THESIS

On

Observations on the Scales of the Chinook Salmon (Oncorhynchus tschawytscha) with Particular Reference to the Variations which may affect the Determination of Age.

Submitted to the

OREGON AGRICULTURAL COLLEGE

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

In

THE SCHOOL OF AGRICULTURE

Department of Zoology

By

Redacted for Privacy

May 26, 1915

APPROVED:

Redacted for Privacy

Professor and Head of Department of Zoology

in charge of Major

Redacted for Privacy

Dean of School of Agriculture

Redacted for Privacy

Chairman of Committee of Graduate Students

and Advanced Degrees

Observations on the Scales of the Chinook Salmon (Oncorhynchus tschawytscha) with Particular Reference to the Variations which may affect the Determination of Age.

Introductory.

Shortly after the writer's arrival in Corvallis, a call came to assist in determining if possible, the etiology of an epidemic which caused a serious loss of salmon fry in one of the State hatcheries. From my work in this connection (the results of which may be found in the files of the departments of zoology and bacteriology of the Oregon Agricultural College) sprung an acquaintance with various other problems which faced the state hatchery workers. But by the time my bacteriological investigations were finished it was too late in the year to get material for a start, and moreover my knowledge of fish cultural practices and principles were still too scanty to be of any assistance in carrying out any applied research work. Accordingly the remainder of the year was confined to gaining this required knowledge, and a more thorough understanding of the problems at hand.

Perhaps the question naturally arises here as to the necessity of artificial propagation. People are wont to remark that in other days the salmon succeeded in reproducing their kind without human aid and that it is not to be expected that they cannot do so to-day. The answer to this question is found in a study of conditions which actually prevent the fish from ever depositing their eggs in that portion of a river where instinct tells the females their eggs are best cared for. We know that the females ascend the coastal streams great distances to deposit their eggs in the fine gravel and cold clear medium of the headwaters. But civilization has seen fit to erect barriers such as power-dams and irrigation dams which prevent this ascent. Cities are built on the banks of the rivers and the sludge from their sewers and the distasteful and poisonous by-products of their manufactures are poured into the stream to sicken and devitalize those individuals that escape the fishermen's nets, racks and wheels. Small wonder then that with the decreased numbers which eventually reach the headwaters via man-made fishways over dams almost impossible of ascent, and the enormous loss due to predatory animals and fishes, that those young which eventually mature come far from being a fair numerical representation of their ancestral hosts.

Before the advent of a system of artificial propagation of the various species involved, the annual take of these food fishes in the Pacific Coast rivers had begun to decrease at an alarming rate. The same crisis was faced in the British isles long before Columbus discovered our continent. Records of the old Scottish courts refer us to an article in the penal code of about 1432 wherein it was set forth that a man convicted for a third time of poaching or over-fishing should forfeit his life for the offense unless he be able to buy himself off. But the introduction of a working scheme for artificially rearing salmon has worked wonders with the supply of the

Oregon Coastal streams. That this is no vainglorious boast on the part of the hatchery superintendents is borne out by the action of the Astoria cannery men, who during the past summer (1914) subscribed $3,000 for the construction of artificial rearing ponds at the Bonneville State Hatchery for the express purpose of rearing a high grade of commercial salmon; viz, Spring, Chinook.

The financial support thus gained marked the winning over of this group of business men who heretofore were just the least bit skeptical about the project. This change of sentiment was due largely to the efforts of the present superintendent of hatcheries, Mr. R. E. Clanton, who upon coming into his present position just five years ago, in the summer of 1910, turned out during his first year an unusually large number of salmon of the blueback variety (O. nerka). The normal life period for the members of this genus has long been assumed to extend over a period of four years (subject to individual digression). If this be the case, it was to be expected that four years from the date of liberation, that season would be marked by a correspondingly large run of this species. And this is exactly what occurred, demonstrating to the fishermen of the lower Columbia the great value of the salmon hatcheries.

It so happens, however, that the blueback salmon is not the most profitable fish to handle, nor is it the best liked by the consumers. The species which is most valuable from both standpoints is one commonly known as the Chinook or King Salmon (O. tschawytscha) and which is characterized by having two distinct spawning runs, one in the spring, the other in the fall of the year. Of the two runs, the former is the more highly prized because of its rich pink color, smooth flesh texture, high fat content and choice flavor. The fall run is notably of a paler tint, is dry and lacking in fat and quite flat to the taste. The cause of this difference is unknown at present and will not be dealt with at greater length in this paper. The subscription before mentioned was raised for the purpose of increasing the output of the more palatable variety.

In the early days of artificial fish propagation it was customary to release the fry as soon as the yolk sack was nearly absorbed and the young began to feed for themselves. I am told by old hatchery employees that it was a very noticeable fact that when these fry were liberated by dumping them from buckets into the river, that the surface of the water literally swirled as the hungry trout and other preying fish eagerly awaited the feast of these unprotected fry. Now the practice has changed; after hatching, the fry are placed in rearing ponds where they are fed until they reach a length of two or three inches or more; they are then able to take care of themselves, consequently the return should be much greater. However, this practice also meets considerable criticism, some claiming that the cost of building retaining ponds and feeding over a stretch of several months entails an expense never met by the increase of fish taken commercially.

For a defense of the present day cultural practices we are at present obliged to rely on our convictions, and such support as that advanced by the Astoria merchants. But it is our hope to demonstrate the value of the work experimentally and in a scientific manner overcome whatever objections still remain.

With this end in view a series of experiments was begun last fall through the medium of which it is hoped to obtain data which shall show what percentage of the fingerlings liberated would eventually return as adults. Of prime importance in this connection is the consideration of the spring and fall varieties. Do the eggs from spring and fall fish give rise to adults which will migrate as spring and fall runs respectively? Can we establish without question a knowledge of the normal life period for these fish and so predict a year when a large return from any one brood may be expected to return?

To settle this latter point it is necessary to devise some scheme by which we can tell the age of a returning individual and perhaps check this record with some mark placed on the fry at the time of liberation. This problem of age at maturity of our Pacific Coast salmon has a peculiar interest as concerns these species because of the fact, now sufficiently demonstrated, that all individuals perish when they attain sexual maturity. They spawn but once and then die, whatever the age or the size at which sexual maturity has been reached and whatever may be their physical condition at the time of spawning.

Gilbert has pointed out the possible exception to this rule in the case of certain male King salmon fingerlings which mature precociously in the streams during their first year, at a length of 3 to 7 inches; the fate of these has as yet not been determined. This peculiarity in their life history renders the question of their age at maturity an unusually important one, both from the scientific fish cultural and the purely economic standpoints.

Many attempts have been made to solve the problem for the most important of our Pacific Coast species; viz., O. tschawytscha and O. nerka, usually by marking hatchery-reared fry with a metal tag or by merely clipping some one fin or a particular combination of fins. Unfortunately these experiments have never been carried through with detailed precision, the data gathered resulting in somewhat discordant and uncertain results. For example, we have partial data on an experiment carried on by a Mr. Rutter in 1896 when he liberated 5,000 marked fry. From this number 376 were reported to have returned in the third year, but the records for ensuing years were not kept. Other fish have been liberated by Mr. Henry O'Malley acting on authority for the United States Government; they were marked with a silver wire loop and are not due to return until the fall of 1915. I am given to understand that Mr. O'Malley is of the opinion that this loop will have become grown over and will be too deeply imbedded in the body to be readily found.

In 1912, Mr. R. E. Clanton conceived the idea of placing the mark on the operculum, a very tough structure which is seldom injured under normal conditions, whereas fish frequently lose fin and tail rays and pass through many natural barriers, on which such things as metal loops and tags may be easily caught and torn out. The scheme used by Mr. Clanton consisted in cutting a "V" shaped piece from the operculum, using a sort of steel punch which he had made for the purpose. Some of these cuts included more of the operculum than others, and during the last spawning season (1914) several fish with peculiar gill marks which seem to have been caused by the method just described were taken. It is a noticeable fact that the clearness of the mark on the adult depends on the amount of operculum originally cut out; those incisions reaching the preopercle being much more clearly defined than those which went no farther than the sub-opercle or the inter-opercle. (See Plates II & III). To my mind this method offers the most feasible system for marking, although there are still several investigators within my acquaintance who have yet to be convinced of it. The best argument advanced in favor of this mark comes from the men who do the actual fishing, and handling of cannery fish along the Columbia. These men are schooled through long years of service to observe peculiar marks on salmon after the fashion of a cattleman trained in observing brands, as the National Government has several times offered attractive rewards for the return of other marked fish. Moreover this group of men are particularly willing to co-operate in establishing new facts concerning the life and habits of the salmon, this willingness amounting to a pleasurable hobby. Before the last spawning season (1914) no fish bearing this mark had ever been observed by these men; net injury to the gills and opercula being of an internal nature or confined to the extremities of the cleft while the mark referred to is always median in position.

This marking experiment was merely to test its value and now in view of the success obtained by its proper use, it is intended to mark a definite number of fingerlings in this manner and await their return. This should yield the data so long desired.

The experiments noted above have been supplemented by others in Tomales Bay, Cal., and in New Zealand (according to Gilbert) where fry were planted in streams not frequented by the species in question and the return of the adults noted. Also in the case of the Sockeye or blueback (O. Nerka) there is the quadrennial increase in the Frazer River, which has generally been accepted as demonstrating a four year cycle for the species.

But these researches cast no light on the individuals of a run, which is without doubt composed of fish exhibiting a great diveristy of age. In the case of several widely different genera, the markings of the scales and otoliths have proved of decided value in classifying various groups as well as giving an insight to the life history and age of various types.

The works published since 1899 by Hoffbauer, Reibisch, Heincke and Stuart Thompson seemed to show that a classification of this kind was feasible in the case of carp, plaice and several of the Gadidae. In some cases by means of the scales, and in others by investigation the bones, it was demonstrated that there existed periodic forms of growth in summer and winter, and that this difference was indicated by annual growth-rings in these parts, similar to the rings found in trees.

In England particularly, there has been a large amount of material written on this problem, much of it, however, of a purely popular nature. Unfortunately it has been some of this more popular material which has come to the attention of some of our untrained investigators, and as it can not be regarded as the exposition of well regulated investigational work it must be shunned as a guide to important research.

The use of the scales of the salmon as a means for studying the age and other biological conditions of the fish is due to Mr. H. W. Johnston. In three papers published in the annual report of the Scottish Board of Fisheries for 1904, 1906, and 1907, he has succeeded in establishing the fact that periodic growth takes place in the scales of the Atlantic salmon (Salmo salar). He found that groups of rings are formed each year, and that it is possible by counting the number of these to ascertain the age of nearly every individual, and thus form an opinion regarding its life history. At first Johnston relied on scales from fish taken at various seasons of the year, but he succeeded in demonstrating by the study of these scales that various growth zones on the scales were formed at various times of the year. Later he marked fish with a silver wire and, upon the recapture of some of these, had fish of a known age to work with.

The work of Johnston was ably supplemented by Knut Dahl for the Norwegian Fisheries Commission. Although Dahl worked with the salmon frequenting the colder waters of the Norwegian coast and fjords, the work is of great value, as it kept within the same species and was painstakingly done. In his researches Dahl observed the growth zones to the season of the year when formed.

For the benefit of those who may desire to apply the principles of Johnston's & Dahl's results to our Pacific Coast salmon, it seems wise to insert here is some detail the results of Dahl's work, which are essentially the same as those of Johnston and are at the time of writing the more available. This extract is taken from Dahl's "The Age and Growth of the Salmon and Trout of Norway as shown by their Scales," Published by the

London Salmon & Trout Ass'n. in English:

. . . "During the summer after hatching, rings are added rapidly and increase with the length of the fish. For example, the following table shows the development of the rings on parr which were hatched in March, 1898, and killed as the dates indicate.

