FRI-UW-8101
January 1981

FISHERIES RESEARCH INSTITUTE
College of Fisheries
University of Washington
Seattle, Washington 98195

SCALE PATTERN ANALYSIS TO DETERMINE AGES OF COHO SALMON RETURNING TO TWO AQUACULTURAL FACILITIES ON COOS BAY, OREGON

by

K.W. Myers, R.V. Walker, and C.K. Harris

CONTRACT COMPLETION REPORT

for

Oregon Aqua-Foods, Inc.
and
Anadromous, Inc.

for the period
October 1, 1980 through December 31, 1980

Submitted January 15, 1981

Approved

Robert J. Bourgeois
Director
Fisheries Research Institute

SCALE PATTERN ANALYSIS TO DETERMINE AGES OF COHO SALMON RETURNING TO TWO AQUACULTURAL FACILITIES ON COOS BAY, OREGON[1]

Contract Completion Report

INTRODUCTION

This paper reports on a study in which scale pattern analysis was used to estimate the freshwater age composition of adult coho salmon (Oncorhynchus kisutch) returning to two neighboring private salmon aquaculture facilities on Coos Bay, Oregon in 1980.

The returning adults of separate "stocks" of coho salmon released by Oregon Aqua-Foods, Inc. (OAF) and Anadromous, Inc. (AI) in Coos Bay are known (by tag returns) to intermingle at the recapture areas. Because the majority of coho salmon released by AI in 1979 were freshwater age-0 fish, and coho salmon released by OAF in 1979 were all freshwater age-1 fish, determination of the age composition of coho salmon returning to each facility in 1980 was expected to provide a means of partial separation of the two stocks. However, because the age-0 fish resulted from an accelerated-growth/early release hatchery program, we did not know whether the scale patterns of the two age classes would be sufficiently different to enable separation.

The study was conducted by visual examination and frequency distribution analysis of characters on the scales of coho salmon in weekly samples taken at each facility from September 4 through October 24, 1980.

---

[1]Not available for general distribution.

METHODS

Scale Sampling

Fish scale samples were collected by personnel at OAF and AI. Scales from a random sample of fish of unknown age were collected from up to 100 fish at each facility on 8 dates spaced at about one week intervals during the coho run. Most samples were collected from fish larger than 50 cm fork length to avoid including scales of jack salmon (ocean age-0). To provide a "standard" sample of fish of known age, scale samples were also collected from all coded wire tagged fish returning to each facility.

Scale Processing

Because of the large number of regenerated scales in the samples, scales were sorted under a binocular microscope, and the largest, non-regenerated scale that could be found for each fish was selected and mounted on a gummed card. Up to 30 scales were mounted on each card, and acetate plastic impressions (6000 psi for 4 min) of the cards were made for examination.

Initially, scales were not mounted for individual fish when microscopic examination showed all of its sampled scales to be regenerated. Later, after becoming concerned that fish from the two age groups might have different rates of scale loss, we mounted the least regenerated scale that we could find for these fish. These scales represented 3.4% of the total sample.

Criteria used for determination of age composition

Prior to determination of the age composition of scale samples by visual examination, samples of coded wire tagged fish of known age returning to the two facilities in 1980 were examined to develop criteria for determining freshwater age. Because freshwater age-1 coho salmon released in 1979 were

not present in the samples of coded wire tagged fish, criteria for recognizing this age group were developed by examination of the freshwater zone of age-1 jack coho salmon released by OAF in 1980 (Fig. 1), taking into account the faster freshwater growth rates of jack salmon, as well as information we had on rearing regimes and release dates of freshwater age-1 coho released in 1979.

The circuli on the scales were visually divided into two broad zones, a "pre-ocean" zone including all circuli formed on the scale prior to emigration of fish to the ocean, and the ocean zone including all circuli formed after ocean emigration. The boundary between these two zones was usually easily identified by scale readers as either the point where there was an abrupt increase in the thickness and spacing of circuli at the beginning of the first summer of ocean growth, or in cases where this transition was not obvious, as the point at which the bases of incomplete circuli in the posterior field of the scale start to bend away from each other.

The pre-ocean zone included a "pre-ocean check" for both age-0 and age-1 coho. A pre-ocean check, although variable in the number, thickness, and spacing of circuli, was observed on the scales of all known freshwater age-0 coho in the coded wire tagged samples, and was the character most likely to be misinterpreted by an untrained observer as a freshwater annulus. A pre-ocean check on the scale of an age-0 coded wire tagged coho is shown in Figure 2. The proximity of this check to the onset of the first summer of ocean growth indicates that this check is formed at or near the time of release into the estuary. A pre-ocean check was also defined for freshwater age-1 coho salmon. In this case, however, the pre-ocean check included a true freshwater annulus. A pre-ocean check on the scale of a coho salmon of unknown age interpreted as a freshwater age-1 fish during this study is shown in Figure 3. The pre-ocean check in Figure 3 includes a freshwater annulus, followed by "plus"

Figure 1. The scale of a freshwater age-1 jack coho salmon released from Oregon Aqua-Foods facilities in Coos Bay, Oregon in late May or early June 1980.

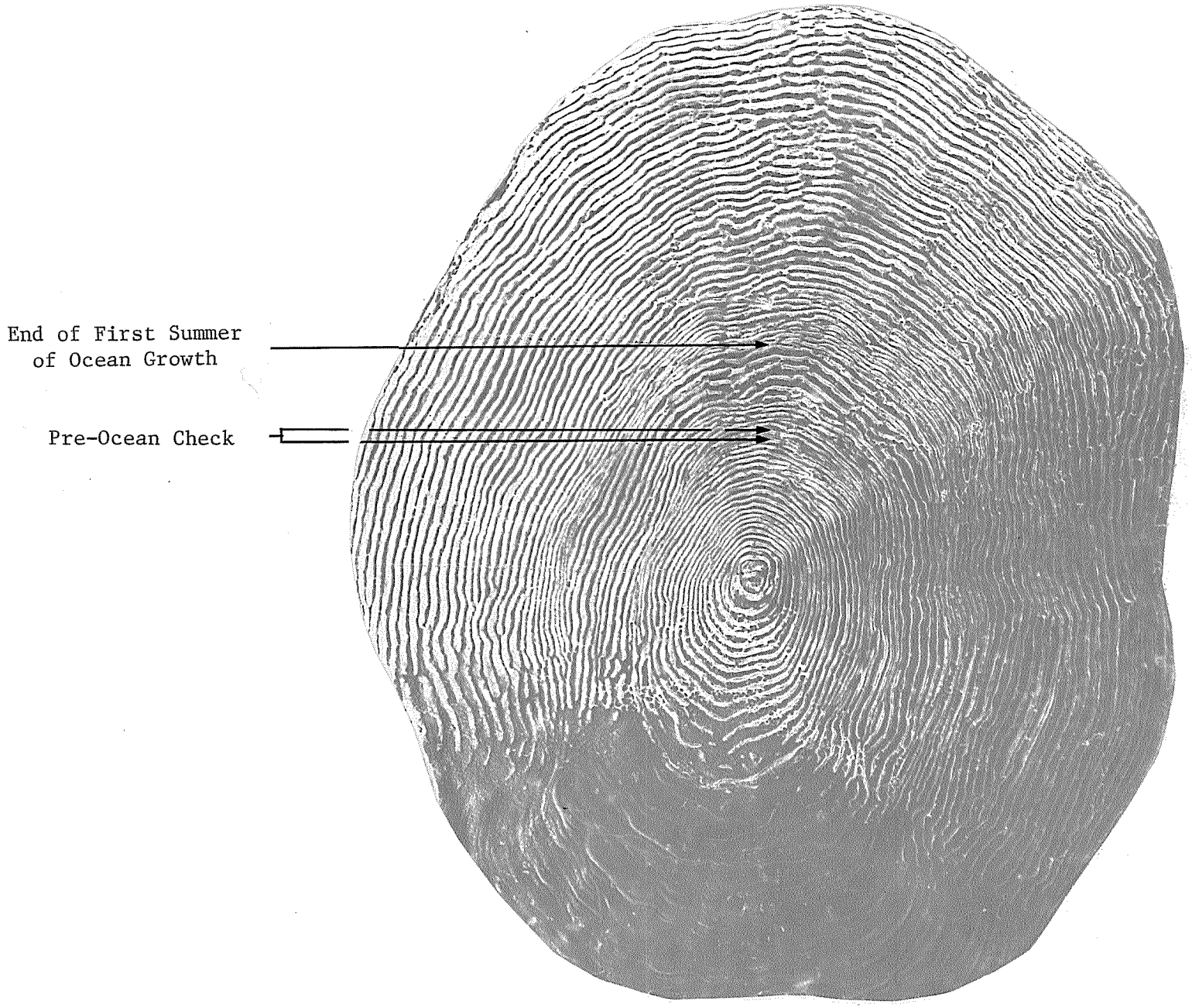


Figure 2. The scale of a known freshwater age-0 coho salmon released by Anadromous, Inc. into Coos Bay, Oregon on August 22, 1979, and returning to their Coos Bay recapture facility in August 1980. The position of the pre-ocean check and the end of the first summer of ocean growth are marked by arrows.

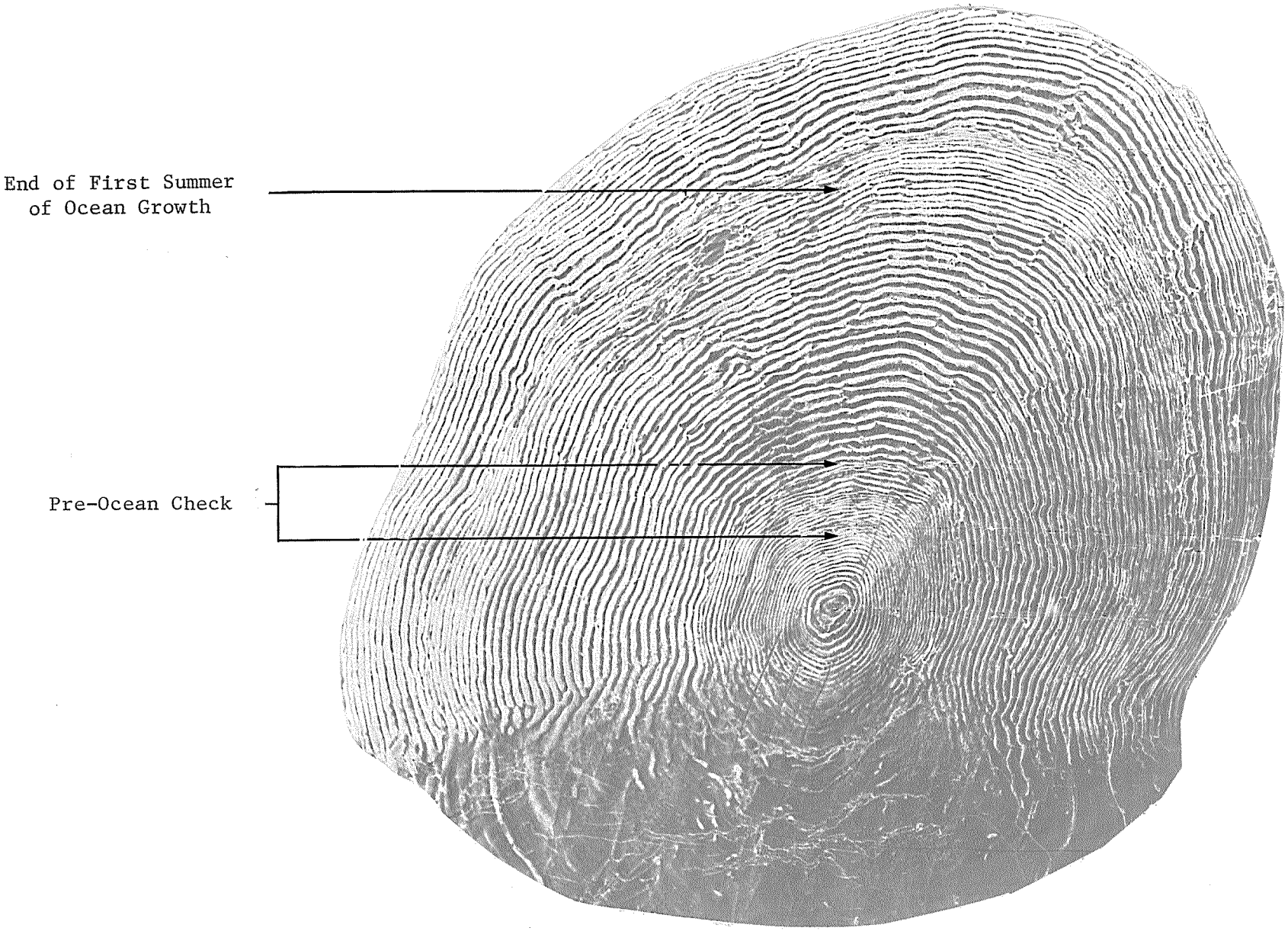


Figure 3. The scale of a coho salmon of unknown age returning to Anadromous, Inc. facilities on Coos Bay, Oregon in September 1980. This exemplifies the type of scale classified as a freshwater age-1. The position of the pre-ocean check and the end of the first summer of ocean growth are marked by arrows.

or spring freshwater growth, and a check occurring just prior to the onset of ocean growth, which probably formed at or near the time of release into the estuary. Although all coho interpreted as age-1 fish were expected to have a freshwater annulus, plus growth and a distinct check at release were not always expected to be present. This variability was expected because of differences in release times and, possibly, the size of age-1 coho at release. For example, plus freshwater growth after the freshwater annulus would be more likely to occur on the scales of age-1 coho released by AI and OAF in April, than on the scales of age-1 coho released by AI in February.

