

# BIOECONOMIC CONTRIBUTION OF COLUMBIA RIVER HATCHERY COHO SALMON, 1965 AND 1966 BROODS, TO THE PACIFIC SALMON FISHERIES

ROY J. WAHLE,<sup>1</sup> ROBERT R. VREELAND,<sup>1</sup> AND ROBERT H. LANDER<sup>2</sup>

## ABSTRACT

Marked coho salmon, *Oncorhynchus kisutch*, smolts of the 1965 and 1966 broods were released from 20 hatcheries on four sections of the Columbia River and tributaries. Commercial and sport fisheries in marine waters from Pelican, Alaska, to Avila Beach, Calif., and on the Columbia River were sampled during 1967-69 for marks.

The net value of the estimated total catch of hatchery fish was calculated after adjusting for the effects of marking. Also estimated for each brood were the total costs of rearing including amortized capital outlay. Total benefits of \$8.58 million for the 1965 brood and \$9.11 million for the 1966 brood were estimated as applicable to normal production years when no marking takes place. Corresponding costs were estimated as \$1.29 million for the 1965 brood and \$1.23 million for the 1966 brood. Estimated benefit/cost ratios for the 20 Columbia River coho salmon hatcheries, as operated under production regimes prevailing during the study, may prove useful in decisions affecting management policies. The ratios are 6.6/1 for the 1965 brood, 7.4/1 for the 1966 brood, and 7.0/1 for both broods combined.

Use of the Columbia River has expanded tremendously in the past 30 years through Federally financed and/or licensed water use projects. This expansion has depleted valuable stocks of Pacific salmon, *Oncorhynchus* spp., and steelhead trout, *Salmo gairdneri*, through the loss and deterioration of natural stream habitat. Therefore, mitigative measures—hatcheries, fish ladders, and spawning channels—to supplement the declining natural production of Columbia River salmon and steelhead trout have been Federally funded.

To counteract the severe loss of salmon and steelhead trout environment in the Columbia River basin, the U.S. Government began financing the Columbia River Development Program in 1949. The Program is a cooperative effort of the fish management agencies of the states of Oregon, Washington, and Idaho and the Federal

Government. The Columbia Fisheries Program Office, National Marine Fisheries Service, Portland, Oreg., administers the Program, which is designed to increase production of salmon and steelhead in the Columbia River. The Program's major thrust has been to improve the runs of salmon and steelhead by protecting and improving stream environment and by production of fish in hatcheries. The main accomplishment is the construction or modernization of 21 salmon and steelhead hatcheries on the lower Columbia River and tributaries.

There are two major reasons for the concentration of effort on salmon and steelhead trout. First, their life histories allow successful hatchery propagation. Second, these species are historically and economically important to the United States. Annual catches of Pacific salmon have ranked first or second for the past 3 decades in landed value of commercial finfishes to United States fishermen. Chinook salmon, *O. tshawytscha*, and coho salmon, *O. kisutch*, landings have accounted for 35% of the 6-yr average (1966-71) commercial value (\$70 million) for salmon—\$12.5 million for chinook and \$11.9

<sup>1</sup> Columbia River Fisheries Program Office, National Marine Fisheries Service, NOAA, 811 Northeast Oregon St., Portland, OR 97208.

<sup>2</sup> Northwest Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98102.

for coho (Lyles, 1968, 1969; National Marine Fisheries Service, 1971; Riley, 1970, 1971; Wheeland, 1972). In addition, the net economic value of marine and freshwater sport fishing for salmon in the U.S. in 1970 was estimated at \$77.7 million. This fishery was made up of 64% coho and 32% chinook.<sup>3</sup>

In 1950 five salmon hatcheries, representing the entire Columbia River production of hatchery coho salmon, released about 1 million juveniles typified by a short rearing period, poor nutrition, and low survival. In contrast, the number of hatcheries rearing coho increased to 20 by 1966-67, and annual releases averaged 20 million smolts. These salmon benefited from advances in fish culture, especially nutrition, applied during the early 1960's and were characteristically large and healthy with a high survival potential (Cleaver, 1969a).

In 1962 the Columbia Fisheries Program Office started a marking study to estimate the contribution of Columbia River hatchery-reared fall chinook salmon to the Pacific coast fisheries. In 1965 this study was expanded to include coho salmon. Accordingly, representative (10%) samples from all Columbia River hatcheries rearing 1965- and 1966-brood coho salmon were marked. Sampling for these marked coho took place from 1967 through 1969 in the sport and commercial fisheries from Alaska to California. A contribution study of this magnitude had never before been undertaken. The information to be gained from this study was critically needed to determine if increased Federal funding for Columbia River hatcheries was economically justified.

The objectives of this report are to (1) describe the design and operations of marking and release procedures, (2) estimate the contribution (catch) to Pacific salmon fisheries during 1967, 1968, and 1969 for the 1965-66 brood coho salmon hatchery releases, and (3) develop benefit/cost ratios for these two broods.

## BIOLOGICAL EVALUATION

### Experimental Design

Procedures were basically the same as

described by Worlund, Wahle, and Zimmer (1969) for the fall chinook salmon study but will be summarized here. The Columbia River was divided into four sections. These sections will be defined later. Releases of marked fish were intended to identify and estimate the catches from each section. Execution of the plan depended, as for the evaluation of fall chinook salmon hatcheries, on the cooperation of many people in the following agencies:

Alaska Department of Fish and Game  
 Fisheries Research Board of Canada  
 Washington Department of Fisheries  
 Fish Commission of Oregon  
 Oregon State Game Commission  
 California Department of Fish and Game  
 National Marine Fisheries Service  
 Bureau of Sport Fisheries and Wildlife

The basic plan was to mark the same proportion of juvenile coho salmon released at each hatchery and to sample for marks in commercial and sport fisheries. Total catches of fish from all hatcheries then could be estimated from (1) fractions of marked fish in each release, (2) numbers of each type of mark actually recovered, (3) fractions of the total catches sampled for marks by time and area in each fishery, and (4) information on any bias associated with application or detection of marks.

### Allocation of Marks

The 20 hatcheries involved in this study are distributed over much of the mainstem Columbia River accessible to anadromous fish (Figure 1). Klaskanine River Salmon Hatchery, the lowermost station, and Leavenworth National Fish Hatchery, the uppermost, are on tributaries about 25 km and 800 km (15 and 500 miles), respectively, above the Columbia River mouth. Some hatcheries (Bonneville, Cascade, OxBow, and Little White Salmon) are adjacent to the main Columbia River and release their fish almost directly into it. In contrast, fish released at the Toutle River station must travel 65 km (40 miles) to reach the Columbia River.

Four different marks were available (from the Pacific Marine Fisheries Commission) for the 1965 brood of coho salmon. The Columbia River was therefore divided into four sections—Lower River, Middle River, Upper River, and Uppermost River—and one mark was assigned to each (Table 1). The adipose-right maxillary

<sup>3</sup> George K. Tanonaka, 1972. A general comparison of the commercial and sport salmon fisheries of the United States, 1940-70. Natl. Mar. Fish. Serv., Northwest Fish. Center, Seattle, Wash. (Unpubl. manuscr.) 15 p., 7 tables, 4 fig., App. A-B.

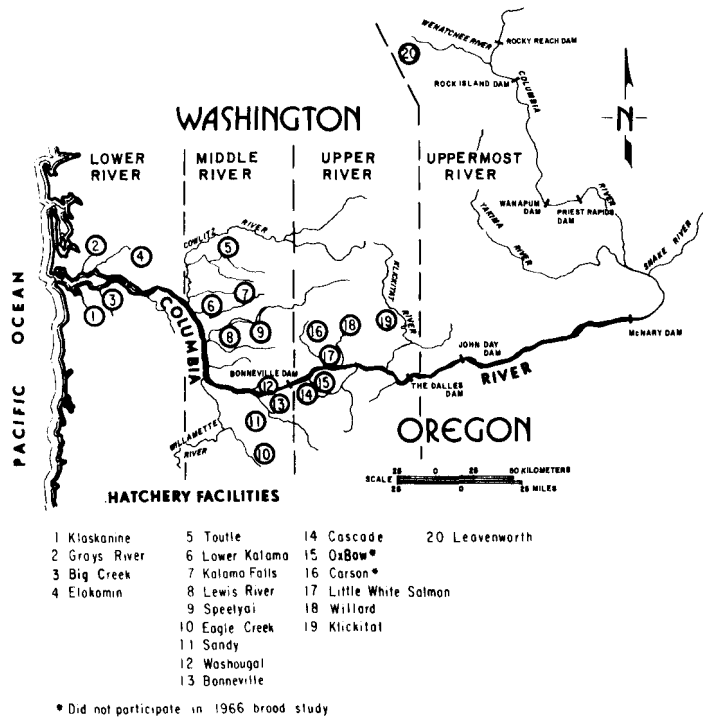


FIGURE 1.—Location and grouping by river section of Columbia River hatcheries participating in this study.

mark (Ad-RM) was used for hatcheries in the Lower River section—Columbia River mouth to Cowlitz River. The adipose-only finclip (Ad) was allotted to hatcheries in the Middle River section—the Cowlitz River to Bonneville Dam. Hatcheries in the Upper River section—Bonneville Dam to The Dalles Dam—were issued the adipose-left maxillary mark (Ad-LM). Leavenworth National Fish Hatchery, the only study hatchery in the Uppermost River section—above The Dalles Dam—was assigned the dorsal-adipose finclip (D-Ad).

The same marks were used for the 1966 brood with one exception; at Leavenworth National Fish Hatchery, maxillary marks were added to the D-Ad finclip. Juveniles with D-Ad-RM marks were released at the hatchery and those with D-Ad-LM were trucked downstream and released below Bonneville Dam. The purpose of the two marks and release sites was to examine differential mortality due to passage through dams; results will be treated in a subsequent report.

#### Sources of Variation and Error

To evaluate variations between broods and river sections, two broods (1965-66) of coho

salmon were included in the study, and each river section was allotted a specific mark. Mortality due to marking, the most important source of error, was evaluated by comparing marked/unmarked ratios in hatchery releases and returns. To evaluate the dilution effect of returning wild fish on the marked/unmarked ratio at study hatcheries, oxytetracycline (TM-50) was added to the diet of both broods of coho salmon reared at Big Creek (Ad-RM mark) and Eagle Creek (Ad finclip) hatcheries. Tetracycline deposits a permanent mark on the bone structure of feeding juvenile salmon and, at spawning, this mark is readily detected on coho vertebrae under ultraviolet light (Weber and Ridgway, 1967). Thus, wild coho were identifiable and were subtracted from the total unmarked returns to Big Creek and Eagle Creek hatcheries.

Marked fish were held at Klickitat State Salmon Hatchery to evaluate the degree of mark regeneration. Markers at all participating hatcheries were asked to record naturally missing fins and maxillary bones. Catch samplers were alerted to possible regeneration so they could look for malformed fins.

Rearing techniques at different hatcheries varied within as well as between river sections.

The limited number of marks available precluded individual hatchery comparisons as made from data of the fall chinook salmon study (Cleaver, 1969b; Worlund, Wahle, and Zimmer, 1969; Lander, 1970; Henry, 1971). The size of fish at release reflects partially the differences in rearing techniques. In both wild and hatchery salmon stocks, it is well known that large smolts survive better and contribute more to catches, other factors being reasonably equal, than do small smolts (Ricker, 1962; Fredin, 1964; Johnson, 1970). The average size of fish in releases varied considerably between hatcheries, somewhat between river sections, and slightly between broods. Again, the limited number of marks prevented evaluation of the effect of size at release on contribution, but average weights are included to complete the data record (Appendix Tables 1a and 1b).

### Estimating Procedures

Simple numerical examples explain the basic estimating procedures. A more formal account was reported in the chinook salmon study (Worlund, Wahle, and Zimmer, 1969).

