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ESTIMATION OF OPTIMAL SIZE FOR COHO SALMON SMOLTS RELEASED BY OREGON AQUA-FOODS INTO YAQUINA BAY, OREGON

by

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Robert L Burgner
Director

TABLE OF CONTENTS

LIST OF FIGURES

No. Page

LIST OF TABLES

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ABSTRACT

Patterns on 930 scales of adult coho salmon returning to the Oregon Aqua-Foods saltwater facility at Yaquina Bay in 1979 were measured on a minicomputer-based scale digitizing system with the intent of backcalculating the most successful smolt size at release into Yaquina Bay. Measurements of scale size at release were converted to estimates of fish length at release using a transformation equation developed with scales and fish length data sampled from 1980 smolt release groups. The precision of estimates of fish length was ± 1.41 cm. Estimates of fish length were converted to estimates of fish weight using length/weight relationships from 1980 smolt release groups. The relationships were highly variable between release times (May-August) and within release times. We feel that fish weight is an inadequate morphometric index of optimal release size.

Results indicate that smolts released into Yaquina Bay at lengths between 11 and 14 cm constituted over 91% of the total adult return from those releases. Smolts released at 12-13 cm accounted for over 46% of the total adult return. Although it is tempting to conclude that 12-13 cm is the optimum smolt size, our results must be regarded as preliminary pending a fuller analysis of the frequency distribution of smolt sizes in the adult return versus the frequency distribution of smolt sizes in the total smolt release.

1.0 INTRODUCTION

Of the many factors that influence return of juvenile salmonids at sea, two that are known to affect survival--size and timing at seaward migration--are controllable to a large extent by hatchery release strategies. Numerous reports have verified that larger smolts of a yearclass tend to return as adults in proportionately greater numbers (Burgner 1962; Carlin 1969; Ritter 1972; Peterson 1973; Bilton 1978). Wedemeyer et al. (1980) relate the importance of smolt release timing to return at sea in terms of the physiological and morphological changes that must be synchronized to entry into seawater. Inasmuch as smolt survival to adult return is the ultimate concern of a commercial ocean ranching operation, it is essential that the hatchery manager have reliable information on the particular smolt size range that affords the highest probability of return at sea. Because production schedules may preclude large smolt releases only at a single optimum time each year, the benefits and costs associated with this aspect of a smolt release strategy are difficult to analyze. The scope of this study consequently is limited primarily to the estimation of an optimum size at release for coho salmon smolts. The effect on smolt survival of release timing is examined only indirectly as a function of post-smolt fish growth.

The most successful smolts of a release group quite obviously are those that return as adults. The scales of these adults carry on them a fairly precise growth history, beginning with scale formation at about 40-45 mm fish length. As Peck (1975) demonstrated for coho juveniles from hatchery and wild stocks, fish growth can be adequately modeled as a linear function of scale growth. This relationship is the analytical tool required to estimate length at release from the scales of returning adults. Herein we report the results of a scale pattern analysis designed to determine the most successful size at release of coho salmon returning in 1979 to the Oregon Aqua-Foods (OAF) facility at Yaquina Bay, Oregon.

2.0 METHODS

2.1 Scale Selection

All adult scales used in this analysis were obtained as acetate replicas which had been prepared by OAF. A preliminary survey of the scale impressions indicated that some sampled early in the coho return had been mounted on gum cards with the sculptured surface down. These scales could not be read and were excluded from further analyses. Regenerated or otherwise damaged scales accounted for approximately 23.7% of the total number of scale impressions received, and these were likewise excluded. The remaining 930 scale impressions were judged suitable for the scale pattern analysis.

2.2 Identification of Scale Patterns

2.2.1 Pre-release Scale Growth

Identification of the portion of each scale corresponding to pre-release growth proved to be at once confusing and enlightening. Confusion was caused primarily by the presence of one or more well-defined checks in the zone assumed to be pre-release growth on many scales from age 0.1 adults (Fig. 1). In some scales such a check was followed immediately by accelerated scale growth, while in others four or five circuli formed between the check and the beginning of accelerated growth. We hypothesized that the outermost check in the pre-ocean zone formed when juveniles were transferred from freshwater to salt water holding ponds, as the stress involved in the physiological adjustment to salt water could conceivably account for disrupted fish and scale growth. We believed, further, that the period of residency in salt water ponds was sufficiently short to preclude the formation of additional circuli prior to release into Yaquina Bay. Circuli between the "salt water" check and the beginning of accelerated scale growth were presumed to have formed during residence in Yaquina Bay prior to departure into the open ocean.

Subsequent analysis of scale patterns from juvenile cohos released in 1980 suggested that this interpretation was not correct. Many scales from smolts sampled in freshwater displayed "salt water" checks and variable numbers of additional circuli (Fig. 2). Since no firm evidence existed to confirm or reject hypotheses concerning the formation of specific scale patterns, we adopted a decision rule governing the measurement of the pre-release portion of each scale. In the interest of consistency in scale measurements, we considered as pre-release scale growth all circuli that showed a tendency toward curving inward as they entered the unsculptured posterior field of the scale (Fig. 1, Fig. 3). This rule was developed to circumvent confusion arising from:

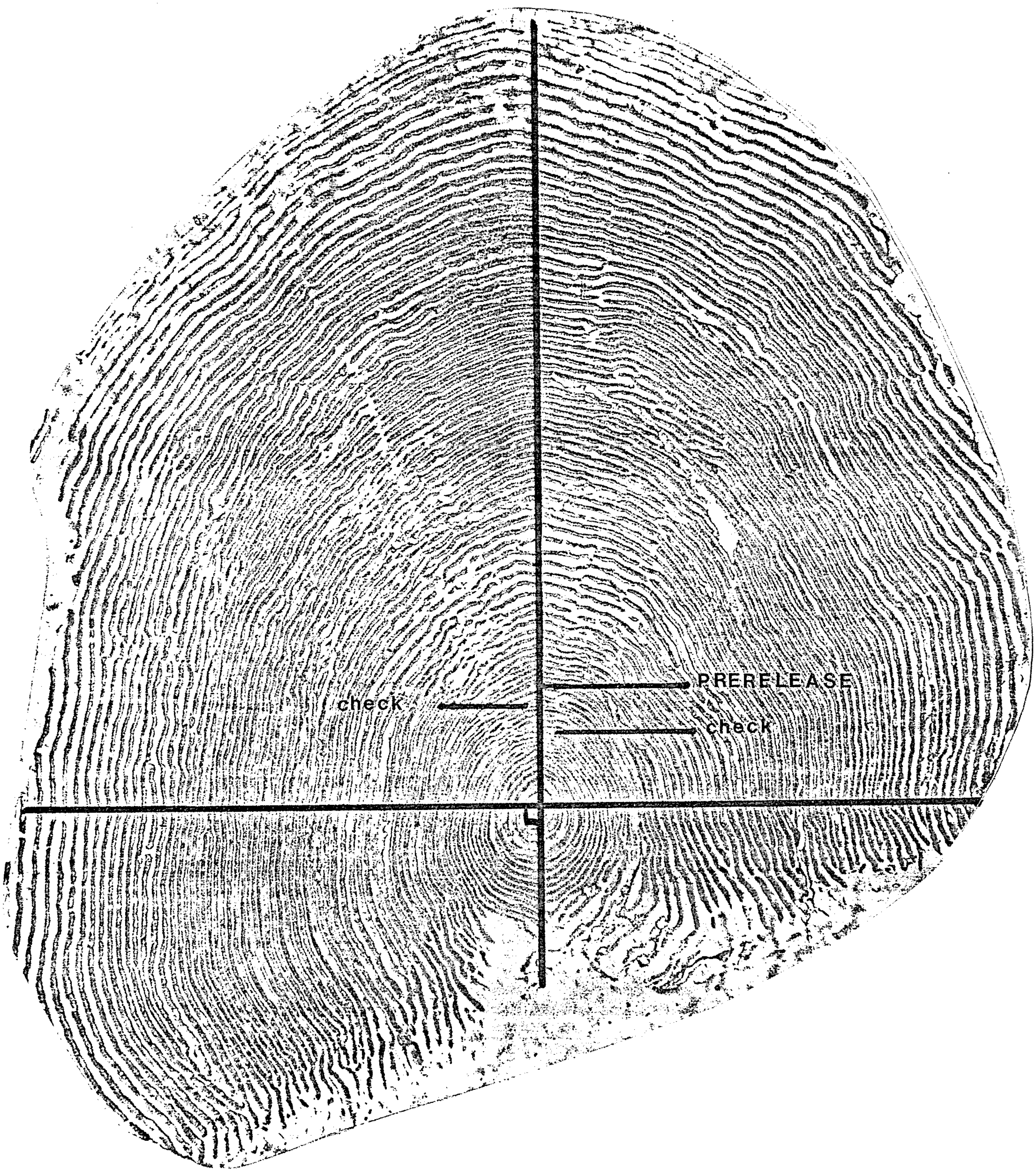

Fig. 1. Scale from an age 0.1 coho adult from the 1979 OAF return to Yaquina Bay, showing orientation for measurement, pre-release scale growth, and checks.

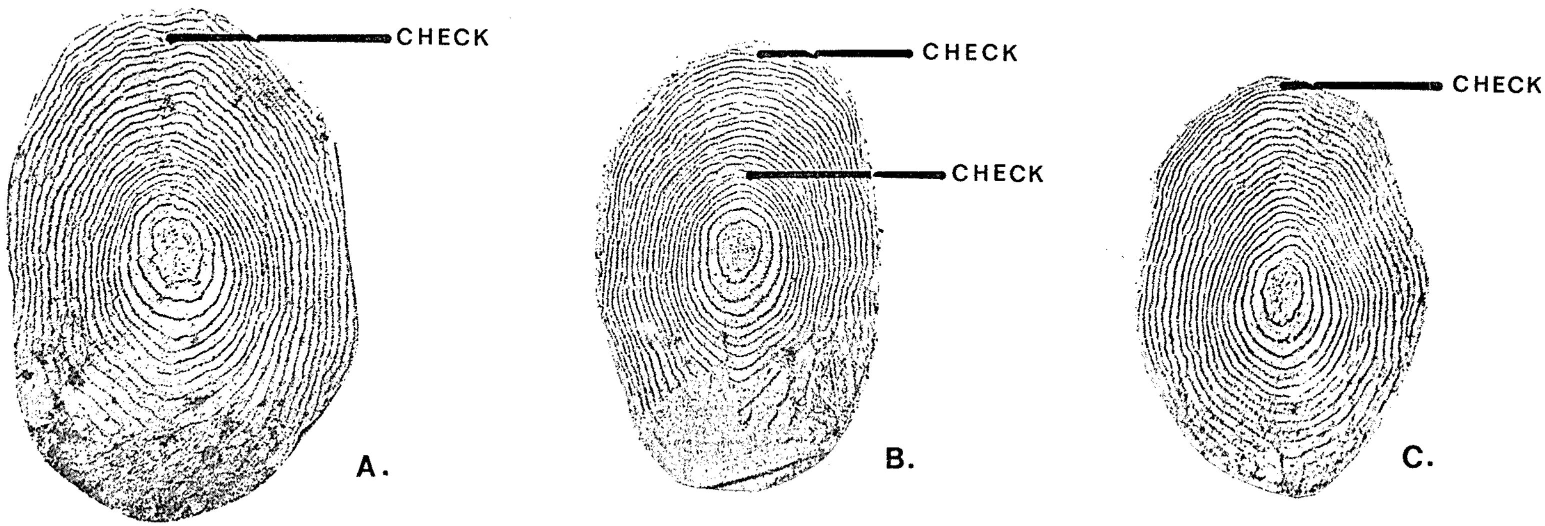

Fig. 2. Scales representative of samples from coho juveniles which were measured for the fish length/scale radius transformation equation. A= large smolt, B= small smolt, C= presmolt. All samples were taken on 8/11/80 from fish in freshwater.

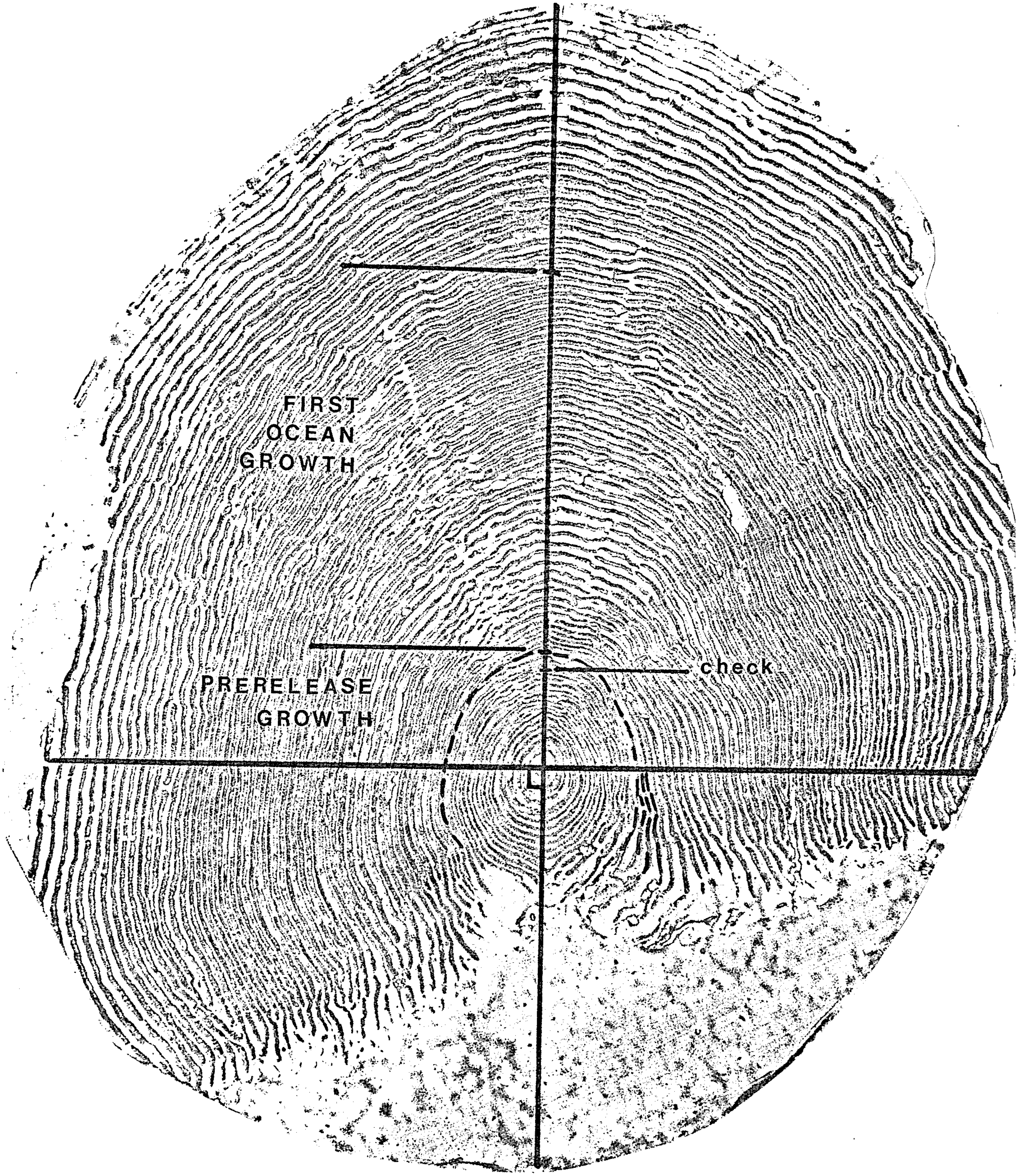

Fig. 3. Determination of the pre-release portion of adult coho scales. Note the size and spacing of pre-release circuli relative to ocean circuli and the tendency for curving inward at the base.

1) Presence of a distinct check and one to several circuli outside the check on scales of fish sampled in freshwater.

2) Uncertainty of the biological basis for check formation in the pre-release zone of scales and, hence, uncertainty in the correlation of specific patterns with known life history events.

3) Variability between scales in the position and arrangement of checks and circuli.

Although we cannot prove a biological basis for our decision rule, two sources of circumstantial evidence provide a rationale for measuring as pre-release growth all circuli which curve inward as they enter the unsculptured posterior field of the scale. Scales sampled from tagged OAF postsmolt cohos collected in Yaquina Bay (see Table 1) showed that the check had just formed on the scale of a coho released on 6/19/78 and collected on 6/22/78 (Fig. 4). A clear check and one to several circuli appeared on scales of fish released on 8/16/78 and collected on 8/17/78 and 8/21/78 (Fig. 5). Furthermore, fish which spent approximately one to three months in Yaquina Bay after release from OAF holding ponds showed the marked acceleration of scale growth and the transition from circuli which curve inward at the base to those that are straight that would be interpreted as post-release growth on adult scales (Fig. 6). These scale samples suggest that the outermost freshwater check may not be a reliable marker of entry into Yaquina Bay. The conclusion of ODF&W that entry into the estuary is marked by the transition from circuli which curve inward at the base to those which tend to straighten at the

Fig. 4. Scale from a juvenile coho released from OAF on 6/19/78 and collected on 6/22/78 (provided K.W. Myers).

