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International Council for the
Exploration of the Sea

C.M.1971/F:2
Demersal Fish (Northern) Committee

https://doi.org/10.17895/ices.pub.9557

REPORT OF THE NORTH-WESTERN WORKING GROUP, 1970

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INTRODUCTION

At the 1970 Council Meeting, it was resolved (C.Res.1970/2:5) that "The North-Western Working Group be re-convened to re-assess in the light of further data, the assessments previously made concerning Icelandic cod".

The Group met in Lowestoft from 30 November to 6 December 1970, and the following members participated:-

A. Schumacher	Germany	Chairman
J. Jónsson	Iceland	
S. A. Schopka	Iceland	
D. J. Garrod	UK	
B. W. Jones	UK	
R. Jones	UK	
J.Møller Christensen	ICES	Secretary of Liaison Cttee.

In the report of its previous meeting (ICES, 1969) the Group considered, amongst other matters, the relative numbers of cod of different ages landed from the various fisheries at Iceland. In particular, it was pointed out that the proportion of fish of 7 years and older in the landings was too high to be consistent with the previous estimate of the mortality rate among fish younger than 7 years of age. This was believed to be of the order of 60% annually. It was recognized however that if the entire stock of fish under 7 years of age was subject to such a rate of mortality, there would be insufficient fish of 7 years and older left to account for the numbers actually landed. It was concluded, therefore, that the mortality rate among fish of less than 7 years of age must be considerably less than 60% per year. To account for this, it was suggested that only part of the stock of young cod was subject to exploitation at any time. This would explain how young cod on the trawling grounds could experience a mortality rate of 60% annually, and yet the total stock of young cod could experience a lower mortality rate. At its previous meeting, the Group recognized two extreme alternatives:

(a) that there was a continual interchange of young cod between those on the exploited grounds and those in regions not subject to exploitation;

(b) that the exploited and unexploited part of the young cod stock were completely independent for at least part of their lives. If this were so it was thought most likely that any mixing that might occur would take place when maturity was reached. For cod at Iceland this occurs over a range of ages from about 6 years onwards, the average age of first maturity being about 8 years of age.

During its previous meeting the Working Group made assessments of the effects of changes in effort and mesh size on the basis of the first of these hypotheses. In this report, new assessments have been made on the basis of the second hypothesis with particular examination of the possibility that the "unexploited" part of the young cod stock might occur in Greenland waters.

RECENT CHANGES IN CATCHES AND FISHING EFFORT

Landings of cod, catch per unit fishing effort, and estimated fishing effort at Iceland (Division Va) are listed in Tables 1-3. Fishing effort by German and particularly English trawlers has declined substantially in recent years but fishing by Icelandic vessels has increased. The total fishing effort as estimated in English units has decreased steadily since 1964, the present (1969) amount of fishing being about half of that in 1964. Catches of cod reached a low level in 1967 (345 000 tons) but in the two most recent years catches have increased to just over 400 000 tons despite the reduced amount of fishing. This has been possible because of the increased abundance of cod as is shown in the table of catch per unit effort. The recent increases in the catch-rates of English and German trawlers are due, in part at least, to the presence of the 1964 year class which was particularly abundant at Iceland. Recent Icelandic catches in the spawning fishery have benefited from the immigrants of the 1961 year class which was exceptionally abundant at Greenland, though the corresponding year class of cod of Icelandic origin was of only average abundance.

EVIDENCE OF MIGRATION OF GREENLAND COD TO ICELAND

It has been known for many years that fish of Greenlandic origin make a contribution to the stock of cod which spawns off the south-western coasts of Iceland. Tagging experiments at Greenland since the early 1920s have yielded a high proportion of recaptures from Iceland, particularly from tagged fish liberated off East Greenland and in ICNAF Divisions 1F and 1E. Additional evidence comes from the study of otoliths. During the course of routine age determinations from otoliths, many workers have observed otoliths with a structure characteristic of Greenland fish in samples obtained from Iceland, and this is borne out by a comparison of the relative strengths of year classes in the different fisheries. For example, for year classes of 1959-65 the only abundant one in the Icelandic non-spawning fishery was that of 1964, with the 1961 year class being only average. Abundance of year classes based on data for all the fisheries, which includes the Icelandic spawning fishery, shows the 1961 year class to be the most abundant. It would therefore appear that there was a large-scale immigration into the spawning fishery of fish of the 1961 year class which were not represented in the non-spawning fisheries. Other year classes which were abundant in the Icelandic spawning fishery but not in the Icelandic non-spawning fisheries were those of 1956, 1953 and 1950. All these year classes are known to have been very abundant at East Greenland, and the implication is that their immigration from Greenland as mature fish accounted for their increased abundance in the spawning fishery.

Yet another indication of immigration is the change in average length at age observed in the Icelandic spawning fishery. Icelandic data from the spawning fishery (Figure 1) show a reduction in the mean length at age of the 1961 year class at the age of 7 and older. This would be consistent with the faster-growing fish of Icelandic origin being diluted with fish from Greenland which have a slower growth rate, commencing at an age when the Greenland fish are expected to mature. The 1961 year class at Greenland which was more abundant than usual contributed a higher than normal proportion of the spawning stock at Iceland resulting in a lower than average mean length at age.

Recaptures of Greenland tagged fish show that the majority taken at Iceland are caught in the spawning fishery. The number of tags recaptured per unit of fishing effort in the spawning fishery reaches a maximum value in April.

Outside the spawning season small numbers of fish tagged at Greenland have been recaptured all around the coasts of Iceland and this, combined with the fact that hardly any of the fish tagged in the Icelandic spawning fishery have been recaptured at Greenland, suggests that fish from Greenland which migrate to Iceland to spawn remain at Iceland after spawning rather than returning to Greenland.

Additional information has also been obtained from immunogenetic studies of cod blood (see Appendix 1).

Although it has been known that Greenland cod contribute to the fisheries at Iceland no previous attempt has been made to obtain a quantitative estimate of their numbers. This has now been attempted by the Working Group by stock analysis and an analysis of tagging data.

ESTIMATE OF IMMIGRATION FROM GREENLAND FROM RESULTS OF TAGGING EXPERIMENTS

The data used were the unpublished results of Danish tagging experiments at Greenland in the period 1946-65, kindly made available to the Working Group by Mr. Sv. Aa. Horsted. A full analysis of the experiments is not yet available and the aim of the present analysis was to obtain an estimate of the order of magnitude of fish of Greenland origin available for capture at Iceland. It is possible that when a fuller analysis of the results is completed it may be necessary to revise the present conclusions.

Tagging results from three Greenland regions have been analysed: ICNAF Divisions 1E and 1F, and East Greenland. Only fish that were 70 cm or over at the time of tagging have been included on the assumption that the majority of fish over 70 cm are mature. It is believed that the migration to Iceland is a spawning migration and that after spawning at Iceland, fish of Greenland origin tend to remain at Iceland rather than return to Greenland.

Over the whole period of the experiments, the averages of the percentages of the totals recaptured (all areas) in successive annual time periods have been calculated. Percentage recaptures from each experiment have been used to avoid the average for all experiments combined being weighted by numbers released in individual experiments.

Time period (Years)	Averages of the percentage of totals recaptured		
	East Greenland	Division 1F	Division 1E
0	-	2.17	3.9
1	4.8	7.3	10.3
2	3.7	4.5	4.6
3	1.25	2.7	2.7
4+	0.55	1.7	3.1

Total mortality coefficients, Z, for the tagged populations have been estimated from the slopes of the regressions of $\log_e$ percentage recaptures against recapture period for periods 1 to 4 in the table. The following values of Z were obtained:

Z = 0.77 East Greenland;
0.48 Division 1F;
0.41 Division 1E.

The intercepts from the same regressions were used to estimate the effective number of tagged fish liberated as percentages of the actual numbers tagged:

	Number of fish tagged	Percentage	Effective number of tags liberated
East Greenland	1 232	47	579
Division 1F	3 575	54	1 931
Division 1E	326	71	216

From the effective number of tags released and the overall total mortality rate, the numbers of tagged fish surviving in each population have been estimated from the relationship:

$$N_t = N_o e^{-Z_t}$$

	East Greenland	Division 1F	Division 1E
Z	0.77	0.48	0.41
N_0	579	1 931	216
N_1	268	1 195	144
N_2	124	739	95
N_3	57	458	63
N_4	27	283	42

The actual numbers of recaptures in each time period at Greenland and Iceland are also known. Average values of the mortality rates in the Icelandic spawning fishery are taken to be F = 0.7 and M = 0.2. From these the actual population of tagged fish actually at Iceland in each time period was calculated from the relationship:

$$N_{It} = \frac{n_{It} \cdot Z_I}{(1 - e^{-Z_I})F_I}$$

where N_I = estimated number of tagged fish at Iceland;

n_I = observed number of recaptures of tagged fish from Iceland.