Criteria used to determine age by visual examination of scales included, primarily, number and spacing of circuli in the pre-ocean zone and size of the first ocean summer zone. Because freshwater age-0 coho grew at an accelerated rate, the spacing of circuli in the pre-ocean zone was expected to be wider for freshwater age-0 coho than for freshwater age-1 coho. Because the pre-ocean check of age-0 coho did not include a true freshwater annulus, the size of the pre-ocean check was expected to be smaller, and the number of circuli in the pre-ocean check was expected to be fewer for age-0 coho than for age-1 coho. In addition, because age-1 coho were released in February and April, while age-0 coho were released in July, August, and September, the size of the first ocean summer zone (Figs. 2 and 3) was expected to be smaller for age-0 coho than for age-1 coho.

After deciding upon these criteria, scales in the unknown samples were examined and aged by two experienced readers, each working independently, and the age determinations for each fish were recorded on age-weight-length (A-W-L) forms. After this initial examination, in cases where there were discrepancies in the ages recorded by the two readers, scales were re-examined, and a freshwater age was agreed upon. In the few cases when no agreement on the

age of a particular fish was reached, the scale was not included in the final calculations of the age composition of the samples. In cases where a scale was regenerated, each reader determined the age of the scale using as many of the same criteria that were used for non-regenerated scales as possible.

Scale character measurement

A minicomputer-based fish scale digitizing system was used to measure 16 characters on each scale in samples of coho of both known and unknown age. Biological data and other descriptive information on each scale were entered on a CRT-terminal. The scale image, magnified 100X, was projected onto an electronic digitizing surface, and a hand-operated free-cursor was moved across the projected image to measure selected scale characters. All counts and measurements were made along a radius which was 17.5 degrees dorsad or ventrad from the anterior-posterior axis of the scale. The measurement radius was chosen in a manner similar to that described by Narver (1963). A FORTRAN program was used to interpret, format, and store the data. Biological data and other identifiers recorded for each digitized scale, their card-image format (column number) and an explanation, where necessary, are listed in Table 1. Scale character measurements or counts recorded from the digitized scale and their card-image format are listed in Table 2.

Statistical analyses

The age composition (percent frequency of freshwater age-0 and age-1 coho) was calculated for each sample of fish of unknown age from each facility using the ages determined by visual examination of scales. Two separate calculations,

Table 1. Biological data and other identifiers recorded for each digitized scale, their format (column no.(s)) on key punched cards, and an explanation, where necessary.

Identifier		Column No.(s)	Explanation
Fish number		1-2	Refers to "sp. no." on age-weight-length (A-W-L) forms.
Sex		3	1 = male, 2 = female
Length in mm		4	
Card number		7-9	Refers to "sample number" on A-W-L forms and number on acetate plastic scale impression card.
Date	Year	10-11	For standards (coded wire tagged fish) the date entered refers to the date of release. For unknowns the date entered refers to the date of sampling.
	Month	12-13	
	Day	14-15	
Facility		16	*1 = ORE-AQUA standard 2 = ORE-AQUA unknown *3 = Anadromous standard 4 = Anadromous unknown
Age		17-18	**The first column refers to the number of winters in freshwater; the second column refers to the number of winters in the ocean.
Length Type		19	1 = Tip of snout to fork of tail
Reader number		20	

*All fish in the ORE-AQUA and Anadromous standards are age 0.1 coded wire tagged coho released by Anadromous, Inc. in 1979. Anadromous standards include both OAF and Anadromous returns.

**For fish of unknown age, the age entered refers to the age determined by visual examination of scales.

Table 2. Scale character measuremements or counts recorded from the digitized scale and their format (column no.) on keypunched cards. Size measurements are in units of .01 inch at 100x.

Character No.	Measurement or Count	Column No.(s)
1	Number of circuli before the pre-ocean check	21-22
2	Size from focus to pre-ocean check	23-25
3	Number of circuli in the pre-ocean check	26-27
4	Size of the pre-ocean check from the outer edge of the first circulus in the check to the outer edge of the last circulus in the check before the onset of ocean growth	28-30
5-12	Eight fields of two digits recording the average interval between circuli for C0-C5 (5), C5-C10 (6), C10-C15 (7), C15-C20 (8), C20-C25 (9), C25-C30(10), C30-C35 (11), and C35-C40 (12), where C0 = the center of the scale nucleus, C5 = the fifth circulus after the center of the scale nucleus, and so on	31-46
13	Number of circuli in the first summer of ocean growth	47-48
14	Size of the first summer of ocean growth from the outer edge of the last circulus in the pre-ocean check to the last circulus before the start of the ocean annulus	49-51
15	Distance between C0 and C3 in the first summer of ocean growth, where C0 = the outer edge of the last circulus in the pre-ocean check	52-54
16	Distance between C3 and C6 in the first summer of ocean growth	55-57

one including and one not including ages for regenerated scales, were made.

Although we had originally planned to establish criteria for determining freshwater age from the results of frequency distribution analysis of characters on the scales of coded wire tagged coho of known freshwater age, and to re-examine the scales of fish in samples of unknown age using these criteria, the absence of tagged freshwater age-1 coho from 1979 releases in the samples collected by OAF and AI prevented this part of the analysis. However, descriptive statistics and frequency distributions of length and scale character data for age-0 and age-1 fish in the unknown samples as well as for age-0 fish in the coded wire tagged samples, were calculated to corroborate our age determination by visual examination of scales and to provide information for future determinations of age composition using scale measurement techniques.

The regression of the percent frequency of age-0 coho on sample date was calculated to provide a means of estimating the percentage of freshwater age-0 and age-1 coho at the two facilities on days when samples were not taken. This approach was considered when a strongly linear change in age composition was found. Samples collected by AI on October 3 and October 6, on October 17 and October 20, and on October 22 and October 24 were pooled, and given the coded mean sample dates of October 4, October 19, and October 23, respectively, for calculating the regressions. Sample date was coded so that the first sample date, September 4, was equal to day number 1. Percent age compositions used in this analysis included ages for regenerated scales.

RESULTS

A total of 1200 non-regnerated scales were assigned freshwater ages of either 0 or 1 by two scale readers, each working independently (Table 3). An initial comparison of the ages assigned to these scales by the two readers showed only 14 discrepancies. This number was reduced to four after a second examination of the scales by the two readers. These four scales were not included in the final calculations of age composition of the unknown samples.

Out of a total of 72 regenerated scales, 59 were assigned ages and 13 were too regenerated to determine an age (Table 3). The ratio of age-0 to age-1 salmon for non-regenerated scales was much higher (3:1) than the ratio for regnerated scales (1.2:1), indicating that age-1 coho may have a higher rate of scale loss.

A total of 1168 non-regnerated scales in the unknown samples were digitized (Table 3). Scales that were regenerated, scales with resorption bands, scales not taken from the preferred area of the fish (identified by their odd shape or small size relative to body length of the fish), and scales originally mounted with the sculptured surface down on the gummed cards were not digitized.

A total of 186 scales in the coded wire tag samples was digitized. All of these fish were freshwater age-0. Scales in this group were not digitized if they were not readable (e.g., regenerated scales). However, because of the small sample size, scales that did not appear to be taken from the preferred area of the fish were digitized and included in the analyses.

Table 3. Sample size, age classification, the total number of scales digitized (non-regenerated scales only), and the number of scales that were too regenerated to age for non-regenerated and regenerated scales in eight samples taken from coho salmon of unknown age at Oregon Aqua-Foods, Inc. and Anadromous, Inc. facilities in Coos Bay, Oregon from September 4, 1980 through October 24, 1980.

	OREGON AQUA-FOODS								ANADROMOUS, INC.							
	Non-Regenerated				Regenerated				Non-Regenerated				Regenerated			
Sample Date	Total #	Age Group 0	Age Group 1	Total digitized	Total #	Age Group 0	Age Group 1	N.A.*	Total #	Age Group 0	Age Group 1	Total digitized	Total #	Age Group 0	Age Group 1	N.A.*
09/04/80	49	49	0	48	2	0	0	2	23	23	0	23	3	3	0	0
09/12/80	93	86	7	92	5	4	0	1	97	94	3	96	3	3	0	0
09/19/80	26	22	4	26	3	2	0	1	95	91	4	93	5	3	2	0
09/26/80	161	113	48	155	10	2	4	4	96	84	12	94	4	2	1	1
10/03-06/80	98	57	39	94	2	1	1	0	97	79	18	97	3	2	1	0
10/10/80	90	43	46	86	10	2	5	3	92	73	19	92	6	2	4	0
10/17-20/80	41	9	31	37	1	1	0	0	21	13	8	20	2	2	0	0
10/22-24/80	49	11	38	45	8	2	5	1	72	50	22	70	5	1	4	0
Total	607[a]	390	213	583	41	14	15	12	593	507	86	585	31	18	12	1

*N.A. = Scale was too regenerated to age.

[a]Four scales in this total were not used because of discrepancies in ages assigned by two readers.

Age determination by visual examination

The percent age composition of coho salmon in the unknown samples resulting from age determination by visual examination is shown in Table 4 and Table 5. In Table 4 only non-regenerated scales were included in the calculations, and in Table 5 both non-regnerated and "readable" regenerated scales were included. No freshwater age-1 coho salmon were present in samples taken at the two facilities on the first sample date (Tables 4 and 5). After the first sample date, the percentage of freshwater age-1 coho gradually increased and the percentage of age-0 coho gradually decreased in samples taken at both facilities until the second to the last sample date. The age compositions of the last two collections were similar at both facilities. With the exception of the first sample date, the percentage of age-0 coho in samples taken at OAF was always less than the percentage of age-0 coho in samples taken at AI. In addition, the percentage of age-0 coho in the samples decreased much more rapidly over the sample period in samples taken at OAF than in samples taken at AI.

Descriptive statistics and frequency distribution analysis of length and scale characters

Means and standard deviations of fork lengths and ten scale characters of age-0 and age-1 coho salmon in the eight samples of fish of unknown age taken at OAF and AI facilities are shown in Tables 6-9. In general, scale characters listed in Table 2 that had missing values in most of the samples were not included in these tables. With the exception of age-0 coho taken in samples at OAF on September 4 (Table 6), the mean values of length and scale characters calculated for age-0 coho at the two facilities on the various sample dates were very similar. The low mean values calculated for the number of circuli before the pre-ocean check (character no. 1) and the size of the scale from the focus to the pre-ocean check (character no. 2)

Table 4. Freshwater age composition of coho salmon in eight samples of fish of unknown age returning to Oregon Aqua-Foods, Inc. and Anadromous, Inc. facilities in Coos Bay, Oregon in 1980 as determined by visual examination of scales.*

Unknown Sample No.	Date	Oregon Aqua-Foods, Inc.					Anadromous, Inc.				
		Age-0		Age-1		Sample Size*	Age-0		Age-1		Sample Size*
		#	%	#	%		#	%	#	%	
0	09/04/80	49	100.0	0	0	49	23	100.0	0	0	23
I	09/12/80	86	92.5	7	7.5	93	94	96.9	3	3.1	97
II	09/19/80	22	84.6	4	15.4	26	91	95.8	4	4.2	95
III	09/26/80	113	70.2	48	29.8	161	84	87.5	12	12.5	96
IV	10/03-06/80	57	59.4	39	40.6	96	79	81.4	18	18.6	97
V	10/10/80	43	48.3	46	51.7	89	73	79.3	19	20.7	92
VI	10/17-20/80	9	22.5	31	77.5	40	13	61.9	8	38.1	21
VII	10/22-24/80	11	22.4	38	77.6	49	50	69.4	22	30.6	72

*Sample size includes non-regenerated scales only.

