BIOECONOMIC CONTRIBUTION OF COLUMBIA RIVER HATCHERY FALL CHINOOK SALMON, 1961 THROUGH 1964 BROODS, TO THE PACIFIC SALMON FISHERIES

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ABSTRACT

This experiment was designed to estimate the contribution to sport and commercial fisheries of the 1961 through 1964 broods of fall chinook salmon, *Oncorhynchus tshawytscha,* from 13 rearing facilities on the Columbia River. These facilities reared 90% of the Columbia River hatchery fall chinook salmon during the four brood years. Marks common to all facilities were applied to 21.3 million of the 213 million 1961-64 brood fish released. Special marks were applied to 9.6 million fish at 11 of the study hatcheries. Sampling for the marks took place from 1963 through 1969.

During the 7 yr of sampling, 65,620 chinook salmon with common and 22,090 fish with special marks were estimated to have been caught in marine commercial and sport fisheries from Pelican, Alaska, to Avila Beach, Calif., and Columbia River fisheries. The potential contribution for the four broods from the 13 study facilities, after adjustment for the effects of marking, was 1,433,300 fish. The value of the contribution was estimated at $12,027,000. Costs applicable to rearing were $2,859,700, yielding an average benefit to cost ratio of 4.2 to 1. Benefit to cost ratios at the 11 special mark hatcheries ranged from 0.3 to 1 to 17.1 to 1.

The Columbia River Development Program (subsequently referred to as "Program"), initiated in 1949, was created to counteract the severe loss of salmon, *Oncorhynchus* spp., and steelhead trout, *Salmo gairdneri,* resulting from the expansion of water-use projects in the Columbia River system. The Program is a cooperative effort of fish management agencies of the States of Oregon, Washington, and Idaho and the Federal Government and is administered by the Columbia Fisheries Program Office, National Marine Fisheries Service, NOAA, Portland, Oreg. The Program's role has included two major functions: 1) the protection and improvement of stream environment which has included improvement of natural habitat, such as clearing obstructions from nearly 2,000 mi of tributary streams, building 87 fishways past natural barriers, and installation of 570 screens in diversion ditches and canals; and 2) the production of fish in hatcheries which has been accomplished by the construction or modernization of 21 salmon and steelhead hatcheries on the lower Columbia River and tributaries. A supplementary function of the Program is funding operational improvement studies to complement the hatchery system. Major achievements have been: 1) improved marking techniques through development of the implanted coded wire fish tag (Bergman et al. 1968); 2) increased natural production through rehabilitation of chinook salmon runs in the Clearwater River system in Idaho and the Willamette River system in Oregon; 3) determination of the physiological factors controlling downstream salmonid smolt migration through understanding the development of osmotic and ionic regulation in coho salmon (Conte et al. 1966), chinook salmon (Wagner et al. 1969), and steelhead trout (Conte and Wagner 1965), thus improving hatchery release timing; 4) reduced natural competition and predation through the development of Squaxin,[2] a selective toxin to squawfish (MacPhee and Ruelle 1969); and 5) improved fish diets through development of the Oregon Moist Pellet (Hublou 1963).

There are two major reasons for concentrating on hatchery produced salmon and steelhead trout: their life histories allow successful hatchery propagation and these species are historically and economically important to the United States. Over the past three decades Pacific salmon have ranked first or second in landed value of commercial

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[2]References to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

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finfishes to U.S. fishermen. The net economic value of salmon sport fishing in the United States was $77.7 million in 1970 (Wahle et al. 1974).

Initially, Program hatcheries were constructed to emphasize rearing of fall chinook salmon rather than coho and spring chinook salmon and steelhead trout because of a serious decline of this run in the early 1950's (Van Hyning 1973).

Releases of migrant size fall chinook salmon have ranged from 10 million fish from 6 hatcheries in 1949 to 94 million fish from 17 hatcheries in 1973. Prior to the study reported by Worlund et al. (1969), little was known about the contribution of these releases to the commercial and sport fisheries. Some marking experiments had demonstrated that hatchery releases contribute to fisheries, but because such experiments were limited and designed for other purposes, the contribution had not been estimated.

Although reports were written for each of the four broods of fall chinook salmon (Worlund et al. 1969; Rose and Arp[3]; Arp et al.[4]; Wahle et al.[5]), brood years were not compared and individual hatchery contributions, values, and benefits were not evaluated or compared. No new studies of this scale on the Columbia River have been initiated to supersede the 1962 through 1969 data. In addition, the contributions, values, and benefits in the individual brood year reports are not comparable with those presented for Columbia River hatchery coho salmon (Wahle et al. 1974). Therefore, we compiled this report to supplement, summarize, and, in some cases, replace previously reported Columbia River hatchery fall chinook salmon contribution and value data.

The marking study discussed in this paper, initiated in 1962 by the Columbia Fisheries Program Office, was designed to estimate the contribution of Columbia River hatchery-reared fall chinook salmon to the fisheries. The effort was brought about by the Bureau of the Budget (now the Office of Management and Budget) which had declared a moratorium on hatchery construction until there was proof that further expansion would be economically justified.

The experiment was confined to 12 hatcheries and 1 rearing pond that during the marking phase of the study propagated nearly 90% of all fall chinook salmon artificially reared in the Columbia River system. Locations of the participating and nonparticipating hatcheries rearing fall chinook salmon during the study period are shown in Figure 1. The marking of four brood years, 1961 through 1964, began in 1962 and data collection was completed in 1969.

This report contains: 1) the experimental design; 2) a description of the field operations; 3) estimation of 10 individual hatchery contributions, values to fisheries, benefit to cost ratios for study facilities, and comparisons between hatcheries; 4) the contributions, values, and benefit to cost ratios for each brood year marked for all participating hatcheries combined, with a comparison of brood years; and 5) the contribution and value to the Pacific Coast fisheries of fall chinook salmon from all Columbia River hatcheries.

EXPERIMENTAL DESIGN

The experimental procedures for this study were the same for the four brood years. The design of the study is described by Worlund et al. (1969), and will be reviewed here. In general, 10% of the fall chinook salmon production from the participating hatcheries was marked by clipping fins and maxillary bones. The commercial and sport fisheries along the Pacific Coast were sampled for these marks. Individual and collective hatchery contributions can be estimated from: 1) proportion of fish marked, 2) number of marks actually recovered, 3) fractions of the total catches sampled for marks by time and area in each fishery, and 4) information on any bias associated with application or detection of marks. The execution of this entire study required the cooperation of personnel from the following agencies: the Alaska Department of Fish and Game, the Fisheries Research Board of Canada (now the Department of Environment), the Washington Department of Fisheries, the Fish Commission of Oregon and the Oregon Game Commission (now the Oregon Department of Fish and Wildlife), the California Department of Fish and Game, the Bureau of Commercial Fisheries (now the National Marine

[3]Joe H. Rose, and Arthur H. Arp. 1970. Contribution of Columbia River hatcheries to harvest of 1962 brood fall chinook salmon (*Oncorhynchus tshawytscha*). Unpubl. manuscr., 27 p. U.S. Fish Wildl. Serv., Bur. Commer. Fish., Columbia Fish. Program Off., Portland, Oreg.

[4]Arthur H. Arp. Joe H. Rose, and Steven K. Olhausen. 1970. Contribution of Columbia River hatcheries to harvest of 1963 brood fall chinook salmon (*Oncorhynchus tshawytscha*). Unpubl. manuscr., 33 p. Natl. Mar. Fish. Serv., Columbia Fish. Program Off., Portland, Oreg., Econ. Feasibility Rep.

[5]Roy J. Wahle, Arthur H. Arp, and Steven K. Olhausen. 1972. Contribution of Columbia River hatcheries to harvest of 1964 brood fall chinook salmon (*Oncorhynchus tshawytscha*). Unpubl. manuscr., 31 p. Natl. Mar. Fish. Serv., Columbia Fish. Program Off., Portland, Oreg., Econ. Feasibility Rep.

Fisheries Service), and the U.S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife.

Allocation of Marks

The experiment was limited to 13 rearing facilities on the Columbia River. The hatchery locations ranged from Big Creek Hatchery, the lowermost station, 40 km (25 mi) above the Columbia River mouth, to Klickitat Hatchery, the uppermost station, 290 km (180 mi) above the Columbia River mouth (Figure 1).

Approximately 10% of the production at each of the 13 facilities was marked with a common mark

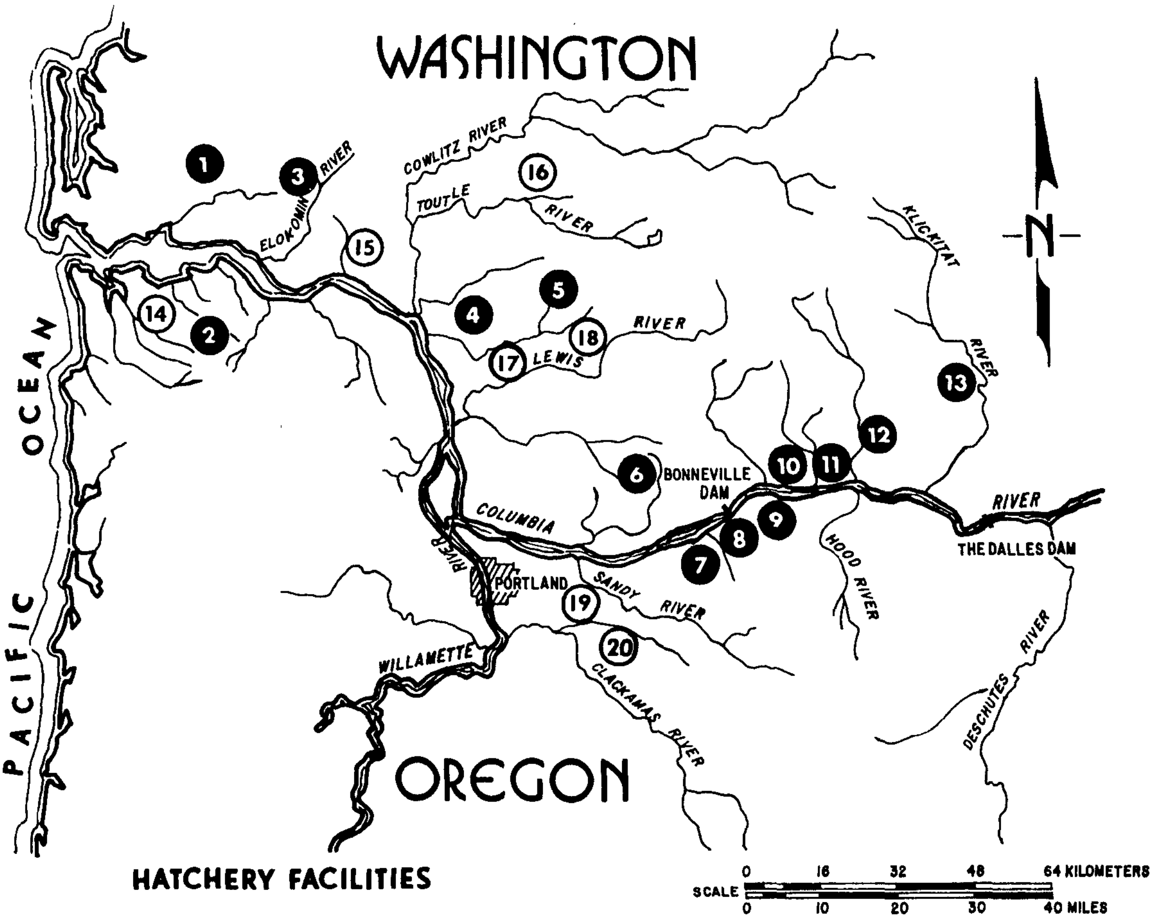

FIGURE 1.—Locations of participating and nonparticipating Columbia River hatcheries rearing fall chinook salmon, 1961-64 broods.

(Table 1). This mark consisted of clipping the adipose fin (Ad) and a right or left maxillary (RM or LM). The maxillary clip was alternated from one brood year to the next. In addition, a portion (as discussed later) of the production at 11 of the study hatcheries was marked with special marks. A portion of four broods at Spring Creek National Fish Hatchery and Kalama River hatcheries (in this study, Kalama Falls and Lower Kalama Hatcheries were treated as one facility) were marked with the following special mark: adipose, a ventral, and a maxillary clip. Spring Creek was assigned the adipose, left ventral (LV), and left or right maxillary clip. The maxillary clip was alternated among brood years. The 1961 brood was marked Ad-LV-RM, the 1962 brood was marked Ad-LV-LM, and so on. Kalama River hatcheries were assigned the adipose, right ventral (RV), and left or right maxillary clip. Again, the maxillary clip was alternated among brood years. Combinations of a single ventral and maxillary were alternated among eight other hatcheries: Elokomin, OxBow, Grays River, Cascade, Klickitat, Big Creek, Bonneville, and Little White Salmon. Two different hatcheries were marked with this combination for each brood year.

TABLE 1.—Releases of marked fall chinook salmon from Columbia River study hatcheries, 1961-64 broods.

Brood	Hatchery	Mark[1]	Number marked	Percent production marked
1961	All hatcheries	Ad-RM	5,446,439	10.15
	Spring Creek	Ad-LV-RM	1,133,019	10.37
	Kalama	Ad-RV-RM	475,964	9.70
	Elokomin	LV-RM	480,533	30.51
	OxBow	RV-RM	450,446	9.90
1962	All hatcheries	Ad-LM	5,249,079	10.00
	Spring Creek	Ad-LV-LM	866,892	10.31
	Kalama	Ad-RV-LM	437,669	9.52
	Grays River	LV-LM	241,494	17.76
	Cascade	RV-LM	541,158	12.83
1963	All hatcheries	Ad-RM	5,986,464	9.96
	Spring Creek	Ad-LV-RM	751,243	10.06
	Kalama	Ad-RV-RM	456,158	9.34
	Klickitat	LV-RM	521,610	18.06
	Big Creek	RV-RM	579,967	29.21
1964	All hatcheries	Ad-LM	4,638,237	9.92
	Spring Creek	Ad-LV-LM	600,953	9.17
	Kalama	Ad-RV-LM	319,412	9.14
	Bonneville	LV-LM	957,110	9.68
	Little White Salmon	RV-LM	797,345	9.53

[1]Ad: Adipose; LV: Left ventral; RV: Right ventral; LM: Left maxillary; RM: Right maxillary.

Sources of Variation and Error

Two major sources of variation in contributions to fisheries are differences among brood years and differences among hatcheries. To evaluate the differences among broods, four broods were marked. The variations among hatcheries were evaluated by special marking at four hatcheries for each brood year.

One possible source of error in estimating contributions is the combination of differential relative survival and differential maturation time for marked and unmarked fish. If the difference in marked and unmarked ratios at release and return were due primarily to delayed maturation caused by marking, then marked fish may have been subjected to more intense fishing pressure due to a longer time in the ocean. This could mean the ratio of marked to unmarked fish in the fisheries would be greater than the ratio at release from the hatcheries. If this were true, the potential contributions would be overestimated in this report. However, since we are making the best estimate of contribution and benefit for the hatcheries, we are assuming all differences in marked to unmarked ratios at release and return are due to differential survival between marked and unmarked fish. This point is discussed in detail under assumption 4.