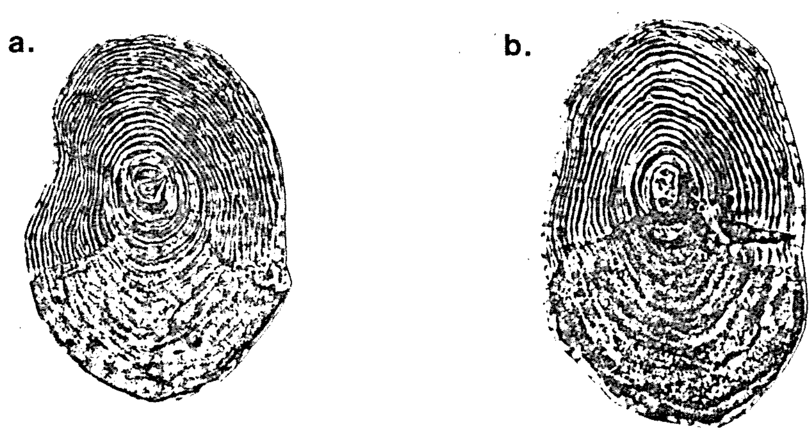

Fig. 5. Scales from juvenile coho released from OAF on 8/16/78 and collected on (a) 8/17/78 and (b) 8/21/78 (provided by K.W. Myers).

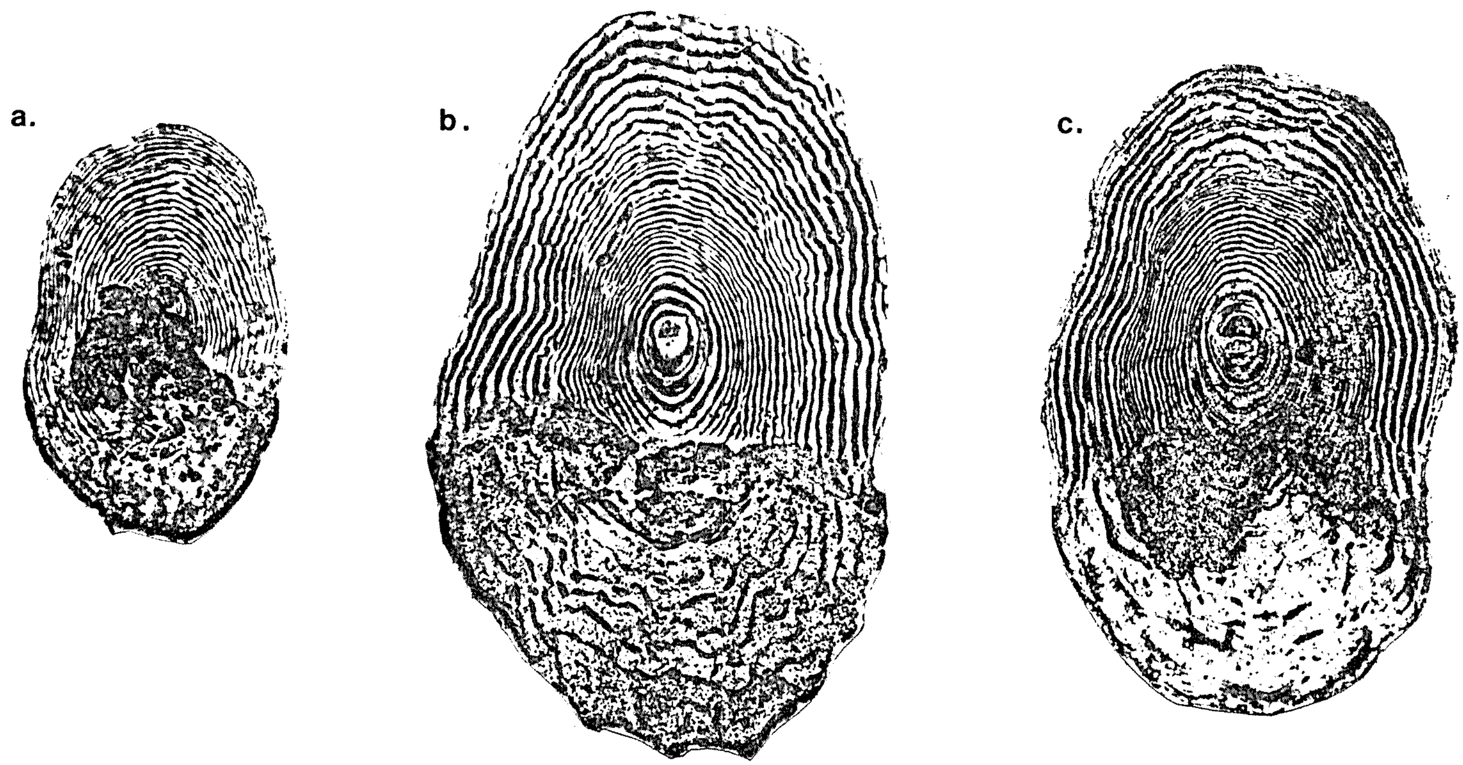

Fig. 6. Scales from juvenile cohos: (a) Released by OAF on 8/16/78 and collected on 9/14/78, (b) released on 6/19/78 and collected on 8/24/78, and (c) released on 6/19/78 and collected on 9/7/78 (provided by K.W. Myers).

base (Lisa Van Dyke, personal communication) lends further support to the validity of our decision rule.

Table 1. Background information on juvenile coho scales shown in Figs. 4-6 (provided by K. W. Myers).

Release		Recapture		
Group	Date	Fork Length(cm)	Weight (g)	Date
600124	6/19/78	9.3	9.46	6/22/78
603108	8/16/78	10.6	15.03	8/17/78
603108	8/16/78	13.3	32.02	8/21/78
603108	8/16/78	12.2	19.14	9/14/78
600137	6/19/78	19.7	113.41	8/24/78
600124	6/19/78	16.5	53.53	9/ 7/78

2.2.2 First Ocean Growth

We measured the growth of scales from smolt release to winter annulus formation as an index of fish growth during that period. Some evidence suggests that survival of juvenile salmon through to adulthood may be influenced by the size attained immediately following smoltification in the first summer and fall of ocean residence. Because smolts were released from OAF holding ponds from April through October, our hypothesis was that differential post-smolt mortality attributable to reduced first ocean growth would favor survival of smolts in early season releases and depress return rates in groups released later. Such a process might be identified by: 1) greater adult returns from early season smolt release groups; or 2) a frequency distribution of first ocean scale growth skewed toward the upper range of scale measurements.

Growth of the fish immediately after release into Yaquina Bay and through the first winter at sea was measured on the scale as the distance between the inside of the first circulus past pre-release growth (Fig. 3) and the outside of the winter check. Measurements were not transformed to units of fish length because we had no scale samples from fish in this size range, and we were unwilling to assume that the fish length/scale radius relationship used to estimate smolt length was appropriate. Since the purpose was simply to inspect the frequency distribution of first ocean growth in returning adults, examination of scale growth as an index of fish growth is a valid means of doing so.

2.3 Scale Measurement

A minicomputer-based scale digitizing system was used to record, store, and edit raw data. Biological information accompanying each measured scale was compiled on a pre-formatted CRT display along with other identifying data. Scale images projected at 200X onto the surface of an electronic digitizer were measured by moving a hand-operated cursor across the projected image. Measurements initialized at the scale focus recorded the distance from the focus to the end of pre-release scale growth and from the beginning to the end of scale growth in the first ocean season (Fig. 3). The scale radius along which these measurements were made was selected in a manner described by Narver (1963) which is now considered to be standard practice. A FORTRAN computer program was written to compile, interpret, and store data. Biological data and other identifiers, scale characters measured, their card-image format, and a brief explanation of codes are presented in Table 2.

Table 2. Biological data and other identifiers, scale characters measured, their format on key-punched cards, and explanations of coded data for coho scales.

Identifier	Card Column	Explanation
Fish number	1-2	Refers to position of scale on scale card
Sex	3	1 = male, 2 = female
Weight	4-6	Weight of adult in kg
Card number	7-9	Last three digits of card number
Group	10-15	Smolt release group
Site	16	Harvest location 1 = Yaquina Bay 2 = Coos Bay 3 = Wright Creek
Age	17-18	Column 17 refers to the number of winters spent in freshwater, column 18 refers to the number of winters spent at sea
Weight unit	19	1 = kilograms
Reader number	20	
PRCIRC	21-22	Number of circuli formed on the scale prior to release into the estuary
PRDIST	23-26	Distance from the focus to the first circulus of ocean growth
OCCIRC	27-28	Number of circuli formed on the scale during the first ocean season
OCDIST	29-32	Distance from the beginning of the first circulus of ocean growth to the beginning of the first circulus of ocean growth following the first ocean annulus

2.4 Calculation of Length at Release

Scale radius measurements originally were to be transformed into units of fish length using Peck's (1975) regression equation relating scale radius to fish length for coho juveniles. Two subsequent discoveries caused us to reconsider:

1) Peck's equation was developed using sample means, which eliminated much of the variance about the regression line and which would produce overly optimistic confidence intervals for estimates of individual fish lengths from scale measurements.

2) Scales from juvenile cohos used in Peck's regression were mounted in glycerine on microscope slides, causing slight shrinkage in scale diameter.

Since measurements of adult scales on the digitizing equipment were taken from acetate impressions of dry specimens, we decided to construct a new fish length/scale radius relationship from dry mounts of individual juvenile scales and fish lengths. Scales of coho juveniles from the 1979 brood year were supplied by OAF for use as a reference collection of scale patterns and data. Scale smears arrived in packets with corresponding lengths and weights of 800 individual juveniles live-sampled in May, June, July, and August 1980. Of these, 96 were selected from among three categories designated (by OAF) as being presmolts, small smolts, and large smolts to obtain as broad a range of fish and scale sizes as possible (actual range was 9.7 to 14.5 cm). Scale smears were examined with a binocular dissecting microscope to ensure that only scales of high quality were chosen for measurement. The largest scale of acceptable quality was identified subjectively from a smear and removed to a microscope slide to be mounted dry. Four such scales from four scale packets were mounted on each slide and their positions recorded on the slide margin. Another microscope slide was placed over the prepared slide and secured with transparent adhesive tape. These scales and accompanying data were subsequently processed in the manner identical to that described previously for scale impressions of the returning adults.

2.5 Estimation of Fish Weight

Results of this study would be incorporated most easily into the hatchery production schedule if reported in units of fish weight rather than fish length, so we prepared a simple weight/length transformation using the juvenile fish data supplied by OAF. The data were stratified by month of sampling in order to account for suspected changes in condition factors of fish released at different times of the spring and summer.

A preliminary plot of the length and weight data segregated by sampling date showed: 1) essentially no variance in the relationship for samples taken in May, indicating that for any measured length a corresponding weight was estimated, or vice versa, and 2) that the relationship was curvilinear for July and August samples. Since the slopes of the lines appeared to differ between months, and because of the obviously artificial nature of the May length/weight data, we felt that transformations of fish length to fish weight should be done specifically by smolt release date. Consequently, estimates of fish length for smolts released in May were transformed to estimates of fish weight using the May equation, those for fish released in June were transformed using the June equation, etc. Estimated lengths of yearlings released in April were transformed to estimates of weight using the May transformation equation. Weights for July and August smolt samples were $\log_{10}$-transformed to eliminate curvilinearity. Predictions of fish weight from these models were antilog-transformed to units of grams.

3.0 RESULTS

3.1 Fish Length/Scale Radius Transformation

The regression of fish length on scale radius for 96 selected presmolt, small smolt, and large smolt scale samples was highly significant ($p \ll .001$; Fig. 7). The equation calculated for this transformation was:

$$Y = 73.415 + 0.190X$$

where Y = predicted fish length

X = measured scale radius

A low coefficient of variability = 5.5% indicates that errors in predictions of fish length are small relative to the predictions themselves. In fact, a 95% confidence interval of $\pm$ 1.41 cm is well within workable precision. We feel that the relatively small magnitude of potential errors associated with calculations of fish length from scale radius does not mask trends in the frequency distribution of release lengths represented in the adult return.

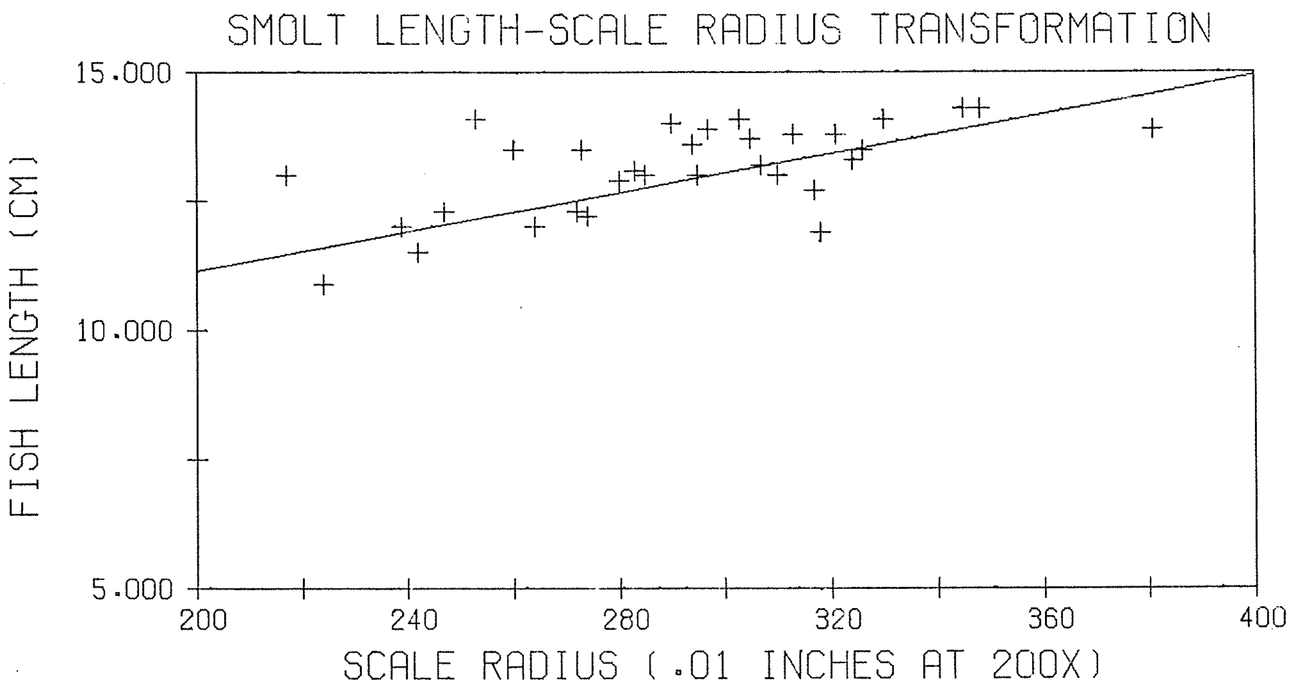

Fig. 7. Regression of fish length on scale radius used to transform scale measurements into units of fish length. Data are plotted at a density of about 10 points per square inch.

3.2 Fish Weight/Fish Length Transformation

The regressions of weight (in grams) on length (in cm) which were used to transform estimates of fish length to estimates of fish weight are presented in Figs. 8a-d. Details of the individual equations are given in Table 3.

Table 3. Regression analysis of fish weight on fish length for coho smolt samples used in the weight/length transformations.

