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An account of the Norwegian coalfish investigations with special reference to the tagging experiments.

by

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Abstract

Total Norwegian landings of coalfish during the last decade averaged 66 000 tons annually. The main types of gear are purse seine, gill nets and otter trawl. Statistics of quantities by month and area are available, but effort data for other than trawl fisheries are lacking.

Regular coalfish investigations were started in 1953/54 with main emphasis on age and growth studies and tagging experiments.

Fluctuations in relative year-class strength are probably apparent already in the littoral stage of the 0-group, but numerical estimates of recruitment at this age have not yet been accomplished.

Variations in growth rate between different localities and from year to year seem to occur, particularly in the younger age-groups. There is some evidence of density dependent growth.

Fall and winter fisheries with gill nets and otter trawl are mainly exploiting the mature stock, while the purse seine fisheries are to a great extent based on a few age-groups if immature fish. In years of great abundance of the III-group some purse seine effort is diverted to fishing small fish for industrial purposes, and this has probably dampened the fluctuations in recruitment to the stock of larger and more valuable fish.

Since 1954 over 11 700 tagged coalfish have been released, mainly in July, August at the coast of Finnmark. More than 3 700 recoveries are reported to date.

The young age-groups are fairly stationary, whereas the mature fish undertake regular distant spawning migrations to the west coast banks and the northern North Sea.

Since 1956/57 yearly emigrations of adult coalfish to Faroe Islands and Icelandic waters have been demonstrated. The tag density at SE Iceland indicates that this emigration is of considerable magnitude.

The tagging data suggest a high yearly reduction rate for coalfish at the Norwegian coast, similar to that shown by German investigations. Factors other than fishing seem to be the dominating cause, and it is suggested that dispersal and emigration are significant contributors to the high apparent total mortality rate.

(1) The Fishery.

During the last decade the annual landings of coalfish in Norway averaged about 66 000 tons. The major part of the catch is taken in North Norway. From May to October purse seine is the most important gear, but large quantities are also taken by gill nets and otter trawl. The period from August to April is the best season for these gears, which during the last few years seem to have increased their proportional share of the total catch.

Most of the vessels engaged in the coalfish fisheries are relatively small, and the catch is usually landed in the nearest port.

This makes representative market sampling and collection of detailed statistics extremely difficult. Presently, records of landings by month and statistical area are available, but with the exception of the trawl fisheries, no differentiation between methods of capture is made in the commercial statistics, and effort data are entirely lacking.

(2) Norwegian Research.

Regular coalfish investigations were started in Norway in 1953/54. The main work has included market and research vessel sampling, analysis of catch statistics and tagging experiments. Scattered information about the spring distribution of coalfish eggs and larvae are available from plankton surveys, and some special effort has been excerted to procure material of the 0-group. Since 1955/56 data on environmental and food conditions have been collected in some areas.

a) Eggs, larvae and fry. The material of eggs and larvae indicates yearly variations in the northern spawning limit, but it is inconclusive with regard to quantitative fluctuations and survival of the young (Wiborg 1952, 1954, 1956).

During its first summer the coalfish fry is primarily distributed in the eulittoral zone along the entire coastline from Egersund to Varanger. At this stage the fry is easily observed merely by vision, and it is quite apparent that the abundance varies greatly from year to year. Thus, in 1954 and 1955 the abundance of littoral fry appeared to be fairly low, whereas in 1956 very great quantities were observed in all areas of the western and northern coasts. No reports are available for 1957 and 1958, but 1959, and particularly 1960, appeared to be good years. This present summer the level of abundance was very low.

As we shall see later, the relative strength of the 1956 year-class, at the age of recruitment to the fishable stock, was probably quite good. This suggests that the strength of a year-class may have been determined already in the littoral stage of the 0-group. Consequently, numerical estimates of the relative abundance of the 0-group would be very valuable, but so far all attempts to this effect within the scope of the available practical and economical means have been unsuccessful.

b) Growth. The time at which the littoral fry is first observed may vary as much as a month from year to year, presumably as a result of variations in spawning time and/or duration of larval stage. Such variations are probably partly responsible for the yearly fluctuations in growth found in the 0-group.

