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

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Clackamas, Oregon

January 1968

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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 Unpublished data from various Fish Commission of Oregon (FCO) sources were also reviewed.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%)

In general, returns to the hatcheries of marked fish used in these experiments have been extremely poor.

Two experiments were conducted with fish reared at Bonneville Hatchery to test the survival of fish released during their first summer with that of fish reared to yearlings. A summary of the pertinent liberation data and returns to the stream are presented in Table 4. In both instances the yearlings produced many more adults than the younger fingerlings. Adults returning from yearling liberations in both tests were smaller at a given age than adults from subyearling releases and unmarked adults in the Columbia River. Fall chinook juveniles normally migrate to sea during their first year, but the yearlings were retained at the hatchery until their second year and were deprived of 1 year of ocean growth. Since they matured as 2-, 3-, and 4-year olds (the expected ages for Columbia River fall chinook), they were approximately the same size as adults 1 year class younger.

Two experiments were conducted at Oxbow Hatchery to compare survivals of fingerlings released at different intervals from April to July of their first year. Each experiment involved four groups, one of each brood released during April, May, June, and July (Table 5). Survival of all groups was extremely poor, ranging from 0 to 0.03%, but in each experiment the group released during April provided the best return. This is in marked contrast to several other experiments discussed later. The returning adults from the Oxbow Hatchery tests were infected with tuberculosis. Wood and Ordal (1959) showed that the effect of tuberculosis was more severe with longer rearing periods; this may have introduced an unknown variable affecting survival of the groups.

Table 4. Summary of liberation and return data for two experiments which compared the effect of length of rearing on survival of fall chinook fingerlings at Bonneville Hatchery

Brood	Mark	Liberation data				Returns 1/ (age in years)			
		Stream	Date	Number	Ave. size (fish/lb)	2	3	4	Total
1954	Ad-LP	Tanner Cr.	Aug. 1955	100,070	60	1	0	0	1
	Ad-RP	Tanner Cr.	Mar. 1956	104,593	35	0	75	49	124 (0.12%)
1955	D-RM	Gnat Cr.	June 1956	26,221	262	0	0	3	3 (0.01%)
	D-LM	Gnat Cr.	Apr. 1957	24,600	29	32	36	24	92 (0.37%)

1/ 1954-brood fish returned to Tanner Creek; 1955-brood fish returned to Gnat Creek Weir.

Table 5. Summary of liberation and hatchery return data for two experiments which compared the effect of time of release on survival of fall chinook fingerlings reared at Oxbow Hatchery and released into Herman Creek

Brood	Mark	Liberation data			Returns 1/ (age in years)				
		Date	Number	Ave. size (fish/lb)	2	3	4	5	Total
1952	Ad	Apr. 1953	105,281	-	0	19	12	0	31 (0.03%)
	RV	May 1953	105,937	181	0	10	11	1	22 (0.02%)
	LV	June 1953	103,147	125	0	8	4	0	12 (0.01%)
	D	July 1953	53,090	67	0	7	4	0	11 (0.02%)
1956	D-Ad-RV	Apr. 1957	99,835	394	3	17	3	0	23 (0.02%)
	D-Ad-LV	May 1957	99,976	181	0	7	1	0	8 (0.01%)
	D-Ad-LM	June 1957	100,041	101	0	0	0	0	0
	D-Ad-RM	June-July 1957	101,615	95	0	0	0	0	0

1/ Includes recoveries from Oxbow, Bonneville, Spring Creek, Little White Salmon, and Big White Salmon hatcheries.

Wallis (1962) showed that there was a significant positive correlation between the pounds of fingerlings released from Bonneville Hatchery and the subsequent return of adults. Increased poundage of fish released was due, in part, to rearing fish to larger sizes.

Washington Department of Fisheries

A summary of returns of marked fall chinook to the Deschutes River, Washington was presented in the 1960 annual report of the WDF. Included in this summary were several groups released at different times and sizes. According to R. E. Noble (personal communication) the results are representative of their findings in other unpublished experiments pertaining to time and size at release.

One experiment (1957 brood) was to determine survival of fingerlings reared for different periods. This involved three groups of fish reared for 17, 45, and 91 days which averaged 800, 382, and 130 per pound, respectively, when released. The combined returns to the hatchery as 2-, 3-, and 4-year-old fish of the different groups were as follows: 17-day rearing period--0.01%; 45-day rearing period--0.09%; and 91-day rearing--0.70% (Figure 1).

Another group (1955 brood) included in the 1960 WDF annual report summary enables a comparison of returns from fish of different sizes at release even though this experiment was intended for a genetics and transplantation study. The relationship of size to per cent return for this group is also indicated in Figure 1. The larger fingerlings at time of release provided more returns than the small fish.

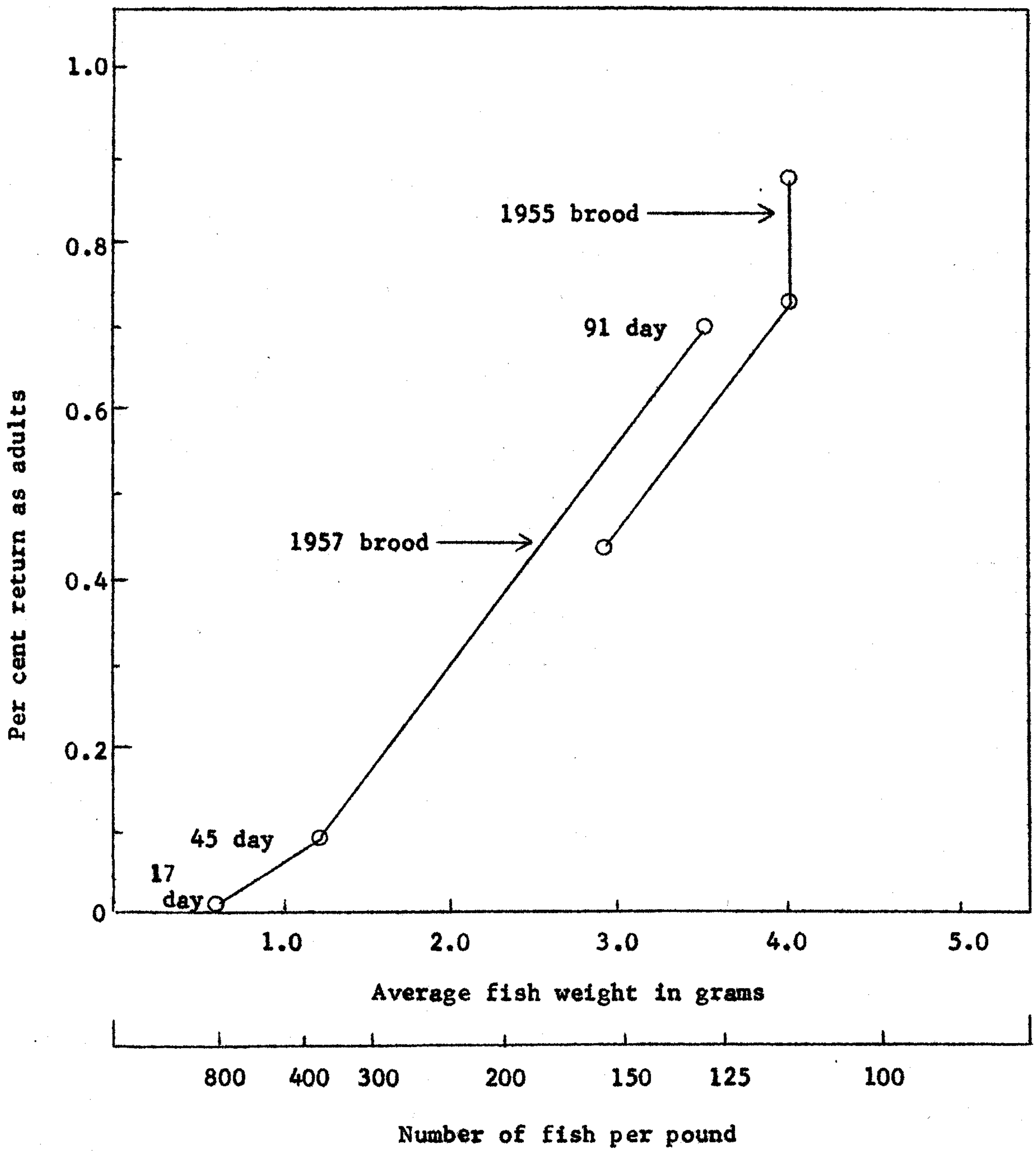

Figure 1. Relation of size of fall chinook fingerlings at time of release to per cent return as adults, Deschutes River, Washington (WDF, 1961, p. 73)

Ellis (1958) reported results of an experiment which compared survivals of fish released directly into the Samish River estuary with groups tempered into different salinities and reared for short periods in salt water. The best return was from a group tempered for 5 days to a salinity comparable to that found in the Samish estuary and released there. The second best return was from a group released directly into the estuary with no tempering. Both of these groups provided better returns than those reared from 25 to 60 days in 100% sea water before release.

U. S. Bureau of Sport Fisheries and Wildlife

Johnson (1962) reported returns of fall chinook to Spring Creek Hatchery in an experiment which compared survival of fish released as unfed fry with that of fingerlings reared for about 90 days. There were three broods of fish involved. Data and returns are incomplete, but returns over a 4 year period have shown that 90-day fingerlings produced adults back to the hatchery at about 20 times the rate for unfed fry.