Month Sampled	Regression Equation	95% Confidence Interval for Y	N	Significance	r
May	Y=4.762-37.113(x)	$Y \pm 13.472$ g	199	$p \ll .001$	.99
June	Y=4.341-32.184(x)	$Y \pm 23.297$ g	198	$p \ll .001$	.98
July	$\log_{10}$ Y=0.349+0.081(x)	$Y \pm 58.004$ g	200	$p \ll .001$	.86
Aug.	$\log_{10}$ Y=0.233+0.092(x)	$Y \pm 16.152$ g	200	$p \ll .001$	.94

Broad confidence intervals around estimates of weight result from using an estimated variable (length) as a predictor. The variance associated with estimates of fish length must be included as a source of variation in predictions of fish weight based on estimates of fish length. We used the "delta method" (Seber 1973) to calculate variances for estimates of fish weight in order to calculate 95% confidence intervals for the estimates. The equation is:

$$\mathrm{Var}(Y) = \mathrm{Var}(a)+\mathrm{Var}(b)X^2+\mathrm{Var}(X)b^2$$

where Y = predicted value (weight)

a = estimate of the intercept

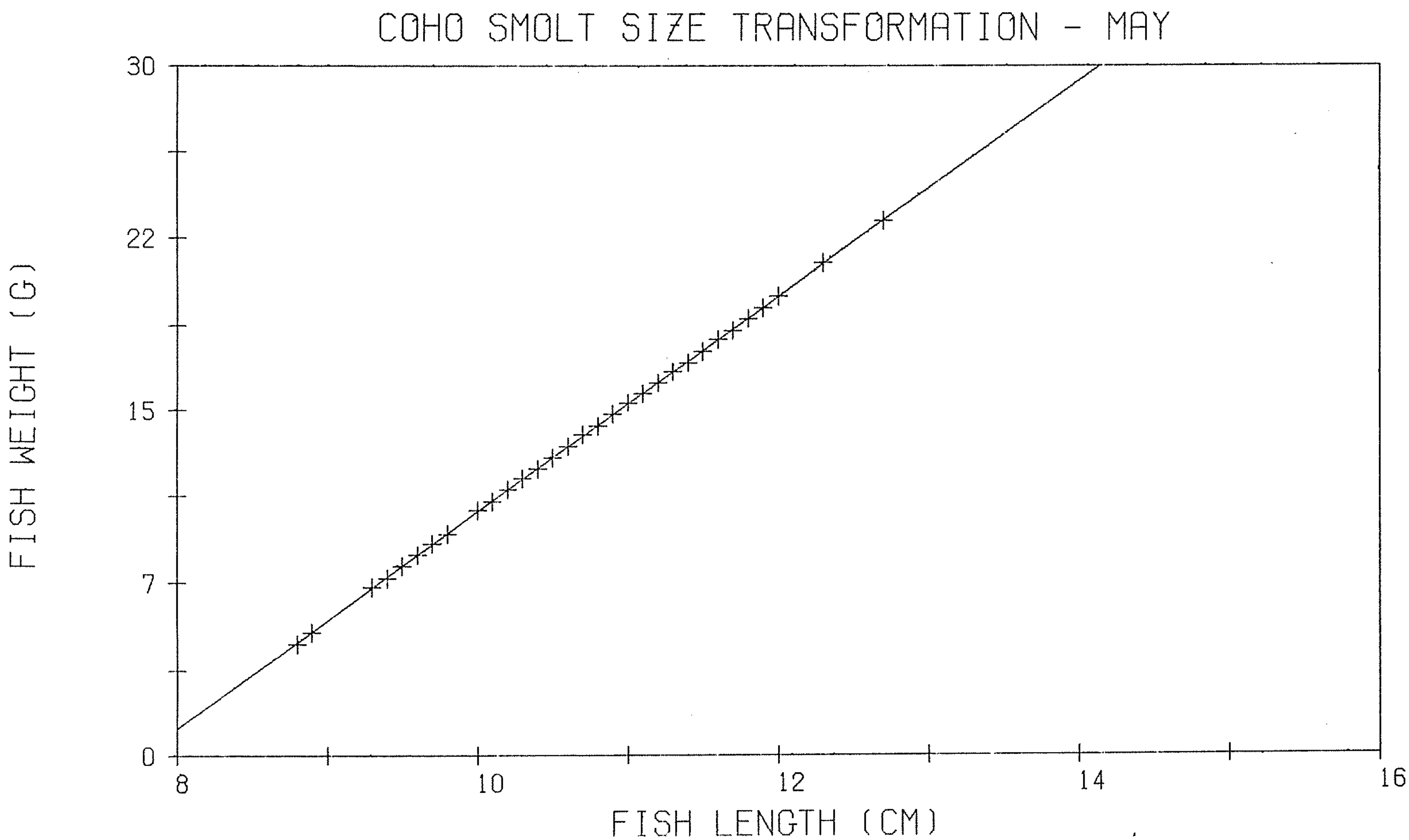

Fig. 8a. Regression of fish weight on fish length for smolt groups sampled in May. This equation was used to estimate weight at release for yearlings released in April. Data are plotted at a density of about 10 points per square inch.

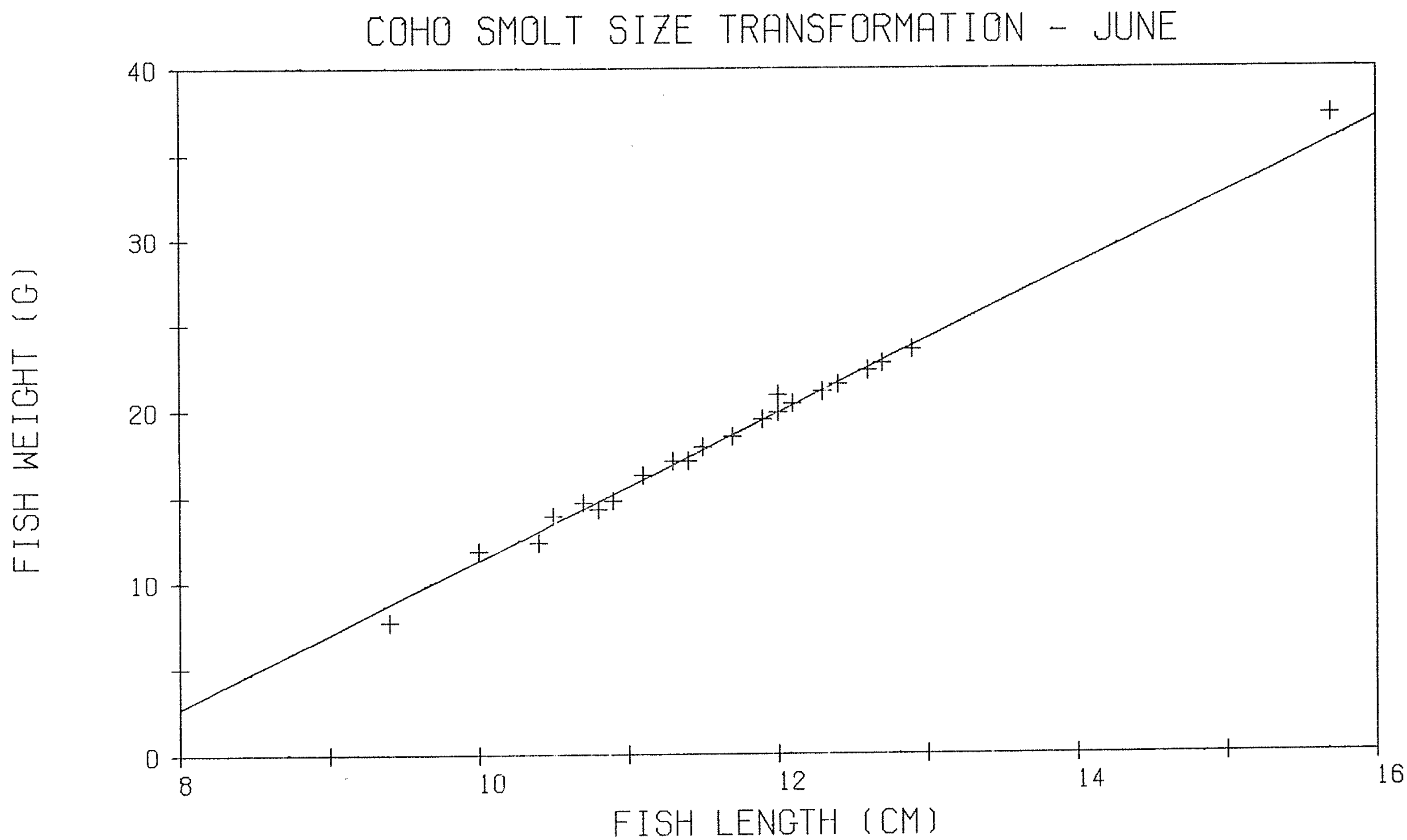

Fig. 8b. Regression of fish weight on fish length for calculating weight of smolts released in June. Data are plotted at a density of about 10 points per square inch.

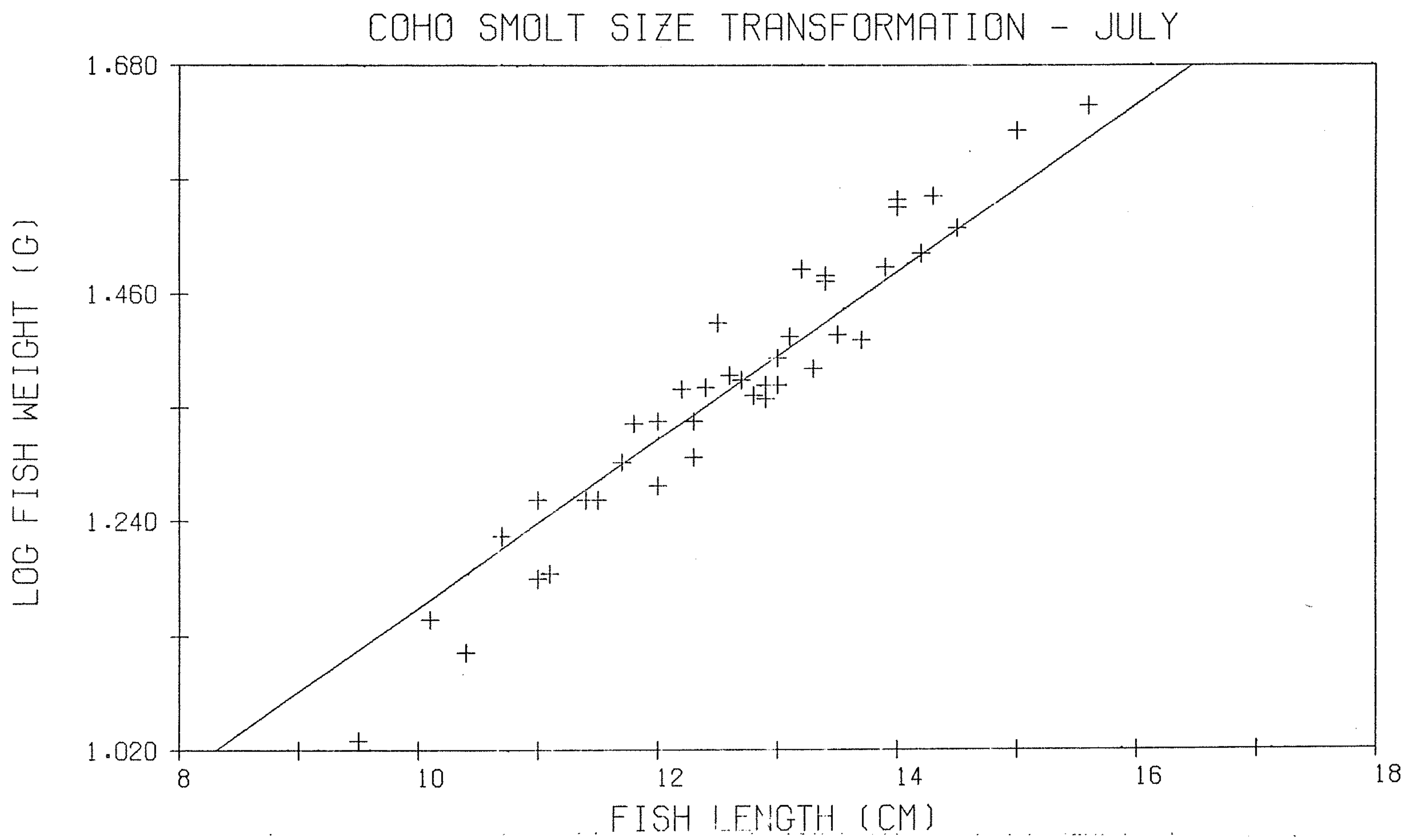

Fig. 8c. Regression of $\log_{10}$ fish weight on fish length for calculating weight of smolts released in July. Data are plotted at a density of about 10 points per square inch.

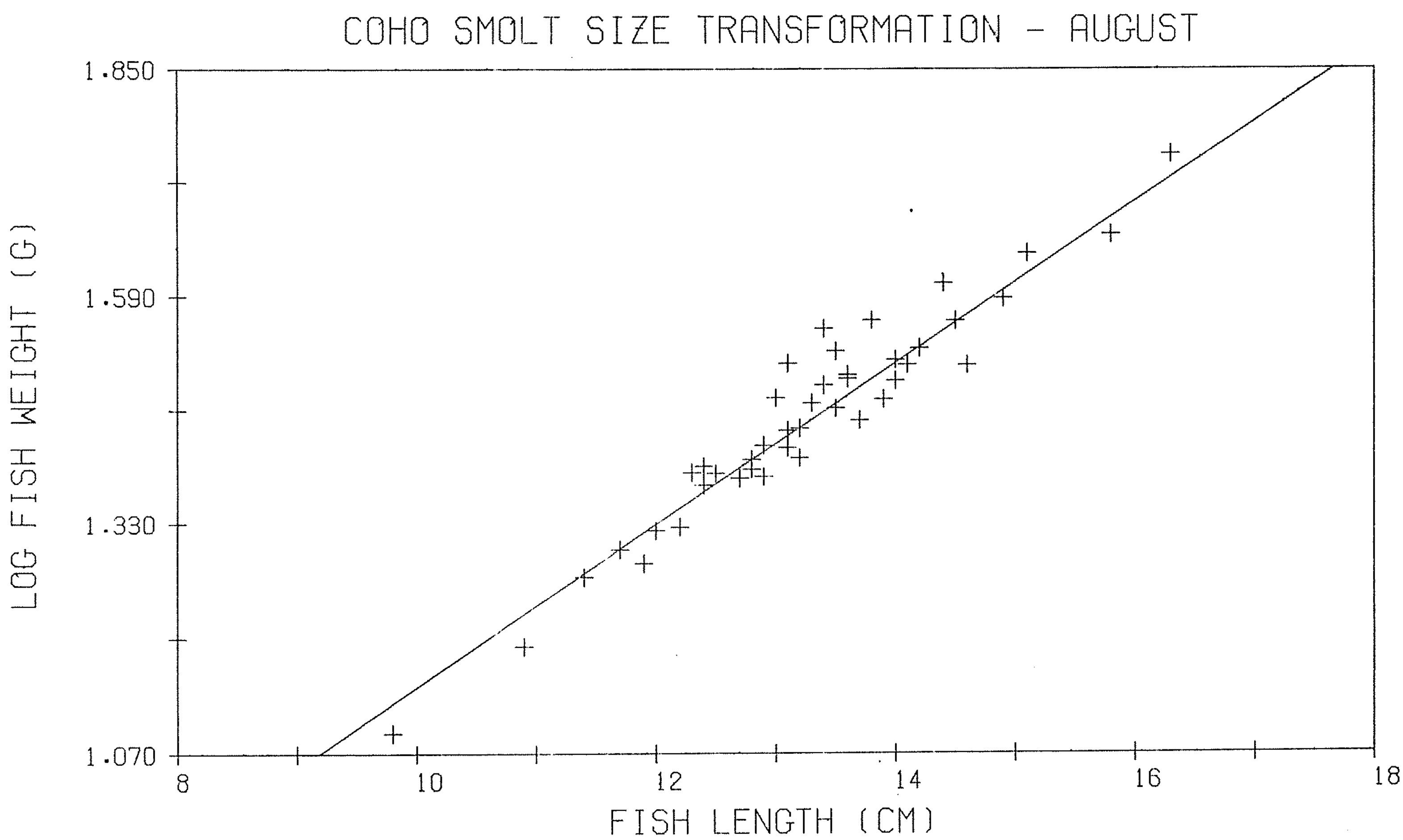

Fig. 8d. Regression of $\log_{10}$ fish weight on fish length for calculating weight of smolts released in August. Data are plotted at a density of about 10 points per square inch.

b = estimate of the slope

X = estimate of the predictor

Since weight estimates are highly variable and less informative, we have reported all results in units of fish length as well.

3.3 Distributions of Smolt Release Sizes in the Adult Return

The frequency distribution of calculated smolt release sizes in tagged and untagged release groups represented in the adult coho return to Yaquina Bay is shown in Fig. 9. Adult cohos that had been released as 12-13 cm smolts constituted fully 46.4% of the total adult return. Adults released as smolts between 11 and 14 cm accounted for 91.7% of the total return. Estimates of length at release were not transformed to estimates of weight at release for the total adult return because the weight/length relationship is variable between groups comprising the total return.

