# PACIFIC MARINE FISHERIES COMMISSION

# BULLETIN 8

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Portland, Oregon
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IDAHO-ALASKA

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# FOREWORD

Bulletin 8 is published in partial fulfillment of the purpose of the Compact which created the Pacific Marine Fisheries Commission in 1947. Since then, the Commission has issued at irregular intervals seven Bulletins which present historical, statistical and biological information on fisheries of common interest on the Pacific Coast of North America. The year of publication, the titles of the papers, and the names of the authors are listed for each of the previous Bulletins on pages 83 and 84 of this Bulletin.

The scientists of the state fishery agencies of Alaska, California, Idaho, Oregon and Washington constitute the Commission's scientific staff. The nine articles in this Bulletin were contributed by salmon specialists from that staff. Copies of an original draft of "Geographical Origin, Trends, and Timing of Washington's Troll Salmon *(Oncorhynchus)* Catches, 1960-1969" were distributed in Seattle at the Commission's 1971 annual meeting. Because these articles deal with chinook and coho salmon and the ocean commercial troll and sport fisheries, it is fitting that they be printed together. Those articles which best introduce the reader to the troll fishery and problems related to its management have been put first.

The Pacific Marine Fisheries Commission thanks the authors and their supporting staffs for these contributions and hopes they will contribute to the most efficient management possible for the chinook and coho stocks of the Pacific Coast of North America and for the ocean troll and sport fisheries which are so dependent on these species.

John P. Harville
Executive Director

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# Plugs (Lures) in the Management of the California Troll Salmon Fishery

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BULLETIN 8

PACIFIC MARINE FISHERIES COMMISSION
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1972

# PLUGS (LURES) IN THE MANAGEMENT OF THE CALIFORNIA TROLL SALMON FISHERY

L. B. Boydstun
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## ABSTRACT

A regulation permitting only large "plugs" (15 cm or longer) in Pacific Coast ocean commercial troll fisheries, primarily for king and silver salmon, has been suggested for Pacific Marine Fisheries Commission (PMFC) resolution with the intent of reducing significant losses of undersize salmon or of silver salmon taken during the closed season for that species. An experiment to pre-test such a regulation was designed and conducted in the northern California troll fishery. Compared to other trolling lures, plugs were found to take a smaller proportion of illegal salmon, but were too inefficient in the taking of legal salmon to suggest the drafting of any realistic "plugs only" regulation.

## INTRODUCTION

The king, chinook, or spring salmon *(Oncorhynchus tshawytscha)* and the silver or coho salmon *(O. kisutch)* are the species of fish sought in all Pacific Coast ocean commercial troll salmon fisheries.

The principal regulations governing the fisheries for both species are minimum-size limits and seasons. In 1969 the year in which the present study was conducted, king salmon regulations were essentially the same coastwide:[1] a 26-inch (66 cm) total-length minimum-size limit and a season which opened April 15 and closed either September 20 in Alaska, September 30 in California, or October 31 elsewhere. Silver salmon regulations varied considerably. In all areas except California, the season opened June 15 and closed either September 20 in Alaska or October 31 elsewhere. In California, the season was April 15—September 30. Minimum-size limits ranged from no size limit in Alaska to 25 inches (approximately 63 cm) total length in California.

Perhaps the most undesirable aspect of the fisheries is the unintentional hooking and mandatory releasing of salmon which are illegal for landing ("shakers"), particularly during the period April 15—June 14. During this period fishermen in all areas may land 26-inch or longer king salmon only, except in California fishermen may land 25-inch or longer silver salmon. All incidentally captured silver salmon less than 25 inches long in California, and all silver salmon elsewhere regardless of length captured prior to June 15 must be released. Consequently, many silvers must be released, and a considerable number of kings must also because of their generally small size during this period of the year. In California, while both species may be harvested, the fishing effort is primarily for kings because it is usually unprofitable to fish for silvers until late May or early June of any year, as before then few silvers meet the California 25-inch minimum-size limit.

The rate of troll hooking mortality in shakers has been reviewed by Wright (1972). Based on the available literature, he states: "Within the 15% to 45% range, it is difficult to assign a narrower zone of 'probably hooking mortality,' much less a 'point value' or 'average.' As a rule, however, estimates above 30% are probably somewhat excessive . . . " In addition to the mortality that results, Fulmer and Ridenhour (1967) conclude that the physical injuries sustained by many of the surviving shakers result in poor condition which lasts until the time of spawning, thereby possibly affecting their chances of spawning successfully.

Lure selectivity studies by Milne (1955) and Pitre (1970) indicate that a way of substantially reducing the incidences of king shakers and all silvers is through the use of a specific size and type of popular commercial salmon lure—large plugs (15 cm and longer).

In August, 1968, Pacific Coast salmon biologists met under the auspices of the Pacific Marine Fisheries Commission and suggested the adoption of a resolution from the Commission calling for the passage of a regulation permitting the use of no trolling lures except large plugs from April 15 to June 14 annually in troll fisheries coastwide. The biologists concluded that such a regulation would substantially reduce the Pacific Coast shaker catch which, during the period in question, was estimated at around 1.0 million fish annually (PMFC, 1968).

In response to this suggested regulation, I conducted an experiment in late April and early May, 1969, testing the efficiency of large plugs in the northern California troll salmon fishery. The following presents the results of the experiment and my conclusions regarding an April 15—June 14 plugs-only regulation in the California fishery.

[1] The salmon troll fisheries of the "inside" marine waters of Alaska and British Columbia are governed by regulations different from those for "outside" marine waters.

No consideration is given the legal and enforcement aspects of implementing such a regulation. Problems could be anticipated which might, in the final analysis, preclude the change. The added cost of increased patrolling for violators, for instance, would have to be weighed against any benefits that the fishery might realize.

## TROLLER CONTRACT AND STUDY LURES

A northern California commercial fisherman who was experienced at trolling commercially for salmon was contracted to (i) fish designated lure types on four of his six trolling lines; (ii) fish the lures between April 14 and June 16, 1969, for a specified minimum number of trolling hours; and (iii) conduct all fishing operations off the coast of California.

All new lures, hooks, and leader materials were provided by the California Department of Fish and Game, but they were selected by the fisherman. Five types of lures were tested: (1) 6-inch plugs; (2) No. 6½ metal-plated spoons; (3) No. 5 painted spoons; (4) bait; and (5) plastic skirts, which are more commonly called "hootchies" (Figure 1). A popular model of flasher was selected for use with the hootchies and some of the baits.

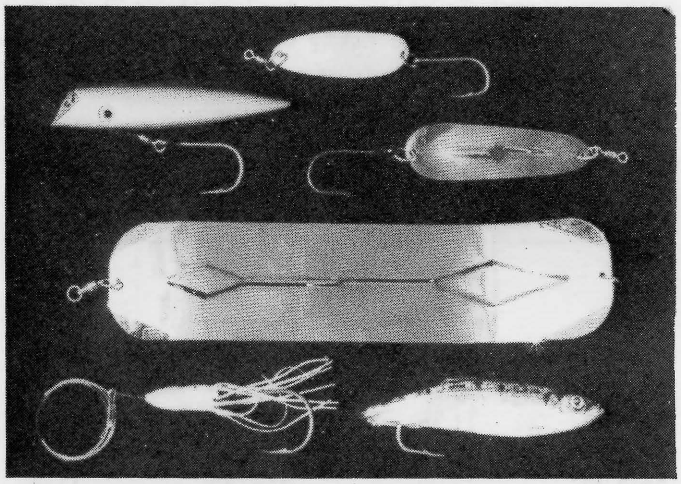

FIGURE 1. Study lures: top—painted or "small" spoon; second row (left)—6-inch or "large" plug, (right)—metal plated or "large" spoon; third row—flasher; bottom row (left)—plastic skirt or "hootchie," (right)—6-inch Pacific herring or "bait."

Two types of spoons were tested because of differences in general usage in the northern California fishery. The larger metal-plated type (large) spoons are used extensively during the spring (April and May) when fishing is primarily for kings. The smaller painted type (small) spoons are also popular during the spring for kings, but are generally more popular later in the season for silvers.

Several colors of the large spoons, small spoons, plugs, and hootchies were selected and tried. Based on their apparent efficiencies for legal salmon, however, only a few colors of each were used regularly (Table 1).

All legal fish captured during the experiment became the salable property of the fisherman, and the experiment was designed so as not to hamper his usual operations. Thus, it was in the fisherman's best interest to fish in the most profitable salmon trolling areas, using his most effective salmon trolling techniques.

**TABLE 1.** Colors of study lures (colors most commonly used are indicated by asterisks)

| Lure type | Colors |
|---|---|
| Large spoons | brass*, phosphor bronze, gold bronze |
| Small spoons | cerise*, red*, green*, golden yellow, orange, flame orange, pearl white* |
| Plugs | pink pearl*, yellow back, blue back*, green back, "baccacio"*, chartreuse, blue back herring scale, green back herring scale, 50/50 yellow and green sides, 50/50 yellow and blue sides |
| Hootchies | white*, 50/50 blue and white*, 50/50 green and white*, 50/50 chartreuse and white, white with red spots* |

## AREAS FISHED

The experiment was conducted between Fort Bragg and Eureka, California, during two 5-day fishing trips: April 24-28 and May 8-12, 1969. Trolling was done in 6 general areas (Figure 2). Depths in the areas fished ranged from 40-100 fathoms.

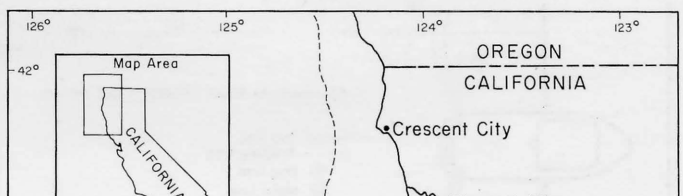


FIGURE 2. Areas fished.

The average daily surface water temperature throughout the experiment taken at Blunt's Reef Lightship was 52° F (U.S. Department of Commerce, 1969a and 1969b).

The areas fished were within the Northern California statistical area (Point Arena to the Oregon border) which, according to O'Brien, Taylor, and Jensen (1972), produced 64% and 58% of estimated California troll shaker catches in 1968 and 1969, respectively. During those same years, troll salmon landings in the area were 58% (4.1 million lb) and 55% (3.4 million lb) of troll salmon landings statewide (Heimann and Carlisle, 1970; Pinkas, 1970).

## METHODS AND PROCEDURES

### Trolling Operations

Six trolling lines were fished at all times—3 from each side of the vessel (Figure 3). The 2 "bow" lines were weighted with 50-pound cannonball-type sinkers, and the 2 "main" and the 2 "dog" lines with 35-pound cannonball-type sinkers. Float bags were used on the dog and main lines and were fished approximately 50 and 10 m, respectively, behind the stern. Eight leaders were fished from each trolling line.

Sinker fishing depths were regulated throughout the experiment so as to fish lures at depths where legal salmon were apparently most abundant. The 2 main and the 2 dog lines were fished at the same depths and were usually fished at the

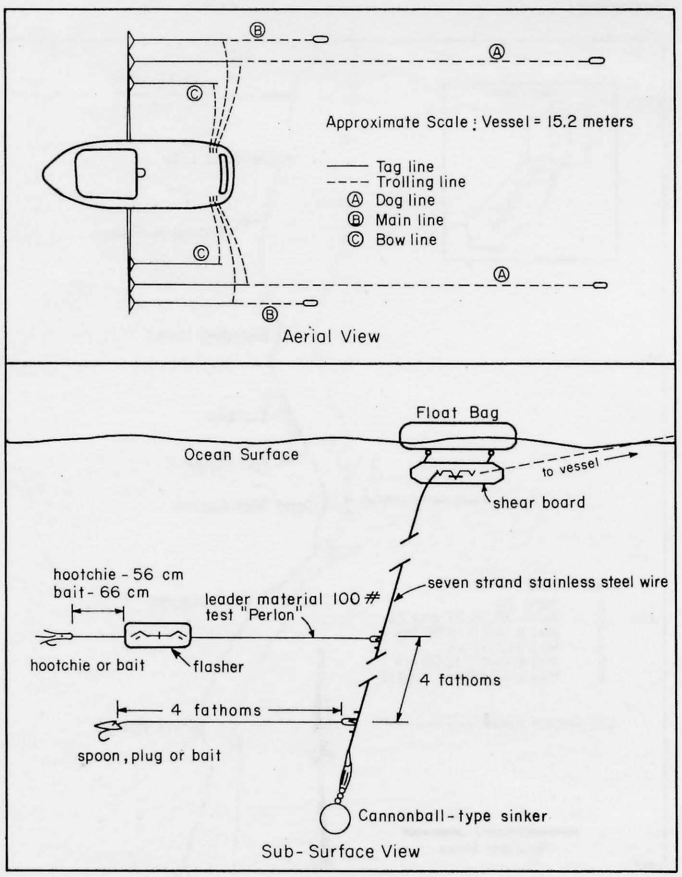


FIGURE 3. Arrangement of main trolling lines (aerial view) and lures on main trolling lines (subsurface view).

same depths as the bow lines. Trolling speed was usually about 3 knots.

### Lure Experiment

I conducted the lure experiment on the main and dog lines. I fished the plugs, small spoons, and baits—one type to a line. On the remaining line I fished 4 to 6 large spoons and 2 to 4 hootchies, totaling 8 lures at all times. I wished to fish the large spoons and hootchies from the same trolling line because of reportedly high relative efficiency when used in combination. As will be shown, the "large spoon and hootchie" line caught the most legal salmon per unit of effort. In the following, the simultaneous fishing of large spoons and hootchies independently on the same line is considered fishing one lure type.

Flashers were used one per lure. Hootchies were always fished with flashers, but the number of flashers used on the bait line varied from 2 to 4 (4 to 6 baits were used without flashers).

I determined daily trolling assignments for the 4 lure types before the experiment was initiated using a table of random numbers. All lure types were fished the same hours each day except the bait line on April 28 (Table 2). On that day, the April 24-28 trip supply of bait was exhausted after 1.5 hours of fishing as catches and the use of bait on the previous 4 days had been unexpectedly high.

**TABLE 2.** Hours of trolling effort with experimental lines by date

| Date | Hours trolled | Date | Hours trolled |
|---|---|---|---|
| April 24 | 13.75 | May 8 | 15.00 |
| April 25 | 13.50 | May 9 | 8.50 |
| April 26 | 11.75 | May 10 | 15.00 |
| April 27 | 13.75 | May 11 | 14.50 |
| April 28* | 13.00 | May 12 | 11.00 |
| Total | 65.75 | | 64.00 |
| Grand total | | | 129.75 |

*On April 28 the bait line was fished only 1.5 hours.

The total length in centimeters of each captured salmon was measured and recorded as whole numbers by dropping off any fraction (e.g., fish 65.0-65.9 cm were assigned a length of 65 cm). Also noted for each fish was the type of lure and the lure's position on the line. All sublegals (shakers) were returned to the ocean, and all legals were kept and later sold by the fisherman.

In California, salmon are commercially landed dressed with the head on; the amount of money the fisherman receives for his catch depends on the species and dressed weights of the individual fish. I estimated the dressed weights of legal-size kings by converting total length to fork length and using the fork length to dressed head-on weight formulas of Fry and

Hughes (1951) for California troll caught king salmon. The prices paid fishermen in Eureka in April and May, 1969 were used to estimate legal king salmon values based on estimated weights of individual fish. Salmon prices per pound according to weight category were: 12-lb and larger, $0.78; 8 to 12-lb, $0.65; and all legals under 8-lb, $0.45. Since most king salmon in the California fishery have red flesh, essentially, there are no price differentials based on flesh color categories. Legal silver salmon weights and values were not computed because of small sample size (only 2 fish).

Differences among mean daily lure-type catch rates were analyzed by the method of one-way analysis of variance. Differences between daily lure-type catch rates were then analyzed using Duncan's New Multiple Range Test (Duncan, 1955).

## RESULTS

A total of 623 salmon was caught on experimental lines.[2] The catch consisted of 485 king salmon and 137 silver salmon (Table 3). On May 10, one pink salmon *(O. gorbuscha)* was captured on a hootchie and will not be considered in the following. Fifty-two percent of the kings were legal size as compared to only 1.5% of the silvers. The average weight per legal king salmon was 7.8 pounds and the average value per pound was $0.56. Lengths of kings and silvers captured on experimental lines are presented in the Appendix.

In terms of either mean daily total weight or mean daily total value of legal kings per lure type, the plugs were nearly 50% less efficient than the 2 most efficient lure types tested—large spoons+hootchies, and bait (Tables 4 and 5). Plug catch rates were 54% by weight or value of the catch rates for the

[2] An additional 544 salmon were caught on the bow lines.

**TABLE 3.** Number pounds (dressed weight), and value (dollars) of legal kings and number of legal silvers and shaker kings and shaker silvers caught, by lure type and fishing date

| | | | | Fishing date | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | April | | | | | May | | | | | |
| Lure type | Fish size | Species | Number, weight & value | 24 | 25 | 26 | 27 | 28 | 8 | 9 | 10 | 11 | 12 | Total |
| Large spoons + hootchies | Legal | King | No. | 13 | 19 | 4 | 4 | 12 | 3 | 2 | 4 | 14 | 10 | 85 |
| | | | lbs. | 103.3 | 147.7 | 25.5 | 42.1 | 78.9 | 20.1 | 13.6 | 28.0 | 118.0 | 83.9 | 661.1 |
| | | | $ | 58.80 | 84.73 | 12.50 | 27.49 | 39.64 | 9.85 | 6.66 | 14.66 | 71.50 | 48.67 | 374.50 |
| | Legal | Silver | No. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| | Shaker | King | No. | 1 | 18 | 3 | 12 | 16 | 3 | 2 | 6 | 17 | 16 | 94 |
| | Shaker | Silver | No. | 0 | 2 | 2 | 0 | 3 | 3 | 7 | 24 | 5 | 3 | 49 |
| Bait | Legal | King | No. | 8 | 16 | 6 | 13 | 2 | 1 | 3 | 3 | 5 | 10 | 67 |
| | | | lbs. | 71.4 | 125.7 | 42.2 | 98.7 | 13.3 | 9.7 | 24.7 | 24.8 | 34.0 | 68.5 | 513.0 |
| | | | $ | 40.68 | 67.99 | 22.56 | 52.74 | 6.52 | 5.82 | 14.07 | 13.38 | 16.66 | 35.40 | 275.82 |
| | Legal | Silver | No. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Shaker | King | No. | 0 | 12 | 5 | 6 | 2 | 1 | 3 | 8 | 11 | 15 | 63 |
| | Shaker | Silver | No. | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 17 | 3 | 4 | 27 |
| Small spoons | Legal | King | No. | 7 | 14 | 2 | 5 | 10 | 2 | 0 | 8 | 6 | 3 | 57 |
| | | | lbs. | 65.6 | 104.6 | 16.4 | 39.4 | 77.6 | 18.6 | 0.0 | 62.2 | 39.5 | 22.5 | 446.4 |
| | | | $ | 41.60 | 55.63 | 9.06 | 21.56 | 44.55 | 12.62 | 0.00 | 33.50 | 20.26 | 12.14 | 250.92 |
| | Legal | Silver | No. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| | Shaker | King | No. | 0 | 10 | 5 | 7 | 5 | 2 | 1 | 6 | 9 | 17 | 62 |
| | Shaker | Silver | No. | 1 | 3 | 3 | 2 | 2 | 5 | 3 | 19 | 6 | 6 | 50 |
| Plugs | Legal | King | No. | 0 | 11 | 6 | 3 | 8 | 2 | 2 | 5 | 4 | 2 | 43 |
| | | | lbs. | 0.0 | 89.3 | 46.9 | 22.7 | 65.6 | 16.6 | 15.9 | 43.3 | 37.9 | 14.1 | 352.3 |
| | | | $ | 0.00 | 49.76 | 25.96 | 12.19 | 37.01 | 9.25 | 8.73 | 24.58 | 24.23 | 7.84 | 199.55 |
| | Legal | Silver | No. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Shaker | King | No. | 0 | 2 | 1 | 2 | 2 | 0 | 1 | 2 | 1 | 3 | 14 |
| | Shaker | Silver | No. | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 4 | 3 | 0 | 9 |
| Totals | Legal | King | No. | 28 | 60 | 18 | 25 | 32 | 8 | 7 | 20 | 29 | 25 | 252 |
| | | | lbs. | 240.3 | 467.3 | 131.0 | 202.9 | 235.4 | 65.0 | 54.2 | 158.3 | 229.4 | 189.0 | 1,972.8 |
| | | | $ | 141.08 | 258.11 | 70.08 | 113.98 | 127.72 | 37.54 | 29.46 | 86.12 | 132.65 | 104.05 | 1,100.79 |
| | Legal | Silver | No. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 |
| | Shaker | King | No. | 1 | 42 | 14 | 27 | 25 | 6 | 7 | 22 | 38 | 51 | 233 |
| | Shaker | Silver | No. | 1 | 6 | 5 | 2 | 5 | 10 | 12 | 64 | 17 | 13 | 135 |

large spoons+hootchies. These differences were significant at the 95% level (Tables 4 and 5). The plug catch rates for legal kings were 57% by weight and 60% by value of the catch rates for bait; the weight differences were significant at the 95% level but the value differences were not.

**TABLE 4.** Pounds (dressed weight) of legal kings captured per line hour of trolling by lure type and fishing date, and results of one-way analysis of variance and Duncan's New Multiple Range Test

| | Fishing date | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | April | | | | | May | | | | | |
| Lure type | 24 | 25 | 26 | 27 | 28 | 8 | 9 | 10 | 11 | 12 | Mean |
| Large spoons + hootchies | 7.51 | 10.94 | 2.17 | 3.06 | 6.07 | 1.34 | 1.60 | 1.87 | 8.14 | 7.63 | 5.03 |
| Bait | 5.19 | 9.31 | 3.59 | 7.18 | 8.87 | 0.65 | 2.91 | 1.65 | 2.34 | 6.23 | 4.79 |
| Small spoons | 4.77 | 7.75 | 1.40 | 2.87 | 5.97 | 1.24 | 0.00 | 4.15 | 2.72 | 2.05 | 3.29 |
| Plugs | 0.00 | 6.61 | 3.99 | 1.65 | 5.05 | 1.11 | 1.87 | 2.89 | 2.61 | 1.28 | 2.71 |

Analysis of variance

| Source of variation | Degrees of freedom | Sum of squares | Mean square |
|---|---|---|---|
| Replications | 9 | 182.9968 | |
| Treatments | 3 | 38.6222 | 12.8740 |
| Error | 27 | 92.8070 | 3.4372 |
| F = 3.75 | | $F_{0.05} = 2.96$ | |

Duncan's New Multiple Range Test (95% level)*

| Lure type: | Plugs | Small spoons | Bait | Large spoons + hootchies |
|---|---|---|---|---|
| Means: | 2.71 | 3.29 | 4.79 | 5.03 |

*Any 2 means underscored by the same line are not significantly different. Any 2 means *not* underscored by the same line are significantly different.

**TABLE 5.** Values (dollars) of legal kings captured per line hour of trolling by lure type and fishing date, and results of one-way analysis of variance and Duncan's New Multiple Range Test

| | Fishing date | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | April | | | | | May | | | | | |
| Lure type | 24 | 25 | 26 | 27 | 28 | 8 | 9 | 10 | 11 | 12 | Mean |
| Large spoons + hootchies | 4.28 | 6.28 | 1.06 | 2.00 | 3.05 | 0.66 | 0.78 | 0.98 | 4.93 | 4.42 | 2.84 |
| Bait | 2.96 | 5.04 | 1.92 | 3.84 | 4.35 | 0.65 | 1.66 | 0.89 | 1.15 | 3.22 | 2.57 |
| Small spoons | 3.03 | 4.12 | 0.77 | 1.57 | 3.43 | 0.84 | 0.00 | 2.23 | 1.40 | 1.10 | 1.85 |
| Plugs | 0.00 | 3.69 | 2.21 | 0.89 | 2.85 | 0.62 | 1.03 | 1.64 | 1.67 | 0.71 | 1.53 |

Analysis of variance

| Source of variation | Degrees of freedom | Sum of squares | Mean square |
|---|---|---|---|
| Replications | 9 | 53.9194 | |
| Treatments | 3 | 11.2091 | 3.7363 |
| Error | 27 | 31.5000 | 1.1666 |
| F = 3.20 | | $F_{0.05} = 2.96$ | |

Duncan's New Multiple Range Test (95% level)*

| Lure type: | Plugs | Small spoons | Bait | Large spoons + hootchies |
|---|---|---|---|---|
| Means: | 1.53 | 1.85 | 2.57 | 2.84 |

*Any 2 means underscored by the same line are not significantly different. Any 2 means *not* underscored by the same line are significantly different.

Mean daily rate of capture of shaker kings on plugs was 15% of that achieved on the large spoons+hootchies. The catch rate for plugs was significantly below that of all the other lures at the 99% level (Table 6).

**TABLE 6.** Numbers of sublegal (shaker) kings captured per line hour of trolling by lure type and fishing date and results of one-way analysis of variance and Duncan's New Multiple Range Test

| | Fishing date | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | April | | | | | May | | | | | |
| Lure type | 24 | 25 | 26 | 27 | 28 | 8 | 9 | 10 | 11 | 12 | Mean |
| Large spoons + hootchies | 0.07 | 1.33 | 0.26 | 0.87 | 1.23 | 0.20 | 0.24 | 0.40 | 1.17 | 1.45 | 0.72 |
| Bait | 0.00 | 0.89 | 0.43 | 0.44 | 1.33 | 0.07 | 0.35 | 0.53 | 0.76 | 1.36 | 0.62 |
| Small spoons | 0.00 | 0.74 | 0.43 | 0.51 | 0.38 | 0.13 | 0.12 | 0.40 | 0.62 | 1.55 | 0.49 |
| Plugs | 0.00 | 0.15 | 0.09 | 0.15 | 0.15 | 0.00 | 0.12 | 0.13 | 0.07 | 0.27 | 0.11 |

Analysis of variance

| Source of variation | Degrees of freedom | Sum of squares | Mean square |
|---|---|---|---|
| Replications | 9 | 4.5636 | |
| Treatments | 3 | 2.1172 | 0.7057 |
| Error | 27 | 1.8350 | 0.0679 |
| F = 10.39 | | $F_{0.01} = 4.60$ | |

Duncan's New Multiple Range Test (95% level)*

| Lure type: | Plug | Small spoons | Bait | Large spoons + hootchies |
|---|---|---|---|---|
| Means: | 0.11 | 0.49 | 0.62 | 0.72 |

*Any 2 means underscored by the same line are not significantly different. Any 2 means *not* underscored by the same line are significantly different.

Because of small sample size, no analyses were made of lure type catch rates for legal silver salmon. For shaker silvers, the mean daily rate of capture on the plugs and the baits were 15% and 53%, respectively, of the catch rates of either the large spoons+hootchies or the small spoons which were the same (Table 7). The lower catch rates of plugs and bait were

**TABLE 7.** Numbers of sublegal (shaker) silvers captured per line hour of trolling by lure type and fishing date, and results of one-way analysis of variance and Duncan's New Multiple Range Test

| | Fishing date | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | April | | | | | May | | | | | |
| Lure type | 24 | 25 | 26 | 27 | 28 | 8 | 9 | 10 | 11 | 12 | Mean |
| Large spoons + hootchies | 0.00 | 0.15 | 0.17 | 0.00 | 0.23 | 0.20 | 0.82 | 1.60 | 0.34 | 0.27 | 0.38 |
| Bait | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 0.24 | 1.13 | 0.21 | 0.36 | 0.20 |
| Small spoons | 0.07 | 0.22 | 0.26 | 0.15 | 0.15 | 0.33 | 0.35 | 1.27 | 0.41 | 0.55 | 0.38 |
| Plugs | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.27 | 0.21 | 0.00 | 0.06 |

Analysis of variance

| Source of variation | Degrees of freedom | Sum of squares | Mean square |
|---|---|---|---|
| Replications | 9 | 3.5825 | |
| Treatments | 3 | 0.6994 | 0.2331 |
| Error | 27 | 0.8183 | 0.0303 |
| F = 7.69 | | $F_{0.01} = 4.60$ | |

Duncan's New Multiple Range Test*

| Lure type: | Plugs | Bait | Small spoons | Large spoons + hootchies |
|---|---|---|---|---|
| 95% level | | | | |
| Means: | 0.06 | 0.20 | 0.38 | 0.38 |
| 99% level | | | | |
| Means: | 0.06 | 0.20 | 0.38 | 0.38 |

*Any means underscored by the same line are not significantly different. Any 2 means *not* underscored by the same line are significantly different.

significantly different at the 99% or 95% levels, respectively, from the higher catch rates of small spoons and large spoons+ hootchies. There was no significant difference at the 95% level between plugs and bait.

## DISCUSSION AND CONCLUSIONS

Two major assumptions in comparing lure type catch rates were made: (1) there were no biasing interactions between lure types because lure types were fished from the same vessel, in relatively close proximity to one another; and (2) each lure type was fished as skillfully as any of the other three lure types tested.

The validity of the first of these two assumptions is indicated by Pitre (1970), who conducted large-plug efficiency experiments off the west coast of Vancouver Island, British Columbia, in 1968 and 1969. In 1968, one vessel was used and the experiment was conducted in essentially the same manner as the present experiment, but in 1969, three vessels were used. Daily, each vessel randomly fished one of three lure types at random, but no two vessels fished the same lure type on the same day. Vessels fished the same general areas, and lure types tested were the same in both years.

Results of the two experiments were very consistent (Figure 4); thus suggesting that interactions from fishing lures from the same vessel in relatively close proximity to one another in 1968 did not bias the analysis of the 1968 data.

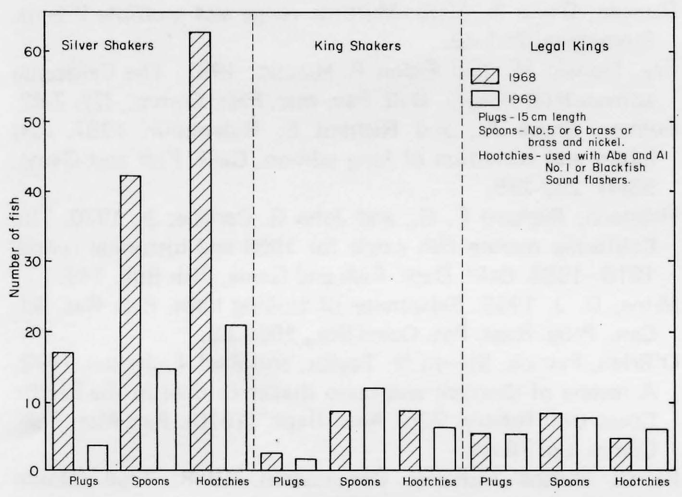


FIGURE 4. Catch per day trolling off the West Coast of Vancouver Island, B.C., comparison of large plugs, spoons, and hootchies. In 1968, one vessel was employed; in 1969, three vessels were employed (from Pitre, 1970).

I have assumed that each of the study lures were fished as skillfully as each of the others. The fisherman was adept at fishing these lures, and owned large numbers of them. I am certain the monetary incentives of the study contract (viz., to fish for a guaranteed fee plus to fish for profit from any legal fish he might catch) prompted him to try to maximize legal salmon catches on all lines at all times.

The California troll shaker problem during the period April 15—June 15 is indicated in the present study wherein the shaker catch on experimental lines was 1.45 times the legal catch. Based on voluntary logbooks, O'Brien, et. al. (1972) estimated California troll shaker catches in 1968 and 1969 were 629,966 and 485,193 fish, respectively. Over half of each year's catch occurred during the 2-month period April 15—June 15. The seasons were each 5½ months long (April 15—September 30).

An April 15—June 14 large-plugs-only regulation for the California fishery would certainly reduce the shaker catch, but it would also probably reduce the catch of legal salmon. In this study, the daily mean total pounds of legal kings landed on plugs was only 54% of that taken by the most efficient gear.

Milne (1955) and Pitre (1970) each conducted lure selectivity studies off the west coast of Vancouver Island, British Columbia. Both authors found that large plugs were highly efficient at avoiding undersize kings (under 26 inches TL) and all silvers (Table 8 and Figure 4). Milne found that large plugs caught 75% as many legal kings as large spoons, the most efficient gear tested for legal kings. Pitre found, in 1968 and 1969, that large plugs caught 63% and 67%, respectively, as many legal kings per unit of effort as brass spoons, his most efficient lures for legal kings.

**TABLE 8.** Number and size of silver and king salmon caught off the west coast of Vancouver Island, B.C., June 29—August 2, 1953 by 4 different trolling lures (from Milne, 1955)

| | Types of lure* | | | | |
|---|---|---|---|---|---|
| | Large spoon | Small spoon | Large plug | Small plug | Total |
| Silver salmon | | | | | |
| Number of fish | 20 | 27 | 2 | 5 | 54 |
| Percentage by number | 37 | 50 | 4 | 9 | 100 |
| Average fork length in cm | 62 | 61 | 65 | 57 | |
| Percentage by weight | 39 | 49 | 5 | 7 | 100 |
| King salmon | | | | | |
| Number of fish | 35 | 30 | 20 | 12 | 97 |
| Percentage by number | 36 | 31 | 21 | 12 | 100 |
| Average fork length in cm | 66 | 58 | 72 | 60 | |
| % under 26-inch total length | 34 | 53 | 10 | 58 | |
| Percentage by weight | 34 | 21 | 36 | 9 | 100 |

*Large spoon—McMahon, 7-inch, brass; Small spoon—Gibb's egg wobbler, No. 2, brass; Large plug—Rex Field, Model 49, 7-inch, painted yellow and blue; Small plug—Rex Field, Little Doug, 5-inch, painted yellow and blue.

It has been my observation that salmon trollers in the northern California fishery use large plugs sparingly, especially during the spring (April and May). Reportedly, they are relatively inefficient lures for legal salmon during this time of the season.

Given a population model of California's salmon resources, the probably effect of an April 15—June 14 large-plugs-only regulation on California troll fishery yield could be estimated, using lure study results to estimate the effect on troll fleet efficiency. Unfortunately, all the parameters and assessments necessary to construct such a model are not available, nor can they be generated at this time. Principally lacking are rates of ocean salmon fishing mortality on legal and shaker salmon. Future research efforts should be directed toward developing a model of California's ocean salmon resources so that the effects of any changes in regulations can be evaluated.

Indications in the present study were that bait is also a relatively efficient lure type for avoiding silver salmon, yet it was nearly the most efficient lure type for legal king salmon tested (Tables 4 and 5). As silvers are not sought in Pacific Coast troll fisheries until after June 15 (slightly earlier in California), the widespread use of bait might substantially reduce the shaker catch. There are certain other features of bait fishing which might also contribute to reducing the shaker catch. Bait is far more costly to use than artificial lures and can be quite costly in areas where shakers abound. Bait fishing, furthermore, requires the fisherman to continually run his lines to check for fish and "scratched" baits. If the fisherman encounters a concentration of shakers, the checking must be speeded up; thereby lowering the amount of time his lines are in the water and lowering his chances of catching legal fish. Whole herring baits were tested in the present study. Other methods of fishing bait might show different results. Future gear selectivity experimentations should include bait.

## SUMMARY

1. An undesirable aspect of Pacific Coast troll salmon fisheries is the hooking and releasing of salmon which are illegal for landing (shakers), especially during the period April 15–June 14 annually.

2. A large-(15 cm or longer) plug-only regulation in Pacific Coast troll salmon fisheries has been suggested as a Pacific Marine Fisheries Commission resolution with the intent of reducing the Pacific Coast shaker catch and the loss that results.

3. In response to this suggestion, I conducted a large-plug efficiency experiment during the period April 15–June 14, 1969, in the northern California troll fishery. A northern California fisherman and his vessel were contracted to fish designated lure types in a predetermined manner on certain of his trolling lines.

4. Lure testing occurred in the ocean between Eureka and Fort Bragg, California, during two 5-day fishing trips, April 24-28 and May 8-12, 1969.

5. All legal salmon captured during the experiment were the salable property of the fisherman; thus it was in the fisherman's best interest to fish in most profitable areas, using his most effective techniques.

6. A total of 623 salmon was captured on the experimental lines: 485 king salmon, 137 silver salmon, and 1 pink salmon. Approximately 50% of the kings and only 1.5% of the silvers were legal size. The 1 pink and 2 legal silvers were disregarded in the study because of small sample sizes.

7. For legal kings, the plugs were approximately half as efficient as the most efficient lure types tested, the large spoon+hootchies and the bait. For shakers of either species, the plugs were 15% as efficient as each of these lure types, except the bait for shaker silvers.

8. As indicated from voluntary logbooks and the present study, the California shaker catch is significant. The situation is undesirable because of the fishery loss and waste that results. The use of plugs in fishery management, however, is dubious because plugs are shown to be less efficient than certain other popular lure types for legal king salmon.

9. Future research efforts should be directed toward developing a model of California's ocean salmon resources so that any changes in fishery regulations could be easily evaluated.

10. Indications were that the widespread use of bait in the troll fishery might also substantially reduce the shaker catch, but without lowering the legal king salmon catch. Further research with bait is recommended.

## ACKNOWLEDGEMENTS

I would like to thank David Mackett, formerly of the California Department of Fish and Game, but now with the Food and Agriculture Organization, for his help in designing the study and suggesting the statistical methods used. My thanks go to Mike Jackson, also formerly of the California Department of Fish and Game, but now of the Alaska Department of Fish and Game, for accomplishing a large part of the field work. I am particularly indebted to Nick Lackey, the owner-skipper of the vessel used in the study. Nick contributed valuable advice to the design of the study and assisted in the field work, moreover, Nick gave me additional insight into the California troll fishery as a whole and the shaker problem in particular.

