CONTRIBUTION OF COLUMBIA RIVER HATCHERIES TO HARVEST OF FALL CHINOOK SALMON (*Oncorhynchus tshawytscha*)

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ABSTRACT

A marking experiment was designed in which fall chinook salmon (*Oncorhynchus tshawytscha*) from 12 Columbia River hatcheries were marked in 4 consecutive years to estimate their contribution to the sport and commercial fisheries. The study was planned and is being executed by scientists of the Fisheries Research Board of Canada, Bureau of Commercial Fisheries, and fishery agencies of the States of Washington, Oregon, California, and Alaska.

Sampling for marked fish is being conducted in most ocean fisheries for chinook salmon from Monterey, Calif., to southeast Alaska, as well as on the Columbia River. The 1963–66 returns from the first year's release (1961 brood) of 5.4 million marked fish make it possible to obtain a preliminary estimate of the contribution of the total hatchery releases as represented by this marked group.

The estimated catch of 1961-brood fish that originated from the hatcheries under study was 287,326, or about 10 percent of the total catch of chinook salmon of that brood in the fisheries sampled. The estimated net value of this catch (to the fisherman) was about $1,900,000, whereas the cost to produce them was $831,000. The benefit to cost ratio was 2.3:1.

The net value of the catch of fall chinook salmon of the 1961 brood that originated from all Columbia River hatcheries (including those not participating in the marking experiments) was estimated at $2,055,000.

The U.S. Fish and Wildlife Service has financed the Columbia River Fishery Development Program, a cooperative effort of the States of Oregon, Washington, and Idaho, since its inception in 1949. The Bureau of Commercial Fisheries Columbia Fisheries Program Office, Portland, Oreg., administers this project, which is designed to increase production of salmon (*Oncorhynchus* spp.) and steelhead trout (*Salmo gairdneri*) in the Columbia River.

A major accomplishment of the program has been the construction and modernization of 19 salmon producing hatcheries on the lower 290 km. (180 miles) of the river. These hatcheries, managed by the Bureau of Sport Fisheries and Wildlife and the States of Washington and Oregon, were built primarily to offset the loss of natural spawning and rearing areas for salmon and steelhead trout caused by water development projects.

Releases of fall chinook salmon have varied from less than 10 million fish from 6 hatcheries in 1949 to about 56 million from 14 hatcheries in 1966. The contribution of these large releases to the commercial and sport fisheries, however, is unknown. Past marking experiments have demonstrated that hatchery releases contribute to the fisheries, but because such experiments were limited and designed for other purposes, the contribution has not been estimated.

A marking experiment was undertaken in 1962 by the Columbia Fisheries Program Office to estimate the contribution of hatchery-reared fall chinook salmon to the fisheries. The experiment was confined to 12 hatcheries that have propagated about 90 percent of all fall chinook salmon artificially reared in the Columbia River. Data collection will be completed by the end of 1969; however, sufficient information is presently available for preliminary estimates of the contribution to the fisheries by one group (1961 brood) of hatchery-reared fall chinook salmon.

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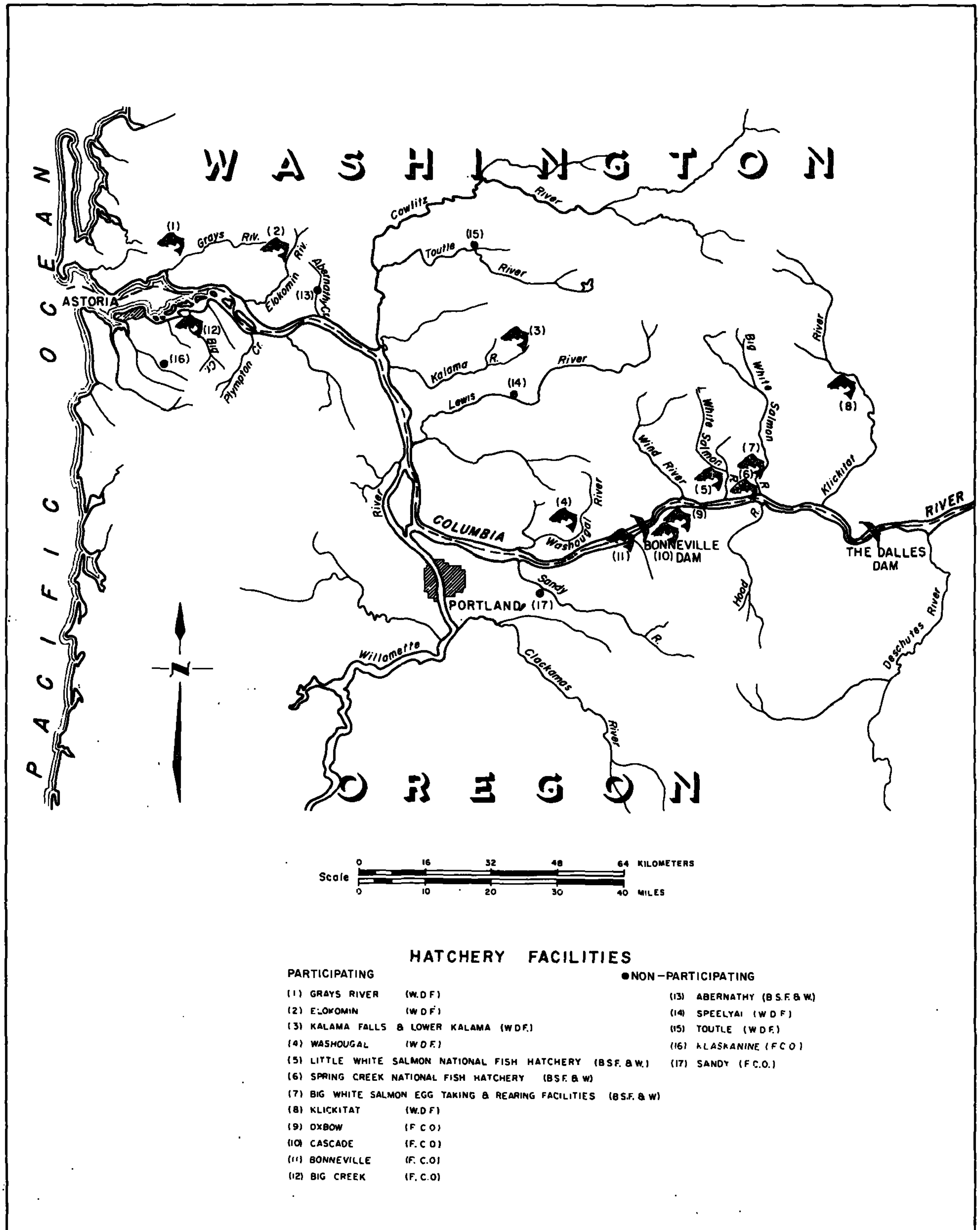

FIGURE 1.—Locations of fall chinook salmon hatcheries on lower Columbia River.

The 12 hatcheries are distributed over about 250 km. (155 miles) of the Columbia River (fig. 1). Big Creek Hatchery, the lowermost station, and Klickitat Hatchery, the uppermost, are on tributaries about 40 and 290 km. (25 and 180 miles), respectively, above the river mouth. Some hatcheries (Bonneville, Cascade, Oxbow, Little White Salmon, and Spring Creek) are adjacent to the Columbia River and release their fish directly into the river. In contrast, fish released at Klickitat Hatchery must travel about 40 km. (25 miles) to reach the main stem of the Columbia.

Artificial propagation procedures are similar at all hatcheries raising fall chinook salmon. Adults normally return to these hatcheries and are spawned during September and October. Depending upon water temperatures, fry typically reach the free swimming stage in February or March and are then placed in ponds. The young fish are released from the hatchery 90 to 120 days later at an average length of 6 to 8 cm. (2–3 inches). During the following 5 years, they are available to commercial and sport fisheries from southeast Alaska to central California. Some fish mature and return to the Columbia River during their second, third, fourth, and fifth years; however, most are in their third (age 3) and fourth years.

This report (1) describes the design of the marking experiment and (2) presents an estimate of the contribution (catch) to the fisheries by the 1961-brood hatchery releases and an estimate of the benefit-cost ratio. This is the first basic analysis of data collected under the hatchery evaluation study directed by Paul D. Zimmer of the Columbia River Fishery Development Program. Several research laboratories and individuals are analyzing data from this study and will develop much additional information.

DESIGN OF EXPERIMENT TO ESTIMATE HATCHERY CONTRIBUTION TO FISHERIES

The general approach for estimating the hatchery contribution of fall chinook salmon was to identically mark the same fraction (about 10 percent) of each hatchery's production and then sample for this mark in the commercial and sport fisheries. From the number of marked fish recovered and the sampling ratio, together with the fraction originally marked (or expected marked to unmarked ratio), we can estimate the number of hatchery-reared fall chinook salmon in the catch. In addition to the "common mark" (i.e., mark applied to portion of fish at all hatcheries under study), "special marks" were used at selected hatcheries each year to examine the variations in contribution among hatcheries. Supplemental data were also collected in an attempt to explain the expected variations among hatcheries and to test some of the assumptions underlying the experimental techniques and estimating procedures.

The success of the marking experiment required the efforts of many people and the cooperation of fishery agencies on the Pacific Coast (table 1). All marking and mark recovery activities were under the direct supervision of experienced biologists.

MARKING

The marking phase of the study began in June 1962 and was completed in June 1965. The 1961–64 broods (progeny of adults that spawned in 1961, 1962, 1963, and 1964) were marked. The "common mark" consisted of removing the adipose fin and a portion of the right or left maxillary bone. The clipped right maxillary was used to identify the 1961 and 1963 broods and the clipped left maxillary the 1962 and 1964 broods (table 2).

TABLE 1.—*Responsibilities of agencies participating in the marking and mark recovery phases of the Columbia River fall chinook hatchery contribution study, 1962–68*

Function	Execution	Supervision	Agency [1]
Coordinating and supervising	Biologist	Biologist	BCF
Obtaining fish for marking	Hatchery personnel	Biologist and hatchery manager	WDF, FCO, BSFW
Marking	Fish markers	Biologist	WDF, FCO, BSFW
Sampling hatchery releases	Hatchery personnel	Biologist and hatchery manager	WDF, FCO, BSFW
Sampling catch for marked fish	Mark samplers	Biologist	ADFG, FRBC, WDF, FCO OGC, CFG, BCF
Sampling hatchery returns and natural spawning populations for marked fish.	do	do	WDF, FCO, BSFW

[1] ADFG—Alaska Dept. of Fish and Game; FRBC—Fisheries Research Board of Canada; WDF—Washington Dept. of Fisheries; FCO—Fish Commission of Oregon; OGC—Oregon Game Commission; CDFG—California Dept. of Fish and Game; BCF—Bureau of Commercial Fisheries; BSFW—Bureau of Sport Fisheries and Wildlife.

TABLE 2.—*Ages of marked Columbia River fall chinook salmon in catches and escapements by brood (1961–64) and sampling years (1963–69)*

Brood	Mark[1]	Release site	Year of sampling						
			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	Ox Bow	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 hatcheries			2	3	4	5	
	Ad-LV-RM	Spring Creek			2	3	4	5	
	Ad-RV-RM	Kalama			2	3	4	5	
	RV-RM	Klickitat			2	3	4	5	
	LV-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
Number 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; RM: Right maxillary.

To obtain the fish for marking, a sampling tool (Hewitt and Burrows, 1948) was modified to remove a random "10 percent" sample. This device is a circular net consisting of 10 equal pie-shaped sections that fits into a cylindrical liner such that all fish contained in the cylinder must pass through one of the sections (fig. 2). The sample for marking was obtained by closing one of the sections. In practice, the sampling device was placed in a tub partially filled with water. Fish were removed from a pond in groups weighing about 18 kg. (40 pounds) each and placed in the sampler, and the device was then raised; the closed section retained the sample for marking. The fish that passed through the open sections remained in the tub and were placed in another pond. This procedure was followed until all fish in each pond were processed.

At each hatchery, fish selected for marking were first anaesthetized with MS–222 [3] (tricaine methanesulfonate), then the markers used bent-nosed dissecting scissors to remove certain fins and maxillaries. Marked fish were held in hatchery troughs for recovery from the anaesthetic and returned to the group of unmarked fish from which they were removed. To ensure proper control of quality, 25 marked fish from each marker were examined daily. In addition, fish that died shortly after marking were carefully examined in an effort to detect improper handling.

The entire production of each hatchery was sampled at time of release (3–8 weeks after marking) to estimate the proportion and numbers of marked fish released. The procedure for obtaining this sample was the same as for selecting fish for marking, except that fish initially removed by the closed section of the sampler were pooled and sampled again. The resultant sample (about 1 percent of the total production) was sorted into marked and unmarked groups and counted and weighed. These counts, together with an estimate of the proportion removed by the particular sampler, were used to estimate the proportions and numbers of marked fish in the release.

RECOVERY OF MARKS

The recovery phase of the investigation began in 1963 and will end in 1969 (table 2).

Sampling for marked fish was designed to cover four areas: major ocean fisheries from southeast Alaska to central California, Columbia River fisheries, parent hatcheries, and certain natural spawning grounds.

Sampling for marks in each area consists of recording numbers of fish examined for marks and the numbers recovered with each type of mark. In addition, all marked fish and a sample of unmarked fish are examined for age, length, and weight. It was recognized that occurrence of marks and compositions of age and size would change with time; thus, the sampling season was stratified into small units (usually biweekly for the ocean and weekly for the Columbia River fisheries).

The general fisheries being sampled are ocean commercial and sport; Columbia River commercial and sport; and Puget Sound sport. For purposes of sampling, most fisheries were further stratified by port of landing. Exceptions are the Alaska and British Columbia troll, purse seine, and gill net fisheries; Columbia River commercial and sport fisheries; and Puget Sound sport fishery, in which the stratification is by area of catch. The specific fisheries being sampled are listed in table

[3] Trade names referred to in this publication do not imply endorsement of commercial products by the Bureau of Commercial Fisheries.

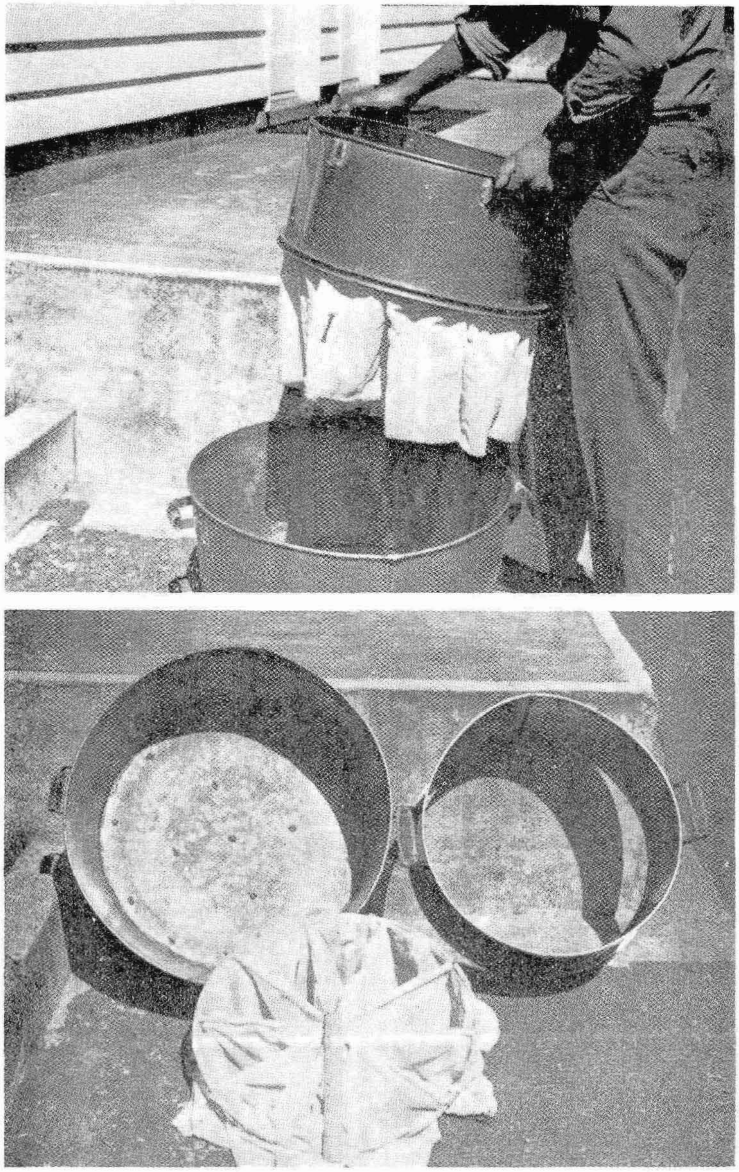

FIGURE 2.—Ten-part sampling net used to obtain fish for marking and to estimate the numbers of marked and unmarked fish released.