Figures 10a through 15b present the frequency distributions of calculated smolt release sizes for release groups having greater than 0.5% return (see Appendix A for percent return by smolt groups). Of the 129 smolt groups released in 1978, only six qualified. Of these, Groups 600123, 600124, 600137, and 630108 were chosen to evaluate the most successful release size of smolts returning as adults. Groups 620144 and 620145 were included because they were the only groups of yearlings released in 1978. Figure 10a illustrates the distribution of successful

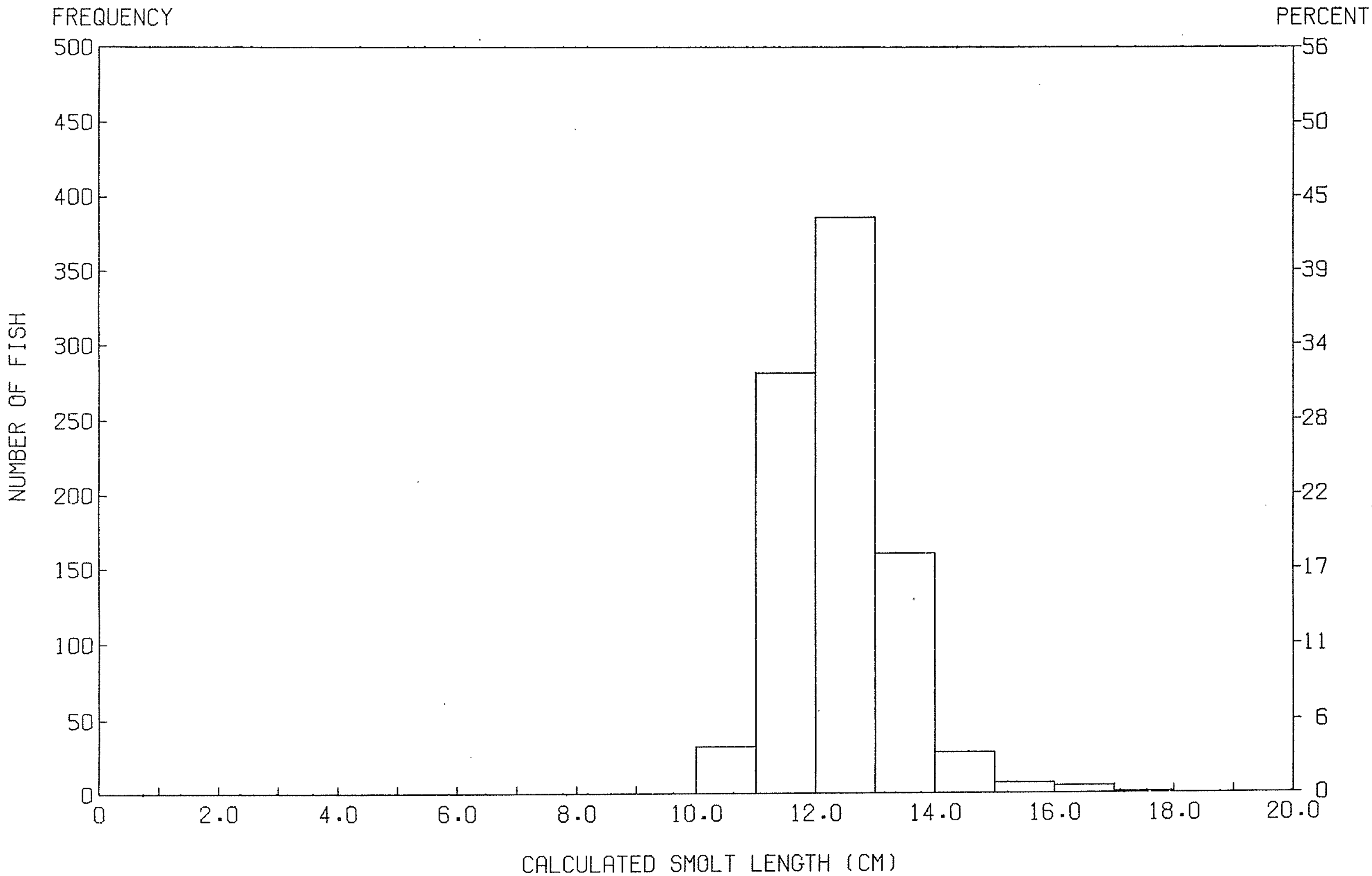

Fig. 9. Frequency distribution of smolt release sizes represented in the adult coho return to the OAF Yaquina Bay facility in 1979.

smolt lengths in Group 600123 (percent return = 0.59%). Note that approximately 80% (n=12) of the adults from this group were released at a length between 11.0 and 13.0 cm. The corresponding weight function (Fig. 10b) is significantly less informative when it is remembered that the 95% confidence interval for the mean value (19.4 g) is ±23.3 g. Figure 11a illustrates the distribution of smolt sizes represented in the adult return from Group 600124 (percent return = 0.67%). About 82% (n=13) of the total return from this group was released at 11.0 to 13.0 cm. The distribution of weights (Fig. 11b) again is less precise. The mean fish weight at release was about 19.0 ± 23.3 g.

The distribution of smolt lengths represented by Group 600137 (percent return = 0.79%) does not conform to the normal and implies that size-dependent return may have modified the range of successful smolt release sizes to favor larger ones (Fig. 12a). The accompanying weight distribution (Fig. 12b) suggests that smolts between 18 and 20 g at release experienced the highest probability of return (mean = 22.9 ± 23.3 g).

The most successful tagged release group was Group 603108 (percent return = 1.21%). Figure 13a indicates that about 79% (n=122) of the smolts returning as adults in this group were released at lengths between 12.0 and 14.0 cm. The distribution is roughly normal and suggests no extreme advantage to larger smolts. Figure 13b illustrates the difference in condition factor between smolts released in August and those released in June. Average and median weights for 12-14 cm smolts are noticeably higher in Group 603108 than those for Groups 600123, 600124, and 600137.

Yearling cohos released in Groups 620144 and 620145 were of a wide range of lengths and weights (K. W. Myers, personal communication). The performance of smolts in these release groups in comparison with age 0 smolts is of interest because they represent a greater investment in hatchery effort. Group 620144 (percent return = 0.18%) returned a total of nine adults in 1979. Furthermore, only smolts released between 10.0 and 17.0 cm returned, with 33% (n=3) falling between 12.0 and 13.0 cm (Fig. 14a). The distribution of weights (Fig. 14b) says essentially nothing about the optimal weight for yearling releases (mean = 26.8 $\pm$ 13.5 g). The frequency distribution of smolt lengths in the adult return from Group 620145 (percent return = 0.26%) verifies that essentially only yearlings released between 12.0 and 14.0 cm returned (Fig. 15a). Figure 15b provides an idea of the weights of successful yearlings (mean = 26.2 $\pm$ 13.5 g), although it must be noted that these weights are estimated using the weight/length relationship for age 0 smolts sampled in May, while all yearlings were released in April.

3.4 Ocean Growth of Juveniles

The distribution in amount of first ocean growth attained by all returning adults is shown in Fig. 16. Since the distribution is not skewed toward the upper range of scale measurements, we can identify from Fig. 16 no pronounced survival advantage for fish released very early in the season relative to those released very late in the season.

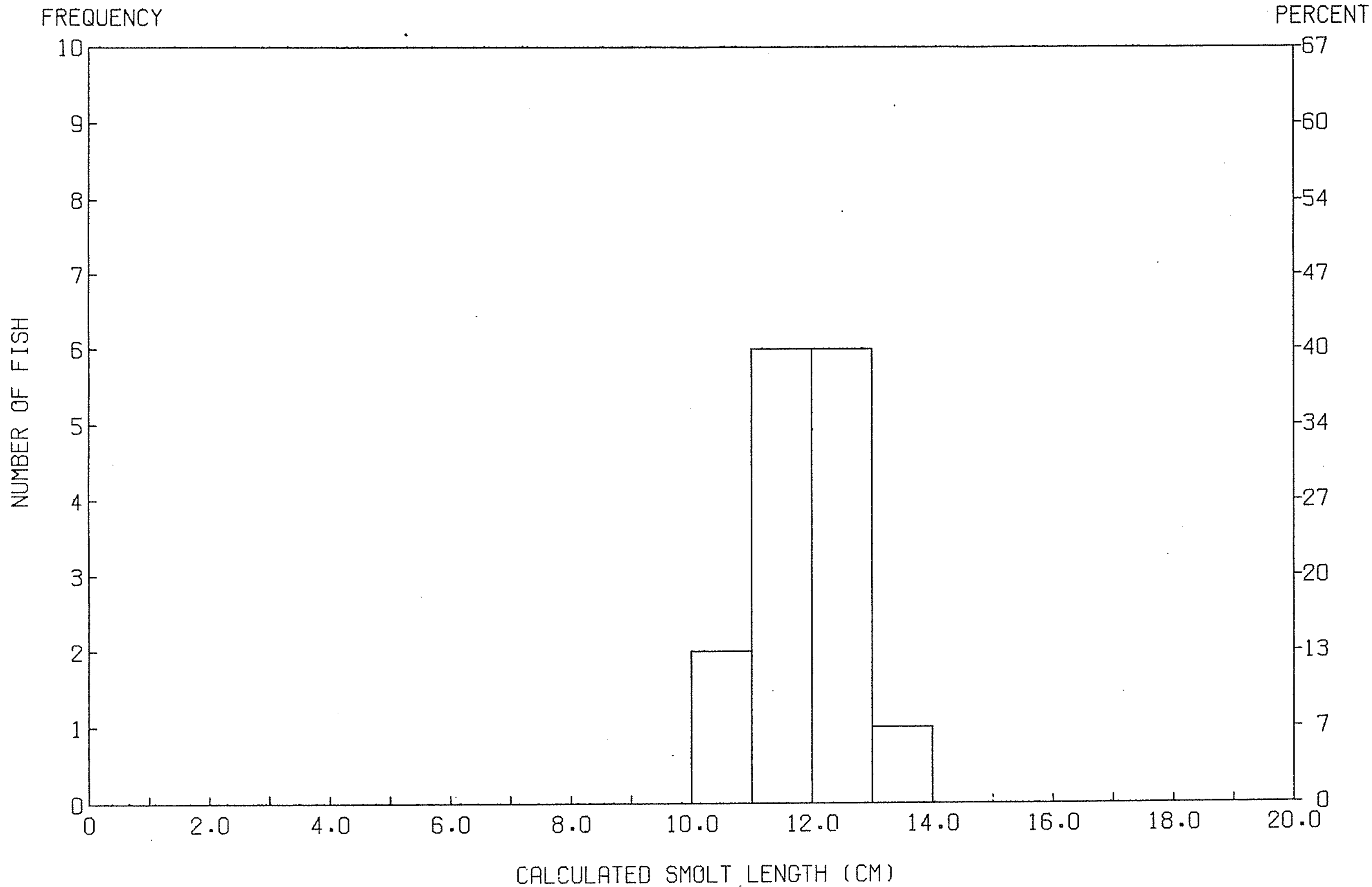

Fig. 10a. Frequency distribution of smolt sizes in Group 600123 represented in the 1979 coho return.

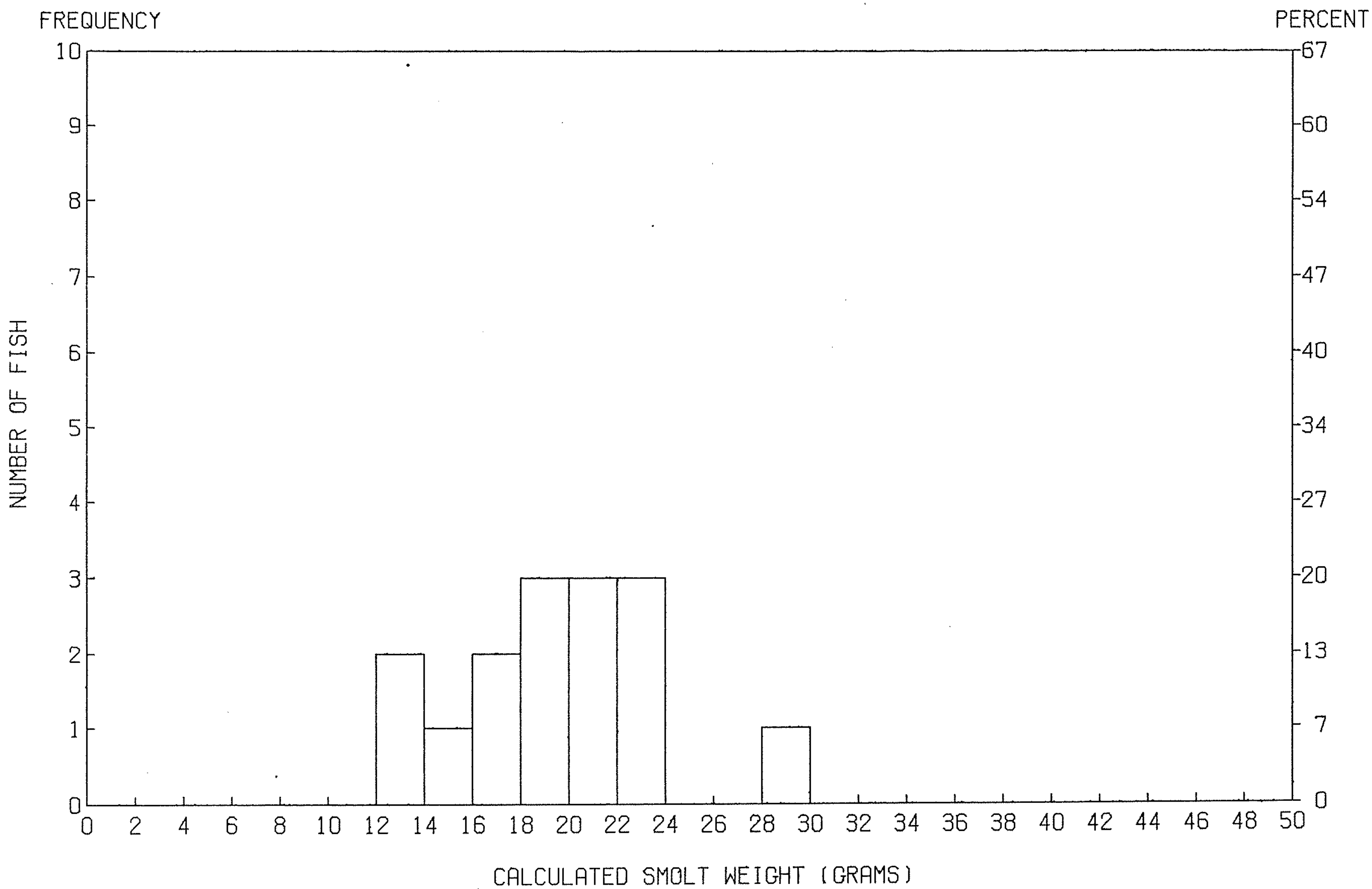

Fig. 10b. Figure 10a expressed in terms of weight.

