International Council for the Exploration of the Sea

COOPERATIVE RESEARCH REPORT

International Council for the Exploration of the Sea
Charlottenlund Slot - Denmark

COOPERATIVE RESEARCH REPORT 6

August 1965

Report of the Coalfish Working Group

Participants: J. S. Joensen (Faroes)
B. W. Jones (United Kingdom)
Steinar Olsen (Norway)
U. Schmidt (Federal German Republic)

1. Terms of reference

The Gadoid Fish Committee at the 49th Statutory Meeting of the ICES received reports about the coalfish (saithe) research carried out in various member countries, and the Committee subsequently decided to establish a Coalfish Working Group with the following terms of reference:-

a) "to collect and examine the data on coalfish and coalfish fisheries contained both in the reports to this meeting of the Gadoid Fish Committee and those which are available, too, in other published and unpublished sources,
b) in the light of their findings to initiate a co-ordinated plan of coalfish research among the countries concerned and to report on progress achieved at the next meeting of the Gadoid Fish Committee".

Two meetings of the Working Group were held, one in Hamburg, May 11th-12th 1962, the other in Copenhagen September 28th-30th 1962 to prepare a first draft report presented at the 1962 meeting of ICES.

A second progress report was submitted at the 1964 meeting of ICES, following a short meeting of three of the members of the Group.

2. Scope of this report and sources of data

Before the Second World War no continuous investigations of the coalfish resources were being carried out, and the literature from this period contains only reports on a few more or less isolated investigations and casual observations.

After the war routine investigations on coalfish were started, first by Germany and Norway and somewhat later by England and the Faroes. These investigations have included market sampling, research vessel surveys, tagging experiments, and to a smaller extent coalfish egg and larval studies.

The present report is based on all national data derived from these investigations, including published and unpublished national statistics of commercial catch and effort. The first parts of the report give a review of the present state of knowledge of the coalfish resources and the way they are exploited, including attempts at making mortality estimates and assessments of the effects of fishing on the stocks. From these emerge the needs for further investigations discussed in the last chapter.

3. General description of the various coalfish fisheries

The total European landings of coalfish, which for the last decade before the Second World War averaged about 150,000 tons annually (see Table 1), have in the post-war period increased greatly to about 250,000 tons per year for the last 10 to 15 years.

Table 1. European coalfish landings (round fresh weight) by areas and total quantities for all areas.

Year	I tons	Region IIa tons	Region IIb tons	IV tons	Va tons	Vb tons	VIa tons	Others tons	Total tons
1929	11,562	25,535	345	18,162	50,233	7,543	6,435	1,662	121,477
1930	9,398	22,142	2,688	23,927	48,618	7,727	5,554	2,088	122,142
1931	7,652	22,254	1,132	24,472	35,080	8,737	6,023	2,016	107,366
1932	9,755	26,538	1,985	22,062	40,840	10,215	7,466	2,151	121,012
1933	8,878	23,921	1,953	24,016	38,585	12,160	5,937	2,720	118,179
1934	8,977	24,368	3,659	20,003	48,018	10,717	4,649	2,719	129,110
1935	10,741	47,759	1,196	30,673	51,301	10,962	4,463	2,783	159,878
1936	11,182	64,807	1,339	31,811	60,841	10,833	5,650	2,808	189,271
1937	11,662	66,272	1,413	38,287	58,152	6,426	5,171	2,451	189,834
1938	11,707	51,325	3,576	29,431	67,734	7,152	4,814	2,287	178,026
Average 1929-1938	10,151	37,492	1,928	26,884	49,940	9,247	5,616	2,369	143,630
%	7.06	26.10	1.38	18.72	34.77	6.44	3.91	1.65	
1946	5,991	27,776	604	24,584	44,326	5,325	4,781	3,154	116,541
1947	16,018	48,465	973	31,263	65,227	8,758	5,596	6,419	182,719
1948	30,549	64,870	910	30,227	117,880	3,569	4,622	3,592	256,219
1949	34,514	65,392	378	27,454	92,479	6,114	3,730	3,958	234,019
1950	30,053	87,231	661	21,975	62,912	5,366	3,522	3,043	214,763
1951	28,095	82,069	1,208	23,142	83,783	8,698	4,362	2,855	234,212
1952	14,846	112,852	635	23,783	97,968	6,851	6,701	2,673	266,309
1953	21,073	103,652	715	23,254	79,220	7,175	6,206	2,591	243,886
1954	11,386	92,778	534	34,565	69,629	6,212	6,646	3,045	224,795
1955	13,321	92,717	905	41,715	47,843	7,234	8,687	6,490	218,912
1956	15,684	100,746	1,270	47,456	67,860	10,884	11,679	8,571	264,150
1957	16,208	115,747	1,345	53,006	62,061	26,858	12,212	8,201	295,638
1958	11,481	102,469	1,167	48,819	53,178	12,978	12,779	7,604	250,475
1959	13,426	114,810	1,061	45,467	48,109	14,545	9,845	9,845	257,108
1960	17,805	116,819	562	43,562	48,130	11,845	8,348	6,339	253,410
1961	12,868	96,717	414	35,810	50,929	9,592	6,652	5,975	218,957
1962	(9,770)	(103,879)	403	40,576	48,278	10,455	7,032	6,482	226,875
1963	(20,130)	125,740	44	47,286	43,985	12,696	6,478	7,321	263,680
Average 1954-1963	14,208	106,242	771	43,826	54,000	12,330	9,036	6,987	247,400
%	5.74	42.94	0.31	17.71	21.83	4.98	3.65	2.82	

Nearly half of this quantity is taken at and off the Norwegian coast and in the Barents Sea by Norwegian, German and English vessels. The Norwegian catch is mainly taken with purse seine in coastal waters from May to October and with gill nets and otter trawl at the coast and on the banks from August to April. The trawl and gill net fisheries are exploiting the migrating population of predominantly mature fish in the northern areas and the spawning concentrations on the southern banks (Svinøy and Halten), while the landings from the purse seine fisheries consist mainly of immature fish. The German fishery is a deep sea trawl fishery and the main coalfish seasons are from September to March in the northern banks, and from January to March on the Svinøy area off the west coast of Norway. The English fishery is also a trawl fishery on the northern banks, mainly in the first four months of the year. It is not a fishery specifically for coalfish, the main catch being cod and haddock.

In the North Sea the coalfish landings are practically all derived from the northern part (Division IVa). There is a German and French winter fishery in the eastern (Viking Bank) and northern (Tampen) part of this area, and these nations also take some coalfish in the western North Sea and the Shetland areas.

The landings from the west of Scotland area (VIa) are almost entirely from British trawlers which extend their area of operation into waters around Shetland and the western side of the North Sea. The greatest quantities from this area are landed in early spring and autumn.

English and Scottish trawlers account for the majority of the catches taken at the Faroes. This is an all year fishery with peak landings in early spring and summer. In recent years German trawlers have also been fishing coalfish at the Faroes. This German fishery is rather irregular and takes place in deeper waters than those of the British fleet. The Faroese fishery is an early summer fishery with hand lines. The annual landings used to be comparatively small, but have increased substantially in the most recent years.

In Icelandic waters the greatest proportion of the coalfish landings is derived from the English and German trawl fisheries. The largest part of the German catches is taken off the NW-coast. The Icelandic landings are also taken mainly with trawl, and the purse seine fisheries which in the early 1950's accounted for a large proportion of the Icelandic catch are presently irregular and of comparatively small importance.

4. Identity of coalfish stocks

The various fisheries for coalfish are fairly well separated in geographical areas which more or less coincide with the ICES statistical regions. This is not to infer, however, that there are individual unit stocks of coalfish corresponding to each area.