3 and shown in figure 3. General sampling levels for each time-location stratum were predetermined; typically, about 20 percent of the catch is sampled for marks, and from 50 to 100 unmarked fish are sampled to obtain age, length, and weight.

Catch data for each time-location stratum are provided by the management agencies. For most fisheries, the catch of chinook salmon in numbers of fish is an estimate. Commercial catches are estimated either from the total weight of landings and an estimate of average fish size or from total salmon landings (numbers) and an estimate of species composition. Estimates of sport catches are from measures of total effort and catch per-unit-effort or from salmon punch cards (filled out by anglers) together with independent sampling by the management agency.

Because the catch of hatchery-reared fish depends on length and timing of the fishing seasons as well as on the numbers of fish available, an estimate of the numbers of hatchery fish which escape the fishery is required to measure the

TABLE 3.—*Areas where catches were examined for marked fall chinook salmon of Columbia River origin by port or zone of landing and type of fishery*

Area sampled	Type of fishery				
	Sport	Commercial			
	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.			
	Depoe Bay	Tillamook.			
	Newport	Nestucca.			
	Florence	Depoe Bay.			
	Reedsport	Newport.			
	Coos Bay	Florence.			
	Gold Beach	Reedsport.			
	Brookings	Coos Bay.			
		Port Orford.			
		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.	

hatchery output. For this reason, plans for mark sampling also included examining the fish returning to the hatcheries and searching for marked fish on certain natural spawning grounds.

Fish returning to the hatcheries are counted and examined for marks. At each hatchery an effort is made to obtain data on age, length, and sex for 25 to 50 unmarked fish per week. In addition to searching for marks at the 12 participating hatcheries, returns to 5 other hatcheries (Abernathy, Speelyai, Toutle, Klaskanine, and Sandy; fig. 1) are also examined for marks.

To estimate natural spawning of hatchery-reared fish, surveys were conducted on hatchery streams as well as those adjacent to or near the hatcheries under study. These streams are Klickitat, Big White Salmon, Little White Salmon, Wind, Washougal, Kalama, Lewis, Elokomin, and Grays Rivers and Plympton and Big Creeks. These surveys were designed to estimate size of the total spawning population, as well as to sample for marks, age, and length.

All data collected during the recovery phase of the study are recorded on a standard form (fig. 4). Data on a group of fish examined for marks are recorded according to the format along the upper part of the form; data for individual marked recoveries are recorded on the same form according to the format along the lower part. A scale sample from each marked fish is sent along with the form to the Fish Commission of Oregon's mark processing center, where the age is determined and entered on the form. [4] Samples of individual unmarked fish are recorded and processed in the same way as the marked fish.

After appropriate coding (e.g., type of mark, fishery and gear, and port of landing) the data are transferred to data processing cards from which tabulations are made. The tabulations are then forwarded to the Biometrics Unit at the Bureau of Commercial Fisheries Biological Laboratory, Seattle, Wash., where they are collated with catch information, and a summary report of each year's sampling effort is assembled.

SOURCES OF VARIATION

Two major sources of variation in the contribution of hatcheries are being considered. The first is the variation from year to year, which is the reason for extending the marking experiment over four brood years. The second source of variation is among hatcheries. To examine this, a group of fish at each of the four hatcheries was marked with a unique fin clip each year. Spring Creek and Kalama Hatcheries were allotted a special mark each year, and two additional special marks were rotated among eight of the remaining hatcheries so all hatcheries, except two, received special

[4] In some instances (British Columbia and Washington fisheries), ages are determined by the agency that collects the data.

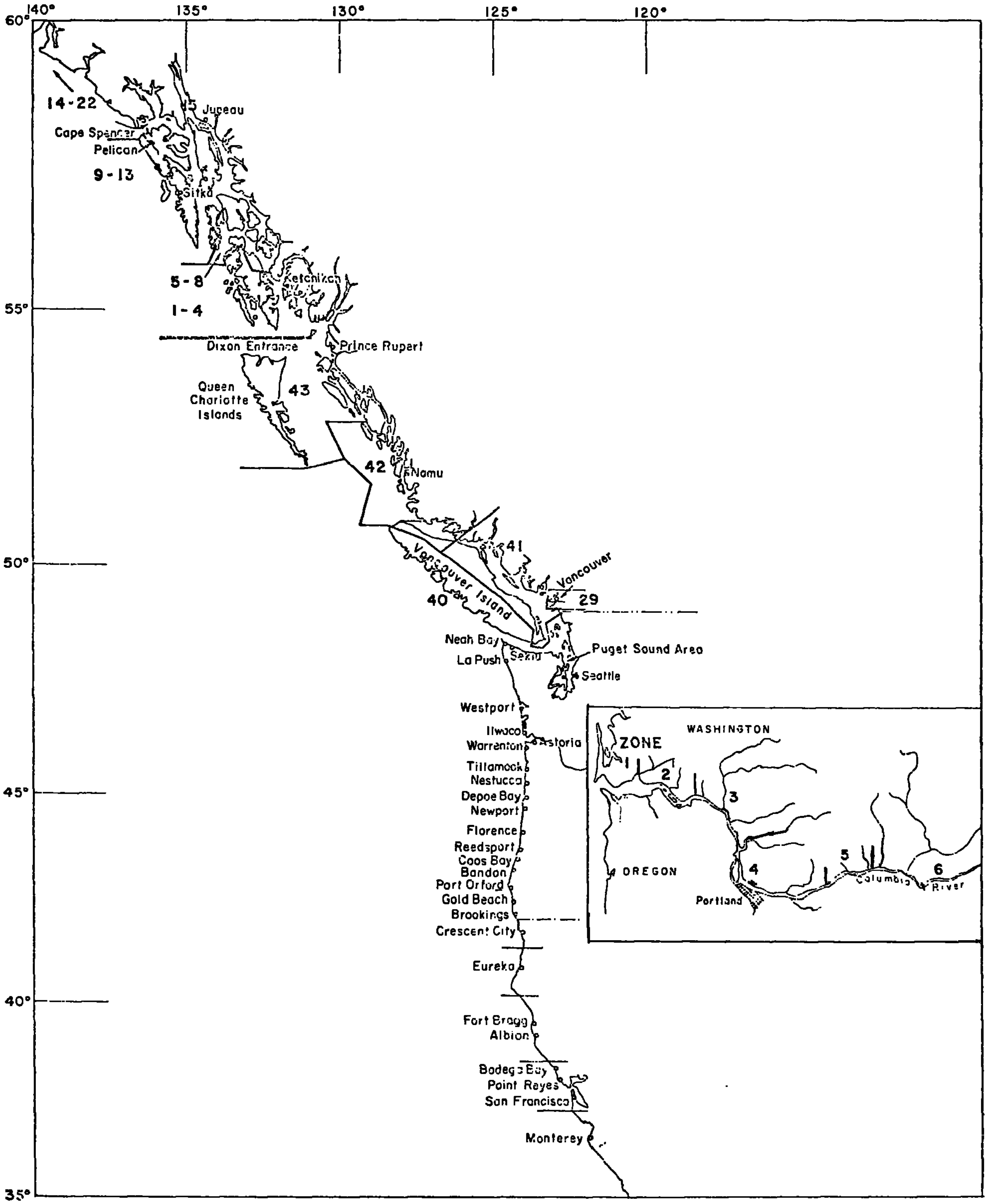

FIGURE 3.—Ports and zones sampled for marked fall chinook salmon of Columbia River origin.

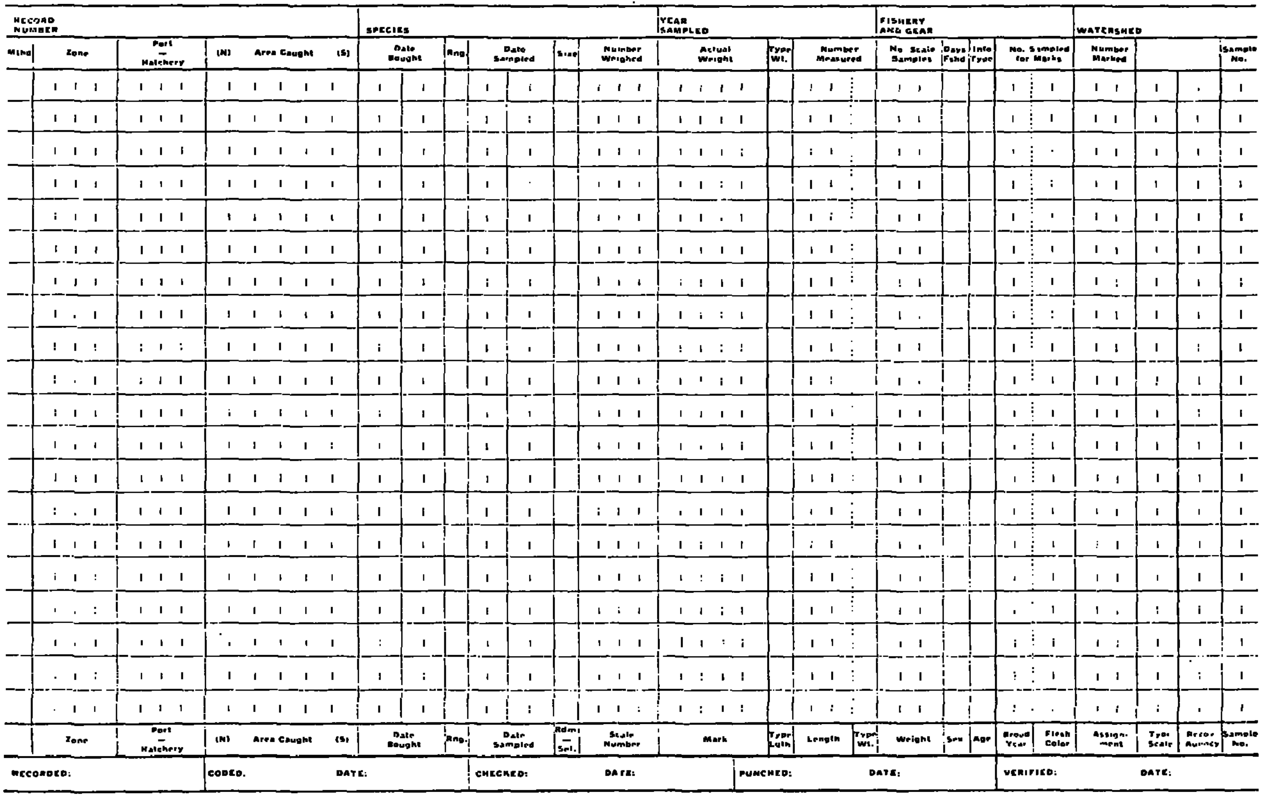

FIGURE 4.—Form for recording mark recoveries and biological data.

marks. Marks selected were the excised right or left ventral fin, with and without the adipose fin. In addition, part of the left maxillary bone was removed in the even numbered brood years and part of the right maxillary in odd numbered brood years. These marks, together with the hatcheries involved and expected age of appearance in the sampling area, are shown in table 2.

Procedures for selecting fish, marking them, and sampling them at release to estimate mark ratios were the same as described earlier for the common (adipose-maxillary) mark.

Certain items of information concerning the rearing history were collected at each hatchery to explain some of the expected variations in contribution between hatcheries and between years. This information included numbers of adults spawned, incidence of disease in adults,, mortalities during incubation of eggs and rearing of young, incidence and treatment of disease in progeny, diet, fish size at release, and water temperatures during incubation, rearing, and at the release site.

For the same purpose, groups of marked and unmarked fish obtained at time of release from each hatchery underwent numerous tests at Abernathy Salmon Cultural Laboratory. Variables of interest included physical capabilities, body composition, hematology, and pathology. Physical capability of each group of fish was indexed by use of a stamina tunnel; body composition of protein, lipid, ash, water and glycogen was determined by proximate analyses; hematology consisted of hematocrit determinations and chemical measurements of blood plasma to determine levels of calcium, phosphorus, chloride, glucose, protein, albumin, cholesterol, icteric index, creatinine, uric acid, ammonia, and urea; and pathology included examinations for disease organisms from which a "disease index" was determined.

ESTIMATING PROCEDURES

The contribution (catch) of hatchery-reared fish will be estimated, as noted earlier, from data on the proportion of hatchery fish that were marked (or expected marked to unmarked ratio), the chinook salmon catch by time period within a season for a particular fishery, the number of fish examined for marks, and the number of marked fish recovered. In addition to obtaining an estimate of the catch of a given age group of hatchery fish, we are estimating the percentage contribution of hatchery fish to the total catch of that age group. This makes it necessary to subdivide the catch by age group on the basis of an estimated age composition.

For a particular fishery (e.g., Washington ocean sport fishery at Westport) let:

c_i = catch during i^{th} period

n_i = number of fish examined for marks during i^{th} period

n_{ijk} = number of marked fish with the k^{th} kind of mark and of the j^{th} age group recovered during the i^{th} period

p_{ijk} = proportion of n_i having k^{th} kind of mark and of the j^{th} age group $= n_{ijk}/n_i$

Then an estimate of the catch of fish with the k^{th} kind of mark and of the j^{th} age group for the i^{th} period is:

$$m_{ijk} = p_{ijk} c_i \qquad (1)$$

An estimate of the catch of all marked fish of the j^{th} age group for the i^{th} period is:

$$m_{ij.} = c_i \sum_k p_{ijk} = \sum_k m_{ijk}$$

and an estimate of the catch of all marked fish of all age groups for the i^{th} period is:

$$m_{i..} = \sum_j m_{ij.}$$

The estimated catch of unmarked fish during the i^{th} period is then:

$$u_i = c_i - m_{i..}$$

If g_{ij} is the proportion of the sample of unmarked fish belonging to the j^{th} age group for the i^{th} period, then an estimate of the catch of unmarked fish of the j^{th} age group for the i^{th} period is:

$$u_{ij} = g_{ij} u_i$$

Hence, the estimate of the total catch (marked and unmarked) of the j^{th} age group for the i^{th} period is:

$$c_{ij} = u_{ij} + m_{ij.}$$

and the estimated seasonal catch of marked and unmarked fish of the j^{th} age group is:

$$c_{.j} = \sum_i c_{ij} \qquad (2)$$

Now, if we designate a particular hatchery evaluation mark (e.g., adipose-right maxillary) by setting $k=1$ in equation (1), then an estimate of the seasonal catch of Columbia River hatchery fish of the j^{th} age group having that mark is:

$$m_{.j1} = \sum_i p_{ij1} c_i \qquad (3)$$

If, for example, we are interested in marked hatchery fish (adipose-right maxillary mark) of the 1961 brood, then their estimated catch in 1963 as 2-year-old fish is:

$${}_3m_{.21} = \sum_i ({}_3p_{i21}) ({}_3c_i)$$

where the presubscript denotes the last digit of the sampling year. Similarly, the estimated catch in 1964 as 3-year-old fish is:

$${}_4m_{.31} = \sum_i ({}_4p_{i31}) ({}_4c_i)$$

and the estimated catch in 1965 as 4-year-old fish is:

$${}_5m_{.41} = \sum_i ({}_5p_{i41}) ({}_5c_i)$$

and similarly for still later years of capture.

