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REPORT 2

THE TASMANIAN TROUT FISHERY

1. SOURCES OF INFORMATION AND TREATMENT OF DATA

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SUMMARY

This paper is a general introduction to a series of reports dealing with the state of the trout fishery in Tasmania. Methods of collecting and analysing information are described, and the general scope of the survey is outlined.

The examination of a large number of scales in relation to the length of fish has shown that scales normally appear when the fish are about 3.5 cm in length. They grow rapidly at first and quickly establish a straight line relationship between fish length and scale length.

Tagging tests carried out on small fish have shown that a large proportion of fish under 14 cm are unable to carry jaw-tags for more than 2 months. This is related to the relative weight of fish and tag in water, when the fish weight is reduced to about 1/20th of its weight in air, and the tag is thus heavier than the fish.

Experimental work on selective breeding failed to yield significant results, probably due to nutritional deficiencies associated with hatchery rearing.

The growth of individual brown and rainbow trout in relation to temperature was followed for about 3 years.

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THE TASMANIAN TROUT FISHERY

I. SOURCES OF INFORMATION AND TREATMENT OF DATA

By A. G. Nicholls

I. INTRODUCTION

For a number of years there has been expressed by anglers an increasing dissatisfaction with the state of the trout fishery in Tasmania. It has been contended that there is a State-wide deterioration both in respect of the numbers taken and the quality, or condition, of the available fish.

The inland fisheries of this State are administered by the Salmon and Freshwater Fisheries Commissioners constituted under Part III of the Fisheries Act, 1935. As a result of representations made to that body by anglers' associations, the Commissioners, in 1945, requested the C.S.I.R. (as it then was) to undertake an investigation into this question of deterioration.

At that time the Division of Fisheries had an officer stationed in Hobart in connection with the marine investigations on hand, and he was requested to make a preliminary survey. During the next few years this officer was relieved from time to time, so that the early stages were handled by more than one officer, whose primary interests were marine.

Thus, little was accomplished during this period apart from the establishment of a simple system of returns of catches to be made by anglers on the reverse of their licences. Prior to this little reliable factual information had been received from anglers whereby an investigation could discover any changes in the fishery. Record books had been in existence at two of the major centres of angling, in which anglers could record their catches, but these cannot be regarded as complete returns of catches. They yield some information which will be referred to in the appropriate places.

In 1947 the writer was appointed to the Division to undertake freshwater investigations, including this particular problem of suspected deterioration of trout in Tasmania. It soon became clear that the problem was of such a magnitude that it required the full-time attention of a resident officer if any progress were to be made and satisfactory conclusions were to be drawn. However, circumstances prevented this from being achieved until May 1949 at which time the writer transferred to Hobart to pursue the investigation.

II. SOURCES OF INFORMATION

(a) The Creel Census

The simple form of return of catches by anglers in use up to the 1948-49 season sought information as to the date of capture, the number and kind of fish taken, and the source. For the 1949-50 season the Commissioners issued a new form of return, the Creel Census, which sought more detailed information from anglers under the following headings: date, kind of fish, sex, length, weight, name of river or lake, locality, type of lure, and number of hours spent fishing.

It was hoped that an analysis of the data provided would yield factual information as to the condition of the fish, as well as to the numbers taken, and that the whole could be analysed for each river or lake in Tasmania in relation to fishing effort, the lure used, and so on, and that a reliable appraisal of the fishery might be made.

This creel census has been in operation from the beginning of the 1949-50 season, and it is intended to publish a series of reports based on analyses of these returns supplemented where possible by additional data accumulated during the five years up to 1954*. The data derived from the returns of the preceding four seasons are also included.

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* The preparation of this report was started during 1954, but completion has been delayed for various reasons. Although it would now be possible to include the returns for the 1954-55 season, the number of these received fell to less than half those of the previous season and analysis was not deemed worthwhile. It is hoped to bring the survey up to date in the final report.

Although it is still not possible to make comparisons between this period and the preceding decades, it is considered that over the nine-year period covered any extensive deterioration, if it existed, should have become apparent.

For various reasons it has not been possible to make as complete an analysis as was anticipated. One of the more serious omissions has been that of discovering any change in the condition of the fish. The majority of anglers do not carry spring balances sufficiently accurate to give weights that can be used for a study of condition. It is very clear from an examination of the returns that in many cases the weights given have been estimated and are not the result of careful weighing.

It is clearly desirable in making a study of the fishing effort to discover whether it took longer to catch a fish in 1953-54 than in 1949-50; but it has proved impossible to use these figures because they are not regarded as statistically reliable.

It was hoped that the records kept by anglers would be kept in such detail that every excursion would be recorded, even if no fish were caught. Although some anglers have done this, in many cases they have neglected to state where they fished, or have omitted other vital information which invalidates an analysis from this aspect. In many cases, too, the total number of fish taken over a period of several days has been given and these could not be included in an analysis of the daily catch. Lengths of fish, where given, have been accepted as it is considered that in general these should be reasonably reliable.

One of the major difficulties in assessing these returns has arisen from the relatively small number of anglers who have co-operated. Table 1 provides figures which show that the number of returns has seldom exceeded 2 per cent. of licences issued. The question which arises, therefore, is the extent to which these returns can be regarded as representative of the angling population.

TABLE 1.

NUMBERS OF LICENCES AND RETURNS FROM 1945-46 TO 1953-5

	Season 1945 -46	1946 -47	1947 -48	1948 -49	1949 -50	1950 -51	1951 -52	1952 -53	1953 -54
Licences	3341	3611	4477	5876	7109	8603	9141	8797	8812
Returns	66	67	89	42	158	181	119	194	124
%	1.98	1.86	1.99	0.71	2.22	2.10	1.30	2.21	1.41

It has had to be assumed that they are representative and while it would seem from the results, which show similar trends throughout, that this assumption is possibl justified, there must remain some doubt as to their being truly representative. This will become evident in the general discussions.

(b) Field Record Books

The supplementary data collected to support and extend the analysis of anglers' returns consists chiefly of the collection and examination of scale samples from a proportion of the fish taken.

For this purpose the co-operation of a number of selected anglers was sought, whereby all the fish taken by them would be carefully weighed and measured, and the full data together with a sample of scales from each fish entered in a field record book provided for the purpose. This book was designed along lines similar to that issued by the Kosciusko State Park Trust of N.S.W.

Many anglers have co-operated in this effort, which has yielded valuable results. Although not all of the weights are accurate, it is possible that some indication of condition may be extracted from this limited number of fish.

(c) Observation of Spawning Runs

Another source of information has been the spawning runs of fish at the Great Lake, Lake Leake, and the Plenty River, which have been studied for a number of year: The additional data collected thus and by various netting operations will be dealt with in the appropriate places.

III. TREATMENT OF DATA

This series of reports will cover firstly, the rivers of the north-western region; secondly, those of the north and east; thirdly, those of the southern part of the State; fourthly, the lakes; and finally, a general review of the fishery with conclusions and recommendations.

As much as is necessary of the historical background of the introduction of trout into Tasmania will be dealt with in the final report. It will suffice for the present to state that it has been the custom of the Commissioners to rear increasing quantities of trout fry, fingerlings, and yearlings for release in the fishing waters. Anglers have come to regard this practice as fundamental to the maintenance of the fishery. On biological grounds, and on the evidence provided by Hobbs (1937, 1940, 1948) based on many years' research in New Zealand waters, this appears to be unsound provided certain conditions are satisfied.

As a result of a statement presented to the Commissioners in November 1951, they agreed to a proposal to cease stocking rivers of the north-western region for a number of years. This question will be fully discussed in the final report. The same method of treatment will be used throughout: available data will be presented under the headings given below, for each river or lake where information is available; it will then be summarized for the whole district and discussed in detail.

(a) Statistical Methods

A short account of the statistical methods used to evaluate the results may be of value.

(i) The Daily Catch.- The method used here was that worked out by Dr. A. T. James, C.S.I.R.O. Division of Mathematical Statistics from whose report some of the following statements have been quoted.

The data showed abundantly the differences in skill of the various anglers. Hence, in estimating the variation of a mean for a river during a certain year two components of variation had to be taken into account - (a) variation between anglers, (b) variation in the performance of the individual anglers from day to day. The contribution of the component (a) to the error of the mean decreases in proportion to the number of anglers, that of (b) in proportion to the number of angler-days. As both components of error of the mean were of the same order of magnitude, neither could be neglected.

The number of fish, x, was transformed to $\sqrt{x-1}$ before analysis in order to reduce the skewness of the distribution and stabilize the variation. For each river and each year an analysis of variation "between and within anglers" was carried out, from which the components of variation (a) and (b) were estimated. When the components (b) did not differ significantly from year to year they were pooled. The components (a) were pooled in any case because the number of anglers was so limited.

In the analysis of the record of angling over a period of 27 years the analysis was carried out on the actual daily catches instead of upon the square root transforms. The analysis of variation was made within and between years for both fresh and tidal waters. To detect trends in the yearly averages curves were fitted through them.

(ii) Fish Lengths.- The standard method of estimating the variation between the means was used in all cases. Where differences are stated to be not significant, this indicates no statistical significance at the conventionally accepted 5 per cent. level. Where they are stated to be significant, without further qualification, this indicates significance at the 0.1 per cent. level. In other cases of significance the level is given in the text.