Table 5. Freshwater age composition of coho salmon in eight samples of fish of unknown age returning to Oregon Aqua-Foods, Inc. and Anadromous, Inc. facilities in Coos Bay, Oregon in 1980 as determined by visual examination of scales.*

Unknown Sample No.	Date	Oregon Aqua-Foods, Inc.					Anadromous, Inc.				
		Age-0		Age-1		Sample* Size	Age-0		Age-1		Sample* Size
		#	%	#	%		#	%	#	%	
0	09/04/80	49	100.0	0	0	49	26	100.0	0	0	26
I	09/12/80	90	92.8	7	7.2	97	97	97.0	3	3.0	100
II	09/19/80	24	85.7	4	14.3	28	94	94.0	6	6.0	100
III	09/26/80	115	68.9	52	31.1	167	86	86.9	13	13.1	99
IV	10/03-06/80	58	59.2	40	40.8	98	81	81.0	19	19.0	100
V	10/10/80	45	46.9	51	53.1	96	75	76.5	23	23.5	98
VI	10/17-20/80	10	24.4	31	75.6	41	15	65.2	8	34.8	23
VII	10/22-24/80	13	23.2	43	76.8	56	51	66.2	26	33.8	77

*Sample size includes non-regenerated scales plus "readable" regenerated scales.

Table 6. Mean and standard deviation of fork length and ten characters on the scales of freshwater age-0 coho salmon in eight samples of fish of unknown age taken at Oregon Aqua-Foods, Inc. recapture facilities on Coos Bay, Oregon from September 4 through October 24, 1980. Tabled values are rounded to the nearest integer.

Sample Data and Sample Size	Mean ($\bar{X}$) and Standard deviation (S.D.)	Length (mm)	Character Number*									
			1	2	3	4	5	6	7	13	14	15
9/04/80	$\bar{X}$	-**	16	203	4	36	16	11	-	14	212	43
n = 48	S.D.	-	3	47	2	15	3	2	-	4	59	7
09/12/80	$\bar{X}$	600	20	268	5	44	17	11	13	14	235	45
n = 85	S.D.	37	3	38	2	17	2	1	2	4	4	8
09/19/80	$\bar{X}$	610	20	270	5	43	18	11	13	14	236	42
n = 22	S.D.	39	3	43	2	17	1	1	1	2	55	7
09/26/80	$\bar{X}$	609	20	271	4	36	18	12	13	15	246	43
n = 109	S.D.	44	3	44	2	15	2	1	2	4	67	9
10/03/80	$\bar{X}$	610	19	260	5	42	17	11	13	14	240	44
n = 55	S.D.	45	3	38	2	19	2	2	1	4	75	9
10/10/80	$\bar{X}$	611	19	259	5	46	18	12	12	15	239	42
n = 43	S.D.	45	3	44	2	20	2	1	1	4	66	9
10/17/80	$\bar{X}$	642	19	260	5	40	17	12	13	15	250	46
n = 9	S.D.	52	3	29	1	12	3	2	2	4	55	8
10/24/80	$\bar{X}$	638	20	268	5	47	18	11	12	18	319	49
n = 9	S.D.	39	4	38	2	13	2	2	2	4	72	11
Total	$\bar{X}$	609[a]	19	258	5	41	17	11	13[b]	15	239	44
n = 380	S.D.	43	3	47	2	17	2	1	2	4	67	9

*Character number refers to character no. and description of measurement or count in Table 2.

**Dash indicates statistics were not calculated because of missing values.

[a] n = 332

[b] n = 378

Table 7. Mean and standard deviation of fork length and ten characters on the scales of freshwater age-0 coho salmon in eight samples of fish of unknown age taken at Anadromous, Inc. recapture facilities on Coos Bay, Oregon from September 4 through October 24, 1980. Tabled values are rounded to the nearest integer.

Sample Date and Sample Size	Mean ($\bar{X}$) and standard deviation (S.D.)	Length (mm)	Character Number*									
			1	2	3	4	5	6	7	13	14	15
09/04/80	$\bar{X}$	-**	19	259	5	40	18	11	13	16	264	43
n = 23	S.D.	-	2	30	2	14	2	1	2	4	67	9
09/12/80	$\bar{X}$	587	20	260	5	39	17	11	12	15	248	46
n = 94	S.D.	38	3	35	2	15	2	1	2	4	63	9
09/19/80	$\bar{X}$	605	20	271	5	41	18	11	13	15	260	46
n = 89	S.D.	40	3	40	2	15	2	1	2	4	70	9
09/26/80	$\bar{X}$	603	20	266	5	39	18	12	13	15	243	42
n = 82	S.D.	41	3	40	2	14	2	2	2	4	71	8
10/03-06/80	$\bar{X}$	613	19	272	5	40	18	12	13	16	256	46
n = 79	S.D.	45	3	40	2	17	2	1	2	4	64	9
10/10/80	$\bar{X}$	605	20	274	4	36	18	11	13	16	260	44
n = 73	S.D.	40	3	39	2	16	2	1	2	3	56	7
10/17-20/80	$\bar{X}$	603	19	253	4	40	19	11	12	16	250	42
n = 12	S.D.	37	4	44	2	15	2	1	1	4	65	6
10/22-24/80	$\bar{X}$	613	19	265	5	38	18	12	13	15	254	45
n = 48	S.D.	47	3	43	2	14	2	1	2	4	61	8
Total	$\bar{X}$	603[a]	20	267	5	39	18	11	13	15	254	44
n = 500	S.D.	42	3	39	2	15	2	1	2	4	65	9

*Character number refers to character no. and description of measurement or count in Table 2.

**Dash indicates that statistics were not calculated because of missing values.

[a]n = 477.

Table 8. Mean and standard deviation of fork length and ten characters on the scales of freshwater age-1 coho salmon in seven samples of fish of unknown age taken at Oregon Aqua-Foods, Inc. recapture facilities on Coos Bay, Oregon from September 12 through October 24, 1980. Tabled values are rounded to the nearest integer.

Sample Date and Sample Size	Mean ($\bar{X}$) and standard deviation (S.D.)	Length (mm)	Character Number*									
			1	2	3	4	5	6	7	13	14	15
09/12/80	$\bar{X}$	615	14	151	13	99	14	9	8	32	574	47
n = 7	S.D.	43	3	36	4	43	1	1	2	4	89	13
09/19/80	$\bar{X}$	635	13	145	12	92	14	9	8	37	639	40
n = 4	S.D.	12	4	35	5	55	2	2	2	4	80	8
09/26/80	$\bar{X}$	650	10	123	16	117	15	9	8	34	582	37
n = 46	S.D.	48	3	31	4	34	2	1	1	5	99	8
10/03/80	$\bar{X}$	644	10	128	16	121	15	9	8	32	562	40
n = 39	S.D.	40	3	34	4	40	2	2	2	4	72	7
10/10/80	$\bar{X}$	652	10	124	18	141	15	9	8	31	559	40
n = 43	S.D.	55	3	31	4	37	2	2	1	5	92	7
10/17/80	$\bar{X}$	664	11	132	16	131	15	9	8	33	576	43
n = 28	S.D.	55	3	37	5	47	2	1	2	4	81	9
10/24/80	$\bar{X}$	663	10	126	18	138	15	9	8	32	567	43
n = 36	S.D.	52	3	37	4	37	2	2	2	6	97	7
Total	$\bar{X}$	652	11	127	16	127	15	9	8	33	571	40
n = 203	S.D.	50	3	34	4	40	2	1	2	5	89	8

*Character number refers to character no. and description of measurement or count in Table 2.

Table 9. Mean and standard deviation of fork length and ten characters on the scales of freshwater age-1 coho salmon in seven samples of fish of unknown age taken at Anadromous, Inc. recapture facilities on Coos Bay, Oregon from September 12 through October 24, 1980. Tabled values are rounded to the nearest integer.

Sample Date and Sample Size	Mean ($\bar{X}$) and standard deviation (S.D.)	Length (mm)	Character Number*								
			1	2	3	4	5	6	7	13	14	15
09/12/80	$\bar{X}$	600	9	116	19	151	16	8	8	41	776	33
n = 2	S.D.	31	7	69	1	8	1	0	0	13	206	11
09/19/80	$\bar{X}$	659	12	126	16	129	14	8	8	32	550	48
n = 4	S.D.	69	4	27	5	53	2	2	1	4	46	10
09/26/80	$\bar{X}$	613	9	120	19	158	15	10	8	32	557	43
n = 12	S.D.	52	3	33	3	34	2	1	1	5	93	9
10/03-06/80	$\bar{X}$	621	10	122	19	156	15	9	8	31	561	45
n = 18	S.D.	51	3	27	5	47	1	1	1	4	77	11
10/10/80	$\bar{X}$	626	10	122	20	160	15	9	8	30	561	45
n = 19	S.D.	43	2	22	3	21	2	2	1	4	90	7
10/17-20/80	$\bar{X}$	641	10	131	18	140	17	9	7	36	626	47
n = 8	S.D.	35	3	26	3	33	1	1	1	3	44	5
10/22-24/80	$\bar{X}$	654	11	133	19	150	16	9	7	32	573	43
n = 22	S.D.	50	4	48	4	36	1	1	1	4	75	9
Total	$\bar{X}$	633	10	126	19	153	15	9	8	32	576	44
n = 85	S.D.	50	3	34	4	35	2	1	1	5	87	9

*Character number refers to character no. and description of measurement or count in Table 2.

for age-0 coho taken in samples at OAF on September 4 (Table 6) indicate that these scales were perhaps not taken from the preferred area of the fish. However, because length data were not provided with this sample, this supposition cannot be verified. The mean values of length and scale characters calculated for age-1 coho from OAF and AI (Tables 8 and 9), although still fairly similar, were more variable than the values calculated for age-0 fish. This can be attributed, primarily, to the small sample sizes, and also to the fact that age-1 coho represented two different "stocks" of fish (i.e., fish released from OAF and fish released from AI).

Sample size, mean, standard deviation, and range of fork lengths and 14 scale characters calculated for pooled samples of age-0 and age-1 coho salmon taken at both facilities on all sample dates, and for combined samples of coded wire tagged age-0 coho returning to both facilities are shown in Table 10. Characters 11 and 12 (Table 2) were not included in this table because almost no fish had over 30 circuli in the pre-ocean zone. A comparison of the mean values of length and scale characters of age-0 coho and coded wire tagged age-0 coho shows that coded wire tagged coho are smaller in size than age-0 coho in the unknown samples, and the mean values of most of the scale characters calculated for age-0 coded wire tagged coho are less than those calculated for age-0 coho in the samples of fish of unknown age. However, mean values of scale characters calculated for coded wire tagged age-0 fish are far more similar to those for determined age-0 fish than to values calculated for determined age-1 fish.

The values shown in Table 10 for coded wire tagged age-0 fish were broken down by month of release in Table 11. The number of circuli (character no. 1) and the size of the scale before the pre-ocean check

Table 10. Sample size, mean, standard deviation, and range of fork lengths and 14 characters on the scales of coho salmon of unknown freshwater age classified as age-0, and age-1, and coho salmon of known freshwater age (age-0) for combined samples taken at Oregon Aqua-Foods, Inc. and Anadromous, Inc. recapture facilities on Coos Bay, Oregon in 1980.

Freshwater Age and Sample Classification	n, $\bar{x}$, S.D., R*	Fork length (mm)	Scale Character Number**													
			1	2	3	4	5	6	7	8	9	10	13	14	15	16
Age-0 Unknowns	n	809	880	880	880	880	880	880	878	818	490	49	880	880	880	875
	$\bar{x}$	605	19	263	5	40	18	11	13	11	10	9	15	247	44	46
	S.D.	43	3	43	2	16	2	1	2	2	2	2	4	66	9	11
	R	490-	9-	103-	2-	10-	3-	6-	7-	6-	6-	7-	4-	63-	24-	20-
		718	29	411	15	125	23	16	18	19	16	14	29	484	75	82
Age-1 Unknowns	n	288	288	288	288	288	288	288	288	283	229	96	288	288	288	288
	$\bar{x}$	646	10	127	17	135	15	9	8	8	8	9	32	572	42	42
	S.D.	50	3	34	4	41	2	1	2	1	2	2	5	88	8	8
	R	500-	2-	50-	6-	33-	9-	5-	5-	4-	4-	5-	20-	344-	25-	25-
		790	27	309	29	282	20	13	14	12	14	14	50	922	67	76
Age-0 Knowns	n	185	186	186	186	186	186	186	183	131	45	2	186	186	186	178
	$\bar{x}$	563	18	223	4	30	16	11	11	10	10	12	13	200	44	44
	S.D.	52	3	45	1	12	2	1	2	2	2	0	4	61	9	9
	R	430-	10-	132-	2-	12-	13-	8-	7-	6-	6-	12	4-	49-	23-	25-
		667	29	384	10	78	22	15	17	14	16		21	349	73	64

* n = sample size, $\bar{x}$ = mean, S.D. = standard deviation, R = range.

** Character number refers to character no. and description of measurement or count in Table 2.

Table 11. Sample size, mean, standard deviation, and range of fork length and 14 characters on the scales of freshwater age-0 coded wire tagged coho salmon released from Anadromous, Inc. facilities on Coos Bay, Oregon in July, August, and September 1979, and returning to Anadromous, Inc. and Oregon Aqua Foods, Inc. recapture facilities on Coos Bay in 1980.