Thus, Norwegian and English tagging experiments together with data on the distribution in time and space of the commercial fisheries clearly demonstrate a regular annual migration of mature fish from the Barents Sea and North-Norwegian coast to the spawning areas off the west coast of Norway (Halten, Svinøy), and also, but probably to a lesser extent, to the northern North Sea, where spawning appears to be concentrated in the Tampen - Viking Bank area. It is further apparent that the distribution of the spawning stock between these areas may vary from year to year, and it seems likely that the spawning population at Tampen is also composed of fish normally living in the northern North Sea and Shetland areas.

In the ICES area there are several distinct coalfish spawning localities, and mass spawning is known to take place at Iceland, Faroes, off the west coast of Norway, to the west of Scotland and in the northern North Sea. It might be reasonable to assume that each spawning population constitutes a separate stock, and there is as yet no direct evidence of fish spawning in different localities in different years. However, very little tagging has been done on the spawning grounds, while other tagging experiments on the Norwegian coast, at the Faroes, Shetland and west of Scotland provide evidence to show that, at least outside the spawning season, there is considerable mixing between fish of different regions. Thus, fish tagged at the Norwegian coast have been recaptured at Iceland, the Faroes, on the Faroe Bank and Bill Bailey's Bank, in the northern North Sea, at the Shetland and west of Scotland (see Fig. 1 and 2).

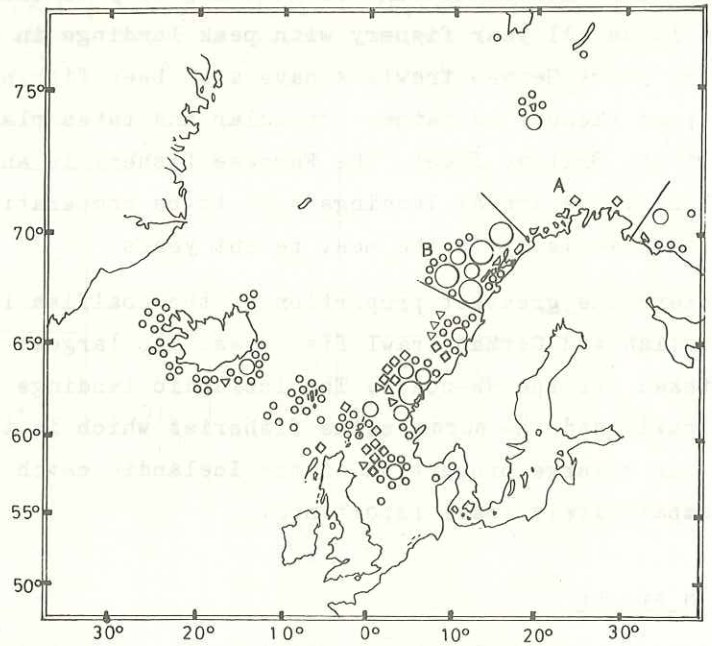

Figure 1. Recaptures of coalfish tagged in northern Norway.
Circles - from Norwegian experiments in area marked A
Squares - from Norwegian experiments in area marked B
Triangles - from English experiments in area marked B
Recaptures within tagging area not shown. Large symbols loo recaptures, medium sized symbols lo recaptures.

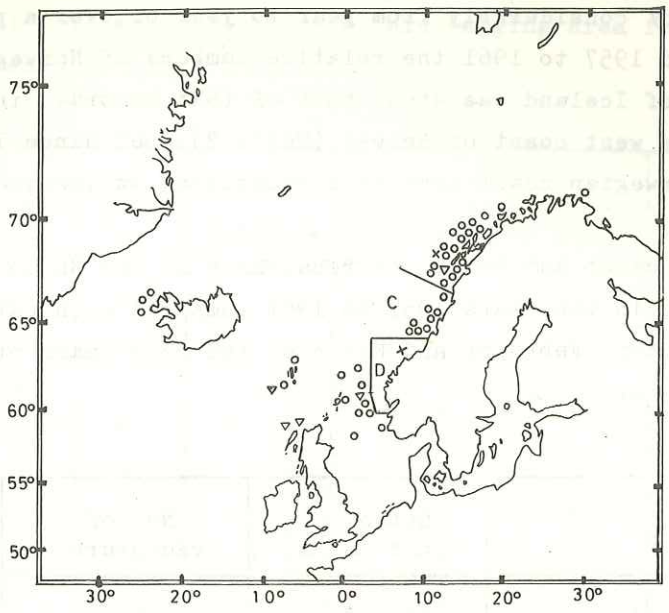

Figure 2. Recaptures of coalfish tagged at the west coast of Norway.
Crosses - from English experiments in area marked C
Circles - from Norwegian experiments in area marked D
Triangles - from English experiments in area marked D
Recaptures within tagging area not shown.

Similarly, migrations have been demonstrated from Shetland to the northern North Sea and to the Norwegian coast; from the Faroe Bank to West of Scotland, Shetland, the Faroes and to Iceland; and from the Faroe plateau to west of Scotland, Shetland, Faroe Bank, northern North Sea, Norway and Iceland (see Fig. 3).

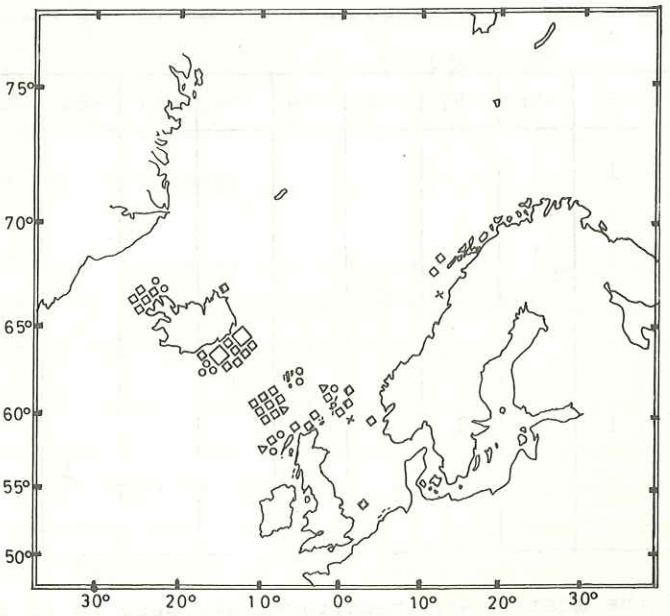

Figure 3. Recaptures of coalfish tagged at the Faroes, on Faroe Bank and at Shetland.
Circles - from English experiments on the Faroe Bank
Squares - from Faroese experiments at the Faroes
Triangles - from English experiments at the Faroes
Crosses - from English experiments at Shetland
Recaptures within tagging area not shown.
(Large symbols lo recaptures.)

The tagging experiments further indicate that the magnitude and direction of mixing may vary considerably from year to year or over a period of years. During the period 1957 to 1961 the relative numbers of Norwegian tagged fish at the SE coast of Iceland was about half of that recorded in the winter fisheries off the west coast of Norway (Table 2), but since 1962 very few fish tagged at the Norwegian coast have been recaptured at Iceland (Table 3).

Table 2. German catch and number of recaptures at the SE and NW coasts of Iceland in the years 1957 to 1961 compared with catch and tag returns in January, February and March of the same years off the Norwegian west coast.

Area	Catch in tons 1)	No. of recaptures	(Tag/ton) x 1000
NW coast of Iceland	53,001	11	0.28
SE coast of Iceland	11,679	15	0.94
Svinøy and Halten (Germ.)	30,814	59	1.91
Stadt to Helgeland (Norw.)	34,750	54	1.55

1) German figures gutted, head on;
Norwegian figures gutted, head off.