The following explanation of the statistical term "significance level" may be of use to readers unfamiliar with the term. The observations are samples (anglers catches) from some given population (all fish in a given river, or taken during a certain year). By statistical methods it is possible to infer from differences between the sample-means the existence or otherwise of differences between the population-means. Such inferences can never be 100 per cent. certain. Statistical methods make it possible to associate a degree of uncertainty with any such inference. This is called a significance level. When it is stated that a difference is significant at the 5 per cent. level it means, roughly speaking, that there is only a 5 per cent. chance of the inference being wrong, or that there is a 95 per cent. chance that it is right to claim a difference in the population-means. Similarly if a difference is significant at the 1 per cent. level there is a 99 per cent. chance that it is right to claim such a difference. In the case of a significant difference at the 0.1 per cent. level, there is a 99.9 per cent. chance of being right in claiming its existence.

Significance at the 0.1 per cent. level implies significance at the 1 per cent. and 5 per cent. levels, and significance at the 1 per cent. level implies significance also at the 5 per cent. level. A result which is not significant even at the 5 per cent. level is said to be "not significant." This does not imply that there is definitely no difference in such a case, but simply that it is not possible to say with reasonable certainty that there is a difference. It implies, however, that if a difference does exist it is not likely to be large. The association of "reasonable certainty" with a particular significance level is essentially a method of convention. In biological work it is unusual to consider any other levels of significance than those used here.

(b) <u>The Daily Catch</u>

Anglers' returns are analysed in respect of the individual catch per day for each season and the results, expressed as the mean number of fish per angler per day, are compared for any changes over the period of nine seasons. For the last five of these, information is available which enables the catch to be analysed according to whether the fish were taken in tidal (estuarine) waters or above (fresh, inland).

This mean value for catch per angler per day has been subjected to statistical treatment to determine the significance of seasonal differences. It should be noted that all records of no fish per day have been omitted from the means, since it is certain that only a small proportion of returns include such values, and during the earlier years no returns included nil catches per day. This omission, which will give a somewhat higher value to the means than is actually the case, will make these figures reliable for comparative purposes, which would not otherwise have been the case.

In a number of cases the data from any one river are too scanty to yield reliable conclusions.

(c) <u>The Size of Fish</u>

Returns are analysed in respect of the size-distribution of fish taken over the last five seasons, during which lengths were recorded by the majority of anglers making returns. It has been necessary to separate fish from tidal and fresh waters throughout, owing to the difference in legal minimum length which operates in each

Owing to the difficulty of delimiting tidal waters, for purposes of the angling regulations an arbitrary boundary has been fixed by the Commissioners, indicated by posts set up at specified points, in each river. Below the boundary fish less than 12 in., measured from the tip of the snout to the end of the central ray of the tail fin, must be released; above the boundary the minimu length now operating is 9 in. Prior to the 1951-52 seasor the length was 8 in. (for brown trout); as a result it has been necessary to omit all fish below 9 in. in making a comparison of the size of fish over the period.

Measurements of fish recorded by anglers were given to the nearest 1/4 in. For convenience in treating the data sizes have been grouped in 1 in. groups, at integral centres, half-inch values being allocated to the group above. This will also serve to counteract possible inaccuracies in measurements. In certain waters, notably lakes and artificial canals, a 14 in. size limit operates.

This analysis of size has been made to discover any change from season to season because, concurrent with any depletion of the stock due to overfishing (or understocking), firstly, there would be a decrease in the average size of the fish taken due to the removal of the larger fish and the increased fishing pressure on the younger fish, and, secondly, the reduction of the population would probably bring about an improved growth rate due to the reduced competition for food. While it is possible that these two factors might counteract one another it is unlikely that one would exactly offset the other and produce stability, but in any case a study of the growth of the fish as shown by their scales would show if there had been any change. Moreover, if the fishery depended on the release of hatchery-reared fish to maintain the stock, a view still held by a proportion of anglers, the cessation of this practice in the rivers of the north-west from 1951 onwards would have resulted in a rapid decline in the numbers taken, an increase in the average size following the reduced competition for food, and a very extensive elimination of fish of the younger age-groups. The last is self-evident, and it follows that if the contribution made by hatchery releases is of any real significance then the proportion of young fish in the catches should have changed during the years following the cessation of stocking.

(d) The Age and Growth of Fish

The various problems associated with the determination of the age of fish as revealed by their scales are well known and have been discussed by various workers. Allen (1951, p. 113) for example has expressed the opinion that scale reading is too subjective to be reliable, and that variations in the spacing of the circuli or the possible absence of one or more winter rings may lead to erroneous conclusions.

It must be conceded that such difficulties are encountered occasionally but it is doubtful if they are of sufficiently frequent occurrence to justify the abandonment of scale reading for age determination or the back calculation of length-for-age. It is essential for the study of a population to be able to analyse it in respect of its age composition; the variation in growth rate within a trout population is such that size-distribution curves do not yield any clue as to age, except for fish up to one year of age; it is often necessary to discover the age composition of a population without resorting to marking the fish; furthermore it is of considerable importance to study growth rates within a population.

False "winter" rings have been encountered occasionally but they are usually readily identifiable by their short duration involving two or three circuli which interrupt the span of normal summer growth; these can be ignored with safety. In the case of fish from some of the Tasmanian lakes some difficulty has been experienced over the obvious omission of one or even two winter rings, but with the great majority of stream fish the scales can normally be interpreted with considerable confidence.

Salmonid scales are much more easily read than those of other fish and the great majority are so clear that the overall picture is probably fairly accurate, especially when the number of fish in any one sample is reasonably good. The test for this is the accuracy with which results can be duplicated, and experience has shown that in samples taken from the same stream in two successive years the agreement in mean length-for-age as determined from the scales was remarkably good, although several months elapsed between the examination of the two season's scales and relatively small numbers of fish were available in each sample. Moreover, different sections o the stream showed considerable variation in growth rate, such an extent that 2-year fish in some sections were as large as, or larger than, 3-year fish in other sections. It is suggested that since the second season's readings, which were made without reference to the first, confirmed this difference between sections the scales had been read with a fair degree of objectivity and the results represe as close an approximation to the truth as the method will allow. These readings were fully supported by the eviden from marked fish of known age which had been released in stream.

In spite of its limitations the method of determinin age and growth from scales is much too valuable a tool to be lightly discarded.

Samples of scales taken from fish by the groups of selected anglers have been studied and from these, which were taken in three of the past five seasons, it has been possible to discover the numbers and size-range of the fi in each age-group. These figures are used to distribute fish taken by anglers as a whole into their respective ag groups, and thus to discover if there has been any change the age distribution of the population over the past five seasons. At the same time it has been possible to study the growth of fish from different sources over the period. It has not been possible to make this analysis for each river separately owing to the small amount of data in som cases.

The technique of scale reading to determine the age growth of fish is now so widely used that it is unnecessa to describe the whole in detail. However, it may be advisable to describe some modifications of the apparatus and method used here, and to define some of the terms.

Scales were cleaned and mounted by the methods described by Lindsay and Thompson (1932). It is not always necessary to make permanent mounts, though these were alw made for tagged fish because of the need for future reference, and when long series of scales had to be examined i was usual to make temporary mounts in water instead of glycerine jelly; but cleaning was usually desirable.

The general principle was followed of projecting an enlarged image of the scale on to an adjustable screen marked with a graduated scale, using the apparatus described by Kesteven and Proctor (1941). For simplicity and speed of operation it is desirable that the microscope should be fitted with an adjustable and rotating stage, so that the long axis of the fish scale can be rapidly aligned with the graduated scale marked on the screen, and its origin centred on the zero. When the microscope has an adjustable but not rotating stage the same objects can be achieved by having a circular screen pivoted at its centre, so that the graduated scale can be aligned with the long axis of the fish-scale image.

In the present case the latter arrangement was used, and the screen was made of perspex to which was clipped a sheet of Bristol Board on which was marked a line of suitable length, graduated to cover the maximum length of fish whose scales were to be examined under the magnification used. Adjustment of magnification by altering the distance of the screen from the projector quickly enables a fish scale to be set up for reading, and the intermediate lengths can be read directly without calculation.

The question of the relationship between fish length and scale length has been considered by many workers for numerous species of fish. A summary of the position has been given by Nall (1930, pp. 46-50). Apart from the work of Lee (1912) based on Dahl's data no attempt appears to have been made to approach this question fundamentally for trout, and students of age determination and growth in trout appear to have accepted Lea's (1913) rebuttal of Lee's hypothesis, although in a later paper (1920) Lee reviewed the question and maintained that the fish length and scale length are not proportional but that "only the increments of growth of each in the same periods are proportional to each other."

In order to discover the true relationship between the growth of the fish and its scales in trout, measurements were made of 3869 scales from 755 brown trout ranging in size from 6 to 33 cm, taken by electro-fishing in the North Esk and St. Patrick's rivers in December 1954 and January 1955. The results are shown in Figure 1, from which it will be seen that for this size range while there is some spread in the data with occasional samples lying some distance from the mean, the general distribution is such that a straight line gives the best fit. The regression equation for these figures is $Y = 0.00519 X + 0.002$, in which X is the fish length in mm and Y is the scale length in mm. From this it is clear that the extrapolated line passes very close to the origin:

(when Y = 0; X = -0.385).