Month of Release	n, $\bar{x}$, S.D., R*	Fork length (mm)	Scale Character Number**													
			1	2	3	4	5	6	7	8	9	10	13	14	15	16
July[a]	n	32	33	33	33	33	33	33	32	24	7	0	33	33	33	32
	$\bar{x}$	550	18	217	4	28	16	10	10	10	8	-	14	232	47	43
	S.D.	55	3	36	1	12	2	1	1	1	1	-	3	61	9	8
	R	430-	12-	148-	2-	12-	13-	8-	8-	8-	6-		5-	77-	32-	25-
		667	26	296	6	58	20	13	14	13	10	-	20	349	66	63
August[b]	n	141	141	141	141	141	141	141	139	95	28	0	141	141	141	138
	$\bar{x}$	567	18	221	4	30	17	11	11	10	10	-	13	200	42	43
	S.D.	51	3	44	1	13	2	1	2	2	2	-	3	54	8	9
	R	440-	10-	132-	2-	12-	13-	8-	7-	6-	8-	-	4-	59-	23-	26-
		660	25	338	10	78	22	15	17	14	14	-	21	345	72	64
September[c]	n	12	12	12	12	12	12	12	12	12	10	2	12	12	12	8
	$\bar{x}$	551	23	272	3	28	16	10	10	10	10	12	7	117	52	52
	S.D.	43	4	55	1	8	1	1	1	2	2	0	3	58	9	6
	R	501-	18-	199-	2-	21-	14-	9-	8-	8-	7-		4-	49-	35-	41-
		641	29	384	5	45	18	11	13	13	16	12	16	268	73	59

*n = sample size, $\bar{x}$ = mean, S.D. = standard deviation, R = range.

**Character number refers to character no. and description of measurement or count in Table 2.

[a]All the coded wire tagged salmon released in July were from one tag group released on July 30, 1980.

[b]Coded wire tagged salmon released in August represent 13 different tag groups released from August 6 through August 22, 1980.

[c]All the coded wire tagged salmon released in September were from one tag group released on September 5, 1980.

(character no. 2) is much greater, and the number of circuli (character no. 13) and the size of the scale in the first summer of ocean growth (character no. 14) is much smaller for fish released in September than for fish released in July and August.

The overlap in frequency distributions of fork lengths and nine scale characters of determined age-0 and age-1 fish and coded wire tagged age-0 fish are shown in figures 4-13. In general, only scale characters that showed a difference in mean values among these groups (Table 10) were included in these figures. As with the mean values of length and scale character data calculated for these three groups (Table 10), these plots show the difference in length and scale character distributions between determined age-0 fish and coded wire tagged age-0 fish, and the usually good separation between age-1 fish and both groups of age-0 fish.

Regression of percent age composition on sample date

Regressions of the percent frequencies of age-0 coho in the samples of fish of unknown age on sample day for fish returning to OAF and AI facilities are shown in Figure 14 and Figure 15, respectively. The equation calculated for age-0 fish returning to OAF was: $Y = -1.69X + 107.15$; ($r^2 = .98$), and the equation calculated for age-0 fish returning to AI was: $Y = -.76X + 103.58$; ($r^2 = .98$). These are highly significant linear relationships, and should be useful in predicting the percentages of freshwater age-0 and age-1 coho at each facility on a particular sample date.

DISCUSSION

Validity of age determination by visual examination

None of the approximately 10,000 coded wire tagged freshwater age-1 coho released by AI in February 1979 were present in samples of coded wire

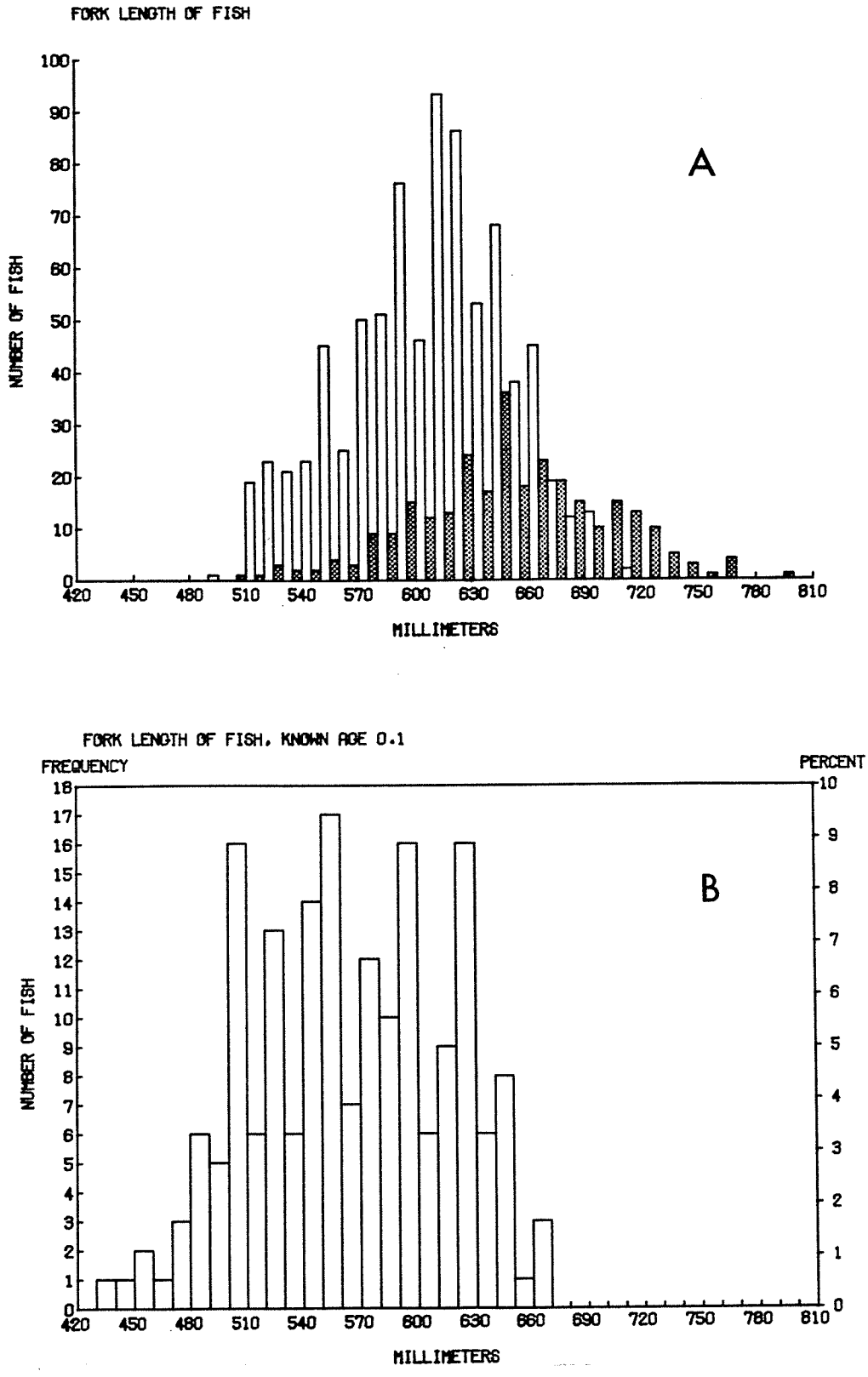


Figure 4. Overlap in frequency distributions of fork lengths of A) coho salmon of unknown freshwater age classified as age-0 (white bars) and age-1 (stippled bars), and B) coho salmon of known freshwater age (age-0) for combined samples taken at Oregon Aqua-Foods, Inc. and Anadromous, Inc. recapture facilities on Coos Bay, Oregon in 1980.

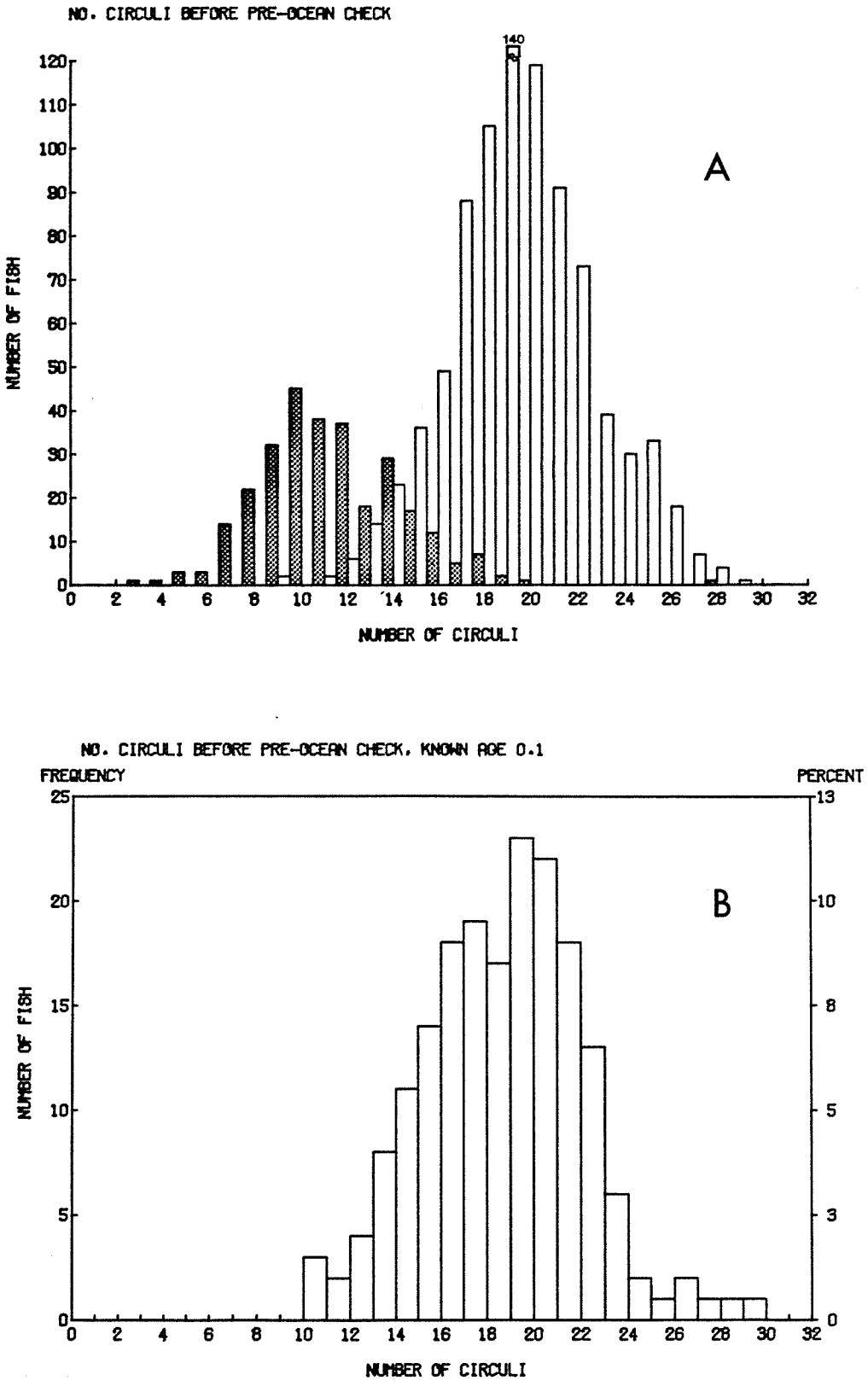


Figure 5. Overlap in frequency distributions of the number of circuli before the pre-ocean check counted on the scales of A) coho salmon of unknown freshwater age classified as age-0 (white bars) and age-1 (stippled bars) and B) coho salmon of known freshwater age (age-0) for combined samples taken at Oregon Aqua-Foods, Inc. and Anadromous, Inc. recapture facilities on Coos Bay, Oregon in 1980.