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**APPENDIX.** Lengths of king salmon (KS) and silver salmon (SS) by lure type and fishing date (More than 1 fish of the same length are shown by numbers in parentheses.)

| Fishing date | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4-24 | | 4-25 | | 4-26 | | 4-27 | | 4-28 | | 5-8 | | 5-9 | | 5-10 | | 5-11 | | 5-12 | |
| KS | SS | KS | SS | KS | SS | KS | SS | KS | SS | KS | SS | KS | SS | KS | SS | KS | SS | KS | SS |
| **Large spoons*** | | | | | | | | | | | | | | | | | | | |
| 64 | | 37 | 60 | 39 | 56 | 40 | | 40 | 46 | 61 | 58 | | 50 | 55 | 53 | 38(2) | 52 | 39 | 56 |
| 66(3) | | 45 | | 49 | 61 | 63 | | 46 | | 65 | 59 | | 53 | 72 | 56 | 42 | 58(2) | 58 | |
| 67 | | 47 | | 57 | | 64 | | 51 | | 69 | | | 60(3) | 75 | 57 | 53 | 60 | 61 | |
| 74(2) | | 49 | | 66 | | 65 | | 61(2) | | 71 | | | | | 58 | 64 | | 62 | |
| 77 | | 54 | | 67 | | 90 | | 64 | | | | | | | 59(2) | 65 | | 64 | |
| 78(2) | | 58(2) | | 68 | | | | 65 | | | | | | | 61 | 67(2) | | 69 | |
| | | 59 | | 73 | | | | 66 | | | | | | | 62(2) | 68 | | 71 | |
| | | 61(2) | | | | | | 68 | | | | | | | 64 | 69 | | 75 | |
| | | 64 | | | | | | 70 | | | | | | | | 71(2) | | 80 | |
| | | 66(2) | | | | | | 71 | | | | | | | | 72 | | | |
| | | 67(2) | | | | | | 72 | | | | | | | | 76 | | | |
| | | 68 | | | | | | 76 | | | | | | | | | | | |
| | | 69(2) | | | | | | | | | | | | | | | | | |
| | | 73(2) | | | | | | | | | | | | | | | | | |
| | | 74 | | | | | | | | | | | | | | | | | |
| | | 75 | | | | | | | | | | | | | | | | | |
| | | 79 | | | | | | | | | | | | | | | | | |
| | | 83 | | | | | | | | | | | | | | | | | |
| **Hootchies*** | | | | | | | | | | | | | | | | | | | |
| 68 | | 51(2) | 55 | | | 39 | | 41(2) | 52 | 49 | 60 | 42 | 49 | 44 | 46+ | 35 | 56 | 41 | 52 |
| 77(2) | | 52 | | | | 40 | | 46 | 55 | 69 | | 65 | 53 | 51 | 54 | 42(2) | | 42(2) | 59 |
| 80 | | 61 | | | | 42(3) | | 47 | | | | 69 | | 54 | 56(6) | 43 | | 43 | |
| | | 62 | | | | 47 | | 59 | | | | 71 | | 61 | 57(2) | 45 | | 46 | |
| | | 63 | | | | 53 | | 60 | | | | | | 65 | 58(2) | 46 | | 48 | |
| | | 65 | | | | 62 | | 63(2) | | | | | | 67 | 59(2) | 47 | | 49 | |
| | | 67(2) | | | | 67 | | 64 | | | | | | 68 | 60 | 48(2) | | 50 | |
| | | 73 | | | | 79(2) | | 66(2) | | | | | | | 62 | 49 | | 53 | |
| | | 75 | | | | | | 67(2) | | | | | | | | 63 | | 55 | |
| | | 77 | | | | | | 70 | | | | | | | | 66 | | 60 | |
| | | 86 | | | | | | 71 | | | | | | | | 68 | | 67(2) | |
| | | | | | | | | | | | | | | | | 72 | | 70 | |
| | | | | | | | | | | | | | | | | 84 | | 71 | |
| | | | | | | | | | | | | | | | | 89 | | 80 | |
| | | | | | | | | | | | | | | | | 90 | | 88 | |
| **Bait** | | | | | | | | | | | | | | | | | | | |
| 66 | | 61(5) | | 35 | | 60 | | 55 | | 65 | 56 | 45 | 49 | 42 | 52 | 42 | 54 | 43 | 48 |
| 68(2) | | 63 | | 43 | | 62(2) | | 61 | | 78 | | 47 | 59 | 48 | 54 | 44 | 55 | 47 | 55 |
| 74 | | 64(3) | | 53 | | 63(3) | | 69 | | | | 64 | | 49 | 55(3) | 45 | 60 | 48 | 56 |
| 79 | | 65(3) | | 55 | | 66 | | 70 | | | | 70 | | 55 | 56(2) | 48 | | 50 | 61 |
| 82(3) | | 66 | | 57 | | 67 | | | | | | 74 | | 57 | 57 | 51 | | 52 | |
| | | 67 | | 67 | | 68(2) | | | | | | 78 | | 59 | 58(2) | 57 | | 54 | |
| | | 68 | | 68(2) | | 69(2) | | | | | | | | 61 | 59(2) | 59(2) | | 55 | |
| | | 69(3) | | 70 | | 70 | | | | | | | | 65 | 60 | 60 | | 56 | |
| | | 72(2) | | 74 | | 72 | | | | | | | | 70(2) | 61(2) | 61 | | 57(2) | |
| | | 73(2) | | 76 | | 73 | | | | | | | | 81 | 62 | 63 | | 62(4) | |
| | | 76(2) | | | | 75(2) | | | | | | | | | 63 | 66 | | 63 | |
| | | 77 | | | | 81 | | | | | | | | | | 68 | | 67(3) | |
| | | 78 | | | | 82 | | | | | | | | | | 72(3) | | 68(2) | |
| | | 79 | | | | | | | | | | | | | | | | 70 | |
| | | 81 | | | | | | | | | | | | | | | | 71 | |
| | | | | | | | | | | | | | | | | | | 73 | |
| | | | | | | | | | | | | | | | | | | 74 | |
| | | | | | | | | | | | | | | | | | | 75 | |
| **Small spoons** | | | | | | | | | | | | | | | | | | | |
| 67 | 57 | 39 | 48 | 34 | 42 | 40 | 51 | 40 | 46 | 49 | 56 | 59 | 56 | 40 | 50 | 39 | 56 | 37 | 53 |
| 70 | | 41 | 49 | 41 | 53 | 47 | 53 | 45 | 54 | 58 | 57 | | 58 | 43 | 54(4) | 45(3) | 58(3) | 40(2) | 54 |
| 72 | | 46(2) | 54 | 50 | 58 | 59 | | 60 | | 69 | 59 | | 59 | 46 | 56 | 47(3) | 63(2) | 42(2) | 55 |
| 79 | | 55 | | 59 | | 61 | | 63 | | 83 | 59(2) | | | 57 | 57 | 48 | | 44(3) | 56(2) |
| 80 | | 58 | | 65 | | 62(2) | | 65 | | | | | | 58 | 58(3) | 63 | | 48 | 61 |
| 83 | | 60(2) | | 71 | | 65 | | 66 | | | | | | 61 | 59(5) | 66 | | 50 | |
| 84 | | 64 | | 77 | | 67(2) | | 67 | | | | | | 67 | 60(3) | 67 | | 51 | |
| | | 65 | | | | 71 | | 68(2) | | | | | | 70(2) | 62 | 69(2) | | 57 | |
| | | 66 | | | | 77 | | 70 | | | | | | 72 | 64 | 70 | | 59 | |
| | | 67(2) | | | | 81 | | 72 | | | | | | 73 | | 74 | | 60 | |
| | | 68(2) | | | | | | 74 | | | | | | 75 | | | | 64(3) | |
| | | 69 | | | | | | 75 | | | | | | 76 | | | | 67 | |
| | | 70(2) | | | | | | 80 | | | | | | 79 | | | | 69 | |
| | | 71 | | | | | | 83 | | | | | | | | | | 79 | |
| | | 73 | | | | | | | | | | | | | | | | | |
| | | 77 | | | | | | | | | | | | | | | | | |
| | | 78 | | | | | | | | | | | | | | | | | |
| | | 79 | | | | | | | | | | | | | | | | | |
| | | 80 | | | | | | | | | | | | | | | | | |
| **Plugs** | | | | | | | | | | | | | | | | | | | |
| | | 58 | 53 | 60 | | 41 | | 58 | | 69 | 55 | 58 | | 51 | 56 | 59 | 54 | 44 | |
| | | 61 | | 67 | | 55 | | 65 | | 79 | | 72 | | 57 | 57 | 71 | 58(2) | 62 | |
| | | 69(2) | | 70 | | 68 | | 69 | | | | 75 | | 66 | 59 | 76 | | 64 | |
| | | 70 | | 71 | | 70 | | 71 | | | | | | 71 | 62 | 77 | | 66 | |
| | | 71 | | 74(2) | | 78 | | 73 | | | | | | 77 | | 84 | | 75 | |
| | | 73 | | 80 | | | | 74 | | | | | | 78 | | | | | |
| | | 75(2) | | | | | | 75(2) | | | | | | 82 | | | | | |
| | | 76 | | | | | | 76 | | | | | | | | | | | |
| | | 77 | | | | | | 79 | | | | | | | | | | | |
| | | 78(2) | | | | | | | | | | | | | | | | | |

*Large spoons and hootchies were used on the same main trolling line and were considered one lure type.

+Indicates 1 pink salmon.

# Estimated Numbers of Salmon Hooked and Released by Washington's Commercial Troll and Ocean Sport Fisheries in 1970-1971

SAM WRIGHT

State of Washington
Department of Fisheries

## BULLETIN 8

PACIFIC MARINE FISHERIES COMMISSION
Portland, Oregon

1972

# ESTIMATED NUMBERS OF SALMON HOOKED AND RELEASED BY WASHINGTON'S COMMERCIAL TROLL AND OCEAN SPORT FISHERIES IN 1970–1971

Sam Wright
State of Washington, Department of Fisheries

## ABSTRACT

Data on numbers of Pacific salmon hooked and released by ocean fisheries because of existing regulatory statutes are needed to intelligently manage the resource. Estimates of these quantities of fish were developed through a logbook program for the commercial fishery and by angler interviews in the sport fishery. From these sources, it was determined that 1¼ million small chinook and coho were hooked and released off the Washington coast in a 2-year period.

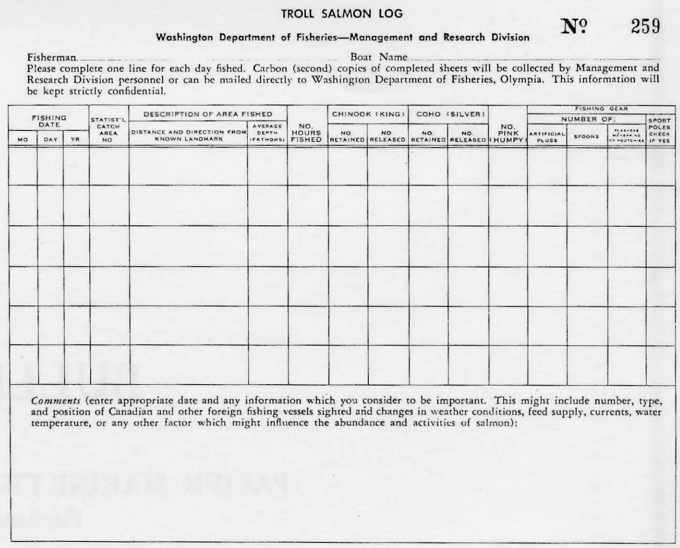
## INTRODUCTION

The number of salmon hooked and voluntarily released in marine fisheries can be viewed in either a positive or negative sense; i.e., as a quantity of fish which might have been retained under liberalized regulations or as a "fishing cost" in terms of a resource loss from the impact of hooking mortality. For example, Van Hyning (1968), in a comprehensive study of factors affecting Columbia River fall chinook, indicated for the commercial troll fishery: " . . . sublegal-sized chinook discarded may, on the average, constitute 25% of the total catch and 40% of these may die. The statistics on numbers of salmon landed could thus be increased by 10% to give a better picture of fishing mortality."

The term "shakers" is commonly used to describe those salmon which must be released because they are either (1) smaller than the prevailing minimum-size limits or (2) of a species for which the season is closed. Recently, the so-called "shaker problem" has been accorded considerable attention by the resource management agencies of Canada and the States of California, Oregon, and Washington. Results from all pertinent troll fishery programs completed through 1969 were documented by O'Brien, Taylor and Jensen (1972). This paper describes studies during 1970 and 1971 for Washington coastal areas.

## COMMERCIAL TROLL FISHERY ESTIMATES

For estimating number of fish released by commercial fishermen, a voluntary troll salmon logbook program was initiated. Information was requested on time and place of fishing, numbers of salmon retained and released by species, and types of terminal fishing gear utilized (Figure 1). During 1970, incoming logbook data were not compiled by individual boat, but it was estimated that usable information was received from 150, or one-third, of 450 fishermen who were originally issued logbooks. The 1970 sample accounted for retained catches of 19,344 chinook and 58,752 coho or about 9% and 8%, respectively, of total Washington troll landings for these species. In 1971, new logbooks were re-issued to many of the fishermen who provided data in 1970, plus some new trollers. Overall, 304 logbooks were distributed, and usable information was received from 132. The 1971 results showed 20,335 chinook and 61,224 coho retained for 8% and 5% samples, respectively, of Washington's total landings.


TROLL SALMON LOG

Washington Department of Fisheries—Management and Research Division

Nº 259

Fisherman ............ Boat Name ............

Please complete one line for each day fished. Carbon (second) copies of completed sheets will be collected by Management and Research Division personnel or can be mailed directly to Washington Department of Fisheries, Olympia. This information will be kept strictly confidential.

| FISHING DATE | | | STATIST'L CATCH AREA NO | DESCRIPTION OF AREA FISHED | | NO. HOURS FISHED | CHINOOK (KING) | | COHO (SILVER) | | NO. PINK (HUMPY) | FISHING GEAR | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | NUMBER OF: | | | SPORT POLES CHECK IF YES |
| MO | DAY | YR | | DISTANCE AND DIRECTION FROM KNOWN LANDMARK | AVERAGE DEPTH (FATHOMS) | | NO. RETAINED | NO. RELEASED | NO. RETAINED | NO. RELEASED | | ARTIFICIAL PLUGS | SPOONS | FLASHERS W/[illegible] OR HOOTCHIES | |

*Comments* (enter appropriate date and any information which you consider to be important. This might include number, type, and position of Canadian and other foreign fishing vessels sighted and changes in weather conditions, feed supply, currents, water temperature, or any other factor which might influence the abundance and activities of salmon):

FIGURE 1. Example of troll fishery logbook page.

Analysis of logbooks indicated this to be a sufficiently comprehensive method for estimating shaker catches in the 5 major fishing areas along the Washington coast (Figure 2). These areas accounted for 95% and 93% of the chinook landed in Washington during 1970 and 1971, respectively, and 98% of the coho landed during both years.

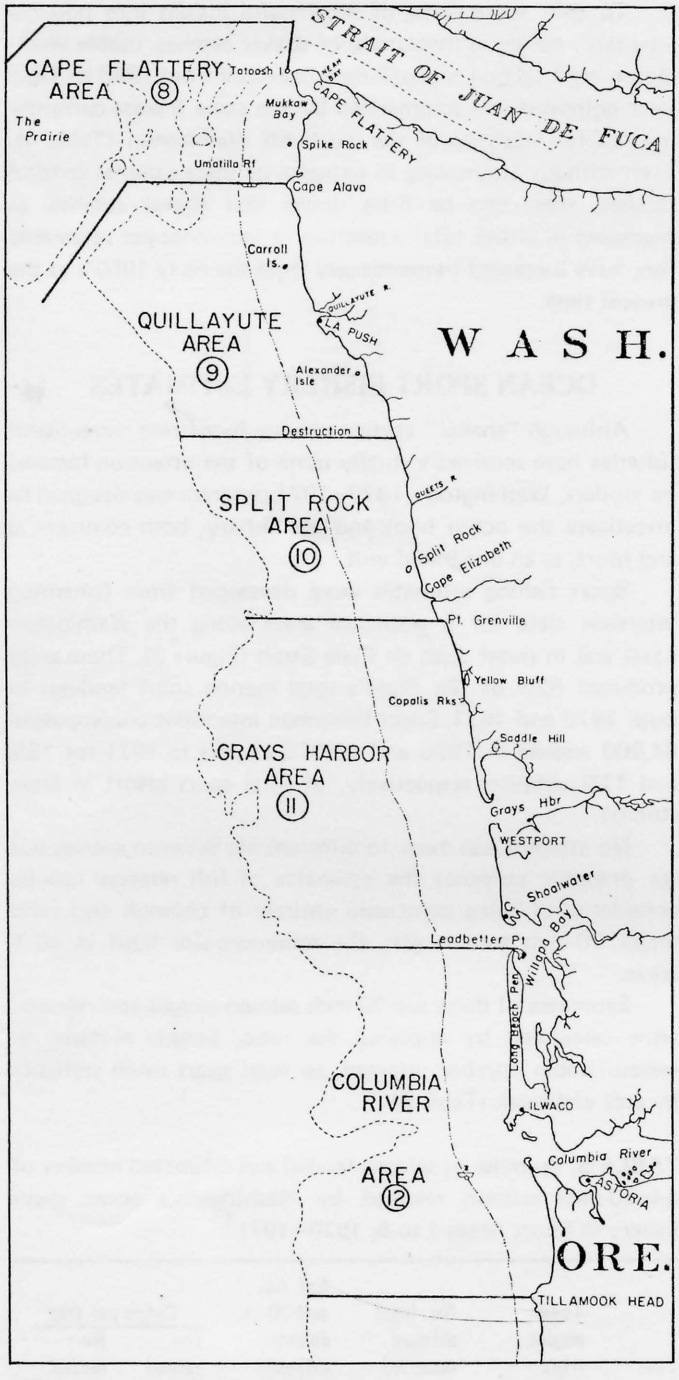



FIGURE 2. Troll salmon Areas 8 to 12.

For chinook, a species subjected to an April 15—October 31 fishing season with a 26-inch total-length minimum-size limit, number of fish released each year was calculated by application of the following formula to actual chinook landings by area and week:

$$\frac{\text{no. released in sample}}{\text{no. retained in sample}}\text{(actual landings)=no. released}$$

Results are summarized in Table 1.

**TABLE 1.** Number of chinook landed and estimated number of chinook released by Washington's commercial troll fishery in Troll Areas 8 to 12, 1970—1971

| Year | Number legal chinook retained (4/15-10/31) | Estimated number sub-26-inch chinook released | Sublegal/ legal ratio |
|---|---|---|---|
| 1970 | 203,877 | 220,828 | 1.08 |
| 1971 | 233,607 | 285,085 | 1.22 |

For coho salmon, with a June 15—October 31 fishing season, estimates of pre-season released were made by applying to the actual pre-June 15 chinook landings by area and week the ratio number of coho released in sample to number of chinook retained (Table 2).

**TABLE 2.** Number of chinook landed and estimated number of coho released by Washington's commercial troll fishery in Troll Areas 8 to 12 prior to June 15, 1970—1971

| Year | Number legal chinook retained (4/15-6/14) | Estimated number coho released | Pre-season coho/legal chinook ratio |
|---|---|---|---|
| 1970 | 104,899 | 37,168 | 0.35 |
| 1971 | 113,890 | 108,228 | 0.95 |

A third group, numbers of small coho caught and released during their regular June 15—October 31 fishing season, was estimated by applying the ratio, sample number coho released/sample number coho retained, to total coho landing statistics by area and week (Table 3).

**TABLE 3.** Number of coho landed and estimated number of small coho released from June 15 to October 31 by Washington's commercial troll fishery in Troll Areas 8 to 12, 1970—1971

| Year | Number legal coho retained (6/15-10/31) | Estimated number small coho chinook released | Sublegal/ legal ratio |
|---|---|---|---|
| 1970[1] | 732,676 | 69,699 | 0.10 |
| 1971[2] | 1,239,870 | 74,480 | 0.06 |

[1] 20-inch total-length minimum-size limit.

[2] No minimum-size limit 6/15—7/31; 16-inch total-length 8/1—10/31. Many fishermen and buyers, however, informally agreed to a 20-inch total-length minimum for all 1971 landings.

In addition to the logbook studies, a supplemental program of onboard observations during actual fishing operations was also initiated during 1970. While only a very small fraction of total fishing effort could be sampled in this manner, it did provide an alternate means for confirming the accuracy of logbook information supplied by fishermen. Emphasis was placed on the pre-June 15 fishery, with the combined 1970–1971 sample showing the following for a total of 50 individual fishing days:

584 legal chinook retained
480 sub-26-inch chinook released
299 coho released.

Onboard observations after June 15 were conducted only in 1970, with a sample of 26 fishing days producing the following catches:

48 legal chinook retained
265 sub-26-inch chinook released
479 legal coho retained
62 sub-20-inch coho released.

In general, area-time comparisons between onboard samples and logbook data indicated the latter to be a reliable method of collecting a large sample from the commercial fishery.

**TABLE 4.** Summary of 1948–1955 Washington troll salmon logbook observations for Troll Areas 8 to 12[1]

| | Cape Flattery (Area 8) | Quilla-yute (Area 9) | Split Rock (Area 10) | Grays Harbor (Area 11) | Columbia River (Area 12) |
|---|---|---|---|---|---|
| Number fishing days sampled | 501 | 369 | 89 | 254 | 15 |
| Number chinook retained, 3/15–10/31 | 6,497 | 1,820 | 411 | 4,486 | 353 |
| Number chinook released, 3/15–10/31 | 999 | 657 | 186 | 324 | 43 |
| Released/retained chinook ratio, 3/15–10/31 | 0.15 | 0.36 | 0.45 | 0.07 | 0.12 |
| Number chinook retained, 3/15–6/14 | 1,111 | 554 | 152 | 4,423 | 353 |
| Number coho released, 3/15–6/14 | 263 | 274 | 20 | 644 | 9 |
| Released coho/retained chinook ratio, 3/15–6/14 | 0.24 | 0.49 | 0.13 | 0.15 | 0.03 |
| Number coho retained, 6/15–10/31 | 9,537 | 9,796 | 2,578 | 324 | 0 |
| Number coho released, 6/15–10/31 | 233 | 127 | 66 | 18 | 0 |
| Released/retained coho ratio, 6/15–10/31 | 0.02 | 0.01 | 0.03 | 0.06 | |

[1]Regulations were: chinook season March 15–October 31 and minimum-size limit 26-inch total-length; coho season June 15–October 31 and minimum-size limit 22-inch total-length.

To gain some form of meaningful insight into possible long-term trends in magnitude of shaker catches, usable Washington troll salmon logbook data collected from 1948 to 1955 were compiled and summarized by the same 5 areas currently utilized for statistics of the catch off Washington (Table 4). Even without attempting to extrapolate these samples to total catches, there can be little doubt that shaker catches, as expressed in either total quantities or incidence per retainable fish, have increased tremendously from the early 1950's to the present time.

## OCEAN SPORT FISHERY ESTIMATES

Although "shaker" salmon catches by marine recreational fisheries have received virtually none of the attention focused on trollers, Washington's 1970–1971 program was designed to investigate the ocean hook-and-line fishery, both commercial and sport, as an integrated unit.

Sport fishing estimates were developed from fisherman interview data for 5 statistical areas along the Washington coast and in outer Juan de Fuca Strait (Figure 3). These areas produced 82% of the State's total marine sport landings in both 1970 and 1971. Sport fisherman interviews encompassed 84,900 anglers in 1970 and 65,370 anglers in 1971 for 15% and 11% samples, respectively, of total sport effort in areas studied.

No attempt was made to differentiate between species but for practical purposes the estimates of fish released can be considered as being composed entirely of chinook and coho under 20-inch total-length, the minimum-size limit in all 5 areas.

Estimates of these sub-20-inch salmon caught and released were calculated by applying the ratio, sample number released/sample number retained, to total sport catch statistics by area and week (Table 5).

**TABLE 5.** Number of salmon landed and estimated number of sub-20-inch salmon released by Washington's ocean sport fishery in Sport Areas 1 to 5, 1970–1971[1]

| Year | Total angler trips | No. legal salmon retained | Est. no. sub-20-in. salmon released | Catch per trip Re-tained | Catch per trip Re-leased |
|---|---|---|---|---|---|
| 1970 | 545,777 | 686,736 | 234,005 | 1.26 | 0.43 |
| 1971 | 584,661 | 988,479 | 204,983 | 1.69 | 0.35 |

[1]April 15–October 31 season in Areas 1 to 4; year-round season in Area 5. Daily bag limit of 3 salmon, regardless of species, in all areas.

In view of the well-known small-fish problem in the Columbia River mouth area (Heyamoto, 1963), a short-term summer test fishery was scheduled for 1971 to provide more definitive information on the area. Spoon and flasher gear was fished from a 20-ft. dory during 28 fishing days between August 5 and September 6. Insofar as existing weather and tidal conditions allowed, an attempt was made to equalize fishing effort in each of 6 areas off the river mouth. Results are summarized in Table 6. Both chinook and adult coho were commonly taken in all areas fished, although very pronounced day-to-day variations were encountered. Small coho appeared in quantity only north of the river mouth during the final week of fishing.

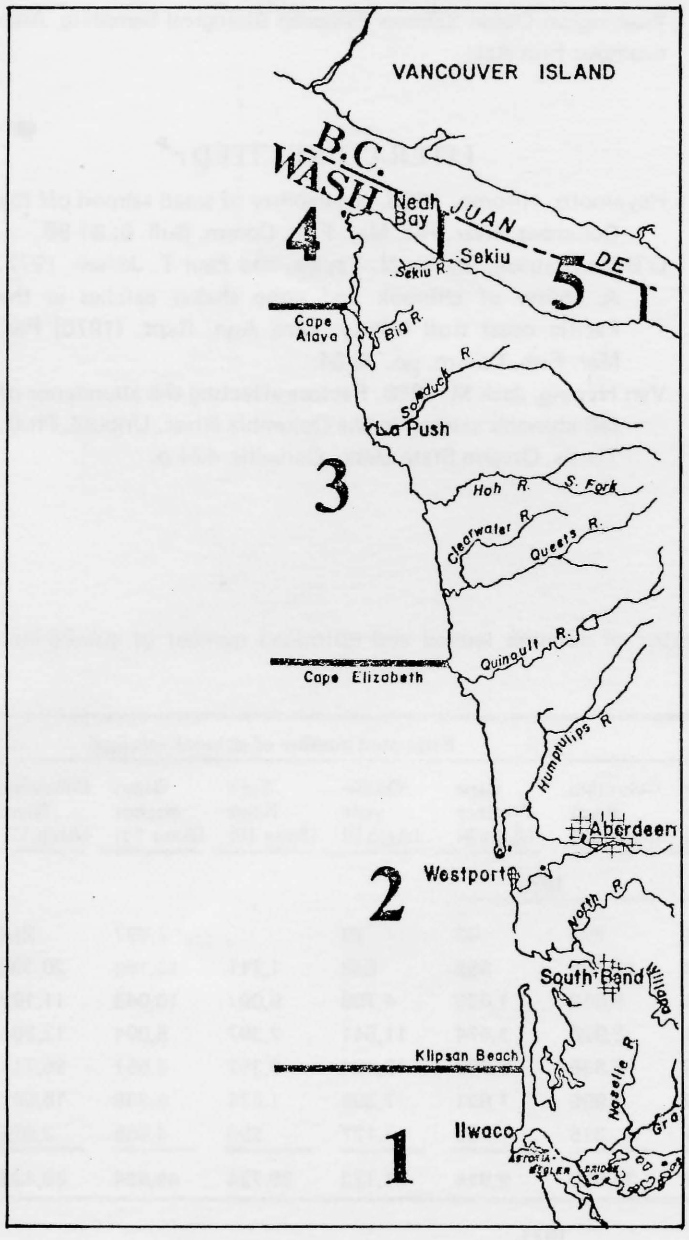



FIGURE 3. Sport salmon Areas 1 to 5.

Most chinook were small, with 235 of 251 fish measured being less than 26 inches in total length. These sub-26-inch fish demonstrated a pronounced mode extending from 34- to 54-centimeter fork-length or about 15- to 23-inch total-length (Figure 4). Sub-26-inch chinook measured during troll on-board observations from July through September 1970 showed a similar distribution. Sport fishery observations indicated that much of the shaker catch was generated during specific efforts to catch occasional legal-size fish from these populations of small chinook.

**TABLE 6**. Columbia River mouth troll test fishery catches, August—September 1971

| | Number of salmonids | | | | |
|---|---|---|---|---|---|
| Fishing area[1] | Chinook | Adult coho[2] | Small coho[3] | Trout (*Salmo sp.*) | Total |
| North— less than 10 fathoms | 57 | 18 | | | 75 |
| North— 10 to 20 fathoms | 60 | 105 | 46 | 3 | 214 |
| North— over 20 fathoms | 25 | 51 | 45 | | 121 |
| South— less than 10 fathoms | 38 | 91 | 1 | | 130 |
| South— 10 to 20 fathoms | 80 | 75 | 6 | 1 | 162 |
| South— over 20 fathoms | 11 | 34 | 3 | | 48 |
| All areas combined | 271 | 374 | 101 | 4 | 750 |

[1] Designations north and south refer to directions from an imaginary line drawn mid-way between seaward projections of the north or "black" buoy line and the south or "red" buoy line at the river's mouth.

[2] Adult or 3-year-old fish over 20-inch total-length.

[3] 2-year-old jacks and immatures less than 20-inch total-length.

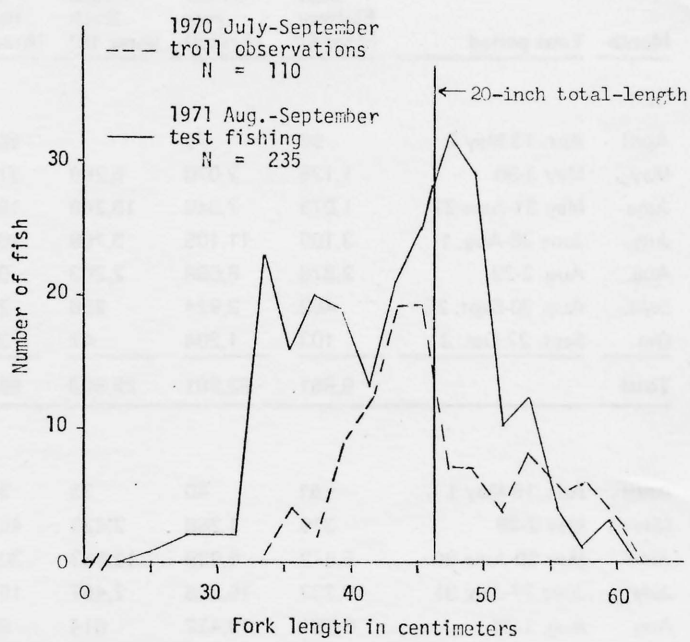



FIGURE 4. Size distribution samples of sub-26-inch chinook salmon taken off the Columbia River mouth, 1970-1971 (by 2-centimeter interval).

## SUMMARY

During the 1970 and 1971 fishing seasons, a study was conducted to estimate numbers of small salmon being hooked and released by Washington's ocean salmon fisheries. A logbook program was initiated to gather data on the troll fishery while fisherman interviews were utilized for ocean sport fishery information. Results were:

1. During the 2 fishing seasons, an estimated 1¼ million small salmon were hooked and released by commercial and recreational fisheries operating off the Washington coast.

2. Sub-26-inch chinook taken by trollers averaged over 250,000 per year at a rate of nearly 1.2 shakers per legal chinook landed.

3. Prior to the June 15 coho season opening, trollers released an average of about 70,000 coho or about 0.7 fish per chinook retained.

4. Trollers averaged an additional 70,000-plus small coho per year during the regular season for this species at an average rate of 0.07 fish per legal coho landed.

5. Ocean sport fishermen also hooked and released substantial quantities of small salmon. An average of nearly 220,000 per year was caught or about 0.4 fish per individual angler trip.

Tables 7 through 9 provide detailed statistics from which other tables in this report were prepared.



## ACKNOWLEDGEMENTS

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**TABLE 7.** Washington commercial troll fishery, 1970-1971: number of chinook landed and estimated number of sub-26-inch chinook released by month in 5 major fishing areas

| | | Number of chinook landed | | | | | Estimated number of chinook released | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Time period | Cape Flattery (Area 8) | Auilla-yute (Area 9) | Split Rock (Area 10) | Grays Harbor (Area 11) | Columbia River (Area 12) | Cape Flattery (Area 8) | Quilla-yute (Area 9) | Split Rock (Area 10) | Grays Harbor (Area 11) | Columbia River (Area 12) |
| | | | | | | | **1970** | | | | |
| April | Apr. 13-May 2 | 90 | 70 | | 16,594 | 756 | 90 | 70 | | 2,697 | 214 |
| May | May 3-30 | 1,126 | 2,070 | 5,259 | 37,813 | 13,909 | 556 | 848 | 1,711 | 10,156 | 20,396 |
| June | May 31-June 27 | 1,075 | 7,340 | 18,269 | 18,694 | 8,012 | 1,020 | 4,708 | 9,097 | 10,043 | 11,192 |
| July | June 28-Aug. 1 | 3,199 | 11,105 | 3,769 | 10,714 | 2,998 | 1,474 | 11,541 | 2,397 | 6,094 | 13,204 |
| Aug. | Aug. 2-29 | 2,876 | 8,088 | 2,203 | 9,248 | 5,536 | 5,088 | 19,434 | 5,352 | 9,551 | 25,711 |
| Sept. | Aug. 30-Sept. 26 | 492 | 2,924 | 256 | 2,720 | 1,999 | 1,631 | 7,395 | 1,574 | 6,238 | 15,091 |
| Oct. | Sept. 27-Oct. 31 | 103 | 1,204 | 47 | 3,004 | 315 | 55 | 7,127 | 593 | 4,855 | 3,625 |
| **Total** | | **8,961** | **32,801** | **29,803** | **98,787** | **33,525** | **9,914** | **51,123** | **20,724** | **49,634** | **89,433** |
| | | | | | | | **1971** | | | | |
| April | Apr. 15-May 1 | 61 | 40 | 33 | 3,818 | 1,438 | 17 | 10 | 13 | 3,235 | 1,185 |
| May | May 2-29 | 376 | 1,286 | 2,428 | 46,484 | 8,085 | 107 | 234 | 172 | 17,148 | 5,756 |
| June | May 30-June 26 | 5,642 | 9,929 | 12,953 | 30,488 | 11,135 | 2,055 | 4,554 | 2,175 | 11,966 | 10,127 |
| July | June 27-July 31 | 18,233 | 15,826 | 2,467 | 15,264 | 2,913 | 9,095 | 24,337 | 3,778 | 29,308 | 17,734 |
| Aug. | Aug. 1-28 | 8,181 | 10,432 | 614 | 9,223 | 5,171 | 11,916 | 29,861 | 649 | 15,247 | 11,698 |
| Sept. | Aug. 29-Sept. 25 | 942 | 1,208 | 148 | 2,903 | 2,522 | 6,905 | 18,165 | 444 | 11,424 | 7,464 |
| Oct. | Sept. 26-Oct. 31 | 83 | 715 | 32 | 2,376 | 158 | 747 | 23,238 | 96 | 2,186 | 2,039 |
| **Total** | | **33,518** | **39,436** | **18,675** | **110,556** | **31,422** | **30,842** | **100,399** | **7,327** | **90,514** | **56,003** |

**TABLE 8.** Washington commercial troll fishery, 1970-1971: number of coho landed and estimated number of coho released by month in 5 major fishing areas

| | | Number of coho landed | | | | | Estimated number of coho released | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Time period | Cape Flattery (Area 8) | Auilla-yute (Area 9) | Split Rock (Area 10) | Grays Harbor (Area 11) | Columbia River (Area 12) | Cape Flattery (Area 8) | Quilla-yute (Area 9) | Split Rock (Area 10) | Grays Harbor (Area 11) | Columbia River (Area 12) |
| | | | | | | 1970 | | | | | |
| April | Apr. 15-May 2 | | | | | | 676 | 526 | | 2,999 | 33 |
| May | May 3-30 | | | | | | 478 | 1,050 | 2,285 | 4,627 | 5,701 |
| | May 31-June 14 | | | | | | 585 | 1,126 | 2,794 | 10,273 | 4,015 |
| | June 15-27 | 6,794 | 62,289 | 43,669 | 14,560 | 29,900 | 204 | 1,238 | 869 | 709 | 2,631 |
| July | June 28-Aug. 1 | 14,392 | 104,089 | 40,012 | 34,271 | 49,686 | 830 | 3,586 | 355 | 1,862 | 3,906 |
| Aug. | Aug. 2-29 | 14,313 | 49,115 | 30,908 | 30,965 | 83,378 | 3,310 | 2,787 | 439 | 4,098 | 13,832 |
| Sept. | Aug. 30-Sept. 26 | 15,890 | 20,641 | 2,658 | 22,915 | 37,469 | 3,240 | 1,644 | 675 | 5,911 | 10,837 |
| Oct. | Sept. 27-Oct. 31 | 95 | 974 | 414 | 18,171 | 5,108 | 14 | 670 | 122 | 1,151 | 4,779 |
| **Total** | | **51,484** | **237,108** | **117,661** | **120,882** | **205,541** | **9,37** | **12,627** | **7,539** | **31,630** | **45,734** |
| | | | | | | 1971 | | | | | |
| April | Apr. 15-May1 | | | | | | 523 | 6 | 7 | 993 | 44 |
| May | May 2-29 | | | | | | 3,222 | 5,543 | 2,144 | 31,653 | 1,719 |
| | May 30-June 14 | | | | | | 3,097 | 28,961 | 13,956 | 13,414 | 2,946 |
| | June 15-26 | 14,566 | 57,055 | 11,775 | 60,886 | 98,370 | 1,981 | 1,788 | 34 | 3,141 | 4,820 |
| July | June 27-July 31 | 30,371 | 69,082 | 28,431 | 96,455 | 149,829 | 2,215 | 2 089 | 2,476 | 6,339 | 5,262 |
| Aug. | Aug. 1-28 | 64,894 | 72,894 | 11,833 | 103,891 | 152,305 | 3,711 | 4,120 | 808 | 4,338 | 9,026 |
| Sept. | Aug. 29-Sept. 25 | 18,725 | 11,565 | 3,711 | 63,146 | 82,461 | 2,440 | 830 | 1,400 | 6,826 | 6,892 |
| Oct. | Sept. 26-Oct. 31 | 491 | 687 | 243 | 31,254 | 4,950 | 348 | 134 | 92 | 1,751 | 1,619 |
| **Total** | | **129,047** | **211,283** | **55,993** | **355,632** | **487,915** | **17,537** | **43,471** | **20,917** | **68,455** | **32,328** |

**TABLE 9.** Washington ocean sport fishery, 1970-1971: number of salmon landed and estimated number of sub-20-inch salmon released by month in 5 major coast and outer Juan de Fuca Strait fishing areas

| | | Number of salmon landed | | | | | Estimated number of salmon released | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Time period | Ilwaco (Area 1) | Westport (Area 2) | LaPush (Area 3) | Neah Bay (Area 4) | Sekiu-Pillar Pt. (Area 5) | Ilwaco (Area 1) | Westport (Area 2) | LaPush (Area 3) | Neah Bay (Area 4) | Sekiu-Pillar Pt. (Area 5) |
| | | | | | | 1970 | | | | | |
| | Jan. 1-Apr. 12 | | | | | 4,149 | | | | | 1,207 |
| April | Apr. 13-May 3 | 624 | 2,642 | | 367 | 991 | 246 | 278 | | 30 | 289 |
| May | May 4-31 | 5,984 | 22,172 | 367 | 955 | 1,394 | 1,734 | 5,540 | | 78 | 340 |
| June | June 1-28 | 27,754 | 41,262 | 1,578 | 1,321 | 771 | 6,748 | 9,012 | 78 | 99 | 45 |
| July | June 29-Aug. 2 | 58,039 | 98,787 | 15,676 | 9,729 | 5,396 | 42,518 | 11,960 | 1,740 | 5,808 | 917 |
| Aug. | Aug. 3-30 | 127,750 | 99,669 | 15,529 | 22,650 | 6,607 | 56,550 | 21,548 | 3,388 | 8,288 | 2,091 |
| Sept. | Aug. 31-Sept. 27 | 46,658 | 35,390 | 3,524 | 11,564 | 10,867 | 33,005 | 8,446 | 795 | 5,351 | 1,965 |
| Oct. | Sept. 28-Nov. 1 | 2,423 | 3,450 | 220 | 73 | 404 | 2,234 | 1,330 | 48 | 53 | 46 |
| | Nov. 2-Dec. 31 | | | | | | | | | | |
| **Total** | | **269,232** | **303,372** | **36,894** | **46,659** | **30,579** | **143,035** | **58,314** | **6,049** | **19,707** | **6,900** |
| | | | | | | 1971 | | | | | |
| | Jan. 1-Apr. 11 | | | | | 2,849 | | | | | 883 |
| April | Apr. 12-May 2 | 877 | 12,168 | | 731 | 1,535 | 192 | 5,065 | | 51 | 683 |
| May | May 3-30 | 4,348 | 20,609 | 804 | 1,791 | 1,315 | 1,631 | 10,744 | 441 | 125 | 1,112 |
| June | May 31-June 27 | 28,941 | 73,811 | 3,434 | 3,398 | 4,458 | 3,622 | 16,182 | 1,291 | 238 | 1,815 |
| July | June 28-Aug. 1 | 78,889 | 110,387 | 7,381 | 19,731 | 11,365 | 19,532 | 25,629 | 2,629 | 3,460 | 2,431 |
| Aug. | Aug. 2-29 | 156,281 | 138,998 | 23,934 | 41,729 | 22,910 | 27,333 | 22,541 | 8,436 | 3,454 | 4,322 |
| Sept. | Aug. 30-Sept. 26 | 70,705 | 78,414 | 3,764 | 19,694 | 26,053 | 19,424 | 8,500 | 1,141 | 6,035 | 3,678 |
| Oct. | Sept. 27-Oct. 31 | 2,887 | 12,351 | 365 | 110 | 1,133 | 1,040 | 494 | 584 | 35 | 147 |
| | Nov. 1-Dec. 31 | | | | | 329 | | | | | 43 |
| **Total** | | **342,928** | **446,738** | **39,682** | **87,184** | **71,947** | **72,774** | **89,155** | **14,542** | **13,398** | **15,114** |

# Experimental Use of Barbless Hooks in Oregon's Troll Salmon Fishery

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Fish Commission of Oregon

# BULLETIN 8

PACIFIC MARINE FISHERIES COMMISSION
Portland, Oregon

1972

# EXPERIMENTAL USE OF BARBLESS HOOKS IN OREGON'S TROLL SALMON FISHERY[1]

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Fish Commission of Oregon

## ABSTRACT

Small salmon are caught and released by the ocean troll salmon fishery. Some mortality results and barbless hooks have been proposed as a "savings gear". A field study involving 8,500 chinook and coho salmon was made of the effectiveness of barbless, as compared to barbed, hooks for catching fish and for reducing immediate and delayed mortality of released fish. Barbless hooks caught fewer salmon, and caused fewer immediate mortalities, than did barbed hooks. The reductions were significant only with coho. The immediate and delayed mortality of both species was influenced by hooking location. It was concluded that the use of barbless hooks would decrease the value of Oregon's troll landings of salmon, but that benefits to other fisheries and to the resource itself might occur.