Length in cm.	Date Killed	Number of rings Min.	Number of rings Max.	Average
3	1 May	1	1	1
3-5	1 June	2	5	4.2
4-5	1 July	4	6	4.8
5-5	1 Aug.	4	8	6.2
6	1 Sept.	6	8	7.4
10	1 Oct.	12	19	16

"Figure I (Plate 1) shows a scale from the largest parr. The inner growth-rings go regularly and practically without a break around the whole of the scale. The ring formation is not broken until the three outer rings are reached. These latter rings are only perfect on the anterior portion of the scale and elsewhere they are merged in the edge of the scale. Note that the fish was killed late in the autumn.

"As a rule, summer rings are unbroken around the circumference, although one may occasionally meet with a scale with incomplete summer rings. This probably arises from the fact that all growth does not proceed simultaneously and therefore the different portions of the scale have not always the same uniform rate of growth in length ang girth. In autumn and winter the growth generally decreases or ceases entirely; such little growth as does take place is shown in the production of narrow rings close to the edge of the scale. After the winter when development begins again, the ring formation of the new season does not exactly coincide with the last formed rings of the preceeding season and the new growth is shown by the formation again of entire and unbroken rings. It should, therefore, be easy to recognize the winter rings formed during the period of stagnation between the two growth zones.

"The chief characters of this period of stagnation are the pronounced branching or ramification of the rings and also the fact that they are narrower and lie closer together so that a magnified representation shows a narrow and more darkly shaded belt. This narrow winter band has also a different optical refractive power as the microscope shows when different methods of illumination are used."

From a government hatchery Dahl obtained samples of parr hatched in April, 1907, and reared in the hatchery until killed in the middle of December, 1908.

"These fish had, therefore, lived for two summers and a portion of the second winter; their scales are shown in Figures 2 & 3, (Plate I). These correspond with the seasons in which the fish lived. The growth zone in the center consisting of relatively unbroken rings corresponds to the first summer. Surrounding this is a band of narrow branching rings depicting the slackened rate of growth during the first winter. Then again surrounding this inner core are similar growth zones corresponding with the second summer and half of the second winter, and which show a repetition of the characteristics of the first year's growth.

"Figures 4,5 & 6 (Plate I) are scales of parr from Softeland River in the Os district, taken in May, June and October, and show clearly how the summer's growth is indicated on the scales. For example, in Fig. 4 we see that the winter band formed during the second year of the parr's existence lies close to the edge of the scale and that only two new broad rings denoting summer growth had been formed. The June scale, Fig. 5, shows that these broad summer rings have increased in number, whereas the October example, Fig. 6, clearly indicates the fact that the formation of broad summer rings had ceased, and the narrow branching winter rings are present, showing the commencement of the third winter of the fish's life."

Dahl presents further evidence to show that this same condition continues to exist during the fish's marine life by data taken from fish of known age which were captured in the sea and placed in salt water aquaria for a time. He also took fish from the sea at various times of the year and demonstrated the gradual passage from broad to narrow ringed areas as each season advanced.

In London, 1910, there was published a book entitled "The Life History and Habits of Salmon, Seatrout, and other Fresh Water Fishes." The author, Mr. P. J. Mallock, attempted therein to set up a new system for the determination of age for the salmon. His studies led him to believe that one had only to count the rings on a scale, divide the total by sixteen, and the age to a month would thus be told. By the aid of several photographs he endeavors to show that each year there are formed sixteen new rings, no more, no less, except in rare cases. From this information he makes the sweeping statement that this furnishes the key to the entire life history, the length of the time spent in fresh and salt water, the age at migration, the type of fish, whether kelt, pike, small spring fish, autumn fish, or large spring fish, weight of the fish and number of times the individual has spawned. In common with previous investigators he noted the varying types of ring formation as caused by esturial or marine life and the seasonal gradations in distance between rings.

That the yearly increase of scale rings is exactly sixteen for the Atlantic salmon is open to serious question, as amply evidenced by Mallock's own observations, for he points out the fact that many of these fish spend as many as sixteen or seventeen months in the rivers prior to spawning without feeding. During this time the fish lose about 25% of their weight and do not increase in length. This being true, how can this long period be represented by an addition of a large number of rings? The study of scale development tells us that the number of scales on a fish's body is constant throughout life and that as the fish increases in size the scales also increase to cover the intervening spaces. In face of this fact, does it seem plausible that scale growth should continue regardless of bodily development, arrested as it is by periods of starvation and emaciation? Moreover, his own observations show that during the spawning sojourns the effect of the fresh water is to play havoc with the edge of the scale, materially reducing its size and resulting in an area of irregular rings which give rise to the so-called spawning mark when growth occurs anew. Again, the dense bands formed in winter are characterized by their irregularity and incompleteness, so that, even if the first year's growth should be marked by the formation of just sixteen rings, what evidence can be brought forward to prove that this number is added each successive year?

The problem as it faces us on the Pacific Coast is still open to conclusive experiment. In 1913 Dr. C. H. Gilbert of Stanford University published an article as Document Number 767 of the U. S. Bureau of Fisheries, entitled "Age at Maturity of the Pacific Coast Salmon of the Genus Oncorhynchus," in which he stated his observations on the scales of the adults of the five most important species of the Pacific salmon. The results are not supplemented by experimental evidence, but the conclusions drawn take their bases from the system as advanced by Johnston & Dahl, and for this reason are rather difficult of interpretation unless one is familiar with the writings of these two men. However, the idea presents itself in a more logical and workable manner than any other yet advanced.

On taking up my work with our state commission, I was quite in ignorance of the methods available for the solution of our problem, but the work to be done was all mapped out and no difficulty was experienced on getting it underway. Mr. M. J. Kinney of the Oregon State Fish Commission was particularly interested in the problem; as a retired cannery man himself, he held an intimate knowledge of the fish in the lower river, as well as of a great many of the problems which confront the hatchery-men. He recognized the importance of a workable age determination scheme, and had searched for available literature on the subject. Unfortunately, it seems to me, his search for literature led him to discover Mallock's treatise on the salmon and he was thus led to an erroneous conclusion. The greatest point at fault in the application of Mr. Mallock's observations to our Pacific coast salmon lies in the fact that the two groups to be compared belong to quite different genera. Were this one fact not sufficient to question the applicability of Mallock's ring count to the genus Oncorhynchus, there still remains the wide difference in the life history and physiology of the two, which of itself is entitled to great consideration. But all of us who had part in the work at the beginning were equally uninformed on the subject of scale growth and age and so were willing to let the system in question stand for the present. As the work went on, it became evident to the writer that there were great possibilities of error to be dealt with; many of the practical hatcherymen also began to doubt the value of the idea and to think it advisable to find some other method for obtaining the desired results. However, the work on hand was carried forward on its original plan, the data for which is included in another part of this paper. It is hoped that something may be gained from the presentation, if nothing more than the statement of facts and principles involved in such a problem, and a general consideration of the many factors which enter in to influence the final results.

At the very outset, therefore, let it be made clear that this paper does not attempt to establish new principles, overthrow previous theories, or greatly enlarge our knowledge of the subject in question. The purpose of the facts and data presented is to clear up in the minds of those of us interested in the various phases of the salmon fishing and propagating industry the situation as it stands today relative to one consideration in the whole field, namely the determination of the age of an individual salmon at any time when captured. The amount of literature dealing with this important subject as applied to our Oregon fishes is pathetically small, widely scattered and difficult to obtain. It is hoped that this paper will help to alleviate these difficulties by compiling the salient facts from the most reliable sources and placing them in a more readily available form for the benefit of those who may desire to carry on further work in this state along similar lines.

There are included a few original observations, some data and facts which should serve the purpose of covering several of the preliminary steps which naturally arise and must be disposed of before protracted research in this field can be attempted.

METHODS

It was not until after the two weeks spent on the spawning grounds of the McKenzie river that the thought occurred to me that the material and data being gathered there might be used as a thesis subject.

Our work on the McKenzie consisted in spawning ripe female salmon and fertilizing the eggs by artificial impregnation; that is to say, impregnation by the milt of the male applied directly to the eggs as they fell into a bucket, as contrasted with the normal fertilization as it occurs in the river. On the eggs thus taken the output of the hatchery is dependent, but the total number taken in a season amounts to a considerable figure; in a single season it is not impossible to collect as many as thirty millions of eggs, altho the number actually taken is considerably less as facilities for handling so large a number are not to be had. As stated before, no data is available which will give us even an approximate statement of the percentage of the fry from these eggs which return as adults. So this work was done for the express purpose of answering this and one or two other important questions such as those following. Do the eggs from spring fish give rise to fry that return as spring adults only or do some return with a fall run? What per cent of the total number liberated return after the expiration of three, four, five or more years?

The idea was to take the females to be spawned, examine the scales and separate out those which fell into the four and five year classes, fertilize their eggs with milt from males of the same age and keep the eggs and fry separate thruout their development, without however, giving them any different treatment from that received by the rest of the eggs in the hatchery. The age of the fish was considered to be determined by the Mallock ring-count system; table(I)gives the results of this work. More or less complete data is given on eighty-eight individuals; several more were examined and either discarded or else the skin with the scales attached was lost thru the ravages of mice. Several of the males are conspiciously lacking in accurate length and weight data as there were but a few used, several females were fertilized by one male, and each male was used as many as three or four times on various days. When not in use the males and females were kept in large pens submerged in the water from which they were removed by a dip net when needed. It so happened that the majority of the males were still living when the spawning operations for our experiment were finished, so were left to be made use of in the regular spawning work. They were all killed a day or so later,however, but at a time when the writer was at the hatchery building working on the scales of the others and was not present to measure or weigh them. An attempt was made to rescue them after butchering from the rest of

Table IA showing data gathered on fish regarded as 4 year olds.

No	Sex	Length inches	Weight lbs.	No.Rings	Yrs	Mos	Seined
2	F	36	20	72	4	6	9/7/14
3	F	41	23	63	4		" "
4	F	40	27	66	4		" "
6	F	37	18	62	3	9	" "
12	F	38	19	60+	3	9+	" "
13	F	40	21	70	4	4	" "
15	M			67-73	4-2to4-6		9/8/14
16	M	38	13	60+	3	9	" "
21	M	40	25	66	4		" "
22	M	40	17	60	3	9	" "
25	M	31	8	58-61	3-8to3-10		9/9/14
29	M			63-66	3-2to3-4		" "
30	M			58-9	3	8	" "

Spawned 9/9/14, yielding 31,000 eggs; 6 females, an average of 5,166.66 eggs to the individual.

Table IB - 4 year-olds continued.

No	Sex	Length inches	Weight lbs.	No.Rings	Yrs	Mos	Seined
37	F	35	15	65-70	4to4	5	9/10/14
38	M			66	4	2	9/12/14
39	M			73	4	6	" "
40	M			69-70	4	5	" "
43	M	40	15	60-67	3-9to4-3		" "
48	F	36	16	66(av.5)	4	2	" "
55	F	36	16	64	4	3	9/11/14
56	F	36	17	72(av.3)	4	6	9/12/14
59	F	36	16	64-70	4	4+	" "
63	F	33	12	63	4-		9/13/14
71	F	37	16	67	4	3	9/10/14

Spawned 9/13/14, yielding 21,000 eggs; 7 females an average of 2,100 eggs to each individual.