The first quantities to be estimated were the numbers of marked and unmarked fish in hatchery releases. This was done with data from a 10-part sampler (see "Marking and Release Procedures"). The device was precalibrated from a number of trials with known numbers of fish to find the average number and percentage retained by a single closed pocket. The following example illustrates the fish enumeration procedure. Suppose a precalibrated pocket is found to remove a 10.1% sample. Also, suppose after passing all the fish in a pond through the sampler, the number of fish retained by the

TABLE 1.—Grouping of Columbia River hatcheries participating in study and type of mark assigned to each group.

River section and hatchery <sup>1/</sup>	Hatchery location	Mark <sup>2/</sup>
Lower River (Columbia River mouth to Cowlitz River)		
Klaskanine (FCO)	Klaskanine River	Ad-RM
Grays River (WDF)	Grays River	" "
Big Creek (FCO)	Big Creek, Columbia River	" "
Elokomin (WDF)	Elokomin River	" "
Middle River (Cowlitz River to Bonneville Dam)		
Toutle (WDF)	Green River, Toutle River	Ad only
Lower Kalama (WDF)	Hatchery Creek, Kalama River	" "
Kalama Falls (WDF)	Kalama River	" "
Lewis River (WDF)	Lewis River	" "
Speelyai (WDF)	Speelyai Creek, Lewis River	" "
Sandy (FCO)	Cedar Creek, Sandy River	" "
Eagle Creek (FCO)	Eagle Creek, Clackamas River	" "
Washougal (WDF)	Washougal River	" "
Bonneville (FCO)	Tanner Creek, Columbia River	" "
Upper River (Bonneville Dam to The Dalles Dam)		
Cascade (FCO)	Eagle Creek, Columbia River	Ad-LM
Oxbow (FCO)	Herman Creek, Columbia River	" "
Carson (BSFW)	Tyee Springs, Wind River	" "
Little White Salmon (BSFW)	Little White Salmon River	" "
Willard (BSFW)	Little White Salmon River	" "
Klickitat (WDF)	Klickitat River	" "
Uppermost River*(above The Dalles Dam)		
Leavenworth (BSFW)	Ice Creek, Wenatchee River	D-Ad D-Ad-LM D-Ad-RM

<sup>1/</sup> Acronyms designate the following agencies: FCO = Fish Commission of Oregon, WDF = Washington Department of Fisheries, and BSFW = Bureau of Sport Fisheries and Wildlife.

<sup>2/</sup> Ad = adipose finclip, D = dorsal finclip, LM = left maxillary bone clip, and RM = right maxillary clip.

closed pocket is found to be 6,060. The total number of fish in that pond is then estimated as  $6,060/0.101 = 60,000$ . Suppose further that of the 6,060 fish retained by the pocket, 606 fish are found to be marked. Then  $606/6,060 = 10\%$  of the estimated 60,000 fish in the pond, or 6,000 fish are estimated to be marked and 54,000 unmarked. The total release, numbers marked and unmarked, and proportion marked were estimated for a hatchery by summing data from all ponds. Finally, estimates of the foregoing quantities for all fish released into a given river section were obtained by summing the estimates for appropriate hatcheries.

To estimate actual recoveries with a certain mark during a specific sampling period in a given fishery, the total catch (of marked and unmarked fish) during that period was multiplied by the fraction of sampled fish observed with that mark during the same period. For example, 16 Ad-RM marks were detected during June 1-30, 1968, from 9,827 coho salmon examined at Crescent City, Calif., in a catch of 31,082 from the commercial troll fishery. Thus,  $16/9,827$  (approximately 0.2%) of the sample had Ad-RM marks. The total marked catch for that period and landing port was estimated to be about 0.2% of the 31,082 fish caught or 62 Ad-RM marks (actual calculations were carried to eight places to avoid rounding errors). Similar calculations were made for each period. The results then were summed for all periods and appropriate landing locations to estimate the seasonal recovery of a certain mark in the given fishery (e.g., Ad-RM marks in the California troll fishery during 1968).

The catch of unmarked hatchery fish for each ocean sport and commercial fishery, and the Columbia River fisheries, was estimated for each year and brood by dividing the estimated catch of fish having a specific mark by the expected marked/unmarked ratio. The latter was calculated from the ratio at release and the estimated relative survival of marked fish. Suppose an estimated 2,000 1965-brood Ad-RM marks were recovered in 1968 in the California ocean sport fishery, the marked/unmarked ratio was 0.1 for all hatcheries where Ad-RM marks were released, and the survival of marked fish was estimated to be 80% that of unmarked fish; then the estimated catch of unmarked fish would be  $(2,000)/(0.1 \times 0.80) = 25,000$  fish.

The catch of hatchery fish released from a given river section was estimated by summing estimates for marked and unmarked hatchery fish from each type of fishery. Nondetection of certain marks in ocean fisheries complicated the estimation of the hatchery contribution.

The relative survival of marked fish was estimated by comparing marked/unmarked ratios at release and return, as noted earlier for tetracycline (internal) and finclip (external) marking at the Big Creek and Eagle Creek stations. At the Big Creek station for the 1965 brood, for example, the pond sampling procedures just described gave an estimated marked/unmarked ratio at release of 0.12083 (for the Ad-RM finclip). Enumeration at the hatchery of all internally- and externally-marked returns ("jacks" or age 2 males in 1967 plus age 3 males and females in 1968) gave a marked/unmarked ratio of 0.09885. The survival of marked fish between the time of release and at return to the hatchery was therefore estimated to be  $0.09885/0.12083 = 0.8181$  that of unmarked fish.

With estimates of all these quantities at hand, it remained only to estimate the average weight and unit value of fish caught to calculate their total economic value. Weight data were collected from a predetermined number of fish throughout the season at different landing locations from which a given fishery operated. Resulting means were assumed to be representative.

### Assumptions

The foregoing method of estimating catches of hatchery fish requires certain assumptions. These are considered after presentation of the data (see "Bias Associated with Marks" and "SUMMARY"). The main assumptions are:

1. A marked fish is identifiable as a marked fish throughout life.
2. All fish detected and reported with the kind of mark applied are hatchery fish.
3. All coho salmon sampled in ocean fisheries are in their third and final year of life.
4. Marked and unmarked fish have the same maturity schedules.
5. The same proportion of releases is marked at each hatchery in a given river section.
6. Marked and unmarked fish from a given river section are equally vulnerable to capture

(i.e., have the same distribution by time and area).

## Field Operations

### Marking and Release Procedures

Artificial propagation procedures were similar at all coho salmon hatcheries during the study period. Adults normally returned to the hatcheries during September-November and were spawned during October-November. Fry generally reach the free-swimming stage in March. The fish were released as smolts 13 months later at an average length of 12-15 cm (4.5-6 inches) and were available during the following year to the fisheries from central British Columbia to central California.

The marking phase of this study began in May 1966 and ended in June 1967. About 10% of the 1965- and 1966-brood coho salmon were marked. A modified sampling tool (Worlund, Wahle, and Zimmer, 1969) was used to obtain a random sample for marking. The "10-part sampler" consisted of a cylindrical liner containing a circular metal frame divided into 10 equal pie-shaped sections with a zipper-bottomed net pocket hung from each section. When a 10% sample was to be taken, the zippers on all but one of the pockets were opened, the frame and liner were placed in a water-filled tub, and about 18 kg (40 pounds) of fish were placed into the liner. The closed net pocket retained the desired sample when the line and frame were lifted. The fish that passed through the open net pockets remained in the tub and were placed into another pond. This procedure was followed until all the coho in each pond were processed.

Fish to be marked were anesthetized with MS-222<sup>4</sup> (tricaine methanesulfonate). The fins and maxillary bones were clipped with bent-nosed scissors. Marked fish were held in hatchery troughs until they recovered from the anesthetic, then returned to the group from which they came. To insure that fins and maxillary bones were actually removed, quality control of marking was maintained by periodic random sampling of the marked fish throughout the marking operation.

<sup>4</sup> Reference to trade names in this publication does not imply endorsement of commercial products by the National Marine Fisheries Service.

The entire coho salmon production of each hatchery was sampled to estimate the proportion and numbers of marked fish released. The "10%" samples removed initially by the calibrated pocket were set aside then resampled to obtain a "1%" sample which was sorted into marked and unmarked groups, counted, and weighed. The counts together with an estimate of the proportion removed by the particular pocket of the sampler were used to estimate the numbers of marked and unmarked fish released.

In Table 2, the estimated numbers of marked and unmarked fish released and the percentages marked are summarized for each mark type and brood year. Detailed data for each hatchery are given in Appendix Tables 1a and 1b. Over 40 million coho salmon of both broods were released from the study hatcheries. The number of marked fish released by section for the 1965- and 1966-brood years combined were Lower River, 0.9 million; Middle River, 1.7 million; Upper River, 1.3 million; and Uppermost River, 0.2 million. A total of 39.1 million coho from both broods was released from the study hatcheries in the Lower, Middle, and Upper River sections. Of these, 9.8% were marked. About 0.9 million coho were released from the Uppermost River section, of which 21.1% were marked.

### Recovery of Marks in Fisheries

The mark-sampling phase of this study was designed in 1963 for fall chinook salmon and was expanded to include coho in 1967, 1 year before the 1965-brood coho were expected to appear in great numbers in the fishery. This advanced sampling was done for two reasons: (1) to locate the sampling problem areas and correct any deficiencies before the major appearance of the 1965-brood coho in the fisheries and (2) to assist the Washington Department of Fisheries in recovering their marked 1964-brood Puget Sound coho. This phase of the investigation ended in 1969. Catch sampling covered major ocean fisheries from Pelican, Alaska, southward to Avila Beach, Calif., and Columbia River fisheries. Sampling for marks in each area consisted of recording numbers of fish examined for marks and the recoveries of each type of mark detected. Lengths and weights of marked coho salmon from both broods were recorded also. The sampling sea-

TABLE 2.—Estimated numbers, percentage marked, and marked to unmarked ratios of 1965- and 1966-brood coho salmon released from evaluation hatcheries by river sections.

Brood year	River section and (in parentheses) mark	Marked released	Unmarked released	Total released	Proportion marked	Marked/unmarked
1965	Lower River (Ad-RM)	508,294	4,670,794	5,179,088	0.0981	0.1088
	Middle River (Ad)	845,674	7,895,360	8,741,034	0.0967	0.1071
	Upper River (Ad-LM)	837,829	7,670,539	8,508,368	0.0985	0.1092
	Uppermost River (D-Ad)	101,734	402,272	504,006	0.2018	0.2529
	Subtotal 1965 brood	2,293,531	20,638,965	22,932,496	0.1000	0.1111
1966	Lower River (Ad-RM)	385,630	3,569,807	3,955,437	0.0975	0.1080
	Middle River (Ad)	764,262	6,965,703	7,729,965	0.0989	0.1097
	Upper River (Ad-LM)	493,110	4,544,676	5,037,786	0.0979	0.1085
	Uppermost River (D-Ad-LM) <sup>1/</sup>	96,643	466	97,109	0.9952	207.3884
	Uppermost River (D-Ad-RM)	78,092	269,355	347,447	0.2248	0.2899
Subtotal 1966 brood	1,817,737	15,350,007	17,167,744	0.1059	0.1184	
TOTAL BOTH BROODS		4,111,268	35,988,972	40,100,240	0.1025	0.1142

<sup>1/</sup> Released below Bonneville Dam.

sons were stratified into relatively small time units (usually 2-wk periods).

The main fisheries sampled were ocean sport and commercial, Columbia River sport and commercial, and Puget Sound fisheries. The ocean fisheries were stratified further by port of landing. The Alaska and British Columbia troll, purse seine, and gillnet fisheries; Columbia River commercial and sport fisheries; and Puget Sound sport and commercial fisheries were stratified by area of catch. The specific fisheries sampled are listed in Table 3 and shown in Figure 2.

Catch data for each time-location stratum were provided by management agencies. The catch of coho salmon in numbers of fish was an estimate for most fisheries. Commercial catches were estimated either from (1) the total weight of landings and an estimate of average fish size or (2) total salmon landings (numbers) and an estimate of species composition. Estimates of sport catches were from measures of total effort and catch per unit of effort or from salmon punch cards together with independent sampling by the management agency.

