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I. THE SALMON AND SEA TROUT FISHERIES

BY

Dr. J. P. JACOBSEN and Dr. A. C. JOHANSEN

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A. Introduction.

FLUCTUATIONS in the yield of the Salmon and Trout Fisheries have for many years been observed in various countries. Generally they have been attributed to some influence by man such as temporary overfishing, contamination of rivers, obstacles in parts of the rivers, etc.

The relative poorness in individuals of these species and their peculiar life, confined as they are in the youngest as well as in the mature stage to parts of the rivers far from their outlet, involves undoubtedly that great fluctuations in the yield are due to the influence of man.

Observations are present, however, suggesting that the yield of the salmon fisheries can also be influenced by physical factors[1]), but very little is known about this at present. The investigations are usually rendered difficult by the want of reliable statistics for a long series of years. For this reason we shall limit our investigations here to one single river, the Gudenaa, in the eastern Jutland (Fig. 1), for which we possess exact statistics of the yield of the salmon and sea trout fisheries for a series of years. Though the Gudenaa is a small river it has undoubtedly its own stock of salmon as well as of sea trout[2]).

The investigations thus concern a small entirety of the field, but the results, which we obtain, will probably be of use for other localities also.

In the lower course of the Gudenaa by Frisenvold, near Randers, a fish wear existed till a few years ago (Fig. 2). This wear crossed the river and in this were captured practically all the ascending salmon and sea trout. The fish wear belonged to the State from 1898—1915, and in this period a series of experiments were carried out concerning the stock of salmon and trout in the Gudenaa system. The fish wear was, however, for a great part of the period mentioned not used for capture during the winter, but in the season from May to November or June to November almost all the running salmon and sea trout were caught in this fishing apparatus[2]). A record of the captures in the years 1899—1914 will be found in the Tables 1 and 2. Also during a long period before 1898, statistics of the catch of salmon and sea trout at Frisenvold fish wear are available, but the distinction between the two species were previously very imperfect. Before the year 1899 the fish recorded as salmon, were only large maturing silvery salmon, that is, winter salmon[3]), together with a small number of large summer salmon which mainly ascend the river in the months May and June. As »sea trout« was recorded the real sea trout, as well as salmon in the spawning dress. Table 3 contains a record of the yield of the large

[1]) H. HENKING: Die Lachsfrage im Ostseegebiet. Rapports et Procès-Verbaux des Reunions. Vol. XVI. Cons. perm. internat. Copenhague 1913.

Prof. Henking calls attention to the fact that contemporaneous fluctuations in the yield of the salmon and sea trout fisheries have been observed in great parts of the Baltic waters.

[2]) A. C. JOHANSEN & J. CHR. LØFTING: Om Fiskebestanden og Fiskeriet i Gudenaaens nedre Løb og Randers Fjord. Skrifter udg. af Kommissionen for Havundersøgelser, Nr. 9. København 1919.

[3]) By »winter salmon« we understand: silvery salmon ascending the river in the time from October to the end of April in order to spawn in the following autumn. By summer salmon we mean salmon ascending in the time after May 1st and spawning in the spawning season of the same year.

maturing silvery salmon in the period 1853—1898, and in Table 12 (p. 34) the catch of sea trout together with summer salmon is represented for the months June-August in the period 1880—1898.

When we, in the following, try to account, as far as possible, for the causes of the fluctuations in the yield of the salmon and sea trout fisheries in Gudenaa, we shall take into consideration, firstly the

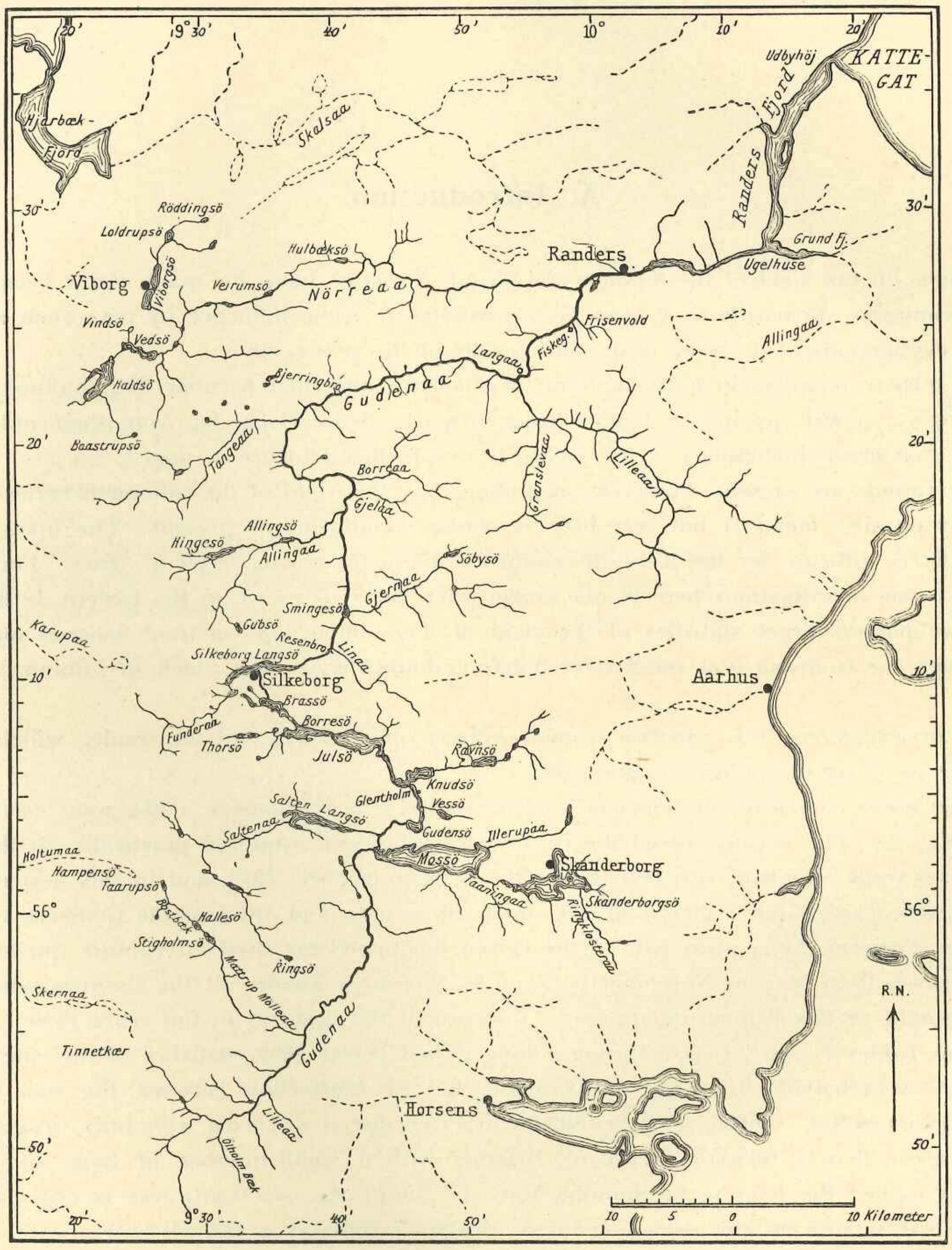

Fig. 1. Gudenaa and its affluents.

Gudenaa has a length of 157 km from its rise in the middle of Jutland to Ugelhuse by Randers Fjord. Its head stream rises ca. 63 metres above the sea. The lower part of the river between Silkeborg and Ugelhuse has a length of ca. 81 km and a fall of 19 m, or $^1/_{4300}$ of the length.

The salmon and sea trout are in the main restricted to the stretch Silkeborg—Randers Fjord. At Silkeborg there is a dam and a fish-ladder which is passed by only very few salmon and sea trout. At Glentholm there is a large eel-trunk which makes an absolute hinderance for a further ascent of the salmon and sea trout to the upper part of the river. In the lakes, which are drained by the Gudenaa, lake trout occur, but there are no fresh water colonies of the salmon. The spawning places for the salmon were situated in the main stream between Resenbro and the outlet of Tangeaa, and probably in the lower part of Tangeaa and Borreaa.

natural amount of fry, secondly the liberated amount of fry and thirdly the temperature. Other circumstances may also have some influence, for instance the amount of food, the number of rapacious fishes, the light, the amount of oxygen in the water, and so on, but such factors can not at present be subjected to an investigation.

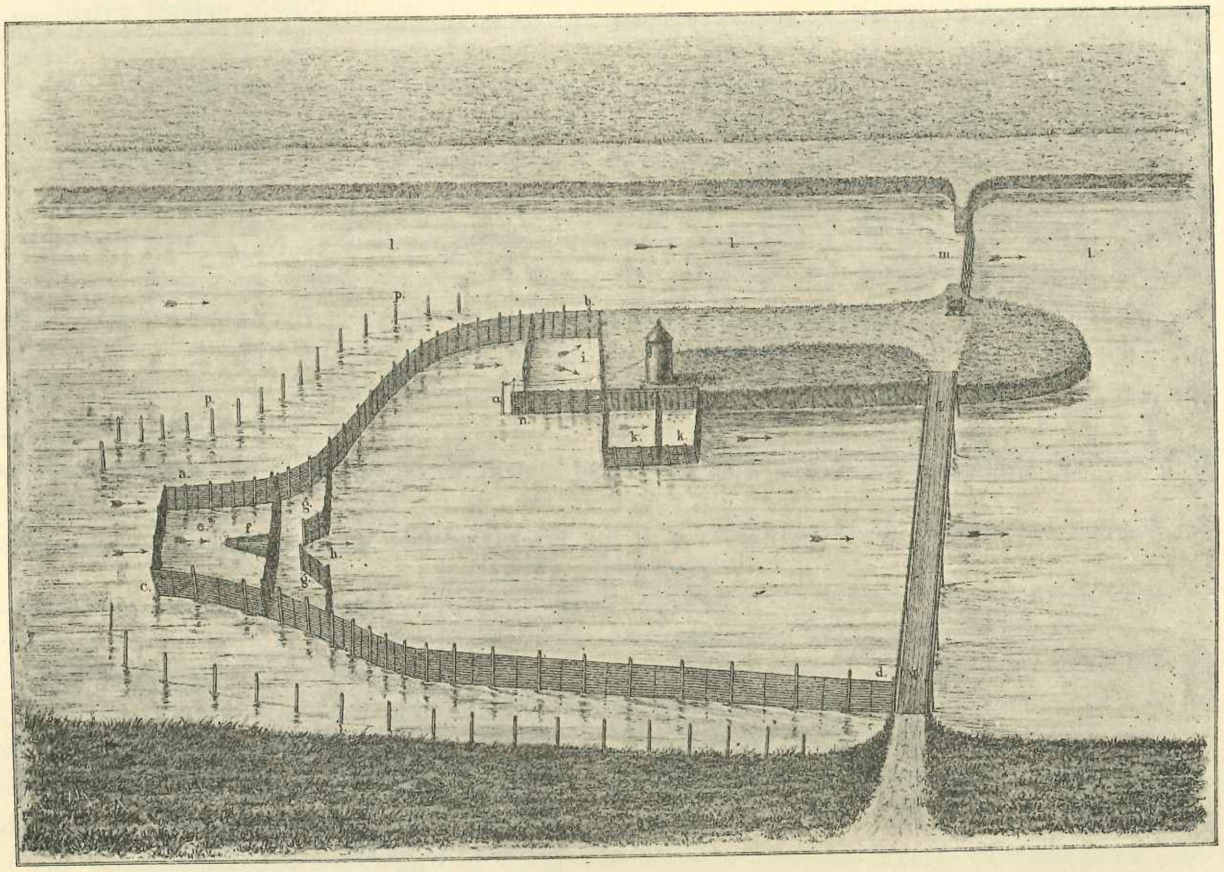

Fig. 2. Frisenvold fish wear. After C. F. Drechsel.

ab and cd. Arms of the fish wear.
e. Head, where many large salmon are caught.
f. Entrance to head.
g. Fore-court.
h. Entrance to Fore-court.
i. Catching court, where some salmon and sea trout are caught. A man in the watch box takes notice when the fish moves over the threshold, and he then shuts the gate of the court.
k. Reservoir for mature salmon from which eggs and sperma are taken for fertilisation.
l. Fairway for prams.
m. Trellised Gate.
n. Gate to the catching court.
p. Pales which protect the fish wear against ice drift.
q. Foot-bridge.

We might, a priori, regard it as probable that the yield of the salmon and sea trout fisheries depends on the amount of food suitable for the fry at the time when the absorption of the yolk sac takes place. The hatching of the fry takes place normally in the month of March, and the absorption of the yolk sac takes place mainly in April. The amount of food is undoubtedly highly dependent in spring on the temperature and probably most abundant when the temperature is highest. It will thus be natural to investigate if the fluctuations in the yield might possibly in some degree be explained by the influence of temperature upon the amount of food in spring and through it on the amount of fry surviving the critical period immediately after the absorption of the yolk sac. An investigation of this kind is possible, as we know the time elapsing between the hatching of the salmon and its ascending from the sea as winter salmon[1]). This time is normally $4^1/_2$—5 years, so that the problem is to undertake a comparison between the temperature in the month of April and the capture of maturing silvery salmon in

[1]) See Johansen and Løfting l. c. 1919. Only very few salmon come to spawn more than once in Gudenaa.

Table 1. Number of Maturing Summer Salmon captured at the Frisenvold Fish Wear in the Various Months of the Period 1899—1913.

	May	June	July	Aug.	Septbr.	Oct.	Novbr.	Decbr.	Total	Time in which the fish wear has been open, so that no capture could take place
1899.	1	17	46	16	2	4	—	—	86	
1900.	15	19	43	25	3	—	—	9	114	
1901.	10	32	73	30	2	—	4	—	151	
1902.	20	29	31	11	5	3	1	—	100	
1903.	11	13	9	11	1	2	—	—	47	
1904.	9	24	39	17	4	—	1	1	95	1.—12. May
1905.	6	11	64	11	4	9	3	—	108	
1906.	11	74	99	21	6	5	5	—	221	
1907.	—	48	35	9	—	—	—	—	92	May
1908.	—	19	33	12	2	—	—	—	66	—
1909.	—	51	60	26	5	4	—	—	146	—
1910.	—	46	180	67	5	10	2	2	312	—
1911.	—	106	94	17	1	3	—	—	221	—
1912.	—	39	43	12	—	2	—	—	96	—
1913.	—	50	56	18	7	1	—	—	132	—

Table 2. Number of Maturing Sea Trout captured at the Frisenvold Fish Wear in the Various Months of the Period 1899—1913.

	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Time in which the fish wear has been open, so that no capture could take place
1899	1	—	33	104	87	96	96	—	—	417	Novbr.—Decbr.
1900	—	1	23	113	106	69	67	9	6	394	until 26. Jan. 1. Febr.—12. March
1901	—	1	24	64	126	54	93	12	1	375	9.—29. Decbr. (part of February)
1902	—	—	13	69	85	72	61	7	—	307	31. Jan.—2. May
1903	—	—	24	38	49	62	35	1	—	209	1. Jan.—27. March
1904	—	1	19	132	105	67	62	14	6	406	c. 1.—23. January c. 9. Febr.—19. March c. 3. April—12. May
1905	—	2	29	79	78	98	97	37	5	425	c. 3. March—9. May
1906	—	3	64	108	71	63	124	48	5	486	Jan.—April
1907	—	—	11	69	100	111	130	12	3	436	—May
1908	—	—	33	119	68	89	83	25	5	422	—
1909	—	—	28	93	53	54	87	3	—	318	—
1910	—	—	90	284	141	86	120	22	6	749	—
1911	—	—	94	186	91	47	162	4	1	585	—
1912	—	—	64	108	210	135	154	7	—	678	—
1913	—	—	65	189	76	117	140	21	2	610	—

the months November-April $4^1/_2$—5 years later. In this connection, however, it must be understood, that the salmon catch $4^1/_2$ – 5 years after the month of April in a certain year cannot, in the material available, be separated from the salmon catch 4—$4^1/_2$ years after the same period; but the catch of salmon, according to the old notion of this term, was in May—October so insignificant in proportion to the catch in November—April, that it will not influence the calculations much, if it is included in the yield from November—April.

The comparison is thus undertaken for the period 1849—1894 with regard to the April temperature and for the period $^1/_5$ 1853—$^{30}/_4$ 1899 with regard to the catch for years running from $^1/_5$ to $^{30}/_4$. During this time no artificially hatched fry of any importance was liberated in the Gudenaa, so we need not consider the effect of this. Corresponding to the values put down in column 2 Table 3 p. 8 for the yield of the periods of capture indicated in column 1, the mean temperature has been put down in column

7 for the month of April in that year (column 6) with which the yield shall be compared. As we have no continuous measurements of temperature in the sea or in Randers Fiord for the greater part of the years in question, we have by this comparison, contrary to what is usually the case in this treatise, been obliged to regard the temperature of the air instead of the temperature of the surface water. We are indebted to the Danish Meteorological Institute for a series of values for the mean temperature in April in Randers for the years 1864–1894, but for the years 1849–1863 we have been obliged to take the mean values for Copenhagen and have corrected these according to the difference between the April temperature in Randers and Copenhagen in the years 1864–1894. The difference was, however, not great, as the April temperature in Randers was only 0°.2 lower than in Copenhagen.

By a direct comparison of the two numerical series in column 2 and in column 7 of Table 3 we obtain the impression, that there is no distinct connection between them, but in order to investigate the question more closely, we shall employ a method, which enables us, to a higher degree than the mere subjective estimation of a direct comparison, to determine if a connection exists between the values for the yield and for the April temperature. This method is what is called the correlation method in a somewhat modified form, and for the sake of the employment of the method later on in this paper, we shall explain here the use of it.

We start from the supposition that we are dealing with two numerical series containing the same number of figures in each for comparison.

Let the two series be:

$$\begin{array}{ll} \text{1st series} & A_1\ A_2\ A_3\ A_4 \ldots\ldots A_n \\ \text{2nd} \quad — & B_1\ B_2\ B_3\ B_4 \ldots\ldots B_n \end{array}$$

If the figures in the two series are connected in such a way that when A of a certain index is great, B of the same index is also great, and vice versa, when A is small B is also small, we say that a positive correlation exists between the quantities, A and B. If we on the other hand have a small A corresponding to a great B and a great A corresponding to a small B the correlation is called negative.

In order to find a quantitative expression for the correlation we calculate first the mean value A_m of the terms A and subtract this mean from all the terms of the series. The quantities: $A_1—A_m$, $A_2—A_m$ . . . and so on, which we obtain in this way, indicate the deviation of the separate values from the normal one. For the sake of shortness we will put $A_1 - A_m = a_1$; $A_2 - A_m = a_2$ and so on. In a similar way we calculate the deviation from the mean for the terms in the series B_1, B_2 etc., and thus we obtain a series b_1, b_2, b_3 etc. The terms in the two series a_1, a_2, a_3 etc. and b_1, b_2, b_3 etc. may now according to the circumstances be positive or negative, as the total sum of the terms in each of the series will be 0.

In the two numerical series for a and b, a positive correlation will as a rule be indicated when the signs for a and b are the same, whereas the signs in a negative correlation are generally different.

If we, in this way, perceive that a correlation exists between the two series, we calculate its quantitative value indicated by r by the formula:

$$r = \frac{\Sigma ab}{\sqrt{\Sigma a^2 \Sigma b^2}}.$$

The numerator of the fraction is the sum of all the products, which can be formed by the corresponding figures a and b. The denominator of the fraction is the square root of a product of the two factors of which one is the sum of the squares of all the terms of the (a) series, the second sum total of all the squares of the (b) series. The denominator of the fraction is always positive, the numerator of the fraction may be positive or negative according to the nature of the correlation. Terms of the (a) series and (b) series with the same signs tend to make it positive, terms of the (a) series and (b)

Table 3. Catch of Salmon in Frisenvold Fish Wear and the Catch Anomaly per cent in the Period 1.—V.—1853 to 30.—IV.—1899, etc.

Period of catch	Catch F No. of specimens	Normal Catch N No. of specimens	Catch anomaly F — N No. of specimens	Catch anomaly per cent $100 \times \frac{F-N}{N}$	Year of temp. observ.	Mean temperature in April	Deviation of the April temperature from the mean value 5.3
From 1.—V.—1853 to 30.—IV.—1854	288	387	— 99	—26	1849	4.7	—0.6
» » » 54 » » » 55	800	369	431	117	50	5.2	—0.1
» » » 55 » » » 56	423	351	72	21	51	6.1	0.8
» » » 56 » » » 57	175	334	—159	—48	52	3.3	—2.0
» » » 57 » » » 58	135	318	—183	—58	53	2.6	—2.7
» » » 58 » » » 59	201	302	—101	—33	54	6.2	0.9
» » » 59 » » » 60	509	287	222	77	55	3.7	—1.6
» » » 60 » » » 61	375	271	104	38	56	6.3	1.0
» » » 61 » » » 62	126	256	—130	—51	57	4.1	—1.2
» » » 62 » » » 63	74	242	—168	—69	58	5.3	0.0
» » » 63 » » » 64	73	228	—155	—68	59	5.1	—0.2
» » » 64 » » » 65	109	215	—106	—49	60	5.1	—0.2
» » » 65 » » » 66	360	205	155	76	61	4.6	—0.7
» » » 66 » » » 67	278	196	82	42	62	5.2	—0.1
» » » 67 » » » 68	71	187	—116	—62	63	6.6	1.3
» » » 68 » » » 69	79	178	— 99	—56	64	5.9	0.6
» » » 69 » » » 70	256	170	86	51	65	6.7	1.4
» » » 70 » » » 71	91	164	— 73	—45	66	6.2	0.9
» » » 71 » » » 72	293	157	136	87	67	4.9	—0.4
» » » 72 » » » 73	235	151	84	56	68	5.9	0.6
» » » 73 » » » 74	83	145	— 62	—43	69	7.6	2.3
» » » 74 » » » 75	74	138	— 64	—46	70	6.5	1.2
» » » 75 » » » 76	118	131	— 13	—10	71	3.8	—1.5
» » » 76 » » » 77	126	125	1	1	72	6.9	1.6
» » » 77 » » » 78	127	120	7	6	73	4.8	—0.5
» » » 78 » » » 79	8	115	—107	—93	74	6.8	1.5
» » » 79 » » » 80	111	110	1	1	75	5.6	0.3
» » » 80 » » » 81	10	105	— 95	—90	76	6.2	0.9
» » » 81 » » » 82	334	102	232	227	77	3.5	—1.8
» » » 82 » » » 83	73	99	— 26	—26	78	7.1	1.8
» » » 83 » » » 84	109	96	13	14	79	3.2	—2.1
» » » 84 » » » 85	130	94	36	38	80	6.4	1.1
» » » 85 » » » 86	149	92	57	62	81	3.1	—2.2
» » » 86 » » » 87	38	90	— 52	—58	82	5.0	—0.3
» » » 87 » » » 88	129	89	40	45	83	5.4	0.1
» » » 88 » » » 89	53	87	— 34	—39	84	5.0	—0.3
» » » 89 » » » 90	140	86	54	63	85	6.5	1.2
» » » 90 » » » 91	74	84	— 10	—12	86	6.3	1.0
» » » 91 » » » 92	43	83	— 40	—48	87	5.2	—0.1
» » » 92 » » » 93	97	82	15	18	88	2.5	—2.8
» » » 93 » » » 94	154	81	73	90	89	5.5	0.2
» » » 94 » » » 95	15	80	— 65	—81	90	5.3	0.0
» » » 95 » » » 96	68	79	— 11	—14	91	4.0	—1.3
» » » 96 » » » 97	33	78	— 45	—58	92	5.0	—0.3
» » » 97 » » » 98	57	77	— 20	—26	93	6.7	1.4
» » » 98 » » » 99	138	77	61	79	94	7.7	2.4
					mean . . .	5.33	0.03

series with different signs tend to make it negative. If the signs for connected (a) and (b) values are alternately alike and different, the numerator of the fraction will have a small casually positive or negative value to mark that no correlation exists between the two series. Should the signs for connected values of a and b on the other hand be the same, and the values proportional ($a = + kb$ or $a = - kb$) the correlation between the series has the greatest possible numerical value, namely 1.