In general the growth rate of young coalfish seem to be uniform from the coast of Møre and northwards, but in the youngest stages the fish are distinctly larger in the outer, more coastal localities than in inshore fjord localities.

Fig. 1 shows deviations from the mean in annual increments during the years 1950-54 for the 1950- to 1954-year-classes. It would appear that the 1952- and 1953-seasons are marked with a below average growth.

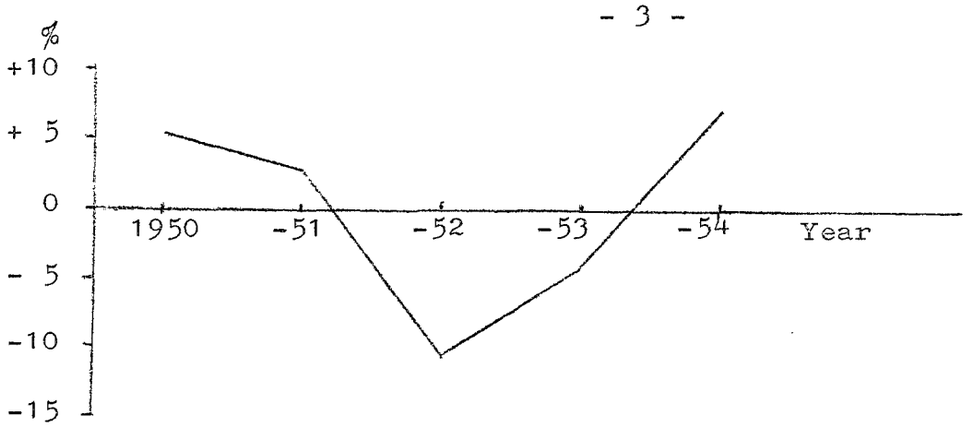

Fig. 1. Deviations from the mean in annual increments during the years 1950-54 for the year-classes 1950 to 1954.

By that time the total biomass of the rich 1950-year-class was probably large enough to make competition for food a significant growth regulating factor. This would suggest that the growth rate in coalfish is density dependent and allowance for this effect must be given in yield assessments.

c) Catch composition. The problems involved in a representative sampling of all the diverse fisheries for coalfish in Norway are obvious, and presently we have only reached the stage of a general knowledge of the catches taken by the various types of gear in the different seasons and areas.

The gill nets are mainly exploiting the mature stock, in North Norway during the spawning emigrations, and at the west coast on the spawning grounds. The catch includes fish of 4 - 5 years and older, but because of gear selectivity the very old age groups are partly escaping this type of gear.

The fisheries with otter trawl during fall and winter are also based on migratory fish and spawning concentrations, i. e. coalfish of 4 - 5 years and older. During spring and summer immature fish, 4 and 5 years of age, may make up a great part of the catches. The 3-year olds are taken to a much lesser extent, probably as a result of segregation and depth stratification by size, rather than mesh selection.

The purse seine exploits the coalfish during the feeding season only, and it is fully effective for any size of fish within reach, for which there is a market. Thus, on the west coast, where the live fish trade has created a market for small fish, the main bulk of the purse seine landings is made up of the III-group, and a substantial number of 2-year olds are also taken. The adult stock is to a great extent in the northern areas during summertime, and fish over 5 - 6 years of age are usually insignificant in the purse seine fisheries at the west coast.

Farther north the size range is complete, but because of market conditions the 4-year olds and larger fish are preferred. The fishermen therefore purposely avoid catching small fish, and this is possible because coalfish of distinctly different sizes seldom school together while feeding actively.

The first part of the season, until July/August, fish of (3) 4 and 5 (6) years of age are usually dominating the catches, and there is

a general trend of increasing size with increasing latitude. Schools of larger fish are more sporadic during early summer on the purse seine grounds, except off Lofoten and Vesterålen where in May/June there is usually a short season of large coalfish passing by on the return migration from the spawning grounds. At the Finnmark coast the large fish are generally more frequent from the middle of August onwards.

