RECOMMENDED TIME, SIZE, AND AGE FOR RELEASE OF HATCHERY REARED SALMON AND STEELHEAD TROUT

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TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

LIST OF FIGURES

LIST OF TABLES

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INTRODUCTION

A requisite for maximum production of adult salmonids from hatchery reared fingerlings is that they must be released at an optimum time and size for survival in the natural environment. Past procedures have not necessarily been sound; in some instances they were founded on false assumptions and in others for convenience. Because of the importance of this phase of hatchery operations, the present study was initiated.

I surveyed the available literature and consulted with personnel in other fisheries agencies to determine procedures currently in use throughout the Pacific Northwest. Unpublished data from various Fish Commission of Oregon (FCO) sources were also reviewed. The references cited are not complete, but contain the most important and pertinent information available at the time of writing (1963).

This report is specifically concerned with determining the optimum time and size for release of fingerlings where essentially the entire fresh-water life of the juveniles is spent in the hatchery. Juveniles planted in natural rearing areas for a portion of their fresh-water residence are not considered, nor are liberation methods and the feasibility of transplanting stocks.

Information is presented on chinook (Oncorhynchus tshawytscha), coho (O. kisutch) and chum (O. keta) salmon, and steelhead trout (Salmo gairdneri). No data are given for sockeye (O. nerka) or pink salmon (O. gorbuscha) because these species are presently not propagated by FCO.

Although this report was first written in 1963, and much information developed since then is not included, it seemed desirable to document the work that had been done up to that date. Recommendations are tentative pending further analysis of hatchery return data and results of current investigations by various agencies of salinity adaptation, downstream migration, estuarine ecology, and maturity.

For clarity, the specific meaning of some terms used in this report are as follows:

In recording age categories, the two-number symbol system developed by Gilbert and Rich (1927) is used. The first numeral designates the year of life in which the fish was captured or age at maturity and the second number, a subscript, designates the year of life in which the fish entered the sea. Examples of symbols used for adult age categories are:

2_2 = a fish which migrated to sea in its second year and returned later the same year;

3_2 = a fish which entered the sea during its second year and matured in its third year;

4_1 = a fish which migrated to sea in its first year and matured in its fourth year of life.

In referring to juveniles, only the subscript is used, since there is no reference to age at maturity or capture:

sub-1 = a fish which migrated to sea in its first year;

sub-2 = one which migrated to sea in its second year;

sub-3 = one which went to sea in its third year of life.

Fry refers to juveniles which are in or have just emerged from the gravel, or in the case of artificially hatched young, have not commenced to feed. Fingerling refers to juveniles which have taken up stream residence, or have commenced to feed; the term is synonomous with parr. The term fingerling is used in its literal definition, and does not imply age. If a reference to age is intended, the age will be combined such as: 1-month fingerling, 90-day fingerling, 1-year fingerling, etc. The term yearling will be synonomous with 1-year fingerling. Smolt refers to juveniles which have commenced a true seaward migration.

WILD FINGERLINGS--TIME, SIZE, AND AGE AT MIGRATION

Published and unpublished reports concerning trapping and seining operations were reviewed to determine the time, size, and age at which wild salmonid fingerlings migrate to sea.

Chinook salmon

General

There are different runs of chinook salmon designated as spring, summer, fall, and winter according to the time they enter fresh water following ocean residence. In those streams where different runs of adults occur, it is not yet possible to identify juveniles according to their parent run. Typically, there is a large downstream movement of fry and small fingerlings soon after emergence, generally limited movement during the summer, and a substantial migration of yearlings during the fall, winter, or spring.

Rutter (1904) reported that the bulk of the chinook fry in the Sacramento River started downstream migration immediately upon

emergence from the gravel. He calculated the rate of migration by comparing the time of peak movement at Balls Ferry (upper river) with that at Walnut Grove (lower river). From this he concluded that fingerlings were about 3 months old when they reached brackish water and were probably 4 to 5 months old when they reached the ocean. He also found that: some fish remained in the river to yearling age; both spring- and fall-run chinook were present in the Sacramento River concurrently; and there was no method of differentiating fingerlings of either run. Other investigators have reported similar times of migration in the Sacramento River and tributaries (Hatton and Clark, 1942; and Moffett, 1949). In addition, Hanson, Smith, and Needham (1940) reported a downstream movement during the fall, where 3- to 4-inch fingerlings were observed descending a dam at Redding. All these investigators found that the peak movement occurred during February and March, shortly after the fry emerged from the gravel, although some fish remained to yearling age.