Junge and Phinney (1963) showed that at Spring Creek Hatchery there was a positive correlation between the pounds of fingerlings released and returns to the hatchery. Increased poundage was generally associated with rearing to larger sizes.

Cope and Slater (1957) summarized the results from several marking experiments conducted at Coleman Hatchery on the Sacramento River. Fall-run chinook fingerlings of four broods were marked and released during April as 3-month fingerlings and during October as 9-month fingerlings. Fingerlings released during April ranged from 625 to 188 per pound, and those released during October ranged from 19.1 to

16.0 per pound. In each instance fingerlings released during October provided slightly greater returns to the hatchery than those released during April.

California Department of Fish and Game

Snyder (1931) reported returns from eight groups of marked fall chinook fingerlings released into the Sacramento and Klamath river systems. Three groups--one of fry, one of fingerlings released during October, and one of yearlings released during February--provided no returns. Five other groups released during October and November provided returns to the hatchery of 0.14 to 0.43%.

Warner, Fry, and Culver (1961) reported a 3.56% return to Nimbus Hatchery on the American River from a group of fall chinook yearlings. The fish ranged from 6.8 to 10.6 per pound (average 8.1) when released during March and April. They returned as 2-, 3-, and 4-year olds. The returning adults were smaller than the usual fish of the same age since they were retained in fresh water for a full year and thus missed 1 year of ocean growth.

Coho

Fish Commission of Oregon

Experiments were conducted at Big Creek (1957 brood) and Klaskanine (1956 brood) hatcheries to provide a comparison of returns of fingerlings reared 5 to 6 months with that of yearlings. In each test there was a 20- to 30-fold increase in return of yearlings over that of fingerlings released during the summer (Table 6).

Data from five FCO experiments which show the effect of size at release on survival are presented in Table 6. In four of the experiments comparable fins were removed, while in the 1948-brood

Table 6. Liberation and return data for several experiments conducted at FCO hatcheries to determine the effect of time or size at release on survival of coho

Hatchery	Liberation data					Returns to hatchery			
	Brood	Mark	Date	Number	Ave. size (fish/lb)	2-year fish No.	2-year fish %	3-year fish No.	3-year fish %
Big Creek	1953 1/	An-LV	Nov. 1954	63,746	15	503	0.79	147	0.23
		An-RV	Nov. 1954	18,262	7	363	2.00	23	0.13
	1955	Ad-RV	Dec. 1956	38,790	18	21	0.05	34	0.09
		Ad-LV	Dec. 1956	37,375	15	72	0.19	56	0.15
	1957	LV-RM	June 1958	93,340	75	14	0.01	11	0.01
		RV-LM	Jan. 1959	52,423	17	201	0.38	92	0.18
		LV-LM	Jan. 1959	51,030	15	328	0.64	107	0.21
Bonneville	1948	D-Ad	May 1950	13,075	22	3 2/	--	225	1.72
		Ad-An	May 1950	9,789	15	4 2/	--	330	3.37
Klaskanine	1956	D-LV	July 1957	70,764	33	41	0.06	7	0.01
		D-RV	Mar. 1958	65,653	18	365	0.56	189	0.29
	1957	D-LM	Feb. 1959	80,227	35	15	0.02	11	0.01
		D-Ad	Feb. 1959	87,147	20	188	0.22	82	0.09

1/ Fingerlings graded to obtain size difference.

2/ Trapping facilities were ineffective in capturing fish of this age class.

Bonneville Hatchery experiment the difference in fins removed may have influenced results. The difference in size in the 1957-brood Klaskanine Hatchery experiment was obtained by manipulating the feeding rate (the smaller-sized fish were fed 1/2 the amount of the larger). The difference in the 1955-brood Big Creek Hatchery experiment was only a normal variation between ponds; the 1953-brood size differences were attained by grading. The relationship between average size and per cent return to the hatchery for these groups is shown in Figure 2 for 2- and 3-year fish. The facilities for capturing adults at Bonneville was not effective in capturing 2_2 fish, hence this relationship cannot be shown. In all of the other experiments, the larger-sized fish produced greater returns of 2_2's than the comparable smaller-size group. In four of five instances the larger-sized fingerlings also produced more 3_2 fish; the one exception, 1953-brood Big Creek, involved graded fish with a much greater size differential than the other experiments.

In 1957 FCO biologists showed that in a given group of coho fingerlings the larger individuals were predominately males, and in grading for larger-sized fish (i.e., 1953-brood Big Creek experiment cited above) it is likely that more males were selected (Oregon Fish Commission, 1957). Since males (especially large-sized fish) tend to mature earlier than females, a greater proportion of this group returned as 2_2 fish and fewer as 3_2's.

Survival of the 1948-brood marked fish from Bonneville Hatchery was much greater than for the other groups. The reason(s) for this is not known, but the marked fish represented the survivors of a group subjected to a water shut-off during the winter which conceivably could have resulted in a select group.

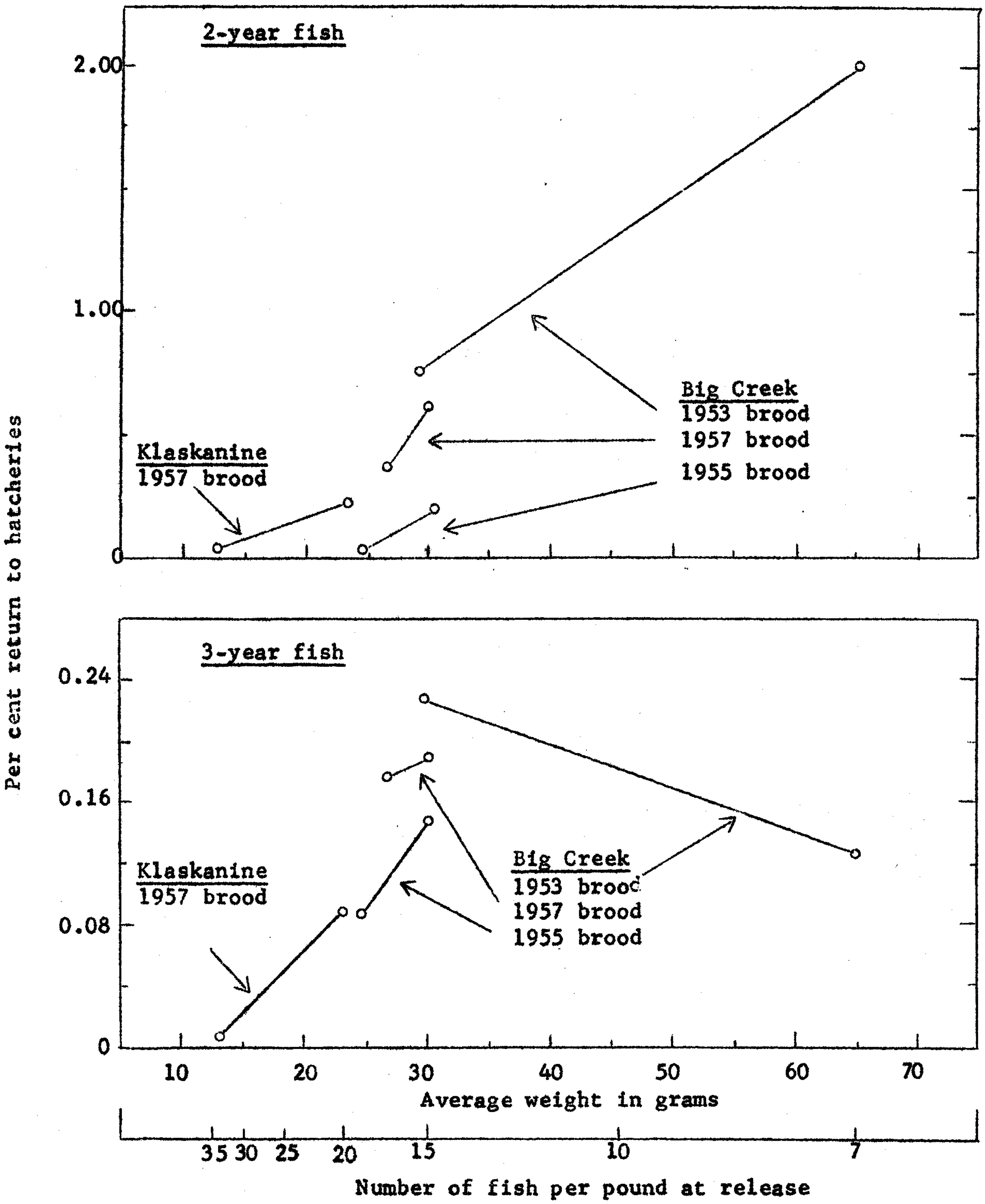

Figure 2. Per cent return of four groups of marked coho to FCO hatcheries by average size at release

The numbers of adult coho of the 1958-60 broods returning to FCO hatcheries were much greater than for previous years. In an attempt to determine some of the factors involved in the high survival of the 1958-60 broods, hatchery production records were evaluated. At certain hatcheries it is not possible to capture all the fish which return due to inadequate trapping facilities. As a result, fish escape above trapping facilities or spawn downstream from the hatcheries in varying degrees. In some cases the facilities may have different efficiencies in capturing 2_2 and 3_2 fish. In spite of this, it is felt that the numbers of fish handled at FCO hatcheries are adequate for the purpose used here.