The population of tagged fish remaining at Greenland was then obtained from the total tagged fish surviving, minus the estimated population of tagged fish at Iceland.

Period	A Iceland recaptures	B Estimated tagged population at Iceland	(%)	C Total tagged population	D Estimated tagged population at Greenland (C-B)	E Greenland recaptures
	(a) East Greenland					
1	37	81	(30)	268	187	23
2	34	74	(60)	124	50	7
3	13	28	(49)	57	29	3
4	4	9	(33)	27	18	4
	(b) Division 1F					
1	40	87	(7)	1 195	1 108	227
2	47	102	(14)	739	637	103
3	33	72	(16)	458	386	68
4	20	44	(16)	283	239	39
	(c) Division 1E					
1	9	19	(13)	144	125	31
2	7	15	(16)	95	80	11
3	6	13	(21)	63	50	5
4	4	9	(20)	45	36	6

An estimate of the total mortality rate within each of the Greenland divisions was calculated from the rate of decline of the tagged population at Greenland. This mortality coefficient will include a component of 'other loss', X, mortality due to emigration to Iceland, i.e.

$$Z_G = F + M + X$$

Values of Z_G were calculated and found to be:

Z_G = 0.88 East Greenland;
0.51 Division 1F;
0.45 Division 1E.

The fishing mortality rate in each Greenland division was then estimated from the relationship:

$$F_{Gt} = \frac{n_{Gt}}{N_{Gt}} \cdot \frac{Z_G}{(1 - e^{-Z_G})}$$

where N_{Gt} = number of tagged fish at Greenland in period t;
n_{Gt} = number of recaptures of tagged fish from Greenland in period t;
F_{Gt} = fishing mortality coefficient at Greenland in period t;
Z_G = total mortality coefficient at Greenland.

Period	Z_G	F	M	X
	(a) East Greenland			
1	0.88	0.18	0.2	0.50
2		0.21		0.47
3		0.16		0.52
4		0.33		0.35
	(b) Division 1F			
1	0.51	0.26	0.2	0.05
2		0.21		0.10
3		0.22		0.09
4		0.21		0.10
	(c) Division 1E			
1	0.45	0.31	0.2	0.00
2		0.17		0.08
3		0.12		0.13
4		0.21		0.04

Taking these estimates of F and Z_G for the Greenland divisions the total stock in each division can be calculated from the catch. For the present purpose it has been assumed that all the fish attain sexual maturity at the age of 7 years and therefore the stock of 7 year old fish in each division has been calculated. Next, using the percentages of Greenland fish at Iceland (calculated above), an estimate was made of the number of 7 year old fish migrating annually from Greenland to Iceland.

	Average annual catch 7 years old (thousands)	F	Z_G	Stock 7 years old (millions)	Average percentage at Iceland	Number (millions) migrating to Iceland
East Greenland	1 235	0.22	0.88	8.4	45	3.8
Division 1F	1 799	0.22	0.51	10.4	12	1.2
Division 1E	2 021	0.20	0.45	12.5	17	2.3
						7.3

THE FISHERY AT ICELAND

The fishery for cod at Iceland cam, for convenience, be divided into two components:

(1) a fishery in the spring off the south-west corner of Iceland for mostly mature spawning cod. This fishery is prosecuted mainly by Icelandic vessels;

(2) a general fishery for cod around the whole Icelandic coast at all times of the year. This fishery is mostly for immature cod and is prosecuted by English, German and Icelandic vessels.

These will be referred to as the 'spawning' and the 'non-spawning' fisheries, but it should be understood, however, that a small proportion of immature fish are taken in the spawning fishery and that a small proportion of mature fish are taken in the non-spawning fishery. The relationship between the stocks of fish and these fisheries is represented diagrammatically in Figure 2.

The numbers of cod taken annually in each of these fisheries for the period 1960-69 are shown in Tables 4-6, with the annual averages shown in Table 7.

STABLE AGE COMPOSITIONS OF THE LANDINGS

Estimates of the mean age compositions of the landings have been determined using the method for determining a 'stable age composition' described by Jones 1961. The method is intended to estimate mean age compositions, with the effect of year class fluctuations removed, and the values obtained are shown in Table 8. The stable age compositions of the numbers landed were obtained using the data on numbers landed at each age in Tables 4-6. The corresponding age compositions by weight were obtained by multiplying the numbers at each age by the mean weight at the corresponding ages given in Table 9.

MORTALITY RATES

At the previous meeting, estimates of the total instantaneous mortality rate, (Z), were made at each age based on data for the period 1960-66. These were applicable to the entire stock: i.e. to both the exploited and unexploited parts of the stock on which the Icelandic fisheries were dependent considered as a single unit. At the present meeting these values were recalculated, using data for the period 1960-69, and assuming values of natural mortality of 0.2 and 0.3. The estimates of the fishing mortality rate at each age so obtained are shown in Table 10.

However, for assessment purposes, estimates of the fishing mortality rates within each of the spawning and the non-spawning fisheries were also required. The method of doing this, which is explained in Appendix 2, gave estimates of fishing mortality rate within each component of the stock, which are also shown in Table 10.

ESTIMATES OF STOCK SIZE

Estimates of the numbers of fish in the sea necessary to account for the actual numbers landed have been made by the virtual population method. Allowance for deaths due to natural causes as well as to fishing has been made, using values of the instantaneous natural mortality rate (M) of 0.2 and 0.3. Estimates have been made to account for the numbers landed from the total and from the non-spawning fisheries on the basis of different assumptions. These are given in Tables 11 and 12. The values obtained depend to some extent on the mortality rate on the oldest fish in the population, estimates of which cannot be made and that have had to be assumed. Estimates have therefore been made assuming:

(a) that the total instantaneous mortality rate (Z) is equal to 0.8 in the oldest age-group in each year class,neglecting the fact that the oldest fish in the different year classes sampled were not necessarily the same;

(b) that Z = 0.7 in 12 year and older fish, but making allowance for the fact that for fish less than 12 years old values of Z lower than 0.7 may be more appropriate.

The results are given in Tables 11 and 12. These alternatives had little effect on the numbers obtained and these were therefore averaged so as to arrive at mean estimates of the numbers of fish in the stock necessary to account for the landings from the total and from the non-spawning fisheries (Table 13). Estimates for the spawning fishery were then arrived at from the differences between these estimates (Table 13).

To account for the Icelandic non-spawning fishery for example, 165-237 million 2 year old cod are required depending on whether a natural mortality rate of 0.2 or 0.3 is adopted. In addition, to account for the spawning fishery, a further 75-151 million 2 year old fish are required.

ASSESSMENTS OF CHANGES IN FISHING EFFORT

Assessments have been made of the effect of changes in fishing effort by applying the method of Jones (1961) to the stable age compositions of the landings (by weight) in Table 8, using the fishing mortality estimates in Table 10. Assessments can be made for limiting possibilities:

(a) that the spawning and non-spawning fisheries are based on a single stock between the component parts of which there is a continual interchange of fish;

(b) that the spawning and non-spawning fisheries are based on stocks that are independent at least until the age of maturity.

Assessments under (a) were carried out in the previous meeting and the results have been carried over; at this meeting new assessments have been made under (b), which is itself subdivided into two alternatives:

b (1) On the assumption that the spawning and non-spawning fisheries are based on completely independent stocks, so that changes in fishing effort in one stock would have no effect whatever on landings from the other stock.

b (2) Because a reduction in effort on the non-spawning fisheries would lead to an increase in the numbers of old, and mature fish, some of these would emigrate to the spawning fishery and hence not be available to the vessels engaged in the non-spawning fishery. To allow for this, the effects of reductions in effort on the non-spawning fishery were determined for fish greater than and less than 8 years of age separately. It was then assumed that the landings of 8 year and older fish in the non-spawning fishery would remain the same and that any potential would simply be transferred to the spawning fishery.

These alternatives will be referred to as hypotheses b(1) and b(2), respectively.

RESULTS OF ASSESSMENTS

Assessments of the effects of changes in effort have been made for various combinations of changes in effort in the non-spawning and spawning fisheries respectively.

Changes in effort by all gears equally

The non-spawning fishery (Table 14)

U.K. Trawlers

Reduction in effort would lead to reduction in yields per recruit for all hypotheses and for both values of natural mortality.