By the calculation of the correlation between two series we thus obtain a figure between + 1 and — 1. In order to determinate, whether we ought to attribute any importance to the obtained value r for the correlations we compare it with its standard deviation σ_r which is calculated by the formula:

$$\sigma_r = \frac{1 - r^2}{\sqrt{N}}$$

where N means the number of all the terms in the (a) series or (b) series. The standard deviation σ_r is an expression for the uncertainty in the calculated value of r, and the formula shows that the standard deviation σ_r becomes the lesser the greater the correlation is and the lesser the greater the number of terms on which its calculation is based.

If any importance is to be attached to the calculated correlation we must demand, that it should be considerably greater than the corresponding standard deviation. Generally we require the correlation r to be 2 à 3 times greater than the standard deviation σ, thus:

$$\frac{r}{\sigma_r} > 2.$$

If the fraction $\frac{r}{\sigma_r}$ is less than 2 we shall generally not attach any importance to the correlation found. We shall however do so, if an examination of the same phenomenon during analogous conditions in a series of cases gives us a correlation of the same kind, positive or negative, be it even in some cases only of the size of the standard deviation.

The method of treatment stated here can, however, not be used directly for the yearly values of the yield of the salmon capture in Gudenaa. The difference between the catch in a certain year and the mean catch for a series of years cannot be regarded as the deviation from the normal yield for the year in question. On account of the systematic decrease in the yield of the fishery, we would obtain essentially positive deviations from the mean figures in the first half of the series 1853—1898, and essentially negative deviations in the last half of the series. Instead of the deviations from the mean catch we will therefore reckon with deviations from a »normal« yield of the fishery, which is different for the different periods, and which is obtained by a graphical smoothing for equalization of the values of the yield for the different years, which are marked on Fig. 3 p. 13. This smoothed curve is represented on Fig. 3, and the values obtained in this way for the yearly normal yield N are put down in the 3rd column of Table 3. In column 2 Table 3 are stated the directly observed values for the capture F, and in the 4th column the difference F—N between the yearly yield and the normal yield. The smoothed curve is drawn in such a way that the total of the differences is about 0, and we might now consider using these differences for the calculation of the correlation between the yield in one year and the temperature of April in question. Owing to the systematical variation in the yield in the course of the years, which is expressed by the smoothed curve on Fig. 3, it must however be considered more rational not to use these differences but the fractions which they form of the corresponding normal captures, as we obtain in this way a series of figures whose deviation values from the zero can only be due to the causes, which we want to trace or to »casual causes« which we cannot account for, and as we have reason to expect a systematical variation in these deviations they have thus the same properties as observations whose deviations from the mean values may be regarded as casual. For use in the calculation we have accordingly in Table 3, column 5, put down the per cent which the difference between the real yield and the normal catch forms of the normal catch. We shall here and in the following call this fraction the catch anomaly per cent.

In the drawing of the curve representing the normal yield, we have taken care that the total of the values put down in Table 3 for the catch anomaly per cent should be 0. By the calculation of the mean of the values put down in column 7 for the April temperature it appears that this, given to two decimals, becomes 5.33. If we approximate it to 5.3, and if we give the difference between the separate April temperatures and this mean value, as it is done in column 8, the total of these differences will not be 0 but 1.5. Nevertheless we can use the figures put down in column 8 for the calculation of the correlation factor when we transform the formula for r, and as we in this way avoid the calculation of the deviations from the means with such great exactness as we might, otherwise, be frequently obliged to do, the method will here be explained.

We suppose the means of the two numerical series for a and b not to be 0, but respectively a_m and b_m. The expression for r will thus be:

$$r = \frac{\Sigma (a - a_m) \cdot (b - b_m)}{\sqrt{\Sigma (a - a_m)^2 \cdot \Sigma (b - b_m)^2}}$$

which by simple transformation may be put down as:

$$r = \frac{\Sigma ab - \frac{\Sigma a \cdot \Sigma b}{N}}{\sqrt{\left(\Sigma a^2 - \frac{(\Sigma a)^2}{N}\right)\left(\Sigma b^2 - \frac{(\Sigma b)^2}{N}\right)}}$$

where Σ a and Σ b signify the sums respectively of the (a) series and of the (b) series, and N the number of the pair of values.

It will be seen that we can calculate r by means of the last formula, when we know Σa^2, Σb^2, Σa, Σb and N independent of the value we have chosen as starting point, by calculating the difference between the original values for A or B and the approximate values for their mean values a_m and b_m. Generally we shall however chose the approximate values for the mean figures of the original series as close as possible to the actual mean figures as this affords the easiest calculations.

It will be seen that the value for r remains the same, whatever unity we chose for a and b. We can e. g. in the case mentioned for the catch anomaly per cent conveniently use 10 % as a unity and round the figures accordingly. For the April temperature we may take $^1/_{10}{}^0$ as a unit and we shall thus obtain for comparison the numerical values put down in the first two columns in the survey below (Table 4). In the columns 3, 4 and 5 of the survey will be found the figures necessary for the calculation of the expressions Σa^2, Σb^2 and Σab; and below in the survey will be found the calculated numerical values for the sums which are to be used for direct insertion in the formula. In the present case N is equal to 46.

$$r = \frac{-578}{\sqrt{1950 \cdot (7593 - \frac{225}{46})}}$$

which gives $$r = -0.150.$$

By means of the formula $\sigma_r = \frac{1 - r^2}{\sqrt{N}}$ for the standard deviation of the correlation coefficient we get

$$\sigma_r = \frac{0.9775}{\sqrt{46}} = 0.144.$$

For the ratio $\frac{r}{\sigma_r}$ we thus find

$$\frac{r}{\sigma_r} = -1.04.$$

That the correlation coefficient is negative would thus suggest the yield of the catch to be relatively great when the April temperature considered was relatively low and vice versa, but as the correlation coefficient is of the same magnitude numerically as its standard deviation we cannot attribute any importance to it, and the result of the investigation carried out will thus be, that no connection

Table 4. Calculation of the Correlation between the Catch Anomalies for Salmon and the Temperature Anomalies of the Month of April $4^1/_2$—5 Years before the Catch.

Catch anomaly per cent a Unity 10 %	Anomaly for April temperature b Unity $^1/_{10}{}^0$	a²	b²	ab
—3	— 6	9	36	18
12	— 1	144	1	— 12
2	8	4	64	16
—5	—20	25	400	100
—6	—27	36	729	162
—3	9	9	81	— 27
8	—16	64	256	—128
4	10	16	100	40
—5	—12	25	144	60
—7	0	49	0	0
—7	— 2	49	4	14
—5	— 2	25	4	10
8	— 7	64	49	— 56
4	— 1	16	1	— 4
—6	13	36	169	— 78
—6	6	36	36	— 36
5	14	25	196	70
—4	9	16	81	— 36
9	— 4	81	16	— 36
6	6	36	36	36
—4	23	16	529	92
—5	12	25	144	— 60
—1	—15	1	225	15
0	16	0	256	0
1	— 5	1	25	— 5
—9	15	81	225	—135
0	3	0	9	0
—9	9	81	81	— 81
23	—18	529	324	—414
—3	18	9	324	— 54
1	—21	1	441	— 21
4	11	16	121	44
6	—22	36	484	—132
—6	— 3	36	9	18
4	1	16	1	4
—4	— 3	16	9	12
6	12	36	144	72
—1	10	1	100	— 10
—5	— 1	25	1	5
2	—28	4	784	— 56
9	2	81	4	18
—8	0	64	0	0
—1	—13	1	169	13
—6	— 3	36	9	18
—3	14	9	196	— 42
8	24	64	576	192
Sum $\Sigma a = 0$	$\Sigma b = +15$	$\Sigma a^2 = 1950$	$\Sigma b^2 = 7593$	$\Sigma ab = -578$

$$r = \frac{\Sigma ab - \frac{\Sigma a \cdot \Sigma b}{N}}{\sqrt{\left(\Sigma a^2 - \frac{(\Sigma a)^2}{N}\right)\left(\Sigma b^2 - \frac{(\Sigma b)^2}{N}\right)}} = \frac{-578}{\sqrt{1950 \cdot \left(7593 - \frac{225}{46}\right)}} = -0{,}150.$$

exists between the April temperature in the year of hatching and the catch of winter salmon $4^1/_2$—5 years later.

We shall now restrict our investigation about the causes of the fluctuations in the catch to the varying amount of fry, and the influence of the temperature upon the time when the salmon are ascending the river.

B. Fluctuations in the Catch of Salmon in the Gudenaa caused by Variations in the Natural Amount of Fry.

If we consider Fig. 3 showing the catch of large silvery salmon (thus mainly winter salmon) at Frisenvold fish wear in the years 1853 to 1898, it will be seen that the curve shows certain maxima and minima, occurring with regular intervals. This phenomenon is specially conspicuous in the period 1853—1868. Between the culminating points there is an interval of 5—6 years. These maxima and minima find their natural explanation in the following way: The life cyclus of the winter salmon is as a rule 6 years, more rarely 5 years[1]). It is supposed that in the years when the yield is large a more abundant amount of fry is hatched than normally, as probably more salmon, on an average, escape the fish wear (in the case of floods etc.) in the years when the run is great than in the years where the run is less, and when proportionately many salmon come to spawn, more fry are developed on an average than usually. The maximum of the curve will in this way repeat itself with an interval of 5—6 years for the winter salmon.

Although it appears rather plainly by a mere consideration of the curve Fig. 3 that there really is a connection between the catch in one year and the catch 5—6 years later, it may be of interest to investigate this connection more closely, and we will, for this purpose, use the method of correlation mentioned before.

As a basis for the calculations we use the values put down in Table 3 (p. 8) for the catch anomaly per cent.

For the sake of brevity we shall indicate these yearly periods by the calendar years, the period will thus be indicated by the calendar year in which for the greater part it is contained.

We will thus compare the anomalies per cent for 1853, 1854 .... 1897 with the anomalies per cent for 1854, 1855 .... 1898. In this way we get an investigation of the connection existing between one year and the following year. In a similar way we shall investigate the connection between the yield in one year and that in the second, third, fourth, fifth, sixth and seventh following year. We shall then at any rate expect that a connection will appear between the yield in one year and the yield 5 and 6 years later.

The calculations for the different displacements give the following result:

Displacement: Number of years

	1	2	3	4	5	6	7
r	÷ 0.17	÷ 0.11	÷ 0.25	0.05	0.06	0.32	÷ 0.31
σ_r	0.14	0.15	0.14	0.15	0.16	0.14	0.14
$\frac{r}{\sigma_r}$	− 1.2	− 0.76	− 1.8	0.36	0.37	2.24	÷ 2.15

From this will be seen that a distinct positive correlation seems to exist between the yield in one year and the yield 6 years later. Thus, had the yield in a certain year been proportionately rich,

[1]) The life time of the young salmon in the fresh water lasts as a rule in Gudenaa 2 years (ca. 80 %) more rarely 1 year. The winter salmon spawns almost always $3^1/_2$—4 years after its migration to the sea. ($2^1/_2$—3 years in the sea, 1 year in the river) comp. A. C. Johansen and J. Chr. Løfting l. c. 1919.

normal or low, we must expect a similar yield 6 years later, in the event of the conditions for the spawning and the development of the fry remaining the same.

By a displacement of 7 years, we have on the contrary found a negative correlation, the meaning of which would be accordingly that 7 years after a rich fishing year we should have a year with a lesser yield and vice versa. The rest of the correlation coefficients are rather inconsiderable in proportion to their standard deviation, but as they, when arranged according to the degree of displacement shew a systematic sequence, in their signs, we dare not a priori say that they are of no importance. If we mark out the fraction $\frac{r}{\sigma_r}$ in a co-ordinate system as ordinates and the displacements as abscissae, as shown in Fig. 4, it will be seen that the correlation coefficients seem to vary systematically with the value of the displacement as indicated by the dotted curve. The correlation coefficient is negative for displacement of 1, 2 and 3 years, positive for displacements of 4, 5 and 6 years, and again negative for displacements of 7 years.

If we ask for the cause of this variation of the correlation coefficient, it will thus be seen, that the proportionately high positive value for a displacement of 6 years can hardly be explained in any other way than by supposing that in the rich catch year proportionately many salmon are also spawning, and that the prolific number of eggs will normally produce an abundant quantity of fry, and this again will cause a great stock of fish and a richer catch 6 years later, the case being, as shewn before, that the life cyclus of the winter salmon from the run into fresh water till the run of the offspring into fresh water is, as a rule, 6 years.

It is also to be expected that some connection exists between the catch in a certain year and the catch 5 years later for the following reasons:

Firstly, some of the winter salmon, perhaps ca. 20 %, have only a life cyclus of

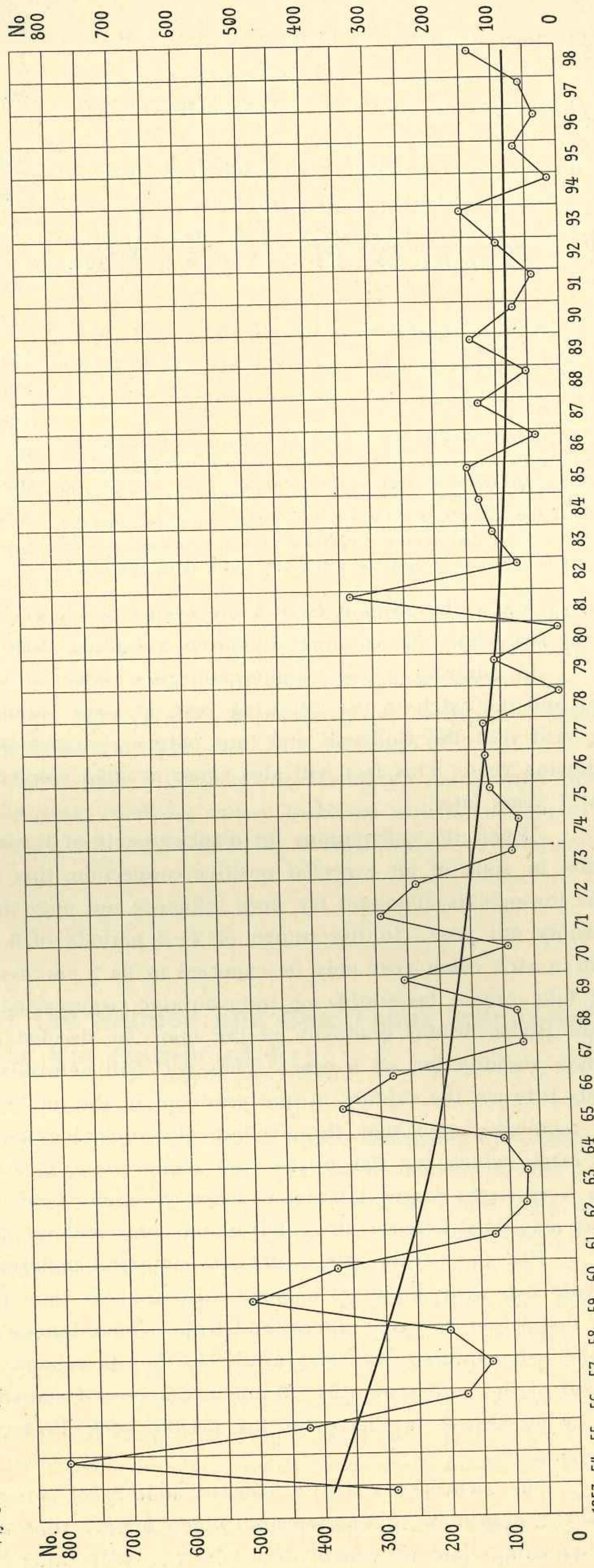

Fig. 3. Catch of winter salmon and large summer salmon at Frisenvold fish wear in the years 1853—1898. The smoothed curve represents the »normal yield«, See p. 9.

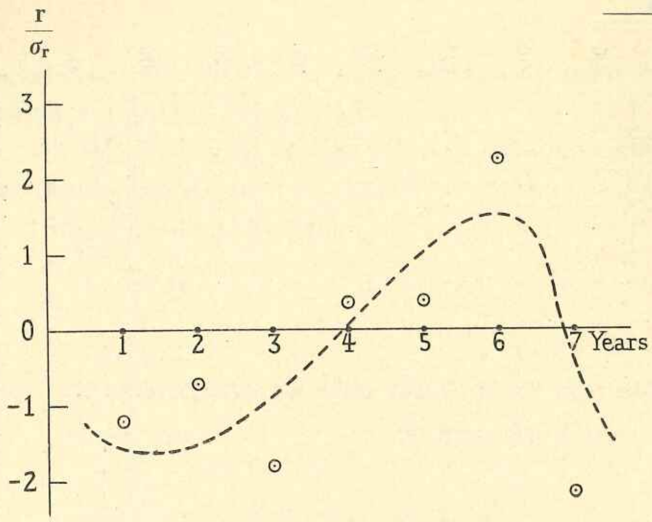

Fig. 4. Graph showing the $\frac{r}{\sigma_r}$ for the connection between the catches of the different years. The value of $\frac{r}{\sigma_r}$ for »1 year« represents the connection between the catch of one year and the following year, the value for »2 years« the connection between the catch of one year and the catch two years later and so on.

5 years as the specimens in question only spend 1 year in fresh water before the migration to the sea takes place.

Secondly, a lesser number of the »salmon« are large summer salmon which are spawning a few months after the running. The offspring of these specimens will mainly go into the Gudenaa 5 years after the period in question, and specimens which only spend 1 year in fresh water will as a rule ascend the river 4 years after the period concerned. There will thus be a certain — though very slight — connection between the catch in a certain year and in the catch 4 years later. This will also reveal itself in the calculations by the fact that the correlation coefficient is positive for 4 and 5 years displacement. A quite insignificant connection must also be supposed to exist between the catch in one certain year and that 7 years later, as quite a few winter salmon have a life cyclus of 7 years, the specimens in question spending $3^1/_2$—4 years in the sea before the running (Johansen & Løfting 1919).

In addition a very slight connection must be supposed to exist between the catch in a certain year and the catch in the following year, as some salmon will escape capture during their first spawning visit into the Gudenaa and thus obtain a chance of a new spawning visit to the Gudenaa in the following year. This fact will also cause a slight connection between the catch in one certain year and that 7 years later.

When the calculations for displacements of 1 and 7 years have given negative correlation coefficients in spite of an expected positive connection, this may be explained by the fact that a rich catch year through its abundant fry does influence not only the following 6th, but also the following 5th and possibly 4th year. In the course of 2—3 periods of 6 years the effects of the abundant fry connected with a rich catch year may be expected to be 3 successive years with rich catch. If we, moreover, do not take casual favourable or unfavourable circumstances into consideration, we might expect that a 6 years period would gradually in the main be divided into a rich and a poor part, to reach at last a certain stability for all 6 years. Thus we shall naturally expect that a considerable negative correlation exists between the capture in one year and in the following third year, as the figures p. 12 shew. When we remember also that the levelling of the catch previously explained takes place in such a way that the catch which for the greater part should come in a certain year, may partly come earlier, but only to a very slight degree later, it will also be understood, that a negative correlation, as shown by the figures may exist between the catch in one year and the catch 7 years later.

For the period 1899—1914 the statistical material available concerning the salmon catch at Frisenvold fish wear allows of a much finer analysis than for the period 1853—1898. In the first instance a true distinction between salmon and trout is maintained after 1898, and secondly, the total length of each of the fish captured was measured. On the other hand the fish wear was not kept closed for catch in certain of the winter months. While we possessed statistics comprising essentially the winter salmon for the earlier period, we have for the period 1899—1914 complete statistics concerning the catch of summer salmon.

The summer salmon consists mainly of two groups: Group A, which spawn ca. 18 months after the migration to the sea and which mainly runs in the months July and August, and Group B, the spawning time of which occurs ca. $2^1/_2$ years after the migration to the sea, and whose main run —

takes place in June and July. To this must be added a few summer salmon of Group C, which have passed 3 years in the sea and which spawn ca. $3^1/_2$ years after the emigration.

The majority of the salmon of all these three groups spend two years in fresh water as young salmon.

We have now as shewn on Table 6 page 28 been able to distinguish between salmon of Group A and salmon of Group B. It has been possible to carry out this distinction approximately by means of a consideration of the size of the specimens and by an investigation of the scales of a smaller number of specimens[1]). The few specimens of Group C could, on the contrary, not be separated from Group B in the material at our disposal.

It will be seen from what has been set forth here, that from the fry in a certain year will partly originate A-salmon three years later, partly B-salmon four years later, and now it just appears that an obvious connection exists between the number of A-salmon in a certain year and the number of B-salmon in the following year.

If we investigate for the months June, July and August the correlation between the catch anomalies for A-salmon in one year and the catch anomalies of B-salmon in the following year in the period 1899—1913 we obtain the following values:

$$r = 0.783;\ \sigma_r = 0.103;\ \frac{r}{\sigma_r} = 7.6.$$

This result points plainly in the direction that the fluctuations in the yield depend essentially upon the amount of fry. It does not shew, however, how far it is the fry naturally developed or the fry artificially hatched which has been more fruitful in the period 1899—1914. As will be seen from the following chapter, it is to be supposed that the majority of the captured summer salmon in this period originate from the artificially hatched fry.

The calculation stated above shews that we, with a considerable certainty, can predict that if relatively many A-salmon are caught in a certain year, relatively many B-salmon will be caught in the following year, and that a small catch of A-salmon will be followed by a small catch of B-salmon in the following year.

C. Fluctuations in the Catch of the Salmon and Sea Trout influenced by Variations in the Output of Fry.

With regard to the summer salmon it will be seen from Fig. 5 which represents the number of the salmon caught in June, July and August in the period 1899—1913, that a few distinct maxima occur, separated by a period of 4 to 5 years. These maxima can hardly be explained as being quite analogous with the maxima before mentioned for the winter salmon, though the normal life cyclus of the summer salmon is for the males as a rule 4 or 5 years and for the females as a rule 5 years. Almost all summer salmon ascending the Gudenaa to spawn, which are not caught already in Randers Fiord, will be captured in the fish wear at Frisenvold. There is no reason to suppose, that many more summer salmon escape the fish wear in the years where the running is greatest than in the other years. Frisenvold fish wear has been used for capture all through summer in all the years from 1899—1913, and large floods are rare in summer. There will thus be reason to investigate if the two distinct maxima in the catch in 1906 and in 1910 may not be due to other causes than variations in the amount of the salmon fry developed in Gudenaa (Fig. 5).

[1]) A. C. Johansen & J. Chr. Løfting: »Über den Gudenaa-Laks« in H. Henking: Die Lachsfrage im Ostseegebiet II. Rapports et Procès-Verbaux Cons. perm. Internat. Vol. XXIII 1916.