The number of yearlings released from all hatcheries was compared with the recorded return to hatchery traps. Figure 3 shows a great variability between numbers of fish released and subsequent return of 2_2 fish even though the correlation is significant. There is also a significant correlation between releases and returns of 3_2 fish, with less, but still a great deal, of variation. For example, releases of about 400,000 to 450,000 yearlings produced from about 3,000 to 6,000 returning adults; about 6,000 adults were produced from about 400,000 to 1,300,000 yearlings.

In an attempt to explain the noted variation in both 2- and 3-year returns, the rate of return was compared to the average sizes at release (Figure 4). The close correlation for 2_2 fish explains much of the variation in this age group. There is still a great deal of variation in the return of 3_2 fish, although the correlation is significant at the 1% level.

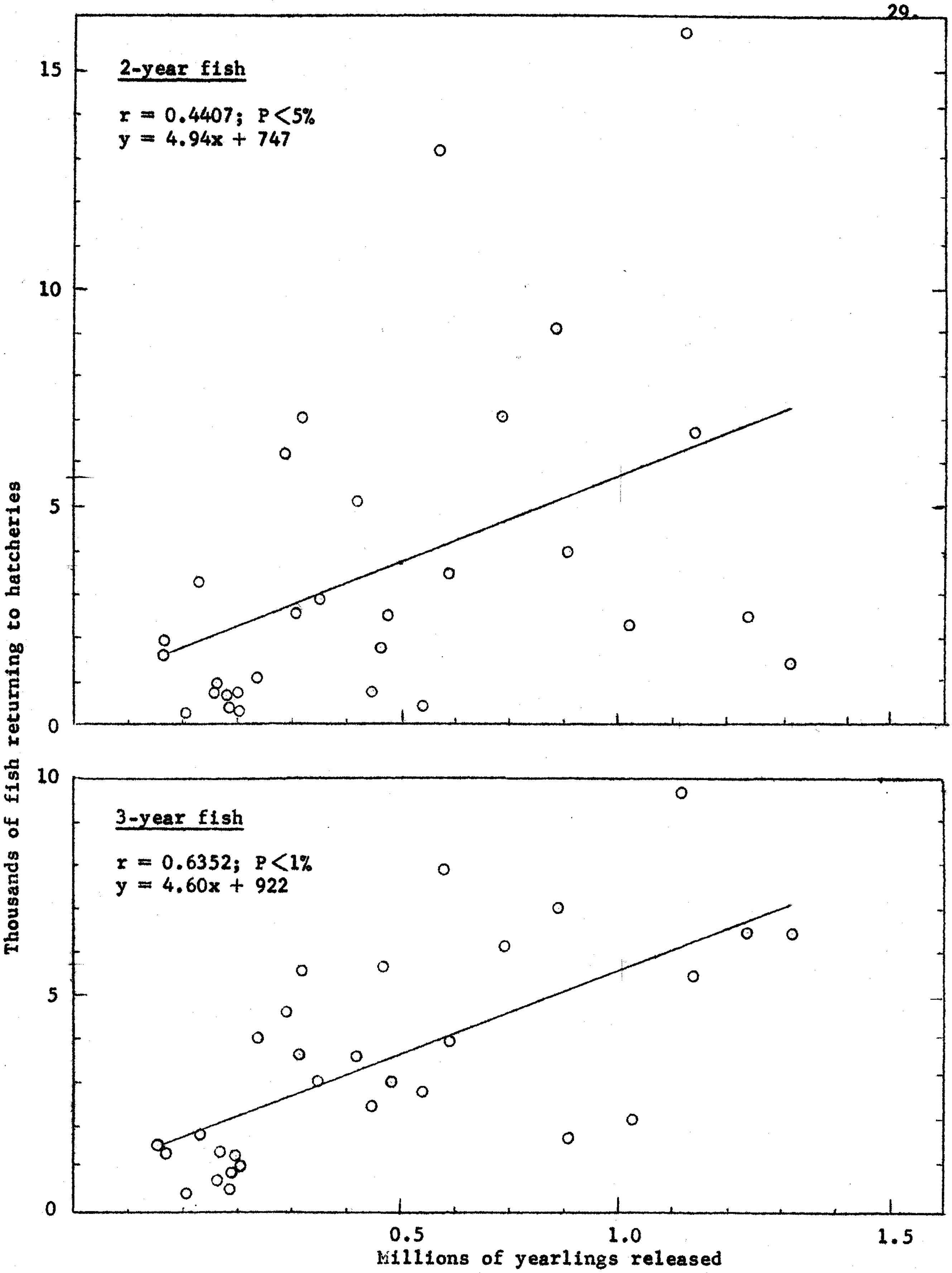

Figure 3. Relation between number of coho yearlings released and subsequent returns to FCO hatcheries, 1958-60 broods

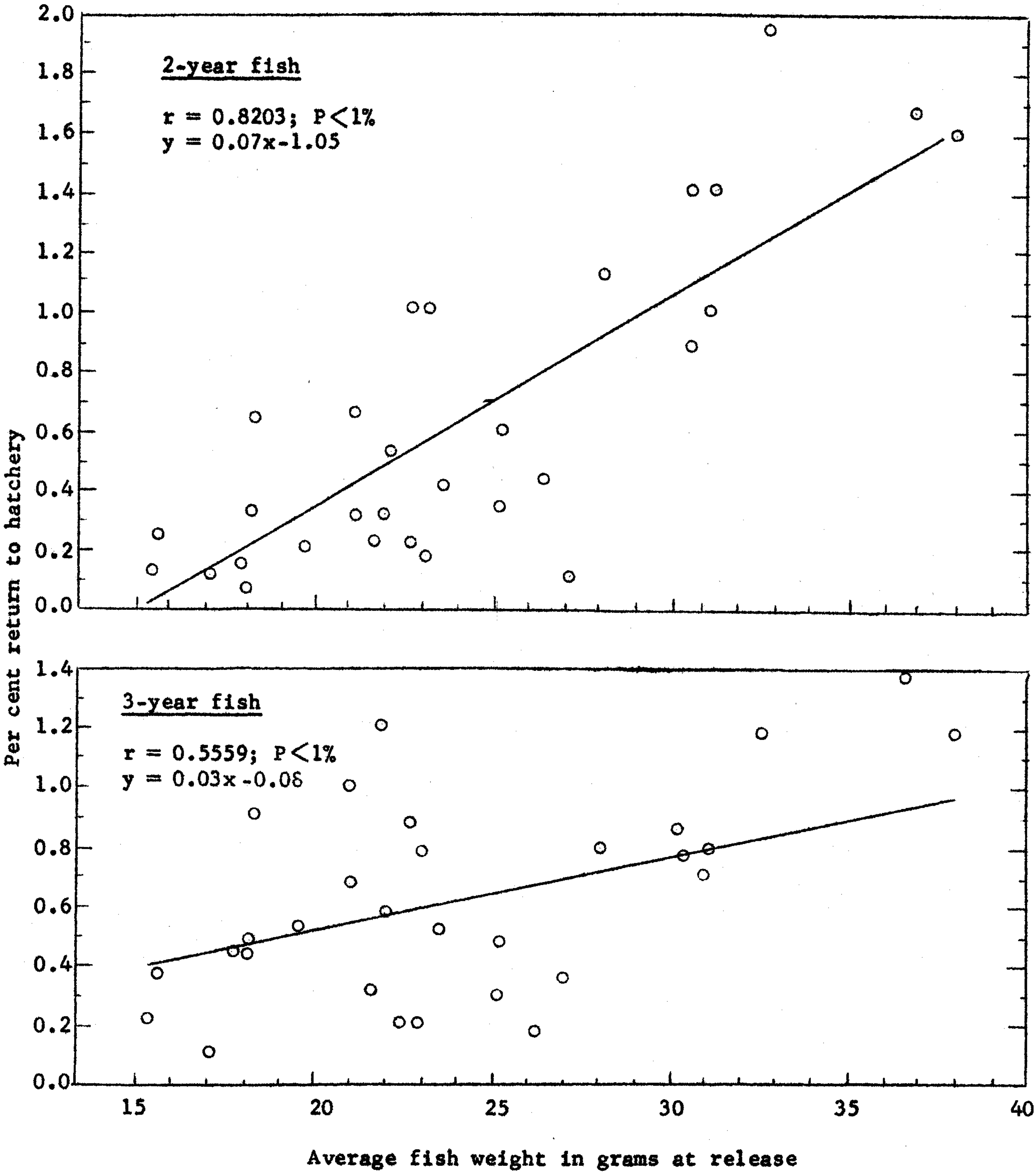

Figure 4. Relation between average weight at release and per cent return of 2- and 3-year-old coho to FCO hatcheries, 1958-60 broods

Since both numbers released and average size at release are related to returns, a combination of the two (total weight released) was compared to the total return. These relationships are shown in Figures 5 and 6 for 2_2 and 3_2 fish, respectively. The data for 2_2 fish do not fit as well as the relationship between size and the rate of return (Figure 4). However, the data for 3_2 fish provides a better fit than for either of the previous correlations.