Table IC showing data gathered on fish regarded as 5 year olds.

No.	Sex	Len. ins.	Wt lbs.	No. Rings	Yrs.	Mos.	Seined
1	F	39	24	76	4	9	9/6/14
5	F	42	27	76	4	9	9/7/14
7	F	38	20	80	5		" "
8	F	41	25	84	5	3	" "
9	F	39	22	84	5	3	9/8/14
10	F	38	18	84	5	3	9/6/14
11	F	39	18	74	4	8	9/8/14
14	F	33	12	85	5	4	" "
17	M	41	24	76	4	9	" "
18	M			78	4	8	" "
19	M			76	4	9	" "
20	M			79	5		" "
23	M			76-7	4	9	9/9/14
24	M	39	32	75-80	4	8	" "
26	M	44	29	81-6	5 to 5	4	" "
27	M			82-5	5 to 5	2 to 5	" "
28	M	45	30	76-85	4 to 5	9 to 2	" "

Spawned 9/9/14, yielding 28,000 eggs, 8 females, an average of 3,500 eggs to the individual.

Table ID - 5 year-olds continued.

No	Sex	Len. ins.	Wt lbs.	No. Rings	Yrs.	Mos.	Seined
31	F	34	13	77	4	9	9/10/14
32	F	34	13	82-3	5	3+	" "
33	F	40	23	72-4	4	6	" "
34	F	23	10	80	5		" "
35	F	33	11	83	5	3	" "
36	F	36	16	81-5	5-1 to 5-3		" "
41	M	38	16	80-83	5 to 5	3	9/11/14
42	M	38	15	82	5	2	" "
44	M	36	12	73-85	4-6 to 5-3		" "
45	F	41	25	83	5	3	" "
46	F	37	16	78	4	10	" "
47	F	37	15	76	4	9	" "
49	F	36	16	88	5	6	" "
50	F	36	16	88	5	6	" "
51	F	38	16	76	4	9	" "
53	F	36	16	87-8	5	5	9/11/14

Spawned 9/11/14, 13 females, 47,000 eggs, average of 3,615.38+ to each.

Table IE - 5 year-olds continued.

No	Sex	Len. ins.	Wt lbs.	No. Rings	Yrs.	Mos.	Seined
52	F	37	17	85-6	5	3	9/11/14
54	F	37	15	77-80	4-10 to	5	" "
57	F	37	19	80-88	5 to 5	6	9/12/14
58	F	36	15	74	4	9	" "
60	F	37	17	85	5	3	" "
61	F			88	5	6	9/13/14
64	F	34	13	83(av)	5	2	" "
65	F	34	15	79-80	5		" "
69	F	35	14	82	5+		9/12/14
70	F	34	12	72+	4	6+	" "

Spawned 9/13/14, yielding 27,000 eggs, 10 females, an average of 2,700 eggs to the individual.

Table IF, 5 year-olds continued.

No.	Sex	Len. ins.	Wt lbs.	No. Rings	Yrs.	Mos.	Seined
62	F	35	16	77	4	9	9/14/14
66	F	33	8	80	5		" "
67	F	36	15	86	5	4	" "
68	F	38	17	84	5	3	" "
72	F	37	17	79	5		" "
73	F	32	9	78	5		" "
74	M			78	5		" "

No	Sex	Len. ins.	Wt lbs.	No. Rings	Yrs.	Mos.	Seined
75	F	35	11	72	4	6	9/14/14
77	M			77	4	9	" "
78	M	35	11	72	4	6+	" "
79	M			81	5+		" "
81	F			79	5		" "
82	F	37	17	85	5	3	" "
83	F	35	12	76	4	9	" "

Spawned 9/15/14, yielding 45,000 eggs, 10 females, an average of 4,500 eggs to the individual.

It will be noticed that there is a wide variation in the average number of eggs taken from the females. An explanation of this difference is not to be had at present, but it is probably due to the variation in fecundity exhibited by the various individuals. Then too we must consider that there is a chance of having incorrectly measuring the eggs, a very easy thing to do, as the process is only intended to be approximate.

the pile, but it was found in most cases a hopeless task as the marks used for identification (the clipping of a fin or a combination of fins) were greatly altered thru the degenerating action of fingers and other agents.

It was found most convenient to divide the work among alternate days, the fish taken in the sein were separated and marked during that day but were not spawned until the following day. Then just before spawning a new batch was taken and tied up for examination during the rest of that day. Each fish as taken was placed in a large common pen, and from these were selected those fish which were not too ripe to hold over a day or two, or were not too badly infested with Saprolegnia. These fish, selected for no other considerations were then tied by the tail, marked, and after giving up a section of skin with the scales attached were allowed to lie in the water near the pen until the scale rings were counted. Then the fish were separated into pens according to whether they approximated the four or five year class. Great diversity was found to exist among the individuals and as it would have been out of the question to obtain fish reading exactly four or five years, they were divided arbitrarily into two groups. Those which had from 56 to 72 rings (between 3 yrs. 6 mos. and 4 yrs. 6 mos.) were taken as four-year-olds; those which had from 76 to 88 rings (between 4 yrs. 9 mos. and 5 yrs. 6 mos.) were taken as five-year-olds. The individuals of the two classes were placed in their respective pans and on the following day were killed, measured, weighed and spawned. They were killed by a blow on the head with an axe; the total length was taken as the distance from the tip of the upper jaw to the tip of the longest dosal ray of the candal fin; the weight was read by suspending each fish by the gills from a large spring scale. Up to this point only one operation necessitated much care or thought and that was the determination of the proper place to take the scale samples, and the best method to employ.

It is a very noticeable fact that spawning salmon and those taken just as they enter the river from the ocean exhibit a great difference in the relative position of the scales. The scales of the latter are readily seen as they overlap and cover the entire surface of the body and may be readily scraped off. It becomes quite impossible to remove them in this manner from those on the spawning grounds, and many times the fishermen raised the question as to why this was true. At that time I was unable to answer the question or to give any opinion, but now further experience seems to indicate that the reason for the difference is caused by a thickening of the integument which leaves the scales deeply imbedded in it. It would be interesting to see to what extent this supposition were borne out by histological study. In taking the samples at first, a very sharp razor blade was used; this always resulted in one or two deep gashes in the body at that point, which were accompanied with a considerable flow of blood; the entire thickness of the skin was removed by this method, the scales being still imbedded and out of sight. To remove them from this position it was necessary to direct the skin apart, a slow and trying process. So a better method was sought and finally we found that the skin could be split with a knife that had a coarser edge, like a sharp meat knife. Mr. Ryckman the superintendent of the Leaburg Station is to be credited with this discovery; it marks an important point in the development of the technique of scale removal. The operation consists merely of making a rapid stroke with the knife in the direction of the head; with a little experience it soon becomes possible to separate the upper layer of the skin with the scales attached, from the lower, thus leaving the scales in a position of complete exposure, and the body at that point still protected by the under layer of skin.

Those pieces of skin with the scales imbedded were subjected to various methods of treatment in the attempt to remove the scales after returning to the laboratory. By this time the skin was quite dry and hard and resisted all treatment while in this condition. Excellent results were obtained however, by soaking the pieces of skin in a little 10% grain alchohol and following the soaking with a short steaming in the same fluid. [Water used in the same manner resulted in a gluey mass that was difficult to handle; moreover if allowed to stand more than an hour or two would begin to show signs of putrefaction especially if steamed. The presence of the alcohol greatly reduced the gluey condition and prevented the decay after steaming. The process was always carried on in small petri dishes, one for each piece of skin, labelled to conform with the envelope in which each piece was filed; the cover of the dish prevented the escape of the alcohol which might be driven off during the warming process.

The scales removed from each piece if skin we filed away in small envelopes each labelled to correspond with the field number of the individual fish. The whole process is one marked by much tedious work, the manipulation of the large fish, the removal of the skin, the removing of scales, the counting of the rings in the field, and the painstaking and close microscopic application to the material in the laboratory.

The importance of the selection of the proper place from which to remove the samples of skin became more evident as the work went on; but with us the position was guaged largely by the condition of each individual fish; particular effort being made to take the samples from good bright fish; if the fish were at all spotted with fungus, care was exercised to avoid infected regions. In most cases it happened that the region chosen was from the posterior half of the body, dorsal to the lateral line and at a point between the adipose fin and the median region of the dorsal fin. Further study is contemplated to determine if possible the region of the least variability in scale growth as applied to the selecting of a proper region. In this paper will be included only the preliminary observations on this important point. While reviewing the literature on the subject as a whole, conflicting opinions were found to exist on this very point, Calderwood claiming that the scales should be taken from the "shoulder" region, while Dahl chose practically the same region as the present writer, but neither presented statistical argument to favor his choice. It is hoped that some of the facts and observations to be discussed later will be of some value in straightening out the question.

A very convenient system for filing scales consists of a series of small manila envelopes arranged in any desired order but numbered so that reference can be made from the data concerning the scales which may be first placed in a small piece of paper folded to fit inside the envelope and numbered to correspond with it. The envelopes are then put away in a box and the scales are always handy for study, and when desired fro use can be readily mounted in water or soft glycerine jelly; permanent mounts are unnecessary and unsatisfactory as if made in balsam, the scales become too highly cleared and do not show the seasonal bands well refracted.

M A T E R I A L S

From the very nature of our problems it became necessary to start the work with adult salmon; moreover, the degree of development reached by fish hatched and observed during the relatively short time allowed for the work would be hardly sufficient to bring results. This whole subject as treated in this paper must then, be considered as merely preliminary work which it is quite important to have in hand before final work can be started.

For study there was available for me a wide variety of scales representing the various environmental conditions met by the fish on its way from the sea to the spawning grounds. Thus I had scales taken from fish just after leaving salt water, when they were playing around in the brackish water off Astoria; time, May 15, June 15, July 15 and August 15, 1913. On July 30, 1913 samples were taken from bright fish on the Rogue River, and during the first two weeks of September a large number of scales were taken on the spawning grounds of the McKenzie River. With the exception of this latter set of scales, all those mentioned so far were taken by some person other than myself; these other scales are the property of the Oregon State Fish Commission and were loaned me by Mr. R. E. Clanton, Superintendent of Hatcheries. About the last of the season, some half a dozen fish were taken which carried the signs of a gill mark like that proposed by Mr Clanton, and first used by him four years previous; we have these opercula and scales from the same fish, but the men who took them failed to gather the rest of the data which seems quite important; e.g. length and weight. The scales from hatchery fish may or may not be of help to us but I have examined some from fish of known ages and I will include my observations along with other data.

In all but the spawning fish and those from the hatchery we have but one scale from each individual, but in as much as the fish were in perfect condition when taken they are considered to be perfect.

S T U D I E S

As just mentioned above, the possession of but a single scale from several individuals was not enough to halt the work, but rather to give it the acid test. When a scheme is ultimately found that will tell us the age of the mature fish, it must be one which does not necessitate the examination of a large number of scales from the same fish, but rather one that is constant for all the scales, making one as reliable as another except for occasional variations due to injury or arrested development of one type or another.

In carrying on the work following, only those scales were used which were accompanied by complete data regarding other conditions such as weight and length. I am inserting through the first part of the text a series of tables which will place before us all the data available on all the fish examined, and arranged with the idea in mind of ascertaining if possible if there might not be some correlation between length and weight, or length and number of rings. If such a correlation does exist then one can very nearly predict the age of a fish by merely knowing these two measurements. So these tables are worked out for the fish from all sources, each special set of which I have chosen to regard as a population.