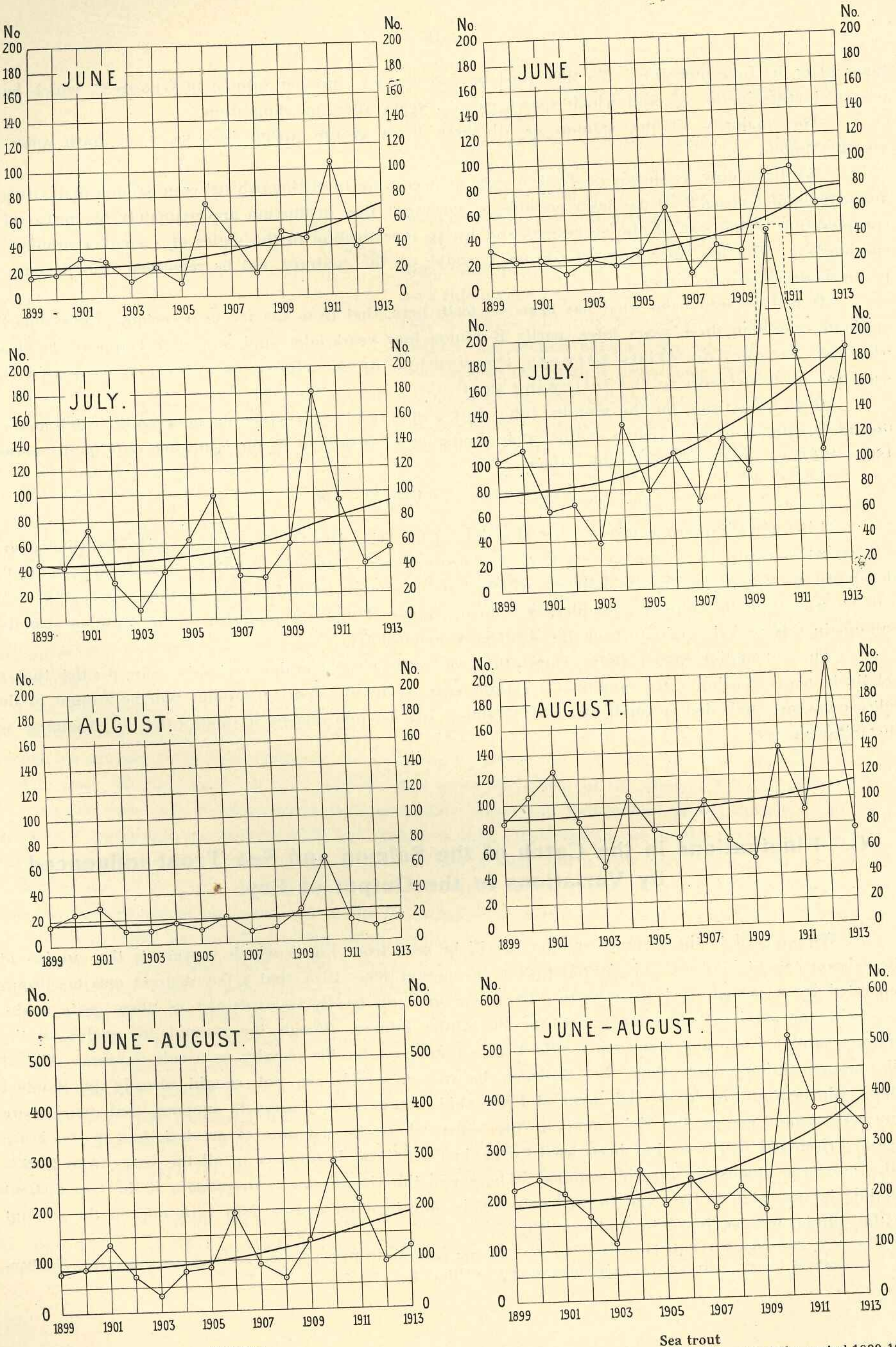

Fig. 5. Number of maturing salmon and sea trout caught at Frisenvold fish wear in June-August in each year of the period 1899-1913.

Table 5. The Output of Fry of Salmon in the Gudenaa and its Affluents and the Catch of A-Salmon and B-Salmon 3 and 4 Years later.

Year for output	Amount of output		Catch of salmon of A-Group 3 years after output	Catch of salmon of B-Group 4 years after output	Sum of the forenamed catch of A-salmon and B-salmon
	Tiny fry thousands	Half-year fish thousands			
	I	II	III	IV	V
1900	0	0	17	49	66
1901	40	3.8	46	21	67
1902	32	4.5	87	*86*	173
1903	*130*	5.0	*135*	*80*	*215*
1904	40	22.0	12	34	46
1905	0	4.2	32	76	108
1906	40	14.0	70	114	184
1907	*152*	*41.0*	*198*	*191*	*389*
1908	20	14.0	30	58	88
1909	30	15.0	38	104	142
1910	20	21.0	28	4*)	32*)
1911	48	19.2	7*)		
1912	0	49.4			
1913	0	28.0			
1914	0	40.0			

*) On account of the high summer temperature in 1914 the fish wear was not used for catch during the whole summer.

We shall now investigate if the maxima in question in 1906 and in 1910—11 can be explained by the fact that proportionately much artificially hatched fry was liberated in Gudenaa or in its affluents in certain years before 1906 and 1910—11.

As will be seen from Table 5 the output comprises especially large amounts of young fry in 1903 and in 1907, and especially large amounts of 6 months fry in 1907 and in the years 1912—14. Should the output of artificially hatched fry shew any effect at all, it would, in the main, be traced 3 years later for Group A and 4 years later for Group B. In order to obtain a total expression for the effect of an output of fry it will thus be natural to regard the two effects upon A-salmon 3 years after and upon B-salmon 4 years after the output.

By means of this proceeding we avoid in the main the disturbing influence of the phenomenon (which will be mentioned in a later chapter) that a high summer temperature will further the maturity of the salmon and will thus produce a relatively great running of A-salmon, while a low summer temperature will have the opposite effect.

It will be seen from Fig. 6 p. 18 that there is a distinct agreement between the curves showing the number of liberated young fry and the curve representing the catch of A-salmon 3 years later plus the catch of B-salmon 4 years later. It is worthy of especial note that the great output of young fry in 1903 was followed by a maximum in the catch of A-salmon in 1906 and B-salmon in 1907. In the year 1902 the salmon catch was less than normal, and there is thus nothing to suggest that specially large amounts of naturally hatched fry should have occurred in the spring of 1903. The liberation of 6 months fry was also inconsiderable in 1903. The great output of tiny fry in 1907 was also followed by a maximum in the catch of A-salmon three years later and B-salmon four years later. The two distinct maxima in the catch of A-salmon in 1906 + B-salmon in 1907 and of A-salmon 1910 + B-salmon in 1911 can thus naturally be explained by the fact that proportionately large amounts of young salmon fry were liberated in 1903 and in 1907. Less conspicuous on the other hand is the accordance between the number of liberated 6 months' fry and the catch of A-salmon 3 years later + the catch of B-salmon 4 years later. It is true that the great

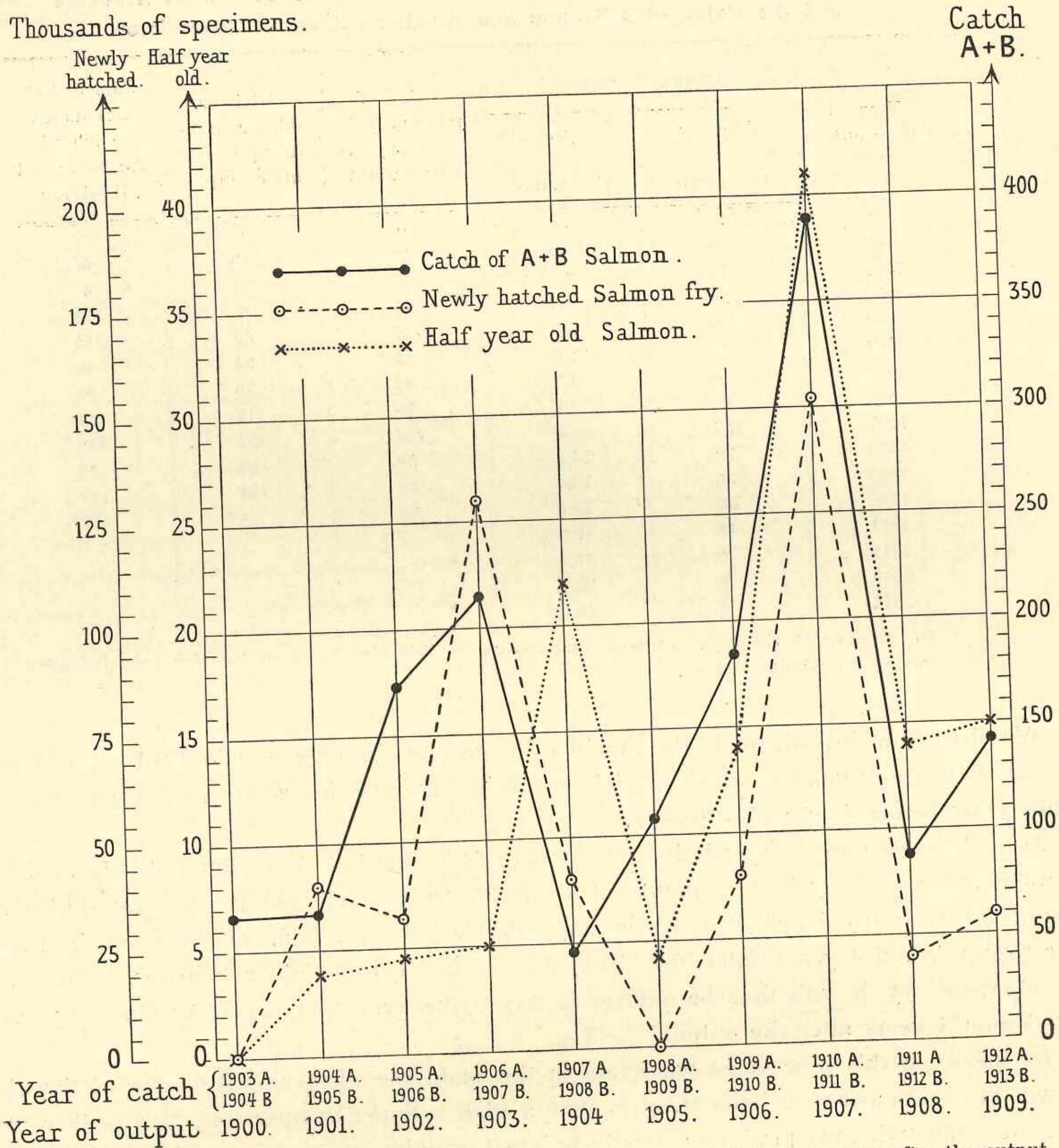

Fig. 6. Comparison between output and catch of A-Salmon 3 years and B-Salmon 4 years after the output.

output of 6 months' fry in 1907 was followed by a maximum in the catch of A-salmon in 1910 + B-salmon in 1911, but we find on the other hand that the great liberation of 6 months' fry in 1904 was followed by a minimum in the catch of A-salmon in 1907 + B-salmon in 1908. It is therefore without doubt that the curve illustrating the liberation of the young fry is much more in agreement with the curve showing the catch of A- and B-salmon 3 and 4 years later than the curve illustrating the 6 months' fry.

The correlations between the amount of fry liberated in the years 1900—1909 and the catch of A-salmon 3 years later plus the catch of B-salmon 4 years later have the following values:

Tiny fry correlated with catch of A-salmon + B-salmon.

$$r = 0.83$$

$$\sigma_r = 0.10$$

$$\frac{r}{\sigma_r} = 8.3$$

6 months fry correlated with catch of A-salmon + B-salmon.

$$r = 0.64$$

$$\sigma_r = 0.18$$

$$\frac{r}{\sigma_r} = 3.5$$[1]

As we have liberated, on an average, about 4 times as many specimens of tiny fry as of 6 months old fry in the period 1901—09 (see Table 5), and as 1000 specimens of 6 months' fry would cost ca. 15 times as much as 1000 specimens of tiny fry, it appears that the liberation of tiny fry is more advantageous than that of 6 months old fry.

For the sake of making clear to what degree the liberation of tiny fry and of 6 month's old fry does influence the catch we have submitted the present material (Tables 5 and 6) to a closer investigation.

If we assume, that from a certain amount of fry Q, a fraction p will be caught 3 years later as A-salmon and another fraction q 4 years later as B-salmon, the total number of specimens captured, F, originating from the amount of fry considered, will be $F = (p + q) Q$. If we take for granted that the fractions p and q will practically be the same for the whole series of years, we will thus obtain the result that the considered total catch F of the specimens of the A and B groups on the whole must be proportional to the amount of fry Q. Casual factors may naturally cause that p and q can only with approximation be considered to be the same for different years, and this will be shewn in the fact that a calculation worked out on this basis will show a considerable standard deviation for the coefficient $p + q$. One of the circumstances which has the effect of causing p and q to differ from one year to another, is that a high temperature in the spring months produces a displacement of specimens from the B-group to the A-group (which will be mentioned later on) as some of the specimens which should run normally as salmon belonging to the B-group, by reason of a high temperature, shorten their stay in the sea and run as salmon of the A-group, and vice versa, a low temperature, has the effect that some of the salmon which should run normally as specimens of the A-group, remain a year longer in the sea and run as specimens of the B-group. In this case we have thus a displacement of a certain number of specimens from the amount q Q of B-salmon captured in one year to the amount p Q of A-salmon captured in the preceding year, or vice versa, but this will not influence the considered total $pQ + qQ$, if we may take it for granted, that the number of the specimens, passing over from one group to another, will not be changed essentially in such a way that a greater part of the B-salmon is destroyed in the course of a year's stay in the sea. It is at any rate to be presumed that we possess the best expression that can be obtained in the total of the captured A-salmon in a certain year plus B-salmon in the following year for the number of the specimens which originate from the fry which has been present three years before the catch of the A-salmon and 4 years before the catch of B-salmon.

In order to obtain the best possible expression of the way in which the total catch depends upon the output partly of the tiny fry, and partly of 6 months' old fish, we have put down the catch total F as a function of the output of tiny fry (m) and 6 months old fish (M) and a constant C, indicating the catch which would have occurred, if no artificially hatched fry had been liberated. Thus we have:

$$F = x \cdot m + y \cdot M + C.$$

F and C express the number of specimens, m and M are given in thousands.

If the calculation is carried out according to the method of the least squares we find from the figures stated in Table 5:

[1] The material for calculating the correlation is, however, not quite satisfactory, a. o. because of the fact that there is a certain correlation between the amount of the tiny fry liberated and the amount of the 6 months old fry ($r = 0.60$; $\sigma_r = 0.20$ $\frac{r}{\sigma_r} = 3.0$) and because the period in which the connection between output and catch has been investigated is rather short.

x = 1.4; standard deviation of x equal to 0.5
y = 1.9; — — » y — 2.0
C = 58; — — » C — 30

This means that 10000 specimens of tiny fry have the effect of adding 14 specimens of running summer salmon to the catch in Frisenvold fish wear, while 10000 specimens of 6 months fish are adding 19 specimens to the catch. Independent of the fry liberated we should on an average have caught 58 specimens yearly. The standard deviation for x, y and C shew that these values certainly suffer from a considerable uncertainty, but that they nevertheless, especially for the tiny fry, give a good expression for the dependance of the catch on the amount of fry liberated. The constant number, 58, for the catch appears also to be a probable value, being not very different from the number, which is calculated as a mean value for the catch total in the 5 years before the liberation of fry began, and it does not differ so much from this as the standard deviation of C, namely 30.

If we subtract from the catch total observed, the number of specimens which, according to the calculation, are due to the fry liberated, we obtain the following figures:

Year for liberation of fry	Year for catch	The catch total minus what is due to liberation of fry
1900	1903 A-Salmon + 1904 B-Salmon	66
1901	1904 — + 1905 —	5
1902	1905 — + 1906 —	121
1903	1906 — + 1907 —	28
1904	1907 — + 1908 —	— 51
1905	1908 — + 1909 —	100
1906	1909 — + 1910 —	103
1907	1910 — + 1911 —	102
1908	1911 — + 1912 —	34
1909	1912 — + 1913 —	72

These figures deviate considerably from the calculated mean value, 58, but hardly more than it was to be expected from the magnitude of the obtained standard deviation: 30.

The calculation, which we have here undertaken, thus affirms the result we arrived at by a comparison between the curves indicating the number of fry liberated and the curve indicating the sum of the catch of A-salmon and of B-salmon 3 and 4 years respectively after liberation.

We have seen now, that 1000 specimens of 6 months' fish will probably not be of a much higher value for liberation than 1000 specimens of tiny fry. There will at any rate be only a very slight probability that 1000 specimens of 6 months' fish, would be worth as much for liberation as 4000 specimens of tiny fry. As the artificially bred 6 months salmon have cost on an average 15 times as much per 1000 of specimens as the tiny fry this result is of great economical importance.

We have hitherto not possessed any real evidence to shew whether the output of 6 months fry or the output of tiny fry was the more profitable. In Denmark there has been a tendency in the course of time to attribute more importance to the output of 6 months fish than to the output of tiny fry. Now we ought to change this proceeding. The investigation which has been undertaken demonstrates clearly that output of artificially bred young salmon ought to give place to output of tiny fry.

It might seem a modest result that the liberation of 10000 specimens of tiny fry will produce an increase in the catch at Frisenvold of 14 summer salmon, but it is in reality a most favourable result. The value of 10000 specimens of tiny fry may be estimated at 60 Kr. (30 Kr. before the war). The weight of 14 summer salmon is ca. 56 kg, and the value is ca. 4 Kr. pr. kg, thus a total of 224 Kr. (before the war 1 to 2 Kr. pr. kg.) To this may be added that many of the running summer salmon were captured in Randers Fiord or in the lower part of Gudenaa, before they reached Frisenvold fish wear, and moreover several salmon probably belonging to the Gudenaa stock were caught at the eastern coasts of Jutland before entering the river Gudenaa.

Finally there is a possibility that winter salmon may be developed partly from the liberated fry which originate from summer salmon, but with regard to this we know nothing at present.

It has certainly been a most profitable undertaking to liberate tiny salmon fry in Gudenaa and the tributaries of the same.

The 6 months' salmon, which were used for liberation in Gudenaa and its affluents, originate mainly from ponds, where they were fed and in this way probably spoiled. Young fish originating from ponds, where they have to provide for their food themselves, are probably more valuable for output in open waters. By the experiments in Gudenaa the tiny salmon fry has proved itself to be valuable fish fry, but still we have no experimental series, scientifically carried out to illustrate the value for liberation of the young fish of salmon or sea trout from »natural ponds« in comparison to the tiny fry.

In the years 1912—1914 no tiny salmon fry was liberated, but on the contrary 6 months fish in a rather considerable number, on an average ca. 39.000 specimens per year. (Table 5 p. 17). As Frisenvold fish wear was laid down in 1915, we cannot from this place provide information concerning the effect of this liberation, but from other sources we can, however, judge that the effect has not been considerable and certainly not greater than the calculated value. When Frisenvold fish wear was laid down it was passed by the running summer salmon, but most specimens were now captured higher up in the river on the stretch between Langaa and Silkeborg (Fig. 1). After the laying down of Frisenvold fish wear the catch of summer salmon increased on this stretch, but not more so than that the total catch of salmon on the stretch in question in the years 1915—1918 came to ca. 160 specimens yearly, according to information from the local fishery official. About half of these fish were summer salmon. As almost all mature salmon are captured in Gudenaa before, during, or after the spawning, we dare conclude that not more than 80 summer salmon annually originating from the 39000 6-months fish have passed by Frisenvold fish wear. The 39000 specimens of 6 months fish should according to the calculations mentioned above have added 74 specimens to the catch annually. It is on the other hand quite possible, that the effect has been considerably less, as several summer salmon do undoubtedly originate from the natural stock of spawning salmon.

With regard to the sea trout the material at hand does not enable us to undertake a similar distinction between the A-group and the B-group as in the case of the salmon. To this comes that the C-group together with specimens that have spawned previously play a far greater rôle with regard to the sea trout than for the summer salmon. These circumstances cause that we cannot carry through an investigation of this kind concerning the effect of the output of tiny fry and of the 6 months fry for the sea trout as for the salmon. But when we consider the great similarity in the biology of the salmon and the sea trout, we shall not hesitate to use the result gained concerning the output of salmon fry for the output of sea trout fry. — Many circumstances do plainly suggest, that the liberation of the artificially hatched sea trout fry in the different stages has strongly influenced the amount of the catch. An exceptionally large output of fry in 1906 was thus followed by an exceptionally large catch in 1910, and after a similar considerable liberation in 1909 followed a catch in 1912 and 1913 which was larger than normal (Fig. 5 p. 16).

D. Fluctuations in the Catch of Salmon and Sea Trout caused by Temperature.

1. Influence of Summer Temperature upon the Running.

We shall now proceed to investigate, if the summer temperature has any influence with regard to the observed fluctuations in the catch of the salmon and the sea trout at Frisenvold fish wear. We begin by considering the catch in the period 1899—1913 for which perfectly reliable statistics are at hand for the summer salmon and for the sea trout, offering a true distinction between the two species (See Tables 1 and 2 p. 6). What we want to compare are the deviations from the normal summer temperature and the catch anomaly per cent per salmon and sea trout (see p. 9).

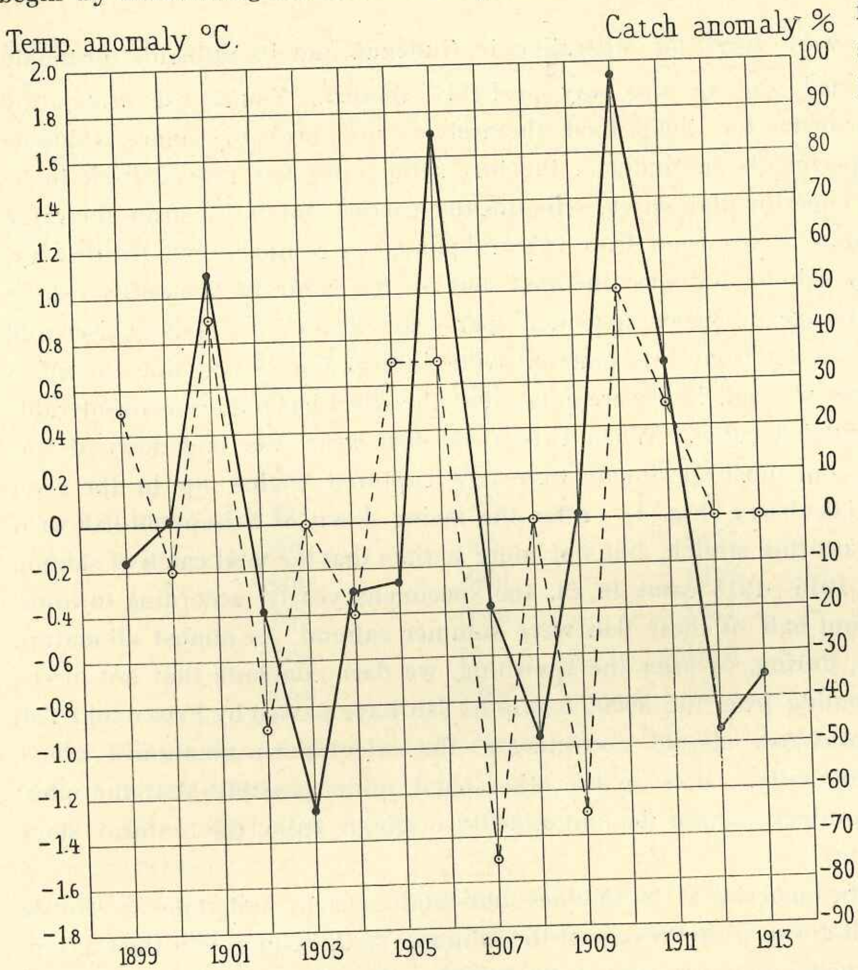

Fig. 7. Temperature anomalies for May to July (broken line) compared with the catch anomaly per cent for salmon in June to August. (See Table 7 and 8).

To express the summer temperature in the living places of the running summer salmon and sea trout we shall take the mean temperature of the surface water by the light vessels »Læsö Rende« and »Schultz' Grund«. On Table 7 p. 32 the temperature and temperature anomalies are put down for the months May—September of the period 1899—1913. Table 8 p. 32 shews the catch and the catch anomalies for salmon in the months June, July, August of the period in question, and Table 9 p. 33 contains a similar survey with regard to the sea trout. The tables are represented graphically in the Fig. 5 where the curve representing the normal catch will also be found inserted.

Finally Table 10 p. 33 contains the calculated correlation between the temperature anomalies and the catch anomalies. The temperature in a certain period is here compared with the catch in a certain period. If we consider at first the correlation coefficients obtained for the salmon, it will be seen that they are all positive and especially great when the temperature in May is compared with the catch in June and in July, and when the temperature in June is compared with the catch in July. In a few of these cases the correlation coefficient is more than three times as great as the standard deviation. If we finally compare the temperature for May-July with the catch for June-August we obtain the correlation coefficient $r = 0.509$ with the standard deviation $\sigma_r = 0.191$. The correlation coefficient is thus here 2.7 times as great as the st. dev. This connection between the temperature anomaly and the catch anomaly is illustrated on Fig. 7. With regard to the sea trout Table 10 p. 33 shews a similar correlation between the temperature anomalies and the catch anomalies as we find for the salmon. The correlation coefficient attains specially great values when we compare the May temperature with the June catch and the June temperature with the June catch. We find here that r in the first mentioned case is 5.8 times as great as its standard deviation, and in the last mentioned case 9.3 times as great as its standard deviation.