In other California streams a similar pattern has been observed wherein the majority of the fry migrate downstream soon after emergence, with relatively small numbers remaining in the stream throughout the summer. This was reported in the San Joaquin River (Hatton and Clark, 1942), the Trinity River (Moffett and Smith, 1950), and in Fall Creek, tributary of the Klamath River (Wales and Coots, 1955).

Rivers and Mastin (1961) found that the peak migration of chinook fingerling smolts in the Rogue River occurred in July, but that some fingerlings migrated from March to December. They found

that the peak migration of yearling chinook occurred from mid-May to mid-June. Both spring and fall chinook are present in the Rogue River.

Meehan and Siniff (1962) reported that chinook in the Taku River, Alaska, migrated largely from mid-April to mid-June with the peak occurring in early May. Most of the fish trapped were sub-2's although there were some sub-3's.

Most investigators have measured chinook fry and small fingerlings at time of capture. These observations show that during the first part of the migration most of the fish are newly emerged fry. During later stages of movement there are fewer numbers of fish, but they have resided in the stream for some time and are larger. Most of these studies were conducted near the spawning areas and the fact that the fish moved downstream does not necessarily mean that they went immediately into salt water.

Rich (1920 and 1925) conducted scale studies on chinook in the Columbia River involving scales from juveniles in fresh water and the estuary, and from adults in the fishery. Chinook fry are approximately 40 mm in length at time of emergence and he showed that specimens taken in brackish water during June, July, and August had begun "intermediate growth," which he interpreted as estuarine growth at about 53 to 55 mm in length. Fish captured during September and October had commenced intermediate growth at about 95 to 105 mm. He also reported that some fingerlings captured during the period December to May above brackish water had started intermediate growth at 73 to 87 mm.

Mains and Smith (1964), Bell (1959a, 1961), and French and Wahle (1959) reported that chinook fry and fingerlings range from about 35 to 50 mm in length during the initial movement from January to March, then there is a rapid increase in size up to about 55 to 85 mm for the migrants during April, May, and June. Fish migrating during their second or third spring, have ranged from about 60 to 180 mm fork length with the bulk of them about 90 to 110 mm. There are considerable size differences between stream systems, however.

Fall Chinook

FCO biologists have examined scales from fall chinook taken in the Columbia River gill-net fishery for several years. These unpublished data show that 92-95% of the fish caught during the late July-August season had migrated to sea during their first year; the remainder had spent a full year in fresh water. In September the percentage of sub-2 scales increased, suggesting that certain races of fall chinook may spend a full year in fresh water.

At Gnat Creek, a lower Columbia River tributary, the bulk of the fall chinook migrated as newly emerged fry or very small fingerlings during January to March, with peaks occurring from mid-February to mid-March (Willis, 1963).

Mains and Smith (1964) found that chinook fry in the Snake River at Central Ferry migrated during March and April with peak movements from mid- to late April. In the Columbia River at Byer's landing chinook fry migrated from March through June, with a peak in April. These fish were probably fall chinook because of a distinct size and time difference between fry and yearlings.

Bell (1959a and 1961) found that chinook fry and fingerlings in the Brownlee-Oxbow Dam area of the Snake River migrated during April, May, and June with peaks in April and early to mid-May. These fish can safely be assumed to be entirely or largely fall chinook.

Spring Chinook

Rich and Holmes (1929) studied scales from adult spring chinook in the Columbia River and found that they all had migrated to sea as 1-year-old (sub-2) fish. This did not rule out the existence of a seaward migration in the first year, but such fish did not appear in adult samples.

FCO biologists have found, unpublished data, that 95-97% of the adult spring chinook taken during the April-May Columbia River gill-net season migrated to sea as yearlings. Most of the remaining fish migrated during their first year (sub-1), but there were a few 2-year-old (sub-3) migrants.

Craig and Townsend (1946) studied spring chinook in the Willamette River, but their data were not adequate to determine the time of migration. They did show that some fish remained in upstream areas until September or October, and had left these areas by March of their second year.