Straying of wild fish into the hatcheries, thus diluting the marked to unmarked ratios at return, is another source of variation and/or error. This dilution would reduce the relative survival rates for marked fish. To minimize this effect of variation and/or error, average relative survival figures for common and special marked fish were calculated and used in the contribution computations.

Estimating Procedures

A formal account of the estimating procedures is presented in the report by Worlund et al. (1969). Simple numerical examples will be used to explain the procedure in this report. Estimating the potential contributions and values of hatchery fall chinook salmon required four steps. First, the number of marked and unmarked hatchery releases had to be estimated. Second, the estimated catch of marked fish was calculated. Third, the total contribution of hatchery fish was estimated. Fourth, dollar values were applied to the contribution estimates.

Hatchery Releases

The numbers of marked and unmarked fish in hatchery releases were estimated by sampling the hatchery population with a 10-part sampler (see Marking and Release Procedures). This device was precalibrated from a number of trials with known numbers of fish to find the average percentage retained by a single closed pocket. The following example illustrates the fish enumeration procedure for a pond of fall chinook salmon. Suppose a precalibrated pocket is found to remove a 10.1% sample. Also, suppose after passing all the fish in a pond through the sampler, the number of fish retained by the closed pocket is found to be 20,200. The total number of fish in that pond is then estimated as 20,200/0.101 = 200,000. Suppose further that of the 20,200 fish retained in the pocket, 2,020 fish are found to be marked. Then 2,020/20,200 = 10% of the estimated 200,000 fish in the pond, or 20,000 are estimated to be marked and 180,000 unmarked. The total release, numbers marked (common and special) and unmarked, were estimated for a hatchery by summing data from all ponds.

Catch of Marked Fish

To estimate the catch of marked fish in a given area and fishery, the following values were needed by time period: total catch; number of fish examined for marks; number of marked fish by species, mark type, and age; and the proportion of each age-group in the total catch. The sampling seasons were stratified into relatively small time units (usually 2-wk periods). The estimated catches of a particular mark were summed over the entire fishing season for a given area and fishery. For example, during the period from 26 June through 9 July 1966 in the Ilwaco sport fishery, 1,193 chinook salmon from a total catch of 5,664 were examined for marks, for a 21.1% sample. Samplers found one Ad-LM marked 1964-brood (2-yr-old) fall chinook salmon during this period. Then the estimated catch of 1964-brood Ad-LM marked fall chinook salmon during this period was 1/0.2106 = 5. Catches of 1964-brood Ad-LM marked chinook salmon for the Ilwaco sport fishery in 1966 were summed for 13 time periods. This resulted in an estimated catch of 196 Ad-LM marked fish.

This procedure was carried out for each port sampled and each mark found. Catch data for each time-location stratum were provided by management agencies. Commercial catches were estimated from total landing weights and average fish size data or from total numbers of salmon landed and species composition estimates. Sport catches were estimated from measures of total effort and catch-per-unit-effort or from salmon punch cards and independent sampling. All catch and sampling information was transferred to computer cards and estimates were calculated by computer. Unpublished reports of catch and mark data were produced for 1963 through 1969 by the Seattle Biological Laboratory, Bureau of Commercial Fisheries (now the Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA).

Contribution of Hatchery Fish

Maxillary regeneration occurred during the ocean lives of some of the common and special marked chinook salmon, resulting in partial marks (see Assumptions). For example, a 1961-brood Kalama Ad-RV-RM mark could have regenerated to an Ad-RV mark, or a 1962-brood Ad-LM common mark could have regenerated to an Ad-only mark. Partial marks were a result of this regeneration and/or an occurrence of naturally marked fish. If partial marks due to regeneration were not claimed as part of the marked hatchery fish total, the hatchery contribution would be underestimated considerably. Therefore, we examined the ocean catches of chinook salmon with partial marks to determine the number that could be claimed as hatchery fish.

A comparison of maxillary regeneration rates of marked fish held at Bowman Bay (Worlund et al. 1969) and the occurrence of Ad-SV (adipose-single ventral) and Ad-only partial marks in the fisheries (Table 2), led us to believe Ad-LV, Ad-RV, and Ad-only marks occurred because of maxillary re-

TABLE 2.—Percent partial mark occurrence in the ocean and Columbia River fisheries and in hatchery returns, 1961-64 broods.

Region	Brood	Partial marks[1]		
		Ad-SV[2]	Ad	SV
Ocean fisheries	1961	15.8	14.6	74.9
	1962	18.8	23.5	72.7
	1963	8.0	9.1	36.4
	1964	12.8	15.2	39.7
Columbia River fisheries	1961	10.3	7.8	51.0
	1962	17.4	5.0	57.4
	1963	9.5	6.0	7.0
	1964	8.0	7.2	28.3
Hatchery returns	1961	10.9	16.1	27.7
	1962	19.8	22.0	20.0
	1963	8.3	8.6	2.0
	1964	11.2	17.2	12.5

[1]Figures are ratios, averaged for all years by brood, of estimated numbers of partial marks to estimated sum of partial marks and corresponding complete marks expressed in percent.
[2]SV signifies "single ventral." Marks of same general type are combined.

generation. This belief is also supported by the absence of Ad-LV and Ad-RV marks in the 1965-brood catches of chinook salmon (Bureau of Commercial Fisheries[6, 7, 8]; Fish Commission of Oregon[9]). The Ad-V marks were not assigned to the 1965-brood fish. Thus, we have claimed all Ad-RV, Ad-LV, and Ad-only marked chinook salmon as hatchery fish.

However, the percentage occurrence of SV marks in the fisheries was much higher than 1) the maxillary regeneration rate, 2) the occurrence of Ad-SV marks in the fisheries, and 3) the occurrence of SV marks in hatchery returns. Thus, we concluded SV marks occurred because of maxillary regeneration and natural marks.

Two steps were required to determine the number of SV marked fish we would claim as part of the hatchery production. First, we assumed the maxillary regeneration rate for all special marked hatcheries was the same. The partial mark percentages for Kalama River and Spring Creek combined were calculated for each fishery, year, and brood. For example, in the 1964 Washington commercial fisheries the estimated catch of 1961-brood Ad-LV-RM and Ad-RV-RM full marked fish was 1,001 and Ad-LV and Ad-RV partial marked fish was 232. The partial mark percentage for this year, fishery, and brood was then 232/1,001 = 23%.

Second, full mark recoveries from other special mark hatcheries (Elokomin, OxBow, Grays River, Cascade, Klickitat, Big Creek, Bonneville, and Little White) for the corresponding brood, year of recovery, and fishery were multiplied by the Kalama-Spring Creek percentages. For example, the estimated full mark recoveries of Elokomin and OxBow 1961-brood chinook salmon in the 1964 Washington commercial fisheries were 48 and 58 fish respectively. The SV marked fish claimed as part of Elokomin and OxBow hatcheries' production were then $48 \times 0.23 = 11$ and $58 \times 0.23 = 13$ respectively. In cases where the calculated claimed partial marks were greater than the partial marks actually recovered, all partial marked fish were claimed. No SV marked fish were claimed for the southeastern Alaska or California fisheries because few Columbia River hatchery special marked fish were captured in these fisheries.

The claimed partial marked fish estimates by year and fishery were summed for each special mark hatchery. The sums are the number of partial marked fish we claimed as part of the special mark hatcheries' catch (Table 3).

Loss of maxillaries due to hooking occurred during the ocean lives of the marked fall chinook salmon (author's pers. obs.), resulting in the possible misidentification of marks. In some cases a marked chinook salmon was assigned to a certain brood year from scale analysis, but the fish had the wrong maxillary mark for that brood. For example, 1961-brood Ad-LM marked chinook salmon, 1962-brood Ad-LV-RM marked fish, 1963-brood LV-RM marked chinook salmon, and so on (see Table 1 for correct marks for each brood) were reported to have been caught in the fisheries. In some cases, double maxillary marks (1961-brood Ad-RM-LM, 1963-brood Ad-LV-RM-LM, etc.) were reported to have been caught.

Duplication of marks or use of marks with the opposite maxillary for the same brood year were prevented by the Pacific Marine Fisheries Com-

TABLE 3.—Estimated catches of 1961- to 1964-brood fall chinook salmon from Columbia River study hatcheries with full marks, misidentified marks, partial marks, and partial marks claimed as study hatchery fish by brood and hatchery.

Brood	Hatchery	Full marks	Misidentified marks[1]	Partial marks	Partial marks claimed	Total estimated marks
1961	All study	18,906	621	2,710	2,710	22,237
	Spring Creek	3,553	115	732	732	4,400
	Kalama	1,955	34	186	186	2,175
	Elokomin	174	18	533	43	235
	OxBow	266	19	594	51	336
1962	All study	6,008	512	1,366	1,366	7,886
	Spring Creek	769	26	172	172	967
	Kalama	498	48	113	113	659
	Grays River	177	8	373	30	215
	Cascade	140	21	418	30	191
1963	All study	19,856	489	1,838	1,838	22,183
	Spring Creek	2,210	48	149	149	2,407
	Kalama	1,053	60	144	144	1,257
	Klickitat	1,048	702	396	108	1,858
	Big Creek	772	71	479	71	914
1964	All study	11,085	489	1,740	1,740	13,314
	Spring Creek	3,798	99	509	509	4,406
	Kalama	849	54	102	102	1,005
	Bonneville	649	43	210	70	762
	Little White	274	6	392	23	303

[1]Double maxillary clips or the opposite maxillary for a particular brood year.

[6]Bureau of Commercial Fisheries. 1969. Data report: Columbia River fall chinook salmon hatchery contribution study: 1967 sampling season. Unpubl. manuscr., 519 p. U.S. Fish Wildl. Serv., Bur. Commer. Fish., Seattle Biol. Lab.

[7]Bureau of Commercial Fisheries. 1970. Data report: Columbia River fall chinook salmon hatchery contribution study: 1968 sampling season. Unpubl. manuscr., 437 p. U.S. Fish Wildl. Serv., Bur. Commer. Fish., Seattle Biol. Lab.

[8]National Marine Fisheries Service. 1971. Data Report: Columbia River fall chinook salmon hatchery contribution study: 1969 sampling season. Unpubl. manuscr., 283 p. Natl. Mar. Fish. Serv., Seattle Biol. Lab.

[9]Fish Commission of Oregon. 1972. 1970 fin-mark sampling and recovery report for salmon and steelhead from various Pacific coast fisheries. Unpubl. manuscr., 102 p. Fish Comm. Oreg., Biom. Sect., Clackamas.

mission. We are assuming aging was correct (see Assumptions). Therefore, we have assumed marked fall chinook salmon with a double maxillary or the wrong maxillary for a particular brood were misidentified. Thus we claimed these marked fish as part of the Columbia River hatchery marked fall chinook salmon catch (Table 3).

Therefore, estimated catches of Columbia River hatchery marked fall chinook salmon (Tables 3, 8-14) include full, misidentified, and claimed partial marked fish.

Before estimating the contribution of hatchery fall chinook salmon if no marking had taken place (hereafter referred to as potential contribution), the survivals of common marked fish had to be calculated. Three methods were used to estimate the common mark relative survival and a median relative survival was calculated from the three answers.

METHOD 1.—All 13 study facilities were combined and four sums—marked releases, unmarked releases, marked returns, and unmarked returns—were obtained for each brood year. The marked to unmarked ratio at return was then divided by the marked to unmarked ratio at release. The formula is:

$$\frac{\dfrac{\text{Marked returns}}{\text{Unmarked returns}}}{\dfrac{\text{Marked releases}}{\text{Unmarked releases}}} = \text{Relative survival.}$$

METHOD 2.—If wild fish strayed into the study hatcheries, diluting the marked to unmarked ratios at return, method 1 would underestimate relative survival. Thus to allow for straying, in method 2 we have calculated relative survivals using releases and returns from four selected hatcheries, Cascade, OxBow, Little White Salmon, and Spring Creek, on streams with no natural runs of fall chinook salmon. Relative survivals were estimated for each brood in the same manner as described in method 1.

METHOD 3.—Even for the four selected hatcheries, straying of wild fish into hatcheries is a possibility, resulting in an underestimated relative survival. To account for this possibility, a method was devised to estimate the number of wild fish straying into the four selected hatcheries. This was done in four steps. First, since the selected hatcheries are between Bonneville and The Dalles Dams, an estimate of the maximum number of fall chinook salmon spawning between the dams was obtained by subtracting both the Indian and sport fall chinook salmon catches between Bonneville and The Dalles Dams as well as The Dalles Dam fall chinook salmon count from the Bonneville Dam fall chinook salmon count. Second, the maximum number of fish spawning at sites other than the selected hatcheries was obtained by subtracting the four hatcheries returns from the total spawners between the dams. Third, the age of fish spawning at sites other than the selected hatcheries was approximated by applying age data from Columbia River gillnet fall chinook salmon catches. Fourth, straying factors (from observed straying of fish marked at Spring Creek Hatchery) were applied by brood and age to the wild spawners to obtain the estimate of wild fish straying into the selected hatcheries. These estimates are maximum since we cannot account for mortalities, uncounted fish passing through navigation locks, double counting of fish that fall back over dam spillways and again ascend the fish ladders, or fish straying from the four hatcheries. Also, we assumed wild fish had the same straying pattern as the hatchery fish in this study, i.e., they strayed to sites near their area of origin.

Once the brood estimate of the number of wild fish entering the hatcheries was obtained, it was subtracted from the appropriate unmarked returns. The resulting unmarked hatchery return quantity for each brood was then used in the formula described in method 1 to calculate the third estimated common mark relative survival.

Examples of the calculations used to obtain the three values for the common mark relative survivals are presented by Worlund et al. (1969). The median common mark relative survivals for the 1961-64 broods of Columbia River study hatchery fall chinook salmon are:

Brood	*Common mark relative survival*
1961	0.608
1962	0.477
1963	0.372
1964	0.448

Special mark relative survivals also had to be calculated to estimate contributions of special marked hatcheries. Calculating special mark relative survivals for each hatchery was impossible because seven hatcheries (Elokomin, OxBow, Grays River, Cascade, Klickitat, Bonneville, and Little White) had too few special mark returns to obtain reliable estimates of marked to unmarked ratios at return. Thus returns to only three hatcheries (Spring Creek, Kalama, and Big Creek), having sufficient special mark returns, were used to calculate average special mark relative survivals for each brood. However, if special marked fish from the other seven hatcheries had lower relative survivals than the average, the contributions of these hatcheries would be underestimated using this method.