Thus it would appear that in trout at least there is a clear correlation between fish length and scale length and that they are directly proportional. However, the dai on which this regression was calculated can be separated into two parts: that derived from fish from the North Esl and that from fish from the St. Patrick's. These are sect ions of the same river system and essentially similar, yet the data for the North Esk (1697 scales from 378 fish) yielded one equation (Y = 0.00545 X -0.057) and that from the St. Patrick's (2172 scales from 377 fish) yielded a different equation (Y = 0.00490 X +0.061).

These equations are not very different yet in the fir case the extrapolated line cuts the X axis at 10.5 mm and in the second it cuts it at -12.4 mm. It is only when the two are combined that these differences cancel out and the extrapolated line passes close to the origin.

The significance of this would appear to be that regression lines based on small samples are likely to be only approximate. In this may lie the explanation of the various positions at which the extrapolated lines cut the X axis in the different species dealt with by Lee (1920), although all the values were positive. Lee does not state the numbers of scales measured, but it would appear from her Table 2 that only one scale was measured from each fish since both fish and scale measurements numbered 200.

It would seem perhaps that too much importance has been placed in the past on the point at which the X axis is cut, and Lee's statement that the position at which this axis is cut indicates the approximate fish length at which scales first appear is, of course, incorrect as is clearly shown below. However, this does not entirely dispose of the problem since Blackburn (1950) claims a differ ential relationship in fish above and below 6 cm for <u>Engraulis australis</u> (White). Since none of the trout taken from the above sources was less than 6 cm it was necessary to use fish from the hatchery at Plenty in order to discover if such a change occurs in trout.

Scale measurements (251) were made on a sample of trout raised at the hatchery in 1948-49 covering a size range from 3.6 to 9.9 cm and these yielded the equation Y = 0.00463 X -0.079 which cuts the X axis at 17.1 mm. While the slope of this line is not very different from

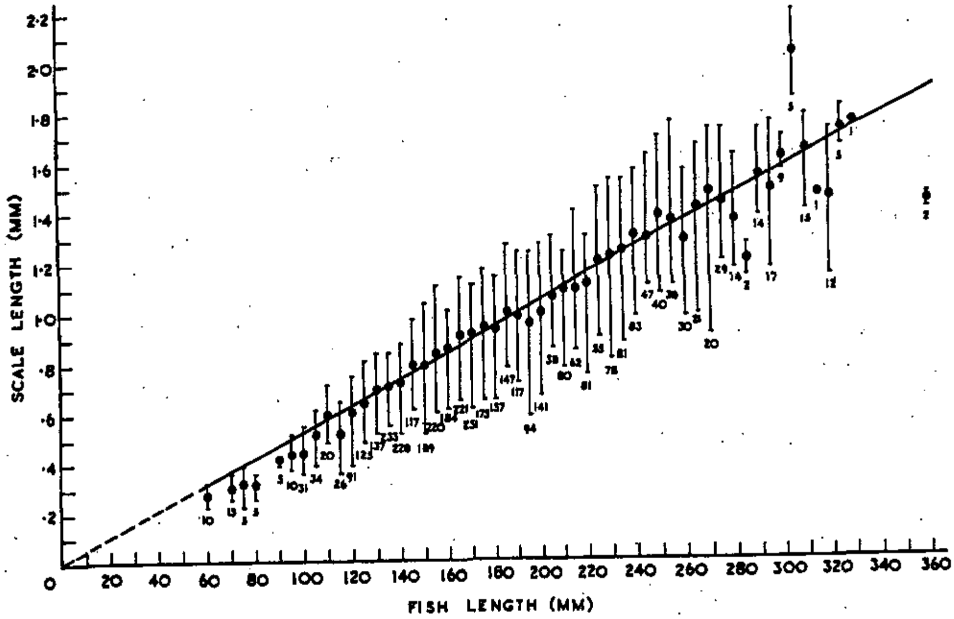

Fig. 1.- The fish-length/scale-length relationship for brown trout from natural sources, ranging from 60 mm to 360mm. Mean values only are plotted, but the range of scale-length for each fish-length is shown by the vertical lines. The number of observations at each fish-length are shown on the graph.

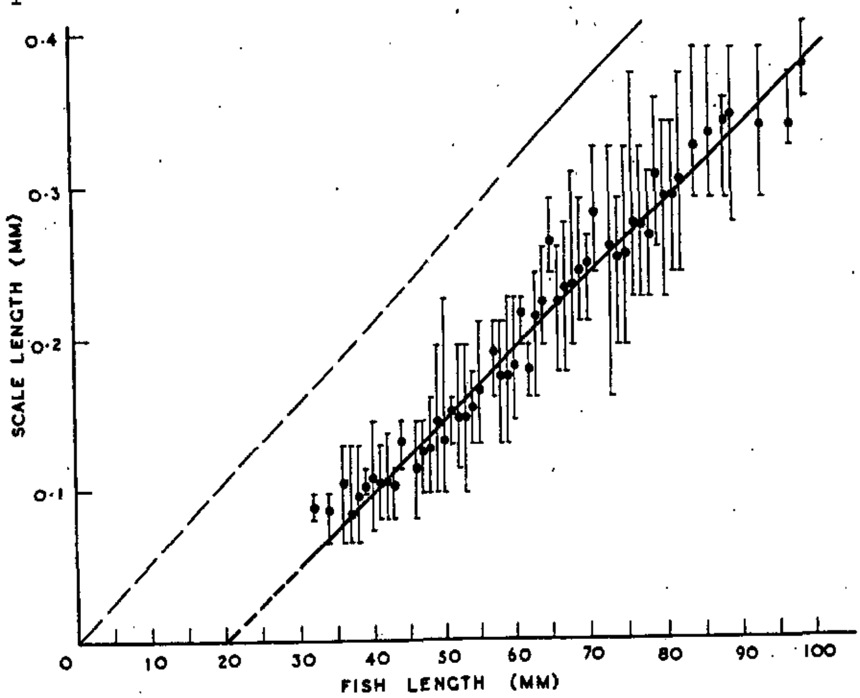

Fig. 2.- The fish-length/scale-length relationship for brown trout from the Plenty Hatchery, ranging from 32 mm to 99 mm. Mean values only are plotted but the range of scale-length for each fish-length is shown by the vertical lines. The number of observations for each fish-length ranged from 3 to 78, with an average of 9.6 and only 13 sets of data were below the average. The regression line for the data from fish from natural sources, shown in Figure 1, has been included to show the similarity in slope.

that for fish taken from the rivers, its height above the X axis is quite different. A second series of 982 scales taken from 99 fish measured at the hatchery in March 1956, ranging from 3.2 to 8.4 cm, gave the equation Y = 0.00483 X -0.098, which cuts the X axis at 20.3 mm. These two sets of data yielded results so similar that they have been combined to give the equation Y = 0.00479 X -0.095, and the results are plotted in Figure 2.

It is clear that there is a striking difference in the fish-length: scale-length relationship as between fish from 3 to 10 cm from the hatchery and fish from 6 to 33 cm from the field. These, however, are consistent in that each shows a straight line relationship and there is no tendency for the slope of the line to change below 6 cm or at any other point. In other words, to quote Tate Regan (<u>fide</u> Nall 1930, p. 50) "The scales are formed rapidly and after a very short interval overlap each other to the same extent in quite young fish as in adults."

This difference between fish from the two sources means that fish reared in the hatchery have smaller scales than fish of the same size which have lived under natural conditions. The relative figures over the comparable range of fish lengths are given in Table 2.

TABLE 2.

MEAN SCALE LENGTH (mm) IN FISH FROM DIFFERENT SOURCES

Source	Mean Fish Length (mm)								
	60	65	70	75	80	85	90	95	100
Hatchery	.180	.226	.242	.263	.290	.328	.343	.337	.376
Natural	.273	-	.300	.320	.316	-	.413	.432	.436

Although these differences may be in part due to the small numbers of fish available from natural sources (the numbers ranged from 5 to 31) they are mathematically quite significant except in the case of the 80 mm group, and must be regarded as real.

There must be some explanation for this difference and it is tentatively suggested that the cause lies in the difference in origin, and that rearing under artificia conditions in the hatchery with the fish crowded together and fed on unnatural food plays some part. In support of this suggestion it may be pointed out that of the fish taken in 1948-49, random samples of which were preserved in formalin at intervals, scales were first found in fish of 3.6 cm preserved in December some 3 months after hatching, and no smaller fish had scales. These scales consisted of the initial platelet with a diameter of about .065 mm. If the straight line relationship between fish length and scale length holds under all conditions, scale formation should be a function of size and not of age. Yet in the sample of fish measured in March 1956, some 6 months after hatching, scales were found on the smallest fish available, 3.2 cm, in which none of the scales consisted of fewer than 2 circuli, or was smaller than .081 mm.*

At first sight this appears to support Molander's discovery (quoted by Lee 1920, p. 21) that in herring of different ages but similar length the older herring have larger scales than the younger. This is so in the case of the two trout quoted here but the larger scales in the older and smaller fish were so because they were older scales, consisting of not less than 2 circuli. Thus, in reality, this shows that if the growth of fish is retarded owing to unfavourable circumstances scale formation will take place even though the fish is smaller than that at which scale formation normally occurs.