The Columbia Population (See Table II)

In this group are represented 197 individuals ranging in length from 19 to 50 inches and bearing from 52 to 128 rings; an average length of 35.58 inches and an average ring rount of 96.73 rings, equivalent to an average age of 6 years. Without going into the mathematics of correlating this data it is quite evident that with such a varied group of individuals no direct correlation exists between these two characters. Examination of the data presented will show that there is a wide variation as to the number of rings retained by fish of the same length. For instance of the 23 specimens measuring 38 inches, one had 74 rings, one 90, one 94, one 96, one 98, one 100, three 102, three 104, two 106, one 110, one 111, one 114, two 116, two 118, one 120 and one 124. Again, 14 individuals are represented as 23 inches long, and show a variation from 54 to 110 rings with the majority however between 90 and 100. As we exceed the average length, it becomes noticeable that the greater part of the scales have by far, more than the average number of rings and less variation is exhibited. This might take on a different aspect if we had more material to work with, both as far as individuals go and as to the number of scales from each. But it seems safe to say that as far as the data available at present writing is concerned, and with particular reference to the locality in question, the tendency seems to be to have a greater development of the rings on those fish attaining a considerable length. And after all, this is only what might naturally be expected.

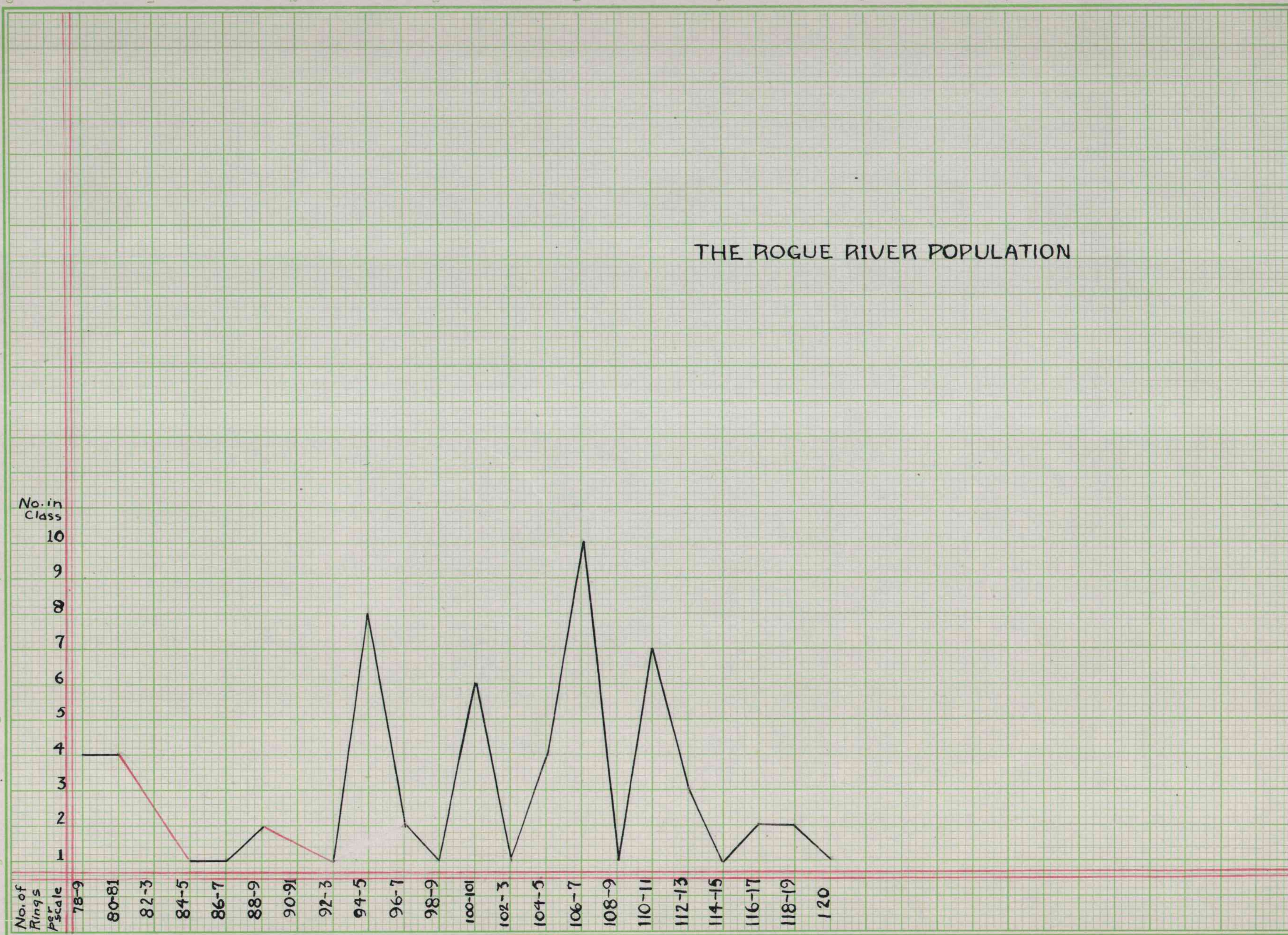
If we plot the characters in this table separately the curves at once assume a certain similarity, which would no doubt be the more striking if the classes in the ring-plot were reduced. The polymodal appearance of most of the curves presented, at once suggests that factors other than those considered are active. A complete analysis of the situation reveals several factors which should without doubt be considered. Probably the most logical assumption is that in a population of this kind, a certain diversity of age as well as individual physiological and environmental conditions play an important role. In as much as plenty of evidence has been advanced to support the theory that certain individuals may mature more or less rapidly than the majority it seems quite within reason to assume that we are dealing with a group of salmon which are of mixed age. Doubtless this is true in the present instance, so that we have a run in which three or more ages are represented, the over-lapping of the ages being caused by the maximum development of those of a younger age over the minimum development of those of a more advanced age.

The explanation of this condition may perhaps be found in the study of the life history of the individuals. But a close observance of the life of the members of this species is quite out of the question at present. Born in the headwaters of our coastal streams, the young salmon remain there only until they are large enough to assume the responsibility of life in the ocean; this they are able to do usually at the end of the second year. Once they reach the sea, all trace of them is lost until they return to spawn, but it is supposed that the greater part of their marine life is spent in the Japanese current where the temperature of the surrounding medium shows little variation through out the year. As a rule all members of the Salmonidae are voracious feeders, but it is quite possible to concieve of certain members of a single brood meeting with more favorable conditions than others, the result being abnormal development, either above or below the average. In either case the result would be evident in the adult. If this supposition be given any weight in the face of our knowledge of the development of the scale, it becomes a relatively simple matter to prove that the development of the number of rings within any given time is subject to such a wide variation as to be practically inapplicable to the principle of age determination.

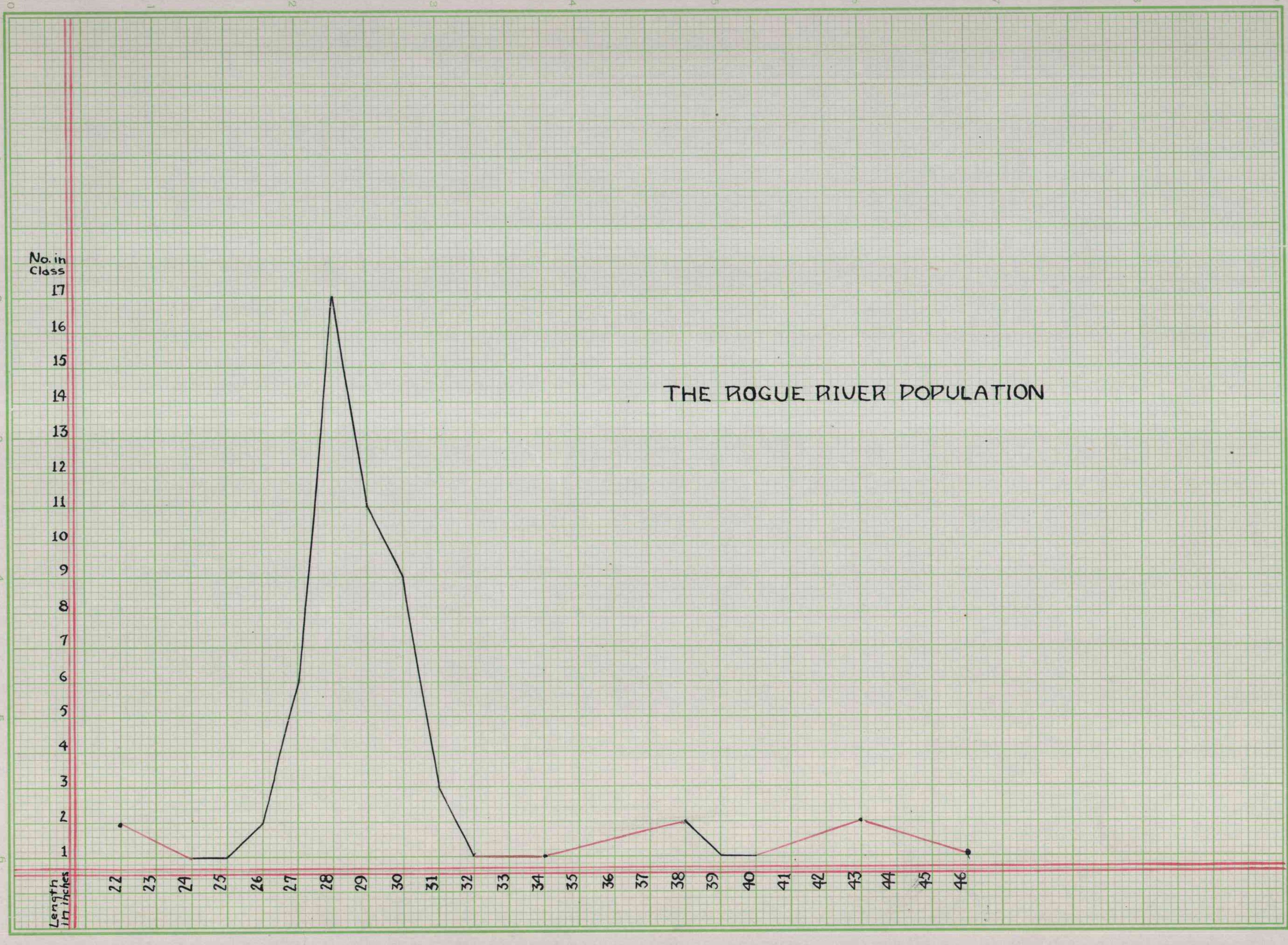
As far as the effect of this variation may influence the number of rings, the same principle does not affect the system advocated by Johnston and Dahl. The examination of the scales themselves gives ample proof of this, as it is readily seen that the growth during the same season may vary in different years. Occasionally winter bands are quite absent, and two successive summer bands may vary widely as to their extent, the completeness of the rings and the distance between them. These various rates of scale development are dependent on the rade of body growth as determined by physiological or evvironmental conditions.

THE ROGUE RIVER POPULATION (See Table III)

The material from this locality was gathered July 30, 1913, and like that of the Columbia River was taken from fish on the cannery floor just after being brought in by the fishermen. Data is given on 63 individuals varying in length from 16 to 46 inches, and bearing



THE ROGUE RIVER POPULATION
No. in Class
10
9
8
7
6
5
4
3
2
1
No. of Rings per scale
78-9
80-81
82-3
84-5
86-7
88-9
90-91
92-3
94-5
96-7
98-9
100-101
102-3
104-5
106-7
108-9
110-11
112-13
114-15
116-17
118-19
120



THE ROGUE RIVER POPULATION
No. in Class
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Length in inches
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46

from 58 to 120 rings. Like those from the Columbia River, but one scale for each fish was available, a condition which really ought to be remedied until satisfactory proof is gained that one scale is as good as another.