Table 3. Recaptures by year and tagging year at Iceland from Norwegian experiments.

Recapt. year	Tagging year										Sum all years
	-54	-55	-56	-57	-58	-59	-60	-61	-62	-63	
1956		1									1
1957		3	3								6
1958		2	1	1							4
1959			3	-	6						9
1960		1	-	-	2	3					6
1961				1	2	6	1				10
1962		1	-	1	3	1					6
1963									1		1
1964											0

On the other hand the most recent recapture data seem to indicate a substantial migration from Norwegian waters to the North Sea, Shetland, west of Scotland and Faroese waters, and from the Faroes and the Faroe Bank to Iceland (Table 4 and 5).

Table 4. Recaptures from Norwegian tagging experiments 1956-1964 in all areas south of Lofoten. Recaptures within tagging area from west coast experiments not included.

Year	Halten Bank area	Svinøy area	North Sea	Skagerak	Shet-land	W.of Scotl. Faroe Bank	Faroes	Iceland	Sum
1956	2	12	3					1	18
1957	6	24	3		1		5	7	46
1958	7	16	5				1	7	36
1959	5	11	7			1	1	9	34
1960	13	32	13	1	2		4	7	72
1961	12	20	9		3	1	2	10	57
1962	26	13	3	1		1	1	6	51
1963	6	11	4		2	1	2	1	27
1964	3	8	3		1	2	4	2	23

Table 5. Recaptures by year and tagging year at Iceland from Faroese experiments in Faroe coastal waters, and from English experiments (figures in brackets) on the Faroe Bank.

Rec. year	Tagging year					Sum all years
	-60	-61	-62	-63	-64	
1961						0
1962	1 x)	1	(1)			2 (1)
1963	1	6 (1)	1			8 (1)
1964		4	12 (3)	3		19 (3)

x) Rec. in Iceland or Norway.

Comparisons of mean length at age indicate that the growth rate is similar in Norwegian waters, northern North Sea, at Shetland and west of Scotland, but somewhat lower than in Faroese and Icelandic waters.

Thus, the evidence so far available suggests that there are probably several stocks of coalfish, some of which are regularly over-lapping as in the northern North Sea. It is, quite evident that the coalfish is a very migratory species, and the migration patterns may change greatly from year to year or over a period of years. Such migrations as have been shown to take place can significantly alter the abundance of fish in the various fishing areas.

5. Trends in catch, effort and catch per unit of effort

In Figures 4 to 9 total landings, total notional effort and catch per unit effort are plotted for each statistical region over the period for which data are available. Total notional effort has been calculated from English and German national data raised by the ratio of total landings to notional landings.

It should be noticed that for alle regions effort data are available for only a part of the total fisheries for coalfish. Notably it is so for the Norway coast region and the Barents Sea, where the Norwegian catch, for which no effort data are available, constitute a large proportion of the total catch, and is also to some extent composed of younger fish than those taken by the English and German trawl fisheries.

A further drawback with the available effort data is that they give the total effort for all species taken. Only in the case of the German Svinøy fishery for spawning coalfish, and to some extent also the German fisheries on the northern Norwegian banks and at Iceland are separate estimates for coalfish effort available.

5.1 Sub-area I. Barents Sea (Fig. 4). The landings from this region showed a moderate trend of increase in pre-war years, reaching a maximum in 1940. In the immediate post-war years landings were high, but decreasing until 1952, after which they have fluctuated around the maximum level reached in the pre-war period. Data on effort and catch per unit effort are available from German and English statistical records. Estimates of total effort and catch per unit of effort based on English data indicate a steep rise in total effort in recent years and a very pronounced decline in catch per unit of effort. Corresponding estimates based on German figures are rather variable. Both the English and German data, however, give probably rather poor indices of total effort and abundance, as the majority of the coalfish taken in this area are landed by Norwegian purse seiners. Especially the German catch of coalfish in this area has been of little importance, and since 1962 no German effort has been recorded in the Barents Sea.

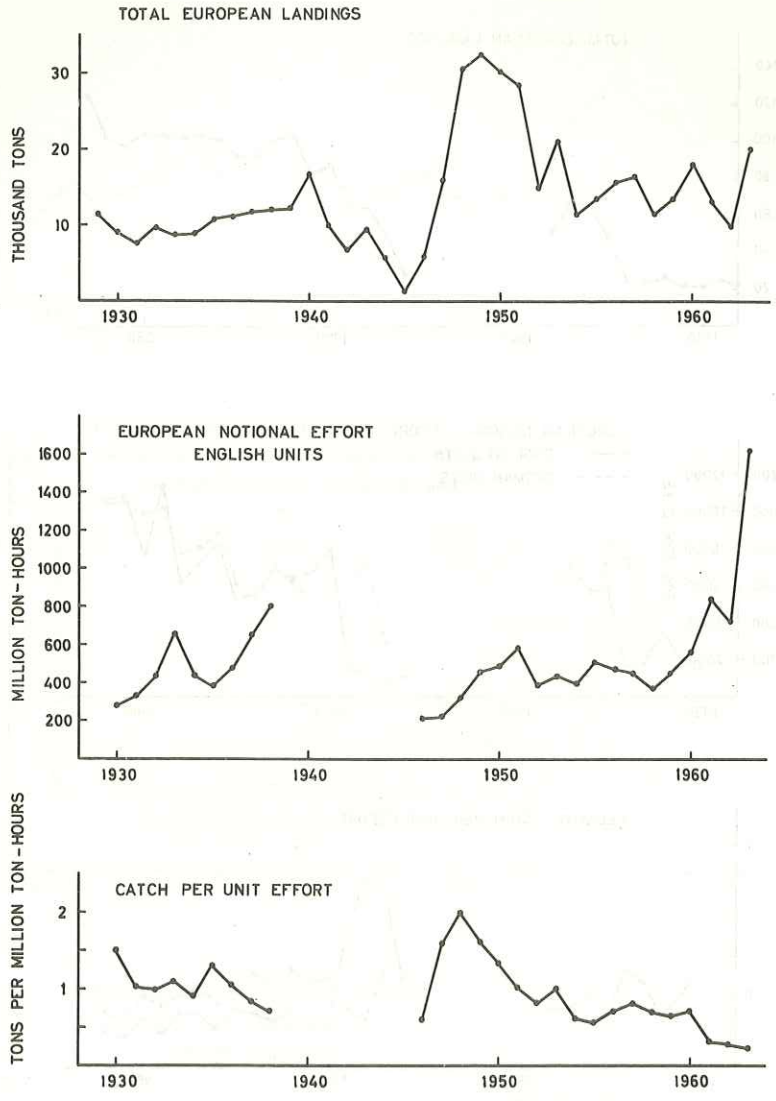

Figure 4. Total catch, effort and catch per unit effort in Sub-area I.

5.2 Division IIa. Norway Coast (Fig. 5). Landings from this region in the pre-war years remained at a steady low level until 1934. The higher landings in the subsequent years were due to increased Norwegian catches and also the commencement of German fishing in this region. The total landings in the post-war period have increased fairly steadily, and the present level is approximately double the pre-war maximum. Estimates of total effort and catch per unit effort based on data for the English, and, for the post-war period, also the German trawl fisheries suggest a low level of total effort in the early pre-war years, before the German fishery started. Except for the first few years the post-war effort level has been high, and both German and English data suggest a marked trend of increasing effort during the last 12-15 years. Similarly, both sets of data indicate a moderate decline over the same period in the catch per unit effort.