About 20% of each time-location stratum was sampled for marks. Table 4 gives the annual

total catch of both broods of coho salmon by year and number sampled for marks each year. During the 3 years of sampling, 15.4% of the total catch of 21.1 million coho were examined for marks. The actual mark sampling percentages were 18.3, 13.5, and 14.3% for 1967, 1968, and 1969, respectively.

#### Enumeration of Returns to Hatcheries

An estimate of the numbers returning to hatcheries was required to measure the total hatchery output and marking mortality. All returns to most hatcheries were examined for marks; at some hatcheries, the numbers marked and unmarked were calculated after a known percentage of the total return was sampled for marks. A breakdown of the returns to each of the study hatcheries is in Appendix Tables 2a and 2b.

#### Estimation of Total Catch from Hatcheries

##### Actual Recoveries

Tables 5a and 5b summarize marked recoveries by brood year, mark, year of recovery,

TABLE 3.—Areas where catches were examined for marked coho 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
British Columbia.....	Alaska area, Zones 29, 40-43, and Area C.1/		Zones 29, 40-43		Zones 40-43
Washington ocean.....	Sekiu.....	Seattle.....	Grays Harbor.		
	Neah Bay.....	Neah Bay.....	Willapa Bay.		
	LaPush.....	LaPush.....			
	Westport.....	Westport.....			
	Ilwaco.....	Ilwaco.....			
Puget Sound and Juan de Fuca Strait....	Zones 6-12.....		Zones 1-15.....		Zones 1-12.
Oregon ocean.....	Warrenton.....	Astoria.			
	Tillamook.....	Tillamook.			
	Pacific City.....	Pacific City.			
	Depoe Bay.....	Depoe Bay.			
	Newport.....	Newport.			
	Florence.....	Florence.			
	Winchester Bay....	Winchester Bay.			
	Coos Bay.....	Coos Bay.			
	Gold Beach.....	Bandon.			
	Brookings.....	Port Orford.			
		Gold Beach.			
		Brookings.			
California ocean.....	Crescent City.....	Crescent City.			
	Trinidad.....	Trinidad.			
	Eureka.....	Eureka.			
	Shelter Cove.....	Fort Bragg.			
	Port Bragg.....	Albion.			
	Albion.....	Point Arena.			
	Bodega Bay.....	Bodega Bay.			
	San Francisco.....	Point Reyes.			
	Half Moon Bay.....	San Francisco.			
	Santa Cruz.....	Half Moon Bay.			
	Monterey.....	Moss Landing.			
	Morro Bay.....	Monterey.			
	Avila.....	Morro Bay.			
		Avila.			
Columbia River and tributaries.....	Zones 1-6.....		Zones 1-7.....		Klickitat River.
	Cowlitz River.				
	Kalama River.				
	Lewis River.				
	Toutle River.				
	Washougal River.				

1/ Canadian catch 3-12 miles off Washington, Oregon, and California.

river section of origin, and fishery. All marks from the Uppermost River section (Leavenworth Hatchery in Appendix Table 4) are combined as D-Ad marks in Table 5b. During the 3 years of sampling, 37,632 marked coho salmon were recovered. More marked 1965- than 1966-brood coho were caught, but more were released from the 1965 brood. Carson National Fish Hatchery and OxBow Salmon Hatchery, while participating in the study for the 1965 brood, did not do so for the 1966 brood (Table 2). The fraction of marked releases actually recovered for the 1965 brood, 0.0089, was slightly less than for the 1966 brood, 0.0093 (Tables 2, 5a, and 5b).

### Estimated Recoveries

As explained under "Estimating Procedures," the total catch of fish with a particular mark was estimated for each stratum (fishery, port of landing or area of capture, and time period) from actual mark recoveries and the sampling fraction. It was assumed that a random sample of coho salmon was examined in each stratum and that in each sample all the marked fish were inspected. The total catch for each mark in each fishery was estimated by summing over the time periods and appropriate ports of landing or areas of capture.

The estimated catches and hatchery returns



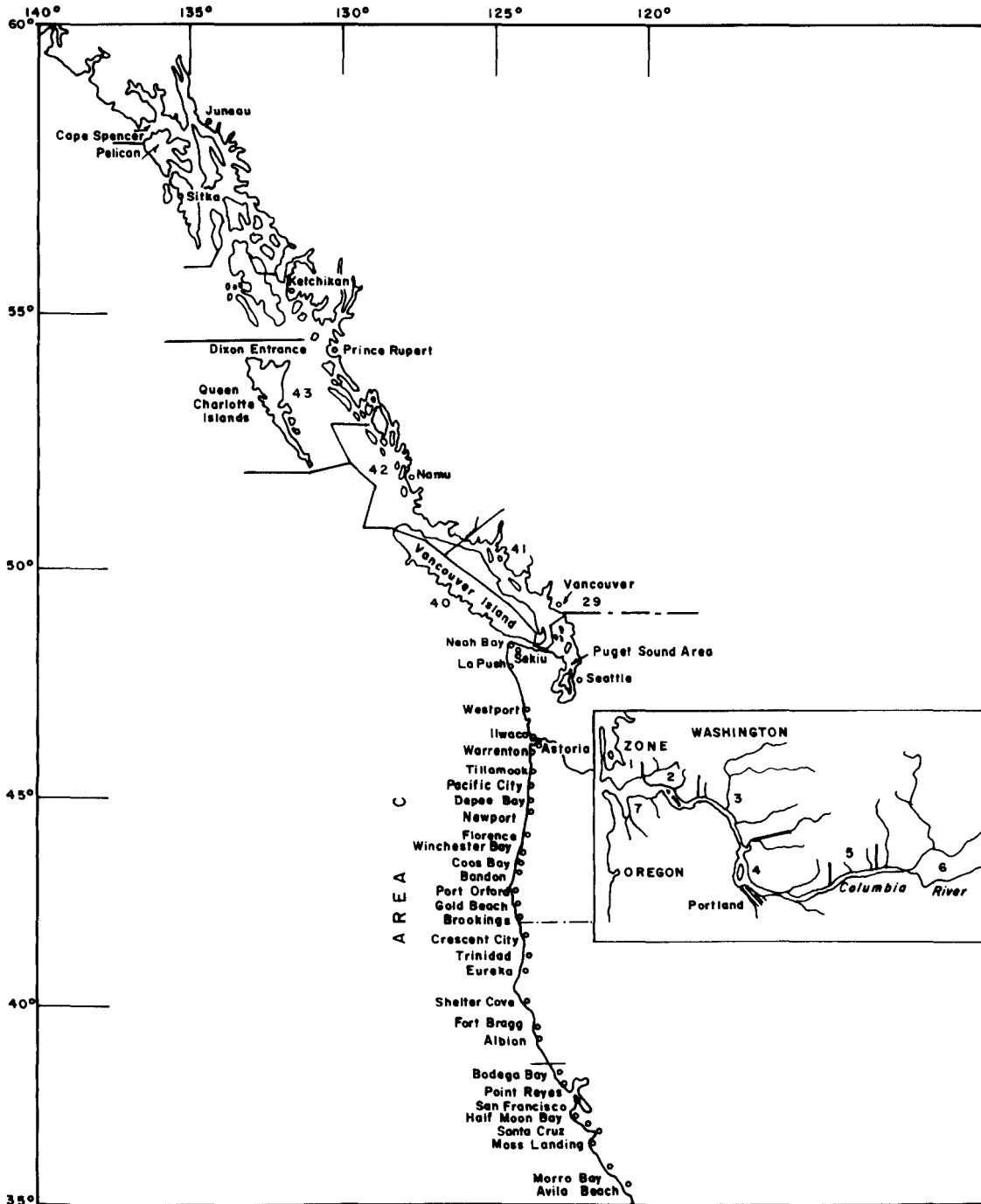


FIGURE 2.—Ports and zones sampled for marked coho salmon of Columbia River origin.

of marked fish are summarized in Tables 6a and 6b by region of recovery, fishery, brood year, and mark. The marks from the Uppermost River section (Appendix Table 5a) are combined in Table 6b. The total estimated catch of marked fish from both broods was 179,096. A total of 33,910 marked coho salmon returned to the study hatcheries during the 3 yr of sampling.

#### Bias Associated with Marks

To proceed from the estimated catch of marked fish to the total catch of hatchery fish, we must be sure that our assumptions (see "EXPERIMENTAL DESIGN") are satisfied. Some elements (e.g., loss of maxillary bones due to hooking, loss of fins due to injury) cannot be evaluated; others (e.g., mark regeneration, natural marks, relative survival of marked fish) can be appraised more adequately.

#### Mark Regeneration (Assumption 1) and Quality of Marking

We have three indications of the permanence of fin and maxillary marks. First, about 550 marked coho salmon of the 1966 brood were held for 2 yr at the Klickitat station for fin regeneration studies. We examined these fish periodically throughout the retention period and observed no adipose regeneration. However, we noted a 4.5% complete maxillary regeneration. Second, the appearance of D-Ad marks in the releases of the 1966-brood coho from Leavenworth National Fish Hatchery indicated maxillary regeneration; the maxillary bone was clipped from all 1966-brood Leavenworth coho marked, yet 5% of the marked coho released had

only a D-Ad finclip. During marking of the Leavenworth coho, 100 marked fish per marker were examined at irregular periods each day to check mark quality. No unclipped maxillaries were observed. This caused us to disregard failure to clip maxillaries as a reason for the appearance of the D-Ad marks. Therefore, we believe the D-Ad marks occurred mainly because of maxillary regeneration. Finally, the percentage of D-Ad-only marks in the 1969 lower Columbia River commercial catch of 1966-brood Leavenworth Hatchery marked fish was 6.5%. This is very close to the percentage of D-Ad-only marks in the release. Because of these indications, we are assuming that mark regeneration caused little bias in this study.

#### Natural Marks (Assumption 2)

The catch of hatchery fish would be overestimated if marks identical to those used in this study occurred naturally. To ensure that no natural marks existed in hatchery stocks, coho salmon returns at most Columbia River and some Puget Sound hatcheries were examined for 2 yr before the study. Approximately 35,000 returns were examined and no marks identical to those we planned to use were observed. Also, fish markers at all participating hatcheries examined approximately 3.5 million coho for naturally missing fins and maxillary bones. Only 26 were found to have naturally missing adipose fins and none had naturally missing dorsal fins or maxillary bones.

The possible occurrence of natural marks from other river systems is more difficult to evaluate. Comparisons of the percentage of each mark caught in the lower Columbia River

TABLE 4.—Estimated catches of coho salmon and number of fish examined for marks, 1967-69.<sup>1</sup>

Year	Catch of coho salmon			Sampled for marks
	1965 brood	1966 brood	All ages	
1967	22,946	0	7,539,255	1,381,255
1968	8,587,969	20,457	8,608,426	1,158,932
1969	0	4,933,706	4,966,589	710,753
Total	8,610,915	4,954,163	21,114,270	3,250,940

<sup>1</sup>/ From all areas sampled (Table 3).

## WAHLE, VREELAND, and LANDER: BIOECONOMIC CONTRIBUTION

TABLE 5a.—Number of marked 1965-brood Columbia River coho salmon by release section recovered in the fisheries by year, region of capture, and type of fishery, 1967-68.

River section and (in parentheses) mark	Year	California		Oregon		Washington (without Puget Sound)		Puget Sound		British Columbia	S. E. Alaska	Columbia River			TOTALS	
		Sport	Com- mer- cial	Sport	Com- mer- cial	Sport	Com- mer- cial	Sport	Com- mer- cial	Com- mer- cial	Com- mer- cial	Sport Commercial				
												Main	Trib.	Gill net		Dip net
Lower River (Ad-RM)	1967	0	0	0	0	0	0	0	0	0	0	1	0	15	0	16
	1968	101	491	135	1,049	212	401	0	5	72	*	0	3	107	5	2,581
Middle River (Ad)	1967	0	0	0	0	0	0	0	0	0	0	4	20	1	0	25
	1968	156	968	1,822	5,106	2,187	3,339	0	67	790	*	2	41	778	1	15,257
Upper River (Ad-LM)	1967	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1968	16	131	77	697	324	489	0	1	65	*	0	0	180	65	2,045
Uppermost River (D-Ad)	1967	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
	1968	6	23	52	194	119	144	0	0	9	*	0	0	67	0	614
TOTALS	1967	0	0	0	0	0	0	0	0	0	0	5	20	18	0	43
	1968	279	1,613	2,086	7,046	2,842	4,373	0	73	936	*	2	44	1,132	71	20,497

\*No sampling.