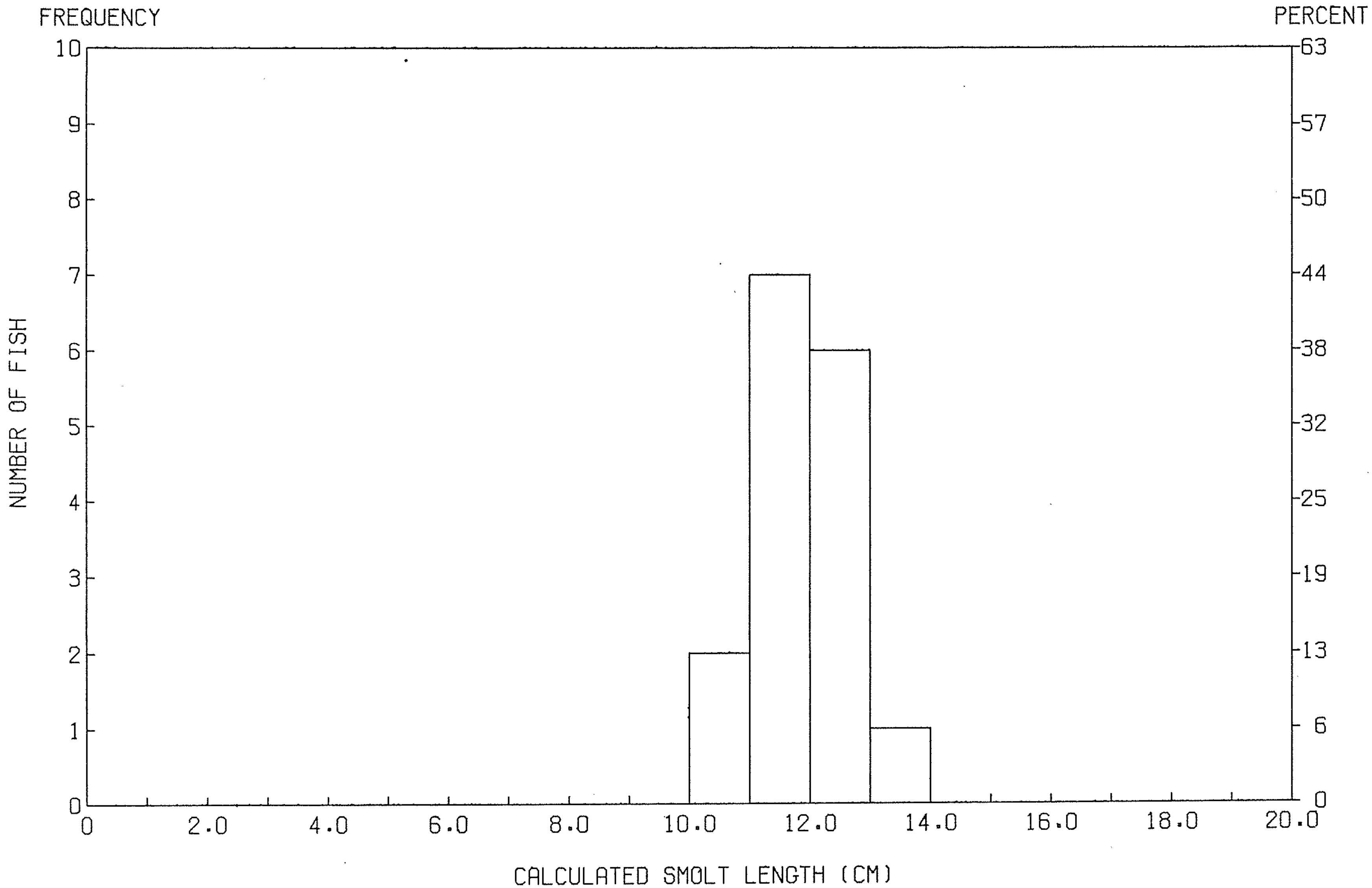

Fig. 11a. Frequency distribution of smolt sizes in Group 600124 represented in the 1979 coho return.

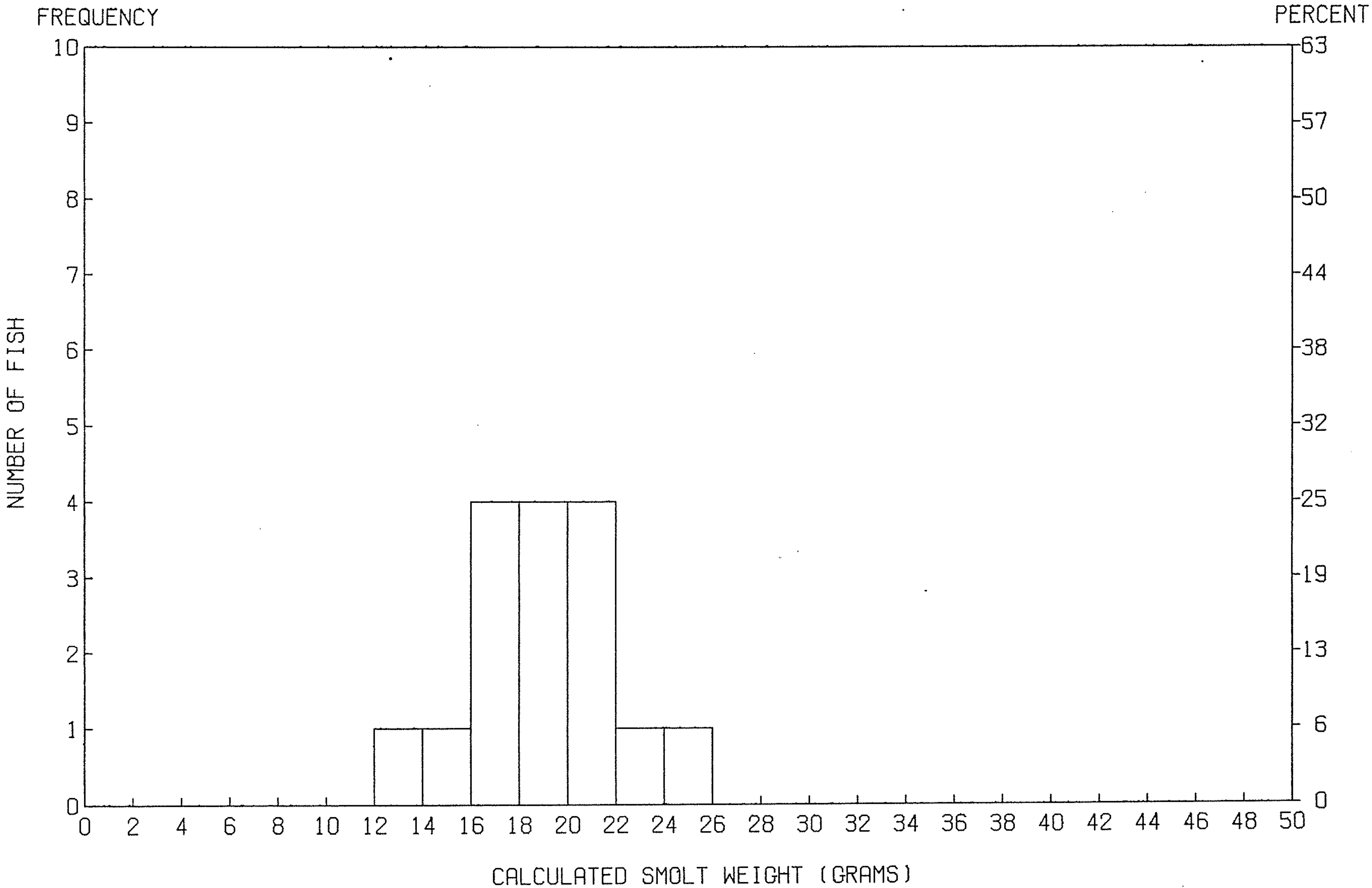

Fig. 11b. Figure 11a expressed in terms of weight.

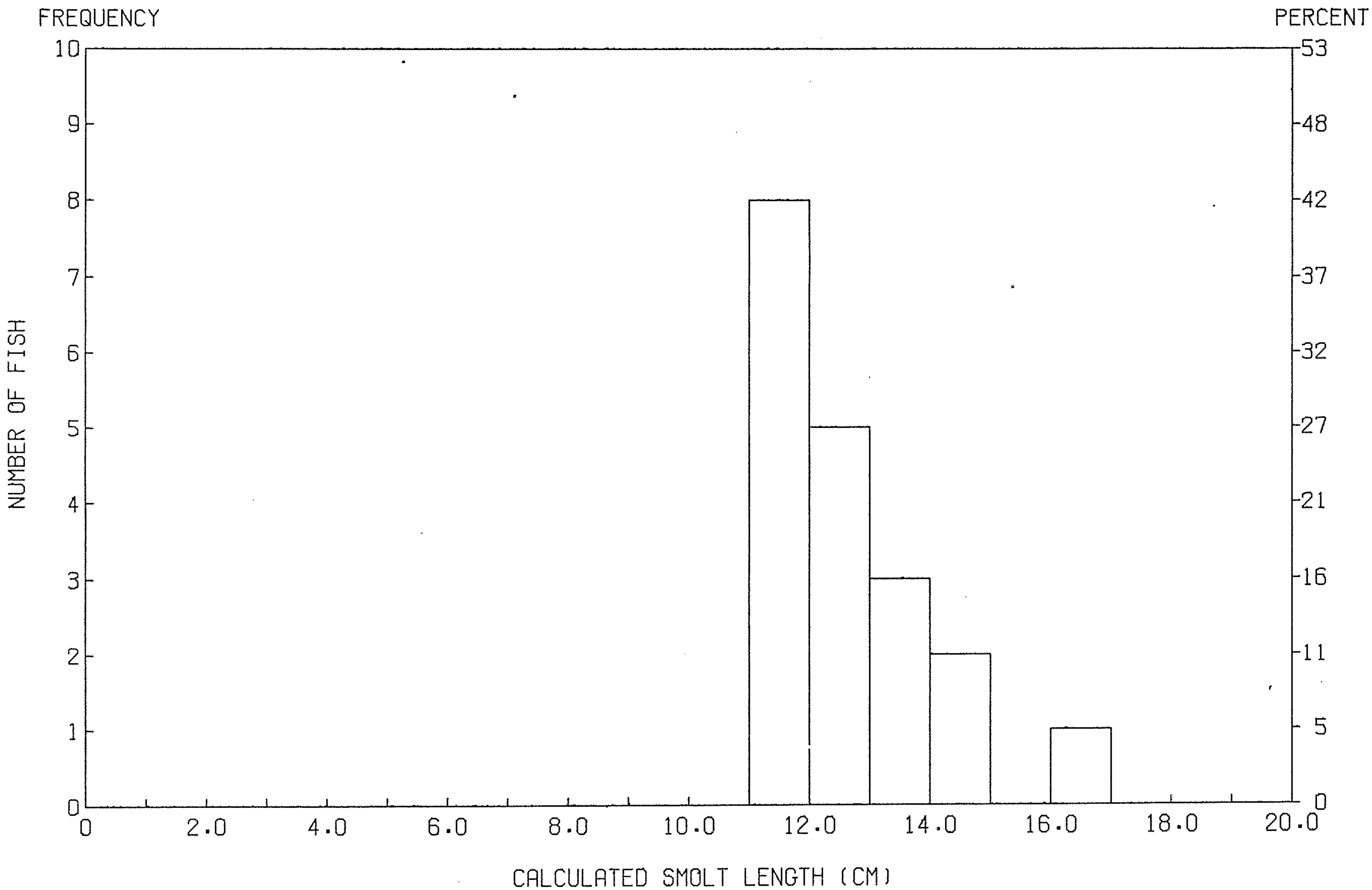

Fig. 12a. Frequency distribution of smolt sizes in Group 600137 represented in the 1979 coho return.

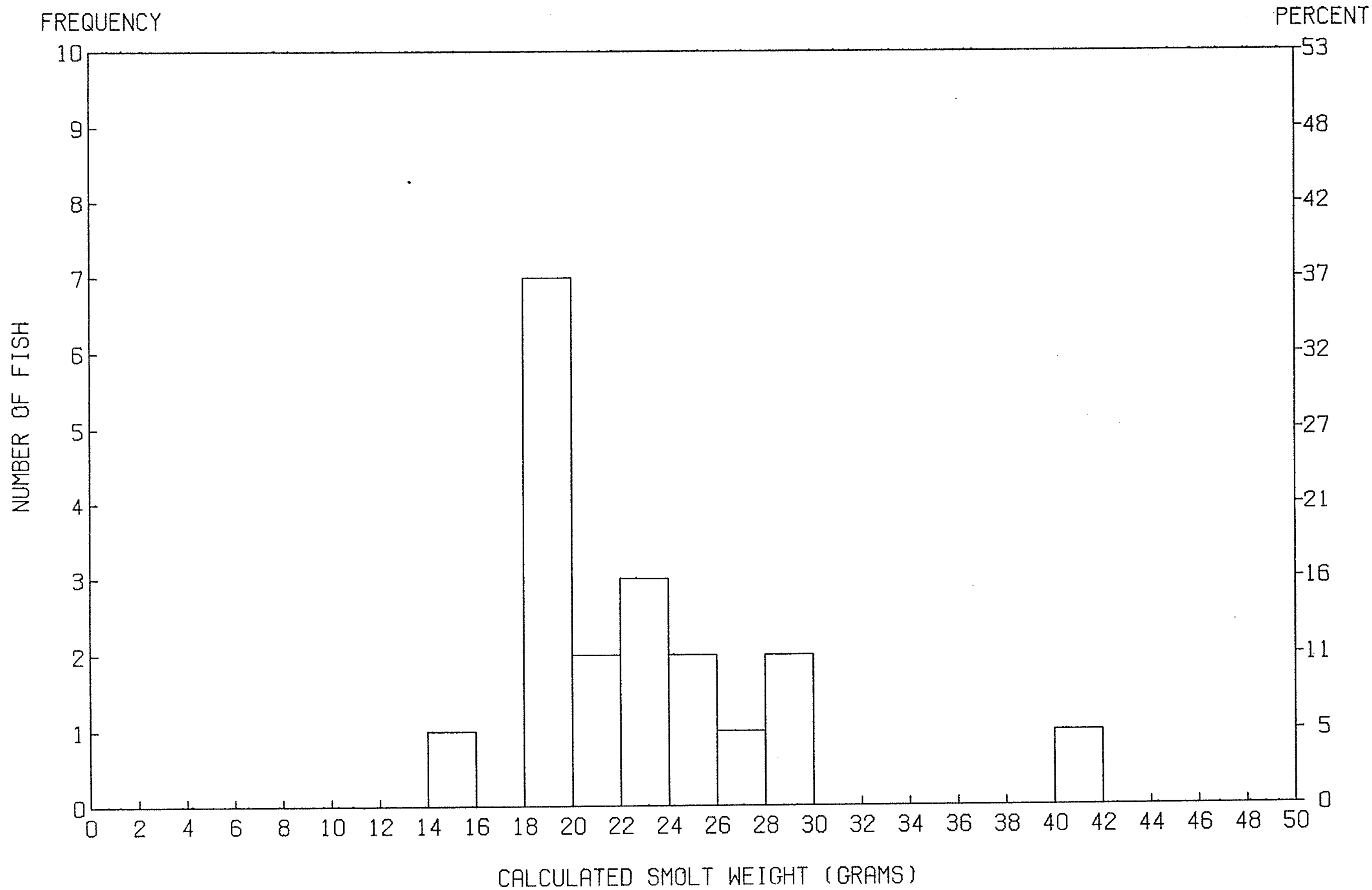

Fig. 12b. Figure 12a expressed in terms of weight.

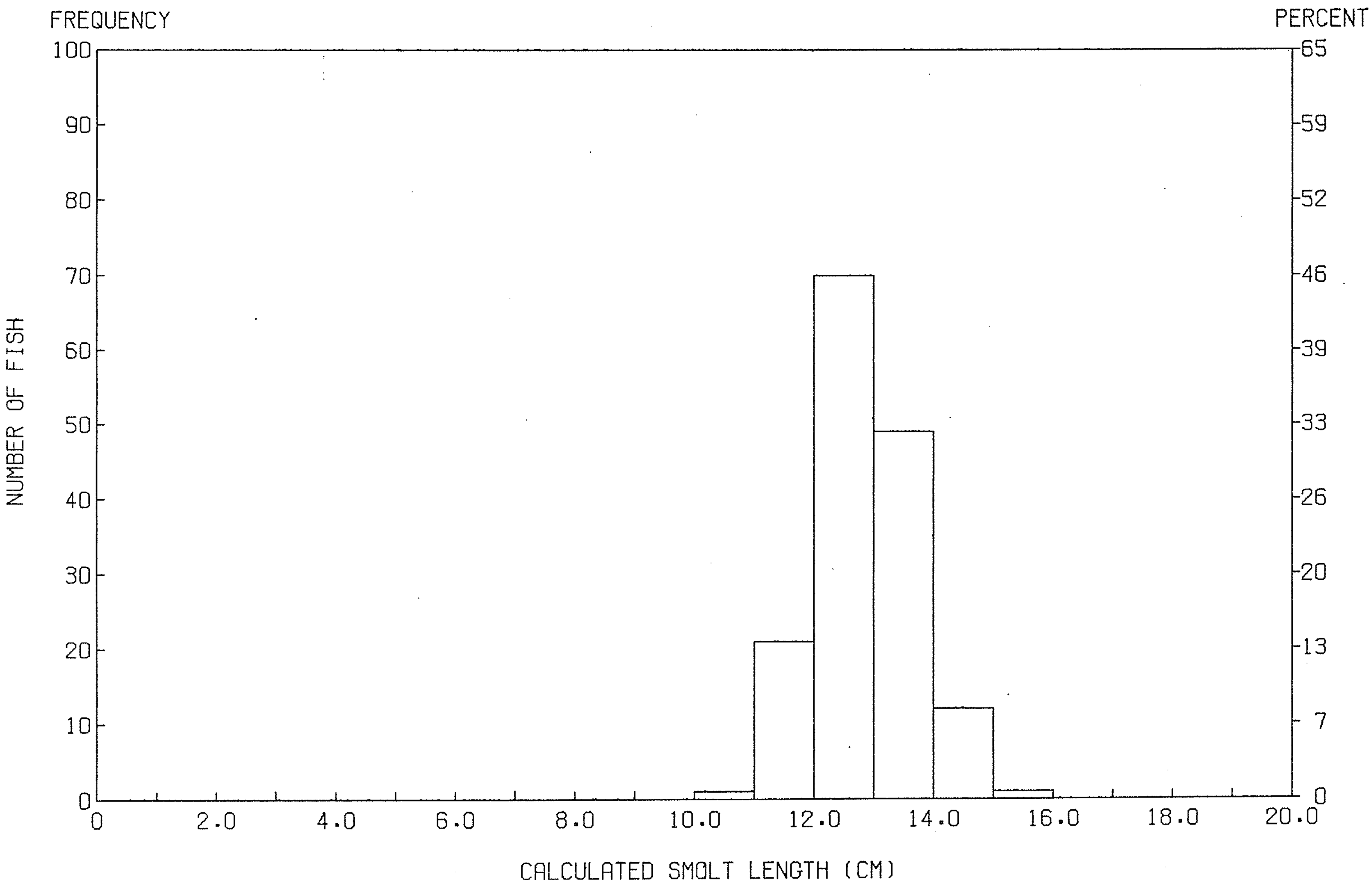

Fig. 13a. Frequency distribution of smolt sizes in Group 603108 represented in the 1979 coho return.