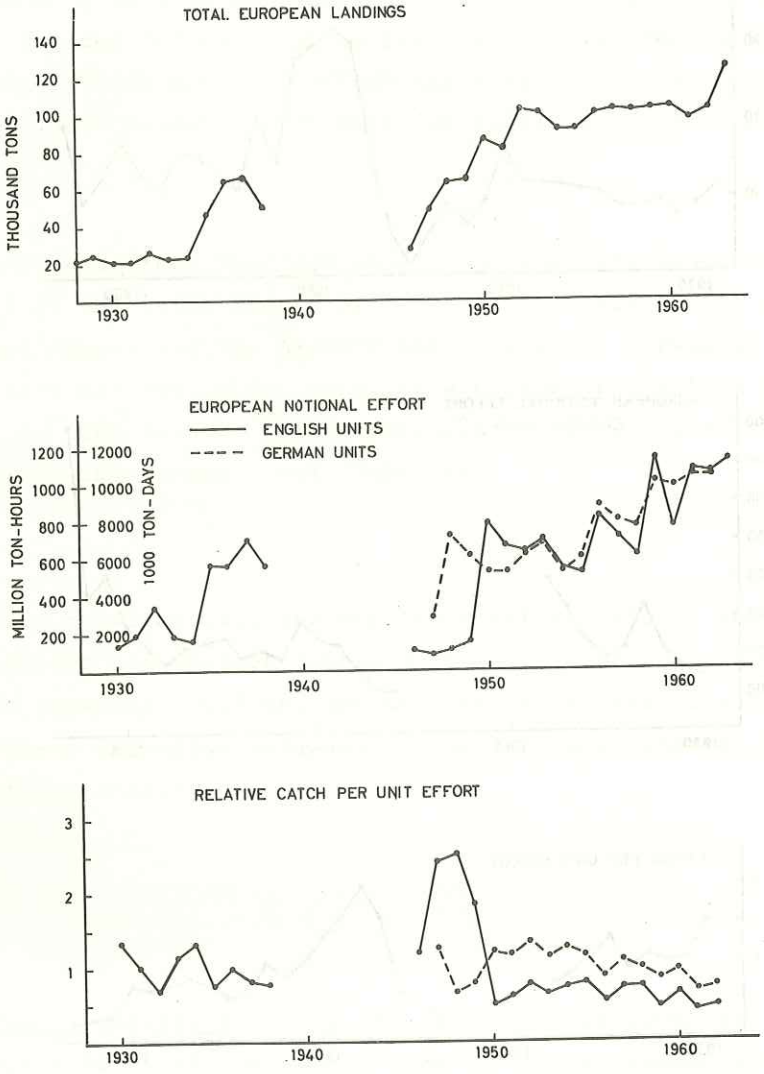

Figure 5. Total catch, effort and catch per unit effort in Division IIa.

5.3 Division IVa. North Sea (Fig. 6). Total landings increased steadily in the pre-war years, and after the war they have increased to about double the average pre-war level. Estimates based on English data indicate a steady level of total effort before the war, and great variations in total in the post-war period, but with a marked trend of increase since 1953. It should be borne in mind, however, that these data represent only a small part of the total fisheries for coalfish in the North Sea, and that statistics for the French catch in this area are lacking prior 1954. Estimates of catch per unit effort from English data suggest great changes in coalfish abundance in this area, but they conform with corresponding estimates based on German data in indicating a drastic decline in catch per unit effort since 1956.

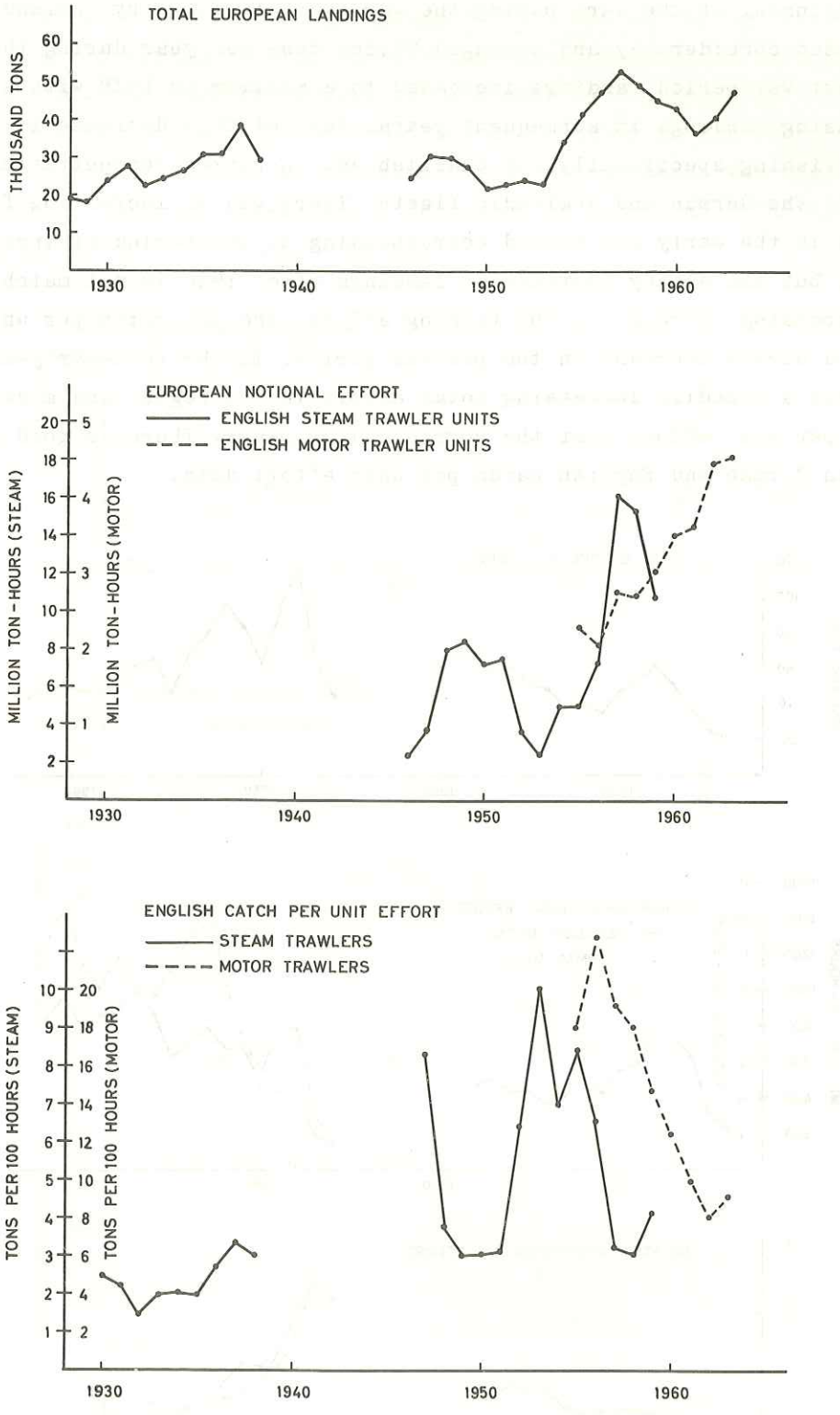

Figure 6. Total catch, effort and catch per unit effort in Division IVa.

5.4 Division Va. Iceland (Fig. 7). Landings increased from 1924 to a maximum in 1928 and then declined until 1930, after which they increased steadily until the beginning of the war. During the war years landings by Icelandic ships increased considerably and averaged 25,000 tons per year during the war. In the post-war period landings increased to a maximum in 1948 with a trend to decreasing landings in subsequent years. Part of this decrease is due to reduced fishing specifically for coalfish and increased concentration on redfish by the German and Icelandic fleets. There was an increasing fishing effort in the early war period corresponding to the period of increased landings, but the steady increase in landings after 1930 is not matched by a corresponding increase in the fishing effort, and the catch per unit effort shows a steady increase in the pre-war period. In the post-war years there has been a steadily increasing total effort in the region and a decreasing catch per unit effort over the corresponding years. There is good agreement between German and English catch per unit effort data.

