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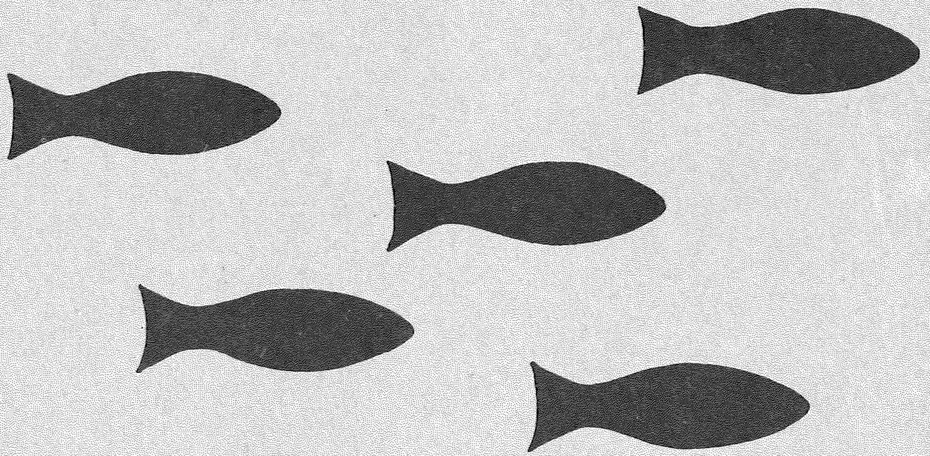

VOLUME 2, NUMBER 1
DECEMBER 1970

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ESTIMATED CONTRIBUTION OF COLUMBIA RIVER HATCHERY FALL CHINOOK SALMON TO SPORT AND COMMERCIAL FISHERIES IN 1966

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Abstract

A program was designed to measure the contribution of Columbia River hatchery produced fall chinook to the salmon fisheries. Approximately 10% of the output from 12 hatcheries were fin marked for 4 consecutive years. In 1966 all four ages (2-5) dominant in the catch were represented by marked salmon. Sampling for marked fish was conducted in all the major salmon fisheries where it was believed they might be caught. This paper provides estimates of the general magnitude of the hatchery contribution to the harvest together with its distribution by geographic area and age of the fish at time of capture.

It is estimated that 274,000 hatchery fall chinook were taken in the fisheries, with 87% being taken in the ocean and 13% in the Columbia River. About 81% were caught along the coasts of Washington and British Columbia, 5% off the Oregon coast, and less than 1% off Alaska and California. The dominant age of hatchery fish at time of capture was 3 years. Two-year-old hatchery chinook contribute little to the troll catch, but are important in the sport catch.

Introduction

An extensive system of state and federal hatcheries has been established on the Columbia River to supplement the production of several species of Pacific salmon, primarily chinook (*Oncorhynchus tshawytscha* Walbaum) and coho (*O. kisutch* Walbaum). In 1961 a cooperative program was undertaken in order to obtain an evaluation of the contribution made to the salmon fisheries from the fall chinook segment of the hatchery production. Most of the funds were supplied by the Bureau of Commercial Fisheries. Approximately 10% of the output from 12 hatcheries was fin marked for 4 years. The production from these hatcheries represents about 88% of the total Columbia River hatchery output of fall chinook fingerlings. The design of this study has been reported by Cleaver (1969) and Worlund, Wahle, and Zimmer (1969).

Ultimately estimates of contribution from the four brood years will be available and thus provide a measure of annual variation. However, it will be several years before these estimates are completed. In 1966 all four ages (2-5) dominant in the catch from the fisheries were represented by marked fall chinook produced in Columbia River hatcheries. Thus in 1966 it is possible to get a direct evaluation over all age classes. This paper provides estimates of the general magnitude of the hatchery contribution to the harvest together with its distribution by geographic area and age of the fish.

Methods

Sampling was conducted in all the major salmon fisheries where it was believed Columbia River salmon might be caught. It is assumed that the ratio between marked and unmarked salmon observed in the sampling is representative of the catch. Expansion of this ratio to the total catch, and a further expansion based on the proportion of the hatchery production marked, provides the basic estimate of number of hatchery fish in the landings. Estimates of precision associated with these ratio estimates have not been worked out in detail, but preliminary estimates provided by Worlund *et al.* (1969) indicate that sampling error may be less than ±10% of the estimated numbers.

Two adjustments to these basic ratio estimates have been made. One was a correction for that segment of the total hatchery production which was not involved in the evaluation (approximately 12%), using the assumption that these fish had a survival rate equal to the other 88%. The second was to correct for differential mortality due to fin marking, whereby the estimated number of hatchery fish caught has been adjusted upward by a factor of 1.428571 (see following section).

Differential Mortality

Hatchery fish were marked by excising the adipose fin and a maxillary bone. The first year (1961 brood) the right maxillary was used in conjunction with the adipose while the left maxillary was used on the 1962 brood. These combinations were repeated on the 1963 and 1964 broods. Marked fish may have a higher mortality rate than the unmarked. To get an unbiased estimate of the numbers taken in the fishery, it is necessary to correct for this differential mortality.

Comparison of the rate of return to the hatcheries of marked and unmarked groups does not provide an unbiased estimate because the unmarked fish may contain an undetermined number of nonhatchery strays. To overcome this difficulty, the entire production at the Little White Salmon Hatchery was marked by feeding the drug oxytetracycline (TM-50) prior to liberation. When the adults return we should be able to estimate the rates of survival of fin-marked and nonfin-marked groups of hatchery fish. Strays can be eliminated as they will not bear a TM-50 mark.

In the absence of results from the studies mentioned, Worlund *et al.* (1969) provided a detailed discussion of the evidence available from the 1961 brood and concluded that at best the marked fish could have survived only 70% as well as the unmarked. Cleaver (1969) estimates for Spring Creek and Kalama hatcheries that the adipose-maxillary marked fish returned only 48% as well as the unmarked. To avoid overcorrecting, the estimate of 70% survival of marked relative to unmarked fish is accepted for this paper and the estimated number of hatchery fish caught has been adjusted upward by a factor of 1.428571 (the reciprocal of 0.70) to account for differential mortality. Later data may show this to be an undercorrection.

Regeneration of Marks

Incorporated into the design was an evaluation of contribution of individual hatcheries to the fall chinook catch. This required the use of additional fin marks. Consequently, combinations of the ventral fins were worked into the adipose and maxillary marks.

Groups of fish bearing marks used in this study were held in salt-water rearing ponds at Bowman's Bay, Washington, up to 34 months. They were examined periodically and signs of regeneration of the marks recorded. No regeneration of the adipose fin was noted, or complete regeneration of the ventral, although partial regeneration was not uncommon. In all cases the fish were bearing recognizable ventral fin marks. The only mark observed to regenerate completely was the maxillary bone—6.9% of the 1961 brood, 11.6% of the 1962 brood, 3.3% of the 1963 brood and only 1% of the 1964 brood had such regenerated marks. A change in the marking technique used on the 1963 and 1964 broods seemed to reduce the rate of regeneration.

In 1966 it is estimated that 15,077 adipose-maxillary marked fall chinook and 1,832 bearing an adipose mark were taken in the fisheries. If we assume that the latter group once also bore a maxillary mark, it appears that 10.8% regenerated the maxillary. This estimate agrees with the observations at Bowman's Bay.

In this report I have concluded that the adipose marks belong to the general evaluation group with the maxillary regenerated. Scale analysis was used to assign the marked fish to the proper brood year.

Results

General Magnitude of the Contribution

The total catch of Columbia River hatchery fall chinook in 1966 is estimated at about 274,000 fish, with 87% taken in the ocean commercial and sport fisheries, and 13% in the Columbia River. Table 1 shows the apportionment of the catch by fishery. The sport fishery in the Columbia River took approximately 7,400 fall chinook in 1966; since no general evaluation marked fish were recovered in sampling, it is impossible to estimate the contribution of hatcheries to this catch.

Table 1. Distribution, by fishery, of the estimated hatchery fall chinook catch in 1966

Fishery	No. of hatchery fish caught	Per cent of total
Ocean troll	172,581	63.1
Ocean sport	66,196	24.2
River commercial	34,820	12.7
River sport	①	①
Total	273,597	100.0

① No estimate.

Geographic Distribution

It is apparent that not many of these fish go as far north as southeast Alaska and

Table 2. Estimated landings in 1966 of Columbia River hatchery fall chinook and their relation to total chinook landings, by area within fishery

Area	Fishery			
	Ocean Troll		Ocean Sport	
	Number hatchery fish landed	Per Cent of total landed①	Number hatchery fish landed	Per Cent of total landed
Southeast Alaska	631	0.2	②	②
Northern British Columbia	1,645	1.1	②	②
Central British Columbia	3,642	2.4	②	②
Strait of Georgia	438	0.8	②	②
West Coast Vancouver Island	98,073	18.6	②	②
Puget Sound	②	②	11,129	11.1
Seattle	2,581	17.6	②	②
Sekiu	②	②	7,084	30.6
Neah Bay	10,165	27.4	3,247	25.3
La Push	16,830	43.9	664	33.3
Westport	14,989	36.1	25,371	36.4
Ilwaco	14,491	42.8	12,452	21.0
Astoria	5,914	33.5	4,317	21.1
Tillamook	763	58.2	②	②
Nestucca	97	14.5	②	②
Depoe Bay	374	21.7	374	29.6
Newport	699	5.2	129	5.4
Florence	129	5.0	97	8.4
Reedsport	②	②	1,219	18.9
Coos Bay	260	1.4	0	0.0
Port Orford	0	0.0	0	0.0
Brookings	0	0.0	0	0.0
California	860	0.2	113	0.1
Total	172,581	10.3	66,196	17.6
	Commercial		Sport	
Columbia River	34,820	23.3	②	②

① In the Columbia River, the proportion of hatchery fish in the catch is based exclusively on fall chinook landings from Columbia fall-run stocks. In the ocean, the hatchery fish landings represent a proportion of the total catch which contains a mixture of several other stocks as well.

② Not estimated.

their contribution to the catch of this area is slight (Table 2). Proceeding south into Northern-Central British Columbia the numbers of hatchery fish increase, but their overall contribution remains low—only 1 to 2%.

The largest number of Columbia River hatchery chinook are taken in the troll fishery off the West Coast of Vancouver Island; here about one out of every five fish landed originates in a Columbia River hatchery.

Off the Washington coast it appears that approximately one out of three fish taken by trollers is a hatchery product. The sport catch at Westport in 1966 had about the same ratio and exceeded the troll catch of hatchery fall chinook in that area by over 10,000 fish (Table 2). The catch of hatchery fish identified as being caught in Puget Sound was more specifically taken in waters of the Eastern Juan DeFuca Strait, and the vicinity of the San Juan Islands. This estimate is based on a rather weak sample with only about 2% of the catch examined.

Of the estimated ocean catch of hatchery fall chinook, about 98% was taken off Astoria and northward; very few were taken south of Astoria.

About one fish in four in the Columbia River gill-net fishery was a hatchery product in 1966. This was less than was found in the ocean fisheries off Washington and not much more than the 19% in the troll fishery off the West Coast of Vancouver Island. A reason for the relatively low contribution to the Columbia catch may be that in order to ensure escapement of both wild and hatchery fish, gillnetting for chinook is forbidden in late August and early September when hatchery fish are most abundant. Also in 1966, the 4-year-old portion of the catch was influenced unfavorably by the poor survival of the 1962 brood. Chinook in their fourth year are normally a more important segment of the river catch than in the ocean troll.

Table 3 shows that about 81% of all hatchery fall chinook caught in 1966 were taken along the coasts of British Columbia and Washington, 5% off the Oregon coast, 13% in the Columbia River, and less than 1% off Alaska and California.

Table 3. Estimated number and percentage of Columbia River hatchery fall chinook landed in 1966, by geographic area

Area	Landings of hatchery fish①	Per cent of total
Alaska	631	0.2
British Columbia	103,798	37.9
Washington coast	119,004	43.5
Oregon coast	14,372	5.3
California	973	0.4
Columbia River	34,820	12.7
Total	273,597	100.0

① Commercial and sport catch combined where both estimates are available.

Age at Capture

While the greatest number of hatchery fish taken were 3-year olds, it is possible, as Appendix Table 1 shows, that this may not be true at the northern extremities of their range. More 4-year olds than 3-year olds were caught in southeast Alaska and down through Northern and Central British Columbia. The significance of this is not clear. It may be an artifact of the data as the numbers are rather small. It may be an indication of less fishing intensity allowing more salmon to survive to the age of 4. Cleaver (1969) and Lander (1970), studying the mark recovery pattern from the 1961 brood, found that salmon released from the Kalama Hatchery tend to mature at a later age, and go farther north than fish from other hatcheries. The bulk of the older hatchery salmon entering the northern fisheries may therefore be from Kalama. From the west coast of Vancouver Island south the dominant age at capture is 3 years.

Two-year-old hatchery fish play a minor role in the troll catch where only about 700 were estimated to have been caught. By comparison over 12,000 were estimated to have been in the ocean sport catch. While this is only about 3.3% of the total ocean sport catch, it demonstrates that the two's are considerably more important to the sport than to the commercial fishery.

Acknowledgments

This report contains information collected in a large-scale cooperative program conducted by agencies in the United States and Canada. Sampling information on the Canadian fishery was provided by the Fisheries Research Board of Canada. Cooperating agencies include the Bureau of Commercial Fisheries, Bureau of Sport Fish and Wildlife, Alaska Department of Fish and Game, California Department of Fish and Game, Fish Commission of Oregon, Oregon State Game Commission, and Washington Department of Fisheries. Data used in this report were developed from the Data Report issued in May 1968 by the Biometrics Unit of the Bureau of Commercial Fisheries Biological Laboratory, Seattle, Washington.

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Appendix

These tables provide data from which summary tables of this report were compiled.

Appendix Table 1. Estimated contribution of Columbia River hatchery fall chinook, by age and area, to the 1966 ocean troll fishery

Area	Age	Hatchery landings (numbers)	Total landings (numbers)	Hatchery percentage
Alaska				
Southeastern Alaska	2	0	3,442	0.0
	3	307	68,153	0.4
	4	291	130,020	0.2
	5	33	66,756	0.05
	Total	631	268,371	0.2
British Columbia				
Northern British Columbia	2	49	2,759	1.8
	3	567	67,125	0.8
	4	647	63,354	1.0
	5	382	18,572	2.1
	Total	1,645	151,810	1.1
Central British Columbia	2	0	8,795	0.0
	3	1,054	79,050	1.3
	4	1,488	45,414	3.3
	5	1,100	17,354	6.3
	Total	3,642	150,613	2.4

Appendix Table 1. Continued

Area	Age	Hatchery landings (numbers)	Total landings (numbers)	Hatchery percentage
Strait of Georgia	2	49	12,511	0.4
	3	276	37,864	0.7
	4	97	6,586	1.5
	5	16	292	5.5
	Total	438	57,253	0.8
West Coast Vancouver Island	2	163	2,571	6.3
	3	79,604	292,329	27.2
	4	14,975	207,645	7.2
	5	3,331	25,063	13.3
	Total	98,073	527,608	18.6
Entire British Columbia Troll	2	261	26,636	1.0
	3	81,501	476,368	17.1
	4	17,207	322,999	5.3
	5	4,829	61,281	7.9
	Total	103,798	887,284	11.7
Washington				
Seattle	2	0	4	0.0
	3	2,275	5,773	39.4
	4	211	7,307	2.9
	5	95	1,577	6.0
	Total	2,581	14,661	17.6
Neah Bay	2	33	151	21.9
	3	9,000	23,793	37.8
	4	955	10,847	8.8
	5	177	2,290	7.7
	Total	10,165	37,081	27.4
La Push	2	320	325	98.5
	3	15,771	28,980	54.4
	4	404	6,888	5.9
	5	335	2,185	15.3
	Total	16,830	38,378	43.9
Westport	2	65	627	10.4
	3	13,906	31,481	44.2
	4	841	7,802	10.8
	5	177	1,578	11.2
	Total	14,989	41,488	36.1
Ilwaco	2	0	147	0.0
	3	14,345	26,152	54.9
	4	146	7,367	2.0
	5	0	185	0.0
	Total	14,491	33,851	42.8
Entire Washington Troll	2	418	1,254	33.3
	3	55,297	116,179	47.6
	4	2,557	40,211	6.4
	5	784	7,815	10.0
	Total	59,056	165,459	35.7

Appendix Table 1. Continued

Area	Age	Hatchery landings (numbers)	Total landings (numbers)	Hatchery percentage
Oregon				
Astoria	2	0	158	0.0
	3	5,817	13,344	43.6
	4	97	4,054	2.4
	5	0	115	0.0
	Total	5,914	17,671	33.5
Tillamook	2	0	16	0.0
	3	763	961	79.4
	4	0	322	0.0
	5	0	13	0.0
	Total	763	1,312	58.2
Nestucca	2	0	5	0.0
	3	97	393	24.7
	4	0	244	0.0
	5	0	25	0.0
	Total	97	667	14.5
Depoe Bay	2	0	28	0.0
	3	374	1,142	32.7
	4	0	485	0.0
	5	0	70	0.0
	Total	374	1,725	21.7
Newport	2	0	211	0.0
	3	699	8,448	8.3
	4	0	4,211	0.0
	5	0	553	0.0
	Total	699	13,423	5.2
Florence	2	0	2	0.0
	3	129	1,457	8.9
	4	0	1,009	0.0
	5	0	114	0.0
	Total	129	2,582	5.0
Coos Bay	2	0	224	0.0
	3	260	12,882	2.0
	4	0	4,571	0.0
	5	0	487	0.0
	Total	260	18,164	1.4
Port Orford	2	0	66	0.0
	3	0	5,436	0.0
	4	0	1,997	0.0
	5	0	20	0.0
	Total	0	7,519	0.0
Brookings	2	0	20	0.0
	3	0	6,816	0.0
	4	0	2,730	0.0
	5	0	132	0.0
	Total	0	9,698	0.0

Appendix Table 1. Continued

Area	Age	Hatchery landings (numbers)	Total landings (numbers)	Hatchery percentage
Entire Oregon Troll	2	0	730	0.0
	3	8,139	50,879	16.0
	4	97	19,623	0.5
	5	0	1,529	0.0
	Total	8,236	72,761	11.3
California				
Crescent City	2	0	15	0.0
	3	0	34,459	0.0
	4	0	11,365	0.0
	5	0	865	0.0
	Total	0	46,704	0.0
Eureka	2	0	0	0.0
	3	245	112,983	0.2
	4	0	55,301	0.0
	5	95	6,530	1.5
	Total	340	174,814	0.2
Fort Bragg	2	0	1,147	0.0
	3	487	125,109	0.4
	4	33	42,016	0.1
	5	0	568	0.0
	Total	520	168,840	0.3
San Francisco	2	0	947	0.0
	3	0	103,876	0.0
	4	0	37,365	0.0
	5	0	841	0.0
	Total	0	143,029	0.0
Monterey	2	0	36	0.0
	3	0	13,698	0.0
	4	0	6,216	0.0
	5	0	227	0.0
	Total	0	20,177	0,0
Entire California Troll	2	0	2,145	0.0
	3	732	390,125	0.2
	4	33	152,263	0.02
	5	95	9,031	1.1
	Total	860	553,564	0.2
Coastwide Ocean Troll	2	679	30,765	2.2
	3	145,976	1,033,551	14.1
	4	20,185	535,096	3.8
	5	5,741	79,656	7.2
	Total	172,581	1,679,068	10.3

Appendix Table 2. Estimated contribution of Columbia River hatchery fall chinook, by age and area, to the 1966 ocean sport fisheries

Area	Age	Hatchery landings (numbers)	Total landings (numbers)	Hatchery percentage
Washington				
Puget Sound	2	522	41,647	1.3
	3	10,607	43,794	24.2
	4	0	12,304	0.0
	5	0	2,252	0.0
	Total	11,129	99,997	11.1
Sekiu	2	783	1,289	60.7
	3	5,573	12,633	44.1
	4	728	7,735	9.4
	5	0	1,483	0.0
	Total	7,084	23,140	30.6
Neah Bay	2	1,027	1,085	94.6
	3	1,804	7,525	24.0
	4	242	3,351	7.2
	5	174	864	20.1
	Total	3,247	12,825	25.3
La Push	2	0	212	0.0
	3	664	1,420	46.8
	4	0	329	0.0
	5	0	35	0.0
	Total	664	1,996	33.3
Westport	2	3,166	11,045	28.7
	3	20,242	43,925	46.1
	4	1,262	12,150	10.4
	5	701	2,567	27.3
	Total	25,371	69,687	36.4
Ilwaco	2	4,210	22,040	19.1
	3	7,521	32,823	22.9
	4	291	3,661	7.9
	5	430	789	5.4
	Total	12,452	59,313	21.0
Entire Washington Ocean Sport Catch	2	9,708	77,318	12.6
	3	46,411	142,120	32.7
	4	2,523	39,530	6.4
	5	1,305	7,990	16.3
	Total	59,948	266,958	22.5
Oregon				
Warrenton	2	2,563	9,596	26.7
	3	1,754	9,294	18.9
	4	0	1,329	0.0
	5	0	194	0.0
	Total	4,317	20,413	21.1

Appendix Table 2. Continued

Area	Age	Hatchery landings (numbers)	Total landings (numbers)	Hatchery percentage
Depoe Bay	2	0	95	0.0
	3	374	790	47.3
	4	0	292	0.0
	5	0	86	0.0
	Total	374	6,263	29.6
Newport	2	0	14	0.0
	3	129	1,332	9.7
	4	0	929	0.0
	5	0	108	0.0
	Total	129	2,383	5.4
Florence	2	0	43	0.0
	3	97	709	13.7
	4	0	375	0.0
	5	0	28	0.0
	Total	97	1,155	8.4
Reedsport	2	65	329	19.8
	3	1,154	4,676	24.7
	4	0	1,317	0.0
	5	0	119	0.0
	Total	1,219	6,441	18.9
Coos Bay	2	0	153	0.0
	3	0	778	0.0
	4	0	183	0.0
	5	0	13	0.0
	Total	0	1,127	0.0
Gold Beach	2	0	187	0.0
	3	0	1,366	0.0
	4	0	989	0.0
	5	0	220	0.0
	Total	0	2,762	0.0
Brookings	2	0	24	0.0
	3	0	560	0.0
	4	0	155	0.0
	5	0	0	0.0
	Total	0	739	0.0
Entire Oregon Ocean Sport Catch	2	2,628	10,441	25.2
	3	3,508	19,505	18.0
	4	0	5,569	0.0
	5	0	768	0.0
	Total	6,136	36,283	16.9

Appendix Table 2. Continued

Area	Age	Hatchery landings (numbers)	Total landings (numbers)	Hatchery percentage
California				
Crescent City	2	0	31	0.0
	3	0	107	0.0
	4	0	40	0.0
	5	0	1	0.0
	Total	0	179	0.0
Eureka	2	0	461	0.0
	3	0	1,662	0.0
	4	0	623	0.0
	5	0	20	0.0
	Total	0	2,766	0.0
Fort Bragg	2	0	172	0.0
	3	0	2,118	0.0
	4	0	895	0.0
	5	0	39	0.0
	Total	0	3,224	0.0
San Francisco	2	0	3,401	0.0
	3	113	39,545	0.3
	4	0	17,874	0.0
	5	0	763	0.0
	Total	113	61,583	0.2
Monterey	2	0	235	0.0
	3	0	2,729	0.0
	4	0	1,233	0.0
	5	0	53	0.0
	Total	0	4,250	0.0
Entire California Ocean Sport Catch	2	0	4,300	0.0
	3	113	46,161	0.2
	4	0	20,665	0.0
	5	0	876	0.0
	Total	113	72,002	0.1
Coastwide Ocean Sport Catch	2	12,336	72,059	13.4
	3	50,032	207,786	24.1
	4	2,523	65,764	3.8
	5	1,305	9,634	13.5
	Total	66,196	375,243	17.6

Appendix Table 3. Estimated contribution of Columbia River hatchery fall chinook, by age and area, to the 1966 Columbia River gill-net fishery

River zone①	Age	Hatchery landings (numbers)	Total landings (numbers)	Hatchery percentage
1	2	392	1,170	33.5
	3	14,670	40,709	36.0
	4	8,912	36,307	24.5
	5	1,852	11,805	15.7
	Total	25,826	89,991	28.7
2	2	49	1,195	4.1
	3	2,404	12,887	18.7
	4	1,294	8,868	14.6
	5	207	3,172	6.5
	Total	3,954	26,122	15.1
3-4-5	2	0	658	0.0
	3	2,160	13,137	16.4
	4	533	6,739	7.9
	5	223	1,918	11.6
	Total	2,916	22,452	13.0
6	2	0	1,157	0.0
	3	1,072	3,782	28.3
	4	211	2,081	10.1
	5	112	652	17.2
	Total	1,395	7,672	18.2
Entire River Gill Net	2	441	4,180	10.6
	3	20,306	70,515	28.8
	4	10,950	53,995	20.3
	5	2,394	17,547	13.6
	Total	34,091	146,237②	23.3

① Zone 1 consists of the lower 18 miles of the river. Zone 2 is from 18 to 52 miles above the mouth. Zones 3, 4, and 5 extend from 52 miles above the mouth to 5 miles below Bonneville Dam. Zone 6 extends from 2 miles above Bonneville Dam upstream for 140 miles.

② Preliminary total. The preliminary total is generally considered to be within about 5% of the final total.

Appendix Table 4. Estimated contribution of Columbia River hatchery fall chinook, by age, to the 1966 Klickitat River dip-net fishery

Area	Age	Hatchery landings (numbers)	Total landings (numbers)	Hatchery percentage
Klickitat River	2	16	101	15.8
	3	584	2,482	23.5
	4	129	438	29.5
	5	0	14	0.0
	Total	729	3,035	24.0

DETERMINATION OF MOVEMENT AND IDENTITY OF STOCKS OF COHO SALMON IN THE OCEAN USING THE RADIONUCLIDE ZINC-65①

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Abstract

The radioisotope, ^{65}Zn, which occurs in the Columbia River plume because of the Atomic Energy Commission operations at Hanford on the Columbia River, is assimilated by coho and if retained long enough biologically has a sufficient half life (245 days) to serve as a natural mark for coho. Zinc-65 was studied as a marker by comparing ^{65}Zn levels in coho taken along the British Columbia-S.E. Alaska coast during the summer months north of the Columbia River plume, and in the suspected migratory path for Oregon-Washington coho during their first few months in the ocean. Bering Sea coho were included to provide a measure of ^{65}Zn that was not of Hanford origin. Samples were collected by the University of Washington Fisheries Research Institute and were passed on to the Oregon State University Department of Oceanography for radioanalysis.

Variation in activity between coho collected in time-space subdivisions within each year was observed. The variation was taken as evidence that coho originating from streams south of the area of collection were in the sample as well as coho from British Columbia and S.E. Alaska. The levels of activity appeared to be high enough that if coho so marked were caught 6 months later on the high seas they would be distinguishable from unmarked coho. Most fish contained some ^{65}Zn above background levels, which suggests that ^{65}Zn is carried farther north than the plume appears to take it. The presence of fish with high levels of ^{65}Zn in the northern samples supports the thesis that a northward migration of Oregon-Washington juvenile coho occurs.

Introduction

Recent information on coho movement suggested that this species makes an extensive migration in the ocean. Evidence regarding movements of Oregon-Washington coho (*Oncorhynchus kisutch* Walbaum) was obtained from tagging fish at distant points and recovering them near their suspected stream of origin. Complementary evidence obtained by recognizing fish captured at distant points was needed. This study sought to recognize coho from the amount of the radionuclide zinc-65 (^{65}Zn) they contained and to identify coho captured on the high seas using this technique. The effort was successful in showing variation in the ^{65}Zn content between coho from different areas, but the statistical significance of the variation was not evaluated. The findings gave support to the concept that coho from the Oregon-Washington coasts make a circular trip around the Gulf of Alaska during their first year of ocean life.

It has been known for 40 years that some chinook originating in the Columbia River system migrate into the northern Gulf of Alaska. Coho from the same river system and from Oregon and Washington coastal streams were believed to have stayed in coastal waters adjacent to their natal area. Tagging and fin marking studies on adult coho led to these conclusions because distances from the point of tagging or the point of recovery of fin-marked coho in the ocean were seldom more than 200 to 300 miles from their stream of origin. The possibility that coho might be migrating extensively during their first 9-12 months in the ocean was not investigated.

Recovery off the Oregon coast in June 1959 of a coho tagged off Kodiak Island,

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① A study conducted by the Oregon Fish Commission and funded in part by the Bureau of Commercial Fisheries under the Anadromous Fisheries Act, PL 89-304.

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Alaska, 10 months earlier provided the first suggestion of a longer coho migration (Hartt, 1966). This was followed by salmon distribution and abundance studies made by the Fisheries Research Board of Canada (FRBC) and the Fisheries Research Institute (FRI), University of Washington, throughout the waters of the eastern North Pacific (32°-59° N, and 125°-165° W) in the years 1961-66. Although other species of salmon were the primary target of the study, coho were taken in surprising numbers during March, April, and May between the 42nd and 47th parallels and west to 160° W longitude. Tagging demonstrated that coho originating all along the eastern rim of the Pacific were spread over vast areas of the eastern Pacific, often 300-600 miles at sea (Fisheries Research Board of Canada, 1967) (Figure 1). More recently tagging of juvenile coho caught from June to September of their first ocean year along the British Columbia and southeast Alaskan coasts has produced recoveries in the Oregon troll fishery and in the Columbia River (U.S. Bureau of Commercial Fisheries, 1967) (Figure 2).

Because coho captured in the ocean during their last summer of life are generally near their stream of origin, the evidence above suggests a migration that takes juvenile Oregon and Washington coho northward along the coast into the Gulf of Alaska by the end of the first ocean summer. This is followed by a southward movement to waters several hundred miles off Oregon and Washington) and finally by an eastward migration back to the coast during their last spring in the ocean. Such a migration pattern could explain the "sudden appearance" that coho characteristically make in the coastal troll fisheries each spring and the scarcity of coho of first ocean year age in the Oregon troll catches. It is also consistent with the suggested patterns of ocean migration for coho and other species of salmon advanced by Royce, Smith and Hartt (1968).

A need to explore the above hypothesis developed in 1966 with the announcement by the Republic of Korea of intent to conduct high seas salmon fishing (Anon., 1966). That country, without treaty bindings, could fish east of the 175° W. longitude line that limits the Japanese, and on stocks of salmon of unknown origin. The possibility of Oregon coho being taken was cause for concern. It would not have led to further study, though, had not a potential means for identifying Oregon-Washington coho been available and the opportunity to sample fish as part of an ongoing program been present. A further inducement to do the study during the 1967-69 period was the planned release in 1967 and 1968 of several million fin-marked 1965- and 1966-brood coho from hatcheries in Oregon and Washington, which provided an opportunity to study coho of known origin.

Methods

The radionuclide ^{65}Zn is brought to the ocean by the Columbia River from the Atomic Energy Commission plant at Hanford, Washington. Once in the ocean it is carried north with the Columbia River plume during the winter and spring months, and south during the summer and fall (Osterberg, Cutshall and Cronin, 1965). Organisms in the ocean between southern Vancouver Island and northern California are exposed to ^{65}Zn and accumulate the material by direct assimilation or by consumption of animals containing ^{65}Zn. The amount accumulated depends on the availability of ^{65}Zn, the time spent in the plume and the organism's need for zinc. Since Oregon-Washington coho generally enter the ocean while the plume is to the north, they could concentrate ^{65}Zn sufficiently to distinguish them from fish that were never in the Columbia River plume. Validation of this thesis was planned by sampling at two points in the ocean, viz., along the British Columbia-Southeast Alaska coast and in the high seas several hundred miles west of Oregon and Washington; however, the high seas sampling was not accomplished.

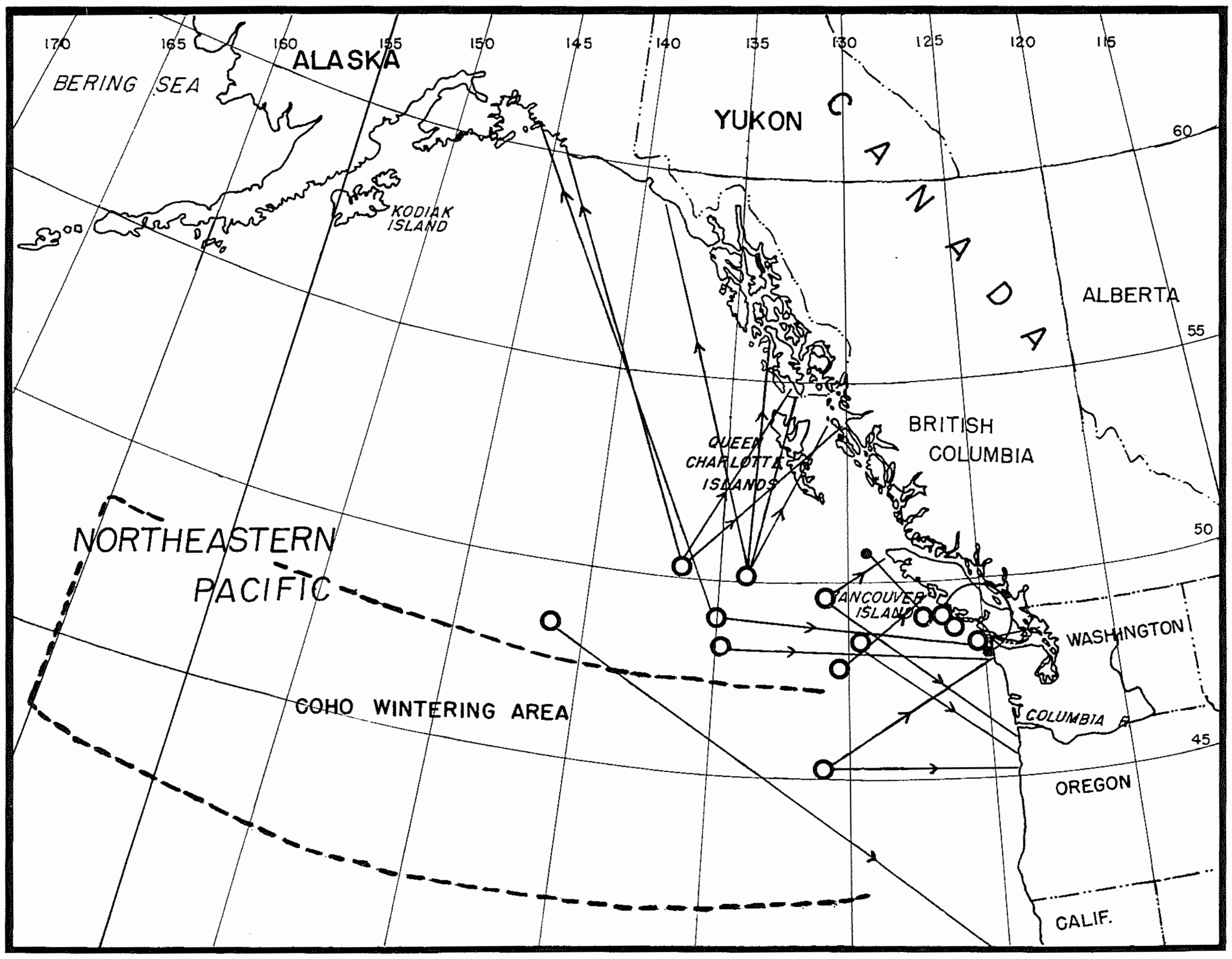

Figure 1. Northeast Pacific Ocean showing the points of tagging and recovery of coho on the high seas (1965) and the area of concentration of coho in late winter.