An approximate variance estimate for $m_{.j1}$ is:

$$V(m_{.j1}) = C^2 \sum_i (w^2_i p_{ij1}/n_i) + V(C)\left[\left(\sum_i w_i p_{ij1}\right)^2 - \sum_i w^2_i p_{ij1}/n_i\right] \qquad (4)$$

where $C = \sum_i c_i$, $w_i = c_i/C$ and $V(C)$ is the variance of the estimated seasonal catch. If the catch, C, is known, then only the first item in (4) contributes to the variance estimate.

Now if ${}_ar_{j1}$ is the expected proportion of Columbia River hatchery fish of the j^{th} age group in sampling year "a," which is marked with a particular mark (e.g., let $k=1$ for adipose–right maxillary), then an estimate of the seasonal catch of hatchery fish (marked and unmarked) of the j^{th} age group in sampling year "a" is (from equation 3):

$${}_aH_j = {}_am_{.j1}/{}_ar_{j1} \qquad (5)$$

Hence, if, as in the example above, we are interested in the contribution of the 1961–brood hatchery fish, then an estimate of their catch (marked and unmarked) in 1963 as 2-year-old fish is:

$${}_3H_2 = {}_3m_{.21}/{}_3r_{21}$$

Likewise then, the estimated catch in 1964 as 3-year-old fish is:

$${}_4H_3 = {}_4m_{.31}/{}_4r_{31}$$

and similarly for the 1965 and 1966 sampling years.

An alternative procedure for estimating the seasonal catch of hatchery fish of the j^{th} age group in sampling year "a" is:

$$_aH_j = (_aM_{.j1}/_aq_{j1}) + \sum_{k=1}^{5} {_aM_{.jk}} \qquad (6)$$

where $_aq_{j1}$ is the expected marked (adipose–right maxillary) to unmarked ratio. The first term in this equation is an estimate of the catch of unmarked hatchery fish, and the second term is the estimated total catch of marked hatchery fish (summed over the five marks identifying hatchery fish).

The percent contribution of hatchery fish to the catch of the j^{th} age group in year "a" is then (from equation 2): $_aP_j = 100(_aH_j/_ac_{.j})$.

Equations (5) and (6) are the basic equations for estimating the catch of Columbia River hatchery-reared fall chinook salmon of a given age in a given year. The numerator, $_aM_{.j1}$, in equation (5) is the estimated number of marked fish (adipose–right maxillary) in the catch at a particular fishery-port combination. As stated before, the denominator, $_ar_{j1}$, is the expected proportion that $_aM_{.j1}$ is of the total catch of hatchery fish of the same age group. Granting certain assumptions (set forth in the following section), the proportion of adipose-right maxillary marked fish in the hatchery releases is an estimate of $_ar_{j1}$. Hence, if r is the proportion of marked fish in the 1961 brood hatchery releases, we set

$$_3r_{21} = {_4r_{31}} = {_5r_{41}} = {_6r_{51}} = r$$

So, we assume that the expected proportions of marked age 2 hatchery fish in 1963, age 3 fish in 1964, etc. are identical and equal to the proportion of marked fish in the releases of the 1961 brood hatchery fish.

The estimated proportion of marked fish in the total release of each brood year from the 12 hatcheries is based on estimates of the proportion of marked fish in the release and the size of release at each of the hatcheries. These latter estimates were obtained from a sampling procedure at the time of release at each of the hatcheries. If N_0 is the total number of fish released from a hatchery, then the number of fish removed by the sampling device at the first stage of sampling is:

$$N_1 = s_1N_0$$

where s_1 is the actual proportion of the total number of fish removed by the sampling device. These fish, N_1, were then sampled again. If s_2 is the actual proportion of the total number of fish, N_1, removed by the sampling device during the second stage of sampling, then the number of fish which comprise the final sample is:

$$N_2 = s_2N_1 = s_2s_1N_0$$

Hence, if s is an estimate of the proportion of fish removed by the sampler during a single stage (i.e., s is an estimate of both s_1 and s_2), then an estimate of the numbers of fish released, N_0, is:

$$N = N_2/s^2$$

The estimated proportion of fish removed by the sampling device was obtained from a number of trials using known numbers of fish, and the number of fish removed by the sampling device, N_2, was counted and sorted into the marked and unmarked groups. Thus, if M is the count of marked fish, then the estimated proportion of marked fish in the release is simply:

$$r = M/N_2$$

If N_i and r_i are the above estimated quantities for the i^{th} hatchery, then the estimated proportion, r, of marked fish in the total release from all hatcheries is:

$$r = \sum_i w_ir_i$$

where $w_i = N_i/\Sigma N_i$

An estimate of the marked to unmarked ratio for the hatchery releases is similarly obtained.

ASSUMPTIONS

Several assumptions are inherent in the foregoing method of estimating the contribution of hatchery-reared fall chinook salmon to the fisheries. Three basic assumptions are:

1. A marked fish is identifiable as a marked fish throughout its life.
2. All observed chinook salmon having the kind of mark used on the hatchery-reared fish are indeed hatchery fish.
3. Chinook salmon are correctly aged from scale examinations and information on size of fish and date of capture.

In addition, we assume that marked fish behave like the unmarked hatchery fish. In particular we must assume:

4. Marked and unmarked hatchery fish have the same survival rates and maturity schedules.
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 that:

6. Either the ocean distribution and timing of migration of fish from each of the hatcheries are the same or the same proportion of each hatchery's production is marked.

The appropriateness of the estimating procedures described above is obviously dependent upon the validity of these assumptions. For this reason, the results must be considered as preliminary until sufficient data are collected to judge their validity. For example, if marked and unmarked fish have different survival rates, then the marked to unmarked ratio in the hatchery release is not appropriate [in equation (6)] and some adjustment should be made. To test the assumptions, additional studies and data collections were incorporated within the design of the marking experiment.

In connection with the first assumption (permanence of fin marks), marked juvenile fish were held and periodically examined to determine degree of mark regeneration. Also, illustrated forms on which missing fins or parts of fins are shaded out provide information on the samplers' interpretation of marked fish (fig. 5).

To test the second assumption (origin of fish marked with hatchery marks), fish were examined for natural marks while being marked. In addition, the cooperating fishery agencies agreed not to use the combination of marks used in this study on any group of 1965–brood chinook salmon. This group will be sampled as 2-, 3-, and 4-year-old fish during the 1967, 1968, and 1969 sampling years. Any observed marks of the kind used in this study will be from the natural loss of fins.

A test of scale readers was designed to test the third assumption (accuracy of age assignments). Scales from 400 marked fish of known age were submitted to six readers from the Fisheries Research Board of Canada, Washington Department of Fisheries, Oregon Game Commission, Fish Commission of Oregon (two readers), and Bureau of Commercial Fisheries. Length of fish and date of capture were available for each scale.

The fourth assumption (equality of survival rates and maturity schedules) will be examined from data on a different type of mark applied to fish at one of the hatcheries. At Little White Salmon Hatchery, a fraction of the 1964 brood was marked with TM 50 (oxytetracycline) that was added to the diet. This mark was selected to identify a hatchery stock because it apparently does not affect their growth or survival (Weber and Ridgway, 1967). As a result, some of the fish are double marked—with a finclip and TM 50. Returns to the hatchery in 1966, 1967, 1968, and 1969 will be examined for changes since release in the proportion of TM 50 marked fish which also have the finclip. In addition to the TM 50 marking at this hatchery, data bearing on the changes in marked to unmarked ratios (i.e., finclip vs. totally unmarked) between release and return will be available from the returns to each of the participating hatcheries.

With the resources available, we could not test the fifth assumption (equality of ocean distribution and vulnerability). Indirect evidence may be obtained, however, by comparing the ocean distribution of marked fish with the distribution as determined by past tagging experiments in the ocean.

The sixth assumption (equality of ocean distribution or proportion marked among hatcheries) will be examined from data collected in that part of the study designed to examine the variations in contribution between hatcheries and, of course, from the data collected from each hatchery at the time of release.

RELEASES OF FISH

The marking phase of the hatchery contribution study (concluded in 1965) included marking a portion of the fall chinook production of each of the 12 hatcheries with the same mark; marking a portion of the production of 4 hatcheries with a unique mark; measuring the quality of marking; examining hatchery fish for naturally missing fins; and obtaining samples of fish to determine regeneration of marks and for measuring certain physical and physiological characteristics of the releases for each of the brood years. Analyses of these latter data in terms of explaining

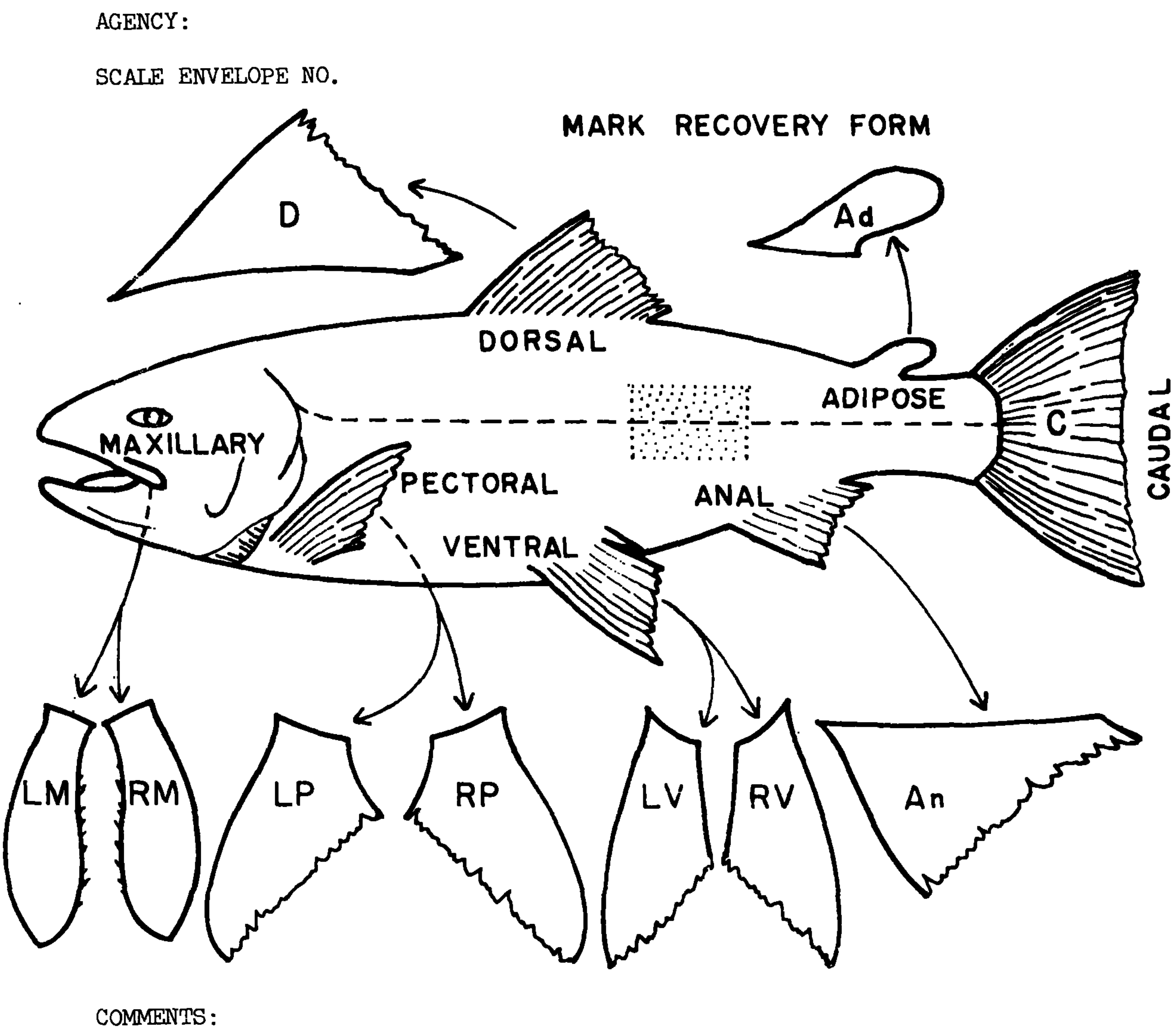

FIGURE 5.—Form for recording type of mark observed.

sources of variation must await completion of the study.

Table 4 shows for each mark type and brood year the estimated numbers of chinook salmon released and the proportions of fish that were marked, and ratios of marked-to-unmarked fish. Detailed data for each hatchery are given in appendix tables 1, 2, 3, and 4.

During the 4 years of marking (i.e., 1961-64 broods), 213 million fall chinook salmon were released from the hatcheries under study. Included were 21.3 million fish with the adipose-maxillary mark. This mark, common to all of the 12 hatcheries, was 9.9 to 10.1 percent of the releases. In addition, the release included 9.6 million fish with special marks unique to individual hatcheries. These special marks were 9.1 to 30.5 percent of the yearly releases from the hatcheries where used.

Samples of over 100,000 marked fish were examined each year and graded according to quality of mark. A score of 5 was assigned for a good mark, 3 for an acceptable mark, and 0 for an unacceptable mark. Average scores were 4.9, 4.9, 4.9, and 4.8 for 1961, 1962, 1963, and 1964 broods, respectively. The lowest average score for any hatchery-mark type combination was 4.1; all remaining scores were greater than 4.5. Although a certain

TABLE 4.—*Estimated numbers and mark ratios of fall chinook salmon released from study hatcheries for 1961–64 brood years*

Brood year	Mark	Origin of mark	Marked release	Marked and unmarked release	Marked/ Marked and unmarked	Marked/ unmarked
			Number	*Number*		
1961	Ad-RM	All hatcheries	5,446,439	53,653,214	0.1015	0.1193
1962	Ad-LM	do	5,249,079	52,470,003	.1000	.1163
1963	Ad-RM	do	5,986,464	60,112,063	.0996	.1155
1964	Ad-LM	do	4,638,237	46,778,552	.0992	.1175
		Subtotal	21,320,219	213,013,832		
1961	Ad-LV-RM	Spring Creek	1,133,019	10,925,933	.1037	.1308
	Ad-RV-RM	Kalama	475,964	4,906,845	.0970	.1210
	LV-RM	Elokomin	480,533	1,575,000	.3051	.5075
	RV-RM	Oxbow	450,446	4,549,959	.0990	.1241
1962	Ad-LV-LM	Spring Creek	866,892	8,408,267	.1031	.1299
	Ad-RV-LM	Kalama	437,669	4,599,326	.0952	.1173
	LV-LM	Grays	241,494	1,359,761	.1776	.2437
	RV-LM	Cascade	541,158	4,217,910	.1283	.1667
1963	Ad-LV-RM	Spring Creek	751,243	7,467,629	.1006	.1264
	Ad-RV-RM	Kalama	456,158	4,883,937	.0934	.1156
	LV-RM	Klickitat	521,610	2,888,208	.1806	.2501
	RV-RM	Big Creek	579,967	1,985,838	.2920	.4770
1964	Ad-LV-LM	Spring Creek	600,953	6,554,455	.0917	.1139
	Ad-RV-LM	Kalama	319,412	3,496,560	.0914	.1129
	LV-LM	Bonneville	957,110	9,887,575	.0968	.1205
	RV-LM	Little White Salmon	797,345	8,365,579	.0953	.1184
		Subtotal	9,610,973			
		Total	30,931,192			

amount of subjectivity is inherent in such a scoring system, these values indicate that a high quality was attained.

