1983-84 winter steelhead creel census. Gage heights above 6.2 feet at the 101 Bridge seemed to be a good indicator that the river was not fishable. Therefore, fishable days were considered all those with gage heights of 6.2 or less. The river was never too low to prevent fishing effort during these surveys.

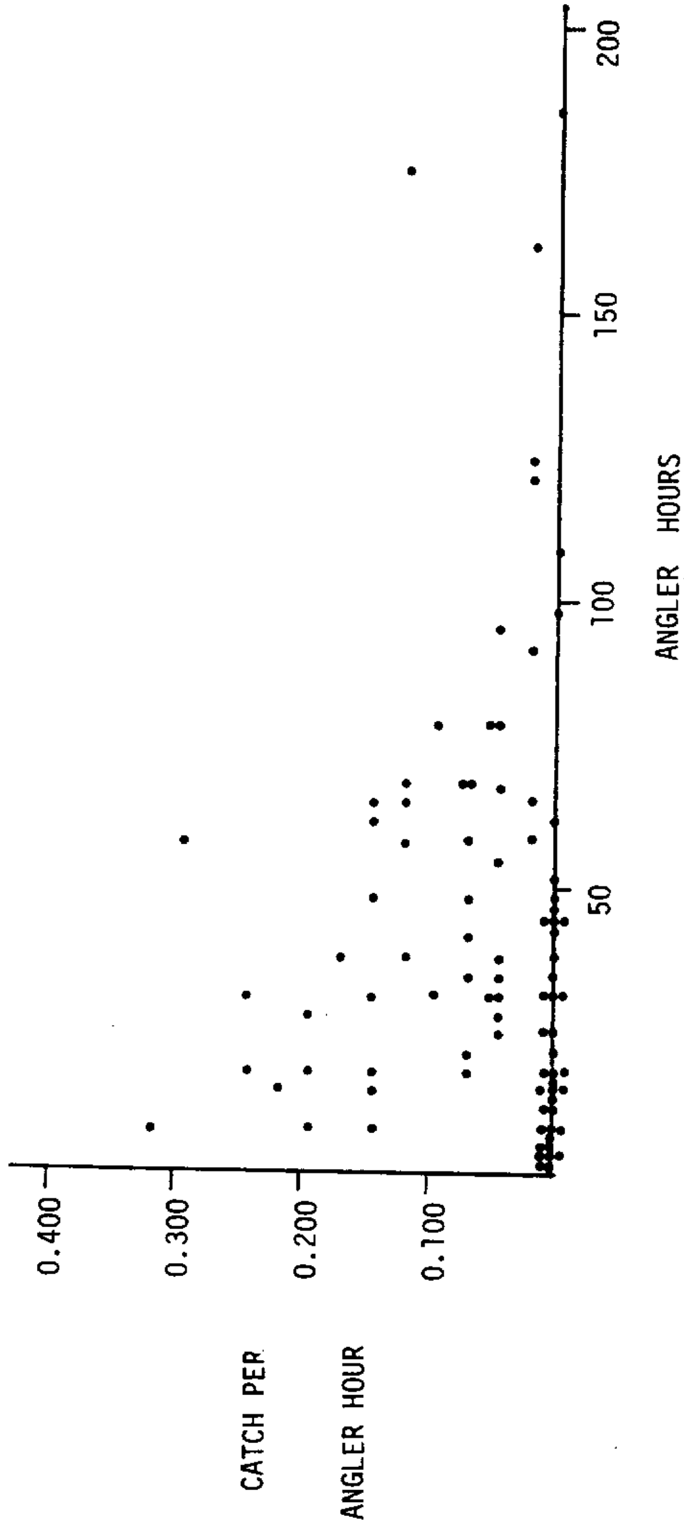
Stratifying the Sampling

Care was taken to avoid over-stratifying the census. Dividing the season into too many strata would have reduced the number of angler hours in some strata to the point where catch per angler hour for the stratum would have been unreasonably high or low. To guard against doing this, catch per angler hour was plotted against angler hours, with one data point for each census day, for the bank fishery (Appendix I Figure 4) and the boat fishery (Appendix I Figure 5). Inspection of the plots suggested that bank strata should be represented by at least 75 angler hours and boat strata, at least 125 angler hours. This required combining the December weekday boat fishery data regardless of tribal fishing activity. All other strata established in the Methods section of this report remained separate.