Others (mainly German and Icelandic vessels)

Reduction in effort could lead to either gains or losses in the yields per recruit depending on the assumptions made. If hypothesis b(1) is regarded as, biologically, the least likely, reductions in effort would probably cause reductions in the yields per recruit (see (a) and b(2).

Increases in effort would give increases in yield per recruit on hypothesis (a) but reductions in yield per recruit on hypotheses b(1) and b(2). In this instance, hypothesis b(2) seems more applicable than hypothesis (a).

Total non-spawning fisheries

Estimates of the effects of effort changes on the total non-spawning fisheries according to hypothesis (a) are not available, as these were not calculated as such in the previous report. According to hypothesis b(1), a reduction in effort of up to 40% could lead to either losses or gains. A reduction to 60% would lead to losses. According to hypothesis b(2), a reduction in effort would lead to losses.

In the case of an increase in effort, the effects on the yield per recruit would lie in the range from +1% to -7% for both hypotheses b(1) and b(2).

The spawning fishery (Table 15)

Reduction in effort would lead to an increase in yields per recruit on hypothesis (a), but a decrease in yields per recruit on hypothesis b(1). In the case of hypothesis b(2) the decreases would not be so great because of the possible immigration of fish from the non-spawning fisheries. To calculate this effect precisely would necessitate consideration of all possible combinations of effort change in the spawning and non-spawning fisheries individually. This has only been done in the special case of the effect of a reduction of effort in the non-spawning fishery due to the closure of the north-east corner of Iceland. This is dealt with in a later section.

Increases in effort could lead to a decrease in the yield per recruit in the spawning fishery on hypothesis (a), but an increase on hypotheses b(1) and b(2).

All fisheries (Table 15)

A reduction in effort would tend to reduce the yields per recruit from all fisheries combined, for both hypotheses (a) and b(1).

An increase in effort would affect the yields per recruit by something of the order of less than 5% on all hypotheses.

ASSESSMENT BY SIMULATION

The evidence that a proportion of the fishery at Iceland is based upon fish from Greenland indicates a complex resource situation of three fisheries, i.e. the non-spawning and spawning fisheries at Iceland and the fishery at Greenland, based upon two mixing stocks. A second method was therefore used for confirmation, based upon a reconstruction of the fishery from recruits which are assumed to originate from East Greenland and in Divisions 1E and 1F at West Greenland.

The virtual population estimate of the stock of 2 year old fish at Iceland necessary to provide the observed catch of fish of known Iceland origin at Iceland is 217 x 10^6 fish. It has been calculated that a balance of 100 x 10^6 fish not available to the Icelandic non-spawning fishery must exist to generate the observed catch at Greenland and in the Icelandic spawning fishery following their emigration from Greenland. These are assumed to be at East Greenland, and in Divisions 1E and 1F at West Greenland. Fishing mortality in the non-spawning fishery at Iceland is taken to be that shown by the virtual population analysis (Table 10); that in the Iceland spawning fishery is taken as $Z = 1.4$, from recent Icelandic data, and that for the fishery at Greenland in the relevant areas as $F = 0.2$. Recruitment from the non-spawning fishery to the spawning fishery at Iceland is governed by the known rate of maturation with age, and the proportion of mature fish at Greenland available to emigrate to Iceland is determined by the same ogive. The actual proportion of mature fish at Greenland emigrating to Iceland is taken as 25% per year, as implied by the analysis of tagging data. All calculations were carried out with a value of natural mortality, $M = 0.2$.

The simulation is carried out by applying the appropriate estimates of mortality to the 'immature' fisheries at Iceland and Greenland. Survivors were then recruited to the spawning fishery at Iceland by maturation at Iceland and by maturation and emigration from Greenland. The mature fish were then subject to the mortality in the Iceland spawning fishery, and survivors within that fishery returned to it in subsequent years. This procedure then simulates the catch in numbers of each age group in each fishery which was raised to the total catch by the known average weight at age.

The degree of correspondance between the actual and simulated catches is tabulated in Table 16. In addition the model suggest that the stock of mature fish of Greenland origin emigrating to Iceland is about 10 million, which corresponds reasonably well with the analysis of the tagging data. The simulation also estimates the spawning fish .....

of Greenland origin to contribute about one-third of the catch by weight of mature fish in the Icelandic spawning fishery and this corresponds with the admittedly tenuous estimates that can be derived from the analysis of otolith types and the decrease in mean length per age of fish in the Iceland spawning fishery.

The Group considered that this model provides a tolerable comparison with the biological data and shows that this allocation of stocks to Iceland and Greenland is consistent with the observed catches at Iceland. The model was then used to construct a number of assessments as set out in Table 17. These confirm the first method of assessment in showing that variation of fishing effort within the Icelandic non-spawning fishery will not make a significant difference to the total yield of cod at Iceland, as implied by the flat-topped yield per recruit curve characteristic of cod stocks at anything but very low or very high levels of exploitation. However, the yield would be distributed between the component fisheries in a different way, the catch of the non-spawning fishery decreasing and that of the spawning fishery increasing with a decrease in fishing mortality in the non-spawning fishery.

The assessment of an effect of a doubling of fishing effort at the relevant parts of Greenland indicates the effect this would have upon the catch of fish of Greenland origin in the spawning fishery at Iceland. In this particular example the total yield at Iceland would be reduced by 20 000 tons and this is equivalent to the gain in the fishery for mature fish at Iceland achieved by a 20% reduction in the fishing mortality in the non-spawning fishery at Iceland. This implies that any diversion of fishing from Iceland to these parts of Greenland (East Greenland and Divisions 1E and 1F) will tend to negate the potential benefits of the reduction at Iceland to the total yield there.

THE EFFECT OF A PROPOSED CLOSURE OF THE NORTH-EAST CORNER OF ICELAND TO TRAWLING

This present reappraisal of the effect of fishing upon the yield of cod at Iceland was requested by NEAFC in 1968 (NC6/98, Annex D) and arose from the Commission's consideration of an earlier proposal by Iceland that an area off the north-east coast of Iceland be closed to all trawling during the months July-December for an experimental period of 10 years (NC5/59, NC6/86). Although NEAFC requested a re-assessment of the entire cod and haddock fisheries at Iceland, a re-evaluation of the original proposal for a closure remains relevant.

The information considered by the Commission included estimates of the proportion of the fishing effort in the non-spawning fishery which takes place within the proposed area of closure. This information has been updated and is found in Table 18. These data are incomplete in that they may exclude small quantities of trawling by countries other than UK and Iceland, and they exclude fishing by gears other than trawling. There has been a reduction in the trawl fishery in the area since 1967 including that by Icelandic vessels, but mainly due to the overall decline in fishing by UK trawls at Iceland (Table 3). As an average for the 1965-69 period, trawling off north-east Iceland accounted for 6.1% of the total landings in the non-spawning fishery; this can be used as an index of the reduction of the fishing effort if the area was closed to trawling throughout the year. The percentage for the July-December period would be rather less than this.

Table 19 summarizes the effect on the various fisheries of a reduction of 20% in the fishing mortality in <u>all</u> sectors (gears) of the non-spawning fishery. Depending upon the value of natural mortality, in the non-spawning fishery, losses from the UK trawl fishery would range from 7 to 11% (15 000 tons), and for other components of that fishery catches might range ± 3% (3 000 tons) from their current level giving a decrease of from 4 to 8 per cent on the total non-spawning fishery. In the spawning fishery itself yield is estimated to increase from 4 to 7% (10 000 tons) leaving theoretical yield from the total fishery at Iceland within 2% of its present yield.

The alternative method of assessment by simulation of the catches of immature and mature fish suggest rather bigger changes but the actual non-spawning and spawning components of the fishery are not purely of immature and mature fish. Thus the loss of 9.3% from the immature fishery (Table 19) should be offset by capture of a proportion of mature fish, if it is to be equated with the non-spawning fishery and conversely the increased yield of mature fish would be decreased by the loss of a proportion of the catch of immature fish if that is to be equated with the spawning fishery. These adjustments bring the two methods of assessment within close agreement. The estimated proportion of the non-spawning fishery which takes place in the proposed area of closure (6.1%) lies well within the 20% reduction used as a basis for Table 19 and the effect of such a closure would therefore be proportionately less.

This assessment presumes that in the event of a closure all trawling within the area would be deployed on fishing grounds other than at Iceland. If the displaced fishing moved to other areas of Iceland the changes would be even lower. Alternatively, the results of the simulation model assessment (Table 17) suggest that if the displaced fishing were deployed at South or East Greenland it would continue to exert an effect upon the catches of cod in the spawning fishery at Iceland. However, at the present time it is not possible to estimate the actual effect of particular levels of fishing effort redeployed from the area of closure to South and East Greenland.