During the marking, over 30 million fingerlings were examined for naturally missing adipose and ventral fins. A total of 156 missing adipose and 201 missing ventral fins were observed. Although insignificant in relation to the fish examined, these numbers represent the frequency of naturally missing fins for these hatchery-reared fish only. A more direct measure of this source of error (i.e., occurrence of natural marks) in the hatchery contribution study will be possible during the years when fish of the 1965 brood are in the fishery. The marks used in the study were not applied to the 1965 brood.

Marked fingerlings obtained at time of release from the hatcheries were held in salt-water rearing ponds at Bowman Bay, Wash., for as long as 34 months. Periodic examinations were made to determine the extent of regeneration of the fin and maxillary marks, and the results are summarized in table 5.

Regeneration of the adipose mark was not apparent. Similarly, complete regeneration of the ventral mark did not occur. Some regeneration of the ventral mark, however, was apparent for a substantial portion of the fish in each group (up to 47 percent). In most cases, the ventral fin regenerated to less than 25 percent of its original size (as judged by the size of the paired ventral

TABLE 5.—*Regeneration of adipose fin, maxillary bone and ventral fin in test lots of fish, 1961–64 brood years, held at Bowman Bay, Wash.*

Adipose fin

Brood year	Age	Fish examined	Regeneration	
	Months	*Number*	*Number*	*Percent*
1961	20	115	0	0
1962	12	626	0	0
	23	452	0	0
	29	381	0	0
1963	12	872	0	0
	17	551	0	0
	26	371	0	0
	34	311	0	0
1964	14	416	0	0
	27	312	0	0

Maxillary bone

Brood year	Age	Fish examined	Complete regeneration	
	Months	*Number*	*Number*	*Percent*
1961	20	291	20	6.9
1962	12	1,079	32	3.0
	23	734	38	5.2
	29	652	76	11.6
1963	12	1,615	8	.5
	17	1,160	25	2.2
	26	774	26	3.4
	34	664	22	3.3
1964	14	751	12	1.6
	27	567	5	.9

Ventral fin

Brood year	Age	Fish examined	Regeneration: Less than 25 percent		Regeneration: Greater than 25 percent	
	Months	*Number*	*Number*	*Percent*	*Number*	*Percent*
1961	20	291	116	39.9	[1] 14	4.8
1962	12	1,079	444	41.1	64	5.9
	23	734	293	39.9	37	5.0
	29	652	247	37.9	39	6.0
1963	12	1,615	559	34.6	(2)	
	17	1,160	408	35.2	62	5.3
	26	774	310	40.0	41	5.3
	34	664	182	27.4	33	5.0
1964	14	575	211	36.7	22	3.8
	27	432	86	19.9	16	3.7

[1] Complete regeneration did not occur in any of the groups.
[2] Degree of regeneration was not determined.

fin). Even where the regeneration was greater (up to 6 percent of the fish examined), the marks were readily identifiable owing to a deformation of the fin rays.

The maxillary mark completely regenerated for varying proportions of the groups examined. The relatively high occurrence of regeneration for the 1961- and 1962-brood fish (6.9–11.6 percent) was the basis for removing more of the maxillary bone for the next 2 brood years. Only the tip of the maxillary was removed for the 1961 and 1962 broods. For the 1963 and 1964 broods, the maxillary was excised at a point below the middle of the eye. This change in marking procedure is reflected in the smaller percentages of fish with regeneration (1–3 percent) for the 1963 and 1964-brood fish.

It is likely that these test fish were examined in greater detail and under better conditions than can be expected in actual sampling. The results of the examinations, however, make it doubtful that fin regeneration is an important source of error in the total program. Maxillary regeneration causes some difficulties and will be considered in a later section.

MARK RECOVERIES AND ESTIMATED CATCH OF MARKED FISH

The mark-sampling phase of the program began in 1963 when the 1961-brood-year fish first entered some of the fisheries as 2-year-olds. During the first year, sampling was limited to the Washington and Oregon ocean fisheries, Columbia River fisheries, and hatchery returns. Beginning in 1964, sampling was expanded to include most chinook salmon fisheries from Monterey, Calif., to and including southeast Alaska. The results reported here concern recoveries of the 1961 brood in 1963, 1964, 1965, and 1966. Recoveries from this brood in 1967 were minor.

The total catches of chinook salmon in the fisheries that were sampled and numbers of fish examined each year for marks and for age are given in table 6. Over the 4 years of sampling, 23 percent of the catch of 8.5 million fish were examined for marks. In addition, 1.5 percent of the total catch was sampled for age determinations and other data (e.g., length and weight). Mark sampling percentages were 28.3, 26.6, 19.8, and 21.5 percent for 1963, 1964, 1965, and 1966, respectively.

TABLE 6.—*Catches of chinook salmon and number of fish examined for marks and age, 1963–66*

Year	Catch [1] chinook salmon		Sampled for marks	Sampled for age
	1961 brood	All ages		
	Number of fish			
1963	41,786	570,172	161,460	20,000
1964	1,565,549	2,671,976	709,660	33,000
1965	998,849	2,572,919	508,730	34,000
1966	206,765	2,645,537	569,265	40,000
Total	2,812,949	8,460,604	1,949,115	127,000

[1] Total catch is only for those fisheries sampled.

RECOVERIES OF MARKED FISH

Table 7 summarizes all marks of possible Columbia River hatchery origin (1961 brood year) recovered in the fisheries. Included in the table are recoveries of marks that could be the result of maxillary regeneration. A total of 9,573 marked fish of possible Columbia River hatchery origin were recovered during the 4 years of sampling. Although fairly large numbers of marked fish of the 1961 brood were recovered in 1966 and during the limited sampling in 1963, most of them were recovered as 3-year-old fish in 1964. Exceptions were the fish marked at Kalama Hatchery; slightly more of these fish were recovered in 1965 than in 1964.

The distribution of recoveries for each year by region of capture and type of fishery is shown in table 8. Only recoveries of the full marks are listed. The distribution of recoveries of the possible experimental marks was similar.

As 2-year-old fish, those with 1961-brood marks were recovered only in the Washington ocean sport and Columbia River gill net fisheries. Although many fisheries were not sampled in 1963, 2-year-old mark recoveries of the 1962- and 1963-brood fish indicate that the contribution of this age group to other fisheries is relatively minor. By 1964 the marked fish were distributed over the entire range of sampling. For ocean fisheries they appeared most frequently, however, in Washington and British Columbia catches (although not shown in table 8, the bulk of the British Columbia recoveries were from the troll fishery landings on the west coast of Vancouver Island). The distributions of recoveries in 1965 and 1966 were similar to 1964 but in fewer numbers.

The distributions of marked fish that originated from Spring Creek and Kalama Hatcheries were different. Proportionately more of the Kalama

TABLE 7.—*Marked 1961 brood-year chinook salmon of possible Columbia River hatchery origin recovered in the fisheries, 1963–66*

Origin of mark	Mark	Year of capture: 1963	1964	1965	1966	Total
		Number of fish				
All hatcheries	Ad-RM	110	4,145	1,885	144	6,284
	Ad	79	561	189	30	859
Spring Creek	Ad-LV-RM	29	861	270	5	1,165
	Ad-LV	19	125	42	2	188
Kalama	Ad-RV-RM	5	248	268	64	585
	Ad-RV	1	17	35	5	58
Elokomin	LV-RM	0	38	18	2	58
	LV	3	75	57	21	156
Oxbow	RV-RM	3	54	16	5	78
	RV	3	65	55	24	147
Total		252	6,189	2,835	302	9,578

marks were recovered in the northern portions of the sampling range. For example in 1964, 3.3 times as many Kalama marks were recovered in the British Columbia troll fishery than were recovered in the Washington troll fishery. Such a comparison for Spring Creek marks shows a figure of 1.3 times. Moreover, Kalama marked fish were the only ones with marks (specific to a hatchery) recovered in the southeast Alaska fisheries.

Distributions of recoveries of marked fish that originated from Elokomin and Oxbow Hatcheries were similar to the distribution of Spring Creek recoveries, but the number of marks recovered was much smaller.

Recoveries of marked fall chinook salmon of the 1961 brood from the Columbia River escapement are presented in appendix table 5 and summarized in table 9. As in the ocean fisheries, most of the recoveries at the hatcheries were made in 1964. The exception was the relatively high 1965 recovery of marks originating from Kalama Hatchery.

Mark recoveries at hatcheries were obtained from examination of the entire hatchery returns. Therefore, it is impossible to make meaningful comparisons between hatchery recoveries and recoveries in tributary streams and fisheries, where only a portion of the populations was examined for marks.

ESTIMATED CATCHES OF MARKED FISH

As shown by equation (3), the total catch of fish with a particular mark is estimated for each stratum (fishery, port of landing or area of capture, and time period) from the catch and the proportion of fish having the mark in the catch sample. (It is assumed that a random sample is examined for marked fish and that all marked fish are observed.) The annual catch of fish with a particular mark is estimated for each fishery category (e.g., Washington troll fishery) by summing over the time periods and appropriate ports of landing

TABLE 8.—*Marked 1961-brood Columbia River chinook salmon recovered by year, region of capture, and type of fishery, 1963–66*

Origin and type of mark	Year	California: Sport[1]	California: Commercial[2]	Oregon: Sport	Oregon: Commercial	Washington: Sport	Washington: Commercial Troll	Washington: Commercial Gill net	Puget Sound: Sport	British Columbia: Troll	British Columbia: Gill net	British Columbia: Purse seine	S.E. Alaska: Commercial Troll	S.E. Alaska: Commercial Gill net	Columbia River: Sport	Columbia River: Commercial Gill net	Columbia River: Commercial Dip net
		Number of recoveries															
All hatcheries (Ad-RM).	1963	(*)	(*)	0	0	88	0	(*)	(*)	(*)	(*)	(*)	(*)	(*)	0	22	(*)
	1964	0	4	18	102	389	1,057	2	(*)	1,654	1	1	0	0	1	880	36
	1965	0	0	7	6	91	128	3	0	505	1	0	2	0	0	1,106	6
	1966	0	1	0	0	13	14	0	0	63	0	(*)	0	(*)	0	53	0
Spring Creek (Ad-LV-RM).	1963	(*)	(*)	0	0	23	0	(*)	(*)	(*)	(*)	(*)	(*)	(*)	0	6	(*)
	1964	0	3	1	31	81	246	0	(*)	321	0	0	0	0	0	178	0
	1965	0	0	0	2	12	21	1	0	41	0	0	0	0	0	193	0
	1966	0	0	0	0	0	0	0	0	2	0	(*)	0	(*)	0	3	0
Kalama (Ad-RV-RM).	1963	(*)	(*)	0	0	5	0	(*)	(*)	(*)	(*)	(*)	(*)	(*)	0	0	(*)
	1964	0	1	0	7	20	49	0	(*)	161	0	0	1	0	0	9	0
	1965	0	0	0	2	14	35	1	0	104	0	0	5	0	0	107	0
	1966	0	0	0	0	1	4	0	0	24	0	(*)	2	(*)	0	33	0
Elokomin (LV-RM).	1963	(*)	(*)	0	0	0	0	(*)	(*)	(*)	(*)	(*)	(*)	(*)	0	0	(*)
	1964	0	1	1	4	3	14	0	(*)	12	0	0	0	0	0	3	0
	1965	0	0	0	2	3	2	0	0	2	0	0	0	0	0	9	0
	1966	0	0	0	0	0	1	0	0	1	0	(*)	0	(*)	0	0	0
Oxbow (RV-RM).	1963	(*)	(*)	0	0	3	0	(*)	(*)	(*)	(*)	(*)	(*)	(*)	0	0	(*)
	1964	0	0	2	9	8	23	0	(*)	4	0	0	0	0	0	8	0
	1965	1	0	1	1	0	3	0	0	7	0	0	0	0	2	1	0
	1966	0	0	0	0	2	0	0	0	1	0	(*)	0	(*)	0	2	0

*No sampling.
[1] All sport fishing is by rod and reel.
[2] Unless otherwise noted commercial fishing is by trolling.

TABLE 9.—*Recoveries of 1961-brood fall chinook salmon in the Columbia River escapement by type of mark, recovery location, and year of capture, 1963–66*

Origin of mark	Mark	Recovery location [1]											
		Study hatcheries				Other hatcheries				Tributary streams			
		1963	1964	1965	1966	1963	1964	1965	1966	1963	1964	1965	1966
		Numbers of recoveries											
All hatcheries	Ad-RM	100	1,296	679	57	(*)	4	1	0	(*)	53	104	9
	Ad	24	215	167	2	(*)	0	0	0	(*)	11	5	0
Spring Creek	Ad-LV-RM	41	364	121	1	(*)	0	0	0	(*)	1	1	0
	Ad-LV	5	51	23	1	(*)	0	0	0	(*)	0	0	0
Kalama	Ad-RV-RM	0	8	112	38	(*)	5	0	0	(*)	0	15	4
	Ad-RV	0	0	4	0	(*)	0	0	0	(*)	0	1	1
Elokomin	LV-RM	2	4	1	0	(*)	0	0	0	(*)	4	1	0
	LV	0	8	5	0	(*)	2	2	0	(*)	0	0	1
Oxbow	RV-RM	4	52	22	1	(*)	0	0	0	(*)	0	0	0
	RV	3	7	10	0	(*)	0	0	0	(*)	0	0	0
Total		179	2,005	1,144	100	(*)	11	3	0	(*)	69	127	15

*Not sampled.
[1] The "study hatcheries" include the 12 hatcheries participating in the marking program. "Other hatcheries" include Abernathy, Speelyai, Toutle, Klaskanine, and Sandy Hatcheries. "Tributary streams" include those tributaries listed in an earlier section.

(or area of capture). The same system is used to estimate the total number of marked fish in spawning populations of tributary streams.

Estimated numbers of marked 1961-brood fish caught in the fisheries, returning to the hatcheries and escaping to tributary streams, are listed in table 10. Estimated numbers include fish which had a partial mark only—not a complete double or triple mark—(e.g., Ad only instead of Ad–RM or Ad–LV only instead of Ad–LV–RM). These numbers are substantial—for example, we estimated that the fisheries took 2,710 adipose-only marked fish or about 14 percent of the number with the full mark (Ad–RM).

The partial marks were from naturally marked fish, from experimentally marked fish with complete regeneration of the maxillary mark, or possibly both. From the mark regeneration experiment described earlier, we expected complete regeneration of the maxillary mark for about 12 percent of the marked fish over a 2.5-year period. To determine if the percentages observed can be explained by the expected regeneration of the maxillary mark, it is necessary to make a detailed

TABLE 10.—*Estimated number of marked fall chinook salmon of 1961 brood in catches, tributary spawning populations, and hatchery returns by type of mark, region of recovery, type of fishery, and year of capture, 1963–66*

Region	Fishery type	Ad-RM				Ad				Total			
		1963	1964	1965	1966	1963	1964	1965	1966	1963	1964	1965	1966
		Number of fish											
Ocean fisheries:													
Southeastern Alaska	Commercial	(*)	0	7	0	(*)	2	23	2	(*)	2	30	2
British Columbia	do	(*)	4,106	1,871	235	(*)	566	370	68	(*)	4,672	2,241	303
Washington	Sport	375	1,681	416	67	196	224	104	15	571	1,905	520	82
	Commercial	0	3,241	455	41	3	397	59	8	3	3,638	514	49
Oregon	Sport	0	72	26	0	0	93	16	0	0	165	42	0
	Commercial	0	324	10	0	0	45	12	0	0	369	22	0
California	Sport	(*)	0	0	0	(*)	0	0	0	(*)	0	0	0
	Commercial	(*)	23	0	6	(*)	0	4	0	(*)	23	4	6
Subtotal	Sport	375	1,753	442	67	196	317	120	15	571	2,070	562	82
	Commercial [1]	0	7,694	2,343	282	3	1,010	468	78	3	8,704	2,811	360
Columbia River fisheries	Sport	0	7	0	0	0	14	0	0	0	21	0	0
	Commercial [2]	72	2,151	3,544	176	76	297	92	24	148	2,448	3,636	200
Total	All fisheries	447	11,605	6,329	525	275	1,638	680	117	722	13,243	7,009	642
Columbia River escapement:													
Study hatcheries	(3)	100	1,296	679	57	24	215	167	2	124	1,511	846	59
Other hatcheries	(4)	(*)	4	1	0	(*)	0	0	0	(*)	4	1	0
Tributary streams		(*)	393	355	21	(*)	74	11	0	(*)	467	366	21
Total	Escapement	100	1,693	1,035	78	24	289	178	2	124	1,982	1,213	80

*Not sampled.
[1] Primarily troll fisheries.
[2] Primarily gill net.
[3] Twelve hatcheries participating in the marking program.
[4] Toutle, Abernathy, Speelyai, Sandy, and Klaskanine Hatcheries.

