CONTRIBUTION OF WILD AND HATCHERY-REARED COHO SALMON, *ONCORHYNCHUS KISUTCH*, TO THE OREGON OCEAN SPORT FISHERY

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ABSTRACT

Eight scale characters of known hatchery and wild coho salmon, *Oncorhynchus kisutch*, were compared, and a linear discriminant function was used to determine whether hatchery and wild adult coho salmon could be reliably separated on the basis of scale characteristics. Attempted separation was based upon known differences in rearing environments of hatchery and wild juvenile coho salmon and upon hatchery smolts being larger than wild smolts. Identifications were correct for 82% of the hatchery fish and 89% of the wild fish. Based on analysis of scales from adult coho salmon of unknown origin (hatchery or wild) and the estimated catch of marked, hatchery-reared coho salmon taken by the Oregon sport fishery, we concluded that 75% of the fish caught in the ocean along the Oregon coast from mid-June to mid-September 1977 had been released as smolts from hatcheries. Percentages of hatchery fish in the catch ranged from 85 near the mouth of the Columbia River to 61 at Winchester Bay on the central Oregon coast. Fisheries along the south and central Oregon coast may have had access to higher percentages of wild coho salmon after mid-August than prior to this time, probably because wild fish from coastal streams remained near these ports, whereas most fish destined for Columbia River hatcheries had already migrated northward.

The coho salmon, *Oncorhynchus kisutch*, is the most abundant species of salmon contributing to Oregon's commercial troll and ocean recreational fisheries (Oregon Department of Fish and Wildlife[3]). Numbers of this species caught commercially in Oregon have historically fluctuated widely. Catches from 1952 to 1962 averaged 292,000 fish and ranged from 551,000 in 1957 to 112,000 in 1960. Numbers of coho salmon caught increased generally in 1963-77 and averaged 860,000 fish/yr while ranging from 1,827,000 in 1976 to 450,000 in 1977. Catches by the Washington and California troll fisheries have also increased in recent years (Wright 1976; Pacific Fishery Management Council 1978). This rise in catch has been attributed to increased production by Federal and state hatcheries of larger and healthier smolts (Pacific Fishery Management Council 1978; Reed[4]).

This increased abundance of coho salmon has coincided with, and partly led to, the development of a substantial sport fishery in the ocean off Oregon, Washington, and California. The number of coho salmon caught in the ocean by sport fishermen has been fairly stable in Oregon since 1964 but has increased rapidly in Washington since the early 1960's (Phinney and Miller 1977; Pacific Fishery Management Council 1978).

Although both total releases of coho salmon smolts from public hatcheries and catch have increased, indices of escapement of wild fish indicate that the numbers of wild coho salmon spawning have decreased (Cummings[5]). In an analysis of counts of spawning salmon from selected areas of eight Oregon coastal streams from 1964 to 1974, we found that counts of adult salmon have declined significantly in the Nestucca ($P<0.01$), Alsea ($P<0.01$), Yaquina ($P<0.05$), and Coquille ($P<0.005$) Rivers and Beaver Creek ($P<0.05$), but no significant trends were observed in the Nehalem, Wilson, and Coos Rivers. For all spawning areas combined, the conclusion is that overall escapements are declining ($P<0.01$) on coastal

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[3]Oregon Department of Fish and Wildlife. 1977 unpubl. stat. of troll salmon investigations group. Marine Science Drive, Bldg. #3, Newport, OR 97365.

[4]Reed, P. H. 1976. A history and current status of Oregon ocean salmon fisheries-troll salmon investigations. Oregon Department of Fish and Wildlife, Marine Science Drive, Bldg. #3, Newport, OR 97365.

[5]Cummings, E. 1977. Spawning coho and chinook salmon surveys in coastal watersheds of Oregon. 1976. Oregon Department of Fish and Wildlife, 17330 SE Evelyn Street, Clackamas, OR 97015.