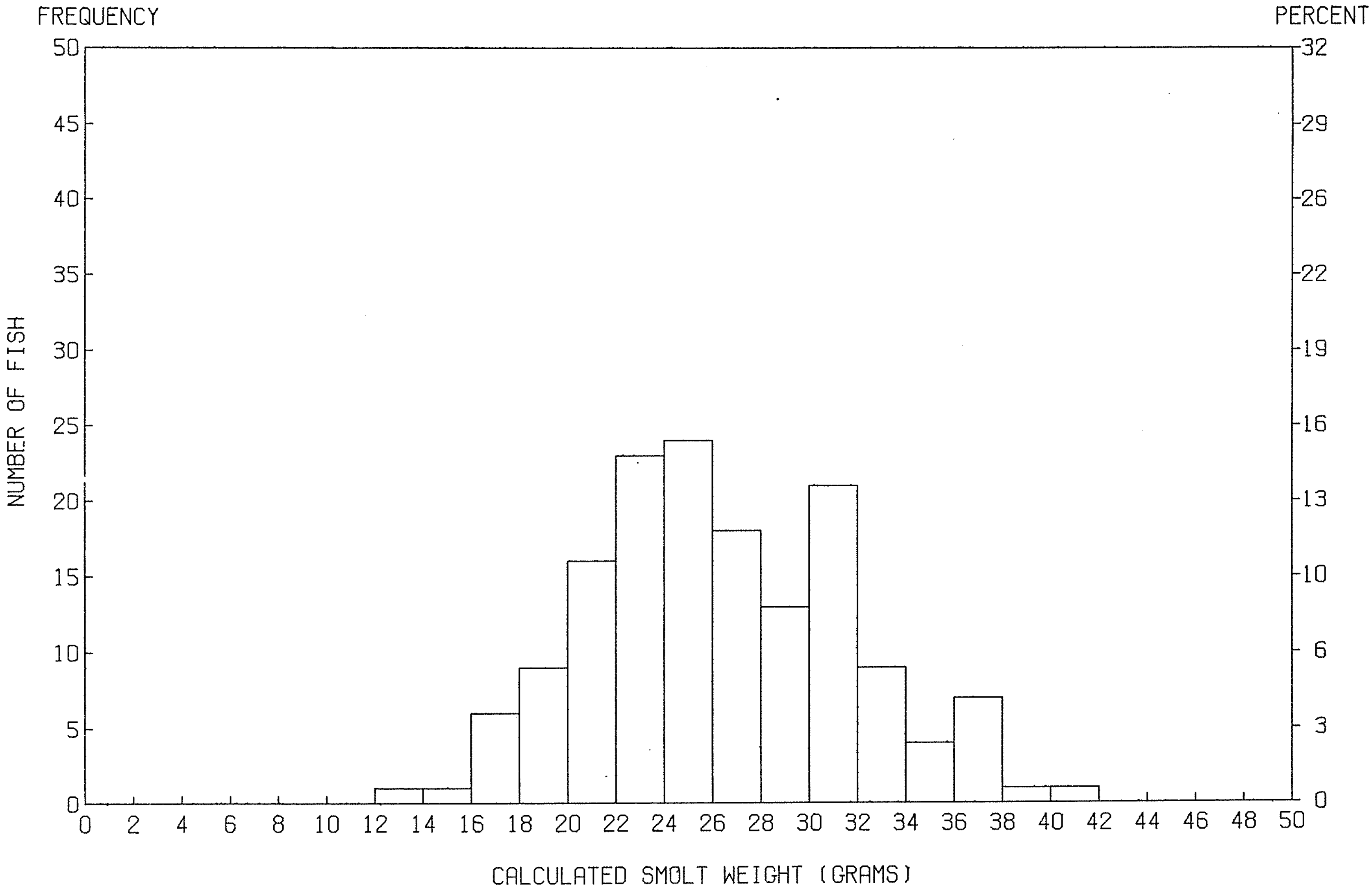

Fig. 13b. Figure 13a expressed in terms of weight.

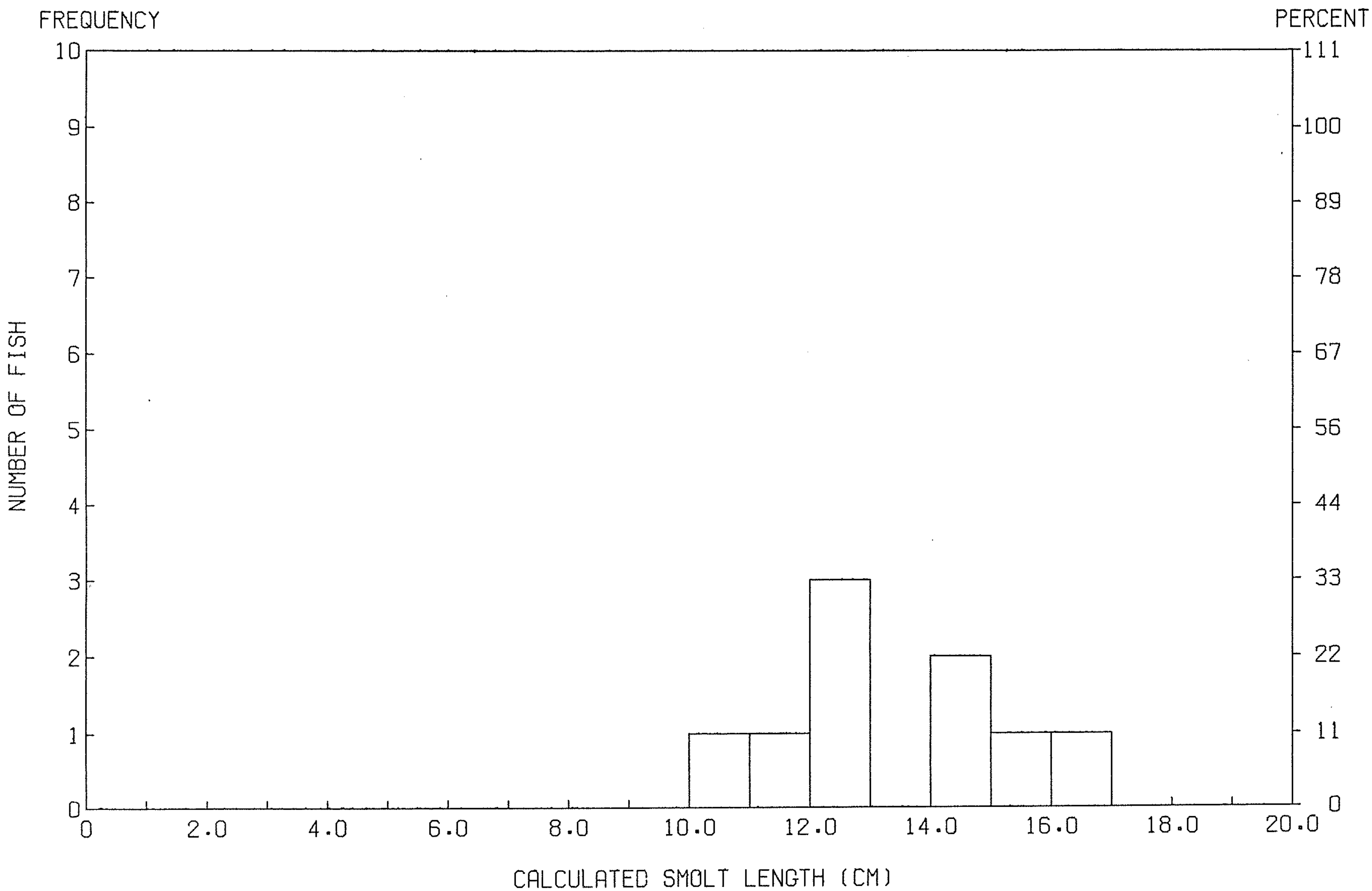

Fig. 14a. Frequency distribution of smolt sizes in Group 620144 represented in the 1979 return.

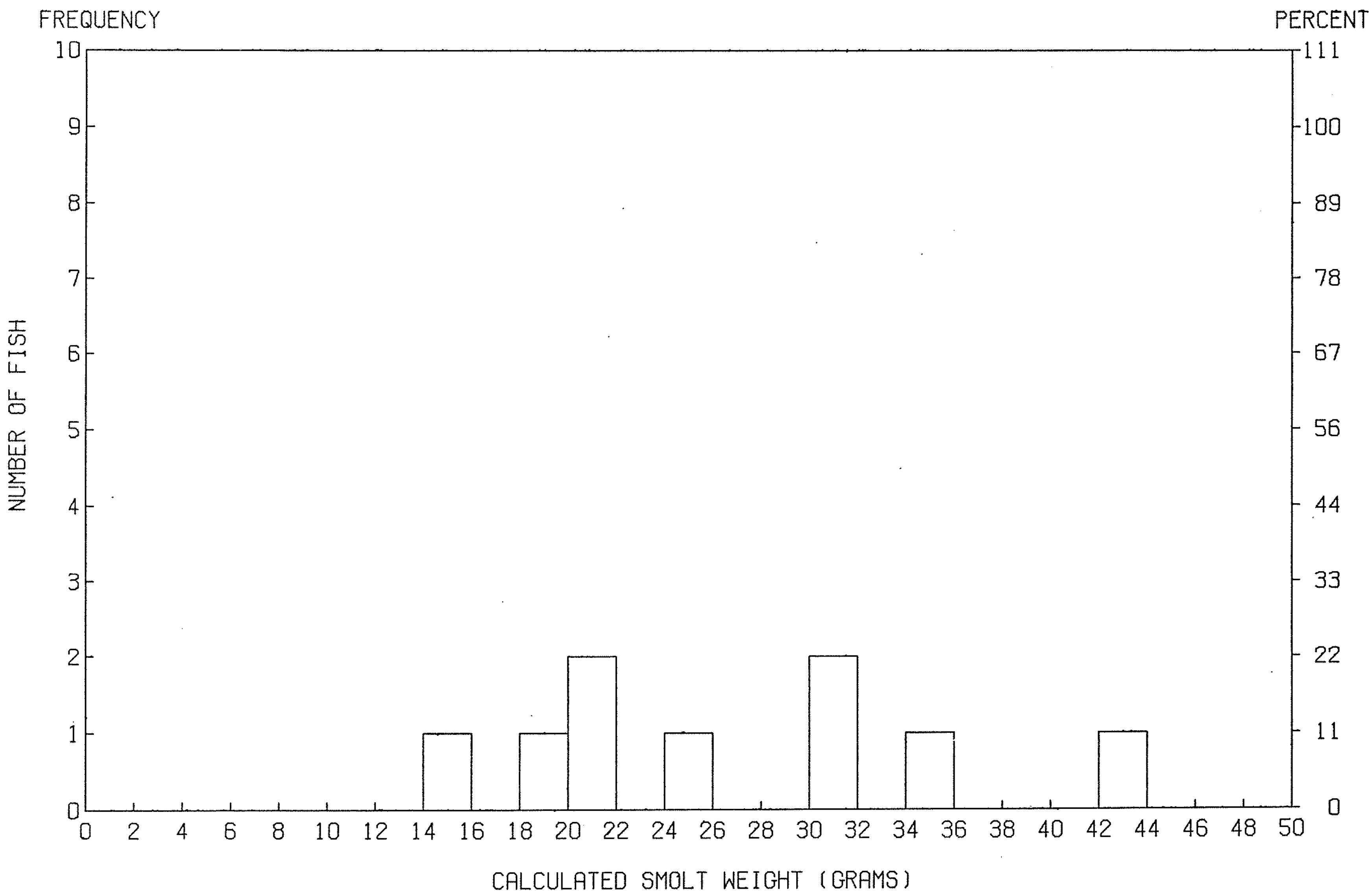

Fig. 14b. Figure 14a expressed in terms of weight.

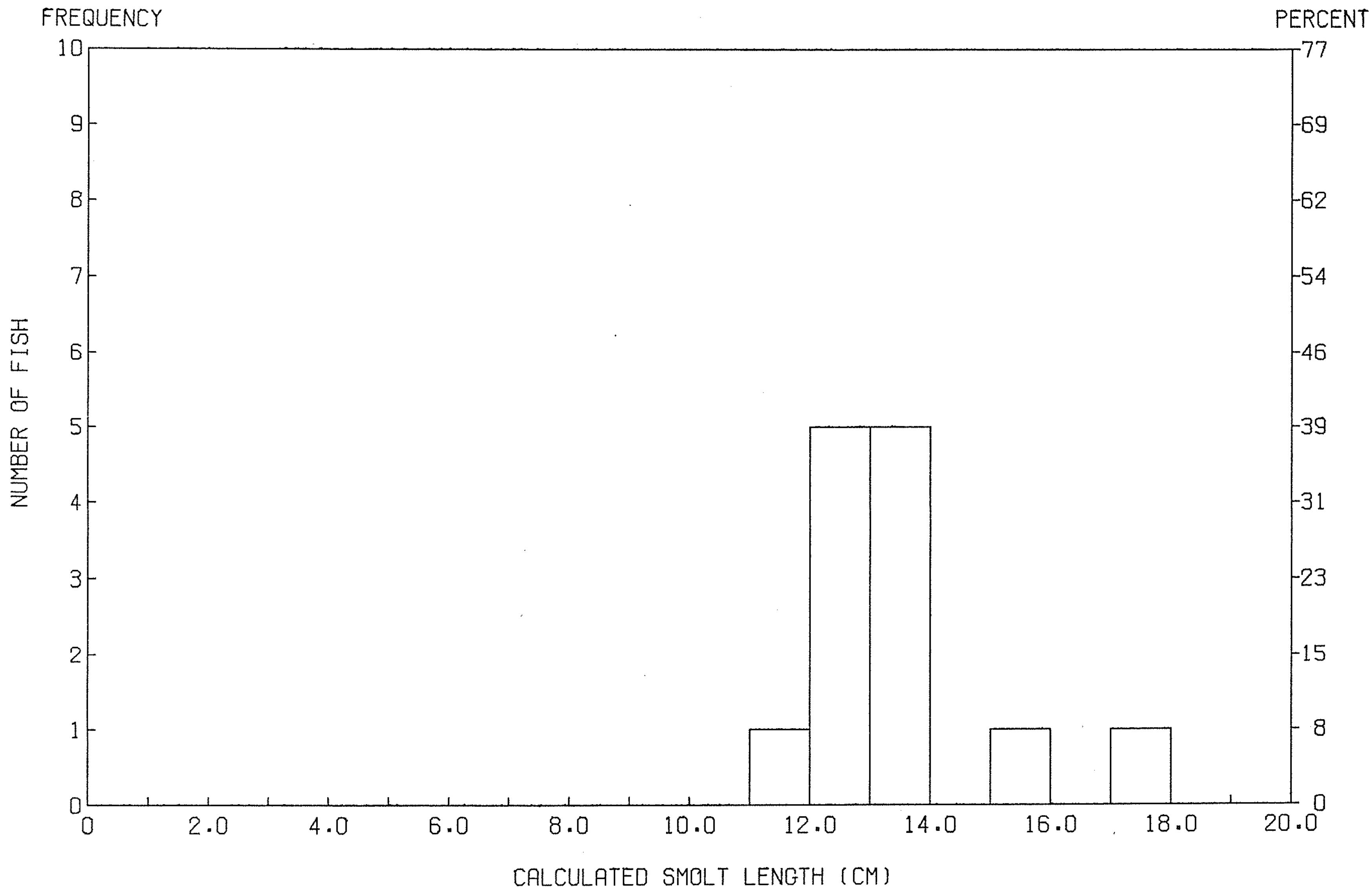

Fig. 15a. Frequency distribution of smolt sizes in Group 620145 represented in the 1979 return.