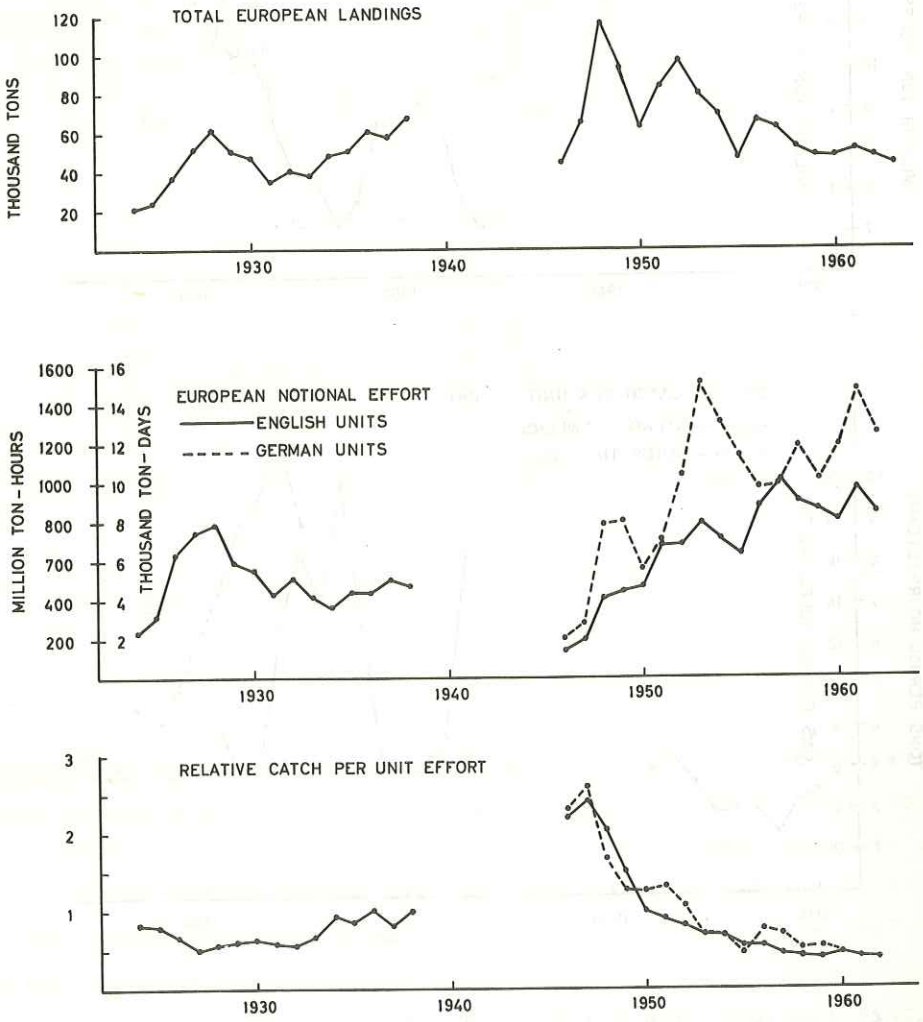

Figure 7. Total catch, effort and catch per unit effort in Division Va.

5.5 Division Vb. Faroes (Fig. 8). There has been little variation in catch and effort in this area, but in the post-war years there has been a gentle rise in both catch and effort. The peaks in 1957 are due to exceptionally high landings by German vessels. In the most recent years the German, and to some extent also the English effort in this area have decreased, while an expansion has taken place in the Scottish, and notably in the Faroese fisheries. Catch per unit effort, as estimated from English data, was high immediately after the war, but subsequently decreased to remain at a fairly steady level similar to that of the pre-war period.

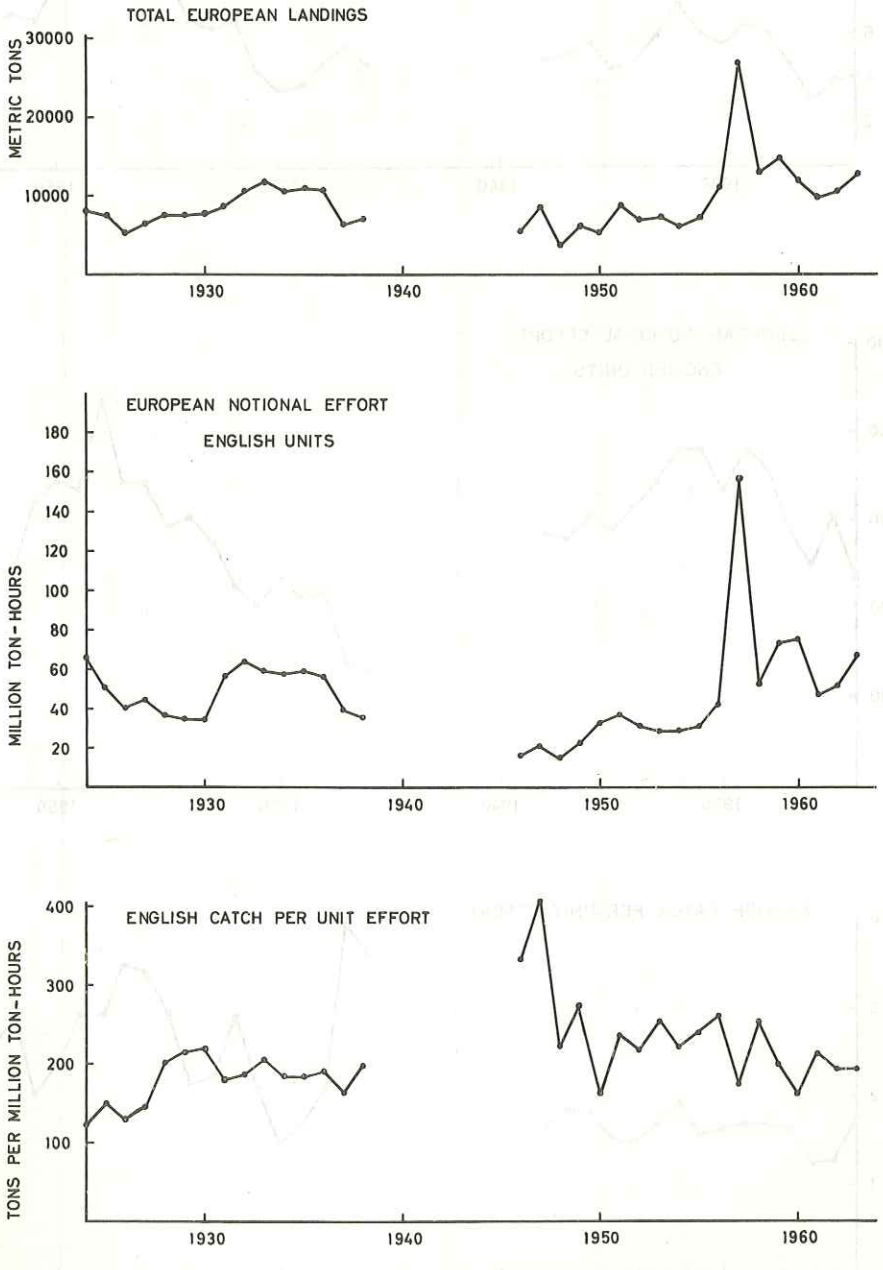

Figure 8. Total catch, effort and catch per unit effort in Division Vb.