## INTRODUCTION

The Fish Commission of Oregon studied the effects that the use of barbless, rather than barbed, hooks would have on the ocean troll fishery for coho salmon *(Oncorhynchus kisutch)* and chinook salmon *(O. tshawytscha)*. The principal points considered were whether the barbless hooks were efficient for catching salmon and whether their use would reduce the hooking mortality of "shaker" salmon (fish released because of size or seasonal limitations). Analysis of the data for both of these considerations is reported in this paper.

## METHODS

Fishing with both barbed and barbless hooks was done from 11 different salmon trolling vessels during 5 seasons from 1959 to 1968. The boats involved and the time periods and areas fished are shown in Table 1. The barbed hooks used were conventional salmon hooks, sizes 5/0, 6/0, or 7/0. Identical hooks with barbs depressed were used as "barbless" hooks. This depressed barb formed a slight hump and may have provided some holding ability and also may have eliminated the ordinary barb's cutting and tearing action. The lures used were usually spoons or plastic "hootchies"; occasionally herring were used for bait. A barbed-hook lure used on one side of a boat was always opposed by an identical lure, but with a barbless hook, used at the same depth on the other side. The fishing gear was switched between boat sides in a predetermined but equal manner. Equal attention was given to removing fish from both sides of the boat. Fishing was done in the fisherman's usual manner and in the areas of his choice (within selected sections of the coast).

A biologist was present aboard each boat to record data and to tag fish. A standard procedure for landing, tagging, and releasing fish was adopted in 1962 to reduce bias due to handling. Fish were lifted aboard by the leader and were "shaken" by inverting the hook with a gaff in a manner similar to that used by most commercial salmon fishermen. Most fish were anesthetized with MS-222 and were placed in a recovery tank for observation after tagging. Fish were left in the recovery tank until they assumed a normal swimming position or died. This holding period ranged from a few minutes to several hours, but was 30 minutes or less for most of the fish. The anesthetic and recovery tank were not used during 1962; instead, fish were tagged and released as quickly as possible.

**TABLE 1.** Boats chartered, time periods and areas fished during barbless hook studies

| Year | Name of boat | Time period fished | Area fished |
|---|---|---|---|
| 1959 | Cluny | March 16 - April 14 | Off the Columbia River |
| 1959 | Flicker | May 26 - June 13 | Cascade Head to Ore.-California border |
| 1960 | Whisper | March 15 - April 14 | Off the Columbia River |
| 1962 | Barracuda | June 1 - June 25 | Off the Columbia River and Grays Harbor |
| 1962 | Elaine Dell | June 28 - July 28 | Off Coos Bay and Heceta Head |
| 1962 | Sea Lanes | July 30 - Aug. 12 | Off Newport and Heceta Head |
| 1962 | Dreamer | Aug. 20 - Sept. 27 | Off the Columbia River |
| 1967 | Ann Marie | April 18 - June 29 | Off the Columbia River |
| 1967 | Sea Fawn | July 21 - Sept. 9 | Port Orford |
| 1967 | Debra K | July 25 - Sept. 9 | Port Orford |
| 1968 | Alibi | May 19 - June 27 | Brookings |

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

Fish that were dead on landing or did not resume normal action in the recovery tank were considered immediate mortalities. During different years, fish were tagged with Petersen disc, spaghetti, or anchor tags. The return of tags from recaptured fish was on a voluntary basis. A reward of one dollar was paid for each tag returned. Tag return rates were used as an indication of delayed mortality.

## RESULTS

Catches for most boats were most numerous on barbed hooks, although some boats caught more fish on barbless hooks (Table 2). Combined boat data showed that 51.3, 50.7, and 52.0% of the legal-size chinook, sublegal chinook, and coho, respectively, were caught on barbed hooks.

To determine whether the differences between catches made by barbed and barbless hooks were statistically significant, the catch data from Table 2 were analyzed using a t-test for paired observations. Results of the analyses indicate that the differences in catch were statistically significant at the 95% confidence level for coho, but not for legal or sublegal chinook, whether considered separately or together.

### Immediate Mortality

The combined boat data indicated that barbed hooks resulted in a higher immediate mortality for both coho and sublegal chinook than did barbless hooks (Table 3). The immediate mortality rates for sublegal chinook caught on barbed and barbless hooks were 8.0 and 6.1%, respectively. The same values for coho were 12.6 and 8.6%, respectively. The total immediate mortality rates for both hook types were 7.0% for sublegal chinook and 10.7% for coho. A chi-square test of the combined boat data indicated that the difference in immediate mortality between barbed and barbless hooks was significant for coho at 95% confidence level, but was not significant for sublegal chinook.

### Delayed Mortality

Delayed mortality, defined as fish dying after release, is not estimated but its effect is indicated by comparing tag return rates from barbed and barbless hooks. A slightly higher percentage of tags was recovered from sublegal chinook caught initially on barbed hooks than on barbless (Table 4). The reverse was true for coho. Chi-square tests indicated that the differences in tag recovery rates for fish tagged from barbed and barbless hooks for all boats combined were not significant at the 95% confidence level for either coho or sublegal chinook.

### Effect of Hooking Location on Mortality

Hooking location had an effect on both immediate and delayed mortality of sublegal chinook (Table 5). Fish hooked in the gills and isthmus suffered higher immediate mortality losses (36.4 and 19.3%, respectively) than those hooked elsewhere. Fish that were hooked elsewhere experienced immediate mortalities of 2.9 to 7.4%.

Sublegal chinook hooked in the maxillary yielded the highest rate of tag recovery among the various hooking-location categories, 35.7% of those released, (the return rate of 34.6% cited in Table 5 is based on the total number of fish caught). The effect of hooking location on delayed mortality was estimated using the assumption that fish hooked in the maxillary did not experience delayed mortality. This assumption may be questionable because it does not consider delayed losses among maxillary-hooked fish due to fatigue, but it does allow the calculation of relative delayed mortality. Therefore, it was assumed that the 64.3% of the maxillary-hooked fish that were not recovered died due to natural (non-hooking related) mortality or lived but were not recovered. It was further assumed that the rates of natural mortality and nonrecovery were the same for all fish regardless of hooking-location. By using these assumptions, the delayed mortality

**TABLE 2.** Numbers of salmon caught using lures with barbed and barbless hooks fished simultaneously and in a similar manner

| | | Chinook | | | | Coho | |
|---|---|---|---|---|---|---|---|
| | | Legal | | Sublegal | | | |
| Year | Boat | Barbed hooks | Barbless hooks | Barbed hooks | Barbless hooks | Barbed hooks | Barbless hooks |
| 1959 | Cluny | 119 | 106 | 62 | 39 | 6 | 2 |
| 1959 | Flicker | 21 | 17 | 19 | 20 | 71 | 69 |
| 1960 | Whisper | 87 | 69 | 32 | 28 | 0 | 0 |
| 1962 | Barracuda | 42 | 38 | 27 | 22 | 170 | 136 |
| 1962 | Elaine Dell | 42 | 68 | 23 | 18 | 318 | 303 |
| 1962 | Sea Lanes | 15 | 12 | 7 | 7 | 358 | 314 |
| 1962 | Dreamer | 6 | 3 | 29 | 17 | 186 | 131 |
| 1967 | Ann Marie | 207 | 213 | 604 | 630 | 705 | 710 |
| 1967 | Sea Fawn | 53 | 57 | 93 | 78 | 70 | 57 |
| 1967 | Debra K | 99 | 82 | 110 | 109 | 163 | 153 |
| 1968 | Alibi | 51 | 40 | 94 | 101 | 483 | 456 |
| Total | | 742 | 705 | 1,100 | 1,069 | 2,530 | 2,331 |
| % | | 51.3 | 48.7 | 50.7 | 49.3 | 52.0 | 48.0 |

**TABLE 3.** Immediate mortality rates for salmon caught on barbed and barbless hooks (numbers and percentages are for fish that were designated immediate mortalities)

| | Sublegal Chinook | | | | Coho | | | |
|---|---|---|---|---|---|---|---|---|
| | Barbed hooks | | Barbless hooks | | Barbed hooks | | Barbless hooks | |
| Boat | No. | % | No. | % | No. | % | No. | % |
| Cluny | 62 | 11.3 | 39 | 2.6 | 6 | 83.3 | 2 | 100.0 |
| Flicker | 19 | 21.1 | 20 | 0.0 | 71 | 9.9 | 69 | 11.6 |
| Barracuda | 27 | 0.0 | 22 | 4.6 | 0 | | 0 | |
| Elaine Dell | 22 | 4.6 | 18 | 5.6 | 0 | | 0 | |
| Sea Lanes | 7 | 0.0 | 7 | 14.3 | 0 | | 0 | |
| Dreamer | 28 | 7.1 | 17 | 0.0 | 0 | | 0 | |
| Ann Marie | 604 | 8.8 | 630 | 8.3 | 500 | 8.6 | 505 | 6.3 |
| Sea Fawn | 93 | 6.5 | 78 | 0.0 | 0 | | 0 | |
| Debra K | 110 | 3.6 | 109 | 2.8 | 0 | | 0 | |
| Alibi | 94 | 8.5 | 101 | 4.0 | 483 | 16.4 | 456 | 10.3 |
| Total | 1,066 | 8.0 | 1,041 | 6.1 | 1,060 | 12.6 | 1,032 | 8.6 |

**TABLE 4.** Numbers of salmon tagged from barbed and barbless hooks and percentages of tags recovered

| | Sublegal Chinook | | | | Coho | | | |
|---|---|---|---|---|---|---|---|---|
| | Barbed hooks | | Barbless hooks | | Barbed hooks | | Barbless hooks | |
| Boat | No. | % | No. | % | No. | % | No. | % |
| Cluny | 55 | 18.2 | 38 | 18.4 | 1 | 0.0 | 0 | |
| Flicker | 15 | 0.0 | 20 | 15.0 | 64 | 15.6 | 61 | 18.0 |
| Barracuda | 27 | 14.8 | 21 | 9.5 | 12 | 8.3 | 13 | 30.8 |
| Elaine Dell | 21 | 14.3 | 17 | 17.7 | 1 | 0.0 | 0 | |
| Sea Lanes | 7 | 0.0 | 6 | 0.0 | 26 | 0.0 | 21 | 0.0 |
| Dreamer | 26 | 11.5 | 17 | 11.8 | 8 | 0.0 | 7 | 0.0 |
| Ann Marie | 551 | 40.7 | 578 | 36.9 | 457 | 36.3 | 473 | 38.7 |
| Sea Fawn | 87 | 26.4 | 78 | 26.9 | 0 | | 0 | |
| Debra K | 106 | 16.0 | 106 | 15.1 | 0 | | 0 | |
| Alibi | 86 | 23.3 | 97 | 20.6 | 404 | 21.3 | 409 | 26.7 |
| Total | 981 | 31.0 | 978 | 29.4 | 973 | 27.0 | 984 | 31.2 |

**TABLE 5.** Effect of hooking location on mortality of sublegal chinook (based on combined barbed and barbless hook data)

| | | Mortality | | | | | | Tag recovery | |
|---|---|---|---|---|---|---|---|---|---|
| | | Immediate | | Delayed[1] | | Total | | | |
| Hooking location | Number caught | No. | % | No. | % | No. | % | No. | % |
| Snout | 234 | 7 | 3.0 | 6 | 2.6 | 13 | 5.6 | 75 | 32.1 |
| Corner of mouth | 444 | 33 | 7.4 | 27 | 6.1 | 60 | 13.5 | 120 | 27.0 |
| Maxillary | 280 | 8 | 2.9 | 0 | 0.0 | 8 | 2.9 | 97 | 34.6 |
| Eye | 158 | 8 | 5.1 | 33 | 20.9 | 41 | 26.0 | 21 | 13.3 |
| Gills | 55 | 20 | 36.4 | 7 | 12.7 | 27 | 49.1 | 5 | 9.1 |
| Tongue | 23 | 1 | 4.3 | 1 | 4.3 | 2 | 8.6 | 7 | 30.4 |
| Cheek | 442 | 30 | 6.8 | 11 | 2.5 | 41 | 9.3 | 136 | 30.8 |
| Lower jaw | 324 | 11 | 3.4 | 11 | 3.4 | 22 | 6.8 | 101 | 31.2 |
| Isthmus | 119 | 23 | 19.3 | 9 | 7.6 | 32 | 26.9 | 25 | 21.0 |

[1]Delayed mortality = 0.357 x (Number caught - Immediate mortality) - number of tag recoveries.

was calculated for fish in each category by the equation: Delayed mortality = 0.357 x (number caught - immediate mortality) - number of tag recoveries. The estimates of delayed mortality among sublegal chinook are listed in Table 5. Fish that were hooked in the eye and gills suffered the highest rates of delayed mortality, 20.9 and 12.7%, respectively. The total delayed mortality loss was 5.1%. Total loss, immediate plus delayed, among sublegal chinook was 11.8%. Depending upon hooking location, total mortalities ranged from 2.9% for fish hooked in the maxillary to 49.1% for fish hooked in the gills.

Immediate and delayed mortality among coho also appeared to be affected by hooking location (Table 6). Immediate mortalities were highest for fish hooked in the tongue, isthmus, or gills (22.2, 34.9, and 44.4%, respectively). As with sublegal chinook, coho that had been hooked in the maxillary gave the highest rate of tag recovery (40.2% of those released). Delayed mortality rates were calculated for coho using the assumptions and equation given previously for sublegal chinook (with the substitution of 0.402, the tag recovery rate for maxillary hooked coho, for 0.357). Delayed losses for coho hooked in the isthmus, gills, tongue, or eye ranged from 10.4% for the isthmus to 28.8% for the eye hooked fish. Delayed mortality for all coho regardless of hook location was 8.0%. Immediate and delayed mortalities totalled 18.4% for all coho and ranged from 6.2 to 55.5% for those hooked in the maxillary or gills, respectively.

## DISCUSSION

Some effects of using barbless hooks are apparent from examination of tables showing fish caught, tags recovered, and observed (immediate) and calculated (delayed and immediate plus delayed) mortality. The merits of the hook depend on the collective effect and on the fate of fish "saved" by using barbless hooks. Judgment of the benefit of this hook is made for the fisheries on chinook and coho separately after a comparison of the data on hooking mortality with those of other workers. Van Hyning (1951) reports that 1.9 and 2.5% of the 794 coho and 393 chinook, respectively, caught off the Oregon coast during tagging studies in 1948 and 1949 were dead when boated. Milne and Ball (1956) considered 12 of 67 (16.4%) troll-caught coho, 15 to 24 inches in length, to be unsuitable for tagging; these fish were probably equivalent to the "immediate mortalities" of other authors. In addition, 29.1% of the remaining tagged coho, died during a 34-day period in which they were held in a large floating wire-mesh pound, anchored in a bay. They also reported in another experiment that 8 of 18 (44.4%) coho, 8 to 16 inches in length, were almost dead on landing. In a later publication, Milne and Ball (1958) stated, regarding fish caught on barbless hooks, "the fish were retained in a live box on the boat for at least one hour after they were caught and tagged. Following this procedure 17.6% . . . of the coho salmon, and 19.8% . . . of the spring [chinook] salmon were unsuitable for tagging purposes." Parker, Black, and Larkin (1959) estimated that 43.7% of 115 troll-caught coho died within 14 hours after capture while being held in a live box. They also suggested that death need not be caused by physical damage alone, but may accompany high concentrations of blood lactic acid caused by hyperactivity and severe exhaustion. However, Ellis (1964) suggested that the high blood lactate levels might have been caused partially by confinement in the live box.

Total hooking mortality estimates derived in this study of 18.4% for coho and 11.8% for sublegal chinook are generally lower than those reported by other workers. One reason for this is the use, in our estimates, of the tag recovery rate for maxillary-hooked fish as if there were no delayed mortality or unknown tag losses for that category of fish.

### Chinook

Barbed hooks caught slightly more legal and sublegal chinook than did barbless hooks (Table 2), but the differences in catch were not statistically significant. However, this catch differential will be used to estimate the effect that the use of barbless hooks could have on Oregon's troll catch of chinook in terms of pounds and value. During the 1969 season,

**TABLE 6.** Effect of hooking location on mortality of coho caught by the boats *Ann Marie* and *Alibi* (based on combined barbed and barbless hook data)

| Hooking location | Number caught | Mortality: Immediate No. | Immediate % | Delayed[1] No. | Delayed % | Total No. | Total % | Tag recovery No. | Tag recovery % |
|---|---|---|---|---|---|---|---|---|---|
| Snout | 327 | 13 | 4.0 | 24 | 7.6 | 37 | 11.6 | 102 | 30.9 |
| Corner of mouth | 313 | 31 | 9.9 | 13 | 4.5 | 44 | 14.4 | 100 | 31.6 |
| Maxillary | 257 | 16 | 6.2 | 0 | 0.0 | 16 | 6.2 | 97 | 37.7 |
| Eye | 250 | 24 | 9.6 | 72 | 28.8 | 96 | 38.4 | 19 | 7.6 |
| Gills | 9 | 4 | 44.4 | 1 | 11.1 | 5 | 55.5 | 1 | 11.2 |
| Tongue | 9 | 2 | 22.2 | 2 | 22.2 | 4 | 44.4 | 1 | 11.2 |
| Cheek | 302 | 17 | 5.6 | 11 | 3.6 | 28 | 9.2 | 104 | 34.4 |
| Lower jaw | 282 | 27 | 9.6 | 13 | 4.2 | 40 | 13.8 | 89 | 31.9 |
| Isthmus | 192 | 67 | 34.9 | 20 | 10.4 | 87 | 45.3 | 30 | 15.6 |

[1] Delayed mortality = 0.402 x (Number caught - Immediate mortality) - number of tag recoveries.

140,285 troll-caught chinook were landed in Oregon (Reed, 1970). Based on data in Table 2, barbless hooks will catch 95.0% as many legal-size chinook as will barbed hooks. Therefore, if barbless hooks had been used exclusively during 1969, approximately 7,000 fewer chinook would have been caught. The percentage age composition of the 1969 troll catch of chinook was 76.0, 22.8, and 0.9 as 3rd-, 4th-, and 5th-year fish, respectively (Reed and McQueen, 1971). There were traces of 2nd- and 6th-year fish, but because of their relative insignificance, they were disregarded. This age composition indicates that of the 7,000 fish that would have been lost from barbless hooks (assuming random hooking and loss), approximately 5,300, 1,600, and 60 would have been 3rd-, 4th-, and 5th-year fish respectively. Assuming an average dressed weight of 8, 12, and 18 pounds per fish for those age groups, respectively, we calculated that the immediate reduction in chinook landings in 1969 would have been 62,700 pounds (dressed weight). Data obtained from recoveries from legal-size chinook tagged and released from the *Ann Marie* and *Alibi* indicated that 6.9% were recaught by troll fishermen off Oregon. Fish that simply escaped from a hook likely would be less severely injured than those that were boated, tagged, and released. Therefore, a recapture rate of 6.9% is probably too low for fish that would have escaped from barbless hooks. Also the 6.9% does not include any corrections for tag loss or non-reporting of recovered tags. If we assume a recapture rate of 15% by trollers off Oregon (approximately 2 times as great as that obtained from the *Ann Marie* and *Alibi* experiments), then 800, 240 and 9 of the 3rd-, 4th-, and 5th-year fish, respectively, that would have escaped from barbless hooks would be caught subsequently. Age composition data of Oregon's troll chinook catch indicates that for an average year class, 70.7, 26.9, and 2.4% of the fish caught from that class would be 3rd-, 4th-, and 5th-year fish, respectively. Using these percentages, it was calculated that of the 800 escaped 3rd-year fish that we have assumed would be recaught, approximately 570 would have been caught in 1969 as 3rd-year fish, 210 in 1970 as 4th-year fish, and 20 in 1971 as 5th-year fish. Using the average weights given above, the total dressed weight of these recaught fish would have been 7,400 pounds. In like manner, the weight of fish caught after having escaped from barbless hooks as 4th- and 5th-year fish in 1969 was calculated to be approximately 3,100 pounds.

The combined weight of the fish caught after escaping from the barbless hooks would have been 10,500 pounds. As calculated initially, the immediate loss due to fish escaping from barbless hooks, if they had been used exclusively, would have been 62,700 pounds in 1969. However, if this loss were corrected for subsequent capture of some of the escaped fish, the estimated net loss to Oregon fishermen would decrease to 52,200 pounds.

It is also possible to estimate the effect that barbless hooks would have on the value of Oregon's chinook landings by using age composition and average weight data and assumptions noted above. The immediate loss of 62,700 pounds due to fish escaping in 1969 would have been composed of 42,400 pounds of medium (8 to 12 pounds), and 20,300 pounds of large (12 and over) chinook. Using the highest prices paid per pound of dressed weight to fishermen in 1969 (63 cents for medium and 80 cents for large chinook), the immediate loss in 1969 would have been $43,000. The calculations involved in determining poundage values indicate that the subsequent capture of some of the fish that escaped from barbless hooks would have yielded 4,600 pounds of medium and 6,000 pounds of large chinook. Using these weights and the highest prices paid to fishermen during the appropriate year of capture, the subsequently caught fish would have been worth approximately $7,700. This $7,700 when subtracted from the immediate loss of $43,000 results in an estimated net loss of $35,300.

Other points to consider when evaluating barbless hooks are immediate and delayed mortality of chinook shakers. During the 1970 troll season, the only season for which we have adequate data, the estimated catch of shaker chinook was 72,600 fish. Assuming that all were caught on barbed hooks, the data in Table 3 indicate that 8.0% or 5,800 of these shakers would be immediate mortalities. The data in Table 2 indicate that barbless hooks caught approximately 97% as many sublegal chinook as did barbed hooks. Therefore, if barbless hooks had been used exclusively during the 1970 season, an estimated 70,000 shaker chinook would have been caught. Table 3 indicated that 6.1% of the sublegal chinook caught on barbless hooks would be dead when released. This suggests that in 1970, if barbless hooks had been used, there would have been an estimated immediate mortality of 4,300 instead of 5,800 shaker chinook, or a saving of 1,500 fish. Using the same 15% recapture rate previously used for estimating the effects of barbless hooks on landed weight and value, it was calculated that approximately 225 of the 1,500 chinook would have been caught by trollers off Oregon. Using the average dressed weights of 8, 12, and 18 pounds for 3rd-, 4th-, and 5th-year chinook, respectively, and the average age-at-capture data previously used, it was calculated that the probable value of these 225 fish when recaught would have been $1,500. This value represents an estimate of the gain that would result from the use of barbless hooks, due to reduction of immediate mortality of shaker chinook.

Because barbless hooks could affect delayed mortality of shaker chinook, estimates of loss were developed for individual hook types (but are not presented) as has been done for combined hook types in Table 5. Delayed mortality rates for sublegal chinook released from barbed and barbless hooks are 7.3 and 6.9%, respectively. As stated previously, the estimated catch of shaker chinook during the 1970 troll season was 72,600 fish, of which 5,800 were immediate mortalities, based on the assumption that all were caught on barbed hooks or that few or insignificant numbers of barbless hooks were used in the fishery. If the 7.3% delayed mortality rate is applied to the remaining 66,800 fish, the estimated number of deaths due to delayed mortality would be 4,900. If only barbless hooks had been used in the 1970 fishery, the estimated catch of shakers would have been 70,000, of which 4,300 would have been immediate mortalities. When the 6.9% delayed mortality rate for barbless hooks is applied to the remaining 65,700 fish, the estimated number of delayed deaths is 4,500. The 400 fish difference between the number of shakers that died after release from barbed hooks and those that died after release from barbless hooks represents another saving. Using the recapture rate, ages, and average dressed weights given above, we calculated that this saving in fish would be worth about $300 to the troll fishermen.

In using an assumed 15% recapture rate to evaluate the total losses and gains for the troll chinook fishery that would acrue from the use of barbless hooks, we concluded that the effect would be a net loss of $33,500 per year for Oregon salmon trollers. The values used in determining this net loss were spread over 1 to 4 years because some of the fish lost from barbless hooks would be recaught in succeeding years. However, if barbless hooks were used for several consecutive years, the average annual net loss would presumably be about $33,500.

Because the assumed recapture rate of 15% is low, the predicted effect of using barbless hooks exclusively in the chinook fishery was recalculated using a high recapture rate. Unpublished data of the Fish Commission indicate that some of Oregon's chinook and coho stocks are subjected to a fishing intensity of approximately 75% in the ocean. Using 75% as a recapture rate, the predicted effect of barbless hooks would be a net gain of $4,500 per year in the value of chinook landings.

## Coho

Barbed hooks caught significantly more coho than did barbless hooks. The difference in catch between the 2 hook types will be used to estimate the effect that barbless hooks might have on Oregon's troll catch of coho in terms of pounds and value. During the 5-year period 1966-1970, the average annual landing of troll-caught coho in Oregon was 806,992 fish weighing 5,358,977 pounds (dressed weight). The 5-year average was used (in contrast to a single year's landings of chinook) because of the great variation in coho landings during recent years. The data in Table 2 indicate that barbless hooks will catch 92% as many coho as will barbed hooks. Therefore, if barbless hooks had been used exclusively, the average catch would probably have been 742,433 coho or approximately 64,600 fish (429,000 pounds) less than were caught on barbed hooks. Data obtained from recoveries of coho tagged and released from the *Ann Marie* and *Alibi* indicate that about 7.3% of the released fish were recaught by boats fishing in Oregon waters. As mentioned in the discussion of chinook, this value is probably lower than that occurring among fish that simply escape from a hook. The same estimate of recapture rate by trollers off Oregon (15%) will be used for coho that was used for chinook. The 15% rate indicates that approximately 9,700 of the 64,600 coho that probably would have escaped from barbless hooks would have been recaught. Since coho are normally maturing during the only season in which they are available to fishermen, the problem involved in calculating recapture in succeeding years is not present. However, coho normally show a significant amount of growth during their final year. This makes it necessary to consider the growth that would occur during the interval between escape from barbless hooks and subsequent capture. During the seasons 1966-1970, in Oregon, the average gain in dressed weight for coho between June and September was 2.4 pounds. Presumably, a fish that escaped from a barbless hook in June and was subsequently caught in September would have gained an estimated 2.4 pounds. Since all the escaped fish that were subsequently caught were not at large that long, we will assume that the average increase in dressed weight that occurred before the capture of the average escaped fish was 1.5 pounds. This indicates that the 9,700 coho that probably would have been recaught would have weighed an estimated 79,000 pounds; therefore, the net reduction in average landings would have been 350,000 pounds (dressed weight). The average price paid to fishermen for coho during the 1969-71 seasons was 49 cents per pound. At this price, the value of the lost fish would have been approximately $171,500.

We also estimated the effects that barbless hooks would have on the immediate mortality of coho shakers. During the entire 1970 troll season, an estimated 72,700 coho were released by commercial fishermen in Oregon waters. Applying the same 92% catch efficiency for barbless hooks that was used initially, we estimated that the released or shaker coho catch probably would have been about 66,900 fish, if barbless hooks had been used. According to the data in Table 3, we expect that approximately 12.6 and 8.6% of the coho shakers released from barbed or barbless hooks, respectively, would be immediate mortalities. These percentages were applied to the shaker number estimates, resulting in immediate mortality values of 9,200 and 5,800 for the coho caught on barbed and barbless hooks, respectively. Using the 3,400-fish reduction in immediate mortality and the assumed 15% recapture rate, we estimated that approximately 500 more coho would have been caught subsequently as a result of the reduction in immediate mortality of shakers by use of barbless hooks. The dressed weight and price information used above indicates that these 500 coho would have been worth about $1,600.

The effect of barbless hooks on the delayed mortality of coho shakers was determined. No decrease in delayed mortality could be attributed to their use; in fact, the data suggest an increase in delayed mortality, a finding that was not used because of inconsistency with the balance of the data.

From the data presented above and an assumed 15% recapture rate, we infer that the effect of the exclusive use of barbless hooks on Oregon's landings of troll-caught coho would be a net loss of approximately $170,000 per year. The effect of using the 75% recapture rate for reasons mentioned when discussing chinook was a net loss of $8,300.

## Chinook plus Coho

The predicted combined effect on the chinook and coho troll fisheries of Oregon as a result of using barbless hooks exclusively is an annual net loss ranging from approximately $3,800 to $203,500.

## Other Considerations

While the estimates derived above show the use of barbless hooks to be of no direct monetary benefit to the troller, both he and the resource manager should consider other benefits before passing judgment. Barbless hooks are easier to remove from either salmon or "scrap fish", which reduces the time that hooks are out of the water. When fishing is good, the additional fishing time and ease are meaningful.

Fish that escape barbless hooks are not lost to the resource. Some succumb to natural mortality but most survive to be taken by other fisheries or to add to the spawning escapement. Their worth in this role could be estimated but the considerations involved would make the estimates questionable.

The benefits to the resource from the use of barbless hooks in the troll fishery may be negative or at best only slightly positive. The use of barbless hooks will not eliminate the shaker mortality problem and the gains may not justify the problems of enforcement if the use of barbless hooks were required by regulation. Even so, trollers may find use of the barbless hook to their liking.

## CONCLUSIONS

Considerations of the data and arguments presented above lead to these conclusions.

1. Barbless hooks are not as effective in catching salmon using commercial trolling techniques as are barbed hooks.
2. Barbless hooks would reduce the mortality of salmon hooked and released by the troll fishery, but would not solve the "shaker" problem.
3. Hooking location greatly influences immediate and delayed mortality rates.
4. Barbless hooks would reduce immediate mortality, but would be less effective regarding delayed mortality.
5. Requiring use of barbless hooks by all trollers would not materially increase the number of salmon harvested by trollers, and it might reduce the poundage and/or value of the trollers' catch.
6. Other fisheries and the spawning escapement would benefit from the use of barbless hooks by trollers. Gains made here might compensate for losses to the trollers.

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# Geographical Origin, Trends and Timing of Washington's Troll Salmon *(Oncorhynchus)* Catches, 1960-1969

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# GEOGRAPHICAL ORIGIN, TRENDS AND TIMING OF WASHINGTON'S TROLL SALMON *(ONCORHYNCHUS)* CATCHES, 1960-1969

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## ABSTRACT

In order to present troll salmon statistics in their most effective format for overall management needs, areas of origin were established in 1970 for ocean catches and past landing statistics were converted to this new area format. Results demonstrated that, during the 1960's, five areas adjacent to Washington's coast ranked as the top producers for chinook and coho, the two species actively sought. A marked decline was noted for numbers of salmon caught off Canada and landed in Washington by U.S. fishermen.

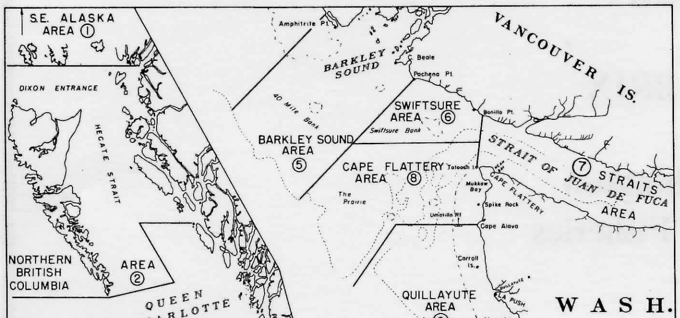


FIGURE 1. Areas established for the 1970 season.

## INTRODUCTION

Historically, Washington's troll salmon catches were reported by district landed in rather than area actually captured in. This persisted in spite of knowledge that some fish landed in Washington were being caught in such distant regions as Hecate Strait and Southeastern Alaska (Kauffman, 1951). Troll fleet studies in 1967 indicated that catch reporting by area caught was preferable (Wright, 1970), thus 15 geographical zones or areas were established for the 1970 season (Figure 1). To provide a background of comparable data, statistics for the 10-year period, encompassing the years 1960 through 1969, were converted to the same format for the 3 major salmon species in the fishery—chinook *(O. tshawytscha)*, coho *(O. kisutch)*, and pink *(O. gorbuscha)*.

## METHODS

To convert from area landed to area caught, sample data obtained during Washington's troll port sampling program were extrapolated to each year's total catch statistics by species, major catch area, and weekly period. These samples consisted basically of oral fisherman interviews conducted while sampling catches for the incidence of fin-marked fish and other biological data. During the 1960-1969 period, a total of 377,922 chinook, 1,348,245 coho, and 304,252 pink were sampled for catch origin information (Table 1).

## RESULTS

### Chinook and Coho Salmon

Troll effort may be directed toward both of these species simultaneously or specifically toward either one with the second being taken only incidentally. Due to this interrelationship of effort, chinook and coho were considered as a unit.

Catches averaged 157,546 chinook per year during the 1960–1969 period with the Grays Harbor area producing 32.1% of the total catch (Table 2). For coho, catches averaged 637,029 fish per annum with Columbia River (28.2%) and Quillayute (27.6%) being the leading areas (Table 3). The top 5 areas for both species were those adjacent to the Washington coast.

Trends were examined from north to south by area in terms of percent of total catch for each species (Figure 2). A striking decline was apparent in quantities of both species caught off Canada and landed in Washington. Chinook declined from a 30% level in the early 1960's to less than 5% late in the period, while coho declined from 20% to a similar low. Cape Flattery, the area adjacent to Canada, also suffered a moderate decline for both species. Four Washington coastal areas to the south, however, showed increasing or at least stable trends for chinook and coho production: Quillayute, Split Rock, and Columbia River generally increasing; and Grays Harbor generally stable. Total numbers listed in Tables 2 and 3 followed the same trends as percentages depicted in Figure 2.

By averaging weekly catches during the 10-year period, a composite of catch timing was determined for 5 fishing areas off the Washington coast (Figure 3). Chinook entered the fishery in significant numbers for a much longer period than coho and a definite south to north progression in catch timing is evident. A general northward dispersion of chinook during the spring and summer months is implied. The known southerly migration of maturing fish is evident only from Grays Harbor to the Columbia River during the fall months. Only the latter area demonstrates more than one definite catch mode. Coho catches were confined to the June 15–October 31 season, but nevertheless, surpassed chinook considerably by late June or early July in all areas. Catch timing, peaking in July and August, was reasonably consistent in all areas with the only obvious deviation being maintenance of significant catches throughout October in the Grays Harbor area.

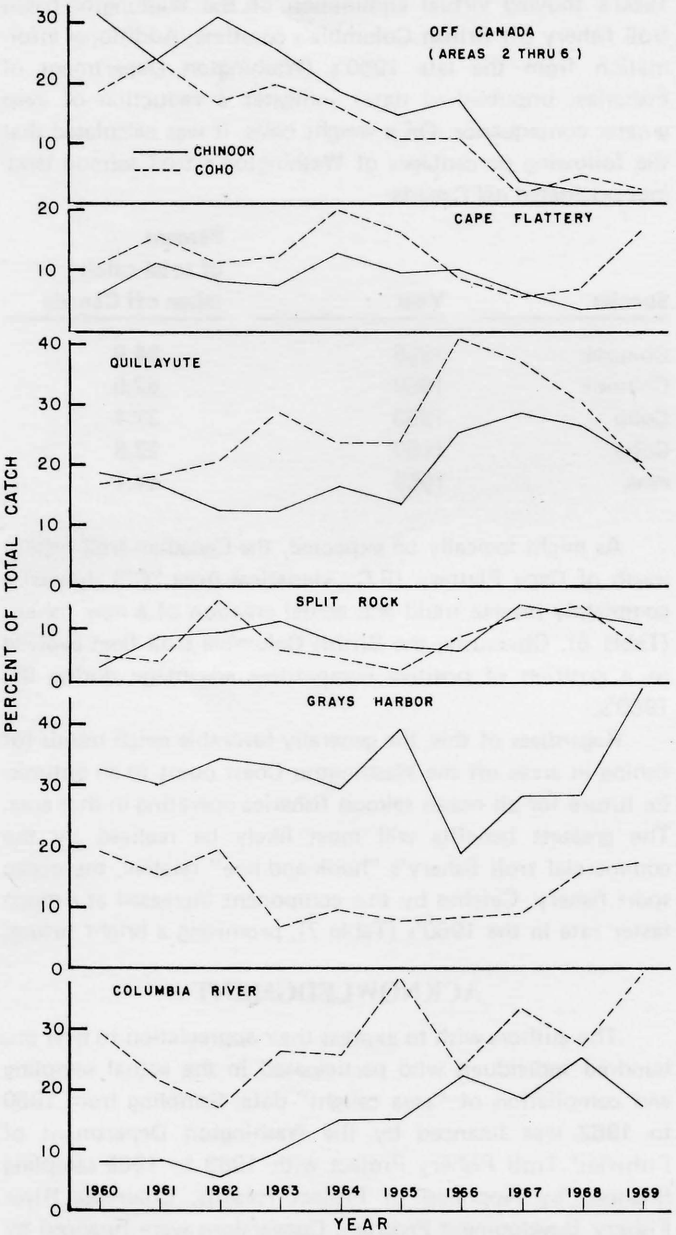


FIGURE 2. Chinook and coho catch trends off Canada and Washington in percent total catches, 1960–1969.

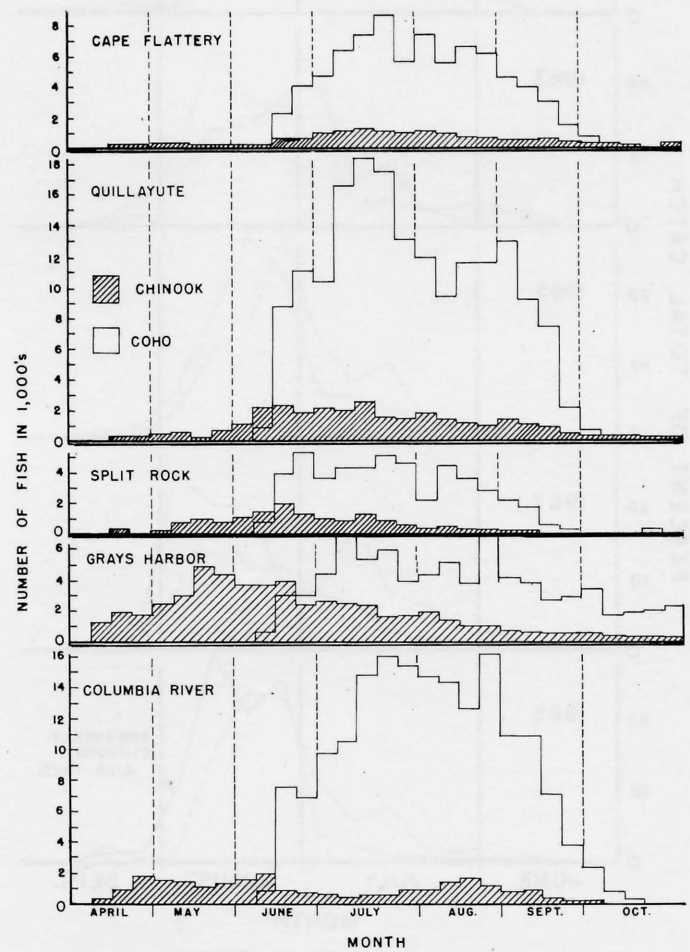


FIGURE 3. Average weekly troll catches of chinook and coho salmon for 5 areas adjacent to the Washington coast, 1960–1969.