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rivers (Berry[6]; Cummings see footnote 5). The escapement of wild fish is also declining in the lower Columbia River (Oregon Department of Fish and Wildlife and Washington Department of Fisheries 1976).

Management agencies do not know how many wild fish are caught in Oregon's troll and sport fisheries, even though they strongly suspect that the number of wild fish in the catch is smaller now than it was 10 yr ago. If they knew the numbers of hatchery and wild fish contributing to Oregon's fisheries, they could recommend management strategies according to the needs of the respective stocks. Also, if they could distinguish hatchery and wild fish caught in the fisheries at various times and localities, they could determine the potential for differentially harvesting the stocks. Consequently, we elected to attempt separating hatchery and wild coho salmon caught in the Oregon ocean sport fishery by measuring and counting characters of scales taken from adult fish. Our objective was to determine the percentages of hatchery and wild fish contributing to the Oregon ocean sport fishery at different times and locations.

METHODS

Scales are a logical choice for separating hatchery and wild coho salmon, since they have been used to differentiate stocks of salmon in rivers (Henry 1961), and for classifying mixed stocks of salmon caught on the high seas to continent of origin (Mosher 1963; Tanaka et al. 1969; Anas and Murai 1969). A review of the use of scales for identification of stocks of salmon was given in Major et al. (1972). Peck (1970) successfully differentiated between hatchery and wild juvenile coho salmon by using several scale characters.

Scales from coho salmon of known hatchery origin (identified by missing adipose fins), and scales of unmarked salmon of unknown origin were collected by personnel of the Oregon Department of Fish and Wildlife from adult fish captured in the ocean by sport fishermen from mid-June to mid-September 1977. Samples were collected weekly from eight coastal ports, listed from north to south: Hammond, Garibaldi, Depoe Bay, Newport, Winchester Bay, Coos Bay, Gold Beach, and Brookings. We obtained scales from 178 adipose clipped salmon and from 2,054 unmarked salmon (Table 1).

Because few wild fish were available, we had to use wild fish of several different brood years to increase our sample. Geographic location, brood year, and number of scale samples used in the subsequent analysis are shown in Table 2.

Two nonregenerated scales obtained from the left side of each fish, one to four rows above the lateral line between the dorsal and adipose fins, were mounted on gummed cards, and acetate impressions were made by methods similar to those described by Clutter and Whitesel (1956). A conscious effort was made to select the largest nonregenerated scales within each sample. Scale impressions were read with the aid of a projector at a magnification of 80×.

Based on Peck's (1970) analysis of scale characters of hatchery and wild smolts of coho salmon and on our analysis and observations of scale characters from known wild adult fish and those from three Oregon hatcheries, we selected eight characters that we believed were potentially useful in separating hatchery from wild fish (Table 3). Characters were selected based on the assumption that the freshwater rearing environments for hatchery and wild coho salmon are distinctly different and differences in scales between the two groups would be manifest during this period.

We selected for analysis preocean radius and preocean circulus counts on the basis of results of Peck (1970) and on data on weights of smolts being

TABLE 1.—Number of adipose clipped and unmarked coho salmon sampled for scales at Oregon ports in 1977. Ports are arranged from north to south.

Port	Marked	Unmarked	Port	Marked	Unmarked
Hammond	5	356	Coos Bay	9	165
Garibaldi	43	188	Gold Beach	0	30
Depoe Bay	64	516	Brookings	0	56
Newport	33	412			
Winchester Bay	24	331	Total	178	2,054

TABLE 2.—Origin of scales of wild coho salmon, brood year, and number of scale samples from each geographic location.

River system	County of collection	Brood year	Number of samples
Necanicum	Clatsop	1974	3
Salmon	Lincoln	1973	45
Salmon	Lincoln	1974	16
Alsea (Flynn Creek)	Lincoln	1962	7
Alsea (Flynn Creek)	Lincoln	1963	32
Alsea (Needle Branch)	Lincoln	1963	27
Alsea (Deer Creek)	Lincoln	1963	28
Coos and Coquille	Coos	1974	4
Total			162

[6]Berry, R. L. 1975. Spawning surveys in coastal watersheds. 1974. Oreg. Dep. Fish Wildl. Coastal Rivers Inf. Rep. 75-4. P.O. Box 529, Tillamook, OR 97141.