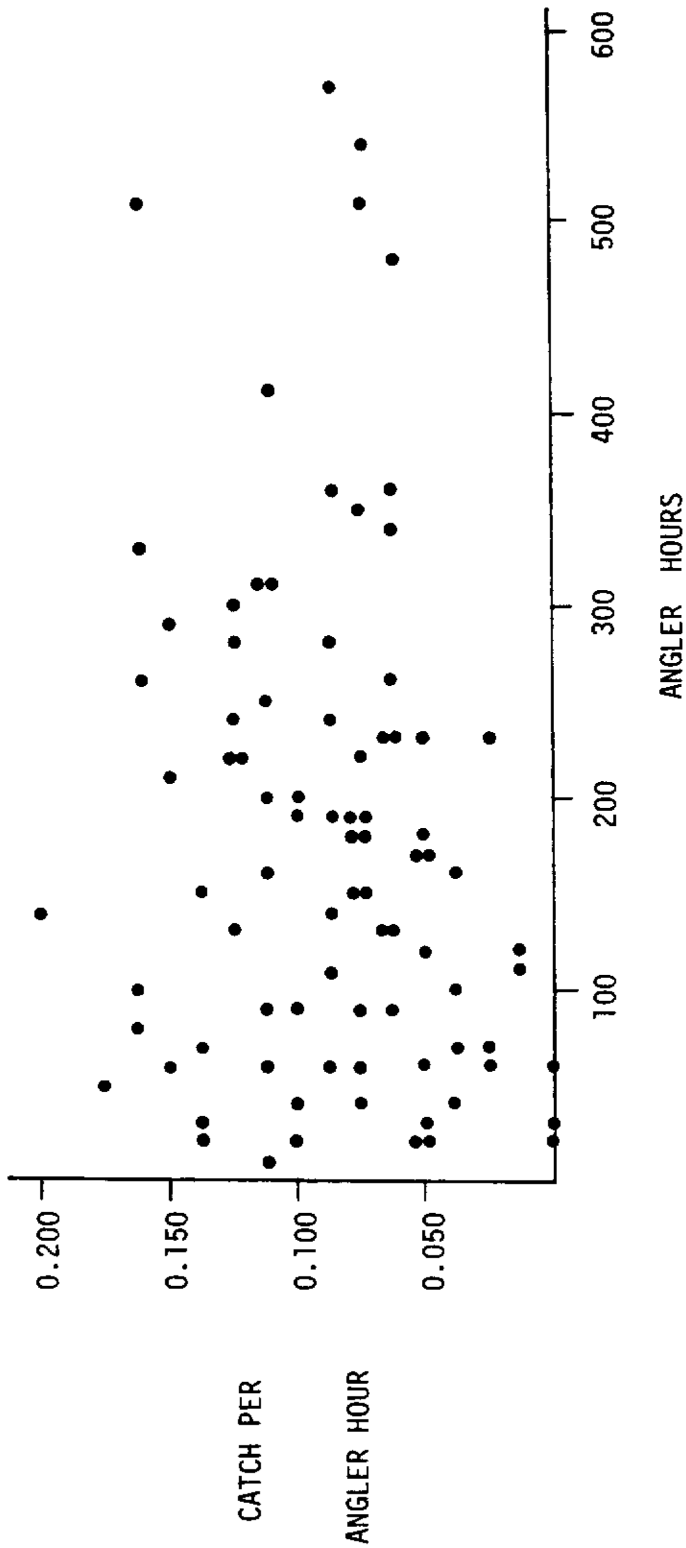
Using Data from Incomplete Fishing Trips

We used only completed fishing trips, whenever possible, to estimate catch per effort. Incomplete trip data were normally discarded because angler interviews suggested that more fish were being caught later in the fishing trip. If so, incomplete trip data is expected to underestimate the true catch per angler hour. Whether or not catch occurred nonrandomly over the fishing day depended largely on how the day was separated for analysis. For example, if the fishing trip was divided in half, then the deviation from randonmess was nonsignificant (Appendix I Table 5). However, 20.8 % of the fish were caught in the last 10% of the fishing day, with very high significance. Analysis of reasons for quitting suggested resolution of the ambiguity in favor of nonrandomness. Of the 51 fishing parties interviewed for this purpose, 29 (56.9 %) reported reasons for quitting having to do with catching enough fish. Furthermore, of these 29, 17 (58.6 %) said they had limited out.