This scheme, which describes the average conditions, is particularly modified by acute variations in recruitment. Thus, in 1953 3-year old fish (i. e. the 1950 year-class) occurred on the usual fishing grounds in very great numbers. Normally the market for fish of this size is strictly limited, but because of the great availability and the easiness of catching such fish, it was a paying venture to fish them for meal and oil production. As a consequence, in 1953 more than 17 000 tons were delivered to the oil and meal factories. The same thing happened in 1959 when the 1956-year-class showed up in large numbers, and over 10 000 tons of coalfish were used for meal and oil. In the intervening years landings of small coalfish for meal and oil production were at a very low level.

It would therefore appear that when strong year-classes reach fishable size, some purse seine effort is diverted to catching small fish. The result is a lower mean age at first capture for the strong year-classes than for the average and weak ones. This has probably had the effect of a dampening of the fluctuations in recruitment of fish of "normal" commercial size.

d) Tagging Experiments. From 1954 to 1961 a total of 11 722 coalfish have been tagged, the majority in July/August at the Finnmark coast. To date more than 3 700 recoveries have been reported.

At the 1959 Council meeting a report on the tagging experiments as regards migrations was presented to this Committee (Olsen 1959 a). The recaptures in the succeeding years have further confirmed the results reported on at that time, and apart from minor details the general conclusions remain unaltered.

During the summer months the coalfish seem to be fairly stationary within limited feeding areas, and the large, mature fish appear to be visiting the same localities year after year. The young immature fish do not migrate over long distances, but there is a trend of a gradual movement towards north and east. The mature fish undertake regular yearly spawning migrations from the northern districts to the spawning grounds off the west coast and in the northern North Sea. Most likely the majority returns to the northern areas for feeding, but there is probably some dispersal of fish remaining in the southern areas after spawning.

e) Migrations to "Foreign Waters". As previously reported (Olsen 1959 b), a number of coalfish tagged at the Norwegian coast have been recaptured at Iceland and Faroe Islands. The first recapture at Iceland was made in 1956 and at Faroe Islands in 1957. Each of the following years new recaptures were reported, and some of these were fish tagged

in recent years. Thus, there can be no doubt that the trans-oceanic migrations have continued right up to present time.

On the map of Fig. 2 are plotted all recaptures of Norwegian tagged coalfish at Iceland, Faroe Islands and Shetland, and recaptures in the North Sea, Skagerak and off the west coast of Norway of fish tagged at the Finnmark coast. The filled symbols indicate recaptures taken before the second winter after tagging, i. e. within the first 16-17 months in freedom.

It appears that a great deal of the recaptures off the Norwegian west coast and in the North Sea were made during the first spawning season after liberation, while the majority of the fish retaken at Shetland and Faroe Islands had been carrying their tags for more than 18 months. At Iceland over 50 per cent of the recaptures were fish tagged only a year or less in advance, and there are three reports of recaptures in January of fish tagged the preceeding summer at the Finnmark coast.

This is evidence of a different and more direct route for the migrations to Icelandic waters than for those to the Faroe Islands.

A further support to this theory is the fact that experiments from several years in one particular tagging locality, namely off the Tanafjord in Finnmark, have given more recaptures at Iceland than all the other tagging experiments together, but not a single one at the Faroe Islands. On the other hand several fish tagged in a locality just 40 miles west of the Tanafjord have been recaptured at Faroe Islands but none at Iceland. In the North Sea and at the Norwegian coast, though, these fish seem to mix freely.

There is presently no explanation to be given for this phenomenon. Neither do we know what is causing the Icelandic migrations and which route they follow. The most likely explanation is still the suggestion offered in 1959 (Olsen 1959 b), that the coalfish leave the west coast spawning grounds about the same time as the herring and follow the herring across the ocean. A more direct route from the coast of North Norway is, however, also likely, and this is in better agreement with the three very fast migrations mentioned above.

From the distribution of recaptures at Iceland it appears that the immigrants arrive at the south-east coast, but within a few months they are also found in other areas, particularly at the north-west coast.

To get some idea about the relative magnitude of the immigration, we may compare the tag density at Iceland with that in Norwegian waters as in Table 2 below.