Several of the lower points in Figure 6 represent groups released prior to February. I believe that variation by time should be removed if these data are used to predict or anticipate returns. The one aberrant point for February-April releases (53,000 pounds, 1,750 fish) represents 1960-brood Cascade Hatchery coho; this low return cannot be explained.

Wallis (1963) showed a relationship between pounds of coho yearlings liberated and 3_2 adult returns to the Klaskanine Hatchery for several broods. There was no significant relation between numbers of yearlings liberated and returning adults when average size was ignored.

Washington Department of Fisheries

Kelez (1937) reported one of the earliest experiments to assess the effect of size and time of release on survival of coho salmon. This experiment consisted of two groups of 1933-brood fingerlings released into Friday Creek, tributary of the Samish River. One group was liberated during May 1934 at an average size of 293 fish per pound; the other was released during November 1934 at an average of 35.5 per pound. The group released during May provided only 7

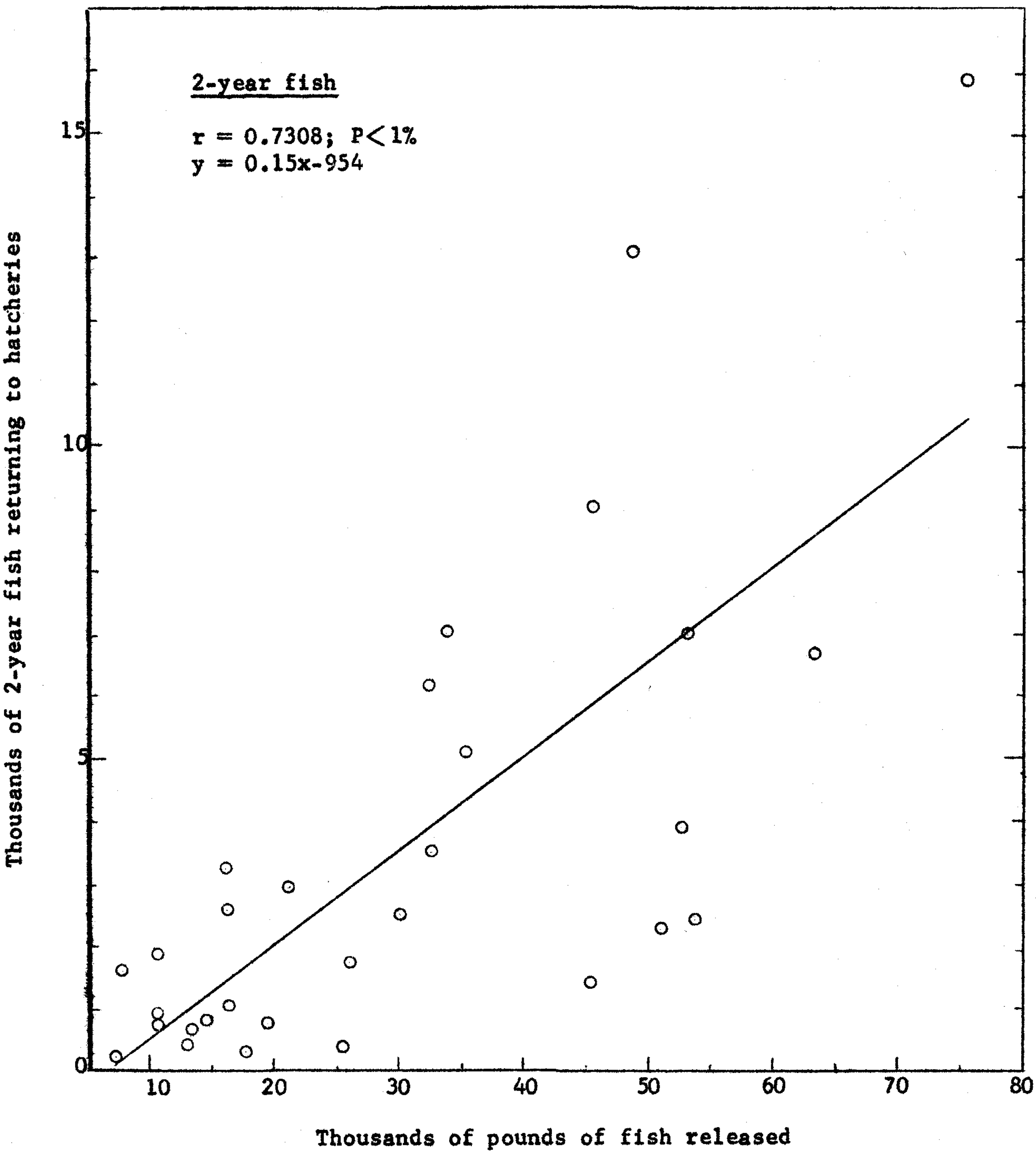

Figure 5. Relation of pounds of coho yearlings liberated to return of 2-year fish to FCO hatcheries, 1958-60 broods

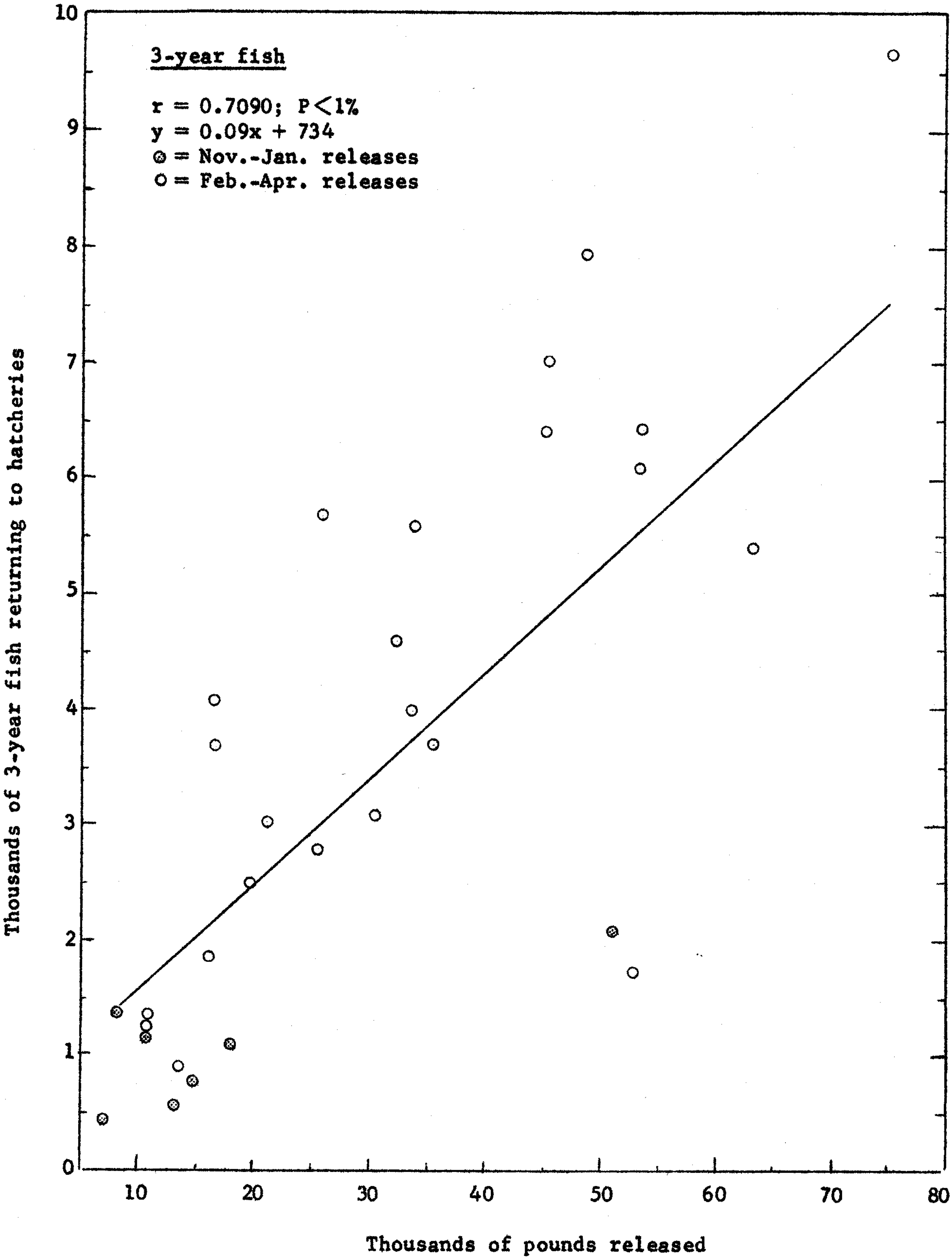

Figure 6. Relation of pounds of coho yearlings liberated to returns of 3-year fish to FCO hatcheries, 1958-60 broods

adults (0.03%) back to the hatchery, while the group released during November produced 462 adults (1.77%); a 66-fold increase from longer rearing.