Mattson (1962) reported three "migration" periods for spring chinook in the Willamette River, based on the capture of fingerlings by seining at different locations. The first and largest peak occurred during the first spring and early summer (April to July). A second peak, usually minor, occurred during the fall (October) and was

associated with increased flows following the first heavy fall rains, and an accompanying decrease in water temperatures. The third migratory period was recorded in winter and spring when the fingerlings were 1 year old. The peaks during this latter period occurred from late March to early May, and accounted for one-third or less of the entire number caught of a given brood. Mattson (1963) reported, on the basis of scale analysis, that about 15% of a sample of adult spring chinook taken in the 1946-48 and 1951 Willamette River sport fishery had migrated to sea as sub-1's; the remainder were sub-2's.

Bell (1959b, 1961) reported the major period of migration of yearling chinook in the Wildhorse River, tributary to the Snake, occurred from November to April, with the peak in March in 2 years and in November 1 year.

Some of the most complete records of spring chinook smolt migration have been obtained at the trapping facilities at Pelton and North Fork dams on the Deschutes and Clackamas rivers, respectively. At both dams, fish must pass through reservoirs before being trapped. At Pelton, where virtually all the migrants are trapped, the major migration occurred during April and May with the peak in April (FCO, unpublished data). The migration at North Fork is somewhat later with the major movement occurring during May and June and the peak from middle to late May. In both rivers the migration begins in late fall, with substantial numbers moving in November in some years.

Coho salmon

Coho salmon fingerlings exhibit three principal periods of movement. The first occurs shortly after they emerge and is

directly related to time of emergence. The second principal movement occurs during October to December. The final movement, generally considered to be the true seaward migration, occurs in their second spring from March through May.

Some investigators do not consider the initial movement a true migration, but a search for suitable rearing area. Usually the magnitude of this movement is related to the numbers of eggs deposited, hence to density of fry. Neave (1949) reported, based on observations of marked fish, that fry spread rapidly throughout the river systems, both upstream and downstream, following emergence. Chapman (1961) called the fry in this initial movement "nomads," which appears to be an apt description. He showed that the nomads were smaller than those remaining in the stream and suggested that their movement downstream resulted from aggressive behavior of the larger fry in selecting and defending certain living areas. He also demonstrated that nomads took up stream residence when placed in an area not containing competing fish.

Even though the initial movement may not be a true seaward migration, fry have been reported in salt water on numerous occasions. Gilbert (1913) observed that coho fry entered salt water, but did not contribute to returning adult runs. Fraser (1917b) reported finding a few coho in the Georgia Straits which had migrated to sea as fry, but the bulk had been yearlings. Pritchard (1940) also reported that a small percentage of troll-caught coho off the coast of British Columbia had scale patterns indicating they had migrated to sea as fry, although the bulk had migrated as sub-2 fish. Marr (1944) found no coho which had migrated to sea as fry among a sample of

adults from the Columbia River. Shapovalov and Taft (1954) observed that fish of the year did migrate downstream in Waddell Creek, but stated that all adult scales examined showed that as juveniles they had remained in fresh water in a full year.

The second principal movement of coho fingerlings occurs during the late fall months and appears to be associated with fall rains, increased flows, and a decrease in water temperatures. Both upstream and downstream movements have been observed during this period, and this is probably not a true seaward migration but a local movement within the stream. While usually of minor magnitude in comparison to numbers migrating during the first or second spring, this movement has been observed in most studies where fish were trapped throughout the year, and in some instances may be of major importance.

Noble (1959) reported that a group of hatchery reared coho fingerlings which exhibited typical smolt characters in November were converted to salt water at a Washington Department of Fisheries (WDF) hatchery and planted into Hoods Canal. Some of these were subsequently observed re-entering nearby streams. Noble also reported that coho which exhibited smolt characters were marked and released upstream from the weir on Minter Creek during November but none migrated until the following spring.