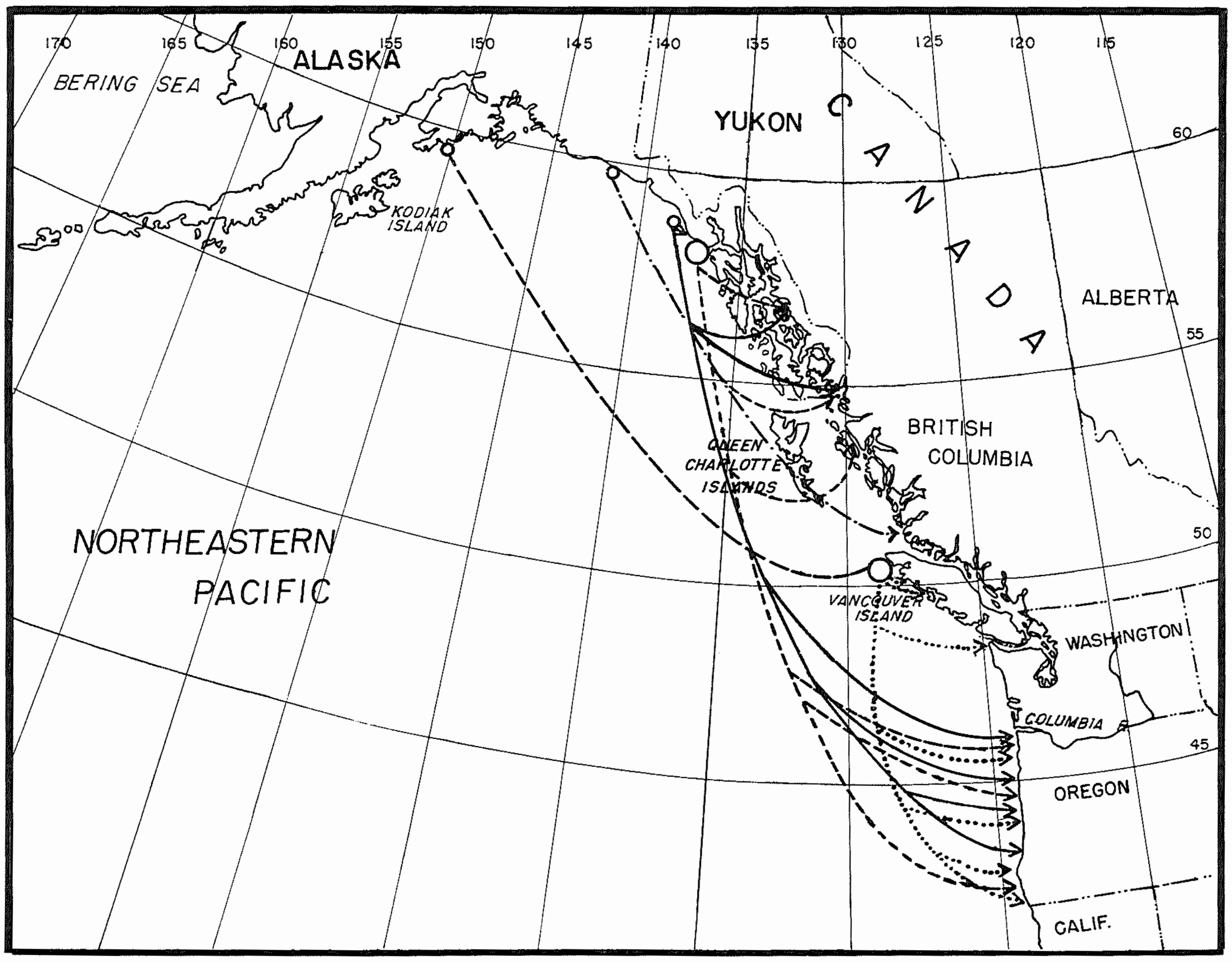

Figure 2. Northeast Pacific Ocean showing the points of tagging (1965) and recovery (1966) of juvenile coho.

Samples of juvenile coho salmon were provided by the FRI in 1967 and 1968. We requested 100 in 1967 and 200 in 1968 from their purse seine operations being carried out off British Columbia, and off the Gulf and Bering Sea shores of Alaska, to study the early ocean migrations of juvenile salmon of all species. In addition, all marked coho were to be kept for ^{65}Zn analysis. Larger samples were not requested due to limited time for analysis.

Sampling of maturing coho on the high seas was to be done by the FRBC, or the FRI, or both, had they continued high seas longline fishing in the area of interest. Unfortunately, the high seas longlining by both organizations was discontinued and examination of high-seas captured maturing coho was not possible.

Coho collected for radioanalysis were preserved in formalin and shipped to Astoria where, after removal of stomach contents, they were ground, dried to a constant weight, and charred. All fish were individually processed through ^{65}Zn analysis.

Evaluation of the ^{65}Zn activity was carried out by the Oregon State University Department of Oceanography, Radiobiology Section, following techniques described by Carey, Pearcy and Osterberg (1966). The charred material was ashed at 450° C and counted by Gamma-Spectroscopy. Counts were made for 100 minutes when ^{65}Zn was high and up to 400 minutes when it was low. All values obtained were adjusted to a standard counting time and corrected to time of collection for loss of activity due to decay (the half life of ^{65}Zn is 245 days).

Results

Sampling of juvenile coho during their first ocean summer fell short of design goals in both 1967 and 1968, and no samples were obtained from the high seas wintering area of coho. However, the fish provided by the FRI were sufficient in number and geographic distribution to permit a meaningful analysis.

Of the 212 coho received in 1967, 45 were analyzed for ^{65}Zn (Table 1). Those not used were in two large samples from which subsamples totalling 19 coho were drawn. The 1968 collection included 74 coho of which 20 carried assignable fin marks (Table 2).

Values for ^{65}Zn activity for the 1967 coho ranged from a low of 7 to 518 picocuries per gram ash (pCi/g ash). The 1968 samples, by contrast, had much lower activity levels ranging from 0.8 to 129.8 pCi/g ash, with the activity in only four fish exceeding 50 pCi/g ash. Stable zinc (^{64}Zn) levels, which indicate the fish's need for zinc, varied little by comparison. Over the 2 years, with the exception of one sample, they ranged from 893 to 2,359 micrograms per gram of ash for a variation of only 2.6 times.

The samples were grouped into 2° latitude intervals starting at 48° and going north. Variation both between and within groups was evident. In 1967 the highest values occurred in the "48°" collection, and activity in those fish having more than background① levels decreased with increasing latitude (Figure 3). Within-group variation great enough to suggest exposure difference was evident in the 48°, 54°, 56°, and 58° groups. Background levels of ^{65}Zn activity appeared to be less than 40, and possibly less than 20, pCi/g ash based on the portion of the samples (33%) with these comparatively low values.

The 1968 Gulf of Alaska samples presented a different but no less interesting picture than that observed in 1967. As mentioned, activity levels were generally in the range assigned as background in 1967. Variation in activity between samples was present but did not display the south to north decrease observed in 1967 (Figure 4). The "hottest" samples were collected at 53° latitude in June. Fish collected 1 month

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① "Background" for the purposes of this paper refers to ^{65}Zn from all sources other than the Columbia River.

Table 1. Date and location of catch and ^{65}Zn activity for juvenile coho sampled during 1967①

Sample No.	Date	Location		^{65}Zn	Stable Zinc
		Long.	Lat.	Picocuries/Gram of Ash	Micrograms/Gram of Ash
B437	7/6	128° 16′ W	50° 26′ N	392	1,856
B438	7/6	128° 16′ W	50° 26′ N	385	2,033
B439	7/6	128° 16′ W	50° 26′ N	339	1,849
B440	7/14	132° 30′ W	54° 42′ N	186	1,847
B441	7/14	132° 30′ W	54° 42′ N	173	1,978
B442	7/20	137° 06′ W	58° 13′ N	23	2,359
B443	7/20	137° 06′ W	58° 13′ N	25	2,192
B444	7/20	137° 06′ W	58° 13′ N	24	1,980
B445	7/23	137° 33′ W	58° 24′ N	97	1,525
B446	7/23	137° 33′ W	58° 24′ N	140	1,759
B447	7/23	137° 33′ W	58° 24′ N	170	1,603
B448	7/24	136° 26′ W	57° 34′ N	231	1,633
B449	7/24	136° 26′ W	57° 34′ N	87	1,840
B450	7/24	136° 26′ W	57° 34′ N	207	1,947
B451	8/17	132° 11′ W	54° 32′ N	45	1,755
B451	8/22	135° 38′ W	56° 45′ N	216	1,752
B453	8/22	135° 38′ W	56° 45′ N	60	1,901
B454	8/28	136° 42′ W	57° 50′ N	28	1,510
B455	8/28	136° 42′ W	57° 50′ N	24	1,800
B456	9/1	136° 35′ W	56° 16′ N	149	1,150
B457	9/1	136° 55′ W	56° 16′ N	151	950
C4-1	6/15	127° 18′ W	49° 47′ N	434	2,074
C4-2	6/15	127° 18′ W	49° 47′ N	508	2,122
C4-3	6/15	127° 18′ W	49° 47′ N	505	2,264
C4-4	6/15	127° 18′ W	49° 47′ N	412	2,025
C4-5	6/15	127° 18′ W	49° 47′ N	490	2,181
C4-6	6/15	127° 18′ W	49° 47′ N	452	1,966
C4-7	6/15	127° 18′ W	49° 47′ N	513	2,164
C4-8	6/15	127° 18′ W	49° 47′ N	498	2,206
C4-9	6/15	127° 18′ W	49° 47′ N	442	1,993
C4-10	6/15	127° 18′ W	49° 47′ N	518	2,192
X57-1	8/27	137° 32′ W	58° 22′ N	132	1,262
X57-2	8/27	137° 32′ W	58° 22′ N	17	1,492
X57-3	8/27	137° 32′ W	58° 22′ N	22	1,926
X57-4	8/27	137° 32′ W	58° 22′ N	7	893
X57-5	8/27	137° 32′ W	58° 22′ N	10	1,093
X67-1	9/11	124° 02′ W	48° 14′ N	391	1,460
X67-2	9/11	124° 02′ W	48° 14′ N	278	936
X67-3	9/11	124° 02′ W	48° 14′ N	477	1,570
X67-4	9/11	124° 02′ W	48° 14′ N	317	1,260
X67-A	9/11	124° 02′ W	48° 14′ N	18	1,490
X67-B	9/11	124° 02′ W	48° 14′ N	17	1,320
X67-C	9/11	124° 02′ W	48° 14′ N	17	1,500
X67-D	9/11	124° 02′ W	48° 14′ N	15	1,280
X67-E	9/11	124° 02′ W	48° 14′ N	10	1,170

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① ^{65}Zn values are for whole salmon less the digestive tract.

Table 2. Date and location of catch and ^{65}Zn activity for juvenile coho sampled during 1968①

Sample No.	Date	Location		^{65}Zn	Stable Zinc
		Long.	Lat.	Picocuries/Gram of Ash	Micrograms/Gram of Ash
X39-1	7/20	130° 23′ W	53° 42′ N	41.7	1,089
X39-2	7/20	130° 23′ W	53° 42′ N	39.3	1,193
X39-3	7/20	130° 23′ W	53° 42′ N	43.6	1,130
X39-4	7/20	130° 23′ W	53° 42′ N	114.4	1,151
X39-5	7/20	130° 23′ W	53° 42′ N	44.5	1,018
X39-6	7/20	130° 23′ W	53° 42′ N	31.5	1,203
X39-7	7/20	130° 23′ W	53° 42′ N	38.7	1,149
X39-8	7/20	130° 23′ W	53° 42′ N	129.8	1,041
X39-9	7/20	130° 23′ W	53° 42′ N	41.6	1,562
X39-10	7/20	130° 23′ W	53° 42′ N	45.3	1,548
X50-1	7/28	137° 02′ W	58° 17′ N	9.4	1,283
X50-2	7/28	137° 02′ W	58° 17′ N	7.2	1,278
X50-3	7/28	137° 02′ W	58° 17′ N	17.7	1,303
X50-4	7/28	137° 02′ W	58° 17′ N	7.1	1,642
X50-5	7/28	137° 02′ W	58° 17′ N	20.7	1,337
X50-6	7/28	137° 02′ W	58° 17′ N	12.1	1,288
X50-7	7/28	137° 02′ W	58° 17′ N	7.3	1,255
X50-8	7/28	137° 02′ W	58° 17′ N	9.8	1,478
X50-9	7/28	137° 02′ W	58° 17′ N	19.1	1,253
X50-10	7/28	137° 02′ W	58° 17′ N	5.3	1,095
X51	8/1	137° 04′ W	58° 13′ N	93.6	1,405
X55	8/6	135° 00′ W	56° 17′ N	6.1	1,899
X57	8/8	132° 33′ W	54° 42′ N	128.9	21,571
X61	8/11	124° 34′ W	48° 32′ N	24.5②	1,651
X64-1	8/12	124° 28′ W	48° 21′ N	15.7②	1,377
X64-2	8/12	124° 28′ W	48° 21′ N	22.4②	1,698
X64-3	8/12	124° 28′ W	48° 21′ N	20.9②	1,532
X65-1	8/13	124° 21′ W	48° 18′ N	9.1②	1,347
X65-2	8/13	124° 21′ W	48° 18′ N	17.8②	1,521
X65-3	8/13	124° 21′ W	48° 18′ N	14.4	1,583
X65-4	8/13	124° 21′ W	48° 18′ N	27.1②	1,424
X65-5	8/13	124° 21′ W	48° 18′ N	12.9②	1,321
X65-6	8/13	124° 21′ W	48° 18′ N	15.0	1,059
X65-7	8/13	124° 21′ W	48° 18′ N	14.9	1,454
X65-8	8/13	124° 21′ W	48° 18′ N	14.7	1,803
X65-9	8/13	124° 21′ W	48° 18′ N	8.2	1,462
X65-10	8/13	124° 21′ W	48° 18′ N	19.6	1,516
X67-1	8/14	124° 24′ W	48° 19′ N	14.4②	1,410
X67-2	8/14	124° 24′ W	48° 19′ N	12.6②	1,138
X67-3	8/14	124° 24′ W	48° 19′ N	8.2②	1,298
C69+70-1	8/18	161° 16′ W	56° 22′ N	2.5	1,168
C69+70-2	8/18	161° 16′ W	56° 22′ N	3.4	1,163
C69+70-3	8/18	161° 16′ W	56° 22′ N	1.6	1,075

Table 2. Continued

Sample No.	Date	Location		^{65}Zn	Stable Zinc
		Long.	Lat.	Picocuries/Gram of Ash	Micrograms/Gram of Ash
C69+70-4	8/18	161° 16′ W	56° 22′ N	1.1	1,062
C69+70-5	8/18	161° 16′ W	56° 22′ N	1.3	1,189
C69+70-6	8/18	161° 16′ W	56° 22′ N	0.8	1,146
C69+70-7	8/18	161° 16′ W	56° 22′ N	1.4	1,021
C69+70-8	8/18	161° 16′ W	56° 22′ N	0.3	1,153
C69+70-9	8/18	161° 16′ W	56° 22′ N	3.0	1,147
C69+70-10	8/18	161° 16′ W	56° 22′ N	2.0	1,286
X71-1	8/22	124° 31′ W	48° 22′ N	17.5	1,584
X71-2	8/22	124° 31′ W	48° 22′ N	19.7②	1,666
X71-3	8/22	124° 31′ W	48° 22′ N	17.4②	1,439
X71-4	8/22	124° 31′ W	48° 22′ N	22.9②	1,316
X71-5	8/22	124° 31′ W	48° 22′ N	20.3②	1,641
X71-6	8/22	124° 31′ W	48° 22′ N	29.0②	1,359
X72-1	8/23	124° 24′ W	48° 19′ N	14.5	1,798
X72-2	8/23	124° 24′ W	48° 19′ N	12.6②	1,553
X72-3	8/23	124° 24′ W	48° 19′ N	16.3②	1,561
X72-4	8/23	124° 24′ W	48° 19′ N	15.1	1,611
X72-5	8/23	124° 24′ W	48° 19′ N	19.4②	1,584
X72-6	8/23	124° 24′ W	48° 19′ N	12.5②	1,771
X80-1	9/2	135° 10′ W	56° 32′ N	44.1	1,429
X80-2	9/2	135° 10′ W	56° 32′ N	12.2	1,163
X80-3	9/2	135° 10′ W	56° 32′ N	31.7	1,234
X80-4	9/2	135° 10′ W	56° 32′ N	7.7	1,192
X83-1	9/9	137° 00′ W	58° 14′ N	11.7	2,055
X83-2	9/9	137° 00′ W	58° 14′ N	41.9	1,680
X95-1	9/30	135° 25′ W	58° 14′ N	4.0	1,420
X95-2	9/30	135° 25′ W	58° 14′ N	6.2	1,095
X100	10/5	132° 33′ W	54° 42′ N	13.4	1,562
X101-1	10/6	132° 34′ W	54° 42′ N	10.6	1,441
X101-2	10/6	132° 34′ W	54° 42′ N	9.0	1,600
X101-3	10/6	132° 34′ W	54° 42′ N	11.1	1,675

① ^{65}Zn values are for whole salmon less the digestive tract.

② This fish carried a double fin mark of Puget Sound origin.

later at 48° had activity levels only about half as great as the 53° collection and not much higher than the values observed at 58° latitude. Variation in activity again occurred within latitude groupings. Four coho had activity levels considerably higher than the rest. The tentative upper limit to background ^{65}Zn activity based on the Gulf of Alaska samples alone was similar to 1967. Bering Sea coho provide an alternate means of evaluation that suggests the upper limit may be no more than 4 pCi/g ash.

Marked fish were present in 1968 only. Those sampled were all from Washington's Puget Sound hatcheries and were taken near the western end of Juan de Fuca Strait. The activity levels were similar to unmarked coho in the same sample (Figure 4, shaded bars).

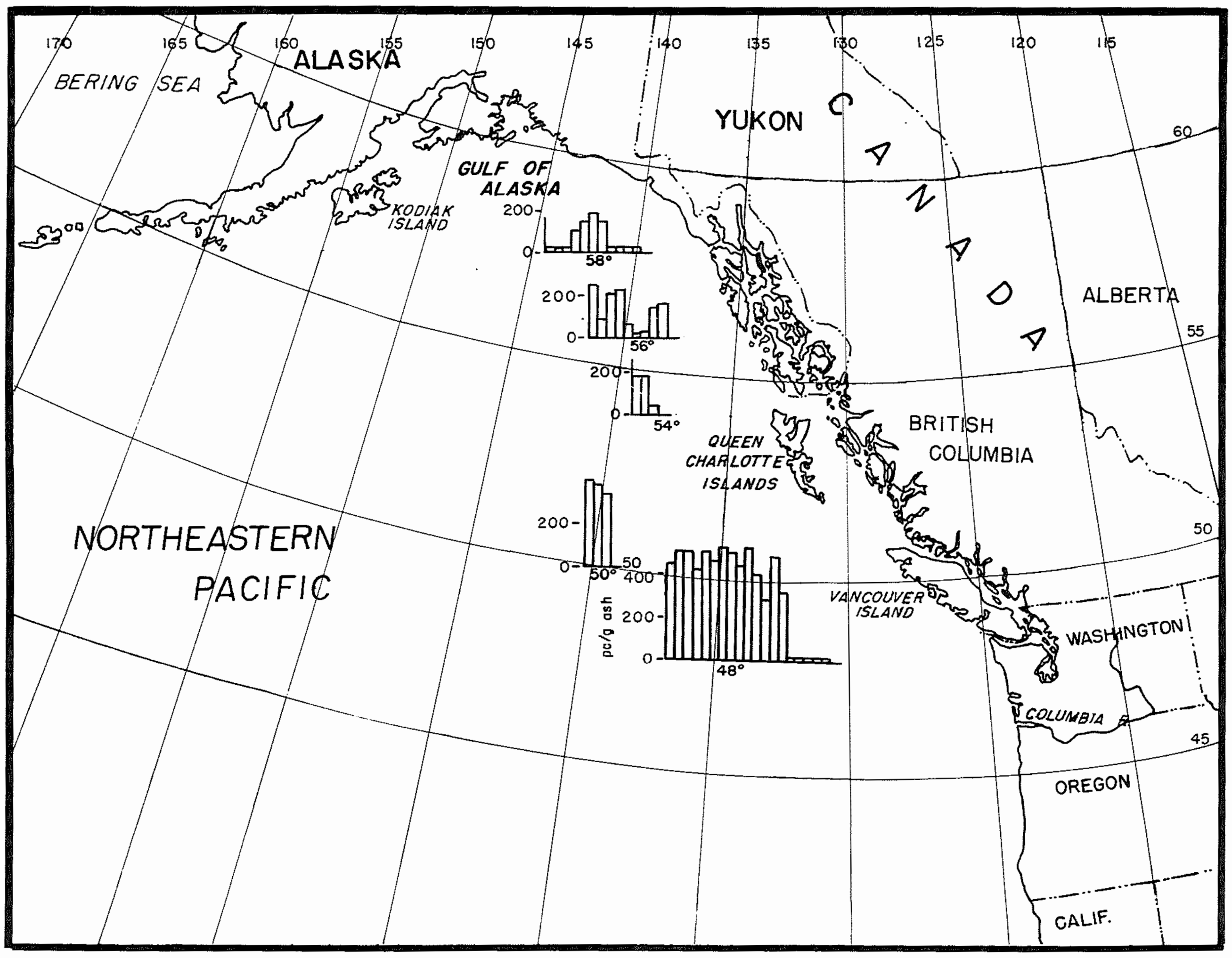

Figure 3. General collection latitude and Zinc-65 activity levels observed for juvenile coho from the Northeast Pacific, 1967.

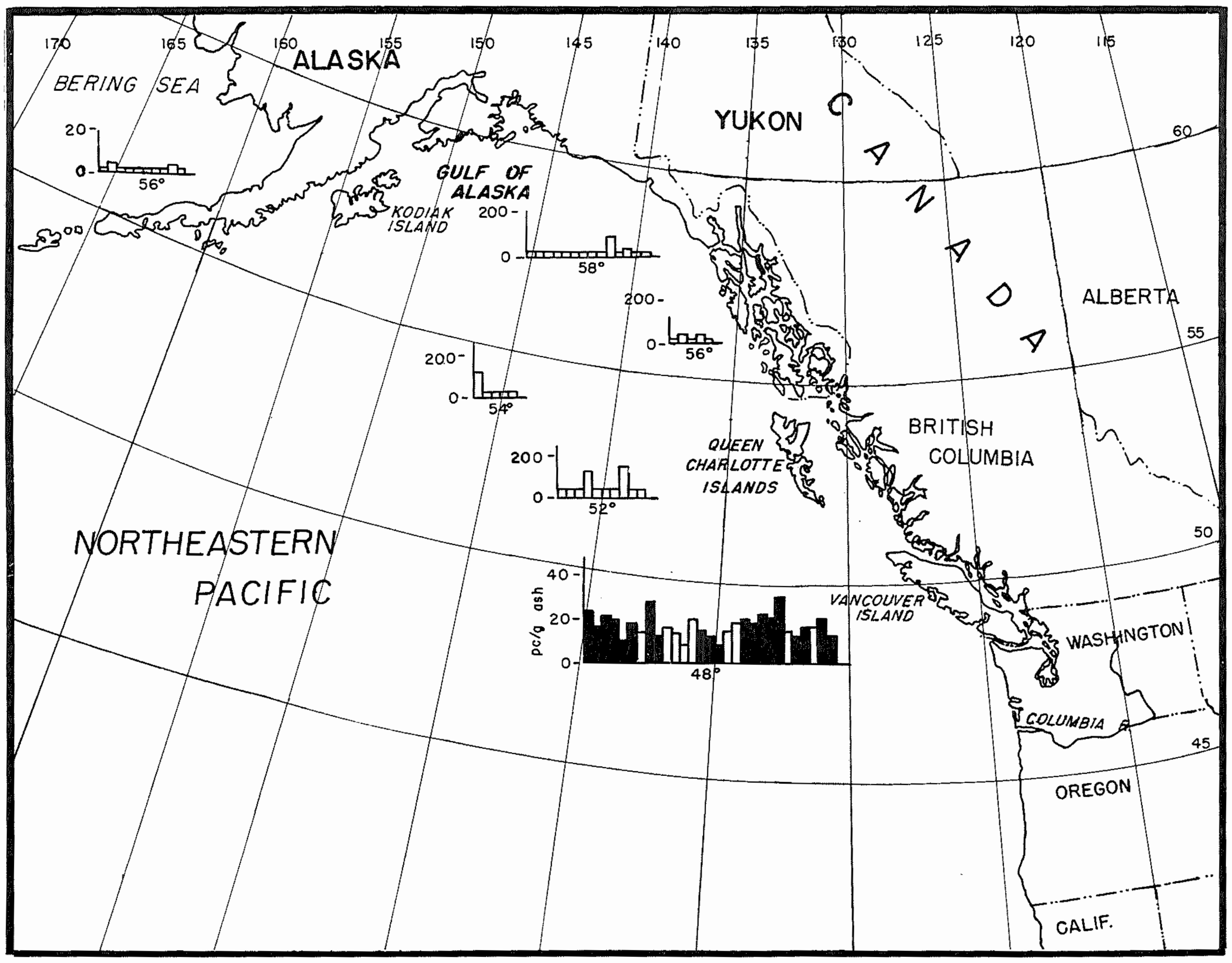

Figure 4. General collection latitude and Zinc-65 activity levels observed for juvenile coho from the Northeast Pacific, 1968.
(Shaded bars indicate fin-marked fish)

Discussion

Since Hanford debris is not the only source of radioactive contamination in the ocean, it is possible for coho living beyond the Columbia River plume influence to obtain ^{65}Zn. The amount of activity coho accumulate from non-Hanford sources, which we are calling "background" activity, must be estimated before the usefulness of ^{65}Zn in identifying Oregon-Washington coho can be stated.

As mentioned, the 1967 collection contained several fish with comparatively low levels of activity (7 to about 40 pCi/g ash). Because of the marked difference in activity between these coho and the remainder of the samples, and because this difference was observed primarily in the northern groups, it appears that the coho involved originated north of the influence of the Columbia plume. As such they should provide a measure of background ^{65}Zn activity. However, the Bering Sea samples obtained in 1968 had activity levels of 0.8 to 3.4 pCi/g ash which is considerably lower than those just discussed (Figure 4). Because of the remoteness of this collection area relative to the Columbia River plume, and because the demand for zinc by the fish in this group as indicated by ^{64}Zn levels was similar to that of fish from the northern Gulf of Alaska, these values are a better indication of background activity than that provided by the coho taken in the Gulf of Alaska. Accordingly, the Gulf-caught coho with low activity values, even though far removed from the measured flow of the Columbia plume, must be acquiring Hanford produced ^{65}Zn. Data presented by Kujala (1966, M.S. thesis) on adult chum (*O. keta*) and pink salmon (*O. gorbuscha*) show a similar relationship between ^{65}Zn activity in fish taken in the Chukchi Sea and the Gulf of Alaska. From this information, background levels of ^{65}Zn in coho appear to be less than 4 pCi/g ash and to exist only in the Bering Sea stocks of North American coho, making them separable from the Gulf of Alaska fish.

The five coho included in the 1967 48° group with ^{65}Zn activity levels, averaging about 1/20th as high as the rest of the group, merit comment. The great difference suggests that they are spurious, but this could not be substantiated. Another explanation is that they may represent Puget Sound-Strait of Georgia fish that remained in inside waters until well after the Columbia plume turned south. The 1968 data included values for 29 coho captured in August within a few miles of the collection site of the five coho in question. Twenty-two of these coho carried fin marks showing that they came from Puget Sound. Zinc-65 activity was about the same for marked and unmarked fish and equal to that observed in the five 1967 coho. Thus, it seems likely that the fish collected at the west end of Juan de Fuca Strait in both 1967 and 1968 that had values of about 30 pCi/g ash or less were fish originating in the Puget Sound-Strait of Georgia area. The capture of these fish in August and September is compatible with the suspected outmigration timing of part of the semi-resident Puget Sound coho.

The absence of fin marked fish from the northern collecting areas was both surprising and disappointing. The large number of 1965- and 1966-brood Oregon and Washington coho that were marked was a prime justification for conducting this study during the 1967 and 1968 field seasons. Failure to obtain valid fin marked fish cost us the opportunity to work with fish of known origin when assigning activity levels to Oregon-Washington coho.

With consideration of the foregoing, the following interpretation of the data is offered. Samples collected in 1967 at 48° latitude show high levels of ^{65}Zn activity, and variation in activity within the samples is small compared to the 54° to 58° groups. These fish probably originated from areas south of the Fraser River, i.e., Oregon and Washington. Much greater variation is evident in the 54° to 58° groups. As mentioned, the lower values are thought to represent fish of northern origin. The remainder of the coho in these groups with their higher activity levels must have been in the plume and are probably of southern origin. The observed decrease in activity levels by latitude could be compared against a closely calculated decrease from a base of about 400 pCi/g ash if migration rate and time of ocean entry were better understood. From what is known, 1 to 4 months is needed for coho to move from the southern to the northern sampling areas. If these times for migration are related to the "effective half-life" for ^{65}Zn in coho, which may be similar to that for rainbow trout—4.5 months—(Nakatani, 1966), a decrease in activity of 10% to 40% would be expected. The observed decrease in activity from the 48° sample to the 56° and 58° samples is about 65%.

The 1968 data while having a different time-area distribution than those for 1967 are in general agreement with them. Thirty-five coho were analyzed from the 52° to 58° groups and, like 1967, activity values fell into two groups pointing to the presence of fish from two different origins. Unlike 1967, the lower values, interpreted to be coho of northern origin, were the most abundant in 1968. Samples were not obtained in June at 48° and 50° to compare with the high values observed in 1967. The absence of these samples to serve as a base for comparison prevents an evaluation of the higher activity values in the 52° to 58° samples, as was possible with the 1967 data.

An original intent of this study was to obtain coho from the "high seas" wintering areas west of Oregon and Washington for ^{65}Zn analysis, but this was not possible. However, we can estimate the levels of activity that could be expected there based on observed values from coho collected earlier inshore. Doing so would pose no problem if the physical decay rate of ^{65}Zn were the only consideration, but biological elimination also reduces activity. Nakatani (1966) studied the combined effect of both factors on the activity levels in rainbow trout and concluded that the effective half-life of ^{65}Zn in rainbow was 19 weeks or 4.5 months. By applying this rate, in the absence of similar data for coho, to the 1967 and 1968 data with a time lag of 6 months, estimates of March-April levels can be obtained.

The lowest values observed in Gulf of Alaska fish were between 5 and 10 pCi/g ash. Using 7 as a median value, a 6-month "decay" would reduce activity by 1.33 half-lives or to about 2.5 pCi/g ash, which is essentially the same as expected background levels. However, many of the coho that were considered to be of northern origin had activity values of 10 to 40 pCi/g ash, which is, at this rate of decay, sufficiently high to permit separation 6 months later from background level activity of 1-3 pCi/g ash. This being the case, coho with much higher activity levels that originated from the Oregon-Washington area would certainly be identifiable.

The observations of Kujala (1966, M.S. thesis) noted previously on pink and chum salmon, and the general similarity in feeding and migrating habits between these species and coho, suggests that levels of ^{65}Zn activity might be used to separate stocks of chums and pinks. Since these data point to a transport of Columbia River ^{65}Zn into the Northwestern Gulf of Alaska, even stocks of salmon originating there might be discernible on the high seas by their ^{65}Zn content from fish originating farther west where less influence of the Columbia River should be felt.

Conclusions

1. Background levels of ^{65}Zn activity for coho are low, probably about 1 to 3 pCi/g ash.
2. Coho using the coastal waters from Cook Inlet, Alaska, to Oregon currently have sufficient intake of Hanford produced ^{65}Zn to develop activity levels at least several times higher than background levels.

3. Further study of the change in amount of ^{65}Zn in coho with time and space should demonstrate that (1) different groups of North American coho can be identified by their ^{65}Zn content and (2) that most coho originating in northeastern Pacific streams can be separated from Bering Sea fish using levels of ^{65}Zn activity as the identifying mechanism even when captured on the high seas.
4. The possibility exists that species of salmon from Alaska and British Columbia streams, other than coho, accumulate sufficient ^{65}Zn to separate them from Western Pacific and Bering Sea stocks.
5. This work was not conclusive regarding migratory patterns of coho but did support the concept of a northerly migration of juvenile coho from Oregon and Washington.

Acknowledgments

As indicated, this study was undertaken because three research entities were sufficiently interested to give time and materials to it. While the agencies have been recognized, individuals have not. Those who contributed greatly to the program's success include: Messrs. Allan Hartt and Michael Dell of the Fisheries Research Institute, University of Washington, who provided the samples under a program funded by the U. S. Bureau of Commercial Fisheries, used in the study; Dr. Charles Osterberg and Mr. Norman Kujala of the Department of Oceanography, Oregon State University, who provided for the ^{65}Zn analysis and gave counsel on program design; and Mr. Robert McQueen of the Fish Commission of Oregon, who prepared the samples for analysis.

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DISTRIBUTION IN MARINE FISHERIES OF MARKED CHINOOK SALMON FROM THE COLUMBIA RIVER HATCHERY PROGRAM, 1963-66

Robert H. Lander①

Abstract

Preliminary data from the hatchery evaluation program of Columbia River system hatcheries were analyzed to determine the distribution of marked fall chinook salmon from different sources in the marine fisheries. Estimated catches of marked fish in 1963-66 from the 1961-64 broods were tabulated by type of fishery and port or zone of recovery.

Differences in distribution from north to south were detected between fish from different hatcheries and ocean ages. Only Kalama River fish demonstrably reached Alaskan waters, but fish from nearly all hatcheries were found as far south as northern California. The relative contributions of marked fish from different hatcheries to the marine fisheries varied considerably.

Specific differences among hatcheries in availability of fish to ocean sport and troll fisheries also were detected for ports between Newport, Oregon, and Neah Bay, Washington. Apparent intraseasonal movements of Spring Creek and Kalama River fish during 1964 and 1965 agreed in some respects, but not in others, with the known schedules of their return to the Columbia River.