This probably has some bearing on the relationship and is worth further investigation, but for the present purposes it is sufficient to assume that under natural conditions growth of the scale is exactly proportional to growth of the fish throughout life, and that the initial lag between hatching and deposition of the first platelet

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* All scales were taken from that part of the fish from which it is customary to take scales for age determination in trout, namely midway between the back of the head and the front of the dorsal fin and equidistant between the dorsal and lateral lines. References to scales first being found in fish of certain lengths are to scales found in this position and do not in any way conflict with the excellent account of the early formation of scales in brown trout, given by Paget (1920). This author stated that the appearance of scales was a function of size and not age, but quoted cases of retarded scale development. The present case is one of 'premature' scale development under conditions of retarded growth, so that age must also have some influence.

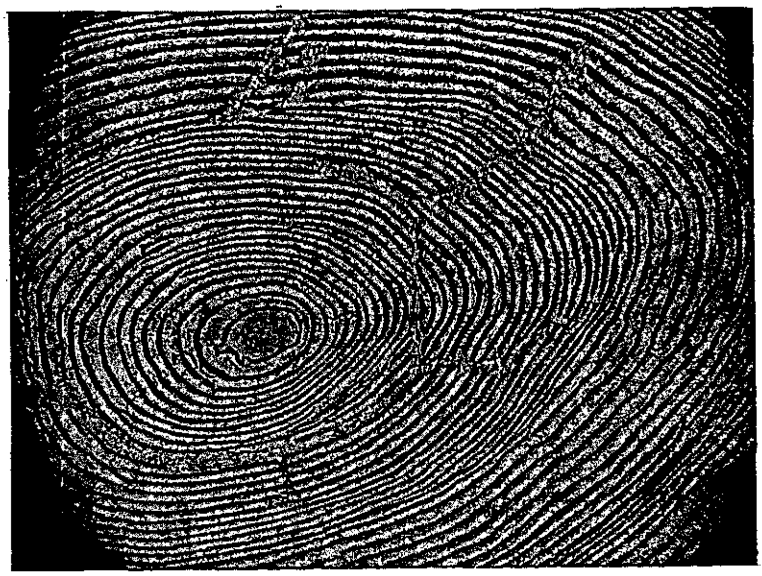


Plate 1. Enlarged central portion of a scale showing how the second and third circuli immediately outside the initial platelet are more widely spaced than those which follow.

is rapidly made good, probably by the time that the second or third circulus is formed. This can be clearly seen in the structure of the scales, since the first platelet has an appreciable diameter (0.065 mm) and the spacing between the first two or three circuli is greater than that between those immediately following, indicating a rapid overtaking of the initial lag. (Plate 1). Since there must be a change in the relationship between lengths of fish and scale over this short period, it should be possible to demonstrate it with sufficient measurements over the critical period, of scales carefully taken from exactly the same position on a series of fish, but the data here available do not show it.

In all scale readings of fish dealt with in this series of reports (apart from the very small fish discussed above) the fish lengths were adjusted, and all intermediate lengths were read, to the nearest 0.5 cm.

This degree of accuracy is regarded as sufficient in view of the nature of the original data. Where fish were measured by members of the Commissioners' staff or by Divisional field officers during spawning runs or netting operations, the fish were always alive and the error of measuring such fish lies within a range of about ± 0.5 cm. In the case of anglers who recorded fish lengths with their scale samples these were probably most often measured some time after death, when some shrinkage is likely to have occurred due to drying-out.

Having determined the age of each fish, and its length at the end of each winter, the results were grouped according to age and mean values obtained for all fish in each age-group. These will be expressed as "mean length-for-age" in the Tables of scale readings. It will be seen that occasionally there is some variation in the mean lengths-for-age in fish of different year classes. It sometimes happens that there tends to be a reduction in the lengths of fish at each year from younger to older fish, which might be regarded as evidence in support of Lee's hypothesis, but it will be seen that this is not constant, and may be completely reversed.

This variation could be real; due to natural fluctuations in the environmental conditions of the rivers from one year to another, or it could be due only to the effect of having small numbers of fish in any particular age-group.

In most cases the mean values at any one year, for fish in different year classes, are very close and statistical tests have shown that it is clearly safe to average these results. This has been done and is calle the Grand Mean (G.M. in Tables); these means are also given in British Units (Br. in Tables). Nomograms for conversion from metric to British units are given in th Appendix. In calculating the grand means, fish of the age-group in tidal waters, and those of the 1+ age-grou in fresh waters, have been excluded throughout. There two reasons why this has been necessary.

Firstly, since the fish of these age-groups approa very closely in length to the legal minimum applicable each case it follows that such fish taken by anglers wi not be representative of their age-group because the smaller fish will have been released as undersized. In other words, only the quicker growing fish of the 2+ ag group in tidal waters will have been large enough to re the legal minimum of 12 in., and similarly not all the age-group in fresh water will have reached the 9 in. minimum.

Secondly, because of the operation of these minimu lengths there is some risk that fish which were close to but did not attain the minimum length will have been retained and recorded as within the legal minimum. Thes will have unduly elevated the numbers taken and the mear lengths for these age-groups.

The first of these factors will operate both in len given in the creel census and in the field record books scale samples; the second is likely to have occurred, i at all, only in the creel census returns. It has had to be assumed that the samples of fish recorded by anglers were representative of the populations of takeable fish.

(e) Mortality

Having allocated the fish taken by anglers into the respective age-groups it follows that simple calculation will reveal the mortality rates in operation from one ye to the next. There are insufficient data to provide reliable mortality rates for each river, and this subjec will be considered when summarizing the results for the region as a whole.

(f) Tagged and Marked Fish

One very good method of assessing the contribution to the fishery made by releasing fish from hatcheries is to mark all such fish, either by the application of tags or, more simply, by the removal of a fin. The former is considerably more laborious and time-consuming and has the added disadvantage that a proportion of the tags will not hold on yearling fish; the latter method is adequate when the fate of individual fish is not required to be followed, and being quicker and easier to carry out and giving equally reliable results when only numbers of fish are required to be known, this method has been employed on several occasions, supplemented by a proportion of tagged fish.

The numbers of these appearing in the spawning runs in successive years yields information as to the mortality rates, and the proportion of them appearing in the catches in their appropriate age-groups provides direct evidence as to the value of hatchery liberations. For the full value to be derived from this method of assessing the contribution from hatcheries it is important that as complete as possible a return should be made of all fish taken, and that those which were marked should be indicated.

It is clear from the poor response from anglers that this approach would yield little or no result where it was dependent on anglers' returns. It has therefore been restricted in the main to the Great Lake, Lake Leake, and to a lesser extent the Derwent River, since in such places it has been possible to recapture representative samples of fish during the spawning runs. Fishing by means of an electric current, however, has made possible the recapture at a reliable level of marked fish released into a population. Small numbers of fish have been taken from estuaries by seine nets, tagged, and released in order to discover if there was any movement of fish from one river to another. Larger numbers of fish taken on the spawning runs referred to above have been tagged for growth studies. A number of tagged yearlings from the hatcheries have also been released in these waters.

Apart from a small number of tags specially designed for small fish, the strap tag was used throughout this work. This is made in three sizes and all were used according to the size of fish being tagged. Because of the marked success with which trout remove tags fixed to the operculum, by rubbing them against fixed objects, th position of attachment is useless. Shetter's (1936) metl of attaching the tag to one side of the lower jaw was adopted. This author described his method of rounding tl tags after application to permit of growth of the bones and to prevent the tags from being pushed off. He found that in rainbow trout from 8 - 12 in. in length the tag held quite well for one year.

A test was carried out to find the lower size limit which trout could be successfully tagged. In October 19 964 yearling brown trout ranging from 7.7 - 14.4 cm (3.0 5.7 in.) were tagged using Shetter's method, and held in rearing ponds at the Plenty hatchery. Two months later only 450 still held their tags and these were roughly divided into two parts, one of which was transferred to a lake; the subsequent fate of these is unknown owing to t difficulties of recapture.

Table 3 shows the percentage size distribution of tl original 964 fish at tagging; of the original lengths oi sample of 213 which were removed from the rearing ponds after 2 months; and of 112 which still held tags 11 mont after tagging.

TABLE 3.

SIZE OF FISH AND ABILITY TO CARRY JAW-TAGS

Size Group (cm)	At Tagging Number	%	After 2 months Number	%	After 11 mc Number	
8	4	0.4	0	0.0	0	
9	12	1.2	0	0.0	0	
10	89	9.2	6	2.8	3	
11	371	38.5	55	25.8	23	[illegible]
12	363	37.7	106	49.8	54	[illegible]
13	110	11.4	37	17.4	29	[illegible]
14	15	1.6	9	4.2	3	
Totals	964	100.0	213	100.0	112	[illegible]

It will be seen that there was a complete eliminatic of all fish which were less than 10 cm when tagged, and that there was an increase in the proportions of fish in larger size groups which held tags up to nearly a year. The 11 cm group comprised 38.5 per cent. of the tagged fish, but only 25.8 per cent. of those holding tags for 2 months, and only 20.5 per cent. of those holding tags for 11 months. For 12 cm fish and over at tagging this trend was reversed and is most strikingly seen in the 13 cm group. There were only 15 fish in the 14 cm group and more than half of these were removed from the ponds after 2 months so that they were not truly represented at 11 months. It would appear that it is possible to tag fish of 13 cm and over with a reasonable degree of success.