5.6 Division VIa. West of Scotland (Fig. 9). The same trend is apparent in both catch and effort data. Both show a steady increase in the post-war period until 1958, but have since declined considerably. Catch per unit effort was relatively steady in the pre-war years, but fluctuated in the post-war period showing no particular trend.

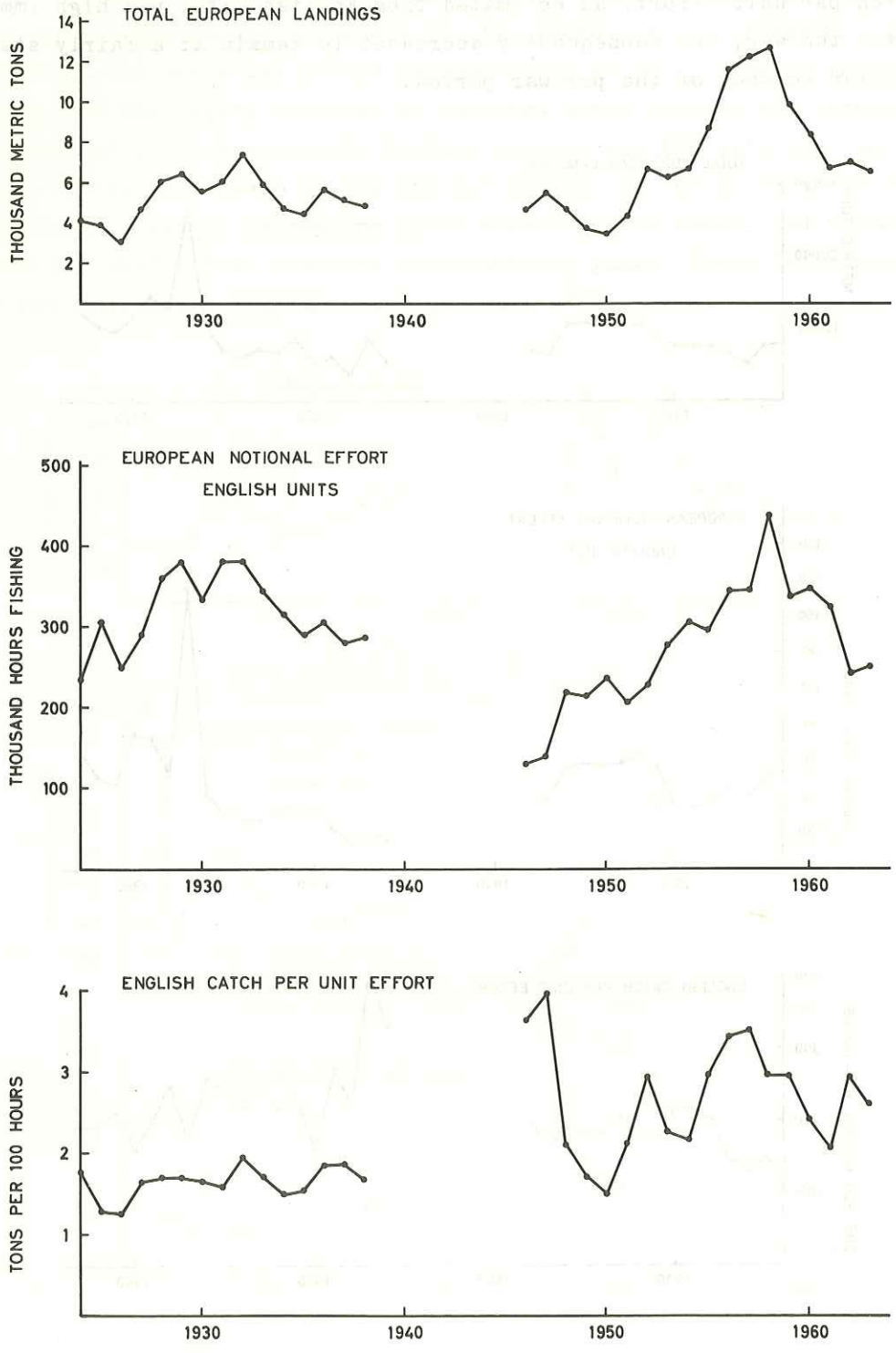

Figure 9. Total catch, effort and catch per unit effort in Division VIa.

Table 6. Mean values of instantaneous total mortality coefficient Z calculated from age compositions of German and English commercial landings.

Year x) / Area	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	Mean
Svinøy (G)				-0.27	1.12	1.21	-0.29	1.03	0.37	0.60	1.31	0.52	0.49				0.61
Lofoten (G)	0.69	-0.06	0.65	1.07	0.46	0.78	0.67	0.69	0.99	1.16	1.31	0.69	1.85				0.84
Lofoten (E)										0.57	0.45	1.11	0.61	1.61	0.45	1.24	0.86
Iceland (G)	0.71	0.67	-0.33	0.51	0.58	0.74	0.47	0.74	0.51	0.40	0.51	0.45	0.49				0.50
Iceland (E)															0.53	0.79	0.66
Faroes (G)										0.27	0.71	0.08	0.87				0.48
Faroes (E)										0.57	0.57	0.80	0.03	0.61	0.34		0.49
W. Scotland (E)											0.29	0.75	0.50	0.71	0.89		0.63

x) German estimates (G) are based on pairs of fishing seasons, i.e. the value entered under 1960 is calculated from the relative abundances in the seasons 1959-60 and 1960-61. The English figures (E) given are for pairs of calender years.

6. Mortality estimates

6.1 From the age composition of English and German commercial landings.

Estimations of total instantaneous mortality coefficients, Z, have been made from English and German data of commercial landings. The total instantaneous mortality coefficient was calculated as the logarithm of the ratio of the abundance of a year-class in two successive years of life, i.e.:

$$Z = \log_e \left({}^{N_1}/_{N_2} \right)$$

The results of these calculations are summarized in Table 6.

For Division IIa separate estimates have been prepared from data of the German fisheries in the Lofoten and the Svinøy area, and also for the English fishery which corresponds in space and time to the German Lofoten fishery. Fluctuations in estimates of Z from year to year are considerable, particularly for the Svinøy area. The average for the years 1951/61 is o.61 for the Svinøy area and no particular trend is detectable. Higher average values were obtained for the Lofoten area, o.84 from German data for the period 1948/61, and o.86 from English data for the period 1956/63. The German data for the Lofoten area also indicate a trend towards increased mortality in recent years, thus the average Z for the period 1948/55 is o.61 and for the period 1955/56 1.11.

English data for the period 1958/63 give values of Z for the west of Scotland Division (VIa) from o.29 to o.89 with a mean for the whole period of o.63.

For the Faroe Division (Vb) the German data give very variable figures for Z and the overall mean for the period 1956/61 is o.48. The English data are also variable giving values of Z from o.34 to o.8o except for a very low value of o.o3 in 196o/61. The over-all mean for the period 1957/61 is o.49. It should be noted, however, that there is a big difference in length composition between the English and German catches, the German fleet fishing in deeper water and catching only on larger fish.

German data for the Iceland Division (Va) for the period 1947/61 give relatively small variations in the value of Z (with the exception of 195o which show a negative figure). The mean for the period is o.5o and there is a slight trend of decrease over the period.

6.2 From Norwegian tagging experiments.

Extensive tagging experiments have been carried out in Norwegian coastal waters each year since 1954. Different methods of analysis of the recapture data have been applied for the purpose of estimating mortality rates.

In Table 7 are given the estimated values of the total instantaneous mortality coefficient, Z, calculated from the ratio between numbers of recaptures in succeeding years. This gives an unbiased estimate of Z, provided that the rate of fishing does not change appreciably from one year to the next. Adjustments for the effects of varying effort have been applied, and the revised estimates are entered in the same table.