Examples illustrating the connections between the temperature anomalies and the catch anomalies are represented on Fig. 7—10 p. 22—25.

The temperature influences in May and June thus plainly the catch in June and July, but we cannot point out with certainty that it has any effect upon the catch in the later months of the year. The temperature in July might appear to have a slight effect on the catch in July and August but this apparent connection is possibly due to the fact that a certain correlation exists between the temperatures in the various summer months. The temperature in August and September does not appear to influence the catch in the later months of the year.

As a connection between the temperature and the catch in summer does evidently exist for the salmon as well as for the sea trout we must also expect to find a connection of this kind, when we regard the catch of the two species together in proportion to the temperature. As it will be seen from Table 11 p. 34 this connection is also very distinct for the period 1899—1913. A calculation of the correlation between the temperature anomalies for May, June and July and the catch anomalies for June, July and August gives the value $r = 0.592$, $\sigma_r = 0.168$, and $\frac{r}{\sigma_r} = 3.5$. For the earlier period from 1880—1898, where the catch of the two species in our statistics are taken together and cannot be kept apart, a positive correlation does also occur, but this is certainly quite small. Se Table 12 p. 34.

It becomes somewhat greater when we leave the year 1889 out of consideration. The temperature was abnormally high in this year and caused that many of the fish captured died in the reservoirs. As this may possibly have influenced the statistics concerning the catch it will presumably be right to leave this year out of consideration. When the connection between the temperature anomalies and the catch anomalies appear to be far less certain and distinct for the period 1880—1898 than for the period 1899—1913 we shall probably have to refer this to the fact that the statistics concerning the catch were hardly as reliable in the first mentioned period, when the fish wear was private property, as in the last mentioned period, when it belonged to the State and had become the property of the State in order that it should serve as an experimental field. We shall moreover lay stress upon the fact that even if a correlation does really exist between the summer temperature and the amount of running salmon, this connection may be veiled by several different circumstances. An essential part of the running salmon and sea trout are for example captured in Randers Fiord or in the lower part of Gudenaa, before

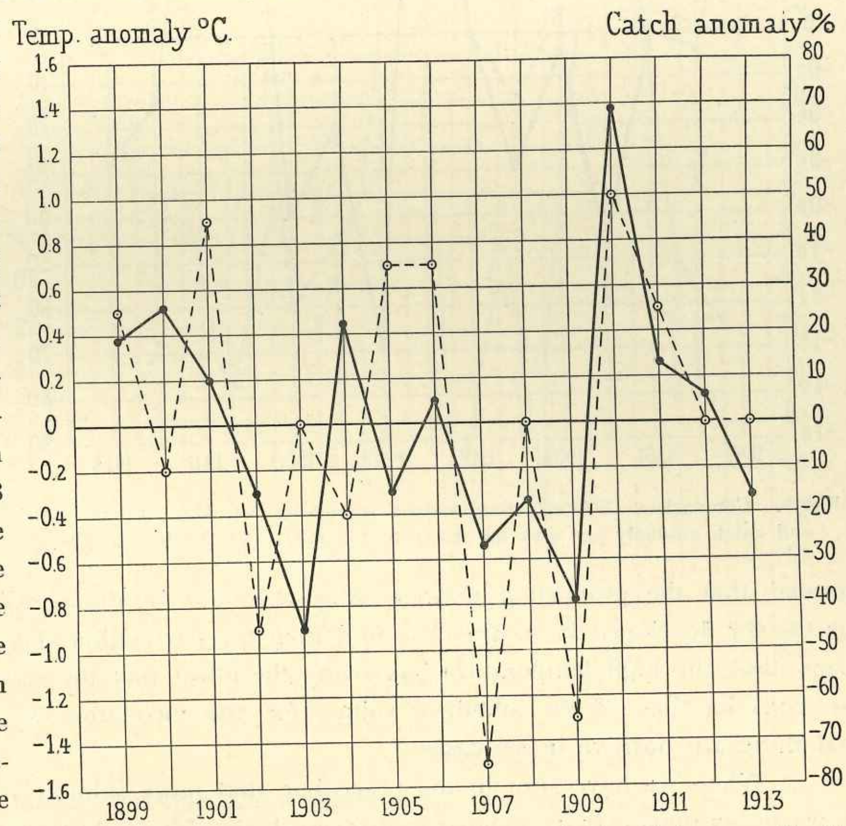

Fig. 8. Temperature anomalies for May to July (broken line) compared with catch anomaly per cent for sea trout for June to August. (See Table 7 and 9).

they get up to Frisenvold fish wear, and the percentage of the running fish which is captured there, may probably vary highly from one year to another. We must on the other hand admit that the correlation between the temperature anomalies and the catch anomalies in the period 1899—1913 may to some degree be casual; it may e. g. be influenced by anomalies produced by output of the artificially hatched fry. Thus we see that a warm summer casually occurred 3 years after the great liberation of fry in 1903 and again 3 and 4 years after the great liberation of fry in 1907. Casualities of this kind cause the correlation coefficient to become greater than it would be otherwise.

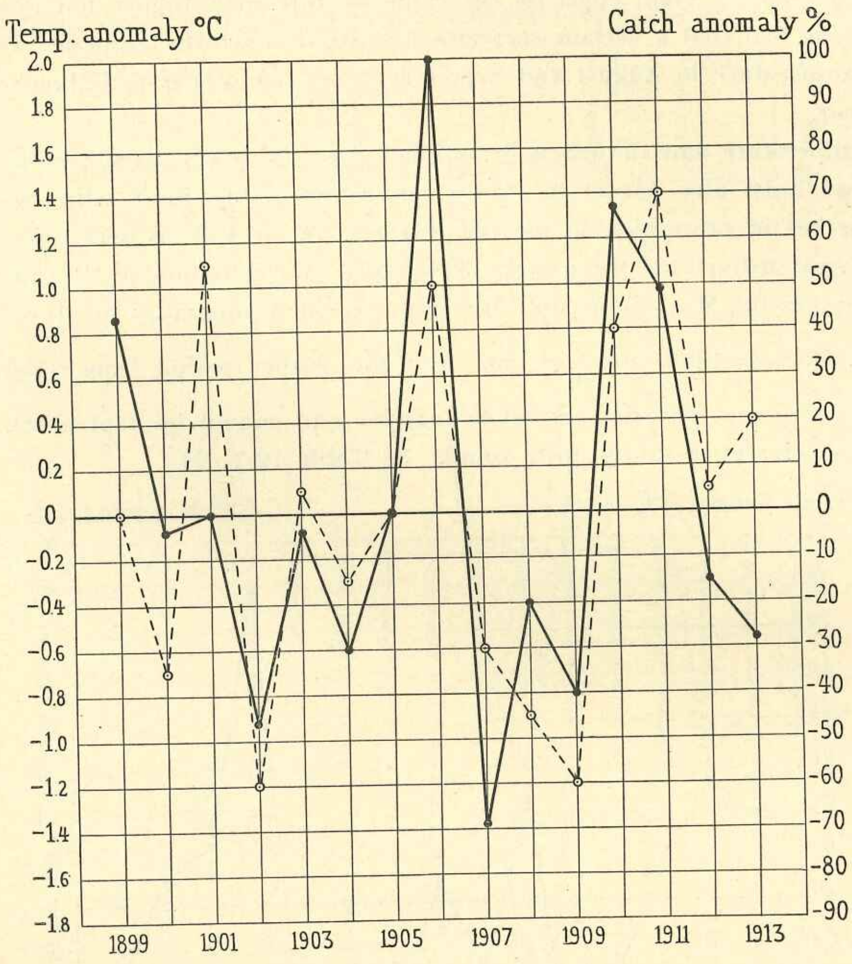

Fig. 9. Comparison between temperature anomalies for May (broken line) and catch anomaly per cent for sea trout for June. (See Table 7 and 9).

In order to avoid the disturbing influence of the artificially hatched fry in the investigation of the connection between the summer temperature and the catch, we shall consider the matter from another point of view. If the high summer temperature has the effect that the number of running salmon increases, this can only be explained by the fact that the temperature promotes maturity, as all the salmon running in summer will spawn in the first coming spawning period. Thus we must suppose that several of the salmon which would become B-salmon by a low or normal summer temperature, will shorten their stay in the sea by a high summer temperature and become A-salmon. We shall now undertake an investigation in order to shew if a relatively high number of A-salmon are caught in hot summers; we shall consider the ratio $\frac{p}{p+q}$ between the catch of A-salmon in a certain year (p) and the catch of A-salmon in the same year (p) plus B-salmon (q) in the following year. We take here for granted that the proportion between A-salmon and B-salmon will be the same for the liberated fry as for the fry developed in nature. We find then the correlation represented on Table 13 p. 35, which confirms that the high temperature has really the effect that the number of running salmon increases. In the consideration of the obtained values for the correlation we should attach importance to the fact that these are positive in all cases.

When we have seen in the preceding, that more salmon and sea trout ascend the river Gudenaa in warm summers than normally, this must signify, as stated before, that the maturity is furthered in some of the specimens and their stay in the sea shortened. It will consequently be of importance to investigate if a displacement takes place from the B-group to the A-group and from the C-group (mainly winter salmon) to the B-group. An investigation of this kind is possible for the salmon, as we are able with great approximation to keep the three groups apart. If we examine the correlation between the temperature anomalies for May, June and July and the deviations from the mean catch during summer for the period 1899—1913 for salmon of A-group and for salmon of B-group respectively, we obtain the following result (see Table 14 p. 35).

Salmon of group A.

$$r = 0.642; \; \sigma_r = 0.152; \; \frac{r}{\sigma_r} = 4.2.$$

Salmon of group B:

$$r = -0.075; \; \sigma_r = 0.257; \; \frac{r}{\sigma_r} = -0.3.$$

A distinct displacement from group B to group A appears thus plainly, whilst a displacement from group C to group B cannot be pointed out. This fact might suggest that group C, which mainly runs in winter, belongs to another race than the groups A and B, which run in summer and autumn. We remark, however, that the size of the correlation coefficients mentioned depends undoubtedly to an essential degree on the amounts of the fry liberated.

Our investigations concerning the influence of temperature upon the salmon catch have raised the question whether the salmon in warm summers runs in the same season as in cold summers. For the sake of investigating this question more closely we examine separately the group of A-salmon running in the time from May to the end of July, and now we want to know, if the percentage which this group makes of the total catch of A-salmon is equally large in warm and in cold summers. We calculate thus the correlation between the temperature anomalies and the deviations from the mean value of the catch per cent of the A-salmon from the months May—July, and in this way we obtain the following result:

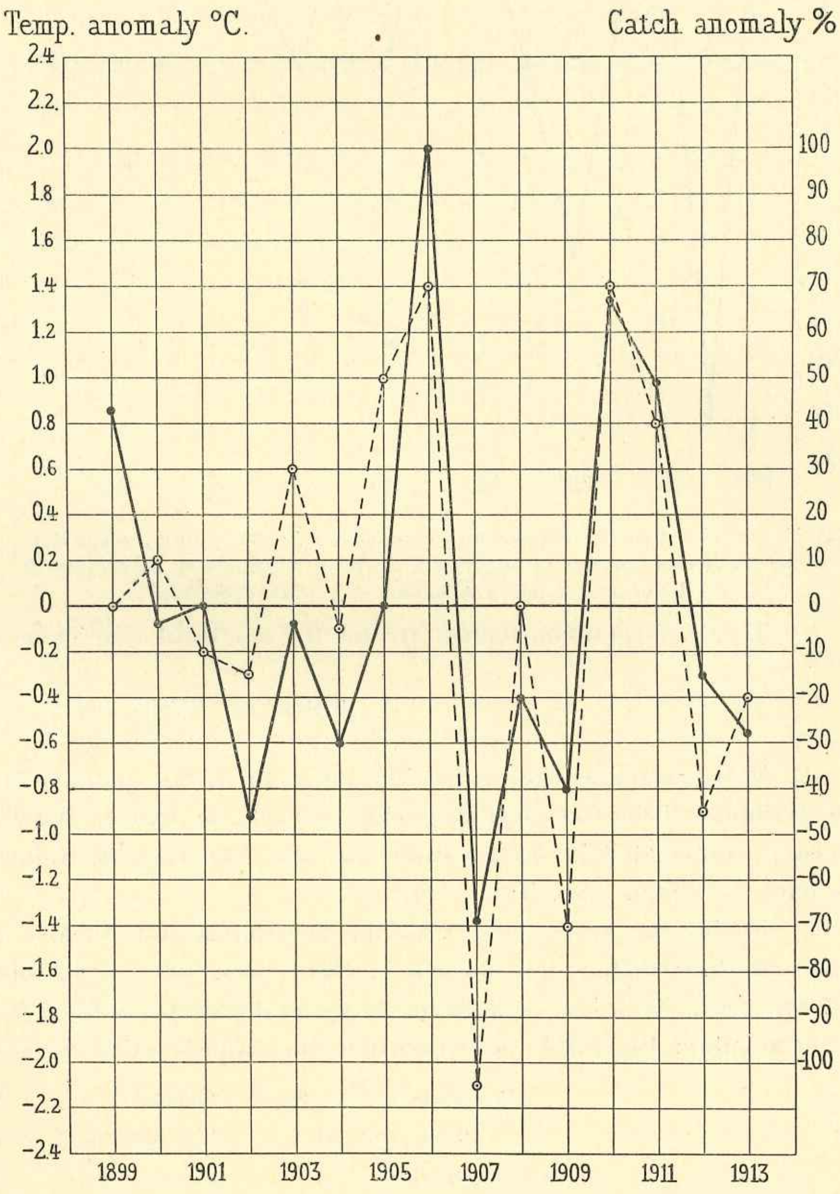

Fig. 10. Temperature anomalies for June (broken line) compared with catch anomaly per cent for sea trout for June. (See Table 7 and 9).

$$r = 0.363; \; \sigma_r = 0.224; \; \frac{r}{\sigma_r} = 1.6.$$

The reality of the correlation obtained can hardly be doubtful as the deviations for the temperature and the deviations for the catch per cent point in the same direction in all cases. (Table 15 p. 36 and Fig. 11 p. 26).

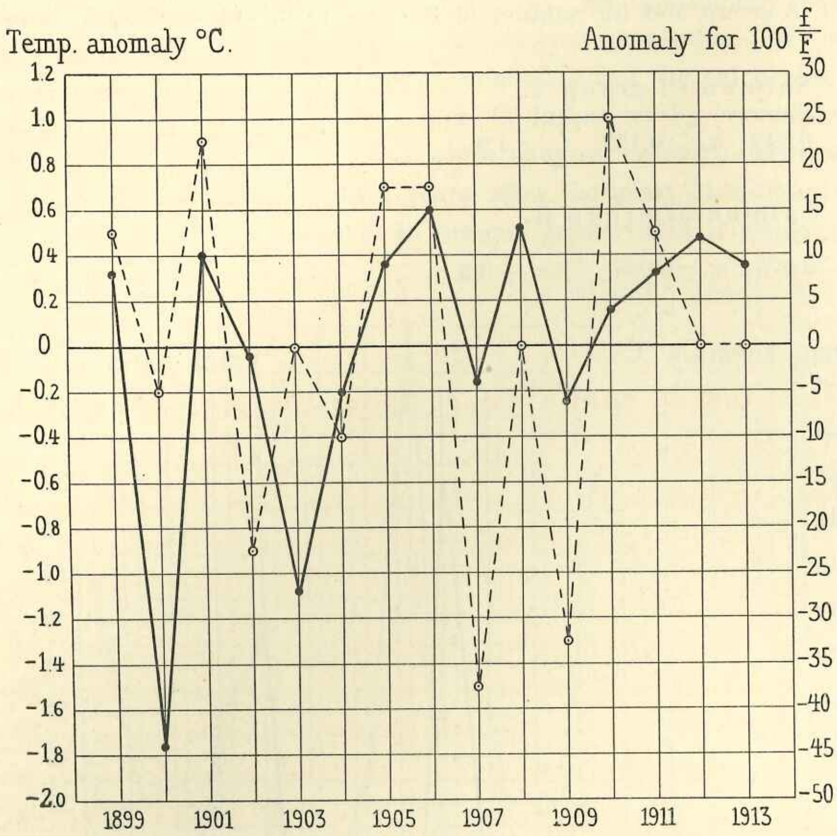

Fig. 11. Correlation between temperature anomalies for May—July (broken line) and the anomalies for the ratio between catch of A-Salmon in May—July (f) and the total catch of A-Salmon (F.). (See Table 15).

2. Influence of Temperature upon the Weight of the Running Specimens.

We have seen in the preceding that a high summer temperature has the effect that it produces a displacement from B-salmon to A-salmon and besides causes an earlier run of the A-salmon than normally occurs. According to this it must be supposed, that the average weight of the running salmon would be less than normal in warm summers, and our calculations also prove that this is the case.

If we correlate the temperature anomalies for May, June and July and the deviations from the average weight of salmons of all groups caught in June, July and August for the period 1899—1913 we obtain the following result (see Table 16 p. 36):

$$r = -0.568,$$

$$\sigma_r = 0.175, \text{ of which } \frac{r}{\sigma_r} = -3.2.$$

The corresponding figures are for the sea trout (see Table 17 p. 37):

$$r = -0.403; \ \sigma_r = 0.216 \text{ and } \frac{r}{\sigma_r} = -1.9.$$

If we examine the connection for each of the months between the temperature anomalies and the deviations from the average weight, it will be found, that the correlation coefficient is negative in all cases, and that it in several cases has very considerable values when compared with the size of its standard deviation. (See Tables 16 and 17).

During the years 1899—1913 the temperature was in May and June very nearly normal in 1903, 1912 and 1913; higher than normal in 1899, 1901, 1905, 1906, 1908, 1910, 1911, and lower than normal in 1900, 1902, 1904, 1907 and 1909. If we examine the average weight for salmon and sea trout caught in the months: June, July and August in the named period we obtain the following result[1]):

Temperature May—July	Salmon	Sea trout
over normal	3.56 kg	2.69 kg
normal	4.27 —	3.00 —
less than normal	4.26 —	2.92 —

We have now seen in the preceding that the number of salmon and sea trout caught is higher in warm than in cold summers. From this fact we dare not conclude, however, that a high temperature should be profitable for the salmon and sea trout fisheries more than quite momentary.

We know from our salmon investigations that the increase in the catch caused by high temperature is due only to an increase in the number of A-salmon whilst the number of B-salmon is not higher than normal. The high temperature thus promotes the maturity and causes that many specimens

[1]) The figures indicate the average of the annual values.

which in a lower temperature would have remained in the sea for another year and not have immigrated till they became B-salmon do now shorten their stay in the sea and immigrate as A-salmon. But this can hardly be regarded as an advantage when looked upon from a fishery economical point of view. The average weight of the specimens of group B is about 2.5 times as high as the average weight of specimens of group A, and it is not probable that the stock of the grown up salmon during its stay in the sea, becomes reduced to $^2/_5$ of its original size in the course of one year through attacks from natural ennemies (irrespective of man).

E. On the Causes of the Oscillations of many Years from the Normal Catch.

In the preceding chapters we have seen that fluctuations of short duration in the yield of the salmon- and trout-fisheries may be due to the influence of temperature upon the running time, and that fluctuations of a somewhat longer — but not of many years — duration is caused by the varying amounts of fry. We shall now proceed to consider the fluctuations which extend over a longer series of years. Thus we see, that the yield from 1853—1886 has in the main been decreasing and that the yield from 1903—1913 has on the whole been increasing (Fig. 3 and Fig. 5). We explain the decreasing yield in 1853—1886 in the following way: In this period Frisenvold fish wear was in full activity summer and winter and only a few specimens escaped to be caught here under normal conditions. The stock of spawning salmon was thus continually diminished and too little fry was consequently produced to keep up the stock. The decrease in the yield must thus presumably be referred to a too intensive fishery.

The increase in the yield of the summer salmon from 1903—1913 we explain in the following way: It is an effect of the output of fry artificially hatched, and possibly also a consequence of the fact that in the years 1901—1905 it was only a smaller part of the running winter salmon which were caught in Frisenvold fish wear and after 1905 hardly any of these. The natural stock of the spawning winter salmon has probably increased in the period in question. But now we do not certainly know whether the winter salmon does belong to another race than the summer salmon. If this be the case, it must be presumed that winter salmon only originate from eggs of the winter salmon. In this case the increase in the yield may be explained solely by the output of fry artificially hatched. This output comprised in the 5 years 1906—10 many more specimens (of tiny fry as well as of 6 months' fry) than in the 5 years 1901—05 (see Table 5 p. 17).

We explain the increase in the catch of the running sea trout in the period 1903—1913 in the same way as for the salmon: It is in all probability an effect of the output of the fry artificially hatched. The first output took place in August 1902 with 100,000 specimens of tiny fry. In the years 1905—1915 from 100,000 to 280,000 specimens of tiny fry were put out annually, and in the years 1908—1915 the output comprised from 8,600 to 99,000 specimens of 6 months fish.

[1]) L. c. A. C. Johansen and J. Chr. Løfting 1919.

Table 6. Showing the Length and Number of A-Salmon and B-Salmon captured in the Frisenvold Fish Wear in the Various Months in 1899—1913.

The measures are given in Danish Tommer (inches) with their eqvivalents in cm.

The number of specimens of the A-Gr. are given in italics, the number of specimens of the B-Gr. in usual types.

Year		1899									1900[1])									
Month		May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	
Length Tm.	cm																			Length Tm.
17	44.45	—	—	—	—	—	—			—	—	—	—	—				—	—	17
18	47.1	—	—	—	—	—	—			—	—	—	—	—				—	—	18
19	49.7	—	—	*2*	—	—	—			2	—	—	—	—				—	—	19
20	52.3	—	—	*7*	*2*	—	*1*			10	—	—	—	—				—	—	20
21	54.9	—	*1*	*5*	*4*	—	*2*			12	—	—	*1*	*1*				—	2	21
22	57 5	—	*1*	*7*	*4*	—	—			12	—	—	—	—				—	—	22
23	60.2	—	—	*5*	*2*	—	—			7	—	—	—	—				*2*	2	23
24	62.8	—	*1*	*3*	—	*1*	—			5	—	—	—	—				*1*	1	24
25	65.4	—	*2*	*2*	*1*	—	—			5	—	—	—	—				—	—	25
26	68.0	—	—	*3*	—	—	—			3	—	—	—	—				—	—	26
27	70.6	—	—	—	—	—	—			—	1	3	—	—				2	6	27
28	73.3	—	2	2	1	—	1			6	1	—	1	—				—	2	28
29	75.9	—	3	1	—	—	—			4	—	—	—	—				1	1	29
30	78.45	—	4	2	—	1	—			7	1	3	2	—				—	6	30
31	81.1	—	1	5	1	—	—			7	—	2	2	—				—	4	31
32	83.7	—	2	2	—	—	—			4	2	6	1	—				2	11	32
33	86.3	—	—	—	—	—	—			—	2	1	2	—				—	5	33
34	89.0	—	—	—	—	—	—			—	3	1	—	—				1	5	34
35	91.6	—	—	—	—	—	—			—	2	—	—	—				—	2	35
36	94.2	—	—	—	—	—	—			—	1	1	1	—				—	3	36
37	96.8	1	—	—	—	—	—			1	1	1	—	—				—	2	37
38	99.4	—	—	—	—	—	—			—	—	1	—	—				—	1	38
39	102.0	—	—	—	—	—	—			—	—	—	—	—				—	—	39
40	104.6	—	—	—	—	—	—			—	1	—	—	—				—	1	40
41	107.2	—	—	—	—	—	—			—	—	—	—	—				—	—	41
42	109.8	—	—	—	—	—	—			—	—	—	—	—				—	—	42
43	112.5	—	—	—	1	—	—			1	—	—	—	—				—	—	43
Total number		1	17	46	16	2	4			86	15	19	10	1				9	54	
Specim. of A-Gr.			*5*	*34*	*13*	*1*	*3*			56	—	—	*1*	*1*				*3*	5	
Specim. of B-Gr.		1	12	12	3	1	1			30	15	19	9	—				6	49	

[1]) 60 specimens not measured.