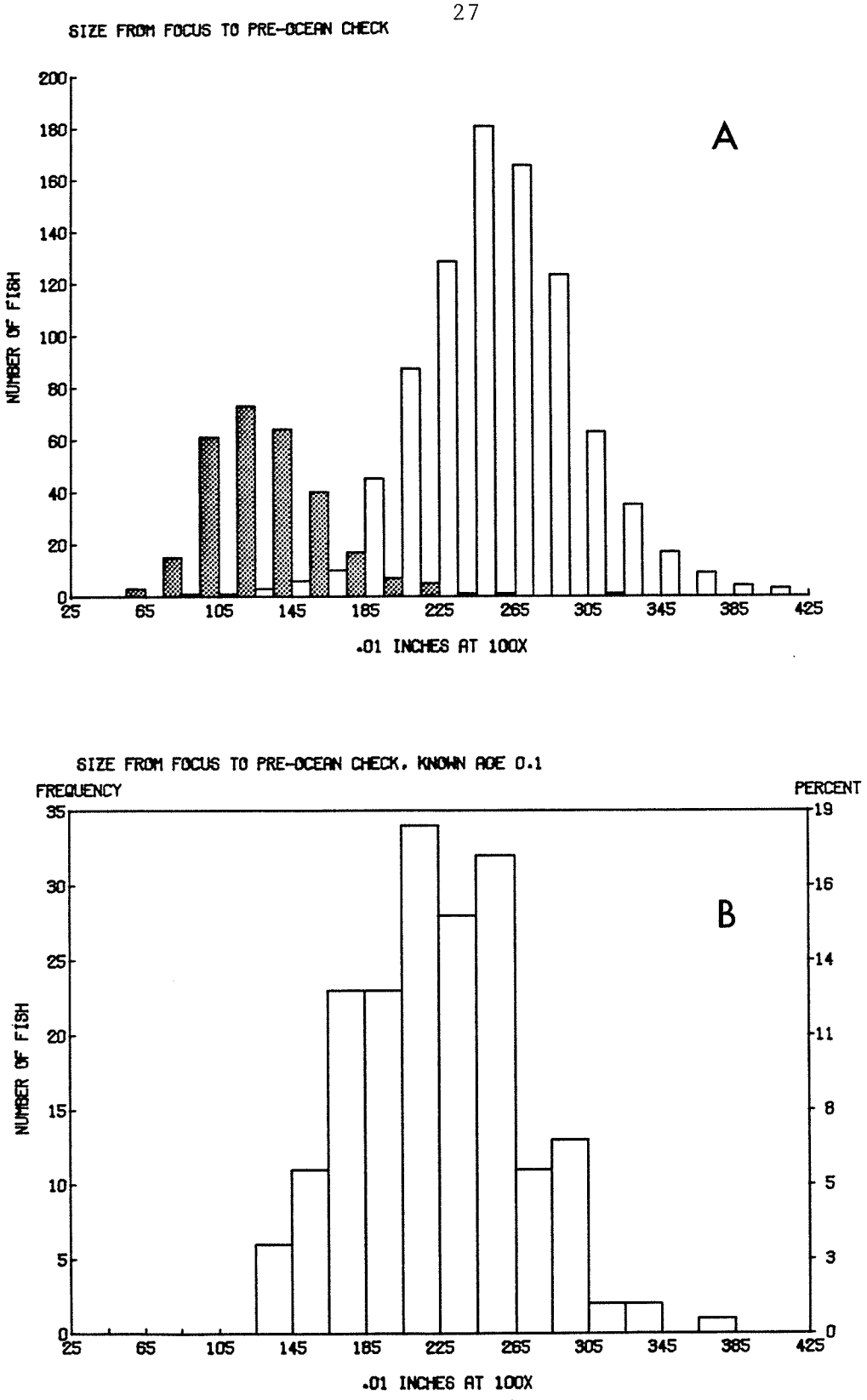


Figure 6. Overlap in frequency distributions of the size from the focus to the pre-ocean check measured on the scales of A) coho salmon of unknown freshwater age classified as age-0 (white bars) and age-1 (stippled bars) and B) coho salmon of known freshwater age (age-0) for combined samples taken at Oregon Aqua-Foods, Inc. and Anadromous, Inc. recapture facilities on Coos Bay, Oregon in 1980.

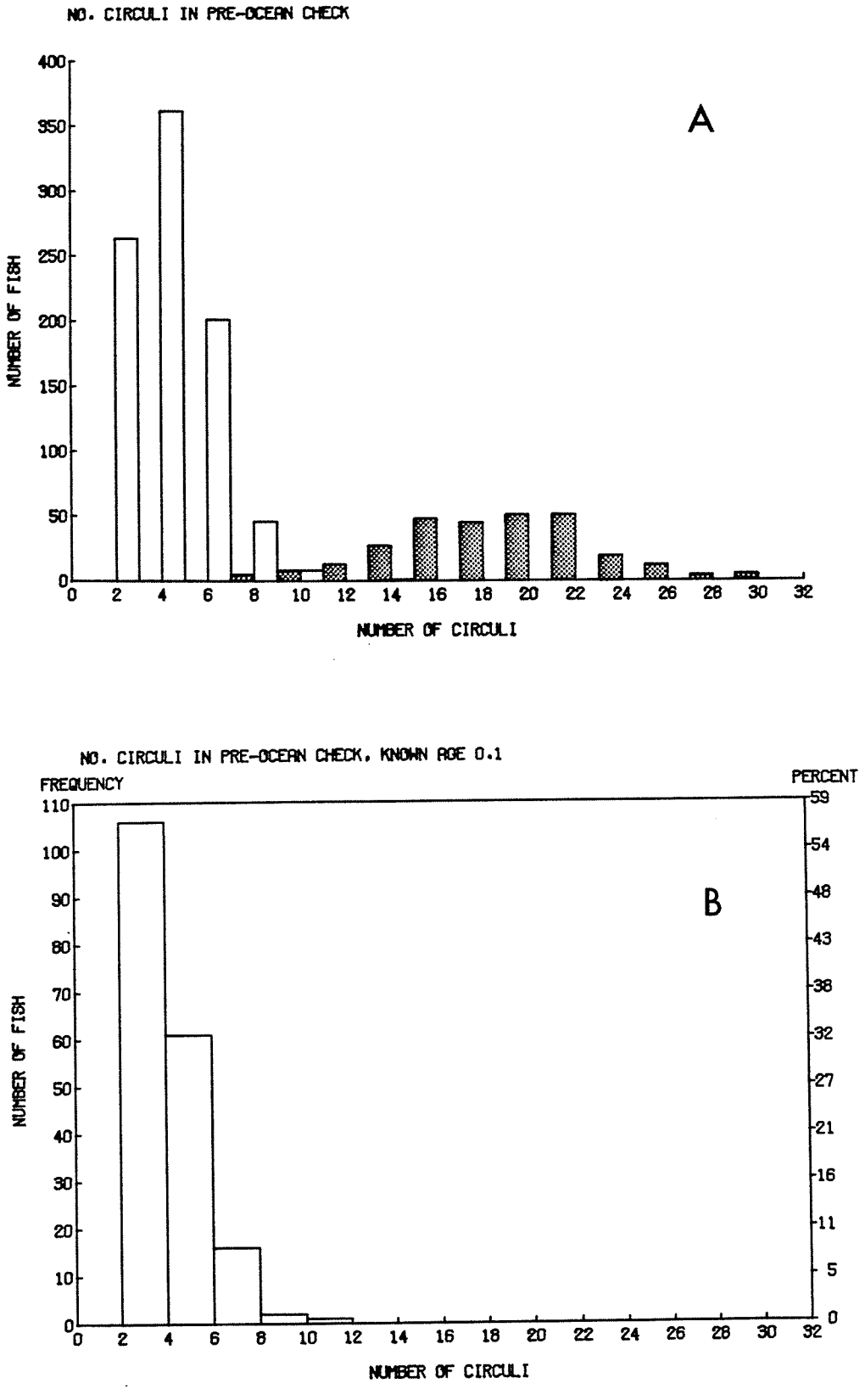
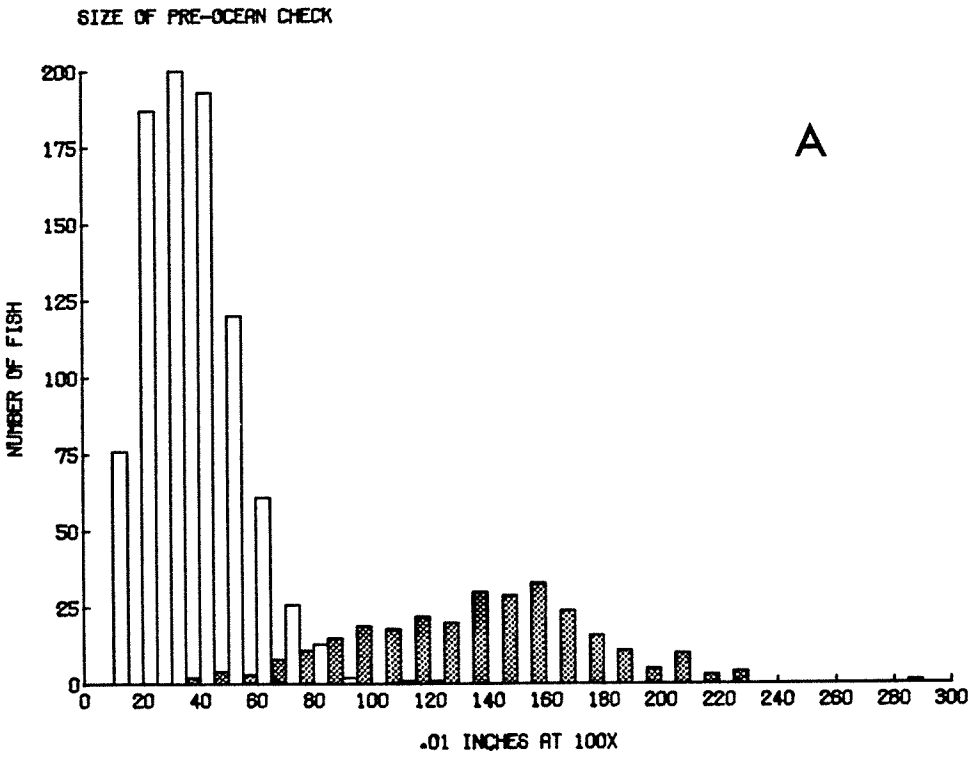


Figure 7. Overlap in frequency distributions of the number of circuli in the pre-ocean check counted on the scales of A) coho salmon of unknown freshwater age classified as age-0 (white bars) and age-1 (stippled bars) and B) coho salmon of known freshwater age (age-0) for combined samples taken at Oregon Aqua-Foods, Inc. and Anadromous, Inc. recapture facilities on Coos Bay, Oregon in 1980.



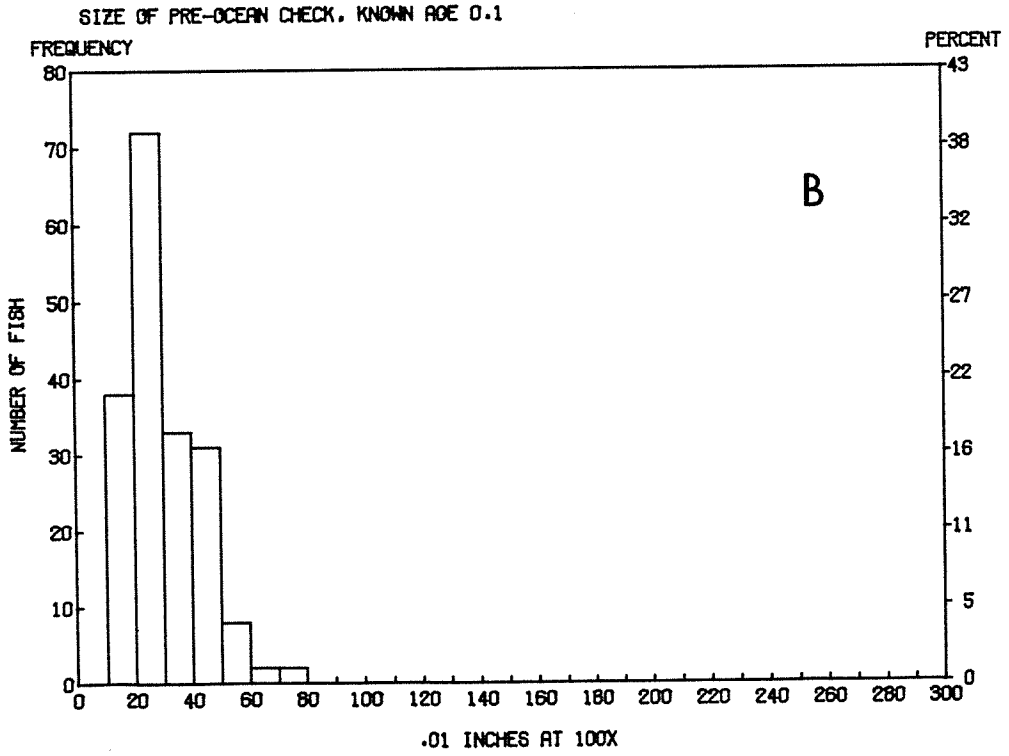
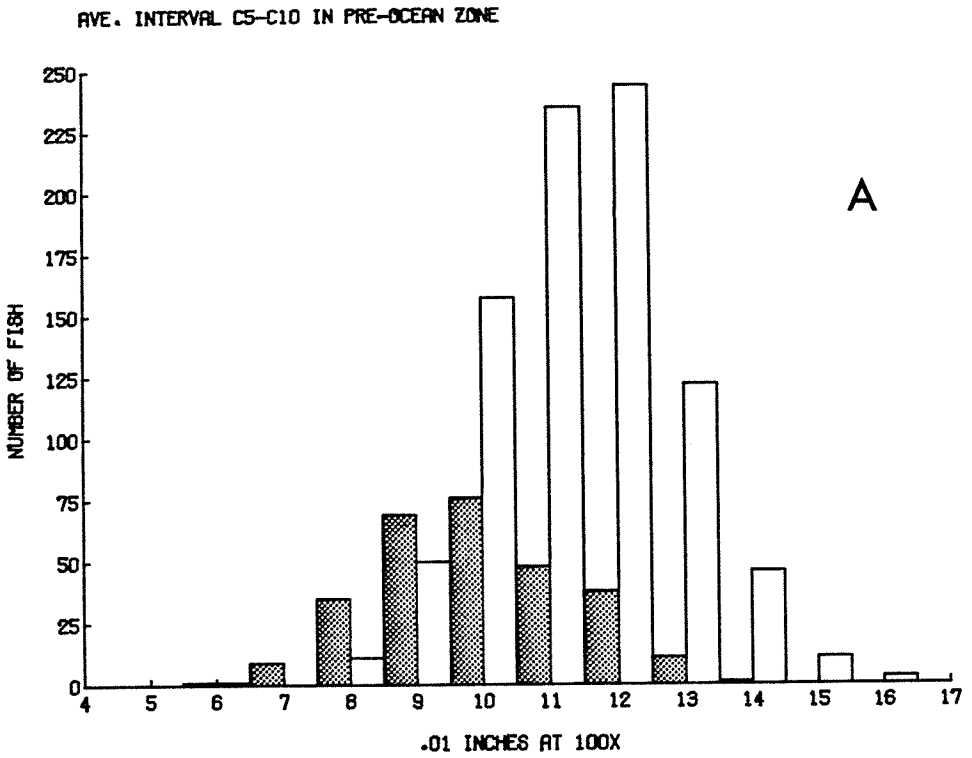


Figure 8. Overlap in frequency distributions of the size of the pre-ocean check measured on the scales of A) coho salmon of unknown freshwater age classified as age-0 (white bars) and age-1 (stippled bars) and B) coho salmon of known freshwater age (age-0) for combined samples taken at Oregon Aqua-Foods, Inc. and Anadromous, Inc. recapture facilities on Coos Bay, Oregon in 1980.