## Pink Salmon

Pink were taken only incidentally during troll effort for chinook and coho, and pink catches cannot be viewed effectively in the same manner as those of the other species due to pronounced differences in both abundance and stock origin for odd- and even-numbered years (DiDonato, 1968). Odd-year catches during the 1960-1969 period averaged 247,999 pink (Table 4), even-years averaged only 10,489 (Table 5).

For the dominant odd-year fishery, Quillayute (42.4% of total catch) and Cape Flattery (33.1%) were major producers. Although catch fluctuation were more extreme than for chinook and coho, a decreased fishery off Canada was again evident. Total pink catches for Areas 2 through 6 (off Canada) accounted for 32.0, 19.8, 12.1, 2.5, and 3.9 percent of total Washington landings during the 1961, 1963, 1965, 1967, and 1969 cycle years, respectively. For small even-year catches, the same areas off Canada contributed, on the average, 44% of the total during the 1960's.

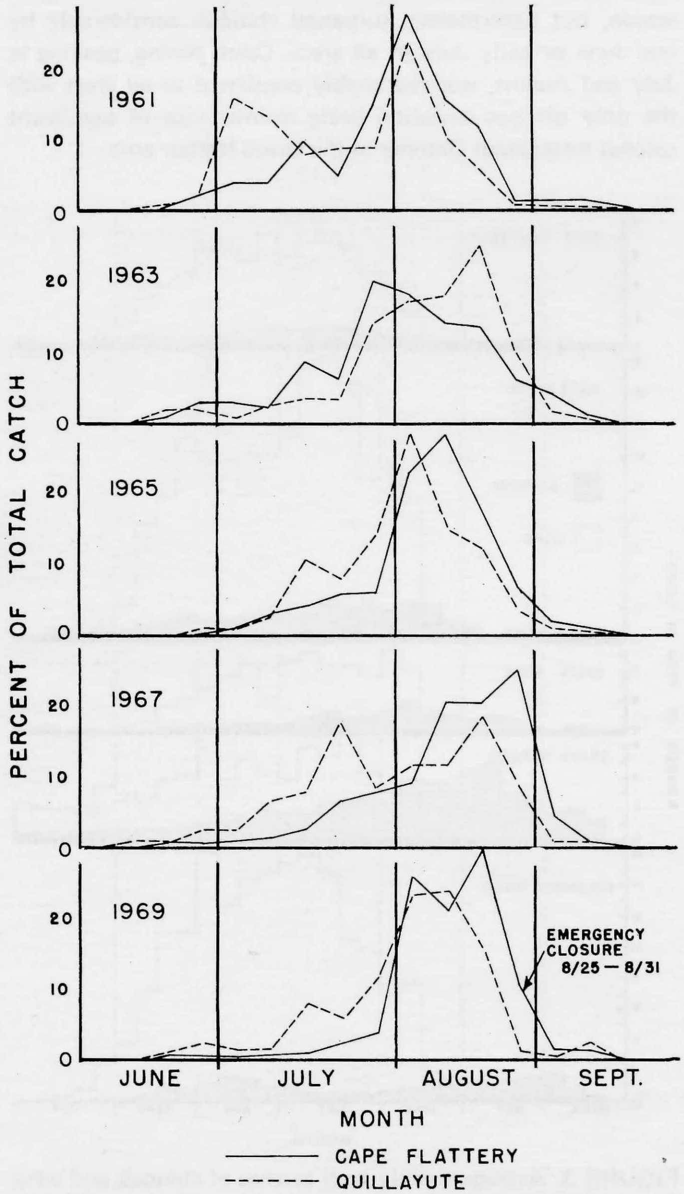


FIGURE 4. Troll pink catches in Cape Flattery and Quillayute areas in percent of total catch, 1961–1969 odd-year cycles.

Catch timing for two major zones, Cape Flattery and Quillayute, confirm the analysis by DiDonato (1968), i.e., although the season extends for a 6½-month span from April 15 through October 31, virtually the entire pink harvest is realized during July and August (Figure 4). As expected, the more southerly area (Quillayute) tended to be slightly earlier, but in two cases (1961 and 1965) departed radically from a "normal" catch curve. The five cycles shown indicate that early Cape Flattery catches may be a more consistent indicator of total abundance for prediction purposes. The high variability in Fraser River-Puget Sound pink production makes a reliable early indicator of stock strength essential for management purposes.

## DISCUSSION AND CONCLUSIONS

Inspection of catch statistics by area caught during the 1960's showed virtual elimination of the Washington-based troll fishery off British Columbia's coastline. Additional information from the late 1950's (Washington Department of Fisheries, unpublished data) indicates a reduction of even greater consequence. On a weight basis, it was calculated that the following percentages of Washington's troll salmon landings originated off Canada:

| Species | Year | Percent of total catch taken off Canada |
|---|---|---|
| Chinook | 1958 | 54.9 |
| Chinook | 1959 | 52.5 |
| Coho | 1958 | 37.4 |
| Coho | 1959 | 22.8 |
| Pink | 1959 | 44.1 |

As might logically be expected, the Canadian troll fishery south of Cape Flattery (B.C., statistical Area "C") showed a completely reverse trend and actual creation of a new fishery (Table 6). Obviously, the British Columbia troll fleet evolved to a position of positive competitive advantage during the 1960's.

Regardless of this, the generally favorable catch trends for fishing in areas off the Washington Coast point to an optimistic future for all ocean salmon fisheries operating in that area. The greatest benefits will most likely be realized by the commercial troll fishery's "hook-and-line" relative, the ocean sport fishery. Catches by this component increased at a much faster rate in the 1960's (Table 7), promising a bright future.

## ACKNOWLEDGMENT

The authors wish to express their appreciation to over one hundred individuals who participated in the actual sampling and compilation of "area caught" data. Sampling from 1960 to 1962 was financed by the Washington Department of Fisheries' Troll Fishery Project with 1963 to 1969 sampling financed by Appraisal of Project Results, Columbia River Fishery Development Program. Conversions were financed by Project No. 1-55-R-1, Ocean Salmon Fisheries Sampling, Commercial Fisheries Research and Development Act (PL 88-309).

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**TABLE 1.** Troll fishery area caught samples, 1960-1969

| | Chinook | | Coho | | Pink | |
|---|---|---|---|---|---|---|
| Year | No. sampled | Percent of total catch | No. sampled | Percent of total catch | No. sampled | Percent of total catch |
| 1960 | 29,834 | 24.49 | 30,754 | 17.02 | 157 | 8.06 |
| 1961 | 33,534 | 18.39 | 76,549 | 14.12 | 14,172 | 21.75 |
| 1962 | 29,556 | 18.59 | 88,588 | 13.99 | 831 | 12.67 |
| 1963 | 51,024 | 24.99 | 171,109 | 28.40 | 120,895 | 19.19 |
| 1964 | 36,832 | 22.51 | 123,697 | 20.52 | [a] | |
| 1965 | 25,951 | 27.07 | 196,996 | 20.38 | 32,408 | 30.90 |
| 1966 | 48,910 | 29.25 | 219,606 | 24.82 | 7,018 | 23.90 |
| 1967 | 28,171 | 21.38 | 122,159 | 15.67 | 107,118 | 28.15 |
| 1968 | 54,637 | 33.56 | 205,097 | 28.73 | 1,699 | 35.37 |
| 1969 | 39,473 | 21.11 | 113,690 | 24.51 | 19,954 | 33.60 |

[a]Sample data inadequate; estimated from WDF daily landing statistics.

**TABLE 2.** Washington's 1960-1969 troll chinook catches in number of fish by year and statistical catch area[a]

| | Statistical catch areas | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | |
| Year | S. E. Alaska | North B. C. | Central B. C. | W. C. Van. I. | Barkley Sound | Swift-sure | Juan de Fuca Str. | Cape Flattery | Quilla-yute | Split Rock | Grays Harbor | Col. River | North Ore. | South Ore. | Calif. Coast | Total |
| 1960 | | 3,473 | 762 | 1,795 | 21,375 | 10,758 | 573 | 7,144 | 22,629 | 2,501 | 40,000 | 9,750 | 329 | 716 | | 121,805 |
| 1961 | | 2,782 | 573 | 1,186 | 11,030 | 27,612 | 3,736 | 19,982 | 30,246 | 13,605 | 55,452 | 14,885 | 286 | 385 | 568 | 182,328 |
| 1962 | | 2,146 | 363 | 71 | 22,611 | 23,616 | 365 | 12,590 | 19,700 | 12,875 | 55,236 | 9,415 | 21 | 21 | | 159,030 |
| 1963 | | 1,532 | 592 | 1,318 | 32,897 | 15,017 | 916 | 15,373 | 24,933 | 22,747 | 67,917 | 20,434 | 502 | | | 204,178 |
| 1964 | 224 | 2,481 | 294 | 12,684 | 6,404 | 8,410 | 844 | 20,715 | 27,355 | 11,709 | 47,783 | 24,530 | 137 | 44 | 4 | 163,618 |
| 1965 | 56 | 1,446 | 209 | 1,457 | 8,598 | 2,331 | 670 | 9,120 | 13,036 | 6,667 | 37,621 | 14,551 | 32 | 61 | | 95,855 |
| 1966 | | 2,540 | 1,121 | 9,252 | 11,297 | 4,080 | 976 | 16,904 | 42,095 | 10,345 | 31,551 | 36,983 | 48 | | | 167,192 |
| 1967 | | 516 | | | 3,781 | 498 | 710 | 8,343 | 37,224 | 18,160 | 37,512 | 24,200 | 792 | | | 131,736 |
| 1968 | 151 | 615 | 194 | 18 | 1,149 | 1,347 | 2,924 | 5,438 | 42,470 | 20,316 | 47,047 | 41,092 | 26 | | | 162,787 |
| 1969 | | | 1,290 | | 717 | 1,412 | 210 | 8,092 | 37,517 | 19,785 | 85,655 | 32,156 | 95 | | | 186,929 |
| 1960-69 Average | 43 | 1,753 | 540 | 2,778 | 11,986 | 9,508 | 1,192 | 12,370 | 29,721 | 13,871 | 50,577 | 22,800 | 227 | 123 | 57 | 157,546 |
| Percent | + | 1.1 | 0.3 | 1.8 | 7.6 | 6.0 | 0.8 | 7.9 | 18.9 | 8.8 | 32.1 | 14.5 | 0.1 | 0.1 | + | 100 |

[a]Ocean season April 15—October 31; Juan de Fuca Strait June 15—October 31; 26-inch total-length minimum-size limit both areas.

**TABLE 3.** Washington's 1960-1969 troll coho catches in number of fish by year and statistical catch area[a]

| | Statistical catch areas | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | |
| Year | S. E. Alaska | North B. C. | Central B. C. | W. C. Van. I. | Barkley Sound | Swift-sure | Juan de Fuca Str. | Cape Flattery | Quilla-yute | Split Rock | Grays Harbor | Col. River | North Ore. | South Ore. | Calif. Coast | Total |
| 1960 | | 10,199 | 940 | 2,434 | 8,755 | 10,669 | 1,890 | 19,558 | 29,984 | 8,194 | 34,451 | 53,372 | 222 | | | 180,668 |
| 1961 | | 8,847 | 1,495 | 7,130 | 50,440 | 62,301 | 8,435 | 84,181 | 98,265 | 19,292 | 83,457 | 116,929 | 455 | 684 | 157 | 542,068 |
| 1962 | | 3,702 | 174 | 912 | 41,654 | 57,856 | 3,432 | 70,571 | 131,863 | 91,966 | 121,468 | 108,306 | 764 | 764 | | 633,432 |
| 1963 | | 6,838 | 4,796 | 1,412 | 65,233 | 38,937 | 2,558 | 73,589 | 174,347 | 33,321 | 40,465 | 159,290 | 1,632 | | | 602,418 |
| 1964 | | 11,990 | 2,008 | 39,353 | 13,530 | 29,384 | 3,280 | 118,790 | 142,912 | 24,370 | 57,459 | 154,740 | 4,972 | | 70 | 602,858 |
| 1965 | | 4,580 | 941 | 7,466 | 65,719 | 20,833 | 3,076 | 156,595 | 231,487 | 20,786 | 76,166 | 368,081 | 2,395 | 8,703 | | 966,828 |
| 1966 | | 5,791 | 3,109 | 29,058 | 43,731 | 11,146 | 2,114 | 75,734 | 358,201 | 75,806 | 74,367 | 204,666 | 1,185 | | | 884,908 |
| 1967 | | 873 | | | 8,454 | 2,617 | 2,595 | 44,068 | 288,546 | 93,392 | 70,025 | 258,398 | 10,449 | | | 779,417 |
| 1968 | 266 | 13,358 | | 110 | 7,819 | 10,411 | 7,738 | 49,492 | 214,416 | 99,092 | 114,057 | 195,898 | 1,199 | | | 713,856 |
| 1969 | | | 1,331 | | 4,006 | 5,102 | | 76,223 | 89,743 | 25,482 | 81,496 | 179,339 | 1,056 | | | 463,838 |
| 1960-69 Average | 27 | 6,618 | 1,479 | 8,788 | 30,934 | 24,926 | 3,512 | 76,880 | 175,976 | 49,170 | 75,341 | 179,908 | 2,433 | 1,015 | 23 | 637,029 |
| Percent | + | 1.0 | .2 | 1.4 | 4.9 | 3.9 | .6 | 12.1 | 27.6 | 7.7 | 11.8 | 28.2 | .4 | .2 | + | 100 |

[a]Season June 15—October 31 in all areas; 22-inch total-length minimum-size limit through 1968; 20-in. T.L. in 1969.

**TABLE 4.** Washington's 1960-1969 odd-year troll pink catches in number of fish by year and statistical catch area[a]

| | Statistical catch areas | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | |
| Year | S. E. Alaska | North B. C. | Central B. C. | W. C. Van. I. | Barkley Sound | Swift-sure | Juan de Fuca Str. | Cape Flattery | Quilla-yute | Split Rock | Grays Harbor | Col. River | North Ore. | South Ore. | Calif. Coast | Total |
| 1961 | | 358 | 119 | 1,934 | 5,009 | 13,452 | 4,399 | 21,518 | 15,947 | 2,075 | 322 | 16 | 9 | 8 | | 65,166 |
| 1963 | | 1,761 | 2,732 | 275 | 35,752 | 84,468 | 19,235 | 223,133 | 249,578 | 9,509 | 3,282 | 263 | | | | 629,988 |
| 1965 | | 970 | 139 | 309 | 6,192 | 5,072 | 774 | 38,542 | 44,547 | 901 | 2,019 | 4,614 | 506 | 287 | | 104,872 |
| 1967 | | 119 | | | 3,391 | 5,866 | 3,536 | 98,604 | 196,182 | 43,387 | 15,748 | 11,693 | 2,048 | | | 380,574 |
| 1969 | | | 356 | | 961 | 1,004 | | 28,779 | 19,526 | 3,107 | 2,809 | 2,726 | 115 | | | 59,393 |
| 1960-69 Odd-year Average | 0 | 642 | 669 | 504 | 10,261 | 21,972 | 5,589 | 82,115 | 105,156 | 11,796 | 4,836 | 3,864 | 536 | 59 | 0 | 247,999 |
| Percent | | .3 | .3 | .2 | 4.1 | 8.9 | 2.3 | 33.1 | 42.4 | 4.8 | 2.0 | 1.6 | .2 | + | | 100 |

[a]Ocean season April 15—October 31; Juan de Fuca Strait June 15—October 31; no minimum-size limit.

**TABLE 5.** Washington's 1960-1969 even-year troll pink catches in number of fish by year and statistical catch area[a]

| | Statistical catch areas | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | |
| Year | S. E. Alaska | North B. C. | Central B. C. | W. C. Van. I. | Barkley Sound | Swift-sure | Juan de Fuca Str. | Cape Flattery | Quilla-yute | Split Rock | Grays Harbor | Col. River | North Ore. | South Ore. | Calif. Coast | Total |
| 1960 | | 1,515 | 63 | 2 | 32 | 31 | 12 | 142 | 147 | 1 | 2 | | | | | 1,947 |
| 1962 | | 1,269 | | 146 | 940 | 718 | 11 | 1,700 | 1,518 | 123 | 133 | | | | | 6,558 |
| 1964 | | 4,295 | 350 | 1,175 | 111 | 133 | 7 | 3,295 | 355 | | 47 | | | | | 9,768 |
| 1966 | | 4,489 | 1,386 | 1,026 | 1,513 | 246 | 10 | 3,186 | 15,163 | 1,756 | 592 | | | | | 29,367 |
| 1968 | 52 | 3,111 | 249 | 18 | 225 | 39 | 16 | 258 | 682 | 52 | 102 | | | | | 4,804 |
| 1960-69 Even-year Average | 10 | 2,936 | 410 | 473 | 564 | 233 | 11 | 1,716 | 3,573 | 386 | 175 | 0 | 0 | 0 | 0 | 10,489 |
| Percent | .1 | 28.0 | 3.9 | 4.5 | 5.4 | 2.2 | .1 | 16.4 | 34.1 | 3.7 | 1.7 | | | | | 100 |

[a]Ocean season April 15—October 31; Juan de Fuca Strait June 15—October 31; no minimum-size limit.

**TABLE 6.** British Columbia troll catches for fishing south of Cape Flattery (Area C), 1960-1969[a]

| Year | No. Chinook | No. Coho | No. Pink |
|---|---|---|---|
| 1960 | 0 | 0 | 0 |
| 1961 | 13 | 67 | 4 |
| 1962 | 474 | 3,137 | 15 |
| 1963 | 506 | 2,295 | 1,135 |
| 1964 | 89 | 949 | 2 |
| 1965 | 263 | 5,401 | 947 |
| 1966 | 1,081 | 9,530 | 44 |
| 1967 | 15,980 | 166,348 | 134,135 |
| 1968 | 10,897 | 113,170 | 1,178 |
| 1969 | 6,308 | 63,368 | 5,361 |

[a]1970 catches were 54,313 chinook, 585,383 coho, and 18,858 pink. Source: British Columbia Catch Statistics, Dept. of Fisheries of Canada.

**TABLE 7.** Washington coastal sport fishery catches, 1960–1969[a]

| Year | No. chinook | No. coho | No. pink |
|---|---|---|---|
| 1960 | 105,900 | 86,900 | |
| 1961 | 105,400 | 196,700 | 13,400 |
| 1962 | 100,800 | 305,900 | |
| 1963 | 110,200 | 304,000 | 157,000 |
| 1964 | 144,400 | 275,400 | |
| 1965 | 161,900 | 533,000 | 18,100 |
| 1966 | 183,500 | 359,000 | |
| 1967 | 204,000 | 485,650 | 67,700 |
| 1968 | 188,200 | 507,700 | |
| 1969 | 176,300 | 446,600 | 26,200 |

[a]Catches for coastal Washington and outer Juan de Fuca Strait. Source: Washington Department of Fisheries Statistical Reports.

# Size and Age Characteristics of Chinook Salmon Taken by Washington's Commercial Troll and Ocean Sport Fisheries, 1963-1969

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## BULLETIN 8

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# SIZE AND AGE CHARACTERISTICS OF CHINOOK SALMON TAKEN BY WASHINGTON'S COMMERCIAL TROLL AND OCEAN SPORT FISHERIES, 1963–1969

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## ABSTRACT

Essential management data concerning biological characteristics of ocean-caught chinook salmon were developed through analysis of a large volume of size-age samples taken over a 7-year period. Magnitude and age composition of commercial and sport catches were presented along with the average length and relative importance of each age group on a monthly basis. Sex ratios by age group and length-weight relationships were also determined.

## INTRODUCTION

During the years 1963 through 1969, a comprehensive coastwise salmon catch sampling program was successfully completed through cooperative efforts of Canada and the States of Alaska, California, Oregon, and Washington. The primary purpose of these efforts was recovery of fin-marked 1961- to 1964-brood-year fall chinook *(Oncorhynchus tshawytscha)* from Columbia River hatcheries and subsequent quantitative analysis of contribution to various Pacific coast chinook salmon fisheries.

Details on reasons for the study, methods employed, and results for the 1961-brood year were presented by Worlund, Wahle, and Zimmer (1969) and by Cleaver (1969). In addition, Van Hyning (1968) presented a comprehensive analysis of factors affecting Columbia River fall chinook, Pulford (1970) documented contributions of four successive brood years to various fisheries in 1966, Lander (1970) described ocean fishery distribution patterns for discrete groups of marked fish, and Henry (1971) reported on mortalities and yields for both the 1961 and 1962 brood years.

With these excellent references available, further description of the overall study and its results would be redundant. Suffice to say, one phase entailed collection of thousands of chinook "non-mark samples" (i.e., age and size measurements of unmarked fish) from landings made by Washington's commercial troll and ocean sport fisheries. This paper presents data developed from selective compilations of aggregate 1963–1969 "non-marked samples."

Earlier age and size information for the troll fishery was presented by Heyamoto and Wright (1970) for the years 1950–1955, and by DiDonato (1970) for the years 1956–1962. Ocean sport fishery information available through 1964 was described by Haw, Wendler, and Deschamps (1967).

## MAGNITUDE OF CATCH AND AGE COMPOSITION BY AREA

For the seven years, 1963–1969, age readings from scale samples of unmarked fish were made for 28,690 troll-caught and 18,487 sport-caught chinook. These samples, plus calculations for incidence of fin-marked fish, were extrapolated to total catches by area and 2-week intervals in a series of 7 reports (Bureau of Commercial Fisheries, 1964–1970). Results were adjusted slightly to match final Washington Department of Fisheries catch statistics (Ward, et al. 1969) since original calculations were commonly made with preliminary figures to expedite analysis. Magnitude and age composition of catches are depicted in Figure 1.

Commercial troll fishery landings in the Grays Harbor District (representing catches made off central Washington) were the dominant component. These were followed by the Puget Sound District (reflecting catches made off northern Washington and southern British Columbia) and the Columbia River District (the Columbia River mouth area) landings. In all cases, fish in their 3rd year predominated, followed in order by 4-, 5-, and 2-year-olds. Continuous application of a 26-inch total-lengh minimum-size limit to this commercial fishery effectively prevented any substantial retainable catch of 2nd-year fish. Some 6-year-olds were taken and even a few 7's but these were of very minor importance. From north to south, a definite shift to younger age classes was evident.

Ocean sport fishery data were compiled for each of 5 popular landing ports along the Washington coast and in outer Juan de Fuca Strait. Westport (at Grays Harbor) was the largest producer followed by Ilwaco (at the Columbia River mouth), Sekiu (inside Juan de Fuca Strait), and the smaller fisheries operating from Neah Bay and LaPush. The prevailing age composition in order of abundance was 3-year-olds followed by 4's, 2's, and 5's. A few 6's and 7's were also landed.

A notable exception in age makeup occurred at the mouth of the Columbia River where, on the average, 2's and 3's appeared in about equal proportions. As noted in the commercial fishery, a north to south catch trend toward younger fish was evident. The higher incidence of 2's in all areas was produced by the sport angler 20-inch total-length minimum-size limit throughout the 1963–1969 period, a 6-inch lower standard than that imposed on trollers.

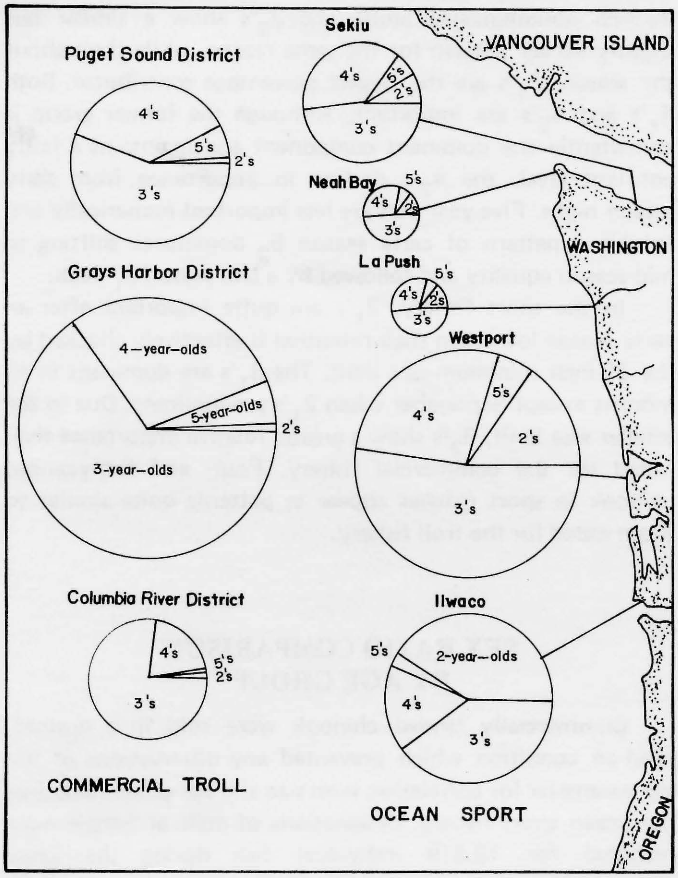


FIGURE 1. Magnitude and age composition of chinook salmon catches by Washington's commercial troll and ocean sport fisheries, 1963–1969 averages. Size of circle indicates relative magnitude of district's catch in specific fishery.

## SIZE RELATIONSHIPS BY AGE GROUP[1]

For the years 1964–1969, age-subtype-length samples were available for 24,727 troll- and 15,328 sport-caught chinook. These were combined by age group and month for all areas and years. Samples for 1963 were omitted from analysis since the designation sub-1 and sub-2 was not recorded for individual fish. These subtypes arbitrarily separate chinook migrating seaward in their first year from those remaining in fresh water until their second year. For example, a "$3_1$" chinook signifies a fish in its 3rd year that migrated seaward during its 1st year, while a "$3_2$" would denote a chinook of the same total age but one that reared in fresh water for a much longer period and then migrated to the ocean during its 2nd year of life. Furthermore, although many exceptions can be found, these subtypes are commonly utilized by fisheries managers to determine relative percentages of fall- and spring-run chinook, respectively, in ocean salmon catches. From these summations, monthly mean sizes were plotted by age group to illustrate several key biological aspects (Figure 2).

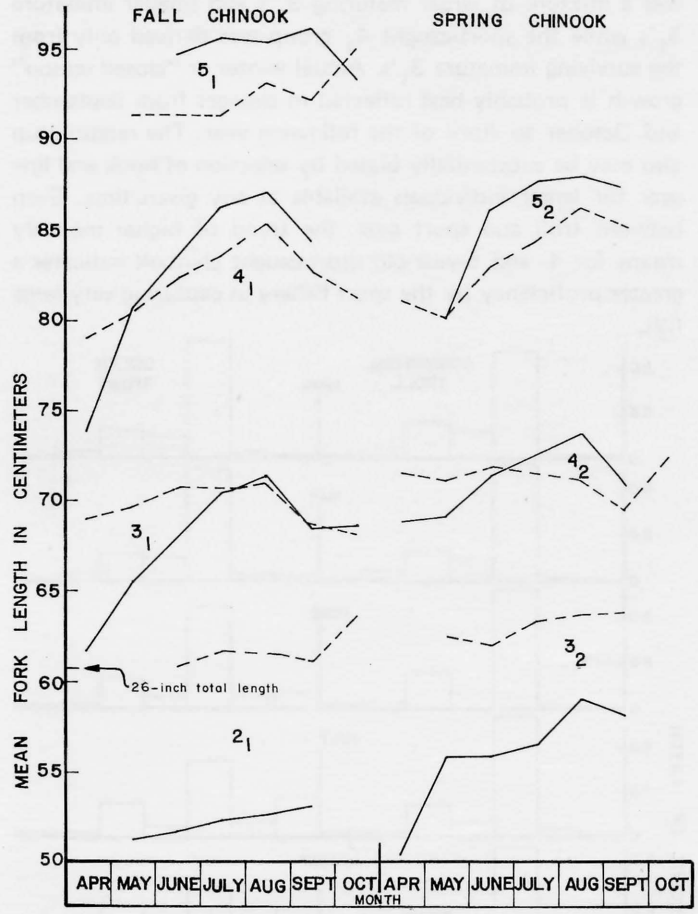


FIGURE 2. Mean monthly chinook lengths by age group for Washington's commercial troll (----) and ocean sport (——) fisheries, 1964-1969 means.

The general comparisons indicated that $3_2$'s and $4_2$'s are only slightly larger than $2_1$'s and $3_1$'s respectively, while $5_2$'s and $4_1$'s are comparable in size. The largest fish taken are commonly $5_1$'s. The wide difference between commercial and sport averages in the two smallest size groups ($2_1$'s and $3_2$'s) is produced by differences in minimum-size limits which restrict commercial landings to only the very largest members of those groups. A large early season spread is apparent for the mean length of the important $3_1$ group but later decreases to

[1] Age composition or "age class" data cited in the previous section reflected extrapolations in terms of total age only. Sugsequent discussion considers "age group," i.e., total age plus subtype designation. These data, strictly speaking, are not a completely random sample of total catch in that they represent only non-marked fish. This group comprised from 96% to 99% of catches for various areas and years considered. There were no feasible means of integrating individual parameters from both non-marked and marked fish due to large differentials in mark and non-mark sampling percentages; i.e., a small percentage of the former compared with nearly 100% of the latter.

equality due to growth of individuals in the population. Apparent growth rates are also signigicant. There is a visual phenomenon of no growth in groups such as the troll-caught $3_1$'s and $4_2$'s while $3_1$'s and $4_1$'s become "smaller" during the fall months. The first effect is mainly the product of a size limit cutting across an age group's length-frequency distribution. The second reflects departure of larger maturing fish of an age group, leaving only the smaller immatures of the same age group available to the fishery. True growth rates within a season are probably best approximated by sport averages through August, particularly as illustrated by the fully recruited (i.e., have reached the 20-inch sport size limit) $3_1$ and $4_1$ groups.

Growth from one year to the next is difficult to determine from these data. For example, the sport-caught $3_1$ group was a mixture of larger maturing $3_1$'s and smaller immature $3_1$'s while the sport-caught $4_1$ group was derived only from the surviving immature $3_1$'s. Actual winter or "closed season" growth is probably best reflected in changes from September and October to April of the following year. The relationship also may be substantially biased by selection of hook and line gear for larger individuals available at any given time. Even between troll and sport gear, the trend of higher monthly means for 4- and 5-year-old sport-caught chinook indicates a greater proficiency by the sport fishery in capturing very large fish.

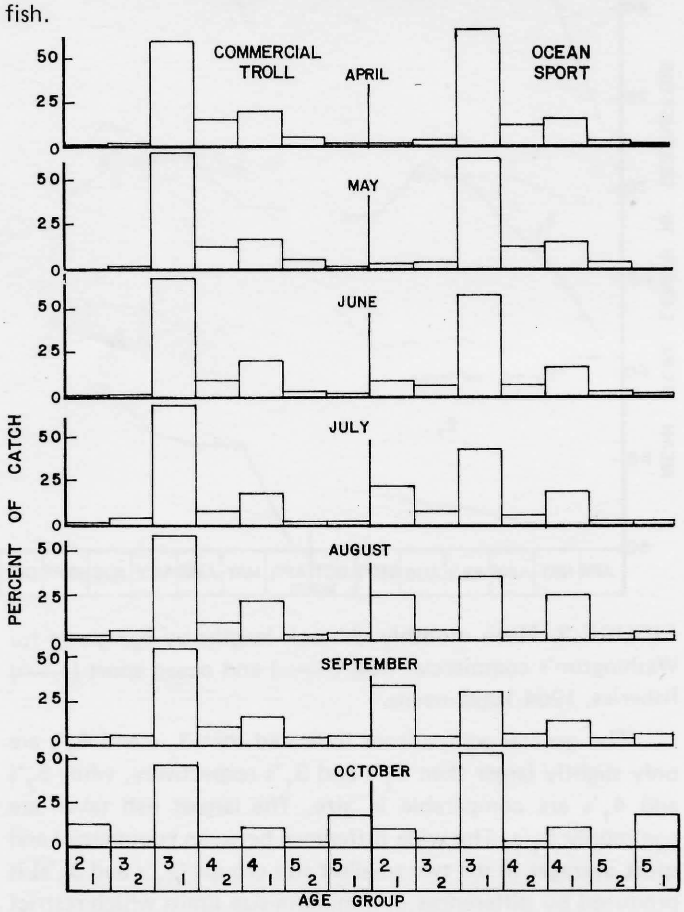


FIGURE 3. Seasonal changes in age group composition for Washington's commercial troll and ocean sport fisheries, 1964—1969 means.

## SEASONAL CHANGES IN AGE GROUP COMPOSITION

By comparing percentage contribution of each age group to combined samples by month and fishery, seasonal variations can be examined during the mid-April through October fishing seasons (Figure 3).

In the commercial troll fishery, $2_1$'s do not appear in any abundance until very late in the season, a product of the 26-inch minimum-size limit. The $3_2$'s show a similar but slightly earlier pattern for the same reason, while throughout the season, $3_1$'s are the largest percentage contributor. Both $4_1$'s and $4_2$'s are important. Although the former group is consistently the dominant component and maintains a fairly constant level, the $4_2$'s decline in importance from early season highs. Five-year-olds are less important numerically and exhibit a pattern of early season $5_2$ dominance shifting to mid-season equality and followed by a late season $5_1$ peak.

In the sport fishery, $2_1$'s are quite important after an early season low when their retention is effectively checked by the 20-inch minimum-size limit. The $3_1$'s are dominant in all months except September when $2_1$'s predominate. Due to the smaller size limit, $3_2$'s show a greater relative importance than noted for the commercial fishery. Four- and five-year-old chinook in sport catches appear in patterns quite similar to those noted for the troll fishery.

## SEX RATIO COMPARISON BY AGE GROUP

Commercially landed chinook were sold in a dressed, head-on condition which prevented any observations of the sex parameter for correlation with size and age group data. For the ocean sport fishery, designations of male or female were recorded for 10,619 individual fish during the years 1964—1969 and these were compiled by age group and month for all areas and years. Viewed on a seasonal basis, results demonstrate additional characteristics of populations comprising actual catches (Figure 4).

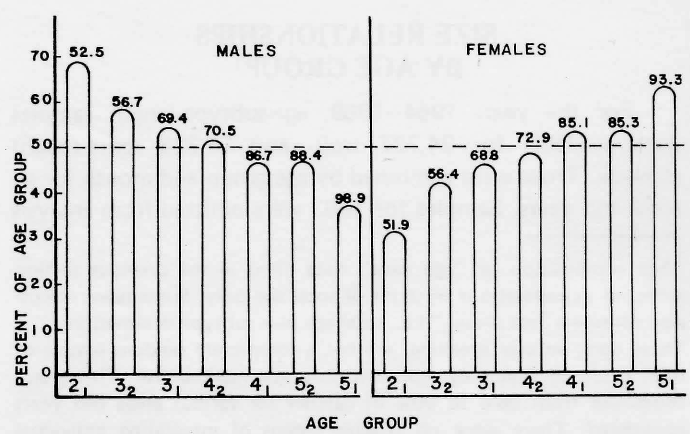


FIGURE 4. Sex ratios by age group for Washington's ocean sport fishery, 1964—1969 means. Values over bars are seasonal mean fork lengths in centimeters.

With age groups arranged by ascending size, males show over a 2 to 1 advantage in abundance for the small $2_1$'s, but they steadily diminish in importance to reach almost a reversal for large $5_1$'s. Overall, the 4 smallest groups show a predominance of males while the 3 largest have more females. In all but one group ($4_2$'s), males show a larger mean length with this difference being most apparent in 5-year-olds. Some of this might be attributed to early development of the hooked snout, a secondary sex characteristic, in maturing males. Larger length would cause a slightly higher exploitation rate for males in smaller age groups due to effect of size limits.

The predominance of females is certainly expected in larger, older age groups of chinook due to the well-known life history trait of males to produce substantial numbers of precocious 2-year-olds (or "jacks") in fall runs and the general tendency toward a much higher proportion of males than females in maturing 3-year-olds. With equal ocean availability, however, a catch of $2_1$'s approximating a 50-50 ratio would logically be expected. The slightly larger length tendency may favor males to some extent due to size limit bias but one might logically conclude the 2-year-old males, and conceivably jacks in particular, are considerably more available to ocean fisheries. Following this reasoning, at age 3, some slightly higher proportion of fall-run females would be expected since a sizeable segment of males already would have been withdrawn from the population. Again, however, males predominate and this also must be attributed to greater availability. Males contribute 54.5% of the total catch for all age groups in aggregate. These conclusions assume an original equal sex ratio for juveniles and comparable early marine natural mortality rates.

**TABLE 1.** Length-weight comparisons for Washington's commercial troll and ocean sport fisheries, 1963–1969 averages (length in centimeters; weight in pounds)

| Fork length | Mean round weight | Mean dressed weight | Fork length | Mean round weight | Mean dressed weight |
|---|---|---|---|---|---|
| 39 | 1.53 | | 71 | 11.28 | 9.52 |
| 40 | 1.75 | | 72 | 12.09 | 10.02 |
| 41 | 1.95 | | 73 | 12.48 | 10.46 |
| 42 | 2.04 | | 74 | 12.76 | 10.93 |
| 43 | 2.20 | | 75 | 13.77 | 11.48 |
| 44 | 2.41 | | 76 | 14.29 | 11.99 |
| 45 | 2.66 | | 77 | 15.00 | 12.53 |
| 46 | 2.81 | | 78 | 15.55 | 13.09 |
| 47 | 3.09 | 2.75 | 79 | 16.19 | 13.55 |
| 48 | 3.29 | 2.92 | 80 | 16.96 | 14.25 |
| 49 | 3.44 | 3.05 | 81 | 17.70 | 15.03 |
| 50 | 3.73 | 3.28 | 82 | 18.51 | 15.60 |
| 51 | 3.87 | 3.40 | 83 | 19.28 | 16.19 |
| 52 | 4.14 | 3.67 | 84 | 19.97 | 16.71 |
| 53 | 4.46 | 3.70 | 85 | 20.81 | 17.37 |
| 54 | 4.75 | 4.11 | 86 | 21.54 | 18.04 |
| 55 | 5.06 | 4.39 | 87 | 22.03 | 18.62 |
| 56 | 5.26 | 4.64 | 88 | 23.09 | 19.25 |
| 57 | 5.43 | 4.87 | 89 | 24.12 | 20.09 |
| 58 | 5.82 | 5.17 | 90 | 25.34 | 21.03 |
| 59 | 6.07 | 5.42 | 91 | 25.72 | 21.64 |
| 60 | 6.47 | 5.63 | 92 | 26.61 | 22.46 |
| 61 | 6.89 | 5.88 | 93 | 27.96 | 23.42 |
| 62 | 7.26 | 6.20 | 94 | 28.11 | 24.16 |
| 63 | 7.65 | 6.47 | 95 | 29.65 | 24.49 |
| 64 | 7.97 | 6.77 | 96 | 30.34 | 26.05 |
| 65 | 8.37 | 7.06 | 97 | 31.41 | 27.06 |
| 66 | 8.81 | 7.47 | 98 | 31.97 | 27.11 |
| 67 | 9.31 | 7.83 | 99 | 34.65 | 28.88 |
| 68 | 9.75 | 8.21 | 100 | 35.05 | 29.85 |
| 69 | 9.83 | 8.58 | 101 | 36.18 | 30.20 |
| 70 | 10.75 | 9.04 | 102 | | 30.86 |

## LENGTH-WEIGHT RELATIONSHIPS

Throughout the years 1963–1969, two different size parameters were consistently measured for virtually all chinook biological samples, In Washington, this resulted in collection of 35,141 length-dressed weight samples from commercial- and sport-caught fish and 12,972 length-round weight measurements from the latter fishery. Averages for length increment samples of 25 or more fish are given in Table 1.

## SUMMARY

Objective of this report was to develop usable fishery management information on size and age characteristics of chinook salmon caught off Washington's coast through analysis of thousands of individual fish age-size samples taken during the 1963 through 1969 period. Results are listed below.

1. By far the largest numbers of chinook, as represented by Grays Harbor District troll fishery and Westport sport fishery landings, were taken adjacent to the Grays Harbor area. A north to south trend toward catches of younger fish was evident along the Washington coast.