TABLE 5b.—Number of marked 1966-brood Columbia River coho salmon by release section recovered in the fisheries by year, region of capture, and type of fishery, 1968-69.

River section and (in parentheses) mark	Year	California		Oregon		Washington (without Puget Sound)		Puget Sound		British Columbia	S. E. Alaska	Columbia River			TOTALS	
		Sport	Com- mer- cial	Sport	Com- mer- cial	Sport	Com- mer- cial	Sport	Com- mer- cial	Com- mer- cial	Com- mer- cial	Sport Commercial				
												Main	Trib.	Gill net		Dip net
Lower River (Ad-RM)	1968	0	0	0	0	0	0	0	0	0	*	1	2	6	0	9
	1969	22	158	107	911	482	432	0	1	32	*	0	1	158	3	2,307
Middle River (Ad)	1968	0	0	0	0	0	0	0	0	0	*	17	34	12	0	63
	1969	191	905	1,578	4,479	2,120	1,865	2	15	312	*	1	33	759	18	12,278
Upper River (Ad-LM)	1968	0	0	0	0	0	0	0	0	0	*	2	1	6	16	25
	1969	14	102	86	662	525	356	0	1	9	*	0	1	233	53	2,042
Uppermost River (D-Ad)	1968	0	0	0	0	0	0	0	0	0	*	0	0	3	0	3
	1969	6	40	31	118	52	67	0	0	1	*	0	0	50	0	365
TOTALS	1968	0	0	0	0	0	0	0	0	0	*	20	37	27	16	100
	1969	233	1,205	1,802	6,170	3,179	2,720	2	17	354	*	1	35	1,200	74	16,992

\*No sampling.

commercial fishery with the percentage of each mark caught in each ocean fishery give an indication of the occurrence of natural marks. After making these comparisons, we noted a prepon-

derance of Ad-only marks especially in the Oregon sport fishery for the 1965 brood and the California sport and commercial fisheries for the 1966 brood. In these fisheries, we observed

TABLE 6a.—Estimated number of marked 1965-brood coho salmon in catches and hatchery returns by type of mark, region of recovery, type of fishery, and year of capture, 1967-68.

Region	Fishery type	D-Ad		Ad-LM		Ad		Ad-RM		Total	
		1967	1968	1967	1968	1967	1968	1967	1968	1967	1968
<b>Ocean fisheries:</b>											
British Columbia.....	Commercial...	0	46	0	459	0	6,339	0	581	0	7,425
Washington.....	Sport.....	0	677	0	1,809	0	11,490	0	1,206	0	15,182
	Commercial...	0	636	0	2,051	0	14,382	0	1,716	0	18,785
Oregon.....	Sport.....	0	226	0	265	0	7,944	0	420	0	8,855
	Commercial...	0	736	0	2,530	0	17,821	0	3,564	0	24,651
California.....	Sport.....	0	18	0	30	0	299	0	331	0	678
	Commercial...	0	109	0	789	0	5,554	0	2,617	0	9,069
Subtotal.....	Sport.....	0	921	0	2,104	0	19,733	0	1,957	0	24,715
	Commercial...	0	1,527	0	5,829	0	44,096	0	8,478	0	59,930
<b>Freshwater fisheries:</b>											
Columbia River.....	Sport.....	0	0	0	0	344	290	25	16	369	306
	Commercial...	7	238	0	846	2	4,907	130	825	139	6,816
Total.....	All fisheries	7	2,686	0	8,779	346	69,026	155	11,276	508	91,767
<b>Columbia River escapement:</b>											
Study hatcheries.....		38	138	1,125	1,882	4,391	9,399	1,568	1,864	7,122	13,283

TABLE 6b.—Estimated number of marked 1966-brood coho salmon in catches and hatchery returns by type of mark, region of recovery, type of fishery, and year of capture, 1968-69.

Region	Fishery type	D-Ad		Ad-LM		Ad		Ad-RM		Total	
		1968	1969	1968	1969	1968	1969	1968	1969	1968	1969
<b>Ocean fisheries:</b>											
British Columbia.....	Commercial...	0	7	0	77	0	2,970	0	278	0	3,332
Washington.....	Sport.....	0	242	0	2,333	0	9,324	0	2,178	0	14,077
	Commercial...	0	281	0	1,456	0	7,782	0	1,807	0	11,326
Oregon.....	Sport.....	0	148	0	392	0	7,304	0	492	0	8,336
	Commercial...	0	645	0	2,930	0	19,952	0	4,261	0	27,788
California.....	Sport.....	0	23	0	38	0	611	0	58	0	730
	Commercial...	0	224	0	465	0	6,024	0	728	0	7,441
Subtotal.....	Sport.....	0	413	0	2,763	0	17,239	0	2,728	0	23,143
	Commercial...	0	1,157	0	4,928	0	36,728	0	7,074	0	49,887
<b>Freshwater fisheries:</b>											
Columbia River.....	Sport.....	0	0	45	35	541	397	31	20	617	452
	Commercial...	6	283	58	2,470	125	8,104	57	1,619	246	12,476
Total.....	All fisheries	6	1,853	103	10,196	666	62,468	88	11,441	863	85,958
<b>Columbia River escapement:</b>											
Study hatcheries.....		8	0	624	1,075	2,191	5,769	2,067	1,771	4,890	8,615

samplers recording partially regenerated Ad-LM and Ad-RM as Ad-only marks. We attribute the preponderance of Ad-only marks in the above mentioned fisheries to the reluctance of samplers to distinguish between partially regenerated maxillaries and maxillaries lost through injury.

#### Age and Maturity Schedules (Assumptions 3 and 4)

Godfrey (1965) noted that ocean catches of coho salmon in the regions sampled in this study are all, or nearly all, age 3 adults. Johnson (1970) estimated that the ocean catch of

marked 1964-brood coho from Big Creek Hatchery (Figure 1) contained only 3% age 2 coho. This available evidence indicates that Assumption 3 (all coho in ocean fisheries are in their third and final year of life) is reasonably satisfied.

A comparison was made of marked and unmarked returns (Appendix Tables 2a and 2b) to hatcheries in the same river section where released to test Assumption 4 (marked and unmarked fish have the same maturity schedules). Appendix Table 3 shows the percent of 2-yr-old coho salmon in the marked and unmarked returns by river section and brood year. Unmarked strays to other river sections could not be identified by origin, so it was necessary to assume that straying was the same for marked and unmarked returns. The D-Ad comparison (Leavenworth Hatchery) was not made because passage difficulties at John Day Dam in 1969 led to no returns of adults to Leavenworth Hatchery. The nearly equal percentages of 2-yr-olds in the marked and unmarked returns by river section and brood year indicate that Assumption 4 is satisfied.

#### Marked Proportions at Release and Capture (Assumptions 5 and 6)

Inspection of mark proportion data in Appendix Tables 1a and 1b shows the variability between hatcheries to be small enough to consider Assumption 5 (same proportion of releases marked at each hatchery in a given river section) reasonably well satisfied. At present, no data exist to support Assumption 6 (equal vulnerability to capture for marked and unmarked fish from a given river section), but it is intuitively satisfied. Fish marked by clipping maxillary bones and/or the adipose fin would not seem to be more vulnerable to capture by fishing gear than unmarked fish.

#### Relative Survival of Marked Fish

Worlund, Wahle, and Zimmer (1969) found that marked fall chinook salmon did not survive as well as unmarked chinook. We also found this for coho salmon. To determine the unmarked catch of hatchery fish, we must account for the lower survival of marked fish. The relative survival values for both broods and each mark type of coho were calculated as explained

under "Estimating Procedures." Oxytetracycline (TM-50) was used to mark both broods of coho at Eagle Creek and Big Creek hatcheries to obtain survival values for Ad and Ad-RM marked coho, respectively. Returns to three hatcheries, Little White Salmon, Cascade, and Klaskanine, on streams having no wild spawning populations were used to obtain relative survival values for both broods of Ad-LM and Ad-RM marked coho. Finally, the marked to unmarked ratios at release and return for each river section were combined to obtain survival values for each mark type in both brood years.

The relative survival estimates are in Appendix Table 6. Marked coho salmon that strayed to sections other than where they were released (Appendix Tables 2a and 2b) were excluded from the marked returns in computing relative survival (see "Bias Associated with Marks"). Therefore, the median value for each of the mark types for both brood years combined was arbitrarily used to obtain reasonable approximations for relative survival. The same value was used for Ad-LM and Ad-RM marked coho. The median values for the Ad-only and Ad-maxillary marked coho were 89 and 72%, respectively.

The relative survival of D-Ad marked 1965-brood coho salmon from Leavenworth National Fish Hatchery (Uppermost section) was obtained from TM-50 marking data. In 1967 and 1968, a total of 174 D-Ad-TM-50 marked and 1,305 TM-50-only marked 1965-brood coho returned to Leavenworth. From these values, the marked to unmarked relative survival of 1965-brood D-Ad marked coho was calculated to be 53%. Few hatchery returns of 1966-brood Leavenworth coho were obtained because of passage difficulties at John Day Dam due to construction of fish ladders and mortalities caused by trapping at Priest Rapids Dam. Hence, a relative survival estimate for the D-Ad-RM and D-Ad-LM marks could not be calculated. The value for the D-Ad marked 1965-brood coho (53%) was therefore used to estimate the 1966-brood Leavenworth catch of unmarked fish.

#### Final Estimates Corrected for Marking

One marked fish represented about 9 unmarked ones at release but about 11-20 (depending on the mark) at return (Tables 2, 6a, and 6b). The foregoing estimates of relative survival for unmarked fish were applied (see "Estimating

Procedures") to estimate the catch of unmarked hatchery fish, then marked fish were added to estimate the total catch.

An additional calculation was required before estimating the unmarked catch associated with the marked 1966-brood Leavenworth Hatchery fish because of the recovery of 1966 brood D-Ad-only marks. The recovery was due to either regeneration or nondetection of D-Ad-maxillary marks (see "Bias Associated with Marks"). Therefore the estimated catch of 1966 brood D-Ad marks had to be apportioned between the estimated catches of D-Ad-RM and D-Ad-LM marks before calculating the catch of unmarked 1966-brood fish. The D-Ad marks were apportioned by the ratio of their occurrence at the time of release. At Leavenworth Hatchery, 5,081 D-Ad marks were estimated to have been released with the D-Ad-RM marks. Below Bonneville Dam, 4,393 D-Ad marks were estimated to have been released with the D-Ad-LM marks. This is a total release of 9,474 D-Ad marks of which 54% (5,081/9,474) came from D-Ad-RM marks and 46% (4,393/9,474) came from D-Ad-LM marks. These ratios were used to apportion the estimated catch of 666 D-Ad marks (Appendix Table 5a) between the D-Ad-RM and D-Ad-LM marked fish in each of the fisheries. For example, 88 D-Ad marked coho (Appendix Table 5a) were estimated to have been caught in the Washington sport fisheries in 1969. Using the occurrence percentages of the D-Ad marks at release,  $88 \times 0.54 = 48$  were calculated to be from D-Ad-RM marks and  $88 \times 0.46 = 40$  were calculated to be from D-Ad-LM marks. This apportioning was done for each fishery and results are in Appendix Table 4b.

The estimated catches of marked fish used to calculate the catches of unmarked hatchery fish are in (1) Table 6a for the estimated 1965 brood D-Ad, Ad-LM, Ad, and Ad-RM marks captured in the ocean and Columbia River fisheries; (2) Table 6b for the estimated ocean and Columbia River catches of 1966 brood Ad-LM, Ad, and Ad-RM marked fish; and (3) Appendix Table 5b for the catches of marked 1966-brood Leavenworth coho salmon. Appendix Table 7 presents the resulting estimated catches of unmarked hatchery fish.