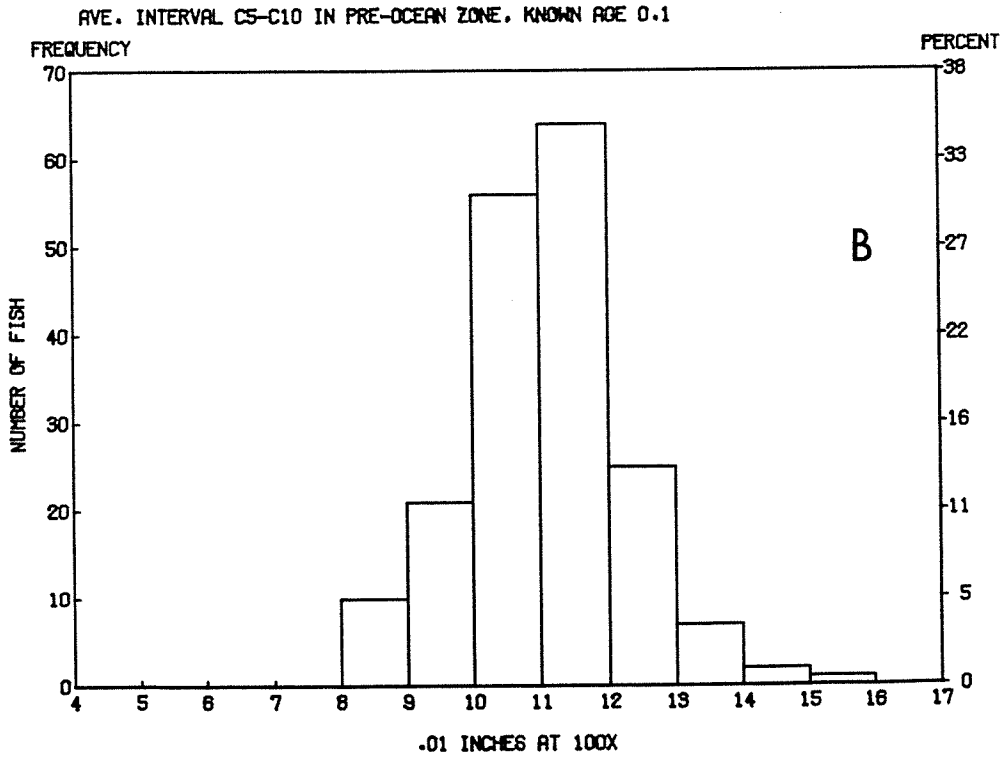
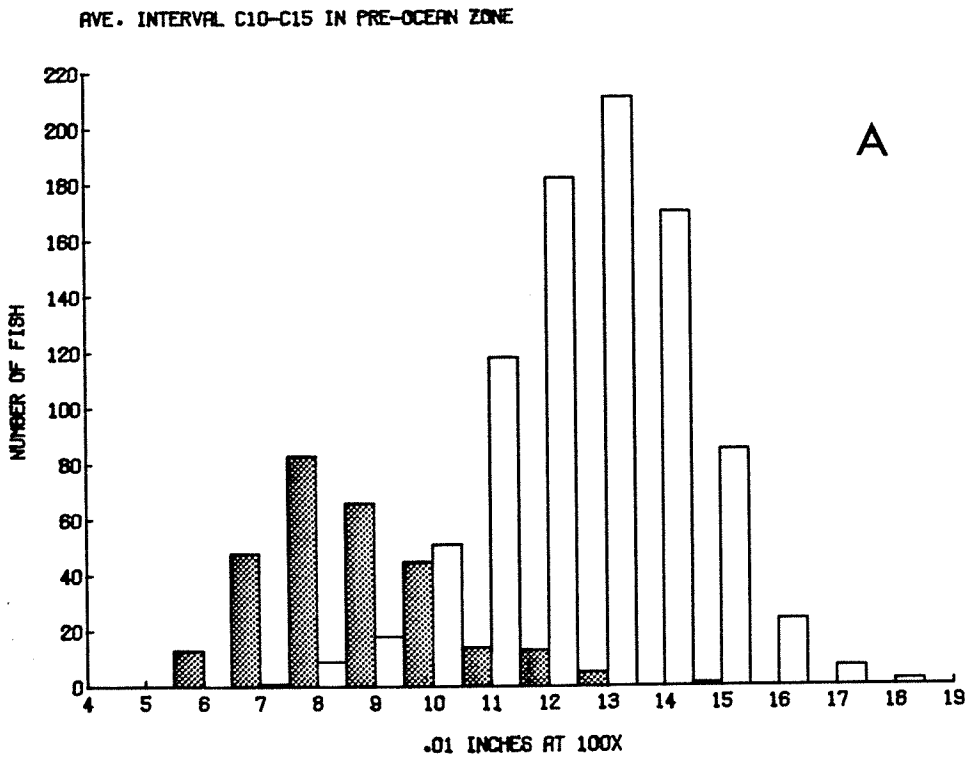


Figure 9. Overlap in frequency distributions of the average interval between circuli measured for the fifth through the tenth circulus in the pre-ocean zone on the scales of A) coho salmon of unknown freshwater age classified as age-0 (white bars) and age-1 (stippled bars) and B) coho salmon of known freshwater age (age-0) for combined samples taken at Oregon Aqua-Foods, Inc. and Anadromous, Inc. recapture facilities on Coos Bay, Oregon in 1980.



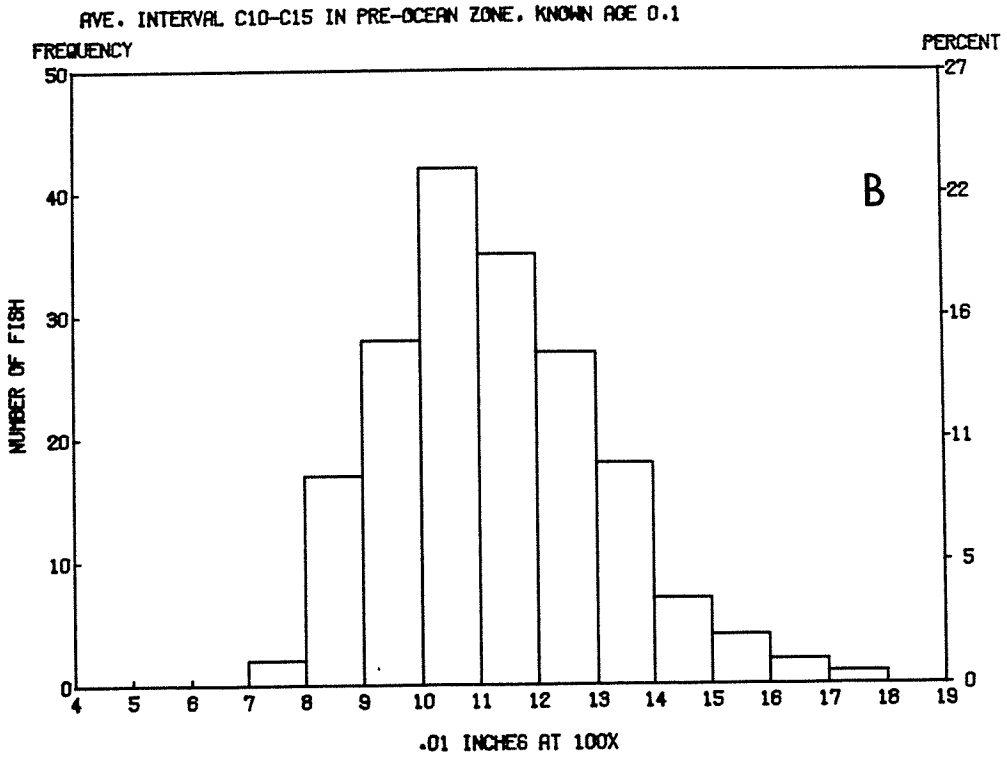


Figure 10. Overlap in frequency distributions of the average interval between circuli measured for the tenth through the fifteenth circulus in the pre-ocean zone on the scales of A) coho salmon of unknown freshwater age classified as age-0 (white bars) and age-1 (stippled bars) and B) coho salmon of known freshwater age (age-0) for combined samples taken at Oregon Aqua-Foods, Inc. and Anadromous, Inc. recapture facilities on Coos Bay, Oregon in 1980.

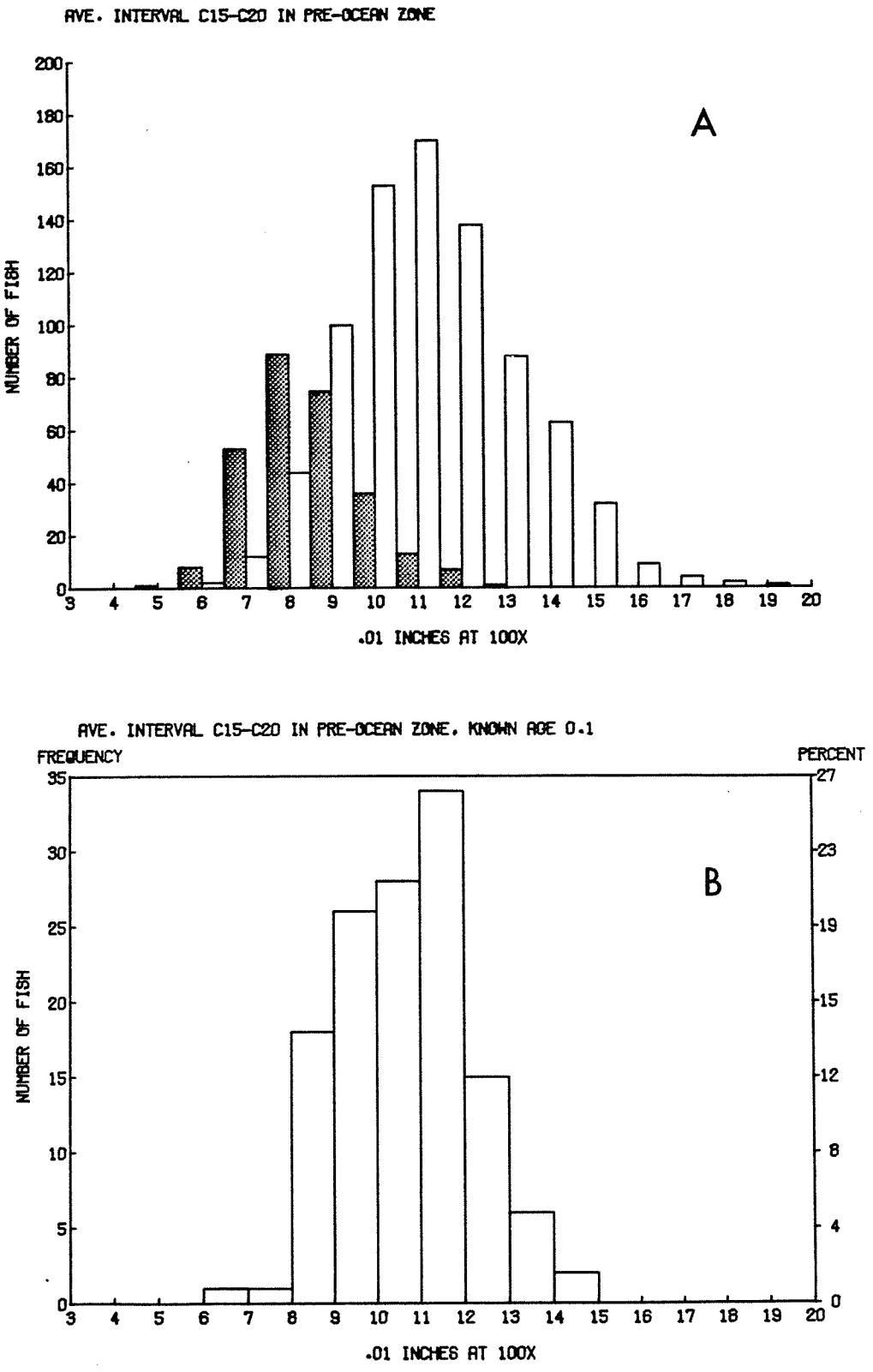


Figure 11. Overlap in frequency distributions of the average interval between circuli measured for the fifteenth through the twentieth circulus in the pre-ocean zone on the scales of A) coho salmon of unknown freshwater age classified as age-0 (white bars) and age-1 (stippled bars) and B) coho salmon of known freshwater age (age-0) for combined samples taken at Oregon Aqua-Foods, Inc. and Anadromous, Inc. recapture facilities on Coos Bay, Oregon in 1980.