Relative survivals of special marks to common marks were first calculated using the formula:

$$\frac{\text{Special mark return/Common mark return}}{\text{Special mark release/Common mark release}}.$$

The relative survivals are:

Brood	*Spring Creek*	*Kalama River*	*Big Creek*
1961	0.526	0.800	—
1962	0.617	0.472	—
1963	0.535	0.498	0.797
1964	0.535	0.731	—

From these values we concluded that special marked fish survived between 50 and 80% as well as common marked fish. Multiplying the common mark relative survivals by 50 and 80% for each brood year yielded the following average special mark relative survivals:

Brood	*Survival*
1961	0.395
1962	0.310
1963	0.242
1964	0.291

The next step was to determine the mark proportions at release for common and special marks for each brood year. Special marks were excluded from the calculation of the common mark proportions. This was done for two reasons: special marked fish had a lower relative survival than the common or unmarked fish, and the special marks could be identified in the fisheries and related back to specific hatcheries. The common marked fish had to be treated as unmarked fish in calculating the special mark proportions at release because common mark catches could not be related to specific hatcheries. These mark porportions at release are presented in Table 4.

TABLE 4.—Mark percentages at release for common and special marked fall chinook salmon by brood year and hatchery.

Mark type and hatchery	Percent of brood marked			
	1961	1962	1963	1964
Common marks[1]				
All hatcheries	10.7	10.4	10.4	10.5
Special marks[2]				
Spring Creek[3]	7.8	7.3	7.6	7.0
Kalama River	9.7	9.5	9.3	9.1
Elokomin	30.5	—	—	—
OxBow	9.9	—	—	—
Grays River	—	17.8	—	—
Cascade	—	12.8	—	—
Klickitat	—	—	18.1	—
Big Creek	—	—	29.2	—
Bonneville	—	—	—	9.7
Little White Salmon	—	—	—	9.5

[1]Special marks not included.
[2]Common marks included with unmarked releases.
[3]Includes Big White Salmon pond releases.

The potential contributions of the hatchery fall chinook salmon were calculated by dividing the estimated catch of marks by the marked fish relative survival times the mark proportion at release. The formula for calculating the potential contributions of Spring Creek, Kalama River, and other special mark hatcheries is:

$$\frac{\text{Estimated catch of spec. marks}}{\text{(Spec. mark relative survival)(Spec. mark propor. at rel.)}}.$$

The potential contribution of all study facilities was calculated with the formula:

$$\frac{\text{Estimated catch of common marks}}{\text{(Common mark relative survival)(Common mark propor. at rel.)}}$$

$$+ \text{ Potential catch of spec. marks.}$$

The potential catch of special marks is an estimate of the special marks that would have been caught if marking had not caused differential mortality. The formula used to calculate this potential catch is:

$$\frac{\text{Estimated catch of special marks}}{\text{Special mark relative survival}}.$$

Value of Hatchery Contribution

With estimates of the potential contribution of Columbia River hatchery fall chinook salmon, the potential value of the catches could be calculated from average weight and unit price data. The average weights for the commercially caught fish were obtained from common marked fish. Total weights of hatchery fish caught in the commercial fisheries are underestimated with this method because marked fish are smaller than unmarked fish (Cleaver 1969). Weights for the ocean troll fisheries are dressed weights and those for Columbia River net fisheries are round weights. Ex-vessel market prices have been used to represent estimated net values for commercially caught fish. The ex-vessel prices were obtained from Washington Department of Fisheries records for the appropriate years and age of fish. (D. Ward, Washington Department of Fisheries, pers. commun.) Washington troll prices were used for other commercial fisheries on the Pacific Coast.

The net value for salmon and steelhead sport fishing is estimated to be $20/day of fishing. This value results from reconciling the existing research that is closely related to estimated net economic values of Columbia River sport caught salmon. The maximum potential benefits from sport fishing at a single market price is predicted at $20/fishing day (Brown et al.[10]). The salmon catch per angler trip data were obtained from Washington, Oregon, and California publications (Campbell and Locke 1964, 1965, 1966, 1967, 1968, 1969; Nye and Ward undated a, b; Greenhood and Mackett 1967; Haw et al. 1967; Heimann and Frey 1968a, b; Heimann and Carlisle 1970; Pinkas 1970). An estimate of 1.09 salmon/angler trip was obtained by averaging data for the three States over the appropriate years. The $20/angler trip was divided by 1.09 salmon/angler trip to yield a value of $18.35/salmon. This value was used in the ocean sport and Columbia River sport fisheries for all broods and years of capture.

Assumptions

Six assumptions are required in our method for estimating contributions of hatchery fall chinook salmon to the fisheries. Three basic assumptions are: 1) a marked fish is identifiable as a marked fish throughout life, 2) all fish detected and reported with the kind of mark applied at the hatcheries are hatchery fish, and 3) chinook salmon are correctly aged from scale examinations and information on size of fish and date of capture. Two assumptions as to the behavior of marked and unmarked hatchery fish are: 4) marked and unmarked hatchery fish have the same survival rates and maturity schedules, and 5) marked and unmarked hatchery fish have the same ocean distribution and are equally vulnerable to the fisheries. Finally, because part of all hatchery releases bear the same mark, we assume: 6) common marks were applied to the same proportion of each hatchery's production in a given year.

The appropriateness of the estimating procedures is dependent on the validity of these assumptions. Assumption 1 was tested by holding marked fish in saltwater ponds for periodic examination of the condition of the mark. There was no regeneration of the adipose fin. However, regeneration of ventral fins and maxillary bones did occur. In most cases, the ventral fin regenerated to <25% of its original size. Greater regeneration was identifiable by deformation of the fin rays.

The high occurrence of maxillary regeneration (7-12%) for the 1961- and 1962-brood chinook salmon resulted in the removal of more of the maxillary bone in the 1963- and 1964-brood fish. This change in marking procedure resulted in a smaller percentage of fish with regenerated maxillaries (1-3%).

Since single and double fin marks were associated with maxillary clips, even when maxillaries completely regenerated, the fish were identifiable as marked fish. Thus we believe assumption 1 to be true.

The validity of assumption 2, the absence of natural marks on hatchery and wild fish, was tested in two ways: First, over 30 million hatchery fingerlings were examined during marking for naturally missing adipose and ventral fins. Only 156 missing adipose and 201 missing ventral fins (none together) were observed indicating the insignificance of naturally occurring marks on these fish. Second, the occurrence of natural marks outside the hatchery system was checked by examining 1965-brood chinook salmon catches for study marks. The allocation of study marks to any 1965 brood on the Pacific Coast was to have been prevented. Unfortunately, the attempt to prevent the application of study marks to this brood was not completely successful. However, no adipose-ventral-maxillary combinations were applied and none were found in the fisheries. Any occurrence of natural marks like those claimed as hatchery marks has been accounted for under Estimating Procedure. Therefore, we believe assumption 2 has been satisfied.

Assumption 3 was evaluated by testing scale

[10]William G. Brown, Ashok K. Singh, and Jack A. Richards. 1972. Influence of improved estimating techniques on predicted net economic values for salmon and steelhead. Unpubl. manuscr., 26 p. Oreg. State Univ., Agric. Exp. Stn., Corvallis.

readers with chinook salmon scales of known age. Scales from 400 marked fish of known age were submitted to six readers: two from the Fish Commission of Oregon and one each from the Fisheries Research Board of Canada, Washington Department of Fisheries, Oregon Game Commission, and Bureau of Commercial Fisheries. Length of fish and date of capture were available for each scale. The six scale readers correctly aged 83% of the 400 test scales (Worlund et al. 1969). Thus, we believe that assumption 3 is reasonably well satisfied.

The equality of marked and unmarked survival rates and maturity schedules, assumption 4, needs some additional study. A lowering of the marked to unmarked ratio at the hatchery from the time of release to the time of return indicated possible problems with this assumption. There are several possible reasons for this change in marked to unmarked ratio. They are: 1) errors in estimating the number of marked and/or unmarked hatchery fish at the time of release; 2) a difference in distribution or timing of marked and unmarked fish, resulting in the marked fish being exposed to a more intense fishery; 3) a selectivity of some fisheries for marked fish; 4) a greater amount of straying for marked fish than unmarked fish; 5) a difference in maturation schedule for marked and unmarked fish; 6) differential survival between marked and unmarked fish because of marking; and 7) mistakes in aging unmarked hatchery returns.

It is unlikely the difference in the marked to unmarked ratios at the time of release and return could have been caused entirely by mistakes in estimating the ratio at release. The differences were too great, considering the randomness of the estimating procedures and the number of hatcheries involved. There is no way to determine nor reason to believe differences in distribution, timing, or straying between marked and unmarked fish caused the differences in the ratios at release and return. Nor is there any way to determine or reason to believe any fishery was selective for marked fish. Thus we rejected these as possible reasons for the change in marked to unmarked ratios between the time of release and return.

There is some indication a difference in time of maturing did occur between marked and unmarked fish (Cleaver 1969). Examination of the marked to unmarked ratios at the hatcheries by year of return shows a trend of increasing ratios. This indicates the marked fish did not mature as soon as the unmarked fish. The marked fish appeared to stay in the ocean longer and thus were subject to a higher natural and fishing mortality.

It is also possible clipping fins and maxillary bones caused mortality after the fish were released from the hatchery. The unmarked fish would obviously not be subjected to this mortality.

Mistakes in aging of unmarked hatchery returns could easily have occurred because of the poor condition of the fish when entering the hatchery. The scales had been partially resorbed, making them difficult to read. Since the same marks were used in alternate brood years, the mark and size of the fish would aid the aging procedure for the marked fish. This would result in more accurate aging of marked than unmarked fish. However, the errors in aging unmarked fish could have been self cancelling. Possible errors in aging seemed to be a very minor reason for the differences in the marked to unmarked ratios.

Thus the two most probable reasons for the change of marked to unmarked ratios from the time of release to return were differences in maturation schedule and differential survival of marked and unmarked fish. These two problems probably acted in combination. Since we have no way of separating the effects of delayed maturity and differential survival and since we are making the best estimate of hatchery contribution, we are assuming the change in marked to unmarked ratio was due only to differences in survival of marked and unmarked fish. Correction factors were applied to adjust for the differential survival.

The validity of assumption 5, equal ocean distribution and vulnerability to the fisheries for marked and unmarked fish, is supported by ocean tagging studies showing similar ocean distribution for marked and unmarked hatchery fish (Cleaver 1969).

Common marks were applied to 10 or 11% of the production at the 13 study facilities for the four brood years, 1961 through 1964 (Table 4). The percentages ranged from 9 to 11 among the hatcheries for each brood. With these ranges we feel assumption 6, application of common marks to the same proportion of each hatchery's production, is satisfied.

FIELD OPERATIONS

Marking and Release Procedures

Artificial propagation procedures were similar at all 13 study facilities. Adult fall chinook salmon returned to these facilities and were spawned during September and October. Fry reached free swimming stage in February or March and were then placed in ponds. They were reared 90 to 120 days in the hatchery and released at an average length of 6 to 8 cm (2-3 in). Since there was considerable variation in time and size of release between hatcheries and brood years, we have included Table 5 to complete the release procedure record. After the hatchery fall chinook salmon spent 1 to 6 yr in the ocean, where they were available to sport and commercial fisheries from southeastern Alaska to central California, they matured and returned to the Columbia River.

The marking phase of this study extended from June 1962 through June 1965. Approximately 10% of the 1961-64 broods were marked. A "10-part sampler," a modified sampling tool (Worlund et al. 1969), was used to obtain the sample of fish for marking. The sampler consisted of a cylindrical liner containing a circular metal frame. The frame was divided into 10 equal pie-shaped sections with a zipper-bottomed net pocket hung from each section. To obtain a sample for marking, the zippers on one or more pockets were closed, the frame and liner were placed in a water-filled tub, and 18 kg (40 lb) of fish were placed into the liner. The closed pocket, or pockets, retained the desired sample when the liner and frame were lifted. The fish remaining in the tub were placed into another pond. This procedure was followed until all chinook salmon in each pond were processed. In the case of the special mark hatcheries, two or more pockets were closed. One pocket retained the fish for common marking and the other pockets retained those for special marking. The intention was to apply special marks to between 500,000 and 1.0 million chinook salmon at each of the special mark hatcheries. We felt this number would provide a statistically sound number of special mark recoveries for each hatchery. The hatchery manager's estimate of the number of fall chinook salmon on hand at the time of sampling was used to determine how many pockets to close at each hatchery to obtain the desired sample for special marking. These estimates were sometimes inaccurate, resulting in a smaller or larger sample than had been desired.

Fish to be marked were anesthetized with MS-222 (tricaine methanesulfonate). The fins and maxillary bones were clipped with bent-nosed scissors. Marked fish were held in hatchery troughs until they recovered from the anesthetic, then returned to the group of unmarked fish from which they came. Mark quality control was maintained by sampling 100 marked fish per marker at irregular periods each day and grading them according to quality of mark. Each year over 100,000 marked fish were sampled and graded. This grading indicated a high mark quality was attained.

The entire production of fall chinook salmon at the study hatcheries was sampled with the 10-part sampler prior to release to estimate the marked and unmarked releases. The "10%" samples were set aside and resampled to obtain a "1%" sample which was sorted into marked and unmarked groups, counted, and weighed. The counts and the estimate of the proportion removed by the particular sampler were used to estimate the numbers of marked and unmarked fish released.

Over 213 million 1961-64-brood fall chinook salmon were released from the study hatcheries. Of these, 21.3 million were given the common mark and 9.6 million were given a special mark (Table 1).

TABLE 5.—Size and date of release of 1961-64 broods of fall chinook salmon from Columbia River hatcheries participating in the fall chinook salmon study by hatchery and brood.

Hatchery	1961 brood		1962 brood		1963 brood		1964 brood	
	Size[1]	Date	Size[1]	Date	Size[1]	Date	Size[1]	Date
Grays River	169	5/24/62	141	5/31/63	114	6/1/64	108	5/26/65
Elokomin	202	5/24/62	206	5/20/63	181	5/9/64	134	5/12/65
Kalama Falls	356-202	6/1-7/31/62	226	6/4/63	198	6/15/64	177	6/20/65
Washougal	187-107	5-6/62	180	5/22/63	153	5/25/64	139	5/2/65
Little White	180	6/22/62	227- 83	6/5-8/15/63	200	6/18/64	177	6/65
Spring Creek	289-173	4/9-5/11/62	282-149	4/8-6/13/63	273-206	4/12-5/12/64	250-142	4/11-5/4/65
Big White	182	5/11/62	190	6/17/63	181	5/12/64	85	6/29/65
Klickitat	166	4/23/62	164	4/20/63	148	4/29/64	132	5/5/65
OxBow	217	5/10/62	195	5/14/63	189	5/6/64	170	6/19/65
Cascade	318	5/20/62	192	6/24/63	215	6/12/64	146	6/29/65
Bonneville	312	6/6/62	152	6/19/63	136	6/26/64	154	6/24/65
Big Creek	174	5/2/62	137	5/7/63	102	5/13/64	91	6/2/65
Lower Kalama	261	6/2/62	199	5/18/63	139	5/18/64	169	5/18/65

[1]Fish per pound.