Introduction

Annual releases since 1950 of fall chinook salmon (*Oncorhynchus tshawytscha* Walbaum) from 19 hatcheries along the lower 180 miles of the Columbia River and its tributaries have averaged about 70 million fish. No estimates of their economic value were available, however, until the recent finding that the 1961 brood, which cost $832,000 to rear, was worth $1.9 million to commercial and sport fishermen in 1963-66 (Worlund, Wahle, and Zimmer, 1969).

This preliminary estimate emerged from a study of the 31 million fingerlings of the 1961-64 broods that were marked and released at 12 stations to assess the bioeconomic contribution of Columbia River hatcheries to the North American catch of chinook salmon. Sampling for marked fish began in certain fisheries off Oregon and Washington during 1963, was expanded during 1964 from California to Alaska, and was continued through 1969 except in Alaska (Figure 1).

The experimental design of the evaluation program (Worlund *et al.*, 1969) involved releases from 12 hatcheries (the "hatchery complex") with a common, brood-specific mark. In addition, fish with hatchery-specific marks were released from each brood from four of the stations with the restriction that releases from Kalama River and Spring Creek hatcheries (Figure 1) be identifiable by brood year during the recovery phase. These two hatchery-specific marks provided continuing comparisons for the 1961-64 broods. Different marks were released from each brood at two other hatcheries and provided brood-specific comparisons with Spring Creek, Kalama River, and the hatchery complex.

Cleaver (1969) investigated the effects of ocean fishing on hatchery stocks of fall chinook salmon, both historically and on the basis of data from the evaluation program for the 1961 brood. He estimated hatchery-specific differences in potential yield from computed rates of ocean growth and mortality, but also considered variations in marine distribution. Marked fish were recovered from California to Alaska, but mainly off Washington and British Columbia; only fish from Kalama River hatcheries were shown conclusively to range as far north as Alaska.

The present report compares individual hatcheries and the hatchery complex with respect to availability of marked fish from the 1961-64 broods, as sampled in marine fisheries during 1963-66. First, annual centers of abundance are inferred even though exploitation rates are unknown and may vary regionally. Preliminary comparisons

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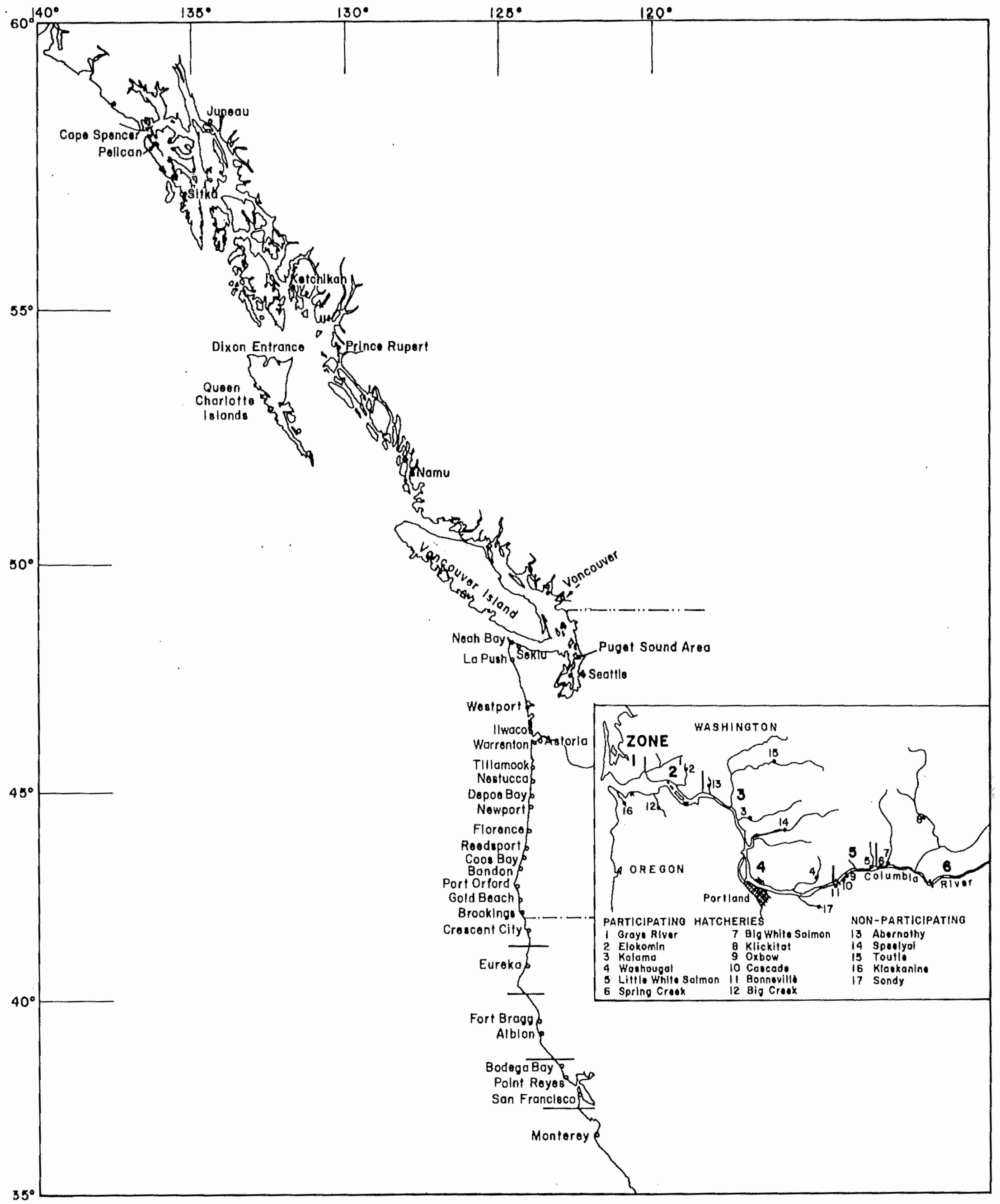

Figure 1. Sampling areas in marine fisheries and release locations (inset) for the Columbia River hatchery evaluation program.

are next made between offshore troll and inshore sport fisheries which operate from the same ports in Oregon and Washington. Finally, intraseasonal movements during 1964 and 1965 are examined for the 1961 brood.

Description of Source Data

The estimated catch of marked hatchery chinook in ocean fisheries during 1963-66, as determined from the evaluation program, is shown in Tables 1-4 by port or zone of landing for the 1961-64 broods (Bureau of Commercial Fisheries, 1964-68).

Worlund *et al.* (1969) analyzed observations and experiments regarding fin regeneration in relation to the occurrence of complete and partial marks in the fisheries and hatcheries. They reported negligible occurrence of naturally missing fins in hatchery releases (only 156 in over 30 million fish examined during marking of the 1961-64 broods). The following results also were reported for marked fish held in salt-water ponds for periods of up to 34 months after marking: (1) no regeneration of the adipose fin; (2) partial regeneration of the ventral fin in substantial portions (to 47%) of the fish held in each group; and (3) complete regeneration of the maxillary bone in 7-12% of the fish held from the 1961-62 broods (only the tip removed), and in 1-3% of the fish held from the 1963-64 broods (about half the bone removed). The authors concluded that maxillary regeneration explained most of the adipose-ventral and adipose-only marks recovered, but that maxillary regeneration or naturally missing ventral fins explained most ventral-only marks recovered.

On this basis, fish with adipose-only marks were assigned in Tables 1-4 to the hatchery complex. Fish with ventral-only marks, while indicated in the tables to complete the record through 1966 by port of landing, were considered to be only of "possible" hatchery origin and were excluded from all other marks ("known" and "probable"). Actual analysis, therefore, is based on estimated recoveries in the last column of each of Tables 1-4 (i.e., "Total less ventral-only").

North-South Distribution

The distribution of marked hatchery fish in the commercial and sports fisheries cannot be given quantitatively from estimated annual catches (Tables 1-4). One reason is that the fisheries take hatchery (and native) stocks selectively with respect to time, size, and area; for instance, recruitment begins about 1 year after survivors of a released group of fish reach the estuary, and is mainly in the sport fisheries, which have lower legal size limits than troll fisheries.① Another reason is that fishing intensity and rate of exploitation were not measured for the various fisheries along the coast for the years in question. Yet appropriate analysis of the data in Tables 1-4 yields useful comparisons among hatcheries.

The distribution among sampled fisheries of all marked fish caught each year from every hatchery source is given in Table 5 from the 1961-64 broods. The estimated total catch of Spring Creek marks (Ad-LV-RM and Ad-LV) of the 1961 brood during 1963, for example, was (0 + 4) + (46 + 39) + (43 + 24) + (0 + 4) = (89 + 71) = 160 (Table 1). These catches, shown in Table 5, were distributed as follows: 4, or 2%, in the Oregon sport fishery; 85, or 53%, in the sport fishery off the mouth of the Columbia River; 67, or 42%, in the Washington ocean sport fishery north of Ilwaco; and 4, or 2%, in the Washington troll fishery. The annual contri-

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① D. D. Worlund (personal communication) notes that data from the evaluation program might be used to make forecasts of the contribution from a specific hatchery at relatively low cost. If the total catch (at all ages in all fisheries) of marked fish from one hatchery (say Spring Creek) is highly correlated in the 1961-64 broods with the partial catch of marked fish at age .1 in sport landings at one port (say Ilwaco), then part of the future releases at that hatchery could be marked and sport landings at that port monitored rather inexpensively as a basis for prediction.

Table 1. Estimated catch in marine fisheries during 1963-66 of 1961-brood chinook salmon with known, probable, and possible hatchery marks

Sampling year	Fishery	Port or zone of recovery	Hatchery and type of mark										Total estimated catch	Total less ventral-only
			Hatchery complex		Spring Creek		Kalama		Elokomin		Oxbow			
			Known	Prob.	Known	Prob.	Known	Prob.	Known	Poss.	Known	Poss.		
			Ad-RM	Ad	Ad-LV-RM	Ad-LV	Ad-RV-RM	Ad-RV	LV-RM	LV	RV-RM	RV		
1963	Oregon, sport	Reedsport	0	0	0	4	0	0	0	0	0	0	4	4
	Columbia River mouth, sport	Warrenton-Ilwaco	201	99	46	39	3	0	0	0	7	4	399	395
	Washington, Ocean sport	Neah Bay	73	5	0	5	0	0	0	0	0	6	89	83
		LaPush	22	35	8	0	0	0	0	0	0	0	65	65
		Westport	79	57	35	19	14	4	0	12	4	0	224	212
		Total	174	97	43	24	14	4	0	12	4	6	378	360
	Washington, troll	LaPush-Westport	0	3	0	4	0	0	0	0	0	0	7	7
	All	All	375	199	89	71	17	4	0	12	11	10	788	766
1964	California, troll	Crescent City	0	0	3	2	2	0	0	0	0	0	7	7
		Eureka	2	0	0	8	0	0	7	0	0	0	17	17
		Ft. Bragg	21	0	6	0	0	0	0	0	0	0	27	27
		San Francisco	0	0	6	0	0	0	0	0	0	0	6	6
		Total	23	0	15	10	2	0	7	0	0	0	57	57
	Oregon, sport	Depoe Bay	3	0	0	2	0	0	0	0	15	0	20	20
		Newport	49	10	5	16	0	0	0	5	3	3	91	83
		Florence	4	27	0	0	0	0	0	0	0	0	31	31
		Reedsport	10	49	0	26	0	0	0	6	0	0	91	85
		Coos Bay	3	7	0	0	0	0	3	0	0	0	13	13
		Brookings	3	0	0	0	0	0	0	0	0	2	5	3
		Total	72	93	5	44	0	0	3	11	18	5	251	235

Table 1. Continued

			Hatchery and type of mark											
			Hatchery complex		Spring Creek		Kalama		Elo-komin		Oxbow			
			Known	Prob.	Known	Prob.	Known	Prob.	Known	Poss.	Known	Poss.		
Sampling year	Fishery	Port or zone of recovery	Ad-RM	Ad	Ad-LV-RM	Ad-LV	Ad-RV-RM	Ad-RV	LV-RM	LV	RV-RM	RV	Total estimated catch	Total less ventral-only
1964	Oregon, troll	Astoria	229	10	40	0	6	0	5	3	0	3	296	290
		Tillamook	4	1	0	0	2	0	0	0	0	0	7	7
		Nestucca	1	0	0	0	0	0	0	0	0	0	1	1
		Depoe Bay	3	1	1	0	0	0	0	0	1	0	6	6
		Newport	24	27	8	1	6	0	3	0	2	0	71	71
		Florence	39	0	15	0	0	0	0	4	4	1	63	58
		Reedsport	10	0	0	0	0	0	0	0	0	0	10	10
		Coos Bay	13	5	6	5	3	2	1	5	7	13	60	42
		Bandon	1	0	2	2	0	1	0	1	1	3	11	7
		Port Orford	0	1	0	0	1	0	0	0	1	1	4	3
		Brookings	0	0	1	0	0	0	0	0	4	0	5	5
		Total	324	45	73	8	18	3	9	13	20	21	534	500
	Columbia River mouth, sport	Warrenton-Ilwaco	86	37	25	20	6	4	0	5	8	6	197	186
	Washington, ocean sport	Sekiu	540	28	114	12	18	0	0	0	17	0	729	729
		Neah Bay	201	38	27	20	9	0	0	9	0	9	313	295
		LaPush	26	8	3	5	0	0	0	0	0	0	42	42
		Westport	828	113	185	20	41	0	8	41	18	37	1,291	1,213
		Total	1,595	187	329	57	68	0	8	50	35	46	2,375	2,279
	Washington, troll	Neah Bay	861	149	208	64	74	0	12	22	17	11	1,418	1,385
		LaPush	565	78	262	121	14	7	4	11	4	0	1,066	1,055
		Westport	1,424	121	312	26	30	10	27	14	29	11	2,004	1,979
		Ilwaco	386	49	87	4	14	0	2	17	8	7	574	550
		Total	3,236	397	869	215	132	17	45	64	58	29	5,062	4,969
	Washington, gill net	Neah Bay-Clallam Bay	5	0	0	0	0	0	0	0	0	0	5	5

	British Columbia, gill net	Zone 42	4	4	0	0	0	0	0	0	0	0	8	8
	British Columbia, purse seine	Zone 40	2	4	0	0	0	0	0	0	0	0	6	6
	British Columbia, troll	Alaska area	0	2	0	0	0	0	0	0	0	0	2	2
		Zone 43	80	37	0	2	29	9	0	8	0	14	179	157
		Zone 42	48	23	6	0	18	0	0	9	0	13	117	95
		Zone 40	3,972	496	761	72	373	12	28	43	8	32	5,797	5,722
		Total	4,100	558	767	74	420	21	28	60	8	59	6,095	5,976
	Southeastern Alaska, commercial	Zone 11	0	0	0	0	5	0	0	0	0	0	5	5
		Zone 13	0	0	0	0	0	0	0	2	0	0	2	0
		Zone 14	0	2	0	0	0	0	0	2	0	0	4	2
		Total	0	2	0	0	5	0	0	4	0	0	11	7
	All	All	9,447	1,327	2,083	428	651	45	100	207	147	166	14,601	14,228
1965	California, sport	Eureka	0	0	0	0	0	0	0	0	2	0	2	2
	California, troll	Crescent City	0	0	0	0	0	0	0	8	0	17	25	0
		Eureka	0	0	0	0	0	0	0	0	0	22	22	0
		Ft. Bragg	0	4	0	0	0	0	0	13	0	27	44	4
		San Francisco	0	0	0	0	0	0	0	0	0	5	5	0
		Total	0	4	0	0	0	0	0	21	0	71	96	4
	Oregon, sport	Depoe Bay	2	0	0	0	0	0	0	0	0	0	2	2
		Reedsport	24	16	0	4	0	0	0	0	4	5	52	48
		Gold Beach	0	0	0	0	0	0	0	0	0	2	2	0
		Brookings	0	0	0	0	0	0	0	0	0	2	2	0
		Total	26	16	0	4	0	0	0	0	4	9	58	50
	Oregon, troll	Astoria	0	3	4	2	0	0	0	2	0	0	11	9
		Tillamook	0	0	12	0	0	0	0	0	0	0	12	12
		Newport	7	4	0	0	0	0	3	1	2	0	17	16
		Florence	2	0	0	2	0	0	0	0	0	0	4	4
		Reedsport	0	2	0	0	0	0	0	0	0	0	2	2
		Coos Bay	0	0	0	0	3	0	0	0	0	0	3	3
		Brookings	1	3	0	0	1	0	0	2	0	1	8	5
		Total	10	12	16	4	4	0	3	5	2	1	57	51

Table 1. Continued

			Hatchery and type of mark											
			Hatchery complex		Spring Creek		Kalama		Elokomin		Oxbow			
			Known	Prob.	Known	Prob.	Known	Prob.	Known	Poss.	Known	Poss.		
Sampling year	Fishery	Port or zone of recovery	Ad-RM	Ad	Ad-LV-RM	Ad-LV	Ad-RV-RM	Ad-RV	LV-RM	LV	RV-RM	RV	Total estimated catch	Total less ventral-only
1965	Columbia River mouth, sport	Warrenton-Ilwaco	93	26	8	21	21	8	0	14	0	0	191	177
	Washington, ocean sport	Sekiu	48	7	11	0	13	0	0	6	0	0	85	79
		Neah Bay	32	6	6	0	13	0	7	0	0	0	64	64
		LaPush	9	0	0	0	0	0	0	0	0	0	9	9
		Westport	234	65	27	24	25	20	8	7	0	21	431	403
		Total	323	78	44	24	51	20	15	13	0	21	589	555
	Washington, troll	Neah Bay	145	5	9	0	28	4	0	4	0	9	204	191
		LaPush	78	23	27	0	13	0	0	11	0	0	152	141
		Westport	201	22	40	0	68	2	5	7	9	5	359	347
		Ilwaco	23	4	0	4	9	12	0	0	0	0	52	52
		Total	447	54	76	4	118	18	5	22	9	14	767	731
	Washington, gill net	Grays Harbor	8	5	2	0	4	2	0	0	0	0	21	21
	British Columbia, gill net	Zone 42	23	0	0	0	0	0	0	0	0	0	23	23
	British Columbia, troll	Alaska area	0	2	0	0	0	0	0	0	0	0	2	2
		Zone 43	71	33	0	0	35	8	0	3	0	0	150	147
		Zone 42	47	59	0	0	59	0	0	0	2	7	174	167
		Zone 41	113	0	0	0	0	0	0	0	0	5	118	113
		Zone 40	1,617	276	140	24	361	17	7	43	14	39	2,538	2,456
		Total	1,848	370	140	24	455	25	7	46	16	51	2,982	2,885

	S.E. Alaska, gill net troll	Various	0	3	0	0	0	0	0	3	0	0	6	3
		Zones 1, 3, 4	0	0	0	0	10	4	0	23	0	33	70	14
		Zones 5, 8	0	0	0	0	0	0	0	3	0	0	3	0
		Zones 9-13	7	5	0	0	0	12	0	3	0	0	27	24
		Zones 10-12, 15	0	10	0	0	0	0	0	3	0	0	13	10
		Zones 14, 18, 22	0	5	0	0	4	5	0	16	0	8	38	14
		Total	7	23	0	0	14	21	0	51	0	41	157	65
	All	All	2,785	588	286	81	667	94	30	172	33	208	4,944	4,564
1966	California, troll	Crescent City	0	0	0	0	0	0	0	0	0	3	3	0
		Eureka	6	0	0	0	0	0	0	0	0	0	6	6
		Total	6	0	0	0	0	0	0	0	0	3	9	6
	Columbia River mouth, sport	Warrenton-Ilwaco	22	5	0	0	5	0	0	0	0	0	32	32
	Washington, ocean sport	Sekiu	0	0	0	0	0	0	0	0	0	11	11	0
		Neah Bay	5	6	0	0	0	0	0	0	5	0	16	16
		Westport	40	4	0	0	0	4	0	0	4	0	52	52
		Total	45	10	0	0	0	4	0	0	9	11	79	68
	Washington, troll	Seattle	2	4	0	0	0	0	0	0	0	0	6	6
		Neah Bay	9	2	0	0	5	0	0	5	0	2	23	16
		LaPush	21	0	0	0	0	0	0	0	0	3	24	21
		Westport	9	2	0	0	2	0	3	0	0	0	16	16
		Total	41	8	0	0	7	0	3	5	0	5	69	59
	Washington, gill net	Willapa Hbr.	0	0	0	0	0	0	0	5	0	3	8	0
	Puget Sound, sport	Zone 11	0	0	0	0	0	0	0	0	0	64	64	0
	British Columbia, gill net	Zone 42	0	0	0	0	0	0	0	36	0	24	60	0
	British Columbia, troll	Zone 43	12	12	0	0	0	0	0	3	0	8	35	24
		Zone 42	48	21	0	0	7	4	6	9	6	29	130	92
		Zone 41	1	0	0	0	0	0	0	0	0	0	1	1
		Zone 40	174	35	5	0	82	2	0	15	0	16	329	298
		Total	235	68	5	0	89	6	6	27	6	53	495	415
	Southeastern Alaska, troll	Zones 14, 16, 18, 22	0	2	0	0	4	0	0	15	0	2	23	6
	All	All	349	93	5	0	105	10	9	88	15	165	839	586
1963-1966	All	All	12,956	2,207	2,463	580	1,440	153	139	479	206	549	21,172	20,144

Table 2. Estimated catch in marine fisheries during 1964-66 of 1962-brood chinook salmon with known, probable, and possible hatchery marks

			Hatchery and type of mark											
			Hatchery complex		Spring Creek		Kalama		Grays		Cascade			
			Known	Prob.	Known	Prob.	Known	Prob.	Known	Poss.	Known	Poss.		
Sampling year	Fishery	Port or zone of recovery	Ad-LM	Ad	Ad-LV-LM	Ad-LV	Ad-RV-LM	Ad-RV	LV-LM	LV	RV-LM	RV	Total estimated catch	Total less ventral-only
1964	Oregon, sport	Newport	0	3	0	0	0	0	0	0	0	0	3	3
	Oregon, troll	Astoria	2	0	0	0	0	0	0	0	0	0	2	2
	Columbia River mouth, sport	Warrenton-Ilwaco	83	21	4	4	0	0	0	0	0	0	112	112
	Washington, ocean sport	Sekiu	0	9	0	12	0	0	0	0	0	0	21	21
		LaPush	3	0	0	0	0	0	0	0	0	0	3	3
		Westport	77	5	10	4	0	0	0	3	0	3	102	96
		Total	80	14	10	16	0	0	0	3	0	3	126	120
	Washington, troll	Neah Bay	3	0	0	0	0	0	0	0	0	0	3	3
		Westport	5	0	0	0	0	0	0	0	0	0	5	5
		Total	8	0	0	0	0	0	0	0	0	0	8	8
	British Columbia, troll	Zone 40	51	8	0	0	0	0	0	0	0	0	59	59
	All	All	224	46	14	20	0	0	0	3	0	3	310	304
1965	California, sport	Eureka	0	5	0	0	0	0	0	0	2	2	9	7
		Ft. Bragg	0	3	0	0	0	0	0	0	0	0	3	3
		Total	0	8	0	0	0	0	0	0	2	2	12	10
	California, troll	Crescent City	0	3	0	0	0	0	0	3	0	0	6	3
		Eureka	0	6	0	0	0	0	6	0	0	5	17	12
		Ft. Bragg	6	53	0	0	0	0	0	8	0	12	79	59
		San Francisco	0	5	0	0	0	0	0	0	0	21	26	5
		Total	6	67	0	0	0	0	6	11	0	38	128	79

Oregon, sport	Depoe Bay	0	2	0	0	0	0	0	0	0	0	2	2
	Newport	0	7	0	0	0	4	0	0	0	0	11	11
	Florence	0	4	0	0	0	0	0	0	0	4	8	4
	Reedsport	12	8	0	0	0	0	0	0	0	0	20	20
	Coos Bay	0	0	2	0	0	0	0	0	0	7	9	2
	Total	12	21	2	0	0	4	0	0	0	11	50	39
Oregon, troll	Astoria	11	2	9	0	2	0	0	0	0	5	29	24
	Newport	8	8	0	0	0	2	2	0	0	4	24	20
	Florence	5	2	0	0	0	0	0	0	0	0	7	7
	Reedsport	0	2	0	0	0	0	0	0	0	0	2	2
	Coos Bay	0	0	0	0	0	0	0	6	0	0	6	0
	Brookings	1	4	0	0	0	0	0	3	0	3	11	5
	Total	25	18	9	0	2	2	2	9	0	12	79	58
Columbia River mouth, sport	Warrenton-Ilwaco	44	27	0	0	11	5	0	0	2	0	89	89
Washington, ocean sport	Sekiu	111	0	33	5	6	0	0	0	0	0	155	155
	Neah Bay	11	5	0	0	0	0	0	0	0	0	16	16
	LaPush	13	4	0	0	4	0	0	0	0	0	21	21
	Westport	280	131	85	17	24	26	0	8	8	11	590	571
	Total	415	140	118	22	34	26	0	8	8	11	782	763
Washington, troll	Neah Bay	149	24	26	0	4	0	0	0	3	29	235	206
	LaPush	119	48	0	12	0	6	0	0	0	12	197	185
	Westport	640	51	95	13	24	0	15	5	3	7	853	841
	Ilwaco	38	45	0	0	2	11	0	0	3	0	99	96
	Total	946	168	121	25	30	17	15	5	9	48	1,384	1,331
Washington, gill net	Grays Hbr.	27	0	4	0	0	0	0	0	0	0	31	31
Puget Sound, sport	Zone 6	81	0	0	0	0	0	81	0	0	0	162	162
British Columbia, troll	Zone 43	16	12	0	0	9	0	0	0	0	0	37	37
	Zone 42	7	15	0	0	18	0	0	22	0	0	62	40
	Zone 41	0	5	0	0	0	0	0	0	0	0	5	5
	Zone 40	1,160	336	68	7	128	7	2	23	45	45	1,821	1,753
	Total	1,183	368	68	7	155	7	2	45	45	45	1,925	1,835

Table 2. Continued

Sampling year	Fishery	Port or zone of recovery	Hatchery and type of mark										Total estimated catch	Total less ventral-only
			Hatchery complex		Spring Creek		Kalama		Grays		Cascade			
			Known	Prob.	Known	Prob.	Known	Prob.	Known	Poss.	Known	Poss.		
			Ad-LM	Ad	Ad-LV-LM	Ad-LV	Ad-RV-LM	Ad-RV	LV-LM	LV	RV-LM	RV		
1965	S.E. Alaska, gill net troll	Various	0	3	0	0	0	0	0	0	0	0	3	3
		Zones 10-12, 15	0	5	0	0	0	0	0	0	0	0	5	5
		Zones 14, 18, 22	0	1	0	0	0	0	0	0	0	0	1	1
		Total	0	9	0	0	0	0	0	0	0	0	9	9
	All	All	2,739	826	322	54	232	61	106	78	66	167	4,651	4,406
1966	California, sport	San Francisco	0	0	0	0	0	0	0	4	0	0	4	0
	California, troll	Eureka	0	0	0	0	0	0	0	0	0	6	6	0
	Oregon, sport	Reedsport	0	0	0	0	4	0	0	0	0	0	4	4
	Oregon, troll	Astoria	3	3	3	0	0	0	3	0	3	0	15	15
		Coos Bay	0	0	0	0	0	0	5	0	0	0	5	5
		Total	3	3	3	0	0	0	8	0	3	0	20	20
	Columbia River	Warrenton-Ilwaco	15	3	12	0	3	0	0	5	3	0	41	36
	Washington, ocean sport	Sekiu	37	8	0	0	0	0	0	11	0	11	67	45
		Neah Bay	10	5	0	0	0	0	0	0	6	0	21	21
		Westport	46	32	4	8	4	0	0	12	4	8	118	98
		Total	93	45	4	8	4	0	0	23	10	19	206	164
	Washington, troll	Seattle	2	11	8	0	2	0	0	0	0	0	23	23
		Neah Bay	49	10	8	0	6	0	0	2	2	2	79	75
		LaPush	25	0	8	0	0	0	0	6	0	0	39	33
		Westport	47	5	7	2	7	0	0	0	2	4	74	70
		Ilwaco	7	2	0	0	0	0	0	0	0	0	9	9
		Total	125	28	31	2	15	0	0	8	4	6	224	210

	Puget Sound, sport	Zone 9	0	0	0	0	0	0	32	8	8	8	32	32
		Zone 10	0	0	0	0	0	0	0	54	0	0	54	0
		Zone 11	0	0	0	0	0	0	0	64	0	0	64	0
		Total	0	0	0	0	0	0	32	118	0	0	150	32
	British Columbia, gill net	Zone 42	12	0	0	0	0	0	0	0	0	48	60	12
	British Columbia, troll	Zone 43	8	32	5	0	6	10	3	3	3	0	70	67
		Zone 42	79	13	0	0	16	0	0	26	4	19	157	112
		Zone 41	4	2	0	0	0	0	0	0	0	1	7	6
		Zone 40	719	207	62	23	113	15	11	45	16	72	1,283	1,166
		Total	810	254	67	23	135	25	14	74	23	92	1,517	1,351
	Southeastern Alaska, troll	Zones 9-13, 15	0	0	0	0	0	0	0	16	0	16	32	0
		Zones 14, 16, 18, 22	5	13	0	0	2	2	0	12	0	10	44	22
		Total	5	13	0	0	2	2	0	28	0	26	76	22
	All	All	1,061	344	117	33	163	27	54	260	43	197	2,299	1,851
1964-1966	All	All	4,024	1,216	453	107	395	88	160	341	109	367	7,260	6,561

Table 3. Estimated catch in marine fisheries during 1965-66 of 1963-brood chinook salmon with known, probable, and possible hatchery marks

			Hatchery and type of mark											
			Hatchery complex		Spring Creek		Kalama		Klickitat		Big Creek			
			Known	Prob.	Known	Prob.	Known	Prob.	Known	Poss.	Known	Poss.		
Sampling year	Fishery	Port or zone of recovery	Ad-RM	Ad	Ad-LV-RM	Ad-LV	Ad-RV-RM	Ad-RV	LV-RM	LV	RV-RM	RV	Total estimated catch	Total less ventral-only
1965	California, troll	San Francisco	0	0	0	0	0	0	0	4	0	0	4	0
	Oregon, sport	Depoe Bay	0	0	0	0	0	2	0	0	0	0	2	2
	Oregon, troll	Astoria	4	0	0	0	0	0	0	0	0	0	4	4
	Columbia River mouth, sport	Warrenton-Ilwaco	242	63	55	16	21	3	15	20	33	21	489	448
	Washington, ocean sport	Sekiu	115	0	0	0	0	0	16	0	0	32	163	131
		Neah Bay	43	0	0	0	0	0	0	0	0	0	43	43
		LaPush	34	12	22	0	0	0	13	0	4	3	88	85
		Westport	130	32	27	0	0	0	32	0	19	28	268	240
		Total	322	44	49	0	0	0	61	0	23	63	562	499
	Washington, troll	Neah Bay	5	0	0	0	0	0	0	0	0	0	5	5
		LaPush	0	0	0	0	0	0	0	3	0	0	3	0
		Westport	0	0	0	0	0	0	3	0	0	0	3	3
		Total	5	0	0	0	0	0	3	3	0	0	11	8
	Puget Sound, sport	Zone 6	562	0	0	0	81①	0	0	0	0	0	643	643
		Zone 9	63	0	0	0	0	0	32	0	0	0	95	95
		Zone 10	0	0	0	0	0	33①	0	0	0	0	33	33
		Total	625	0	0	0	81	33	32	0	0	0	771	771
	British Columbia, troll	Zone 42	0	7	0	0	0	0	0	0	0	0	7	7
		Zone 40	55	0	23	0	0	0	0	0	0	0	78	78
		Total	55	7	23	0	0	0	0	0	0	0	85	85
	All	All	1,253	114	127	16	102	38	111	27	56	84	1,928	1,817

1966	California, sport	Ft. Bragg	0	0	4	0	0	0	0	0	0	0	4	4
		San Francisco	0	7	0	0	0	0	4	0	0	11	22	11
		Monterey	0	0	0	0	0	0	0	0	0	1	1	0
		Total	0	7	4	0	0	0	4	0	0	12	27	15
	California, troll	Eureka	2	13	0	0	0	0	0	11	0	0	26	15
		Ft. Bragg	10	20	0	0	0	0	0	9	0	2	41	30
		San Francisco	0	0	0	0	0	0	0	0	7	0	7	7
		Total	12	33	0	0	0	0	0	20	7	2	74	52
	Oregon, sport	Depoe Bay	14	9	3	0	0	0	3	0	0	0	29	29
		Newport	8	0	0	0	0	0	0	0	0	0	8	8
		Florence	6	0	0	0	0	0	0	0	3	0	9	9
		Reedsport	67	4	13	4	0	0	0	4	0	0	92	88
		Coos Bay	0	0	3	0	0	0	0	0	0	0	3	3
		Gold Beach	0	0	2	0	0	0	0	0	0	2	4	2
		Total	95	13	21	4	0	0	3	4	3	2	145	139
	Oregon, troll	Astoria	332	26	17	2	0	2	10	0	9	6	404	398
		Tillamook	47	0	0	0	0	0	0	0	0	0	47	47
		Nestucca	6	0	2	0	0	0	2	0	0	0	10	10
		Depoe Bay	15	8	0	0	0	0	0	0	0	0	23	23
		Newport	38	5	5	0	2	0	5	0	5	0	60	60
		Florence	8	0	0	0	0	0	0	16	11	0	35	19
		Coos Bay	13	3	2	0	1	0	6	0	5	5	35	30
		Brookings	0	0	0	0	2	0	2	1	0	0	5	4
		Total	459	42	26	2	5	2	25	17	30	11	619	591
	Columbia River mouth, sport	Warrenton-Ilwaco	1,183	171	168	12	78	12	63	8	65	21	1,781	1,752
	Washington, ocean sport	Sekiu	255	88	20	11	0	2	4	6	40	11	437	420
		Neah Bay	91	20	23	0	15	0	15	0	20	0	184	184
		LaPush	39	2	3	0	20	0	20	0	0	0	67	67
		Westport	1,085	161	158	12	58	12	63	8	55	21	1,633	1,604
		Total	1,470	271	204	23	76	14	102	14	115	32	2,321	2,275
	Washington, troll	Seattle	125	13	2	0	2	0	2	0	0	2	146	144
		Neah Bay	533	21	54	2	16	8	37	13	50	10	744	721
		LaPush	891	78	111	0	35	0	36	10	48	8	1,217	1,199
		Westport	809	47	136	4	30	0	55	16	41	15	1,153	1,122
		Ilwaco	867	16	71	1	12	0	35	6	11	0	1,019	1,013
		Total	3,225	175	374	7	95	8	165	45	150	35	4,279	4,199

Table 3. Continued

			Hatchery and type of mark											
			Hatchery complex		Spring Creek		Kalama		Klickitat		Big Creek			
			Known	Prob.	Known	Prob.	Known	Prob.	Known	Poss.	Known	Poss.	Total esti- mated catch	Total less ventral- only
Sampling year	Fishery	Port or zone of recovery	Ad-RM	Ad	Ad-LV-RM	Ad-LV	Ad-RV-RM	Ad-RV	LV-RM	LV	RV-RM	RV		
1966	Washington, gill net	Willapa Hbr.	2	3	0	0	4	0	0	0	0	2	11	9
	Puget Sound, sport	Zone 6	540	0	0	0	0	0	0	0	0	0	540	540
		Zone 7	81	0	0	0	0	0	0	0	0	0	81	81
		Zone 8	32	0	38	0	0	0	0	0	0	0	70	70
		Total	653	0	38	0	0	0	0	0	0	0	691	691
	British Columbia, troll	Zone 43	26	9	0	0	9	3	0	10	0	3	60	47
		Zone 42	58	7	0	0	22	0	55	7	9	9	167	151
		Zone 41	1	16	0	0	0	0	0	25	0	0	42	17
		Zone 40	4,498	402	530	27	190	17	194	59	18	92	6,027	5,876
		Total	4,583	434	530	27	221	20	249	101	27	104	6,296	6,091
	Southeastern Alaska, troll	Zones 1-4	0	8	0	0	0	0	0	0	0	0	8	8
		Zones 9-13, 15	0	0	0	0	0	0	0	0	0	16	16	0
		Zones 14, 16, 18, 22	0	11	0	0	5	0	0	5	0	0	21	16
		Total	0	19	0	0	5	0	0	5	0	16	45	24
	All	All	11,682	1,168	1,365	75	484	56	611	214	397	237	16,289	15,838
1965-1966	All	All	12,935	1,282	1,492	91	586	94	722	241	453	321	18,217	17,655

① Estimates of triple-only and double-only marks from the same origin in different zones were related to low mark sampling (1.4-3.0%) in this fishery.