2. Three-year-old chinook were the dominant component in both fisheries with important numbers of 4- and 5-year-old fish being taken. Due to a less restrictive minimum-size limit, substantial numbers of 2nd-year chinook were also taken by sportsmen, particularly off the Columbia River mouth.

3. Considering early life patterns, fish migrating seaward in their first year (sub-1's or fall-run chinook) were both far more numerous in catches during all months and were much larger at the same total age when contrasted to fish that did not enter the more productive marine habitat until their second year of life (sub-2's or spring-run chinook).

4. Apparent growth rates were often misleading due to effects of minimun-size limits and mixture of larger mature and smaller immature individuals within the same age classes. In fully available groups, increases in sport fishery monthly average lengths represented the best approximation of in-season growth from April through August. Off-season or

winter growth was best reflected in size change from October until April of the following year.

5. In comparing sex ratios of sport-caught chinook, a definite trend was found from a 2 to 1 advantage favoring males in the youngest age group to a 60+% predominance of females in the oldest group. Within each individual age group, males generally were slightly larger than females.


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# APPENDIX

Appendix Tables 1 through 5 provide detailed data from which figures in this report were drawn. They also provide many of the vital statistics required to evaluate proposed changes in regulation of the ocean chinook fisheries.

## APPENDIX TABLE 1

Washington commercial troll fishery: Age composition of chinook salmon catches in numbers of fish, 1963–1969

| | | Year | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Area[a] | Age | 1963 | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 |
| Puget Sound | 2 | 79 | 397 | 38 | 155 | 23 | 51 | 60 |
| district | 3 | 35,826 | 33,909 | 15,014 | 29,574 | 12,967 | 9,878 | 11,157 |
| (mainly Neah | 4 | 35,117 | 20,954 | 9,534 | 18,158 | 5,240 | 4,964 | 4,356 |
| Bay-Seattle) | 5 | 4,617 | 3,678 | 2,084 | 3,868 | 692 | 1,106 | 565 |
| landings | 6 | 220 | 344 | 247 | 615 | 107 | 10 | 29 |
| Total | | 75,859 | 59,282 | 26,917 | 52,370 | 19,029 | 16,009 | 16,167 |
| Grays Harbor | 2 | 240 | 465 | 874 | 952 | 227 | 581 | 3,385 |
| district | 3 | 37,918 | 51,103 | 29,563 | 60,461 | 66,109 | 92,745 | 115,994 |
| (mainly | 4 | 62,199 | 28,435 | 22,873 | 14,690 | 21,439 | 19,848 | 29,659 |
| Westport-LaPush) | 5 | 11,527 | 3,556 | 5,661 | 3,763 | 3,304 | 4,323 | 2,104 |
| landings | 6 | 285 | 55 | 275 | 1,046 | 461 | 177 | 133 |
| | 7 | 0 | 0 | 64 | 10 | 110 | 0 | 0 |
| Total | | 112,169 | 83,614 | 59,310 | 80,922 | 91,650 | 117,674 | 151,275 |
| Columbia River | 2 | 179 | 635 | 438 | 147 | 0 | 232 | 477 |
| district[b] | 3 | 9,834 | 16,916 | 6,465 | 26,152 | 16,479 | 23,706 | 16,021 |
| (mainly | 4 | 5,453 | 3,063 | 2,511 | 7,367 | 4,435 | 4,743 | 2,799 |
| Ilwaco) | 5 | 684 | 101 | 211 | 185 | 119 | 423 | 202 |
| landings | 6 | 0 | 7 | 3 | 49 | 24 | 0 | 0 |
| Total | | 16,150 | 20,722 | 9,628 | 33,900 | 21,057 | 29,104 | 19,499 |
| All areas | 2 | 498 | 1,497 | 1,350 | 1,254 | 250 | 864 | 3,922 |
| combined | 3 | 83,578 | 101,928 | 51,042 | 116,187 | 95,555 | 126,329 | 143,172 |
| | 4 | 102,769 | 52,452 | 34,918 | 40,215 | 31,114 | 29,555 | 36,814 |
| | 5 | 16,828 | 7,335 | 7,956 | 7,816 | 4,115 | 5,852 | 2,871 |
| | 6 | 505 | 406 | 525 | 1,710 | 592 | 187 | 162 |
| | 7 | 0 | 0 | 64 | 10 | 110 | | 0 |
| Total | | 204,178 | 163,618 | 95,855 | 167,192 | 131,736 | 162,787 | 186,941 |

[a]Neah Bay-Seattle and Westport-LaPush estimates were combined for all years as Puget Sound and Grays Harbor district totals, respectively. Since estimates were in this form for early years of the study, data were kept in their original "area landed" form instead of being converted to the more meaningful "area caught" format. This was necessary since individual biological samples from multiple catch areas could not be divided as accurately in numbers of fish as could mark samples.

[b]Including very small landings from Willapa Harbor.

## APPENDIX TABLE 2

Washington ocean sport fishery: Age composition of chinook salmon catches in numbers of fish, 1963–1969.

| | | Year | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Area** | **Age** | **1963** | **1964** | **1965** | **1966** | **1967** | **1968** | **1969** |
| Sekiu[a] | 2 | 1,409 | 1,780 | 4,187 | 1,287 | 593 | 2,219 | 1,253 |
| (Area 5) | 3 | 2,977 | 13,425 | 6,682 | 12,614 | 12,188 | 13,711 | 11,202 |
| | 4 | 4,692 | 9,810 | 5,416 | 7,724 | 9,466 | 8,790 | 8,949 |
| | 5 | 554 | 1,232 | 1,693 | 1,481 | 1,490 | 1,780 | 992 |
| | 6 | 68 | 153 | 222 | 94 | 163 | 0 | 104 |
| Total | | 9,700 | 26,400 | 18,200 | 23,200 | 23,900 | 26,500 | 22,500 |
| Nea Bay | 2 | 1,690 | 290 | 1,192 | 1,086 | 639 | 827 | 3,004 |
| (Area 4) | 3 | 1,449 | 4,255 | 1,632 | 7,533 | 4,373 | 3,755 | 6,304 |
| | 4 | 2,017 | 3,437 | 1,931 | 3,354 | 949 | 3,025 | 2,275 |
| | 5 | 446 | 818 | 668 | 865 | 200 | 893 | 296 |
| | 6 | 98 | 0 | 77 | 162 | 39 | 0 | 21 |
| Total | | 5,700 | 8,800 | 5,500 | 13,000 | 6,200 | 8,500 | 11,900 |
| LaPush | 2 | 1,761 | 113 | 1,230 | 212 | 886 | 660 | 88 |
| (Area 3) | 3 | 660 | 1,193 | 2,008 | 1,418 | 3,889 | 3,796 | 2,707 |
| | 4 | 948 | 623 | 2,191 | 329 | 1,426 | 1,574 | 3,084 |
| | 5 | 124 | 284 | 371 | 35 | 107 | 355 | 221 |
| | 6 | 7 | 87 | 0 | 6 | 92 | 15 | 0 |
| Total | | 3,500 | 2,300 | 5,800 | 2,000 | 6,400 | 6,400 | 6,100 |
| Westport | 2 | 7,723 | 6,564 | 10,248 | 11,027 | 11,246 | 11,224 | 24,683 |
| (Area 2) | 3 | 14,670 | 34,538 | 21,082 | 43,855 | 49,246 | 63,410 | 52,859 |
| | 4 | 24,098 | 22,151 | 29,689 | 12,130 | 20,117 | 13,709 | 21,317 |
| | 5 | 5,163 | 4,426 | 7,195 | 2,563 | 3,170 | 3,363 | 2,859 |
| | 6 | 346 | 321 | 386 | 408 | 242 | 94 | 582 |
| | 7 | 0 | 0 | 0 | 17 | 79 | 0 | 0 |
| Total | | 52,000 | 68,000 | 68,600 | 70,000 | 84,100 | 91,800 | 102,300 |
| Ilwaco[b] | 2 | 14,377 | 8,033 | 27,877 | 22,035 | 24,053 | 13,986 | 13,653 |
| (Area 1) | 3 | 6,954 | 12,152 | 13,210 | 32,816 | 23,944 | 18,452 | 14,366 |
| | 4 | 9,517 | 6,235 | 7,531 | 3,660 | 12,522 | 4,490 | 4,771 |
| | 5 | 1,615 | 1,680 | 82 | 789 | 2,861 | 972 | 590 |
| | 6 | 137 | 0 | 0 | 0 | 370 | 0 | 120 |
| Total | | 32,600 | 28,100 | 48,700 | 59,300 | 63,750 | 37,900 | 33,500 |
| All areas | 2 | 26,960 | 16,780 | 44,734 | 35,647 | 37,417 | 28,916 | 42,681 |
| combined | 3 | 26,710 | 65,563 | 44,614 | 98,236 | 93,640 | 103,124 | 87,438 |
| | 4 | 41,272 | 42,256 | 46,758 | 27,197 | 44,480 | 31,588 | 40,396 |
| | 5 | 7,902 | 8,440 | 10,009 | 5,733 | 7,828 | 7,363 | 4,958 |
| | 6 | 656 | 561 | 685 | 670 | 906 | 109 | 827 |
| | 7 | 0 | 0 | 0 | 17 | 79 | 0 | |
| Total | | 103,500 | 133,600 | 146,800 | 167,500 | 184,350 | 171,100 | 176,300 |

[a]Open on a year-round basis. Regular ocean sport season for other areas extended from April 15 through October 31.

[b]Washington and Oregon Columbia River mouth catches were combined for 1963 and 1964. Washington landings only from 1965 through 1969.

**APPENDIX TABLE 3.** Washington commercial troll fishery. Size distribution of chinook salmon catches in number of fish by 2-centimeter intervals, age group and month, 1964-1969[a]

| Fork length in centimeters | $2_1$ | | | | | $3_2$ | | | | | $3_1$ | | | | | | | $4_2$ | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | June | July | Aug. | Sept. | Oct. | May | June | July | Aug. | Sept. | Apr. | May | June | July | Aug. | Sept. | Oct. | Apr. | May | June | July | Aug. | Sept. | Oct. |
| 55- 56 | 1 | | 2 | 4 | | | | 1 | 2 | | | | | 1 | | | | | | 1 | | 1 | | |
| 57- 58 | 2 | 4 | 7 | 11 | | 2 | 2 | 3 | 3 | 1 | 1 | 5 | 5 | 12 | 10 | 4 | 1 | | | | 1 | 1 | | |
| 59- 60 | 1 | 11 | 21 | 25 | 3 | 2 | 14 | 24 | 26 | 13 | 7 | 41 | 58 | 105 | 67 | 33 | 3 | 1 | | 5 | 9 | 9 | 5 | |
| 61- 62 | 1 | 24 | 34 | 57 | 14 | 5 | 21 | 72 | 68 | 43 | 53 | 167 | 214 | 307 | 217 | 102 | 6 | 2 | 16 | 28 | 27 | 32 | 17 | 1 |
| 63- 64 | 4 | 11 | 18 | 28 | 5 | 7 | 14 | 45 | 68 | 40 | 102 | 242 | 341 | 435 | 341 | 183 | 20 | 14 | 30 | 23 | 43 | 53 | 35 | 1 |
| 65- 66 | 1 | 3 | 8 | 5 | 4 | 2 | 5 | 23 | 29 | 27 | 102 | 276 | 325 | 461 | 366 | 243 | 11 | 10 | 41 | 39 | 45 | 57 | 39 | 1 |
| 67- 68 | | 2 | 1 | | 2 | | 1 | 21 | 14 | 11 | 113 | 281 | 350 | 391 | 350 | 254 | 16 | 18 | 58 | 37 | 41 | 53 | 43 | 2 |
| 69- 70 | | | | | 1 | 1 | 1 | 4 | 14 | 9 | 131 | 318 | 371 | 403 | 333 | 198 | 17 | 36 | 67 | 56 | 29 | 42 | 46 | 1 |
| 71- 72 | | | | | | | | 1 | 4 | 2 | 119 | 351 | 393 | 328 | 305 | 163 | 12 | 36 | 63 | 47 | 47 | 48 | 31 | |
| 73- 74 | | | | | | | | 2 | 3 | 1 | 93 | 312 | 428 | 311 | 253 | 103 | 7 | 30 | 77 | 48 | 42 | 32 | 17 | 2 |
| 75- 76 | | | | | | | | | 1 | 2 | 56 | 209 | 365 | 357 | 276 | 84 | 5 | 18 | 51 | 57 | 38 | 41 | 13 | 1 |
| 77- 78 | | | | | | | | 1 | 1 | | 34 | 123 | 280 | 318 | 229 | 65 | 1 | 24 | 32 | 37 | 42 | 45 | 17 | |
| 79- 80 | | | | | | | | 1 | 1 | | 11 | 60 | 173 | 251 | 191 | 31 | 3 | 8 | 22 | 28 | 28 | 27 | 5 | 2 |
| 81- 82 | | | | | | | | 1 | | | | 12 | 86 | 167 | 147 | 13 | 2 | 3 | 7 | 20 | 16 | 12 | 6 | |
| 83- 84 | | | | | 1 | | | | 1 | | 1 | 5 | 37 | 108 | 85 | 13 | | | 3 | 7 | 13 | 20 | 5 | |
| 85- 86 | | | | | | | | | | | | | 18 | 44 | 56 | 1 | | | | 4 | 7 | 8 | 1 | 2 |
| 87- 88 | | | | | | | | | | | | 2 | 7 | 21 | 21 | 1 | | | | 2 | 2 | 3 | 2 | |
| 89- 90 | | | | | | | | | | | | | 1 | 6 | 12 | | | | | | 2 | 2 | 2 | |
| 91- 92 | | | | | | | | | | | | | | 4 | 5 | | | | | | | 1 | | |
| 93- 94 | | | | | | | | | | | | | | | 2 | | | | | | 1 | 2 | | |
| 95- 96 | | | | | | | | | | | | | | | | 1 | | | | | | | | |
| 97- 98 | | | | | | | | | | | | | | | | | | | | | | 1 | | |
| Total | 10 | 55 | 91 | 130 | 30 | 19 | 58 | 199 | 235 | 149 | 823 | 2,404 | 3,452 | 4,030 | 3,299 | 1,492 | 104 | 200 | 467 | 439 | 433 | 490 | 284 | 13 |
| Mean | 60.8 | 61.6 | 61.5 | 61.2 | 63.7 | 62.5 | 62.0 | 63.3 | 63.7 | 63.9 | 69.0 | 69.6 | 70.7 | 70.8 | 71.0 | 68.7 | 68.2 | 71.6 | 71.2 | 71.8 | 71.5 | 71.1 | 69.5 | 72.6 |

| Fork length in centimeters | $4_1$ | | | | | | | $5_2$ | | | | | | $5_1$ | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Apr. | May | June | July | Aug. | Sept. | Oct. | Apr. | May | June | July | Aug. | Sept. | May | June | July | Aug. | Sept. | Oct. |
| 59- 60 | | | | 1 | | | | | | | | | | | | | | | |
| 61- 62 | | 1 | 4 | 3 | 1 | 2 | 1 | | | | | | | | | | | | |
| 63- 64 | 1 | | 5 | 6 | 6 | | | | | 1 | 1 | | | | | 1 | | 1 | |
| 65 -66 | 5 | 2 | 7 | 9 | 3 | 1 | | | | | | | | | | | | | |
| 67- 68 | 7 | 9 | 9 | 14 | 9 | 2 | | | 1 | | 1 | 1 | | | | | | | |
| 69- 70 | 7 | 10 | 15 | 11 | 7 | 5 | 1 | | 7 | 2 | | | | | | | | | |
| 71- 72 | 18 | 20 | 22 | 22 | 21 | 11 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | | | 1 | | | |
| 73- 74 | 16 | 38 | 34 | 27 | 16 | 16 | 1 | 4 | 17 | 2 | 1 | 3 | 3 | | | | 4 | | |
| 75- 76 | 22 | 46 | 58 | 46 | 35 | 31 | 2 | 4 | 17 | 6 | 5 | 2 | 3 | 1 | 1 | | | | |
| 77- 78 | 37 | 77 | 90 | 52 | 53 | 46 | 1 | 5 | 19 | 12 | 9 | 8 | 7 | | 1 | 5 | | | |
| 79- 80 | 49 | 100 | 140 | 120 | 85 | 48 | 4 | 13 | 28 | 21 | 9 | 9 | 10 | 1 | 2 | 2 | 5 | | |
| 81- 82 | 37 | 90 | 156 | 132 | 134 | 46 | 2 | 13 | 20 | 19 | 8 | 22 | 12 | 1 | 4 | 5 | 2 | 5 | 2 |
| 83- 84 | 29 | 61 | 139 | 141 | 133 | 61 | 5 | 10 | 11 | 15 | 16 | 14 | 21 | | 3 | 4 | 4 | 4 | |
| 85- 86 | 15 | 60 | 126 | 111 | 168 | 47 | 2 | 2 | 14 | 18 | 11 | 27 | 18 | 2 | 2 | 3 | 4 | 9 | 1 |
| 87- 88 | 14 | 28 | 66 | 117 | 148 | 42 | 3 | 2 | 12 | 12 | 8 | 16 | 11 | 2 | 3 | 7 | 17 | 18 | 3 |
| 89- 90 | 4 | 15 | 67 | 85 | 112 | 24 | | 1 | 5 | 6 | 10 | 18 | 10 | 2 | 11 | 9 | 20 | 14 | 4 |
| 91- 92 | 2 | 10 | 40 | 60 | 92 | 19 | 3 | 1 | 2 | 3 | 6 | 12 | 7 | 2 | 10 | 10 | 26 | 16 | 2 |
| 93- 94 | 2 | 2 | 24 | 42 | 65 | 16 | | 2 | 3 | 5 | 7 | 5 | 5 | 5 | 6 | 11 | 17 | 23 | 4 |
| 95- 96 | 1 | 3 | 14 | 30 | 42 | 9 | | 1 | | | 3 | 5 | 4 | 5 | 6 | 7 | 25 | 20 | 7 |
| 97- 98 | | 3 | 9 | 11 | 20 | | | | | 3 | 1 | 9 | 2 | 1 | 6 | 11 | 12 | 17 | 6 |
| 99-100 | | 1 | 6 | 5 | 12 | 2 | | | 1 | 1 | 1 | 2 | 1 | 3 | 4 | 6 | 21 | 9 | 5 |
| 101-102 | | | | 3 | 4 | 2 | | | 1 | | | 2 | | | 5 | 4 | 8 | 4 | 2 |
| 103-104 | | | 3 | 2 | 5 | 1 | | | | 1 | | | | | | 3 | 2 | 2 | 2 |
| 105-106 | | | | 1 | 5 | 2 | | | | | | | | | | 1 | 3 | 4 | |
| 107-108 | | | | | 4 | | | | | | | 1 | | | | 1 | 2 | 1 | 1 |
| 109-110 | | | | | | | | | | | | | 1 | | | | 1 | | 1 |
| 111-112 | | | | | | | | | | | | | | | | | | | |
| 113-114 | | | | | | | | | | | | | | | | | 1 | | |
| Total | 266 | 576 | 1,034 | 1,051 | 1,180 | 433 | 26 | 59 | 160 | 129 | 99 | 157 | 116 | 25 | 64 | 91 | 174 | 147 | 40 |
| Mean | 79.0 | 80.4 | 82.4 | 83.6 | 85.4 | 82.8 | 81.3 | 81.2 | 80.2 | 83.0 | 84.3 | 86.3 | 85.1 | 91.4 | 91.3 | 91.3 | 93.1 | 92.2 | 95.1 |

[a]Age-group-month samples of less than 10 fish omitted from table were $2_1$'s - 2 in April, and 6 in October; $3_2$'s - 3 in October; $4_2$'s - 2 in October; $4_1$'s - 7 in October; $5_2$'s - 9 in April; $5_1$'s - 3 in April, and 3 in May.

**APPENDIX TABLE 4.** Washington ocean sport fishery. Size distribution of chinook salmon catches in numbers of fish by 2-centimeter intervals, age group and month, 1964-1969[a]

| Fork length in centimeters | Age group $2_1$ May | June | July | Aug. | Sept. | $3_2$ Apr. | May | June | July | Aug. | Sept. | $3_1$ Apr. | May | June | July | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 41- 42 | | | 2 | 5 | 1 | | | | | | | | | | | | | |
| 43- 44 | | 1 | 5 | 11 | 4 | | | | | | | | | | | | | |
| 45- 46 | 1 | 3 | 29 | 49 | 8 | | | | | 1 | 1 | | | | | | 1 | |
| 47- 48 | 2 | 36 | 138 | 136 | 73 | 3 | 1 | 7 | 12 | 5 | 3 | 2 | 2 | 4 | 5 | 4 | 1 | |
| 49- 50 | 3 | 59 | 213 | 229 | 131 | 6 | 2 | 19 | 29 | 10 | 4 | 1 | 4 | 10 | 17 | 7 | | |
| 51- 52 | 4 | 47 | 213 | 232 | 126 | 1 | 5 | 19 | 48 | 10 | 7 | 14 | 7 | 26 | 30 | 17 | 3 | |
| 53- 54 | 3 | 33 | 169 | 173 | 97 | 2 | 5 | 22 | 56 | 24 | 14 | 22 | 14 | 33 | 45 | 28 | 3 | |
| 55- 56 | 1 | 16 | 98 | 121 | 71 | 1 | 2 | 22 | 48 | 27 | 10 | 29 | 21 | 58 | 57 | 41 | 16 | |
| 57- 58 | 1 | 14 | 74 | 101 | 62 | | 3 | 28 | 51 | 33 | 17 | 37 | 31 | 93 | 80 | 58 | 18 | |
| 59- 60 | | 8 | 51 | 55 | 37 | | 2 | 14 | 48 | 36 | 11 | 34 | 44 | 96 | 98 | 74 | 34 | 1 |
| 61- 62 | | 3 | 18 | 38 | 30 | | 2 | 13 | 21 | 26 | 19 | 26 | 30 | 78 | 121 | 99 | 41 | 5 |
| 63- 64 | | | 10 | 21 | 13 | | | 8 | 20 | 19 | 3 | 13 | 30 | 105 | 123 | 90 | 58 | 3 |
| 65- 66 | | | 8 | 6 | 2 | | | 4 | 15 | 11 | 7 | 22 | 25 | 104 | 124 | 122 | 56 | 2 |
| 67- 68 | | | 3 | 7 | 1 | | | 4 | 10 | 7 | 3 | 25 | 35 | 112 | 133 | 109 | 73 | 6 |
| 69- 70 | | | | | 1 | | | | 3 | 4 | 3 | 19 | 48 | 99 | 142 | 117 | 73 | 4 |
| 71- 72 | | | | 1 | | | 1 | | 1 | 7 | | 14 | 33 | 108 | 154 | 107 | 65 | 2 |
| 73- 74 | | | | | | | 1 | | | 1 | | 11 | 42 | 115 | 188 | 130 | 61 | 3 |
| 75- 76 | | | 1 | | | | | | | 4 | 1 | 6 | 26 | 144 | 206 | 167 | 48 | 4 |
| 77- 78 | | | | | 2 | | | | 1 | | | 2 | 14 | 93 | 224 | 157 | 23 | 1 |
| 79- 80 | | | | | | | | | | 1 | | | 3 | 67 | 163 | 147 | 18 | |
| 81- 82 | | | | | | | | | | | | | 1 | 36 | 111 | 107 | 7 | 1 |
| 83- 84 | | | | | | | | | | | | | | 21 | 60 | 64 | 7 | |
| 85- 86 | | | | | | | | | | | | | | 7 | 29 | 47 | 2 | |
| 87- 88 | | | | | | | | | | | | | | 3 | 18 | 28 | 2 | |
| 89- 90 | | | | | | | | | | | | | | 2 | 6 | 13 | 1 | |
| 91- 92 | | | | | | | | | | | | | | 1 | 3 | 4 | 2 | |
| 93- 94 | | | | | | | | | | | | | | 1 | 1 | 3 | | |
| Total | 15 | 220 | 1,032 | 1,185 | 659 | 13 | 24 | 160 | 363 | 226 | 103 | 227 | 410 | 1,416 | 2,138 | 1,740 | 613 | 32 |
| Mean | 51.1 | 51.6 | 52.3 | 52.6 | 53.1 | 50.4 | 55.8 | 55.9 | 56.5 | 59.1 | 58.2 | 61.7 | 65.5 | 68.0 | 70.4 | 71.4 | 68.5 | 68.6 |

| Fork length in centimeters | Age group $4_2$ Apr. | May | June | July | Aug. | Sept. | $4_1$ Apr. | May | June | July | Aug. | Sept. | $5_2$ May | June | July | Aug. | Sept. | $5_1$ June | July | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 47- 48 | | | | 1 | | | | | | | | | | | | | | | | | | |
| 49- 50 | | | | | 1 | | | | | | | | | | | | | | | | | |
| 51- 52 | | 1 | | 1 | 2 | | | | | | | | | | | | | | | | | |
| 53- 54 | | 2 | 1 | 1 | 2 | | | | | 1 | | | | | | | | | | | | |
| 55- 56 | | 2 | | | | | 1 | | 1 | 3 | | 1 | | | | | | | | | | |
| 57- 58 | 2 | 1 | 1 | 2 | 4 | | | | | 2 | | | | | | | | | | | | |
| 59- 60 | 2 | 3 | 5 | 3 | 2 | 3 | | 1 | | 3 | 3 | | | | | | | | | | | |
| 61- 62 | 6 | 4 | 10 | 11 | 8 | 6 | 3 | | 1 | 3 | 1 | | | | | | | | | | | |
| 63- 64 | 2 | 7 | 11 | 20 | 11 | 12 | 3 | 1 | 3 | 5 | 3 | | 1 | | | | | | | | | |
| 65- 66 | 5 | 9 | 15 | 20 | 11 | 17 | 2 | | 7 | 4 | 2 | 2 | | | | 1 | | 1 | 1 | | | |
| 67- 68 | 4 | 6 | 13 | 15 | 9 | 12 | 5 | 1 | 2 | 3 | 6 | 1 | | | | | | | | | | |
| 69- 70 | 10 | 8 | 22 | 21 | 8 | 13 | 7 | 4 | 5 | 2 | 6 | | | | | | 1 | | | | | |
| 71- 72 | 5 | 6 | 18 | 15 | 10 | 16 | 9 | 5 | 7 | 9 | 13 | 6 | 1 | | | | | | | 1 | | |
| 73- 74 | 4 | 10 | 20 | 21 | 18 | 16 | 2 | 8 | 15 | 14 | 20 | 9 | 2 | | | 1 | | 1 | | 1 | | |
| 75- 76 | 5 | 4 | 17 | 21 | 19 | 7 | 8 | 11 | 13 | 13 | 10 | 6 | 3 | | 2 | 1 | 3 | | 1 | 1 | | |
| 77- 78 | 3 | 4 | 11 | 30 | 17 | 11 | .3 | 4 | 25 | 34 | 45 | 19 | 1 | 3 | 3 | 5 | 1 | | 1 | 1 | | |
| 79- 80 | 2 | 5 | 7 | 14 | 14 | 7 | 8 | 9 | 56 | 72 | 77 | 16 | 4 | 2 | 9 | 12 | 7 | 1 | 2 | 1 | | |
| 81- 82 | | 1 | 5 | 9 | 8 | 4 | 5 | 17 | 50 | 102 | 107 | 38 | | 11 | 13 | 11 | 7 | | 1 | 2 | 2 | 1 |
| 83- 84 | | 1 | 5 | 13 | 10 | 1 | 1 | 8 | 44 | 101 | 155 | 35 | 4 | 5 | 10 | 10 | 6 | 1 | 1 | 5 | | 1 |
| 85- 86 | | 1 | 2 | 6 | 11 | 3 | 3 | 13 | 46 | 113 | 146 | 47 | 2 | 8 | 10 | 16 | 10 | | 2 | 6 | 4 | |
| 87- 88 | | 1 | 2 | 2 | 5 | 2 | 2 | 10 | 34 | 111 | 157 | 21 | 3 | 4 | 8 | 10 | 9 | 2 | 3 | 9 | 7 | 1 |
| 89- 90 | | | 1 | 3 | 4 | | | 1 | 22 | 92 | 128 | 19 | | 3 | 9 | 10 | 8 | 1 | 5 | 22 | 8 | 1 |
| 91- 92 | | | 1 | | 1 | | | 1 | 27 | 60 | 110 | 15 | 1 | 3 | 6 | 12 | 5 | 6 | 15 | 19 | 15 | |
| 93- 94 | | | | 2 | 1 | | | 4 | 15 | 49 | 86 | 7 | | 3 | 10 | 10 | 8 | 5 | 13 | 27 | 15 | 2 |
| 95- 96 | | | | 1 | | | | 1 | 9 | 28 | 54 | 14 | | 4 | 4 | 10 | 5 | 5 | 8 | 20 | 25 | |
| 97- 98 | | | | | | | | 1 | 7 | 41 | 57 | 3 | | | | 6 | 3 | 4 | 12 | 19 | 25 | 2 |
| 99-100 | | | | | | | | | 4 | 24 | 30 | 5 | | | 2 | 6 | | 4 | 11 | 25 | 9 | 1 |
| 101-102 | | | | | | | | | 5 | 12 | 13 | 1 | | | 2 | 1 | 1 | 1 | 6 | 19 | 3 | 1 |
| 103-104 | | | | | | | | | | 12 | 5 | | | | 2 | 1 | | 1 | 4 | 8 | 5 | 1 |
| 105-106 | | | | | | | | | 1 | 5 | 3 | | | 1 | | | | 1 | 3 | 7 | 4 | |
| 107-108 | | | | | | | | | 1 | 1 | 3 | | | | 1 | 1 | | 1 | 2 | 3 | 2 | |
| 109-110 | | | | | | | | | | 2 | 5 | | | | | | 1 | 3 | 3 | 4 | 4 | |
| 111-112 | | | | | | | | | | | | | | | | | | | | 2 | 3 | |
| 113-114 | | | | | | | | | | | 1 | | | | 1 | | | | 2 | | 1 | |
| 115-116 | | | | | | | | | | | | | | | | | | | 1 | 1 | | |
| 117-118 | | | | | | | | | | | | | | | | | | | | | 1 | |
| Total | 50 | 76 | 167 | 232 | 176 | 130 | 62 | 100 | 400 | 921 | 1,246 | 265 | 22 | 47 | 92 | 124 | 75 | 38 | 97 | 203 | 133 | 11 |
| Mean | 68.8 | 69.2 | 71.4 | 72.8 | 73.8 | 71.0 | 73.8 | 80.6 | 83.5 | 86.3 | 87.0 | 84.4 | 80.1 | 86.1 | 87.6 | 88.0 | 87.4 | 94.7 | 95.6 | 95.3 | 96.2 | 93.3 |

[a]Age-group-month samples of less than 10 fish omitted from table were $2_1$'s - 0 in April, and 1 in May; $3_2$'s - 5 in April, and 6 in October; $5_2$'s - 7 in October; $5_1$'s - 9 in April.

## APPENDIX TABLE 5

Chinook sex ratios and mean fork lengths in centimeters by age group and month for Washington ocean sport fishery, 1964-1969 means[a]

| Age group | Sex | April | May | June | July | Aug. | Sept. | Oct. | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| $2_1$ | Male | | | | | | | | |
| | No. | 2 | 8 | 108 | 504 | 521 | 242 | 4 | 1,389 |
| | Mean | | | 49.9 | 52.7 | 52.8 | 52.7 | | 52.5 |
| | Female | | | | | | | | |
| | No. | 1 | 9 | 58 | 195 | 218 | 138 | 4 | 623 |
| | Mean | | | 49.9 | 51.5 | 51.8 | 53.3 | | 51.9 |
| $3_2$ | Male | | | | | | | | |
| | No. | 6 | 11 | 55 | 139 | 84 | 38 | 0 | 333 |
| | Mean | | 55.3 | 55.8 | 55.9 | 58.5 | 57.3 | | 56.7 |
| | Female | | | | | | | | |
| | No. | 8 | 6 | 44 | 97 | 58 | 26 | 0 | 239 |
| | Mean | | | 54.9 | 56.0 | 57.9 | 58.9 | | 56.4 |
| $3_1$ | Male | | | | | | | | |
| | No. | 128 | 126 | 474 | 798 | 623 | 203 | 3 | 2,355 |
| | Mean | 62.5 | 65.2 | 68.7 | 70.9 | 70.7 | 67.7 | | 69.4 |
| | Female | | | | | | | | |
| | No. | 137 | 149 | 424 | 672 | 470 | 156 | 1 | 2,009 |
| | Mean | 61.0 | 62.7 | 67.2 | 70.3 | 72.1 | 69.4 | | 68.8 |
| $4_2$ | Male | | | | | | | | |
| | No. | 21 | 24 | 45 | 88 | 72 | 61 | 0 | 311 |
| | Mean | 66.7 | 68.9 | 70.7 | 70.3 | 72.5 | 69.0 | | 70.5 |
| | Female | | | | | | | | |
| | No. | 28 | 26 | 58 | 86 | 53 | 42 | 0 | 293 |
| | Mean | 69.6 | 68.6 | 72.1 | 74.8 | 75.3 | 72.5 | | 72.9 |
| $4_1$ | Male | | | | | | | | |
| | No. | 27 | 30 | 143 | 384 | 468 | 69 | 0 | 1,121 |
| | Mean | 76.6 | 81.3 | 83.4 | 87.6 | 88.1 | 84.8 | | 86.7 |
| | Female | | | | | | | | |
| | No. | 39 | 42 | 152 | 370 | 551 | 119 | 0 | 1,273 |
| | Mean | 74.6 | 79.6 | 83.2 | 85.8 | 86.4 | 84.8 | | 85.1 |
| $5_2$ | Male | | | | | | | | |
| | No. | 4 | 4 | 15 | 40 | 51 | 31 | 0 | 145 |
| | Mean | | | 88.5 | 89.6 | 87.2 | 88.6 | | 88.4 |
| | Female | | | | | | | | |
| | No. | 6 | 9 | 18 | 43 | 59 | 31 | 0 | 166 |
| | Mean | | | 83.7 | 85.8 | 87.6 | 85.9 | | 85.3 |
| $5_1$ | Male | | | | | | | | |
| | No. | 2 | 1 | 8 | 32 | 71 | 19 | 1 | 134 |
| | Mean | | | | 98.8 | 98.0 | 101.8 | | 98.9 |
| | Female | | | | | | | | |
| | No. | 0 | 0 | 23 | 52 | 94 | 55 | 4 | 228 |
| | Mean | | | 91.8 | 92.7 | 93.5 | 94.0 | | 93.3 |

[a]Means not computed for samples less than 10 fish.

# Maturity Rates
# of Ocean-Caught Chinook Salmon

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# BULLETIN 8

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# MATURITY RATES OF OCEAN-CAUGHT CHINOOK SALMON

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## ABSTRACT

To enhance the existing management data base, over 2,500 chinook caught off the Washington coast during the 1970 and 1971 fishing seasons were sampled for maturity information. Immatures were separated from maturing fish by examination of gonadal volume displacement frequencies and division points were recommended by sex and age group. Three-year-old chinook accounted for about half the sample population and, in contrast to younger and older fish, contained substantial numbers of both immature and maturing individuals.

## INTRODUCTION

Maturity rates for Pacific salmon *(Oncorhynchus sp.)* exploited by high-seas fisheries have long been deemed essential parameters for understanding the dynamics of various stocks involved. This understanding, in turn, is a prerequisite for rational management of all existing or planned fisheries that will extract harvestable excesses from those stocks. Maturity of chinook salmon, while receiving considerably less attention than accorded maturity of sockeye and chum, is no exception to this generality.

## REVIEW OF PREVIOUS INVESTIGATIONS

In early work, Rich (1925) studied maturity of female chinook by measuring egg diameters, but he did not consider males or the effect of maturity on his growth analyses. More recently, the consensus has been that growth, sex, and maturity are closely related. As a general rule, the males and fastest growing salmon of each age class mature earlier than the females and slowest growing salmon. For example, Van Hyning (1968) analyzed 721 troll fishery maturity samples taken in 1954 and 1955 between Grays Harbor (Washington) and Newport (Oregon), and found that 44% of 3-year-old males but only 15% of the females were maturing. Most samples were taken in the spring and early summer and were grouped for all years, months, and areas. He concluded that maturity appeared to be more a function of size and sex than of age.

Cleaver (1969) discussed the relationships between size, growth, and maturity for Columbia River hatchery fish, and developed a range of maturity rates for use in yield equations. He also discussed the maturity work of Van Hyning and Washington coastal 1962 samples (P. K. Bergman, unpublished data). A case for earlier maturity schedules of faster growing chinook stocks was proved. Cleaver concluded that hatchery stocks have adapted to earlier maturity as an apparent result of fishing pressure.

In a study specific to the sport fishery at the mouth of the Columbia River during August and early September 1967, Fiscus (1969) concluded that female chinook in each total-length inch-interval less than 28 inches and males less than 25 inches were primarily immature. Those in each greater inch-interval were primarily mature, with one exception. Additional maturity determinations for sport-caught chinook from this same area were made for a number of years prior to 1967 through visual examinations (Fiscus, 1965, 1966, 1969; Haw, Wendler, and Deschamps, 1967).

In a more distant area, from tagging and recovery data, Parker and Kirkness (1956) determined maturity of chinook taken off S.E. Alaska. However, the markedly older age composition of the population precludes application of their findings to southerly areas.

The possibility of maturity schedule changes with time was also of concern. Van Hyning (1968) reviewed tagging results as an alternate means of examining size-maturity relationships. Obviously, fish of known size when tagged and recovered in streams the same year were maturing, while those recovered in both ocean and river fisheries during years following tagging were immatures. He concluded a definite change occurred in maturity and/or survival pattern of chinook found in the Columbia River to Grays Harbor area between the periods of 1948–1952 and 1957–1962.

Although the cited data were available, fishery managers dealing with chinook salmon have generally felt the data to be somewhat less precise than required for intelligent management of the resource. For instance, in a section entitled "What We Need to Know" (page 38), the U. S. Section of the Informal Chinook and Coho Committee (1969) stated, "... additional work is required to determine at which stage in the life cycle of chinook and coho does maximum weight occur. Results from existing studies on sorely needed natural

[1]Presently with State of Washington, Department of Ecology.

and fishing mortality rates and maturity schedules are restricted by assumptions which limit the validity of the studies to an unknown degree . . . " (Maximum weight refers to the yield or harvest from the resource.) In addition, a conclusion of the same report stated, ". . . The average age of troll-caught chinook has decreased with time." These prevailing beliefs, plus apparent area-time period limitations of previous studies, and the possibility of recent maturity schedule changes, ultimately led to the planning of additional studies for Washington coastal areas in 1970-1971.

## DEVELOPMENT OF METHODS

With knowledge gained during previous investigations, it was logical to first consider proper methodology prior to commencement of actual field work. Toward this end, original records for Washington coastal maturity samples collected in 1962 were readily available for analysis. Cleaver (1969) examined these same raw data and made maturity designations for ocean-type or sub-1 chinook taken during July and August, but he did not describe his methods.

During the 1962 study, 2,787 samples were collected by paying a small reward per maturity sample to commercial salmon trollers. The fishermen preserved viscera of legal-size chinook (i.e., 26-inch total length or larger) in cellophane bags and attached numbered identification markers to both the sample bag and donor fish. Upon landing at dockside, project personnel could then relate samples to specific fish; and could obtain data on sex, fork length (centimeters), gonad[2] displacement volume (milliliters), date, and area caught. Scale samples were taken for laboratory determination of age and sub-type.

In 1969, these data were reexamined by arraying them in various manners suggested by other investigators. These arrays included (1) graphically comparing gonad size with fish size, (2) gonad weight or volume frequency distributions, and (3) the use of a computed "Index of Maturity" (Godfrey, 1961; Fiscus, 1969; Ishida and Miyaguchi, 1958; Van Hyning, 1968). The latter method utilized a ratio of weight or displacement volume of gonads to total body weight.

Although the three methods yielded somewhat comparable results, the most accurate means of separating immature and maturing chinook appeared to be frequency of gonadal displacements in milliliters (ml) graphed by sex, age, subtype, and month of capture. Comparisons by fish length were generally less dependable. The index of maturity, which was used quite successfully on sockeye and chum salmon, did not appear readily applicable to chinook. The larger size range of this species, plus lack of relatively constant proportions between gonad size and body size within this extensive range, probably limited its usefulness.