TABLE 3.—Description of scale characters measured or counted in this study from known hatchery and wild coho salmon. All measurements are made at angles ventral to the longest axis.

Character	Description
1	Radius of preocean zone at 20°
2	Number of circuli in the preocean zone at 20°
3	Distance between circuli 1 and 5 of the preocean zone at 90°
4	Distance between circuli 1 and 10 of the preocean zone at 90°
5	Distance between circuli 1 and 15 of the preocean zone at 90°
6	Radius of preocean zone at 90°
7	Number of circuli in preocean zone at 90°
8	Number of broken or branched circuli within precisely defined zone (see Methods).

released by hatcheries of the Oregon Department of Fish and Wildlife. Most hatchery-reared smolts currently being released by Oregon's hatcheries are larger than wild smolts (Oregon Department of Fish and Wildlife[7]). Because radii of scales and number of circuli appear to be well correlated to length of Pacific salmon smolts (Clutter and Whitesel 1956), they are logical selections for scale characters to use in separating hatchery and wild fish.

Some scales had no "plus" (Anas and Murai 1969) or estuarine growth whereas others had substantial amounts. We chose to measure total freshwater growth plus any spring and estuarine growth and to call that distance the "preocean" zone.

We chose three spacing characters, 3 through 5 (Table 3), to determine whether the plentiful food supply of hatchery coho salmon would yield different spacing of circuli than that observed for wild fish. We measured these characters at 90° to the longest axis of the scale because breaking and branching of circuli is less at that angle than at lower angles to the longest axis.

The number of broken or branched circuli (character 8, Table 3) was used to determine if circuli of hatchery fish were more or less branched than circuli of wild fish. It was postulated that regular feeding by hatchery fish would result in less breaking and branching of circuli. For this character an acetate sheet with thin parallel lines 1 cm apart and a dotted line parallel to and midway between these lines was used as a guide. A small point at the end of the dotted line was placed at the center of the focus of the scale and a dotted line extended outward at 90° ventral to the longest axis. The two solid outer lines then enclosed a rectangular area. Within this area, we counted circuli 5 through 12 inclusive in the preocean zone of the scale and recorded the number of these circuli that were broken or branched.

The eight characters in Table 3 were measured and counted from scales of known hatchery fish (Table 1) and known wild fish (Table 2). These measurements were subjected to discriminant function analysis, which reduced all characters for each scale to a single value and then, through a linear model, classified the scales as hatchery or wild (Nie et al. 1975). Assumptions in this analysis were that data were multivariate normal and had common variance-covariance matrices. Plotting the data for each of the eight characters individually showed that only character 8 deviated somewhat from normal. Although normality of individual characters does not imply joint normality, it indicates that the data conform fairly well with the assumption of multivariate normality.

From the discriminant function analyses, it was concluded that preocean radius at 20° (character 1) was the most efficient individual character for separating hatchery and wild fish. Preocean radius at 20° is generally larger in hatchery fish than in wild fish. By using the character, we reliably separated 82% of the hatchery fish and 89% of the wild fish.

While characters 1, 3, and 8 in combination would do as well, there would be no benefit to their use except that a slightly higher percentage (1.1) of hatchery fish would be correctly classified at the expense of a lower percentage (1.2) of wild fish correctly classified (Table 4).

Since preocean radius at 20° was the most useful character for discriminating between adult hatchery and wild coho salmon, this character was mea-

TABLE 4.—Combinations of scale characters to which discriminant function analysis was applied and effectiveness at classifying coho salmon as to wild or hatchery origin.