Salo and Bayliff (1958) summarized data for several years from Minter Creek in Washington and concluded that coho fingerlings should be reared at least 6 months to realize a noticeable increase in stream survival over that provided by natural production alone. They further showed that maximum fresh-water survival could be realized by rearing for about 14 months (May release date), but concluded that maximum total survival (fresh water plus marine) could be attained by rearing for 9 to 10 months (December to January release date). Subsequent data has shown that rearing for periods up to 14 months has further increased total survival (R. E. Noble, personal communication).

Results of marking experiments conducted on 1951- and 1956-brood coho yearlings at Minter Creek are shown in Figure 7 to illustrate the relationship between size at release and subsequent returns of 3_2's (WDF, 1960). In the 1951-brood experiment there was no significant difference in survival between the groups, but in the 1956-brood experiment the larger-sized group provided a four-fold increase over the smaller group.

In a previous section it was noted that a group of coho fingerlings was induced to migrate during their first spring (Noble, 1959). Adults from one of these groups returned in 1959 as 2-year-old (2_1) fish, but none were observed the following year as 3_1's (R. E. Noble, personal communication). A total of 0.35% of the number released returned as 2_1's. They averaged 20 inches in length compared to

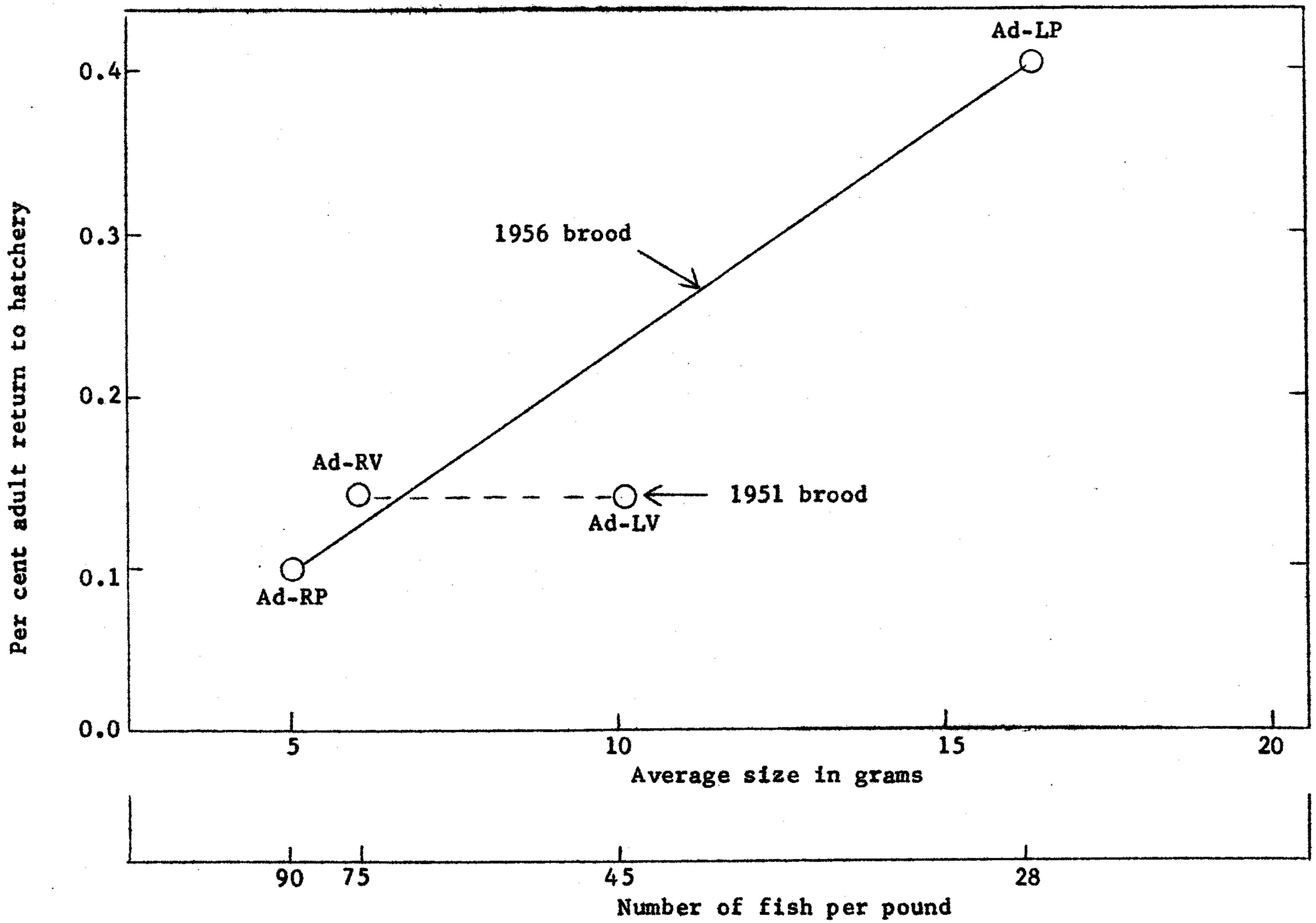

Figure 7. Relation of average size of coho at time of release to per cent return to hatchery Data from Annual Report, WDF (1960), p. 53

about 16 inches for normal 2_2's and an average of about 25 inches for normal 3_2 fish.

U. S. Bureau of Sport Fisheries and Wildlife

Johnson (1962) reported preliminary results of experiments designed to test the effect of time of release on survival of coho released from Little White Salmon Hatchery. Two groups of each of three broods were involved, with one group of each brood being released during November and the other the following February. Returns of only two broods are complete at the time of writing (1963). For each of the two broods, the fingerlings released during February provided a greater return to the hatchery than the earlier release. There were differences in size of the fingerlings when released, and in this experiment it is not possible to separate the effects of time of release and size at release upon survival.

Chum

Chum salmon are usually released as unfed fry because they normally migrate to sea almost immediately upon emergence. There have been few experimental studies related to rearing in hatcheries, but there are indications that rearing for short periods may result in increased survival over releasing unfed fry.

A few chum are normally hatched at the FCO Big Creek Hatchery, and in most years have been released as unfed fry. Inadequate data precludes a precise evaluation of this operation, but there is no indication that it has been of any value in increasing production. However, fingerlings of the 1954 and 1955 broods were reared until April and May and there were noticeably greater returns to the hatchery in

1957 and 1958 than in previous years. The returning adults were heavily infected with tuberculosis which is evidence that they were reared in a hatchery.

The WDF has experimented with hatchery rearing of chum. Based on results of marking experiments they concluded that rearing for approximately 45 days provides greatly increased survival over releasing unfed fry (R. E. Noble, personal communication).

reared 45-60 days.

Steelhead

Many experiments have been conducted in an attempt to determine the optimum time and size for release of hatchery reared steelhead fingerlings. No attempt is made here to list the pertinent data from numerous studies related to this problem, but the reader is referred to the following reports containing these data: Pautzke and Meigs (1940); Larson and Ward (1955); Hallock, Van Woert, and Shapovalov (1962); and Wagner, Wallace, and Campbell (1963).

The evidence from all the studies has shown that maximum survivals of steelhead are obtained by releasing fish during the normal migratory period (March to May) at a size of 10 fish per pound (6 to 7 inches) or larger. If fingerlings are smaller than about 10 per pound substantial numbers remain in the stream for an additional year, and do not have a high survival rate.

RELATIONSHIP OF SIZE OR GROWTH RATE TO AGE AT MATURITY

There has been a great deal of interest in, and concern over, the relatively large numbers of 2_2 coho (jacks) returning to FCO hatcheries in recent years. Among most animals it is common for rapidly growing individuals to mature earlier than those with a slower growth rate.

Alm (1959) presented an excellent and comprehensive literature survey on this subject and discussed this phenomenon in fishes. He concluded that age at maturity is partly a function of heredity, wherein certain species and/or races mature at certain ages, and partly a function of growth rate. To illustrate, a given stock may mature at 2 and 3 years of age--these ages may be a function of heredity. However, the relative proportions which mature at each age are partly determined by growth rate, i.e., those fish which mature as 2-year olds have a faster growth rate than those which mature as 3's.

The WDF has conducted several experiments with chinook and coho salmon to determine the effect of heredity on age at maturity (R. E. Noble, personal communication). Their findings have agreed generally with those reported by Alm (1959).

Fraser (1917a) showed that spring (chinook) salmon which matured in their 4th year showed a greater growth throughout each year of their life than those which matured as 5-year olds.

Gilbert (1922) demonstrated that the rate of growth in the ocean was related to age at maturity for chinook from the Yukon River. For example, fish which matured at 4 years of age showed a greater growth during their 3rd year than those which matured at 5 years. His data further showed that fish which matured as 5-year olds had a greater growth rate during their 3rd and 4th years than those which matured in their 6th year. A similar relationship existed between fish which matured at 6 and 7 years.

The International Pacific Salmon Fisheries Commission (1962) reported that a rapid growth rate during the first year of ocean residence was associated with early maturity of sockeye salmon in the Fraser River.

Natural populations of coho sometimes contain substantial numbers of 2_2 fish. On four streams from which data are available, 2_2 fish comprised from 2 to 74% of the return to weirs of adult coho from a given brood (Table 7).

Table 7. Per cent of total coho returns which were 2_2 fish to four streams.