TABLE 10.—*Estimated number of marked fall chinook salmon of 1961 brood in catches, tributary spawning populations, and hatchery returns by type of mark, region of recovery, type of fishery, and year of capture, 1963–66*—Continued

Region	Fishery type	Ad-LV-RM (Spring Creek) 1963	1964	1965	1966	Ad-LV 1963	1964	1965	1966	Total 1963	1964	1965	1966
		Number of fish											
Ocean fisheries:													
Southeastern Alaska	Commercial	(*)	0	0	0	(*)	0	0	0	(*)	0	0	0
British Columbia	do	(*)	767	140	5	(*)	74	24	0	(*)	841	164	5
Washington	Sport	89	354	52	0	63	77	45	0	152	431	97	0
	Commercial	0	869	78	0	4	215	4	0	4	1,084	82	0
Oregon	Sport	0	5	0	0	4	44	4	0	4	49	4	0
	Commercial	0	73	16	0	0	8	4	0	0	81	20	0
California	Sport	(*)	0	0	0	(*)	0	0	0	(*)	0	0	0
	Commercial	(*)	15	0	0	(*)	10	0	0	(*)	25	0	0
Subtotal	Sport	89	359	52	0	67	121	49	0	156	480	101	0
	Commercial [1]	0	1,724	234	5	4	307	32	0	4	2,031	266	5
Columbia River fisheries	Sport	0	0	0	0	0	0	16	0	0	0	16	0
	Commercial [2]	19	453	608	10	3	65	61	7	22	518	669	17
Total	All fisheries	108	2,536	894	15	74	493	158	7	182	3,029	1,052	22
Columbia River escapement:													
Study hatcheries	(3)	41	364	121	2	5	51	23	1	46	415	144	3
Other hatcheries	(4)	(*)	0	0	0	(*)	0	0	0	(*)	0	0	0
Tributary streams		(*)	1	4	0	(*)	0	0	0	(*)	1	4	0
Total	Escapement	41	365	125	2	5	51	23	1	46	416	148	3

*Not sampled.

[1] Primarily troll fisheries.
[2] Primarily gill net.
[3] Twelve hatcheries participating in the marking program.
[4] Toutle, Abernathy, Speelyai, Sandy, and Klaskanine Hatcheries.

TABLE 10.—*Estimated number of marked fall chinook salmon of 1961 brood in catches, tributary spawning populations, and hatchery returns by type of mark, region of recovery, type of fishery, and year of capture, 1963–66*—Continued

Region	Fishery type	Ad-RV-RM (Kalama) 1963	1964	1965	1966	Ad-RV 1963	1964	1965	1966	Total 1963	1964	1965	1966
		Number of fish											
Ocean fisheries:													
Southeastern Alaska	Commercial	(*)	5	14	4	(*)	0	21	0	(*)	5	35	4
British Columbia	do	(*)	420	480	89	(*)	21	25	6	(*)	441	480	95
Washington	Sport	17	74	72	5	4	4	28	4	21	78	100	9
	Commercial	0	132	122	7	0	17	20	0	0	149	142	7
Oregon	Sport	0	0	0	0	0	0	0	0	0	0	0	0
	Commercial	0	18	4	0	0	3	0	0	0	21	4	0
California	Sport	(*)	0	0	0	(*)	0	0	0	(*)	0	0	0
	Commercial	(*)	2	0	0	(*)	0	0	0	(*)	2	0	0
Subtotal	Sport	17	74	72	5	4	4	28	4	21	78	100	9
	Commercial [1]	0	577	595	100	0	41	66	6	0	618	661	106
Columbia River fisheries	Sport	0	0	0	0	0	0	0	0	0	0	0	0
	Commercial [2]	0	32	377	106	0	6	22	5	0	38	399	111
Total	All fisheries	17	683	1,044	211	4	51	116	15	21	734	1,160	226
Columbia River escapement:													
Study hatcheries	(3)	0	8	112	38	0	0	4	0	0	8	116	38
Other hatcheries	(4)	(*)	5	0	0	(*)	0	0	0	(*)	5	0	0
Tributary streams		(*)	0	56	9	(*)	0	4	2	(*)	0	60	11
Total	Escapement	0	13	168	41	0	0	8	2	0	13	176	49

*Not sampled.
[1] Primarily troll fisheries.
[2] Primarily gill net.
[3] Twelve hatcheries participating in the marking program.
[4] Toutle, Abernathy, Speelyai, Sandy, and Klaskanine Hatcheries.

examination of the data on mark recoveries and accuracy of determining the age of fall chinook salmon.

In test readings of scales from marked chinook salmon of known age, six scale readers correctly aged (total age) 83 percent of the 400 test scales (Godfrey, Worlund, and Bilton, 1968). Table 11 shows the estimated and actual percentage age compositions of the 400 test scales. From the results of this test, it appears that in any one year scale readers can estimate reasonably well the numbers of partially marked fish of a given age (and, hence, brood-year).

A summary of partially marked fish is presented in table 12; the data resulted from the combination of years and general mark types (e.g., Ad–LV and

TABLE 10.—*Estimated number of marked fall chinook salmon of 1961 brood in catches, tributary spawning populations, and hatchery returns by type of mark, region of recovery, type of fishery, and year of capture, 1963–66*—Continued

Region	Fishery type	LV-RM (Elokomin)				LV				Total			
		1963	1964	1965	1966	1963	1964	1965	1966	1963	1964	1965	1966
		Number of fish											
Ocean fisheries:													
Southeastern Alaska	Commercial	(*)	0	0	0	(*)	4	51	15	(*)	4	51	15
British Columbia	do	(*)	28	7	6	(*)	60	46	63	(*)	88	53	69
Washington	Sport	0	8	15	0	12	55	27	0	12	63	42	0
	Commercial	0	45	5	3	0	64	22	10	0	109	27	13
Oregon	Sport	0	3	0	0	0	11	0	0	0	14	0	0
	Commercial	0	9	3	0	0	13	5	0	0	22	8	0
California	Sport	(*)	0	0	0	(*)	0	0	0	(*)	0	0	0
	Commercial	(*)	7	0	0	(*)	0	21	0	(*)	7	21	0
Subtotal	Sport	0	11	15	0	12	66	27	0	12	77	42	0
	Commercial [1]	0	89	15	9	0	141	145	88	0	230	160	97
Columbia River fisheries	Sport	0	0	0	0	0	0	0	0	0	0	0	0
	Commercial [2]	0	7	28	0	0	24	17	13	0	31	45	13
Total	All fisheries	0	107	58	9	12	231	189	101	12	338	247	110
Columbia River escapement:													
Study hatcheries	(3)	2	4	1	0	0	8	5	0	2	12	6	0
Other hatcheries	(4)	(*)	0	0	0	(*)	2	2	0	(*)	2	2	0
Tributary streams		(*)	5	2	0	(*)	0	0	2	(*)	5	2	2
Total	Escapement	2	9	3	0	0	10	7	2	2	19	10	2

*Not sampled.
[1] Primarily troll fisheries.
[2] Primarily gill net.
[3] Twelve hatcheries participating in the marking program.
[4] Toutle, Abernathy, Speelyai, Sandy, and Klaskanine Hatcheries.

TABLE 10.—*Estimated number of marked fall chinook salmon of 1931 brood in catches, tributary spawning populations, and hatchery returns by type of mark, region of recovery, type of fishery, and year of capture, 1963–66*—Continued

Region	Fishery type	RV—RM (Oxbow)				RV				Total			
		1963	1964	1965	1966	1963	1964	1965	1966	1963	1964	1965	1966
		Number of fish											
Ocean fisheries:													
Southeastern Alaska	Commercial	(*)	0	0	0	(*)	0	41	2	(*)	0	41	2
British Columbia	do	(*)	8	16	6	(*)	59	51	77	(*)	67	67	83
Washington	Sport	11	43	0	9	10	52	21	75	21	95	21	84
	Commercial	0	58	9	0	0	29	14	8	0	87	23	8
Oregon	Sport	0	18	4	0	0	5	9	0	0	23	13	0
	Commercial	0	20	2	0	0	21	1	0	0	41	3	0
California	Sport	8	0	2	--------	(*)	0	0	0	(*)	0	2	0
	Commercial	(*)	0	0	0	(*)	0	71	3	(*)	0	71	3
Subtotal	Sport	11	61	6	9	10	57	30	75	21	118	36	84
	Commercial [1]	0	86	27	6	0	109	178	90	0	195	205	96
Columbia River fisheries	Sport	0	0	17	0	0	0	8	0	0	0	25	0
	Commercial [2]	0	24	3	16	2	14	16	5	2	38	19	21
Total	All fisheries	11	171	53	31	12	180	232	170	23	351	285	201
Columbia River escapement:													
Study hatcheries	(3)	4	52	22	1	3	7	10	0	7	59	32	1
Other hatcheries	(4)	(*)	0	0	0	(*)	0	0	0	(*)	0	0	0
Tributary streams		(*)	0	0	0	(*)	0	0	0	(*)	0	0	0
Total	Escapement	4	52	22	1	3	7	10	0	7	59	32	1

*Not sampled.
[1] Primarily troll fisheries.
[2] Primarily gill net.
[3] Twelve hatcheries participating in the marking program.
[4] Toutle, Abernathy, Speelyai, Sandy, and Klaskanine Hatcheries.

Ad–RV were combined as were their corresponding full marks Ad–LV–RM and Ad–RV–RM). Under the hypothesis that the partial marks are primarily from maxillary regeneration, each entry is an estimate of percentage regeneration of the maxillary. For the returns to the hatcheries under study, the percentages of adipose-ventral and adipose-only marks (10.9 and 16.1) were similar to the expected magnitude of maxillary regeneration from the fin regeneration experiments. It is likely, therefore, that these partial marks in the hatchery returns were from maxillary regeneration. The same cause is not indicated for the ventral-only marks, which, in the hatchery returns, were about twice as numerous as expected.

If the percentage of partial marks in the ocean fisheries (compared with that observed for the hatchery returns) is generally high, then we

TABLE 11.—*Actual and estimated age composition of 400 test scales read by 6 scale readers*

Evaluation	Age composition (years)				
	2	3	4	5	6
	Percent				
Estimated	18.4	38.5	28.2	12.5	2.4
Actual	20.2	41.8	24.5	13.5	.0

would tend to reject the hypothesis that these marks are caused primarily by regeneration and conclude that many of these partial marks occurred naturally.

Because the Ad–RV and Ad–LV partial marks are double fin marks, we assume that their occurrence (in catch and hatchery returns) was primarily the result of maxillary regeneration. Hence, the data in the column Ad–EV of table 12 reflects the variability in rate of maxillary regeneration. When we compare the percent occurrence of Ad and EV marks with that of Ad–EV marks and the percentages of Ad and EV marks in the catches and at the hatcheries, the Ad mark appears to have been caused primarily by maxillary regeneration; and single RV or LV marks appear to have resulted from naturally marked fish in addition to maxillary regeneration.

In view of the above, we combined the estimated numbers of partially marked fish with their corresponding full mark for each mark type except for the LV and RV marks. On this basis

TABLE 12.—*Recoveries of partially marked fish by region of capture, type of fishery, and type of mark, 1963–66*

Region	Fishery type	Partial mark [1]		
		Ad–EV [2]	Ad	EV
		Percent		
Ocean fisheries:				
Southeastern Alaska	Commercial	47.7	79.4	100.0
British Columbia	do	7.4	13.9	83.4
Washington	Sport	25.3	17.5	74.6
	Commercial	17.7	11.1	55.0
Oregon	Sport	91.2	52.6	50.0
	Commercial	11.9	14.6	54.0
California	Sport			0
	Commercial	37.0	12.1	93.1
Subtotal	All	15.8	14.6	74.9
Columbia River fisheries	All	10.3	7.8	51.0
Columbia River escapement:				
Study hatcheries		10.9	16.1	27.7
Other hatcheries		0	0	100.0
Tributary streams		7.9	10.0	22.0
Subtotal		10.6	14.5	29.5

[1] Data in table are ratios (average for all years) of estimated numbers of partial marks to estimated sum of partial marks and corresponding complete marks expressed in percent.
[2] EV signifies "either ventral." Marks of same general type are combined.

TABLE 13.—*Estimated catch and escapement of marked fall chinook salmon of Columbia River hatchery origin by area of recovery, 1963–66*

Recovery category	Type of mark				
	Ad–RM [1]	Ad–LV–RM [1] (Spring Creek)	Ad–RV–RM [1] (Kalama)	LV–RM (Elokomin)	RV–RM (Oxbow)
	Numbers of fish				
Ocean fisheries	15,163	3,043	1,593	139	206
Columbia River fisheries	6,453	1,242	548	35	60
Total fisheries	21,616	4,285	2,141	174	266
Total escapement	3,399	612	238	14	79

[1] Includes partially marked fish.

the estimated numbers of marked fall chinook salmon of Columbia River hatchery origin in the catch and escapement are summarized in table 13.

Of the 1961 brood released from the 12 hatcheries with Ad–RM mark, we estimated that 21,600 were caught by the various fisheries between 1963 and 1966. An additional 3,400 fish escaped the fisheries and returned to spawn. The catch to escapement ratio for the 12 hatcheries is, therefore, about 6:1. For the four hatcheries represented by the other marks, this ratio was 12:1, 9:1, 3:1, and 7:1 (Elokomin, Kalama, Oxbow, and Spring Creek Hatcheries, respectively).

The estimated catch of marked fish (Ad–RM) that originated from the 12 hatcheries relative to numbers released was 21,616/5,446,439 or 3.97 fish per 1,000 released. Considerable variation in contribution occurred between hatcheries. The catch per 1,000 fish released was 0.36, 4.50, 0.59, and 3.78 for Elokomin, Kalama, Oxbow, and Spring Creek Hatcheries, respectively. Values for Elokomin and Oxbow Hatcheries are undoubtedly too low—some of the partial marks must have resulted from maxillary regeneration. If we assume that all the partial marks actually originated from Elokomin and Oxbow Hatcheries, their respective contribution would have been 1.53 and 1.95 per 1,000 fish released. These contributions still would be only one-half of those for Kalama and Spring Creek Hatcheries.

Before proceeding with the estimate of total contribution (marked and unmarked) of hatchery-reared fish to the catch, we will consider the precision of the estimate of the total catch of marked fish.

Equation (4), which provides an approximation of the variance of the estimated number of marks in the catch, requires an estimate of the precision of the seasonal chinook catch for each of the fisheries. Such estimates are not published except in a few instances (e.g., California troll and Oregon ocean sport fisheries). Lacking this information, we have assumed that the seasonal chinook catches in each fishery (except for Alaska troll and the ocean gill net and purse seine fisheries) are estimated within 15 percent of the true value; i.e., the variance of the catch, V(C), is such that one-half the width of the 95 percent confidence interval, $2[V(C)]^{1/2}$, is 15 percent of the estimated catch, C. We then have:

$$V(C) = (0.5 \times 0.15 \times C)^2$$
$$= 0.0056\ C^2.$$

Where available (e.g., California troll), estimates of the precision of the catches are well within the assumed value.