Table 7. Mean total instantaneous mortality coefficient Z estimated from ratios between recapture numbers in succeeding years from Norwegian tagging experiments of medium and large coalfish. Recaptures within year of tagging and recaptures at Iceland, Faroes and Faroe Bank not included.

Recapt. periods	55/56	56/57	57/58	58/59	59/6o	6o/61	61/62	62/63	63/64	Aver.
Z	o.64	o.91	1.o1	o.93	o.88	o.93	o.82	o.85	1.o3	o.89
Z_a x)	o.92	o.82	o.99	1.14	o.78	1.o4	o.81	(o.89)		o.92

x) Adjusted for changes in total effort as estimated from German statistics.

The unadjusted estimates show a gradual increase in total mortality from Z=o.64 in 1955/56 to Z=1.o1 in 1957/58, after which it levelled off a little, until the high value of Z=1.o3 was reached in 1963/64.

The adjusted estimates are more variable, and it is noticed that they fluctuate with a trend very similar to that of the total instantaneous mortality coefficient estimated from German data of commercial landings.

For the purpose of obtaining separate estimates of F and X (i.e. the coefficient for "other losses") the method of Beverton and Holt was applied. The estimates of F and X are given by:

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

$$\text{and } X = \frac{1}{t} \cdot \log_e\left(\frac{n_1}{n_2}\right) \cdot \left(1 - \frac{n_1}{N_o\,(1 - n_2/n_1)}\right)$$

The results are given in Table 8.

Table 8. Mortality rates estimated by the Beverton-Holt method from Norwegian taggin data. (Numbers in brackets, assuming an initial loss of 1o per cent).

Year of tagging		Recapture periods								
		1954-1956	1955-1957	1956-1958	1957-1959	1958-196o	1959-1961	196o-1962	1961-1963	1962-1964
1954	F	o.38 (o.42)	o.29 (o.33)	o.35 (o.46)						
	X	o.63 (o.58)	o.o8 (o.o5)	o.91 (o.81)						
	Z	1.oo	o.38	1.27						
1955	F		o.17 (o.19)	o.22 (o.24)	o.23 (o.26)					
	X		o.11 (o.o9)	o.62 (o.6o)	o.76 (o.73)					
	Z		o.28	o.84	o.99					
1956	F			o.18 (o.2o)	o.27 (o.3o)	o.28 (o.31)				
	X			o.o3 (o.o1)	o.92 (o.89)	1.o1 (o.98)				
	Z			o.21	1.19	1.29				
1957	F				o.17 (o.18)	o.24 (o.27)	o.17 (o.18)			
	X				o.2o (o.19)	o.94 (o.91)	o.17 (o.16)			
	Z				o.37	1.18	o.34			
1958	F					o.28 (o.3o)	o.36 (o.4o)	o.28 (o.32)		
	X					o.39 (o.37)	o.93 (o.89)	o.45 (o.41)		
	Z					o.67	1.29	o.73		
1959	F						o.29 (o.3o)	o.29 (o.33)	o.33 (o.36)	
	X						o.44 (o.43)	o.47 (o.43)	o.66 (o.63)	
	Z						o.73	o.76	o.99	
196o	F							o.37 (o.41)	o.43 (o.48)	o.38 (o.41)
	X							o.46 (o.42)	o.77 (o.72)	o.5o (o.47)
	Z							o.83	1.2o	o.88
1961	F								o.38 (o.42)	o.1o (o.11)
	X								o.73 (o.69)	o.2o (o.19)
	Z								1.11	o.3o
1962	F									o.16 (o.17)
	X									o.17 (o.16)
	Z									o.33
Weigh. mean	F	o.38 (o.42)	o.19 (o.21)	o.21 (o.23)	o.22 (o.24)	o.27 (o.3o)	o.31 (o.33)	o.33 (o.37)	o.39 (o.43)	o.18 (o.2o)
	X	o.62 (o.58)	o.1o (o.o8)	o.33 (o.31)	o.57 (o.55)	o.54 (o.51)	o.59 (o.57)	o.46 (o.42)	o.73 (o.69)	o.23 (o.21)
	Z	1.oo	o.29	o.54	o.79	o.81	o.9o	o.79	1.12	o.41

With the exception of the figure for 1955, which is based on the recapture numbers from one single experiment, these estimates indicate a large increase in total mortality from 1956 to 1962, but for the most recent period a more moderate value of Z is estimated. It is apparent that the main part of the increase in estimated Z for the period 1956/62 was caused by an increase in the "other loss" coefficient X, but over the same period there was also approximately a doubling of the estimated fishing mortality coefficient, i.e. from F = o.2 to F = o.4.

A third method of analysis is the one developed by Paloheimo when the natural mortality (or "other loss") coefficient is assumed to be known. The fishing mortality coefficient is then given by:

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

By assuming different values of X a relationship between X and Z is found, which in the present material is linear. This indicates that the fishing mortality coefficient has on an average for the period in question constituted only between 3o and 4o per cent of the calculated value of Z.

7. Discussion and conclusions

It appears from the data presented under paragraph 5 that the estimated catch per unit effort has in some statistical areas remained fairly steady, in other areas it has decreased or varied in both directions.

Thus, for the total of Division IIa both German and English estimates show considerable fluctuations in catch per unit effort, but there is a general trend of decrease in the post-war period. Separate German estimates for the Svinøy area alone, however, show very great fluctuations from year to year. The German Svinøy fishery is a genuine coalfish fishery during the spawning season, and the catch per unit effort estimates are therefore likely to give a reliable index of the coalfish available to the bottom trawl in this area. Also for the German winter fisheries in the northern part of Division IIa (Lofoten area) coalfish is one of the main species, and the catch per unit effort estimates is presumably also in this area a fairly reliable index of the available stock. However, for most fisheries and statistical areas no separate data of effort for the individual species are available, and indeed a great proportion of the coalfish catch, for instance in the English trawl fisheries, is taken as by-catch in the fisheries for cod and haddock. There are further no data available which might facilitate assessments of the possible effects on the effective coalfish effort in the trawl fisheries, to be expected from changes in species preference as caused by market conditions, reduced or increased abundance of other species (cod,haddock, redfish etc.). These effects might well be significant in all areas both in the English and the German fisheries.

It is thus apparent that variations in catch per unit effort as calculated from the statistics of English and German trawl fisheries, may be caused by a great many factors, some of which are inherited with the nature and reliability of the available data, while others are connected with the frequently occurring changes in distribution of coalfish and/or their behaviour pattern. There is evidence to show that such variations may develop abruptly, and that the resulting anomalies in distribution and behaviour may be local and of short duration, as well as extending over larger areas and last for several years. With our present knowledge such variations are quite unpredictable, and neither do we know much about why they occur. Under these circumstances it is conceivable that catch per unit effort estimates based on statistics of fisheries with bottom trawl, which at the most give reliable density indices only of the stock available to these fisheries, are rather unreliable as true indices of coalfish stock abundance.

It could perhaps be assumed that the effect of these discrepancies might even out in the long run. In this case the data would still be useful for the purpose of assessing what effects the fisheries have on the stock. The possible relation between stock density, as expressed in catch per unit effort, and total effort excerted on the stocks has been investigated for all areas by plotting catch per unit effort against two years sums of total effort. For most areas these plots are irregularly distributed or show no trend at all. Only in the case of the Icelandic area (Fig. 11a), and to some extent, but less convincing, also the Norway coast area (Fig. 1o) this method of analysis gives a clear indication of reduced stock strength at high levels of total effort, an vice versa.