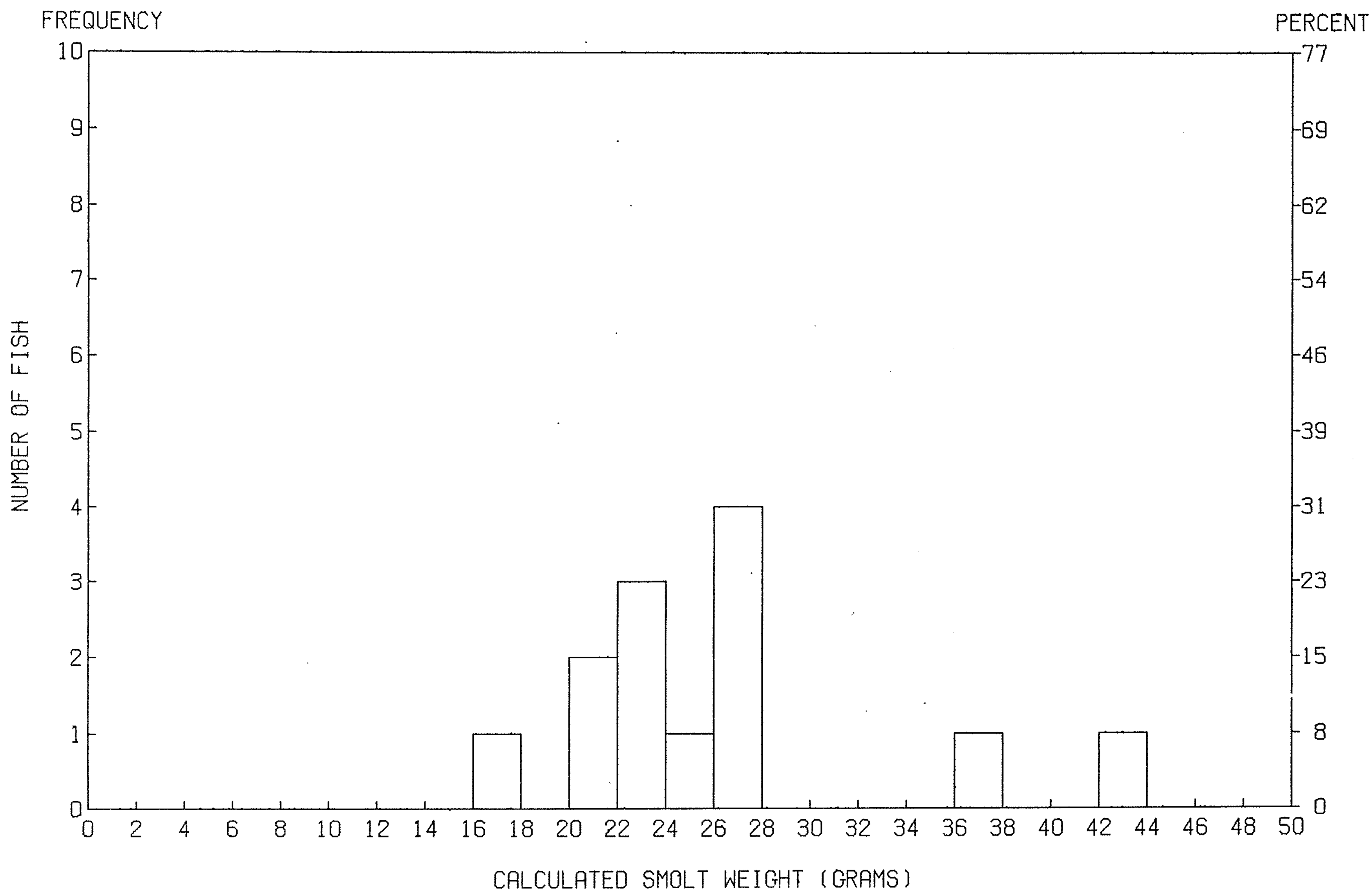

Fig. 15b. Figure 15a expressed in terms of weight.

In fact, tagged fish released in August represented about 11.1% of the total 1978 release of tagged fish and about 25.9% of the total return of tagged fish in 1979. It is important to note, however, that Fig. 16 represents only age 0 smolts which return after one year in the ocean. Myers et al. (1981) present evidence that smolts released in September and October of 1978 may not be represented accurately in Fig. 16 if a disproportionate number of them returned in 1980 rather than 1979.

4.0 DISCUSSION AND RECOMMENDATIONS

4.1 Evaluation of the Study

4.1.1 Estimation of Fish Size

The results of this study clearly show that fish length is considerably more useful than fish weight as an indicator of optimal release size. The relation of fish length to scale radius is less variable than fish weight to scale radius, principally because short-term fluctuations in fish weight are not reflected in scale formation to the extent that long-term changes in hard tissue growth are. Further, variability in condition factor between individual fish within a smolt group and between smolt groups over time makes the estimation of an optimal release weight even more difficult and unattractive.

Optimal size for smolts released into Yaquina Bay, expressed in terms of fish length, appears to be in the range 12 to 14 cm. It is extremely interesting to note that this size is relatively constant regardless of release time or group. For example, yearling smolts released between 12

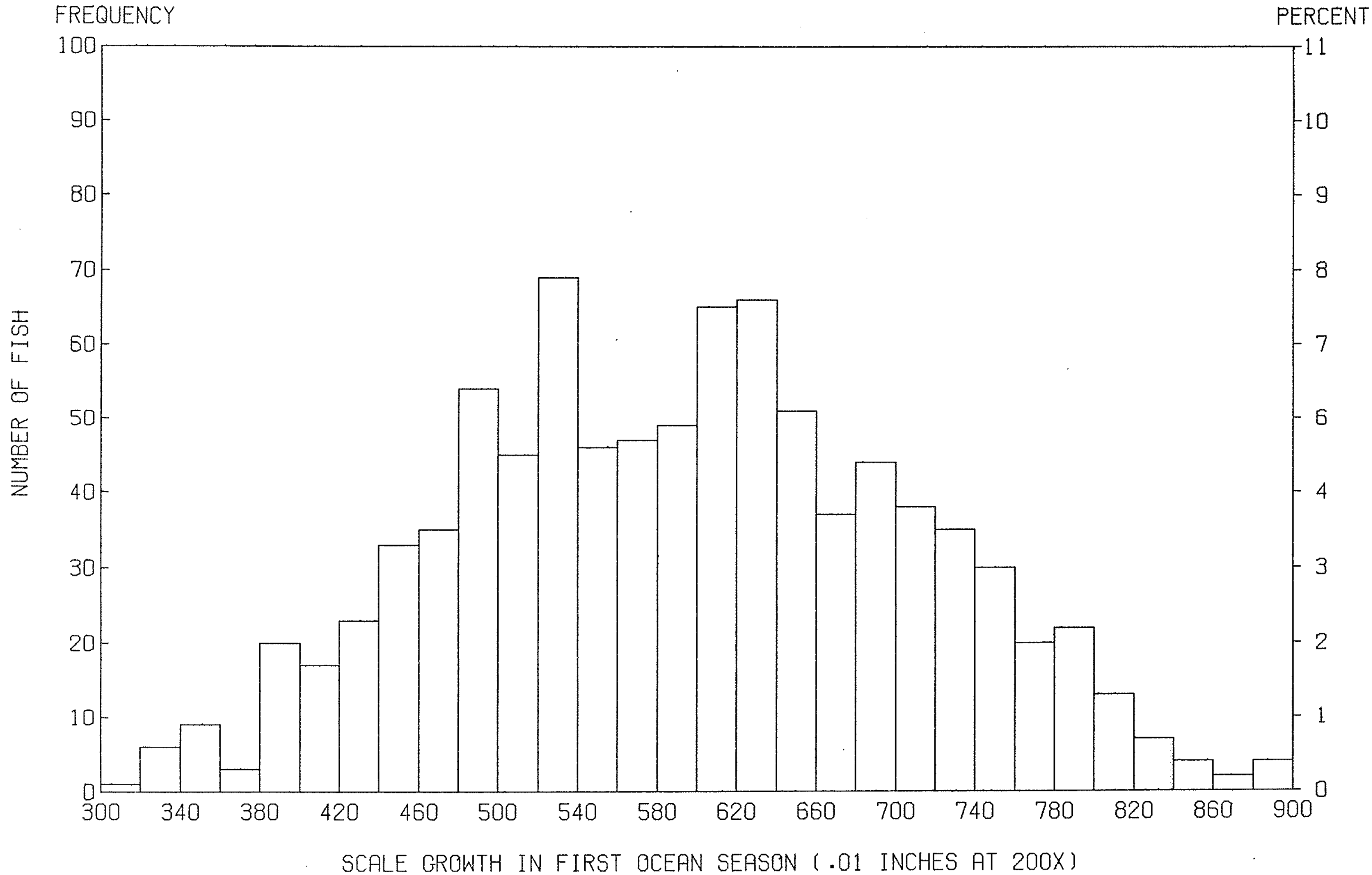

Fig. 16. Frequency distribution of fish growth attained in the first ocean season (expressed as scale growth) represented in the 1979 coho return. Scale measurements are untransformed to units of fish length because a length/scale radius relationship was not developed for ocean growth.

and 14 cm accounted for nearly 62% of the total return from yearling releases. None released at larger than 18 cm returned, possibly due to heavy fishing mortality immediately after release into Yaquina Bay (K. W. Myers, personal communication). Smolts released between 12 and 14 cm accounted for 79% of the total return of the most successful smolt group. Of the other groups showing returns greater than 0.5%, optimum release size appears to have been between 11 and 13 cm. Based on the return of Group 603108 relative to the other release groups, and to some extent on the length at release of successful yearling smolts, we conclude that the overall best length for smolts released into Yaquina Bay is 13 $\pm$ 1.4 cm.

Because studies similar to this one typically are reported in units of fish weight, our recommended optimum release size cannot be compared directly with the results of others. However, the mean size of smolts released in June 1978 that returned as adults in 1979 was approximately 19 g, which compares well with Bilton's (1978) suggestion of a 19 g smolt released in June as being the optimal in terms of size and timing for Vancouver Island cohos. The mean weight estimated for smolts returning from Group 603108 released in August suggests a smolt of about 27 g may be more successful in later releases. This is consistent with Senn et al. (In Review), who found that larger Toutle River coho smolts released in midsummer experienced higher survival than smaller, earlier releases.

4.1.2 Limitations of the Analysis

Results herein reported, and conclusions derived from them, should be considered as being preliminary until a more extensive collection of background data on juvenile cohos reared at OAF facilities can be analyzed. The absence of such information weakens our conclusions in the following ways:

1) Our interpretation of the pre-release portion of adult coho scales is circumstantial at present. There is considerable variability in the patterns of scales from pre-release cohos, post-release cohos (K. W. Myers collection), and adult returns. This variability leads to speculation about the timing and biological significance of specific patterns, and thus inconclusive interpretations. Although available evidence substantiates our decision to include as pre-release growth all circuli curving inward at the base, we cannot positively identify the pattern on each scale corresponding to entry into Yaquina Bay.

2) The equations used to transform length measurements to weight measurements were developed with data from 1980 smolt release groups. The assumption that condition factors were constant between groups within years and between groups between years (1978 and 1980) may not be, and probably is not, valid. In other words, length and weight data for smolt groups released in June of 1980 may not accurately reflect length and weight

characteristics of smolt groups released in June of 1978. This could severely bias our estimates of optimal release weight.

3) The frequency distributions of release sizes in the adult return indicates only that the return was comprised primarily of fish released between 12 and 14 cm. Because we have no corresponding information on the distribution of smolt lengths in those release groups, we cannot determine whether or not survival is size-dependent. For example, smolts in Group 603108 released at 11-12 cm represented about 15% of the adult return from that group, smolts released at 12-13 cm were about 46% of the return, those in the 13-14 cm range were about 33%, and smolts between 14 and 15 cm were about 9% of the adult return. The question remains whether this distribution of percentage return by length differs from the distribution of percentage released by length, or if it merely represents the proportions of smolt lengths in the group at the time of release. Because we have no distribution of smolt lengths in Group 603108 at release we cannot determine if a) 12-14 cm smolts composed 79% of the return because they composed 79% or more of the smolts released, or b) smolts in the upper size ranges returned in proportionately higher numbers than released. In effect, we are concluding in this report that 12-14 cm is the optimal smolt release size solely on the basis that 12-14 cm smolts predominated in the adult return, not because we identified

some smolt length that showed maximum return. In order to calculate return by size increment, which is the essence of a study such as this one, we must first know the distribution of sizes in the smolt release.

Should the data needed to fill the gaps outlined above be collected and analyzed, a scale pattern analysis could provide a reasonably robust model of optimal release size for coho smolts.

4.2 Recommendations

1. Assemble a reference collection of scale samples from juvenile coho for calibrating patterns displayed on scales of adult cohos. Scales, lengths, and weights from approximately 100 fish should be taken two weeks after any handling event, vaccination, nose tag implantation, or transfer to salt water ponds. Such a collection of sequential information will eliminate the confusion associated with interpreting the significance and time of formation of specific scale patterns.

2. Obtain length frequency and weight frequency data for individual smolt groups prior to release. The distributions of smolt release sizes represented in the adult return can then be compared by smolt group with the distributions of sizes at release to check for size-dependent survival.

3. For purposes of determining whether juveniles have attained adequate size for release into Yaquina Bay, measure a sample of approximately 1% of the population within a holding pond in units of fish length.

4. Release coho juveniles into Yaquina Bay at lengths betwen 12 and 14 cm.

5. Verify the conclusions from this analysis with further studies on size-related survival of 1980 and 1981 smolt release groups. Detailed length and weight data are available for individual smolt groups in the releases of these years, thus a thorough analysis of survival by release size increment may pinpoint an optimal smolt release strategy.

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APPENDIX A

Frequency in total adult return, biomass, percent survival, and month of release by smolt group released in 1978.

APPENDIX A

Group	N	Biomass(kg)	Percent Return	Month of release
600101	1	3.0	.04	6/78
600102	7	22.9	.29	6/78
600103	1	3.4	.04	6/78
600104	11	27.6	.46	6/78
600105	10	20.9	.42	6/78
600106	7	19.4	.29	6/78
600107	2	4.6	.08	6/78
600108	6	13.6	.25	6/78
600109	1	3.2	.04	6/78
600110	1	.8	.04	6/78
600111	2	5.7	.08	6/78
600112	1	2.7	.04	6/78
600113	16	38.0	.67	6/78
600114	4	10.6	.17	6/78
600115	2	3.2	.08	6/78
600116	0	0	0	6/78
600117	9	23.3	.38	6/78
600118	14	39.8	.59	6/78
600119	0	0	0	6/78
600120	4	10.5	.17	6/78
600121	1	3.9	.04	6/78

Group	N	Biomass(kg)	Percent Return	Month of release
600122	6	15.5	.25	6/78
600123	14	29.5	.59	6/78
600124	16	36.1	.67	6/78
600125	1	2.4	.04	6/78
600126	8	19.0	.33	6/78
600127	2	5.5	.08	6/78
600128	4	9.6	.17	6/78
600129	2	4.0	.08	6/78
600130	6	9.9	.25	6/78
600131	3	8.6	.12	6/78
600132	1	3.5	.04	6/78
600133	0	0	0	6.78
600134	2	3.0	.08	6/78
600135	4	12.9	.17	6/78
600136	2	4.2	.08	6/78
600137	19	55.6	.79	6/78
600138	6	17.7	.25	6/78
600139	8	23.9	.33	6/78
600140	2	7.4	.08	6/78
600141	4	9.5	.17	6/78
600142	2	6.3	.08	6/78
600143	3	6.8	.12	6/78

Group	N	Biomass(kg)	Percent Return	Month of release
600144	2	4.3	.08	6/78
600145	4	9.0	.17	6/78
600146	0	0	0	6/78
600147	4	7.1	.17	6/78
600148	2	5.6	.08	6/78
600149	7	18.0	.29	6/78
600150	0	0	0	6/78
600151	5	14.9	.21	6/78
600152	0	0	0	6/78
600153	4	10.8	.17	6/78
600154	1	2.0	.04	6/78
600155	4	13.7	.17	6/78
600156	0	0	0	7/78
600157	2	3.4	.08	7/78
600158	2	3.2	.08	7/78
600159	0	0	0	7/78
600160	1	1.2	.04	6/78
600201	0	0	0	6/78
600202	0	0	0	6/78
600203	0	0	0	6/78
600204	5	17.4	.21	6/78
600205	8	17.4	.33	6/78
600206	6	15.9	.25	6/78