In the Alaska troll fishery and the ocean net fisheries, catches are reported in numbers of fish. The variance of the catch and, therefore, the second term in equation (4) is zero for each of these fisheries.

Substituting these values of V(C) in equation (4) and summing over the strata (i.e., fisheries and years) gives 357,000; 26,000; 13,000; 1,100; and 2,300 as approximate variances for the estimated numbers of Ad–RM, Ad–LV–RM, LV–RM, and RV–RM marks, respectively, in the total catch. The resulting estimates of the 95 percent confidence intervals for the numbers of marked fish in the catch are: Ad–RM 21,616±5.6 percent; Ad–LV–RM 4,285±7.5 percent; Ad–RV–RM 2,141±10.6 percent; LV–RM 174±37.9 percent; RV–RM 266±36.1 percent; where, for example, the 5.6 percent refers to the estimated number of Ad–RM marks (21,616) in the catch. Although these confidence interval estimates are approximate, they illustrate the general level of precision of the estimated total number of marks in the catch.

ESTIMATED CATCH OF 1961-BROOD HATCHERY FISH

In estimating the total number of marked hatchery fish in the catch on the basis of an observed number of mark recoveries and a sampling ratio, as was done in the preceding section, we made certain assumptions. These are assumptions 1, 2, and 3, which dealt with the permanence of fin marks, origin of observed fish marked with the hatchery marks, and accuracy of age assignments. Data presented in the preceding section supported these assumptions.

Additional assumptions are inherent in the procedure for estimating the catch of unmarked and, hence, total catch of hatchery fish. These are assumptions 4, 5, and 6, which were listed previously.

From the distribution of mark recoveries it appears that chinook salmon from Kalama and Spring Creek Hatcheries had different ocean distributions. It is not likely, then, that the first part of assumption 6 (same ocean distribution of fish from each hatchery) is satisfied. This poses no problem, however, provided the second part of assumption 6 (same proportion of fish marked at each hatchery) is satisfied. In this regard, it appears from appendix table 1 that with the possible exception of Klickitat Hatchery, proportions of Ad–RM marked fish in the releases were much the same at all of the hatcheries. Accordingly, we consider that assumption 6 is reasonably satisfied.

Information to test the assumption (assumption 5) concerning the distributions of marked and unmarked hatchery fish is limited. The distribution of marked fish is available from the present study; however, concurrent data for unmarked fish are lacking. The only information available on this subject is from a review by Cleaver (1967) of past tagging experiments in the ocean. Of 290 tagged fish recovered in the Columbia River from these experiments (during 1925–52 in coastal areas from northern Oregon to Cape Fairweather, Alaska), only 13 were recovered in hatcheries. Twelve of the 13 recoveries, however, had been tagged in areas off the west coast of Vancouver Island, Canada—an area of high concentration of marked hatchery fish as shown by recoveries of the marked 1961 brood. Although this result is consistent with assumption 5, it does not, of course, conclusively support it. The assumption must, therefore, remain an assumption.

The validity of assumption 4 (equality of maturity schedules and survival rates between marked (Ad–RM) and unmarked hatchery fish) can be examined by comparing the ratios of marked to unmarked fish at times of release and return. The marked to unmarked ratios by type of mark and age of fish for the 1961-brood hatchery returns are given in table 14. Ratios for Elokomin (LV–RM) and Oxbow (RV–RM) hatcheries are not presented because the number of recoveries was small.

TABLE 14.—*Marked to unmarked ratios for hatchery returns of 1961-brood chinook salmon by type of mark and age of fish*

Mark	Origin	Age (years)				
		2	3	4	5	All ages
		Marked/unmarked				
Ad-RM	All study hatcheries	0.059	0.063	0.075	0.106	0.067
Ad-RV-RM	Kalama	0	.016	.046	.092	.047
Ad-LV-RM	Spring Creek	.046	.038	.050	.062	.041
Ad-RM	Selected hatcheries [1]	.065	.067	.085	.081	.072

[1] Cascade, Oxbow, Little White Salmon, and Spring Creek Hatcheries.

The increase in ratios with age seems to indicate that marking had some delaying effect on the age of maturity. This effect was much greater for fish marked at Kalama than for fish marked at Spring Creek, although a similar type of mark was used. From the standpoint of survival, the ratios for all ages combined are smaller than those at release (table 4), thus indicating lower total survival for marked fish. The survival of Ad-RM marked fish, for example, was (0.067/0.1193)100=56.2 percent of that for the unmarked fish.

If the differences between the ratios of marked and unmarked fish at times of release and return are interpreted as indicative of delayed maturity or lower survival of marked fish, it is necessary to assume that all unmarked fish returning to a hatchery originated from that hatchery. It is apparent that straying [5] (provided the probability of straying is the same for marked and unmarked hatchery fish) reduces the marked to unmarked ratio for any given year of return. Thus, the indicated survival of marked fish relative to the survival of unmarked fish is too small. Also, if the probability that nonhatchery fish stray into a hatchery changes each year or is related to the age of fish, then the dilution of unmarked hatchery fish by nonhatchery fish in the return is disproportionate from year to year and the change in the marked to unmarked ratios with age of return is impossible to interpret.

Some of the hatcheries, such as Kalama Hatchery, are located on streams in which natural spawning occurs. In these cases, fish which are spawned at the hatcheries and comprise what we term "hatchery returns" are simply a selected sample (of various sizes in proportion to the total return) of adults returning to the stream. Marked to unmarked ratios would, therefore, be difficult to interpret in terms of the effects of marking on survival and age of maturity.

Only 5 of the 12 hatcheries (Bonneville, Cascade, Oxbow, Little White Salmon, and Spring Creek) are on streams that do not support natural spawning populations. Marked (Ad-RM) to unmarked ratios in the returns to four of these hatcheries, Bonneville Hatchery excluded,[6] are presented in table 14. The change in the ratio of marked to unmarked fish with age is not as pronounced as for the 12 hatcheries combined. In addition, the ratio, 0.072, for all ages is somewhat larger than it was for all 12 hatcheries, indicating that survival of marked (Ad-RM) fish relative to unmarked fish was (0.072/0.1193)100=60.4 percent.

Even for the four selected hatcheries, however, straying of nonhatchery fish into hatcheries is a possible source of error. Unfortunately, a direct measure of the extent of this straying is not available. General indications of straying of nonhatchery fish are obtained from observations of marked fish straying away from the hatcheries. Recoveries of specially marked fish released at Elokomin, Kalama, Oxbow, and Spring Creek Hatcheries are presented in table 15. Of the recoveries of marked fish at hatcheries and on spawning grounds, 71.4, 6.3, 38.0, and 4.9 percent of Elokomin, Kalama, Oxbow, and Spring Creek fish were recovered at places other than the release site. The higher percentage of strays from Elokomin and Oxbow Hatcheries may possibly be explained by the fact that 75 percent of the fish released at Elokomin and 30 percent of the fish released at Oxbow were the progeny of fish spawned at Spring Creek Hatchery.

Some indication that younger fish stray more than older fish can be seen in table 15. Groves, Collins, and Trefethen (1968) tagged two groups of chinook salmon at Spring Creek Hatchery and released them into the main stem of the Columbia

[5] The term "straying" is used here in the sense that fish spawn or are spawned at a location other than their point of origin as fingerlings. Indeed, straying into a hatchery may be different from straying into a natural spawning area where the fish are free to leave again.

[6] Bonneville Hatchery is excluded because it is immediately below Bonneville Dam. The potential for straying may be greater if the fish are delayed in their upriver passage at the dam.

TABLE 15.—*Escapement recoveries of marked chinook salmon of 1961 brood by location of release and recovery and age of capture, 1963–66*

Recovery location [2]	Release location [1]															
	Elokomin				Kalama				Oxbow				Spring Creek			
	Age				Age				Age				Age			
	2	3	4	5	2	3	4	5	2	3	4	5	2	3	4	5
	Number of fish															
Grays River																
Big Creek			2													
Plympton		5														
Elokomin	2	2	0	0												
Abernathy																
Toutle																
Kalama						7	171	45								1
Lewis River (Speelyai)						5		4								
Washougal																
Tanner Creek (Bonneville)		1	1				4		1	12	5		1	1	1	
Eagle Creek (Cascade)										2			2	9		
Herman Creek (Oxbow)									1	35	12	1	1	6	2	
Wind River																
Little White Salmon									2	3	4					
Spring Creek		1				1	1				1		42	398	141	2
Big White Salmon														2		
Klickitat															4	
Total	2	9	3	0	0	13	176	49	4	52	22	1	46	416	148	3
Number of strays	0	7	3	0	0	6	5	4	3	17	10	0	4	18	7	1
Percentage strays	0	77.8	100.0	0	0	46.2	2.8	8.2	75.0	32.7	54.4	0	8.7	4.3	4.7	33.3
Percentage strays (all ages)	71.4				6.3				38.0				4.9			

[1] Elokomin: LV–RM; Kalama: Ad–RV–RM and Ad–RV; Oxbow: RV–RM; Spring Creek: Ad–LV–RM and Ad–LV.

[2] Recoveries in tributary streams were adjusted on the basis of the appropriate sampling ratios. Recovery locations are arranged in upstream order (see fig. 1).

River. A smaller fraction of the fish under 80 cm. (31.5 inches) long returned to Spring Creek than did the group over 80 cm. long (3-year-old chinook at Spring Creek average about 80 cm.).

These results offer an alternative explanation for the observed increase in the marked to unmarked ratio with age of return. That is, if the probability of straying is greater for younger fish than for older fish, as indicated above, then it is likely that the marked to unmarked ratio would increase with age even if marking had no effect on maturation.

Additional information of the effect of marking on maturation will be available later from the TM 50 marking experiment at Little White Salmon Hatchery. For the present, we will assume that marked and unmarked 1961-brood hatchery fish had the same maturity schedule.

Another point of interest in table 15 is that the fish generally strayed to areas near the hatchery of origin. Except for the one marked fish from Spring Creek recovered in the Kalama system all marked fish recovered at any great distance from the hatchery of origin were recovered upstream. If the pattern of straying is the same for nonhatchery fish, it is possible to obtain a maximum estimate of straying of nonhatchery fish into the four selected hatcheries—Cascade, Oxbow, Little White Salmon, and Spring Creek. These hatcheries are between Bonneville and The Dalles Dams (fig. 1). Most of the fall chinook salmon return to these hatcheries during the last week of August and September. Spawning occurs between mid-September and mid-October but is generally concentrated within a 2-week period.

Most (about 70 percent in 1965) of the fall chinook salmon that passed The Dalles Dam between August 26 and September 30 are generally brightly colored and are thought to spawn as much as a month later than the darker hatchery fish.[7, 8]

Because of the short duration of spawning at the four hatcheries, it is not likely that fish destined for areas above The Dalles Dam would contribute substantially to these hatchery returns. This generally agrees with the indicated "upstream" straying of the marked hatchery fish. That is, straying probably comes primarily from populations of fish that normally spawn near or downstream from the four hatcheries.

[7] Smith, Eugene M. 1966. Final report. A study to identify the race of fall chinook salmon whose spawning grounds will be inundated by the John Day impoundment on the Columbia River. Fish Comm. Oreg. Res. Div. (U.S. Army Corps Eng., Walla Walla Dist., contract DA–45–164–CIVENG–66–5). 53 pp. [Processed.]

[8] McKee, Thomas B. 1966. Deschutes River adult fall chinook holding study. 1965. Fish Comm. Oreg. Res. Div. (U.S. Army Corps Eng., Walla Walla Dist., contract DA–45–164–CIVENG–66–7). 26 pp. [Processed.]

The difference between fall chinook salmon counts [9] at Bonneville and The Dalles Dams is an estimate of the number of fish removed by the fishery and spawning (aside from mortalities and passage through navigation locks where they are not counted) between the two dams.[10]

By subtracting the number of returns to the four selected hatcheries and the number removed by the fishery from this estimate, we obtain a maximum estimate of the fish that spawned between the two dams at sites other than the four hatcheries—these are the fish that did not stray into the four selected hatcheries. The estimate is maximum because it includes losses between the two dams and fish that strayed from the four hatcheries. Finally, by applying age composition data and estimates of straying (from observed straying of fish marked at Spring Creek Hatchery, table 15), we obtain estimates of the number of 1961-brood nonhatchery fish spawned at the four selected hatcheries (table 16).

An example of the information in table 16 follows. In 1963 an estimated 11,759 fall chinook salmon spawned between the two dams but not at the four subject hatcheries. An estimated 14 percent, or 1,646, were 1961-brood fish. We assumed that these fish are the $(100-8.7)=91.3$ percent of the nonhatchery fish that did not stray into the four hatcheries. The 8.7 was the observed percentage of the 2-year-old fish straying from Spring Creek Hatchery (table 15). It follows that $(1{,}646/0.913)-1{,}646=157$ nonhatchery fish strayed into the hatcheries. Similar calculations for 1964, 1965, and 1966 give an estimated total of 2,126 nonhatchery fish of the 1961 brood that were spawned at the four selected hatcheries during the 4 years.

Total return of marked (Ad–RM and Ad-only) and unmarked fish to the four hatcheries was 1,898 and 26,538 fish, respectively (appendix table 5).

[9] U.S. Army, Corps of Engineers. 1963–66. Annual fish passage report: North Pacific Division, Bonneville, The Dalles, McNary and Ice Harbor Dams, Columbia and Snake Rivers, Oregon and Washington. 1963–66. U.S. Army Eng. Dist., Corps Eng., Portland (Oreg.) and Walla Walla (Wash.). Various pagination.

[10] In an analysis of fishway counts (1957–65) at Bonneville and The Dalles Dams (among others), Fredd [11] found that the differences in counts of fall chinook salmon generally exceeded estimates of the numbers removed by the fishery and the numbers spawned in intermediate areas. He concluded that counting errors could not be a major contributor to the discrepancy, thus indicating a "loss" of fish between the two dams.

[11] Fredd, Louis C. 1966. Analysis of differences in fish counts at Columbia River dams, 1957–65. Fish Comm. Oreg. (U.S. Army Corps Eng. Portland Dist., contract DA–35–026–CIVENG–65–44). 47 pp. [Processed.]

TABLE 16.—*Estimated number of nonhatchery chinook salmon of 1961 brood spawned at four hatcheries [1] between Bonneville and The Dalles Dams, 1963–66*

Item	Year of run				Total
	1963	1964	1965	1966	
Count at Bonneville Dam [2]	121,184	154,534	134,469	135,095	545,282
Count at The Dalles Dam [2]	66,473	56,150	87,096	69,018	278,737
Hatchery returns [1]	24,377	28,409	12,025	31,023	95,834
Catch [3]	18,575	23,338	25,051	7,008	73,972
Bonneville count minus The Dalles count minus hatchery return minus catch	11,759	46,637	10,297	28,046	96,739
Percent 1961 brood [4]	14	78	66	9	....
Number of 1961 brood year not straying	1,646	36,377	6,796	2,524	47,343
Percent straying [5]	8.7	4.3	4.7	0	....
Estimated number of 1961-brood fish straying into four hatcheries [1]	157	1,634	335	0	2,126

[1] Spring Creek, Little White Salmon, Oxbow, and Cascade Hatcheries.
[2] Counts for period August 26 to September 30.
[3] Chinook catch between Bonneville and The Dalles Dams for period August 26 to September 30. Sport catch not included.
[4] Estimated age composition from fishery samples.
[5] Estimates from Spring Creek mark (Ad–LV–RM), table 11. Assumed 0 for age 5 because of the small number of returns.

Subtracting the estimated number of nonhatchery strays, 2,126, from the unmarked return, we found the marked to unmarked ratio becomes $1{,}898/24{,}412=.078$. Estimated survival of marked relative to the unmarked fish is then $(.078/.1193)100=65.4$ percent.