Year		1901[1])									1902									
Month		May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	
Length Tm.	cm																			Length Tm.
17	44.45	—	—	—	—	—		—		—	—	—	—	—	—	—	—		—	17
18	47.1	—	—	—	—	—		—		—	—	—	—	—	—	—	—		—	18
19	49.7	—	*1*	—	—	—		—		1	—	—	—	—	—	—	—		—	19
20	52.3	—	—	*1*	—	—		—		1	—	—	—	—	—	—	—		—	20
21	54.9	—	*1*	*17*	*1*	—		—		19	—	—	*3*	—	—	—	—		3	21
22	57.5	—	*3*	*16*	*1*	—		—		21	—	*1*	*1*	—	—	—	—		2	22
23	60.2	—	—	*6*	*3*	—		—		9	—	—	*4*	*3*	—	*1*	—		8	23
24	62.8	—	—	*11*	*3*	—		—		14	—	—	*2*	*3*	—	—	—		5	24
25	65.4	—	—	*5*	*10*	—		—		15	*1*	—	—	—	—	*1*	—		2	25
26	68.0	—	—	*7*	*5*	—		—		12	—	—	*2*	—	*1*	—	—		3	26
27	70.6	—	1	*1*	*4*	—		—		6	2	1	—	—	—	—	—		3	27
28	73.3	1	2	*1*	*1*	—		—		5	—	2	1	—	—	—	—		3	28
29	75.9	1	4	1	—	—		—		6	1	3	2	—	—	—	—		6	29
30	78.45	1	—	1	—	—		—		2	3	5	2	1	2	1	1		15	30
31	81.1	—	3	1	—	1		1		6	2	5	4	1	—	—	—		12	31
32	83.7	—	6	1	—	—		—		7	4	2	5	2	1	—	—		14	32
33	86.3	—	1	1	1	—		—		3	—	3	2	—	—	—	—		5	33
34	89.0	1	4	1	1	—		—		7	1	4	1	—	—	—	—		6	34
35	91.6	3	2	1	—	—		—		6	3	1	1	1	1	—	—		7	35
36	94.2	1	3	—	—	—		—		4	1	—	1	—	—	—	—		2	36
37	96.8	1	—	—	—	—		—		1	—	1	—	—	—	—	—		1	37
38	99.4	—	1	—	—	—		—		1	2	—	—	—	—	—	—		2	38
39	102.0	—	1	—	—	—		1		2	—	1	—	—	—	—	—		1	39
40	104.6	—	—	—	—	—		—		—	—	—	—	—	—	—	—		—	40
41	107.2	—	—	—	—	—		—		—	—	—	—	—	—	—	—		—	41
42	109.8	—	—	—	—	—		—		—	—	—	—	—	—	—	—		—	42
43	112.5	—	—	—	—	—		—		—	—	—	—	—	—	—	—		—	43
Total number		9	33	73	30	1		2		148	20	29	31	11	5	3	1		100	
Specim. of A-Gr.		—	*5*	*65*	*28*	—		—		98	*1*	*1*	*12*	*6*	*1*	*2*	—		23	
Specim. of B-Gr.		9	28	8	2	1		2		50	19	28	19	5	4	1	1		73	

[1]) 3 specimens not measured.

Table 6 (continued).

Year		1903									1904									
Month		May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	
Length Tm.	cm																			Length Tm.
17	44.45	—	—	—	—	—	—			—	—	—	—	—	—		—	—	—	17
18	47.1	—	—	*1*	—	—	—			1	—	—	—	—	—		—	—	—	18
19	49.7	—	*1*	—	—	—	—			1	—	*1*	—	—	—		—	—	1	19
20	52.3	—	—	—	—	—	—			—	—	—	*3*	—	—		—	—	3	20
21	54.9	—	—	*1*	—	—	—			1	—	—	*4*	*1*	—		—	—	5	21
22	57.5	—	—	—	*2*	—	—			2	—	—	*3*	*5*	—		—	—	8	22
23	60.2	—	—	*2*	—	—	—			2	—	—	*9*	*1*	*2*		—	—	12	23
24	62.8	—	—	—	*3*	—	—			3	—	—	*5*	*2*	*2*		*1*	—	10	24
25	65.4	—	—	*1*	*3*	—	*1*			5	—	—	*1*	*3*	—		—	*1*	5	25
26	68.0	—	—	—	—	*1*	*1*			2	—	—	—	*2*	—		—	—	2	26
27	70.6	—	1	—	1	—	—			2	—	1	—	—	—		—	—	1	27
28	73.3	1	1	2	1	—	—			5	—	—	—	—	—		—	—	—	28
29	75.9	2	—	—	—	—	—			2	2	1	3	—	—		—	—	6	29
30	78.45	2	3	—	—	—	—			5	1	8	4	1	—		—	—	14	30
31	81.1	—	2	—	1	—	—			3	1	2	3	1	—		—	—	7	31
32	83.7	1	2	1	—	—	—			4	—	3	2	—	—		—	—	5	32
33	86.3	1	1	1	—	—	—			3	—	—	—	—	—		—	—	—	33
34	89.0	1	1	—	—	—	—			2	—	3	—	—	—		—	—	3	34
35	91.6	—	—	—	—	—	—			—	—	1	—	—	—		—	—	1	35
36	94.2	2	—	—	—	—	—			2	—	—	1	—	—		—	—	1	36
37	96.8	—	1	—	—	—	—			1	—	—	—	—	—		—	—	—	37
38	99.4	1	—	—	—	—	—			1	4	1	1	—	—		—	—	6	38
39	102.0	—	—	—	—	—	—			—	1	1	—	1	—		—	—	3	39
40	104.6	—	—	—	—	—	—			—	—	—	—	—	—		—	—	—	40
41	107.2	—	—	—	—	—	—			—	—	1	—	—	—		—	—	1	41
42	109.8	—	—	—	—	—	—			—	—	1	—	—	—		—	—	1	42
43	112.5	—	—	—	—	—	—			—	—	—	—	—	—		—	—	—	43
Total Number		11	13	9	11	1	2			47	9	24	39	17	4		1	1	95	
Specim. of A-Gr.		—	*1*	*5*	*8*	*1*	*2*			17	—	*1*	*25*	*14*	*4*		*1*	*1*	46	
Specim. of B-Gr.		11	12	4	3	—	—			30	9	23	14	3	—		—	—	49	

Year		1905									1906									
Month		May	June	July	A ug.	Sept.	Oct.	Nov.	Dec.	Total	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	
Length Tm.	cm																			Length Tm.
17	44.45	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—		—	17
18	47.1	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—		—	18
19	49.7	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—		—	19
20	52.3	—	—	—	—	—	—	—		—	—	—	*1*	—	—	—	—		1	20
21	54 9	—	—	—	—	—	—	—		—	—	*7*	*8*	*2*	*1*	—	—		18	21
22	57.5	—	—	—	—	—	—	—		—	—	*2*	*5*	*2*	—	—	—		9	22
23	60.2	—	*1*	7	—	—	—	—		8	—	*5*	*14*	—	*1*	—	—		20	23
24	62.8	—	*1*	*14*	*3*	*1*	—	—		19	—	*6*	*18*	*2*	—	—	—		26	24
25	65.4	—	—	*14*	*2*	—	*4*	*1*		21	—	*2*	*18*	*5*	*2*	*1*	*2*		30	25
26	68.0	*2*	—	*11*	*3*	*2*	*1*	—		19	—	*2*	*7*	*4*	*1*	*2*	—		16	26
27	70.6	—	—	*9*	*1*	*1*	*4*	—		15	—	—	*8*	*2*	*1*	*1*	*1*		13	27
28	73.3	—	*1*	*2*	—	—	—	*1*		4	—	1	*1*	—	—	*1*	—		3	28
29	75.9	1	—	—	*1*	—	—	—		2	—	1	—	—	—	—	—		1	29
30	78.45	—	—	1	—	—	—	—		1	2	6	—	—	—	—	—		8	30
31	81.1	—	1	3	—	—	—	—		4	—	4	4	—	—	—	2		10	31
32	83.7	—	3	2	—	—	—	1		6	5	19	8	—	—	—	—		32	32
33	86.3	1	1	—	—	—	—	—		2	3	8	4	2	—	—	—		17	33
34	89.0	1	—	1	1	—	—	—		3	1	3	—	1	—	—	—		5	34
35	91.6	1	1	—	—	—	—	—		2	—	4	2	1	—	—	—		7	35
36	94.2	—	—	—	—	—	—	—		—	—	—	1	—	—	—	—		1	36
37	96.8	—	1	—	—	—	—	—		1	—	—	—	—	—	—	—		—	37
38	99.4	—	—	—	—	—	—	—		—	—	1	—	—	—	—	—		1	38
39	102.0	—	1	—	—	—	—	—		1	—	—	—	—	—	—	—		—	39
40	104.6	—	—	—	—	—	—	—		—	—	1	—	—	—	—	—		1	40
41	107.2	—	—	—	—	—	—	—		—	—	1	—	—	—	—	—		1	41
42	109.8	—	—	—	—	—	—	—		—	—	1	—	—	—	—	—		1	42
43	112.5	—	—	—	—	—	—	—		—	—	—	—	—	—	—	—		—	43
Total Number		6	11	64	11	4	9	3		108	11	74	99	21	6	5	5		221	
Specim. of A-Gr.		*2*	*3*	*57*	*10*	*4*	*9*	*2*		87	—	*24*	*80*	*17*	*6*	*5*	*3*		135	
Specim. of B-Gr.		4	8	7	1	—	—	1		21	11	50	19	4	—	—	2		86	

Table 6 (continued).

Year		1907									1908									
Month		May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Length Tm.
Length Tm.	cm																			
17	44.45		—	—	—					—		—	*1*	—	—				1	17
18	47.1		—	—	*1*					1		—	*2*	—	—				2	18
19	49.7		—	*2*	—					2		—	—	—	*1*				1	19
20	52.3		—	*1*	—					1		—	*3*	*1*	—				4	20
21	54.9		—	—	—					—		—	*2*	—	—				2	21
22	57.5		—	*1*	*1*					2		—	*3*	*1*	—				4	22
23	60.2		—	*2*	*1*					3		—	*2*	*1*	—				3	23
24	62.8		—	*1*	*2*					3		—	*4*	*4*	—				8	24
25	65.4		—	—	—					—		*1*	5	—	—				6	25
26	68.0		—	—	—					—		—	*1*	—	—				1	26
27	70.6		1	1	—					2		2	1	—	—				3	27
28	73.3		2	—	—					2		2	—	—	1				3	28
29	75.9		4	1	—					5		2	2	—	—				4	29
30	78.45		1	—	2					3		4	2	1	—				7	30
31	81.1		13	5	—					18		4	3	—	—				7	31
32	83.7		7	4	—					11		1	1	1	—				3	32
33	86.3		9	4	—					13		2	—	1	—				3	33
34	89.0		7	9	—					16		—	—	2	—				2	34
35	91.6		2	2	—					4		—	—	—	—				—	35
36	94.2		1	1	—					2		—	1	—	—				1	36
37	96.8		1	—	2					3		—	—	—	—				—	37
38	99.4		—	1	—					1		—	—	—	—				—	38
39	102.0		—	—	—					—		—	—	—	—				—	39
40	104.6		—	—	—					—		—	—	—	—				—	40
41	107.2		—	—	—					—		1	—	—	—				1	41
42	109.8		—	—	—					—		—	—	—	—				—	42
43	112.5		—	—	—					—		—	—	—	—				—	43
Total Number			48	35	9					92		19	33	12	2				66	
Specim. of A-Gr.			—	7	5					12		*1*	*23*	7	*1*				32	
Specim. of B-Gr.			48	28	4					80		18	10	5	1				34	

Year		1909									1910									
Month		May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Length Tm.
Length Tm.	cm																			
17	44.45		—	—	—	—	—			—		—	—	—	—	—	—	—	—	17
18	47.1		—	*1*	—	—	—			1		—	*2*	—	—	—	—	—	2	18
19	49.7		—	*2*	—	—	—			2		*1*	*3*	—	—	—	—	—	4	19
20	52.3		—	*4*	—	—	—			4		—	*16*	*2*	—	—	—	—	18	20
21	54.9		—	5	*3*	—	*2*			10		*1*	*30*	*12*	—	—	—	—	43	21
22	57.5		—	*4*	*3*	*2*	*1*			10		—	*34*	*6*	—	*3*	—	—	43	22
23	60.2		*1*	5	*4*	—	—			10		*1*	*23*	*11*	—	—	—	*1*	36	23
24	62.8		—	*9*	*6*	*1*	—			16		*2*	*6*	*14*	—	*2*	*1*	—	25	24
25	65.4		*1*	5	*4*	*1*	—			11		2	5	7	—	—	—	—	14	25
26	68.0		1	*2*	*4*	—	—			7		3	5	*4*	—	*2*	—	—	14	26
27	70.6		2	—	—	—	—			2		3	3	*2*	—	—	—	—	8	27
28	73.3		3	—	—	—	—			3		5	5	2	1	2	—	—	15	28
29	75.9		5	5	—	—	—			10		6	4	—	—	—	—	1	11	29
30	78.45		4	2	—	—	1			7		8	7	1	—	1	1	—	18	30
31	81.1		8	8	1	1	—			18		9	13	3	1	—	—	—	26	31
32	83.7		11	5	—	—	—			16		4	12	—	—	—	—	—	16	32
33	86.3		6	1	—	—	—			7		1	9	1	1	—	—	—	12	33
34	89.0		2	1	—	—	—			3		—	—	2	—	—	—	—	2	34
35	91.6		4	—	1	—	—			5		—	2	—	—	—	—	—	2	35
36	94.2		2	1	—	—	—			3		—	—	—	1	—	—	—	1	36
37	96.8		—	—	—	—	—			—		—	—	—	—	—	—	—	—	37
38	99.4		1	—	—	—	—			1		—	1	—	1	—	—	—	2	38
39	102.0		—	—	—	—	—			—		—	—	—	—	—	—	—	—	39
40	104.6		—	—	—	—	—			—		—	—	—	—	—	—	—	—	40
41	107.2		—	—	—	—	—			—		—	—	—	—	—	—	—	—	41
42	109.8		—	—	—	—	—			—		—	—	—	—	—	—	—	—	42
43	112.5		—	—	—	—	—			—		—	—	—	—	—	—	—	—	43
Total Number			51	60	26	5	4			146		46	180	67	5	10	2	2	312	
Specim. of A-Gr.			*2*	*37*	*24*	*4*	*3*			70		7	*124*	*58*	—	7	*1*	*1*	198	
Specim. of B-Gr.			49	23	2	1	1			76		39	56	9	5	3	1	1	114	

Table 6 (continued).

Year		1911									1912									
Month		May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	
Length Tm.	cm																			Length Tm.
17	44.45		—	—	—	—	—			—		—	—	—		—			—	17
18	47.1		—	—	—	—	—			—		—	—	—		—			—	18
19	49.7		—	2	—	—	—			2		—	—	—		—			—	19
20	52.3		—	*3*	—	—	—			3		—	*3*	—		*1*			4	20
21	54.9		—	2	*1*	—	—			3		*1*	*8*	—		—			9	21
22	57.5		—	7	—	—	—			7		*1*	*4*	*3*		—			8	22
23	60.2		—	5	*2*	—	—			7		—	*1*	*2*		—			3	23
24	62.8		*1*	*1*	*3*	—	—			5		2	*4*	*1*		—			7	24
25	65.4		2	2	*1*	—	*1*			6		—	*1*	*3*		—			4	25
26	68.0		1	3	—	—	*1*			5		—	*3*	—		—			3	26
27	70.6		4	5	—	—	—			9		3	2	—		—			5	27
28	73.3		16	4	1	—	—			21		2	1	—		1			4	28
29	75.9		6	3	—	—	—			9		1	3	1		—			5	29
30	78.45		19	18	3	—	1			41		6	6	—		—			12	30
31	81.1		9	10	3	1	—			23		13	3	—		—			16	31
32	83.7		21	16	1	—	—			38		—	2	2		—			4	32
33	86.3		14	8	1	—	—			23		2	1	—		—			3	33
34	89.0		4	2	—	—	—			6		6	—	—		—			6	34
35	91.6		4	1	1	—	—			6		—	—	—		—			—	35
36	94 2		2	1	—	—	—			3		—	1	—		—			1	36
37	96.8		1	1	—	—	—			2		—	—	—		—			—	37
38	99.4		2	—	—	—	—			2		—	—	—		—			—	38
39	102.0		—	—	—	—	—			—		—	—	—		—			—	39
40	104.6		—	—	—	—	—			—		1	—	—		—			1	40
41	107.2		—	—	—	—	—			—		—	—	—		—			—	41
42	109.8		—	—	—	—	—			—		—	—	—		—			—	42
43	112.5		—	—	—	—	—			—		1	—	—		—			1	43
Total Number			106	94	17	1	3			221		39	43	12		2			96	
Specim. of A-Gr.			*1*	*20*	7	—	2			30		*4*	*24*	*9*		*1*			38	
Specim. of B-Gr.			105	74	10	1	1			191		35	19	3		1			58	

Year		1913									1914[1]									
Month		May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	
Length Tm.	cm																			Length Tm.
17	44.45		—	—	—	—	—			—			—	—	—	—			—	17
18	47.1		—	—	—	—	—			—			—	—	—	—			—	18
19	49.7		—	—	—	—	—			—			—	—	—	—			—	19
20	52.3		—	*1*	—	—	—			1			—	—	—	*1*			1	20
21	54.9		*1*	*3*	—	—	—			4			—	—	—	—			—	21
22	57.5		*1*	*6*	—	—	—			7			—	—	—	—			—	22
23	60.2		—	*1*	—	—	—			1			—	—	—	—			—	23
24	62.8		*1*	*3*	2	—	—			6			—	*1*	—	—			1	24
25	65.4		*1*	*1*	*1*	—	—			3			*1*	—	—	—			1	25
26	68.0		*1*	—	*3*	*1*	—			5			*1*	—	*1*	—			2	26
27	70.6		—	—	—	—	—			—			*1*	—	—	*1*			2	27
28	73.3		7	5	1	—	*1*			14			—	1	—	—			1	28
29	75.9		2	2	—	—	—			4			—	1	—	—			1	29
30	78.45		4	2	3	2	—			11			—	—	—	—			—	30
31	81.1		5	10	3	—	—			18			—	—	—	—			—	31
32	83.7		16	11	—	1	—			28			1	—	—	—			1	32
33	86.3		3	4	2	1	—			10			—	—	—	—			—	33
34	89.0		2	3	3	1	—			9			1	—	—	—			1	34
35	91.6		3	4	—	1	—			8			—	—	—	—			—	35
36	94.2		1	—	—	—	—			1			—	—	—	—			—	36
37	96.8		—	—	—	—	—			—			—	—	—	—			—	37
38	99.4		2	—	—	—	—			2			—	—	—	—			—	38
39	102.0		—	—	—	—	—			—			—	—	—	—			—	39
40	104.6		—	—	—	—	—			—			—	—	—	—			—	40
41	107.2		—	—	—	—	—			—			—	—	—	—			—	41
42	109.8		—	—	—	—	—			—			—	—	—	—			—	42
43	112.5		—	—	—	—	—			—			—	—	—	—			—	43
Total Number			50	56	18	7	1			132			5	3	1	2			11	
Specim. of A-Gr.			*5*	*15*	*6*	*1*	*1*			28			*3*	*1*	*1*	2			7	
Specim. of B-Gr.			45	41	12	6	—			104			2	2	—	—			4	

[1]) On account of an unusually high summer temperature, which caused a great mortality of the specimens captured, the fish wear was only used for catch in part of the summer.

Table 7. Monthly Mean Temperatures and Temperature Anomalies of the Surface Waters at the Light-Vessels Læsø Rende (L. R.) and Schultz' Grund (S. G.) in the Period 1899—1913.

Year	Monthly mean Temperatures										Temperature anomalies at Læsø Rende and Schultz' Grund					
	May		June		July		August		Septbr.		May	June	July	August	Septbr.	May—July
	L. R.	S. G.	L. R.	S. G.	L. R.	S. G.	L. R.	S. G.	L. R.	S. G.						
1899	8.8	9.2	14.0	13.8	17.9	18.0	16.9	17.3	13.9	14.7	0.0	0.0	1.5	0.8	0.3	0.5
1900	8.2	8.3	14.2	14.0	15.7	16.9	16.6	17.2	14.3	15.1	–0.7	0.2	–0.1	0.6	0.6	–0.2
1	10.4	9.7	13.5	13.9	18.2	18.2	17.4	18.6	14.5	14.6	1.1	–0.2	1.8	1.7	0.5	0.9
2	7.6	8.0	13.5	13.6	14.9	15.4	13.8	14.4	12.7	13.2	–1.2	–0.3	–1.3	–2.2	–1.1	–0.9
3	9.1	9.1	14.6	14.3	15.4	16.1	14.8	15.3	13.5	13.6	0.1	0.6	–0.7	–1.2	–0.5	0.0
4	8.5	8.8	13.4	14.1	15.5	15.7	16.1	16.4	14.2	14.4	–0.3	–0.1	–0.8	0.0	0.2	–0.4
5	9.2	8.9	14.8	14.9	17.2	17.7	16.0	16.9	13.6	14.2	0.0	1.0	1,0	0.2	–0.2	0.7
6	9.9	10.0	15.3	15.3	15.4	16.8	16.0	17.1	14.2	14.9	1.0	1.4	–0.4	0.2	0.5	0.7
7	8.3	8.5	11.3	12.3	14.4	14.6	13.8	14.7	12.6	13.4	–0.6	–2.1	–1.9	–2.0	–1.0	–1.5
8	8.0	8.2	13.8	13.9	17.1	17.9	16.4	17.1	13.5	13.8	–0.9	0.0	1.0	0.4	–0.4	0.0
9	7.7	7.8	12.4	12.5	14.8	15.9	14.9	15.3	13.6	13.9	–1.2	–1.4	–1.1	–1.2	–0.3	–1.3
10	9.9	9.6	15.2	15.4	17.1	17.2	16.7	17.0	14.4	14.9	0.8	1.4	0.7	0.6	0.6	1.0
11	10.5	10.2	14.5	14.8	15.7	15.9	18.1	18.8	14.8	15.4	1.4	0.8	–0.6	2.1	1.0	0.5
12	8.9	9.3	12.9	13.0	17.1	17.6	15.6	16.7	12.8	13.1	0.1	–0.9	0.9	–0.1	–1.1	0.0
13	9.0	9.7	13.3	13.8	16.4	16.5	16.1	16.7	14.7	15.3	0.4	–0.4	0.0	0.1	0.9	0.0
Mean	8.9	9.0	13.8	14.0	16.2	16.7	15.9	16.6	13.8	14.3						

Table 8. Number of Salmon caught in Frisenvold Fish Wear in each of the Months June, July and August in the Period 1899—1913. Adjusted Values for the Catch, and the Catch Anomaly per cent.

Year	Number of salmon caught				Catch adjusted				Catch anomaly per cent			
	June	July	August	Sum June—August	June	July	August	Sum June—August	June	July	August	June—August
1899	17	46	16	79	24	45	17	86	—29	2	— 6	— 8
1900	19	43	25	87	24	45	17	86	—21	— 4	47	1
1	32	73	30	135	25	45	17	87	28	62	76	55
2	29	31	11	71	25	46	17	88	16	—33	—35	—19
3	13	9	11	33	26	47	17	90	—50	—81	—35	—63
4	24	39	17	80	28	49	17	94	—14	—20	0	—15
5	11	64	11	86	30	51	18	99	—63	25	—39	—13
6	74	99	21	194	32	54	19	105	131	83	11	85
7	48	35	9	92	36	57	20	113	33	—39	—55	—19
8	19	33	12	64	41	62	21	124	—54	—47	—43	—48
9	51	60	26	137	46	68	22	136	11	—12	18	1
10	46	180	67	293	50	75	24	149	— 8	140	179	97
11	106	94	17	217	56	81	25	162	89	16	—32	34
12	39	43	12	94	63	87	26	176	—38	—51	—54	—47
13	50	56	18	124	72	93	26	191	—31	—40	—31	—35
Sum	578	905	303	1786	578	905	303	1786				

Table 9. Number of Running Sea Trout caught in Frisenvold Fish Wear in each of the Months June, July August, September and October in the Period 1899—1913. Adjusted Values for the Catch and the Catch Anomaly per cent.