HADDOCK

In Tables 20 and 21 data on nominal catch and catch per unit of effort are given for the period 1946 to 1969 for haddock in Icelandic waters.

Changes in landings and fishing effort

Table 22 gives the number of fish landed of the various year classes and from them it is evident that in the period 1951-69 only the year classes from 1956 and 1957 have contributed any considerable amount to the haddock fishery.

There has been a considerable decrease in the English fishing effort for haddock in Icelandic waters in recent years and this is responsible for the decline in the English haddock landings. Icelandic fishing effort increased in the period 1967-69 and this has managed to keep the landings on a steady level although much lower than the 1962-65 average.

The main cause for the decline in the total haddock fishery in Icelandic waters must be considered to be the absence of any good year classes since 1960.

Mortality estimates

Examination of the estimates of fishing mortality on Iceland haddock indicates that, as might be expected from the decline in fishing effort, fishing mortality has fallen slightly since 1965. However, the current level of fishing mortality does not differ significantly from the value of fishing mortality which provided the basis for the 1968 assessment which remains valid and is reproduced in Table 23.

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APPENDIX 1

COD STOCK IDENTIFICATION STUDIES AT ICELAND USING SEROLOGICAL, BIOCHEMICAL AND GENETIC TECHNIQUES

Contributed by A. Jamieson (Fisheries Laboratory, Lowestoft)

Information on the frequency occurrences of recognizable genes in cod stocks can be used as metaphorical tags capable of defining a pool of genes perpetuated in each genetic isolate or contemporary unit of stock. The available data about genes in cod show that this approach is particularly relevant to this species. Isolates of cod stocks are known to have differentiated genetically allover the range of this species. The few marker genes known to characterize the stocks can be put to work in those stock identification problems that are bedevilled by the phenotypic bias in the more familiar morphometric data. Genetic analyses should supplement the latter also.

The past 10 years have witnessed a gradual increase in the number of genetic variants in cod. Although few have been applied in the present context their potential value is undeniable, but practical application of the available methods to date has been confined to the well-tried variants at two independent genetic loci called Hb and Tf. As the symbols suggest, the alleles at those loci control haemoglobin variants in cod erythrocytes and transferrin variants in cod blood plasma. The series of alleles at both these polymorphic loci occur in clearly different proportions in certain stocks of cod.

An international cod blood sampling programme in Iceland area has produced several thousand blood samples which have been tested at Lowestoft and at Reykjavik. The greatest numbers of samples were from spawning cod at south-west Iceland during the spring of 1969 and again in 1970. Samples were also taken and tested in different parts of the Iceland cod fishery through different seasons, also at Greenland.

A preliminary analysis of this blood data suggest the following:

1. Plurality of stocks in the Iceland area. This is evident in the erratic differences in allele frequencies at Iceland, particularly during the spawning season.

2. The differences in allele frequencies did not show consistent regional effects. This was presumably due to migrations in and out of the Iceland area giving what may be described as a mosaic effect.

3. Mixing of stocks was occasionally evident within single hauls of cod. Genetic imbalance in hauls was interpreted as evidence for mixing.

4. A genetic change in the composition of the spawning aggregate of cod at south-west Iceland occurred about early April. This change was expressed as a conspicuous drop in the frequency of the allele HbI^1 during the 1969 spawning season and again in 1970.

5. The East Greenland cod allele frequencies were close to the average values for the same alleles at Iceland as a whole. More East Greenland cod blood samples would be welcome at Lowestoft.

6. The transferrin allele frequencies at West Greenland were represented in occasional hauls at south-west Iceland at spawning time.

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APPENDIX 2

SUBDIVISION OF FISHING MORTALITY RATES

Estimates of total and fishing mortality rates were obtained in the way described in the Appendix to the previous Working Group Report for values of $M = 0.2$ and 0.3, using (a) the numbers landed at successive ages in the entire fishery and (b) the numbers landed at successive ages in the non-spawning fishery alone.

These provide respectively (a) estimates of fishing mortality (F_T), on the entire stock at each age, and (b) estimates of fishing mortality (F_N), within the stock supporting the non-spawning fishery at each age.

The assumption was then made that

$$F_T = p\,F_N + (1 - p)F_s \text{ at each age, so that } F_s = \left(\frac{1}{1 - p}\right)\left[F_T - p\,F_N\right]$$

where p = the proportion of the stock supporting the non-spawning fishery at any particular age

and F_s = the fishing mortality rate within the stock supporting the spawning fishery at the same age.

Values of p were estimated directly from the values in Table 10 relating to the numbers of fish in the sea in the non-spawning and total fisheries at each age. These and other values required for calculating F_s at each age are shown in Table 10.

Table 1. Nominal catch in metric tons of cod from Iceland grounds, Division Va, according to Bulletin Statistique[1]

Years	Iceland	England	Germany	Faroes	Scotland	France	Norway	Holland	Belgium	Denmark	Sweden	Total
1946	199 165	36 846	11 011	15 000[2]	4 756	-	188	27	894	-	-	267 887
1947	200 242	52 369	10 817	15 000[2]	4 068	1 905	57	-	5 150	-	-	289 608
1948	213 177	90 702	11 193	15 000[2]	4 147	2 830	13	242	3 184	8	-	340 496
1949	221 419	91 125	24 120	15 000[2]	4 954	1 538	108	-	4 387	16	-	362 667
1950	197 433	108 901	30 327	15 000[2]	5 218	98	892	970	4 249	267	-	363 355
1951	183 252	103 485	33 805	15 000[2]	2 652	579	3 831	342	5 591	45	-	348 482
1952	237 314	94 568	41 808	15 014	1 560	-	4 108	99	4 940	16	16	399 943
1953	263 516	173 798	56 005	16 215	1 418	-	7 465	-	7 634	-	10	526 061
1954	306 191	165 694	45 253	15 365	1 467	-	7 224	116	6 220	-	-	547 530
1955	315 438	138 705	48 236	18 667	1 028	-	7 053	-	9 002	1	-	538 130
1956	292 586	127 786	30 071	16 187	2 529	-	4 575	-	6 975	-	-	480 709
1957	247 087	144 265	23 292	20 924	1 360	-	8 231	2	6 748	-	-	451 909
1958	284 407	150 517	37 849	17 875	1 204	-	6 829	-	9 946	-	56	508 683
1959	284 259	112 740	35 562	7 680	1 347	-	5 460	-	5 456	-		452 504
1960	295 668	109 414	37 939	11 781	1 236	-	3 429	-	5 556	-	USSR	465 023
1961	233 874	96 539	21 776	10 602	2 066	77	4 214	70	5 427	-		374 645
1962	221 820	105 144	34 157	8 657	3 112	100	4 700	453	8 199	-	-	386 342
1963	232 839	123 185	33 034	6 254	3 180	-	3 510	-	-	-	-	402 002
1964	273 584	122 207	19 336	6 887	4 582	-	2 688	-	-	-	-	429 284
1965	233 483	128 136	15 274	5 246	6 781	-	419	512	3 747	-	-	393 598
1966	223 974	109 038	9 851	3 414	4 849	100	469	78	2 987	-	1 995	356 755
1967	193 449	126 566	15 397	2 774	3 607	375	185	-	2 367	-	302	345 022
1968	227 594	111 571	29 569	4 259	2 832	124	277	-	3 488	-	1 356	381 070
1969	281 680	95 386	19 368	2 579	3 996	124	363	22	2 716	-	177	406 411

1) German figures according to national statistics from 'Bundesforschungsanstalt für Fischerei,' Hamburg.

2) Estimated.

Table 2. Catches per unit effort of Iceland cod.

Years	A England	B Germany	C Iceland
1946	2 310	5.1	-
1947	1 766	3.8	-
1948	1 527	3.0	-
1949	1 397	3.3	-
1950	1 190	3.3	-
1951	1 155	3.2	-
1952	1 116	3.2	-
1953	1 353	4.0	-
1954	1 237	3.2	-
1955	1 272	4.5	-
1956	1 249	3.5	-
1957	993	2.6	-
1958	980	3.8	-
1959	822	4.2	-
1960	701	3.8	1 185
1961	569	2.7	663
1962	611	4.3	462
1963	626	4.0	365
1964	546	2.1	411
1965	567	1.5	475
1966	604	1.0[x)]	517
1967	686	1.5	483
1968	921	3.3	650
1969	1 035	2.3	617

A: Tons per million ton hours (steam trawlers)

B: Tons per day fished

C: Tons per million ton hours

[x)] German value low because effort mainly directed towards redfish.