Table 4. Estimated catch in marine fisheries during 1966 of 1964-brood chinook salmon with known, probable, and possible hatchery marks

			Hatchery and type of mark											
			Hatchery complex		Spring Creek		Kalama		Bonneville		Little White			
			Known	Prob.	Known	Prob.	Known	Prob.	Known	Poss.	Known	Poss.		
Sampling year	Fishery	Port or zone of recovery	Ad-LM	Ad	Ad-LV-LM	Ad-LV	Ad-RV-LM	Ad-RV	LV-LM	LV	RV-LM	RV	Total estimated catch	Total less ventral-only
1966	California, troll	San Francisco	0	0	0	0	0	0	5	0	0	0	5	5
	Oregon, sport	Depoe Bay	0	0	0	0	0	0	11	0	0	0	11	11
		Reedsport	4	0	0	0	0	0	13	0	0	0	17	17
		Coos Bay	0	0	0	0	0	0	3	0	0	0	3	3
		Total	4	0	0	0	0	0	27	0	0	0	31	31
	Oregon, troll	Coos Bay	0	0	0	0	0	0	7	0	0	0	7	7
	Columbia River mouth, sport	Warrenton-Ilwaco	343	72	132	108	0	0	20	23	0	0	698	675
	Washington, ocean sport	Sekiu	22	26	0	0	0	0	0	0	0	0	48	48
		Neah Bay	63	0	54	0	0	0	0	0	0	0	117	117
		Westport	170	24	69	8	4	34	29	0	0	4	342	338
		Total	255	50	123	8	4	34	29	0	0	4	507	503
	Washington, troll	Seattle	2	0	0	0	0	0	0	0	0	0	2	2
		Neah Bay	2	0	0	0	0	0	2	0	0	0	4	4
		LaPush	0	24	0	0	0	0	0	0	0	0	24	24
		Westport	4	0	0	0	0	0	3	0	0	0	7	7
		Total	8	24	0	0	0	0	5	0	0	0	37	37
	British Columbia, gill net	Zone 42	0	0	0	0	0	0	12	0	0	0	12	12
	British Columbia, troll	Zone 43	0	3	0	0	0	0	0	3	0	0	6	3
		Zone 42	0	0	0	15	0	0	34	0	0	0	49	49
		Zone 41	3	0	0	0	0	0	0	0	0	0	3	3
		Zone 40	7	3	0	0	0	0	9	0	4	0	23	23
		Total	10	6	0	15	0	0	43	3	4	0	81	78
	All	All	620	152	255	131	4	34	148	26	4	4	1,378	1,348

Table 5. Percentage catch of marked 1961-64-brood chinook salmon in marine fisheries from evaluation hatcheries during 1963-66 (read percentages across), and percentage contribution of each hatchery to annual catch of evaluation marks (read percentages down last column); (A dash (—) indicates no mark sampling and a plus (+) indicates less than 0.5%)

				Location of fishery and type of gear													
				California		Oregon		Washington					British Columbia			Southeastern Alaska	Contribution to total catch of marked fish
Brood year	Recovery year	Age at recovery①	Hatchery	Sport	Troll	Sport	Troll	Col. R. mouth sport	Ocean sport	Troll	Gill net	Puget Sound sport	Gill net	Purse seine	Troll	Commercial	
1961	1963	.1	Complex	—	—	0	0	52	47	1	—	—	—	—	—	—	75%
			Spring Cr.	—	—	0	—	53	42	2	—	—	—	—	—	—	21%
			Kalama	—	—	2	0	14	86	0	—	—	—	—	—	—	3%
			Elokomin	—	—	0	0	0	0	0	—	—	—	—	—	—	0
			Oxbow	—	—	0	0	64	36	0	—	—	—	—	—	—	1%
			All	—	—	1%	0	52%	47%	1%	—	—	—	—	—	—	②
	1964	.2	Complex	0	+	2	3	1	17	34	+	—	+	+	43	+	76%
			Spring Cr.	0	1	2	3	2	15	43	0	—	0	0	33	0	18%
			Kalama	0	+	0	3	1	10	21	0	—	0	0	63	1	5%
			Elokomin	0	7	3	9	0	8	45	0	—	0	0	28	0	1%
			Oxbow	0	0	12	14	5	24	40	0	—	0	0	5	0	1%
			All	0	+	2%	4%	1%	16%	35%	+	—	+	+	42%	+	②
	1965	.3	Complex	0	+	1	1	4	12	15	+	0	1	0	66	1	74%
			Spring Cr.	0	0	1	5	8	19	22	+	0	0	0	45	0	8%
			Kalama	0	0	0	1	4	9	18	1	0	0	0	63	5	17%
			Elokomin	0	0	0	10	0	50	17	0	0	0	0	23	0	1%
			Oxbow	6	0	12	6	0	0	27	0	0	0	0	48	0	1%
			All	+	+	1%	1%	4%	12%	16%	+	0	1%	0	63%	1%	②
	1966	.4	Complex	0	1	0	0	6	12	11	0	0	0	—	69.	+	76%
			Spring Cr.	0	0	0	0	0	0	0	0	0	0	—	100	0	1%
			Kalama	0	0	0	0	0	4	6	0	0	0	—	86	4	19%
			Elokomin	0	0	0	0	0	0	33	0	0	0	—	67	0	2%
			Oxbow	0	0	0	0	0	60	0	0	0	0	—	40	0	3%
			All	0	1%	0	0	5%	12%	10%	0	0	0	—	71%	1%	②

	1963-1966	.1.4	Complex	0	+	1	3	5	17	27	+	0	+	+	47	+	75%
			Spring Cr.	0	1	2	3	5	17	38	+	0	0	0	33	0	15%
			Kalama	0	+	0	2	3	10	18	+	0	0	0	64	3	8%
			Elokomin	0	5	2	9	0	17	38	0	0	0	0	29	0	1%
			Oxbow	1	0	11	11	7	23	33	0	0	0	0	15	0	1%
			All	+	+	1%	3%	4%	16%	29%	+	0	+	+	46%	+	②
1962	1964	.1	Complex	0	0	1	1	39	35	3	0	—	0	0	22	0	89%
			Spring Cr.	0	0	0	0	24	76	0	0	—	0	0	0	0	11%
			Kalama	0	0	0	0	0	0	0	0	—	0	0	0	0	0
			Grays	0	0	0	0	0	0	0	0	—	0	0	0	0	0
			Cascade	0	0	0	0	0	0	0	0	—	0	0	0	0	0
			All	0	0	1%	1%	37%	39%	3%	0	—	0	0	19%	0	②
	1965	.2	Complex	+	2	1	1	2	16	31	1	2	0	0	44	+	81%
			Spring Cr.	0	0	1	2	0	37	39	1	0	0	0	20	0	9%
			Kalama	0	0	1	1	5	20	16	0	0	0	0	55	0	7%
			Grays	0	6	0	2	0	0	14	0	76	0	0	2	0	2%
			Cascade	3	0	0	0	3	12	14	0	0	0	0	68	0	1%
			All	+	2%	1%	1%	2%	17%	30%	1%	4%	0	0	42%	+	②
	1966	.3	Complex	0	0	0	+	1	10	11	0	0	1	—	76	1	77%
			Spring Cr.	0	0	0	2	8	8	22	0	0	0	—	60	0	8%
			Kalama	0	0	2	0	2	2	8	0	0	0	—	84	2	10%
			Grays	0	0	0	15	0	0	0	0	59	0	—	26	0	3%
			Cascade	0	0	0	7	7	23	9	0	0	0	—	53	0	2%
			All	0	0	+	1%	2%	9%	11%	0	2%	1%	—	74%	1%	②
	1964-1966	.1-.3	Complex	+	1	1	1	4	15	24	1	2	+	0	51	1	80%
			Spring Cr.	0	0	+	2	4	32	32	1	0	0	0	29	0	9%
			Kalama	0	0	2	1	4	13	13	0	0	0	0	67	1	7%
			Grays	0	4	0	6	0	0	9	0	71	0	0	10	0	2%
			Cascade	2	0	0	3	5	17	12	0	0	0	0	62	0	2%
			All	+	1%	1%	1%	4%	16%	24%	4%	3%	+	0	50%	+	②
1963	1965	.1	Complex	0	0	0	+	22	27	+	0	46	0	0	5	0	75%
			Spring Cr.	0	0	0	0	50	34	0	0	0	0	0	16	0	8%
			Kalama	0	0	1	0	17	0	0	0	81	0	0	0	0	8%
			Klickitat	0	0	0	0	14	55	3	0	29	0	0	0	0	6%
			Big Creek	0	0	0	0	59	41	0	0	0	0	0	0	0	3%
			All	0	0	+	+	25%	27%	+	0	42%	0	0	5%	0	②

Table 5. Continued

				Location of fishery and type of gear													
				California		Oregon		Washington					British Columbia			South-eastern Alaska	Contribution to total catch of marked fish
Brood year	Recovery year	Age at recovery①	Hatchery	Sport	Troll	Sport	Troll	Col. R. mouth sport	Ocean sport	Troll	Gill net	Puget Sound sport	Gill net	Purse seine	Troll	Commercial	
1963	1966	.2	Complex	+	+	1	4	11	14	26	+	5	0	—	39	+	81%
			Spring Cr.	+	0	2	2	13	16	26	0	3	0	—	39	0	9%
			Kalama	0	0	0	1	17	17	19	1	0	0	—	45	1	3%
			Klickitat	1	0	+	4	10	17	27	0	0	0	—	41	0	4%
			Big Creek	0	2	1	8	16	29	38	0	0	0	—	7	0	3%
			All	+	+	1%	4%	11%	14%	27%	+	4%	0	—	38%	+	②
	1965-1966	.1-.2	Complex	+	+	1	4	12	15	24	+	9	0	0	36	+	81%
			Spring Cr.	+	0	2	2	16	17	24	0	2	0	0	37	0	9%
			Kalama	0	0	+	1	17	13	15	1	17	0	0	35	1	4%
			Klickitat	1	0	+	3	11	23	23	0	4	0	0	34	0	4%
			Big Creek	0	2	1	7	22	30	33	0	0	0	0	6	0	3%
			All	+	+	1%	3%	12%	16%	24%	+	8%	0	0	35%	+	②
1964	1966	.1	Complex	0	0	+	0	54	40	4	0	0	0	—	2	0	57%
			Spring Cr.	0	0	0	0	62	34	0	0	0	0	—	4	0	29%
			Kalama	0	0	0	0	0	100	0	0	0	0	—	0	0	3%
			Bonneville	0	3	18	5	14	20	3	8	0	0	—	29	0	11%
			Little White	0	0	0	0	0	0	0	0	0	0	—	100	0	+
			All	0	+	2%	1%	50%	37%	3%	1%	0	0	—	6%	0	②

① Age designations follow the Koo (1962) system. No fresh-water annuli were laid down on the scales because the smolts were fingerlings; an Arabic numeral preceded by a dot gives the number of winters at sea.

② Individual entries in each row and in this column were rounded to the nearest whole percentage and therefore do not add to exactly 100 in all cases; the actual range for all sums is 98-101.

bution of marked fish from each hatchery to the total annual catch of fish with evaluation marks is in the last column of Table 5. Fish from Spring Creek thus accounted for 21% (160/766 from Table 1) of all evaluation marks caught in 1963 from the 1961 brood.

Coastwide differences in exploitation rate biased the relative availability (percentages along each row) of marked fish from any single source. The relative location of centers of abundance can be inferred for fish from various hatcheries, however, from comparisons of the ratios of percentages in Table 5. A ratio of 3:1 (Hatchery A: Hatchery B) under any column but the last means that three times as many marked fish from Hatchery A were caught in the sampled fishery than from Hatchery B.

An example of this reasoning follows for the Kalama:Spring Creek ratios at age .3 from the 1965 sampling. From south to north, with one or both elements nonzero, these were: 0:1, 1:5, 4:8, 9:19, 18:22, 1:+, 63:45, and 5:0. Marked fish from each hatchery were assumed to be (1) large enough from age .2 onward for nonselective retention and detection in all sampled fisheries where present, and (2) caught in proportion to their relative abundance within each fishery no matter how exploitation rates varied among fisheries. The geographic sequence of ratios indicates that for all marked fish at large from each hatchery, those from Spring Creek predominated south of the central or north coast of Washington, and those from Kalama farther north off Vancouver Island. The inference is that Kalama fish were concentrated farther north.

Further inferences from Table 5 follow for each brood. Centers of abundance are distinguished from ranges of distribution. Incomplete recruitment, mentioned previously, prevents valid statements for age .1, but the data were included to complete the available record.

1961 Brood

At age .2 in 1964, when most—if not all—survivors were larger than the minimum legal size (26 inches total length), Kalama fish evidently ranged as far south as fish from other hatcheries, but the British Columbia troll fishery accounted for most (63%) of the Kalama releases. They were centered farthest north and, along with fish with the general or Ad-RM mark, (some released at Kalama) were found in Alaskan waters. Chinook from Elokomin and particularly Oxbow stations (28% and 5%, respectively, in the British Columbia troll fishery) were concentrated farthest south and contributed least to the total catch of marked fish. Centers of relative abundance of fish from the hatchery complex and Spring Creek were probably off the north coast of Washington and in between those from other hatcheries.

At age .3 in 1965, Kalama fish again were centered farther north (off Vancouver Island) than those from Spring Creek, Elokomin, and Oxbow; they were distributed much like fish from the hatchery complex and ranged as far as Alaska, but apparently not to California. Oxbow and Spring Creek chinook may have been found at least as far north as the Strait of Juan de Fuca, but only Oxbow fish were recovered off California. Elokomin fish evidently were centered off the southern coast of Washington. Elokomin and Oxbow hatcheries again contributed least (1% each) to the total. Kalama contributed much more than to the Spring Creek catch (17 and 8%) than at age .2 (5 and 18%). This contribution partially reflects the higher proportion of Spring Creek and Kalama fish which matured at age .2 (Cleaver, 1969).

Small numbers (Table 1) may well have distorted the data on distribution at age .4 in 1966.① Kalama fish were still centered

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① This problem is to be anticipated in future analyses of the hatchery evaluation data. Anything less than complete examination for marks in all marine landings south of Washington and north of Vancouver Island, where most of the hatchery fish were caught (Tables 1-4), implies a higher chance of "O" recoveries from broods (or hatcheries) with lower survival and a distorted picture of the range of distribution. Cleaver (1969) noted much higher survival for the 1961 than 1962 brood. Nearly 8 million marked fish were released from each brood; Tables 1-2 show respective catches of 14,228 and 4,406 at the dominant age of capture in marine fisheries (.2).

northward and off Alaska. Their contribution was much greater than that of Spring Creek (19 and 17%), even at age .3; the difference again reflects the higher average age at maturity of Kalama fish.

For the 1961 brood as a whole, then, Oxbow fish were centered farthest south, Kalama fish farthest north, and only they are known to have ranged as far as southeastern Alaska. Elokomin and Spring Creek releases were intermediate, but those from Spring Creek, particularly at age .3, tended to be farther north. Fish from all identifiable hatcheries and from the complex were in California waters at some time during their lives but only Oxbow fish unquestionably entered the California sport fishery.

1962 Brood

At age .2 Kalama fish again were farther north than Spring Creek fish, but only the hatchery complex was represented off Alaska. Although Cascade Hatchery releases may have been centered nearly as far north as Kalama fish, they also ranged south to California. Fish from Grays River entered the Puget Sound sport catch.①

By age .3 in 1966, some Kalama fish had migrated to Alaska where the hatchery complex was again represented. Centers of abundance from all hatcheries but Cascade apparently had shifted northward since age .2. Kalama contributed about the same percentage of total marks as Spring Creek at age .2 (total range for both years and hatcheries was 7-10%); this figure contrasted sharply with Kalama's higher relative contribution at age .3 in the 1961 brood (17% compared with 8% for Spring Creek). Grays River and Cascade each contributed only 2% during the 3 years of sampling.

1963 and 1964 Broods

Few data are available for the 1963 and 1964 broods. Kalama and hatchery complex fish from the 1963 brood again appeared in Alaskan waters at age .2. The centers for the complex, Kalama, Spring Creek, and Klickitat were similar but only Kalama chinook were not recovered south of Oregon. Big Creek fish were concentrated farthest south, probably off southern Washington. The similarity in distribution between Kalama and Spring Creek fish contrasted with the more northerly location for Kalama fish in the 1961 and 1962 broods.

Incomplete recruitment again prevented comparisons at age .1. Of special interest in the 1964 brood, however, are (1) the rather high relative contribution of Bonneville Hatchery releases (11%), and (2) the fact that Spring Creek contributed much more (29%) than in the 1963 and 1962 broods (8 and 11%, respectively). See also Tables 1-4 regarding hatchery-specific marks in the Puget Sound sport catch.

North-South Distribution Summary

The foregoing inferences on north-south distribution of hatchery releases substantiate two general findings by Cleaver (1969): (1) fish from different sources were widely distributed at the same age, and (2) the distribution of fish from a given hatchery varied with age.

To the extent that fishing intensity was similar among areas in different years, marked fish from the 1961 and 1962 broods (except from Cascade hatchery) evidently were farther north at age .3 than at age .2. Only fish from Kalama and the hatchery complex (some released at Kalama) were recovered in Alaskan waters. Additional inferences on distribution by age, brood, and hatchery source are shown in Table 5.

Offshore-Inshore Distribution

Knowledge of offshore-inshore distribution also may be needed to understand and predict the contribution of hatcheries to the fisheries. Marked fish from two or more

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① About 2% of the Puget Sound sport catch was examined for marks, and only during 1965 and 1966. The small sample precluded inferences on relative distribution, but the presence of marked fish in the Puget Sound sport catch from various hatcheries is summarized as follows (Tables 2-4): 1962 brood, from Grays River at ages .2 and .3; 1963 brood, from Kalama and Klickitat at age .1 and Spring Creek at age .2; and 1964 brood, from Bonneville at age .1.

hatchery sources were recovered from troll and sport landings in California, Oregon, and Washington (Tables 1-4). Anglers typically fished closer inshore than did trollers off ports where both types of catches were landed. For ports between Newport, Oregon, and Neah Bay, Washington, the hypothesis that availability to offshore (troll) and inshore (sport) fisheries is independent of hatchery source was tested for ages .2 and .3 in the 1961-63 broods when sample sizes permitted. Unknown differences in exploitation rates and known differences in mark sampling ratios occurred between the two types of fisheries landed at each port, hence estimated catches of marked fish rather than unadjusted recoveries were compared.①

The hypothesis that availability of marked fish to offshore and inshore fisheries is independent of hatchery source was rejected in 9 of 14 tests (Table 6). Relative availability evidently depended in general on which hatcheries had released the fish.

Seasonal Comparisons for the 1961 Brood

Movements in the marine fisheries during a given season should reflect migration routes and maturity schedules of fish released from different hatcheries. Small samples and lack of information on fishing intensity by time and area typically limit the inferences from marking and tagging studies, but data from the 1961 brood warrant a trial comparison of seasonal movements of Spring Creek and Kalama fish during 1964 and 1965.

Most recoveries were off the mouth of the Columbia River and northward (Table 1). Estimated ocean catches of these marked fish during successive 14-day periods (longer at the start and end of the season) were combined into successive 28-day periods to increase the sample size. The results by time period and major ocean age in each of five areas, converted to percentages are shown in Table 7 and Figure 2.①

Fish from both hatcheries were widely dispersed and apparently similarly distributed at the start of the 1964 season (age .2). However, larger proportions of Spring Creek than Kalama fish were found in landings toward the Columbia River as the season progressed to August 23. A substantial portion of the Kalama fish either moved north of Vancouver Island or became available to the fisheries during July. The residue of immature fish from both hatcheries was also distributed similarly by September 20. At age .3, some Kalama chinook were north of Vancouver Island near the start of the season (Table 7), but July was again the main month of northerly migration or recruitment in the northern area. Substantial southerly movement was detectable only during August for Spring Creek fish and during August and September for Kalama fish.

The data in Figure 2 and Table 7, when compared with return schedules in Table 8, are consistent in some respects and puzzling in others. Southerly movement of Spring Creek fish at age .2 (Figure 2) agreed with their slightly higher returns to the Columbia at age .2 than at age .3 (Table 8, bottom). Yet it failed to substantiate the theory that fall chinook salmon move slowly northward during the summer (Cleaver, 1969; Van Hyning, 1968). Also, the relatively few age .2 fish (12%) found near the Columbia, and the high percentage (47%) discovered near Cape Flattery during the recovery period ending August 23, 1964 (Table 7) does not agree with the idea that most Spring Creek fish slowly move south during the summer of predominant maturity. The rapid return of these fish during August at age .3 (Figure 2), however, agreed with return schedules (Table 8, top). Nearly half the available Kalama fish, on the other hand, remained off Vancouver Island in September at age .3

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① For the Columbia River mouth, sport landings of marked fish at Warrenton, Oregon, and Ilwaco, Washington, were compared with troll landings of marked fish at Astoria, Oregon, and Ilwaco, Washington.

① Only catches exceeding 50 fish in any period were used in graphing percentages except for 33 Kalama fish at the start of the 1964 season.

Table 6. Tests of the hypothesis that availability of marked chinook salmon to offshore (troll) and inshore (sport) fisheries is independent of hatchery source

Brood year	Recovery Year	Ocean age at recovery	Recovery port	Hatchery source	Estimated troll catch① (No.)	Estimated sport catch① (No.)	Total (No.)	Chi-square	Result at 5% level
1961	1964	.2	Newport	Complex	51	59	110	—	—
				Spring Cr.	9	21	30	—	—
				Total	60	80	140	2.58	Accept
1961	1964	.2	Astoria, Warrenton and Ilwaco	Complex	574	123	697	—	—
				Spring Cr.	186	45	231	—	—
				Kalama	20	10	30	—	—
				Oxbow	8	8	16	—	—
				Total	788	186	974	14.80	Reject
1961	1964	.2	Westport	Complex	1,555	941	2,496	—	—
				Spring Cr.	338	205	543	—	—
				Kalama	14	41	55	—	—
				Oxbow	8	18	26	—	—
				Total	1,915	1,205	3,120	41.27	Reject
1961	1964	.2	LaPush	Complex	643	34	677	—	—
				Spring Cr.	383	8	391	—	—
				Total	1,026	42	1,068	5.80	Reject
1961	1964	.2	Neah Bay	Complex	1,010	239	1,249	—	—
				Spring Cr.	272	49	321	—	—
				Kalama	74	9	83	—	—
				Total	1,356	297	1,653	5.60	Accept
1961	1965	.3	Astoria, Warrenton and Ilwaco	Complex	30	119	149	—	—
				Spring Cr.	10	29	39	—	—
				Kalama	21	29	50	—	—
				Total	61	177	238	9.39	Reject
1961	1965	.3	Westport	Complex	223	299	522	—	—
				Spring Cr.	40	51	91	—	—
				Kalama	70	45	115	—	—
				Elokomin	5	8	13	—	—
				Total	238	403	741	12.92	Reject

1962	1965	.2	Astoria, Warrenton and Ilwaco	Complex	96	71	167	—	—
				Kalama	15	16	31	—	—
				Total	111	87	198	17.80	Reject
1962	1965	.2	Westport	Complex	691	411	1,102	—	—
				Spring Cr.	108	102	210	—	—
				Kalama	24	50	74	—	—
				Cascade	3	8	11	—	—
				Total	826	571	1,397	37.43	Reject
1962	1966	.3	Westport	Complex	52	78	130	—	—
				Spring Cr.	9	12	21	—	—
				Kalama	7	4	11	—	—
				Total	68	94	162	2.33	Accept
1963	1966	.2	Astoria, Warrenton and Ilwaco	Complex	1,241	1,354	2,595	—	—
				Spring Cr.	91	180	271	—	—
				Kalama	14	80	94	—	—
				Klickitat	45	63	108	—	—
				Big Creek	20	65	85	—	—
				Total	1,411	1,742	3,153	73.37	Reject
1963	1966	.2	Westport	Complex	883	1,246	2,129	—	—
				Spring Cr.	140	170	310	—	—
				Kalama	30	70	100	—	—
				Klickitat	55	63	118	—	—
				Big Creek	41	55	96	—	—
				Total	1,149	1,604	2,753	8.41	Accept
1963	1966	.2	LaPush	Complex	969	41	1,010	—	—
				Spring Cr.	111	3	114	—	—
				Total	1,080	44	1,124	0.56	Accept
1963	1966	.2	Neah Bay	Complex	554	111	665	—	—
				Spring Cr.	56	23	79	—	—
				Kalama	24	15	39	—	—
				Klickitat	37	15	52	—	—
				Big Creek	50	20	70	—	—
				Total	721	184	905	22.37	Reject

① Of the 96 expected values involved in the 14 independent tests, all exceeded 3.0 and all but 4 exceeded 5.0.

Table 7. Estimated catch and relative occurrence, by time and area during 1964 and 1965, of marked 1961-brood chinook salmon from Spring Creek and Kalama hatcheries in sampled marine fisheries from the Columbia River and northward; (A plus (+) indicates less than 0.5%)

			Number and percentage of area total during period ending—															
	Ocean		May 3		May 31		June 28		July 26		Aug. 23		Sept. 20		End of season		Total	
Source	age	Area①	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Spring Creek	.2	Northern	0	0	2	+	4	1	2	+	0	0	0	0	0	0	8	+
		Vancouver Is.	193	73	167	34	213	30	97	23	62	25	68	39	33	37	833	35
		Cape Flattery	13	5	130	26	257	37	204	48	118	47	68	39	56	62	836	35
		Grays Harbor	33	13	120	24	214	31	118	28	41	16	7	4	0	0	543	23
		Columbia R.	25	9	77	16	7	1	4	1	29	12	33	18	1	1	176	7
		Total	264	100	496	100	695	100	425	100	250	100	176	100	90	100	2,396	100
Kalama	.2	Northern	0	0	0	0	0	0	30	29	26	14	0	0	0	0	56②	8
		Vancouver Is.	23	70	30	56	82	79	39	37	105	55	74	47	32	100	385	57
		Cape Flattery	0	0	0	0	9	9	11	10	37	19	65	42	0	0	122	18
		Grays Harbor	6	18	8	15	13	12	25	24	18	10	11	7	0	0	81	12
		Columbia R.	4	12	16	29	0	0	0	0	4	2	6	4	0	0	30	5
		Total	33	100	54	100	104	100	105	100	190	100	156	100	32	100	674	100
Spring Creek	.3	Northern	0	0	0	0	0	0	0	0	0	0	0	—	0	—	0	0
		Vancouver Is.	18	75	37	57	43	47	45	56	21	24	0	—	0	—	164	47
		Cape Flattery	4	17	12	18	21	23	12	15	4	5	0	—	0	—	53	16
		Grays Harbor	2	8	14	22	28	30	20	25	27	31	0	—	0	—	91	26
		Columbia R.	0	0	2	3	0	0	3	4	34	40	0	—	0	—	39	11
		Total	24	100	65	100	92	100	80	100	86	100	0	—	0	—	347	100
Kalama	.3	Northern	1	3	15	13	22	17	59	30	40	21	0	0	0	—	137	18
		Vancouver Is.	16	44	53	45	63	50	121	62	88	46	37	44	0	—	378	50
		Cape Flattery	19	53	8	7	3	2	6	3	21	11	14	16	0	—	71	10
		Grays Harbor	0	0	41	35	39	31	7	4	20	11	8	9	0	—	115	15
		Columbia R.	0	0	0	0	0	0	3	1	21	11	26	31	0	—	50	7
		Total	36	100	117	100	127	100	196	100	190	100	85	100	0	—	751	100

① Areas, coded in Figure 2, are defined as follows:
Columbia River—Ilwaco, Astoria, and Warrenton troll and sport .... "0"
Grays Harbor—Westport troll and sport .... "1"
Cape Flattery—LaPush, Neah Bay, and Sekiu troll and sport .... "2"
Vancouver Island—B. C. troll, Zone 40 (west coast) .... "3"
Northern—B. C. troll, Zones 42-43, and Alaska troll .... "4"

② Recovery dates were not available for an estimated catch of five more marked Kalama fish in the Alaskan fishery of 1964 (Table 1).

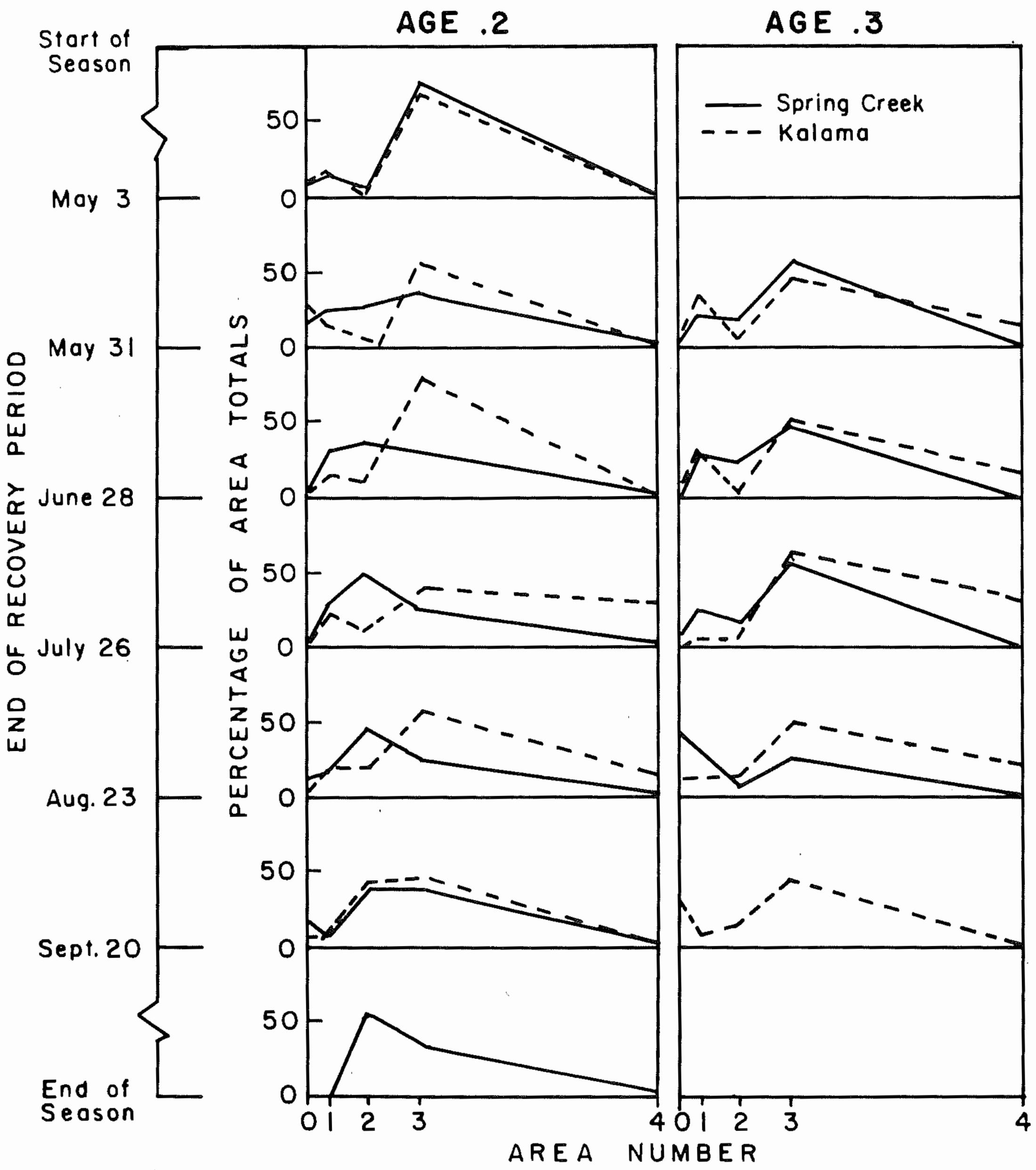

Figure 2. Relative occurrence, by time and area, of marked 1961-brood chinook salmon from Spring Creek and Kalama, in sampled marine fisheries from the Columbia River northward during 1964 (age .2) and 1965 (age .3). (Areas are numbered from "0" at the mouth of the Columbia, and are defined in a footnote in Table 7. Distances on the horizontal axis are roughly proportional to those between fisheries. Values are not plotted for time-area totals of less than 50 fish except for 33 estimated recoveries to May 3 for Kalama age .2 fish.)

during 1965 (Table 7), when 74% of all 1961 brood returns to the Columbia River were accounted for (Table 8, bottom).