Mark Recovery

The sampling phase of this study began in 1963 and was completed in 1969. Table 6 shows the marks and the age of the marked fish in the fisheries during these years. Sampling and catch estimation procedures are explained under Catch of Marked Fish. Sampling for these fish occurred in the major ocean sport and commercial fisheries from southeastern Alaska to central California, the Columbia River fisheries (Figure 2, Table 7), at parent hatcheries, and certain natural spawning grounds (Worlund et al. 1969; Rose and Arp see footnote 3; Arp et al. see footnote 4; Wahle et al. see footnote 5). During the first sampling year, 1963, only Washington and Oregon ocean fisheries, Columbia River fisheries, and hatchery returns were examined for marks. In 1964, the sampling was expanded to include most chinook salmon fisheries from Avila Beach, Calif. to Pelican, Alaska. The Puget Sound sport fishery was not sampled in 1964. The British Columbia purse seine fishery was not sampled in 1966. The sampling of the southeastern Alaska gillnet fishery

TABLE 6.—Ages of marked Columbia River fall chinook salmon in catches and escapements by brood (1961-64) and sampling years (1963-69).

			Year of sampling						
Brood	Mark[1]	Hatchery	1963	1964	1965	1966	1967	1968	1969
			Years old						
1961	Ad-RM	12 hatcheries	2	3	4	5			
	Ad-LV-RM	Spring Creek	2	3	4	5			
	Ad-RV-RM	Kalama	2	3	4	5			
	RV-RM	OxBow	2	3	4	5			
	LV-RM	Elokomin	2	3	4	5			
1962	Ad-LM	12 hatcheries		2	3	4	5		
	Ad-LV-LM	Spring Creek		2	3	4	5		
	Ad-RV-LM	Kalama		2	3	4	5		
	RV-LM	Cascade		2	3	4	5		
	LV-LM	Grays River		2	3	4	5		
1963	Ad-RM	12 htacheries			2	3	4	5	
	Ad-LV-RM	Spring Creek			2	3	4	5	
	Ad-RV-RM	Kalama			2	3	4	5	
	LV-RM	Klickitat			2	3	4	5	
	RV-RM	Big Creek			2	3	4	5	
1964	Ad-LM	12 hatcheries				2	3	4	5
	Ad-LV-LM	Spring Creek				2	3	4	5
	Ad-RV-LM	Kalama				2	3	4	5
	RV-LM	Little White Salmon				2	3	4	5
	LV-LM	Bonneville				2	3	4	5
No. of marks in catches and escapements			5	10	15	20	15	10	5

[1]Ad: adipose; LV: left ventral; RV: right ventral; LM: left maxillary; and RM: right maxillary.

TABLE 7.—Areas where catches were examined for marked fall chinook salmon of Columbia River origin by port or zone of landing and type of fishery.

	Sport fishery	Commercial fisheries			
Area sampled	Rod and reel	Troll	Gill net	Dip net	Purse seine
Southeast Alaska		Zones 1, 3-15, 18, 22	Zones 1, 6, 8, 11, 15, 18, 19		
British Columbia		Alaska area Zones 29, 40-43, Area C.	Zones 29, 40, 41-43		Zones 40-43
Washington ocean	Sekiu	Seattle	Juan de Fuca Strait		
	Neah Bay	Neah Bay	Grays Harbor		
	La Push	La Push	Willapa Bay		
	Westport	Westport			
	Ilwaco	Ilwaco			
Puget Sound	Zones 6-12				
Oregon ocean	Warrenton	Astoria, Tillamook			
	Depoe Bay	Nestucca, Depoe Bay			
	Newport	Newport			
	Florence	Florence			
	Reedsport	Reedsport			
	Coos Bay	Coos Bay			
	Gold Beach	Port Orford			
	Brookings	Brookings			
California ocean	Crescent City	Crescent City			
	Eureka	Eureka			
	Fort Bragg	Fort Bragg			
	San Francisco	San Francisco			
	Monterey	Monterey			
Columbia River	Zones 1-5		Zones 1-6	Klickitat River	

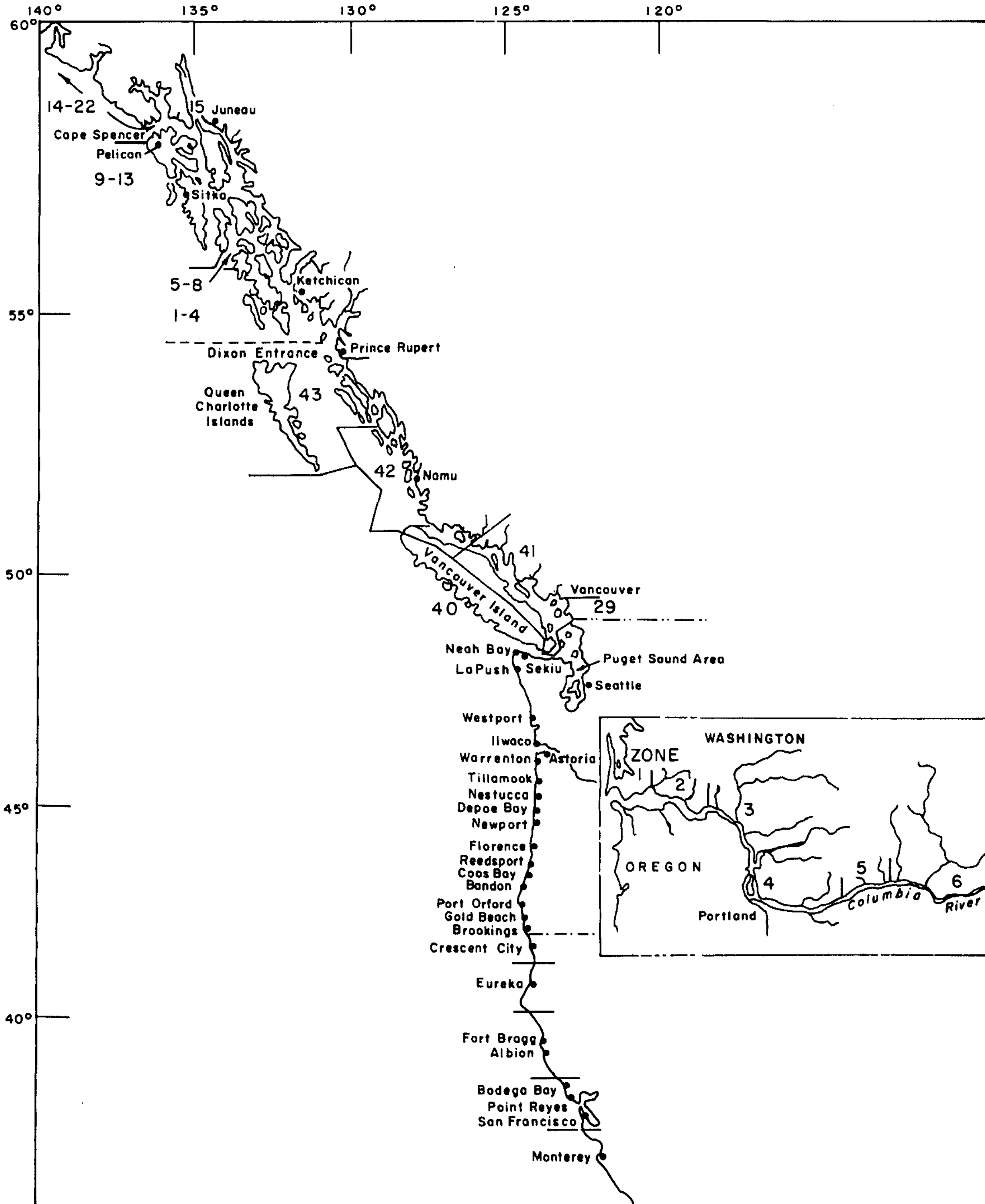

FIGURE 2.—Ports and zones sampled for marked fall chinook salmon of Columbia River origin.

was discontinued after 1966 and the Alaska troll fishery sampling stopped after 1967. Over the 7 yr of sampling, 3.3 million chinook salmon were examined for marks and 208,000 were sampled for age. This was an average sampling percentage of 20 and 1% for marks and age, respectively. The yearly mark sampling rate ranged from 14 to 28% of the catch and the age sampling ranged from 1 to 4%.

Enumeration of Returns

Returns to all study facilities were counted and examined for marks. Age, length, and sex data were also collected from 25 to 50 unmarked chinook salmon/wk at each hatchery. Returns to five other Columbia River hatcheries (Abernathy, Speelyai, Toutle, Klaskanine, and Sandy) were also examined for marks. Total hatchery returns for the 1961-64 broods of fall chinook salmon were 155,783, of which 8,527 were marked.

Hatchery and adjacent fall chinook salmon spawning streams were surveyed to estimate natural spawning of hatchery fish. The Klickitat, Big White Salmon, Little White Salmon, Wind, Washougal, Kalama, Lewis, Elokomin, and Grays Rivers and Plympton and Big Creeks were surveyed in 1964, 1965, and 1966. The surveys were designed to estimate the total spawning population and to gather mark, age, and length data. During the 3 yr, 62,400 chinook salmon were examined of which 1,600 were marked. The stream surveys were discontinued after 1966 because of a funding reduction.

INDIVIDUAL HATCHERY MARK CATCH AND POTENTIAL CONTRIBUTION, 1961-64 BROODS

In this study 12 hatcheries and one rearing pond were marked with a common mark for four brood years. All but two of these facilities (Big White Salmon Pond and Washougal Hatchery) had a portion of at least one brood year's production marked with a special mark. A portion of all four brood years' production at Spring Creek and the two Kalama River hatcheries were marked with special marks. This special marking was done to give an indication of the migration patterns and contributions to the fisheries for each individual hatchery in the study. The estimated catches and potential contributions will now be presented for each hatchery with special marks.

Spring Creek National Fish Hatchery, 1961-64 Broods

Spring Creek Hatchery was allocated the Ad, LV, combination mark for the four brood years. The RM mark was used in combination with the Ad-LV mark for the 1961 and 1963 broods and the LM mark was used with the 1962 and 1964 broods. Approximately 10% of Spring Creek's production was marked for each brood year. The number of fish given special marks ranged from 1.1 million for the 1961 brood to 600,000 for the 1964 brood.

Spring Creek special marked chinook salmon were available to the ocean and Columbia River fisheries from 1963 through 1969. During this 7-yr period, we estimated 12,180 special marked fish were recovered in the fisheries (Table 8). Over 65% of the fish were captured in their third year of life, with nearly 27% taken as 4-yr-olds. Ocean recoveries occurred primarily from the Columbia River mouth north to the west coast of Vancouver Island. Fisheries in the marine areas took 74% of the fish, with 26% being caught in the Columbia River commercial fisheries (Figure 3).

The potential contribution of Spring Creek chinook salmon (had no marking taken place) was estimated at 401,700 fish for the four broods combined. The average Spring Creek contribution to the fisheries for the four broods combined was 12

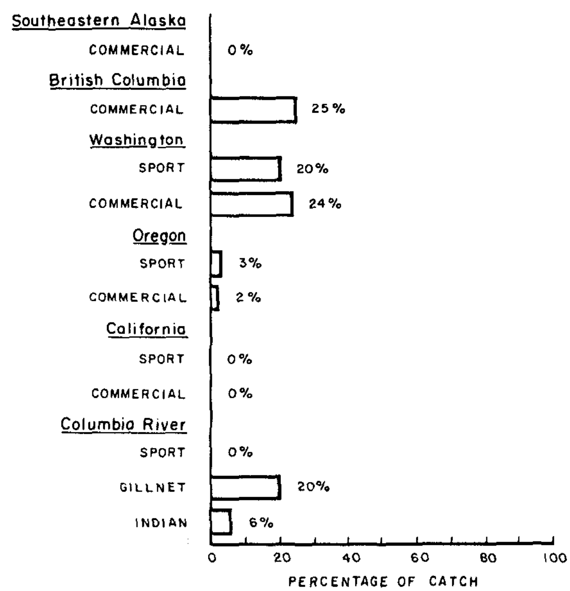

FIGURE 3.—Percentage of catch of 1961- to 1964-brood fall chinook salmon from Spring Creek National Fish Hatchery taken by area and fishery, 1963-69.

TABLE 8.—Estimated catches of special marked fall chinook salmon from Spring Creek National Fish Hatchery and potential contributions by fishery type and brood (1961-64), 1963-69.

Brood year and fishery type	Estimated catch of marked fish by year 1963	1964	1965	1966	1967	1968	1969	Catch	Potential contribution (in thousands)
1961:									
Marine sport	156	488	129	0	—	—	—	773	18.9
Marine commercial	4	2,031	269	5	—	—	—	2,309	56.4
Columbia River sport	0	14	16	0	—	—	—	30	0.7
Columbia River gillnet	11	388	633	17	—	—	—	1,049	25.6
Columbia River Indian[1]	11	147	81	0	—	—	—	239	5.8
Total	182	3,068	1,128	22	—	—	—	4,400	107.4
1962:									
Marine sport	—	34	142	28	0	—	—	204	6.4
Marine commercial	—	0	234	135	14	—	—	383	12.0
Columbia River sport	—	0	0	0	0	—	—	0	0.0
Columbia River gillnet	—	10	242	88	0	—	—	340	10.6
Columbia River Indian[1]	—	0	40	0	0	—	—	40	1.3
Total	—	44	658	251	14	—	—	967	30.3
1963:									
Marine sport	—	—	120	368	133	0	—	621	25.5
Marine commercial	—	—	23	966	282	9	—	1,280	52.6
Columbia River sport	—	—	0	0	0	0	—	0	0.0
Columbia River gillnet	—	—	15	151	203	7	—	376	15.4
Columbia River Indian[1]	—	—	14	13	95	8	—	130	5.3
Total	—	—	172	1,498	713	24	—	2,407	98.8
1964:									
Marine sport	—	—	—	378	685	87	10	1,160	43.5
Marine commercial	—	—	—	7	1,634	582	16	2,239	83.9
Columbia River sport	—	—	—	0	0	0	0	0	0.0
Columbia River gillnet	—	—	—	15	260	351	19	645	24.2
Columbia River Indian[1]	—	—	—	0	201	156	5	362	13.6
Total	—	—	—	400	2,780	1,176	50	4,406	165.2

[1]Setnet and dip net fisheries.

fish per 1,000 released and 2.3 fish per pound of fish released.

Kalama River Hatcheries, 1961-64 Broods

The production at Kalama Falls Salmon Hatchery and Lower Kalama Salmon Hatchery was combined for this study. Common and special marks were applied to the production at both facilities. The Ad, RV, and M special mark was allocated to the Kalama facilities. The RM clip was used with the 1961 and 1963 broods, and the LM mark was used with 1962 and 1964 broods. For all brood years, approximately 10% of both hatcheries' fall chinook salmon production was marked with a special mark.

We estimated 5,096 chinook salmon with special marks from Kalama River hatcheries were captured in the ocean and Columbia River fisheries from 1963 through 1969 (Table 9). Generally for the four brood years, over half of the Kalama fish were caught in their fourth and fifth years of life. However, the age distribution did vary by brood year. The 1961 and 1964 broods were over 60% 4- and 5-yr-old fish while these two age-groups contributed less than 50% to the 1962- and 1963-brood catches. The Kalama chinook salmon contributed to the Alaska fisheries primarily as 4-yr-olds; and the larger the Canadian catch, the larger the Alaskan catch. In 1968 the Canadian catch of Kalama fish was large and no sampling took place in the Alaska fisheries. Thus a significant contribution to Alaska of 1964-brood Kalama fall chinook salmon in 1968 could have been missed.