The estimated total catch of Columbia River hatchery fish (Appendix Table 8) was obtained by adding the estimated catch of marked fish

(Tables 6a and 6b) to the estimated unmarked catches (Appendix Table 7). The resulting catch estimates may affect management decisions in years when no marking studies take place. Therefore, as a final step, we divided the estimated catch of each mark in each fishery (Tables 6a and 6b) by the estimated relative survival for that mark (see "Relative Survival of Marked Fish") to obtain a theoretical catch of marked fish assuming no marking mortality. The results were then added to the estimated unmarked catch (Appendix Table 7) to obtain a theoretical total catch of Columbia River hatchery coho salmon. The results are in Table 7 by region of recovery, type of fishery, and year of capture. The table includes the estimated sport catches of hatchery fish in Columbia River tributaries where no creel census took place. This is broken down in detail by year of capture, brood, and stream in Appendix Table 9.

An estimated total of 2,188,172 Columbia River hatchery coho would have been caught during the 3 years of sampling had no marking taken place. This is about 16% of the total catch in areas sampled (Table 3) of 1965- and 1966-brood coho caught during 1967-69 (Table 4)—13% for the 1965 brood and 21% for the 1966 brood. Another useful statistic is the catch/1,000 fish released. For the combined 1965 and 1966 broods, this was 55/1,000—50/1,000 for the 1965 brood and 61/1,000 for the 1966 brood (Tables 2 and 7).

## ECONOMIC EVALUATION

A main purpose of this paper is to develop benefit/cost ratios for the 1965 and 1966 broods of coho salmon from Columbia River hatcheries. To develop these ratios, estimates must be made of (1) the costs of rearing the 40.1 million smolts released (Table 2) and (2) the value of the theoretical catch of 2,188,172 coho (Table 7). The rearing costs will be presented first.

### Cost Accounting

Production costs are broken down into two categories: (1) amortized construction costs or capital costs and (2) operational costs.

#### Capital

The "annual imputed capital charge" for each hatchery was computed by amortizing the capital expenditures at each hatchery into 30 equal

TABLE 7.—Theoretical catch of 1965- and 1966-brood hatchery coho salmon by region of recovery, type of fishery, and year of capture, 1967-1969.<sup>1</sup>

Region	Fishery type	1965 brood			1966 brood		
		1967	1968	Total	1968	1969	Total
<b>Ocean fisheries:</b>							
British Columbia.....	Commercial...	0	88,755	88,755	0	38,824	38,824
Washington.....	Sport.....	0	182,372	182,372	0	171,035	171,035
	Commercial...	0	226,212	226,212	0	136,016	136,016
Oregon.....	Sport.....	0	104,063	104,063	0	96,371	96,371
	Commercial...	0	300,004	300,004	0	332,075	332,075
California.....	Sport.....	0	8,750	8,750	0	8,393	8,393
	Commercial...	0	113,700	113,700	0	86,573	86,573
Subtotal.....	Sport.....	0	295,185	295,185	0	275,799	275,799
	Commercial...	0	728,671	728,671	0	593,488	593,488
<b>Freshwater fisheries:</b>							
Columbia River.....	Sport.....	18,739	10,627	29,366	15,584	10,855	26,439
	Commercial...	1,929	82,831	84,760	3,087	151,377	154,464
Total.....	All fisheries	20,668	1,117,314	1,137,982	18,671	1,031,519	1,050,190

<sup>1/</sup> Corrected for differential finclip mortality and assuming no marking had taken place.

annual payments using an interest rate of 3.5%.<sup>5</sup> This rate was the average 3- to 5-yr government bond interest rate weighted by the total annual capital outlay at all hatcheries from 1949 (inception of Columbia River Development Program) through 1970. All outlays prior to this period are assumed to be depreciated out completely. The imputed capital charge for each study hatchery was apportioned among the broods and species present by using the percentage of time spent caring for each group of fish. The total annual imputed capital charges for the 1965- and 1966-brood coho salmon are \$271,600 and \$235,600, respectively.

### Operation

The operation and maintenance costs at each hatchery are divided into two categories. They are fish food and drugs and other operational costs. The cost of fish food and drugs is apportioned between each brood and species according to the pounds of each brood and species produced. The operational costs other than food and drugs include costs for labor, personal services, travel, transportation of items, communication services, equipment, supplies and materials, and administration. These costs are allocated to each brood and species in the same manner as the capital costs. The operational costs appor-

tioned to the 1965- and 1966-brood coho are \$1,020,700 and \$991,000, respectively. The total costs applicable to rearing the 1965- and 1966-brood coho are then \$1,292,300 and \$1,226,600, respectively.

### Benefits

To determine the benefit provided by hatchery releases of 1965- and 1966-brood coho salmon to the commercial and sport fisheries, an estimate of the net economic value to these fisheries must be made. Additional information is critically needed to improve the basis for estimating values for fishery resources; however, the values used in this report are based on the best information now available and the limitations of these values are discussed.

#### Commercial

Ex-vessel market prices have been used to represent estimated net values for commercially caught fish. There are two quite different reasons why this method can provide satisfactory estimates.

The Columbia River salmon production from hatcheries included in this study provide only a portion of the total salmon production. Use of the ex-vessel price in the standard benefit-cost technique would require the deduction of all associated costs. However, excess capacity typically exists in the fishing sector, so little or

<sup>5</sup> The "annual imputed capital charge" is the estimated cost of government funds over the life of the project.

no additional fishing effort would be needed to land the production from these hatcheries. While this provides an adequate reason to omit fishing costs for hatchery fish, this would not be true for total salmon production.

A stronger basis for omitting costs necessary to land fish and using the ex-vessel price, results from current fishery management policies. Regulated inefficiency has been used in salmon fisheries to prevent overharvest thus excluding efficient fishing methods. This process probably results in dissipation of at least 75% of potential net benefits and may be as high as 95% (Richards, 1969).<sup>6</sup> Since the market prices used result from normal market activities and thus represent the market value of the fish resource to users, this potential benefit could be realized if society elects to change management methods and reduce fishing costs.

Several inadequacies exist in the use of the ex-vessel price as a representation of the net value for commercially caught fish. The first inadequacy is that the ex-vessel market price fails to completely measure market value. Gear or supplies furnished by processors and bonuses paid are examples of values that are not included in estimated market values. A second inadequacy exists since ex-vessel values fail to completely measure potential production. For example, a large share of the catch is now taken on troll gear and many sublegal size fish are caught. In the removal from the gear and release of these sublegal fish, many sustain injuries that result in death or reduced growth. This wastage significantly reduces the total production from the resource to society. Also, estimated market values do not include other types of benefits. For example, ex-vessel prices may not always be determined in markets with adequate competition to indicate total benefits, resulting in a producer surplus (i.e., additional profits to fish buyers). Benefits due to employment and income generated for coastal communities and the regional and national economy are not included. Consumer surplus or benefits to consumers that are not included in market prices are also omitted.

These factors indicate that using the ex-vessel price for commercially caught fish is a reason-

able estimate of benefits that could be realized. If all factors were included, this could prove to be a quite conservative estimate of total benefits.

Tables 8a and 8b present the net value of commercially caught 1965- and 1966-brood coho salmon by ocean regions and Columbia River commercial fisheries. Two calculations were required to obtain the net value. The theoretical commercial catch was multiplied by the average Ad marked coho weight to obtain the total pounds of Columbia River coho caught by region. The total pounds were then multiplied by the average ex-vessel price paid in each region to obtain the net value of the coho catch to that region.

### Sport

The net value for salmon and steelhead sport fishing is estimated to be \$20 per day of fishing. This value results from reconciling the existing research that is closely related to estimated net economic values of Columbia River sport caught salmon. The maximum potential benefits from sport fishing at a single market price is predicted at \$20 per fishing day by Brown, Singh, and Richards (1972).<sup>7</sup> A single market price is intended to be comparable with typical conditions that underlie normal market price determination. The original data for this report were from a 1962 survey in Oregon with results published in 1964. The net value that resulted in maximum benefits was estimated at \$8 per day of fishing in the original analysis (Brown, Singh, and Castle, 1964). However, Brown and Nawas (in press) developed research techniques that more efficiently utilize available information. When these techniques were used in an analysis of the 1962 survey data, an estimated value of \$20 per day was derived. This is the estimated value used in this report.

Two other reports support the revised Oregon results. The estimated net economic value for the 1967 sport salmon fisheries of Washington resulted in a recommended value of \$28 per day of fishing (Mathews and Brown, 1970). An evaluation of the net economic values for the Idaho sport fisheries, based on a 1968 survey, resulted

<sup>6</sup> Jack A. Richards. 1969. An economic evaluation of Columbia River anadromous fish programs. U.S. Dep. Int., Fish Wildl. Serv., Bur. Commer. Fish., Working paper 17, 274 p. (Processed.)

<sup>7</sup> William G. Brown, Ashok K. Singh, and Jack A. Richards. 1972. Influence of improved estimating techniques on predicted net economic values for salmon and steelhead. (Oreg. State Univ., Corvallis), Agric. Exp. Stn. unpubl. manusc., 26 p. (Typescript.)



TABLE 8a.—Estimated value of the theoretical catch of 1965-brood coho salmon from Columbia River hatcheries.

Region	Fishery type	Age	Fish	Sample size	Average weight <sup>1/</sup>		Total weight		Value per unit catch <sup>2/ 3/</sup>		Total value
			Number	Number of fish	Lbs.	Kg.	Lbs.	Kg.	Dollars	Dollars	
Ocean fisheries:											
British Columbia.....	Commercial...	3	88,755	143	5.5	2.5	488,152	221,888	0.45		\$ 219,668
Washington.....	Sport.....	3	182,372	-----	-----	-----	-----	-----	15.82		2,885,125
	Commercial...	3	226,212	--5/	5.5	2.5	1,244,166	565,530	0.45		559,875
Oregon.....	Sport.....	3	104,063	-----	-----	-----	-----	-----	20.53		2,136,413
	Commercial...	3	300,004	386	5.6	2.5	1,680,022	750,010	0.45		756,010
California.....	Sport.....	3	8,750	-----	-----	-----	-----	-----	19.01		166,338
	Commercial...	3	113,700	272	6.3	2.9	716,310	329,730	0.45		322,340
Subtotal.....	Sport.....	3	295,185	-----	-----	-----	-----	-----	-----		5,187,876
	Commercial...	3	728,671	-----	-----	-----	4,128,650	1,867,158	-----		1,857,893
Freshwater fisheries:											
Columbia River.....	Sport.....	2	18,739	-----	-----	-----	-----	-----	42.02		787,412
		3	10,627	-----	-----	-----	-----	-----	46.51		494,262
Zones 1-5 & 7.....	Commercial...	2	1,883	--6/	3.0	1.4	5,649	2,636	0.26		1,469
		3	78,825	385	7.8	3.5	614,835	275,888	0.28		172,154
Indian fisheries <sup>4/</sup> .....	Commercial...	2	46	--6/	3.0	1.4	138	64	0.18		25
		3	4,006	--7/	7.8	3.5	31,247	14,021	0.24		7,499
Subtotal.....	Sport.....	2&3	29,366	-----	-----	-----	-----	-----	-----		1,281,674
	Commercial...	2&3	84,760	-----	-----	-----	651,869	292,609	-----		181,147
Total.....	All fisheries		1,137,982	-----	-----	-----	-----	-----	-----		8,508,590

- 1/ Weights for ocean commercial fisheries are dressed weights and those for Columbia River fisheries are round weights. Original weights are in pounds for Ad marked fish.
- 2/ Entries for Washington and Columbia River fisheries (dollars per pound) were obtained from Dale Ward, Washington State Department of Fisheries (personal communication). Washington price was used for British Columbia and Oregon commercial fisheries. Entry for California was obtained from Pat O'Brien, California Department of Fish and Game (personal communication).
- 3/ The value of a sport caught coho is based on a value of \$20.00 per angler day divided by the catch per angler.
- 4/ Columbia River set net and dip net fisheries and Klickitat River dip net fishery.
- 5/ No sampling for weight was done in the Washington commercial fisheries. Average weight obtained from Sam Wright, Washington Department of Fisheries (personal communication).
- 6/ Catches of Ad marked fish were too small to obtain an adequate sample for average weight. Average weight obtained from Paul Hirose, Fish Commission of Oregon (personal communication).
- 7/ Catches of Ad marked fish were too small to obtain an adequate sample for average weight. Average weight from zones 1-5 used.