The average length in inches of this group of fish is 28.6 while the average number of rings is 93.8. Thus an interesting comparison is found between these two sets of data; these from the Rogue River dealing with fish noticeably smaller than those from the Columbia. That the development of the area of the scale goes hand in hand with the size of the fish seems to be well borne out from these facts, for the scale rings show a tendency to increase with the length of the fish tho by no means is the correlation actually demonstrated mathematically.

The degree of variation in the ring count in those fish grouped about the average length again becomes quite noticeable, for among the 6 individuals 27 inches in length, we get a variation of from 80 to 116 rings, while again of the 11 fish 29 inches in length there is found a variation of from 78 to 120 rings.

Here again, the curve is strikingly polymodal (see curve 2) possibly somewhat over emphasized through the relatively small amount of data presented. The curve for length variation seems to bear out the above statement, as it is decidedly regular, being plotted for only a few individuals, where as a larger selection would doubtless have included many fish with widely varying length.

THE McKENZIE POPULATION (See Table IV)

By introducing this series of data, a new factor is brought into consideration. Heretofore, all scales have been taken from clean fish, fresh from the tidal waters, now we are dealing with those on the spawning grounds. The members of this group have been a long time without food, they have completely changed their environment and are open to the deleterious action of fungus coupled with the effects of a long, tedious journey. The external changes brought on by this great change are very noticeable; the fish have fallen off in weight, their skin has lost its bright lustre and in many cases, large patches of white fungus have developed on the body, especially in the head region.

The results of investigations with these fish are of the utmost importance, because it is with these that we have to deal in taking our eggs for artificial propagation. If it is planned to carry on extensive breeding experiments, it at once becomes of importance to know the age of the parent fish so that there may be a check on all the work. If our interest were solely to determine the age at maturity of the species in question then the bright clean fish from the lower river would answer the purpose very well, for then we could determine the age at the time of capture and make an allowance for the time elapsing before spawning; this would then be accurate with a discripancy of no more than a month or two.

Other things being equal, it seems quite reasonable to suppose that the readings at the cannery and at the spawning grounds should be practically the same, because during the interim no feeding takes place; hence it is probable that the body does not increase over any dimension. If this be true, then from what we know of the development of the scale, there can be no addition to its area. As a matter of fact, the fish loose weight in their passage up the river; this does not however, necessarily mean that any body dimension is on the decrease, except perhaps a comparison of the fish at the two stations, they being hard, plump and well rounded down river, but soft and flabby on the grounds, the change being one solely to the absorption of stored fat from the body cells.

Investigation of the data available on spawning fish reveals some interesting facts. Of particular significance is the comparison of the two sets of scale data, one being the reading taken direct from the report on the McKenzie spawning work, the other from further observations with scales from the same fish.

Occasionally, it was observed, while examining the scales on the grounds to determine to which group a fish belonged, there appeared a scale which was devoid of rings over a large portion of the center. In this case, the scale was discarded and a new one taken, generally with the result that the second appeared perfect in every way. But as the work went on, the writer found himself becoming more familiar with the scales, and ere long it became evident that the variation in the ring count of scales from the same fish would vary, so that an average would have to be struck. Or else, the number of scales that presented the ringless center was so great that a new patch of skin was chosen or the fish discarded entirely. This made the work very trying as the difficulties encountered in following out the rings; for counting are great and must be experienced to be appreciated.

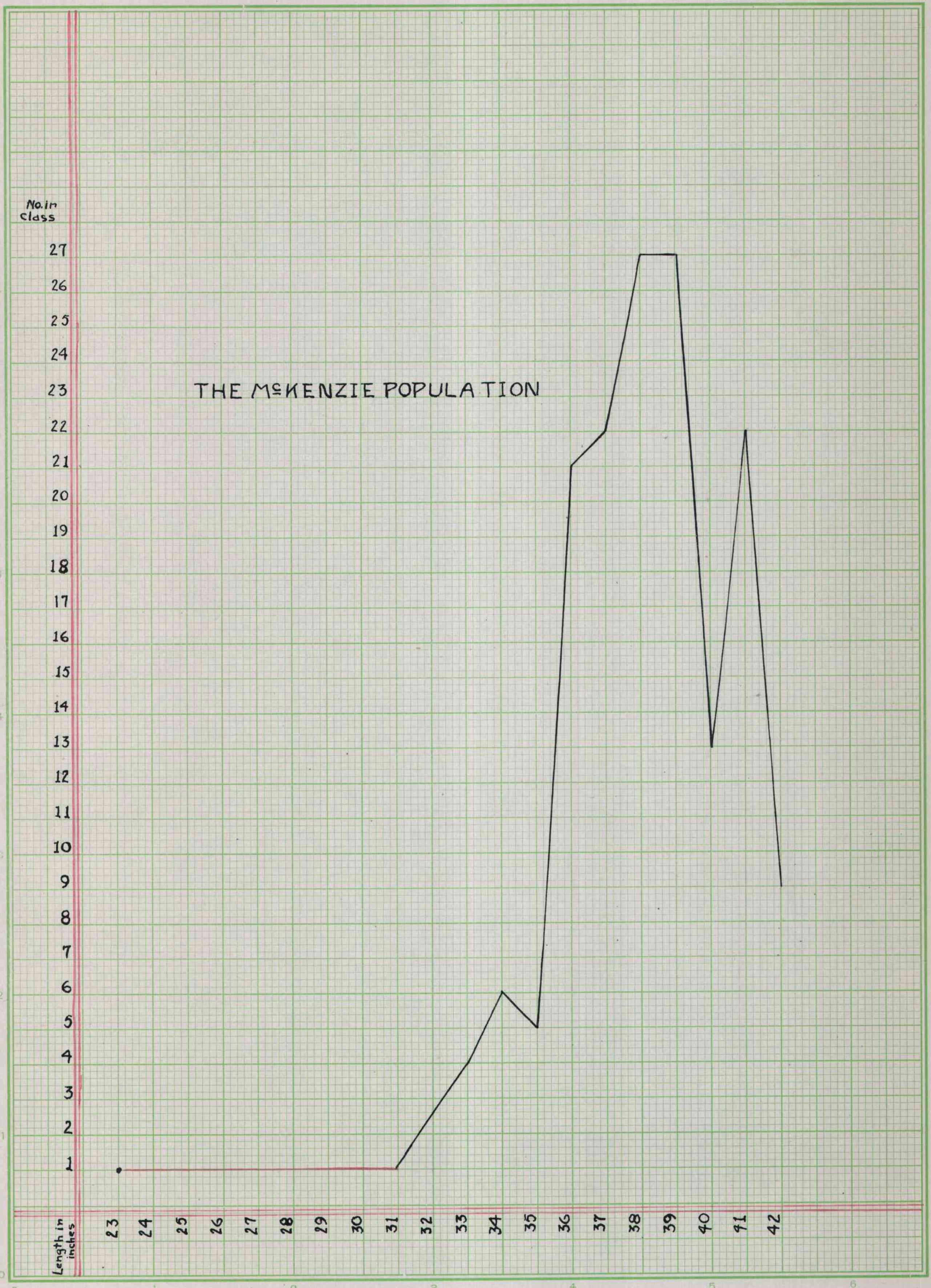
That great error may easily be introduced into the work at this end is borne out by the data presented. For instance table IV shows the record of 59 individuals, all within the age limits set by the experiments in question, the ring count varying from 60 to 88 and the length from 23 to 42 inches. Further record of the same type may be found in the tabulation of the complete data taken at the McKenzie hatchery, to be found in another part of this paper. Here, little variation is to be found, for as a matter of fact, the scales were selected, those lacking rings at the center being discarded because at first the cause of this loss of rings was not understood. Other scales were found which lacked rings at the edge and

Len. in ins. \ No. of Rings	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	Total
23																					1									1
31		1																												1
32																			1											1
33				1																	1			1		1				4
34													1					1			1			3						6
35													2				1	1					1							5
36					1		1						2		1			1									1		1	8
37			1					1									1		1	1	1	1				2	1		2	12
38	2																1				1		1	1	2					8
39																1	1								1					3
40	1						2				1				1															5
41				1													1							1	1					4
42																1														1
Total	3	1	1	2	1	0	3	1	0	0	1	0	5	0	2	2	5	3	2	1	5	1	2	6	4	3	2	0	3	59

Av. Length 36.5"
Av. no. Rings 74.9

TABLE IV

THE McKENZIE POPULATION


THE McKENZIE POPULATION
No. in class
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
Length in inches
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42


THE McKENZIE POPULATION
No. in Class.
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
No. of rings per scale
5-6
7-8
9-10
11-12
13-14
15-16
17-18
19-20
21-22
23-24
25-26
27-28
29-30
31-2
33-4
35-6
37-8
39-40
41-2
43-4
45-6
47-8
49-50
51-52
53-54
55-6
57-8
59-60
61-2
63-4
65-6
67-8
69-70
71-72
73-4
75-6
77-8
81-2
83-4
85-6
87-8
89-90
91-2
93-4
95-6
97-8

were likewise discarded.

As a check on these scales, ten individuals were selected upon the return to the laboratory and all the scales removed from one small area of about two square inches were examined. The variation existing over so small an area was found to be quite alarming (see table V). Here we find scales from the same fish with from 9 to 80 rings in one case, from 6 to 80 in another and from 52 to 89 in a third. It is evident that these fish are quite typical of the entire catch and for such a wide variation over a limited area, some explanation must be found.

TABLE V.

Ring-Count from McKenzie Fish--Selected

Fish No.	Ring-Count
1.	43, 51, 55, 79, 79, 81, 82, 85, 85, 87, 87, 93
2.	20, 46, 51, 54, 63, 64, 66, 69, 70, 75, 75, 78, 80
3.	18, 36, 38, 41, 41, 47, 75, 77, 80
4.	6, 11, 25, 27, 60, 60, 76, 80
5.	34, 61, 61, 62, 62, 65, 74, 78, 79, 80
6.	9, 10, 39, 57, 59, 62, 65, 75, 80
7.	62, 69, 71, 73, 77, 78, 84, 86
8.	34, 36, 66, 74, 80, 91, 92, 95, 97
9.	60, 60, 62, 66, 69, 71, 73, 75, 78, 78
10.	52, 54, 65, 69, 83, 84, 84, 87, 87, 89