The potential contribution of Kalama River hatcheries fall chinook salmon totaled 172,400 fish for the four brood years (Table 9). The contributions ranged from a low of 22,300 fish for the 1962 brood to a high of 56,800 fish for the 1961 brood. The average contribution for all four broods combined was 43,100. This is an average potential contribution to Pacific coast fisheries of 9.6 fish for each 1,000 smolts released and 2.0 fish caught for every pound of fish released.

Kalama chinook salmon contributed primarily to British Columbia, Washington, and Columbia River gillnet fisheries (Figure 4). The largest contribution was to British Columbia followed by Washington, Columbia River, Oregon, and Alaska, in that order.

TABLE 9.—Estimated catch of special marked fall chinook salmon from Kalama River hatcheries and potential contributions by fishery type and brood (1961-64), 1963-69.

	Estimated catch of marked fish by year								Potential contribution
Brood year and fishery type	1963	1964	1965	1966	1967	1968	1969	Catch	(in thousands)
1961:									
Marine sport	23	78	103	9	—	—	—	213	5.6
Marine commercial	0	618	683	106	—	—	—	1,407	36.7
Columbia River sport	0	0	0	0	—	—	—	0	0.0
Columbia River gillnet	0	38	402	111	—	—	—	551	14.4
Columbia River Indian[1]	0	0	4	0	—	—	—	4	0.1
Total	23	734	1,192	226	—	—	—	2,175	56.8
1962:									
Marine sport	—	0	84	11	8	—	—	103	3.5
Marine commercial	—	0	240	194	23	—	—	457	15.5
Columbia River sport	—	0	0	16	0	—	—	16	0.5
Columbia River gillnet	—	6	21	46	10	—	—	83	2.8
Columbia River Indian[1]	—	0	0	0	0	—	—	0	0.0
Total	—	6	345	267	41	—	—	659	22.3
1963:									
Marine sport	—	—	140	167	66	12	—	385	17.0
Marine commercial	—	—	0	366	320	53	—	739	32.7
Columbia River sport	—	—	0	0	0	0	—	0	0.0
Columbia River gillnet	—	—	7	32	44	50	—	133	5.9
Columbia River Indian[1]	—	—	0	0	0	0	—	0	0.0
Total[1]	—	—	147	565	430	115	—	1,257	55.6
1964:									
Marine sport	—	—	—	38	61	40	0	139	5.2
Marine commercial	—	—	—	0	132	533	69	734	27.6
Columbia River sport	—	—	—	0	0	17	0	17	0.6
Columbia River gillnet	—	—	—	3	0	41	68	112	4.2
Columbia River Indian[1]	—	—	—	0	3	0	0	3	0.1
Total	—	—	—	41	196	631	137	1,005	37.7

[1]Setnet and dip net fisheries.

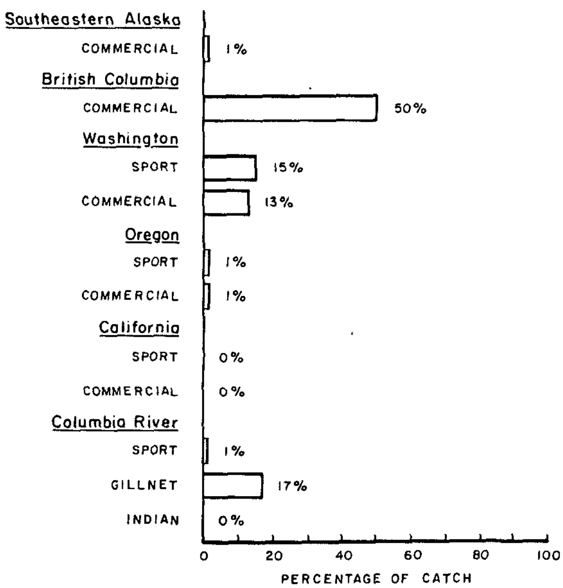

FIGURE 4.—Percentage of catch of 1961- to 1964-brood fall chinook salmon from Kalama River hatcheries taken by area and fishery, 1963-69. Percentages do not add to 100% due to rounding.

Elokomin and OxBow Hatcheries, 1961 Brood

A portion of the 1961-brood fall chinook salmon productions at Elokomin and OxBow Hatcheries were given special marks. At Elokomin Hatchery, 480,500 or 30% of the production was LV-RM clipped. Approximately 450,400 or 10% of OxBow's fall chinook salmon production was marked with a RV-RM clip. These fish contributed to the fisheries from 1963 through 1966.

During the 4 yr, 235 Elokomin and 336 OxBow fish with special marks were estimated to have been caught (Table 10). Chinook salmon from both hatcheries were taken primarily as 3-yr-olds. A larger portion of Elokomin fish than OxBow fish were taken as 4-yr-olds, and a larger portion of OxBow than Elokomin fish were taken as 2- and 5-yr-olds. Potential contributions were estimated at 2,000 and 8,500 fish for Elokomin and OxBow respectively. The catch per 1,000 fish released at Elokomin Hatchery was 1.3 fish and at OxBow 1.9 fish. The catches per pound of fish released at Elokomin and OxBow Hatcheries were 0.2 and 0.4 fish respectively.

About one-half of the catch from the two hatch-

TABLE 10.—Estimated catch of 1961-brood special marked fall chinook salmon and potential contribution from Elokomin and OxBow Hatcheries by fishery type, 1963-66.

Hatchery and fishery type	Estimated catch of marked fish by year 1963	1964	1965	1966	Total catch	Potential contribution (in thousands)
Elokomin Hatchery:						
Marine sport	0	25	31	0	56	0.5
Marine commercial	0	109	23	9	141	1.2
Columbia River sport	0	0	0	0	0	0.0
Columbia River gillnet	0	6	30	0	36	0.3
Columbia River Indian[1]	0	2	0	0	2	0.0
Total	0	142	84	9	235	2.0
OxBow Hatchery:						
Marine sport	18	78	6	16	118	3.0
Marine commercial	0	107	41	6	154	3.9
Columbia River sport	0	0	17	0	17	0.4
Columbia River gillnet	0	27	3	14	44	1.1
Columbia River Indian[1]	3	0	0	0	3	0.1
Total	21	212	67	36	336	8.5

[1]Setnet and dip net fisheries.

eries occurred in the Washington fisheries. (Figure 5). Nearly 30% of the Elokomin catch was taken in the Washington commercial fisheries. Washington sport fishermen took over one-fourth of the OxBow catch. Fish from Elokomin appear to have a more northerly distribution than those from OxBow.

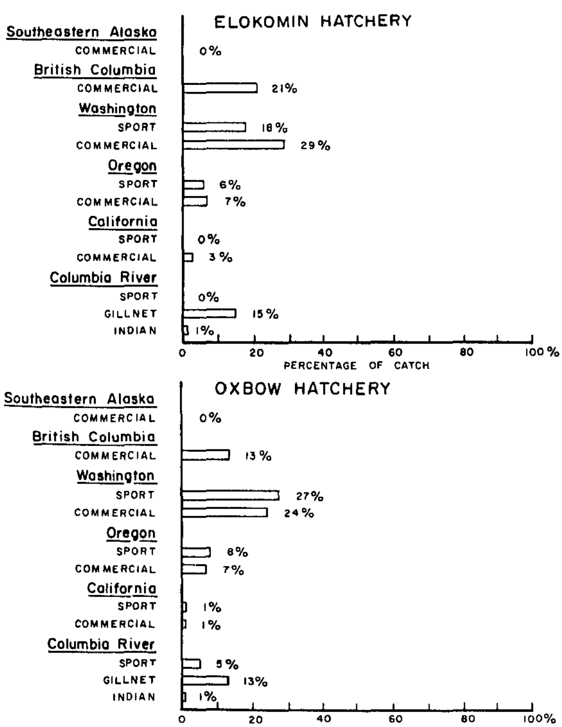

FIGURE 5.—Percentage of 1961-brood fall chinook salmon from Elokomin and OxBow Hatcheries taken by area and fishery, 1963-66.

Grays River and Cascade Hatcheries, 1962 Brood

The 1962-brood fall chinook salmon at Grays River Hatchery were given a LV-LM special clip and the Cascade fish were RV-LM clipped. Special marks were applied to approximately 18% or 241,500 Grays River and 13% or 541,200 Cascade Hatchery fish. These fish contributed to the fisheries from 1964 through 1967.

Approximately equal numbers of Grays River and Cascade fall chinook salmon with special marks were estimated to have been taken in the fisheries (Table 11). Fish from both hatcheries were caught almost exclusively as 3- and 4-yr-olds. Few were taken as 2's and 5's. The potential contributions of Grays River and Cascade were 3,900 and 4,800 fish, respectively. For each 1,000 chinook salmon released at Grays River Hatchery, 2.9 were caught in the fisheries and 0.4 fish were caught per pound of fish released. The contribution from Cascade Hatchery was 1.1 chinook salmon per 1,000 released and 0.2 per pound of fish released.

The catch distributions of Grays River and Cascade Hatcheries were very different (Figure 6); for example, a much greater portion of Cascade's than Grays River's fish were taken in the British Columbia fishery. Most of Grays River's fish (65%) but only 24% of Cascade's fish were taken in the Washington sport fishery.

Klickitat and Big Creek Hatcheries, 1963 Brood

A LV-RM special mark was applied to 18% or 521,600 1963-brood fall chinook salmon at Klick-

TABLE 11.—Estimated catch of 1962-brood special marked fall chinook salmon and potential contribution from Grays River and Cascade hatcheries by fishery type, 1964-67.

Hatchery and fishery type	Estimated catch of marked fish by year 1964	1965	1966	1967	Total catch	Potential contribution (in thousands)
Grays River Hatchery:						
Marine sport	0	89	50	0	139	2.5
Marine commercial	3	29	35	4	71	1.3
Columbia River sport	0	0	0	0	0	0.0
Columbia River gillnet	0	0	5	0	5	0.1
Columbia River Indian[1]	0	0	0	0	0	0.0
Total	3	118	90	4	215	3.9
Cascade Hatchery:						
Marine sport	0	19	28	0	47	1.2
Marine commercial	0	66	38	3	107	2.7
Columbia River sport	0	0	0	0	0	0.0
Columbia River commercial	3	6	24	0	33	0.8
Columbia River Indian[1]	0	0	4	0	4	0.1
Total	3	91	94	3	191	4.8

[1] Setnet and dip net fisheries.

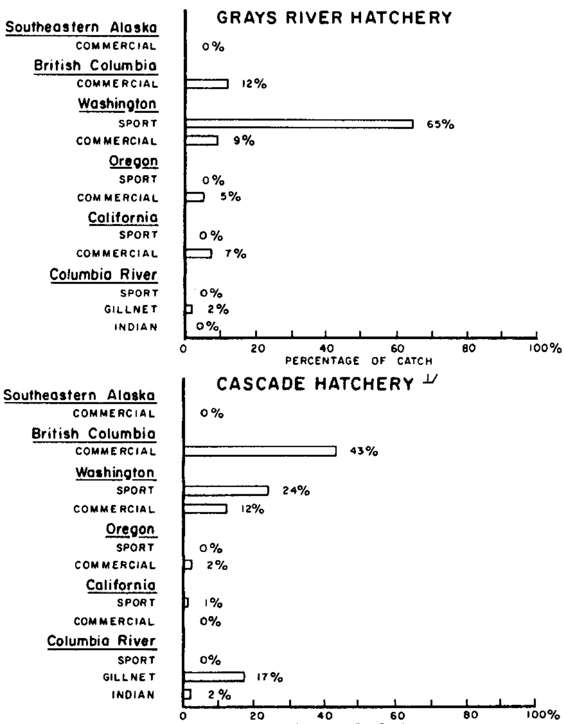

FIGURE 6.—Percentage of catch or 1962-brood fall chinook salmon from Grays River and Cascade Hatcheries taken by area and fishery, 1964-67. Percentages do not add to 100% due to rounding.

itat Hatchery. At Big Creek Hatchery nearly 30% or 580,000 1963-brood chinook salmon were given RV-RM special clips. These fish contributed to the fisheries from 1965 through 1968.

The estimated catches of chinook salmon with special marks from Klickitat and Big Creek Hatcheries were 1,858 and 914 fish, respectively (Table 12). The Klickitat fish were caught primarily as 3- and 4-yr-olds, except in the ocean sport fishery where 2-yr-olds were predominant. In the marine commercial and Columbia River fisheries, the predominant age class was 3-yr-olds. Nearly 60% of Big Creek's special marked fish were caught in their third year of life, and about one-third were taken as 4-yr-olds.

Klickitat and Big Creek Hatcheries' potential contributions to the fisheries were 42,500 and 12,900 fish, respectively. From Klickitat the contribution was 14.7 fish per 1,000 released and 2.2 fish for each pound of fish released. The contribution per 1,000 chinook salmon released at Big Creek was 6.5 fish and 0.7 fish for each pound of fish released.

Distribution of both facilities' catches can be compared by examination of Figure 7. Thirty-nine percent of Klickitat's fish were taken in the British Columbia commercial fisheries compared with 16% for Big Creek, suggesting a more northerly distribution for Klickitat fish. Although Big Creek fish pass through only a small portion of the Columbia River commercial fishery, the portion taken in this fishery is larger (19%) than the Klickitat portion (10%). Over half of Big Creek's estimated catch was taken in the Washington marine fisheries.

Bonneville and Little White Salmon Hatcheries, 1964 Brood

About 10% (957,100) of the 1964-brood Bonneville Hatchery fall chinook salmon were marked with a LV-LM clip. The RV-LM mark was applied to about 10% (797,300) of the Little White

TABLE 12.—Estimated catch of 1963-brood special marked fall chinook salmon and potential contribution from Klickitat and Big Creek hatcheries by fishery type, 1965-68.

Hatchery and fishery type	Estimated catch of marked fish by year				Total catch	Potential contribution (in thousands)
	1965	1966	1967	1968		
Klickitat Hatchery:						
Marine sport	161	146	81	0	388	8.9
Marine commercial	3	633	617	32	1,285	29.4
Columbia River sport	0	0	0	0	0	0.0
Columbia River commercial	0	72	45	0	117	2.7
Columbia River Indian[1]	0	47	21	0	68	1.5
Total	164	898	764	32	1,858	42.5
Big Creek Hatchery:						
Marine sport	70	209	73	0	352	5.0
Marine commercial	0	240	144	7	391	5.5
Columbia River sport	0	0	0	0	0	0.0
Columbia River commercial	0	93	78	0	171	2.4
Columbia River Indian[1]	0	0	0	0	0	0.0
Total	70	542	295	7	914	12.9

[1]Setnet and dip net fisheries.