TABLE 8b.—Estimated value of the theoretical catch of 1966-brood coho salmon from Columbia River hatcheries.

Region	Fishery type	Age	Fish	Sample size	Average weight <sup>1/</sup>		Total weight		Value per unit catch	Total value
				Number of fish	Lbs.	Kg.	Lbs.	Kg.	Dollars	Dollars
Ocean fisheries:										
British Columbia.....	Commercial...	3	38,824	100	5.8	2.6	225,179	100,942	0.48	\$ 108,086
Washington.....	Sport.....	3	171,035	-----	-----	-----	-----	-----	18.05	3,087,182
	Commercial...	3	136,016	--5/	6.2	2.8	843,299	380,845	0.48	404,784
Oregon.....	Sport.....	3	96,371	-----	-----	-----	-----	-----	24.94	2,403,493
	Commercial...	3	332,075	331	5.7	2.6	1,892,828	863,395	0.48	908,557
California.....	Sport.....	3	8,393	-----	-----	-----	-----	-----	19.92	167,189
	Commercial...	3	86,573	92	6.3	2.9	545,410	251,062	0.48	261,797
Subtotal.....	Sport.....	3	275,799	-----	-----	-----	-----	-----	-----	5,657,864
	Commercial...	3	593,488	-----	-----	-----	3,506,716	1,596,244	-----	1,683,224
Freshwater fisheries:										
Columbia River.....	Sport.....	2	15,584	-----	-----	-----	-----	-----	46.51	724,812
		3	10,855	-----	-----	-----	-----	-----	49.63	538,734
Zones 1-5 & 7.....	Commercial...	2	2,580	--6/	3.6	1.6	9,288	4,128	0.28	2,601
		3	145,242	329	8.7	4.0	1,263,605	580,968	0.35	442,262
Indian fisheries <sup>4/</sup> .....	Commercial...	2	508	--6/	3.6	1.6	1,829	813	0.24	439
		3	6,134	--7/	8.7	4.0	53,366	24,536	0.29	15,476
Subtotal.....	Sport.....	2&3	26,439	-----	-----	-----	-----	-----	-----	1,263,546
	Commercial...	2&3	154,464	-----	-----	-----	1,328,088	610,445	-----	460,778
Total.....	All fisheries		1,050,190	-----	-----	-----	-----	-----	-----	9,065,579

1/ Weights for ocean commercial fisheries are dressed weights and those for Columbia River fisheries are round weights. Original weights are in pounds for Ad marked fish.

2/ Entries for Washington and Columbia River fisheries (dollars per pound) were obtained from Dale Ward, Washington State Department of Fisheries (personal communication). Washington price was used for British Columbia and Oregon commercial fisheries. Entry for California was obtained from Pat O'Brien, California Department of Fish and Game (personal communication).

3/ The value of a sport caught coho is based on a value of \$20.00 per angler day divided by the catch per angler.

4/ Columbia River set net and dip net fisheries and Klickitat River dip net fishery.

5/ No sampling for weight was done in the Washington commercial fisheries. Average weight obtained from Sam Wright, Washington Department of Fisheries (personal communication).

6/ Catches of Ad marked fish were too small to obtain an adequate sample for average weight. Average weight obtained from Paul Hirose, Fish Commission of Oregon (personal communication).

7/ Catches of Ad marked fish were too small to obtain an adequate sample for average weight. Average weight from zones 1-5 used.

in estimates comparable to those originally reported for the 1962 Oregon survey (Gordon, n.d.).<sup>8</sup>

The value of \$20 per day is believed to be a reasonable estimate based on existing research information. However, limitations associated with this estimated value should be recognized. A range of values is needed for sport-caught fish that reflect differences in quality variables such as distance from metropolitan areas, environmental conditions, species involved, and success level. The reports mentioned here not only indicate an average value for these different variables but involve different time periods, geographic areas, and research methods. This is also an estimated market value and does not include other values such as consumer surplus (i.e., benefits to consumers that are not measured by market prices), benefits due to employment and income generated in local communities and the regional and national economy, and benefits to nonusers who may not fish but may want fishing preserved and available.

Since the value per fishing day is an average of various quality factors, no values by species are estimated directly. The only method presently available to determine values for fish is by success levels. This requires careful interpretations; for example, greater success results in lower values per fish. This means that higher total values would result with poorer success since the number of fish involved at the estimated market price is not fully taken into account. For this report, success is assumed to be estimated at an average of the total landings of all species. This is probably reasonable since mostly ocean fishing and entire seasons are involved.

Limitations of estimated sport and commercial values need to be emphasized. The estimated market price of \$20 per fishing day excludes consumer surplus whereas the estimated number of fishing days does not. Consequently, multiplying market prices by actual participation is not comparable with the ex-vessel prices used for values of commercially caught fish since these values do not contain consumer surplus. Therefore extreme caution should be observed in comparing values between fish species or total values of sport and commercial fishing.

To obtain values for the 1965- and 1966-brood sport-caught coho salmon, the estimated market value of \$20 per day of fishing is divided by the success level in each region. This value per fish is then multiplied by the number of coho taken in each region. The results are presented in Tables 8a and 8b.

### Benefit/Cost

The total net economic values of the 1965- and 1966-brood coho salmon were \$8,508,590 and \$9,065,579, respectively. Benefits were also derived from the sale of excess 1965- and 1966-brood coho carcasses at the study hatcheries. The revenue from carcass sales is used to purchase additional fish food. This allows additional fish to be reared, thus providing future benefits to society.

Coho carcasses were sold at Fish Commission of Oregon and Washington Department of Fisheries hatcheries. The values of the 1965- and 1966-brood coho carcasses sold are \$75,035 and \$40,973, respectively. When these values are added to the net economic values, total benefits of \$8,583,625 for the 1965 brood and \$9,106,552 for the 1966 brood are obtained. The benefit to cost ratios are then \$8,583,625/\$1,292,300 or 6.6/1 and \$9,106,552/\$1,226,600 or 7.4/1 for the 1965 and 1966 broods, respectively. The average benefit to cost ratio is 7.0/1.

### SUMMARY

When this marking study was designed, four marks were available from the Pacific Marine Fisheries Commission. The Columbia River was divided into four sections. Each section was assigned a specific mark. All study hatcheries within a given section (except Leavenworth station in the Uppermost River section) marked approximately 10% of their coho salmon production with the assigned mark (Table 2). Two broods, 1965 and 1966, of coho salmon were included in the study. During the 2-year marking phase, 4.1 million of the 40.1 million total coho production were marked (Table 2). Approximately 22.9 million 1965-brood and 17.2 million 1966-brood coho were released (Table 2).

Sampling for marks was conducted in most coho salmon fisheries, with few exceptions, from Avila Beach, Calif., to Pelican, Alaska (Figure

<sup>8</sup> Douglas Gordon. (n.d.). An economic analysis of Idaho sport fisheries. Univ. Idaho, Coll. Forestry, Wildl. and Range Sci., Idaho Coop. Fish. Unit., Review draft, 60 p. (Processed.)

2 and Table 3). During 1968 and 1969, there was no sampling done in the southeast Alaska troll and gillnet fisheries. During the 3 yr of mark sampling, an average of 15.4% of the coho catch was examined for marks (Table 4). A total of 37,632 marked coho was recovered from 1967 through 1969 (Tables 5a and 5b).

The appropriateness of the estimating procedures used to determine hatchery contribution is dependent on the validity of six assumptions. Additional studies and data collections previously described were incorporated into the marking experiment to help test the assumptions. The first assumption, permanence of fin marks, was tested by holding marked fish in fresh water over a period of months. Little total regeneration occurred, but maxillary regeneration caused confusion between maxillary-adipose and adipose-only marked coho salmon. The second assumption, origin of fish marked with hatchery marks, was tested by examining returning adult coho prior to the marking study and coho fingerlings at the time of marking for natural marks. No noteworthy numbers of naturally missing adipose fins or maxillary bones were observed. Prior to this study, a number of age studies have supported that Assumption 3, all adult coho are 3 yr old, is valid (Godfrey, 1965). The mark sampling data (Appendix Tables 2a and 2b) indicate that the fourth assumption, same maturity schedule for marked and unmarked fish, is valid. Appendix Tables 1a and 1b show the validity of Assumption 5, hatcheries in a given section have the same proportion of marked releases. Assumption 6, equality of ocean distribution could not be tested because regeneration and nondetection of maxillary marks distorted the picture.

A total of 179,096 marked 1965- and 1966-brood coho salmon were estimated to have been caught. An additional 33,910 marked coho returned to study hatcheries to spawn (Tables 6a and 6b). The theoretical estimated catch assuming no marking had taken place was 2,188,172 coho and comprised about 16.1% of the total catch of 1965-66 brood coho in the fisheries sampled (Table 7).

The estimated costs of rearing the 1965 and 1966 broods of coho salmon are \$1,292,300 and \$1,226,600, respectively. The estimated benefits, including carcass sales, received from the harvest of these two broods of coho are \$8,583,625

and \$9,106,552, respectively. The benefit to cost ratios are then 6.6 to 1 for the 1965 brood and 7.4 to 1 for the 1966 brood.

## ACKNOWLEDGMENTS

Many agencies and individuals assisted in planning and implementing the hatchery evaluation study. The Canadian Government financed and conducted a program of mark sampling in the British Columbia fisheries. The State agencies provided research and management personnel and necessary catch data. Donald D. Worlund, National Marine Fisheries Service, developed the design of this study and was the primary mathematical consultant. Jack Richards, National Marine Fisheries Service, developed the justification for the sport and commercial economic evaluation. Robert C. Lewis, Fish Commission of Oregon, improved the method of amortizing hatchery construction costs. Harold Godfrey, Fisheries Research Board of Canada; Gary Finger, Alaska Department of Fish and Game; Emanuel A. LeMier, Samuel G. Wright, and Harry Senn, Washington Department of Fisheries; Fred E. Locke, Oregon Game Commission; Ernest R. Jeffries, Earl F. Pulford, and Roy E. Sams, Fish Commission of Oregon; Paul T. Jensen, L. B. Boydston, and William H. Sholes, California Fish and Game Department; Harlan E. Johnson and Warner G. Taylor, Bureau of Sport Fisheries and Wildlife; Arthur H. Arp, Dean A. Eggert, Steven K. Olhausen, William D. Parente, Joe H. Rose, and Paul D. Zimmer, National Marine Fisheries Service; and many members of their respective agencies gave their time and effort. Helpful editorial comments were contributed by Frederick Cleaver, George M. Kaydas, Richard T. Pressey, John I. Hodges, Kenneth Henry, Roger Pearson, and Paul Macy, National Marine Fisheries Service; and William G. Brown, Oregon State University.

## LITERATURE CITED

- BROWN, W. G., AND F. NAWAS.  
In press. Effect of aggregation upon the estimation and specification of outdoor recreation demand function. *Western Agric. Econ. Assoc., Annu. Proc.*
- BROWN, W. G., A. SINGH, AND E. N. CASTLE.  
1964. An economic evaluation of the Oregon salmon and steelhead sport fishery. *Oreg. State Univ., Agric. Exp. Stn., Tech. Bull.* 78, 47 p.