Year	Number of sea trout caught						Catch adjusted						Catch anomaly per cent					
	June	July	Aug.	Sept.	Octb.	Sum June —Aug.	June	July	Aug.	Sept.	Octb.	Sum June —Aug.	June	July	Aug.	Sept.	Octb.	Sum June —Aug.
1899	33	104	87	96	96	224	23	77	89	69	69	189	43	35	— 2	39	39	19
1900	23	113	106	69	67	242	24	79	89	69	70	192	— 4	43	19	0	— 4	26
1	24	64	126	54	93	214	24	81	89	70	73	194	0	— 21	42	— 23	27	10
2	13	69	85	72	61	167	24	83	90	71	76	197	— 46	— 17	— 6	1	— 20	— 15
3	24	38	49	62	35	111	25	86	91	72	79	202	— 4	— 56	— 46	— 14	— 56	— 45
4	19	132	105	67	62	256	27	91	91	74	84	209	— 30	45	15	— 9	— 26	22
5	29	79	78	98	97	186	29	98	92	76	89	219	0	— 19	— 15	29	9	— 15
6	64	108	71	63	124	243	32	106	93	78	95	231	100	2	— 24	— 19	31	5
7	11	69	100	111	130	180	36	116	95	81	101	247	— 69	— 41	5	37	29	— 27
8	33	119	68	89	83	220	41	126	97	84	107	264	— 20	— 6	— 30	6	— 22	— 17
9	28	93	53	54	87	174	47	137	100	86	115	284	— 40	— 32	— 47	— 37	— 24	— 39
10	90	284	141	86	120	515	54	148	102	90	124	304	67	92	38	— 4	— 3	69
11	94	186	91	47	162	371	63	161	105	95	133	329	49	16	— 13	— 51	22	13
12	64	108	210	135	154	382	75	176	109	100	143	360	— 15	— 39	93	35	8	6
13	65	189	76	117	140	330	90	190	114	105	153	394	— 28	— 1	— 33	11	— 8	— 16
Sum	614	1755	1446	1220	1511	3815	614	1755	1446	1220	1511	3815						

Table 10. The Correlation Coefficients (r) their Standard Deviations (σ_r) and the Fraction $\frac{r}{\sigma_r}$ for the Connection between the Temperature Anomalies and the Catch Anomaly per cent for Summer Salmon and Sea Trout in the Period 1899—1913.

Part of the year for which the temperature anomalies are used	Part of the year for which the catch anomaly per cent are used	r	σ_r	$\frac{r}{\sigma_r}$	Part of the year for which the temperature anomalies are used	Part of the year for which the catch anomaly per cent are used	r	σ_r	$\frac{r}{\sigma_r}$
May	June	0.438	0.209	2.1	May	June	0.719	0.125	5.8
»	July	0.570	0.174	3.3	»	July	0.238	0.244	1.0
»	August	0.320	0.232	1.4	»	August	0.219	0.246	0.9
June	June	0.134	0.254	0.5	»	September	—0.299	0.235	—1.3
»	July	0.577	0.172	3.4	»	October	0.473	0.200	2.4
»	August	0.394	0.218	1.8	June	June	0.812	0.088	9.3
July	July	0.340	0.228	1.5	»	July	0.496	0.195	2.5
»	August	0.299	0.235	1.3	»	August	—0.123	0.256	—0.4
August	August	0.359	0.225	1.6	»	September	—0.293	0.236	—1.2
May—July	June—August	0.509	0.191	2.7	»	October	0.009	0.258	0.0
					July	July	0.232	0.244	0.9
					»	August	0.386	0.220	1.8
					»	September	0.252	0.242	1.0
					»	October	0.318	0.232	1.4
					August	August	0.249	0.242	1.0
					»	September	—0.283	0.238	—1.2
					»	October	0.436	0.209	2.1
					September	September	—0.449	0.206	—2.2
					»	October	0.271	0.239	1.1
					May—July	June—August	0.568	0.175	3.2

Table 11. Temperature Anomalies for the Surface Water at the Light-vessels Læsø Rende and Schultz' Grund in the Period 1899—1913 and the Catch of Salmon and Sea Trout in June, July and August in Frisenvold Fish Wear in the same Period; adjusted Values for Catch and the Catch Anomaly per cent.

Year	Temperature anomaly				Catch	Catch adjusted	Catch per cent
	May	June	July	May—July			
1899	0.0	0.0	1.5	0.5	303	275	10
1900	—0.7	0.2	—0.1	—0.2	329	278	18
1	1.1	—0 2	1.8	0.9	349	281	24
2	—1.2	—0.3	—1.3	—0.9	238	285	—16
3	0.1	0.6	—0.7	0.0	144	292	—51
4	—0.3	—0.1	—0.8	—0.4	336	303	11
5	0.0	1.0	1.0	0.7	272	318	—14
6	1.0	1.4	—0.4	0.7	437	336	30
7	—0.6	—2.1	—1.9	—1.5	272	360	—24
8	—0.9	0.0	1.0	0.0	284	388	—27
9	—1.2	—1.4	—1.1	—1.3	311	420	—26
10	0.8	1.4	0.7	1.0	808	453	78
11	1.4	0.8	—0.6	0.5	588	491	20
12	0.1	—0.9	0.9	0.0	476	536	—11
13	0.4	—0.4	0.0	0.0	454	585	—22
					5601	5601	

Correlation between temperature anomalies for May and catch anomaly for June—August: $r = 0.556$ $\sigma_r = 0.178$ $\frac{r}{\sigma_r} = 3.1.$

» » » » June » » » » $r = 0.529$ $\sigma_r = 0.186$ $\frac{r}{\sigma_r} = 2.8.$

» » » » July » » » » $r = 0.323$ $\sigma_r = 0.231$ $\frac{r}{\sigma_r} = 1.4.$

» » » » May—July » » » » $r = 0.592$ $\sigma_r = 0.168$ $\frac{r}{\sigma_r} = 3.5.$

Table 12. Monthly Mean Temperatures and Temperature Anomalies for the Surface Water at the Light-vessels Læsø-Rende (L. R.) and Schultz' Grund (S· G.) and the Number of Salmon and Sea Trout caught in Frisenvold Fish Wear in each of the Months June, July, August in 1880—1898, together with the Values adjusted for Catch and the Catch Anomaly per cent.

Year	Monthly mean temperatures						Temperature anomalies for Læsø-Rende and Schultz' Grund May—July	Year	No. of specimens caught				Catch adjusted	Catch anomaly per cent
	May		June		July				June	July	August	Sum June—August		
	L. R.	S. G.	L. R.	S. G.	L. R.	S. G.								
1880	9.4	9.9	14.3	14.4	16.3	17.6	0.3	1880	21	41	104	166	210	—21
81	8 0	8.4	12.9	13.8	14.6	16.2	—1.1	81	10	32	20	62	179	—65
82	9.3	10.1	13.5	14.2	16.7	17.7	0.2	82	48	132	94	274	151	81
83	9.3	9.5	14.4	14.9	16.5	17.5	0.3	83	12	70	155	237	127	87
84	9.4	9.2	14.3	14.3	17.4	17.7	0.3	84	19	94	32	145	106	37
85	8.3	8.7	13.1	13.4	16.6	17.7	—0.4	85	11	59	29	99	90	10
86	9.4	10.1	13.9	14.8	15.2	16.0	—0.2	86	4	26	35	65	77	—16
87	8.9	9.1	13.9	13.5	16.1	16.4	—0.4	87	15	45	18	78	68	15
88	7.5	7.4	12.9	12.6	14.5	14.9	—1.8	88	6	20	33	59	63	— 6
89	11.4	10.9	18.0	19.2	16.6	17.9	2.3	89	4	17	16	37	59	—37
90	10.8	10.7	13.0	13.5	14.0	15.1	—0.6	90	1	9	21	31	58	—47
91	8.7	8.9	13.8	13.3	17.4	17.8	—0.1	91	1	17	15	33	58	—43
92	8.5	8.7	13.4	13.9	15.0	15.3	—0.9	92	—	9	36	45	61	—26
93	9.4	9.7	14.1	14.5	17.0	17.8	0.4	93	20	87	50	157	65	142
94	9.7	10.5	14.5	14.7	17.3	17.6	0.7	94	17	20	12	49	71	—31
95	10.6	10.4	13.9	15.1	15.6	16.1	0.2	95	1	40	28	69	81	—15
96	10.7	10.6	16.8	16.6	18.2	17.9	1.7	96	18	40	22	80	95	—16
97	9.5	9.7	14.7	15.6	16.4	16.8	0.4	97	4	39	23	66	112	—41
98	8.3	8.4	13.5	13.2	14.9	14.4	—1.3	98	7	24	83	114	135	—16
Mean	9.3	9.5	14.2	14.5	16.1	16.8		Sum	219	821	826	1866	1866	

Correlation between the temperature anomaly for May—July and the catch anomaly per cent for June—August

$$r = 0.111 \quad \sigma_r = 0.227 \quad \frac{r}{\sigma_r} = 0.5$$

Is the Year 1889 omittet, we get $r = 0.248$ $\sigma_r = 0\ 221$ $\frac{r}{\sigma_r} = 1.1.$

Table 13. Temperature Anomalies for the Surface Water at the Light-vessels Læsø Rende and Schultz' Grund in 1899—1913, and the Ratio between Catch of Salmon of the A-group in one year and the Sum of the Catch of A-group in this Year plus B-group in the following Year, and Anomalies for this Ratio.

Year	Temperature anomaly				No. of Salmon — p — of A-group caught in one year	No. of Salmon — q — of B-group caugth in the following year	p + q	$\frac{p}{p+q} \cdot 100$	Anomaly for $\frac{p}{p+q} \cdot 100$
	May	June	July	May—June					
1899	0.0	0.0	1.5	0.0	56	103*)	159	35	— 5
1900	—0.7	0.2	—0.1	—0.2	11*)	51*)	62	18	—23
1	1.1	—0.2	1.8	0.4	100*)	77	177	57	16
2	—1.2	—0.3	—1.3	—0.7	23	30	53	43	3
3	0.1	0.6	—0.7	0.3	17	49	66	26	—15
4	—0.3	—0.1	—0.8	—0.2	46	21	67	69	28
5	0.0	1.0	1.0	0.5	87	86	173	50	10
6	1.0	1.4	—0.4	1.2	135	80	215	63	22
7	—0.6	—2.1	—1.9	—1.3	12	34	46	26	—14
8	—0.9	0.0	1.0	—0.5	32	76	108	30	—11
9	—1.2	—1.4	—1.1	—1.3	70	114	184	38	— 2
10	0.8	1.4	0.7	1.1	198	191	389	51	11
11	1.4	0.8	—0.6	1.1	30	58	88	34	— 6
12	0.1	—0.9	0.9	—0.4	38	104	142	27	—14
13	0.4	—0.4	0.0	0.0	—	—	—	—	—

*) These figures were calculated from the total catch after an analysis of only part of the specimens caught.

Correlation between temperature anomaly for May and anomalies for the proportion $\frac{p}{p+q} \cdot 100$ $r = 0.362$ $\sigma_r = 0.232$ $\frac{r}{\sigma_r} = 1.6$

» » June » » » $r = 0.374$ $\sigma_r = 0.230$ $\frac{r}{\sigma_r} = 1.6$

» » July » » » $r = 0.111$ $\sigma_r = 0.264$ $\frac{r}{\sigma_r} = 0.4$

» » May—June » » » $r = 0.412$ $\sigma_r = 0.222$ $\frac{r}{\sigma_r} = 1.9$

Table 14. Temperature Anomalies for the Surface Water at the Light-vessels Læsø Rende and Schultz' Grund for the Months May—July in the Period 1899—1913, and the Catch of Salmon of A-Group and B-Group together with the Catch Anomaly per cent of same.

Year	Temperature anomaly	A-Group	B-Group	A-Group plus B-Group	Adjusted catch of A-group	Adjusted catch of B-group	Catch anomaly per cent	
							A-Group	B-Group
1899	0.5	56	30	86	42**)	53**)	33	—43
1900	—0.2	11*)	103*)	114	42	53	—74	94
1	0.9	100*)	51*)	151	43	54	133	— 6
2	—0.9	23	77	100	44	54	—48	43
3	0.0	17	30	47	44	56	—61	—46
4	—0.4	46	49	95	47	58	— 2	—16
5	0.7	87	21	108	49	61	78	—66
6	0.7	135	86	221	52	65	160	32
7	—1.5	12	80	92	56	70	—79	14
8	0.0	32	34	66	61	77	—48	—56
9	—1.3	70	76	146	67	84	4	—10
10	1.0	198	114	312	74	92	168	24
11	0.5	30	191	221	80	100	—62	91
12	0.0	38	58	96	87	109	—56	—47
13	0.0	28	104	132	95	118	—71	—12
		883	1104	1987	883	1104	+75	— 4

*) The figures were calculated from the total catch after an analysis of only part of the specimens caught.
**) The adjustment for the catch is calculated after the values adjusted for June—August given in Table 12.

Correlation between temperature anomaly May—July and the catch anomaly per cent for A-Gr. $r = 0.642$ $\sigma_r = 0.152$ $\frac{r}{\sigma_r} = 4.2$

» » » » » » B-Gr. $r = -0.075$ $\sigma_r = 0.257$ $\frac{r}{\sigma_r} = -0.3$

Table 15. Temperature Anomalies for the Surface Water at the Light-vessels Læsø Rende and Schultz' Grund in 1899—1913 and the Ratio between Catch of A-Salmon in May—July (f) and the total Catch of A-Salmon (F) and Anomalies for this Ratio.

Year	Temperature anomaly May—July	Catch of salmon of A-group May—July (f)	Total catch of A-gr. (F)	$100 \cdot \frac{f}{F}$	Anomalies for $100 \cdot \frac{f}{F}$
1899	0.5	39	56	70	8
1900	—0.2	2*)	11	18	—44
1	0.9	72*)	100	72	10
2	—0.9	14	23	61	— 1
3	0.0	6	17	35	—27
4	—0.4	26	46	57	— 5
5	0.7	62	87	71	9
6	0 7	104	135	77	15
7	—1.5	7	12	58	— 4
8	0.0	24	32	75	13
9	—1.3	39	70	56	— 6
10	1.0	131	198	66	4
11	0.5	21	30	70	8
12	0.0	28	38	74	12
13	0.0	20	28	71	9

*) The figures were calculated from the total catch after an analysis of only part of the specimens caugth.

Correlation between temperature anomalies and anomalies for the ratio $100 \cdot \frac{f}{F}$ $r = 0.363$ $\sigma_r = 0.224$ $\frac{r}{\sigma_r} = 1.6$

Table 16. Temperature Anomalies for the Surface Water at the Light-vessels Læsø Rende and Schultz' Grund in 1899—1913 and the Average Weight for the Summer-Salmon, and the Anomalies of this in the same Period.

Year	Temperature anomalies				Average weight per specimen, Kgs.				Anomalies for the average weight			
	May	June	July	May-July	June	July	August	June-Aug.	June	July	August	June-Aug.
1899	0.0	0.0	1.5	0.5	4.16	2.67	2.29	2.92	— 1.11	— 0.76	— 0.91	— 1.01
1900	— 0.7	0.2	— 0.1	— 0.2	5.34	3.28	2.66	3.55	0.07	— 0.15	— 0.54	— 0.39
1	1.1	— 0.2	1.8	0.9	5.16	2.26	2.68	3.04	— 0.11	— 1,17	— 0.52	— 0.90
2	— 1.2	— 0.3	— 1.3	— 0.9	5.31	4.17	3.59	4 55	0.04	0.74	0.39	0.61
3	0.1	0 6	— 0.7	0.0	5.23	2 96	2.41	3.67	— 0.04	— 0.47	— 0,79	— 0.27
4	— 0.3	— 0.1	— 0.8	— 0.4	5.86	2.91	2.43	3.69	0.59	— 0.52	— 0.77	— 0.25
5	0.0	1.0	1.0	0.7	5.94	2.97	2.86	3.33	0.67	— 0.46	— 0.34	— 0.61
6	1.0	1.4	— 0.4	0.7	4.95	3.11	3.71	3.88	— 0.32	— 0.32	0.51	— 0.06
7	— 0.6	— 2.1	— 1.9	— 1.5	6.01	5.44	4.10	5.60	0.74	2.01	0.90	1.66
8	— 0.9	0.0	1.0	0.0	5.09	2.87	3.73	3.69	— 0.18	— 0.56	0.53	— 0.25
9	— 1.2	— 1.4	— 1.1	— 1.3	5.37	3.19	2.66	3.90	0.10	— 0.24	— 0.54	— 0.04
10	0.8	1.4	0.7	1.0	4.18	2.78	2.56	2.95	— 1.09	— 0.65	— 0.64	— 0,99
11	1.4	0.8	— 0.6	0.5	5.67	4.71	4.27	5.14	0.40	1.28	1.07	1.20
12	0.1	— 0.9	0.9	0.0	5.19	3.36	3.23	4.10	— 0.08	— 0.07	0.03	0.16
13	0.4	— 0.4	0.0	0.0	5.52	4.71	4.78	5.04	0.25	1.28	1.58	1.10
Mean figures					5.27	3.43	3.20	3.94				

Correlation between the temperature anomalies for May and anomalies for the average weight in Juni $r = -0.212$ $\sigma_r = 0.247$ $\frac{r}{\sigma_r} = -0.9$

» » » » June » » » » » July $r = -0.434$ $\sigma_r = 0.210$ $\frac{r}{\sigma_r} = -2.1$

» » » » July » » » » » August $r = -0.313$ $\sigma_r = 0.233$ $\frac{r}{\sigma_r} = -1.3$

» » » » May—July » » » June—August $r = -0.568$ $\sigma_r = 0.175$ $\frac{r}{\sigma_r} = -3.2$

Table 17. Temperature Anomalies for the Surface Water at the Light-vessels Læsø Rende and Schultz' Grund in 1899—1913 and the Average Weight for the Sea Trout and the Anomaly for this in the same Period.

Year	Temperature anomalies				Average weight per specimen, Kgs.				Anomaly for the average weight			
	May	June	July	May-July	June	July	August	June-Aug.	June	July	August	June-Aug.
1899	0.0	0.0	1.5	0.5	3.76	2.88	1.65	2.53	—0.20	0·11	—0.75	—0.30
1900	—0.7	0.2	—0.1	—0.2	4.65	3.15	2.25	3 44	0.69	0.38	—0.15	0.61
1	1.1	—0.2	1.8	0.9	4.18	2.70	2.36	2.67	0.22	—0.07	—0.04	—0.16
2	—1.2	—0.3	—1.3	—0.9	4.18	2.59	2.13	2.48	0.22	—0.18	—0.27	—0.35
3	0.1	0.6	—0.7	0.0	4.41	3.05	2.41	3.06	0.45	0.28	0.01	0.23
4	—0.3	—0.1	—0.8	—0.4	4.33	2.32	2.42	2.51	0.37	—0.45	0.02	—0.32
5	0.0	1.0	1.0	0 7	4.09	2.59	1.99	2.57	0.13	—0.18	—0.41	—0.26
6	1.0	1.4	—0.4	0.7	3.64	2.49	2.59	2.83	—0.32	—0.28	0.19	0.00
7	—0.6	—2.1	—1.9	—1.5	4.14	3.32	2.70	3.00	0.18	0.55	0.30	0,17
8	—0.9	0.0	1.0	0.0	4.06	3.05	2.33	2.98	0.10	0.28	—0,07	0.15
9	—1.2	—1.4	—1.1	—1.3	4.06	3.00	3.03	3.18	0.10	0.23	0.63	0.35
10	0.8	1.4	0.7	1.0	3 22	2.21	2.37	2.43	—0.74	—0.56	—0.03	—0.40
11	1.4	0.8	—0.6	0.5	3.53	2.74	2.18	2.80	—0.43	—0.03	—0.22	—0.03
12	0.1	—0.9	0.9	0.0	3.65	2.43	2.86	2.87	—0.31	—0.34	0.46	0.04
13	0.4	—0.4	0.0	0.0	3.55	3.04	2.70	3.06	—0.41	0.27	0.30	0.23
					3.96	2.77	2.40	2.83				

Correlation between the temperature anomalies for May and the anomalies for average weight in June $r = -0.575$ $\sigma_r = 0{,}173$ $\frac{r}{\sigma_r} = -3.3$

» » » » June » » » » » » July $r = -0.509$ $\sigma_r = 0.191$ $\frac{r}{\sigma_r} = -2.7$

» » » » July » » » » » » Aug. $r = -0.399$ $\sigma_r = 0.217$ $\frac{r}{\sigma_r} = -1.8$

» » » » May—July » » » » June—Aug. $r = -0.403$ $\sigma_r = 0.216$ $\frac{r}{\sigma_r} = -1.9$

Table 18. Mean Temperature Anomalies for the Surface Water at the Light-vessels Læsø Rende and Schultz' Grund in the Month of April in each of the Years 1896—1909 and the Sum of A-Salmon caught 3 Years after plus B-Salmon caught 4 Years after the Years named. The sums for the Catch of A-Salmon and B-Salmon are corrected for the Influence which is normally due to the Output of Fry. (See p. 20).

Year	Mean temperature	Temperature Anomalies	Sum of A-Salmon and B-Salmon	Anomalies for the sum of A-Salmon and B-Salmon
1896	5.1	0.8	159*)	82
97	4.6	0.3	62*)	—15
98	4.2	—0.1	177*)	100
99	4.6	0.3	53	—24
1900	3.7	—0.6	66	—11
1	4.1	—0.2	5	—72
2	4 2	—0.1	121	44
3	4.9	0.6	28	—49
4	4.8	0.5	0**)	—77
5	3.6	—0.7	100	23
6	4.5	0.2	103	26
7	4.6	0.3	102	25
8	4.3	0.0	34	—43
9	3.2	—1.1	72	— 5
mean	4.3	—	77	—

*) The figures were calculated from the total catch after an analysis of only part of the specimens caught.

**) The catch total is put down as 0, as the catch calculated from the amount of fry liberated is greater than the real catch of A-Salmon plus B-Salmon.

For the correlation between the temperature anomalies and anomalies for the sum of A-Salmon and B-Salmon we get:

$$r = -0.014 \quad \sigma_r = 0.267 \quad \frac{r}{\sigma_r} = -0.05.$$

DANSK RESUMÉ.

J. P. JACOBSEN og A. C. JOHANSEN:

OM AARSAGERNE TIL FLUKTUATIONERNE I UDBYTTET AF VISSE AF VORE FISKERIER.

I. Lakse- og Ørredfiskerierne.

A. Indledning.

Fluktuationerne i Udbyttet af Lakse- og Ørredfiskerierne har fra gammel Tid tiltrukket sig Opmærksomhed i en Række forskellige Lande. I Almindelighed har man været tilbøjelig til i Hovedsagen at føre dem tilbage til en eller anden Indflydelse, der øves af Mennesket: temporær Overfiskning, Forurening af Floderne, Spærringer af Dele af Vandløbene etc., og naar man ser hen til Laksen og Ørredens relative Individfattigdom og ejendommelige Levevis, idet de baade i det yngste og i det modne Stadium er knyttet til Dele af Floderne, der ligger langt fra disses Udløb, maa det ogsaa erkendes, at store Fluktuationer i Udbyttet maa kunne fremkaldes af Mennesket.