A deficiency in the 1962 study itself was noted. In order to measure all gonad samples, including ovaries approaching 1,000 ml displacement, technicians were provided with a large graduated cylinder and were instructed to subsequently round off all displacement readings to the nearest 5 ml. While data on females remained usable, male samples were of questionable accuracy since the probable immature-maturing separation point for testes was less than 10 ml.

For 1970–1971 studies, exactly the same data were collected, but with two modifications. First, since the 1962 study demonstrated that any male or female chinook having a gonad volume displacement of 50 ml or more was almost certainly a maturing fish, personnel were instructed to classify these as "maturing." For smaller gonads, samplers were provided with a small graduated cylinder and instructed to measure carefully to the nearest whole ml. Secondly, sport landings were also sampled to provide data on chinook less than 26-inch total length. Sport-caught fish were sampled at five ports along the Washington coast (Ilwaco, Westport, LaPush, Neah Bay, and Sekiu) while troll-caught chinook, which are landed and sold in a dressed condition, were sampled onboard vessels during actual fishing operations.

## DETERMINATION OF CHINOOK MATURITY

During the 1970-1971 ocean fishing season (April 15–October 31), complete chinook maturity samples (sex, length, gonad displacement, age, and subtype) were obtained from 2,513 sport-caught chinook and 420 examined onboard commercial trollers. The latter means of collecting samples, while considerably more costly in terms of manpower expended per sample collected, was pursued until we were satisfied that no meaningful differences in size-maturity relationships existed between sport- and troll-caught fish from Washington coastal fishing areas. In subsequent analysis, the 420 troll samples were omitted from further consideration since they included only chinook over 26-inch total length as opposed to a 20-inch T. L. minimum for sport fishery samples.

In various preliminary reviews, the maturity data showed no discernible differences between the five areas or two years involved, but definite changes were noted by time, sex, and age group. Final data were compiled by month, sex, and age group for all areas, and were combined for the two years.

To determine the best division points for separating immature and maturing chinook, gonadal displacement volume frequencies were plotted by sex and month for each age group. Results for the important $3_1$-age group, which contributed 1,228 of 2,513 samples taken, are shown in figure 1. The proper separation point can be discerned by contrasting one mode of low magnitude volumes (immatures) that remains relatively constant and shows little change with a second group of observations (matures) that increases markedly in volume as the season progresses. A comparable division point might also be derived by working backwards from the distinct group shown late in the season. In either case, the $3_1$ fish appeared to show the best division points at 25 ml for females and 5 ml for males. The accuracy of these somewhat arbitrary division points is most suspect early in the season, when it is obvious that some degree of overlap must have occurred between the two groups. Most of the samples were taken, however, from mid-June to early September when greater reliability prevailed.

[2]Displacement of the 2 gonads together was measured for each fish.

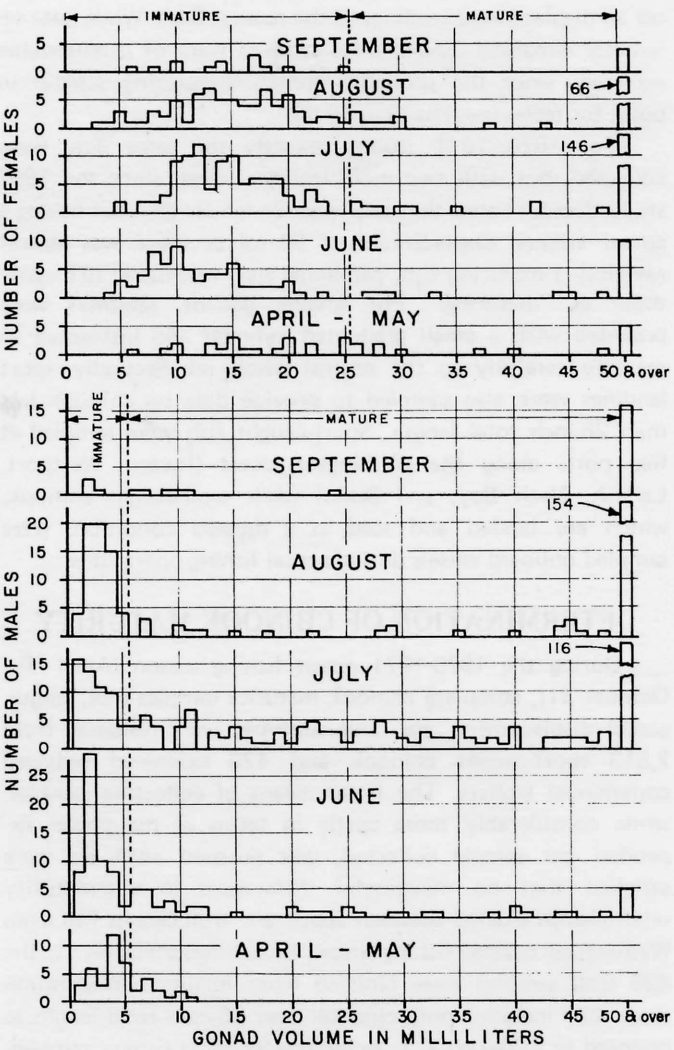


FIGURE 1. Gonad volume frequency of $3_1$-age group chinook salmon by month, 1970–1971.

Other sub-1 or ocean-type nuclei age groups were plotted and examined in a similar manner, with proper division points being relatively clear. The total sample contained only 72 sub-2 or stream-type nuclei chinook, but these negated any precise analysis. Regardless, division points were established based on those of sub-1 age groups of comparable size distribution (i.e., $2_1$, $3_1$, and $4_1$ points for the $3_2$, $4_2$, and $5_2$ groups, respectively). Recommended values for all groups are summarized in Table 1.

Further, these values were then extrapolated to each age-subtype-sex group to illustrate composite results (Table 2). The $2_1$ group had only 5 maturing females compared to 142 immatures, but had 90 maturing males compared to 211 immatures. The large $3_1$ category had approximately equal numbers of both matures and immatures for females (266 to 273), but mature males predominated by well over a 2 to 1 margin (479 to 210). In the $4_1$ group, only 7 of 699 chinook regardless of sex were immature while all $5_1$'s sampled were maturing.

**TABLE 1.** Recommended maturity rating division points for chinook salmon (age groups determined by scale analysis, and stage of maturity by gonad volume)

| | Sub-1 or ocean-type nuclei | | Sub-2 or stream-type nuclei | |
|---|---|---|---|---|
| Age-sex-group | Immature | Maturing | Immature | Maturing |
| 2-year-old males | ≤4 ml. | >4 ml. | | |
| 3-year-old males | ≤5 ml. | >5 ml. | ≤4 ml. | >4 ml. |
| 4-year-old males | ≤5 ml. | >5 ml. | ≤5 ml. | >5 ml. |
| 5-year-old males | ≤5 ml. | >5 ml. | ≤5 ml. | >5 ml. |
| 6-year-old males | ≤5 ml. | >5 ml. | ≤5 ml. | >5 ml. |
| 2-year-old females | ≤15 ml. | >15 ml. | | |
| 3-year-old females | ≤25 ml. | >25 ml. | ≤15 ml. | >15 ml. |
| 4-year-old females | ≤30 ml. | >30 ml. | ≤25 ml. | >25 ml. |
| 5-year-old females | ≤30 ml. | >30 ml. | ≤30 ml. | >30 ml. |
| 6-year-old females | ≤30 ml. | >30 ml. | ≤30 ml. | >30 ml. |

**TABLE 2.** Maturity designations for 2,513 chinook salmon by age group and sex, 1970–1971

| | Number of fish | | | | |
|---|---|---|---|---|---|
| Age group | Immature males | Immature females | Mature males | Mature females | Group total |
| $2_1$ | 211 | 142 | 90 | 5 | 448 |
| $3_2$ | 17 | 16 | 9 | | 42 |
| $3_1$ | 210 | 273 | 479 | 266 | 1,228 |
| $4_2$ | 4 | 3 | 5 | 11 | 23 |
| $4_1$ | 3 | 4 | 321 | 371 | 699 |
| $5_2$ | | | 5 | 1 | 6 |
| $5_1$ | | | 30 | 35 | 65 |
| $6_2$ | | | 1 | | 1 |
| $6_1$ | | | | 1 | 1 |

## RELATIONSHIP BETWEEN SIZE AND MATURITY

For management considerations, particularly with respect to minimum-size limits for commercial fisheries, any maturity data ultimately must be expressed in some unit of size measurement. For ocean-caught chinook, the 1970–1971 samples could now be readily plotted by size, specifically in terms of fork length by 2-centimeter group without regard to sex (Figure 2).

For males and females combined, immature chinook predominated in all groups of small fish up to the 65 to 66-cm

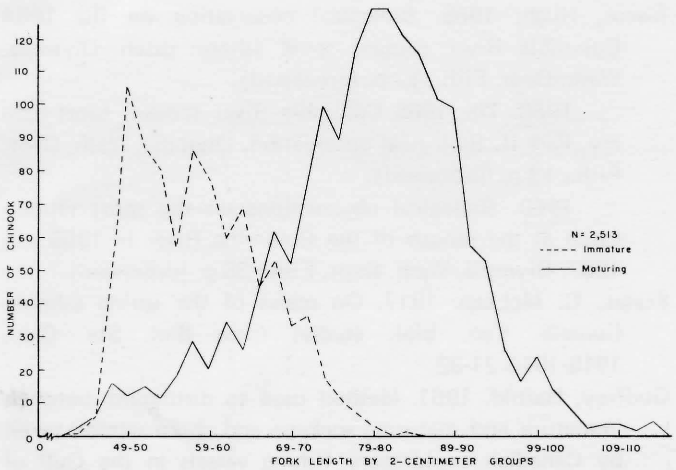


FIGURE 2. Size-maturity relationship for ocean-caught chinook salmon.

cell where a 50-50 relationship occurred. Maturing fish predominated in all groups 67–68 cm or over. Within the immatures, males showed a definite tendency to predominate in the smallest size groups, those below the 55 to 56-cm interval, while females generally were most numerous among the larger immatures. For maturing chinook, few females were observed in any group below the mid-60-cm range, and males continued to prevail until the mid-70's. Females tended to be in the majority in most centimeter-size ranges from the high 70's to low 90's, with a definite male predominance again prevailing in the largest-size categories.

## EXAMINATION OF THIRD-YEAR FALL CHINOOK

The key to consideration of chinook maturity lies almost entirely with the $3_1$-age group due to a combination of two factors: (1) an overall abundance approximating that of all other age groups combined, and (2) substantial numbers of both immature and maturing fish within the age group. A combination of these factors in turn makes the $3_1$-age group almost entirely responsible for a significant overlap of immatures and matures within the central portion of the population's length-frequency distribution.

To examine the relationship between immature and maturing fall-run fish in their third year, weekly mean lengths were calculated during a 10-week period from mid-June through August, when week-interval samples of 20 or more fish were available from each category (Figure 3). The size data illustrate that maturing fish are, on the average, much larger than immature fish during summer months in spite of identical total age and early life history types. Immatures, however, while being decidedly smaller, demonstrate a much faster growth rate. Simple logic supports this conclusion since maturing fish must provide for rapidly developing gonads in addition to any increase in body size. It also can be speculated that immatures, with no immediate requirements for migrating toward their stream of origin, can more readily remain in areas of abundant feed throughout the summer.

To further explore growth relationships, usable scale samples from $3_1$-age group chinook sampled in 1971 were measured in order to back calculate first- and second-year growth. The method utilized was first described by Fraser (1917) and expressed in detail by Parker and Kirkness (1956). Results for 319 scale samples examined showed the following:

| | Growth | (fork length in cm) | |
|---|---|---|---|
| Category | 1st year | 2nd year | 2-year total |
| Immature | 14.0 | 25.8 | 39.8 |
| Maturing | 15.3 | 29.8 | 44.3 |

Thus, maturing fall-run fish taken in their third year were, on the average, larger at the end of both their first and second years. Both the immature and maturing groups added nearly 40% to their length by the time they were captured in their third year, resulting in a 3- to 4-fold increase in body weight.

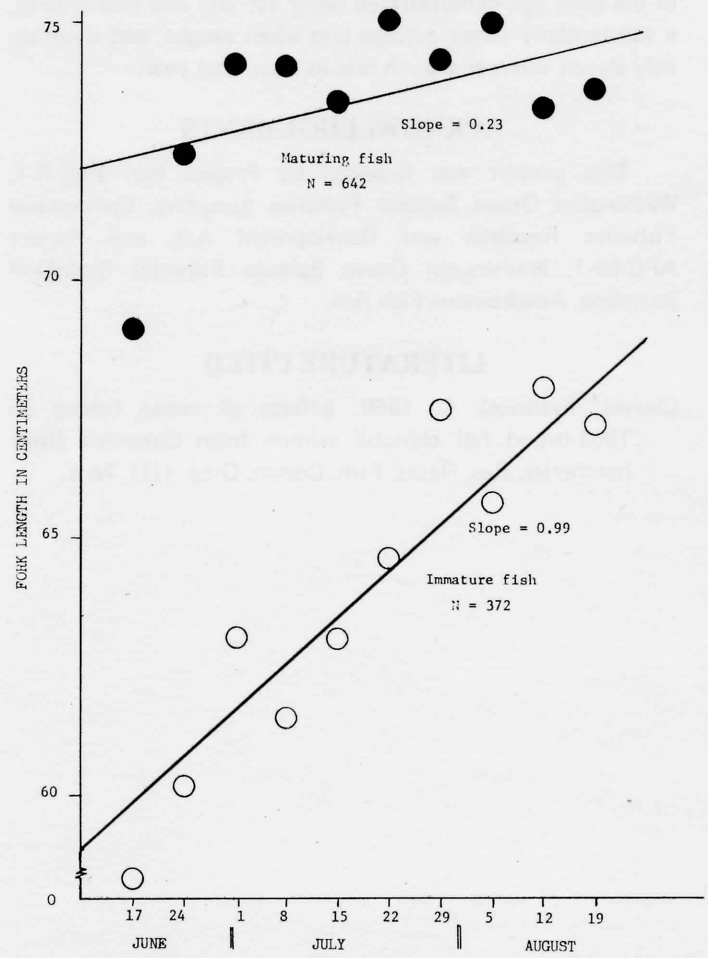


FIGURE 3. Summer months' size-growth relationship for immature and maturing $3_1$-age group chinook salmon.

## SUMMARY

Research conducted in 1970–1971 determined maturity of chinook salmon available to commercial and recreational fisheries operating off the Washington coast. The most accurate means of segregating immature from maturing fish appeared to be through examination of gonadal volume displacement frequencies, but even this method was of marginal value early in the season. Division points were recommended by sex for each age group. Results were:

1. Fall-run of sub-1 type chinook accounted for all but 72 of 2,513 samples analyzed.

2. For the youngest age group, small 2-year-olds, over two-thirds of the males and virtually all females were immatures.

3. For older, larger chinook, a high percentage of 4-year-olds and all 5-year-olds were found to be maturing.

4. The important 3-year-old fall chinook group accounted for nearly one-half the fish sampled and contained substantial numbers of both immature and maturing chinook. This age group produced a sizable overlap of the two maturation categories within the middle of the population's overall size distribution.

5. Maturing 3rd-year fish, when compared to immatures of the same age, demonstrated faster 1st- and 2nd-year growth, a substantially larger average size when caught, and a noticeably slower summer growth rate in their final year.

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# APPENDIX I

Appendix Tables 1 through 5 provide detailed data from which tables and figures in this report were developed.

**APPENDIX TABLE 1.** Gonad displacement volumes of male chinook salmon by age group and month, 1970-1971

| Gonad displacement volume in milliliters | Age group $2_1$ | | | | | $3_2$ | | | | $3_1$ | | | | | $4_2$ | | | $4_1$ | | | | | $5_2$ | | $5_1$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Apr.-May | June | July | Aug. | Sept. | Apr.-May | June | July | Aug. | Apr.-May | June | July | Aug. | Sept. | Apr.-May | June | July | Apr.-May | June | July | Aug. | Sept. | July | Aug. | June | July | Aug. | Sept. |
| 1 | 1 | 8 | 48 | 57 | 10 | 1 | 1 | 4 | 2 | 3 | 8 | 16 | 4 | | | | | | | | | | | | | | | |
| 2 | 2 | 5 | 19 | 29 | 6 | | | 2 | | 6 | 29 | 14 | 20 | 3 | | | 1 | | | | | | | | | | | |
| 3 | 1 | 2 | 5 | 9 | 1 | | 3 | | 1 | 3 | 10 | 11 | 20 | 1 | | | | | | | | | | | | | | |
| 4 | 1 | 1 | 2 | 3 | 1 | | | 3 | | 12 | 8 | 10 | 15 | | 2 | | | | 1 | 1 | | | | | | | | |
| 5 | | | 3 | | | | 1 | | 1 | 7 | 2 | 4 | 4 | | 1 | | | 1 | | | | | | | | | | |
| 6 | | | 1 | 1 | | | | | | 2 | 5 | 4 | | 1 | | | | | 1 | | | | | | | | | |
| 7 | | | 3 | 2 | | | | | | 4 | 5 | 6 | 3 | 1 | | | | | | | | | | | | | | |
| 8 | | | 2 | | | | | | | 2 | 2 | 4 | | | | | | 3 | | | | | | | | | | |
| 9 | | | 1 | | | | | | | 1 | 3 | | | 1 | | | | | 1 | | | | | | | | | |
| 10 | | | 1 | | | | | | | 2 | 1 | 4 | 2 | 1 | | | | 1 | | | | | | | | | | |
| 11 | | | | | | | | 1 | | 1 | 2 | 7 | 1 | 1 | | | | 1 | | | | | | | | | | |
| 12 | | | 1 | 3 | | | | | 1 | | 2 | | 1 | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | 3 | | | 1 | | | | 1 | | | | | | | | | |
| 14 | | | | 2 | | | | | | | | 2 | | | | | 1 | 2 | | 3 | | | 1 | | | | | |
| 15 | | | 2 | 1 | | | | | | | 1 | 4 | 1 | | | | | | 2 | | | | | | | | | |
| 16 | | | | | | | | | | | | 2 | | | | | | | | 1 | | | | | | | | |
| 17 | | | 1 | | | | | | | | | 1 | | | | | | | | 1 | | | | | | | | |
| 18 | 1 | | | 1 | | | | | | | | 1 | 1 | | | | | | | | | | | | | | | |
| 19 | | | | 1 | | | | | | | | 3 | | | | | | 1 | | | 1 | | | | | | | |
| 20 | | | 2 | 1 | | | | | | | 2 | 1 | | | | | | | 2 | | | | | | | | | |
| 21 | | | 1 | | | | | | 1 | | 1 | 4 | | | | | | | | | | | | | | | | |
| 22 | | | 1 | 1 | | | | | | | 1 | 5 | 1 | | | | | 1 | 1 | | | | | | | | | |
| 23 | | | | 1 | | | | | | | 1 | 3 | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | 3 | | 1 | | | | | | 1 | | | | | | | | |
| 25 | | | | | | | | | | | 2 | 1 | | | | 1 | | | 1 | 1 | | | | | | | | |
| 26 | | | 1 | | | | | | | | 1 | 3 | | | | | | | | 5 | | | | | | | | |
| 27 | | | | 1 | | | | | | | | 3 | | | | | | | | | | | | | | | | |
| 28 | | | | 1 | | | | | | | | 5 | 1 | | | | | | 1 | 2 | | | | | | | | |
| 29 | | | | | | | | | | | 1 | 3 | 2 | | | | | | 1 | 1 | | | | | | | | |
| 30 | | | | 1 | | | | | 1 | | 1 | 2 | | | | | | | | 2 | | | | | | | | |
| 31 | | | | | | | | | | | | 1 | | | | | | | | 1 | 1 | | | | | | | |
| 32 | | | | 1 | | | | | | | 1 | 3 | | | | | | | | | | | | | | | | |
| 33 | | | 1 | | | | | | | | 1 | 2 | | | | | | | | | 1 | | | | | | | |
| 34 | | | | 4 | | | | | | | | 2 | | | | | | | | | 1 | | | | | | | |
| 35 | | | 1 | | | | | | | | | 4 | 1 | | | | | | 2 | | | | | | | | | |
| 36 | | | | | | | | 1 | | | | 2 | | | | | | | | 1 | | | | | | | | |
| 37 | | | | | | | | | | | | 1 | | | | | | | | 1 | 1 | | | | | | | |
| 38 | | | 1 | 1 | | | | | | | 1 | 2 | | | | | | | | 1 | | | | | | | | |
| 39 | | | | 1 | | | | | 1 | | | 1 | | | | | | | 1 | | | | | | | | | |
| 40 | | | 1 | | | | | | | | 2 | 4 | 1 | | | | | | | | | | | | | | | |
| 41 | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | |
| 42 | | | 2 | | | | | | | | | | | | | | | | | 1 | | | | | | | | |
| 43 | | | 1 | 2 | | | | | | | | 2 | | | | | | | | | | | | | | | | |
| 44 | | | | | | | | 1 | | | 1 | 2 | 2 | | | | | | | | | | | | | | | |
| 45 | | | | | | | | | | | 1 | 2 | 3 | | | | | | | | | | | | | | | |
| 46 | | | | | | | | | | | | 2 | 1 | | | | | | 1 | 3 | | | | | | | | |
| 47 | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | |
| 48 | | | 1 | 1 | | | | | | | 1 | 3 | 1 | | | | | | | 1 | | | | | | | | |
| 49 | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| >50 | | | 9 | 22 | 2 | | | | | | 5 | 116 | 154 | 16 | | | 2 | 1 | 9 | 89 | 154 | 13 | 2 | 2 | 3 | 5 | 17 | 5 |

Not included: one $6_2$ male, mature.

**APPENDIX TABLE 2.** Gonad displacement volumes of female chinook salmon by age group and month, 1970-1971

| Gonad displacement volume in milliliters | Age group $2_1$ | | | | | $3_2$ | | | | $3_1$ | | | | | $4_2$ | | | | $4_1$ | | | | | $5_2$ | $5_1$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Apr.-May | June | July | Aug. | Sept. | Apr.-May | June | July | Aug. | Apr.-May | June | July | Aug. | Sept. | Apr.-May | June | July | Aug. | Apr.-May | June | July | Aug. | Sept. | Apr.-May | June | July | Aug. | Sept. |
| 1 | | | 5 | 7 | 1 | | | 1 | | | | | | | | | | | | | | | | | | | | |
| 2 | | 1 | 11 | 15 | 3 | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | 8 | 13 | 2 | | | | | | | | 1 | | | | | | | | | | | | | | | |
| 4 | | 3 | 10 | 12 | 1 | | | 2 | | | 1 | | 1 | | | | | | | | | | | | | | | |
| 5 | | 2 | 6 | 3 | 2 | | 3 | 1 | | | 3 | 2 | 3 | | | | | | | | | | | | | | | |
| 6 | | 1 | 4 | 7 | | | 1 | 1 | | 1 | 2 | | 1 | 1 | | | | | | | | | | | | | | |
| 7 | | | 2 | 3 | | | | | | | 4 | 2 | 1 | | | | | | | | | | | | | | | |
| 8 | 1 | | 1 | | | 1 | 1 | 1 | 1 | | 8 | 2 | 3 | 1 | | | | | | | | | | | | | | |
| 9 | | | 4 | 5 | | | | | | 1 | 6 | 3 | 2 | | | | | | | | | | | | | | | |
| 10 | | | 2 | 1 | 1 | | | 2 | | 2 | 9 | 9 | 5 | 2 | | | | | | | | | | | | | | |
| 11 | | | 1 | 2 | | | | | | | 5 | 10 | 1 | | | | | | | | | | | | | | | |
| 12 | | | | 1 | | | | | | | 3 | 12 | 6 | | | 1 | | | | | | | | | | | | |
| 13 | | | 1 | | | | | | | 2 | 4 | 4 | 7 | 1 | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | 1 | 4 | 9 | 5 | 2 | | | | | | | | | | | | | | |
| 15 | | | | | | | 1 | | | 3 | 6 | 10 | 5 | | 1 | | | | | | | | | | | | | |
| 16 | | | | | | | | | | 1 | 2 | 5 | 4 | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | 1 | 2 | 6 | 4 | 3 | | | | | | | 1 | | | | | | | |
| 18 | | | | | | | | | | | 2 | 6 | 7 | 1 | | 1 | | | | | | | | | | | | |
| 19 | | | | | | | | | | 1 | 2 | 6 | 4 | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | 3 | 3 | 3 | 6 | 1 | | | | | | 1 | | 1 | | | | | | |
| 21 | | | | | | | | | | | 1 | 1 | 3 | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | 2 | | 4 | 1 | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | 1 | 2 | 2 | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | 2 | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | 3 | | | 1 | 1 | | | | | | 1 | | | | | | | | |
| 26 | | | | | | | | | | 2 | | 2 | 3 | | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | 1 | 1 | 1 | | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | 2 | 1 | 1 | 1 | | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | 1 | | 1 | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | 1 | | 1 | 2 | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | |
| 32 | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| 33 | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | |
| 34 | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | |
| 35 | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | |
| 36 | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | |
| 37 | | | 1 | 1 | | | | | | 1 | | | | | | | | 1 | 1 | | | | | | | | | |
| 38 | | | | | | | | | | | | | 1 | | | | | | | | 1 | | | | | | | |
| 39 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 40 | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | |
| 41 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 42 | | | | | | | | | | | | 2 | | | | | | | | | | | | | | | | |
| 43 | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | |
| 44 | | | | | | | | | | | 1 | | | | | | | | 1 | | 1 | | | | | | | |
| 45 | | | | | | | | | | | 1 | | | | | | | | | | | | | | 1 | | | |
| 46 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 47 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 48 | | | | | | | | | | 1 | 1 | 1 | | | | | | | | | | | | | | | | |
| 49 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ≤50 | | | | 3 | | | | | | 5 | 10 | 146 | 66 | 4 | | 1 | 7 | 1 | 7 | 24 | 132 | 189 | 13 | 1 | 4 | 7 | 18 | 5 |

Not included: one $6_1$ female, mature.

**APPENDIX TABLE 3.** Immature chinook salmon size distribution: by sex, age group, and month, 1970-1971

| Fork length in centimeters | Male age group $2_1$ | | | | | $3_2$ | | | | $3_1$ | | | | | $4_2$ | | $4_1$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Apr.-May | June | July | Aug. | Sept. | Apr.-May | June | July | Aug. | Apr.-May | June | July | Aug. | Sept. | Apr.-May | July | Apr.-May | June | July |
| 43-44 | | | 1 | | | | | | | | | | | | | | | | |
| 45-46 | | | 1 | 2 | | | | | | | | | | | | | | | |
| 47-48 | | 2 | 12 | 14 | | 1 | | 1 | | | | | | | | | | | |
| 49-50 | 3 | 4 | 16 | 27 | 3 | | 1 | 1 | 1 | 1 | 5 | | | | | | | | |
| 51-52 | | 5 | 19 | 15 | 4 | | | | | | 5 | 1 | | | | | | | |
| 53-54 | | 3 | 12 | 18 | 2 | | | 4 | | 2 | 7 | | 1 | | | | | | |
| 55-56 | | 1 | 5 | 9 | 3 | | | 1 | 2 | 2 | 1 | 5 | | | | | | | |
| 57-58 | 2 | 1 | 4 | 5 | 6 | | 2 | 2 | | 2 | 10 | 4 | 3 | | | | | | |
| 59-60 | | | 4 | 6 | | | 1 | | | 5 | 10 | 8 | 2 | | | | | | |
| 61-62 | | | | 2 | | | | | | 3 | 6 | 7 | 7 | | | | | | |
| 63-64 | | | | | | | | | | 5 | 4 | 7 | 8 | 2 | | | | | |
| 65-66 | | | | | | | | | | 4 | 2 | 4 | 10 | 1 | 1 | | | | |
| 67-68 | | | | | | | | | | 3 | 5 | 6 | 6 | 1 | 1 | | | | |
| 69-70 | | | | | | | | | | | 1 | 5 | 8 | | 1 | | | | |
| 71-72 | | | | | | | | | | 3 | | 3 | 6 | | | | 1 | | |
| 73-74 | | | | | | | | | | | 1 | 3 | 3 | | | 1 | | 1 | |
| 75-76 | | | | | | | | | | | | 1 | 3 | | | | | | 1 |
| 77-78 | | | | | | | | | | | | 1 | 6 | | | | | | |
| 79-80 | | | | | | | | | | 1 | | | | | | | | | |
| Cum. No. | 5 | 16 | 74 | 98 | 18 | 1 | 4 | 9 | 3 | 31 | 57 | 55 | 63 | 4 | 3 | 1 | 1 | 1 | 1 |

| Fork length in centimeters | Female age group $2_1$ | | | | | $3_2$ | | | | $3_1$ | | | | | $4_2$ | | $4_1$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Apr.-May | June | July | Aug. | Sept. | Apr.-May | June | July | Aug. | Apr.-May | June | July | Aug. | Sept. | Apr.-May | June | June | July | Aug. |
| 45-46 | | | 1 | 1 | 1 | | | | | | | | | | | | | | |
| 47-48 | | 1 | 4 | 8 | 2 | | | 1 | | | | | 1 | | | | | | |
| 49-50 | | 4 | 16 | 20 | 2 | | 2 | | | | | 1 | | | | | | | |
| 51-52 | 1 | | 7 | 18 | 1 | 1 | 2 | 3 | | | 5 | 1 | | | | | | | |
| 53-54 | | 2 | 8 | 5 | 2 | | 1 | 1 | | | 9 | 1 | 1 | | | | | | |
| 55-56 | | | 5 | 8 | 2 | | | 1 | | | 6 | 4 | 2 | | | | | | |
| 57-58 | | | 10 | 7 | | | 1 | 2 | 1 | 1 | 10 | 7 | 3 | 2 | | 1 | | | |
| 59-60 | | | 4 | 2 | | | | | | 5 | 14 | 9 | 5 | | | 1 | 1 | | |
| 61-62 | | | | | | | | | | 3 | 12 | 15 | 1 | 2 | 1 | | | | |
| 63-64 | | | | | | | | | | 6 | 6 | 19 | 9 | 2 | | | 1 | | |
| 65-66 | | | | | | | | | | 2 | | 7 | 12 | 2 | | | | | |
| 67-68 | | | | | | | | | | 1 | 3 | 11 | 14 | 2 | | | | | |
| 69-70 | | | | | | | | | | 2 | | 9 | 5 | 1 | | | | 1 | |
| 71-72 | | | | | | | | | | 1 | 3 | 7 | 12 | | | | | | |
| 73-74 | | | | | | | | | | | | 2 | 6 | 1 | | | | | |
| 75-76 | | | | | | | | | | | | 3 | 3 | | | | | | |
| 77-78 | | | | | | | | | | | | | | | | | | | |
| 79-80 | | | | | | | | | | | | | 1 | 1 | | | | | |
| 81-82 | | | | | | | | | | | | | | | | | | | |
| 83-84 | | | | | | | | | | | | | | | | | | | 1 |
| Cum. No. | 1 | 7 | 55 | 69 | 10 | 1 | 6 | 8 | 1 | 21 | 68 | 96 | 75 | 13 | 1 | 2 | 2 | 1 | 1 |

**APPENDIX TABLE 4.** Mature male chinook size distribution by age group and month, 1970-1971

| Fork length in centimeters | $2_1$ Apr.-May | $2_1$ July | $2_1$ Aug. | $2_1$ Sept. | $3_2$ June | $3_2$ July | $3_2$ Aug. | $3_1$ Apr.-May | $3_1$ June | $3_1$ July | $3_1$ Aug. | $3_1$ Sept. | $4_2$ Apr.-May | $4_2$ June | $4_2$ July | $4_1$ Apr.-May | $4_1$ June | $4_1$ July | $4_1$ Aug. | $4_1$ Sept. | $5_2$ July | $5_2$ Aug. | $5_1$ June | $5_1$ July | $5_1$ Aug. | $5_1$ Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 43-44 | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | |
| 45-46 | | 1 | 5 | | | | | | | | | | | | | | | | | | | | | | | |
| 47-48 | | 4 | 11 | 1 | | | | | | | | | | | | | | | | | | | | | | |
| 49-50 | | 3 | 9 | | | | | | | | | | | | | | | | | | | | | | | |
| 51-52 | | 5 | 6 | | | | | | 1 | 1 | | | | | | | | | | | | | | | | |
| 53-54 | | 4 | 5 | | | | 1 | | 1 | | | | | | | | | | | | | | | | | |
| 55-56 | | 4 | 6 | | 1 | | 1 | | 2 | 4 | | | | | | | | | | | | | | | | |
| 57-58 | | 8 | 4 | | | 2 | 1 | 1 | 1 | 4 | 3 | | | | | | | | | | | | | | | |
| 59-60 | | 4 | | | | | 1 | | 4 | 4 | 2 | 1 | | | | | | | | | | | | | | |
| 61-62 | | 2 | | | | 1 | 1 | | 4 | 12 | 12 | 2 | | | | | | | | | | | | | | |
| 63-64 | | | 1 | 1 | | | | | | 9 | 6 | 2 | | | 1 | | | | | | | | | | | |
| 65-66 | | 1 | 1 | | | | | 4 | 3 | 10 | 10 | 4 | 1 | | | | | | | | | | | | | |
| 67-68 | 1 | | | | | | | 1 | 2 | 17 | 20 | 4 | | | | | | 1 | 1 | | | | | | | |
| 69-70 | | | | | | | | | 1 | 20 | 10 | | | | 1 | | | 1 | 1 | | | | | | | |
| 71-72 | | | 1 | | | | | 2 | 2 | 19 | 22 | 3 | | 1 | | 1 | | 2 | | | | | | | | |
| 73-74 | | | | | | | | 2 | 3 | 22 | 20 | 1 | | | | | 2 | 1 | | | | | | | | |
| 75-76 | | | | | | | | 2 | 2 | 29 | 11 | 2 | | | | 1 | | 2 | 2 | | | | | | | |
| 77-78 | | | | | | | | | 2 | 25 | 18 | 1 | | | | | 1 | 3 | 4 | | | | | | | |
| 79-80 | | | | | | | | | 5 | 17 | 20 | 1 | | | | 2 | 3 | 11 | 4 | 1 | | | | | | |
| 81-82 | | | | | | | | | 4 | 14 | 8 | 1 | | | | 2 | 4 | 11 | 18 | 5 | | | | | | |
| 83-84 | | | | | | | | | 4 | 6 | 8 | | | | 1 | | 3 | 15 | 21 | 2 | 1 | | | | | |
| 85-86 | | | | | | | | | 3 | 7 | 4 | | | | | 2 | | 12 | 19 | | 1 | | | | | |
| 87-88 | | | | | | | | | 1 | 3 | | | | | | 1 | 2 | 17 | 21 | 2 | | | | | | |
| 89-90 | | | | | | | | | | 1 | | | | | | 1 | 3 | 14 | 18 | 3 | | | | | | |
| 91-92 | | | | | | | | | | | 2 | | | | | | | 5 | 14 | | | | | | 1 | |
| 93-94 | | | | | | | | | | | | | | | | | 2 | 10 | 15 | | 1 | | | | | |
| 95-96 | | | | | | | | | | | | | | | | | | 2 | 9 | | | | 1 | | 4 | |
| 97-98 | | | | | | | | | | | | | | | | | 1 | 4 | 4 | | | | | | 2 | 1 |
| 99-100 | | | | | | | | | | | | | | | | | 1 | 2 | 4 | | | 2 | | 1 | 4 | 1 |
| 101-102 | | | | | | | | | | | | | | | | | 1 | 1 | 1 | | | | | | 4 | |
| 103-104 | | | | | | | | | | | | | | | | | | | 2 | | | | 1 | 2 | | |
| 105-106 | | | | | | | | | | | | | | | | | | | | | | | | 1 | | |
| 107-108 | | | | | | | | | | | | | | | | | | | 1 | | | | 1 | | | 1 |
| 109-110 | | | | | | | | | | | | | | | | | | 1 | | | | | | 1 | 1 | |
| 111-112 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 113-114 | | | | | | | | | | | | | | | | | 1 | | | | | | | | 1 | 2 |
| Cum. No. | 1 | 37 | 50 | 2 | 1 | 3 | 5 | 12 | 45 | 224 | 176 | 22 | 1 | 1 | 3 | 10 | 24 | 115 | 159 | 13 | 3 | 2 | 3 | 5 | 17 | 5 |

Not included: one $6_2$ male, 103 cm.

**APPENDIX TABLE 5.** Mature female chinook size distribution by age group and month, 1970-1971

| Fork length in centi-meters | $2_1$ July | $2_1$ Aug. | $3_1$ Apr.-May | $3_1$ June | $3_1$ July | $3_1$ Aug. | $3_1$ Sept. | $4_2$ June | $4_2$ July | $4_2$ Aug. | $4_1$ Apr.-May | $4_1$ June | $4_1$ July | $4_1$ Aug. | $4_1$ Sept. | $5_2$ Apr.-May | $5_1$ June | $5_1$ July | $5_1$ Aug. | $5_1$ Sept. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 51- 52 | | 1 | | | | 1 | | | | | | | | | | | | | | |
| 53- 54 | | | | | | | | | | | | | | | | | | | | |
| 55- 56 | | | | | | | | | | | | | | | | | | | | |
| 57- 58 | 1 | 1 | | 1 | 2 | | | | | | | | | | | | | | | |
| 59- 60 | | 1 | | 1 | 1 | 1 | | | | | | | | | | | | | | |
| 61- 62 | | 1 | | | | | | | | | | | | | | | | | | |
| 63- 64 | | | 2 | 2 | 1 | 1 | | | | | | | | | | | | | | |
| 65- 66 | | | 2 | 1 | 2 | 5 | | | | | | | 1 | | | | | | | |
| 67- 68 | | | 1 | 3 | 8 | 3 | | | | | | | | | | | | | | |
| 69- 70 | | | 2 | 2 | 7 | 5 | | | | | | 1 | 1 | | | | | | | |
| 71- 72 | | | 1 | 3 | 10 | 4 | 1 | | | | 2 | | 1 | | | | | | | |
| 73- 74 | | | 1 | 1 | 20 | 15 | 1 | 1 | | | 3 | 3 | 4 | | | | | | | |
| 75- 76 | | | | | 21 | 7 | 1 | | 3 | | | 1 | 2 | 3 | | | | | | |
| 77- 78 | | | 3 | 1 | 27 | 12 | | | 2 | 1 | 1 | 1 | 9 | 3 | 1 | | | | | |
| 79- 80 | | | | | 27 | 11 | 1 | | 1 | | | 1 | 13 | 10 | 1 | | | | | |
| 81- 82 | | | | 1 | 17 | 9 | | | 1 | 1 | | 1 | 15 | 13 | 4 | | | | | |
| 83- 84 | | | | 1 | 8 | 2 | | 1 | | | | 2 | 19 | 24 | 1 | | | 1 | | |
| 85- 86 | | | | | 5 | | | | | | 2 | 1 | 19 | 37 | 1 | | | | 1 | |
| 87- 88 | | | | | | | | | | | | 4 | 16 | 33 | | | | 1 | | |
| 89- 90 | | | | | | | | | | | | 4 | 11 | 33 | 3 | | 2 | 1 | 5 | |
| 91- 92 | | | 1 | | | | | | | | | 2 | 10 | 17 | 1 | | 2 | | 1 | 1 |
| 93- 94 | | | | | | | | | | | | 1 | 11 | 9 | 1 | | | 1 | 1 | |
| 95- 96 | | | | | | | | | | | | 1 | 2 | 2 | | | 1 | 1 | 2 | 1 |
| 97- 98 | | | | | | | | | | | 1 | 1 | | 1 | | | | | 1 | |
| 99-100 | | | | | | | | | | | | | 1 | 3 | | | | | 4 | 1 |
| 101-102 | | | | | | | | | | | | 1 | | | 1 | | | 1 | 2 | 1 |
| 103-104 | | | | | | | | | | | | | | 1 | | | | 1 | | |
| 105-106 | | | | | | | | | | | | | | | | | | | 1 | |
| 107-108 | | | | | | | | | | | | | | | | | | | | |
| 109-110 | | | | | | | | | | | | | | | | | | | | |
| 111-112 | | | | | | | | | | | | | | | | | | | | 1 |
| Cum. No. | 1 | 4 | 13 | 17 | 156 | 76 | 4 | 2 | 7 | 2 | 9 | 25 | 134 | 190 | 13 | 1 | 5 | 7 | 18 | 5 |

Not included: one $6_1$ female, 102 cm.