It was noted during the first two months while the fish were in the rearing ponds that they tended to take up an almost vertical position in the water, with their heads close to the bottom, and to gyrate in this position. This was undoubtedly due to the relative weight of tag and fish in water, and some data on this are presented in Table 4.

TABLE 4.

WEIGHT OF TROUT AND TAGS IN AIR AND WATER

Length of fish (cm)	Weight in air (g)	Weight in water (g)	Volume of fish (ml)	Weight of tag in air (g)	Weight of tag in water (g)	Wt. of tag in water / Wt. of fish in water
7.7	4.650	0.235	4.7	0.480	0.401	1.7
8.4	5.625	0.295	5.7			1.4
9.6	8.600	0.375	8.3			1.1
11.7	15.670	c.0.69	15.9			0.6

Four small fish were stunned by a blow on the head and carefully weighed in air and in water, being suspended from the balance with thread. Volumes were measured approximately by displacement. Ten tags were weighed in air and in water to overcome any variation in the weight of individual tags.

It will be seen that in the case of the smallest fish while the actual weight of the tag is only about 1/10 of the weight of the fish, when they are immersed in water the tag is more than 1½ times the weight of the fish. It is surprising that any fish of 9 or 10 cm could adjust themselves to the burden.

This difference becomes increasingly less important as the fish grow and in older fish (up to about 3 lb in weight) tagged with medium or large tags the weight of the tag was relatively insignificant. It will be seen that a fish loses approximately 95 per cent. of its weigh when in water so that one weighing 1 kg (about 2 lb) woul weigh about 50 g in water, and a medium tag weighing 1.71 g in air and 1.52 g in water would not constitute a serious burden. The weight of the largest tag was 2.63 g in air and 2.33 g in water.

The result of the prolonged assumption of the near vertical position together with the freedom of movement given to the rounded tag was that it gradually moved forward along the lower jaw and finally cut through between the two halves and fell off. Many of the fish which had lost their tags in this way survived and were recognizabl by the "crossbill" effect of the two halves of the lower jaw. Such fish did not appear to suffer any disadvantage and grew almost as well as those which held their tags. The mean length of all fish tagged was 11.9 cm. At 11 months from tagging the mean length of fish which held their tags was 22.0 cm and of those which lost tags 21.2 cm; the corresponding weights were 113.7 g and 99.2 g giving condition factors of 1.07 and 1.04 respectively. Statistical test shows that for both length and weight the difference between these means was significant only at the 5 per cent. level. Since the fish which lost their tags were almost certainly smaller when tagged than were those which held tags it is doubtful if there is any real difference.

The mean length of some 1500 fish without tags kept in the rearing ponds with the tagged fish to act as a control was 21.4 cm which indicates that despite the disability from which the tagged fish suffered their growth was not affected.

It appears that rounding the tag when affixed to the jaw is unnecessary since the metal is sufficiently tough to resist pressure from the growing jaw and subsequent recoveries have shown that the tag tends to become embedded in the tissue rather than to be forced open. Rounding of the tag is also undesirable because the freedo of movement prevents rapid healing around the point of insertion. Experience has shown that even with the larger sizes of tags one which is left unrounded with little or no freedom of movement will soon heal into position provided the fish is in good condition, whereas the rounded tag maintains an open sore on the jaw. It is no disadvantage if the tag when applied pierces the bone as this helps to keep it firmly in position.

(g) Releases from Hatcheries

An additional approach which will throw some light on the value of hatchery releases is provided by the figures for the known rates at which rivers have been stocked in the past. It is possible to arrive at approximate figures for the estimated total annual catch for each river. Mortality rates applicable to Tasmanian rivers have been discovered and these in conjunction with the numbers of fry or yearlings released will yield approximate numbers surviving for anglers.

The relationship which the total annual catch from any one river bears to the estimated survival of hatchery-released fish will further establish the value of this practice.

(h) Condition

This is normally expressed by the Condition Factor (K), or length-weight relationship. There are several methods of calculating this factor depending on the measurements used. Throughout this investigation the standard formula $K = \frac{AW}{L^3}$ has been used, in which A is constant, W is the weight in pounds or grams, and L is the length in in. or cm measured from the tip of the snout to the end of the central ray of the tail fin. (See Appendix).

Hile (1936) discussed condition and the relation between length and weight (pp. 237-249) reviewing objections to it on the grounds of inaccuracy. The following paragraph quoted from this author is particularly significant. "Clark's conclusion that the failure of the cube law to describe the length-weight relationship makes inaccurate the use of coefficients of condition (weight-length factors) based on the cube relationship is scarcely justifiable, particularly in view of the fact that coefficients based on empirical exponents fail to reflect differences in form or relative heaviness while those based on the cube relationship off(direct measure of relative heaviness independent of gene: length-weight relationships and comparable as measures o: relative heaviness between fish of any length." (p. 240

It may be added that the cube relationship also presents a direct means of comparison between fish of an; species, whose average K values may lie considerably abo\ or below unity. The only effect of using a coefficient based on empirical exponents is to bring the average for any particular species to unity (using the metric system of length and weight). There is little value in this sir it removes the possibility of direct interspecific compar sons and does not overcome the disadvantage inherent in both methods, that of seasonal variation within a species due to gonad development or to other causes.

Klak (1941) also discussed the use of this formula a gave the conversion factor for interchanging between the British and metric systems of measurement. ($K_{(m)} = B_{(Br)}$ 0.02768). It has also been discussed by Le Cren (1951) a by Allen (1951). The latter used the cube relationship i his study on trout and it would appear preferable to adhe to this for purposes of comparison.

It is obvious that the use of a condition factor as means of comparing fish from different places, taken at different seasons, or at different times of the day canno be regarded as more than a rough guide because of the var ing degrees of development of the gonads and variations i the quantity of food in the stomach, both of which will affect the weight.

For the reason given above the weights of fish as given by anglers in their returns of catches have not bee: used. However, the importance of accurate weights was stressed to those anglers who undertook to collect scale samples, and in the majority of such cases the weights given appear to be reasonably accurate.

The weights and condition factors derived from them will be given in the Tables setting out the results of scale readings. The original measurements were in Britis] units and these have been converted to the metric equival· ents, rounded to the nearest 10 g for larger fish and 5 g for smaller fish, and the K value calculated for each fis] The values given in the Tables are the means of the indiv: ual values. On those occasions on which fish were netted for tagging, or during spawning runs, the lengths and weights were accurately determined. Mean K values are tabulated for these fish.

(i) Type of Lure

An analysis of the relation between type of lure used and number and size of fish taken will be included in the final report of this series.

IV. BIOMETRICAL DIFFERENCES BETWEEN THE SEXES

In the fish caught by anglers there does not appear to be any significant difference between the sexes as regards length, and for most of the year there is no appreciable difference as regards weight. Differences in weight become apparent as the spawning season approaches, and immediately after, and such differences are of course reflected in the condition of the fish. Since the fishery is closed to anglers during the spawning months this difference can be ignored. In those cases where spawning fish have been studied the differences between the sexes will be considered.

Examination of a sample of 164 fish (108 females and 56 males) taken by one angler from the same stretch of river throughout one season showed no significant difference between the sexes as regards length, weight, or condition. The data were then pooled and analysed by months and again no significant differences were found in these respects as between months of capture, neither was any significant seasonal difference found between the sexes. It is probable that many anglers have considerable difficulty in determining the sex of fish, particularly the smaller river fish, and this fact supported by the findings of the statistical analysis justifies the decision to treat all fish together without separation into sexes.

At the same time it is not claimed that no difference exists either between sexes or between months of capture, for it is clear that growth of fish and development of gonad are gradual and continuous processes, which must result in real seasonal and sexual differences. Fish taken early in the season, following spawning, show a poorer condition and later fish show recovery. It should be emphasized that it is only for the purpose of the present comparison of fish from anglers' catches that the data are pooled, because these differences are nc statistically significant in these samples.

One reason for the absence of any significant difference from month to month during the fishing season is that as the season progresses and growth takes place, fish which at the beginning of the season were below the legal minimum begin to enter the fishery in the latter half of the season and so lower the average length and weight of fish taken at that time.

V. GROWTH AND REPRODUCTION IN HATCHERY-REARED FISH

The normal practice when stripping fish for hatchery-rearing as carried out by the staff of the Salmon and Freshwater Fisheries Commission is to strip a number of females into a clean bucket, to add the sperm from one or more males and after a few minutes to wash the fertilized ova which are allowed to harden and then packed in trays with moss for transport to the hatchery. Sometimes the males are stripped first. Fish are taken as they come so that a cross section of the population is represented in the resulting offspring.

Hatchery-reared fish are normally fed on finely-ground cooked ox liver, with or without added biscuit, occasionally varied with raw liver; this deprives the fish of much of their essential vitamins. A little natural food will enter the hatchery with the water supply but the quantity must be insignificant while the fry are ir the troughs. As soon as possible after hatching the majority are released in fishing waters, but enough are normally retained for rearing to fingerlings and yearlings as can be accommodated in the rearing ponds. Here the supply of natural food will be somewhat greater but still almost negligible compared with the requirements of growing fish, owing to the density of the fish in the ponds.