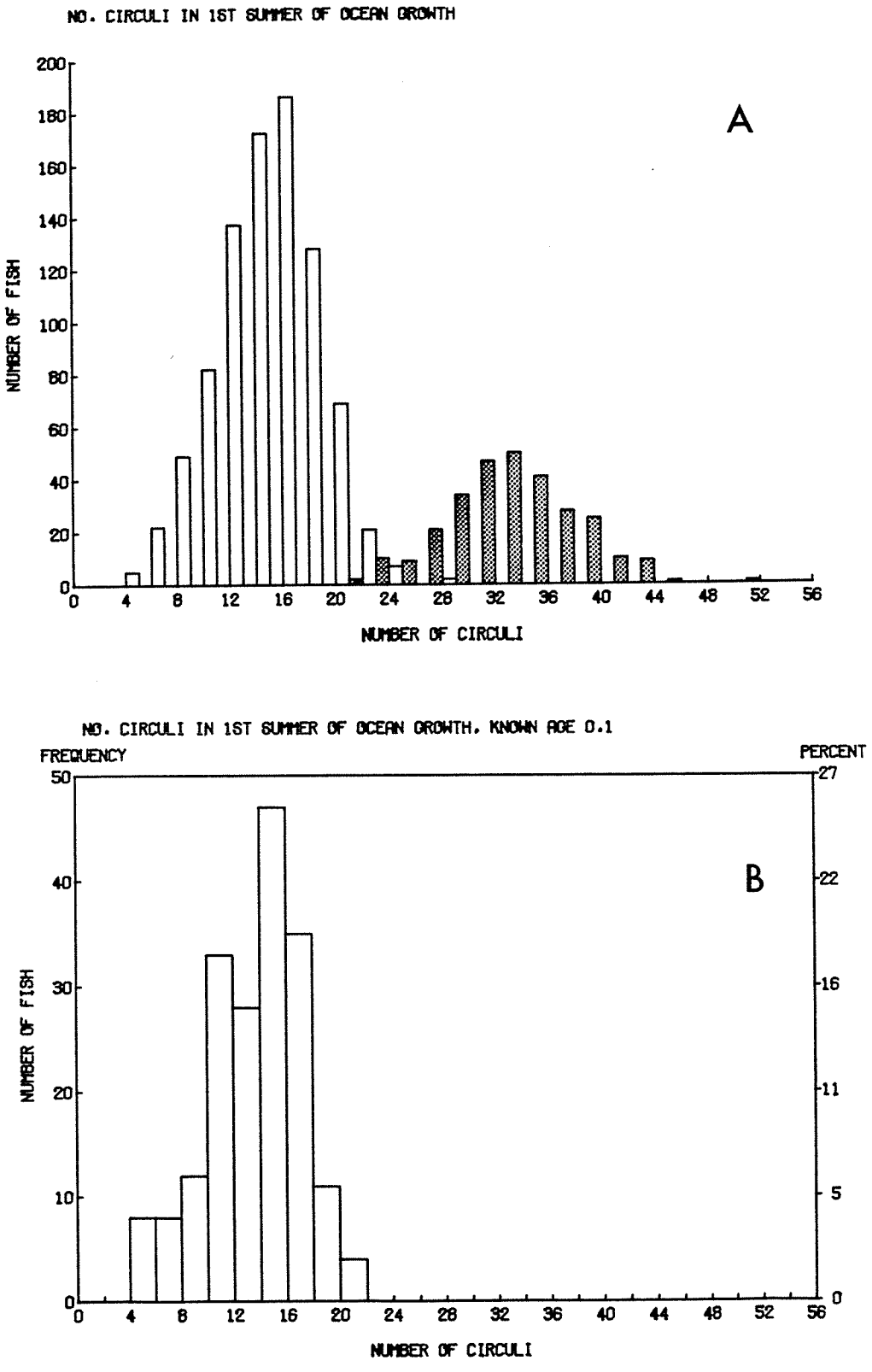


Figure 12. Overlap in frequency distributions of the number of circuli in the first summer of ocean growth counted on the scales of A) coho salmon of unknown freshwater age classified as age-0 (white bars) and age-1 (stippled bars) and B) coho salmon of known freshwater age (age-0) for combined samples taken at Oregon Aqua-Foods, Inc. and Anadromous, Inc. recapture facilities on Coos Bay, Oregon in 1980.

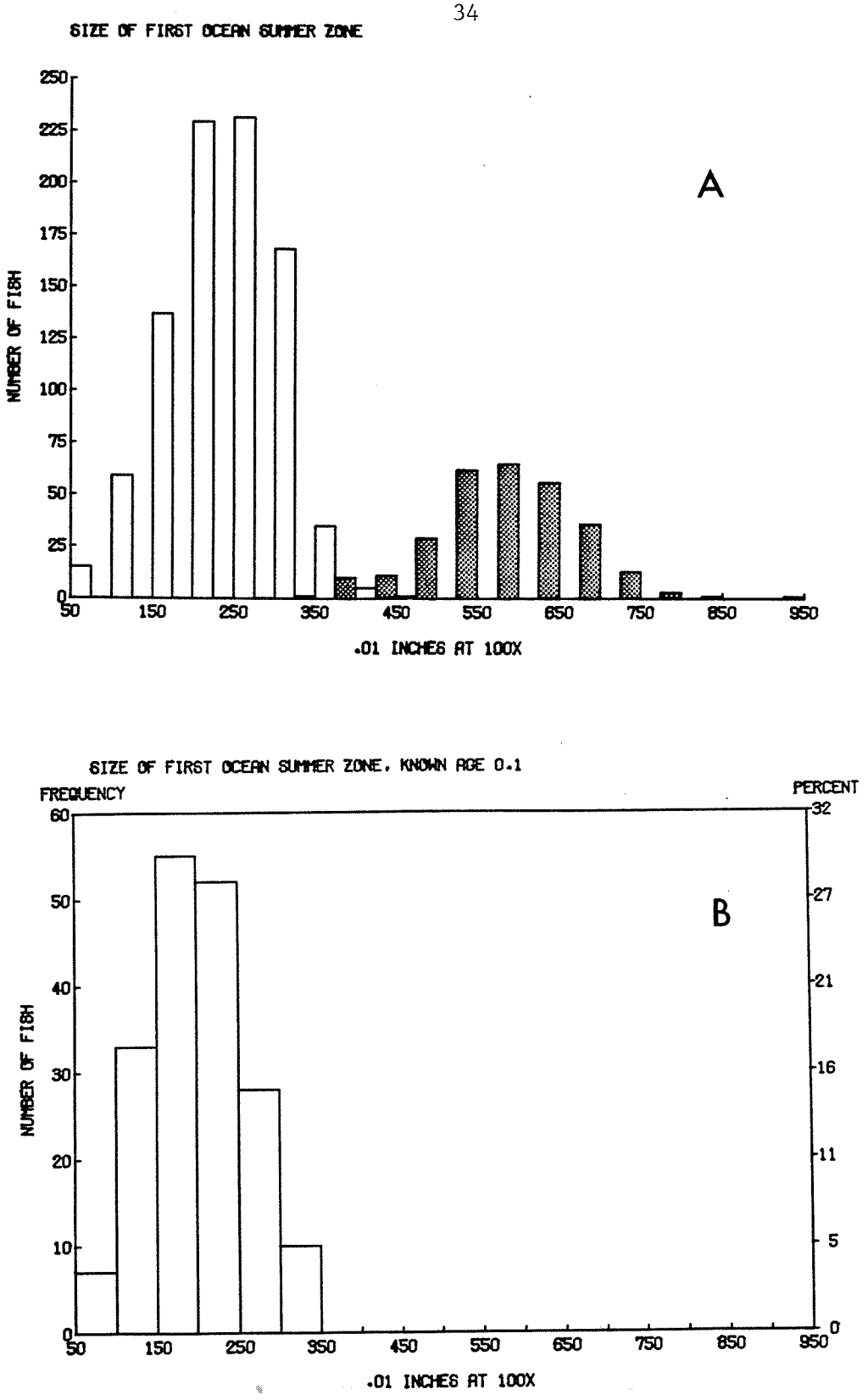


Figure 13. Overlap in frequency distributions of the size of the first ocean summer zone measured on the scales of A) coho salmon of unknown freshwater age classified as age-0 (white bars) and age-1 (stippled bars) and B) coho salmon of known freshwater age (age-0) for combined samples taken at Oregon Aqua-Foods, Inc. and Anadromous, Inc. recapture facilities on Coos Bay, Oregon in 1980. One fish in the known sample with a first ocean summer zone measuring .49 inches at 100X was not included in Figure 12B.

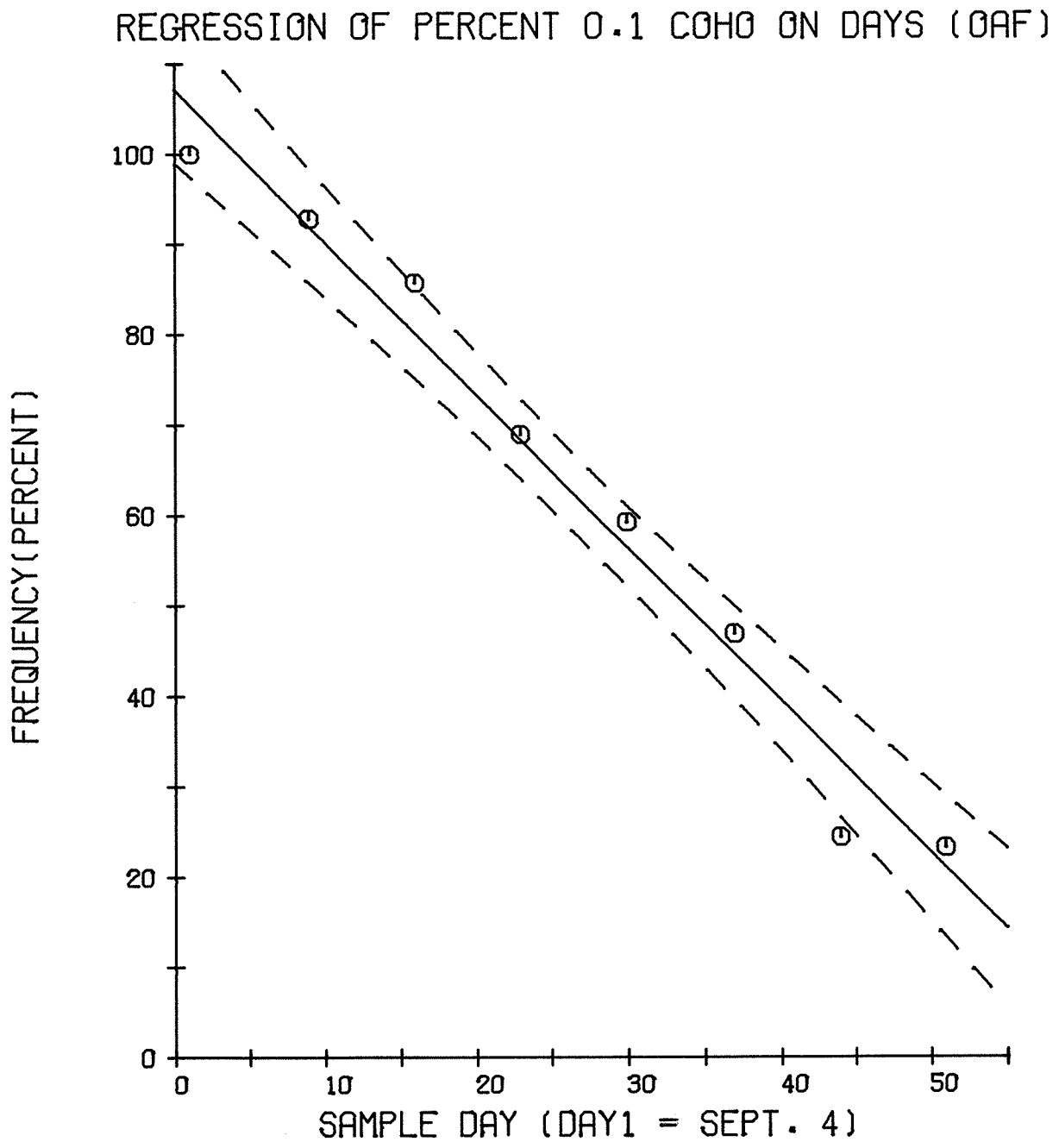


Figure 14. Regression of the frequency of freshwater age-0 coho salmon returning to Oregon Aqua-Foods, Inc. facilities at Coos Bay, Oregon in 1980 on mean sample day. The regression is Y = -1.69X + 107.15; 95% confidence intervals for the regression are shown.