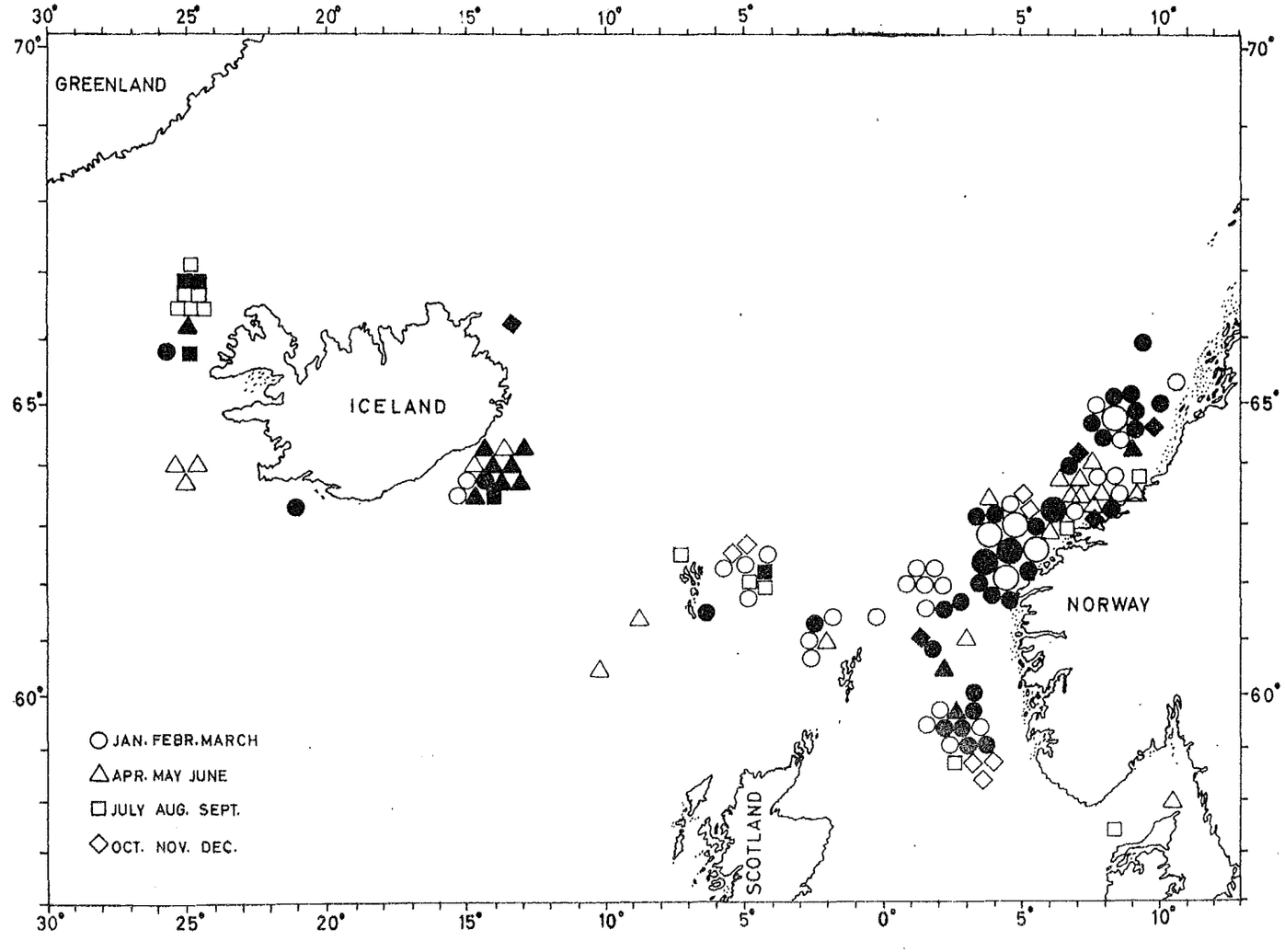

Fig. 2 Recaptures at Iceland, Faroe Islands and Shetland from all tagging experiments, and in the North Sea and off the west coast of Norway from the Finnmark taggings only. Filled symbols indicate recaptures before the second winter after tagging. Large symbols - 10 recaptures.

Table 1. German catch and number of recaptures at the SE- and NW-coasts of Iceland in 1957, -58 and-59 compared with catch and tag returns in Jan., Febr., and March of the same three year period off the Norwegian west coast.