Table 3. Estimates of fishing effort on Iceland cod.

Years	A England	B Germany	C Iceland	Total effort
1946	15 952	2 174	-	115 971
1947	29 543	2 858	-	163 373
1948	59 306	3 725	-	222 635
1949	65 202	7 117	-	259 504
1950	91 510	8 851	-	305 369
1951	89 109	9 957	-	300 030
1952	83 825	11 732	-	354 496
1953	128 143	13 349	-	387 889
1954	133 521	13 546	-	441 153
1955	108 789	10 442	-	422 101
1956	101 840	8 307	-	383 122
1957	144 229	8 375	-	451 725
1958	153 601	9 865	-	519 171
1959	137 455	8 683	-	551 744
1960	157 309	9 731	38 300	668 563
1961	171 282	7 795	46 139	664 745
1962	177 962	7 938	28 038	653 832
1963	210 897	8 371	39 116	688 157
1964	234 447	9 185	36 735	823 612
1965	225 425	9 965	43 609	694 095
1966	181 784	9 630	38 708	591 717
1967	184 548	10 143	45 997	503 088
1968	127 965	8 839	61 788	437 063
1969	91 571	8 581	61 871	390 156

A: Thousand ton hours. Motor and steam trawlers combined.

B: Days fishing.

C: Thousand ton hours.

$$\text{Total effort} = \text{English effort} \times \frac{\text{Total catch}}{\text{English catch}}$$

Table 4. Cod. Iceland. Total landings in No x 10^{-6}.

Age / Year	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
2	0.7	1.7	0.6	0.9	1.9	1.6	1.9	6.2	3.2	0.2
3	7.9	12.5	8.4	14.3	12.4	22.2	13.2	26.9	13.1	10.3
4	24.1	15.9	25.5	25.9	22.4	30.6	28.2	25.0	44.1	21.8
5	24.4	15.9	14.4	19.5	18.3	19.1	18.3	23.4	19.8	35.6
6	10.7	12.7	13.3	10.2	11.8	9.6	11.1	11.7	15.4	14.0
7	9.0	7.6	12.2	17.1	8.1	8.5	5.9	9.0	16.0	12.8
8	7.0	9.0	4.3	7.9	20.0	5.9	10.7	2.8	5.5	19.0
9	7.2	4.8	10.6	3.0	5.4	12.7	2.8	7.2	1.9	2.1
10	15.0	4.0	3.6	7.7	1.8	1.5	7.2	1.8	3.3	0.6
11	4.9	8.9	2.2	1.9	3.4	0.9	0.4	2.6	0.9	0.6
12	0.8	1.8	4.3	1.1	0.9	0.8	0.2	0.1	0.7	0.1
13+	0.7	0.5	0.8	2.1	2.1	0.7	0.2	0.2	0.4	0.2

Table 5. Cod. Iceland. Non-spawning fishery landings in No x 10^{-6}.

Age / Year	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
2	0.7	1.7	0.6	0.9	1.9	1.6	1.9	6.2	3.2	0.2
3	7.8	12.5	8.4	13.9	11.6	16.5	12.6	26.3	12.2	9.2
4	22.8	15.5	25.1	24.8	20.0	27.1	26.0	23.4	42.6	18.6
5	18.1	14.2	13.2	18.2	16.7	16.2	15.6	19.8	17.2	32.8
6	6.8	7.2	10.7	8.1	8.9	7.3	6.5	8.1	10.4	10.4
7	4.7	3.7	5.3	10.7	3.7	4.9	2.4	4.9	7.9	5.3
8	2.7	4.6	1.7	2.3	7.5	2.2	4.2	0.8	2.3	3.8
9	2.5	1.9	4.0	1.0	1.1	4.8	0.9	1.4	0.5	0.7
10	6.9	1.5	1.5	2.2	0.2	0.4	2.0	0.3	0.5	0.1
11	2.4	3.3	0.6	0.6	0.5	0.1	0.1	0.3	0.1	0.1
12	0.3	0.8	1.4	0.3	0.1	0.2	0.1	0.03	0.1	0.03
13+	0.1	0.2	0.4	0.6	0.4	0.1	0.1	0.03	0.1	0.1

Table 6. Cod. Iceland. Spawning fishery landings in No x 10^{-6}.

Age / Year	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
2	-	-	-	-	-	-	-	-	-	-
3	0.2	-	-	0.4	0.8	5.7	0.6	0.6	0.8	1.1
4	1.4	0.4	0.4	1.0	2.3	3.6	2.2	1.6	1.4	3.2
5	6.2	1.7	1.2	1.4	1.6	3.0	2.8	3.6	2.6	2.8
6	3.9	5.5	2.6	2.2	2.9	2.4	4.6	3.6	5.0	3.6
7	4.3	3.9	7.0	6.3	4.4	3.6	3.5	4.1	8.1	7.5
8	4.3	4.5	2.6	5.3	12.5	3.8	6.5	2.0	3.2	15.2
9	4.7	3.0	6.5	2.0	7.3	7.9	1.9	5.7	1.4	1.4
10	8.1	2.5	2.1	5.4	1.6	1.0	5.2	1.5	2.8	0.5
11	2.5	5.7	1.6	1.4	2.9	0.82	0.28	2.3	0.8	0.5
12	0.48	0.94	2.9	0.86	0.72	0.59	0.14	0.08	0.6	0.1
13+	0.04	0.31	0.37	1.5	1.7	0.56	0.14	0.15	0.27	0.1

Table 7. Mean numbers (million) of cod landed from Iceland (period 1960-1969).

Age	Non-spawning fishery	Spawning fishery	Total
2	1.9	-	1.9
3	13.0	1.0	14.0
4	24.6	1.7	26.3
5	18.2	2.7	20.9
6	8.4	3.6	12.0
7	5.4	5.3	10.7
8	3.2	6.0	9.2
9	1.9	4.2	6.1
10	1.6	3.1	4.7
11	0.8	1.9	2.7
12	0.3	0.7	1.0
13+	0.2	0.5	0.7

Table 8. Iceland Cod. Stable age compositions of landings (based on 1960-1969 landings).

Age	Numbers landed (million)				
	Non-spawning fishery			Spawning fishery	
	U.K.	Others	Total		Total
2	1.2	0.5	1.7	0.2	1.9
3	7.6	3.3	10.9	2.6	13.5
4	14.1	5.8	19.9	4.9	24.8
5	9.9	4.4	14.3	4.6	18.9
6	5.0	2.5	7.5	4.4	11.9
7	2.6	2.3	4.9	5.9	10.8
8	1.2	1.8	3.0	6.8	9.8
9	0.6	1.1	1.7	5.1	6.8
10	0.3	0.5	0.8	3.1	3.9
11	0.1	0.2	0.3	1.5	1.8
12	0.04	0.06	0.1	0.6	0.7
13+	0.04	0.06	0.1	0.4	0.5
	Corresponding weights landed (thousands of metric tons)				
2	0.7	0.2	0.9	0.1	1.0
3	11.3	4.8	16.1	3.9	20.0
4	34.1	13.9	48.0	11.8	59.8
5	34.1	15.3	49.4	15.7	65.1
6	21.6	10.6	32.2	19.1	51.3
7	13.6	11.6	25.2	30.6	55.8
8	6.7	10.5	17.2	39.1	56.3
9	4.1	6.8	10.9	31.8	42.7
10	1.8	3.8	5.6	20.4	26.0
11	0.8	1.5	2.3	10.8	13.1
12	0.4	0.5	0.9	4.3	5.2
13+	0.2	0.4	0.6	3.1	3.7

Table 9. Mean weight (round fresh) of age-groups of cod at Iceland (German and Icelandic Data).

Age (years)	Weight (kg)
1	0.10
2	0.54
3	1.48
4	2.41
5	3.45
6	4.32
7	5.16
8	5.72
9	6.29
10	6.73
11	7.19
12	7.58
13	8.00
14	8.47
15+	8.90

Table 10. Iceland Cod. Estimates of the fishing mortality rate (F) within the various components of the stock (based on 1960-69 data).