	Percentage correctly classified		
Character	Hatchery	Wild	Total
1	81.5	88.9	85.0
2	69.7	82.1	75.6
3	74.7	72.8	73.8
4	69.1	81.5	75.0
5	75.3	75.3	75.3
6	78.7	85.8	82.1
7	70.2	69.1	69.7
8	68.0	65.4	66.8
1, 8, and 3	82.6	87.7	85.0
1 and 2	79.8	88.9	84.1
1 through 8	82.6	87.0	84.7
1, 8, 3, 2, and 5	81.5	87.0	84.1

[7]Oregon Department of Fish and Wildlife. Unpubl. stat. of the Fish Culture Division. 17330 SE Evelyn Street, Clackamas, OR 97015.

sured from scales from 2,054 unmarked coho salmon (Table 1). In all scale readings only scales that had one or more ocean annuli were read. Fewer than 0.5% of the fish were age 2.1, and the scales indicated that the fish grew slowly in their first year of life.[8] These scales were assumed to be from wild fish.

Wild and hatchery fish were assumed to have similar numbers of regenerated scales, most of which were regrown because of scale loss during freshwater rearing. If wild fish tend to lose more scales because of their more rigorous rearing environment in freshwater, the numbers of wild fish are slightly underestimated, since those samples taken from unmarked salmon that were discarded for lack of useable scales would have been biased toward being wild fish.

Once we had classified scales from unmarked fish as hatchery or wild we weighted the number of unmarked fish that were landed at each port during 2-wk periods (sampling strata) for the season by our estimated percentages of hatchery and wild fish for that stratum. The estimated catch of known marked fish was then added to the unmarked hatchery fish to find the total number of hatchery fish caught in that stratum (Table 5).

[8]Most adult coho salmon caught off Oregon are age 1.1, where numbers left and right of the decimal indicate number of freshwater and marine annuli on the scales, respectively. Age 1.1 fish are in their third year of life.

Because of the small number of scales available from unmarked fish for several strata, we combined 2-wk periods for a given port where necessary to obtain a sample of at least 50 fish. Small sample sizes necessitated combining samples for Brookings and Gold Beach.

The observed percentage of hatchery coho salmon in the unmarked sample was corrected for wild fish incorrectly classified as hatchery fish, and hatchery fish incorrectly classified as wild fish. Confidence levels were also computed. Both procedures are described by Worlund and Fredin (1962).

RESULTS

The percentages of hatchery fish contributing to Oregon's sport fishery were highest near the Columbia River and decreased steadily southward (Table 6). The percentages of wild fish in the catch were highest late in the season at Garibaldi, Depoe Bay, Newport, and Winchester Bay and near midseason at Hammond. Total estimated percentages of hatchery fish landed at each port from mid-June to mid-September 1977 were 85 at Hammond, 83 at Garibaldi, 79 at Depoe Bay, 77 at Newport, 61 at Winchester Bay, 65 at Coos Bay,

TABLE 5.—Estimated number of coho salmon landed and the catch per angler day (in parentheses) by Oregon sport fishery by port in 1977. Data are for 2-wk periods from 16 June to 15 September.

Port	16-30 June	1-15 July	16-31 July	1-15 Aug.	16-31 Aug.	1-15 Sept.
Hammond	5,548	10,058	12,701	11,810	5,056	1,845
	(1.34)	(1.33)	(1.35)	(0.88)	(0.45)	(0.36)
Garibaldi	217	859	2,285	1,438	1,625	279
	(0.06)	(0.28)	(0.45)	(0.24)	(0.28)	(0.09)
Depoe Bay	1,090	2,624	7,909	2,927	5,032	616
	(0.24)	(0.32)	(0.70)	(0.28)	(0.46)	(0.13)
Newport	568	2,447	4,349	4,492	3,283	516
	(0.11)	(0.27)	(0.41)	(0.59)	(0.43)	(0.16)
Winchester Bay	2,602	5,328	10,175	9,217	1,639	1,287
	(0.65)	(0.57)	(0.99)	(0.65)	(0.24)	(0.27)
Coos Bay	641	1,923	3,522	1,553	638	244
	(0.23)	(0.33)	(0.60)	(0.35)	(0.13)	(0.14)
Gold Beach	9	2	812	337	68	17
	(0.05)	(0.00)	(0.29)	(0.08)	(0.02)	(0.01)
Brookings	33	19	8,603	2,141	96	180
	(0.01)	(0.00)	(0.49)	(0.16)	(0.03)	(0.04)

TABLE 6.—Estimated percentages and 95% confidence intervals of hatchery-reared coho salmon in the total catch landed in 1977 by the Oregon sport fishery.