# Evaluation
# of the March 15–April 15
# Pacific Coast Troll Chinook Closure

**PETER K. BERGMAN**
**Washington Department of Fisheries**

**and**

**ROBERT E. LOEFFEL**
**Fish Commission of Oregon**

# BULLETIN 8

PACIFIC MARINE FISHERIES COMMISSION
Portland, Oregon

1972

# EVALUATION
# OF THE MARCH 15–APRIL 15
# PACIFIC COAST TROLL CHINOOK CLOSURE

Peter K. Bergman,
State of Washington, Department of Fisheries
and
Robert E. Loeffel
Fish Commission of Oregon

## ABSTRACT

The effects of the Pacific coast March 15–April 15 troll chinook closure on the Westport–Columbia River area and on the fall run to the Columbia River were evaluated. Troll tagging results indicated that the closure added between 2,500 and 11,500 chinook to the Columbia fall escapement under the exploitation intensities of the early 1960's. Chinook not taken in the Westport-Columbia River area as a result of the closure were subsequently caught approximately equally among: (1) the California to Washington troll fishery; (2) the sport fishery over the same area; and, (3) The Columbia River gill-net fishery. A small proportion were caught off Canada. Total fishing effort increased following the closure, but not because of it. Despite this change, the numbers of Columbia River fall chinook appear to have increased, indicating that other factors in addition to fishing are involved in the welfare of this stock. The primary effect of the closure was catch re-distribution. No regulation changes are recommended until guidelines for catch distribution are established.

## INTRODUCTION

A rapidly developing troll fishery for chinook in waters off the southwest Washington coast was curtailed by a closed season extension effective in Oregon and Washington in 1956. The effect of the closure as indicated by use of recoveries of tagged chinook and other techniques is reviewed in this paper.

### Westport-Columbia River Fishery

Prior to the formation of the Pacific Marine Fisheries Commission (PMFC) in 1947, commercial trolling for salmon was permitted the year-around from Oregon to Alaska. California had an open season beginning April 1 and ending September 15. In 1948, PMFC recommended a chinook season of March 15 to October 31 for all segments of the troll fishery. Washington and Oregon adopted this season effective in 1949, while California chose a May 1 to September 30 season effective in 1950. Alaska and Canada had no closed season until the late 1950's.

The Westport-Columbia River fishery was recognized as "something special" after an opening date for the troll chinook fishery was established in 1949. While fishing must have been good in this area prior to 1949, the discovery of excellent fishing in that year attracted boats from along the coast and particularly from California where the season opened May 1 beginning in 1950. This fishery, which was exceptionally productive into late April each year, continued until 1956 when the opening date was changed to April 15. Washington Department of Fishery statistics (WSDF, 1958) show that January to April 15 landings from Westport and Washington Columbia River ports averaged 9.2% and 4.8%, respectively, of the annual landings for these areas for the years 1946-1949. For the period of intensive fishing, 1950-1955, the one month period, March 15 to April 15, produced 21.1% of Westport's annual landings and 22.7% of those from the Columbia River area. Comparable increases were observed at Oregon Columbia River ports. Actual January-April 15 average landings in dressed weight increased from 117,000 pounds in 1946-1949 to 423,000 pounds in 1950-1955 at Westport and from 45,000 pounds to 230,000 pounds at Oregon and Washington Columbia River ports.

The fall run to the Columbia River averaged about 700,000 chinook for the period 1938 to 1950 (Figure 1). The

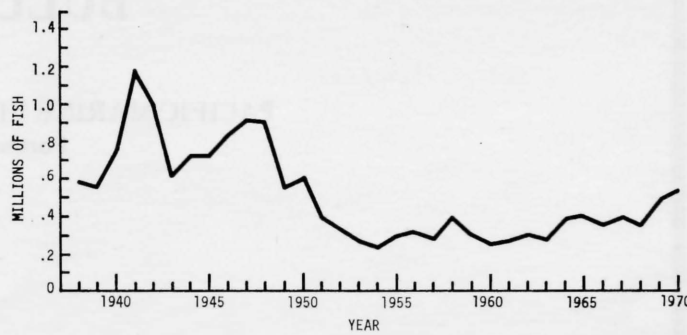


FIGURE 1. Fall chinook run entering Columbia River ("Minimum" run, Fish. Comm., Ore., and Wash. Dept., Fish. 1971).

run decreased sharply after 1950, averaging only 300,000 fish annually for 1951-1955. Catches in the fall gill-net fishery in the River dropped proportionally and indices of escapement to spawning grounds and hatcheries declined.

Concurrent with the decline in the fall chinook run to the Columbia River, total troll landings increased in the area from the Columbia River to northern Vancouver Island, British Columbia (Figure 2). Biologists believed that the troll fishery in this area was heavily dependent upon Columbia River fall chinook, so the drop in the run to the Columbia River was logically, but circumstantially, related to the increased troll catch. The period March 15-April 15 was closed in 1956 to, "decrease the fishing intensity on the Columbia River fall runs." (PMFC, 1955). Coincident restriction of the river fishery was enacted to increase the spawning escapement. While "conservation" was a popular basis for this action, the welfare of the resource was not in jeopardy from the ocean fishery as long as the run to the river could supply an adequate spawning escapement. More correctly, additional closure was expected to transfer fish from the ocean troll catch to the river fisheries and to forestall the time when the spawning escapement would be inadequate.

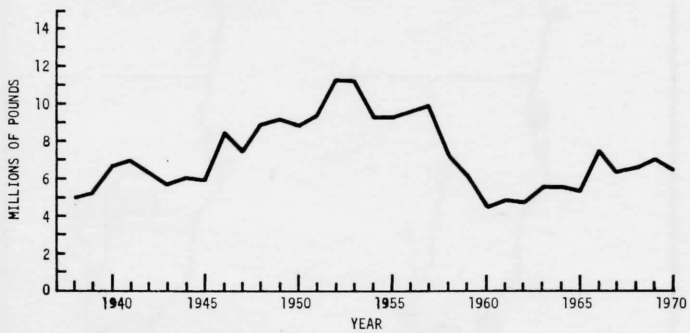


FIGURE 2. Washington and west coast Vancouver Island troll chinook catches in millions of pounds dressed weight.

Except for the good catches made in late April 1956, the closure of the March 15 to April 15 period eliminated the intensive early fishery for chinook between Westport and the Columbia River. Processors and fishermen of this area felt the loss of the fishery and maintained that the Canadian fishery, not themselves, was the benefactor of the closure since the fish were known to move northward as the summer progressed. They further argued that the action denied them the opportunity to fish other stocks, e.g., Columbia River spring chinook, using the area early in the year. They requested reestablishment of the March 15 opening for the troll chinook season. Biologists and administrators recognized these problems, but recommended no change in the season because they believed that the fall run to the Columbia River was being augmented by the closure and that all segments of the fishery should share in solving its management problems.

## Biological Considerations

Because this paper focuses primarily on Columbia River fall-run stocks, it is useful to review the reasons for contending that a large portion of Columbia River fall chinook remain between the Columbia and the northwest coast of Vancouver Island during their ocean residence and that Columbia River fall chinook represent a large fraction of the catch from this area. The evidence presented to support these contentions includes work done since the 1956 closure.

The presence of Columbia River fall chinook in this area has been shown by a series of fin-marking and ocean-tagging experiments. Important examples of the tagging evidence are contained in Kauffman (1951) and Milne (1957), and a key fin-marking experiment is discussed by Worlund, Wahle, and Zimmer (1969). By far the most useful and comprehensive discussion of both distribution and abundance is given in Van Hyning (1972), who reviewed virtually all historical information on the Columbia River fall chinook through the mid-sixties. Generalization of these data indicates that lower river stocks (we have assigned The Dalles Dam as the dividing point) tend to be shorter-run in the ocean than upper river stocks and are not commonly found north of Vancouver Island, or in abundance south of the Columbia. Upper river fall chinook, on the other hand, are probably found in at least fair abundance from the Columbia to Southeast Alaska, and clearly range farther than the lower river fish. While several authors have speculated from tagging studies about relative abundance of Columbia stocks in the area considered, e.g., Milne (1957) gives an estimate of 30% Columbia River chinook for 1949-1950, Van Hyning (1972) shows, based on the data of Worlund, Wahle, and Zimmer (1969), that a 50% contribution of Columbia River falls to the Washington and Vancouver Island fisheries is reasonable for recent years. The fraction could well be higher. We prefer Van Hyning's estimate since fin-marking experiments present fewer difficulties of interpretation than tagging experiments.

Van Hyning also showed that ocean fishing effort is considerably higher in the area from the Columbia River to the northern west coast of Vancouver Island than it is in more northern areas (about 3½ times as great in 1963). If fishing pressure was an important factor in the decline of fall stocks, then trends in the more southerly area, presumably encompassing the below-The Dalles fall stocks but only partially the above-The Dalles stocks, should be most meaningful for examining relationships between ocean fishing and stock condition.

For the purposes of this paper, we considered Columbia River fall chinook to migrate to the ocean in their first year of life and so to have a "sub-1" type scale pattern. The preponderance of spring chinook in the Columbia are known to have "sub-2" type scales indicating a full year in fresh water as juveniles. Most fall chinook leave fresh water early in their first year of life (Heyamoto and Wright, 1970), but some not recognized separately in this paper remain in fresh water until fall or until spring of the year following hatching (Reimers and Loeffel, 1967).

Because scale readings and their life history interpretations are imperfect and actual time of river entry was known for tag recoveries, we have used this superior information when available to make spring or fall run assignments to Columbia River tag returns used directly to estimate savings.

## EVALUATION OF THE CLOSURE BY TAGGING

PMFC in response to the concern of industry instructed its scientific staff to make a study of the effect of the opening date on the Westport area chinook fishery (PMFC, 1958). A tagging program to be done in 1959 was chosen to determine, (1) the stocks involved and the degree, (2) the disposition of the fish protected by the closure, i.e., to Canada, to sport fisheries, to coastal troll fisheries, to river escapement, and (3) if the escapement to the Columbia River fall chinook run increased? After reviewing the results of the 1959 study, PMFC decided that the tagging program should be repeated in 1960.

### Procedures

Washington and Oregon each hired one experienced troller to catch chinook over the March 15-April 15 period during both 1959 and 1960. These trollers fished from just south of the Columbia River to just north of Grays Harbor (Figures 3 and 4), and generally operated in the pattern that had been established in the years prior to the closure. As fish were brough aboard, they were anesthetized, tagged with "spaghetti", Peterson disc, or "dart"-type tags, allowed to recover in clean sea water, and placed overboard. The fish were measured, and scales were taken for age determination. Other procedural detail is reported by PMFC (1960).

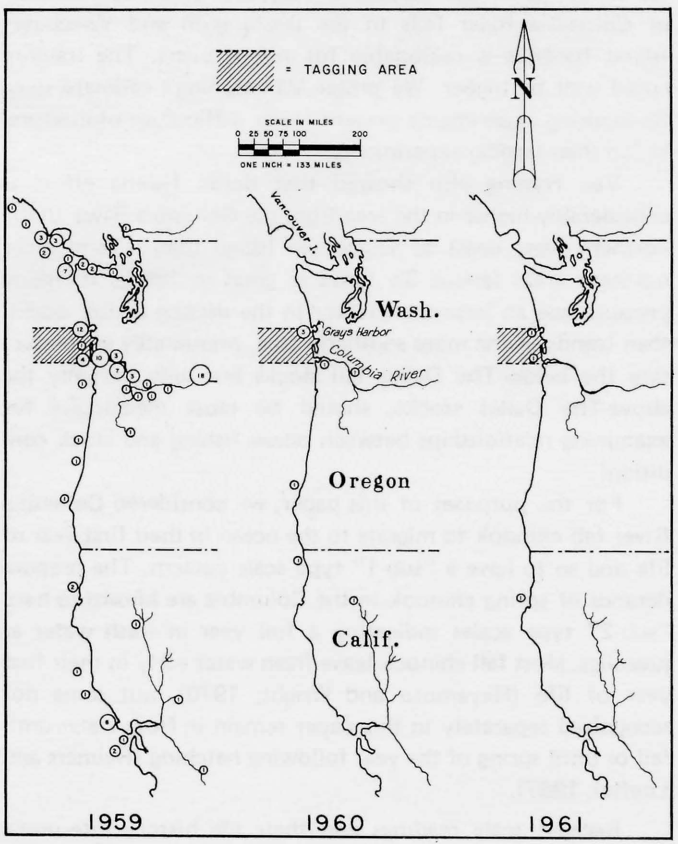


FIGURE 3. Recoveries in 1959, 1960 and 1961 of chinook salmon tagged in March and April 1959 between the Columbia River and Grays Harbor, Washington. Encircled numbers indicate numbers of recoveries and places.

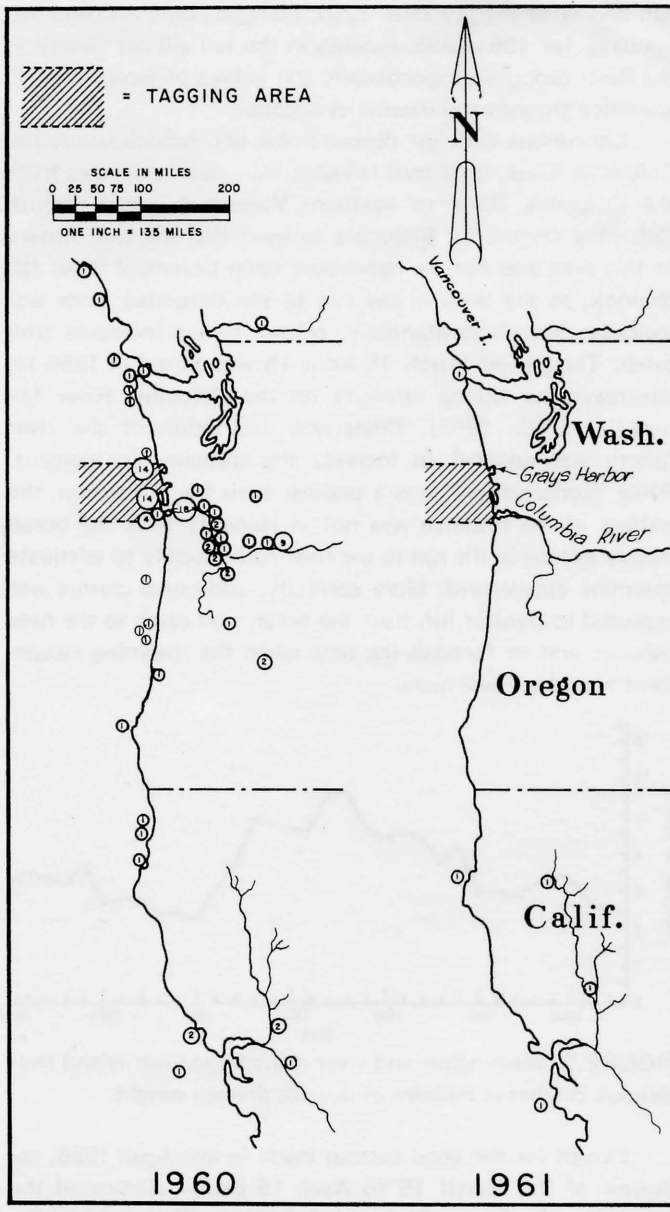


FIGURE 4. Recoveries in 1960 and 1961 of chinook salmon tagged in March and April 1960 between the Columbia River and Grays Harbor, Washington. Encircled numbers indicate numbers of recoveries and places.

### Results

Preliminary results from the tagging are given by PMFC (1960) and Bergman (1963). Chinook tagged totaled 422 in 1959 and 349* in 1960 (Table 1). Recoveries totaled 229 chinook that were recaptured from 0 to 2 years after tagging (Tables 2 and 3).

### *Distribution of Tag Returns and Stock Composition*

Tags were recovered between the middle west coast of Vancouver Island on the north and central California on the south; recoveries came from the Fraser, Columbia, Umpqua, and Sacramento-San Joaquin rivers, indicating that fish in the tagging area were of diverse origins (Figures 3 and 4; Tables 2 and 3). It is clear that the Columbia was an important

*The number 349 replaces the 343 reported as tagged in 1960 by PMFC (1960) and Bergman (1963).

**TABLE 1.** Numbers of chinook tagged and recovered by scale type and recovery location and means for the 1959 and 1960 tagging

| | | Recovery location and means | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1959 TAGGING** | | | | | | | | | | | | |
| | | Ocean | | | Fraser | Columbia River | | | Sacramento | | Other | |
| Tagging age | No. tagged | Troll | Sport | Net | Net | Sport | Net | Escape-ment | Sport | Escape-ment | Sport | Total |
| $2_1$ | 32 | 1 | 4 | | | | | | | | | 5 |
| $3_1$ | 198 | 24 | 12 | 1 | | 4 | 7 | 14 | 1 | 2 | | 65 |
| $4_1$ | 40 | 7 | 2 | | | | 1 | 1 | | | | 11 |
| $5_1$ | 4 | | | | | | | | | | | |
| Subtotal | 274 | 32 | 18 | 1 | | 4 | 8 | 15 | 1 | 2 | | 81 |
| $3_2$ | 18 | 1 | 1 | | | | 1 | | | | | 3 |
| $4_2$ | 38 | 2 | 2 | | 1 | | 8 | 1 | | | 1 | 15 |
| $5_2$ | 24 | | | | | 2 | 3 | | | | | 5 |
| $6_2$ | 3 | | | | | | | | | | | |
| Subtotal | 83 | 3 | 3 | | 1 | 2 | 12 | 1 | | | 1 | 23 |
| N.A.[1] | 65 | 5 | 2 | | | | 2 | 5 | | 1 | | 15 |
| Total | 422 | 40 | 23 | 1 | 1 | 6 | 22 | 21 | 1 | 3 | 1 | 119 |
| **1960 TAGGING** | | | | | | | | | | | | |
| | | Ocean | | | Fraser | Columbia River | | | Sacramento | | Other | |
| Tagging age | No. tagged | Troll | Sport | Net | Net | Sport | Net | Escape-ment | Sport | Escape-ment | Sport | Total |
| $2_1$ | 17 | | 1 | | | | 1 | | | | | 2 |
| $3_1$ | 173 | 19 | 16 | | | 1 | 10 | 10 | 1 | 3 | | 60 |
| $4_1$ | 67 | 9 | 7 | | | | 4 | | | 1 | | 21 |
| $5_1$ | 1 | 1 | | | | | | | | | | 1 |
| Subtotal | 258 | 29 | 24 | | | 1 | 15 | 10 | 1 | 4 | | 84 |
| $3_2$ | 4 | | | | | | 2 | | | | | 2 |
| $4_2$ | 54 | 3 | | | 1 | 1 | 8 | 2 | | | | 15 |
| $5_2$ | 19 | | | | | 2 | 5 | 1 | | | 1 | 9 |
| Subtotal | 77 | 3 | | | 1 | 3 | 15 | 3 | | | 1 | 26 |
| N.A.[1] | 14 | | | | | | | | | | | |
| Total | 349 | 32 | 24 | | 1 | 4 | 30 | 13 | 1 | 4 | 1 | 110 |

[1]N.A. = not assigned, i.e., no age determination could be made.

contributor to this area (96 tags were returned from the Columbia; 59 from the fall run, and 37 from the spring and summer runs), but just how important cannot be determined straightforwardly from these data. The problems inherent in the use of ocean tagging to determine the contribution of chinook by various river systems are extensive. It is clear that the Sacramento-San Joaquin River system was also a major contributor to the tagging area. Nine tags were returned from this system even though there was no river net fishery and reproduction was primarily natural. Numerous recoveries made along the California coast suggest fish of Sacramento-San Joaquin origin. Two tags were recovered from the Fraser net fisheries, indicating that a small portion of the stocks in the tagging area were produced by that river; no other river system contributed more than one recovery.

The tag recoveries suggest that the troll, sport, and net fisheries shared about equally in capturing chinook not taken by the troll fishery because of the closure (Table 1). Forty-two per cent of the "non-escapement" tags from the 1959 tagging came from the troll fishery, 34% from the sport fishery, and 24% from the gill-net fishery. The corresponding figures from the 1960 tagging were 35% troll, 31% sport, and 34% gill net. The sport fishery recoveries were largely from the ocean, and the gill-net recaptures were almost entirely from the Columbia River.

Surprisingly, only 6% of the tags were recaptured in the ocean fisheries off the coast of Canada (Figures 3 and 4). The chinook moved north and south, but the greatest concentration of ocean recoveries was in the general vicinity of the tagging. Tag losses or non-reporting of tags could obviously affect the interpretation of these results; we will discuss these factors later.

## *Savings to the Columbia River Fall Run*

There are a number of procedures that could be used to estimate from our tagging data the savings to the fall chinook run to the Columbia resulting from the troll closure; we use two relatively simple methods based on different assumptions. It is important to understand that "savings" refers to the gain of fall chinook spawners in the Columbia River as a result of the closure when the effort over the remainder of the season is approximately as it was during the years of tagging. Later we will show that the effort almost surely has increased. Nevertheless, it is useful to understand what the probable immediate gains were from the closure.

If we know the expected catch of chinook for the closed period and the rate at which these fish survive the ocean fisheries to reach the spawning river, we can multiply the survival rate by the expected catch to estimate the savings. The expected catch for the closure years is assumed to be the same as the average catch for the 3 years immediately prior to the closure (after the fishery had developed), or about 79,000 fish. An estimate of the survival rate to the spawning grounds per fish "not caught" as a result of the closure can be obtained by dividing the number of tagged fish reaching the spawning grounds by the number of fish tagged. Because we do not know how many tags reached the river in the form of unobserved non-hatchery spawners, it is necessary to estimate to overall tagged escapement. We assume that all tags from hatchery spawners will be observed and returned; thus, if we know the ratio of hatchery to non-hatchery spawners, we can calculate total tags because we know the number of hatchery tags for the two important years of return (1959 and 1960). Unfortunately, this involves the assumption that hatchery and non-hatchery spawners had similar oceanic distributions, which is probably only roughly correct. Offsetting this, Worlund, Wahle, and Zimmer (1969) have indicated that a sizable portion of non-hatchery fall-run spawners in the lower Columbia originated from hatcheries.

The procedure used to estimate numbers of non-hatchery fall chinook does not involve chinook stocks from above The Dalles Dam (see Table 4). To obtain the total fall chinook between The Dalles and Bonneville Dams, we subtracted the count at the upper dam from the lower dam. From this number, we subtracted the known hatchery escapement and

**TABLE 2.** Recoveries from the 1959 chinook tagging by area of recovery, age at tagging, and month and recovery year

| Recovery area | Tag age | 1959 Recoveries | | | | | | | | | | 1960 Recoveries | | | | | 1961 Recoveries | | | Grand total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total | June | July | Aug. | Nov. | Total | June | Aug. | Total | |
| 1 | $3_1$ | | | | | | | 1 | | 1 | 2 | | | | 1 | 1 | | | | 3 |
| Sacramento-San Joaquin River | N.A. | | | | | | | | 1 | | 1 | | | | | | | | | 1 |
| Total | | | | | | | | 1 | 1 | 1 | 3 | | | | 1 | 1 | | | | 4 |
| 2 | $3_1$ | | | | 2 | 1 | | | | | 3 | | | | | | | | | 3 |
| Central | $4_2$ | | | | 1 | | | | | | 1 | | | | | | | | | 1 |
| California | $4_1$ | | | | 2 | | | | | | 2 | | | | | | | | | 2 |
| | N.A. | | | | 3 | 1 | | | | | 4 | | | | | | | | | 4 |
| Total | | | | | 8 | 2 | | | | | 10 | | | | | | | | | 10 |
| 3 | $2_1$ | | | | | | | | | | | | | | | | 1 | | 1 | 1 |
| Northern | $3_1$ | | | 1 | | | | | | | 1 | | 1 | | | 1 | | | | 2 |
| California | $4_1$ | | | 2 | | | | | | | 2 | | | | | | | | | 2 |
| Total | | | | 3 | | | | | | | 3 | | 1 | | | 1 | 1 | | 1 | 5 |
| 4 | $3_2$ | | | | | | | | | | | | 1 | | | 1 | | | | 1 |
| Southern Oregon | $3_1$ | | | | 1 | | | | | | 1 | | | | | | | | | 1 |
| Total | | | | | 1 | | | | | | 1 | | 1 | | | 1 | | | | 2 |
| 5 | $3_1$ | | | 1 | | | | | | | 1 | | | | | | | | | 1 |
| Central Oregon | $4_2$ | | | | 1 | | | | | | 1 | | | | | | | | | 1 |
| Total | | | | 1 | 1 | | | | | | 2 | | | | | | | | | 2 |
| 6 | $2_1$ | | | | | 1 | | | | | 1 | | | | | | | 1 | 1 | 2 |
| Northern | $4_2$ | 1 | | | | 2 | | | | | 3 | | | | | | | | | 3 |
| Oregon | $4_1$ | | | | 1 | | | | | | 1 | | | | | | | | | 1 |
| & Southern Washington | N.A. | | | | | 1 | | | | | 1 | | | | | | | | | 1 |
| Total | | 1 | | | 1 | 4 | | | | | 6 | | | | | | | 1 | 1 | 7 |
| 7 | $3_2$ | | | | | | | | | | | 1 | | | | 1 | | | | 1 |
| Columbia | $3_1$ | | | | | 7 | 12 | 5 | | | 24 | | | 1 | | 1 | | | | 25 |
| River | $4_2$ | | 8 | | 1 | | | | | | 9 | | | | | | | | | 9 |
| | $4_1$ | | | | | 1 | 1 | | | | 2 | | | | | | | | | 2 |
| | $5_2$ | 1 | 3 | 1 | | | | | | | 5 | | | | | | | | | 5 |
| | N.A. | | 1 | | | 1 | 3 | 2 | | | 7 | | | | | | | | | 7 |
| Total | | 1 | 12 | 1 | 1 | 9 | 16 | 7 | | | 47 | 1 | | 1 | | 2 | | | | 49 |
| 8 | $2_1$ | | | | | | | | | | | | 1 | | | 1 | 1 | | 1 | 2 |
| Central | $3_1$ | | 1 | 3 | 2 | 4 | | | | | 10 | 1 | 1 | | | 2 | | | | 12 |
| Washington | $4_1$ | | | | | 1 | | | | | 1 | | | | | | | | | 1 |
| | N.A. | | | | | 1 | | | | | 1 | | | | | | | | | 1 |
| Total | | | 1 | 3 | 2 | 6 | | | | | 12 | 1 | 2 | | | 3 | 1 | 1 | | 16 |
| 9 | $3_1$ | | 1 | 2 | 5 | 2 | 2 | | | | 12 | | | | | | | | | 12 |
| Northern | $4_1$ | | | 1 | | | | | | | 1 | | | | | | | | | 1 |
| Washington & Juan de Fuca Str. | N.A. | | | 1 | | | | | | | 1 | | | | | | | | | 1 |
| Total | | | 1 | 4 | 5 | 2 | 2 | | | | 14 | | | | | | | | | 14 |
| 10 | $3_1$ | | | 1 | | | | | | | 1 | | | | | | | | | 1 |
| Puget Sound & Georgia Strait | $4_2$ | | | | | | 1 | | | | 1 | | | | | | | | | 1 |
| Total | | | | 1 | | | 1 | | | | 2 | | | | | | | | | 2 |
| 11 | $3_2$ | | | | 1 | | | | | | 1 | | | | | | | | | 1 |
| West Coast | $3_1$ | | 1 | 3 | | 1 | | | | | 5 | | | | | | | | | 5 |
| Vancouver I. | $4_1$ | | | 1 | 1 | | | | | | 2 | | | | | | | | | 2 |
| Total | | | 1 | 4 | 2 | 1 | | | | | 8 | | | | | | | | | 8 |
| Grand total | | 2 | 15 | 17 | 21 | 24 | 19 | 8 | 1 | 1 | 108 | 2 | 4 | 1 | 1 | 8 | 2 | 1 | 3 | 119 |

Recovery areas defined:

| No. | Description |
|---|---|
| 1. | Sacramento-San Joaquin River systems including San Francisco Bay. |
| 2. | Central California Coast - Montery to Pt. Arena. |
| 3. | Northern California Coast - Pt. Arena to California-Oregon border. |
| 4. | Southern Oregon Coast - Border to south of Heceta Head. |
| 5. | Central Oregon Coast - Heceta Head to south of Cape Lookout. |
| 6. | Northern Oregon & Southern Washington - Cape Lookout to Willapa Bay. |
| 7. | Columbia River and tributaries. |
| 8. | Central Washington Coast - Willapa Bay to Cape Johnson. |
| 9. | Northern Washington and Strait of Juan de Fuca - north of Cape Johnson to Pachena Point and east to Port Angeles and Sooke, including 40-mile Bank. |
| 10. | Puget Sound and Strait of Georgia - east of and including Port Angeles; includes Fraser River and San Juan Islands. |
| 11. | West Coast Vancouver Island - north of Pachena Point. |

N.A. = not assigned, i.e., no age determination could be made.

**TABLE 3.** Recoveries from the 1960 chinook tagging by area of recovery, age at tagging, and month and recovery year

| Recovery area | Tag age | 1960 Recoveries Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total | 1961 Recoveries May | Aug. | Sept. | Dec. | Total | Grand total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | $3_1$ | | | | | | | | | | | 1 | | 1 | | 2 | 2 |
| Sacramento- | $4_1$ | | | | | | | | | 1 | 1 | | | | | | 1 |
| San Joaquin | | | | | | | | | | | | | | | | | |
| River | | | | | | | | | | | | | | | | | |
| Total | | | | | | | | | | 1 | 1 | 1 | | 1 | | 2 | 3 |
| 2 | $3_1$ | | | | | 1 | | | | | 1 | 1 | | | | 1 | 2 |
| Central | $4_1$ | | | 1 | | | | | | | 2 | | | | | | 2 |
| California | | | | | | | | | | | | | | | | | |
| Total | | | | 1 | | 2 | | | | | 3 | 1 | | | | 1 | 4 |
| 3 | $3_1$ | | | | 2 | | | | 2 | | 4 | | | | | | 4 |
| Northern | $4_2$ | | 1 | | | | | | | | 1 | | | | | | 1 |
| California | $4_1$ | | | | | | | | | | | | | 1 | | 1 | 1 |
| Total | | | 1 | | 2 | | | | 2 | | 5 | | | 1 | | 1 | 6 |
| 4 | $5_2$ | | 1 | | | | | | | | 1 | | | | | | 1 |
| Southern | $5_1$ | | | | 1 | | | | | | 1 | | | | | | 1 |
| Oregon | | | | | | | | | | | | | | | | | |
| Total | | | 1 | | 1 | | | | | | 2 | | | | | | 2 |
| 5 | $3_1$ | | 1 | | | 1 | | | | | 2 | | | | | | 2 |
| Central | $4_1$ | | 1 | | 1 | | | | | | 2 | | | | | | 2 |
| Oregon | | | | | | | | | | | | | | | | | |
| Total | | | 1 | | 1 | 2 | | | | | 4 | | | | | | 4 |
| 6 | $2_1$ | | | | | 1 | | | | | 1 | | | | | | 1 |
| Northern | $3_1$ | | | | 2 | 1 | | | | | 3 | | | | | | 3 |
| Oregon | $4_1$ | | | | | 1 | | | | | 1 | | | | | | 1 |
| & Southern | | | | | | | | | | | | | | | | | |
| Washington | | | | | | | | | | | | | | | | | |
| Total | | | | | 2 | 3 | | | | | 5 | | | | | | 5 |
| 7 | $2_1$ | | | | | 1 | | | | | 1 | | | | | | 1 |
| Columbia | $3_2$ | | 1 | | | 1 | | | | | 2 | | | | | | 2 |
| River | $3_1$ | | | | 1 | 7 | 11 | 2 | | | 21 | | | | | | 21 |
| | $4_2$ | 1 | 8 | 1 | | | 1 | | | | 11 | | | | | | 11 |
| | $4_1$ | | | | | 4 | | | | | 4 | | | | | | 4 |
| | $5_2$ | 4 | 2 | 1 | | 1 | | | | | 8 | | | | | | 8 |
| Total | | 5 | 11 | 2 | 1 | 14 | 12 | 2 | | | 47 | | | | | | 47 |
| 8 | $3_1$ | | 3 | 2 | 8 | 7 | | | | | 20 | | | | | | 20 |
| Central | $4_2$ | | | 2 | | | | | | | 2 | | | | | | 2 |
| Washington | $4_1$ | | | 5 | 1 | 2 | | | | | 8 | | | | | | 8 |
| Total | | | 3 | 9 | 9 | 9 | | | | | 30 | | | | | | 30 |
| 9 | $3_1$ | | | 1 | 4 | | | | | | 5 | | 1 | | | 1 | 6 |
| Northern | | | | | | | | | | | | | | | | | |
| Washington | | | | | | | | | | | | | | | | | |
| & Juan de | | | | | | | | | | | | | | | | | |
| Fuca Strait | | | | | | | | | | | | | | | | | |
| Total | | | | 1 | 4 | | | | | | 5 | | 1 | | | 1 | 6 |
| 10 | $4_2$ | 1 | | | | | | | | | 1 | | | | | | 1 |
| Puget Sound | | | | | | | | | | | | | | | | | |
| & Georgia | | | | | | | | | | | | | | | | | |
| Strait | | | | | | | | | | | | | | | | | |
| Total | | 1 | | | | | | | | | 1 | | | | | | 1 |
| 11 | $4_1$ | 1 | | | 1 | | | | | | 2 | | | | | | 2 |
| West Coast | | | | | | | | | | | | | | | | | |
| Vancouver I. | | | | | | | | | | | | | | | | | |
| Total | | 1 | | | 1 | | | | | | 2 | | | | | | 2 |
| **Grand total** | | 7 | 17 | 13 | 21 | 20 | 12 | 2 | 2 | 1 | 105 | 2 | 1 | 2 | | 5 | 110 |

For definition of recovery areas, see Table 2.

the catch; the remainder is the non-hatchery spawning population. Our procedure for below-Bonneville, non-hatchery spawner estimation is similar to the above-Bonneville method except that we have no direct assessment of total population size. Therefore, we employed the ratio of above-Bonneville to below-Bonneville total spawners that was developed by Stockley, Fiscus, and Tracy (1969). According to their calculations, the total below-Bonneville escapement was approximately 37% of the Bonneville count in each of the years 1964 and 1965.

**TABLE 4.** Procedure for estimating number of non-hatchery fall chinook spawning in Columbia River and its tributaries downstream from The Dalles Dam

| | 1959 | 1960 |
|---|---|---|
| Bonneville Dam fall chinook count | 194,943 | 101,282 |
| The Dalles Dam fall chinook count[1] | - 85,225 | - 63,241 |
| Fall chinook remaining between dams | 109,718 | 38,041 |
| Fall chinook returning to hatcheries between the 2 dams[2,3] | 54,578 | 28,298 |
| Fall chinook caught between the 2 dams | 1,220 | 1,589 |
| Fall chinook accounted for between the 2 dams | 55,798 | 29,887 |
| Fall chinook unaccounted for or spawning naturally between the 2 dams | 53,920 | 8,154 |
| Total fall chinook escapement below Bonneville = 0.37 x Bonneville count[4] | 72,129 | 37,474 |
| Fall chinook returning to hatcheries below Bonneville[2,5] | - 4,657 | - 7,120 |
| Fall chinook unaccounted for or spawning naturally below Bonneville | 67,472 | 30,354 |
| Total unaccounted for or spawning naturally below The Dalles Dam | 121,392 | 38,508 |

[1]U.S. Army Corps of Engineers (1970).

[2]Washington Dept. Fish. (1961) and personal communication with R. J. Wahle, National Marine Fisheries Service, Portland, Oregon.

[3]Hatcheries were Spring Creek, Little White Salmon, Big White Salmon, Oxbow, Cascade, and Klickitat.

[4]Stockley, Fiscus and Tracy (1969).

[5]Hatcheries were Bonneville, Klaskanine, Sandy, Big Creek, Elokomin, Lower Kalama, Kalama Falls, Washougal, Toutle, and Lewis. Several hatcheries have been placed in operation since the pertinent period.

The number of tagged fall chinook recovered at Columbia River hatcheries was 20 in 1959. There were no recoveries in the Columbia escapement in the year following tagging for either the 1959 or the 1960 tagging; this seems surprising and will be examined later. An estimate of total tags in the spawning escapement is: No. hatchery tag recoveries x

$$\frac{\text{No. hatchery chinook + No. non-hatchery chinook}}{\text{No. hatchery chinook}} =$$

$$(20)\,\frac{59{,}235+121{,}392}{59{,}235} = 61.0$$

Thus, 422 fish tagged in 1959 yielded an approximate savings of 61.0 spawners. Total savings is estimated by:

$$\frac{\text{Expected catch during closure}}{\text{No. tagged in given year}} \times \text{No. tags in escapement}$$

$$= \frac{79{,}000}{422}\,(61.0) = 11{,}419 \text{ spawners}$$

The 1960 tagging of 349 chinook yielded 10 hatchery recoveries in the fall run. Calculations parallel to those for 1959 are: $10 \times \frac{35{,}418 + 38{,}508}{35{,}418} = 20.9$ tags in escapement; $\frac{79{,}000}{349}(20.9) = 4{,}733$ spawners (total savings).

The 1959 and the 1960 estimates are minimums because of the use, in the calculations, of the total chinook tagged in the pertinent year regardless of whether they were spring or fall fish together with the use of tag recoveries from fall fish only.

Because of possible errors in the method of determining total tags in the escapement, we generated estimates based on tags recovered in the gill-net fisheries, expanded according to published exploitation rates (Fish Comm. Oregon and Washington Dept. Fish., 1970). Here we utilized all tags recovered in the net fishery after July, so that it was not necessary to separate upper and lower river stocks. We assumed that primarily lower river chinook were tagged and that river fishery exploitation rates were the same for both stocks (Henry O. Wendler, personal communication, Washington Dept., Fish. Olympia).

From the 1959 tagging, 7 tags were recovered in the 1959 fall fishery, and 1 was recovered in 1960. The gill-net exploitation rate in 1959 was 34.6% on fall stocks, so the estimate of total tags in the river in 1959 is:

$$\frac{\text{No. tags in net fishery}}{\text{Net fishery exploitation rate}} = \text{No. tags in river}$$

$$= \frac{7}{.346} = 20.2 \text{ tags.}$$

Tags in the escapement, then, are:
(No. tags in river) - (No. tags in fishery) = 20.2 - 7 = 13.2 and the savings to the Columbia in 1959 is:

$$\left(\frac{\text{Expected catch during closure}}{\text{No. chinook tagged in 1959}}\right) \text{(No. tags in escapement)}$$

$$= \frac{79{,}000}{422}(13.2) = 2{,}471 \text{ spawners.}$$

Added to this is the estimated savings to the 1960 run from the 1959 closure. The gill-net exploitation rate in 1960 was 58.1% and one 1959 tag was returned. Therefore, the estimate of total tags in the river is:

$\frac{1}{.581} = 1.72$ tags, and tags in the escapement are 1.72 - 1 = .72.

The savings is, therefore: $\frac{79{,}000}{422}\,(.72) = 135$ spawners.

Thus, this method indicated that the 1959 closure added approximately 2,471 + 135 = 2,606 spawners to the Columbia River fall runs in 1959 and 1960, combined.

The savings to the 1960 run from the 1960 closure is computed similarly. Gill netters returned 15 tags from the 1960-fall chinook, and the gill-net exploitation rate on fall stocks in 1960 was 58.1%, so the estimate of total tags in the river is: $\frac{15}{.581} = 25.8$ tags; and the estimate of the number of tags in the escapement is: 25.8 - 15 = 10.8. The savings is: $\frac{79{,}000}{349}(10.8) = 2{,}445$.