Age	P	Z_T	F_T	F_N	F_s
			M = 0.2		
3	0.55	0.27	0.07	0.11	0.02
4	0.48	0.37	0.17	0.31	0.04
5	0.41	0.39	0.19	0.39	0.05
6	0.34	0.38	0.18	0.36	0.09
7	0.29	0.45	0.25	0.43	0.18
8	0.26	0.58	0.38	0.50	0.34
9	0.23	0.70	0.50	0.62	0.46
10	0.21	0.80	0.60	0.70	0.57
11	0.17	0.83	0.63	0.64	0.63
12	0.21	0.72	0.52	0.55	0.51
			M = 0.3		
3	0.44	0.34	0.04	0.08	0.01
4	0.43	0.42	0.12	0.24	0.03
5	0.37	0.44	0.14	0.31	0.04
6	0.33	0.44	0.14	0.29	0.07
7	0.28	0.50	0.20	0.35	0.14
8	0.24	0.61	0.31	0.43	0.27
9	0.24	0.72	0.42	0.54	0.38
10	0.21	0.81	0.51	0.62	0.48
11	0.16	0.85	0.55	0.58	0.54
12	0.21	0.78	0.48	0.51	0.47

P = the number of fish in the non-spawning fishery as a proportion of the total number in the sea (calculated from data in Table 13).

Z_T = total mortality on the total stock.

F = fishing nortality on the total stock (F_T), within the non-spawning fishery (F_N), and within the spawning fishery (F_s).

Table 11. Estimates of the total numbers of cod in the sea (millions) necessary to account for the total landings from Iceland.

M	0.2		0.3	
Age	A	B	A	B
2	216	264	317	460
3	182	205	267	324
4	147	163	204	242
5	96	109	128	153
6	61	65	78	88
7	44	46	55	59
8	28	29	34	36
9	16	16	19	20
10	12	12	15	15
11	6.2	6.5	7.6	8.3
12	3.2	3.5	3.9	4.5
13	1.9	2.2	2.3	2.8
14	0.3	0.3	0.4	0.4
15+	0.3	0.3	0.3	0.4

A Calculated on the assumption that Z = 0.8 in the oldest age-group in each year class, irrespective of actual age.

B Calculated on the assumption that Z = 0.7 in 12 year and older fish, but making allowance for the fact that for fish less than 12 years old values of Z other than 0.7 may be more appropriate.

Table 12. Estimates of the total numbers of cod in the sea (millions) necessary to account for the total landings at Iceland from the non-spawning fisheries only.

M	0.2		0.3	
Age	A	B	A	B
2	161	169	223	251
3	129	131	172	177
4	96	98	122	125
5	55	56	67	69
6	26	26	31	32
7	15	15	18	17
8	7.7	7.5	9.1	8.8
9	3.9	4.0	4.6	5.0
10	3.1	3.4	3.7	4.5
11	1.4	1.6	1.7	2.3
12	0.7	0.9	0.8	1.4
13	0.4	0.6	0.5	0.9
14	0.07	0.08	0.09	0.1
15+	0.06	0.07	0.07	0.09

A Calculated on the assumption that Z = 0.8 in the oldest age group in each year class, irrespective of actual age.

B Calculated on the assumption that Z = 0.7 in 12 year and older fish, but making allowance for the fact that for fish less than 12 years old values of Z other than 0.7 may be more appropriate.

Table 13. Estimates of the numbers of cod in the sea necessary to account for the Icelandic fisheries.

M	0.2			0.3		
Age	Non-spawning fishery (A)	Spawning fishery (B-A)	Total (B)	Non-spawning fishery (A)	Spawning fishery (B-A)	Total (B)
2	165	75	240	237	151	388
3	130	64	194	174	122	296
4	97	58	155	124	99	223
5	55	48	103	68	72	140
6	26	37	63	31	52	83
7	15	30	45	18	39	57
8	7.6	20	28	9.0	26	35
9	4.0	12	16	4.8	15	20
10	3.2	9	12	4.1	11	15
11	1.5	4.8	6.3	2.0	6	8
12	0.8	2.6	3.4	1.1	3	4.1
13	0.5	1.5	2.0	0.7	1.8	2.5
14	0.07	0.23	0.3	0.1	0.3	0.4
15+	0.06	0.24	0.3	0.08	0.2	0.3

Table 14. Percentage changes in yield per recruit due to changes in fishing effort*.

	% change in effort*	M	Non-Spawning Fisheries UK 0.2	UK 0.3	Others 0.2	Others 0.3	Total 0.2	Total 0.3
DECREASE OF EFFORT	-60	a	-37	-44	-25	-39	-	-
		b(1)	-17	-30	+16	- 8	- 4	-21
		b(2)	-34	-40	- 8	-21	-24	-33
	-40	a	-21	-26	-17	-24	-	-
		b(1)	- 6	-12	+16	+ 3	+3	- 6
		b(2)	-18	-20	+ 1	- 7	-11	-15
	-20	a	- 9	-12	- 3	- 6	-	-
		b(1)	- 2	- 6	+ 8	+ 2	+ 2	- 3
		b(2)	- 7	-11	+ 2	- 3	- 4	- 8
INCREASE OF EFFORT	+20	a	+ 8	+10	+ 3	+ 6	-	-
		b(1)	0	+ 5	- 8	- 3	- 3	+ 1
		b(2)	0	+ 5	- 8	- 3	- 3	+ 1
	+40	a	+14	+19	+ 6	+10	-	-
		b(1)	- 2	+ 5	-15	- 7	- 7	+ 1
		b(2)	- 2	+ 5	-15	- 7	- 7	+ 1

* More precisely this refers to the percentage change in the fishing mortality rate at each age in relation to the average values for the period 1960-1969.

a Assuming that the spawning and non-spawning fisheries are based on a single stock of cod. Values taken from report of the previous Working Group.

b(1) Assuming that the spawning and non-spawning fisheries are based on two completely independent stocks of cod.

b(2) Assuming that the spawning and non-spawning fisheries are based on stocks that are independent until they are 8 years of age. After this age, it is assumed that potential gains to the non-spawning fishery of fish older than 8 years of age are transferred to the spawning fishery by the migration of these fish.

Table 15. Percentage changes in yield per recruit due to changes in fishing effort*.

	% change in effort *		M 0.2 Total Spawning fishery	0.3	0.2 Total All fisheries	0.3
DECREASE OF EFFORT	-60	a	+39	+ 5	- 6	-24
		b(1)	-24	-33	-14	-28
		b(2)	-	-	-	-
	-40	a	+28	+ 9	- 2	-12
		b(1)	-18	-17	- 8	-12
		b(2)	-	-	-	-
	-20	a	+13	+ 5	0	- 5
		b(1)	- 4	- 7	- 1	- 5
		b(2)	-	-	-	-
INCREASE OF EFFORT	+20	a	-10	- 6	- 1	+ 3
		b(1)	+ 2	+ 5	- 1	+ 2
		b(2)	+ 2	+ 5	- 1	+ 2
	+40	a	-20	-11	- 2	+ 6
		b(1)	+ 3	+ 9	- 3	+ 4
		b(2)	+ 3	+ 9	- 3	+ 4

* More precisely this refers to the percentage change in the fishing mortality rate at each age in relation to the average values for the period 1960-1969.

a Assuming that the spawning and non-spawning fisheries are based on a single stock of cod. Values taken from report of the previous Working Group.

b(1) Assuming that the spawning and non-spawning fisheries are based on two completely independent stocks of cod.

b(2) Assuming that the spawning and non-spawning fisheries are based on stocks that are independent until they are 8 years of age. After this age, it is assumed that potential gains to the non-spawning fishery of fish older than 8 years of age are transferred to the spawning fishery by the migration of these fish.

Table 16. Summary of landings predicted by the simulation model.

Age	Fishery at Iceland: Non-spawning	Fishery at Iceland: Spawning	Both Fisheries: Total immature	Both Fisheries: Total mature	Mature Fish of Greenland Origin	Total Mature	Total All Fish
	(a) Stable age composition of landings of cod at Iceland (millions)						
2	1.8	0.2	2.0	-	Not separated	-	2.0
3	10.9	2.6	13.5	-		-	13.5
4	19.9	4.9	24.8	-		-	24.8
5	14.3	4.6	18.9	-		-	18.9
6	7.5	4.4	7.5	4.4		4.4	11.9
7	4.9	5.9	4.9	5.9		5.9	10.8
8	3.0	6.8	3.0	6.8		6.8	9.8
9	1.7	5.1	1.7	5.1		5.1	6.8
10	0.8	3.1	0.8	3.1		3.1	3.9
11	0.3	1.5	0.3	1.5		1.5	1.8
12	-	0.6	-	0.6		0.6	0.6
13+	-	0.4	-	0.4		0.4	0.4
Total Number (millions)			77.4	-		27.8	105.2
Total Weight (thousand tons)			239			159	398
	(b) Simulation of stable age composition and catches of cod at Iceland						
2			-	-	-	-	-
3			17.1	-	-	-	17.1
4			31.6	-	-	-	31.6
5			23.2	-	-	-	23.2
6			10.3	3.6	1.0	4.6	14.9
7			4.8	4.9	1.6	6.5	11.3
8			1.3	4.0	1.9	5.9	7.2
9			0.2	1.9	1.7	3.6	3.8
10			-	0.6	1.3	1.9	1.9
11			-	0.1	0.8	0.9	0.9
12			-	-	0.4	0.4	0.4
13+			-	-	0.3	0.3	0.3
Total Number (millions)			88.5	15.1	9.0	24.1	112.6
Total Weight (thousand tons)			259	80	54	134	393

Table 17. Summary of assessments based upon simulation of the fishery.