<table>
<tr><th rowspan="2">Port</th><th colspan="6">Period</th></tr>
<tr><th>16-30 June</th><th>1-15 July</th><th>16-31 July</th><th>1-15 Aug.</th><th>16-31 Aug.</th><th>1-15 Sept.</th></tr>
<tr><td>Hammond</td><td colspan="2">91.8±5.6</td><td>69.2±11.7</td><td>90.9±6.2</td><td colspan="2">90.6±5.3</td></tr>
<tr><td>Garibaldi</td><td colspan="3">84.8±7.3</td><td colspan="3">80.8±8.0</td></tr>
<tr><td>Depoe Bay</td><td>79.7±6.7</td><td>95.7±4.4</td><td>88.3±6.4</td><td>68.6±12.0</td><td colspan="2">64.1±7.8</td></tr>
<tr><td>Newport</td><td>100.0±0.2</td><td>92.3±5.5</td><td colspan="2">74.1±6.1</td><td colspan="2">72.0±10.9</td></tr>
<tr><td>Winchester Bay</td><td colspan="2">64.5±11.7</td><td>70.7±7.3</td><td colspan="3">49.7±8.9</td></tr>
<tr><td>Coos Bay</td><td colspan="2">58.9±10.3</td><td colspan="4">67.3±10.3</td></tr>
<tr><td>Gold Beach/Brookings</td><td colspan="6">62.8±10.1</td></tr>
</table>

and 63 at Brookings/Gold Beach. An estimated 75% of all coho salmon landed by the entire sport fishery from mid-June to mid-September 1977 originated from hatchery releases. Percentages of hatchery coho salmon by port and period, along with confidence intervals, are shown in Table 6.

Since the sport fishery is mainly composed of private and charter boats on day-long trips, our estimated percentages of hatchery and wild fish by port probably reflect fairly well the actual percentages occurring near each port, assuming similar catchability of hatchery and wild fish.

DISCUSSION

Of the estimated 140,660 coho salmon caught in the ocean in 1977 by Oregon sport fishermen from mid-June to mid-September, 35,300 were wild fish. Although scales from fish caught by the commercial troll fishery were not analyzed in 1977, it is likely that the overall percentages of wild and hatchery fish were similar to those of sport fishery. To evaluate this likelihood, we compared observed percentage of marked fish in the monthly catch of the sport fishery for six Oregon ports with the percentage of marked fish in the corresponding commercial catch. In only 7 of the 18 comparisons for which sample sizes were adequate did percentages of marked fish caught in a given strata by the sport fishery differ from those of the commercial fishery ($P<0.05$), which indicates that overall percentages of hatchery and wild fish are similar for the two fisheries.

We can explain the north to south trend toward increasing percentage of wild fish in the catch (Table 6) by assuming a northward movement of hatchery and wild coho salmon as the season progresses, as Van Hyning (1951) concluded, with wild fish from south and north coastal streams ceasing their northward movement near their natal streams. Since over 80% of the coho salmon produced by hatcheries in California, Oregon, and Washington (excluding Puget Sound) are released in the Columbia River and its tributaries (Oregon Department of Fish and Wildlife see footnote 7), many of the hatchery fish off the Oregon coast are probably headed for the Columbia River. These hatchery fish continue northward and concentrate near the mouth of the Columbia River. The argument for south to north movement of coho salmon is supported by the occurrence of lower percentages of hatchery fish late in the fishing season in catches off of Garibaldi, Depoe Bay, Newport, and Winchester Bay (Table 6). Late in the season, hatchery fish may be proportionately less abundant along the south and central coast, since most Columbia River fish would have moved northward by this time, leaving mostly coastal hatchery and wild fish contributing to the south and central coast fisheries. The lowest percentage of hatchery fish noted was 49.7 at Winchester Bay, from 1 August to 15 September.