Discrepancies between intraseasonal movements through the marine fisheries and schedules of return to the Columbia may be related to the conclusion from Table 6 that the relative availability to offshore and inshore fisheries depended generally on hatchery of origin. A more detailed explanation, however, must await further analyses. Because trollers from different ports fish to some extent in the same areas, sport catches might be analyzed separately or troll catches examined by fishing area instead of port of landing. A compilation of data by area of capture is in progress.①

Summary and Conclusions

1. Preliminary comparisons of the distribution in marine fisheries of marked fall chinook from various hatcheries were made from data of the Columbia River hatchery evaluation program. Estimated total recoveries of known, probable, and possible marks in the ocean fisheries during 1963-66 were as follows: 1961 brood—20,144; 1962 brood—6,561; 1963 brood—17,655; and 1964 brood—1,348. Sampling through 1966 was substantially complete for the 1961-62 broods, but incomplete for the 1963-64 broods. In addition to the fact that complete analysis must await tabulation of data through 1969 sampling, incomplete recruitment prevented drawing inferences on distribution for fish which had spent only one winter at sea. The available data are tabulated by port or zone of landing in the various fisheries (Tables 1-4).

2. Fall chinook salmon of the 1961 brood from hatcheries on the Kalama River were found in the ocean from Alaska to California by July 1964 (age .2). No other identifiable hatcheries were represented in

Table 8. Return schedules of marked 1961-brood chinook salmon from Spring Creek and Kalama hatcheries for 1964 (age .2) and 1965 (age .3), and total returns for 1963-66 (ages .1-.4). (A plus (+) indicates less than 0.5%)

			Spring Creek		Kalama	
Item	Date	Year	Number of fish	Percentage of total	Number of fish	Percentage of total
Estimated catch by period (end dates given) in Zone 1 of Columbia River gill-net fishery	Aug. 1	1964	3	1	0	0
	Aug. 8		51	20	3	17
	Aug. 15		127	50	3	17
	Aug. 22		74	29	12	66
	Aug. 29		0	0	0	0
	All		255	100	18	100
	July 31	1965	2	+	0	0
	Aug. 7		12	2	0	0
	Aug. 14		49	10	22	7
	Aug. 21		219	42	95	32
	Aug. 28		235	46	155	53
	Sept. 18		0	0	23	8
	All		517	100	295	100
Estimated return to the Columbia River	Total	1963	68	4	0	0
		1964	934	50	51	7
		1965	833	45	575	74
		1966	20	1	160	19
		All	1,855	100	786	100

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① S. G. Wright, Washington Dept. of Fisheries, personal communication, March 1969.

Alaskan waters by this (or any) brood, although fish with the common mark of the hatchery complex (some released at Kalama) were recovered in this area. All hatcheries were represented southward from British Columbia to California at some time in the marine life of the 1961 brood, but only Oxbow fish were detected in the California sport fishery.

3. Hatchery fish from the following sources were found in the Puget Sound sport fishery sampled during 1965-66 but not 1963-64: 1962 brood, from Grays River at ages .2 and .3; 1963 brood, from Kalama and Klickitat at age .1 and Spring Creek at age .2; and 1964 brood, from Bonneville at age .1. The low fraction of landings (about 2%) sampled each year for marks in the Puget Sound sport fishery made it necessary to exclude this fishery in drawing inferences on relative distribution by origin.

4. Apparent centers of distribution for the 1961 brood (Kalama, Spring Creek, Elokomin, Oxbow and the hatchery complex) were from Vancouver Island to the south coast of Washington. Except possibly for Cascade fish of the 1962 brood during 1965, Kalama fish apparently were centered farther north at all ages than those from any other hatchery in the 1961-63 broods.

5. Because of unknown differences in fishing intensity along the coast, it was not possible to determine that actual centers of distribution were identical to apparent centers as inferred from recovery data. To the extent that fishing intensity was similarly distributed in different years, fish were typically farther north at age .3 than at age .2.

6. Relative availability to offshore troll fisheries and inshore sport fisheries between Newport, Oregon, and Neah Bay, Washington, depended in general on hatchery of origin.

7. Apparent intraseasonal movements of the 1961 brood from Spring Creek and Kalama were not wholly consistent with schedules of return to the hatcheries. In 1964 at age .2, immature Kalama fish either moved north of Vancouver Island during July or were already in northern waters. In 1965 at age .3, maturing Spring Creek fish rapidly moved south from Vancouver Island into the Columbia River during August.

Acknowledgments

I wish to thank R. A. Fredin, D. D. Worlund, and Dr. Fred C. Cleaver of the Bureau of Commercial Fisheries for their criticism. Comments from R. N. Thompson and R. E. Loeffel of the Fish Commission of Oregon also were extremely helpful.

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THE EFFECT OF SUPERIMPOSED MORTALITIES ON REPRODUCTION CURVES

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Abstract

The relative effects of salmonid smolt kills, "racial" kills, and adult kills on a completely general reproduction curve are studied. It is shown that for nonselective mortalities, smolt kills have a greater effect on the optimum sustainable yield than racial kills and a much more severe effect than adult kills of the same magnitude. For illustration, the results are applied to a Ricker-type reproduction curve.

Introduction

Studies of optimum fishing based on reproduction curves usually assume that environmental conditions are either constant or random. Salmonids utilizing river systems where increasing pressures of industrialization are developing, however, may be subject to increasingly severe mortalities during all phases of their life cycle that are spent in fresh water. The Columbia River, with historic runs of several species of salmonids, has been undergoing such changes for several decades. During the last 15 years the construction of a series of dams on both the Columbia River and its main tributary, the Snake River, have sharply accelerated these changes.

In order to study the effects of mortalities on the reproduction curve, a classification of the three major sources of mortality is helpful:

(1) Mortalities to downstream migrants —"smolt kill."

(2) Extermination of "races"—"racial kill."

(3) Mortalities to the adult escapement—"adult kill."

Mortalities to downstream migrants passing over spillways, through the turbines of hydroelectric dams, or through areas where toxic waste products are discharged into a river exemplify the first source. Improperly screened water sources for irrigation may also contribute mortalities to smolts or fry.

When fish passage facilities are not constructed at a dam all races utilizing the spawning grounds above such a dam will be exterminated. Even when fish passage facilities are present, the flooding of spawning areas in the forebays of dams may have the same effect on some groups of fish (i.e., the complete loss of the productivity of some groups). Examples of both of these "racial kill" situations can be found in the Columbia River system.

Mortalities to adults escaping from a fishery may occur before they have reached their spawning areas. Merrell and Collins (1965) estimated mortalities as high as 20% occurring to salmon passing a single Columbia River Dam during periods of high flow. Possibilities of "adult kill" due to delay or induced indirectly by increased temperature or pollution cannot be ruled out. As a result, the actual spawning escapement may be considerably less than the apparent escapement if estimated before these mortalities occur.

The direct effects of all three types of mortality have been studied extensively, but the effects of such changes on the overall production of the stocks have, in general, either been ignored or assumed to be proportional to the particular mortality observed. That such proportionality is not generally the case should be of concern to those involved in the control of mortalities induced by environmental changes as well as to fishery management agencies. It will be shown in the following analysis, for example, that a smolt kill generally has a much more severe effect on the optimum yield to the fisheries than an adult kill of the same magnitude.

It might be noted that the effects of all three sources of mortality on production would be the same if, and only if, all population density effects were confined to the salt-water environment. It is very unlikely that this could be the case with any species of salmonids, and for those species which spend at least their 1st year in fresh water it seems reasonable to assume that population density effects would be most severe during this fresh-water phase. In the following development, we shall assume, in fact, that density dependent effects, in the marine environment are negligible. Such an assumption might be questionable for chum salmon (*Oncorhynchus keta* Walbaum) or pink salmon (*O. gorbuscha* Walbaum) insofar as they may enter salt water very shortly after emerging from the gravel as fry. The assumption, however, may not be unreasonable for those species that spend more time as juveniles in fresh water such as sockeye salmon (*O. nerka* Walbaum), steelhead trout (*Salmo gairdneri* Richardson), and the spring runs of chinook salmon (*O. tshawytscha* Walbaum).

Reproduction Curves and Optimum Fishing

Ricker (1958) discusses in some detail the use of reproduction curves for estimating optimum escapement and develops a theoretical family of reproduction curves which has been used rather extensively in the study of salmon and other anadromous fish. These curves are referred to as compensatory since the production rate① decreases as escapement increases. Ward and Larkin (1964) give evidence of a process where one phase of the life history of sockeye salmon may be depensatory, i.e., the production rate increases as escapement increases.

Insofar as some of the most significant relationships for the three sources of mortality listed here are independent of the form of the original reproduction curve, a completely general reproduction curve, $y = f(x)$, will be considered in the following development. For purposes of illustrating the possible magnitude of these effects, however, some specific types of reproduction curves will also be considered.

For this development the following notation will be used.

$x =$ escapement from the fishery in numbers of adults.

$y = f(x)$ defines the reproduction curve or the average production in numbers of adults resulting from an escapement of x spawners.

$C = y - x$ is the average catch sustained by an escapement of x spawners.

$x_0 =$ optimum escapement, i.e., the escapement supporting the maximum sustainable catch.

$y_0 =$ production resulting from an escapement of x_0.

$C_0 = y_0 - x_0$ is the maximum sustainable catch.

$P = \dfrac{y}{x}$ is the production rate for an escapement of x, i.e., the return per spawner.

$P_0 = \dfrac{y_0}{x_0}$ is the optimum (not maximum) production rate.

The only restriction on $f(x)$ required for the following development is that it is a single valued function and there exists a finite value x_0 for which C_0 is maximized.

A graphic representation of these variables is given in Figure 1A. Here the un-

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① Here production rate is the ratio of the total adults produced to the total spawning escapement that produced them, i.e., the return per spawner.

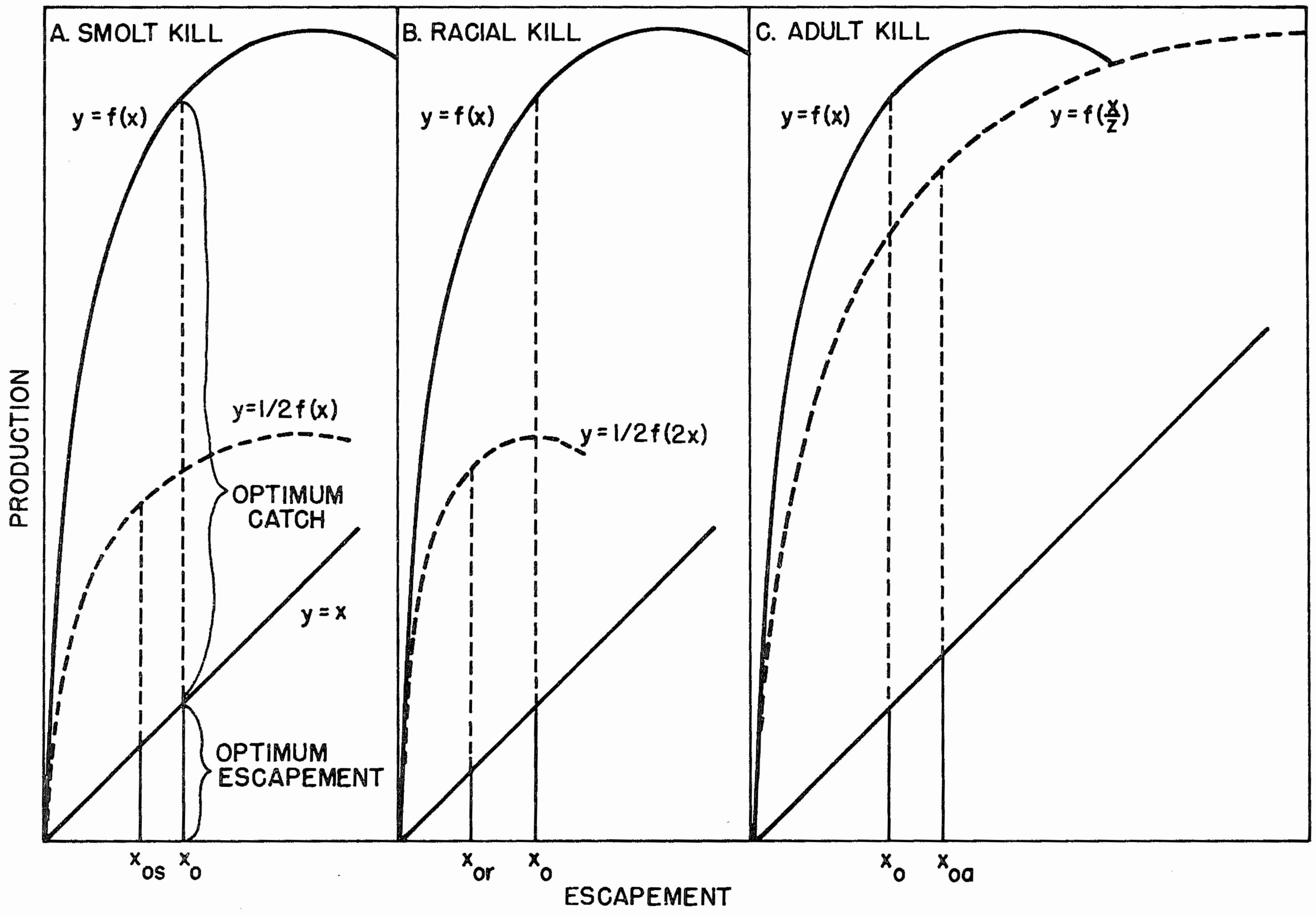

Figure 1. Effect of a 50% kill from three different sources on the reproduction curve.

broken reproduction curve defines $y = f(x)$, and the vertical distance between the curve and the straight line $y = x$ defines the average catch for any escapement, x. This catch is maximized for an escapement of x_0 for which the component parts of the production representing the optimum catch and escapement have been labeled.

Modification of a Reproduction Curve by Mortalities

Let us examine separately the consequences of augmenting normal mortalities by a smolt kill, a racial kill, or an adult kill. For this purpose, let

$m =$ mortality rate (fraction killed); $0<m<1$

$s =$ (1-m) or the survival rate (fraction surviving).

Since the consequences of a zero kill or 100% kill are obvious we shall omit these cases for the sake of mathematical simplicity.

Subscripts s, r, or a on the previously defined variables will denote the value of the variable after a fraction m have been killed by a smolt kill, a racial kill, or an adult kill, respectively. For example:

Let: $f_s(x)$, $f_r(x)$, $f_a(x)$ denote the modified reproduction curves following respective smolt kills, racial kills, and adult kills of magnitude m,

x_{os}, x_{or}, x_{oa} denote the corresponding optimum escapement levels following these changes,

C_{os}, C_{or}, C_{oa} denote the corresponding maximum sustainable catches.

Smolt Kill

In order to study the effect of a smolt kill we shall assume that such a kill is random, i.e., is independent of the viability of the individual smolt. Although this assumption may be questionable under some conditions (pollution kills, for example), Schoeneman, Pressey, and Junge (1961) found that dam mortalities were independent of size for downstream migrants ranging from 45 mm to 140 mm and including fry and yearling releases. This strongly suggests that such mortalities are random.

Combined with the original assumption that density dependent effects in the marine environment are negligible, we may conclude that a reduction of smolts by a fraction m will on the average reduce the production of returning adults also by a fraction m. If $s=1-m$ is the survival rate and $y = f(x)$ the original reproduction curve, then the resulting reproduction curve will be defined by,

$$f_s(x) = s\,f(x) \qquad (1)$$

Therefore, the modified reproduction curve merely suppresses the original curve by the constant factor s. Since slopes for any value of x to the left of the turning point are obviously reduced by this process, optimum escapement under the altered condition is always less than the original① or:

$$x_{os} < x_o \qquad (2)$$

where x_{os} is the optimum escapement for the resulting reproduction curve. The result of a 50% smolt kill is shown graphically by the dashed curve in Figure 1A. The loss to the fishery after adjusting to the new optimum level is almost 60% of the original catch.

Racial Kill

Since there is no reason to assume that a racial kill is selective, we shall assume that the general density dependent effects are the same for the deleted stocks as for the residual ones. Under this assumption if a fraction m of all cycles of the original escapement are exterminated, then, if originally an escapement of x produced $f(x)$ fish, under the altered condition an escapement of (sx) will put the same number of spawners on the residual spawning

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① The reasoning above assumes a unimodal curve, but (2) can be proved quite generally for any single valued function for which x_0 is finite.

areas and will produce $sf(x)$ fish. Hence the modified reproduction curve is geometrically similar to the original one with x and y reduced by a scale factor, s. Functionally, we have:

$$f_r(sx) = sf(x) \quad \text{or}$$

$$f_r(x) \;= sf\left(\frac{x}{s}\right). \tag{3}$$

Because the two curves are geometrically similar we have immediately,

$$x_{or} = sx_o$$
$$C_{or} = sC_o \tag{4}$$

where x_{or} and C_{or} are the resulting values of the optimum escapement and optimum catch, respectively. Figure 1B illustrates the effect of a 50% racial kill. The loss to the fishery after adjusting to the new optimum level is 50% of the original catch.

Adult Kill

Let us assume that a fraction m of the adults escaping from the fishery are killed. We shall again assume that this kill is nonselective. Under such a change an escapement of x fish will now produce what was formerly produced by sx fish since under the new situation sx fish will actually survive to spawn. Functionally we have:

$$f_a(x) = f(sx) \tag{5}$$

Although no such inequality as (2) may be stated unequivocally for an adult kill, from a practical point of view it can be shown that except for kills approaching complete extinction an increase in escapement is required to maintain an optimum catch or:

$$x_{oa} > x_o \tag{6}$$

When both compensatory and depensatory effects occur such as the case considered by Ward and Larkin (1964, p. 92), or Junge (1966), it is possible that (6) will hold for all values of m even to extinction.

In Figure 1C the effects of a 50% adult kill are illustrated. The rather mild reduction in the optimum catch here may be compared with the very severe reduction caused by a smolt kill of the same magnitude (Figure 1A). In the following section some relationships will be derived to show the general nature of the increased severity of a smolt kill.

Comparative Relationships

Let us suppose that a fraction m of an adult kill is imposed on a stock of fish so that (5) defines the modified reproduction curve. Let us suppose that a racial kill also of a magnitude m is then superimposed on this. Then combining (5) and (3) we have as the final reproduction curve,

$$f_{ar}(x) = sf_a\left(\frac{x}{s}\right) = sf(x) \tag{7}$$

Here, the right hand member of (7) is exactly the same as $f_s(x)$ given by (1). Hence a doubly induced mortality due to a racial and adult kill each of magnitude m produces the same reproduction curve as a single mortality of magnitude m induced by a smolt kill.

Further, since a racial kill imposed on the adult kill produced the smolt kill reproduction curve, the smolt kill curve given by (1) must be geometrically similar to the adult kill curve given by (5) in the same way as $f_r(x)$ is similar to $f(x)$. It therefore follows from (4) that:

$$x_{os} = s\,x_{oa} \tag{8}$$
$$C_{os} = s\,C_{oa}. \tag{9}$$

Equation (9) defines quite generally the relative severity of smolt and adult kills.

Although an exact general relationship such as (9) above cannot be shown between C_{os} and C_{or}, it follows from the above considerations that the residual optimum catch following a smolt kill is always less than the residual optimum catch following a racial kill of the same magnitude or:

$$C_{os} < C_{or}. \tag{10}$$

Application to a Ricker Reproduction Curve

In the present notation a Ricker curve is given by the following equation:

$$y = xe^{a(1-x)} \tag{11}$$

The above single parameter form (a) is unfortunate since it is adjusted to go through the point $x = 1$, $y = 1$, and as a result, for example, a racial kill would leave the equation unchanged. For present purposes we shall use the more general form,

$$y = kxe^{-ax}. \tag{12}$$

Initially, $k = e^a$ gives the same scale as the one used by Ricker. Under a smolt kill, we have from (1),

$$f_s(x) = skxe^{-ax} = k_1xe^{-ax} \tag{13}$$

giving another Ricker curve with a reduced value of k ($k_1 = sk$), but with a unchanged. Similarly, from (3),

$$f_r(x) = sk\left(\frac{x}{s}\right)e^{-a\left(\frac{x}{s}\right)} = kxe^{-a_1x} \tag{14}$$

giving a Ricker curve with k unchanged but the value of a increased $\left(a_1 = \frac{a}{s}\right)$

For an adult kill we have from (5),

$$f_a(x) = k(sx)e^{-a(sx)} = k_1xe^{-a_2x} \tag{15}$$

with both k and a reduced ($k_1 = sk$ as in (13) and $a_2 = sa$).

It should be noted that the percentage loss to a fishery following increased mortalities depends on its initial "level" of production. For example, a 40% kill on a stock that has already been reduced by a 50% kill yields a condition equivalent to a 70% kill on the original reproduction curve. The optimum production rate ($P_o = y_o/x_o$), which may be taken as a rough measure of the initial level, increases as a in (11) increases.

For many Columbia River salmonids, the indicated production rate at optimum fishing levels was greater than six before the construction of Bonneville Dam (Junge and Oakley, 1966). A Ricker curve with a value of $a = 2.609$ (in (11)) corresponding to an optimum production rate of $P_o = 5.9$ has been considered for varying values of m. In Figure 2A the percentage loss to the fishery has been plotted against the percentage mortality occurring under each of the three sources. Values here are based on optimum catches before and after the mortality (C_o, C_{os}, C_{or}, C_{oa}). Again the relative severity of the different kills is apparent. For example an adult kill of 50% results in a loss to the fishery of less than 20%, whereas a smolt kill of the same magnitude reduces the catch by almost 60%.

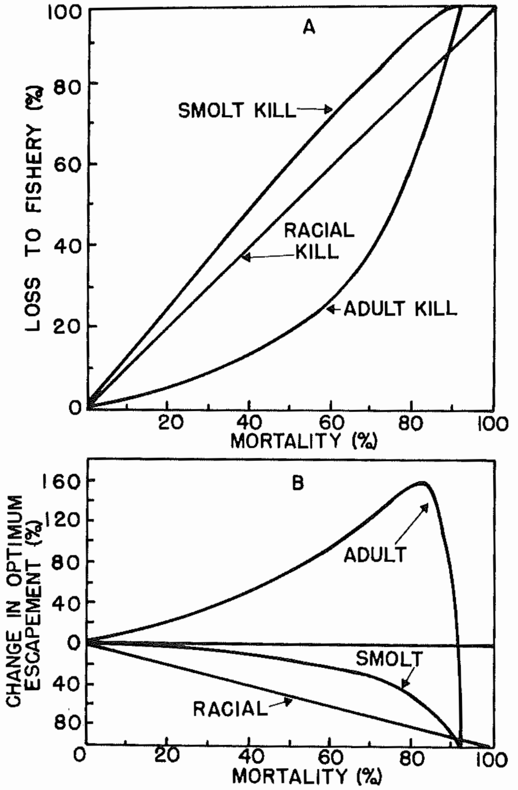

Figure 2. The effect of three types of mortality on a "healthy" stock following a Ricker-type reproduction curve, ($a = 2.609$).

In Figure 2B the change in optimum escapement is plotted against the percentage mortality. As pointed out earlier, $x_{oa} > x_o$ (positive change) except for kills approaching complete extinction. Changes following smolt and racial kills, of course, follow the relationships given by (2), (4), and (8). In both figures it can be seen that a mortality greater than 92% will lead to extinction for both a smolt kill and an adult kill.

It should be noted that if the initial optimum production rate is reduced [a less in (11)], as for a stock of fish that has already been influenced by environmental changes, the effects will be more severe than indicated by Figure 2. Extinction, for example, will occur under smolt or adult kills if m exceeds $1 - e^{-a}$. Values of m resulting in extinction for smolt or adult kills are plotted against a in Figure 3.

Mixed Sources of Mortality

It has already been shown that a mixed racial and adult mortality of the same magnitude is equivalent in its effect on the reproduction curve to a smolt kill only, of the same magnitude. This result supplies some insight to the possible effects when all three sources of mortality may be present. Clearly, under all three sources of mortality, if the magnitudes of the racial and adult kills are the same, say m_1, then if the magnitude of the smolt kill is m_2, the resulting reproduction curve will be equivalent to a reproduction curve on which a smolt kill of magnitude $(1 - s_1 s_2)$ has been imposed. Under this condition the original reproduction curve is merely suppressed by a factor of $s_1 s_2$. If, on the other hand, the magnitude of the racial kill is greater than (conversely, less than) the magnitude of the adult kill, then regardless of the magnitude of the smolt kill the reproduction curve will be suppressed and the peak will be shifted to the left (conversely, shifted to the right).① The degree of suppression of C_o will, however, be much more sensitive to smolt kills than to the other sources of mortality.

Implications

It must be recognized that in the present development a number of simplifying assumptions have been made in order that the relative effects of the three sources of mortality considered here could be compared. The major indication under these assumptions is that smolt kills have much more serious consequences than adult or racial kills of the same magnitude. Perhaps the most restrictive assumption is that the kills are not selective. Indications that this may be true for direct smolt mortalities passing dams have been noted. If, however, adult kills are selective for fish that are genetically "weaker," then the relative effects of adult kills are even less important than indicated by the present analysis.

On the other hand, if smolt mortalities favored the less viable juveniles whereas adult mortalities were more severe on the genetically "superior" fish with higher fecundity rates, the severity of an adult kill could approach or perhaps surpass the severity of smolt kills of the same magnitude.

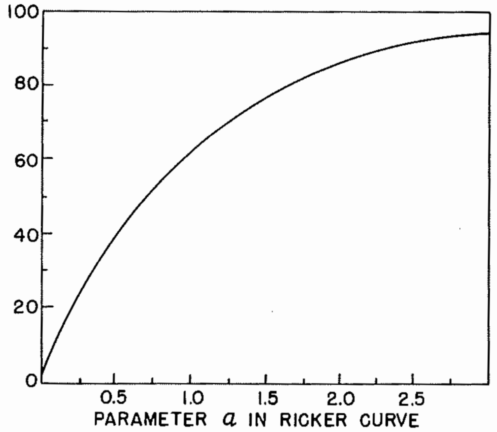

Figure 3. Mortalities by a smolt or adult kill leading to extinction for different initial values of a in Ricker's reproduction curve.

Under the assumption made in the present development, it may appear that what has been shown here is the rather obvious result that a mortality preceding a compensatory process is less severe than one following it, with a reversal of this for a depensatory process. It has been shown here,

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① The above result assumes that the reproduction curve has a peak and does not guarantee that the change in optimum escapement will follow the same rule. Of course if the racial kill exceeds the adult kill a reduced optimum escapement will result. The reverse, however, is not necessarily true.

however, that for any combination of compensatory and depensatory processes, a nonselective adult kill preceding the density-dependent processes is generally much less severe than a nonselective smolt kill at the end of such a process. The only assumptions required to guarantee this result are that the original overall reproduction curve is of such a form that an optimum escapement does exist (and it is difficult to imagine a situation where this would not be the case) and that marine survival is independent of density. If predation on fry were depensatory as in the case considered by Ward and Larkin (1964), or Junge (1966), then a smolt kill would be less severe than a kill preceding the fry stage but more severe than an adult kill as indicated by equation (9), which would still apply.

Acknowledgments

The author is indebted to Earl F. Pulford of the Fish Commission of Oregon and Jack M. Van Hyning of the University of Alaska for a number of helpful suggestions in the preparation of this paper.

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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

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Abstract

In March 1966, two groups of fin-marked 1964-brood coho salmon were released from the Fish Commission of Oregon's Big Creek Hatchery. One group marked An-RV (anal-right ventral) was released at a size of 10.7 fish per pound, while the other group, marked An-LV (anal-left ventral), was released at a size of 27.3 per pound. The estimated catch of 3rd-year coho relative to the numbers released for the An-RV and An-LV groups was 22.1 and 11.4 fish per 1,000 released, respectively. Approximately 77% of the combined contribution of both groups were landed in the ocean fisheries. The catch distribution within the troll fishery indicated that relatively equal recoveries occurred to the north and south of the Columbia River, with recoveries to the south slightly predominating. The percentage jack returns of the numbers released for the An-RV and An-LV groups were 2.7% and 0.2% respectively, while the percentage return of An-RV and An-LV adults was 0.7% and 0.4% respectively. Based on numbers released, there was no significant difference in the percentage return of adult males between the An-RV (0.20%) and An-LV (0.18%) groups; however, the percentage return of An-RV group females (0.51%) was over twice that of An-LV group females (0.25%). The catch-to-escapement ratio for the An-RV group was 3.1:1, and for the An-LV group 2.7:1. Benefit-cost values of 1.97:1 and 2.60:1 were computed, respectively, for the An-RV and An-LV groups.

Introduction

Coho salmon (*Oncorhynchus kisutch* Walbaum) hatchery liberation and escapement records are regularly reviewed to ascertain the relationship between size at release and the percentage return of 2nd and 3rd-year fish. These data suggest that as size at release increases, the percentage return of 2nd and 3rd-year fish increases; however, the percentage return of 2nd-year fish (jacks) increases at a greater rate than for 3rd-year fish. There is limited information on the effect of size at release on contribution to the fisheries and few data are available for release sizes larger than 12 fish per pound.

This report examines the influence of two extreme sizes at release on the contribution to the fisheries of 1964-brood coho salmon liberated from a lower Columbia River hatchery. Detailed accounts of catch distribution, hatchery escapement, catch-to-escapement ratios and benefit-cost values are also included.

Rearing of Experimental Fish

The two experimental groups of coho salmon discussed in this paper were randomly selected from the 1964-brood Big Creek production stock at an average size of 206 fish per pound. They were ponded separately in April 1965 and fed Oregon Pellets at two predetermined levels to provide extremes in average size of fish at time of release.

Through November 1965, the growth and general health of the study fish were monitored periodically by the Fish Commission's Nutrition-Physiology section. Blood condition, as measured by hematocrit values, was considered satisfactory in both groups; however, from August through November there was indication of slightly lower hematocrit values among fish in the low-ration group. Fish in the high-ration group contained consistently heavier fat deposits than fish in the low-ration group and this was reflected in average condition factors of 1.28 and 1.14, respectively, in November. In August 1965 a slight incidence of furunculosis (*Aeromonas salmonicida*) was diagnosed among the experimental and production groups. As a result, all 1964-brood coho were treated with a tetracycline antibiotic (TM-50) for 4 days at a dosage of 25 grams per 100 pounds of fish per day, followed by a 6-day treatment with sulfamethazine. Mortality abruptly subsided and remained at low level thereafter in all groups.

All experimental fish were fin-marked in January 1966, and released with the production fish in mid-March 1966. The high-ration group marked anal-right ventral (An-RV), was released at an average size of 10.7 fish per pound while the low-ration group, marked anal-left ventral (An-LV), was released at a size of 27.3 fish per pound. Prerelease data of the experimental and production groups are shown in Table 1.

Methods

The two general areas of mark recovery sampling dealt with in this report are the major 1966 and 1967 coho salmon fisheries, and the 1966 and 1967 coho salmon escapements to Big Creek Hatchery.

Fisheries Mark Sampling

As a result of cooperative Columbia River hatchery contribution studies, an extensive mark recovery sampling effort has been conducted in the ocean fisheries from Southeastern Alaska to Monterey, California, as well as in the Columbia River. Mark recovery data collected in the 1966 and 1967 sampling seasons have been processed and distributed. Included in these data are unduplicated An-RV and An-LV fin-mark recoveries assigned to 1964-brood Big Creek coho. The data used in this report were obtained from 1966 coho salmon mark recovery listings compiled by the Washington Department of Fisheries and the Fish Commission of Oregon, and from a 1967 listing compiled by the Bureau of Commercial fisheries.① These data encompass statistics of total catch, number of fish sampled for marks, and the actual and calculated numbers of marked fish recovered in the catch. Recoveries are projected on a time basis by port or zone of landing. Major ocean ports and Columbia River zones sampled for marked coho salmon are shown in Figure 1.

In the 1966 sampling season, 28.7% and 24.5%, respectively, of the combined Washington, Oregon and California coho salmon troll catch (1,748,971 fish) and ocean sport catch (583,946 fish) were examined for marks. Sampling effort in the Columbia River gill-net fishery was 10.3% of the total catch (430,340 fish), and in the river sport fishery, 5.0% of the total catch (11,-

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① Data Report: Columbia River Coho Salmon Hatchery Contribution Study: 1967 Sampling Season, issued April, 1969 by the Biometrics Unit of the Bureau of Commercial Fisheries Biological Laboratory, Seattle, Washington.

Table 1. Prerelease sampling data from 1964-brood Big Creek Hatchery experimental and production groups of coho salmon, March 16, 1966

Group	Date released	Number released	Pounds released	Avg. size released		Fin Mark
				No./Lb.	Length (mm)	
Experimental	3/16/66	59,984	5,606	10.7	151	An-RV
Experimental	3/16/66	83,649	3,064	27.3	114	An-LV
Production①	3/14-18/66	1,236,180	67,816	18.0	129	None
Total		1,379,813	76,486			

① In addition to the TM-50 marked An-RV, An-LV, and production group releases in March 1966, 321,100 non-TM-50 marked surplus fingerlings weighing 5,369 pounds were released into Big Creek in July 1965. In February 1965, 889,200 fry weighing 823 pounds were transferred to the Willamette River system. The total production of 1964-brood Big Creek Hatchery coho was, therefore, 2,590,113 fish weighing 82,678 pounds.

552 fish). The Big Creek jack sport fishery was not sampled in 1966.