This procedure for estimating the number of nonhatchery fish entering the hatcheries is subject to error. If, for example, the percentage straying was as large as 10 percent (for each age group), then the estimated total of 1961-brood nonhatchery fish that entered the four hatcheries would be 5,260; the estimate of the survival of marked to unmarked fish would then be 74.6 percent. In spite of the inexactness, however, it seems clear that the small value of the marked to unmarked ratio observed in the hatchery returns relative to that in the hatchery releases cannot be solely attributed to straying of nonhatchery fish. Furthermore, it appears that the total survival of marked (Ad–RM) relative to unmarked 1961-brood-year fish could not have exceeded 70 percent.

In summary, it appears from the present data that assumption 6 (equality of proportions marked at each hatchery) is satisfied, but for the present we must assume that marked and unmarked hatchery fish have the same ocean distribution and maturity schedules. In addition, we will assume that total survival of marked fish was 70 percent of the survival of unmarked fish—and further, that all additional mortality of marked fish occurred during their first year of life.

On the basis of the preceding summary, estimates of the total catch of 1961–brood hatchery fish were made and are presented in table 17. These estimates were obtained from equation (6) and the estimated numbers of marked fish in the catch (table 10). For example, estimated 1964 total catch of hatchery fish (115,755) by the ocean commercial fisheries was computed as follows. First, the marked to unmarked ratio required in equation (6) was estimated by the product of the marked (Ad–RM) to unmarked ratio, 0.1193, at release (table 4) and the assumed relative survival of marked fish, 0.70. The catch of unmarked hatchery fish (104,227) was then estimated from the ratio: 104,227=8,704/(0.1193)(0.7) where 8,704 is the estimated catch of Ad–RM marked fish (including Ad-only). Estimated catches of the other marked hatchery fish were 2,031, 618, 89, and 86 for the Ad–LV–RM, Ad–RV–RM, LV–RM, and RV–RM marks, respectively.[12] The total catch of hatchery fish in 1964 is then simply the sum of the catches of marked and unmarked fish (i.e., 115,755=104,227 +8,704+2,031+618+89+86).

TABLE 17.—*Estimated catch of hatchery fall chinook salmon of 1961 brood by type of fishery and year of capture, 1963–66*

Fishery type	Year of catch				
	1963	1964	1965	1966	Total
	Number of fish				
Ocean sport	7,597	27,487	7,514	1,082	43,680
Ocean commercial	43	115,755	37,441	4,797	158,036
Columbia River sport	0	272	33	0	305
Columbia River commercial	1,942	32,349	48,275	2,739	85,305
Total	9,582	175,863	93,263	8,618	287,326

During the 4 years of sampling an estimated 287,326 fall chinook salmon that originated from the 12 hatcheries were caught. This number comprised about 10 percent of the total catch (2,812,-949) of 1961-brood chinook salmon in the fisheries sampled. The fish from these hatcheries accounted for 23, 11, 9, and 4 percent of the catches of 1961-brood chinook salmon in 1963, 1964, 1965, and 1966, respectively.

An approximate interval estimate[13] (95 percent confidence interval) for the total catch of hatchery fish is 258,593 to 316,059 (287,326±10 percent). This estimate is rough and is presented solely to indicate the general level of precision of the estimated catch of hatchery fish (287,326) obtained under the assumptions stated previously. Sources of error other than sampling variation are in fact more important at this time. For example, if survival of marked relative to unmarked fish was 60 or 100 percent, rather than the assumed 70 percent, then the estimated catch of hatchery fish would have been 330,465 or 209,672, respectively. Both of these values are well outside the interval estimate. It should, therefore, be clearly understood that the above estimated catch of hatchery fish (287,326), although reasonable (but probably minimal), is preliminary.

ESTIMATED VALUE OF CATCH FOR 1961–BROOD HATCHERY FISH

To determine the benefit to cost ratio of the 1961-brood-year releases of fall chinook salmon from the 12 hatcheries under study, estimates were made of production cost for the 53.6 million fish released and of the net value of the 287,326 fish caught by the sport and commercial fisheries. In addition to the release of 53.6 million fish from the 12 hatcheries, 3.86 million fish were released from Abernathy, Speelyai, Toutle, Klaskanine, and Sandy Hatcheries. By making certain assumptions it is also possible to estimate the catch and value of these releases.

The cost of producing fish released from the 12 hatcheries was estimated from 1962 fiscal year costs at individual hatcheries. Costs were apportioned between the brood year-species groups at each hatchery on the basis of either estimated relative man-hours expended or relative size of each group. At each hatchery costs were divided into three categories:

1. Amortized and discounted capital investment
2. Fish food and drugs
3. Operational costs other than food

Capital investment in the hatcheries was amortized over 50 years and was charged a simple interest rate of 5 percent per annum,[14] which amounts to 7 percent of the total capital invest-

[12] Total estimates for LV–RM and RV–RM marks do not include the corresponding partial marks.

[13] Calculated by assuming that the variance of the estimate of the marked to unmarked ratio, (.1193)(0.7)=0.0835, in the catch is such that 2 times the standard deviation is equal to 0.0835.

[14] Amortization period and discount rate are from J. A. Crutchfield, Department of Economics, University of Washington, Seattle, Wash. (personal communication).

ment chargeable to each year's operation. This 7 percent was then apportioned among the broods and species present by using the percentage of time spent caring for each group of fish. Cost of fish food and drugs during the fiscal year was apportioned according to the pounds of each brood year-species group produced.[15] Operational cost other than food and drugs was apportioned the same as capital investment. This category includes personal services, travel, transportation of items, communication services, rents and utilities, other contractual services, equipment, supplies and materials, and administration.

Klickitat Hatchery is used as an example of the above procedure. Table 18 shows the estimated cost ($68,773) to produce the 1961-brood fall chinook salmon at Klickitat Hatchery.

TABLE 18.—*Costs in rearing salmon at Klickitat Hatchery for fiscal year 1962, by brood and species*

Brood and species	Authorized and discounted capital investment	Fish food and related items	Operational costs other than food	Total
1961 fall chinook	$23, 169. 30	$4, 959. 82	$40, 643. 85	$68, 772. 97
1960 coho	6, 360. 20	4, 046. 17	11, 157. 14	21, 563. 51
1961 coho	12, 266. 10	2, 871. 48	21, 517. 33	36, 654. 91
1960 spring chinook	908. 60	130. 52	1, 593. 88	2, 633. 00
1961 spring chinook	2, 725. 80	1, 044. 17	4, 781. 63	8, 551. 60
Total	45, 430. 00	13, 052. 16	79, 693. 83	138, 175. 99

Capital investment through 1962 fiscal year for Klickitat Hatchery was $649,000. Seven percent, or $45,430, of this total, was attributable to the 1962 fiscal year. Because an estimated 51 percent of the man-hours was expended in caring for fall chinook salmon during fiscal year 1962, $23,169.30 (0.51 x 45,430) was the portion of the capital investment cost assigned to the fall chinook.

Total cost for food and drugs during the year at Klickitat Hatchery was $13,052.16. As 38 percent of the total weight of fish produced was fall chinook salmon, an estimated $4,959.82 (.38 x 13,-052.16) of the food cost was assigned to them.

Total operational costs (other than food) were apportioned in the same manner as the capital investment. Hence, 51 percent or $40,643.85 of the year's operational cost ($79,693.83) was assigned to fall chinook salmon.

Adding these costs gives $68,772.97 as the estimated total cost in rearing the 1961-brood chinook salmon at Klickitat Hatchery. Following this procedure at each hatchery, we estimated the total cost in rearing the 1961-brood chinook salmon released at all hatcheries under study at $831,522.

To determine the benefit provided by the contribution of these hatchery releases to the commercial and sport fisheries, it is necessary to estimate their net economic value.

For commercially caught fish, the gross economic value was determined from estimated landings and average prices paid to fishermen in 1963–66. The standard benefit-cost technique would require the deduction of all associated costs, but on the basis of arguments similar to those presented by Crutchfield, Kral, and Phinney,[16] we assumed that the capacity of present commercial salmon fisheries in terms of vessels and gear is such that additional catches can be made with little increase in cost.

The above assumption is supported in part from an examination of recent catch and effort data for the Washington and British Columbia troll fisheries (table 19). The two fisheries accounted for over 90 percent of the estimated ocean commercial catch of hatchery fish. Beginning in 1958, the size (number of boats) of the troll fleet increased considerably. The increase was not accompanied, however, by a corresponding increase in the catch of chinook and coho salmon (target species of the troll fisheries). The average catch per boat for 1958–62 was 390–40 percent less than the average catch per boat of 650 for the preceding period (1952–57). Even with the increased catches during 1963–66, the average catch per boat (assuming the number of boats was at least as great as during 1958–62) was only about 550—again, considerably less than the 1952–57 level. It seems reasonably clear from these data that the catch capacity of the troll fleet of Washington and British Columbia is greater than their present success. Larger catches could, therefore, be made without investment in additional units of gear.

The assumption (excess fishing capacity) is also indicated for the Columbia River gill-net fishery, which together with the above two troll fisheries accounted for over 95 percent of the estimated com-

[15] Amount of food given to the various groups of fish at a hatchery is generally proportional to their weight.

[16] Crutchfield, James A., Kenneth B. Kral, and Lloyd A. Phinney. 1965. An economic evaluation of Washington State Department of Fisheries controlled natural-rearing program for coho salmon (*Oncorhynchus kisutch*). Wash. Dep. Fish., Res. Div. (U.S. Fish Wildl. Serv. contract #14–17–0007–246, Part II). 26 pp. [Processed.]

TABLE 19.—*Catch of chinook and coho salmon and number of boats in commercial troll fisheries of Washington and British Columbia, 1952–66*

Year	Catch of fish [1]	Boats [2]
	Millions	*Number*
1952	4.09	5979
1953	3.48	5410
1954	2.75	5240
1955	3.03	4560
1956	3.15	4277
1957	3.34	5061
1958	3.32	6606
1959	2.64	7511
1960	1.86	7390
1961	2.91	7654
1962	3.16	7115
1963	3.11	
1964	3.79	
1965	4.26	
1966	4.77	

[1] Washington State Department of Fisheries (1964) and International North Pacific Fisheries Commission (1952–66).
[2] Cleaver (1967): data are actually number of licenses sold.

mercial catch of hatchery chinook salmon of the 1961 brood. To conserve the chinook salmon resource, fishing seasons have been steadily shortened (Pulford, 1964). The length of the fishing season has been decreased from 272 days in 1936 to 101 days in 1960 and 80 days in 1966. It would seem, then, that the present fishery is capable of making additional catches without increasing the present number of fishing units.

We also assume that additional running expenses of vessels and labor costs—attributed to the contribution of these hatcheries to the salmon resource—are negligible for the present fisheries. This assumption is reasonable if one considers: (1) the estimated catch of hatchery fish (287,000 fish) is small compared to annual catches of salmon (e.g., Washington and British Columbia troll catches, table 19), and (2) crews of vessels engaged in fishing are effectively precluded from working at other occupations during closed fishing periods (Crutchfield et al.).[16]

Thus, the gross economic value to the commercial fisherman of additional catches of chinook salmon made possible by hatchery releases essentially constitutes a net benefit.

Estimation of net value for the catch of hatchery chinook salmon by sport fishermen was made from an assumed net value per fish of $8.87.[17] This value represents an estimate of the amount an angler is willing to pay for the right to fish. It was obtained by extrapolation from a 1962 survey of Oregon salmon-steelhead anglers reported upon by Brown, Singh, and Castle (1964).

Calculation of total net value ($1,917,003) of the commercial and sport catch of fall chinook salmon that originated from the hatcheries under study is shown in table 20. The benefit to cost ratio is obtained from the ratio $1,917,003/$831,522 and is estimated as 2.3 : 1.

This benefit to cost ratio applies, of course, only to chinook salmon at the study hatcheries. As indicated above for Klickitat Hatchery (table 18), other species of salmon (principally coho) are raised at these hatcheries. To fully use all production facilities, the hatchery complex is now managed on a multispecies basis. A more complete and meaningful benefit to cost analyses of the hatchery system must, therefore, await completion (1969) of the study of the contribution that hatchery-reared coho salmon make to the fisheries.

[17] U.S. Department of the Interior, Bureau of Commercial Fisheries, Division of Economics. 1966. An economic evaluation of Columbia River anadromous fish programs. 58 pp. [Processed.]

TABLE 20.—*Estimated value of the catch of fall chinook salmon of 1961 brood that were released from study hatcheries, by type of fishery*

Fishery	Age	Fish	Sample size	Average weight [1]		Total weight [1]		Value per unit catch [2]	Total value
		Number	*Number of fish*	*Lbs.*	*Kg.*	*Lbs.*	*Kg.*	*Dollars*	*Dollars*
Sport	All	43,985						[3] 8.870	390,147
Ocean commercial	2	43	27	4.00	1.81	172	78	.380	65
	3	115,755	2,040	8.45	3.83	978,130	443,689	.435	425,487
	4	37,441	538	15.29	6.94	572,473	259,653	.610	349,208
	5	4,797	56	18.71	8.49	89,752	40,712	.650	58,339
Columbia River commercial	2	1,942	22	6.11	2.77	11,866	5,381	.360	4,272
	3	32,349	870	17.98	8.16	581,635	263,838	.360	209,389
	4	48,275	1,135	26.10	11.84	1,259,978	571,528	.360	453,592
	5	2,739	57	28.13	12.76	77,048	34,950	.344	26,504
Total		287,326							1,917,003

[1] Weights for ocean commercial fisheries are dressed weights, and those for Columbia River fisheries are round weights. Original weights were in pounds for Ad–RM marked fish.
[2] Entries for commercial fisheries (dollars per pound) are based on prices paid for Washington State troll landings obtained from Dale Ward, Washington State Department of Fisheries (personal communication).
[3] See footnote 17 of text.

It must further be understood that hatchery methods have changed significantly since 1962. This change is reflected in the increased size of fish released from hatcheries. For example, the average weight of fall chinook salmon released from Columbia River hatcheries operated by Washington Department of Fisheries increased from 2.18 g. in 1962 to 3.89 g. in 1966.[18] It is likely, therefore, that survival of hatchery fish and, hence, the contribution of given numbers released has changed since 1962.

To estimate the value of the catch of 1961-brood fall chinook salmon from all Columbia River hatcheries, we must assume that the 3.86 million fish released from hatcheries not included in the study contributed to the fisheries in the same proportion as the fish released (53.65 million) from the hatcheries under study. On this basis the value of the catch of these releases would be:

$$137,832=\frac{(3.86)\ (1,917,003)}{(53.65)}$$

or about $138,000. The value of the catch of fish released from all hatcheries is then estimated as $2,055,000.

Because of the conservative nature of the estimate of survival of marked fish relative to unmarked fish, we believe that the estimated value of the catch of hatchery fish, as well as the benefit-cost estimate presented above, is minimal.

SUMMARY

1. During 4 years of marking at 12 hatcheries, 21.3 million fish (10 percent of the total production of 213 million) were marked with an adipose-maxillary mark. An additional 9.6 million were identified with special marks unique to a hatchery.

2. The 1961-brood release of 53.6 million fish included 5.4 million (10.1 percent of the total release) marked with a "common mark" (Ad–RM). Fish with marks unique to a hatchery were released from Elokomin, Kalama, Oxbow, and Spring Creek Hatcheries.

3. Auxiliary data collected suggested that the quality of marking and the permanence of marks (except possibly for the maxillary mark in the 1961 and 1962 broods) were reasonably satisfactory.

4. During the first 4 years of mark sampling (1963–66), an average of 23 percent of the chinook salmon catch was examined for marked fish.

5. Except for 1963, sampling for marked fish was conducted in most chinook fisheries from Monterey, Calif., northward to southeast Alaska. In 1963, sampling was limited to the Washington, Oregon, and Columbia River fisheries.