It is obvious that some form of selection of parents could be exercised in the field at the time of stripping, provided a limit were placed on the number of ova required to be collected. No such limit has been fixed in the past, the aim having been to collect as many ova as possible. In order to discover if there were any difference in the growth rate of the progeny of selected parents as compared with those of the average as represented by the customary methods of stripping, experiments were carried out on both brown and rainbow trout.

(a) Brown Trout

In June 1948 two pairs of fish, selected for their large size and good shape, colour, and condition were used as the test fish and a random sample of ova taken by the normal method was used as a control. The fish were stripped and the ova fertilized in the usual way, except that the resulting embryos were kept apart for transport and rearing. Subsequent treatment was the same for all, and the food and other conditions were the same as those normally used.

The first pair (A) comprised a 63.5 cm female, weighing 3290 g (K = 1.29) and a 62.0 cm male weighing 2610 g (K = 1.10); the female yielded approximately 4850 eggs weighing 510 g (8 per cent. of her weight); the eggs were of even size and average diameter 5.92 mm.

The second pair (B) comprised a 50.5 cm female weighing 1815 g (K = 1.40) and a 55.5 cm male weighing 2270 g (K = 1.33); approximately 3680 eggs were obtained, weighing 255 g at stripping (5 per cent. of her weight), of even size with an average diameter of 5.25 mm.

The sample of ova used as a control (C) comprised about 3890. They were of mixed sizes and in a sample of 106 measured, 9, 60, and 37, had mean diameters of 4.62, 5.07, and 5.51 mm respectively; the mean for the sample was 5.18 mm.

Samples of approximately 100 from each set were preserved as ova, at hatching, and thereafter at about 2-monthly intervals until June 1949 after which data were obtained from the live fish. Set B was discontinued in April 1949 as there were insufficient survivors, a big loss being due to a faulty screen. Until December 1948 the fry were held in the hatchery troughs but at the end of that month A and C were transferred to outside ponds; no space was available for B. The survivors of these fish were raised to maturity.

Although there were slight differences in the growth rates of the three sets of fish during the first year after hatching they were not mathematically significant. The mortality rates for these fish during the forty weeks following stripping are shown in Figure 3.

In June 1951 when the survivors were three years of age and mature 3 pairs each from A and C were selected for stripping. At that time they averaged about 38 cm in length. The best female, a C fish, 36.5 cm, weighed 620 g (K = 1.28) and yielded almost 1600 ova; the other two females from C, somewhat smaller and in slightly lower condition, yielded 540 and 370 ova. The mean diameter of all ova was 4.44 mm and they were of even size.

Of the A fish suitable for stripping the three females were close to 32 cm, weighed 350 to 400 g (K = 1.12 - 1.16) and yielded 650, 480, and 420 ova of even size with mean diameter of 4.65 mm. The subsequent fate of these progeny is dealt with below, where the detailed growth of individuals is shown. (Section VI). The mortality of the offspring of these fish was surprisingly high as shown in Figure 3. There was a large proportion of infertility, up to 100% in one pair from A. It was a C fish which produced the largest number of ova but the fry suffered a much heavier mortality than those from other pairs. The lowest infertility and lowest post-hatching mortality occurred in the A fish with the smallest number of ova.

An interesting fact shown in Figure 3 is that the survival of fish hatched in 1951 was in general at a lower level than that of their parents hatched in 1948 from natural stock. The temperature in both seasons rose gradually from 40° to 61° F during the course of the experiment.

Thus, although the offspring of the A fish were better at the beginning there was little to distinguish them from C fish as regards either growth or reproduction after three years in the hatchery.

It is not, of course, normal practice to hold a breeding stock of fish in the hatchery but the results of this experiment strongly suggest that such a practice would be unsuccessful unless special precautions were taken with regard to food and, also, that irrespective of their origin fish which are kept under the same conditions react to the environment equally as shown by their similar growth rates and poor reproductive capacity.

(b) <u>Rainbow Trout</u>

An identical experiment to that described for the brown trout was started in October 1948 with rainbow trout.

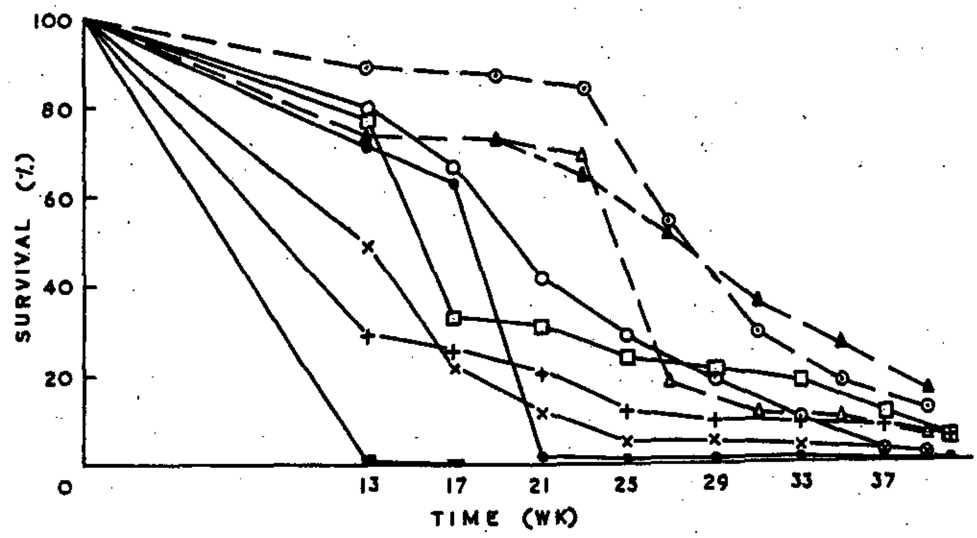


Fig. 3.- Survival of hatchery-reared brown trout. An average period of 13 weeks has been allowed for hatching. The broken lines indicate values for 1948: A; B; C. The continuous lines represent values for 1951, progeny of C fish:
I; II; III; progeny of A fish:
IV; V; VI. For explanation see text.

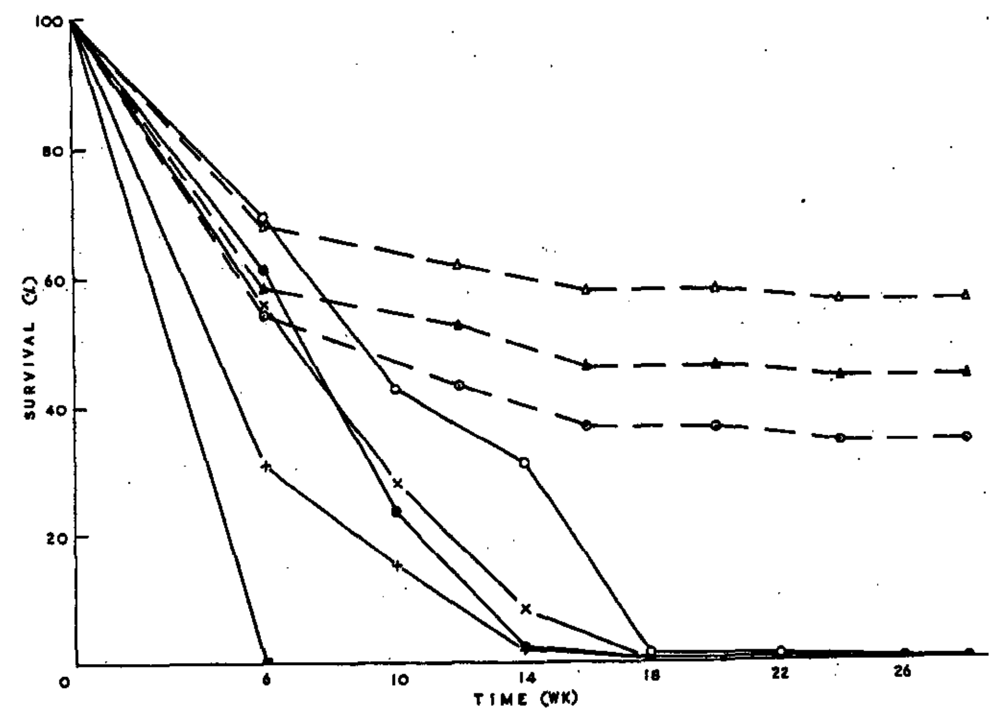


Fig. 4.- Survival of hatchery-reared rainbow trout. Hatching occurred after 6 weeks. The broken lines represent values for 1948: A; B; C. The continuous lines represent values for their progeny in 1951, A fish: VII; VIII; C fish: IX; X; B fish: XI. At 28 weeks from fertilization survival values for VIII to XI were all 0.6 per cent. or less.

The first pair (A) comprised a 58.0 cm female weighing 2720 g (K = 1.39) and a 61.0 cm male weighing 2380 g (K = 1.05). About 3820 ova were obtained weighing 355 g (13 per cent. of her weight) of even size and average diameter 5.49 mm.

The second pair (B) comprised a 59.0 cm female weighing 2720 g (K = 1.33) and a 46.0 cm male weighing 1250 g (K = 1.28); the number of ova was about 5900 and weighed 470 g (17 per cent. of her weight), of even size averaging 5.03 mm in diameter.

The control sample of ova (C) numbered about 5480 and had an average diameter of 5.03 mm.