However, we were forced to combine incomplete trip data with complete trip data in estimating the catch for the March weekday bank strata because completed trip data alone fell short of the required 75 angler hours. We attempted to eliminate the bias by applying a correction factor equal to the ratio of (catch per



Appendix I Figure 4. Catch per effort versus angler hours interviewed per day for bank fishery.



Appendix I Figure 5. Catch per effort versus angler hours interviewed in boat fishery.

Appendix I Table 5. Distribution of catch over length of bank fishing trip (a).

% of Trip Completed	Cumulative Catch Reported	Cumulative Catch Expected(b)	Chi-squared (c)	P
50	42	48	1.500	GT 0.1
60	52	58	1.361	GT 0.1
70	65	67	0.240	GT 0.5
75	66	72	2.000	GT 0.1
80	67	77	6.253	LT 0.025
90	76	86	12.518	LT 0.005
100	96	96		

(a) Based on total catch of 96 fish from 71 completed fishing party days distributed over entire fishing season.
(b) Based on equal probability of catch in any given segment of the fishing trip.
(c) X-squared = (f - 96p)squared / 96pq where:
f = reported cumulative catch
p = percent of fishing trip completed
q = percent of fishing trip not yet completed

effort in the combined March bank fishery based on completed trips only)/(catch per effort in the same fishery based on combined complete and incomplete trips).

REFERENCE

Snedecor, G.W. and W.G. Cochran. 1967. Statistical methods. Iowa State University Press, Ames.

APPENDIX II: METHODS FOR ESTIMATION OF CATCH COMPOSITION

Appendix II Table 1. Hatchery/wild designation for 1984-85 Hoh sport catch.

Freshwater Age	Dorsal Stubbing	Adipose Clip	Designation
1	--	--	Hatchery(a)
2	Yes	--	Hatchery(b)
2	No or Undetermined	Yes	Hatchery(b)
2	No or Undetermined	No	Wild
Undetermined	Yes	--	Hatchery
Undetermined	No	Yes	Hatchery
Undetermined	No	No	Wild
Undetermined	Undetermined	Yes	Hatchery
Undetermined	Undetermined	No	Undetermined

(a) Except in one instance where scale reader had designated otherwise.
(b) Accounts for release of two-year-old smolts.

Appendix II Table 2. Expansion of observed tags for estimate of timing.

Month	Observed Adipose Clips (A)	Fish Examined for Adipose Clips (M)	Snouts Taken (S)	Estimated Catch (C)	Expansion Factor for Observed Tags (AM/SC)
Dec.	62	184	43	936	7.33
Jan.	90	240	59	1,943	12.28
Feb.	25	115	17	591	7.56
Mar.	19	115	16	740	7.64
Apr.	10	79	8	255	4.03
Total(a)	211	738	148	4,454	8.60

(a) Includes 5 recoveries of unknown date.

Appendix II Table 3. Adjustment of observed tags for estimate of distribution.

Location (a)	Observed Adipose Clips	Snouts Taken	Adjustment
South Fork	0	0	--
Park	1	1	1.00
Upper	59	32	1.84
Subtotal	60	33	1.82
Willoughby	22	16	1.38
Lower	118	88	1.34

(a) Locations defined in "Methods" section of main report.

APPENDIX III: CATCH ESTIMATION DATA

Appendix III Table 1. Estimate of catch per angler hour by stratum, Hoh River 1984-85 winter steelhead sport fishery.