Stream	No. of broods	Per cent of total returns as 2_2 fish	Source
Gnat Creek, Ore.	6	52-74	Willis (1963)
Spring Creek, Ore.	6	8-49	FCO (unpublished data)
Minter Creek, Wash.	16	2-32	Salo and Bayliff (1958)
Waddell Creek, Calif.	8	6-33	Shapovalov and Taft (1954)

Morgan and Henry (1959) reported that approximately 45% of the coho returning to the Tenmile Lakes system on the Oregon coast during the 1955-56 spawning season were 2_2's. (The 2's and 3's were of different broods and not comparable to the data in Table 7.) FCO biologists have commonly noted relatively large numbers of 2_2 adults in this system as compared to other coastal areas during spawning ground surveys (Oakley, 1961). Observations indicate that the smolts migrating from the lake are substantially larger than smolts from streams of other systems.

High proportions of 2_2 coho have been recorded at Merwin Dam on the Lewis River, Washington. These have resulted from fingerlings which attain an extremely large size in the reservoir. Fingerlings from Speelyai Creek, tributary to Merwin Reservoir, do not attain as great a size, and have not produced excessive numbers of 2_2's (J. A. R. Hamilton, personal communication).

It is well established that the number of scale circuli is related to length of salmonids, with longer fish having greater numbers of circuli than shorter fish. FCO biologists have examined scales from coho of several broods returning to Klaskanine Hatchery (lower Columbia River tributary) and in the Youngs Bay fishery, which catches predominately Klaskanine Hatchery fish (FCO, 1958, and unpublished data). Age determinations were made and the number of circuli formed in the fresh-water portion of the scale were counted (Figure 8). It was obvious that 2_2 adults resulted from fingerlings with greater numbers of fresh-water circuli than did 3_2 adults (although there was a good deal of overlap) suggesting that 2_2 adults were produced by the larger juveniles.

There were substantial differences between broods in size of the fish at time of release, but the bulk of the 3_2 adults were produced by yearlings which had from 20 to 30 fresh-water circuli, regardless of the average size of fish released. This fact suggests that there is an optimal size for release of hatchery reared coho yearlings. Based on a relationship between numbers of circuli and length of coho at Klaskanine Hatchery reported by Niska and Willis (1963), fingerlings with 20 to 30 circuli range from approximately 4.4- to 6.2-inches fork length. The modal frequency of the four broods (Figure 8) ranged from 24 to 28 circuli. This corresponds with fish from about 5.1 to 5.8 inches in length, or approximately 18 to 14 fish per pound, respectively.

Data from all pertinent FCO coho marking experiments were analyzed to determine if there was a relationship between average size at release and the proportionate return of 2_2 and 3_2 fish.

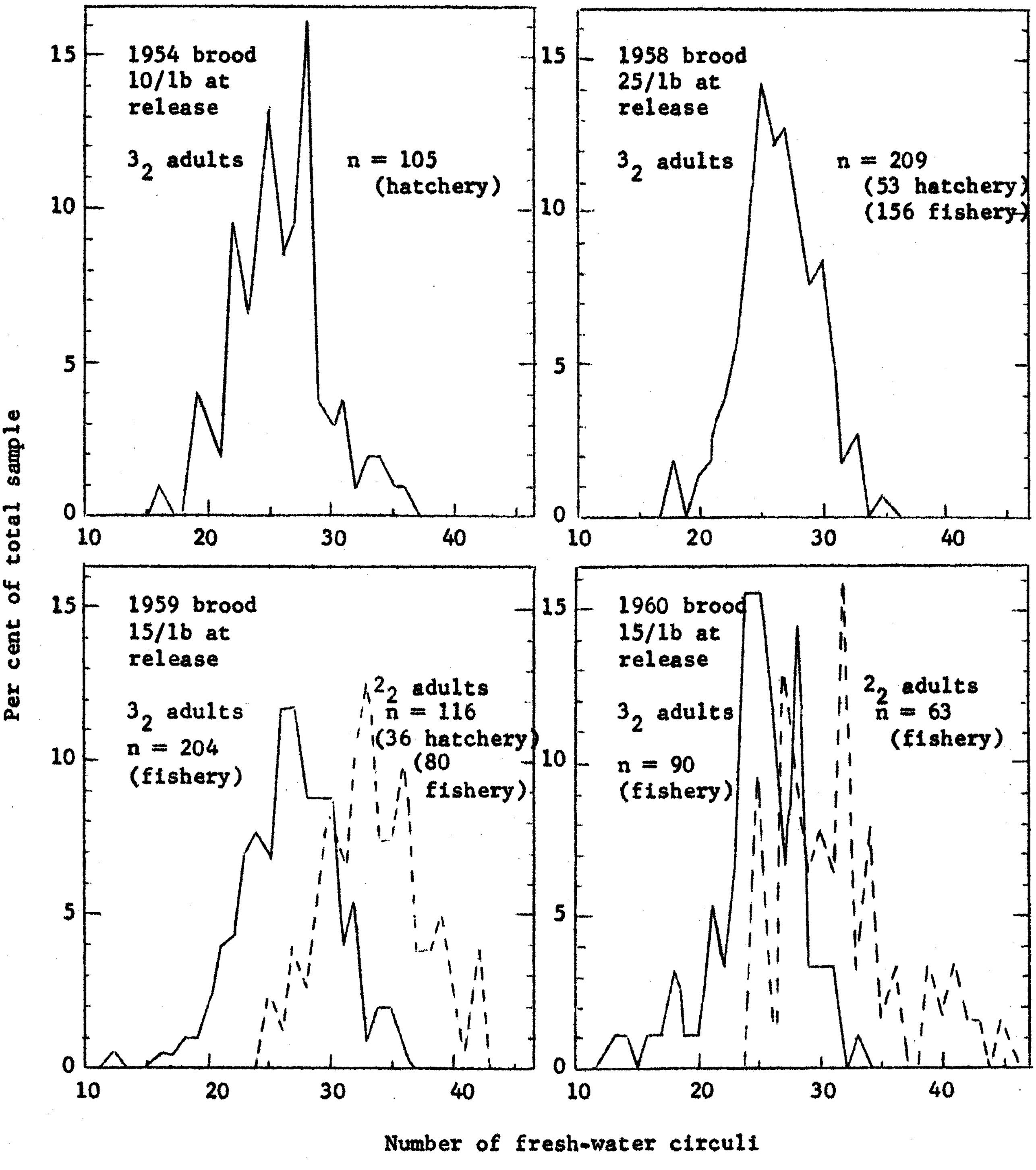

Figure 8. Number of fresh-water circuli on adult coho at Klaskanine Hatchery and in the Youngs Bay commercial fishery

In these experiments 2_2 fish accounted for 38 to 94% of the total return to the hatcheries (Figure 9). In each of the experiments the larger-sized fish produced a greater proportion of 2_2's than the comparable smaller group.

Data for the 1958-60-brood unmarked coho returning to FCO hatcheries were treated in a similar manner (Figure 10). These data also show an increase in the proportion of 2_2 fish with an increase in average size, although there is a great deal of variation, especially in those groups about 15 to 20 grams average weight (about 30 to 20 fish per pound, respectively).

Mastin (1956) found that size at release played a major role in return of 2_2 female coho reared at the OGC Bandon Hatchery. He reported that females which were larger than 8 inches when released returned as 2_2's; those smaller than 7 inches returned as 3_2's; and those between 7 and 8 inches returned as either 2- or 3-year fish.

Very limited data from two spring chinook marking experiments suggest that average size of fingerlings at time of release may also affect the age at return for this species (Table 8). These data are of very limited value due to the many variables involved, but in both experiments larger-sized fish produced a greater proportion of 4-year adults than smaller-sized fish of the same brood.

ENVIRONMENTAL AND PHYSIOLOGICAL FACTORS ASSOCIATED WITH MIGRATION

Environmental

Many investigators have noted that migrations are associated with changes in water flows and/or temperatures. Bell (1959a) found