Another possible factor contributing to lower percentage of hatchery coho salmon in the fishery to the south is that a substantial portion of adult hatchery fish released as smolts from Columbia River hatcheries do not migrate far southward along the Oregon coast. The argument is supported by the large number of coho salmon caught per angler day at Hammond early in the fishing season (Table 5), perhaps indicating that coho salmon returning to the Columbia River are concentrated near the river in early summer. The high percentage of hatchery fish caught at Hammond from 16 June to 15 July further supports this hypothesis (Table 6).

The total catch of coho salmon and catch per angler day were low after mid-August 1977 from Winchester Bay southward, and were low for all ports after August (Table 5), so that while the percentage of wild coho salmon caught rose late in the season, the numbers caught were low, especially along the southern coast. Closing the season for salmon fishing after mid-August would not have protected many wild coho salmon, and would have made only a small sacrifice in catch of hatchery fish. Almost twice as many chinook salmon, *O. tshawytscha*, would have been lost to the sport fishery.

Combined data obtained from the Oregon Department of Fish and Wildlife from Winchester Bay to Brookings from mid-August to mid-September showed that an estimated 1.8 chinook salmon were caught for every coho salmon landed by sport fishermen. During years of higher abundance of coho salmon, fishermen may tend to fish more for coho and less for chinook salmon than they did in 1977, which would increase fishing pressure on wild stocks of coho salmon late in the season.

If wild and hatchery fish are distributed differently in oceanic areas, fishing pressure could be adjusted to meet management goals. If, however, there is substantial variability in the localities of capture of wild fish, either because of the fishery or because of environmental factors, and if hatchery fish intermingle extensively with wild fish, it will be difficult to protect wild stocks while maintaining high rates of harvest of hatchery fish in the ocean.

Total Oregon troll and sport catch of coho salmon in the ocean plus the Columbia River commercial catch was only 645,000 fish in 1977. Assuming that 75% are hatchery fish, only 162,000 of the fish originated from natural production. Average annual catch of coho salmon by the Oregon troll fishery alone from 1952 to 1956 was 312,000 fish, probably almost all wild fish. The lowest catch over the 5-yr period was 227,000 fish in 1954. This figure excludes fish caught in the ocean by sportsmen and also excludes the Columbia River catch. The average catch from 1952 to 1956 was 1.9 times higher than the catch of wild coho salmon from the combined ocean troll and Columbia River net fisheries in 1977. Yet, the catch of wild fish in the 1950's was considered low enough to warrant closure of commercial gill net fisheries in all Oregon coastal streams to increase the escapement of wild stocks. The efficient net fisheries of the 1950's were considered a primary threat to the production of wild salmon by some biologists. Recent analyses of marking experiments with coho salmon show some Oregon coastal stocks of hatchery fish with a catch to escapement ratio of 6 (Pacific Fishery Management Council 1978). Assuming wild fish are as readily catchable as hatchery fish, the effectiveness of the troll and offshore sport fisheries in harvesting coho salmon now rivals that of many terminal fisheries. Despite elimination of coastal Oregon net fisheries, abundance of wild coho salmon, from all indications of catch and escapement, is at an alltime low.

The catch of wild fish might be considerably less if it were not for the natural spawning of some hatchery fish and later rearing of their progeny in streams. The number of wild coho salmon that results from natural spawning of hatchery fish that fail to return to hatcheries is unknown. Considering the large numbers of smolts being released, even a small percentage of straying by returning adults could lead to significant production in the wild, assuming that the progeny do not differ significantly in fitness from the progeny of wild parents.

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