During the 1967 sampling season 20.8% of the total coho salmon troll catch (3,801,817 fish) from Southeastern Alaska to Monterey, California, was examined for marks. In the ocean sport fishery, 21.7% of the total catch (858,393 fish) was sampled from the Straits of Juan de Fuca at Sekiu, Washington to Monterey, California. Mark recoveries west, or seaward, of the Astoria-Megler Bridge, near the mouth of the Columbia River, were included in the ocean sport catch. Sampling levels in the Columbia River fisheries were 14.6% and 2.6%, respectively, of the total gill-net catch (358,694 fish) and river sport catch (14,831 fish). In the Big Creek sport fishery, calculated mark recoveries were projected using hatchery escapement ratios of marked to unmarked fish and the total sport catch as indicated by salmon punch cards. The total

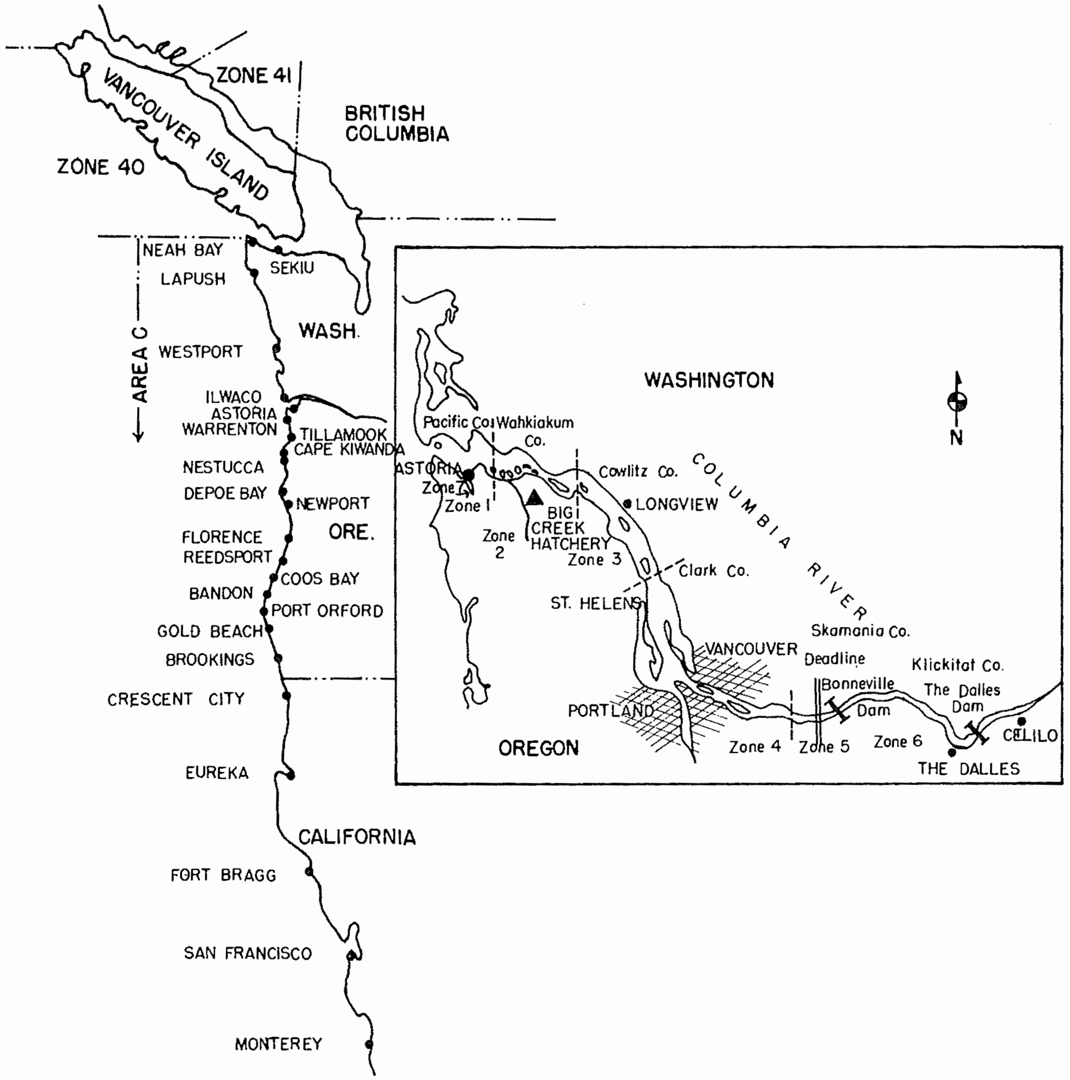

Figure 1. Pacific Ocean ports and Columbia River zones associated with coho salmon mark recovery sampling

catch and number of coho salmon examined for marks by fishery and port of landing are shown in Appendix tables 1 through 4.

Hatchery Escapement Mark Sampling

In the fall of 1966, all jack returns to Big Creek Hatchery were examined for fin-marks. In addition, fork lengths were obtained from 13% and 10%, respectively, of all An-RV and An-LV jacks recovered.

In 1967, a method of electrocuting surplus fish was used to insure recovery of the entire escapement, and facilitate mark sampling (Junge *et al.*, 1967). As a result, all adults were examined for fin-marks, aged (by length), and sexed. The degree of straying and natural spawning of marked fish below the hatchery trapping facility was not investigated.

To determine the effect of anal-ventral fin-clips on survival, an estimate of relative survival of the nonfin-marked production group fish was necessary. This was possible, since as a result of the tetracycline antibiotic treatment in August 1965, all fish released in March 1966 were presumed to be marked with TM-50. When antibiotics of the tetracycline series are fed to growing animals, a residue of the drug is fixed in the bone tissue which produces a fluorophore under ultraviolet light (Weber and Ridgway, 1962). Tetracycline mark sampling was not performed in 1966; however, in 1967, vertebra were obtained from a carefully selected 9.2% subsample of all nonfin-marked adults.

Results

Fisheries Mark Recoveries and Catch Distribution

The first recoveries, as 2nd-year fish, were observed among troll fishery landings in August 1966 at Pacific City and Astoria, Oregon. By September, the zone of recovery extended from Westport, Washington, to Coos Bay, Oregon, and resulted in the calculated recovery of 57 Big Creek Coho (52 An-RV and 5 An-LV), ranging in fork-length from 41 to 52 cm. No anal-ventral 2nd-year coho were recovered in the ocean sport or Columbia River sport fisheries. However, 50 An-RV 2nd-year coho were recovered in the Columbia River gill-net fishery. The principal area of recovery was zone 1 with additional recoveries reported in zone 7 (Youngs Bay), and zone 2 (Figure 1 inset). Mark recovery data for the 1966 jack sport fishery in Big Creek were not available.

Calculated recoveries in the 1967 troll fishery indicated that 1,099 marked Big Creek coho (640 An-RV and 459 An-LV) were landed in the fishery from Vancouver, British Columbia, to Monterey, California (Appendix, table 1). Exploitation by area, expressed as a percentage of the total 1967 calculated troll contribution was: Washington troll—40.1%, California troll—34.2%, Oregon troll—18.6% and the Canadian troll —7.1%. The total calculated recovery of anal-ventral marked coho in the 1967 ocean sport fishery was 652 (386 An-RV and 266 An-LV), with recoveries reported from Sekiu, Washington, to San Francisco, California (Appendix, table 2). The catch by area expressed as a percentage of the total calculated ocean sport contribution was: Washington—50.8%, Oregon—46.8% and California—2.4%. No marked Big Creek coho were recovered in the Columbia River sport fishery. In the 1967 season, a total of 432 marked Big Creek coho (246 An-RV and 186 An-LV) were recovered in the Columbia River gill-net catch (Appendix, table 3). The recovery percentage of marked Big Creek coho by area, i.e., zone 1—66.9%, zone 2—24.1%, zones 3, 4, 5—5.8% and zone 7—3.2%, was relatively consistent with what might be expected, since the mouth of Big Creek lies near the lower boundary of zone 2 (Figure 1, inset). The total calculated recovery of anal-ventral marked coho in the 1967 Big Creek sport fishery was 95 fish (52 An-RV and 43 An-LV). Columbia River and Big Creek sport fishery data are shown in the Appendix, table 4.

The total calculated recovery of 2nd- and

Table 2. Calculated numbers of anal-ventral marked coho recovered in the 1966 and 1967 fisheries, and overall ratio of recovery.

Group	Age class	Year recovered	Ocean troll	Ocean sport	Columbia River gill-net	River sport	Total calculated recoveries	Percentage recovered of no. released
An-RV								
	2	1966	52	0	50	①	102	0.17
	3	1967	640	386	246	52	1,324	2.21
Total			692	386	296	52	1,426	2.38
An-LV								
	2	1966	5	0	0	①	5	0.01
	3	1967	459	266	186	43	954	1.14
Total			464	266	186	43	959	1.15

① The jack sport fishery in Big Creek was not sampled in 1966.

3rd-year coho in all fisheries sampled for the An-RV group was 1,426 or 2.38% of the number released. For the An-LV group the total calculated recovery amounted to 959 or 1.15% of the number released (Table 2).

The estimated catch of 3rd-year coho relative to the numbers released for the An-RV group was 1,324/59,984 or 22.07 fish per 1,000 fish released. For the An-LV group the rate was 954/83,649 or 11.40 per 1,000 fish released. Expressed as catch per unit of weight released, contributions of 236 and 311 fish per 1,000 pounds released were calculated for the An-RV and An-LV groups, respectively.

The total calculated recovery rate of marked anal-ventral coho in all fisheries sampled in the 1967 season was 2,278/143,633 or 1.58% of the numbers released. The percentage catch distribution within the fisheries, relative to the combined contribution is shown in Table 3.

Approximately 77% of the total Big Creek contribution were landed in the ocean fisheries. The catch distribution within the troll fishery indicates that relatively equal recoveries occurred to the north and south of the Columbia River, with recoveries in the latter area slightly predominating.

Hatchery Mark Recoveries, Sex Ratios and Length Measurements

Hatchery Mark Recoveries

In the fall of 1966, a total of 11,668 jacks was recovered at the hatchery. Tetracycline mark sampling was not performed and, therefore, an estimate of the number of jack returns for the production group is not available. However, 1,590 An-RV and 150 An-LV jacks were recovered, represent-

Table 3. Estimated percentage of 3rd-year anal-ventral marked Big Creek coho recovered by fishery and area, 1967.

Area	Troll	Ocean sport	Gill-net	River sport	Per cent by area
Canada	3.4	......	......	......	3.4
Washington	19.4	14.7	......	......	34.1
Washington & Oregon	......	......	18.9	......	18.9
Oregon	9.0	13.4	......	4.1	26.5
California	16.4	0.7	......	......	17.1
Per cent of total	48.2	28.8	18.9	4.1	100.0

Table 4. The number and percentage return of marked 1964-brood coho salmon recovered at Big Creek Hatchery in 1966 and 1967

Group	Age class	Year recovered	Number recovered	Percentage return of number released
An-RV	2	1966	1,590	2.65
	3	1967	424	0.71
Total			2,014	3.36
An-LV	2	1966	150	0.18
	3	1967	356	0.43
Total			506	0.61
Production (TM-50)	2	1966	①	------
	3	1967	9,064	0.73
Total			9,064	0.73

(1) Not sampled.

ing returns of 2.65% and 0.18%, respectively, of the numbers released. These values are minimal, as many jacks were restricted from the hatchery trap during periods of peak migration.

In 1967 the total adult escapement (11,444) resulted in the recovery of 780 fin-marked and 10,664 nonfin-marked fish. A total of 424 An-RV and 356 An-LV adults was recovered, representing returns of 0.71% and 0.43%, respectively, of the numbers released. Tetracycline mark analysis of vertebra sampled from 984 adults indicated that 85% of the nonfin-marked escapement (9,064) was marked with TM-50.

Numbers of fin- and TM-50 marked 1964 brood coho salmon recovered at the hatchery and percentage return of numbers released, by age class for each group, are shown in Table 4.

Sex Ratios and Length Measurements

Based on total numbers released, there was no significant difference in percentage return of adult males betwen the An-RV (0.20%) and the An-LV groups (0.18%); however, the percentage return of females from the An-RV group (0.51%) was over twice that of the An-LV group females (0.25%) Table 5. Adult male-to-female sex ratios were 1:2.6 and 1:1.4, respectively, for the An-RV and An-LV groups.

Jack lengths were measured to the nearest one-half centimeter and adults to the nearest centimeter. Fork length measurements, by sex and marked group, are shown in Table 5. Analysis of variance indicated

Table 5. Sex composition and mean fork length of fin-marked hatchery recoveries, by age class and group

						Fork length (cm)		
Group	Age class	Sex	Number recovered	Percentage of no. recovered	Percentage of no. released	Range	Mean	Std. error
An-RV	2	Jacks	1,590	100.00	2.65	35.0-54.5	45.4	0.23
	3	Males	117	27.59	0.20	59.0-85.0	74.1	0.58
		Females	307	72.41	0.51	54.0-82.0	70.7	0.32
An-LV	2	Jacks	150	100.00	0.18	37.0-46.5	41.6	0.67
	3	Males	151	42.42	0.18	57.0-85.0	72.5	0.52
		Females	205	57.58	0.25	50.0-79.0	68.9	0.37

that adult males were significantly larger than adult females in both groups ($P<0.01$), while An-RV jacks, adult males, and adult females were each significantly larger than corresponding An-LV group fish ($P<0.01$).

Catch-to-Escapement Ratios

The following catch-to-escapement ratios for the anal-ventral marked groups are based on the calculated number of marks recovered in the 1967 fisheries (Table 2) relative to the number of marked adults recovered at Big Creek Hatchery in the fall of 1967 (Table 4). Totals of 1,324 An-RV and 954 An-LV marked coho were recovered in the fisheries, and an additional 424 An-RV and 356 An-LV adults were recovered at the hatchery. The catch-to-escapement ratios for the An-RV and An-LV groups are therefore, 3.1:1 and 2.7:1, respectively. A chi-square test based on calculated (catch) and actual (escapement) mark recovery values unduly increases the sensitivity of the test. Nevertheless, when these values were tested no significant difference between the catch-to-escapement ratio of either anal-ventral group was indicated ($x^2 = 3.36$ with 1 d.f., $P<0.05$). These data and the data reported by Senn and Noble (1967) for 3 groups of 1961-brood Washougal Hatchery coho salmon suggest that for a given brood year, hatchery, and time of release the catch-to-escapement ratio of 3rd-year coho is independent of size at release.

Effect of Fin Marks

It is generally agreed that fin-marking juvenile salmonids results in reduced growth and survival. Fry (1961) reported that survival of marked fish is usually impaired and that the degree of mortality varies with the size of fish at time of release. The smaller the fish the greater the loss.

Because of differences in average size of fish at release, comparison of the survival rate of either anal-ventral group with that of the production group would result in a misleading estimate of fin-mark mortality. Therefore, the similarly fin-marked groups are combined and an average survival rate is used for comparison. There is some justification in this approach since the average size of fish at release for the combined anal-ventral groups (16.4 fish per pound) approximates the average size of fish for the production group (18.0 fish per pound). However, the method assumes that the relationship between size at release and percentage survival is linear at the size range covered by the anal-ventral groups, and that fish marked left or right ventral are equally affected.

The combined return of all anal-ventral adults was 780 or 0.54% (780/143,633 x 100) of the total number of all anal-ventral juveniles released. Similarly, the return of nonfin-marked hatchery adults, based on TM-50 mark recoveries, was 9,064 or 0.73% (9,064/1,236,180 x 100) of the number released. The ratio of these rates indicates that the survival of the anal-ventral marked fish was 73.9% (0.54/0.73 x 100) that of the unmarked fish.

Estimated Benefit-Cost Values

Rearing Costs

Analysis of the cost of rearing a particular group of fish at Big Creek is complicated by the presence of various species and age groups which contribute differential cost factors to the overall operating expenses of the hatchery. In addition, the cost of rearing 1964-brood coho was reflected in 1965 and 1966 fiscal year expenditures. The duration of handling and rearing from time of egg take to time of release was 17 months (November 1964-March 1966).

The following methods of computing rearing costs are largely patterned after those presented by Worlund *et al.* (1969) in their contribution report concerned with Columbia River hatchery fall chinook (*O. tshawytscha* Walbaum). Big Creek Hatchery expenditures for the 1965 and 1966 fiscal years were divided into three categories (Table 6). Capital investment and operational costs other than food and drugs

Table 6. Total categorized expenditures of Big Creek Hatchery for 1965 and 1966 fiscal years

Category	Fiscal Year 1965	Fiscal Year 1966	Total biennial expenditures
Capital investment①	$ 33,747	$ 33,747	$ 67,494
Operational costs②	51,452	57,074	108,526
Fish food and drugs	34,068	25,740	59,808
Total expenditures	$119,267	$116,561	$235,828

① Capital investment, through 1966 fiscal year, for Big Creek Hatchery was $482,095. This amount was amortized over 50 years and was charged a simple interest rate of 5% per annum. This amounts to 7% of the total capital investment or $33,747 (0.07 x $482,095) chargeable per annum.

② Costs include personal services, travel and transportation, communications, rents and utilities, contractual services, equipment and supplies, and administration.

were apportioned, by fiscal year, among the various brood year-species groups by using the estimated annual percentage of man-hours expended for each group, while the cost of fish food and drugs was apportioned by the actual amount of food each group was fed.

It was estimated that the rearing of 1964-brood coho required 33.0% and 27.0%, respectively, of the total man-hours expended in the 1965 and 1966 fiscal years while the amount of food fed was 11.5% and 57.4% respectively, of the total weight of all food expended in the same years. When these percentage values were applied to the categorized expenditures shown in Table 6, the total costs assigned 1964-brood coho were: capital investment—$20,248, operational costs—$32,389, and fish food and drugs—$18,693 (Table 7). Adding these costs gave $71,330 or 30.2% of the total biennial expenditure ($235,828) as the estimated cost of rearing all 1964-brood coho at Big Creek Hatchery.

Table 7. Total estimated cost of rearing 1964-brood Big Creek coho, 1965 and 1966 fiscal years

Category	Fiscal Year 1965	Fiscal Year 1966	Total biennium expenditures
Capital investment	$11,136	$ 9,112	$20,248
Operational costs	16,979	15,410	32,389
Fish food and drugs	3,918	14,775	18,693
Total	$32,033	$39,297	$71,330

The units of man-hours expended per group of coho could not be reliably estimated; therefore it was not possible to apportion capital investment and operational costs for each group in a manner similar to that for the entire group in the preceding analysis. Apportionment of these costs on the basis of numbers of fish per group would have resulted in improper cost assignments. For example, An-LV group fish comprised 58.2% of the total number of all experimental fish reared; however, in regard to food storage and labor costs, they received only 30.4% of the total amount of food fed to both groups. An alternative method using average cost per pound as the basis for apportioning rearing costs is subject to slight error since food conversions (i.e., pounds of food to produce a pound of fish) were not the same for the An-RV (2.0:1) and An-LV (1.8:1) groups. However, it appeared to be the most reasonable method available and was used in the following analysis.

The total gross weight of all 1964-brood coho produced at Big Creek Hatchery was 82,678 pounds. Therefore, the average cost per pound of the total weight produced was $0.86 ($71,330/82,678). The total weight released of coho pertinent to this study, i.e., those fish released in March

1966, was 76,486 pounds (Table 1). Hence, the cost of rearing these fish was $65,778 ($0.86 x 76,486) or 92.2% of the total estimated cost of rearing all 1964-brood Big Creek coho ($71,330). Further, of the total weight released in March, 7.3% or 5,606 pounds was comprised of An-RV group fish and 4.0% or 3,064 pounds of An-LV group fish. At the above rates the estimated cost of rearing An-RV and An-LV group fish was $4,821 ($0.86 x 5,606) and $2,635 ($0.86 x 3,064), respectively.

Catch and Salvage Net Benefit Values

The gross value of commercially caught coho salmon was determined from estimated landings and average prices paid to fishermen in the 1967 fisheries. Based on arguments presented by Worlund, *et al.* (1969), the gross economic value of hatchery coho to the commercial fisherman is assumed to constitute a net benefit value.

An assumed value of $8.87 per fish is used to estimate the total net benefit value of coho caught in the 1967 sport fisheries. The value was extrapolated from a study by Brown *et al.* (1964) in which they estimated the net economic value of all salmon and steelhead caught in the 1962 Oregon sport fisheries to be in the range of from $2.5-$3.1 million. When the minimum value is divided by the total Oregon sport catch for the same season (281,984)① a net value per fish of $8.87 ($2.5 million/281,984) is indicated.

The estimated net salvage value of adult carcasses in 1967 was obtained from the actual value received from spawned-out carcass sales, and the assumed value of carcasses transferred to state institutions. Spawned-out carcasses were sold at a rate of $0.52 per fish to processors of animal food and fertilizer. The value is considered a net benefit value in that no additional work, beyond the actual spawning operation, was expended by the hatchery staff in the handling of fish, i.e., carcasses were loaded and transported by the processor. The assumed net value of prime quality carcasses transferred to state institutions for human consumption is based on a whole-

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① Catch data from the Game Commission of Oregon, 1967 Annual Report.

Table 8. Unadjusted net benefit value of experimental groups of Big Creek Hatchery coho, 1967.

Group	Fishery	Estimated number of fish	Dollar value per fish①	Total value
An-RV	Sport	438	$8.87	$3,885
	Ocean commercial	640	3.29	2,106
	River commercial	246	2.53	622
	Salvage Values			
	Processed	286	0.52	149
	State Institutions	70	3.79	265
	Total	1,680		$7,027
An-LV	Sport	309	8.87	2,741
	Ocean commercial	459	3.29	1,510
	River commercial	186	2.53	470
	Salvage Values			
	Processed	240	0.52	125
	State Institutions	59	3.79	224
	Total	1,253		$5,070

① The 1967 ocean commercial value is based on an average seasonal value of 7.3 pounds dressed weight @ $0.45 cents per pound. The 1967 river commercial value is based on an average seasonal value of 10.1 pounds (round weight) @ $0.25 cents per pound.

sale round weight price of $3.79① per fish, f.o.b., Astoria, Oregon. The value is an assumed net benefit value since it represents the minimum wholesale price the state would have been charged for fresh salmon had the product not been provided by the hatchery.

Of the total 1967 adult escapement (11,444), 67.5% or 7,719 carcasses were sold to processors and 16.5% or 1,893 were transferred to state institutions. When these percentage values were applied to the An-RV and An-LV escapement data in Table 4, an estimate of the number of carcasses in each category, by group, is obtained (Table 8).

Total unadjusted net benefit values of $7,027 and $5,070 were calculated, respectively, for the An-RV and An-LV groups. When these values are adjusted upward by the assumed relative survival of fish with anal-ventral fin-clips (i.e., 1.353, the reciprocal of 0.739), calculated values of $9,508 ($7,027 x 1.353) and $6,860 ($5,070 x 1.353) are obtained for the respective An-RV and An-LV groups. These values are considered minimal from the standpoint that catch and carcass benefit values for 2nd-year coho are not included.

The preceding analysis discounts the slightly larger size of An-RV fish in those categories where the benefit value is based on weight of fish. However, as a result of the extreme difference in size at release, expanding the total benefit value of each fin-marked group by the relative survival rate computed for the combined groups (1.353) tends to overestimate the An-RV benefit value and underestimates the An-LV value.

Benefit-Cost Ratios

When the adjusted net benefit value calculated for An-RV group fish ($9,508) was divided by their cost of rearing ($4,821) a 1.97:1 benefit-cost ratio was obtained. Similarly, when the calculated value of An-LV group fish ($6,860) was divided by their cost of rearing ($2,635) a 2.60:1 ratio was obtained.

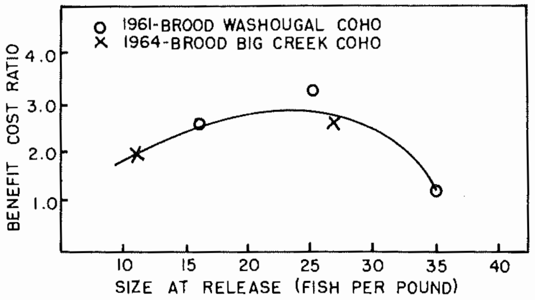

Figure 2. Estimated benefit-cost values for different sizes at release of 1961-brood Washougal and 1964-brood Big Creek coho salmon. (The Washougal data are from Senn and Noble, 1967.)

In recent years the average size of coho salmon released from Fish Commission hatcheries has ranged from 12-17 fish per pound. Since only two extreme sizes were evaluated in this study, an optimum size has yet to be determined. However, when the results of this study and the Washougal study by Senn and Noble (1967) are compared (Figure 2), it appears that a release size smaller than 17 fish per pound may be economically preferred.

Acknowledgments

Sampling information relative to the Canadian fishery was provided by the Fisheries Research Board of Canada. Within the United States, cooperating federal agencies included the Bureau of Commercial Fisheries and the Bureau of Sport Fisheries and Wildlife, while cooperating state agencies include the Alaska Department of Fish and Game, Washington Department of Fisheries, Fish Commission of Oregon and Oregon State Game Commission, and the California Department of Fish and Game.

Special thanks are extended to Charles

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① Based on average round weight of 10.1 pounds per fish in the 1967 river gill-net fishery, and a price quotation of $0.375 per pound (round weight) from Mr. Connelly, Accountant, Bumble Bee Seafoods, Astoria, Oregon.

O. Junge, Fish Commission of Oregon, for his assistance in the interpretation of the data, to Irving W. Jones, Fish Commission of Oregon, for his TM-50 mark analysis work, to the Big Creek Hatchery staff, and to R. E. Noble, Washington Department of Fisheries, for his review of the paper. Roy J. Wahle, Bureau of Commercial Fisheries, provided assistance in benefit-cost analysis. Dr. James A. Crutchfield reviewed the economic evaluation section.

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APPENDIX

Appendix Table 1. Estimated 1967 troll landings of fin-marked Big Creek coho①

Port	Total Catch	Sample Size	An-RV		An-LV		Total Estimated Marks
			Estimated	Actual	Estimated	Actual	
Alaska	463,698	69,527	0	0	0	0	0
Canada							
Zone 40	1,009,640	320,641	6	2	3	1	9
Area C1②	30,305	⑧	15	......	0	......	15
Area C2③	92,968	⑧	9	......	19	......	28
Area C3④	5,585	⑧	10	......	0	......	10
Area C4⑤	789	⑧	1	......	0	......	1
Area C5⑥	15,162	⑧	6	......	4	......	10
Area C6⑦	3,136	⑧	3	......	2	......	5
Total	1,157,585	320,641	50	2	28	1	78
Washington							
Seattle	44,989	27,119	14	7	9	7	23
Neah Bay	74,744	17,569	12	2	4	1	16
LaPush	286,738	57,486	28	5	64	11	92
Westport	136,456	20,566	62	10	36	5	98
Ilwaco	236,349	36,113	120	20	92	15	212
Total	779,276	158,853	236	44	205	39	441

Appendix Table 1. Continued

Oregon							
Astoria	155,871	22,285	14	2	14	2	28
Tillamook	111,367	7,377	0	0	0	0	0
Pacific City	44,447	6,738	10	1	10	1	20
Depoe Bay	72,530	15,473	7	2	8	2	15
Newport	175,488	47,243	21	6	20	6	41
Florence	8,564	1,399	0	0	10	1	10
Reedsport	42,043	8,100	0	0	0	0	0
Coos Bay	267,248	31,146	28	6	26	5	54
Bandon	22,701	2,550	0	0	0	0	0
Port Orford	29,681	1,521	0	0	0	0	0
Gold Beach	369	190	0	0	0	0	0
Brookings	56,839	38,089	23	15	13	9	36
Total	987,148	182,111	103	32	101	26	204
California							
Crescent City	92,572	18,585	51	11	27	5	78
Eureka	103,807	15,565	82	12	46	7	128
Fort Bragg	87,088	11,473	31	4	42	5	73
San Francisco	113,151	11,949	71	8	0	0	71
Monterey	17,492	2,787	16	4	10	3	26
Total	414,110	60,359	251	39	125	20	376
Grand Total	3,801,817	791,491	640	117	459	86	1,099

① California marks are projected on a monthly sampling basis. All other marks are projected on a 2-week basis.

② Cape Flattery south to Cape Johnson

③ Cape Johnson south to Cape Elizabeth

④ Cape Elizabeth south to Point Brown

⑤ Point Brown south to Leadbetter Point

⑥ Leadbetter Point south to Tillamook Head

⑦ South of Tillamook Head

⑧ Estimated marked fish are based on mark recoveries and mark sampling ratios for Washington troll trip boats during comparable time periods and catch areas.

Appendix Table 2. Estimated 1967 ocean-sport landings of fin-marked Big Creek coho①

Port	Total Catch	Sample Size	An-RV Estimated	An-RV Actual	An-LV Estimated	An-LV Actual	Total Estimated Marks
Washington							
Sekiu	19,556	2,755	0	0	0	0	0
Neah Bay	42,883	8,504	5	1	0	0	5
LaPush	37,979	7,484	17	3	13	2	30
Westport	124,328	19,333	61	11	23	6	84
Ilwaco	249,770	47,245	123	21	89	15	212
Total	474,516	85,321	206	36	125	23	331

Appendix Table 2. Continued

Oregon							
Warrenton	82,671	10,047	66	7	55	5	121
Tillamook	10,415	1,514	0	0	8	1	8
Cape Kiwanda	21,295	6,059	0	0	0	0	0
Depoe Bay	60,319	15,778	4	2	15	5	19
Newport	61,073	13,387	33	8	0	0	33
Florence	12,410	3,629	3	1	0	0	3
Reedsport	44,257	16,857	28	12	33	11	61
Coos Bay	31,756	12,503	30	13	16	8	46
Gold Beach	4,029	3,034	7	4	2	1	9
Brookings	5,372	3,619	0	0	5	3	5
Total	333,597	86,427	171	47	134	34	305
California							
Crescent City	4,921	2,172	3	1	0	0	3
Eureka	13,630	4,933	3	1	0	0	3
Fort Bragg	6,372	3,751	3	2	2	1	5
San Francisco	17,990	3,372	0	0	5	1	5
Monterey	7,367	127	0	0	0	0	0
Total	50,280	14,355	9	4	7	2	16
Grand Total	858,393	186,103	386	87	266	59	652

① California marks are projected on a monthly sampling basis, all other marks are projected on a 2-week basis.

Appendix Table 3. Estimated 1967 Columbia River Gill-net landings of fin-marked Big Creek Coho.①

Zone	Total Catch	Sample Size	An-RV Estimated	An-RV Actual	An-LV Estimated	An-LV Actual	Total Estimated Marks
1	91,869	18,564	167	32	122	22	289
2	112,775	9,321	49	8	55	5	104
3-4-5	107,464	16,716	18	3	7	2	25
6	12,829	808	0	0	0	0	0
7 (Youngs Bay)	33,757	7,089	12	5	2	1	14
Total	358,694	52,498	246	48	186	30	432

① All marks are projected on a weekly sampling basis.

Appendix Table 4. Estimated 1967 Columbia River and Big Creek sport landings of fin-marked Big Creek Coho

Area	Total Catch	Sample Size	An-RV Estimated	An-RV Actual	An-LV Estimated	An-LV Actual	Total Estimated Marks
Columbia River	14,831	386	0	0	0	0	0
Big Creek	1,393①	......②	52	......	43	......	95
Total	16,224	386	52	0	43	0	95

① Total sport catch in Big Creek as indicated by salmon punch cards.

② Projection of marks is based on hatchery escapement ratios.

THE COMMERCIAL FISHERY FOR FRESH-WATER CRAWFISH, *Pacifastacus leniusculus* (Astacidae), IN OREGON, 1893-1956①

George C. Miller② and Jack M. Van Hyning③

Abstract

A minor fishery has existed for fresh-water crawfish in Oregon since 1893. Annual landings, which reached a maximum of 176,000 pounds in 1930, have fluctuated considerably throughout the history of the fishery. *Pacifastacus leniusculus leniusculus*, *Pacifastacus leniusculus trowbridgii*, and intergrades between these two subspecies are taken primarily in the Willamette River tributaries and in the Columbia River below Portland, Oregon. Only a small percentage of the incoming year class of crawfish enters the trap fishery, probably because the juveniles and adults differ in food habits. In the fishery for human consumption, the fishermen select crawfish more than 3½ inches in body length; for bait, smaller crawfish are retained. The catch is seasonal, with the largest landings in June to November. Most female crawfish are at least 17 months old before they bear eggs. The weight-length relationship and length-frequency distributions of a single sample of *P. l. leniusculus* are given.

Introduction

Fresh-water crawfish have been fished commercially in Oregon since 1893. A survey of the commercial fishery was made in 1957 by the senior author while at Oregon State University. Its purpose was to determine the species and subspecies in the catch, delineate the fishing areas, review the fishery from its inception, review the laws and regulations made for the management of the fishery, and make biological observations pertinent to fishery management. This report deals with the survey as it relates to the commercial fishery.

Commercial Fishery

Species and Subspecies

The western crawfish are difficult to identify because many characters used in taxonomic keys change with growth, and intergrade specimens are intermediate in character between the subspecies. Riegel (1959) recognized *Pacifastacus leniusculus* (Dana) and *Pacifastacus klamathensis* (Stimpson) as distinct species, and considered *Pacifastacus trowbridgii* (Stimpson) as a junior synonym of *P. leniusculus*. In this study we follow Miller (1960), who relegated *P. leniusculus*, *P. trowbridgii*, and *P. klamathensis* to subspecies of *P. leniusculus*. A taxonomic paper on the relationship of the three subspecies of *P. leniusculus* is now in preparation by the senior author.

Western crawfish reported in the literature have commonly been misidentified. Crawfish from Johnson Creek (Portland, Oregon) identified and figured as *P. klamathensis* by Faxon (1914) were examined by the senior author and found to be large *P. l. trowbridgii*. Subsequent misidentifications by biologists were caused by the use of Faxon's key to the western crawfish species. For example, the crawfish reported in the commercial catch of Oregon as *P. klamathensis* by Cleaver (1951) were probably large *P. l. trowbridgii*.

For proper management it is necessary to be able to identify the species or subspecies in a fishery. The characters used in the identification of the subspecies of craw-

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fish are illustrated in Figure 1. The adults of the three subspecies of *P. leniusculus* may usually be distinguished by the following description and illustration (Figure 2).

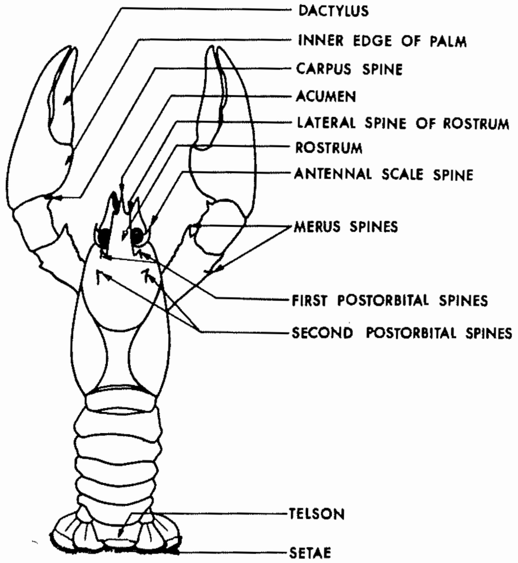

Figure 1. Characters used in the identification of the subspecies of *Pacifastacus leniusculus*.

Adult *P. l. leniusculus* are large and reach more than 150 mm total length (used synonymously with body length in this paper, and measured from tip of acumen to distal end of telson, excluding setae). The subspecies is distinguished by a long acumen, greater than 1.05 times the width of the rostrum at the lateral spines. It is heavily spined and bears large sharp rostral spines, large first and second postorbital spines, large carpus and merus spines on the major chela, and a large antennal scale spine. The major chela has the inner edge of the palm short and highly convex; the dactylus is nearly twice as long as the palm (Figure 2a).