- CLEAVER, F.  
 1969a. Recent advances in artificial culture of salmon and steelhead trout of the Columbia River. U.S. Fish Wildl. Serv., Fish. Leaflet. 623, 5 p.  
 1969b. Effects of ocean fishing on 1961-brood fall chinook salmon from Columbia River hatcheries. Fish Comm. Oreg., Res. Rep. 1(1):1-76.
- FREDIN, R. A.  
 1964. Ocean mortality and maturity schedules of Karluk River sockeye salmon and some comparisons of marine growth and mortality rates. U.S. Fish Wildl. Serv., Fish. Bull. 63:551-574.
- GODFREY, H.  
 1965. Salmon of the North Pacific Ocean—Part IX. Coho, chinook and masu salmon in offshore waters. 1. coho salmon in offshore waters. Int. North Pac. Fish. Comm., Bull. 16:1-39.
- HENRY, K. A.  
 1971. Estimates of maturation and ocean mortality for Columbia River hatchery fall chinook salmon and the effect of no ocean fishing on yield. Fish. Comm. Oreg., Res. Rep. 3:13-27.
- JOHNSON, A. K.  
 1970. The effect of size at release on the contribution of 1964-brood Big Creek Hatchery coho salmon to the Pacific coast sport and commercial fisheries. Fish Comm. Oreg., Res. Rep. 2(1):64-76.
- LANDER, R. H.  
 1970. Distribution in marine fisheries of marked chinook salmon from the Columbia River Hatchery Program, 1963-66. Fish Comm. Oreg., Res. Rep. 2(1):28-55.
- LYLES, C. H.  
 1968. Fisheries statistics of the United States, 1966. U.S. Fish Wildl. Serv., Stat. Dig. 60, 676 p.  
 1969. Fisheries statistics of the United States, 1967. U.S. Fish Wildl. Serv., Stat. Dig. 61, 486 p.
- MATHEWS, S. B., AND G. S. BROWN.  
 1970. Economic evaluation of the 1967 sport salmon fisheries of Washington. Wash. Dep. Fish., Tech. Rep. 2, 19 p.
- NATIONAL MARINE FISHERIES SERVICE.  
 1971. Fisheries statistics of the United States 1968. Stat. Dig. 62, 576 p.
- RICKER, W. E.  
 1962. Comparison of ocean growth and mortality of sockeye salmon during their last two years. J. Fish. Res. Board Can. 19:531-560.
- RILEY, F.  
 1970. Fisheries of the United States . . . 1969. U.S. Fish Wildl. Serv., Curr. Fish. Stat. 5300, 87 p.  
 1971. Fisheries of the United States, 1970. U.S. Dep. Commer., Natl. Ocean. Atmos. Admin., Natl. Mar. Fish. Serv., Curr. Fish. Stat. 5600, 79 p.
- WEBER, D., AND G. J. RIDGWAY.  
 1967. Marking Pacific salmon with tetracycline antibiotics. J. Fish. Res. Board Can. 24:849-865.
- WHEELAND, H. A.  
 1972. Fisheries of the United States, 1971. U.S. Dep. Commer., Natl. Ocean. Atmos. Admin., Natl. Mar. Fish. Serv., Curr. Fish. Stat. 5900, 101 p.
- WORLUND, D. D., R. J. WAHLE, AND P. D. ZIMMER.  
 1969. Contribution of Columbia River hatcheries to harvest of fall chinook salmon (*Oncorhynchus tshawytscha*). U.S. Fish Wildl. Serv., Fish. Bull. 67:361-391.

APPENDIX TABLE 1a.—Estimated numbers, percent marked, and mean weights of 1965-brood coho salmon released from study hatcheries.

Hatchery group and (in parentheses) mark	Number of fish			Percent marked	Mean weight <sup>1/</sup>
	Marked	Unmarked	Total		
Lower River (Ad-RM)					
Elokomin	118,137	1,170,725	1,288,862	0.0917	14
Big Creek	164,759	1,363,618	1,528,377	0.1078	29
Grays River	106,986	946,441	1,053,427	0.1016	23
Klaskanine	118,412	1,190,010	1,308,422	0.0905	33
Total Ad-RM	508,294	4,670,794	5,179,088	0.0981	25
Middle River (Ad)					
Bonneville	81,402	786,425	867,827	0.0938	22
Washougal	245,489	2,152,336	2,397,825	0.1024	24
Sandy	85,871	868,250	954,121	0.0900	27
Eagle Creek <sup>2/</sup>	69,988	610,113	680,101	0.1029	16
Lewis <sup>3/</sup>	65,453	649,490	714,943	0.0915	28
Kalama Falls	148,242	1,434,022	1,582,264	0.0937	27
Lower Kalama	37,069	315,463	352,532	0.1052	27
Toutle	112,160	1,079,261	1,191,421	0.0941	25
Total Ad	845,674	7,895,360	8,741,034	0.0967	19
Upper River (Ad-LM)					
Klickitat	146,123	1,365,134	1,511,257	0.0967	16
Little White Salmon <sup>4/</sup>	357,407	3,290,348	3,647,755	0.0980	15
Willard	--	--	--	--	19
Carson	158,868	1,477,931	1,636,799	0.0971	15
OxBow <sup>2/</sup>	47,578	424,892	472,470	0.1007	29
Cascade	127,853	1,112,234	1,240,087	0.1031	26
Total Ad-LM	837,829	7,670,539	8,508,368	0.0985	19
Uppermost River (D-Ad)					
Leavenworth	101,734	402,272	504,006	0.2018	25
<hr/>					
TOTAL ALL HATCHERIES	2,293,531	20,638,965	22,932,496	0.1000	--

<sup>1/</sup> Mean weights in grams per fish. Values in total lines are averages weighted by total release at each hatchery in that river section.

<sup>2/</sup> Additional 70,198 fish released with LM mark.

<sup>3/</sup> Includes release from Speelyal hatchery.

<sup>4/</sup> Includes release from Willard hatchery.

<sup>5/</sup> Released from Bonneville hatchery.

## WAHLE, VREELAND, and LANDER: BIOECONOMIC CONTRIBUTION

APPENDIX TABLE 1b.—Estimated numbers, percent marked, and mean weights of 1966-brood coho salmon released from study hatcheries.

Hatchery group and (in parentheses) mark	Number of fish			Percent marked	Mean weight <sup>1/</sup>
	Marked	Unmarked	Total		
Lower River (Ad-RM)					
Elokomin	85,319	761,349	846,668	0.1008	28
Big Creek	122,552	1,159,780	1,282,332	0.0956	23
Grays River	60,852	530,173	591,025	0.1030	27
Klaskanine	116,907	1,118,505	1,235,412	0.0946	28
Total Ad-RM	385,630	3,569,807	3,955,437	0.0975	26
Middle River (Ad)					
Bonneville	146,457	1,361,388	1,507,845	0.0971	24
Washougal	85,741	769,789	855,530	0.1002	25
Sandy	98,702	920,106	1,018,808	0.0969	22
Eagle Creek <sup>2/</sup>	130,384	1,028,499	1,158,883	0.1125	20
Lewis <sup>3/</sup>	85,442	882,958	968,400	0.0882	27
Kalama Falls	85,022	789,515	874,537	0.0972	28
Lower Kalama	38,792	357,123	395,915	0.0980	27
Toutle	93,722	856,325	950,047	0.0986	24
Total Ad	764,262	6,965,703	7,729,965	0.0989	24
Upper River (Ad-LM)					
Klickitat	79,864	770,023	849,887	0.0940	28
Little White Salmon <sup>4/</sup>	369,935	3,339,807	3,709,742	0.0997	20
Willard	--	--	--	--	17
Carson <sup>5/</sup>	--	--	--	--	--
OxBow <sup>5/</sup>	--	--	--	--	--
Cascade	43,311	434,846	478,157	0.0905	23
Total Ad-LM	493,110	4,544,676	5,037,786	0.0979	20
Uppermost River (D-Ad-RM, D-Ad-LM <sup>6/</sup> )					
Leavenworth	78,092	269,355	347,447	0.2248	23
Leavenworth <sup>6/</sup>	96,643	466	97,109	0.9952	23
TOTAL ALL HATCHERIES	1,817,737	15,350,007	17,167,744	0.1059	--

<sup>1/</sup> Mean weights in grams per fish. Values in total lines are averages weighted by total release at each hatchery in that river section.

<sup>2/</sup> Additional 126,323 fish released with LM mark, 87,733 released with An mark, and 127,514 released with RM mark.

<sup>3/</sup> Includes release from Speelyal hatchery.

<sup>4/</sup> Includes releases from Willard hatchery.

<sup>5/</sup> Nonparticipating for 1966 brood.

<sup>6/</sup> Released below Bonneville Dam.

APPENDIX TABLE 2a.—Number of marked and unmarked 1965-brood coho salmon recovered at hatcheries in each section of the Columbia River in 1967 and 1968.

Recovery location, by hatchery	Marked and unmarked	Origin	Year of return	
			1967	1968
Middle River--Continued				
Lewis River	Unmarked	--	1,072	1,894
	Ad-IM	Upper river	0	0
	Ad	Lewis	88	235
	Ad-RM	Lower river	0	0
Kalama Falls	Unmarked	--	1,176	10,451
	Ad-IM	Upper river	0	0
	Ad	Kalama Falls	107	865
	Ad-RM	Lower river	0	0
Lower Kalama	Unmarked	--	524	1,915
	Ad-IM	Upper river	0	0
	Ad	Lower Kalama	89	227
	Ad-RM	Lower river	0	0
Toutle	Unmarked	--	4,417	24,931
	Ad-IM	Upper river	0	0
	Ad	Toutle	416	2,030
	Ad-RM	Lower river	0	0
Upper River				
Klickitat	Unmarked	--	916	1,398
	Ad-IM	Klickitat	41	117
	Ad	Mid river	6	27
	Ad-RM	Lower river	0	0
Little White Salmon	Unmarked	--	1,044	5,403
	Ad-IM	Little White Salmon	46	419
	Ad	Mid river	8	58
	Ad-RM	Lower river	0	0
OxBow	Unmarked	--	(*)	103
	Ad-IM	OxBow	(*)	3
	Ad	Mid river	(*)	2
Cascade	Unmarked	--	7,247	7,227
	Ad-IM	Cascade	549	576
	Ad	Mid river	44	104
	Ad-RM	Lower river	5	21
Uppermost River				
Leavenworth	Unmarked	--	310	1,849
	D-Ad	Leavenworth	38	138

\*Returns not examined.



APPENDIX TABLE 2a.—Continued.

Recovery location, by hatchery	Marked and unmarked	Origin	Year of return	
			1968	1969
Middle River--Continued				
Lewis River	Unmarked	--	1,911	2,945
	Ad-LM	Upper river	0	0
	Ad	Lewis River	233	302
	Ad-RM	Lower river	0	0
Kalama Falls	Unmarked	--	1,592	10,696
	Ad-LM	Upper river	0	0
	Ad	Kalama Falls	148	888
	Ad-RM	Lower river	0	1
Lower Kalama	Unmarked	--	1,887	2,739
	Ad-LM	Upper river	0	1
	Ad	Lower Kalama	192	263
	Ad-RM	Lower river	0	1
Toutle	Unmarked	--	2,546	23,664
	Ad-LM	Upper river	0	0
	Ad	Toutle	200	2,093
	Ad-RM	Lower river	0	0
Upper River				
Klickitat	Unmarked	--	181	1,347
	Ad-LM	Klickitat	15	163
	Ad	Mid river	2	13
	Ad-RM	Lower river	0	0
Little White Salmon	Unmarked	--	5,036	8,131
	Ad-LM	Little White Salmon	341	666
	Ad	Mid river	44	105
	Ad-RM	Lower river	1	2
Cascade	Unmarked	--	2,144	1,374
	Ad-LM	Cascade	146	83
	Ad	Mid river	41	22
	Ad-RM	Lower river	3	14
Uppermost River				
Leavenworth	Unmarked	--	69	32
	D-Ad	Leavenworth	1	0
	D-Ad-LM	Leavenworth	7	0
	D-Ad-RM	Leavenworth	0	0

APPENDIX TABLE 2b.—Number of marked and unmarked 1966-brood coho salmon recovered at hatcheries in each section of the Columbia River in 1968 and 1969.