Area	Catch in tons	No. of recaptures	Tons/tag
SE-coast of Iceland	6 956	7	994
NW-coast of Iceland	32 188	9	3 576
"Svinøy Gebiet" (German catch)	16 723	23 1)	727
Møre & Romsdal county (Norw. catch)	14 533	25	581

1) Several recaptures with doubtful position omitted here may belong to this area.

It would appear that the catches taken in 1957, -58 and -59 at SE-Iceland contained a very considerable element of Norwegian origin, but the number of recaptures at Iceland is too small to justify exact numerical calculations.

f) Mortality. Schmidt (1960) on the basis of German age and effort data found that the Norwegian coalfish stock is presently reduced at an annually rate of 60 - 70 %, against about 40 % for the decade 1945-1955. He concluded that only part of this extremely high reduction is caused by fishing and suggested emigration as a major contributing factor.

The Norwegian tagging data may throw some light on this problem, and for that purpose we shall study the recapture data given in Table 2 for the taggings of medium and large coalfish at the Finnmark coast.

Most fish tagged were nearly 60 cm in length or larger, i. e. fish of 4 years or older, and with the exception of the fish tagged in 1954, a great number was immature or maturing for the first time when tagged.

They were all caught with purse seine near the surface, giving a good quality and presumably a low tagging mortality.

By excluding all recaptures within the year of liberation and taking the ratios between the numbers recovered in succeeding years, (Ricker 1958), we arrive at the following table of instantaneous total mortality rate, Z:

Table 3. Total instantaneous mortality rate, Z, estimated from ratios between recapture numbers in succeeding years. Recoveries within the year of tagging excluded.

	Year of tagging					
	1954	1955	1956	1957	1958	Combined
1956/55	.72					.72
1957/56	.72	.85				.83
1958/57	.75	.64	1.13			.94
1959/58		1.08	.84	.98		.92
1960/59			1.42	.64	.98	.98

It is noticed that with the exception of the 1954-experiment there is a marked drop in Z for the second period after tagging. This is probably because the immature fish are not fully exploited in the

winter fisheries, and for those years substantial numbers of immature fish were tagged, the number of recaptures is relatively high during the second spawning season after tagging.

The combined data shows a progressively increasing rate of mortality, and the values for the latter years agree well with the 60 - 70 % total mortality rate (i. e. Z = 0.9 - 1.2) given by Schmidt.

To estimate the rate of fishing mortality, F, separately, we may employ the method developed by Beverton & Holt (1954) where:

$$F = \frac{\frac{n_1}{t} \log\left(\frac{n_1}{n_2}\right)}{N_o \left(1 - \frac{n_2}{n_1}\right)}$$

and the coefficient for the rate of "other losses"

$$X = \frac{1}{t} \left\{\log\left(\frac{n_1}{n_2}\right)\right\} \left\{1 - \frac{n_1}{N_o\left(1-\frac{n_2}{n_1}\right)}\right\}$$

The mean values for the different years are given in Table 4 below.

Table 4. Mean values for separate estimates of F and X by the Beverton & Holt method.

Period	1954-55	1955-56	1956-57	1957-58	1958-59
$\bar{F}$	.45	.23	.26	.21	.24
$\bar{X}$	.49	.25	.43	.65	.82

It appears that apart from the 1954-55 figures, which are based on one single tagging experiment only, the fishing mortality has remained fairly constant, but the "other loss" coefficient has more than tripled during the period 1955-56 to 1958-59.

If we instead of chronological periods arrange the data in years after tagging, we find that F here also remain fairly constant, and X increases with time. For the 1st, 2nd and 3rd year after tagging values of .31, .64 and .85 respectively are found for $\bar{X}$. This might indicate that the "other loss" rate is dependent on the size or age of the fish.

A third method of analysis is the one developed by Paloheimo (1958), where the natural mortality (or "other loss") coefficient is assumed to be known and the fishing mortality for a certain period is given by

$$F_v = \frac{n_v}{N_v} \Big/ \left(1 - \frac{\frac{n_v}{N_v} + X_v}{2}\right)$$

By assuming different values of X a relationship between X and Z is found.