Adult *P. l. trowbridgii* are of moderate size, and reach 130 mm total length, but usually are less than 110 mm. The subspecies is distinguished by a short acumen usually less than 1.05 times the width of the rostrum at the lateral spines. It is less spinous than *P. l. leniusculus* and bears small or tubercle-like spines on the rostrum, large to small first postorbital spines, small to obsolete second postorbital spines, tubercle-like carpus and merus spines on the

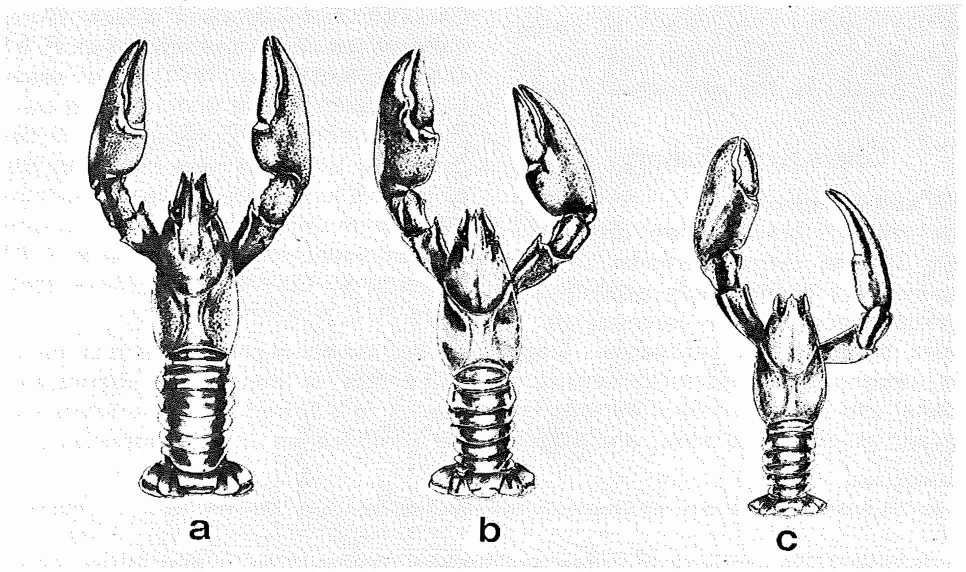

Figure 2. Three subspecies of *Pacifastacus leniusculus:* **a.** *P. l. leniusculus;* **b.** *P. l. trowbridgii;* **c.** *P. l. klamathensis.*

chela, and a small to large antennal scale spine (usually small). The major chela has the inner edge of the palm variable from short and highly convex (like *P. l. leniusculus*) to moderately long and slightly convex; the dactylus is moderately long in both sexes (Figure 2b).

Adult *P. l. klamathensis* are small and generally less than 110 mm total length. The subspecies is distinguished by a very short acumen, usually less than 0.95 times the width of the rostrum at the lateral spines. It is less spinous than the other two subspecies and bears tubercle-like rostral spines, minute or tubercle-like first postorbital spines, small and fragile or obsolete second postorbital spines, tubercle-like carpus and merus spines on the major chela, and a small or obsolete antennal scale spine. The major chela has the inner edge of the palm long, and nearly straight; the dactylus is short and of about the same length as the palm in both sexes (Figure 2c).

The commercial fishery is conducted on two subspecies of *P. leniusculus* which occupy distinct ecological niches. *P. l. leniusculus* lives in the deep channels of major rivers on muddy bottom, whereas *P. l. trowbridgii* is found upstream in rivers and in rocky bottom riffles, deep holes, and in lakes. *P. l. trowbridgii* moves down into the lower portion of rivers at times, and intergrades between the two subspecies are evident in these regions (Miller, 1960). The commercial fishery is conducted primarily in the deep channels of the rivers. The catch, therefore, consists primarily of *P. l. leniusculus* but may include small numbers of *P. l. trowbridgii* and intergrades between the two subspecies.

Fishing Areas

The commercial catch is taken primarily from the tributaries of the Willamette River and the sloughs of the Columbia River near Portland and Astoria, Oregon (Figure 3). Other streams and lakes that are being (or have been) fished commercially in Oregon are the Tualatin, Clackamas, Pudding, Yamhill, Luckiamute, John Day (Clatsop Co.), Youngs, Siletz and Yaquina rivers; Dairy, Rickreall, and McKay creeks; McKay Reservoir near Pendleton; Lake Oswego near Portland; and Tenmile Lakes near Coos Bay (the latter three locations are not shown in Figure 3). In Washington, the commercial fishery has taken place in Deep River and in the sloughs of the Columbia River near Longview.

During the early fishery, the Willamette River between Salem and Portland was fished, as well as the Columbia River downstream from Portland. However, fishermen stated that by 1957 the numbers of crawfish had declined in the main Willamette River to a point where it was uneconomical to fish between Salem and Portland. Pollution below Longview, Washington, also has eliminated a portion of the fishing grounds in the Columbia River by increasing bacterial growth which fouls the fishing gear.

P. l. leniusculus has been collected in all rivers and lakes where the commercial fishery has been known to exist with the exception of the Siletz and Yaquina Rivers, and Tenmile Lakes. *P. l. trowbridgii* has been taken in the upper portions of the rivers and creeks listed with the exception of Dairy and McKay creeks. It is very possible that *P. l. trowbridgii* also occurs in these creeks but has not been collected.

Fishermen, Gear, and Methods of Capture

Fishing was conducted by three types of fishermen: (1) professional fishermen, whose basic annual income was derived from crawfishing; (2) occasional fishermen, who fished if the profit outlook was favorable; and (3) sport fishermen, who purchased a commercial license to take crawfish in excess of the personal use possession limit for home consumption or bait. When a regulation, passed in 1956, removed the possession limit for personal use, the sportsman no longer needed to purchase a commercial license and he ceased to contribute to the commercial catch statistics.

The boats used in the fishery are small Columbia River gill-net boats or skiffs. The

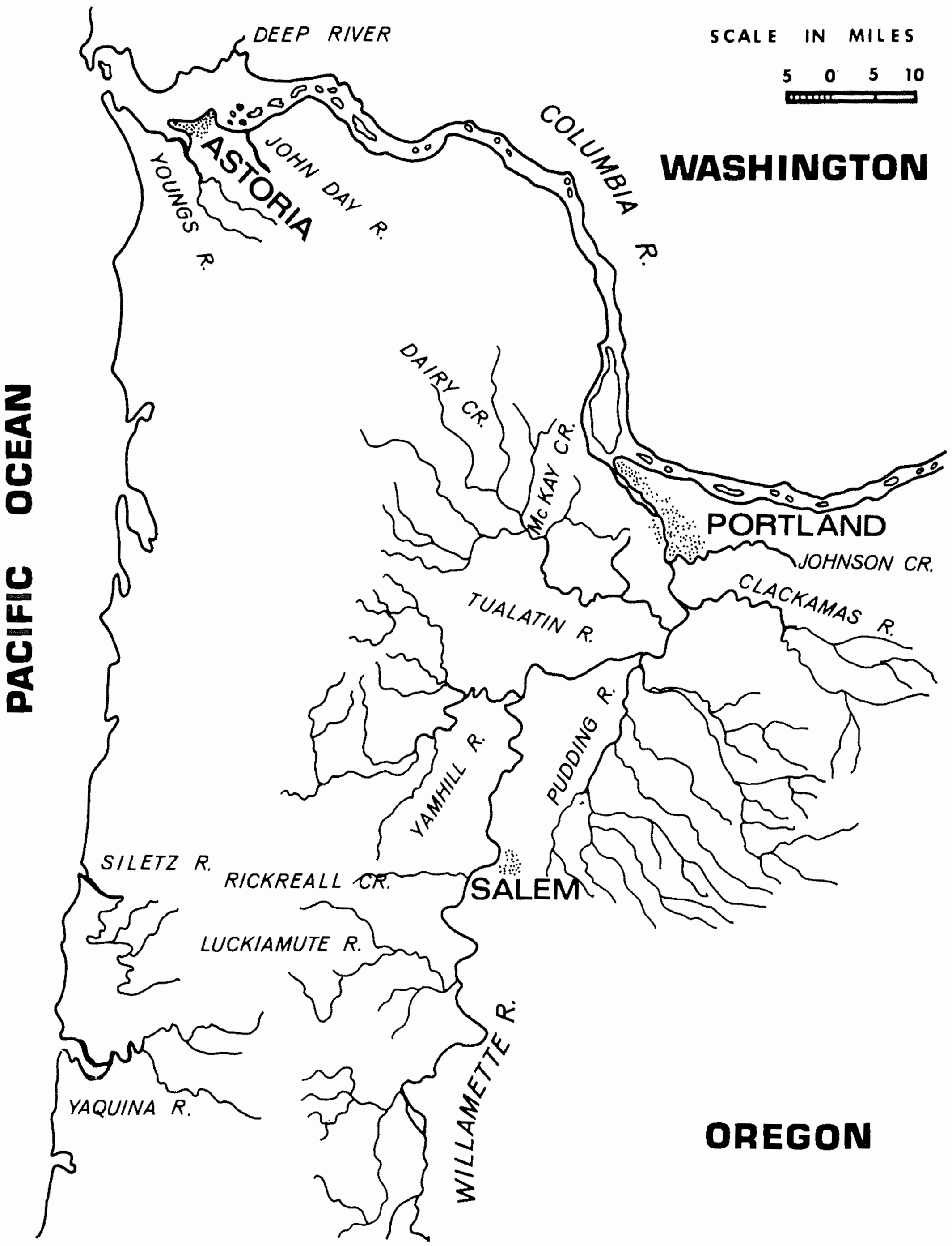

Figure 3. The primary commercial crawfish fishing areas.

traps developed by the fishermen are approximately 24 inches long and 10 inches wide, cylindrical or rectangular, and covered by small-mesh hardware cloth or webbing with an entrance at each end 2½ to 3 inches in diameter.

When fishing near large cities, theft of traps is a problem. To discourage theft, the traps are not buoyed. The fishermen connect 10 or more traps to a single ground line with 25 feet of line between traps. The traps are generally laid out in a straight line on the bottom of the river and the ground line must be grappled for with a snagging hook. A fisherman tends from 30 to 100 traps daily. In less populated areas every trap is buoyed or tied to pilings in the river. The fishermen have found that when traps are repeatedly set in the same area, the catch per trap decreases rapidly within a few days; consequently the traps are moved regularly.

Salmon heads, American shad, and carp are the best baits for crawfish. Contrary to popular belief, fresh or frozen bait is better than partially deteriorated bait. The bait (about one-half pound per trap) is replaced daily. In 1957 the bait was either caught by the fishermen or purchased from a cannery for 1 to 2 cents per pound.

Crawfish are held in live boxes at the fisherman's wharf until they are sold to consumers or to fish buyers. Live crawfish held for market are fed lettuce, corn, carrots, and beets. Fishermen report that crawfish will not eat cabbage, and if fed cucumbers will develop an objectionably bitter taste.

Commercial Utilization

In the early days of the fishery, crawfish were sold to home consumers, restaurants, and taverns, and were exported from the state. Wilcox (1902) stated:

> A large part of the catch is used at Portland, with a considerable demand from Seattle, Tacoma, San Francisco, and as far east as Salt Lake City and St. Louis.

The tavern trade no longer exists, having been replaced in part by crawfish sold as bait by sporting goods stores. The delicacy of the Oregon crawfish is still recognized; in 1957, 10% of those bought by one major buyer were exported. The sale of crawfish as specimens to biological supply houses had gained some importance by 1957.

Before 1957, major purchasers bought crawfish from the fishermen by the dozen, according to size. The "small" size was 3½ to 4 inches in body (total) length—an average of 8 to 9 whole crawfish per pound. The "large" size included crawfish of more than 4 inches in body length—2 to 8 per pound. The restaurant trade classified all crawfish over 5 inches long as "jumbo." In 1957, the major buyer ceased purchasing by number and bought all crawfish by the pound. This change eliminated counting by the buyer and disagreements over size. The buyer still required the fishermen to separate their catch into "small" and "large" sizes—"large" crawfish were sold whole in restaurants, and tail and claw meats were removed from the "small" crawfish for use in cocktails and other dishes.

Laws and Regulations

In 1897, concern over the increasing crawfish catch in the Portland area led to the recommendation to close the season from October 1 to May 1 to protect the egg-bearing females (Oregon Annual Report for 1897-98). The Oregon Annual Report of 1901 reported that such a bill had passed the legislature. The Biennial Report of 1909-10 reported:

> The closed season on Crabs, Clams, and Crawfish provided by the last legislature, are working to good advantage, and our shellfish are now receiving the protection that was needed.

Lake Oswego, near Portland, was closed to all fishing from 1911 to 1934. All counties of the state were closed to commercial fishing from November 1 to February 1, from 1911 to 1934, except Clatsop County which remained open the entire year from 1924 to 1934. During the early years, no minimum size limit was placed on the crawfish taken commercially. In 1939, a law was passed lifting the seasonal restriction but protecting all females and all crawfish less than 3½ inches long. From 1945 to 1952, all crawfish were protected from April 15 to June 1; the minimum size of 3½ inches was retained, but the females were no longer protected. From 1953 to 1956, crawfish were protected from April 15 to June 15. In 1957, a regulation was passed which closed the season from November 1 to March 31 to protect egg-bearing females.

Methods of Determining Catch Statistics

Catch statistics for the crawfish fishery in Oregon have been published intermittently since 1896 in the annual and biennial reports of the Fish Commission of Oregon and its predecessor agencies, and in the reports of the U. S. Commissioner of Fish and Fisheries (Wilcox, 1898 and 1902). Cleaver (1951) gave crawfish catch statistics for 1943-49, and Smith (1956) for 1950-53. Catch statistics were also obtained from unpublished figures, and from annual pass books issued by the Fish Commission of Oregon, in which fishermen were required to list the crawfish they sold. It was possible to ascertain the annual catch, the catch per fisherman, the catch composition by size, and the dollar value, from the pass books.

The statistics for the fishery have either been given in pounds or dozens caught, number of licenses issued, or both; for some years no data were recorded. Inspection of the annual number of licenses issued and poundage of crawfish landed suggested that a correlation existed between these two variables (Figure 4). The correlation was positive for the years 1928-56 ($r = 0.8495$). From the regression equation, estimates of the poundages landed were determined for years in which only the number of licenses issued were known (1915-18 and 1921-27). The years for which neither license nor landing data were available (1894, 1896-97, 1904, 1913-14, and 1919-20) were interspersed between years when catch or license data were recorded. The poundage for those years were estimated from the general catch trend of the period.

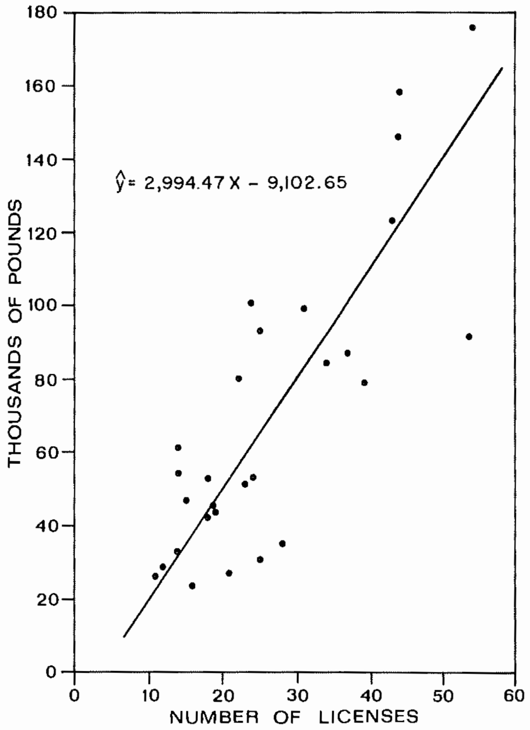

Figure 4. Relationship between number of crawfish licenses issued and poundage landed annually, 1928-56.

Published catch statistics for 1893, 1895, and 1900, which listed the landings in dozens of crawfish, were converted to pounds. Reports of the weight of western crawfish vary widely: in 1895, 1.5-2.0 pounds per dozen (Wilcox, 1898); in 1898, 2.7 pounds per dozen (State or Oregon Annual Report, 1897-98); in 1899, 3.0 pounds per dozen (Wilcox, 1902); and in 1943-49, 2.5 pounds per dozen (Cleaver, 1951). In a sample of the commercial catch from the Tualatin River in April 1958, we found that 205 "small" crawfish averaged 1.4 pounds per dozen, and 145 "large" crawfish averaged 1.8 pounds per dozen. A conversion factor of 2.5 pounds per dozen was used in this report for obtaining the poundages for the early years of the fishery (1893, 1895, and 1900).

The annual poundages landed which we list are mostly underestimates. No attempt was made to estimate the catches by licensed fishermen who failed to turn in their pass books, sports fishermen with commercial licenses, or fishermen without licenses. Annual landings after 1956 have not been compiled by the Fish Commission of Oregon.

Historical Review

The crawfish fishery has fluctuated widely since its inception (Table 1, Figure

Table 1. Oregon commercial crawfish landings and number of licenses, 1893-1956.

Year	Landings in pounds	Number of licenses	Year	Landings in pounds	Number of licenses
1893	66,288 ①	----	1925	125,500 ⑥	45
1894	72,000 ②	----	1926	116,500 ⑥	42
1895	76,055 ③	----	1927	134,500 ⑥	48
1896	96,000 ②	----	1928	158,200 ⑧	44
1897	120,000 ②	----	1929	146,000 ⑧	44
1898	140,000 ①	----	1930	176,800 ⑧	54
1899	138,248 ④	----	1931	123,000 ⑧	43
1900	111,321 ④	----	1932	80,000 ⑧	22
1901	62,445 ⑤	----	1933	99,000 ⑧	----
1902	21,673 ⑤	----	1934	143,600 ⑧	----
1903	8,650 ⑤	----	1935	79,300 ⑧	39
1904	8,800[1]②	----	1936	86,900 ⑧	37
1905	9,100 ⑤	----	1937	84,200 ⑧	34
1906	13,500 ⑤	----	1938	93,700 ⑧	25
1907	5,800 ⑤	----	1939	98,900 ⑧	31
1908	42,360 ⑤	----	1940	100,400 ⑧	24
1909	45,720 ⑤	----	1941	51,900 ⑧	23
1910	9,490 ⑤	----	1942	23,600 ⑧	16
1911	10,640 ⑤	----	1943	26,128 ⑧	11
1912	132,843 ⑤	----	1944	28,625 ⑧	12
1913	137,000 ②	----	1945	26,568 ⑧	21
1914	141,000 ②	----	1946	35,035 ⑧	28
1915	146,610 ⑥	52	1947	52,722 ⑧	24
1916	128,643 ⑥	46	1948	42,285 ⑧	18
1917	101,693 ⑥	37	1949	53,750 ⑧	14
1918	50,787 ⑥	20	1950	44,813 ⑨	19
1919	62,000 ②	----	1951	44,453 ⑨	19
1920	74,000 ②	----	1952	60,408 ⑨	14
1921	86,500 ⑥	32	1953	52,918 ⑨	18
1922	89,500 ⑥	33	1954	46,596 ⑩	15
1923	80,500 ⑥	30	1955	32,711 ⑩	24
1924	143,200 ⑥	51	1956	30,503 ⑩	25

① Estimated from State of Oregon Ann. Reports of the Fish and Game Protector, 1897-98.
② Estimated from catch trend.
③ Wilcox, 1898.
④ Wilcox, 1902.
⑤ State of Oregon, Department of Fisheries Ann. Reports, 1901-17.
⑥ Estimated from calculated poundage-license regression.
⑦ Fish Commission of Oregon Biennial Reports, 1919-57.
⑧ Cleaver, 1951.
⑨ Smith, 1956.
⑩ H. S. Smith, personal communication, 1957.

Figure 5. Annual Oregon crawfish landings, 1893-1956.

5). After an early peak of 140,000 pounds in 1898, the fishery declined to a low of 8,650 pounds in 1903. In 1912 the catch rose sharply again and reached an estimated peak of 146,000 pounds in 1915; it then declined during World War I. After the war the catch increased steadily until 1930 when a record 176,000 pounds was landed. From 1920 to 1940, when the fishery experienced its greatest period of prosperity, more than 74,000 pounds were landed each year. During World War II the catch again declined and the fishery has never regained its earlier prosperity. Since World War II (1946-56) the catch has ranged from 30,000 to 60,000 pounds.

Possible explanations for the periodic declines in the catch are (1) low prices paid the fishermen, (2) inducement of fishermen into industrial jobs by higher wages, (3) loss of fishermen to the armed forces during the wars, and (4) loss of market after years of low production due to changes in consumer food habits. Crawfish production remained high during the depression years of the 1930's. Large numbers of crawfish were reported by the fishermen to have been consumed at that time at free lunch counters in taverns.

Economic Value

The average price paid to the fishermen for crawfish has fluctuated widely since the beginning of the fishery. In 1895, fishermen were paid $0.10 per dozen or $0.05 per pound, and crawfish retailed at $0.15 to $0.20 per dozen or $0.075 to $0.10 per pound (U. S. Commission of Fish and Fisheries, 1896). The price increased from $0.05 per pound in 1896 to $0.10 in 1899 and then declined to a low of $0.035 in 1908-09 (Table 2). The low price probably explains the extremely low landings from 1903 to 1911. In 1955, the fishermen received $0.25 per dozen for "small" and $0.45 per dozen for "large" crawfish. The price increased in 1956 to $0.30 per dozen for "small" and $0.50 per dozen for "large". The major buyer in 1957 ceased purchasing by size and number, and bought all crawfish at $0.25 per pound.

Detailed statistics for the crawfish fishery from 1947 to 1956 are given in Table 3. The number of crawfish landed annually for the 10-year period ranged from 12,201 to 24,163 dozen. The mean annual income of the fishermen varied from $301 to $690. The total annual value of the fishery to the fishermen ranged from $4,514 to $8,940.

Table 2. Value of the early Oregon crawfish fishery.

Year	Pounds landed	Price per pound	Total value
1896	60,844	$0.05	$ 3,042
1898	132,665	0.075	9,950
1899	138,248	0.10	13,825
1908	42,360	0.035	1,483
1909	45,720	0.035	1,600

The pass books showed that four fishermen were outstanding (Table 4). In the 10 years from 1947 to 1956, two caught 76,530 dozen, or 42% of the total, and four accounted for 55% of the reported catch.

Table 3. Oregon commercial crawfish fishery catch statistics and economic value, 1947-56.

Year	Pass books issued	Pass books returned	Total dozens landed	Total value	Mean annual income per fisherman
1947	15	15	21,089	$7,803	$520
1948	18	18	16,914	6,257	348
1949	14	14	21,500	7,955	568
1950	19	19	17,925	6,633	349
1951	19	19	17,781	6,579	346
1952	14	14	24,163	8,940	639
1953	21	18	21,167	7,831	435
1954	15	10	18,638	6,896	690
1955	24	13	13,084	4,841	372
1956	25	15	12,201	4,514	301

BIOLOGY OF *P. l. leniusculus*

Catch in Relation to Season and Temperature

The commercial landings were plotted by month for the 10-year period from 1947 to 1956. During these years the commercial season extended through the winter but was closed in late spring when the young hatch (see section on Laws and Regulations). Approximately 90% of the catch was taken from June to October (Figure 6). The low catch in winter, despite the open season, can be attributed to the decrease in feeding by crawfish of both sexes as water temperatures decrease. Miller (1960) found that catch per unit of effort decreased to nearly zero at 3.2° C. Fishing conditions also are poor during the winter because rivers are in flood stage or partly frozen over. The catch is low in spring as the males moult and the females bearing eggs and young do not enter the traps. The females usually moult about early June after the young hatch and drop off. The small landings in May, when the season was closed, were recorded in passbooks by fishermen ignorant of the law.

Table 4. Total catch and income of the four leading fishermen from the crawfish fishery, 1947-56.

Fisherman	Total dozens landed	Total value of catch	Mean annual income
1	43,756	$16,116	$1,612
2	32,974	12,134	1,213
3	14,567	5,390	539
4	10,862	4,019	402

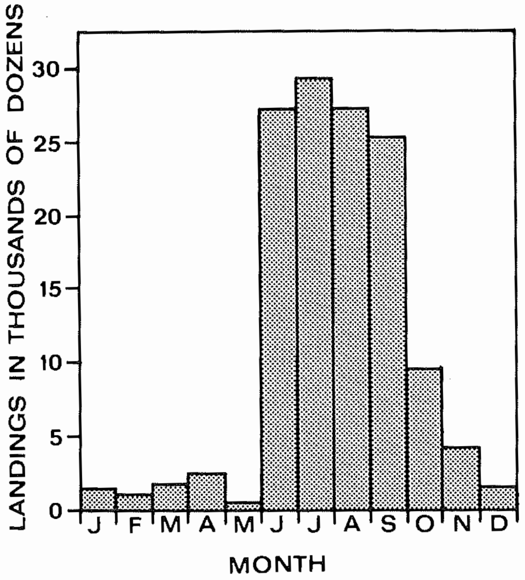

Figure 6. Commercial landings of crawfish in Oregon by month, 1947-56.

Size and Sex Variation by Season

Sexual dimorphism is evident in *Pacifastacus;* males are larger and bear more massive chelipeds. In Deep River, Washington, male *P. l. leniusculus* were dominant in the catch during winter, spring, and early summer (June) and the females in middle to late summer and fall (Miller, 1960). Additional evidence to confirm the dominance of males in the catch during the spring was present in a sample of the commercial landing from the Tualatin River on April 1, 1958. In the sample of 350 crawfish, 332 (92%) were males.

If the larger males are dominant in the catch by seasons, the percentage of "large" crawfish in the commercial catch should be greatest from December to July and smallest from July to December. The catch of the leading fisherman (43,756 dozen landed in 1947-56) was separated into "large" and "small" sizes and plotted by month. As was expected the "large" category contributed over 60% of the catch by month from December to July, but less than 60% from July to December (Figure 7). This preponderance of "large" crawfish would seem to confirm the dominance of males in the catch during the winter, spring, and early summer.

Figure 7. Percentage by month of "large" crawfish in a leading fisherman's catch, 1947-56.

Size Selectivity and Length-Frequency Distribution of Catch

Traps are highly selective as to the size of crawfish caught. Miller (1960) found that in the trap catch in Deep River, specimens of *P. l. leniusculus* smaller than 60 mm (approximate minimum size of maturity) made up less than 1% of the catch. In an area fished repeatedly, the adult crawfish stop entering the traps and the catch rate declines to nearly zero even though the adults remain abundant in the vicinity of the traps. The small juveniles at this time do not enter the traps even though they are not prevented from entering by adults outside the traps. Observations made by the senior author on juveniles hatched at the Squaw Creek Laboratory, Oregon State University, indicate that the young differ in food habits from the adults and prefer algal and fine detrital material. Small crawfish that are caught in traps are returned to the water by the commercial fishermen since the buyers find that they are uneconomical to handle for human consumption. Difference in diet is probably the primary reason for small crawfish not entering traps.

Our investigation did not entail a major sampling of the commercial catch. However, the length-frequency distribution of the 205 "small" and 145 "large" crawfish from the commercial landings of the Tualatin River, April 1, 1958 (Figure 8), indicate that the minimum size of crawfish sold for human consumption is 90 mm (or approximately 3½ inches). Crawfish between 60 and 90 mm long which enter the traps are discarded. In this April sample, the mode of the "small" crawfish was at 104 mm and that of the "large" was at 119 mm.

Maturity

Maturity, age, and growth are pertinent to the management of a fishery. Andrews (1904) in a study of *P. l. leniusculus* reared eight juveniles from eggs hatched in late April or early May to lengths of 30 to 63 mm (average 54 mm) in 22 weeks. This rate of growth would indicate that only a very small percentage of the young-of-the-year crawfish reach the minimum size of maturity by the breeding season in October; that most females are 17 months old at the time of first breeding; and that age-group 1 is discarded by the food fishery as being too small for human consumption.

Weight-Length Relationship

The weight-length relationship of *P. l. leniusculus* was determined from 85 male specimens, 105 to 140 mm body length, with chelipeds which appeared normal. The specimens were from the sample of "large" crawfish from the Tualatin River taken on April 1, 1958 (Figure 9). The weights were not taken from the "small" crawfish because they were cooked at the time of sampling. The regression of weight on length of male crawfish, calculated by the least-squares method, was Log Weight = 3.298 Log Length —4.993.

The weights and lengths of a sample of 64 male *P. l. leniusculus*, 79 to 128 mm long, taken on April 12, 1958 from Deep River, Washington, agreed well with the calculated curve for the large males from the Tualatin River (Figure 9). This close agreement suggests that the weight-length relationship of *P. l. leniusculus* does not vary noticeably between populations from widely separated areas. The weight-length relation of male *P. l. leniusculus* was compared with those of *P. l. trowbridgii* and *P. l. klamathensis* by Miller (1960); the comparison showed that *P. l. leniusculus* was lighter.

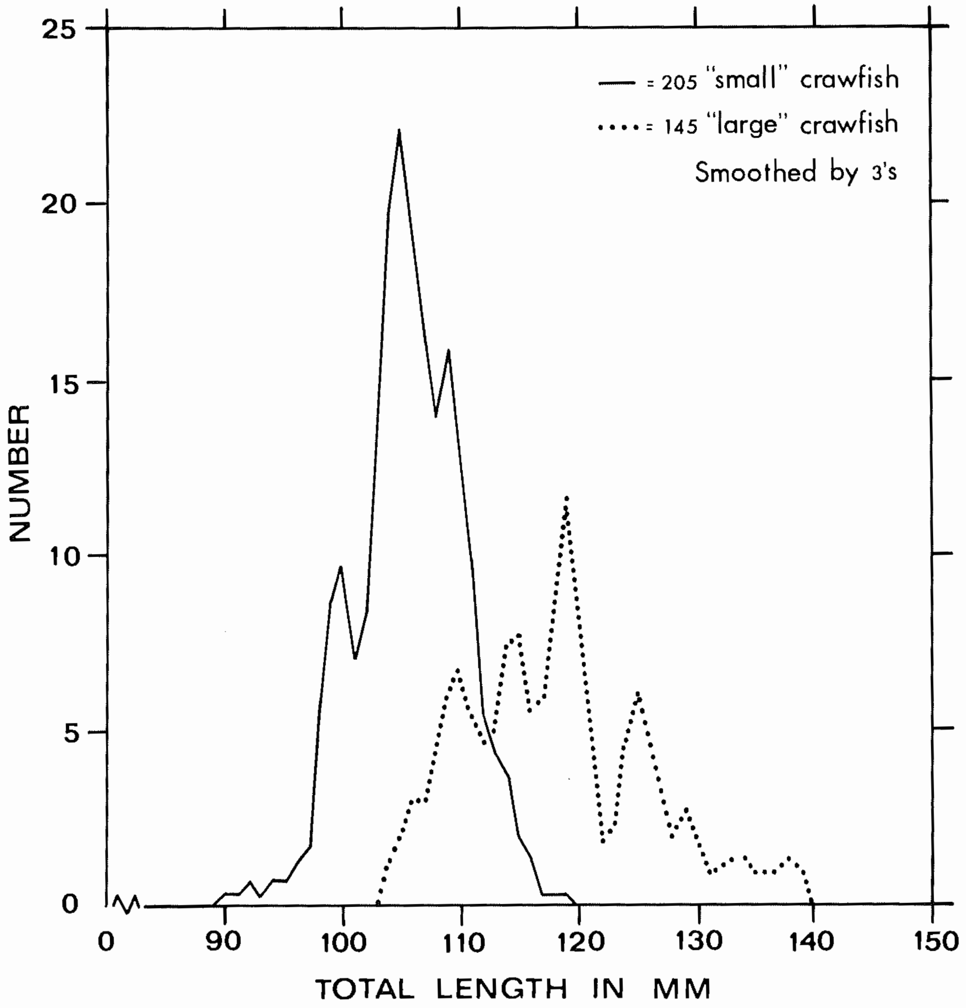

Figure 8. Length-frequency distribution of "small" and "large" crawfish, *P. l. leniusculus*, from the Tualatin River commercial catch, April 1958.

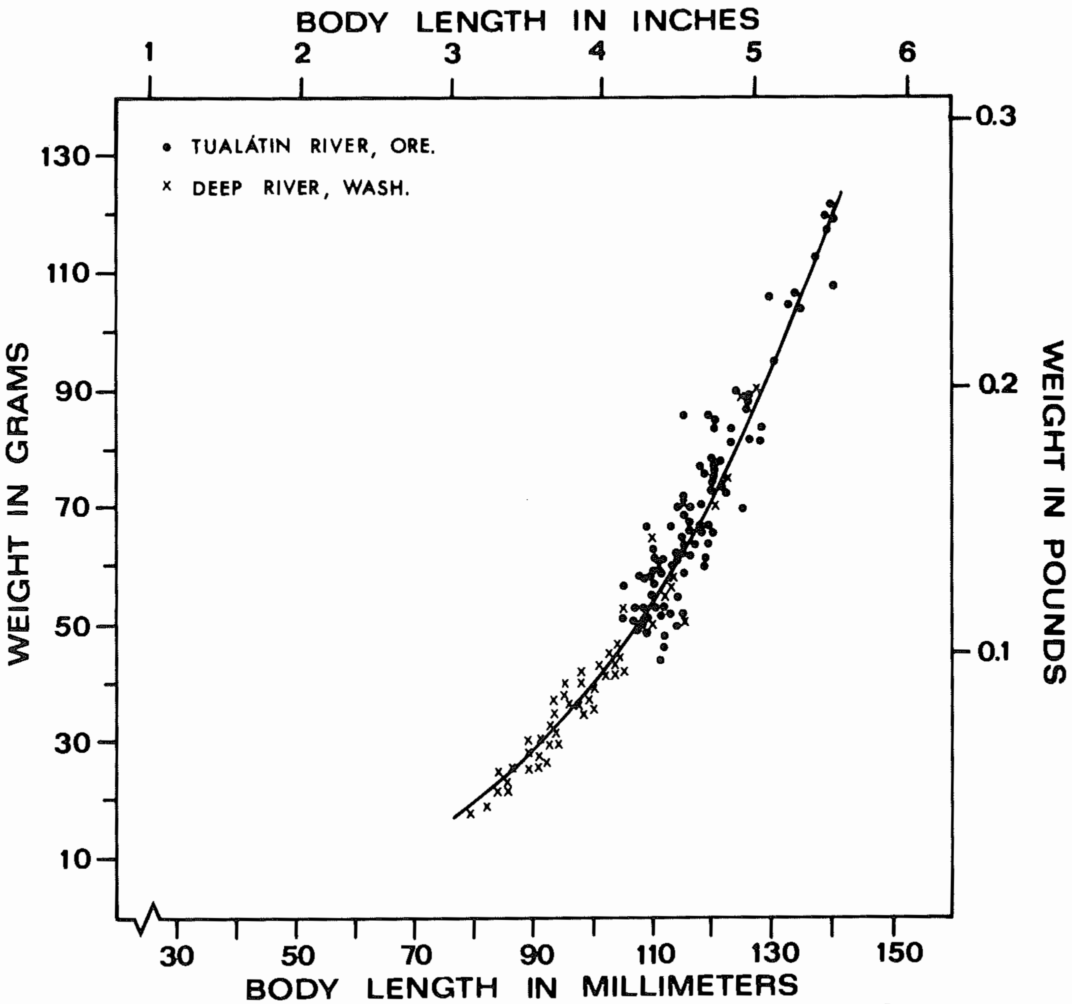

Figure 9. The weight-length relationship of male crawfish, *P. 1. leniusculus*, April 1958.