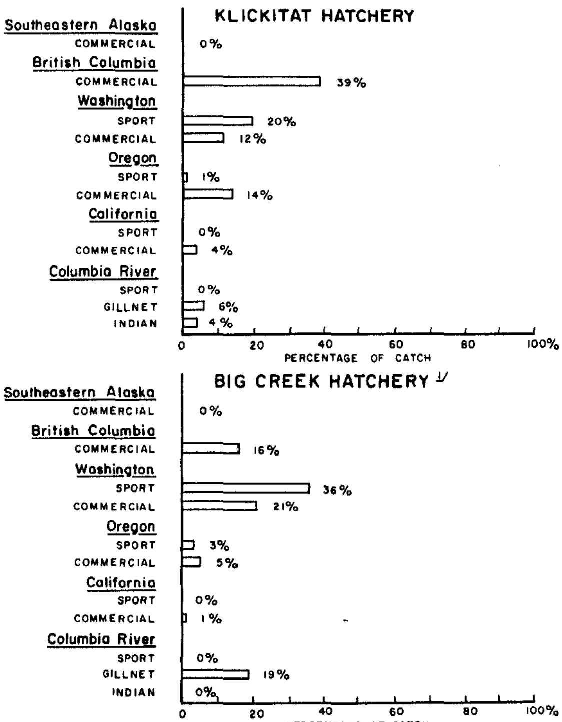

FIGURE 7.—Percentage of catch of 1963-brood fall chinook salmon from Klickitat and Big Creek Hatcheries taken by area and fishery, 1965-68. Percentages do not add to 100% due to rounding.

Salmon National Fish Hatchery 1964-brood fish. Both groups contributed to the fisheries from 1966 through 1969.

The estimated catches of special marked fish from Bonneville and Little White Salmon Hatcheries were 762 and 303 fish respectively. Significant numbers of Bonneville special mark chinook salmon were caught in the ocean fisheries as 2-, 3-, and 4-yr-olds, while the Little White fish contributed as 3's and 4's (Table 13). The largest numbers of both hatcheries' fish were taken in the ocean commercial fisheries.

The potential contributions for Bonneville and Little White were 27,100 and 11,000 fish, respectively. Bonneville produced 2.7 fish per 1,000 or 0.4 fish per pound of fish released. Little White produced 1.3 fish per 1,000 or 0.2 fish per pound of fish released.

The distribution of the Bonneville Hatchery catch was more southerly than that of Little White Salmon Hatchery (Figure 8). Nearly 50% of the catch from both facilities occurred in the Washington fisheries. The British Columbia fisheries took most of the remaining Little White catch (41%).

Common Mark Catch and Potential Contribution All Study Facilities Combined, 1961-64 Broods

An Ad-M common mark was applied to a portion of the 1961-64-brood fall chinook salmon production at all 13 study facilities. The RM was clipped from the 1961- and 1963-brood fish, and the LM was clipped from the 1962- and 1964-brood chinook salmon. Common marks were applied to 21,320,000 (approximately 10%) of the 213,014,000 fall chinook salmon released over the four brood years from the 13 study facilities.

We estimated 65,620 common marked fish were caught from 1963 through 1969 (Table 14). On the average over the four broods 76% of the common marked fish were taken in the ocean, with 56% caught in the ocean commercial fisheries. In the

TABLE 13.—Estimated catch of 1964-brood special marked fall chinook salmon and potential contribution from Bonneville and Little White Salmon National Fish hatcheries by fishery type, 1966-69.

Hatchery and fishery type	Estimated catch of marked fish by year 1966	1967	1968	1969	Total catch	Potential contribution (in thousands)
Bonneville Hatchery:						
Marine sport	99	70	95	0	264	9.4
Marine commercial	62	230	172	8	472	16.8
Columbia River sport	0	0	0	0	0	0.0
Columbia River commercial	0	0	17	5	22	0.8
Columbia River Indian[1]	4	0	0	0	4	0.1
Total	165	300	284	13	762	27.1
Little White Salmon Hatchery:						
Marine sport	0	40	37	0	77	2.8
Marine commercial	4	84	125	0	213	7.7
Columbia River sport	0	0	0	0	0	0.0
Columbia River commerical	0	5	8	0	13	0.5
Columbia River Indian[1]	0	0	0	0	0	0.0
Total	4	129	170	0	303	11.0

[1]Setnet and dip net fisheries.

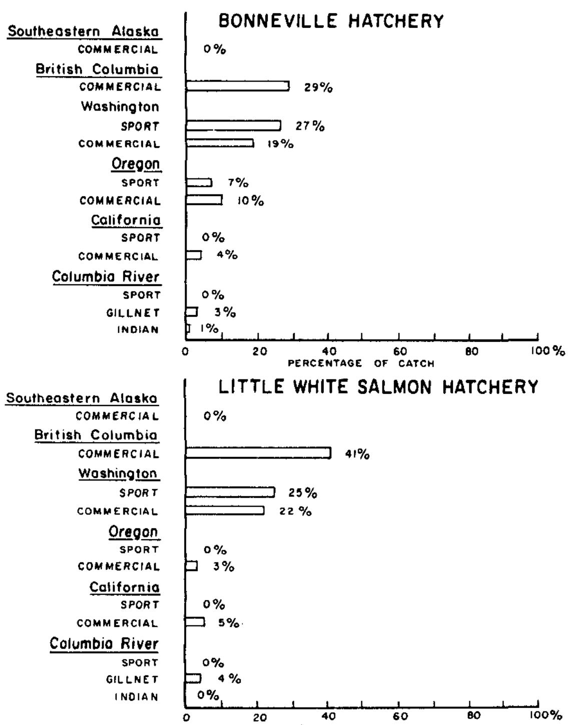

FIGURE 8.—Percentage of catch of 1964-brood fall chinook salmon from Bonneville and Little White Salmon Hatcheries taken by area and fishery, 1966-69.

ocean fisheries, the 3-yr-old exceeded the 4-yr-old catch. However, in the river the 4-yr-old catch was larger than the 3-yr-old. The Columbia River fall chinook salmon sport fishery was small and few marked fish were observed.

The potential contribution for the four broods combined was 1,433,300 fall chinook salmon. The contribution ranged from a low of 165,200 fish for the 1962 brood to a high of 602,200 for the 1963 brood. The contribution figures in Table 14 include fish with common and special marks as well as unmarked fish from the 13 study facilities. The average catch to release ratio was 6.7 fish per 1,000 released, with ratios of 6.7, 3.1, 10.0, and 6.5 for the 1961-64 broods respectively. The average catch per pound released was 1.2 fish with ratios by brood of 1.4, 0.6, 1.7, and 0.9 fish per pound released. The catch was distributed primarily among the British Columbia commercial (34%), the Washington marine sport and commercial (38%), and the Columbia River gillnet (19%) fisheries (Figure 9).

CATCH TO ESCAPEMENT AND SURVIVAL

Returns to Columbia River hatcheries, both study and nonstudy, and to streams adjacent to these hatcheries were examined for marked chinook salmon (see Enumeration of Returns).

Mark return data were used to estimate catch to escapement ratios and total survival percentages for each special mark hatchery and all study hatcheries combined (Table 15). Only marked catches and escapements were used to develop the estimates to eliminate possible inflation of escapement values due to unmarked wild fish in hatchery returns. Survival estimates were calculated by dividing the potential marked catches and escapements by the marked releases. Potential marked catches and escapements are those that would be expected if marking did not cause post release mortalities. Potential marks were es-

TABLE 14.—Estimated catches of common marked fall chinook salmon and potential contribution from all Columbia River study hatcheries by fishery type and brood, 1963-69.

Brood year and fishery type	Estimated catch of common marked fish by year							Total Catch	Potential contribution[1] (in thousands)
	1963	1964	1965	1966	1967	1968	1969		
1961:									
Marine sport	576	2,091	613	82	—	—	—	3,362	54.8
Marine commercial	3	8,778	3,034	366	—	—	—	12,181	198.1
Columbia River sport	0	21	0	0	—	—	—	21	0.4
Columbia River gillnet	98	1,651	3,407	197	—	—	—	5,353	86.8
Columbia River Indian[2]	50	852	411	7	—	—	—	1,320	21.0
Total	727	13,393	7,465	652	—	—	—	22,237	361.1
1962:									
Marine sport	—	204	773	166	27	—	—	1,170	25.1
Marine commercial	—	79	2,981	1,490	108	—	—	4,658	97.0
Columbia River sport	—	12	8	0	0	—	—	20	0.5
Columbia River gillnet	—	31	879	680	21	—	—	1,611	33.9
Columbia River Indian[2]	—	11	392	21	3	—	—	427	8.7
Total	—	337	5,033	2,357	159	—	—	7,886	165.2
1963:									
Marine sport	—	—	1,304	3,140	594	56	—	5,094	139.4
Marine commercial	—	—	71	9,016	3,317	284	—	12,688	344.5
Columbia River sport	—	—	0	0	0	0	—	0	0.0
Columbia River gillnet	—	—	88	1,194	2,168	315	—	3,765	101.0
Columbia River Indian[2]	—	—	38	103	453	42	—	636	17.3
Total	—	—	1,501	13,453	6,532	697	—	22,183	602.2
1964:									
Marine sport	—	—	—	797	1,966	466	4	3,233	74.2
Marine commercial	—	—	—	53	4,757	2,492	108	7,410	169.8
Columbia River sport	—	—	—	0	0	0	0	0	0.1
Columbia River gillnet	—	—	—	27	692	1,034	188	1,941	43.9
Columbia River Indian[2]	—	—	—	1	405	307	17	730	16.8
Total	—	—	—	878	7,820	4,299	317	13,314	304.8

[1]Special marks included.
[2]Setnet and dip net fisheries.

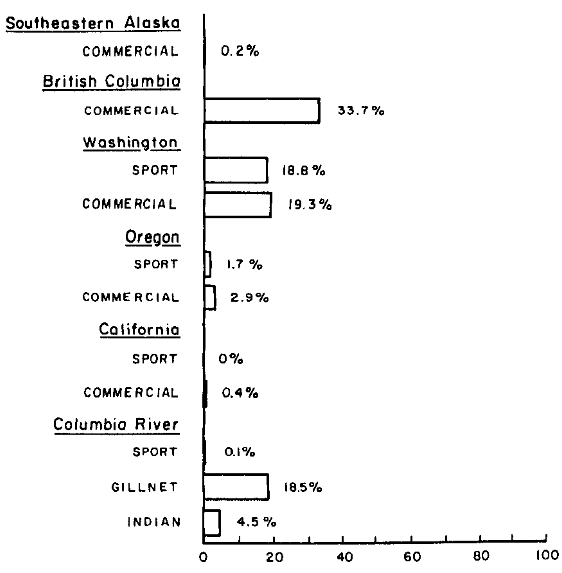

FIGURE 9.—Percentage of catch of 1961- to 1964-brood fall chinook salmon from 13 Columbia River study facilities taken by area and fishery, 1963-69. Percentages do not add to 100% due to rounding.

timated by dividing the mark recoveries by the appropriate special or common marked to unmarked relative survivals (see Contribution of Hatchery Fish).

Catch to escapement and survival estimates are of limited value for several reasons. First, adjacent tributary streams were surveyed during only three of the seven return years of the study (1964-66). Survey data are unavailable for at least one return year for each brood. Thus, all catch to escapement ratios are probably overestimated and survivals underestimated. Second, only a portion of the fish returning to the streams could be examined for marks. Total mark recoveries had to be estimated from the survey samples. Third, in some cases fish were delayed in entering adult holding facilities and may have strayed to other areas. Thus, some marked hatchery fish may not have been counted. Fourth, use of average relative survivals limited the accuracy of potential mark catches and returns and thus the total survival percentages. Relative survivals for individual hatcheries could have differed greatly from the averages.

Catch to escapement ratios and total survivals are needed to develop values for fisheries compensation and enhancement projects related to water use projects on the Columbia River system. Thus,

TABLE 15.—Marked catches and escapements, catch to escapement ratios, and total survivals for fish from each special mark hatchery and all study facilities combined, 1961-64 broods.

Hatchery	Brood	Marked catch	Marked escapement	Catch to escapement	Potential marked catch and escapement[1]	Marked releases	Total survival
Spring Creek	1961	4,400	613	7.2:1	12,691	1,133,019	0.011
	1962	967	92	10.5:1	3,416	866,892	0.004
	1963	2,407	374	6.4:1	11,492	751,243	0.015
	1964	4,406	228	19.3:1	15,924	600,953	0.026
Kalama River	1961	2,175	238	9.1:1	6,109	475,964	0.013
	1962	659	38	17.3:1	2,248	437,669	0.005
	1963	1,257	106	11.9:1	5,632	456,158	0.012
	1964	1,005	41	24.5:1	3,595	319,412	0.011
Elokomin	1961	235	33	7.1:1	678	480,533	0.001
OxBow	1961	336	99	3.4:1	1,101	450,446	0.002
Grays River	1962	215	5	43.0:1	710	241,494	0.003
Cascade	1962	191	6	31.9:1	635	541,158	0.001
Klickitat	1963	1,858	129	14.4:1	8,210	521,610	0.016
Big Creek	1963	914	380	2.4:1	5,347	579,967	0.009
Bonneville	1964	762	27	28.2:1	2,711	957,110	0.003
Little White Salmon	1964	303	37	8.2:1	1,168	797,345	0.001
All study facilities[2]	1961	22,237	3,399	6.5:1	42,164	5,446,439	0.008
	1962	7,886	675	11.7:1	17,948	5,249,079	0.003
	1963	22,183	2,737	8.1:1	66,989	5,986,464	0.011
	1964	13,314	856	15.6:1	31,629	4,638,237	0.007

[1]Assuming no mortality due to marking.
[2]Includes common marks only.

despite the limitations, we have included the values in this report.

Catch to escapement ratios for special mark hatcheries (Table 15) ranged from 2.4 to 1 (Big Creek, 1963 brood) to 43 to 1 (Grays River, 1962 brood). Average catch to escapements for Spring Creek and Kalama River hatcheries were 9.3 to 1 and 12.0 to 1 respectively. The catch to escapement ratios for all hatcheries combined, common marks only, show much less yearly variation than those for the special mark hatcheries. The average catch to escapement, all hatcheries and broods combined, was 8.6 to 1. Only common marks were combined for all hatcheries because these marks show only the variations among broods, not those among marks.

Total survivals ranged from 0.1% (Elokomin, 1961 brood; Cascade, 1962 brood; Little White Salmon, 1964 brood) to 2.6% (Spring Creek, 1964 brood). Average survivals for Spring Creek and Kalama River hatcheries were 1.3 and 1.0% respectively. For all hatcheries combined, the average survival was 0.7%.

Examination of Table 15 does not reveal any relationship between catch to escapement ratios and survivals. For example, at Spring Creek the 1964 brood had the highest catch to escapement ratio and percent survival. At Kalama River hatcheries, the 1964 brood had the highest catch to escapement ratio and the second highest survival value. The 1961 brood had the lowest catch to escapement and highest survival. For all study facilities, the 1964 brood had the highest catch to escapement ratio, and the 1963 brood had the highest total survival. The 1964 and 1961 broods had nearly equal survivals, but markedly different catch to escapements. The major reason for high 1964 brood catch to escapement ratios is the absence of adjacent stream surveys during three of the four return years for this brood.