Month	Type	Week Day (a)	Reported Catch	Reported Angler Hours	Catch/ Angler-Hour
Dec.	Bank	WDT	7	274.5	0.0485
		WDNT	8	92.0	0.0870
		WE	34	317.8	0.1070
	Boat	WD	222	1,484.5	0.1500
		WE	50	551.0	0.0907
Jan.	Bank	WDT	8	379.0	0.0211
		WDNT	20	217.5	0.0920
		WE	44	477.5	0.0921
	Boat	WDT	153	1,758.0	0.0870
		WDNT	134	1,231.5	0.1090
		WE	197	2,436.5	0.0809
Feb.	Bank	WDT	1	178.5	0.0056
		WDNT	8	344.0	0.0233
		WE	8	457.0	0.0175
	Boat	WDT	40	554.0	0.0722
		WDNT	61	764.5	0.0798
		WE	102	1,564.5	0.0652
Mar.	Bank	WDT(b)	6	136.0	0.0579
		WDNT(b)	13	188.5	0.0906
		WE	15	274.5	0.0546
	Boat	WDT	54	773.0	0.0699
		WDNT	94	1,154.5	0.0814
		WE	89	1,514.0	0.0588
Apr.	Bank	WDNT	1	140.0	0.0071
		WE	7	139.5	0.0502
	Boat	WDNT	76	779.5	0.0975
		WE	44	622.5	0.0707

(a) WDT = weekday with tribal fishery; WDNT = weekday without tribal fishery; and WE = weekend
(b) Combined incomplete plus complete trip data multiplied by correction factor of 1.313. See text of this appendix for details of calculation.

Appendix III Table 2. Estimate of instantaneous angler effort by stratum, Hoh River 1984-85 winter steelhead sport fishery.

Month	Type	Week Day (a)	Anglers per Boat	Mean Instantaneous Counts: Trailers	Index Anglers	Total Anglers
Dec.	Bank	WDT			16.4	18.1
		WDNT			10.6	11.7
		WE			22.0	24.3
	Boat	WD	2.30	7.2	16.6	19.6
		WE	2.14	6.3	13.5	16.0
Jan.	Bank	WDT			15.4	17.0
		WDNT			34.6	38.2
		WE			42.8	47.2
	Boat	WDT	2.24	11.2	25.0	29.6
		WDNT	2.24	17.5	39.2	46.4
		WE	2.33	23.4	54.5	64.5
Feb.	Bank	WDT			5.9	6.5
		WDNT			15.8	17.4
		WE			18.7	20.6
	Boat	WDT	2.23	3.9	8.8	10.4
		WDNT	2.17	7.4	16.1	19.0
		WE	2.38	15.8	37.6	44.5
Mar.	Bank	WDT			2.9	3.2
		WDNT			5.3	5.8
		WE			9.1	10.0
	Boat	WDT	2.15	5.7	12.3	14.6
		WDNT	2.09	9.3	19.3	22.8
		WE	2.20	10.9	24.0	28.4
Apr.	Bank	WDNT			6.3	6.9
		WE			10.7	11.8
	Boat	WDNT	1.86	4.8	8.9	10.5
		WE	1.76	8.8	15.5	18.3

(a) WDT = weekday with tribal fishery; WDNT = weekday without tribal fishery; and WE = weekend

Appendix III Table 3. Calculation of sport catch by stratum, Hoh River winter steelhead 1984-85 season.