Recovery location, by hatchery	Marked and unmarked	Origin	Year of return	
			1968	1969
Lower River				
Elokomin	Unmarked	--	4,527	6,316
	Ad-LM	Upper river	3	1
	Ad	Mid river	2	10
	Ad-RM	Elokomin	280	532
Big Creek	Unmarked	--	5,682	7,719
	Ad-LM	Upper river	0	0
	Ad	Mid river	0	5
	Ad-RM	Big Creek	430	489
Grays River	Unmarked	--	5,375	5,310
	Ad-LM	Upper river	0	2
	Ad	Mid river	0	10
	Ad-RM	Grays River	518	516
Klaskanine	Unmarked	--	10,473	2,623
	Ad-LM	Upper river	0	0
	Ad	Mid river	0	0
	Ad-RM	Klaskanine	788	172
Middle River				
Bonneville	Unmarked	--	7,034	3,115
	Ad-LM	OxBow	90	148
	Ad	Bonneville	585	567
	Ad-RM	Lower river	26	24
Washougal	Unmarked	--	2,204	9,060
	Ad-LM	Upper river	0	0
	Ad	Washougal	237	1,033
	Ad-RM	Lower river	0	7
Sandy	Unmarked	--	4,134	3,079
	Ad-LM	Upper river	27	11
	Ad	Sandy	422	267
	Ad-RM	Lower river	20	13
Eagle Creek	Unmarked	--	929	1,799
	Ad-LM	Upper river	2	0
	Ad	Eagle Creek	85	191
	Ad-RM	Lower river	1	0
	LM	Eagle Creek	77	221

APPENDIX TABLE 2b.—Continued.

Recovery location, by hatchery	Marked and unmarked	Origin	Year of return	
			1967	1968
ower River				
Elokomin	Unmarked	--	533	1,616
	Ad-LM	Upper river	0	0
	Ad	Mid river	0	3
	Ad-RM	Elokomin	41	105
Big Creek	Unmarked	--	10,540	10,573
	Ad-LM	Upper river	0	0
	Ad	Mid river	26	5
	Ad-RM	Big Creek	936	1,079
Grays River	Unmarked	--	1,363	2,651
	Ad-LM	Upper river	3	0
	Ad	Mid river	41	0
	Ad-RM	Grays River	40	213
Klaskanine	Unmarked	--	7,201	4,151
	Ad-LM	Upper river	0	0
	Ad	Mid river	0	1
	Ad-RM	Klaskanine	527	365
iddle River				
Bonneville	Unmarked	--	7,401	16,602
	Ad-LM	OxBow	468	735
	Ad	Bonneville	188	787
	Ad-RM	Lower river	5	44
Washougal	Unmarked	--	22,098	43,264
	Ad-LM	Upper river	0	3
	Ad	Washougal	2,651	4,316
	Ad-RM	Lower river	0	3
Sandy	Unmarked	--	6,021	5,222
	Ad-LM	Upper river	18	24
	Ad	Sandy	664	517
	Ad-RM	Lower river	14	32
Eagle Creek	Unmarked	--	593	2,371
	Ad-LM	Upper river	0	5
	Ad	Eagle Creek	63	222
	Ad-RM	Lower river	0	2
	LM	Eagle Creek	58	215

APPENDIX TABLE 3.—Percentage of two-year-old coho salmon in the marked and unmarked returns to Columbia River hatcheries by river section and brood year, 1965-66.

River section and (in parentheses) mark	Brood	Percent of 2-year-olds	
		Marked	Unmarked
Lower (Ad-RM)	1965	47	51
	1966	54	54
Middle (Ad)	1965	32	29
	1966	27	28
Upper (Ad-LM)	1965	36	40
	1966	36	40

APPENDIX TABLE 4.—Actual number of marked coho salmon of the 1966 brood from Leavenworth National Fish Hatchery recovered—by type of mark, year of recovery, region of capture, and type of fishery, 1968-69.

Region	Fishery type	D-Ad		D-Ad-RM		D-Ad-LM <sup>1/</sup>		Total	
		1968	1969	1968	1969	1968	1969	1968	1969
British Columbia.....	Commercial.....	0	0	0	0	0	1	0	1
Washington.....	Sport.....	0	18	0	5	0	29	0	52
	Commercial.....	0	30	0	7	0	30	0	67
Oregon.....	Sport.....	0	20	0	5	0	6	0	31
	Commercial.....	0	34	0	32	0	52	0	118
California.....	Sport.....	0	2	0	1	0	3	0	6
	Commercial.....	0	19	0	8	0	13	0	40
Columbia River.....	Sport.....	0	0	0	0	0	0	0	0
	Commercial.....	3	2	0	15	0	33	3	50
Total.....	All fisheries..	3	125	0	73	0	167	3	365

<sup>1/</sup> Released below Bonneville Dam.

## WAHLE, VREELAND, and LANDER: BIOECONOMIC CONTRIBUTION

APPENDIX TABLE 5a.—Estimated number of marked coho salmon of the 1966 brood from Leavenworth National Fish Hatchery recovered—by type of mark, year of recovery, region of capture, and type of fishery, 1968-69.

Region	Fishery type	D-Ad		D-Ad-RM		D-Ad-LM <sup>1/</sup>		Total	
		1968	1969	1968	1969	1968	1969	1968	1969
British Columbia.....	Commercial.....	0	0	0	0	0	7	0	7
Washington.....	Sport.....	0	88	0	23	0	131	0	242
	Commercial.....	0	123	0	30	0	128	0	281
Oregon.....	Sport.....	0	114	0	15	0	19	0	148
	Commercial.....	0	184	0	176	0	285	0	645
California.....	Sport.....	0	7	0	2	0	14	0	23
	Commercial.....	0	137	0	35	0	52	0	224
Columbia River.....	Sport.....	0	0	0	0	0	0	0	0
	Commercial.....	6	7	0	90	0	186	6	283
Total.....	All fisheries..	6	660	0	371	0	822	6	1,853

<sup>1/</sup> Released below Bonneville Dam.

APPENDIX TABLE 5b.—Estimated recovery of D-Ad-RM and D-Ad-LM marked 1966-brood coho salmon from Leavenworth National Fish Hatchery after redistribution of the D-Ad-only marks.

Region	Fishery type	D-Ad-RM		D-Ad-LM <sup>1/</sup>		Total	
		1968	1969	1968	1969	1968	1969
British Columbia.....	Commercial.....	0	0	0	7	0	7
Washington.....	Sport.....	0	71	0	171	0	242
	Commercial.....	0	96	0	185	0	281
Oregon.....	Sport.....	0	77	0	71	0	148
	Commercial.....	0	275	0	370	0	645
California.....	Sport.....	0	6	0	17	0	23
	Commercial.....	0	109	0	115	0	224
Columbia River.....	Sport.....	0	0	0	0	0	0
	Commercial.....	3	94	3	189	6	283
Total.....	All fisheries..	3	728	3	1,125	6	1,853

<sup>1/</sup> Released below Bonneville Dam.

APPENDIX TABLE 6.—Relative survival of marked 1965- and 1966-brood coho salmon by mark type and hatchery groups.

Brood	Mark	Tetracycline group	Cascade, Little White, Klaskanine	All hatcheries
1965	Ad-LM	--	.69 <sup>3/</sup>	.69 <sup>2/</sup>
	Ad	.89 <sup>1/</sup>	--	.92 <sup>6/</sup>
	Ad-RM	.82 <sup>2/</sup>	.79 <sup>4/</sup>	.79
1966	Ad-LM	--	.68 <sup>3/</sup>	.72
	Ad	.83 <sup>1/</sup>	--	.89 <sup>6/</sup>
	Ad-RM	.68 <sup>2/</sup>	.70 <sup>4/</sup>	.72

1/ Eagle Creek National Fish Hatchery.

2/ Big Creek Salmon Hatchery.

3/ Cascade Salmon Hatchery, Little White Salmon National Fish Hatchery.

4/ Klaskanine River Salmon Hatchery.

5/ Klickitat State Salmon Hatchery, Cascade Salmon Hatchery, Little White Salmon National Fish Hatchery.

6/ Bonneville Salmon Hatchery returns not included in calculations.

APPENDIX TABLE 7.—Estimated catch of unmarked 1965- and 1966-brood hatchery coho salmon by region, fishery type, brood year, and year of capture.

Region	Fishery type	1965 brood			1966 brood		
		1967	1968	Total	1968	1969	Total
Ocean fisheries:							
British Columbia.....	Commercial...	0	80,101	80,101	0	34,981	34,981
Washington.....	Sport.....	0	163,997	163,997	0	153,837	153,837
	Commercial...	0	203,620	203,620	0	122,210	122,210
Oregon.....	Sport.....	0	93,759	93,759	0	86,658	86,658
	Commercial...	0	270,127	270,127	0	298,453	298,453
California.....	Sport.....	0	7,878	7,878	0	7,529	7,529
	Commercial...	0	102,523	102,523	0	77,724	77,724
Subtotal.....	Sport.....	0	265,634	265,634	0	248,024	248,024
	Commercial...	0	656,371	656,371	0	533,368	533,368
Freshwater fisheries:							
Columbia River.....	Sport.....	3,928	3,246	7,174	6,516	4,771	11,287
	Commercial...	1,733	74,548	76,281	2,775	136,057	138,832
Total.....	All fisheries	5,661	999,799	1,005,460	9,291	922,220	931,511

APPENDIX TABLE 8.—Estimated total catch of 1965- and 1966-brood hatchery coho salmon by region, fishery type, brood year, and year of capture.

Region	Fishery type	1965 brood			1966 brood		
		1967	1968	Total	1968	1969	Total
Ocean fisheries:							
British Columbia.....	Commercial...	0	87,526	87,526	0	38,313	38,313
Washington.....	Sport.....	0	179,179	179,179	0	167,914	167,914
	Commercial...	0	222,405	222,405	0	133,536	133,536
Oregon.....	Sport.....	0	102,614	102,614	0	94,994	94,994
	Commercial...	0	294,778	294,778	0	326,241	326,241
California.....	Sport.....	0	8,556	8,556	0	8,259	8,259
	Commercial...	0	111,592	111,592	0	85,165	85,165
Subtotal.....	Sport.....	0	290,349	290,349	0	271,167	271,167
	Commercial...	0	716,301	716,301	0	583,255	583,255
Freshwater fisheries:							
Columbia River.....	Sport.....	4,297	3,552	7,849	7,133	5,223	12,356
	Commercial...	1,872	81,364	83,236	3,021	148,533	151,554
Total.....	All fisheries	6,169	1,091,566	1,097,735	10,154	1,008,178	1,018,332

APPENDIX TABLE 9.—Estimated 1967-69 sport catch in Columbia River tributaries (where no creel census was made) of 1965- and 1966-brood hatchery coho salmon.

Stream	1965 brood			1966 brood			Estimation method
	1967	1968	Total	1968	1969	Total	
Icicle River	50	15	65	10	10	20	1/
Klickitat River	5	6	11	5	0	5	2/ 3/ 4/
Little White Salmon R.	111	8	119	7	2	9	2/ 3/ 5/
Wind River	2	0	2	--	--	--	2/ 3/ 4/
Washougal River (upper)	10,382	2,048	12,430	2,493	872	3,365	1/ 3/ 5/
	(lower) 1,385	273	1,658	332	116	448	1/ 3/ 4/
Elokomin River	59	75	134	92	115	207	2/ 3/ 4/
Grays River	10	218	228	265	213	478	2/ 3/ 4/
Sandy River	513	944	1,457	1,457	1,198	2,655	3/ 4/ 6/
Eagle Creek (Clackamas)	928	1,709	2,637	1,744	1,433	3,177	3/ 4/ 6/
Big Creek	410	754	1,164	603	496	1,099	3/ 4/ 6/
Klaskanine River	534	983	1,517	1,346	1,106	2,452	3/ 5/ 6/
TOTAL	14,389	7,033	21,422	8,354	5,561	13,915	

1/ Estimates from discussions with Gene Nye, Washington Department of Fisheries, and local fishery personnel.

2/ Catches from Washington Department of Fisheries punch card returns 1967-1969.

3/ Age groups broken down by using jack to adult ratios obtained in creel census on Lewis, Kalama, Cowlitz, and Toutle Rivers.

4/ 70% of catch apportioned to hatchery production.

5/ Entire catch assumed hatchery.

6/ Catches from Oregon State Game Commission punch card returns 1967-1969.