ECONOMIC EVALUATION

A major purpose of this paper is to develop benefit to cost ratios for each of the special mark hatcheries and for each brood of the combined study facilities. To develop these ratios, the cost of rearing the four broods of chinook salmon and their potential value to the fisheries had to be estimated. The development of benefit to cost ratios is explained in detail by Worlund et al. (1969) and Wahle et al. (1974), but certain modifications will be discussed here briefly.

The values and benefit to cost ratios are higher in this report than those reported in our previous reports for five reasons: 1) the interest rate applied to capital costs is lower in this report (Wahle et al. 1974), 2) the sport value used is higher (see Value of Hatchery Contribution), 3) a lower marked fish relative survival figure was used for the 1961-brood (see Contribution of Hatchery Fish), 4) misidentified and partial marks were included in this report (see Contribution of Hatchery Fish), and 5) the potential catch contribution figures were used in this report rather than estimated catches (see Contribution of Hatchery Fish).

Cost Accounting and Value Estimation

Costs in Table 16 include capital and operation and maintenance costs applicable to the rearing of fall chinook salmon at each study facility. Capital costs for each facility were amortized over a 30-yr period from1940 to 1970 and divided among the species reared at the facilities. Capital costs applied to fall chinook salmon at all study facilities combined were $193,867, $169,616, $193,102, and $186,437 for the 1961-64 broods respectively.

Operation and maintenance costs were divided into two categories at each facility: fish food and drugs, and other operational costs. Operational costs other than food and drugs include costs for labor, personal services, travel, transportation of items, communication services, equipment, supplies and materials, and administration. Total operational and maintenance costs for the 1961-64 broods were $554,171, $489,947, $534,146, and $538,418 respectively.

Estimation of values is described under Value of Hatchery Contribution. Basically, the weights of commercial catches in each fishery were multiplied by the appropriate ex-vessel prices. The numbers of sport caught fish in all fisheries were multiplied by $18.35.

Valuation of the Potential Contributions

The value of the potential contribution to the fisheries of fall chinook salmon from Spring Creek National Fish Hatchery and Big White Salmon Pond were combined (Table 16). This was done because Spring Creek Hatchery personnel operated the Big White Pond, and Spring Creek fall chinook salmon stock was reared in the pond. Thus available Spring Creek operation and maintenance, and capital costs include the Big White facility. Values of Big White contributions were estimated using the ratio:

$$\frac{\text{Spring Creek value}}{\text{Spring Creek releases}} = \frac{\text{Big White value}}{\text{Big White releases}}.$$

For example, the 1961-brood Spring Creek value was $797,300. Releases were 10,925,933 and 3,545,865 1961-brood chinook salmon for Spring Creek and Big White respectively (Worlund et al. 1969). Thus, the Big White Salmon Pond value was estimated at $258,700. Values for the other broods were calculated in the same manner.

TABLE 16.—Values of the potential contributions, costs of rearing, and benefit (B) to cost (C) ratios for fish from each special mark hatchery and all study facilities combined, 1961-64 broods.[1]

Hatchery	Brood	Value ($)	Cost ($)	B/C ratio
Spring Creek[2]	1961	1,056,000	99,900	10.5/1
	1962	373,900	84,800	4.4/1
	1963	1,131,400	99,200	11.4/1
	1964	1,917,300	112,000	17.1/1
Kalama River	1961	481,900	100,700	4.8/1
	1962	199,800	104,700	1.9/1
	1963	582,000	97,600	6.0/1
	1964	392,700	110,700	3.5/1
Elokomin	1961	16,900	53,400	0.3/1
OxBow	1961	93,100	42.100	2.2/1
Grays River	1962	56,100	38,800	1.4/1
Cascade	1962	44,800	57,800	0.8/1
Klickitat	1963	373,200	32,800	11.4/1
Big Creek	1963	141,400	33,700	4.2/1
Bonneville	1964	279,300	81,000	3.4/1
Little White Salmon	1964	108,200	99,400	1.1/1
All study facilities	1961	2,738,800	748,000	3.7/1
	1962	1,306,100	659,600	2.0/1
	1963	5,224,100	727,200	7.2/1
	1964	2,758,000	724,900	3.8/1

[1]Values and costs rounded to the nearest $100.
[2]Includes Big White Salmon Pond values and costs.

Combined Spring Creek and Big White values ranged from $373,900 (1962 brood) to $1,917,300 (1964 brood). The average value was $1,119,600. The costs averaged approximately $100,000 per brood. Benefit to cost ratios ranged from 4.4 to 1 to 17.1 to 1 and averaged 11.2 to 1. The 1961 brood had the largest contribution to the fisheries, yet the 1963 and 1964 broods had higher values. The reason for this is the increase in prices paid for troll caught fish from 1963 to 1969.

Values for the Kalama River hatcheries ranged from $199,800 (1962 brood) to $582,000 (1963 brood). The 1963 brood value was larger than the 1961 brood despite a smaller contribution for the 1963 brood. Again this was due to higher prices paid for troll chinook salmon in the later years of the study and also a larger 1963 than 1961 brood contribution to Washington and Oregon ocean sport fisheries. The average benefit over the four broods was $414,100. The average cost of rearing was $103,400 per brood. Benefit to cost ratios varied from 1.9 to 1 to 6.0 to 1 and averaged 4.0 to 1. The value of Elokomin Hatchery's potential contribution was $16,900 for the 1961 brood and the cost of rearing was $53,400. The benefit to cost ratio was then 0.3 to 1. OxBow's 1961 brood value was $93,100 and costs were $42,100 for a benefit to cost ratio of 2.2 to 1. The ratio was much higher for OxBow because OxBow chinook salmon contributed more heavily to ocean sport fisheries than Elokomin fish.

Contributions of 1962-brood Grays River and Cascade Hatchery fish were valued at $56,100 and

$44,800 respectively. The Grays River value is higher because of a larger contribution to the ocean sport fishery. The costs of rearing were $38,800 at Grays River and $57,800 at Cascade. The benefit to cost ratios were 1.4 to 1 and 0.8 to 1 for Grays River and Cascade respectively.

Klickitat and Big Creek Hatcheries' potential contributions of 1963-brood chinook salmon were valued at $373,200 and $141,400 respectively. The costs of rearing were $32,800 and $33,700 for the two hatcheries respectively. Benefit to cost ratios were 11.4 to 1 for Klickitat Hatchery and 4.2 to 1 for Big Creek Hatchery.

The values of the 1964 brood potential contributions were estimated at $279,300 for Bonneville Hatchery and $108,200 for Little White Salmon National Fish Hatchery. Rearing costs were $81,000 and $99,400 for the respective facilities. The benefit to cost ratios were 3.4 to 1 and 1.1 to 1 for Bonneville and Little White respectively.

Values of potential contributions for all study facilities combined ranged from $1,306,100 for the 1962 brood to $5,224,100 for the 1963 brood and averaged $3,006,800. Costs ranged from $659,600 to $748,000 for the 1962 and 1961 broods respectively. The average rearing costs were $714,900 per brood. Benefit to cost ratios ranged from 2.0 to 1 (1962 brood) to 7.2 to 1 (1963 brood) and averaged 4.2 to 1.

During the later years of the study, fall chinook salmon carcasses from study hatcheries were sold to commercial processors or donated to various institutions and groups. The value of these carcasses was determined from the average price paid by commercial processors. The estimated value was $31,467 for the 1963 brood (Arp et al. see footnote 4) and $42,000 for the 1964 brood (Wahle et al. see footnote 5). Thus the total value of 1963- and 1964-brood study hatchery fall chinook salmon was $5,255,600 and $2,800,000 respectively.

DISCUSSION

Brood Year Comparison

The 1963-brood Columbia River hatchery fall chinook salmon had the best potential contribution and value to the Pacific coast fisheries (Tables 16, 17). The 1963 brood had a potential contribution of 602,900 fish or 10 fall chinook salmon caught for every 1,000 releases and 1.7 fish per pound released. The 1963 brood contribution and catch to release ratios were followed in order by the 1961, 1964, and 1962 broods. The benefit to cost ratios followed a similar pattern, with the best ratio (7.2 to 1) for the 1963 brood followed by the 1964, 1961, and 1962 broods. The 1964 brood had a lower potential contribution than the 1961 brood, but a higher benefit to cost ratio because of higher prices paid for salmon when the 1964 brood was in the fisheries. Also total rearing costs for the 1964 brood were lower than the 1961 brood because fewer fish were raised.

The ocean distribution of the fall chinook salmon for all hatcheries combined was similar for all

TABLE 17.—Potential contributions, numbers of smolts released, pounds of smolts released, contribution in fish caught per 1,000 released, and contribution per pound released for each special mark hatchery and all study facilities combined, 1961-64 broods.

Hatchery	Brood	Contribution (in thousands)	Releases (in thousands)		Contribution	
			Number	Pounds	Per 1,000 released	Per pound released
Spring Creek	1961	107.4	10,925.9	48.0	9.8	2.2
	1962	30.3	8,408.3	48.9	3.6	0.6
	1963	98.8	7,467.6	34.7	13.2	2.8
	1964	165.2	6,554.5	42.4	25.2	3.9
Kalama River	1961	56.8	4,906.8	16.8	11.6	3.4
	1962	22.3	4,599.3	21.0	4.8	1.1
	1963	55.6	4,883.9	26.8	11.4	2.1
	1964	37.7	3,496.6	21.0	10.8	1.8
Elokomin	1961	2.0	1,575.0	8.1	1.3	0.2
OxBow	1961	8.5	4,550.0	21.0	1.9	0.4
Grays River	1962	3.9	1,359.8	9.6	2.9	0.4
Cascade	1962	4.8	4,217.9	21.9	1.1	0.2
Klickitat	1963	42.5	2,888.2	19.5	14.7	2.2
Big Creek	1963	12.9	1,985.8	19.4	6.5	0.7
Bonneville	1964	27.1	9,887.6	62.1	2.7	0.4
Little White Salmon	1964	11.0	8,365.6	47.3	1.3	0.2
All study facilities	1961	361.1	53,653.2	250.9	6.7	1.4
	1962	165.2	52,470.0	278.5	3.1	0.6
	1963	602.2	60,112.1	350.7	10.0	1.7
	1964	304.8	46,778.6	322.2	6.5	0.9

four brood years (Table 18). Washington marine fisheries took the largest catch of Columbia River study hatchery fall chinook salmon followed by British Columbia, Columbia River, and Oregon fisheries. The combined Washington commercial and sport marine catches from the 1961-63 broods were equal to or greater than the British Columbia commercial catch and were between 33 and 39% of the catch of Columbia River study hatchery fall chinook salmon. For the 1964 brood the Washington catch was over 1½ times as large as the British Columbia catch and approached one-half of the total 1964-brood study hatchery fall chinook salmon catch. The British Columbia commercial catch ranged from 27 to 39% of the study hatchery fall chinook salmon catch. The combined Columbia River sport and commercial catch by brood ranged from 20 to 30% of the study hatchery catch. The Oregon ocean portion of the catch ranged from 1 to 9%. The California portion was 1% or less. Less than 0.5% of Columbia River study hatchery fish were taken in the Alaska fisheries, but these fisheries were incompletely sampled.

Kalama River and Spring Creek hatcheries, the only hatcheries with special marks all four brood years, did not follow the combined hatchery pattern. For the Kalama River hatcheries the 1961 brood had the largest contribution and best catch to release ratio, followed in order by the 1963, 1964, and 1962 broods (Table 17). The benefit to cost ratios, however, did not follow this pattern primarily because of higher prices paid for salmon in the later years of the study. The 1963 brood had the best benefit to cost ratio, followed by the 1961, 1964, and 1962 broods respectively (Table 16).

Distribution of the Kalama fish was more northerly than the combined distribution for all study hatcheries (Table 18). About 1% of the Kalama fish were caught in the Alaska fisheries during the years when these fisheries were sampled. The British Columbia portion of the Kalama contribution ranged from 42 to 60%. The Washington marine fisheries took from 23 to 43% of the Kalama fall chinook salmon. When the Washington catch was at its highest (1963 brood), the British Columbia catch was at its lowest. The Columbia River sport and commercial catches of Kalama fish ranged from 11 to 26%. In general, the larger the percentage taken by the British Columbia and Washington fisheries, the smaller the percentage of Kalama fish taken by the Columbia River fisheries. The Oregon ocean fisheries took 1 to 3% of the Kalama chinook salmon and the California fisheries took very few Kalama fish.

The brood year comparison of Spring Creek contribution also differed from the comparison of all hatcheries combined. The 1964 brood showed the best potential contribution followed by the 1961, 1963, and 1962 broods (Table 17). The catch to release and benefit to cost ratios were best for the 1964 brood followed by the 1963, 1961, and 1962 broods (Table 16).

The ocean distribution of the Spring Creek

TABLE 18.—Percentage of catch of Columbia River study hatchery fall chinook salmon taken by each fishery, 1961-64 broods.[1]

		Fishery					
Hatchery	Brood	Alaska	British Columbia	Washington	Oregon	California	Columbia River
Spring Creek	1961	0	23	43	4	1	30
	1962	0	18	41	2	0	39
	1963	0	34	41	3	(2)	21
	1964	0	24	45	7	(2)	23
Kalama River	1961	2	48	23	1	(2)	26
	1962	1	58	24	2	0	15
	1963	2	42	43	3	0	11
	1964	0	60	23	3	1	13
Elokomin	1961	0	21	47	13	3	16
OxBow	1961	0	13	51	15	2	19
Grays River	1962	0	12	74	5	7	2
Cascade	1962	0	43	36	2	1	19
Klickitat	1963	0	39	32	15	4	10
Big Creek	1963	0	16	57	8	1	19
Bonneville	1964	0	29	46	17	4	4
Little White	1964	0	41	47	3	5	4
All study facilities	1961	(2)	33	33	3	(2)	30
	1962	(2)	39	33	1	1	26
	1963	(2)	36	39	5	(2)	20
	1964	(2)	27	44	9	(2)	20

[1]Percentages may not add to 100 due to rounding.
[2]Less than 0.5%.

Hatchery fall chinook salmon was more southerly than those of the Kalama or combined study hatcheries (Table 18). The British Columbia catch ranged from 18 to 34% of the total Spring Creek contribution. The Washington marine fisheries took 41 to 45%. The catch of Spring Creek fish in the Oregon ocean fisheries ranged from 2 to 7%. The maximum California take of these fish was just over 0.5%. The Columbia River catch of Spring Creek fish (21 to 39%) was higher than the percent catch of Kalama or all hatcheries combined. This is to be expected since the Spring Creek chinook salmon are exposed to more river fisheries because of the upriver location of the hatchery.

Hatchery Comparison

A hatchery comparison is made difficult by the great differences in contribution between brood years. Thus these comparisons are not a reflection of the value of any particular hatchery as a fall chinook salmon station nor are they a criticism of rearing techniques at any of the hatcheries. In general, the best catch to release and benefit to cost ratios occurred for the 1963-brood special marked hatchery fish (Tables 16, 17). The poorest ratios generally occurred for the 1962-brood special mark hatchery chinook salmon. This follows the pattern of the common marked fish. The 1964-brood Spring Creek fall chinook salmon had the best catch to release and benefit to cost ratios of 10 special mark hatcheries. The Cascade Hatchery 1962-brood chinook salmon had the poorest catch to release ratio, and the 1961-brood Elokomin Hatchery fish had the poorest benefit to cost ratio.