Summary

1. Crawfish have been fished commercially in Oregon since 1893.
2. The maximum annual catch was 176,000 pounds in 1930; in 1941-56 the annual catch was about 40,000 pounds.
3. The commercial fishery is conducted primarily in the Columbia River and its sloughs from Portland to Astoria, and in the lower Willamette River and its tributaries.
4. A positive correlation between the number of licenses issued and the poundage landed each year enabled us to estimate missing statistics.
5. The catch has fluctuated with changing economic conditions, changing consumer food preferences, and the number of fishermen.
6. The mean annual income of the fishermen in 1947-56 ranged from $301 to $690.
7. Four fishermen landed 55% of the reported catch from 1947-56.
8. The commercial catch comprises primarily *Pacifastacus leniusculus leniusculus*, with smaller numbers of *P. l.*

trowbridgii and intergrades between the two subspecies.

9. The catch is seasonal; 90% of the landings are made from June through October.
10. Large male crawfish dominate the catch during the winter and spring.
11. Most female crawfish do not bear eggs until they are 17 months old.
12. The fishermen fishing for human consumption release crawfish less than 90 mm.
13. The regression of weight on length of male *P. l. leniusculus* is described by the equation Log Weight = 3.298 Log Length —4.993.

Acknowledgments

We wish to thank former and present members of the Fish Commission of Oregon who assisted or gave guidance to this study: G. Y. Harry, Jr., R. W. Schoning, E. J. Wagner, R. J. Ayers, L. D. Marriage, H. Smith, and C. D. Snow. All members of the crawfish industry cooperated and we thank them for their help. H. H. Hobbs, Jr., U. S. National Museum, and J. W. Gehringer, W. W. Anderson, and J. Thompson, U. S. Fish and Wildlife Service, reviewed the manuscript and made suggestions. The illustrations are by Grady W. Reinert.

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THE FALL IMMIGRATION OF JUVENILE COHO SALMON INTO A SMALL TRIBUTARY

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Abstract

The Fish Commission operated an upstream-downstream trap on Spring Creek, Wilson River from 1948 through 1958. Each fall an upstream migration of relatively large juvenile coho occurred. An average of 62.6% of the fall upstream migrants survived and returned downstream in the spring as smolts. The fall upstream migrants which survived to the smolt stage averaged 14 mm longer at emigration than smolts which had spent their entire lives in Spring Creek. The recapture rate of mature fish that had been fall upstream-migrant juveniles was 0.3% while the recapture rate from fish native to the stream was 0.8%. I theorized that (1) the juveniles had spent the summer rearing in the Wilson River where they had grown rapidly; (2) the juveniles entered Spring Creek in the fall to escape the high, turbulent water conditions of the main river; and (3) adults, that had been immigrants, received a permanent imprint of their natal stream and had returned there rather than to Spring Creek. Observations from two other river systems are reported to substantiate the behavior pattern and suggest that other species may have similar habits. Changes in habitat management and research concepts that will be necessary, if this behavior pattern is widespread, are discussed.

Introduction

A fall movement of fingerling coho (*Oncorhynchus kisutch* Walbaum) into small tributaries has never been described. In this report, information collected at a weir on Spring Creek, tributary of the Wilson River on the northern Oregon coast, identifies this behavior pattern.

The study stream is 472 meters (1,550 feet) long and has an annual flow range of 20 to 170 liters per second (0.75 to 6 cfs).

Methods

The Fish Commission of Oregon operated Spring Creek weir from 1948 through 1958 to study movements of coho.

The weir, with upstream- and downstream-migrant traps, was located 105 meters (340 feet) above the mouth. Both traps were operated throughout each year, except that the upstream-migrant trap was not functional during summers of exceptionally low flow.

Beginning with the 1948 brood, migrants were measured and identified with different fin marks depending upon the direction and the time of movement. Movement of juveniles in either direction was tabulated by weekly interval and reported in Fish Commission Progress Reports. These data were extracted from the progress reports for use in this paper.

Results

Upstream Movement of Juveniles

The number of juvenile upstream migrants that were trapped at Spring Creek weir each year averaged 232 and ranged from 90 to 374 (Table 1).

The immigration period extended from May to March but 93% of the movement occurred in October, November and December. The timing and probably the magnitude of immigrations of juveniles into Spring Creek were affected by a cascade at the mouth of the creek that was impassable at lower flows. In 1952, for example, the stream flow remained too low for juvenile movement or trap operation until November 14. Consequently, the immigration was the lowest recorded during the study and also was one of the latest. Similar circumstances prevailed in 1948 and 1956.

Survival and Growth in Spring Creek

The survival from immigration until emigration the next spring averaged 62.6% and ranged from 45.7 to 91.0% (Table 2). Part of the mortality could have been caused by handling and fin clipping (anal-pectoral combinations were used most frequently).

The mean length of the fingerlings increased 11.2 mm during the period of residence. The average length at immigration was 89.4 mm with a range from 55 to 146 mm, and the average length at emigration was 100.6 mm with a range from 72 to 138 mm.

Downstream Migration from Spring Creek

From 1951 through 1958, 1,451 immigrants and 10,906 indigenous juveniles survived to emigrate from the creek as smolts.

Table 1. Immigration of juvenile coho through Spring Creek weir, 1948-58

Migration Season	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total	Average Length (mm)	Length Range (mm)
1948-49	......	......	......	......	......	......	38	39	12	2	......	91	92.6	63–140
1949-50	1	......	......	......	......	57	159	22	1	......	1	241	90.7	73–113
1950-51	......	......	3	20	12	104	188	1	2	3	......	333	85.9	55–112
1951-52	1	10	15	11	......	88	68	1	......	......	......	194	85.6	59–107
1952-53	......	......	......	......	......	......	5	79	2	3	1	90	95.6	88–123
1953-54	......	......	......	1	......	17	129	53	1	......	......	201	90.6	....
1954-55	1	......	......	1	23	34	298	12	......	......	......	369	91.9	....
1955-56	......	......	......	......	......	60	188	17	......	......	......	265	91.4	74–146
1956-57	......	......	......	......	......	......	42	118	2	......	......	162	86.3	67–114
1957-58	......	......	......	......	......	16	255	72	29	2	......	374	88.5	55–116
Total	3	10	18	33	35	376	1,370	414	49	10	2	2,320		
Per Cent	0.1	0.4	0.8	1.4	1.5	16.2	59.1	17.8	2.1	0.4	0.1			
Yearly Average Number												232		
Grand Average Length (mm)													89.4	
Maximum Range (mm)														55–146

Table 2. Survival and average size of smolts resulting from the fall immigration compared to average size of indigenous smolts from Spring Creek

	Smolts resulting from immigrants			Smolts from indigenous population	
Year	No.	Per cent survival	Average length (mm)	No.	Average length (mm)
1949	......	......	......	274①	92.0
1950	......	......	......	970①	85.0
1951	260	79.3	99.3	1,214	83.2
1952	119	63.3	101.1	1,946	83.0
1953	78	90.7	107.9	1,209	80.1
1954	183	91.0	94.6	1,887	77.2
1955	263	71.3	102.1	1,633	90.9
1956	184	69.7	102.6	816	92.5
1957	69	45.7	101.9	842	92.7
1958	295	78.8	100.4	1,359	98.8
Mean		62.6	100.6		86.4

① Upstream migrants not differentially marked in 1948 and 1949.

Thus, immigrants represented 12% of the total smolt yield from Spring Creek during that period. The smolts from the immigrants averaged 14.2 mm longer than all indigenous smolts from Spring Creek (Table 2).

The average size of the indigenous smolts from 1951-55 is probably a better base for comparison. Prior to 1951, the smolts could not be segregated, and after 1955, indigenous smolts were from a spawning population deliberately limited to five females per year. During the 1951-55 period, smolts from immigrants averaged 100.1 mm while smolts from the indigenous population averaged 82.8 mm. Thus the immigrant smolts averaged 17.3 mm longer.

The timing of the downstream movement of coho which had been immigrants the previous fall was very similar to the movement of yearlings which had spent their entire lives in Spring Creek (Figure 1). The major smolt emigration of each group was March through May with a peak in April.

Adult Returns

Of 1,056 (1,087 minus trapping mortality) fall immigrant smolts, from 1951 through 1956, that were released below the weir, three returnees were observed at Spring Creek weir for a recapture rate of 0.3%.

During the same period, of 8,407 (8,705 minus trapping mortality) smolts native to the stream, 69 were trapped at the weir as adults for a recovery rate of 0.8%.

Discussion

The fall immigration pattern observed in this study has raised certain questions. To gain a better understanding of this behavior we need to know (1) where these immigrants came from, (2) why they entered Spring Creek, and (3) why fewer than expected returned to Spring Creek as adults.

Origin of Fall Immigrants

The two possible sources of fall immigrants to Spring Creek weir are direct translocation from lower Spring Creek and other tributaries of Wilson River, or indirect translocation from other tributaries but with a period of residence in the main Wilson River.

Direct translocation is unlikely because these fish were larger than juveniles in typical Oregon coastal coho streams. Chapman (1962) observed average lengths of 64 and 66 mm in November 1961 and 1962 in Deer Creek of the Alsea River system. Fish Commission studies of populations of juveniles in six coastal streams in 1963 and 1964 indicate average lengths ranging from 57 to 75 mm in late summer representing lengths of 65 to 83 mm by November. Thus, the fall immigrants, averaging 89.4 mm, were anywhere from 6 to 25 mm greater in average length than any other coastal populations sampled.

Also, the literature on juvenile coho behavior provides no information on intertributary movement in the fall. This is not surprising since the fish are approaching a period of winter quiescence. Mason (1966) found that juvenile coho remained quiet in the winter, lived near the bottom of pools and rarely exhibited aggression.

Further, one would not expect juveniles to leave one area of suitable habitat in search of another in the fall.

Indirect translocation offers a better explanation of the phenomenon. Downstream movement of young-of-the-year in the spring is a regular occurrence in coho streams. An average of 2,328 per year were marked and released below Spring Creek weir. These fish, along with nomads from all the other tributaries, end up in the main Wilson River. The main stem of the Wilson River would not be considered normal coho habitat because of its size (minimum flow approximately 20 cfs), summer temperature (73° F maximum) (Gaumer and Skeesick, 1969) and lack of suitable spawning gravel. However, it appears that some of these nomads were able to take up summer residence in the river. The large average size of the fall immigrants indicates that they

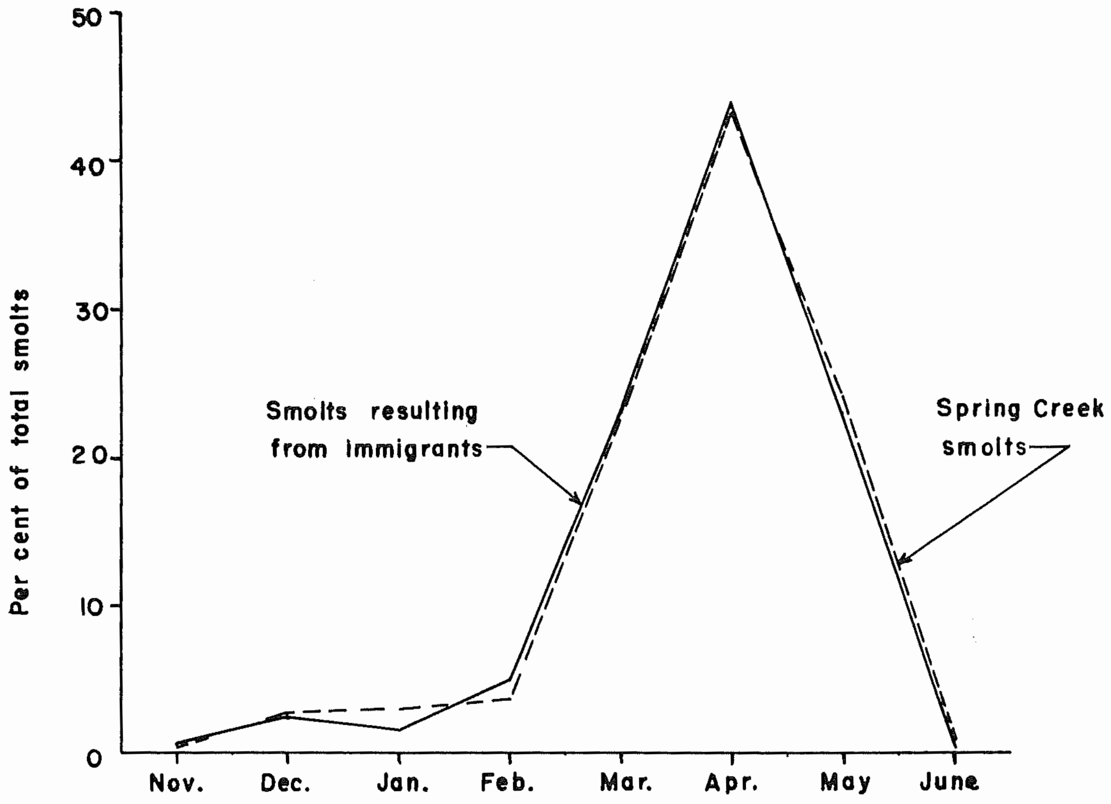

Figure 1. Timing of smolt emigration for fall immigrants and the indigenous population, 1949-58.

grew well prior to their capture at Spring Creek weir. In 1964, 10 young-of-the-year marked nomads from Spring Creek returned upstream in October and November at an average length of 90.7 mm, supporting the hypothesis that the rearing occurs in the main river.

Since the territorial behavior pattern described by Chapman (1962) breaks down in winter, there would be nothing preventing immigrants from moving in and sharing the habitat with the indigenous population.

Fall and winter upstream migrations of juvenile salmonids have also been documented in a tributary of Siuslaw Bay and a pseudo-tributary of Elk River. In 1964, I observed immigrating juvenile coho salmon at a weir on Munsel Creek, tributary to Siuslaw Bay, at times when the Siuslaw River became high and turbid. Floods allowed most of the immigrants to pass the weir, but 21 were marked and released above the weir. In the ensuing downstream migration in 1965, 18 marked and 171 unmarked coho were trapped. From these data an estimate of 220 upstream migrants with an 86% survival was made. No native coho were above the weir because there is no spawning area in the watershed. The mean length of the emigrants was 143 mm, which was 53 mm longer than smolts which had reared entirely in Spring Creek.

In late October 1968, juvenile steelhead and coho began entering the adult trap at the new Elk River Hatchery. In 3 weeks, 450 trout ranging from 60 to 200 mm and nine coho averaging 88.5 mm had entered the trap (Paul Reimers, personal communication, October 1968).

Cause of Immigration

The most likely explanation for the immigration is that the juvenile coho moved into the small streams to escape the high-flow, turbid-water environment prevalent in the main rivers in the winter. Spring Creek and Munsel Creek remain clear all winter while the hatchery facilities filter out most of the turbidity of Elk River water. Since coho rely on sight for feeding and orientation, it appears that the small, clear-water streams offer the better winter quarters.

Returns of Adults

Although the small number of adults returning to Spring Creek weir precludes definite conclusions, the differential return rate of adults from the two groups (0.3% for fall immigrants vs. 0.8% for Spring Creek native stocks) leads one to suspect a different behavior pattern by the adults which had been upstream migrants as juveniles. Studies with coho (Wallis, 1968) have shown that larger smolts typically have higher rates of survival to adulthood. Thus, a comparatively higher return rate would have been expected from the juvenile coho which had immigrated into Spring Creek because they were larger when they smolted. A logical explanation for these fish not having a higher return rate is that the juvenile fish had received a permanent imprint for their natal streams prior to the time they entered Spring Creek. If this was the case, only the ones for which Spring Creek was the natal stream could have been expected back as adults. The others would have homed to their own natal streams.

Importance

This fall immigration pattern suggests that there are gaps in our knowledge of the ecology of coho and weakness in our habitat management programs. If this behavior pattern is common to other streams and other species of salmonids, many concepts regarding fish passage and habitat protection must be re-evaluated. For example, we presently base fish passage criteria for road culverts, stream channeling and other activities on stream use by adult fish. We may need to require that any stream change be compatible with juvenile fish movement. Also, even though a stream as large as the Wilson River or as small as Munsel Creek does not have a spawning population, we may need to protect it because of the habitat that it offers for juveniles during part of the year.

Our current criteria for judging a stream's importance for coho, based upon availability of spawning gravel and rearing area, will need to be broadened. Such factors as contribution of nomads to downstream-rearing areas, availability of downstream-rearing areas and accessibility to juveniles seeking a winter haven will need to be added to the criteria mentioned above to formulate a broader base for establishing the values of streams.

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BEHAVIOR TROUGHS WITH SIMULATED REDDS TO STUDY RECENTLY EMERGED SALMON FRY

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Introduction

Various stream aquaria have been designed to study the social behavior of juvenile salmonids (Lindroth, 1954; Chapman, 1962; Hartman, 1965; Mason and Chapman, 1965; Reimers, 1968). Most of these aquaria either lacked provisions or had only rudimentary systems for incubating experimental eggs and alevins in gravel and allowing natural emergence of fry. Because the fate of juvenile fall chinook salmon, *Oncorhynchus tshawytscha* (Walbaum), in relation to residence or downstream movement is apparently determined within the first few days following emergence (Reimers, unpublished), systems possessing both simulated redds and rearing area were developed to study this behavior.

Two systems were designed: (1) Observation troughs to examine the emergence and subsequent fate of fry in detail, and (2) emergence boxes to allow fish to emerge unobserved and enter a trap for relocation into various experimental situations.

Water entered both systems at the upstream end over a forebay panel with most of the water passing downstream and out an overflow notch at the lower end. Some water drained through the gravel and out a hole below the simulated redd.

Observation Troughs

The observation troughs were 244 cm long, 61 cm wide, and 61 cm deep (Figure 1). They were constructed with exterior plywood 1.9 cm thick. All seams were re-

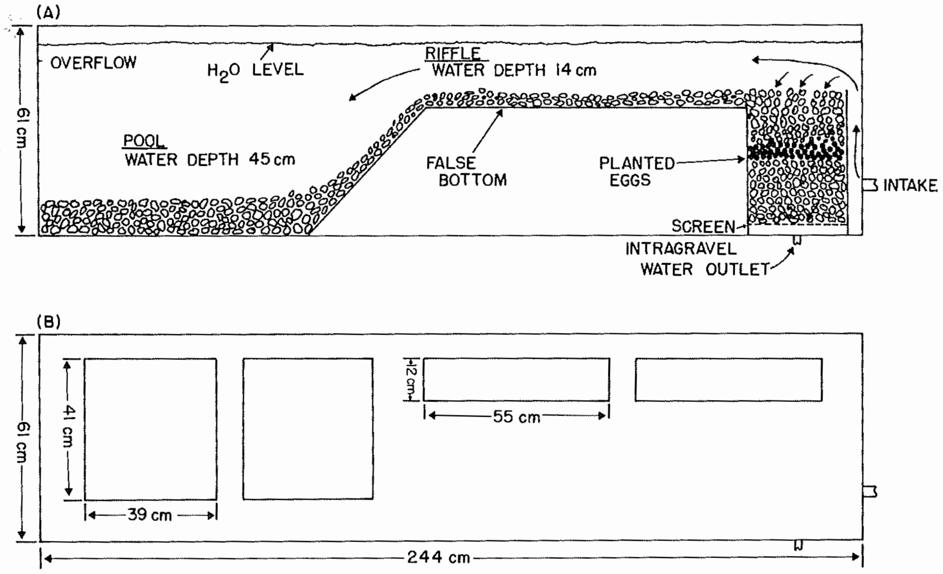

Figure 1. Side view of the observation troughs showing (A) a cutaway of the gravel locations, primary water currents, and location of planted eggs, and (B) location of viewing windows.

inforced with boards 5 cm by 5 cm. The troughs were put together with screws and water resistant glue. Reinforcing binders were also placed around the troughs at three places. Each system was divided into a riffle and a pool that were visible through plexiglass windows large enough to provide nearly complete vision of fish activity in the trough. The windows were 0.7 cm thick and inset, glued, and screwed to the inside of the trough.

Water entered each trough through a 3.2 cm polyethylene pipe from a headbox in the natural stream. A forebay panel extending to the level of the riffle directed the flow upward. The drain hole below the simulated redd was 1.3 cm in diameter and the overflow notch at the lower end of the trough was 10 cm by 10 cm. The forward 30 cm of the riffle formed the simulated redd. Gravel in the simulated redd extended to the bottom of the trough and was retained by a downstream wall. The bottom of the simulated redd was raised 5 cm and screened to prevent the alevins from going down the drain. The rear part of the riffle consisted of gravel overlain on a false bottom that graded into the pool. The false bottom was constructed of 1.9 cm thick plywood.

Gravel used in the troughs was mostly in the range of 1 to 4 cm. Fine material was excluded by screening and washing. Gravel was about 5 cm deep on the false bottom of the riffle and about 11 cm deep in the pool.

Water depth was 14 cm on the riffle and 45 cm in the pool. The intragravel flow through the simulated redd was maintained at about 20 liters/minute. The overflow discharge was maintained at about 110 liters/minute. Based on the flow measurements, average velocity over the riffle was about 2.2 cm/sec. Food entered the systems in the form of natural drift in the water supply.

A trap was installed below the outfall of the overflow notch to catch fish moving downstream. Screens could be installed in the overflow notch to retain experimental populations in the troughs.

The systems were set on stands in pairs so that the windows faced together. The intermediate area was framed and covered with black polyethylene sheeting to provide a darkened observation area (Figure 2).

The primary advantages of these systems are:

(1) All experimental fish hatch and reside in the gravel environment and then emerge directly into the observation area.

(2) Alteration and measurement of redd quality is possible, i.e., gravel composition, intragravel flow, depth of planting, oxygen, and metabolite levels.

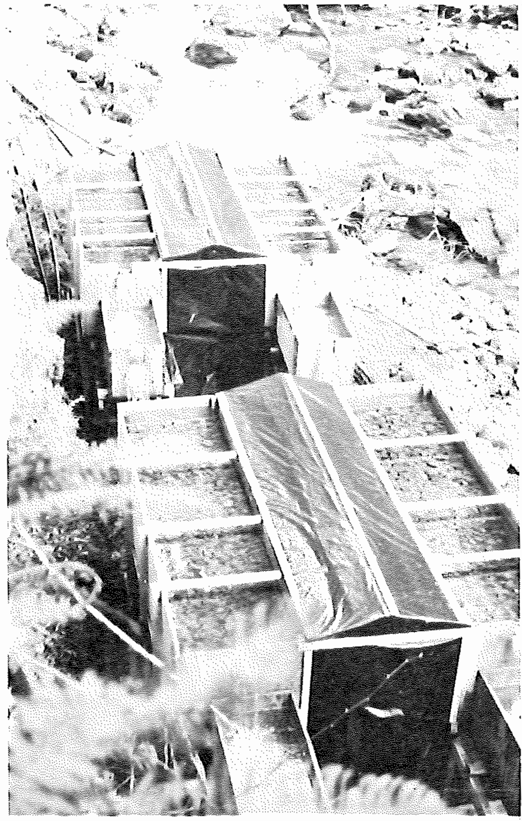

Figure 2. Observation troughs set up in pairs with a central observation area.

(3) Various experimental situations important in understanding behavioral ecology of salmonids can be set up under simulated natural conditions.

Emergence Boxes

The emergence boxes were constructed of the same material as the observation troughs, were much smaller, and consisted only of the simulated redd (Figure 3). The boxes were 61 cm deep, 40 cm long, and 44 cm wide. Water was supplied from a headbox through a 2.5 cm polyethylene pipe. The overflow notch was 7 cm by 7 cm and the drain was 1.3 cm in diameter. Water depth over the simulated redd was maintained at about 7 cm. The intragravel flow was 15 liters/minute, and the overflow was 30 liters/minute. Traps were constructed at the outfall of the overflow notch.

Discussion

Preliminary experiments with the observation troughs have been rewarding. Initial studies were run on the effect of moonlight on the diel emergence pattern and residence. Actual emergence and subsequent fate of fall chinook salmon fry have been observed. Up to 75 recently emerged fish resided in the systems during the experiments. Several experiments were also run on the effect of resident fish on the fate of emerging fry.

The emergence boxes have also worked well. Preliminary experiments were run on the effect of depth of planting and gravel composition on the survival and emergence pattern. Nearly all fish moved immediately downstream into the trap. Measurements were made on the change in characteristics of the fry throughout the emergence period. Trapped fish were relocated into other troughs for density experiments.

Results of the various experiments will be reported as the studies are completed.

Although the systems have been useful in studying recently emerged fry, the small space and limited flow have allowed for

Figure 3. Emergence boxes and traps (without water).

continued residence of only a few larger fish. Also, because these systems have utilized natural stream water acquired through a headbox, they were subject to clogging and water stoppage during freshets. Regular inspection of the water system was necessary. However, if water stoppage occurred while the eggs were in the gravel, drainage prevented the eggs from suffocating.

These systems are small, portable, and relatively inexpensive depending on the quality of the materials used. The useful life of the systems could certainly be extended by coating with fiberglass or paint. However, our earlier systems, without this protection, have been in use for 5 years and are still functioning.

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A HERMAPHRODITIC SOFT-SHELL CLAM, *Mya arenaria*, FROM UMPQUA BAY, OREGON

W. N. Shaw①

Introduction

A hermaphroditic soft-shell clam, *Mya arenaria*, was found in a sample of 36 collected from Umpqua Bay, Oregon, on July 13, 1965. The specimen is exceptional because sexes are nearly always separate in this species. The only known previous report of hermaphroditism in *Mya* is by Coe and Turner (1938), who found three in over 1,000 clams examined from New Haven, Connecticut. Fitch (1953) stated that the sexes of the soft-shell clam are strictly separate. No hermaphrodites were found among more than 800 clams collected from the Tred Avon River, Chesapeake Bay, Maryland (Shaw, 1965), more than 700 from the Patuxent River, Maryland (H. T. Pfitzenmeyer, personal communication), or more than 1,400 collected in various areas from Maine to Massachusetts (Ropes and Stickney, 1965; and Ropes, 1968).

According to Foster (1946), soft-shell clams were accidentally introduced to California and Washington around 1870 in a shipment of eastern oysters, *Crassostrea virginica*. They are now found from California to Alaska, but in recent years have been of commercial importance only in Oregon (Amos, 1966).

Umpqua Bay is comparatively long and narrow (Marriage, 1958). Clams are found in eight areas between Winchester Bay and the highway bridge across Bolon Island, but the largest concentration is in Middleground on the western bank. It is not uncommon to find clams that measure 6 inches in shell length.

When examined histologically, the 36 Umpqua Bay clams were found to consist of 1 hermaphrodite, 19 males, and 16 females. Most of the clams were approaching ripeness and some contained mature ova or sperm, but only two were considered fully ripe. No spawning was evident.

Female Qualities of Alveolus

The hermaphrodite was of the mixed type (Coe and Turner, 1938)—each alveolus contained male and female sex products. Coe and Turner (1938) and Ropes (1968) reported on examples of bilateral hermaphroditism, which is characterized by male and female sex cells occurring in separate alveoli of the same gonad. In comparison to other female clams in the Umpqua Bay sample, the hermaphrodite was far less mature. It contained a few ova in each alveolus, and most of these were in the early stages of development (Figure 1). Missing were the typical female cellular inclusions

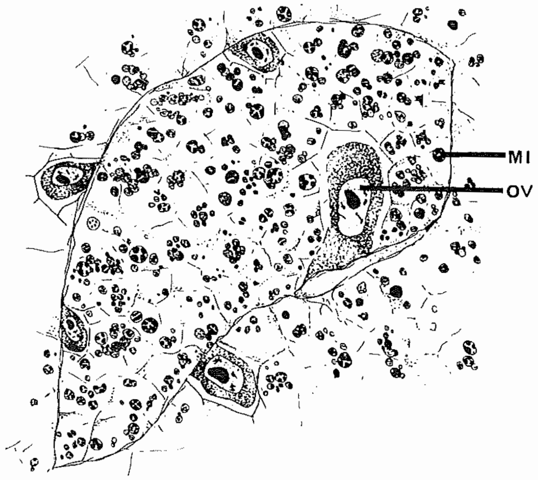

Figure 1. Drawing of a section of the gonad from a hermaphroditic soft-shell clam, Umpqua Bay, Oregon. Developing ova (OV) and male inclusion (MI) are in the same alveolus.

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which, according to Coe and Turner (1938), are small globules of lipoid nature and larger globules of albuminous composition. The inclusions in the 16 female Umpqua Bay clams were similar to those I found (Figure 2) in samples collected from Chesapeake Bay (Shaw, 1962).

Male Qualities of Alveolus

In place of the female inclusions were the smaller, typical male inclusions, many of which were multinucleated (Figure 1). Similar inclusions have been associated with male clams (Coe and Turner, 1938; Shaw, 1965; Ropes and Stickney, 1965; and Pfitzenmeyer, 1965) and were found in all the male clams from Umpqua Bay. Coe and Turner (1938) observed some multinucleated inclusions forming spermatids which later transformed into spermatazoa. The formation of spermatids was not observed, however, in the hermaphrodite.

No active spermatogenesis was observed in the alveoli of the hermaphrodite although all the other male clams in the collection were in the active phase of development. Perhaps the hermaphroditic condition in some way inhibited gonad development.

Relation to Sex Reversal

Coe (1943) states, "Even in species which are otherwise strictly of separate sexes, there may be an occasional individual with functional hermaphroditism." In this category are surf clams, *Spisula solidissima* (Ropes, 1968); quahogs, *Mercenaria mercenaria* (Loosanoff, 1936 and 1937); sea scallops, *Placopecten magellanicus* (Merrill and Burch, 1960); and ocean quahogs, *Arctica islandica* (Loosanoff, 1953). Unlike the eastern oyster which can change sex after spawning (Loosanoff, 1942; Galtsoff, 1961 and 1964), sex reversal has not been observed in the soft-shell clam or other species named above—a fact that possibly explains the rarity of hermaphrodites.

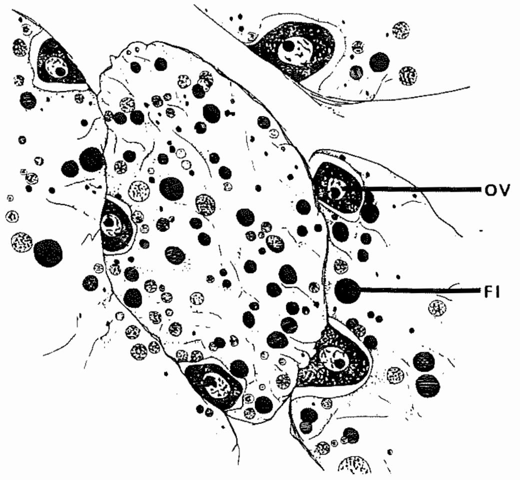

Figure 2. Drawing of a section of the gonad from a female soft-shell clam, Tred Avon River, Maryland, taken at approximately the same stage as the clam in Figure 1. Compare the developing ova (OV) and typical female inclusions (FI) with those in the hermaphrodite.

Acknowledgments

I wish to thank Mr. Dale Snow, Fish Commission of Oregon, who collected the clams and Mr. Robert Tolley who made the drawings for the two figures.

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TWO ACCOUNTS OF THE NORTHERN OCTOPUS, *Octopus doefleini*, BITING SCUBA DIVERS

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Introduction

The secretions of the posterior salivary glands of cephalopods contain a toxin called cephalotoxin which is used by the animal to kill its prey (Halstead, 1965). The northern octopus (*Octopus doefleini* Wulker) has been reported to have bitten a human on only one previous occasion where the animal was positively identified (Halstead, 1949). This report documents two additional occasions where the northern octopus has bitten divers.

Four other octopi identified as *O. rubescens, O. Fitichi* (Berry and Halstead, 1954), *O. maculosus* (Halstead, 1965), and *O. joubini* (Wittich, 1968), and also two of unknown species (Berry and Halstead, 1954), are reported to have bitten people. In the case of the *O. maculosus* bite, the victim died. The bites of these octopi resulted in profuse bleeding, swelling of the injured part, and pain.

Discussion

On June 1, 1969, David Bonkowski, working as a diver for the Undersea Gardens at Newport, Oregon, was bitten on the right wrist while handling a northern octopus. The Undersea Gardens is a huge aquarium built below sea level in Yaquina Bay, and periodically SCUBA divers go down and display animals for the viewing public. The procedure for displaying the octopus is as follows: The diver goes to the den of the octopus and reaches in, irritating the animal until it leaves its lair. The diver then grabs the octopus by the mantle and guides it to the viewing window for display (Figure 1). Frequently the diver will reach under the octopus in order to better display the suction discs on the tentacles. On the date under discussion, the diver was bitten on the right wrist by a 4- to 5-foot octopus① that had been recently received from the wild. The bite removed a circular section of skin and flesh approxi-


Figure 1. SCUBA diver holding octopus for public display.

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① Sizes are estimated for total width from tip of tentacle to tip of tentacle.

mately 1.5 cm in diameter. The wound bled profusely and the man was rushed to the Newport hospital where he was given a precautionary injection of ACTH. The wound resulted in virtually no pain or reaction other than a mottling of the skin on the back of the bitten hand, possibly a capillary reaction. This reaction lasted for only a brief period. The wound had not completely healed after 20 days. However, none of the reactions noted by other writers were reported by the victim.

On another occasion in 1963, a northern octopus bit a diver in Hood Canal, Washington. The incident related by Thomas Gaumer, Fish Commission of Oregon biologist, occurred as follows: Roland Montagne, and his diving companion, George Miller, were trying to capture a 12- to 14-foot octopus. While trying to remove the animal from its den, Mr. Miller was severely bitten between the thumb and the forefinger. Profuse bleeding occurred and he was immediately taken to the nearest town for medical treatment, but no doctor was available and no medication was taken. No painful reaction was experienced and healing was considered normal for such a wound.①

In both cases the divers were wearing tight wet suits which probably reduced circulation in the extremities. They were under water and profuse bleeding occurred. This could have reduced the amount of toxin entering the wound by washing it away. In both cases, the divers were trying to remove the animal from its home territory. In the fatality reported by Halstead (1965), the animal was allowed to crawl about on the diver's body while out of the water.

The bite of the northern octopus reported by Halstead (1949) resulted in pain similar to, but more intense than, a bee-sting and continued for about 1 hour. The hand immediately began to swell and exuded a serious discharge for 3 days. In this case, the animal was collected intertidally. Although no ill effects, other than the wound, occurred in either of the northern octopus biting incidents reported here, I strongly suggest that octopi be handled with extreme care, particularly out of water where maximum toxin penetration can occur.

Acknowledgments

I wish to express my sincere appreciation to Mr. David Bonkowski and Mrs. Norma Saunders (Manager), of the Newport, Oregon Undersea Gardens, for their cooperation in reporting this incident.

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① Verified by Mr. Montagne in personal communications.