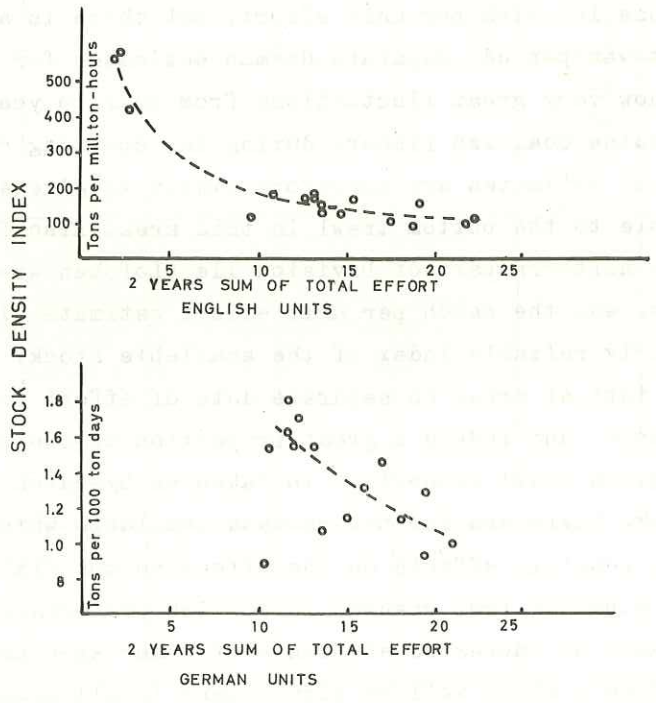

Figure 1o. Catch per unit effort in Division IIa plotted against 2 years sums in total effort in English and German units.

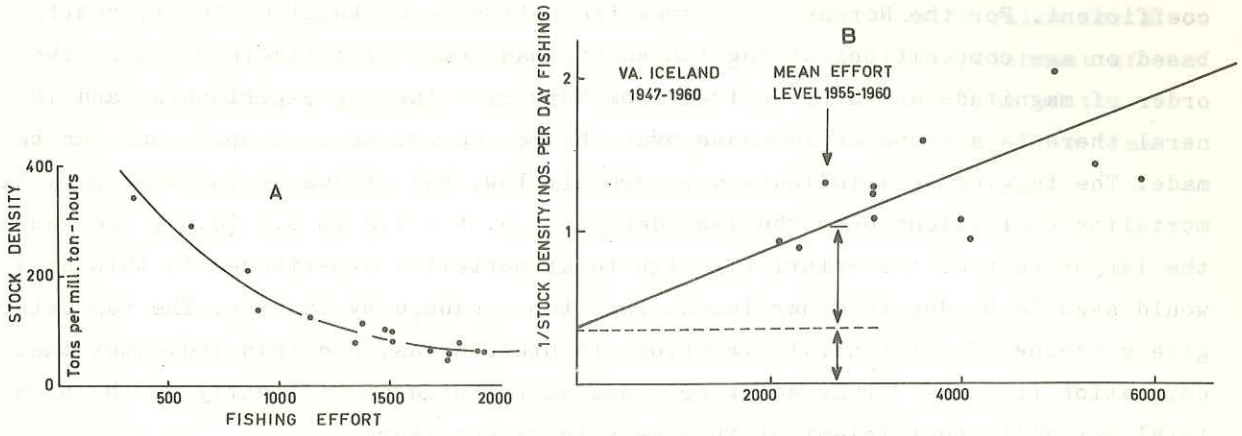

Figure 11. A. Catch per unit effort in Division Va plotted against 2 years sums of total effort in English units.
B. Reciprocals of stock density in German units of numbers per unit effort plotted against 2 years sums of total effort in Division Va.

For the Icelandic area the reciprocals of stock density expressed as numbers of fish per unit effort when plotted against 2-year sums of total effort (Fig. 11b), show a clear trend of increasing reciprocals with increasing effort, and at the present level of effort this relationship gives a ratio of F : M in the order of 2 : 1. On the other hand, there appears to be no increase in estimated total mortality coefficient in the increasing effort for the Icelandic region as calculated from the German data.

In appraising the reliability of these investigations it should be borne in mind that most of the coalfish landed from the Icelandic area are taken by trawl fisheries for which statistics of catch and effort are available. For the Norway coast and Barents Sea areas the estimates of total effort may be seriously biased since no effort data are available for the Norwegian fisheries, which are partly exploiting younger age-groups of coalfish than those taken in the English and German trawl fisheries. Differences of this sort are also apparent between the national landings in other areas, and this may be part of the reason why the effect of the fisheries on the stocks is not demonstrated by the available statistics of catch and effort. However, it may be assumed that unless this effect is very pronounced it is easily masked by the combined effects of fluctuations in recruitment to the fishable stock and variations in distribution and behaviour.

The mortality estimates based on measures of the relative catch of a year-class in succeeding years varies greatly from year to year and from year-class to year-class, but the estimated mean value of Z is of the same order of magni-

tude in nearly all areas, i.e. $Z \approx 0.5$-0.6 with the exception of Division IIa for the period 1955/61. At the present state of knowledge it cannot be ascertained whether these estimates approximate the true values, but considering the sources of bias which may effect these estimates it is assumed that they are not likely to result in serious underestimates of the magnitude of the total mortality coefficient. For the Norway coast area the estimates of total mortality coefficient based on age compositions of English and German commercial landings are of the same order of magnitude as those derived from Norwegian tagging experiments, and in general there is a trend of increase over the period for which comparisons can be made. The tagging data indicate a moderately low, but gradually increasing fishing mortality coefficient over the last decade, i.e. $F = 0.2$ to 0.3 (0.6), and hence, the larger part of the relatively high total mortality experienced in this area would seem to be due to other losses than those caused by fishing. The tag returns give evidence of substantial migrations to other areas, and this indicates that emigration from the Norway coast area has contributed significantly to the high total mortality coefficient of this area in recent years.

The investigations dealt with in this report do not give reason to assume that the various coalfish stocks in the ICES areas have been seriously depleted because of fishing. When this has been possible in spite of the very great increase in total fishing activities in the same areas since the war, it is probably because the distribution and behaviour of the young coalfish protect them from trawl exploitation. The young stages of coalfish are therefore very little fished except by purse seine, notably in the Norway coast area. There is of course, bound to be some effects resulting from the exploitation by man, although this is not demonstrated for other than the Iceland area. So far as can be judged from the available data, however, the output of the coalfish fisheries has to a very great extent been effected by changes in availability and by fluctuations in recruitment to the fishable stock, particularly in the Norway coast area, from which nearly half the total catch is derived.

8. Needs for further research

The studies of the Working Group have brought to light many gaps in the present knowledge of the coalfish resources which are relevant to problems of estimating vital parametres of the stock and other factors effecting the yield of the fisheries. Thus, it is evident that, especially for some fisheries, more complete and detailed data of the fisheries and the catch composition are needed. The tagging experiment have been very useful for this study and they should be continued and extended to other areas and seasons than hitherto done. There is in particular a need for tagging coalfish on the spawning grounds. It is possible that the distribution and relative abundance of coalfish eggs and larvae might contribute towards better estimates of stock abundance. Special studies should be carried out to investigate sources and magnitude of factors effecting catch per unit effort estimates in coalfish, and which possible steps could be taken to assess or minimize their bias as indices of true abundance. Finally, the

possibilities of applying other methods of estimating abundance, for example echo-surveys, should be explored, and for the purpose of stock identification serological methods might prove to be very useful.

The coalfish resources are exploited by several different nations, and it is essential that the existing close contact between the investigators working on these problems remains, and that whenever a case arises which calls for a joint project, facilities for this should be provided. The establishment of the present Working Group has for the first time produced a pooling of the available national coalfish data, and this might well be desirable from time to time in the future also.