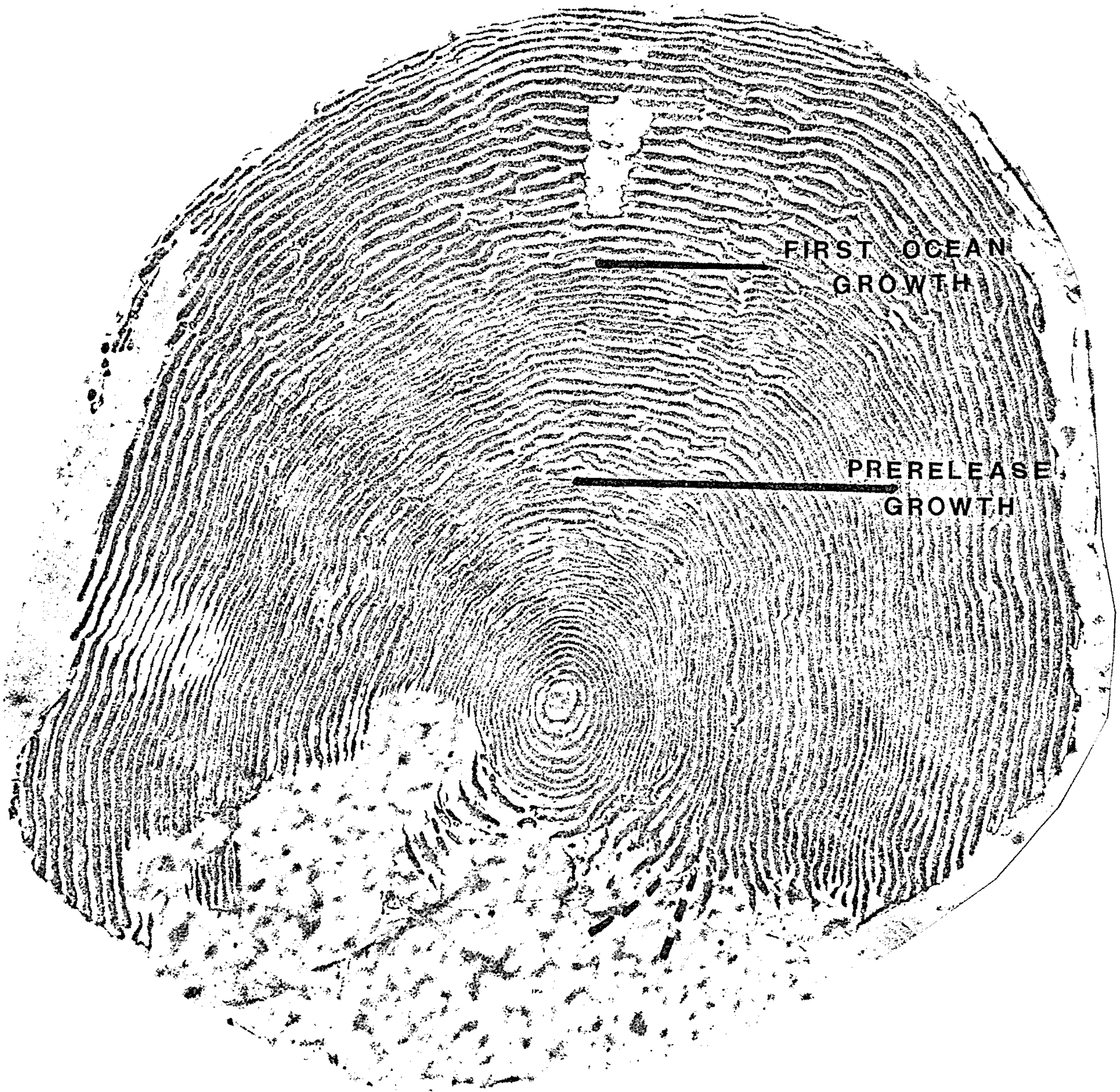
Group	N	Biomass(kg)	Percent Return	Month of release
600207	3	7.4	.12	6/78
600208	0	0	0	6/78
600209	3	8.6	.12	6/78
600210	7	15.1	.29	6/78
600211	5	11.7	.21	6/78
600212	2	4.3	.08	6/78
600213	6	12.0	.25	6/78
600214	5	11.1	.21	6/78
600215	0	0	0	7/78
600216	2	4.5	.08	6/78
600217	1	2.0	.04	6/78
600218	1	2.2	.04	7/78
600219	2	4.3	.08	7/78
600220	1	1.6	.04	7/78
600221	4	7.0	.17	6/78
600222	8	15.5	.33	6/78
600223	4	6.9	.17	6/78
600224	4	10.5	.17	6/78
600225	5	8.0	.21	6/78
600226	0	0	0	7/78
600227	0	0	0	7/78
600228	3	7.5	.12	6/78
600229	1	2.6	.04	6/78

Group	N	Biomass(kg)	Percent Return	Month of release
600230	0	0	0	7/78
600231	2	4.9	.08	7/78
600232	5	9.5	.21	7/78
600233	4	7.6	.17	6/78
600234	0	0	0	7/78
600235	3	5.9	.12	6/78
600236	1	2.3	.04	6/78
600237	0	0	0	7/78
600238	2	3.3	.08	7/78
600239	2	3.8	.08	7/78
600240	2	3.0	.08	6/78
600241	3	9.7	.12	6/78
600242	3	6.7	.12	6/78
600243	10	26.5	.20	6/78
600244	5	10.9	.10	7/78
600245	2	3.6	.04	7/78
600246	7	15.0	.10	7/78
600247	0	0	0	7/78
600248	5	10.8	.06	8/78
600249	0	0	0	8/78
600250	0	0	0	8/78
600251	3	6.1	.20	8/78
600252	2	4.9	.08	8/78
600253	2	4.4	.07	8/78

Group	N	Biomass(kg)	Percent Return	Month of release
603101	0	0	0	6/78
603102	0	0	0	7/78
603103	6	11.7	.04	6/78
603104	27	64.8	.18	6/78
603105	5	11.4	.04	7/78
603106	4	8.6	.03	6/78
603107	20	40.2	.14	7/78
603108	154	304.4	1.21	8/78
603109	53	109.2	.37	8/78
603110	5	11.7	.06	9/78
603112	14	30.6	.17	6/78
603114	31	85.8	.33	6/78
603115	9	15.6	.11	8/78
603116	5	9.2	.06	8/78
620144	9	28.0	.18	4/78
620145	13	44.2	.26	4/78

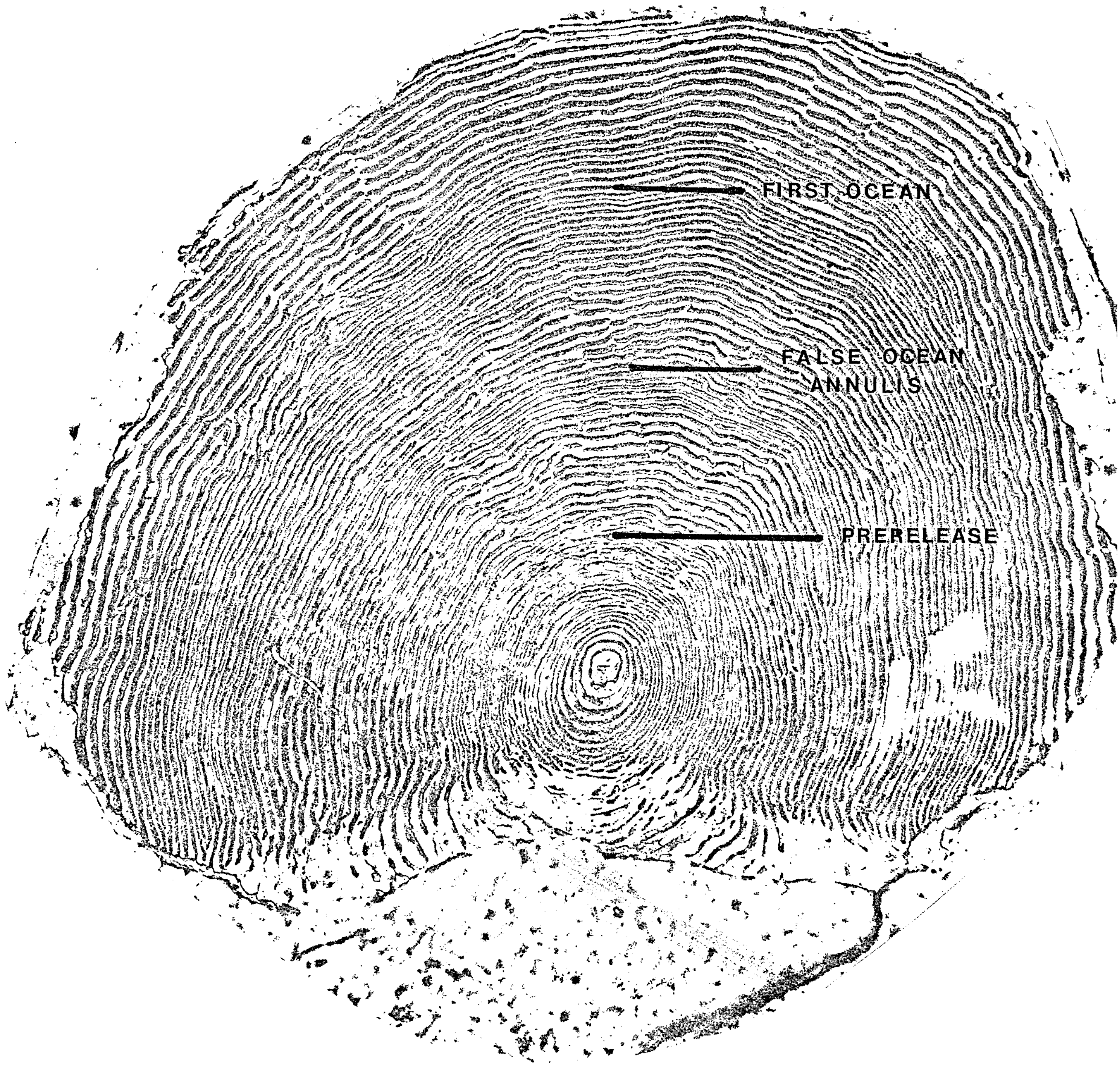
APPENDIX B

Photographic atlas of patterns observed on the scales of adult cohos returning in 1979 to OAF, Yaquina Bay.



Appendix Fig. B-1. Scale from a yearling coho released in April 1978. Note: 1) the transition from inward-curving circuli to relatively straight circuli; 2) accelerated growth inside the outermost circulus of pre-release growth.

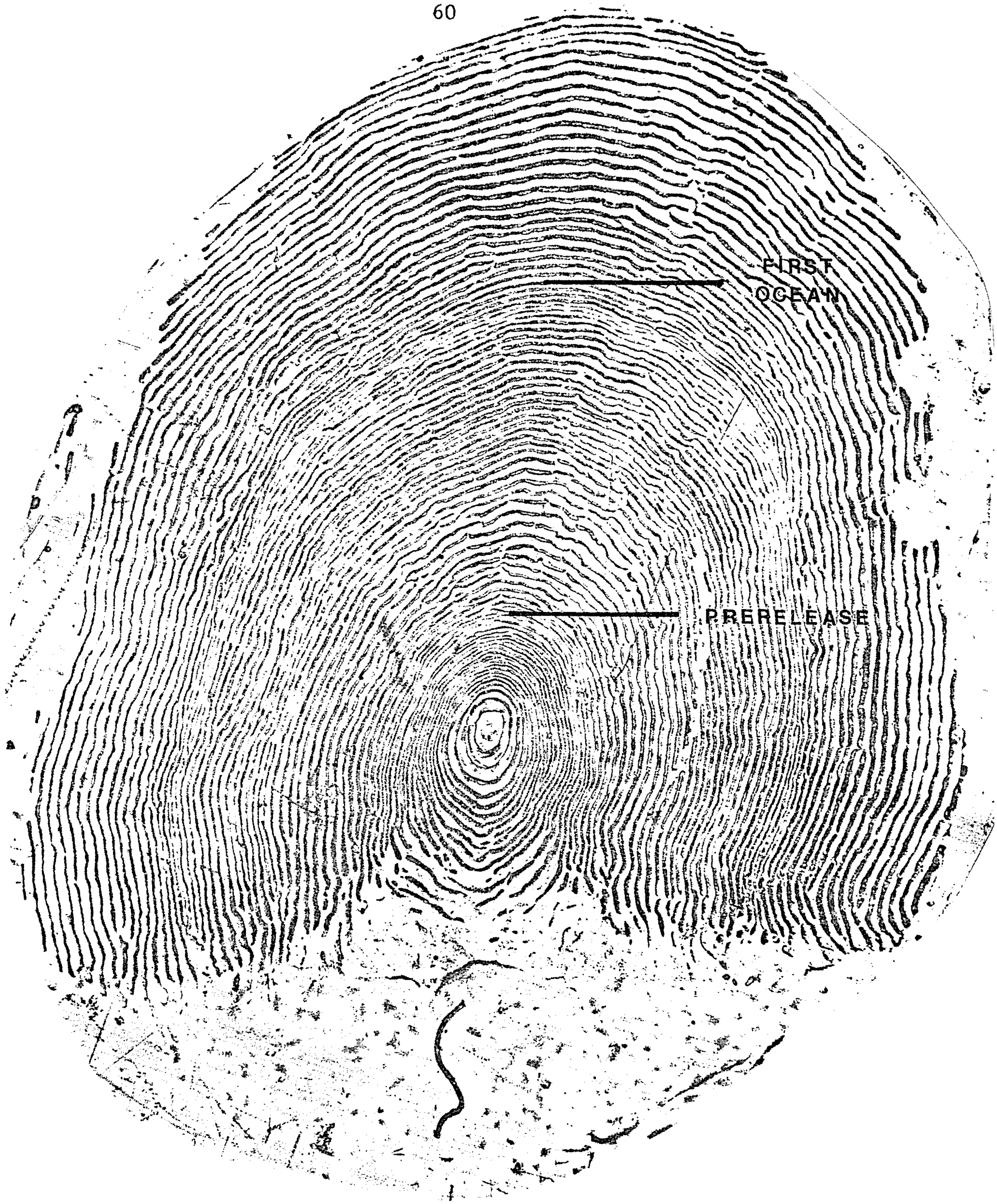
Appendix Fig. B-2. Scale from a yearling coho released in April 1978. Determination of pre-release scale growth is somewhat more difficult; however, the presence of a circulus which is complete through the unsculptured field of the scale often is a good delimiter of estuary, or transition, growth.



Appendix Fig. B-3. Scale from a yearling released in April 1978. Pre-release growth is easily discerned by inward-curving circuli. Note the apparent check in ocean growth prior to annulus formation. This check was present on many scales, and has also been observed on scales of coho adults returning to the OAF facility at Coos Bay.

Appendix Fig. B-4. Scale from an age 0.1 adult released into Yaquina Bay in June 1978. Pre-release circuli can be separated from ocean circuli at the lower right position. Note the presence of checks.

Appendix Fig. B-5. Scale from an age 0.1 adult released in June 1978. On this scale, only one check is apparent near the edge of pre-release growth.



Appendix Fig. B-6. Scale from an age 0.1 adult released in June 1978. Circuli which curve inward at the base are easily distinquished from others. Note that the last circulus of pre-release growth is followed on the scale by two additional circuli which are similar in appearance.

Appendix Fig. B-7. Pre-release growth on this scale of an age 0.1 adult released in June 1978 is difficult to identify using only the decision rule given in the text. Careful examination shows that the position marked on the scale separates inward-curving circuli from straight ones.

Appendix Fig. B-8. Scale from an age 0.1 adult released in July 1978. Pre-release growth is clearly defined. Note: 1) the check near the scale focus; 2) absence of a distinct transition from relatively thin, closely-spaced circuli to thicker, more widely-spaced ocean circuli; 3) distinct ocean annulus.

Appendix Fig. B-9. The pre-release portion of the scale from an age 0.1 adult released in July 1978 is easy to delineate. Only one check is present on the scale, and pre-release growth abruptly gives way to accelerated ocean growth.

Appendix Fig. B-10. Careful inspection of this scale from an age 0.1 adult released in July 1978 shows that the decision rule for designation of pre-release scale growth places the last circulus of pre-release growth amid circuli of very similar appearance. To avoid confusion, we must rely on the consistency of the decision rule.

Appendix Fig. B-11. Scale from an age 0.1 adult released in August 1978 showing considerable resorption at the margin. Pre-release scale growth is reasonably difficult to delineate, since many circuli formed later curve inward at the base as well. In a case such as this, one must consider 1) where the most noticeable separation at the bases of adjacent circuli occurs; and 2) the extent to which a transition to accelerated scale growth suggests the end of pre-release growth.