TABLE II

THE COLUMBIA POPULATION

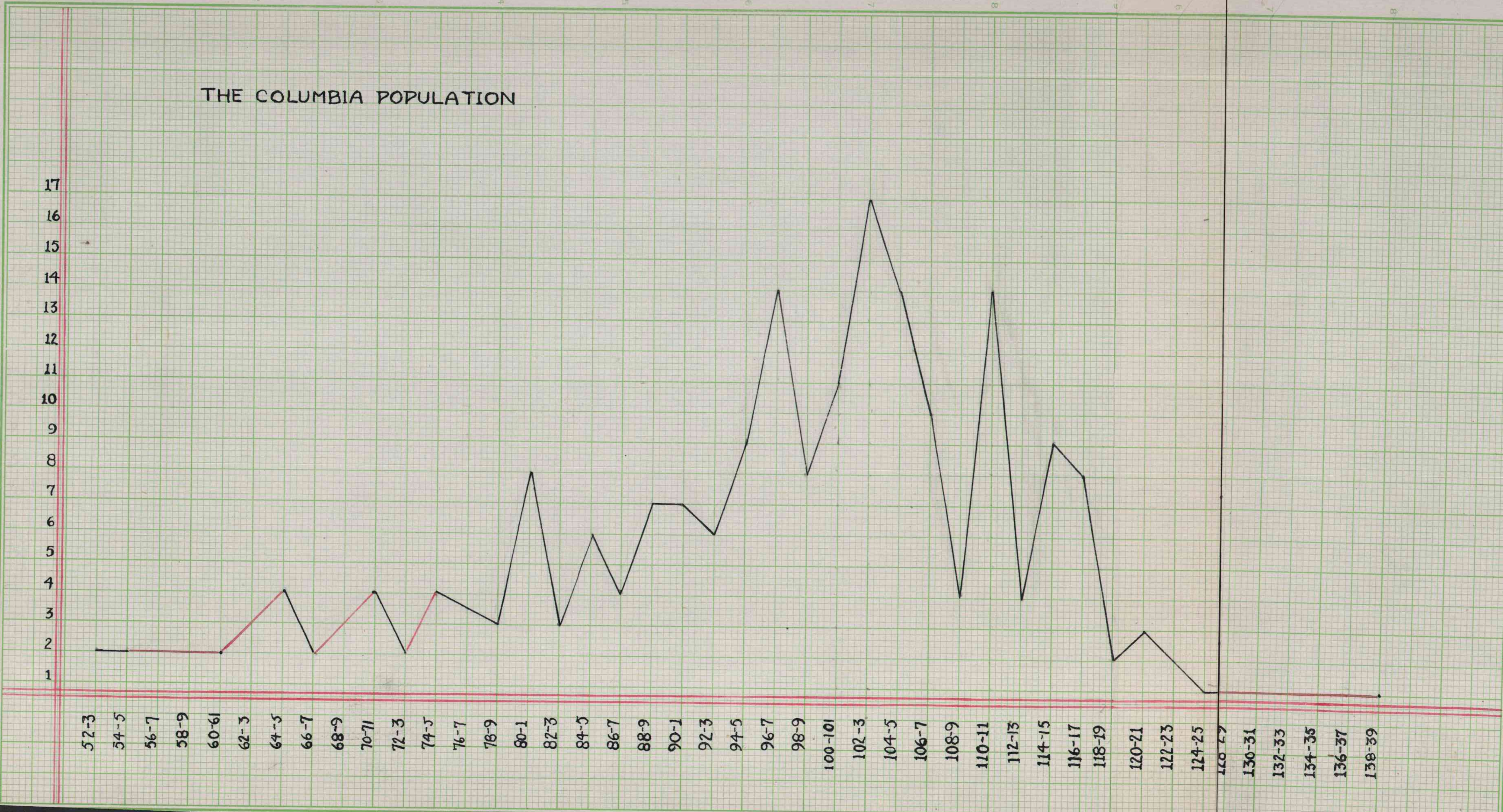
Len. in ins. / No. of Rings	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
19																										
20																										
21									1																	
22																										
23																										
24													1													
25																							1			
26																										
27			1																							
28																							1			
29	1																									
30															1											
31																					1					
32									1				2													
33			3																		1					
34																										
35													1						1							
36																			1							
37																			1				1			
38																							1			
39																										
40															1											
41																										
42																										
43																										
44																			1							
45																										
46																										
47																										
48																										
49																										
50																										
Total	1		4						2				4		2				4		2		4			

Len. in ins. / No. of Rings	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102
19																			1						
20																	1								
21																									
22																									
23																									
24																									
25																									
26																									
27																									
28			1				1				1														
29	1				1		1		1								1								1
30			1								1						1								
31		1			1				1										1						
32	1		1				2						2				3		2		2				
33			2									1	1		3							1			1
34							1		1		2		2				1		2			1	2		1
35									1						1				1						2
36							1				1					1			3				1		
37			1																2				1		3
38													1				1		1		1		1		3
39			1												1						1		2		1
40					1								1				1								
41			1									1											1		2
42																					1		1		1
43																			1		1		2		
44																									
45																									
46																									
47																									
48																									
49																									
50																			1						
Total	2	1	8		3		6		4		5	2	7		5	1	9		15		6	2	11		15

Len. in ins. / No. of Rings	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	Total
19																									1
20																									1
21																									1
22																									
23																									
24																									1
25																									1
26																									
27																									1
28																									4
29																									7
30																									4
31																									5
32				1																					17
33								1																	14
34						1																			14
35		1																							8
36			1																						9
37		4		1						2		1		1											18
38		3		2				1		1		2		2		2		1				1			24
39		1		1				2							1	1									12
40		2		2				1		1		1			1										13
41																		1							6
42	1			2		1		1		1				2						2					13
43		1				1		1						2								1		1	11
44		1				1		1		1				1						1					7
45				1												1									2
46		1																							1
47																1									1
48																									
49																									
50														1		1									3
Total	1	14	1	10		4		8		6		4		9	2	6		2		3		2		1	

Av. Length 35.5"
Av. no. Rings 96.7

No. in Class
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
THE COLUMBIA POPULATION
Length in inches
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50


THE COLUMBIA POPULATION
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
52-3
54-5
56-7
58-9
60-61
62-3
64-5
66-7
68-9
70-71
72-3
74-5
76-7
78-9
80-1
82-3
84-5
86-7
88-9
90-1
92-3
94-5
96-7
98-9
100-101
102-3
104-5
106-7
108-9
110-11
112-13
114-15
116-17
118-19
120-21
122-23
124-25
130-31
132-33
134-35
136-37
138-39

This same condition was found to exist by Dahl and Calderwood and is attributed to the general condition of degeneration exhibited by all spawning fish. The immediate cause of this degeneration is doubtless due to the great change encountered by the fish in passing from the sea to fresh water and the great emaciation and decay found in all spawning salmon both males and females coupled with the deteriorating action of the fungus.

With the Atlantic salmon (Salmo sebago) which spawns two or three times, scale growth again begins upon the return to the sea, and the addition of new rings to the frayed and torn edges results in a very noticeable region of union known as the spawning mark.

Here again we face a condition of affairs from which it becomes quite difficult to understand just how Mallock would proceed in determining the age of a fish that had spawned once or twice and had at that time lost a number of marginal rings thus greatly reducing the total.

So great is this loss among the different scales of the same fish that many of the seasonal bands described by Johnston, Dahl and Gilbert may become totally effaced. So that, which ever system we employ, in face of these changes, it becomes impossible to say to any degree of accuracy how much of any one scale, no matter how perfect it may appear, remains for examination. In as much as this loss is common to all spawning fish it soon becomes evident that the scales from any one are so liable to be in this same state as to make accurate determination of age quite out of the question.

If this be true, must our researches stop here? We trust not, because the nature of the experiments outlined previously demands that we have this data to start with. Perhaps a more comprehensive study along similar lines as indicated here may do much toward perfecting our knowledge of the present problem. If this fails then there remain other avenues of attack which should be investigated before giving up the task as futile. One thing is certain, and has been amply proven by the experience of the present writer, that is the necessity of having material of a known age as a matter of check on all studies. This was not appreciated until this work was well under way, then it was too late to get such material this season.

Had this need been forseen, we could have instructed the fishermen to be on the look-out for specimens marked by Mr. Clanton's gill punch. As it was, eight of these fish were taken; the marked opercula and several of the scales from each were saved, but the men who captured these fish were not informed of the desirability of taking the measurements and weight of each, so we have nothing to strike a comparison with. Moreover, all these marked specimens were ripe for spawning and the scales in poor shape as is shown by Table VI which gives the ring count from these individuals, as determined from a few scales accompanying the marked opercula.

TABLE VI.

Ring-count from Fish with Marked Opercula

Fish No.	Ring-count
1.	43, 46, 48, 51, 56, 57, 63, 63, 63
2.	41, 47, 47, 49, 49, 51, 51, 56, 56, 58
3.	50, 51, 51, 53, 54, 54, 56, 57, 60, 63
4.	57, 67, 68, 70, 70, 71, 72, 72, 72, 75
5.	68, 72, 73, 74, 74, 74, 74, 79, 84, 89
6.	65, 67, 70, 71, 74, 74, 76, 79
7.	50, 54, 55, 56, 58, 58, 59, 68, 70
8.	41, 56, 58, 61, 65, 70, 76, 80, 85, 85

In view of the fact that we have no comparative data to accompany the ring count from these fish as we had in the case of all the others, it might seem at first that the inclusion of the data at this point were somewhat irrelevant. But it seems to me that this very lack of data offers an excellent opportunity for testing the value of the ring count on the spawning ground. Is this system reliable as a means for determining the age of spawning fish? Is the ring count an index to the size of the fish either as to length or weight?

Certainly the evidence as presented gives no indication of the possibility of a correlation such as indicated above. The variation in ring count on the same fish is in most cases strikingly great, so that is seems at once possible to state that so far as spawning fish are concerned the ring count is so liable to great variation on the same individual as to be of no value in translating many of the unknown facts in the fish's life.

Of course allowance must be made here for the possibility of the inadaptability of the gill mark in question to this purpose. It may be that some of the specimens at hand were of different ages and that some of the marks or scars on the opercula were misinterpreted. In either event, the conclusions drawn seem to be still viable. The reader is here refered to Plates II & III where are presented photographs of twelve opercula bearing scars claimed to be due to a gill punch; eight of these opercula correspond to the ring data presented, the others were necessarily omitted because scales were not taken with the opercula. Those having the scales to correspond are numbered accordingly; the arrangement on the plates however is the least bit out of order from the necessity of conserving space in arrangement.

One phase of our work not yet mentioned has been carried on with a few specimens of hatchery reared fish of a known age, for the express purpose of determining if possible (1), the amount of variation found in the ring count over various portions of the body; (2) the region or regions least liable to variation as a means to determining the regions best suited for taking scale samples; and (3) the relation if any between size and scale growth (ring count) as exhibited by hatchery fish.

For this purpose, the writer gained access to a few young fish, some fourteen, some twenty-three months old. The younger of these, three innnumber, are spring Chinook from eggs taken on the McKenzie River; the larger three are fall Chinook for which no record as to the locality of the eggs is available. Both were hatched and reared at the Klaskanine River hatchery, and were there retained until late this last winter (1915) when they were all liberated. The six specimens used in this work were all killed December 26, 1915, and arrived at the laboratory in rather poor condition despite the fact that they were well packed and promptly delivered. Examination of the scales showed that a large portion were without the nuclear rings, the total number thus being much reduced; whether this was due to a partial decay or whether it was the common condition of all the hatchery fish at that time it is now impossible to say.

To facilitate the examination of the scales the body of each fish was marked off into eight regions as shown in the accompanying figure. (Fig.1)

Nearly all the scales from each region were removed and it was planned at first to count a large proportion of these but it later developed into a task of such proportions that this proceedure was carried out only with the first large fish. With the other five, but ten scales from each region, selected at random from those removed, were examined; the data for this work is to be found in tables VII & VIII.