Month	Type	Day of Week	Catch per Angler-Hour	Instantaneous Anglers (expanded)	Fishable Days	Hours per Day	Estimated Catch	Subtotal
Dec	Bank	WDT	0.0485	17.6	11	8.5	80	
		WDNT	0.0870	11.9	7	8.5	62	
		WE	0.1070	24.3	10	8.5	221	
	Boat	WD	0.1500	19.6	18	8.5	450	
		WE	0.0907	16.0	10	8.5	123	936
Jan	Bank	WDT	0.0211	16.5	10	8.9	31	
		WDNT	0.0920	37.4	12	8.9	367	
		WE	0.0921	47.0	9	8.9	347	
	Boat	WDT	0.0870	29.6	10	8.9	229	
		WDNT	0.1090	46.4	12	8.9	540	
		WE	0.0809	64.5	9	8.9	418	1,932
Feb	Bank	WDT	0.0056	6.5	7	10.2	3	
		WDNT	0.0233	17.4	12	10.2	50	
		WE	0.0175	20.6	9	10.2	33	
	Boat	WDT	0.0722	10.4	7	10.2	54	
		WDNT	0.0798	19.0	12	10.2	186	
		WE	0.0652	44.3	9	10.2	265	591
Mar	Bank	WDT	0.0579	3.2	8	11.8	17	
		WDNT	0.0906	5.8	13	11.8	81	
		WE	0.0546	10.0	10	11.8	64	
	Boat	WDT	0.0699	14.6	8	11.8	96	
		WDNT	0.0814	22.8	13	11.8	285	
		WE	0.0588	28.4	10	11.8	197	740
Apr	Bank	WD(b)	0.0071	6.9	11	13.2	7	
		WE	0.0502	11.8	4	13.2	31	
	Boat	WD(b)	0.0975	10.5	11	13.2	149	
		WE	0.0707	18.3	4	13.2	68	255
Total								4,454

(a) WDT = Weekdays on which tribal fishery occurred atleast for part of day. WDNT = weekdays when no tribal fishery occurred. WE = weekend. WD = all weekdays combined.
(b) No tribal fishery occurred in April.

APPENDIX IV: MARKED RECOVERY DATA

Appendix IV Table 1. Cumulative catch per angler hour for total sport catch and selected categories, 1984-85 season.

Group		Month					
		Dec.	Jan.	Feb.	Mar.	Apr.	Total
Wild	Catch	77	122	109	144	94	
	CPUE	0.0088	0.0055	0.0094	0.0136	0.0228	0.0601
	Monthly %	14.6	9.2	15.6	22.6	38.0	
	Cum. %	14.6	23.8	39.4	62.0	100.0	
Hatchery	Catch	859	1,810	482	596	161	
	CPUE	0.0672	0.0823	0.0415	0.0562	0.0391	0.2863
	Monthly %	23.5	28.7	14.5	19.6	13.7	
	Com. %	23.5	52.2	66.7	86.3	100.0	
Unknown	Catch	277	437	296	439	111	
	CPUE	0.0316	0.0199	0.0255	0.0414	0.0270	0.1454
	Monthly %	21.7	13.7	17.5	28.5	18.6	
	Cum. %	21.7	35.4	52.9	81.4	100.0	
5-11-49 (Cook Creek)	Catch	197	362	97	59	5	
	CPUE	0.0225	0.0165	0.0083	0.0056	0.0012	0.0541
	Monthly %	41.6	30.5	15.3	10.4	2.2	
	Cum. %	41.6	72.1	87.4	97.8	100.0	
5-13-56 (Lake Quinault)	Catch	295	686	25	71	25	
	CPUE	0.0337	0.0312	0.0022	0.0067	0.0061	0.0799
	Monthly %	42.2	39.0	2.8	8.4	7.6	
	Cum. %	42.2	81.2	84.0	92.4	100.0	

Appendix IV Table 2. Observed recovery of tag groups and total estimated contribution (accounts for sampling rate and percent of group tagged) by month in Hoh River 1984-85 sport fishery.

	% Tagged		Dec. 7.33	Jan. 12.28	Feb. 7.56	Mar. 7.64	Apr. 4.03	Unknown 8.60	Total
			Month and Expansion Factor						
5-11-49		Obs.	21	23	10	6	1	4	65
	78.0	Cont.	197	362	97	59	5	44	764
5-13-56		Obs.	13	18	1	3	2	0	37
	32.2 (a)	Cont.	295	686	25	71	25	0	1,102
5-10-42		Obs.	3	3	2	0	0	0	8
	34.5	Cont.	64	107	43	0	0	0	214
5-10-43		Obs.	2	2	0	0	0	0	4
	57.3	Cont.	26	44	0	0	0	0	70
5-10-44		Obs.	0	0	2	0	1	0	3
	70.0	Cont.	0	0	21	0	6	0	27
5-10-44/		Obs.	0	0	0	3	3	0	6
5-11-32	85.0	Cont.	0	0	0	27	14	0	41
5-9-57		Obs.	0	1	0	0	0	0	1
(b)	30.9	Cont.	0	39	0	0	0	0	39
5-9-60		Obs.	0	1	0	0	0	0	1
(c)	26.7	Cont.	0	45	0	0	0	0	45
5-13-60		Obs.	0	1	0	0	0	0	1
(d)	13.3	Cont.	0	90	0	0	0	0	90
Total Contribution			582	1,373	186	157	50	44	2,835
Total Hatchery Catch			859	1,810	482	596	161	--	3,908
Hatchery Catch of Unknown Origin			277	437	296	439	111	--	1,073