Imidlertid foreligger der Iagttagelser, der peger i Retning af, at ogsaa fysiske Faktorer kan influere paa Udbyttet af Laksefiskerierne[1]), men herom er i Øjeblikket kun lidet kendt. Hvad der vanskeliggør Undersøgelserne, er i Reglen Manglen paa en paalidelig Fangst-Statistik, der strækker sig over en længere Aarrække. Vi har da begrænset vore Undersøgelser til en enkelt Flod, nemlig Gudenaa i det østlige Jylland (Fig. 1 Side 4), hvor en nøjagtig Statistik over Laksefangsten og Ørredfangsten foreligger, og hvor de to Arter i en Aarrække er holdt ude fra hinanden. Skønt det kun er en lille Flod, der her er Tale om, har den utvivlsomt sin egen Bestand saavel af Laks som af Havørred[2]), saa at Undersøgelsen kommer til at omhandle en afsluttet Helhed, men antagelig vil de Resultater, som vi er kommet til, ogsaa kunne finde Anvendelse for andre Lokaliteter.

Ved Gudenaaens nedre Løb, ved Frisenvold i Nærheden af Randers, fandtes indtil for faa Aar siden en Laksegaard, der gik tværs over Aaen, og i hvilken man under normale Forhold var i Stand til at fange praktisk talt alle de opstigende Laks og Ørreder (Fig. 2 Side 5). I en Aarrække, fra 1898 til 1915, sorterede denne Laksegaard under Staten, og den blev i denne Periode drevet som en Forsøgsanstalt. Laksegaarden var dog i en stor Del af den nævnte Periode ikke monteret til Fangst om Vinteren, men i Sæsonen fra Maj til November eller Juni til November fangedes næsten alle de opstigende Laks og Ørreder i dette Fangstredskab[2]). En Oversigt over Fangsterne i Aarene 1899—1914 er givet i Tabellerne 1 og 2 (Side 6). Ogsaa for en længere Periode forud for 1898 førtes der Statistik over Fangsten af Laks og Ørred ved Frisenvold Fiskegaard, men Adskillelsen mellem de to Arter var i tidligere Tid meget ufuldkommen. Hvad der forud for Aaret 1899 betegnedes som Laks var i Reglen kun

[1]) H. Henking: Die Lachsfrage im Ostseegebiet. Rapports et Procès-Verbaux des Reunions. Vol. XVI. Cons. perm. internat. Copenhague 1913. Prof. Henking henpeger her paa, at ensartede Fluktuationer i Udbyttet af Lakse- og Ørredfiskerierne er iagttaget over store Dele af de baltiske Farvande.

[2]) A. C. Johansen og J. Chr. Løfting: Om Fiskebestanden og Fiskeriet i Gudenaaens nedre Løb og Randers Fjord. Skrifter udg. af Kommissionen for Havundersøgelser, Nr. 9. København 1919.

store blanke Laks, d. v. s. Vinterlaks[1]) plus et mindre Antal af store Sommerlaks[1]), der navnlig stiger op i Maanederne Maj og Juni. Hvad der betegnedes som Ørred var saavel Ørred som Laks i Yngledragt. I Tabel 3 Side 8 er der givet en Oversigt over Udbyttet af blanke Laks i Perioden 1853—1898 og i Tabel 12 (Side 34) er fremstillet Fangsten af Ørred plus Sommerlaks, i Maanederne Juni—August i Perioden 1880—1898.

Naar vi, saa vidt det er muligt, har gjort Rede for Aarsagerne til Fluktuationerne i Udbyttet af Lakse- og Ørredfiskerierne i Gudenaa, har vi taget baade den naturlige Yngelmængde, den udsatte Yngelmængde og Temperaturen i Betragtning. Ogsaa andre Forhold øver muligt deres Indflydelse, som f. Eks. Næringsmængde, Mængden af Rovfisk, Lysforholdene, Vandets Iltindhold m. fl., men disse Faktorer unddrager sig for Tiden en nærmere Undersøgelse.

Man kunde paa Forhaand anse det for sandsynligt, at Udbyttet af Lakse- og Ørredfiskerierne er afhængigt af, om der paa den Tid, da Absorptionen af Blommesækken finder Sted, er en mere eller mindre rigelig Adgang til Ernæring for Yngelen. Udklækningen af Yngelen finder hos os normalt Sted i Marts Maaned, og Absorptionen af Blommesækken foregaar overvejende i April. Næringsmængden er utvivlsomt i Foraarstiden i ikke ringe Grad afhængig af Temperaturen, og sandsynligvis gennemsnitlig størst, naar Temperaturen er højest. Det ligger da nær at undersøge, om Fluktuationerne i Fangstudbyttet muligt kunde forklares ved Temperaturens Indflydelse paa Næringsmængden i Foraarstiden og derigennem paa Mængden af spæd Yngel, der overlever den kritiske Periode umiddelbart efter Blommesækkens Absorption. En saadan Undersøgelse er mulig, da vi kender den Tid, der forløber mellem Laksens Udklækning og dens Opgang fra Havet som Vinterlaks[2]). Denne Tid er normalt $4^1/_2$—5 Aar. Den Opgave, der nu foreligger, er da at foretage en Sammenligning mellem Temperaturen i April Maaned og Fangsten af Blanklaks i Maanederne November—April $4^1/_2$—5 Aar senere. Herved er at bemærke, at Laksefangsten $4^1/_2$—5 Aar efter April Maaned i et bestemt Aar ikke i det forhaandenværende Materiale kan udskilles fra Laksefangsten 4—$4^1/_2$ Aar efter samme Termin, men Fangsten af Laks, saaledes som dette Begreb i ældre Tid opfattedes, er i Maanederne Maj—Oktober saa ringe i Forhold til Fangsten i November—April, at det ikke vil kunne influere stærkt paa Beregningerne, om den medregnes til Udbyttet fra November—April.

Sammenligningen er da foretaget for Tiden 1849—1894 for Temperaturens Vedkommende og for Tiden $^1/_5$ 1853—$^{30}/_4$ 1899 for Fangstens Vedkommende. I denne Tid har der ikke været udsat kunstig udklækket Yngel af nogen Betydning, saa at man ikke behøver at regne med den forstyrrende Indflydelse herfra. Udfor de i Kolonne 2 Tabel 3 (Side 8) opførte Værdier for Fangstudbyttet for de i Kolonne 1 angivne Fangstperioder er der i Tabellens Kolonne 7 opført Middeltemperaturen for April Maaned i det Aar (Kolonne 6), med hvilket Fangstudbyttet skal sammenlignes. Paa Grund af, at der ikke findes sammenhængende Maalinger af Temperaturen i Havet eller Randers Fjord for Størstedelen af den her omhandlede Aarrække, har vi ved denne Sammenligning, i Modsætning til, hvad der ellers er Tilfældet i denne Afhandling, maattet nøjes med Lufttemperaturen som Udtryk for Overfladevandets Temperatur. Ved Velvilje fra Dansk meteorologisk Institut har vi kunnet benytte en Række Værdier for Middeltemperaturen i April i Randers for Aarrækken 1864—1894, men for Aarene 1849—1863 har vi maattet gaa ud fra de for København foreliggende Middelværdier, idet disse blev korrigeret med den Forskel, som der for Aarene 1864—1894 viste sig at være paa Apriltemperaturen i Randers og i København. Forskellen var forøvrigt ikke stor, idet Apriltemperaturen i Randers kun var 0.2° lavere end i København.

Ved en direkte Sammenligning af de to Talrækker i Kolonne 2 og Kolonne 7 Tabel 3 vil man faa det Indtryk, at der ikke er nogen udpræget Sammenhæng mellem dem, men for at faa Spørgsmaalet

[1]) Ved Vinterlaks forstaas her blanke Laks, der stiger op i Tiden fra Oktober til Slutningen af April for at yngle i det paafølgende Efteraar. Ved Sommerlaks forstaas Laks, der stiger op i Tiden efter første Maj, og som yngler i den første derefter følgende Gydeperiode.

[2]) Kun meget faa Laks yngler mere end 1 Gang i Gudenaa, se Johansen og Løfting l. c. 1919.

nøjere undersøgt, har vi anvendt en Metode, som i højere Grad end det ret subjektive Skøn, som faas ved en direkte Sammenligning, kan benyttes til at afgøre, om der findes en Forbindelse mellem de omhandlede Værdier for Fangstudbyttet og Apriltemperaturen. Denne Metode er den saakaldte Korrelationsmetode i en lidt modificeret Form, hvis Anvendelse vi har gjort Rede for paa Side 7. Ved Anvendelsen af denne Metode kommer vi til det Resultat, at der ingen Sammenhæng kan paavises mellem Apriltemperaturen i Udklækningsaaret og Fangsten af Vinterlaks $4^1/_2$—5 Aar senere.

B. Fluktuationer i Udbyttet fremkaldt af Variationer i den naturlige Yngelmængde.

Betragter man Fig. 3 S. 13, der viser Fangsten af blanke Laks (altsaa hovedsagelig Vinterlaks) ved Frisenvold Fiskegaard i Aarene 1853 til 1898, vil det ses, at der er visse Toppe og visse Dale paa Kurven, der kommer igen med regelmæssige Mellemrum. Særlig markeret er dette Fænomen for Laksen i Perioden 1853—1868. Mellem Toppene er der et Tidsrum af 5 à 6 Aar. Disse Maksima og Minima forklares naturligt paa følgende Maade: Vinterlaksens Livscyklus er i Reglen 6 Aar, sjeldnere 5 Aar[1]). Det antages, at der i de Aar, da Fangstudbyttet er stort, ogsaa udvikles en rigeligere Yngelmængde end normalt, idet der rimeligvis gennemsnitlig slipper flere Laks forbi Fiskegaarden (under Oversvømmelser etc.) i de Aar, hvor Opgangen er stor, end i de Aar, hvor Opgangen er ringe, og naar forholdsvis mange Laks kommer til at yngle, udvikles der gennemsnitlig mere Yngel end sædvanlig. Toppene paa Kurven gentager sig derfor for Vinterlaksens Vedkommende med 5 à 6 Aars Mellemrum.

Skønt det saaledes ved en simpel Betragtning af Kurven Fig. 3 ret tydeligt fremgaar, at der virkelig findes en Sammenhæng mellem Fangsten i et Aar og Fangsten 5 à 6 Aar senere, kan det dog være af Interesse at undersøge denne Sammenhæng noget nærmere, og vi har dertil anvendt den foran omtalte Korrelationsmetode.

Som Grundlag for Beregningerne anvender vi de i Tabel 3 (Side 8) opførte Værdier for den procentiske Fangstanomali[2]) for de i Tabellens første Kolonne anførte Perioder fra 1. Maj til 30. April. For Kortheds Skyld vil vi betegne disse aarlige Perioder ved Kalenderaarene, saaledes at en Periode betegnes ved det Kalenderaar, i hvilket den største Del af den er beliggende.

Vi vil da sammenligne de procentiske Anomalier for 1853, 1854, ... 1897 med de procentiske Anomalier for 1854, 1855, ... 1898, hvorved vi faar undersøgt, hvilken Sammenhæng der er mellem Fangstudbyttet i et Aar og det følgende. Paa lignende Maade vil vi undersøge Sammenhængen mellem Fangstudbyttet i et Aar og det andet, tredje, fjerde, femte, sjette og syvende følgende Aar, idet vi, efter hvad vi saa ved en umiddelbar Betragtning af Kurven, i hvert Fald maa vente, at der vil vise sig en Sammenhæng mellem Fangstudbyttet i et Aar og Fangstudbyttet 5 eller 6 Aar senere.

Beregningerne for de forskellige Forskydninger giver følgende Resultat:

Forskydning, Antal Aar	1	2	3	4	5	6	7
$r =$	— 0.17	— 0.11	— 0.25	0.05	0.06	0.32	— 0.31
$\sigma_r =$	0.14	0.15	0.14	0.15	0.16	0.14	0.14
$\frac{r}{\sigma_r} =$	— 1.2	— 0.76	— 1.8	0.36	0.37	2.24	— 2.15

Man ser heraf, at der er en positiv Korrelation mellem Fangstudbyttet i et Aar og Fangstudbyttet 6 Aar senere. Har derfor Fangstudbyttet et bestemt Aar været henholdsvis rigt, normalt eller ringe, maa man vente et Fangstudbytte af lignende Art 6 Aar senere, forudsat at de samme Betingelser for Gydningen og Yngelens Udvikling er til Stede som i det betragtede Aar. (Se Fig. 4 Side 14).

[1]) Unglaksens Levetid i det ferske Vand varer i Gudenaa i Reglen 2 Aar (70—80 %), sjeldnere 1 Aar. Vinterlaksen yngler næsten altid $3^1/_2$—4 Aar efter dens Udvandring til Havet ($2^1/_2$—3 Aar i Havet, 1 Aar i Floden. A. C. Johansen og J. Chr. Løfting l. c. 1919.

[2]) Ved den procentiske Fangstanomali forstaar vi det Antal Procent, som Forskellen mellem det virkelige Fangstudbytte og Normalfangsten udgør af Normalfangsten.

For Perioden 1899—1914 muliggør det forhaandenværende statistiske Materiale vedrørende Laksefangsten ved Frisenvold Fiskegaard en langt finere gennemført Analyse end for Perioden 1853—1898. For det første gennemførtes efter 1898 en fuldstændig Adskillelse mellem Laks og Ørred, og dernæst maaltes Totallængden af hver enkelt af de indfangede Fisk. Paa den anden Side holdtes Fiskegaarden nu ikke lukket til Fangst i visse af Vintermaanederne. Medens vi for den tidligere Periode besad en Statistik, der væsentligst omfattede Vinterlaksen, har vi for Perioden 1899—1914 kun en fuldstændig Statistik for Fangsten af Sommerlaks.

Sommerlaksen bestaar hovedsagelig af to Grupper: Gruppe A, der yngler ca. $1^1/_2$ Aar efter Udvandringen til Havet, og overvejende stiger op i Maanederne Juli og August, og Gruppe B, hvis Yngletid falder ca. $2^1/_2$ Aar efter Udvandringen til Havet, og hvis Hovedopgang falder i Juni og Juli. Hertil kommer enkelte Sommerlaks af Gruppe C, der har tilbragt ca. 3 Aar i Havet og yngler ca. $3^1/_2$ Aar efter Udvandringen. Hovedmassen af Laksen af alle disse tre Grupper tilbringer som Unglaks to Aar i Ferskvand.

Vi har nu paa Tabel 6 (Side 28) gennemført en Adskillelse mellem Laks af Gruppe A og Laks af Gruppe B. Det har været muligt at gennemføre denne Adskillelse med stor Tilnærmelse ved en Betragtning af Individernes Størrelse og ved en Undersøgelse af Skællene af et mindre Antal Individer[1]). De faa Individer af Gruppe C har derimod ikke i det forhaandenværende Materiale kunnet adskilles fra Gruppe B.

Det fremgaar af det her anførte, at der af Yngelen i et bestemt Aar dels fremkommer A-Laks tre Aar senere, dels B-Laks fire Aar senere, og nu viser det sig netop, at der mellem Antallet af A-Laks i et bestemt Aar og Antallet af B-Laks det følgende Aar er en tydelig Forbindelse. Undersøger man Korrelationen mellem Fangstanomalierne for A-Laks i et Aar og Fangstanomalierne for B-Laks i det følgende Aar i Perioden 1899—1913 faas følgende Værdier:

$$r = 0.783; \quad \sigma_r = 0.103; \quad \frac{r}{\sigma_r} = 7.6.$$

Dette Forhold peger tydeligt hen paa, at Fluktuationerne i Udbyttet er afhængige af Yngelmængden, men det viser intet nærmere om, hvorvidt det er den naturligt udviklede Yngel eller den kunstigt udklækkede Yngel, der i Perioden 1899—1914 har givet de væsentligste Udslag. Som det fremgaar af det følgende Kapitel, maa det antages, at Hovedmassen af de indfangede Sommerlaks i denne Periode stammer fra den kunstigt udklækkede Yngel.

Den anførte Beregning viser, at man med betydelig Sikkerhed kan forudsige, at hvis der fanges relativt mange A-Laks i et bestemt Aar, vil der ogsaa fanges relativt mange B-Laks i det følgende Aar, og at en ringe Fangst af A-Laks vil blive fulgt af en ringe Fangst af B-Laks i det følgende Aar.

C. Fluktuationer i Udbyttet af Lakse- og Ørredfangsten paavirket af Variationer i Mængden af udsat Yngel.

For Sommerlaksens Vedkommende viser Fig. 5 (Side 16), som fremstiller Antallet af de i Juni, Juli og August fangede Laks for Tidsrummet 1899—1913, nogle faa udprægede Maksima, der er adskilte ved et Tidsrum af 4 à 5 Aar. Disse Maksima kan ikke forklares helt analogt med de foran omtalte Maksima for Vinterlaksens Vedkommende, skønt Sommerlaksens normale Livscyclus for Hannernes Vedkommende i Reglen er 4 eller 5 Aar og for Hunnernes Vedkommende i Reglen 5 Aar. Næsten alle Sommerlaks, der stiger op i Gudenaa for at yngle, og som ikke allerede fanges ved Fiskeriet i Randers Fjord, fanges nemlig i Fiskegaarden ved Frisenvold. Der er ikke Grund til at antage, at der slipper mange flere Sommerlaks forbi Fiskegaarden i de Aar, hvor Opstigningen er størst, end i de øvrige Aar.

[1]) A. C. Johansen og J. Chr Løfting: Über den Gudenaa-Laks in H. Henking: Die Lachsfrage im Ostseegebiet II. Rapports et Procès-Verbaux Cons. perm. Internat. Vol. XXIII 1916.

Frisenvold Fiskegaard har været anvendt til Fangst hele Sommeren igennem i alle Aarene fra 1899—1913, og i Sommertiden er større Oversvømmelser sjeldne. Der er da Grund til at undersøge, om de to udprægede Maksima i Fangsten i 1906 og 1910 ikke skulde skyldes andre Aarsager end Vekslinger i Mængden af den i Gudenaa udviklede Lakseyngel.

Vi har da først og fremmest undersøgt, om de nævnte Maksima i 1906 og 1910—11 ikke kan forklares ud fra den Omstændighed, at der i visse Aar forud for 1906 og 1910—11 har været udsat forholdsvis megen kunstig udklækket Lakseyngel i Gudenaa eller dennes Tilløb.

Som det vil ses af Tabel 5 Side 17 omfatter Udsætningen særlig store Mængder af spæd Yngel i 1903 og 1907 og særlig store Mængder af Halvaarsyngel i 1907 og i Aarene 1912—14. Hvis Udsættelsen af kunstig udklækket Yngel i det Hele har nogen Virkning, maa denne da i Hovedsagen spores efter tre Aars Forløb for Gruppe A og efter fire Aars Forløb for Gruppe B's Vedkommende (Side 17). For at faa et samlet Udtryk for Virkningen af en Yngeludsætning vil det derfor være naturligt at betragte de to Virkninger: paa A-Laks 3 Aar efter Yngeludsætningen og paa B-Laks 4 Aar efter Yngeludsætningen under eet. Ved denne Fremgangsmaade undgaar vi en forstyrrende Indflydelse af det Fænomen (der senere er omtalt), at en høj Sommertemperatur fremskynder Modningen hos Laksen og derved fremkalder en relativ stor Opgang af A Laks, medens en lav Sommertemperatur har den modsatte Virkning.

Som det vil ses af Fig. 6 (Side 18) er der en udpræget Overensstemmelse mellem de Kurver, der viser Antallet af udsat spæd Yngel og Størrelsen af Fangsten af A-Laks 3 Aar senere plus Fangsten af B-Laks 4 Aar senere. Særlig fortjener det at fremhæves, at den store Udsætning af spæd Yngel i 1903 fulgtes af et Maksimum i Fangsten af A-Laks i 1906 og B-Laks i 1907. I Aaret 1902 var Laksefangsten mindre end normal, og der er derfor intet der tyder paa, at der i Foraaret 1903 skulde være fremkommet særlig store Mængder af naturligt udklækket Lakseyngel. Ogsaa Udsættelsen af Halvaarsyngel var ringe i 1903. Den store Udsættelse af spæd Yngel i 1907 fulgtes ogsaa af et Maksimum i Fangsten af A-Laks tre Aar senere og af B-Laks fire Aar senere. De to udprægede Maksima i Fangsten af A-Laks i 1906 + B-Laks i 1907 samt af A-Laks i 1910 + B-Laks i 1911 forklares saaledes naturligt ved, at der blev udsat forholdsvis store Mængder af spæd Lakseyngel i 1903 og 1907. Mindre iøjnefaldende er derimod Overensstemmelsen mellem Antallet af udsatte Halvaarslaks og Fangsten af A-Laks 3 Aar senere plus Fangsten af B-Laks 4 Aar senere. Ganske vist fulgtes den store Udsætning af Halvaarsyngel i 1907 af et Maksimum i Fangsten af A-Laks i 1910 plus B-Laks i 1911, men omvendt fulgtes den store Udsætning af Halvaarsyngel i 1904 af et Minimum i Fangsten af A-Laks i 1907 plus B-Laks i 1908. Der er saaledes ikke Tvivl om, at den Kurve, der illustrerer Udsætningen af den spæde Yngel, viser langt større Overensstemmelse med Fangstkurven end den Kurve, der illustrerer Udsætningen af Halvaarsyngelen.

Korrelationen mellem den udsatte Mængde af Yngel i Aarene 1900—1909 og Fangsten af A-Laks 3 Aar senere plus Fangsten af B-Laks 4 Aar senere har følgende Værdier[1]):

Spæd Yngel korreleret med Fangst af A-Laks plus B-Laks:

$$r = 0.83$$

$$\sigma_r = 0.10$$

$$\frac{r}{\sigma_r} = 8.3.$$

Halvaarsfisk korreleret med Fangst af A-Laks plus B-Laks:

$$r = 0.64$$

$$\sigma_r = 0.18$$

$$\frac{r}{\sigma_r} = 3.5.$$

[1]) Materialet for en Korrelationsberegning er dog ikke helt tilfredsstillende, bl. a. fordi der er en vis Korrelation mellem Mængden af den udsatte spæde Yngel og Mængden af Halvaarsyngelen ($r = 0.60$; $\sigma_r = 0.20$; $\frac{r}{\sigma_r} = 3.0$), og fordi den Aarrække, for hvilken Forbindelsen mellem Udsætning og Fangst undersøges, er forholdsvis kort.

Da der af den spæde Yngel i Perioden 1901—09 gennemsnitlig kun er udsat ca. 4 Gange saa mange Individer som af Halvaarsyngelen, medens 1000 Stk. Halvaarsyngel koster ca. 15 Gange saa meget som 1000 Stk. spæd Yngel, peger dette Forhold med Bestemthed hen paa, at Udsætningen af spæd Yngel har været mere fordelagtig end Udsætningen af Halvaarsfisk.

For nærmere at komme til Klarhed over, i hvilken Grad Udsættelsen af spæd Yngel og af Halvaarsyngel har Indflydelse paa Størrelsen af Fangsten, har vi underkastet det foreliggende Materiale (Tabel 5 og 6) en mere indgaaende Undersøgelse.

Gaar vi ud fra, at der af en vis Yngelmængde Q, 3 Aar senere genfanges en Brøkdel (p) som A-Laks og 4 Aar senere en Brøkdel (q) som B-Laks, bliver det samlede Antal fangne Individer F, der hidrører fra den betragtede Yngelmængde $F = (p + q) \cdot Q$. Gaar man ud fra, at Størrelserne p og q væsentlig er de samme for den hele Aarrække, vil man altsaa have, at den betragtede Fangstsum F af A og B Gruppens Individer i det væsentlige maa være proportional med Yngelmængden Q. Naturligvis kan tilfældige Faktorer bevirke, at p og q kun med Tilnærmelse kan anses for at være de samme for forskellige Aar, og dette vil da ogsaa give sig til Kende ved, at en Beregning, der gennemføres paa det anførte Grundlag, vil vise en betydelig Middelfejl for Størrelsen $p + q$. Et af de Forhold, som bevirker, at p og q kan være forskellige fra Aar til andet, er det, at en høj Temperatur i Foraarsmaanederne fremkalder en Forskydning fra B-Gruppen til A-Gruppen, som det senere skal omtales, idet nogle af de Individer, som normalt skulde gaa op som Individer af B-Gruppen, ved en høj Temperatur forkorter deres Ophold i Havet og gaar op som Laks af A-Gruppen, og omvendt ved lav Temperatur, at nogle af de Laks, som normalt skulde gaa op som Individer af A-Gruppen, forbliver et Aar længere i Havet og gaar op som Individer af B-Gruppen. Imidlertid maa man gaa ud fra, at man i Summen af fangede A-Laks i et bestemt Aar og B-Laks i det følgende Aar har det bedste Udtryk, der kan tilvejebringes, for Antallet af de Individer, der stammer fra den Yngelmængde, som har været til Stede tre Aar før Fangsten af A-Laksen og 4 Aar før Fangsten af B-Laks.