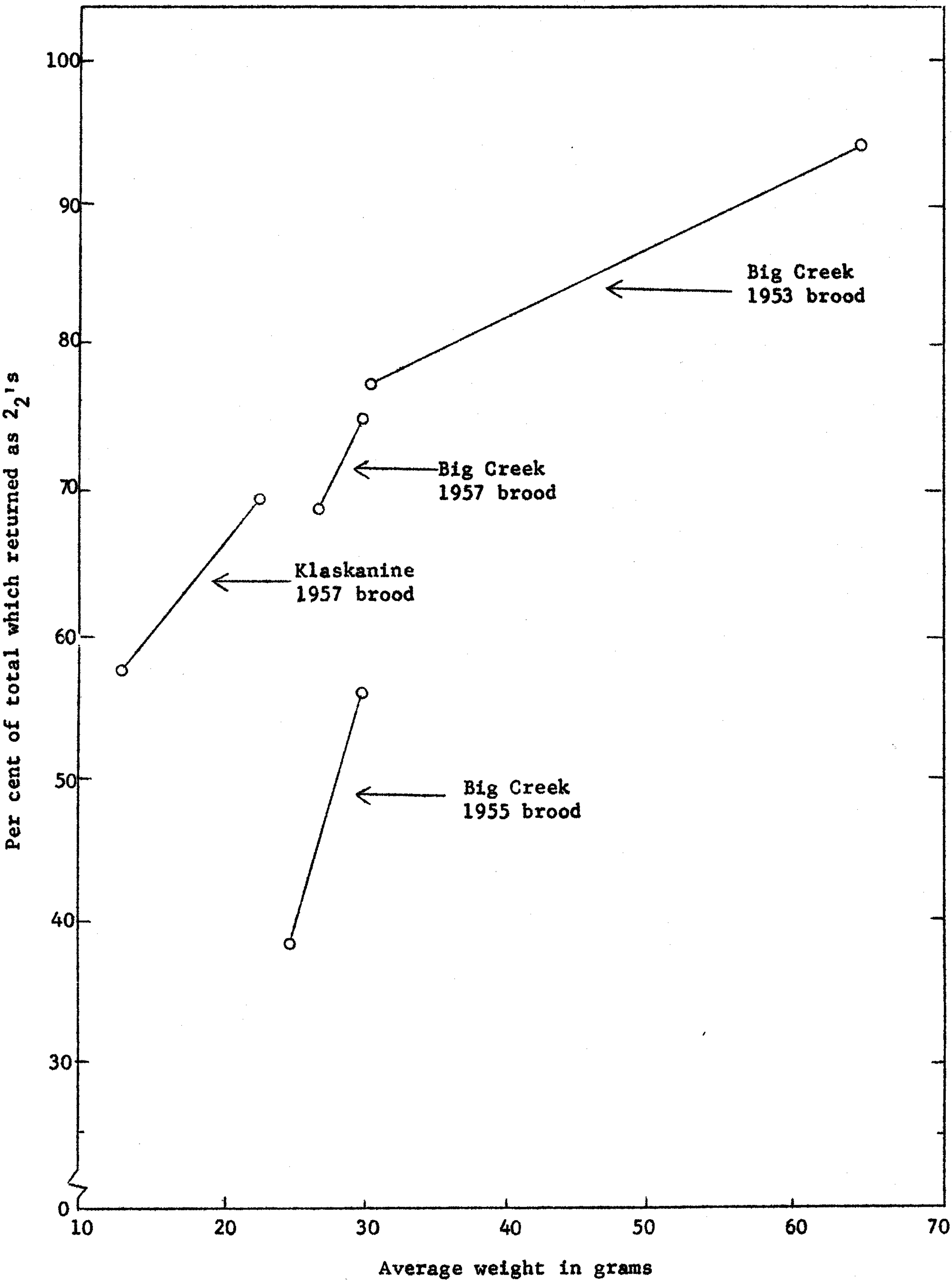

Figure 9. Relation of average size at release to proportionate return of 2_2 coho

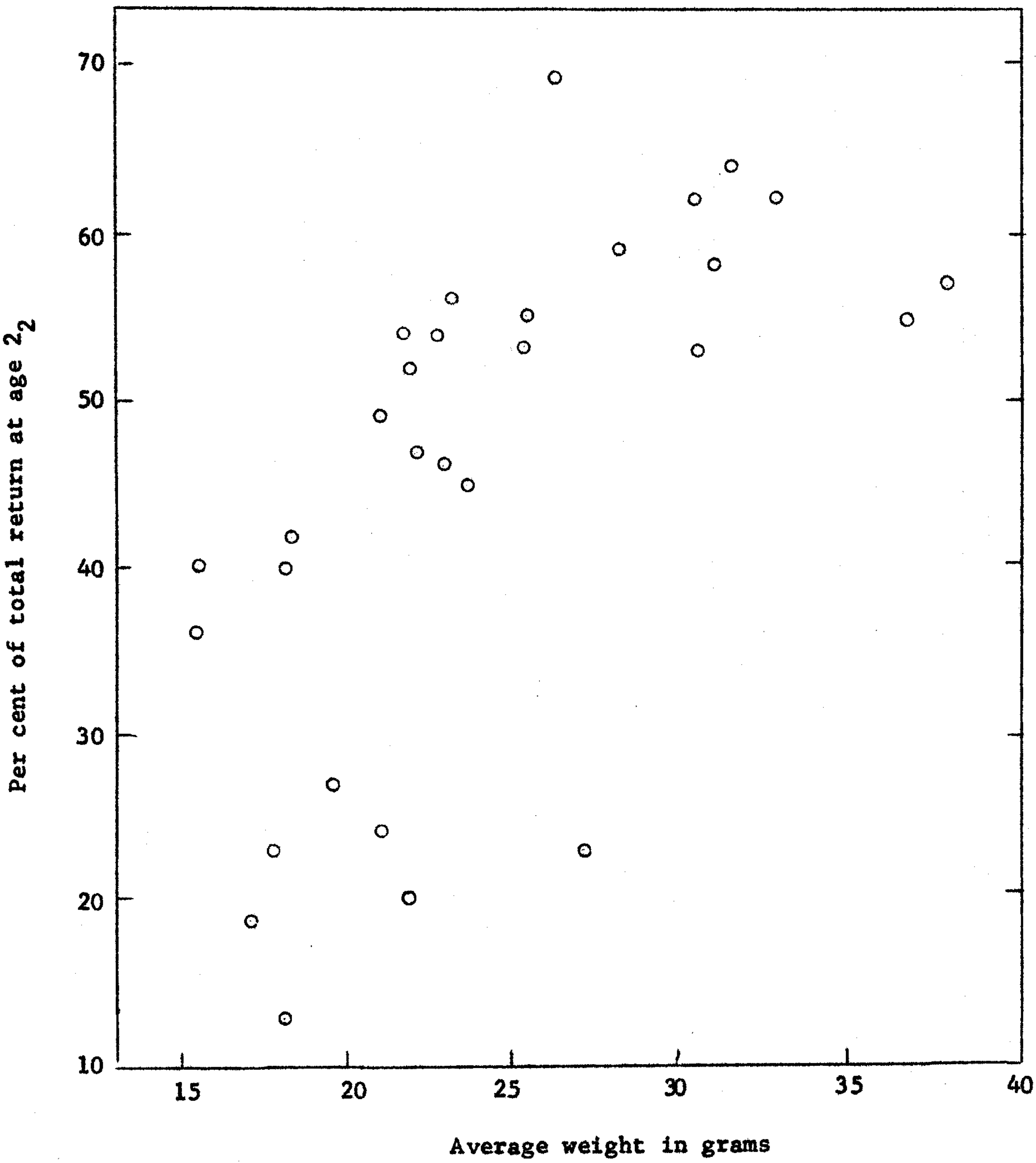

Figure 10. Relation of average size at release to per cent of return which was 2_2 coho, FCO hatcheries, 1958-60 broods

Table 8. Average size of selected groups of spring chinook fingerlings at time of release from Willamette Hatchery, and age composition of adult returns

Brood	Liberation data			Age composition of adult return to Dexter ponds (per cent of total)			
	Mark	Date	Ave. size (fish/lb)	3	4	5	Total
1953	Ad-RV	Mar. 1955	10	3.0	55.0	42.0	100.0
	Unmarked (entire hatchery production)	Jan.-Apr. 1955	15-26	0.2	33.0	66.8	100.0
1955	LV-LM	Sept.-Oct. 1956	39	6.2	52.5	41.3	100.0
	RV-LM	Dec. 1956	30	4.7	65.5	29.8	100.0
	LV-RM	Feb. 1957	29	0.0	78.8	21.2	100.0

that the largest catches of chinook fingerlings in the Snake River at the Brownlee-Oxbow dam site were related to a rise in water temperature and flow during April, May, and June. Peak numbers were trapped when the weekly mean water temperature was from 55 to 56 F.

Mains and Smith (1964) noted that: (1) chinook migration in the Snake River at Central Ferry was associated with increased flows and to some extent with increased temperatures accompanying the spring flood, and (2) chinook fry in the Columbia River at Byers Landing were observed to migrate upon emergence and the movement was not associated with temperature or flow changes, while yearlings migrated when the temperature increased.

French and Wahle (1959) showed that the principal migration of chinook in the Wenatchee River occurred during the spring run-off and commenced soon after an increase in temperature.

Moffett and Smith (1950) stated that in the Trinity River, California, the main migration of chinook fingerlings occurred during the spring run-off and was only generally influenced by fluctuations of flow or temperature.

Andrews (1959) showed that the greatest movement of steelhead in the Alsea River occurred when mean water temperature was from 50 to 55 F, and the smolts migrated during declining flows following peak discharges.

Shapovalov and Taft (1954) presented data and discussed factors related to migration of coho and steelhead, and concluded that fish size, flow, temperature, and light intensity were probably all important. They suggested that the most important factor may vary, e.g., a change in flow may precipitate movement at one time, while at another time temperature change may be responsible. They showed that during seasons of relatively low flow the migration period tended to be earlier than during seasons of relatively high flow, and suggested this may have been associated with water temperatures.

Greeley (1955) concluded that, in the case of Atlantic salmon smolts "---a period of some days at good feeding temperatures is necessary to precipitate migration of salmon wintering in the streams." His conclusion was based on the fact that migrating fish have commenced new growth in the spring and were actively feeding.

Time of peak migrations within a given stream may vary as much as 2 months from year to year. These differences may be associated with annual variations in environmental conditions.

Physiological

Pronounced physiological and behavioral changes are associated with smoltification and approach of the migration period. These factors are only briefly mentioned in this report, although it is recognized that a thorough understanding of the processes is important and necessary before the phenomenon of migration can be fully explained.