The true smolt migration occurs during the spring months when the juveniles are 1 year old. The major migration extends from March to June with the peak usually during April or May. A brief summary of pertinent data on the time of peak migration periods found in various streams is presented in Table 1. In a few tributaries, especially those in the upper areas of a watershed, peak migrations

Table 1. Summary of time of peak migration of coho smolts in selected streams

Stream	Years	Period(s) of major migration	Peak period(s)	Source
Waddell Creek, Calif.	1933-42	Mid-March to late June	April 15 to May 12	Shapovalov and Taft (1954)
Alsea River, Oregon	1957	Late April to mid-May	April 27 to May 10	Andrews (1959)
Drift Creek	1958-61	Late Feb. to mid-May	March to early April	Chapman (1962)
Wilson River, Oregon				
Spring Creek	1947-56	Late Feb. to early June	March 18 to May 6	FCO (unpublished data)
Columbia River, Ore.-Wn.				
N. F. Clackamas R.	1959-62	Nov. to Dec. April to mid-June	Mid-May to early June	FCO (unpublished data)
Gnat Creek	1956-62	Early April to early June	May 5-25	Willis (1963)
Minter Creek, Wn.	1937-62	Mid-April to late May	May 1-20	Salo and Bayliff (1958) and WDF
Cultus Lake, B.C.	Intermitt. 1925-41	Late April to mid-June	Late May to early June	Foerster and Ricker (1953)
Lakelse Lake, B.C.	1952	May 13 to June 14	May 28	Foerster (1952)
Taku R., Alaska	1961	Mid-April to mid-June	May 14-27	Meehan and Siniff (1962)

have been recorded as early as March. At Spring Creek, a small tributary of the Wilson River, the peak migration occurred 1 year in mid-March, but in 9 other years it came from early April to early May (FCO, unpublished data). Chapman (1962) showed that the peak migration in Deer Creek, Flynn Creek, and Needle Branch in the Alsea River watershed occurred in March and early April during 2 years. Andrews (1959) reported that in the main Alsea River in 1957 the peak smolt movement was from late April to early May.

Coho smolts in various studies have ranged from 60 to 165 mm fork length. The bulk of these have been from 80 to 120 mm with mean lengths ranging from about 90 to 115 mm. As with spring chinook, there is a substantial size variation from stream to stream.

While most smolts are sub-2's at migration in the southern latitudes, it is not uncommon for them to move to sea as sub-3's. Gilbert (1922) found that most of the Yukon River coho spent 2 years in fresh water. Meehan and Siniff (1962) reported that 46% of the coho migrating from the Taku River, Alaska, were sub-2 fish and the remainder were sub-3's. FCO biologists have noted the occurrence of a few sub-3 migrants in scales of adults taken in the Columbia River gill-net fishery. Salo and Bayliff (1958) reported sub-3 migrants from Minter Creek. Noble (1959) observed that if fingerlings did not attain a size of about 60 mm in their first year they did not migrate from Minter Creek until the following spring as 2-year smolts. Chapman (1961) noted a similar tendency in coho in tributaries of the Alsea River.

Noble (1959) reported on three groups of hatchery reared fingerlings which developed the typical smolt appearance during their first

spring and summer. One group attained a size of about 96 mm (50 per pound) during May; they were released upstream from the weir in Minter Creek, and 81% of the fish migrated out at the same time as the normal 1-year stream fish. Two other groups which developed smolt appearance during July were also released into Minter Creek; one group averaged 50 per pound and the other averaged 30 per pound (104 mm). From July 21, when they were planted, until August 10, only 20% and 8%, respectively, of these groups migrated past the weir. Noble felt the reason such a small percentage of the latter two groups migrated was because they had been released too late for the "normal" spring migration.

Chum salmon

Few chum salmon are propagated in Oregon. Chums migrate to sea almost immediately upon emergence from the gravel. The time of migration is dependent upon the time of spawning and stream temperatures during the incubation period.

Steelhead trout

More data are available from life-history studies of steelhead trout than for most of the Pacific salmon, and in general there is a better understanding of their fresh-water life history. No attempt has been made here to tabulate the data pertaining to timing of migrations or size of smolts, rather, the important points are summarized. For specific details, the reader is referred to the following reports: Shapovalov and Taft (1954), Chapman (1958), Pautzke and Meigs (1940), Whitt and Pratt (1955), Maher and Larkin (1954), and Bali (1959).

Steelhead smolts migrate largely during the spring from March to June with the peak movements occurring in April or May. The time of the migration may vary slightly from one stream to another and from year to year, but it is markedly similar over the entire range of the species.

The size of steelhead smolts has been found to be relatively consistent from area to area. Most of the smolts range from 120 to 200 mm (4.7-7.9 inches) in length with the mode at about 150-165 mm (5.9-6.5 inches) regardless of the age of the fish. If fingerlings do not reach a certain size by the migration season, they remain in fresh water until they do and migrate during the following spring. In most streams the majority of smolts are 2-year fish, but substantial numbers of either or both 1- and 3-year fish may be present.