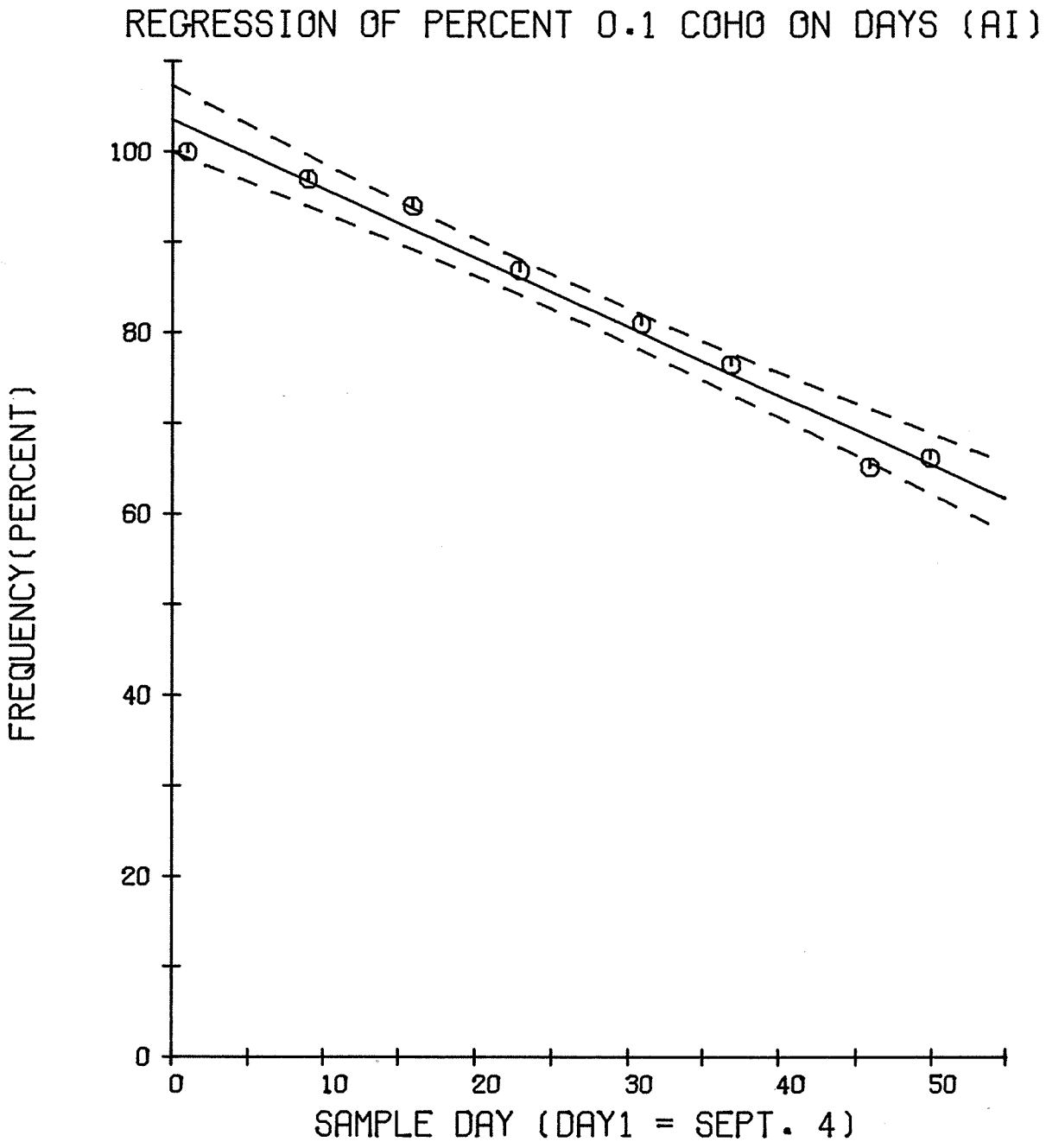


Figure 15. Regression of the frequency of freshwater age-0 coho salmon returning to Anadromous, Inc. facilities at Coos Bay, Oregon in 1980 on mean sample day. The regression is Y = -.76X + 103.58; 95% confidence intervals for the regression are shown.

tagged fish returning to AI and OAF facilities in 1980. In addition, none of the freshwater age-1 coho salmon released by OAF in 1979 were tagged. Because scales of known freshwater age-1 coho released in 1979 were not available, their appearance was inferred from what was known about rearing regimes and release times of freshwater age-1 coho in 1979 and from the appearance of the scales of coded wire tagged freshwater age-1 jack coho salmon released by OAF in 1980 (Fig. 1), and then contrasted with the appearance of the scales of coded wire tagged freshwater age-0 coho salmon released in 1979. Although the criteria for age determination developed from these inferences were very subjective, two experienced scale readers, each working independently, initially disagreed on the ages of only 14 out of a total of 1200 non-regenerated scales in the samples of fish of unknown age. In addition, a comparison of means and frequency distributions of scale character measurements and counts calculated for age-0 and age-1 coho in unknown samples showed, in most cases, significant differences between these two groups (Tables 6-10 and Figs. 4-13). Even measurements of intervals between circuli in the pre-ocean zone, which involved no subjective judgements on the part of the scale readers, showed a fairly good separation between the two groups in several cases (Figs. 9-11). Therefore, we have a reasonably high degree of confidence in our age determination by visual examination of scales. However, the causes of differences in means and frequency distributions of scale character measurements and counts for age-0 coho in the unknown samples and age-0 coho in the coded wire tagged samples (Table 10 and Figs. 4-13) require further examination.

The mean size of freshwater age-0 coho in the coded wire tagged samples was approximately 4 cm less than the mean size of age-0 coho in the unknown

samples (Table 10). This difference is probably the main factor responsible for the lower mean values of scale characters calculated for age-0 coded wire tagged coho. This size difference is at least partially the result of scale sampling methods used in this study. Scales were sampled from all coded wire tagged fish regardless of their size, but were usually only sampled from fish of unknown age that were larger than 50 cm.

In addition to the smaller mean size of age-0 coho in the coded wire tag samples, the presence of scales that did not appear to be taken from the preferred area of the fish may have lowered the mean values of scale characters calculated for age-0 coded wire tagged coho, particularly those counts and measurements made in the pre-ocean zone. Approximately 28% of the scales in the coded wire tag samples did not appear to be taken from the preferred area of the fish. However, these scales were included in the analyses because of the small sample size.

Coho salmon in the coded wire tagged samples were, also, not totally representative of all age-0 coho salmon expected to return in 1980. Twenty-four different groups (different size or time of release, different rearing regimes, etc.) of freshwater age-0 coho salmon were released by AI in 1979. A varied percentage of the fish in 15 of these release groups were tagged. In nine of these groups (representing only 14% of the total number of fish released) 90-100% of the fish were tagged. Because of the high percentage of tagged fish, coho from these groups were probably not present in the unknown samples, yet they accounted for 42% of the fish in the sample of age-0 coded wire tagged coho. The fish in the remaining 6 coded wire tag groups (representing 28% of the total number of fish released) accounted for 56% of the coded wire tag sample. In nine release groups, representing approximately 58% of the total number of age-0 coho salmon released by AI

in 1979, none of the fish were coded wire tagged. The variability in mean values of length and scale characters between groups of coded wire tagged coho released in July, August, and September (Table 11) attests to the fact that a large sample of coded wire tagged fish, weighted to represent the percentages of fish released in each group, would provide a much more accurate reflection of means and frequency distributions of scale characters of coho in the unknown samples.

Problems with the use of visual examination of checks formed on the scales of coho salmon to determine their freshwater age are well known. Marr (1943) and Peck (1970) found that accessory checks on the scales of coho salmon and circuli representing freshwater and estuarine growth in the early part of the year when juveniles emigrated to the ocean were often confused with a full year's growth. In a test of three scale readers, Peck (1970) found that 66-77% of the fish in his samples of hatchery coho from Washington and 15-40% of the fish in his samples of hatchery coho from Oregon were classified as freshwater age-2 when they were actually freshwater age-1. According to Peck (1970), the "true" freshwater annulus was formed in July on the scales of 75% of the hatchery and wild coho in his samples, while a second accessory check formed in December through March. Kato (1977) found up to three checks occurring on the scales of juvenile hatchery coho salmon reared for one year in freshwater. The first check, found on the scales of 22% of the fish, was formed in April, the second, found on the scales of 90% of the fish, was formed in June and July, and the third, found on the scales of 97% of the fish, was formed in October and November. Kato labeled the first two checks as "false" and the third as the "true" freshwater annulus.

The difficulties involved in identifying true freshwater annuli are compounded when determining the age of coho salmon from accelerated growth programs or programs in which coho are released at times other than their natural migration periods. These difficulties occur, primarily, because size of fish at release and release times are so variable, but also because so little is known about the behavior of these fish after release. Feldmann (1974) found anywhere from two to twenty circuli in the "transition zone" (called the pre-ocean check in the present study) on the scales of adult 1970 brood year coho that were reared at an accelerated rate for 6 mos. and released into freshwater in late May of 1971. Feldmann reported that some of the fish from these releases were found rearing in freshwater in November of 1971, and that some of the fish from the 1971 releases did not return until the fall of 1973. Although Feldmann did not include any figures showing the appearance of the scales of these fish, a true freshwater annulus probably formed on their scales. Therefore, although these fish were released as freshwater age-0 fish, they were actually age-1 fish when they emigrated to the ocean, probably in spring 1972. Another example is the scale shown in Figure 16. This is the scale of a brood year 1976 coho salmon released as a freshwater age-1 fish into Coos Bay on September 21, 1978, and recaptured in Coos Bay in the fall of 1980. Even with this knowledge of the fish's life history, it is difficult to decide which checks represent "true" annuli.

The ability of a scale reader to correctly interpret the freshwater ages of fish with these types of complex life histories may be difficult, if not impossible, without adequate reference collections of scales. If stock separation of coho salmon returning to private salmon hatcheries in Coos Bay

Figure 16. The scale of a coded wire tagged brood year 1976 coho salmon released from Anadromous, Inc. facilities on Coos Bay, Oregon on September 21, 1978, and recaptured at Oregon Aqua-Foods, Inc. facilities on Coos Bay, Oregon in the fall of 1980.

using scale pattern analysis continues to be necessary, coded wire tagging of a representative sample of each release group, or at least each age class, in sufficient numbers to ensure a collection of adult scales with known life histories would aid tremendously in the ease, accuracy, and validity of the resulting separation. Scales collected from the juvenile release groups would also greatly augment these studies, as well as provide a data base for other practical analyses of the life history of artificially reared coho.

LITERATURE CITED

Feldmann, C.L. 1974. The effect of accelerated growth and early release on the timing, size, and number of returns of coho salmon (Oncorhynchus kisutch). M.S. Thesis, University of Washington, Seattle. 46 pp.

Kato, M. 1977. Study of body and scale growth of young coho salmon, Oncorhynchus kisutch (Walbaum), in hatchery. Bull. Far Seas Fish. Res. Lab. 15:21-34.

Marr, J.C. 1943. Age, length, and weight studies of three species of Columbia River salmon (Oncorhynchus keta, O. gorbuscha, and O. kisutch). Stanford Ichthyo. Bull. 2(6):157-197.

Narver, D.W. 1963. Identification of adult red salmon groups by lacustrine scale measurements, time of entry, and spawning characteristics. M.S. Thesis, University of Washington, Seattle. 96 pp.

Peck, T.H. 1970. Differentiation of hatchery and stream juvenile coho salmon (Oncorhynchus kisutch) from Washington and Oregon by the use of scales and otoliths. M.S. Thesis, University of Washington, Seattle. 67 pp.