The general distribution of fall chinook salmon from special mark hatcheries was similar in that a majority of the fall chinook salmon were caught north of the Columbia River mouth in the Washington and British Columbia ocean fisheries (Table 18). However, the percent catch of each hatchery's fish varied greatly within each fishery. The percent catch ranged from 12% (Grays River 1962-brood falls) to 60% (Kalama 1964 brood) in the British Columbia fisheries. Percent catch by Washington ocean fisheries ranged from 23% for 1961- and 1964-brood Kalama River fish to 74% for 1962-brood Grays River chinook salmon. Washington fisheries took the largest portion of the catch for all but Kalama, Cascade, and Klickitat hatcheries. The British Columbia exceeded the Washington catch for these facilities except for the 1963-brood Kalama fish where the Washington catch was slightly higher. As the percentage of the catch taken by the British Columbia fisheries increased, the percentage taken by other fisheries (particularly Washington) naturally decreased. Percent catches in the Oregon fisheries ranged from 1 to 17% for 1961-brood Kalama and 1964-brood Bonneville fish respectively. In the California fisheries, percentages ranged from 0% for Spring Creek and Kalama fish to 7% for Grays River fish. Columbia River catch portions ranged from 2 to 39% for the Grays River and Spring Creek 1962-brood fish respectively.

COLUMBIA RIVER HATCHERY CONTRIBUTION TO PACIFIC COAST FISHERIES

This report covers the contributions of 13 fall chinook salmon study facilities on the Columbia River for brood years 1961 through 1964. These broods were also released from other hatcheries on the Columbia system. From 1962 through 1965, seven nonparticipating facilities released fall chinook salmon during one or more years (Table 19). Experimental releases made from three facilities were not included. A total of 26 million 1961-64-brood fall chinook salmon migrants were released from nonstudy hatcheries. We have assumed nonstudy hatchery releases had the same distribution and contribution as the study facility average. In this way, we have incorporated the catches of nonstudy hatchery fall chinook salmon into those from study hatcheries to estimate the total contribution and value of Columbia River 1961-64-brood hatchery fall chinook salmon. From 1963 through 1969 the estimated total catch in the fisheries sampled of the 1961-64-brood chinook salmon, wild and hatchery, was 9,894,200 (Table 20). Marine sport and commercial catches include three races of chinook salmon, i.e., spring, summer, and fall. Columbia River catches include

TABLE 19.—Releases of 1961- to 1964-brood migrant fall chinook salmon from Columbia River nonstudy hatcheries.

Hatchery	1961 brood	1962 brood	1963 brood	1964 brood
Abernathy	1,077,519	1,806,164	836,375	719,228
Lewis River	477,462	0	275,965	0
Speelyai	456,550	0	0	0
Toutle	992,559	3,075,052	2,580,198	5,730,659
Klaskanine	568,032	137,132	252,216	191,636
Sandy	231,999	144,848	969,154	1,000,418
Eagle Creek	0	2,435,531	1,427,326	1,054,720
Total	3,804,121	7,598,727	6,341,234	8,696,661

TABLE 20.—Percent contribution of Columbia River hatchery fall chinook salmon in the Pacific coast fisheries sampled for marks, 1961-64 broods.

Region	Fishery type	Estimated catch of hatchery fall chinook salmon[1]	Estimated total catch of chinook salmon[2]	Percent hatchery contribution
Marine fisheries:				
Southeastern Alaska	Commercial	2.6	754.3	0.3
British Columbia	Commercial	496.1	4,048.4	12.3
Washington	Sport	276.3	897.4	30.8
	Commercial	286.0	576.5	49.6
Oregon	Sport	24.6	97.6	25.2
	Commercial	43.0	302.6	14.2
California	Sport	0.4	248.1	0.2
	Commercial	5.6	2,171.0	0.3
Freshwater fisheries:				
Columbia River	Sport	0.9	27.4	3.3
	Gillnet	273.6	658.3	41.6
	Indian[3]	58.5	112.6	52.0
Total	All fisheries	1,467.6	9,894.2	14.8

[1]Includes study and nonstudy Columbia River hatcheries which reared 1961- to 1964-brood fall chinook salmon.
[2]Marine catches include all races of chinook salmon; Columbia River catches include only fall chinook salmon.
[3]Setnet and dip net fisheries.

only fall chinook salmon. We estimated 1,467,600 fish or 14.8% were Columbia River hatchery fall chinook salmon. The proportions of fall chinook salmon in each of the fisheries sampled that were of Columbia River hatchery origin are presented in Figure 10. The percentages are averages obtained by summing the 1961-64-brood fall chinook salmon catches from Columbia River hatcheries and dividing by the total 1961-64-brood chinook salmon catches in the Pacific coast fisheries sampled for marks (Table 20).

The importance of Columbia River hatchery fall chinook salmon to the Pacific coast fisheries is readily evident in Figure 10. Columbia River hatchery fall chinook salmon compose nearly one-half of the Washington commercial and nearly one-third of the Washington marine sport chinook salmon catches. The Oregon ocean sport catch of chinook salmon is one-fourth Columbia River hatchery fall chinook salmon. The low sampling percentage (averaging <5%) may be the reason for the apparent lack of hatchery contribution to the Columbia River sport fall chinook salmon fishery.

The contributions to the fisheries from the seven Columbia River nonstudy hatcheries were 24,100, 22,700, 61,800, and 53,500 fall chinook salmon for the 1961-64 broods respectively. Values of the contributions were calculated using the ratio:

$$\frac{\text{Study hatchery value}}{\text{Study hatchery contribution}} = \frac{\text{Nonstudy hatchery value}}{\text{Nonstudy hatchery contribution}}.$$

The values calculated for the nonstudy hatchery chinook salmon were $182,900, $179,100, $538,700, and $484,600 for the four broods respectively. The total values for all 1961-64-brood Columbia River hatcheries by brood were $2,921,700, $1,485,200, $5,794,300, and $3,284,600 respectively.

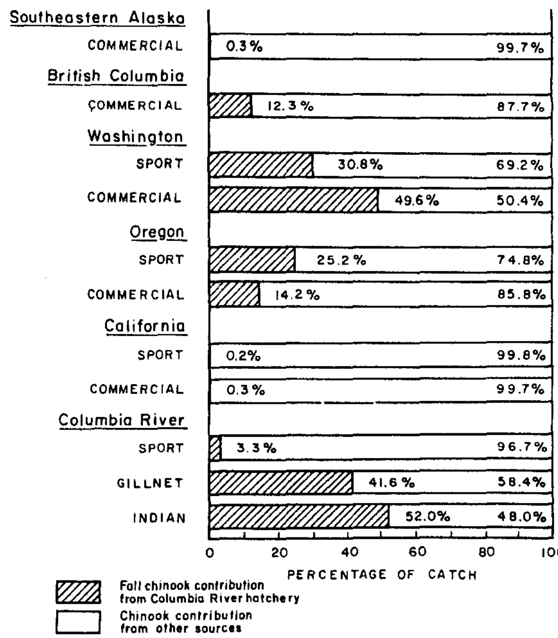

FIGURE 10.—Percentage contribution of 1961- to 1964-brood Columbia River hatchery fall chinook salmon to the total chinook salmon catch in each Pacific coast fishery, 1963-69. Marine fisheries include all races of chinook salmon; Columbia River fisheries include only fall chinook salmon.

SUMMARY

In 1962 a marking experiment was initiated to determine the bioeconomic contribution of Columbia River hatchery fall chinook salmon. From

1962 through 1965, 30.9 million 1961-64-brood fall chinook salmon were marked at 12 Columbia River hatcheries and one rearing pond. Four brood years were marked to examine the differences between broods. A mark common to all 13 facilities was used for each brood. Common marks were applied to 21.3 million fish. To examine the differences between hatcheries, four hatcheries were assigned special marks for each brood. Two hatcheries, Kalama River (in this study Kalama Falls and Lower Kalama Hatcheries were treated as one facility) and Spring Creek, had special marks for all four brood years. Special marks were applied to 9.6 million fish.

Sampling for these marked chinook salmon took place from 1963 through 1969. Major marine sport and commercial fisheries from southeastern Alaska to central California and Columbia River fisheries were sampled for marks, and scale samples were taken for age determination. Mark sampling ranged from 14 to 28% of the catch, and age sampling ranged from 1 to 4% by year. During the 7 yr of sampling, 3.3 million chinook salmon were sampled for marks and 208,000 were sampled for age.

Returns to the 13 study facilities, adjacent streams, and nonstudy hatcheries rearing fall chinook salmon were sampled for marked 1961-64-brood fish. Hatchery returns of these broods numbered 155,800 fish, of which 8,500 were marked. The stream sampling was conducted from 1964 through 1966 with 62,400 chinook salmon examined and 1,600 marked fish found.

Hatchery contribution estimation is dependent on the validity of six assumptions. Where practical, these assumptions were tested with additional studies and data collections. Assumption 1 (that the marks were permanent) was tested by holding marked fish in saltwater ponds for periodic examination. Some regeneration did occur but, since double and triple marks were applied, the marked fish remained identifiable throughout their life. Assumption 2 (that fish detected and reported with the kinds of marks applied at the hatcheries are hatchery fish) was tested by examining hatchery fingerlings and 1965-brood chinook salmon catches for study marks. Over 30 million hatchery fingerlings were examined, and only 201 missing ventral and 156 missing adipose fins (none together) were found. The attempt to keep 1965-brood chinook salmon from being marked with study marks was unsuccessful. However, ocean and Columbia River catches of study marks were adjusted for those marks that appeared to have a natural origin. Assumption 3 (fish were correctly aged from scales) was examined by having six scale readers from State, Provincial, and Federal agencies read 400 scales from fish of known age. The readers correctly aged 83% of the scales. Hatchery returns showed survival adjustments had to be made for assumption 4 (equality of survival and maturity schedules for marked and unmarked fish). Assumption 5 (the equality of ocean distribution and catch vulnerability of marked and unmarked fish) is supported by ocean tagging studies showing similar distributions for marked and unmarked hatchery fish. A 10-part sampler was used to select fish for marking thus insuring the validity of assumption 6 (the marking of equal proportions of each hatchery's production).

Estimated catches of special marked fish from the 10 special mark facilities ranged from 191 (Cascade, 1962 brood) to 4,406 (Spring Creek, 1964 brood). During the 7 yr of sampling, 65,620 common marked fish were estimated to have been caught: 22,237, 1961 brood; 7,886, 1962 brood; 22,183, 1963 brood; and 13,314, 1964 brood.

Columbia River hatchery fish were captured in marine fisheries from Alaska to California. Marine catches were primarily in British Columbia and Washington fisheries. Fall chinook salmon from the Kalama River hatcheries had a more northerly distribution than those from other special mark hatcheries. Kalama fish had the highest percentage catches of any special marked hatchery chinook salmon in Alaska and British Columbia fisheries. The average common marked fish catch distributions in percent of the total chinook salmon catch for the 1961-64 broods combined were: 0.2, Alaska commercial fisheries; 33.7, British Columbia commercial fisheries; 38.1, Washington marine fisheries; 4.6, Oregon ocean fisheries; 0.4, California ocean fisheries; and 23.1, Columbia River fisheries.

The potential contribution of Spring Creek 1961-64-brood fall chinook salmon ranged from 30,300 (1962 brood) to 165,200 (1964 brood) with an average of 100,500 fish per brood. The average catch to release ratio was 12 fish per 1,000 fish released from Spring Creek. The Kalama hatcheries potential contribution ranged from 22,300 (1962 brood) to 56,800 (1961 brood) and averaged 43,100 fish per brood. The average catch to release ratio for the two Kalama facilities was 9.6 fish for each 1,000 released. Potential contributions at the eight other special mark hatcheries (OxBow, Elokomin, Grays River, Cascade, Klickitat, Big Creek, Bonneville, and Little White Salmon) ranged from 2,000 fish (Elokomin, 1961 brood) to 42,500 (Klickitat, 1963 brood). The range of catch per 1,000 fish released was from 1.1 (Cascade, 1962 brood) to 14.7 (Klickitat, 1963 brood). The potential contribution for all study facilities combined ranged from 165,200 (1962 brood) to 602,200 (1963 brood). The average contribution was 358,500 fall chinook salmon per brood. The average catch per 1,000 smolts released was 6.7 fish.

Catch to escapement ratios ranged from 2.4 to 1 (Big Creek, 1963 brood) to 43.0 to 1 (Grays River, 1962 brood). Total survivals ranged from 0.1% (Elokomin, 1961 brood; Cascade, 1962 brood; Little White Salmon, 1964 brood) to 2.6% (Spring Creek, 1964 brood). Spring Creek Hatchery's average catch to escapement ratio was 9.3 to 1 and the average survival was 1.3%. The average catch to escapement and survival values for the Kalama River hatcheries were 12.0 to 1 and 1.0%. For all facilities and the four broods combined, the average survival was 0.7% and the average catch to escapement was 8.6 to 1.

Spring Creek Hatchery and Big White Pond values were combined because Spring Creek personnel operated the Big White facility making costs inseparable. The average cost of rearing each brood at the two facilities was approximately $100,000. The average value of the potential contribution was $1,119,600. The average benefit to cost ratio was 11.2 to 1. The average cost of rearing the 1961-64 broods of chinook salmon at the two Kalama hatcheries was $103,400. The average benefit from their production was $414,100, yielding a benefit to cost ratio of 4.0 to 1. For the other eight special mark hatcheries, costs ranged from $32,800 (Klickitat, 1963 brood) to $99,400 (Little White, 1964 brood), benefits from $16,900 (Elokomin, 1961 brood) to $373,200 (Klickitat, 1963 brood), and benefit to cost ratios from 0.3 to 1 (Elokomin, 1961 brood) to 11.4 to 1 (Klickitat, 1963 brood). The average cost of rearing the four broods, all study facilities combined, was $714,900. The average benefit was $3,006,800, for an average benefit to cost ratio of 4.2 to 1.

Fall chinook salmon releases from seven nonstudy Columbia River hatcheries totaled 26 million fish for the 1961-64 broods. If we assume these fish had a catch distribution and contribution like the 13 study facilities, then the estimated total catch of fall chinook salmon from all Columbia River hatcheries is 1,467,600 fish. The 1961- to 1964-brood fall chinook salmon caught in marine fisheries sampled from Alaska to California and Columbia River fisheries was 14.8% of the total chinook salmon catch. The portions of the total chinook salmon catch by region originating from fall chinook salmon raised at Columbia River hatcheries were: Alaska, 0.3%; British Columbia, 12.3%; Washington, 38.2%; Oregon, 16.9%; California, 0.2%; and Columbia River, 41.7%.

The 1961-64-brood Columbia River hatchery (study and nonstudy) contributions were valued at $2,921,700, $1,485,200, $5,794,300, and $3,284,600 by brood respectively.

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