There were no recoveries in the gill-net fishery from the 1960 tagging after 1960 so the estimated savings for 1960 is 2,445 chinook.

The fishery exploitation method of estimating savings to the fall run yielded results consistently lower than the hatchery:non-hatchery method (1:4.4 in 1959 and 1:1.9 in 1960). One possible reason for this is failure of gill netters to return tags. Sport fishermen, who might be expected to cooperate better in returning tags, reported 4 tags versus 7 for gill netters in the 1959 season. We do not know the number of chinook caught by the freshwater sport fishery, but we presume that it was a small fraction of the catch by net fishermen, which suggests that non-return bias was involved. Such was not the case for 1960 when the ratio was 15 gill net tags to 1 sport tag. There is no reason known to us why such bias, if any, would occur primarily during 1 year.

The hatchery:non-hatchery method of estimating total tags to the spawning ground suffers from our inability to easily enumerate non-hatchery spawners of appropriate populations. Also, it is possible that hatchery chinook were more available to our tagging gear than were non-hatchery chinook (suggested in part by the high savings estimate for this method relative to the fishery exploitation technique).

We would tend to over-estimate non-hatchery spawners between The Dalles and Bonneville Dams if a large fraction of the chinook that apparently died between these dams (Fredd, 1966) were of upriver and presumably untagged stocks. Further, we are aware that our simple designation of The Dalles Dam as a dividing point for races that primarily inhabit different ocean areas is imperfect. Smith (1966) indicated that about 9% of the above-The Dalles chinook in 1965 were "dark" and another 22% were "intermediate dark", presumably characteristics of lower-river fish. Stock separation is further confused by knowledge that some chinook (primarily dark) which were tagged above The Dalles were recovered at below-The Dalles hatcheries. In addition, we are aware that some chinook that we have included as typical lower-river types are known to be more like upper-river stocks in ocean migration, e.g., Kalama River fish had a more northerly ocean dispersion than most lower-river fish (Worlund, Wahle, and Zimmer, 1969).

There was an obvious lack of tag recoveries in the years following tagging in our study relative to results of earlier studies (Van Hyning, 1972). However, a considerable portion of the fish we tagged were mature spring chinook that were clearly on their spawning migration and, therefore, would not be available for recovery in subsequent years. Still, the data of Worlund, Wahle, and Zimmer (1969) and Cleaver (1969) indicate that hatchery-reared Columbia fall chinook can be expected to return to the hatcheries in only slightly greater abundance as 3-year-olds than as 4-year-olds. We did not observe similar proportions from chinook tagged as $3_1$'s in our study. Tag loss may have occurred and if so the computations based on tagging underestimate savings. This disproportion could also be explained by other causes, such as a different ocean distribution for our tagged fish than for Columbia fall chinook as a whole.

## DISCUSSION AND CONCLUSIONS

### Applicability of Tagging Results

The instructions were to make a study of the effect of the opening date on the Westport area chinook fishery. The method chosen was tagging which was done in specific years, 1959 and 1960. While the techniques used should produce representative data for the years of study, the question remains: are they indicative of conditions existing before and after the study?

#### *Stock Composition*

Tagging and fin marking studies done prior to 1959 showed that Columbia River spring and fall chinook, and Fraser River, Puget Sound, and Sacramento River chinooks were found off the southwest Washington coast in the early spring months. Other stocks, if present, were undetected. The proportion each stock was of the total stocks in the area at the time of the 1959 and 1960 tagging was not well established except that Columbia fall chinook dominated in the troll catches and Columbia spring chinook were probably next in abundance. Other tag returns followed the earlier pattern with Sacramento, Fraser, and Umpqua River fish present in that order of decreasing abundance. Unmeasured differences in recovery opportunity in the streams of origin preclude a more precise statement of relative abundance.

The 1955-1957 brood years which supported the 1959-1960 catches were poor production years for Columbia spring and fall chinook as shown by runs returning to the river and Washington-Vancouver Island troll catches. The studies of Van Hyning (1972) show that ocean temperatures in the following June at Amphitrite Point, Vancouver Island, British Columbia are statistically related to brood year success of Columbia River fall chinook. His data indicate fair to poor strength for the 1955 to 1957 brood years. Sacramento River fall chinook spawning escapements were good in 1955, but poor to very poor in 1956 and 1957. Nevertheless, the California ocean troll fishery was good in 1959 and 1960. No information is available regarding annual Fraser River stock size from examination of troll fishery landings or the gill-net fishery catches in that river. These data suggest that the major stocks, while generally low in abundance, were about proportionately represented in the study area.

#### *United States-Canada Division of Protected Fish*

The concern expressed by U.S. industry was that the fish escaping the troll fishery because of the March 15—April 15 closure would leave U.S. fishing areas and would be taken during the summer months off Canada. As shown, this didn't develop *per se;* only 6% of all recoveries came from waters off Canada. Again, does the tagging reflect what is actually happening?

One answer is that tags were not returned in proportion to the numbers actually recovered in the fisheries of the two nations. The only data available for evaluating this premise is mark recovery information and for reasons mentioned previously, it is not suitable. While evaluation is not possible, incentive for Canadian fishermen not to return tags did exist. By 1959-1960, Canadian fishermen were aware of the U.S. problem and realized that the tags could show that they were taking fish of U.S. origin. Returning tags might hasten the day when the U.S. would ask for a reduced season on these fish.

Another answer is that Columbia River fall chinook wintering in the Columbia River-Westport area do not migrate northward to waters off Canada as fin marking results might lead one to expect (Lander, 1970). Tagging done in 1948-1952 near the mouth of the Columbia River in March and April produced a distribution of recoveries similar to that from the 1959-1960 tagging (Van Hyning, 1972). Certainly, fin marking has shown racial groups of Columbia River fall chinook to vary in ocean distribution from each other. This suggests that fall chinook found in one area at a given time would not necessarily redistribute themselves in a manner typical of the general distribution of that stock.

Neither answer can be dismissed; both may be involved. More chinook may leave the study area to migrate to Canada than the study shows, but certainly a large share of them remain in U.S. fishing areas.

### *Comparative Savings Estimate Based on Fin Mark Data*

Because of the many factors influencing the preceding savings estimates, it is difficult to judge their accuracy. However, Cleaver (1969) published estimates of rates of maturation and natural and fishing mortality for Columbia River hatchery chinook during the mid-1960's that we used to compute an expected rate of savings to compare with tagging estimates. We used the population parameter estimates for Spring Creek, following Cleaver's advice (page 57) that "It may be hypothesized that for races which tend to remain south of the middle of Vancouver Island, the rates shown for Ad-LV-RM (Spring Creek) are suitable". Savings estimates are based on these rates, an assumed 50% proportion of Columbia River falls among the legal-size chinook in the fishing area, and the river exploitation rates for 1959 through 1962. The expected savings based again on the pre-closure average catch of 79,000 are 8,000 additional spawners from the 1959 closure and 6,500 from the 1960 closure (Table 5). These values support the order-of-magnitude of savings indicated by the estimates based on tagging which ranged between 2,500 and 10,000 chinook.

## Status of the Stocks

The troll closure was intended to increase the number of Columbia fall chinook returning to the river. Figure 1 shows that, in fact, the fall run increased gradually during the 1960's. Further, if we examine the total chinook stock in the ocean area of concern, as judged from the trend of the total catch in the area plus the fall run to the Columbia River (Figures 1 and 5), we see that the stock has recovered to the level prevailing in the early 1950's.

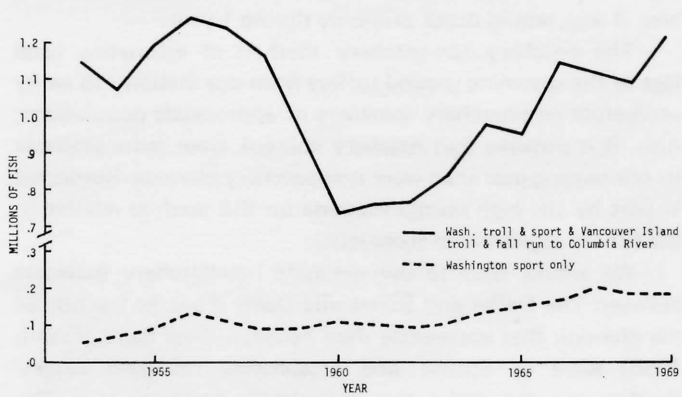


FIGURE 5. Chinook catches in numbers of fish by Washington ocean sport fishery, and by combined Washington ocean sport and Washington and west coast of Vancouver Island troll fisheries plus fall chinook entering the Columbia River.

**TABLE 5.** Expected catches and savings of Columbia River fall chinook resulting from the spring closure, based on the population parameters of Cleaver (1969)

| Tagging year | Age group | Age group proportion during tagging | Assumed no. troll caught Columbia R. fall chinook if spring season open | Ocean catch with spring season closed 1959 | 1960 | 1961 | 1962 | Total | Savings: spawners added to Columbia fall run escapement 1959 | 1960 | 1961 | 1962 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $3_1$ | .818 | 32,311 | 12,795 | 1,717 | 48 | | 14,560 | 3,191 | 1,847 | 36 | | 5,074 |
| 1959 | $4_1$ | .165 | 6,518 | 1,461 | 40 | | | 1,501 | 2,451 | 27 | | | 2,478 |
| | $5_1$ | .017 | 671 | 217 | | | | 217 | 225 | | | | 225 |
| Total | | | 39,500 | 14,473 | 1,757 | 48 | | 16,278 | 5,867 | 1,874 | 36 | | 7,777 |
| | $3_1$ | .718 | 28,361 | | 11,230 | 1,507 | 42 | 12,779 | | 1,795 | 1,849 | 27 | 3,671 |
| 1960 | $4_1$ | .278 | 10,981 | | 2,461 | 68 | | 2,529 | | 2,645 | 52 | | 2,697 |
| | $5_1$ | .004 | 158 | | 51 | | | 51 | | 34 | | | 34 |
| Total | | | 39,500 | | 13,742 | 1,575 | 42 | 15,359 | | 4,474 | 1,901 | 27 | 6,402 |

## Changes in Fishing Intensity

The evidence of increased return to the Columbia suggests that the troll closure did have the desired effect. However, the closure's benefit would be the result of less exploitation due to reduction of fishing time. Because it is possible that fishing intensity during the remaining open season has changed since the closure was initiated, which could affect our conclusions about the value of the closure *per se,* it is useful to examine this factor.

Troll effort appears to have increased off Washington and off the west coast of Vancouver Island in recent years (Figure 6). Measurement of effective effort is extremely difficult, particularly for Washington where landings rather than days fished are available (days fished per landing could change over time). We are aware of three important changes in the Washington fleet: (1) mechanical aids such as radios, echo sounders, and stabilizers have become widespread among trolling boats, making them more effective; (2) lures have improved; and (3) there has been a great influx of sport-type boats. The latter change probably more than offsets the two other changes. "Kicker" boats and cabin cruisers fishing with sport gear generally fish fewer days per landing and catch fewer fish per day than regular trollers. Thus, a landing as a measure of effort has less significance now than in 1956. Taking this into account, effective Washington troll effort probably has been less on the average than before the closure, although the decline has not been great.

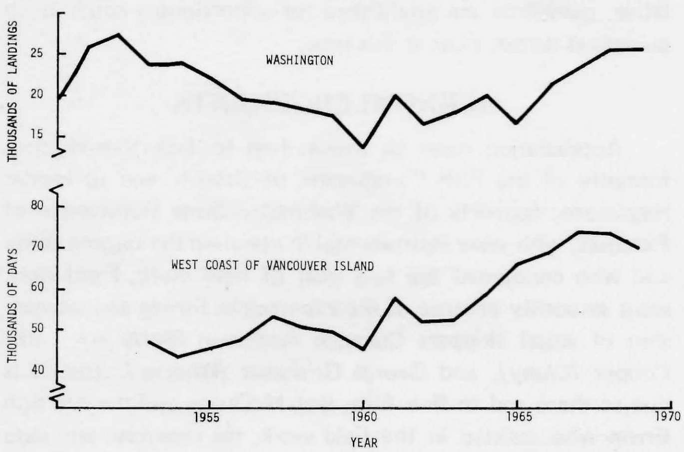


FIGURE 6. Troll effort off west coast of Vancouver Island and State of Washington.

While Washington troll effort declined slightly since the closure, Figure 5 shows that another important related factor, the chinook catch by the Washington sport fishery, roughly doubled over the same period. It is not convenient to put sport effort in the same terms as troll effort, but angler days increased roughly in relation to the catch (Haw, Wendler, and Deschamps, 1967). It seems reasonable that total Washington effort, (troll plus ocean sport) did not differ greatly from the level at the time of the closure.

Effort by Canadian trollers along the west coast of Vancouver Island is more convenient to measure. The influx of sport-commercial gear has not occurred as rapidly as off Washington, sport effort has not increased appreciably, and finally, effort have been recorded in terms of the more meaningful days fished rather than number of landings. When we consider that the Canadian troll fleet has also mechanically modernized and has been a leader in improving lures, it is probable that Vancouver Island effort has increased even more dramatically since the spring troll closure than shown in Figure 6.

An additional change during this period should be mentioned for clarification: U.S. trollers caught a substantially smaller fraction of their chinook off the west coast of Vancouver Island in the 1960's than they did in the 1950's. While to some extent this was due to a southward shift in effort, it does not change our conclusions about overall effort on the stocks of interest, because the shift was within the total area of concern.

Because it seems clear that fishing pressure on the stocks of concern has increased beyond the intensity that existed prior to the closure, yet the total stock and the return to the Columbia have increased, we conclude that the closure was not responsible for the recovery. Van Hyning (1972) states that escapement over the period was adequate. Despite fewer fish arriving in the river, the management agencies assured escapement to the spawning grounds and hatcheries by reducing the gill-net catches in the river. Thus, the basic requirement for recruitment to the fisheries was present. The trend toward recovery of the stocks in the face of increased pressure indicates the fall run to the Columbia was affected by additional factors, e.g., poor watershed or oceanic conditions as well as by ocean fishing. It is possible that hatcheries have supplemented these stocks at a greater rate after the 1950's, but still the primary point is that the stocks have recovered to a higher level than at the time of the closure despite subsequent increased fishing.

## Present Value of the Closure

We indicate that the fall run to the Columbia River would have increased whether or not the spring troll closure was instituted. This does not mean that re-opening would not reduce the present rate of return of fall chinook to the river; there was a saving from the closure and added pressure would decrease the numbers entering the Columbia. There would be similar but lesser savings to runs of Columbia River spring chinook and Sacramento River chinook.

The primary effect of the closure was re-distribution of the catch; it was not a conservation measure since overfishing did not exist. While U.S. trollers re-caught about a third of what they initially lost from the closure, an obvious effect was that the Columbia River-Westport area lost the benefit of major troll landings, and other areas gained. We know that some chinook were transferred to Canadian fisheries, but the tagging data indicate this loss was small. The Columbia River gill-net fishery gained a substantial amount of spring and fall chinook from the closure.

We do not doubt that the trollers and fish processors who were benefited by the early-season troll fishery feel that something was unjustly taken from them. On the other hand, as this March-April troll fishery developed, it clearly took from others—certainly from Columbia River gill netters and California trollers fishing Sacramento River stocks. Unfortunately, there are no clear-cut biological or conservation issues here to guide us in recommending whether the spring troll closure should be retained. The problems are economic, or better, legislative, and there are few guidelines. We note that the troll fishery grew without important restriction until the 1950's, even though it was obviously taking salmon from stocks that were being adequately harvested by existing means. This happened because no basis existed for catch distribution. We are still without guidelines; their development is requisite to determining the merits of reopening the March 15—April 15 period. We recommend no change in the status of this closure be made until appropriate distribution criteria are established.

## SUMMARY

1. Washington and Oregon had no seasonal restrictions on trolling for chinook salmon prior to 1949 when they adopted a March15—October 31 season. Following this action, an intense fishery built up during March and April in the Westport-Columbia River area, and troll chinook landings generally increased in the area between the Columbia River and northern Vancouver Island. Concurrently, the fall run of chinook to the Columbia declined. Biologists believed that Columbia River fall chinook were abundant during March and April in the Westport-Columbia River area. The troll season opening was delayed one month, beginning in 1956, until April 15 in an effort to decrease trolling intensity on those fall chinook stocks by eliminating the early-season fishery.

2. PMFC requested a study be made of the effect of the opening date on the Westport area chinook fishery. The response to this request was a troll tagging program conducted in the Westport-Columbia River area in which 422 and 349 chinook were tagged in 1959 and 1960, respectively.

3. From the 771 chinook tagged, 229 were recovered. The recoveries indicated that Columbia River fall chinook were important in the tagging area, as were Columbia River spring chinook and Sacramento River chinook. Fraser River chinook were present in small amounts, and one tag was returned from the Umpqua River. The troll, sport, and net fisheries (primarily Columbia River) of the Pacific coast shared about equally in recapturing tagged chinook not taken by the troll fishery because of the closure. A high proportion of the tags was recovered in the Oregon-Washington area, a considerable number was returned from California, and relatively few—about 6%—were recaptured off Canada.

4. Estimates of savings from the March 15—April 15 troll closure to the fall spawning escapement of the Columbia River were computed from tags recaptured at artificial production facilities and, separately, from tags taken in the gill-net fishery. These estimates indicated that between 2,500 and 11,500 fall chinook were added to the Columbia escapement in 1959 and 1960 because of the troll closure.

5. Because there were many assumptions and other possible sources of error in computing savings based on the troll tagging, published population parameters based on fin marking of Columbia River hatchery fall chinook were used to compute expected savings from the closure. These calculated savings and savings indicated from the tagging data were of the same order-of-magnitude.

6. An important question is whether the tagging was indicative of conditions before and after the study. The 1955-1957 brood years that produced the chinook stocks tagged in 1959 and 1960 were generally weak, but major stocks were probably proportionally represented in the study area. The information is inconclusive, but it seems unlikely that actual catches off the Canadian coast from those stocks represented by the tagged fish were much greater than indicated by the tag returns.

7. After the March—April troll closure was instituted, numbers of fall chinook returning to the Columbia increased, and the total ocean stocks in the area of concern returned to the level of abundance of the early 1950's. Over the same period, ocean fishing effort increased beyond the amount that existed just prior to the troll closure. Thus, we conclude that the closure was not necessary *per se* for the recovery of these stocks, and that overfishing was not indicated because escapement of Columbia River fall chinook was adequate over the period.

8. The primary effect of the closure was re-distribution of catch. Changes in the present status of the closure are not recommended until appropriate economic, or perhaps legislative, guidelines are established for apportioning catch. Such guidelines do not exist at this time.

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# Economic Evaluation of Washington's 1967 Troll Salmon Fleet

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## BULLETIN 8

PACIFIC MARINE FISHERIES COMMISSION
Portland, Oregon

1972

# ECONOMIC EVALUATION OF WASHINGTON'S 1967 TROLL SALMON FLEET

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## ABSTRACT

Application of average ex-vessel prices to reported landings of a random 10% sample of Washington's 1967 commercial ocean salmon fleet showed the troller boat category producing 80% of total landed value and demonstrating the highest gross return on investment. Hypothetical elimination of less efficient boat categories demonstrated potential economic benefits of various license limitation schemes. Deficiencies in 1967 data were noted and recommendations were made for future troll fishery economic studies.

## INTRODUCTION

Concern about overinvestment in Washington's commercial salmon fisheries has led to discussion of various methods of limiting entry into the fishery. At the request of the Washington State Senate's Interim Committee on Fisheries, Game and Game Fish, the Department of Fisheries provided several potential license limitations schemes for Washington's salmon fisheries (Washington Department of Fisheries, 1971).

Primary rationale for license limitation is to sufficiently reduce the fishing industry's capitalization level to allow a "reasonable" return for labor and capital. Theoretically, by significantly reducing number of boats participating, income of remaining boats (as a result of stabilized or increased catches per boat or fisherman) could be increased and thus a larger return of labor and capital would be produced. Secondary justifications for license limitation include achieving greater efficiency of resource use and reduction in management costs by simplifying or eliminating various management problems.

Development and implementation of a rational limitation program in any fishery must be predicated on a true and accurate assessment of biologic, sociologic, and economic factors affecting the fishery. Mechanisms of license limitation are primarily economic and are traditionally aimed at the least efficient boats. This report provides basic insight into economics of the 1967 troll salmon fishery, demonstrates how such an evaluation may be used to predict effects of a given limitation program, and determines what data will probably be needed to evaluate the present and future fishery.

## METHODS

To determine gross economic yields, average 1967 troll prices paid to fishermen (ex-vessel) were applied to reported Washington landings (by district and species) of a random 10% sample of the fleet originally selected and described by Wright (1970).

Statistics available included earnings from all salmon and incidental groundfish taken in any area by trolling and landed in Washington. These excluded earnings from salmon catches landed in other Pacific Coast States and earnings from any fishing efforts directed toward other species (crab, albacore, lingcod, etc.). In an attempt to separate part-time trollers or those fishermen landing only a portion of their season's catch in Washington from full-time trollers fishing only for salmon and landing their catches entirely in Washington, "incomplete" and "complete" categories were established. A "complete troller" was arbitrarily defined as making one or more landings in May, consistent landings (no gaps of 21 days or more between landings) in June, July, and August, and one or more landings in September. The calculated investment figures used represent the boat and gear value as estimated by fishermen and do not include other expense items (e.g., fuel, maintenance, depreciation license fees, etc.).

Washington treaty Indians landed $62,000 worth of troll-caught fish in 1967 (ex-vessel), but they will be excluded from further discussion as no precise estimate was available on the number or types of boats actually involved.

**TABLE 1.** Dollar value of in-sample landings by boat type and percent contribution to the total sample

| Boat type | Value of landings | Percent contribution |
|---|---|---|
| Troller | $308,723 | 80.1 |
| Com-sport | 34,671 | 9.0 |
| Day boat | 22,599 | 5.9 |
| Kelper | 16,100 | 4.2 |
| Charter | 3,262 | 0.8 |
| Total | $385,355 | 100.0 |

## RESULTS

Regular trollers or trip-boats were the most important boat category, accounting for 80% of the total value of Washington troll fishery landings. Com-sport, day-boats, kelpers, and charter boats followed in order of importance and collectively accounted for the remaining 20% of total value (Table 1). Definition of gear types can be found in Wright (1970).

A comparison of gross yields and boat investments is presented in Table 2. As expected, the highest gross return on investment was obtained by trollers (56%). Day-boats and kelpers were approximately equal (27% and 28%, respectively), followed by com-sports (13%) and charter boats (5%). The latter group, however, relied heavily on income from regular sport chartering operations and is not directly comparable to other boats for this reason. The calculated gross investment return for "complete" and "incomplete" trollers was 129% and 39% respectively (Table 3).

By compiling catch values as percentage contribution to major port areas or regional fisheries, the importance of various boat types to each major landing area was determined (Table 4). In all areas, trollers were most important, accounting for at least 60% of the ex-vessel values. The significance of day-boats and kelpers in various regions ranged from 1 to 14%. Com-sports accounted for 22% of landing values at Neah Bay and 29% at the Columbia River, but only 1% at LaPush and 7% at Grays Harbor.

**TABLE 3.** Comparison of calculated gross income and investment return for complete and incomplete troller categories in 1967

| | Complete troller | Incomplete troller |
|---|---|---|
| Average investment ($) | 9,100 | 9,100 |
| No. boats reporting landings | 11 | 50 |
| In-sample income ($) | | |
| Total income | 129,138 | 179,585 |
| Range | 3,753-24,782 | 10-11,675 |
| Average | 11,740 | 3,592 |
| Gross return on investment | 129% | 39% |

**TABLE 4.** Values of in-sample landings expressed in percentage contribution by major port area

| Area | Troller | Com-sport | Day-boat | Kelper | Charter |
|---|---|---|---|---|---|
| Puget Sound | 99 | | | 1 | |
| Neah Bay | 61 | 22 | 3 | 14 | |
| LaPush | 86 | 1 | 9 | 4 | |
| Grays Harbor | 84 | 7 | 3 | 2 | 4 |
| Columbia River | 64 | 29 | 2 | 4 | 1 |

**TABLE 2.** Comparison of gross income and investment return by boat type for 1967

| | Troller | Com-sport | Day-boat | Kelper | Charter | Fleet total |
|---|---|---|---|---|---|---|
| Number sampled | 70 | 97 | 24 | 33 | 13 | 237 |
| Boats reporting landings | | | | | | |
| Number | 61 | 66 | 17 | 23 | 7 | 174 |
| Percent | 87 | 68 | 71 | 70 | 54 | |
| Boat investment (from Wright, 1970) | | | | | | |
| Average ($) | 7,800 | 3,600 | 4.200 | 2,100 | 8,700 | |
| Range ($) | 900-35,000 | 200-20,000 | 700-15,000 | 300-10,000 | 1,500-25,000 | |
| Gear investment (from Wright, 1970) | | | | | | |
| Average ($) | 1,300 | 400 | 700 | 400 | 900 | |
| Range ($) | 100-5,000 | 100-2,300 | 200-2,000 | 100-3,000 | 200-4,000 | |
| Total average investment ($) | 9,100 | 4,000 | 4,900 | 2,500 | 9,600 | |
| Estimated in-sample investment (million $) | | | | | | |
| All boats | 0.637 | 0.388 | 0.118 | 0.082 | 0.125 | 1.350 |
| Boats reporting landings | 0.555 | 0.264 | 0.083 | 0.058 | 0.067 | 1.027 |
| Boat income ($) | | | | | | |
| Boat type total | 308,723 | 34,671 | 22,599 | 16,100 | 3,262 | 385,355 |
| Range | 10-24,782 | 12-3,552 | 10-4,857 | 22-700 | 8-2,166 | |
| Average all boats | 4,410 | 357 | 942 | 488 | 251 | |
| Average boats reporting landings | 5,061 | 525 | 1,329 | 700 | 466 | |
| Gross return on investment for boats reporting landings | 56% | 13% | 27% | 28% | 5% | 38% |

By hypothetically omitting various portions of the 1967 fleet and assuming the boats left would have proportionally taken the catch of omitted boats, effects of various license limitation programs might be predicted. The return percentages cited in Table 2 are based only on boats actually reporting landings in Washington and would have been appreciably less if the boats not reporting any landings had been included in the calculation. By using statistics for numbers of vessels by boat type and average value per category, it was determined that the total 1967 licensed troll salmon fleet had a value of $13,543,000, but that portion of the fleet actually landing the entire salmon catch was valued at only $10,237,000. In this case, the omission of boats not reporting landings produced only a "paper benefit" to those boats landing salmon, i.e., there was absolutely no increase in the actual income of boats landing salmon whether or not the boats reporting no landings were included.

For the fleet as a unit, hypothetical elimination of charter boats and the least efficient major component (com-sport) produce a 45% increase in gross return on investment. The elimination of all but the most efficient group (trollers) produces an 82% increase (Table 5).

**TABLE 5.** Potential fleet increases on investment return through hypothetical elimination of specific components and maintenance of a constant catch level

| Category | Gross in-sample fleet income (constant) | In-sample fleet investment | Percent return on investment | Percent change on investment return |
|---|---|---|---|---|
| All boats reporting landings (N=174) | $385,355 | $1,027,000 | 38% | |
| Fleet minus charters and com-sports (N=101) | 385,355 | 696,000 | 55 | +45% |
| Fleet minus all categories except trollers (N=61) | 385,355 | 555,000 | 69 | +82 |

When examining benefits to individual boat types, however, the increase in gross investment return through hypothetical elimination of charter boats and com-sports is only 11% for each of three remaining boat types. Similarly, elimination of all components except trollers produces only a 25% increase in gross investment return for this group (Table 6).

Benefits in terms of net income might be considerably greater when the relatively fixed costs of equipment, maintenance, and labor are considered. Realistically, however, some shift in catches to various other fisheries, sport, commercial net, and Indian would logically be expected with any decrease in troll fleet size. The troll fishery currently operates on a 7-day-per-week basis for 6½ months annually, with no significant gear limitations. As such, it has little of the potential for increased efficiency inherent to various commercial net fisheries.

**TABLE 6.** Potential boat type percentage increases on investment return through hypothetical elimination of specific components of the trolling fleet and maintenance of a constant catch level

| Boat type | Charter boats and com-sports eliminated | All components except trollers eliminated |
|---|---|---|
| Troller | +11% | +25% |
| Day-boat | +11% | |
| Kelper | +11% | |

## DISCUSSION AND RECOMMENDATIONS

Gross investment returns discussed in this report are not a precise indicator of overinvestment in the fishery. These data exclude earnings from salmon and incidental groundfish landed in other States, as well as income from fishing efforts for other non-salmonid species. In addition, calculated investment values included only the reported boat and gear value and excluded all other investment items. Calculated gross investment returns, however, do provide a moderately useful means for relative comparisons between various boat types. Because the various vessel types have different depreciation rates, fuel oil, maintenance, etc., costs, even this relative comparison of gross investment returns must be viewed cautiously. It is obvious from the above that no concise data exist for an estimation of net returns by the various boat types in 1967.

The separation of full-time salmon trollers, who were believed to have landed their catches entirely in Washington, from the remaining trollers, results in a significant increase in gross investment return for these "complete trollers." The calculated gross investment return for this group (129%) is probably satisfactory regardless of limitations of the data.

The actual value of eliminating large numbers of boats in the less efficient categories to promote greater net earning by the more efficient troller group is certainly questionable. To achieve any meaningful results, it would probably be necessary to significantly reduce the troller category as well. In addition, no measure of social or recreational benefits derived by small-boat fishermen exists and these benefits might provide additional, yet admittedly nebulous, values to small-boat catches. With their exceptionally low return on investment, it certainly seems that a genuine and valuable incentive over and above actual fish sales must exist to sustain the small-boat fishermen from year to year. The impact of any fleet reduction on support businesses in coastal communities would also be a real and important consideration in any license limitation scheme, since a viable industry has developed to support a large and seemingly inefficient fleet.

For future studies, more precise measures of investment return must be developed to evaluate the extent of real or imagined overinvestment in the salmon troll fishery, and to determine net benefit of license limitation proposals. To accomplish this, all investment and operating costs and all income; including that from other States and fisheries, must be determined.

## SUMMARY

Information on gross economic yields by Washington's 1967 troll salmon fleet was determined through application of average ex-vessel prices to reported landings of a random 10% sample of the fleet. Results were:

1. The troller boat category contributed about 80% of the estimated troll salmon, plus incidental groundfish, catch value on a state-wide basis and at least 60% of the catch value in any regional area.

2. Trollers, as a group, had the highest gross return on investment, and those full-time fishermen landing their entire catch in Washington showed a 129% gross return on boat and gear investment.

3. Elimination of various less efficient fleet components can produce significant economic improvements on paper (i.e., omission of boats not landing salmon) but translation to real benefits for those individuals remaining may be difficult.

4. Values additional to fish sales probably play a definite role in maintenance of the small-boat fishery and should be carefully considered in any license limitation plan.

5. Future fleet economic studies must be designed to obtain more complete cost and income data, particularly landing information from other Pacific Coast States.

6. Table 7 provides basic economic data.

## ACKNOWLEDGEMENT

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**TABLE 7.** Dollar values in-sample 1967 troll catch

| | | Pacific salmon | | | | Incidental groundfish | | | | Totals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Boat type** | **Port area** | **Chinook** | **Coho** | **Pink** | **Sockeye and chum** | **Eggs sold** | **Lingcod** | **Pacific halibut** | **Rock fishes** | **All salmon** | **All groundfish** | **Cumulative total** |
| Complete troller | Puget Sound | 2,043 | 4,741 | 1,216 | | | 31 | 110 | 1 | 8,000 | 142 | 8,142 |
| | Neah Bay | 2,296 | 2,483 | 1,866 | 2 | | 100 | 115 | 6 | 6,647 | 221 | 6,868 |
| | LaPush | 17,399 | 44,099 | 7,914 | 10 | 203 | 253 | 92 | 125 | 69,625 | 470 | 70,095 |
| | Grays Harbor | 9,984 | 12,301 | 711 | | 12 | 132 | 16 | 54 | 23,008 | 202 | 23,210 |
| | Columbia River | 2,467 | 17,956 | 335 | | | 5 | 1 | 59 | 20,758 | 65 | 20,823 |
| Total | | 34,189 | 81,580 | 12,042 | 12 | 215 | 521 | 334 | 245 | 128,038 | 1,100 | 129,138 |
| In-complete troller | Puget Sound | 2,841 | 6,592 | 1,690 | | 1 | 43 | 154 | 2 | 11,124 | 199 | 11,323 |
| | Neah Bay | 3,193 | 3,452 | 2,594 | 2 | | 140 | 161 | 9 | 9,241 | 310 | 9,551 |
| | LaPush | 24,196 | 61,326 | 11,005 | 14 | 283 | 352 | 129 | 174 | 96,824 | 655 | 97,479 |
| | Grays Harbor | 13,884 | 17,105 | 988 | | 17 | 184 | 22 | 74 | 31,994 | 280 | 32,274 |
| | Columbia River | 3,431 | 24,970 | 466 | | | 7 | 1 | 83 | 28,867 | 91 | 28,958 |
| Total | | 47,545 | 113,445 | 16,743 | 16 | 301 | 726 | 467 | 342 | 178,050 | 1,535 | 179,585 |
| Com-sport | Puget Sound | | | | | | | | | | | |
| | Neah Bay | 1,633 | 3,233 | 1,000 | 2 | | 9 | 5 | 12 | 5,868 | 26 | 5,894 |
| | LaPush | 319 | 1,590 | 206 | | 1 | | | 3 | 2,116 | 3 | 2,119 |
| | Grays Harbor | 2,303 | 1,994 | 8 | | 10 | 4 | | 7 | 4,315 | 11 | 4,326 |
| | Columbia River | 5,186 | 17,089 | 28 | | 10 | 1 | | 18 | 22,313 | 19 | 22,332 |
| Total | | 9,441 | 23,906 | 1,242 | 2 | 21 | 14 | 5 | 40 | 34,612 | 59 | 34,671 |
| Day-boat | Puget Sound | | | | | | | | | | | |
| | Neah Bay | 105 | 328 | 288 | 24 | | 11 | 6 | 5 | 745 | 22 | 767 |
| | LaPush | 2,951 | 12,978 | 1,845 | | 60 | 19 | 21 | 47 | 17,834 | 87 | 17,921 |
| | Grays Harbor | 787 | 1,424 | 36 | | 2 | 8 | | 13 | 2,249 | 21 | 2,270 |
| | Columbia River | 132 | 1,472 | 36 | | | 1 | | | 1,640 | 1 | 1,641 |
| Total | | 3,975 | 16,202 | 2,205 | 24 | 62 | 39 | 27 | 65 | 22,468 | 131 | 22,599 |
| Kelper | Puget Sound | 19 | 3 | 1 | | | | | | 23 | | 23 |
| | Neah Bay | 107 | 2,153 | 1,392 | 2 | | 16 | 20 | 8 | 3,654 | 44 | 3,698 |
| | LaPush | 1,281 | 5,932 | 572 | 3 | 13 | 8 | 4 | 8 | 7,801 | 20 | 7,821 |
| | Grays Harbor | 627 | 846 | 1 | | 12 | 2 | | 2 | 1,486 | 4 | 1,490 |
| | Columbia River | 472 | 2,584 | 8 | | | | | 4 | 3,064 | 4 | 3,068 |
| Total | | 2,506 | 11,518 | 1,974 | 5 | 25 | 26 | 24 | 22 | 16,028 | 72 | 16,100 |
| Charter | Puget Sound | | | | | | | | | | | |
| | Neah Bay | | | | | | | | | | | |
| | LaPush | | | | | | | | | | | |
| | Grays Harbor | 1,600 | 786 | 47 | | 3 | 43 | 21 | 15 | 2,436 | 79 | 2,515 |
| | Columbia River | 84 | 661 | 1 | | | | | 1 | 746 | 1 | 747 |
| Total | | 1,684 | 1,447 | 48 | | 3 | 43 | 21 | 16 | 3,182 | 80 | 3,262 |
| Statewide totals | | 99,340 | 248,098 | 34,254 | 59 | 627 | 1,369 | 878 | 730 | 382,378 | 2,977 | 385,355 |
| Overall % contribution | | 26 | 64 | 9 | + | + | + | + | + | 99 | 1 | 100 |

# Comparison of Retention of Anchor and Spaghetti Tags by Salmon

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Fish Commission of Oregon

# BULLETIN 8

PACIFIC MARINE FISHERIES COMMISSION
Portland, Oregon

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# COMPARISON OF RETENTION OF ANCHOR AND SPAGHETTI TAGS BY SALMON

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Fish Commission of Oregon

## ABSTRACT

A field study to compare the usefulness of anchor tags with spaghetti tags on salmon in the ocean demonstrated the suitability of anchor tags for studies where minor tag loss can be accepted.

## INTRODUCTION

The Fish Commission of Oregon compared the retention of anchor and spaghetti tags by salmon in the ocean. Interest in anchor tags is due to the increased ease of tag application; spaghetti tags were used for the comparison because of their general acceptance. Coho salmon *(Oncorhynchus kisutch)* and chinook salmon *(O. tshawytscha)* were double tagged with Floy FD-67 anchor tags and Floy FT-4 spaghetti tags. Floy Tag and Manufacturing Company provided 1,000 anchor tags, without cost, for the study.

## METHODS

The fish were tagged off Brookings, Oregon from the chartered fishing vessel, *Alibi,* during May and June, 1968. Each fish was tagged on the left side with an anchor tag ½ inch below the origin of the dorsal fin, and a spaghetti tag about the same distance below the dorsal fin insertion. The tagging gun used for the anchor tag was fitted with a "regular" needle. No attempt was made to lock the anchor tag into the basal bones of the dorsal fin. The ends of spaghetti tags were secured by crimping with numbered metal bands, a procedure that has produced good results.

## RESULTS

The results of the tag retention study are shown in Table 1. Of the 266 double-tagged chinook released, 60 or 22.6% were recovered. Forty-two of the recovered chinook retained both tags, 15 lost the anchor tag and 3 lost the spaghetti tag. Of the 18 chinook that retained only 1 tag, 8 were recovered in 1968, the year of tagging, and 7, 2, and 1 were recovered during 1969, 1970 and 1971 respectively.

Of the 588 double-tagged coho released, 133 or 22.6% were recovered, all in 1968. Among the recoveries were 119 with both tags retained, 13 with anchor tag lost, and 1 with spaghetti tag lost. The numbers and the percentages that they represent of the total tagged coho recoveries are compared in Table 1 with the respective numbers and percentages of the 28 tagged chinook recovered in 1968 and the 32 tagged chinook recovered in 1969, 1970 and 1971.

**TABLE 1.** Numbers of tagged fish recovered, and numbers and percentages of recoveries with both tags retained, or with anchor tag lost, or with spaghetti tag lost

| Species | No. recovered tagged fish | Both tags retained No. | Both tags retained % | Anchor lost No. | Anchor lost % | Spaghetti lost No. | Spaghetti lost % |
|---|---|---|---|---|---|---|---|
| Chinook | 60 | 42 | 70.0 | 15 | 25.0 | 3 | 5.0 |
| Coho | 133 | 119 | 89.4 | 13 | 9.8 | 1 | 0.8 |
| Chinook (1968 only) | 28 | 20 | 71.4 | 7 | 25.0 | 1 | 3.6 |
| Chinook (1969, 1970 & 1971) | 32 | 22 | 68.8 | 8 | 25.0 | 2 | 6.2 |

## DISCUSSION AND CONCLUSIONS

Coho retained both types of tags better than did chinook. Eighty-nine percent of the recovered coho retained both tags; 70% of the chinook retained both (Table 1). Only 9.8% of the coho recovered had lost an anchor tag, whereas the loss among chinook was 25%. The poorer retention of the anchor tag by chinook does not appear to be due to the longer time period that may elapse before recovery, since chinook tag returns from the year of tagging gave the same pattern as did the total recovery. Thus, it appears that the anchor tag we tested is better suited for studies involving coho than chinook. However, even with chinook, the advantages that the anchor tag offers in the reduction of handling fish may outweigh the tag loss that occurs.

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