In the tables just referred to, it will be noticed that the scale readings are grouped according to letters, these groups correspond to the body regions so

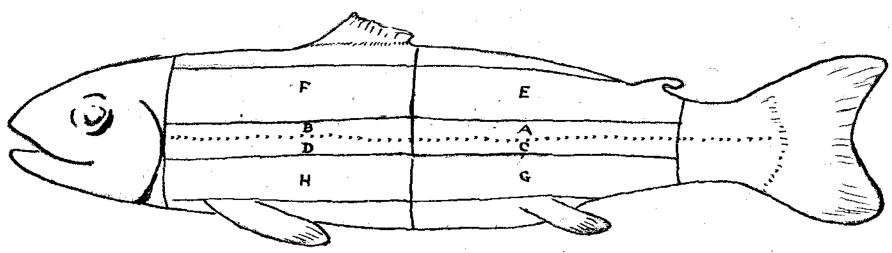


Fig. 1.

marked in the above figure. The reason for thus dividing up the fish into various regions was to determine if possible which portion of the body is the most reliable for gathering data on the scales. It will be recalled that Calderwood and Dahl chose widely different areas for their work, each believing he had found the least variable area. As regards other fish the writer has been unable to find reference to any such possible variation but he has been told by Mr. W. L. Rich of the U. S. Bureau of Fisheries that in the case of the steel-head trout (Salmo gairdneri) the region of the lateral line was found to be least subject to variations in scale growth.

Referring to Table VII, fish No. 1, 23 months old, length 11.5 inches. From this specimen are recorded the readings on 273 scales as listed, regions "E", "F", "G" and "H" showing by far more scales counted than "A", "B", "C", and "D". The reason for this is at once apparent from the size of the areas in question, they being nearly twice that of the others. This same condition does not hold throughout this table and the next, as the scope of the work was materially changed at this point, and but ten scales from each area were taken. Throughout the work an attempt was made to select for apparently perfect scales; those with frayed edges, or with nuclear rings missing were discarded.

Fish No. 1 shows the greatest range of variation in the ring count for the three larger specimens, the count ranging from 35 to 56, but with the greatest number of rings in the vicinity of 43 to 46.

Fish No. 2 has a variation of from 35 to 49, with a slight majority about the count of 40 to 44, while No. 3, the largest of the group, seems to hold its majority about 44 to 47.

It seems rather interesting to note the position assumed by the scales from region "E" as this formed the base of operations in the work of the present writer, al-

TABLE NO. VII.

Hatchery Fish No. 1 Age 23 mos. Len. 11.5"
Body Region and no. of scales

No. of Rings	A	B	C	D	E	F	G	H	Totals
35								1	1
36							1	1	3
37		1				3		1	5
38		1				3		4	8
39				5		2	1	3	11
40		3		4		5		4	16
41		3		6		1	2	4	16
42		2		2		2	2	4	12
43		7		7	1	5	6	4	30
44		3	1	3	3	4	5	1	20
45	2	3	4	1	9	8	3	1	31
46	3	5	4	1	7	4	7		31
47	2	1	4	1	6	2	3		19
48	6	1	2		8		2		19
49	4		6		4		4		18
50	2	1	4		2				9
51		1	3						9
52	5		1				1		2
53	1								1
54	1								1
55									
56	1								1
Totals	27	32	29	30	40	39	37	28	273

No. 2 Age 23 mos. Len. 11.5"

No. of Rings	A	B	C	D	E	F	G	H	Totals
35		1		1		4	1	3	10
36				2				1	3
37				2		1		1	4
38		2				1			3
39		2					1	1	4
40		2			2	1	3	1	9
41	1		3	4	3	1	1	1	14
42		2		1	3	1		1	8
43		2				1			3
44	1		2				2	1	6
45	3		1		2		2		8
46	2		2						4
47	1								1
48			1						1
49	1		1						2
50									
51									
52									
53									
54									
55									
56									
	10	11	10	10	10	10	10	10	81

No. 3 Age 23 mos. Len. 12"

No. of Rings	A	B	C	D	E	F	G	H	Totals
35						1		2	3
36						2		1	3
37						2		1	3
38				1		2			3
39						1		1	2
40	1	1		2	1	1		3	9
41		1		2	1		2		6
42				1	1	1	2		5
43		1		1					2
44		2	3	2	2		2		11
45	2	1			1		3	1	8
46	2		2		1				5
47	3	2	1		1		3		10
48		1	1		1				3
49		1	1						2
50			1		1				2
51	3								3
52									
53									
54									
55			1						1
56									
	11	10	10	9	10	10	12	9	81

VII

TABLE N.O. VIII.

Hatchery Fish No. 4 Age 14 mos. Len. 9.75"
Body Region and no. of Scales

No. of Rings	A	B	C	D	E	F	G	H	Totals
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29								1	1
30						1			1
31									
32						1			1
33									
34								1	1
35						1		2	3
36		1				3		1	5
37		1				1	1		3
38		2		2	1	1		3	9
39				1					1
40		1		2	2	2	1	2	10
41	1	1		2	1		1		6
42		2		3	1		2		8
43		1			3		1		5
44	2				1		2		5
48	1		1						2
49	1		1						2
50			1						1
Totals	10	10	10	10	10	10	10	10	80

No. 5 Age 14 mos. Len. 8.25"

No. of Rings	A	B	C	D	E	F	G	H	Totals
19								2	2
20						1		1	2
21							1	2	3
22							2		2
23						1	2		3
24		1			1	1	2	2	7
25	1	2				3	2	4	12
26	2	1	1	2	2	2	1		11
27			1	4	3	1			9
28	1	3		4	1				9
29	1	3	3		2	1			10
30	1		2		1				4
31	4		1						5
32			1						1
33									
34			1						1
35									
36									
37									
38									
39									
40									
41									
42									
43									
44									
48									
49									
50									
	10	10	10	10	10	10	10	11	81

No. 6 Age 14 mos. Len. 8.5"

No. of Rings	A	B	C	D	E	F	G	H	Totals
19									
20									
21									
22						1		2	3
23						2		2	4
24									
25						3	1		4
26		1					1	3	5
27			1		1	3	1	2	8
28	2	1	2	1	1		1	1	9
29	1	3		3	3				10
30	2	1	1	2	1	1	2		10
31	2	2	2	3			1		10
32	1	1			3		3		8
33	1	1	4	1	1				8
34	1								1
35									
36									
37									
38									
39									
40									
41									
42									
43									
44									
48									
49									
50									
	10	10	10	10	10	10	10	10	80

VIII

so of Dahl. In the first two cases especially the grouping of the rings of this area about the majority count for the whole fish is quite striking. Another fact brought out in examining the scales, but which is not evident from the tables presented is the relative degree of perfection exhibited by those scales from region "E" as compared with that found over other areas. Scales from other regions particularly "F", "G", and "H" were found to be greatly affected with abnormalities and injuries such as double nuclei, whorls in the body of the scale, punctures and blank centers. In some cases the predominance of such conditions was so marked as to offer considerable difficulty in finding scales whole enough or perfect enough to count.

With the exception of the disappearance of the nuclear rings, a condition found quite generally over the entire body of all the fish, the region designated as "E" in all cases was found to be remarkably free from other inequalities or abnormalities of growth. This statement is not made on the examination of the first ten scales from each area, but from a much larger number, varying in individual cases; sometimes as many as thirty scales were examined before ten were chosen as perfect. Doubtless the loss of nuclear rings is due to the rapid degeneration of the integument upon removal from the water. It may be that hatchery fish are never as perfect in this respect as the naturally hatched specimens; but further investigation only will settle this point.

Region "D" along the lateral line also shows signs of adhering closely to the mean ring count for the individual, but abnormalities and injuries are rather frequent; the other lateral line areas are more variable.

After all might we not expect just this condition to hold true because of the relation of these various areas to the contours of the body? Thus region "F", chosen by Calderwood in taking scales for study and called by him the "shoulder", is that which naturally first comes in contact with obstructions and which would tend to show the effect of these forces. Again, the ventral portions "G" and "H" are continually at the mercy of the rough character of the bed of the pond or stream and might be expected to respond to the wear and tear thus encountered.

It is not necessary to determine the one best region for taking scale samples, but rather to make certain of what regions cannot be relied on for this purpose, and what limits we may safely set and so avoid undue variations. With this idea in mind, and in face of the facts presented it seems safe to say that ideal conditions may be found within the limits indicated by regions "A", "C" and "E".

While working with the six hatchery raised fish a very interesting condition was found to exist as regards the relation of the size of fish No. 4 to its ring count, especially when this relation was compared with the same data from No's. 5 and 6 on the other. The former are all either 11.5 or 12 inches in length, the latter are 8.25 and and 8.5 inches respectively. The ring-count of the larger three varies from 35 to 56, that of the smaller two from 19 to 34. The fish in question, No. 4 is 9.75 inches long and presents a ring-count which zig-zags back and forth between 29 and 50. These facts would seemingly tend to place this fish in a position intermediate between the others as regards age if the number of rings is any index to this factor. But this seems quite out of the question in-as-much as all the eggs of any one kind in a hatchery have given up their fry before so great a difference of time could elapse. Moreover this fish was taken from a pond which was supposed to contain only 14 months old fish and the possibility of getting these mixed with others is very slight if the work is painstakingly done, which I believe to be true at the station under observation. If, as the evidence seems to show, this fish is really one of the older group, why does it not more closely approximate their measurements? In appearance the specimen is typically one of the younger fish, lacking the rounded body and well proportioned parts of the more mature types. It seems as though one of the older fish placed in a pond with a number of others nearly a year yuunger would have such a decided advantage over its fellows as to develop into an over rather than an undersized individual. Allowances must of course be made for some factor which might influence this individual to develop abnormally.

On the other hand, however, if the fish be of the same age as those of the smaller size, the statement, that as an index to age, the ring-count is praqtically useless, seems to be well grounded.

The Seasonal Bands as an Index to Age.

So far the work has dealt largely with the relation between the ring-count and other factors as a means of solving the problem of age determination. Little or nothing has been said of the application of the seasonal bands of Johnston to this principle. At the outset, the writer feels bound to state that but little has been done as yet with this phase of the work owing chiefly to the difficulties encountered.

Sometime, during the past winter, Mr. Rich was kind enough to show me some very good photographs of salmon and steelhead trout scales which showed these bands very plainly. Excellent photomicrographs may also be found in Dr. Gilbert's paper on this subject and quite unwittingly many of the illustrations in Malloch's book afford beautiful pictures of the banding.

At this laboratory, however, considerable difficulty has been experienced in trying to demonstrate the presence of the bands, due either to improper illumination or lack of experience in discerning them. This latter point is probably the main reason for the failure, as Mr. Rich pointed out the fact that it did take considerable application and experience to be able to observe them readily.

However, observation on the hatchery fish has shown that the majority of the scales exhibit hands of narrow and broadly spaced rings. The hatchery fish used were all killed in December and those scales which are not injured or malformed show a region of narrow spaced rings about the periphery, a condition bearing considerable significance, as it goes to show that these bands may be formed at this time. (See Plates IV, V & VI) But we cannot say from the evidence at hand that the winter season is the only factor which will cause a similar growth. Difficulty was experienced in demonstrating two such regions in the twenty-three months old fish, but I believe that further work with material in better condition will result in more satisfactory findings. If each winter is to leave a band of narrow spaced rings to mark the growth during that season, the presence of two of these bands may be reasonably expected to be present in fish of sufficient age. Perhaps, however the conditions existing in the hatchery ponds were so even throughout the year, especially as regards the food supply, that growth proceeded so regularly as to preclude the necessity of retarding development and giving a chance for a band of narrow rings to appear.

What effect may be produced in the scales by the various changes possible to create in the fishes' environment, can only be determined experimentally.

Other Observations.

While the examination of the scales at hand proceeded, my attention was called frequently to abnormal growths and signs of degeneration which might materially affect the ease and precision of the work.