Treatment of material and collection of data was on the same lines as described for the brown trout except that all fish were transferred to outside ponds on January 1, 1949. Again the differences in growth rates were not statistically significant. The A fish were consistently somewhat larger than either of the others, but the B fish were consistently slightly smaller than the control fish (C). Interest in this experiment again centres on the differential survival rates as between the progeny of the original fish in 1948 and their progeny at first spawning after three years in the hatchery.

The same general picture is shown (Fig. 4) but the difference is much more striking than for the brown trout. The survival in the 1948 samples was relatively high but that of their progeny taken in 1951 was remarkably poor. Only 5 pairs of fish could be stripped in 1951, there being insufficient suitable fish in the B set to provide more than one pair. The temperatures were very similar in both seasons and rose gradually from about 45° to 61°F during the time covered.

It would seem from the above that rainbow trout are more difficult to rear under hatchery conditions than are brown. There is little doubt that they are more susceptible to nutritional disorders and that they require a higher standard of food. It has frequently been noticed in the Plenty Hatchery that rainbow trout retained for rearing tend to develop what is known there as the "whirling disease", the chief symptoms of which are loss of appetite, pronounced darkening in colour, and loss of equilibrium resulting in gyratory movements. Woodbury (1943) fully recounts the symptoms of a disorder due to Vitamin B_1 deficiency in hatchery-reared rainbow trout which leaves little doubt that the circumstances are identical with those met with here. The disorder affects the nervous system causing loss of equilibrium leading to progressive weakness and finally to paralysis. It is accompanied by inability to feed and pronounced darkening of the fish due to the expansion of the melanophores, by which affected fish can be readily identified. According to this author it can be cured by injecting thiamin hydrochloride or prevented by the addition of dried brewer's yeast when the diet is low in thiamin, such as occurs when boiled or canned foods are used or when the food is dried at too high a temperature.

It is of interest to note here that the Pemberton-Warren Trout Acclimatisation Society in Western Australia experienced similar trouble with pond-reared rainbow trout, in that the ova resulting from such fish were infertile. This was overcome with complete success by feeding such fish on bran, to supplement the vitamin B, and dicalcic phosphate. (16th Annual Report, for 1946).

VI. GROWTH IN RELATION TO TEMPERATURE

Since most of the work on the growth of fish has been carried out in the northern hemisphere it was thought advisable to follow the seasonal growth here as a direct aid to age determination. It is important to be able to fix with some certainty the time of year at which the 'summer' growth recommences after the end of the period of 'winter' growth.

In order to carry out this study four brown and four rainbow trout which had been hatched five or six months previously were held separately in specially constructed boxes each with its own water supply. These fish were fed daily with a slight excess of food. Water temperature records were kept throughout the period, being measured twice daily at 8.30 a.m. and 5 p.m. and for the present purposes averaged on a weekly basis. The fish were weighed and measured at approximately 4-weekly intervals and scale samples were taken.

The fish used were survivors from the experiment previously described (Section V). Numbers I and III were brown trout from the control sample, stripped in June 1951; numbers IV and V were from the A stock. Hatching took place about the middle of September. Numbers III and V died within 6 months of setting up the experiment; I survived for 18 months; IV lived for 38 months and was finally killed at an age of 3 years and 8 months from hatching, at the conclusion of the study.

Of the rainbow trout, VIII was from the A stock; IX and X were from the control sample, and XI was of B stock. These were stripped in September and hatching occurred about the middle of October. Numbers X and XI died at 6 and 12 months from the start of the study respectively. Fish number X showed the early symptoms of vitamin B_1 deficiency in May 1952; it was injected with 0.5 mg thiamin hydrochloride and recovered, surviving until September 1952. VIII and IX survived for 34 and 30 months respectively. Number IX was found to be carrying mature ova at 2 years of age and was stripped and fertilized with sperm from number VIII; 196 ova (average diameter 3.42 mm) were taken from this fish. These ova were infertile and all were dead within 48 hours.

Conditions in these hatchery boxes were not ideal for the growth of fish; the food was of the normal type described above and little natural food would have found its way in with the water supply. The boxes were painted black, were inside a building and received only a little indirect sunlight. The results cannot be expected to show the normal growth rate for trout, even in a hatchery, as fish held for rearing are normally placed in rearing ponds exposed to sunlight in which some natural food would grow.

The data resulting from the regular measurements of length and weight for the three fish which survived for the longest periods (IV, VIII, and IX) are shown in Figure 5. It will be seen that for the brown trout (IV) the growth rate which was steady but slow during the winter months began to increase when the water temperature approached 50°F (10°C), usually at about the end of September or early in October. This was followed by rapid growth while temperatures were between 50° and 70° F. A summer check in growth occurred in January 1954 when the mean water temperature exceeded 70° F (21°C) for a fortnight during which the morning temperatures ranged from 62° to 72° F and the afternoon temperatures from 70° to 80° F. Such temperatures were not recorded in either 1953 or 1955 although afternoon readings rose to just over 70° F on a few occasions.

For simplicity the weights of the fish are not shown in Figure 5, but the K values are given from which the approximate weight in grams can be calculated by reading from the graph the corresponding length and K values for any date and substituting these in the formula $W = KL^3/100$ when L is measured in cm.

The growth of the two rainbow trout was generally similar to that of the brown, but the female (IX) showed more rapid growth during its second summer though the advantage thus gained was subsequently lost.

There is a slight tendency for the condition of the brown trout to show seasonal fluctuations, rising in summer and falling in winter. This is more pronounced in the rainbows which showed remarkable improvement in condition despite the rapid increase in length during the summer of 1952-53, and this high condition was not lost during the following winter until after the fish were stripped (shown by the vertical line near the end of October 1953). Further loss in condition in both rainbows occurred, followed by a rapid recovery by the end of December in the male, less pronounced in the female.

Measurements of 486 scales taken from 111 brown trout ranging from 15.5 cm to 42.0 cm in length reared at the hatchery for this experimental work showed that the difference in size between the scales of fish from natural sources and from the hatchery (shown in Figure 2) was maintained. The regression equation for all scale lengths for hatchery reared fish from 3.2 cm to 42.0 cm is $Y = 0.00501 X - 0.106$ which cuts the X axis at 21.2 mm.

Statistical comparison between this equation and that for the fish from natural sources given in Section III (d) shows that the difference in slope is quite significant. These regression lines meet at negative values for X (-600 mm) and Y (-3.1 mm) and thus diverge as the fish grow, indicating that if the smaller scale-size in hatchery reared fish is real, as suggested above, it is a continuing process. If it may be accepted that for practical purposes the lines are more or less parallel over the size range involved here, then statistical comparison shows a very highly significant value for the distance separating the two lines in this range.

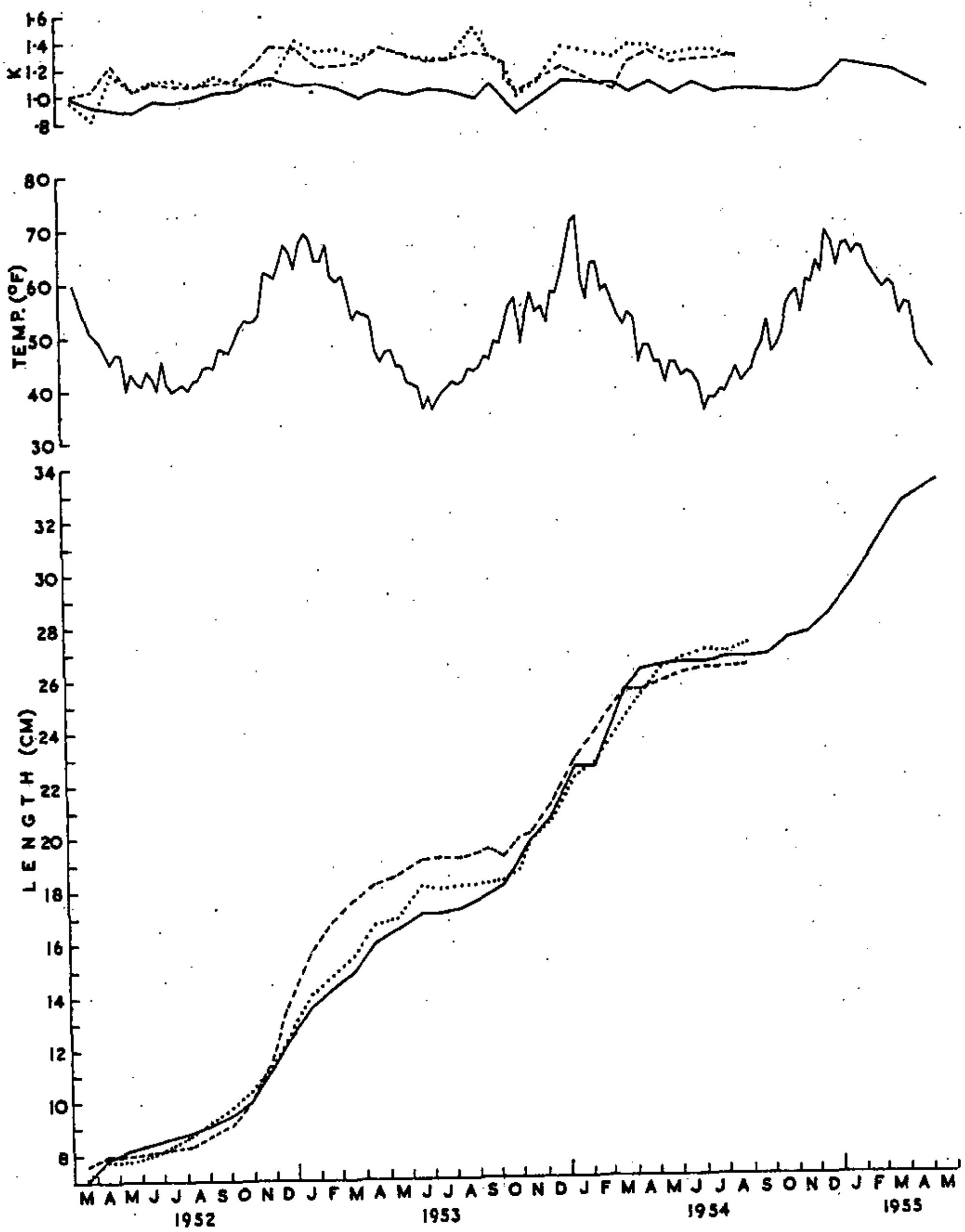


Fig. 5.- The growth of three trout in the hatchery, recorded at approximately 4-weekly intervals, together with the corresponding K values. ——— brown trout (IV; .... male rainbow trout (VIII); ------- female rainbow trout (IX). The mean weekly temperatures over the period are also shown.