6. A total of 9,573 marked fish from the 1961 brood of possible Columbia River hatchery origin were recovered during the 4 years. The majority, 6,189, were recovered as age–3 fish in 1964.

7. Although marked fish were recovered in the ocean fisheries over the entire range of sampling, most were recovered from landings made north of the Columbia River mouth (Washington and west coast of Vancouver Island fisheries).

8. Marked fish that originated from Kalama Hatchery were the only ones (specific to a hatchery) recovered in the southeast Alaska fishery. In general, proportionately more of the Kalama fish were recovered in the northern parts of the sampling range than were the marked fish originating from Elokomin, Oxbow, or Spring Creek Hatcheries.

9. An estimated total of 21,600 marked (Ad–RM) fish that originated from the 12 study hatcheries were caught. An additional 3,400 escaped the fisheries and returned to spawn.

10. The estimated average catch to escapement ratio for the hatcheries under study was about 6:1. For marked fish from Elokomin, Kalama, Oxbow, and Spring Creek Hatcheries this ratio was 12:1, 9:1, 3:1, and 7:1, respectively.

11. The catch of Ad-RM marked fish from all 12 hatcheries in terms of the numbers released was 3.97 per 1,000 released. This quantity was 4.50 and 3.78 for Kalama and Spring Creek Hatcheries, respectively. The contribution per 1,000 released for Elokomin and Oxbow Hatcheries was at most only one-half that for Kalama and Spring Creek.

12. By assuming that marked and unmarked hatchery fish have the same ocean distribution and maturity schedules and that survival of marked fish was 70 percent of the survival of unmarked fish, we estimated that the total catch of hatchery fish (marked and unmarked) was 287,326.

13. The estimated catch, 287,326, of hatchery fish comprised about 10 percent of the total catch

[18] Harry Senn, Washington State Department of Fisheries (personal communication).

of 1961-brood chinook salmon in the fisheries sampled.

14. If survival of marked relative to unmarked fish was 60 or 100 percent rather than the assumed 70 percent, then the estimated catch of hatchery fish would have been 330,465 or 209,672, respectively. The latter value is considered too low: it is not likely that the survival of marked fish exceeded 70 percent of the survival of unmarked fish.

15. The estimated cost of rearing the fall chinook salmon of the 1961 brood released from the study hatcheries was $831,522. The estimated net value to the fishermen of the catch of these fish was $1,917,003. The benefit to cost ratio was, therefore, 2.3:1.

16. The estimated total value of the catch of fall chinook salmon of 1961 brood that originated from all Columbia River hatcheries (including five hatcheries not participating in the marking experiment) was $2,055,000.

17. We considered that the estimated catch of hatchery fish, and, therefore, the value and benefit-ratio, is minimum.

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Appendix Table 1.—*Estimated numbers of fall chinook salmon fingerlings of 1961 brood released from Columbia River hatcheries*

Hatchery	Fish released		Proportion of fish marked				Fish marked			
			Proportion		Standard deviation		Total		Standard deviation	
	Total	Standard deviation	Ad-RM	Special mark	Ad-RM	Special mark	Ad-RM	Special mark	Ad-RM	Special mark
	Number	*Number*					*Number*	*Number*	*Number*	*Number*
Grays River	893, 028	20, 240	0. 0951		0. 00310		84, 927		3, 370	
				(LV-RM)						
Elokomin	1, 575, 000	33, 888	. 0937	0. 3051	. 00232	0. 00366	147, 578	480, 533	4, 837	11, 838
				(Ad-RV-RM)						
Kalama	4, 906, 845	65, 737	. 1013	. 0970	. 00136	. 00133	497, 063	475, 964	9, 364	9, 165
Washougal	2, 314, 940	46, 983	. 0932		. 00191		215, 752		6, 219	
Little White Salmon	12, 077, 844	348, 596	. 1061		. 00280		1, 281, 459		50, 338	
				(Ad-LV-RM)						
Spring Creek	10, 925, 933	229, 319	. 1033	. 1037	. 00203	. 00203	1, 128, 649	1, 133, 019	32, 409	32, 659
Big White Salmon	3, 545, 865	133, 488	. 0947		. 00348		335, 793		17, 655	
Klickitat	3, 177, 958	133, 217	. 0891		. 00508		283, 153		20, 075	
				(RV-RM)						
Oxbow	4, 549, 959	76, 956	. 1034	. 0990	. 00137	. 00134	470, 466	450, 446	10, 100	9, 762
Cascade	4, 842, 554	81, 014	. 1015		. 00132		491, 519		10, 401	
Bonneville	3, 829, 617	71, 368	. 1054		. 00150		403, 642		9, 472	
Big Creek	1, 013, 671	26, 210	. 1050		. 00292		106, 435		4, 039	
Total	53, 653, 214	568, 071	. 1015		. 00088		5, 446, 439		74, 630	

Appendix Table 2.—*Estimated numbers of fall chinook salmon fingerlings of 1962 brood released from Columbia River hatcheries*

Hatchery	Fish released		Proportion of fish marked				Fish marked			
			Proportion		Standard deviation		Total		Standard deviation	
	Total	Standard deviation	Ad-LM	Special mark	Ad-LM	Special mark	Ad-LM	Special mark	Ad-LM	Special mark
	Number	*Number*		(LV-LM)			*Number*	*Number*	*Number*	*Number*
Grays River	1, 359, 761	27, 825	0. 0936	0. 1776	0. 00249	0. 00327	127, 274	241, 494	4, 273	6, 648
Elokomin	*2, 391, 219	61, 000	. 0934		. 00195		223, 340		7, 360	
				(Ad-RV-LM)						
Kalama	4, 599, 326	102, 405	. 0938	. 0952	. 00135	. 00136	431, 206	437, 669	11, 272	11, 632
Washougal	3, 315, 613	84, 648	. 0956		. 00161		316, 973		9, 687	
Little White Salmon	11, 588, 405	171, 575	. 1022		. 00088		1, 183, 865		20, 298	
				(Ad-LV-LM)						
Spring Creek	8, 408, 267	146, 575	. 1033	. 1031	. 00105	. 00105	868, 574	866, 892	17, 521	17, 496
Big White Salmon	3, 438, 295	55, 505	. 0993		. 00160		341, 554		7, 818	
Klickitat	2, 624, 470	35, 540	. 0889		. 00170		233, 315		5, 479	
Oxbow	4, 916, 873	76, 396	. 0951		. 00127		467, 595		9, 576	
				(RV-LM)						
Cascade	4, 217, 910	66, 149	. 1021	. 1283	. 00141	. 00156	430, 649	541, 158	9, 000	10, 735
Bonneville	4, 635, 279	73, 539	. 1139		. 00150		527, 958		10, 895	
Big Creek	974, 585	20, 996	. 0993		. 00290		96, 776		3, 513	
Willard **										
Total	52, 470, 003	366, 201	. 1000		. 00041		5, 249, 079		42, 532	

*Includes an estimated 169,000 fish not sampled at release. ** Included in the release for Little White Salmon.

Appendix Table 3.—*Estimated numbers of fall chinook salmon fingerlings of 1963 brood releasea from Columbia River hatcheries*

Hatchery	Fish released		Proportion of fish marked				Fish marked			
			Proportion		Standard deviation		Total		Standard deviation	
	Total	Standard deviation	Ad-RM	Special mark	Ad-RM	Special mark	Ad-RM	Special mark	Ad-RM	Special mark
	Number	*Number*					*Number*	*Number*	*Number*	*Number*
Grays River	1,576,680	20,798	0.1023	...	0.00234	...	161,294	...	4,263	...
Elokomin	2,383,919	31,374	.0912	...	.00181	...	217,413	...	5,179	...
				(Ad-RV-RM)						
Kalama	4,883,937	85,028	.0987	0.0934	.00133	0.00130	482,176	456,158	10,490	10,119
Washougal	3,157,696	38,786	.0953	...	.00160	...	300,928	...	6,268	...
Little White Salmon	11,915,503	186,493	.0936	...	.00084	...	1,115,614	...	20,208	...
				(Ad-LV-RM)						
Spring Creek	7,467,629	131,916	.1032	.1006	.00111	.00110	770,659	751,243	15,934	15,607
Big White Salmon	2,448,904	49,017	.0998	...	.00191	...	244,401	...	6,768	...
				(LV-RM)						
Klickitat	2,888,208	37,171	.0974	.1806	.00169	.00220	281,311	521,610	6,086	9,238
Oxbow	6,124,048	91,818	.1051	...	.00119	...	643,637	...	12,083	...
Cascade	5,734,238	75,382	.0991	...	.00122	...	568,091	...	10,228	...
Bonneville	9,545,463	141,289	.1059	...	.00095	...	1,010,865	...	17,515	...
				(RV-RM)						
Big Creek	1,985,838	28,781	.0957	.2920	.00208	.00322	190,075	579,967	4,987	10,545
Total	60,112,063	356,945	.0996	...	.00037	...	5,986,464	...	42,071	...

Appendix Table 4.—*Estimated numbers of fall chinook salmon fingerlings of 1964 brood released from Columbia River hatcheries*

Hatchery	Fish released		Proportion of fish marked				Fish marked			
			Proportion		Standard deviation		Total		Standard deviation	
	Total	Standard deviation	Ad-LM	Special mark	Ad-LM	Special mark	Ad-LM	Special mark	Ad-LM	Special mark
	Number	*Number*					*Number*	*Number*	*Number*	*Number*
Grays River	1,369,522	28,017	0.0938	...	0.00248	...	128,461	...	4,300	...
Elokomin	2,069,739	32,740	.0935	...	.00204	...	193,485	...	5,199	...
				(Ad-RV-LM)						
Kalama	3,496,560	67,730	.0993	0.0914	.00158	0.00152	347,248	319,412	8,691	8,215
Washougal	2,643,924	50,114	.1004	...	.00184	...	265,450	...	7,005	...
				(RV-LM)						
Little White Salmon	8,365,579	120,972	.0995	.0953	.00108	.00105	832,221	797,345	14,996	14,530
Spring Creek	6,554,455	86,840	.1031	.0917	.00122	.00116	675,493	600,953	11,999	10,921
Big White Salmon	2,007,409	32,925	.0874	...	.00208	...	175,448	...	5,072	...
Klickitat	2,935,065	54,478	.0934	...	.00172	...	274,135	...	7,174	...
Oxbow	1,290,497	17,367	.0949	...	.00248	...	122,516	...	3,599	...
Cascade	4,709,551	72,825	.1044	...	.00131	...	491,677	...	9,896	...
				(LV-LM)						
Bonneville	9,887,575	121,640	.1000	.0968	.00093	.00092	988,974	957,110	15,242	14,876
Big Creek	1,448,676	19,111	.0988	...	.00241	...	143,129	...	3,964	...
Total	46,778,552	258,073	.0992	...	.00044	...	4,638,237	...	32,729	...

Appendix Table 5.—*Marked and unmarked returns of fall chinook salmon of 1961 brood year to Columbia River hatcheries and tributary streams*

Recovery location	Group	Year of return			
		1963	1964	1965	1966
		Number of fish			
Hatcheries:					
Grays River	Unmarked	0	35	34	0
	Ad-RM	0	0	1	0
Big Creek	Unmarked	103	902	281	6
	Ad-RM	5	33	20	0
	Ad	1	2	3	0
	LV	0	0	1	0
Elokomin	Unmarked	11	414	8	0
	Ad-RM	0	3	0	0
	Ad	0	1	0	0
	LV-RM	2	2	0	0
	LV	0	7	0	0
Kalama	Unmarked	49	434	2,429	411
	Ad-RM	0	20	134	47
	Ad	0	2	2	0
	Ad-RV-RM	0	7	111	38
	Ad-LV-RM	0	0	0	1
Washougal	Unmarked	14	53	12	3
	Ad-RM	1	2	0	0
Bonneville	Unmarked	369	2,527	1,867	13
	Ad-RM	13	157	84	1
	Ad-	0	14	36	0
	Ad-LV	1	1	1	0
	Ad-RV	0	0	4	0
	LV-RM	0	1	1	0
	LV	0	0	1	0
	RV-RM	1	12	5	0
	RV	1	0	4	0
Little White Salmon	Unmarked	197	3,429	2,035	45
	Ad-RM	9	158	139	1
	Ad	1	45	41	0
	LV	0	0	1	0
	RV-RM	2	3	4	0
	RV	1	0	1	0
Cascade	Unmarked	156	2,010	1,078	38
	Ad-RM	5	117	64	1
	Ad	2	1	13	0
	Ad-LV-RM	2	8	0	0
	Ad-LV	0	1	0	0
	RV-RM	0	2	0	0
Spring Creek	Unmarked	922	10,374	2,849	32
	Ad-RM	57	641	190	6
	Ad	17	130	64	2
	Ad-LV-RM	38	353	119	1
	Ad-LV	4	45	22	1
	Ad-RV-RM	0	1	1	0
	LV-RM	0	1	0	0
	LV	0	0	2	0
	RV-RM	0	0	1	0
	RV	0	1	0	0
Oxbow	Unmarked	242	2,457	666	8
	Ad-RM	4	116	47	0
	Ad	3	16	8	0
	Ad-LV-RM	1	2	2	0
	Ad-LV	0	4	0	0
	LV	0	1	0	0
Hatcheries—Continued					
Oxbow	RV-RM	1	35	12	1
	RV	1	6	5	0
Big White Salmon	Unmarked	17	1,064	(*)	(*)
	Ad-RM	0	33	(*)	(*)
	Ad	0	4	(*)	(*)
	Ad-LV-RM	0	1	(*)	(*)
Klickitat	Unmarked	15	334	38	0
	Ad-RM	6	16	0	1
Toutle	Unmarked	(*)	956	1,289	107
Abernathy	Unmarked	(*)	1,797	661	0
	Ad-RM	(*)	1	0	0
	LV	(*)	2	2	0
Speelyai	Unmarked	(*)	1,202	2,084	0
	Ad-RM	(*)	4	0	0
	Ad-RV-RM	(*)	5	0	0
Tributary streams: [1]					
Big Creek	Unmarked	(*)	313	362	1
	Ad-RM	(*)	5	11	0
	Ad	(*)	0	2	0
	LV-RM	(*)	0	2	0
Kalama	Unmarked	(*)	6,330	2,884	120
	AD-RM	(*)	0	161	14
	Ad	(*)	45	7	0
	Ad-RV-RM	(*)	0	56	7
	Ad-RV	(*)	0	4	0
Little White Salmon	Unmarked	(*)	30	34	4
	Ad-RM	(*)	1	3	0
Big White Salmon	Unmarked	(*)	905	956	45
	Ad-RM	(*)	9	6	2
	Ad	(*)	1	0	0
	Ad-LV-RM	(*)	1	0	0
Klickitat	Unmarked	(*)	12,496	3,907	22
	Ad-RM	(*)	370	162	0
	Ad	(*)	22	0	0
	Ad-LV-RM	(*)	0	4	0
Plympton	Unmarked	(*)	333	172	1
	Ad-RM	(*)	8	4	0
	Ad	(*)	6	2	0
	LV-RM	(*)	5	0	0
Grays	Unmarked	(*)	87	36	0
	Ad-RM	(*)	0	2	0
Washougal	Unmarked	(*)	333	172	16
	Ad-RM	(*)	0	4	0
Wind	Unmarked	(*)	422	34	0
	Ad-RM	(*)	0	2	0
Lewis	Unmarked	(*)	643	160	1,835
	Ad-RM	(*)	0	0	5
	Ad-RV-RM	(*)	0	0	2
	Ad-RV	(*)	0	0	2
	LV	(*)	0	0	2
Elokomin	Unmarked	(*)	(*)	421	0

See footnotes at end of table.

*Not sampled

[1] Total return of marked fish for tributary stream estimated from mark recoveries.