Fishing Effort on Iceland Immature Fishery as % of present	Landings (thousand tons)			
	Immature Fish of Icelandic Origin	Total Mature Fishery		Total
		Mature Fish of Icelandic Origin	Mature Fish of Greenland Origin	
50	148	187	54	389
80	235	106	54	396
100	259	80	54	393
125	277	58	54	389
Greenland fishing doubled	259	80	33	372

NB. Calculations checked only by graphical methods.

Table 18. Iceland Cod. Total landings of different fisheries, 1965-1969. (Thousand of tons).

Year	Non-Spawning				Spawning	Overall Total
	North-East Fishing Area			Total non-spawning Fishery		
	UK trawl	Iceland trawl	Total trawl			
1965	16.9	1.7	18.6	206	195	401
1966	18.1	2.3	20.4	175	168	343
1967	5.6	1.5	7.1	205	151	356
1968	8.5	1.1	9.6	230	159	389
1969	5.5	1.5	7.0	213	198	411
Mean	10.9	1.6	12.5	206	174	380
% of the Total Landings	2.9	0.4	3.3	54	46	100
% of the Immature Fishery	5.3	0.8	6.1	100	-	-

Table 19. Percentage change in yield for 20% reduction in fishing effort in the non-spawning fishery. (Equivalent thousand tons in brackets).

	Assessment (Hypothesis b(2))		Assessment by Simulation
Non-spawning Fishery, UK	-7.4 (9.6)	-10.6 (13.6)	-
Others	+1.7 (1.4)	- 2.6 (2.1)	-
Total	-3.9 (8.1)	- 7.5 (15.7)	-
Spawning Fishery	+6.5 (12.5)	+ 4.6 (8.8)	-
Total Fishery	+1.1 (1.0)	- 1.7 (6.9)	-
Fishery for Immature Fish	-	-	- 9.3(23)
Fishery for Mature Fish	-	-	+19.6(26)
Total Fishery	-	-	+ 0.8(3)

Table 20. Nominal catch in metric tons of haddock from Iceland grounds, Division Va, according to Bulletin Statistique[1].

Years	Iceland	England	Germany	Faroes	Scotland	France	Norway	Holland	Belgium	Denmark	Sweden	Total
1946	14 120	12 078	4 601	150[2]	1 679	-	-	45	472	-	-	33 145
1947	18 601	14 901	3 762	150[2]	2 246	-	-	-	2 019	-	-	41 679
1948	24 862	23 610	7 553	150[2]	2 907	-	-	350	1 314	57	21	60 824
1949	30 264	28 683	10 499	150[2]	3 960	-	-	-	2 120	96	170	75 951
1950	27 099	26 886	7 300	150[2]	2 271	-	-	759	1 640	603	41	66 749
1951	22 173	21 576	7 326	150[2]	1 365	-	-	220	2 857	362	-	56 029
1952	15 166	18 571	7 734	168	660	-	-	41	4 063	84	-	46 487
1953	14 954	28 268	6 384	219	708	-	-	-	4 295	-	-	54 828
1954	21 322	28 872	6 133	435	611	-	-	89	5 187	3	-	62 652
1955	21 703	27 936	7 153	359	683	-	-	-	7 105	6	-	64 945
1956	22 054	23 748	8 750	610	980	-	-	-	6 147	-	-	62 289
1957	31 302	28 663	7 796	1 168	1 137	-	-	29	6 631	-	-	76 726
1958	28 624	27 483	6 311	1 376	966	-	-	-	5 738	-	USSR	70 498
1959	26 534	30 002	3 794	1 025	811	-	-	-	2 412	-	-	64 578
1960	41 988	31 803	6 238	1 330	936	-	-	-	5 198	-	-	87 493
1961	51 360	47 164	4 067	770	2 314	125	-	49	4 237	-	-	110 086
1962	54 288	51 862	3 965	919	4 024	164	-	204	4 189	-	-	119 615
1963	51 834	39 538	3 064	2 108	3 818	-	-	198	1 884	-	-	102 444
1964	56 586	33 269	2 077	1 200	4 877	-	-	181	857	-	-	99 047
1965	53 506	37 643	1 753	1 006	3 761	-	40	89	1 235	-	-	99 033
1966	36 028	19 706	1 139	968	1 498	10	-	6	676	-	69	60 100
1967	37 997	17 409	1 517	484	1 011	916	-	-	897	-	194	60 425
1968	34 014	11 906	2 558	277	1 358	6	-	-	1 073	-	-	51 192
1969	35 036	7 806	1 626	20	1 138	-	-	26	961	-	-	46 613

1) German figures according to national statistics from "Bundesforschungsanstalt für Fischerei", Hamburg.

2) Estimates.

Table 21. Landings per unit effort of haddock from Iceland.

Years	A England	B Germany	C Iceland
1946	757	2.2	-
1947	496	1.3	-
1948	393	2.0	-
1949	435	1.4	-
1950	288	0.8	-
1951	238	0.5	-
1952	220	0.6	-
1953	220	0.4	-
1954	216	0.5	-
1955	258	0.6	-
1956	233	1.1	-
1957	201	0.7	-
1958	178	0.6	-
1959	219	0.5	-
1960	211	0.3	221
1961	260	0.5	212
1962	268	0.5	274
1963	152	0.4	223
1964	111	0.2	227
1965	126	0.2	201
1966	74	0.1	158
1967	64	0.1	195
1968	49	0.3	166
1969	38	0.2	166

A - Tons per million ton hours (steam trawlers)

B - Tons per day fished

C - Tons per million ton hours

Table 22. Iceland Haddock. Total landings (thousands of fish) of the various year classes.

Age	Year Classes 1948	1949	1950	1951	1952	1953	1954	1955	1956
1	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	7 936
3	-	-	-	-	200	57	423	12 306	28 263
4	-	-	-	2 524	2 598	2 332	6 546	13 093	37 735
5	-	-	10 641	10 386	8 228	5 351	3 101	13 317	23 067
6	-	13 546	9 859	14 979	3 955	1 083	2 046	4 370	11 884
7	209	5 489	7 037	5 301	1 250	999	395	2 001	5 216
8	85	1 565	1 619	1 116	653	335	222	424	3 574
9	69	651	390	1 098	282	148	37	217	1 621
4-6	-	-	-	27 889	14 781	8 766	11 693	30 780	72 686
4-9	-	-	-	35 404	16 966	10 248	12 347	33 422	83 097
Total	363	21 251	29 546	35 404	17 166	10 305	12 770	45 728	119 296

Table 22 (continued)

Age	Year Classes 1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
1	-	-	-	31	34	45	14	27	98	-	-	3
2	3 604	3 531	5 800	1 959	2 331	2 391	1 312	2 012	6 140	2 397	2 045	-
3	32 260	9 615	9 288	19 790	7 088	13 316	3 734	23 124	8 051	10 361	-	-
4	35 783	14 509	7 582	16 938	7 745	5 540	8 604	10 044	3 811	-	-	-
5	41 340	9 493	6 920	21 055	4 683	4 268	3 578	11 935	-	-	-	-
6	26 635	4 251	3 410	11 992	1 735	1 646	1 490	-	-	-	-	-
7	14 118	2 445	1 131	2 419	983	538	-	-	-	-	-	-
8	7 235	618	234	1 167	386	-	-	-	-	-	-	-
9	1 063	105	129	507	-	-	-	-	-	-	-	-
4-6	103 758	28 253	17 912	49 985	14 163	11 454	13 672	-	-	-	-	-
4-9	126 174	31 421	19 406	54 078	-	-	-	-	-	-	-	-
Total	162 038	44 567	34 494	75 858	24 985	27 744	18 732	47 142	18 100	13 298	2 015	3

Table 23. Iceland Haddock. Effect of yield in percent of changes in effort by all gears equally.