In the present material this relationship is approximately linear and for the period 1955-60 there appear to be only slight variations from year to year. The mean for the combined material is described by

the equation:

$$X = .665\ Z - 0.044$$

Thus, if we except .9 as a likely value for Z, we get an X of .55 and accordingly F = .35, that is, a value somewhat higher than estimated by the Beverton & Holt method.

The three methods of analysis used here are based on various assumptions, many of which are not strictly valid for this case. Further developments of methods and more detailed analysis of the data are required, and it is also necessary to utilize other sources of information if we are to get a better understanding of the dynamics of the coalfish.

From the present treatment we may, however, sum up the following conclusions:

The adult stock of coalfish in Norwegian waters has in recent years been reduced at an instantaneous rate of about .9 (approx. 60 % per year), of which about one third is caused by fishing. The magnitude of "other losses" has increased from 1955 to 1959 and seem to be greater in the old mature fish than in the younger age groups. The most likely explanation of this phenomenon is emigration and dispersal to less fished areas after the fish has attained sexual maturity.

(3) References :

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1954. Forekomst av fiskeegg og -yngel i nord-norske farvann våren 1952 og 1953. "Fiskets Gang", No. 1, 1954.

1956. Forekomst av fiskeegg og fiskeyngel i nord-norske farvann våren 1954 og 1955. "Fiskets Gang", No. 9, 1956.

Table 2. Numbers of recaptures by 6 months periods for medium and large coalfish tagged at the Finnmark coast.

Exp. no.	Date	No. released	Size range	No. recaptured 1954 II	1955 I	1955 II	1956 I	1956 II	1957 I	1957 II	1958 I	1958 II	1959 I	1959 II	1960 I	1960 II
08/54	17/8-54	528	50-101	79	43	29	19	16	13	4	5	3	4	3	0	1
18/55	23/7-55	301	49- 78			53	5	30	7	6	5	7	1	1	1	0
19/55	26/7-55	200	42- 72			16	2	14	4	3	2	0	0	1	0	0
20/55	3/8-55	313	53- 89			28	13.5	24.5	7	12	5	5	2	1	0	2
21/55	4/8-55	126	46- 81			1	8	6	1	5	1	1	2	0	0	0
22/55	15/8-55	436	49- 91			43	18	45	9	21	7	4	3	5	1	0
23/55	17/8-55	350	44- 96			50	20	36	6	14	8	5	0	1	0	0
Sum 1955		1726				191	66.5	155.5	34	61	28	22	8	9	2	2
04/56	31/7-56	200	50- 81					26	11	12	2	5	4	2	0	0
05/56	1/8-56	198	58- 82					27	10	22	4	2	1	0	2	0
07/56	14/8-56	300	45- 81					26	18	40	9	9	5	5	0	0
08/56	17/8-56	340	64-103					25	21.5	36.5	8	9	5	3	1	4
09/56	21/8-56	160	48- 92					15	11	16	6.5	5.5	0	1	0	0
Sum 1956		1198						119	71.5	126.5	29.5	30.5	15	11	3	4
14/57	22/7-57	254	50- 80							15	13.5	18.5	8.5	3.5	2	7
16/57	26/7-57	130	56- 80							14	13	9	6.5	3.5	1	0
17/57	30/7-57	370	36- 73							11	7	28	11	12	6	4
18/57	3/8-57	135	62- 92							26	11	10	2	2	2	0
19/57	6/8-57	147	57- 97							26	11	8	1	0	0	1
Sum 1957		1036								92	55.5	73.5	29	21	11	12
22/58	22/7-58	62	56- 80									12	4	4	2.5	0.5
23/58	23/7-58	79	55- 85									10	5	4	1	0
24/58	29/7-58	333	37- 77									50	14	26	7	5
25/58	29/7-58	524	42- 76									100	12	47	14	15
26/58	7/8-58	98	60- 95									18	5	8	2	0
27/58	12/8-58	320	64- 96									41	21	19	12	5
28/58	13/8-58	410	59- 95									63	25	17	7.5	7.5
Sum 1958		1826										294	86	125	46	33
01/59	28/7-59	390	59-105											49	32.5	20.5
02/59	31/7-1/8-59	259	44- 74											16	11	22
03/59	4/8-59	337	53-100											40	30	17
04/59	5/8-59	218	49- 95											45	13	8
Sum 1959		1204												150	86.5	67.5