The transformation from parr to smolt is characterized by gross changes in external appearance. Parr marks disappear, the fish become silvery with a dark band on the tail, and scales become deciduous. Significant changes in hormone activity, specifically of the thyroid and pituitary complexes, have been observed (Hoar, 1957; Evropeizeva, 1959). Changes in metabolic activity, with subsequent changes in chemical composition, as well as body configuration, have also been observed (Evropeizeva, 1959). Behavioral changes have consisted of changes in photo response, preference for heavy cover and deeper pools, increased nocturnal activity, and a more pronounced schooling tendency (Hoar, 1951; Chapman, 1962).

DISCUSSION

The time of smolt migration for all species is relatively consistent. The major movement is from the first of March through the middle of June with the peak during April and May. Many investigators have associated timing of migration with changes in stream flows, water temperatures, or both. It is likely that such changes have an immediate and precipitating influence on the migration, and may be responsible for observed variations in peak movements from year to year and between streams.

We have assumed the logical time to liberate hatchery fingerlings is when they exhibit typical smolt characteristics, but the solution may not be that simple. Fingerlings in hatcheries, especially fast growing fish, may exhibit typical smolt appearance at various times throughout the year. Observations indicate that fish begin to exhibit smolt characteristics when they attain a certain size. It has also been demonstrated that fish with the external appearance of smolts may not migrate except during the usual spring migration season (Noble, 1959). All evidence suggests that migration to the sea occurs only when a proper physiological state exists during the proper season. From all information it appears that the optimal time for release would be during the months of March through May, when the fish have smolted.

The available data on the effect of time and size at release on survival of hatchery reared chinook salmon are inadequate to formulate a sound liberation program. In part this stems from an incomplete understanding of chinook life history, and the experiments involving hatchery reared fingerlings have generally produced too few recoveries to provide the needed information.

The data presented here indicate that maximum production of fall chinook can be attained by releasing fish during late spring or early summer (May and June) at an average size of at least 100 to 150 fish per pound. While there are inadequate data on returns from fish released during midsummer, there is an indication of reduced returns from releases during this period. There is evidence that adult returns (in numbers of fish) can be increased by rearing to yearling age, but there is a reduction in size of such fish due to less ocean growth. Warner _et al_. (1961) suggested that if the primary concern is in building up or maintaining a spawning stock there would be real merit in rearing yearlings; however, if production to the fisheries at the most efficient cost-to-benefit ratio is most important, then fish should be released during their first year.

Available experimental data show that maximum survival of spring chinook fingerlings can be realized from releases from late fall to spring (October to March) at an average size of about 10 fish per pound. Some experiments show that the month of release may not be too important as long as fish are released during this period. This is in contrast to findings for other salmonids, and it is the writer's opinion that this is due to a lack of adequate data.

Certain aspects of spring chinook life history are similar to other salmonids, and it appears that the effect of time at release on survival would be similar. There is a definite need for additional experiments to determine precisely the effect of time of release on survival. The conclusion that a size of about 10 fish per pound produces the highest survivals in spring chinook is from rather sparse data, and this too needs a more precise determination. There are indications that rearing spring chinook to relatively large sizes results in a greater proportion of young adults, but the available data are inadequate to assess such an effect.

Data for coho salmon are more extensive than for chinook, and appear adequate to formulate a sound hatchery management program. Some experiments have demonstrated that coho fingerlings released during November, December, and January do not survive as well as those held until February or later. Most of the experiments have not shown significant differences in survival between groups released at different times during the period February to May. However these studies were not designed to measure differences during this period, and should not be expected to answer this question. It seems likely that maximum survival would be realized from groups released during the "normal" spring migration season, but additional study is needed to clarify the point.

All the available data show that the survival rate of coho increases with an increase in size at time of release. The total survival (2_2 and 3_2 fish combined) increased at all sizes for which comparisons were possible. In one instance, 3_2 returns were reduced for fish which averaged 7 per pound from a graded population which may have influenced sex ratio of the graded groups. Up to about 10 per pound the survival rate of 3_2 fish increases, although the 2_2's increase at a faster rate. Data are lacking to adequately determine the effect of producing coho larger than 10 fish per pound.

Time and size at release are not the only factors which influence survival. An assessment of fish health or condition would be of great value as a gauge of survival ability. Within the last few years several workers have initiated programs to identify and evaluate factors associated with survival. These studies are primarily concerned with: stamina, or ability to swim in a current; chemical and biochemical characteristics; hematology; incidence of disease; and ability to adapt to salt water. It is anticipated these studies will provide more precise criteria for determining what characteristics we should attempt to impart to hatchery reared fish.

SUMMARY

Literature pertaining to time of and size at migration for naturally reared salmonids was reviewed. Pertinent published and unpublished data on the relation of time and size of hatchery reared fingerlings to adult survival were presented.

Chum salmon spend little time in fresh water and migrate to the sea upon emergence from the gravel. Time of migration is determined by time of spawning and duration of the incubation period. There is no obvious relationship between size and age at migration.

Fingerlings of the fall run of chinook salmon typically begin a seaward migration soon after emergence, but the precise time of entry into salt water is not known. Data suggest that most of the fingerlings spend about 3 to 4 months in fresh or brackish water. At the time of writing it is not known if there is a relationship between size and movement to the ocean.

Spring chinook and coho salmon characteristically rear for an extended period in fresh water and have their greatest seaward migration during the spring. While there is some movement within streams during late fall and winter months, the bulk of the seaward migration occurs from March to June, with peak migration in April or May. It has been demonstrated that there are minimum sizes associated with transformation into smolts, and fingerlings remain in fresh water until such size is attained, then migrate the following spring.

Smolt migration is associated with environmental changes and probably account for some variation in time of peak movements. Definite physiological and behavioral changes have been associated with the process of smoltification which prepare the young salmonids for ocean life.

Experiments with hatchery reared fall chinook have shown that survival increases with longer rearing. The best returns (in numbers) have been from groups reared to yearling age, but maximum production (in pounds) may be realized from groups released during late spring and early summer (May to July) of their first year. The data indicate that the optimal size at release is 150 to 100 per pound or larger.

Results of spring chinook experiments have suggested that the best time for release is during October to March, but the data are not adequate to determine precisely the optimal time. The evidence indicates that maximum survivals result from yearlings at an average size of 10 per pound or larger.

Results of coho salmon experiments show that the optimal time for release of yearlings is during February to May. The data are not adequate to compare survival of groups released at different intervals during this period. Maximum survival rate of 3_2 fish may be attained from fingerlings at an average size of about 10-12 per pound, but limited scale studies have shown that fish of approximately 15-20 per pound may be optimal.

Limited data indicate that rearing chum salmon for a period of about 45 days increases survival over releasing unfed fry.

All the experiments with hatchery reared fish showed that larger-sized fingerlings survived at a greater rate when other factors are comparable.

There is considerable evidence that fast growing individuals tend to mature earlier than those growing slower, and that growth during either fresh-water or marine periods may influence early maturity of Pacific salmon. Quantitative measures of the growth responsible for such early maturity are lacking. I conclude that rapid growth rate in fresh water (in the hatcheries) is at least partly responsible for the return of large numbers of 2_2 coho. There is also an indication that rapid growth in the hatcheries prompts earlier maturity of spring chinook.

RECOMMENDATIONS

The available data relating to the time of downstream migration and the size of salmonid smolts which produce the best returns have been reviewed. Certain tentative recommendations concerning hatchery procedure can be made to provide basic guidelines in accordance with conditions which have produced the best known returns. Future evidence will allow us to refine these guidelines.

A need for additional research is apparent in some areas to fill in gaps of our knowledge. Recommendations for research are made to point out areas where information is deficient.

Hatchery procedures

Fall Chinook

1. Rear until May, June, or early July of their first year.
2. Rear to a size of 150 to 100 per pound or larger if possible.
3. If development or maintenance of a spawning stock is of primary importance, rear to yearling age and release during March to May at a size of from 10 to 30 fish per pound.

Spring Chinook

1. Rear to yearling age and release during March to May.
2. Rear to a size of about 10 to 30 per pound.

Coho

1. Rear to yearling age and release during March to May.
2. Rear to a size of about 15-20 per pound; control size variation to 4.5 to 6.0 inches fork length, with mean length from 5.0 to 5.5 inches.

Chum

1. Rear for about 45 to 60 days.

Steelhead

1. Rear to at least 1 year of age (sometimes 2 years will be necessary to attain the desired size) and release during March to May.
2. Rear to a size of at least 10 per pound or larger.

Research

1. There is need for comprehensive life history and ecological studies of spring and fall runs of chinook, in fresh water, estuarine and marine environments.
2. More specific data on the effect of time and size at release on survival are needed for chinook and coho.
3. Precise data pertaining to the effect of growth during different periods on age and size at maturity of all species is not presently available, but is necessary for a sound hatchery management program.
4. The merits of rearing chum salmon fingerlings for extended periods in fresh water should be explored further.
5. A study to investigate the feasibility of producing first year coho salmon smolts would be of great interest.
6. There is an urgent need for a study of two subjects not related to time or size at release: (1) a method of separating hatchery and naturally produced fish returning to hatchery streams; and (2) reliable catch-to-escapement ratios to properly assess production or changes in techniques.

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