For at faa det bedst mulige Udtryk for, paa hvilken Maade Fangstsummen afhænger af den udsatte Yngelmængde, dels af spæd Yngel, dels af Halvaarsyngel, har vi opstillet Fangstsummen F som en Funktion af de udsatte Mængder af spæd Yngel, m, halvaars Yngel, M, og en konstant Størrelse C, der skal betegne den Størrelse, som Fangstsummen skulde have haft, hvis der ingen kunstig Yngel havde været udsat. Man har da:

$$F = x \cdot m + y \cdot M + C.$$

F og C udtrykkes som Antallet af Individer, m og M angives i Tusinder.

Gennemføres Beregningen ved de mindste Kvadraters Metode, finder man af de i Tabel 5 anførte Tal:

$x = 1.4$ Middelfejl paa $x = 0.5$
$y = 1.9$ — — $y = 2.0$
$C = 58$ — — $C = 30$.

Dette vil altsaa sige, at man som Resultat finder, at der af 10000 Stk. udsat spæd Yngel genfanges 14 Stk. som Laks af A- eller B-Gruppen ved Frisenvold, medens man af 10000 Stk. $^1/_2$ Aars Yngel genfanger 19 Stk. Uafhængig af den udsatte Yngel skulde man gennemsnitlig have fanget 58 Individer om Aaret. Middelfejlen paa de beregnede Størrelser viser, at Beregningerne vel er usikre, men at man dog særlig for den spæde Yngels Vedkommende maa antage, at de giver et godt Udtryk for Fangstens Afhængighed af den udsatte Yngelmængde. Det konstante Antal 58 for Fangstsummen synes ogsaa en rimelig Værdi, idet det ikke er meget forskellig fra det Antal, som beregnes som Middelværdi for Fangstsummen de 5 Aar før Yngeludsætningen begyndte, og ikke afviger saa meget fra dette som Middelfejlen paa det beregnede Antal C, nemlig 30.

De foretagne Beregninger bekræfter saaledes det Resultat, vi kom til ved en Sammenligning mellem de Kurver, der betegner Størrelsen af Yngeludsætningen og den Kurve, der betegner Størrelsen af Fangsten af A-Laks og B-Laks henholdsvis 3 og 4 Aar efter Udsætningen.

Vi har nu set, at 1000 Stk. Halvaarsfisk sandsynligvis ikke har en synderlig større Værdi til Udsætningsbrug end 1000 Stk. spæd Yngel, og at der i alt Fald kun er en ringe Sandsynlighed for, at 1000 Stk. Halvaarsfisk skulde være lige saa meget værd til Udsætningsbrug som 4000 Stk. spæd Yngel. Da opdrættede Halvaarslaks gennemsnitlig har kostet ca. 15 Gange saa meget som spæd Yngel, er det Resultat, vi er kommet til, af stor økonomisk Rækkevidde. Man har hidtil ikke haft noget Holdepunkt for, om Udsætning af Halvaarsyngel eller Udsætning af spæd Yngel betaler sig bedst. I Danmark har der været en Tendens til i Tidens Løb at lægge større og større Vægt paa Udsætningen af Halvaarsyngel. Denne Vej bør nu forlades. De foretagne Undersøgelser taler med Bestemthed for, at Udsætning af kunstig fodrede Sættefisk bør opgives til Fordel for Udsætning af spæd Yngel.

Det kunde synes at være et meget beskedent Resultat, at Udsætningen af 10000 Stk. spæd Yngel fremkalder en Stigning i Fangsten ved Frisenvold af 14 Sommerlaks. Men dette er i Virkeligheden et meget gunstigt Resultat. Værdien af 10000 Stk. spæd Yngel kan sættes til ca. 60 Kr. (før Krigen ca. 30 Kr.). Vægten af 14 Sommerlaks er ca. 56 kg, og Værdien ca. 4 Kr. pr. kg, altsaa ialt 224 Kr. (før Krigen 1 à 2 Kr. pr. kg). Men hertil kommer, at mange af de opstigende Sommerlaks fangedes i Randers Fjord eller i Gudenaaens nederste Løb, førend de naaede Frisenvold Fiskegaard, og endvidere fangedes adskillige Laks, der rimeligvis tilhørte Gudenaa-Stammen, ved Jyllands østlige Kyster.

Endelig er der en Mulighed for, at der af den udsatte Yngel, som stammer fra Sommerlaks, delvis kan være udviklet Vinterlaks, men herom vides i Øjeblikket intet.

Det har da sikkert været et meget rentabelt Foretagende at udsætte spæd Yngel af Laksen i Gudenaa og dennes Tilløb.

De Halvaarslaks, der har været anvendt til Udsættelse i Gudenaa og dennes Tilløb, stammer i det store og hele fra Damme, hvor de er blevne fodrede og derved sandsynligvis forkælede. Ungfisk, der stammer fra Damme, hvor de selv maa sørge for Føden, er rimeligvis mere værdifulde som Sættefisk. Ved Forsøgene i Gudenaa har den spæde Yngel af Laksen bestaaet Prøven som en værdifuld Sættefisk, men endnu foreligger der ingen videnskabeligt gennemført Forsøgsrække, der kan vise, hvilken Værdi Ungfisken af Laks eller Ørred fra »Naturdamme« har til Udsætningsbrug i Forhold til den spæde Yngel.

I Aarene 1912—14 blev der i Gudenaa og dennes Tilløb ikke udsat spæd Yngel af Laks, men derimod Halvaarsfisk i ret betydeligt Antal, gennemsnitlig ca. 39000 Stk. pr. Aar (Tabel 5). Da Frisenvold Fiskegaard blev nedlagt i 1915, kan der ikke fra dette Sted skaffes Oplysninger om Virkningen af denne Udsættelse, men det kan ad anden Vej skønnes, at Virkningen ikke har været betydelig og sikkert ikke større end den beregnede. Efter Nedlæggelsen af Frisenvold Fiskegaard passerede Sommerlaksen forbi denne, men de allerfleste Individer indfangedes nu højere oppe i Aaen paa Strækningen mellem Langaa og Silkeborg (Fig. 1). Efter Nedlæggelsen af Frisenvold Fiskegaard steg Fangsten af Sommerlaks paa denne Strækning, men dog ikke mere, end at den samlede Fangst af Laks paa den nævnte Strækning i Aarene 1915—1918 efter Oplysninger fra den stedlige Fiskeribetjent var ca. 160 Stk. gennemsnitlig pr. Aar, hvoraf Sommerlaksen udgjorde ca. Halvdelen. Da næsten alle de kønsmodne Laks fanges i Gudenaa før, under eller efter Gydningen, tør det ikke antages, at der af de 39000 Halvaarsfisk aarlig er fremkommen mere end ca. 80 Sommerlaks, der har passeret forbi Frisenvold Fiskegaard. Derimod er det meget vel muligt, at Virkningen har været betydelig ringere, idet adskillige Sommerlaks utvivlsomt hidrører fra den naturlige Bestand af ynglende Laks.

De 39000 Stk. Halvaarsfisk skulde i Følge Beregning efter det før anførte have forøget Fangsten med 74 Individer pr. Aar.

For Havørredens Vedkommende muliggør det forhaandenværende Materiale ikke en saadan Adskillelse mellem A-Gruppen og B-Gruppen som for Laksens Vedkommende. Desuden spiller saavel C-Gruppen som Individer, der tidligere har ynglet, en langt større Rolle for Havørredens end for Sommerlaksens Vedkommende. Disse Forhold bevirker, at vi ikke kan gennemføre en saadan Undersøgelse angaaende Virkningen af den udsatte spæde Yngel og af Halvaarsyngelen for Ørredens Vedkommende som for Laksens Vedkommende. Men naar man ser hen paa den store Overensstemmelse i Laksens og Havørredens Biologi, vil man ikke tage i Betænkning at bringe de indvundne Resultater ved Udsætning af Lakseyngelen i Anvendelse ogsaa ved Udsætningen af Havørredens Yngel. Adskillige Forhold peger tydeligt nok hen paa, at Udsætningen af den kunstigt udklækkede Ørred-Yngel i de forskellige Alderstrin har influeret stærkt paa Størrelsen af Fangsten. Efter en usædvanlig stor Udsætning af Yngel i 1906 fulgte saaledes en usædvanlig stor Fangst i 1910, og efter en lignende stor Udsætning i 1909 fulgte en Fangst, der var større end normalt, i 1912 og 1913 (Fig. 5).

D. Fluktuationer i Lakse- og Ørredfangsten fremkaldt af Sommertemperaturen.

1. Sommertemperaturens Indflydelse paa Antallet af opstigende Individer.

Vi har foretaget en Undersøgelse af, om Sommertemperaturen har nogen Virkning paa de iagttagne Svingninger i Udbyttet af Laksefangsten og Ørredfangsten ved Frisenvold Fiskegaard. Vi har da først betragtet Fangsten indenfor Perioden 1899—1913, for hvilken der foreligger en aldeles paalidelig Statistik for Sommerlaksens og Havørredens Vedkommende med en nøje gennemført Adskillelse mellem de to Arter. (Se Tabellerne 1 og 2).

Det, vi ønsker at sammenligne, er Udsvingene fra den normale Sommertemperatur og den procentiske Fangstanomali for Laks og Havørred (se Side 9). Som Udtryk for Sommertemperaturen paa Sommerlaksens og Opgangsørredens Opholdssteder har vi taget Middeltemperaturen i Overfladevandet ved Fyrskibene Læsø Rende og Schultz' Grund. Paa Tabel 7 er Temperaturen og Temperaturanomalierne opførte for Maanederne Maj—September for Perioden 1899—1913. Paa Tabel 8 er opført Fangsten og Fangstanomalierne for Laks i Maanederne Juni—Juli—August, i den anførte Periode, og Tabel 9 indeholder en lignende Oversigt for Havørredens Vedkommende. Tabellerne er givet i grafisk Fremstilling i Figur 5, paa hvilken tillige den udjævnede Kurve, der repræsenterer Normalfangsten, er indtegnet. Endelig indeholder Tabel 10 den beregnede Korrelation mellem Temperaturanomalierne og Fangstanomalierne. Temperaturen i en bestemt Periode stilles her overfor Fangsten i en bestemt Periode. Betragter vi først de fundne Korrelationskoefficienter for Laksens Vedkommende, vil det ses, at disse alle er positive og særlig store, hvor Temperaturen i Maj sammenholdes med Fangsten i Juni og Juli, og hvor Temperaturen i Juni sammenholdes med Fangsten i Juli. I et Par af disse Tilfælde er Korrelationskoefficienten mere end 3 Gange saa stor som Middelfejlen paa denne. Sammenholder man endelig Temperaturen for Maj—Juli med Fangsten for Juni—August faas Korrelationskoefficienten (r) = 0.509 med Middelfejlen (σ_r) = 0.191, saaledes at Korrelationskoefficienten her er 2.7 Gange saa stor som Middelfejlen. Denne Forbindelse mellem Temperaturanomalien og Fangstanomalien er illustreret paa Fig. 7 Side 22.

For Havørredens Vedkommende viser Tabel 10 en tilsvarende Korrelation mellem Temperaturanomalierne og Fangstanomalierne som for Laksens Vedkommende. Særlig store Værdier faar Korrelationskoefficienten, naar vi sammenholder Maj-Temperaturen med Juni-Fangsten og Juni-Temperaturen med Juni-Fangsten. Vi finder her, at r i førstnævnte Tilfælde er 5.8 Gange saa stor som dens Middelfejl, og i sidstnævnte Tilfælde 9.3 Gange saa stor som dens Middelfejl.

Eksempler paa Forbindelsen mellem Temperaturanomalier og Fangstanomalier er fremstillet paa Fig. 7—10 Side 22—25.

Temperaturen i Maj og Juni paavirker saaledes kendelig Fangsten i Juni og Juli, men har ingen sikkert paaviselig Virkning paa Fangsten i de senere Maaneder af Aaret. Temperaturen i Juli kunde synes at have en vis ringe Virkning paa Fangsten i Juli og August, men muligvis skyldes dog denne tilsyneladende Sammenhæng den Omstændighed, at der er en vis Korrelation mellem Temperaturen i de forskellige Sommermaaneder. Temperaturen i August og September synes ikke at influere paa Fangsten i Aarets senere Maaneder.

Den Mulighed kan ikke afvises, at den iagttagne Korrelation mellem Temperaturanomalierne og Fangstanomalierne i Perioden 1899—1913 i nogen Grad kunde være af tilfældig Art, og f. Eks. skyldes Anomalier fremkaldt ved Udsætning af den kunstigt udklækkede Yngel. Det viser sig f. Eks. rent tilfældigt, at der indtraf varme Somre 3 Aar efter den store Yngeludsætning i 1903 og 3 og 4 Aar efter den store Yngeludsætning i 1907. Tilfældigheder af denne Art medfører, at Korrelationskoefficienten bliver større end den ellers vilde være blevet.

For at undgaa en forstyrrende Virkning af den kunstigt udklækkede Yngel ved Undersøgelsen af Forbindelsen mellem Sommertemperaturen og Størrelsen af Fangsten, har vi betragtet Sagen fra et andet Synspunkt. Hvis den høje Sommertemperatur har den Virkning, at Antallet af opstigende Laks vokser, kan dette ikke forklares paa anden Maade end ved at Temperaturen virker fremmende paa Modningen, idet alle de Laks, der stiger op i Sommertiden, skal yngle i den første derpaa følgende Gydeperiode. Det maa da antages, at adskillige af de Laks, der ved en lav eller normal Sommertemperatur bliver til B-Laks, ved en høj Sommertemperatur forkorter deres Ophold i Havet og bliver til A-Laks. Vi har da foretaget en Undersøgelse, der kan vise, om der i varme Somre fanges et relativt stort Antal af A-Laks, idet vi har betragtet Forholdet mellem Fangsten af A-Laks i et bestemt Aar (p) og Fangsten af A-Laks i samme Aar plus B-Laks (q) det følgende Aar. Vi er herved gaaet ud fra, at Forholdet mellem A-Laks og B-Laks bliver det samme for den udsatte Yngel som for den i Naturen udviklede Yngel. Vi finder da ved Beregning den paa Tabel 13 anførte Korrelation, der bekræfter, at den høje Temperatur virkelig har den Virkning, at Antallet af opstigende Laks vokser.

Der maa ved Betragtning af de fundne Værdier for Korrelationen lægges Vægt paa, at disse i alle Tilfælde er positive.

Naar vi i det foregaaende har set, at der i varme Somre stiger flere Laks og Havørreder op end normalt, maa dette som foran anført betyde, at Modningen fremskyndes hos en Del af Individerne, saaledes at deres Ophold i Havet forkortes. Det vil da være af Betydning at undersøge, om der her finder en Forskydning Sted baade fra B-Gruppe til A-Gruppe og fra C-Gruppe til B-Gruppe. For Laksens Vedkommende er en saadan Undersøgelse mulig, idet vi her med stor Tilnærmelse kan adskille de tre Grupper fra hinanden.

Undersøger man Korrelationen mellem Temperaturanomalierne for Maj, Juni og Juli og Udsvingene fra Middelfangsten i Løbet af Sommeren for Perioden 1899—1913 henholdsvis for Laks af Gruppe A og Laks af Gruppe B, faas følgende Resultat (se Tab. 14):

Laks af Gruppe A.

$$r = 0.642, \quad \sigma_r = 0{,}152, \quad \frac{r}{\sigma_r} = 4.2.$$

Laks af Gruppe B.

$$r = -0.075, \quad \sigma_r = 0.257, \quad \frac{r}{\sigma_r} = -0\,3.$$

Der viser sig saaledes en tydelig Forskydning fra Gruppe B til Gruppe A, medens en Forskydning fra Gruppe C til Gruppe B ikke kan paavises. Dette Forhold kunde fremkalde en Formodning om, at Gruppe C, der i Hovedsagen stiger op i Vintertiden, tilhører en anden Race end Grupperne A og B, der stiger op i Sommer- og Efteraarstiden.

Det bemærkes, at Størrelsen af de nævnte Korrelationskoefficienter utvivlsomt i væsentlig Grad er afhængige af Virkningerne af den kunstigt udsatte Yngel.

Vore Undersøgelser over Temperaturens Indvirkning paa Laksefangsten har ført os ind paa Spørgsmaalet, om Laksen i varme Somre stiger op paa samme Aarstid som i kolde Somre. For at undersøge dette Spørgsmaal nærmere, har vi betragtet den Gruppe af A-Laks for sig, der stiger op i Tiden fra Maj til Slutningen af Juli, og vi har nu undersøgt, om den Procentdel, som denne Gruppe udgør af den samlede Fangst af A-Laks, er lige stor i varme og i kolde Somre. Vi har da beregnet Korrelationen mellem Temperaturanomalierne og Udsvingene fra Middelværdien af den procentiske Fangst af A-Laksen, der falder paa Maanederne Maj—Juli, og har herved faaet følgende Resultat:

$$r = 0.363;\quad \sigma_r = 0.224;\quad \frac{r}{\sigma_r} = 1.6.$$

Realiteten af den fundne Korrelation er næppe tvivlsom, da Udsvingene for Temperaturen og Udsvingene for den procentiske Fangst i alle Tilfælde gaar i samme Retning (se Tabel 15 og Fig. 11 Side 26).

2. Temperaturens Indflydelse paa de opstigende Individers Vægt.

I det foregaaende har vi set, at en høj Sommertemperatur baade har den Virkning, at den fremkalder en Forskydning fra B-Laks til A-Laks, og foraarsager en tidligere Opgang af A-Laksen end normalt. Det maa herefter antages, at Gennemsnitsvægten af Opgangslaksen i varme Somre er mindre end normalt, og vore Beregninger viser ogsaa, at dette er Tilfældet.

Betragter man Temperaturanomalierne for Maj, Juni og Juli i Forhold til Udsvingene fra Middelvægten af Laks af alle Grupper fanget i Juni, Juli og August for Perioden 1899—1913 faar man følgende Resultat (se Tabel 16):

$$r = -0.568,\quad \sigma_r = 0.175,\quad \text{hvoraf } \frac{r}{\sigma_r} = -3.2.$$

De tilsvarende Tal for Havørredens Vedkommende er (se Tabel 17):

$$r = -0.403,\quad \sigma_r = 0.216 \quad \text{og} \quad \frac{r}{\sigma_r} = -1.9.$$

Undersøger man, hvorledes Forbindelsen er mellem Temperaturanomalierne og Udsvingene fra Middelvægten for de enkelte Maaneder, finder man, at Korrelationskoefficienten i alle Tilfælde er negativ, og at den i adskillige Tilfælde har meget betydelige Værdier i Forhold til Størrelsen af Middelfejlen paa denne. (Se Tabellerne 16 og 17).

Inden for Aarrækken 1899—1913 var Temperaturen i Maj—Juni meget nær normal i 1903, 1912, 1913; højere end normal i 1899, 1901, 1905, 1906, 1908, 1910, 1911, og lavere end normal i 1900, 1902, 1904, 1907 og 1909. Undersøger man Middelvægten for Laks og Ørred fanget i Maanederne Juni, Juli og August i de anførte Aarrækker faar man følgende Resultat[1]):

Temp. Maj—Juli	Laks	Havørred
over normal	3.56 kg	2.69 kg
normal	4.27 -	3.00 -
under normal	4.26 -	2.92 -

Vi har nu i det foregaaende set, at Antallet af fangede Laks og Ørreder er større i varme end i kolde Somre. Fra dette Forhold tør vi dog ikke slutte, at en høj Sommertemperatur skulde være gavnlig for Lakse- og Ørredfiskerierne, mere end rent momentant.

Fra Undersøgelserne over Laksen ved vi, at den ved en høj Temperatur fremkaldte Forøgelse i Fangsten, alene skyldes en Tiltagen i Mængden af A-Laks, medens Antallet af fangede B-Laks ikke er større end normalt. Den høje Temperatur fremskynder altsaa Modningen og bevirker, at talrige Individer, der ved en lavere Temperatur vilde have gaaet et Aar endnu i Havet og først være indvandret som

[1]) Tallene angiver Gennemsnittet af de aarlige Middeltal.

B-Laks, forkorter deres Ophold i Havet og indvandrer som A-Laks. Men dette er næppe nogen Fordel set fra et fiskerimæssigt Synspunkt. Gennemsnitsvægten af Individerne af Gruppe B er omtrent 2.5 Gange saa høj som Gennemsnitsvægten af Individer af Gruppe A, og det er ikke sandsynligt, at Bestanden af opvoksne Laks under sit Ophold i Havet bliver reduceret til $\frac{2}{5}$ af sin oprindelige Størrelse i Løbet af et Aar ved Angreb fra naturlige Fjender (bortset fra Mennesket).

E. Om Aarsagerne til de mangeaarige Udsving fra Normalfangsten.

I de foregaaende Kapitler har vi set, at kortvarige Fluktuationer fremkaldes i Udbyttet af Lakse- og Ørredfiskerierne ved Temperaturens Indflydelse paa Opgangstiden og Fluktuationer af noget længere — men dog ikke mangeaarig — Varighed ved de vekslende Yngelmængder.

Vi vil nu gaa over til at betragte de Fluktuationer, der strækker sig over en lang Aarrække. Vi ser da, at Udbyttet fra 1853—1886 i det store og hele har været nedadgaaende, og at Udbyttet fra 1903 til 1913 i det hele har været opadgaaende. (Se Fig. 3 og Fig. 5). Det nedadgaaende Udbytte i 1853—1886 forklarer vi paa følgende Maade: I denne Periode var Frisenvold Fiskegaard i Virksomhed baade Sommer og Vinter, og kun meget faa Individer undgik under normale Forhold at blive fanget der. Bestanden af ynglende Laks er da stadig blevet formindsket, og der er da fremkommet for lidt Yngel til Vedligeholdelse af Bestanden. Nedgangen i Udbyttet maa saaledes antagelig føres tilbage til et for intensivt drevet Fiskeri.

Stigningen i Udbyttet af Sommerlaksen fra 1903—1913 forklarer vi paa følgende Maade: Den er en Virkning af Udsætningen af kunstig udklækket Yngel og muligvis tillige en Følge af, at i Aarene 1901—1905 er kun en mindre Del af de opstigende Vinterlaks og efter 1905 næsten ingen af disse blevet fanget ved Frisenvold Fiskegaard. Den naturlige Bestand af ynglende Vinterlaks er da sandsynligvis vokset i den anførte Periode. Men nu vides det ganske vist ikke, om Vinterlaksen er en anden Race end Sommerlaksen eller ikke. Er dette Tilfældet, maa det antages, at der af Vinterlaksens Æg kun fremkommer Vinterlaks. I saa Fald maa Stigningen i Udbyttet alene forklares ved Udsætningen af kunstig udklækket Yngel. Denne Udsætning omfattede i Femaaret 1906—10 mange flere Individer (saavel af spæd Yngel som af Halvaarsyngel) end i Femaaret 1901—05 (se Tabel 5, S. 17).

Stigningen i Fangsten af de opstigende Ørreder i Perioden 1903—1913 forklarer vi paa samme Maade som for Sommerlaksens Vedkommende: Den er utvivlsomt en Virkning af Udsættelsen af den kunstigt udklækkede Yngel. Den første Udsættelse fandt Sted i August 1902 med 100.000 Stk. spæd Yngel. I Aarene 1905—1915 udsattes aarlig fra 100.000—280.000 Stk. spæd Yngel, og i Aarene 1908—1915 fra 8600 til 99.000 Stk. Halvaarsyngel.

[1]) Jvfr. A. C. Johansen & J. Chr. Løfting 1919.

MEDDELELSER FRA KOMMISSIONEN FOR HAVUNDERSØGELSER.

Serie: Fiskeri.

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