VII. ACKNOWLEDGEMENTS

The investigation which is covered by the series of reports of which this is the first, could not have been carried out without the co-operation of the Salmon and Freshwater Fisheries Commissioners and their staff. The assistance rendered by this body through their Chairman (the late Mr. O. H. Hedberg until 1953, Mr. G. C. Cramp in 1953-54, and Mr. C. O. Holmes since 1954) is gratefully acknowledged.

The Commissioners' Chief of Staff, Mr. Hector V. Jones, has given valuable help both in the field and at the Hatchery throughout the investigation. During the first two years he carried on the experimental work during my absence from the State, and during the last three years he has been largely responsible for carrying out the field work.

Acknowledgements and thanks are also due to those anglers who have co-operated by making returns of their catches, and especially to those who have undertaken the collection of scale samples, made fishing diaries available, or helped in many other ways.

The assistance given by Dr. A. T. James of the C.S.I.R.O. Division of Mathematical Statistics in the statistical analysis of the data on the daily catch per angler, and by Mr. P. Sprent, Lecturer in the Department of Mathematics in the University of Tasmania, in the statistical treatment of fish lengths, is gratefully acknowledged.

The help received from Divisional field and laboratory assistants is also acknowledged, in particular that of Mr. T. R. Marriott who was associated with the work for 5 years.

VIII. APPENDIX

The following nomograms have been constructed for the rapid conversion of metric units into their British equivalents, and vice versa.

Number 1 is for the conversion of centimetres into inches; Number 2 for grams to ounces; and Number 3 for kilograms to pounds.

Conversions are made by finding the point at which the vertical line corresponding to the value it is desired to convert in the metric system cuts the diagonal line and reading the corresponding value in the British system on the horizontal line.

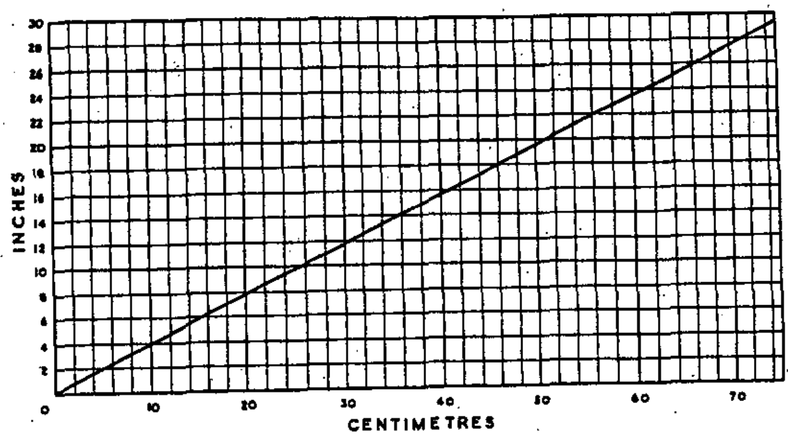
These can be extended beyond the limits of the values shown by adding readings; for example, 850 g in ounces equals the sum of 500 g (17.1/2 oz) and 350 g (12.1/4 oz) which equals 1 lb 13.3/4 oz.

Number 4 shows the relationship between the Metric and British methods of evaluating the Condition Factor (K).

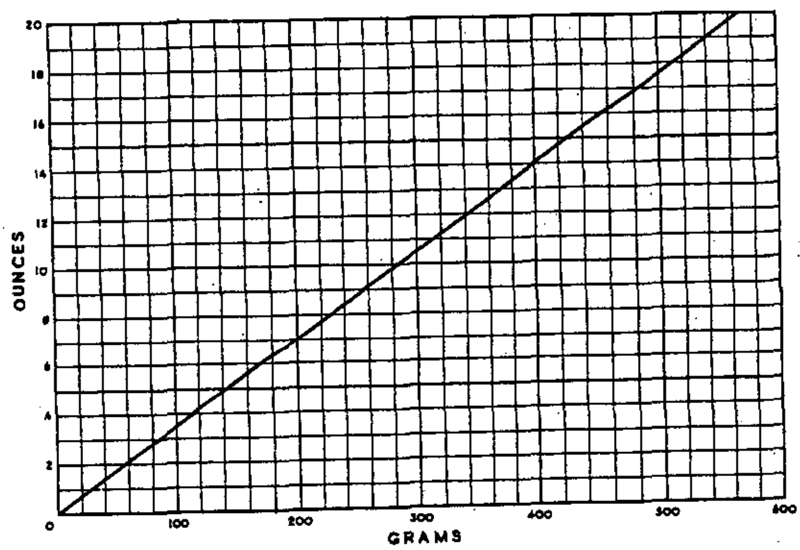
It is unfortunately not possible to give a simple diagram from which the Condition Factor may be read, but the respective formulae for calculating these values are:

Metric: $$K = \frac{\text{Weight in grams} \times 100}{(\text{Length in centimetres})^3}$$

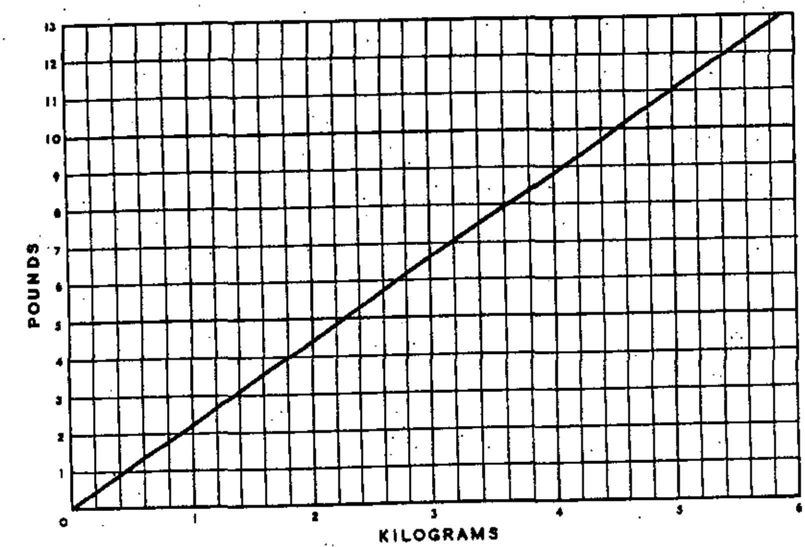
British: $$K = \frac{\text{Weight in pounds} \times 100{,}000}{(\text{Length in inches})^3}$$



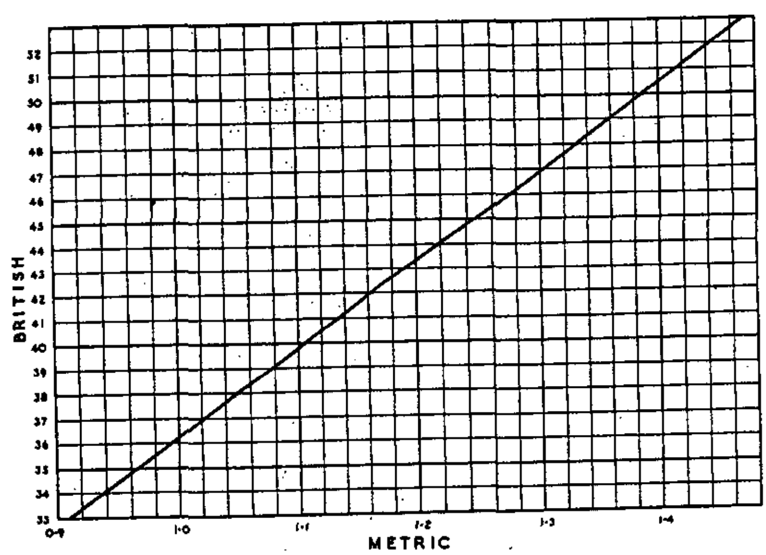
1. Nomogram for conversion of cm to in.



2. Nomogram for conversion of g to oz.



3. Nomogram for conversion of kg to lb.



4. Nomogram showing relationship between metric and British methods of evaluating the condition factor (K).

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