The most common variation of this nature was found among the spawning fish and the hatchery fish and consisted of the loss of the nuclear rings thus leaving a large bare spot in the center of the scale. In many cases not more than two or three rings were left about the periphery. This is a very annoying feature and greatly reduces the rapidity of the work if the condition is very common. Photo-micrographs of such scales may be found on Plates IV, V, & VI.

Spawning fish also lose many of the peripheral rings, the result being that a clear margin surrounds the ringed portion. (See Plate VII).

Another condition peculiar to spawning fish is found in the presence of a dense callous growth which frequently obscures a large portion of the scale. This must not be confused with the raised line which traverses the long axis of scales covering the lateral line organs. The rings outside this dense area are usually distorted and have lost their definite concentric arrangement.

The power of regeneration among the scales seems to be quite marked. Scales were repeatedly observed which had evidently been punctured at a point outside the nucleus. In most cases this puncture was filled in by a new growth showing distinct ring marks resembling a secondary nucleus or the remainder of the scale. Such a condition was particularly noticeable in scales taken from the "shoulder" region, and may be found represented on plate IV, figure 3.

All scales, except those from very young fish, show that development does not proceed by the addition of rings about the entire periphery. With the long axis, it is readily seen that the ring-count varies from that of the broad; this gives the scale its somewhat elongated form. It seems probable from this that the growth is the more rapid over the long axis, time not being given for the development of complete rings.

Among the more common of the malformations is that of the development of a double nucleus about which may be formed a double series of rings sometimes extending to the periphery. Such a type is shown in plate IV, figure 4.

Summary of Results.

1. No direct correlation was found to exist between the ring-count of salmon scales and the length of the individual from which removed.

2. The determination of age at the spawning grounds is subject to great error owing to the amount of degeneration undergone by the entire organism.

3. The number of rings found on a single scale or on a series of scales from the same individual is not a direct index to the age of the fish.

4. In line with "3" above, the assessment of age for our Pacific Coast salmon cannot be based on the Malloch scheme of sixteen annual rings.

5. No proof has been found experimentally that definite ring bands are formed during the warm and cold seasons of the year.

6. Accurate determination of age cannot be based on the study of any one scale, because of the liability of malformation or degeneration.

7. It is necessary to have adult material of a known age to serve as a check on all results.

Acknowledgments

The writer wishes to thank Prof. G. F. Sykes, Prof. E. J. Kraus, Mr. R. H. Clanton, Mr. M. J. Kinney and Mr. W. L. Rich for their many kind acts of assistance and advice in the preparation of this paper. He is also indebted to Mr. A. J. Stover for invaluable guidance in the preparation of the accompanying plates.

Literature Cited

Calderwood, W. L.

The Life of the Salmon. London, 1910

Cockerell, T. D. A.

Observations on Fish Scales, in Doc. No 779 U. S. Bur. Fisheries, p.125

Ibid.

The Scales of Fresh-water Fishes. In Biol. Bulletin, Vol. XX, No. 6.

Ibid.

The Scales of some American Cyprinidae. In Proc. Biol.Soc. of Washington XXII, 157-164, July 28, 1909.

Dahl, Knut

The Age and Growth of the Salmon and Trout of Norway as shown by their scales. English translation by Iaan Baillie for the London Salmon and Trout Association. London, 1910.

Gilbert, C. H.

Age at Maturity of the Pacific Coast Salmon of the Genus Oncorhynchus. In Doc. No 767, U. S. Bur. of Fisheries.

Ibid.

The Salmon of the Swiftsure Bank and the Frazer River Sockeye Run of 1912. In Report of British

Columbia Commissioner of Fisheries, 1912.

Greene, C. W.

The Storage of Fat in the Muscular Tissue of the King Salmon and its Reabsorption During the Fast of the Spawning Migration. In Doc. No. 799, U. S. Bur. of Fisheries.

Heincke, F.

Naturgeschichte des Herrings. Abstract from Abb. d. Deutch. Seefischereiverein 1897-98: in Einfuhrüng in die Vererbungswissenschaft (P. 82). R. Goldschmidt. Leipsig 1911.

Description of Plates

PLATE I

Fig. 1, Parr 10 c.m. Hatched 1898, killed Nov. 8, 1898.

Fig. 2, Parr 13 c.m. Hatched April 1907, killed Dec., 1908

Fig. 3, Parr 13 c.m. Hatched April 1907, killed Dec., 1908

Fig 4 Parr. 12 c.m. Softeland May 25, 1909.

Fig. 5, Parr 10 c.m. June 11, 1908

Fig. 6, Parr 12 c.m. Softeland, middle of Oct. 1908.

From Dahl, H. W. H. del.

PLATES II & III

Opercula from spawning salmon, showing scars left by wound claimed to have been caused by Mr. Clanton's gill punch.

PLATE IV

Fig. 1, Scale from Hatchery Fish No. 1, Region "A".

Fig. 2, Scale from Hatchery Fish No. 1, Region "A".

Fig. 3, Scale from Hatchery Fish No. 1, Region "F".

Figs. 4, 5, 6, Scale from Hatchery Fish No 1.

Region "F".

PLATE V

Fig. 1, Scale from Hatchery Fish No. 3, Region "H".

Fig. 2, Scale from Hatchery Fish, No. 3, Region "H".

Fig. 3, Scale from Hatchery Fish No. 3, Region "E".

Fig. 4, Scale from Hatchery Fish No. 4, Region "D".

Fig. 5, Scale from Hatchery Fish No. 4, Region "B".

PLATE VI

Fig. 1, Scale from Hatchery Fish No. 5, Region "B".

Fig. 2. Scale from Hatchery Fish No. 5, Region "B".

Fig. 3, Scale from Hatchery Fish No. 5, Region "D".

Fig. 4, Scale from Hatchery Fish No. 4, Region "B".

Fig. 5, Scale from Hatchery Fish No. 5, Region "E".

Fig. 6, Scale from Hatchery Fish No. 5, Region "E".

PLATE VII

Scales from spawning fish showing condition exhibited by the majority of the scales taken from the fish with marked opercula.

Highland

PLATE I.

Fig.1

Fig.2

Fig.3

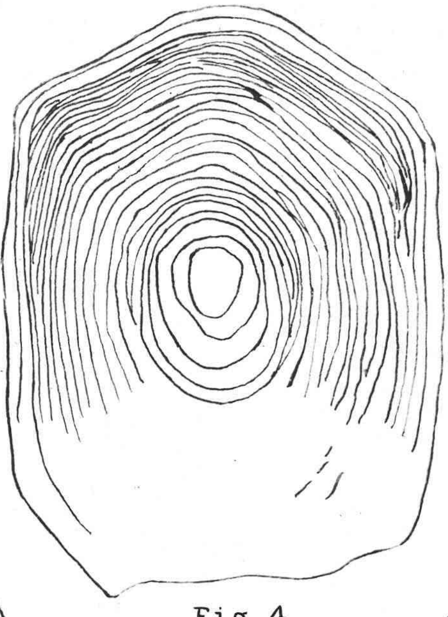
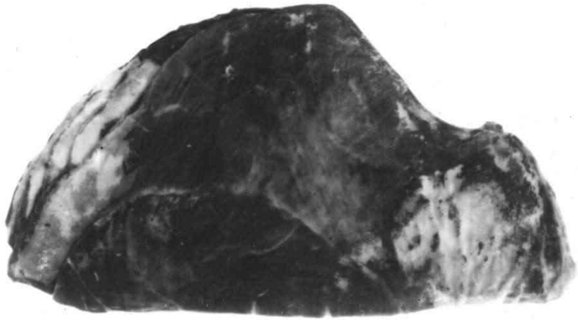


Fig.4

Fig.5

Fig.6

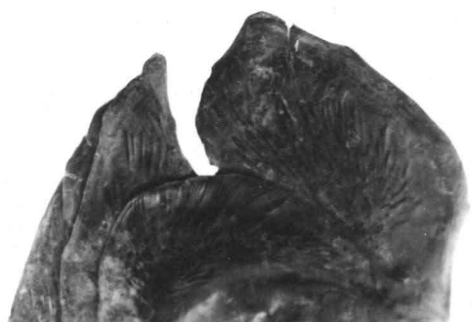
PLATE II.



NO.7

NO.1

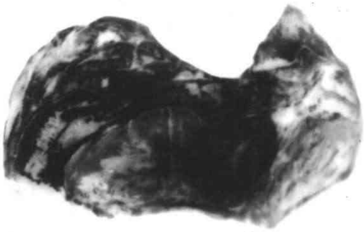
NO.5

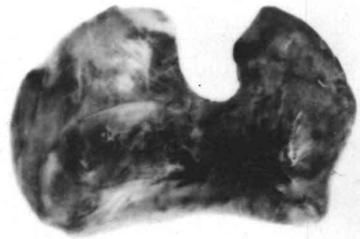


NO.2

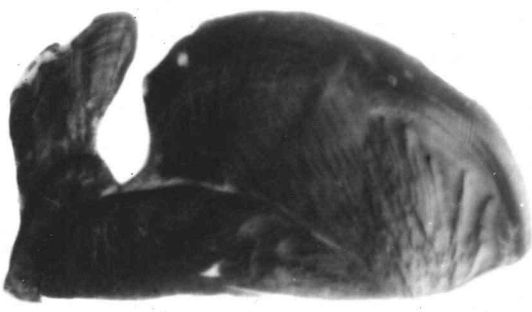
NO.4

PLATE III.





NO.3



NO.6

NO.8

PLATE IV.


Fig.1


Fig.2


Fig.3


Fig.4

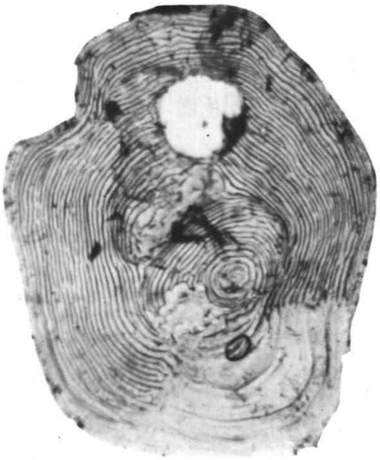


Fig.5


Fig.6

PLATE V.

Fig.I

Fig.2

Fig.3

Fig.4

Fig.5

PLATE VI.

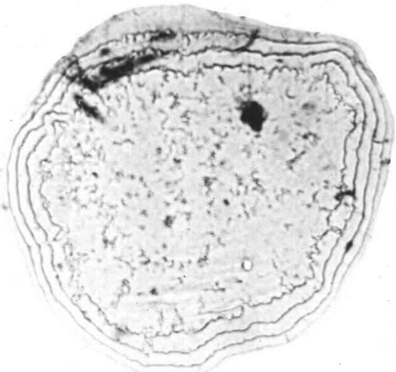


Fig.1

Fig.2

Fig.3

Fig.4

Fig.5

Fig.6

PLATE VII.

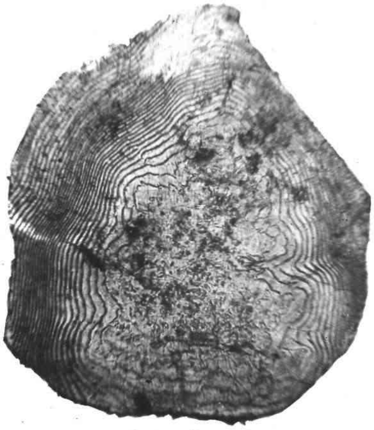


Fig.I

Fig.2

Fig.3

Fig.4

Fig.5