HATCHERY FINGERLINGS--RELATIONSHIP OF TIME, SIZE, AND AGE AT LIBERATION TO SURVIVAL

Many experiments have been conducted to determine the optimum time, size, and age to release fingerlings from hatcheries. I have summarized data from studies where adequate data were available and where adult returns provided valid results.

The comparisons made herein are largely between groups where there are as few variables as possible. No attempt has been made to compare marked fish returns from different broods or from different hatcheries. In some cases differential survival of experimental fish may have been affected by removal of different fins. In most of the experiments it is difficult to isolate the effect of time, size, and age upon survival, because one is often dependent upon another. In some tests pertaining to the effect of size at

release, different sizes were obtained by artificial means, i.e., grading or manipulation of feeding techniques. The results may not be comparable to situations where other methods were used to obtain groups of fish of desired sizes.

Spring chinook

Fish Commission of Oregon

Several marking experiments were conducted at FCO hatcheries during the period 1916 to 1927 (Rich and Holmes, 1929). The results reported did not answer the question of the optimal time for release because of inadequate recoveries. However, their conclusions were that longer periods of rearing (minimally from emergence until September) provided the best returns, with few recoveries from fish released during their first summer.

Experiments from the mid-1950's on provided some evidence as to the proper time, size, and age to liberate spring chinook. Five groups of 1955-brood spring chinook of Middle Willamette River origin were marked and released at intervals from June 1956 to February 1957 in an attempt to determine the best time for release. The available liberation and return data are presented in Table 2. Only one fish was recovered from the groups released during June and July, but the particular fins removed from the fish released then may have had an adverse influence on survival. The groups released during September-October and December had comparable returns (0.07%). Each of these groups had a significantly higher return than the group released during February (0.05%). Disease (tuberculosis) was detected in returning adults and may have been a factor in survivability.

Table 2. Summary of liberation and return data for marked 1955-brood Willamette Hatchery spring chinook

Mark	Liberation data			Return to Dexter ponds (age in years)			
	Date	Number	Ave. size (fish/lb)	3	4	5	Total
D-LP	6/1/56	117,314	396	0	0	1	1
D-RP	7/31/56	118,457	91	0	0	0	0
LV-LM	9/27-10/4/56	121,069	39	5	42	33	80 (0.07%)
RV-RM	12/15/56	121,526	30	4	55	25	84 (0.07%)
LV-RM	2/13/57	110,709	29	0	41	11	52 (0.05%)

Two groups of 1958-brood spring chinook of Willamette River origin were marked before release to compare the survival of fish fed Oregon Pellets with that of fish fed the usual fish-meat diet which contained pasteurized salmon viscera. In addition to different diets, there was a marked size difference between the two groups. Pertinent liberation and return data are presented in Table 3. The group marked Ad-RV (pellet diet) produced more than twice as many adults as the Ad-LV group, but it is not possible to separate the effect of diet and size on increased survival.

Oregon Game Commission

Rivers and Mastin (1960) summarized the results for several Rogue River spring chinook marking experiments. They concluded that there was little difference in returns of yearlings attributable to the month of release (October to March). They further concluded that the proper size for maximum returns was about 8 to 9 fish per pound. Other factors which appeared related to good survival were: relatively small rearing losses in the hatchery, possibly indicating a low level of disease; and the absence of extremely high flows following liberation.

The Oregon Game Commission (OGC), unpublished data, has reported very good survivals of spring chinook released into the Umpqua River. Most of the yearlings involved in these plants have been from about 5 to 10 fish per pound.

Fall chinook

Fish Commission of Oregon

The FCO has conducted several experiments designed to compare survivals of fall chinook fingerlings reared for different periods.

Table 3. Summary of liberation and return data for marked 1958-brood Willamette Hatchery spring chinook

Mark	Liberation data			Return to Dexter ponds (age in years)		
	Date	Number	Ave. size (fish/lb)	4	5	Total
Ad-RV (pellet diet)	Jan. 1960	110,252	18	135	254	389 (0.35%)
Ad-LV (meat-fish diet)	Jan. 1960	111,734	28	69	111	180 (0.16%)