(a) Includes both Chalaat Creek and Allen's Bar releases.
(b) Released on Lake Quinault.
(c) Released on Humptulips River.
(d) Released on Salmon River (tributary of Queets).

Appendix IV Table 3. Observed recovery of tag groups and total estimated contribution (accounts for sampling rate and percent of group tagged) by area in Hoh River 1984-85 sport fishery. See "Methods" section of text for designation of catch sampling areas.

	% Tagged		Area (Sampling Rate(a) in parentheses) "P" (1.00)	"S" (1.00)	"U" (0.54)	Subtotal	"W" (0.72)	"L" (0.75)
5-11-49		Obs.	1	0	23	24	10	25
	78.0	Cont.	1	0	54	55	18	44
5-13-56		Obs.	0	0	2	2	1	32
	38.5 (b)	Cont.	0	0	10	10	3	112
5-10-42		Obs.	0	0	0	0	2	3
	34.5	Cont.	0	0	0	0	9	12
5-10-43		Obs.	0	0	0	0	0	4
	57.3	Cont.	0	0	0	0	0	9
5-10-44		Obs.	0	0	1	1	0	2
	70.0	Cont.	0	0	3	3	0	4
5-10-44/		Obs.	0	0	0	0	0	6
5-11-32	85.0	Cont.	0	0	0	0	0	9
5-9-57		Obs.	0	0	0	0	1	0
	30.9	Cont.	0	0	0	0	3	0
5-9-60		Obs.	0	0	0	0	0	1
	26.7	Cont.	0	0	0	0	0	4
5-13-60		Obs.	0	0	0	0	0	1
	13.3	Cont.	0	0	0	0	0	8
Total Tagged Release Group Contribution to Mark Sample			1	0	67	68	33	202
Total Hatchery Contribution to Mark Sample (c)			3	1	154	158	55	389
Hatchery Fish of Unknown Origin in Mark Sample(d)			2	1	87	90	22	187
Mark Sample			5	1	175	181	70	456

Footnotes appear on following page.

Appendix IV Table 4. Distribution of recovery groups in 1984-85 sport catch.

Group		Area and Recoveries "P"+"S"+"U"	"W"	"L"	Chi-squared	P
Mark Sample	N	181	70	456		
	% of Total	25.6	9.9	64.5		
Wild	Observed	21	14	63		
	Expected (a)	25	10	63		
	% of M.S.	11.6	20.0	13.8	2.240	0.1
Total Hatchery	Observed	158	55	389		
	Expected	154	60	388		
	% of M.S.	87.3	78.6	85.3	0.523	0.5
Unknown Hatchery	Estimated	90	22	187		
	Expected	76	30	193		
	% of M.S.	48.6	31.4	40.8	4.899	LT 0.05
5-11-49	Expanded	55	18	44		
	Expected	30	12	75		
	% of M.S.	30.9	25.7	9.6	39.007	LT 0.005
5-13-56	Expanded	10	3	112		
	Expected	32	12	81		
	% of M.S.	5.5	4.3	24.6	33.739	LT 0.005

(a) Based on null hypothesis of random distribution over the three tag recovery areas.

Footnotes to Appendix IV Table 3 from previous page.

(a) Equals the number of snouts taken for dissection divided by the number of adipose clips observed. See Appendix II Table 3 for data.
(b) Includes both Chalaat Creek and Allen's Bar releases.
(c) Not restricted to adipose clips. See Methods section of main report for details on hatchery/wild determination.
(d) Equals total hatchery contribution of mark sample minus total contribution of tagged groups to mark sample.