		% Change in Fishing Mortality Rate from the 1960-1966 Level				
Gear	M	-60	-40	-20	+20	+40
English and German Trawl	0.15	-4	+4	+3	-5	-10
	0.30	-20	-8	-2	+0.4	+ 0.2

(1) Estimates for English and German trawlers were similar and so mean values are given in the Table.

(2) Owing to the lack of comprehensive age composition data the trawl estimates above must also be used as the best estimates for "all gears".

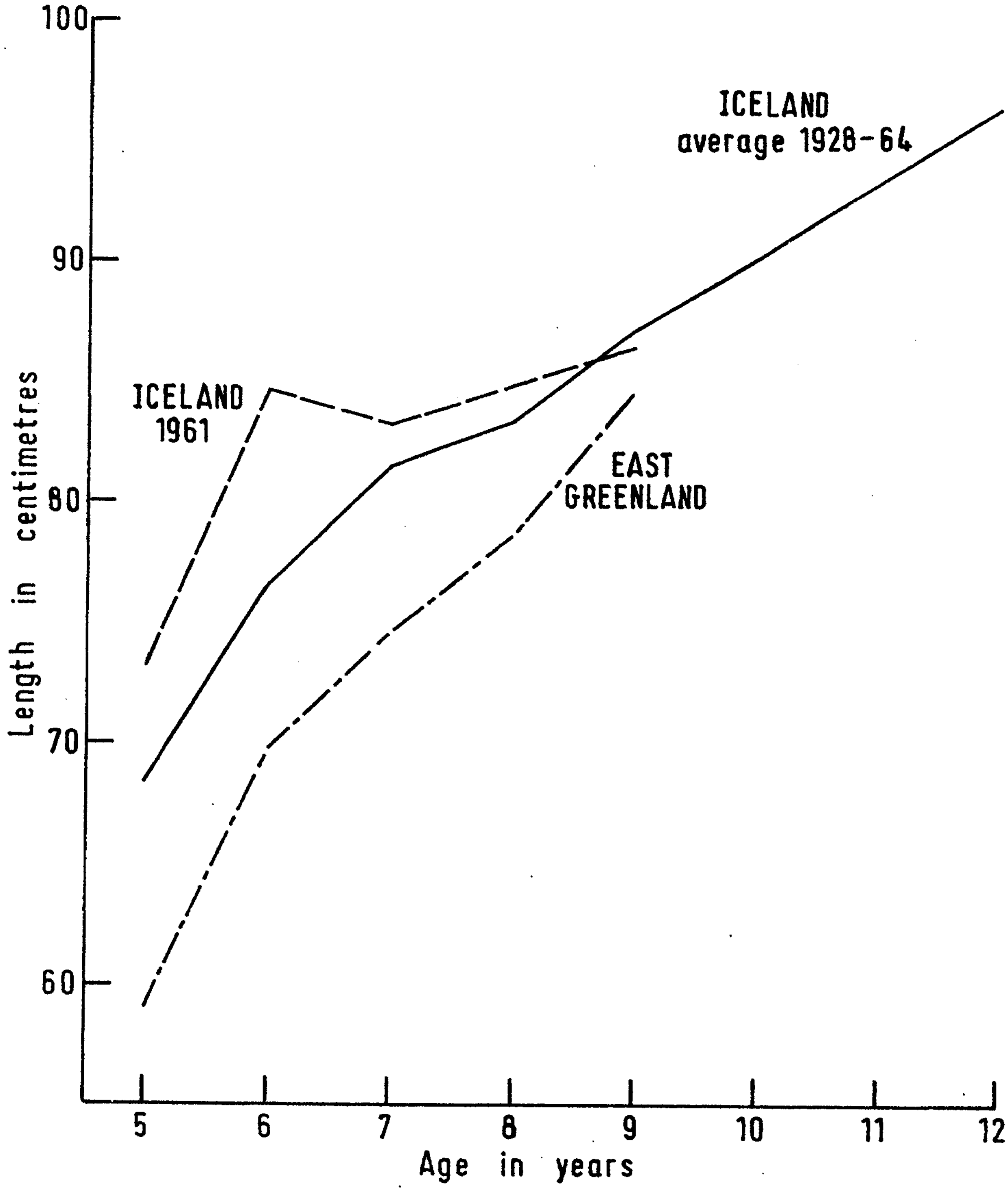

Figure 1 Growth curve for cod of the 1961 year-class in the Icelandic spawning fishery compared with the average growth curve in the Icelandic fishery (1928-64) and with the average for East Greenland.

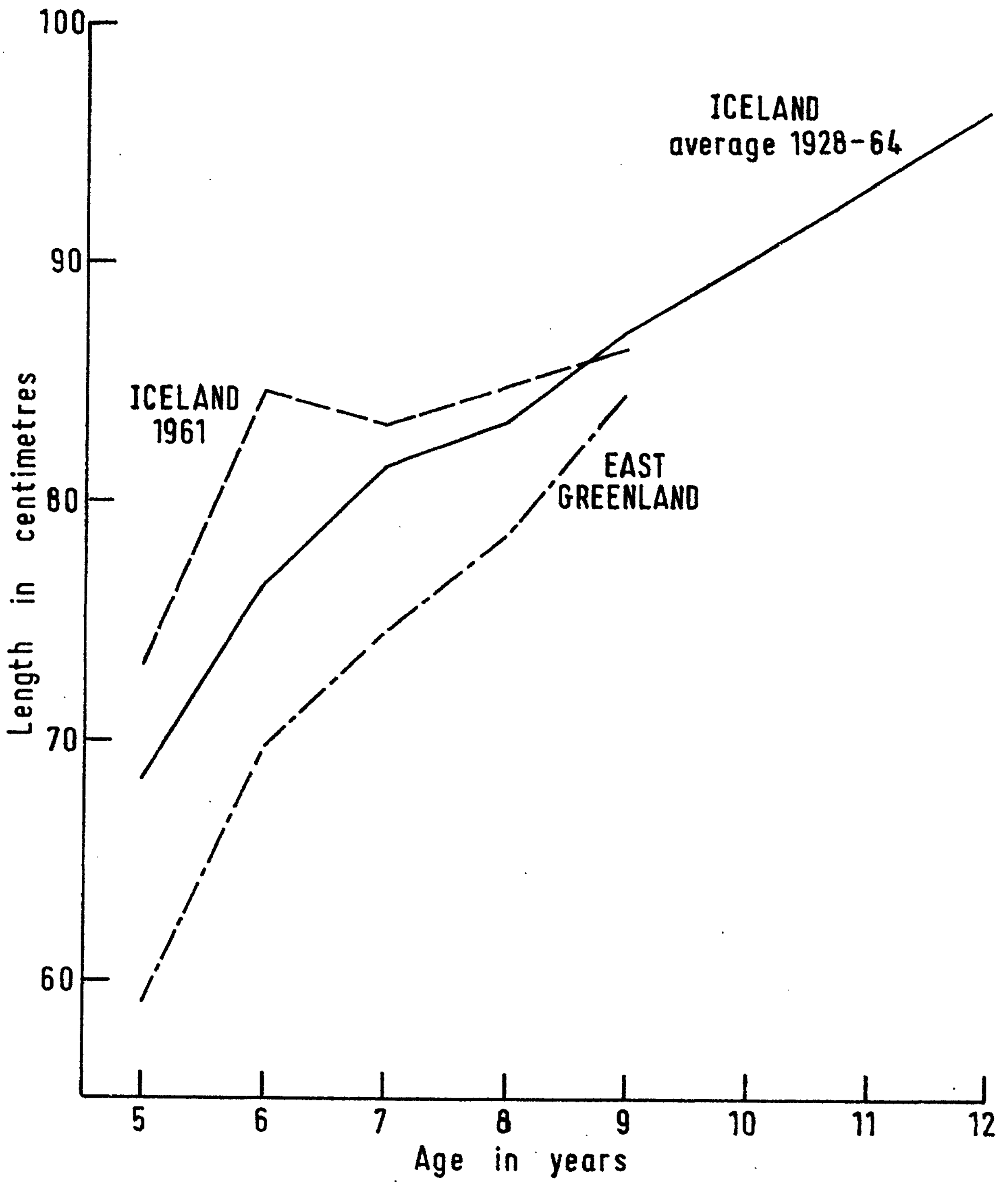

Figure 1 Growth curve for cod of the 1961 year-class in the Icelandic spawning fishery compared with the average growth curve in the Icelandic fishery (1928-64) and with the average for East Greenland.

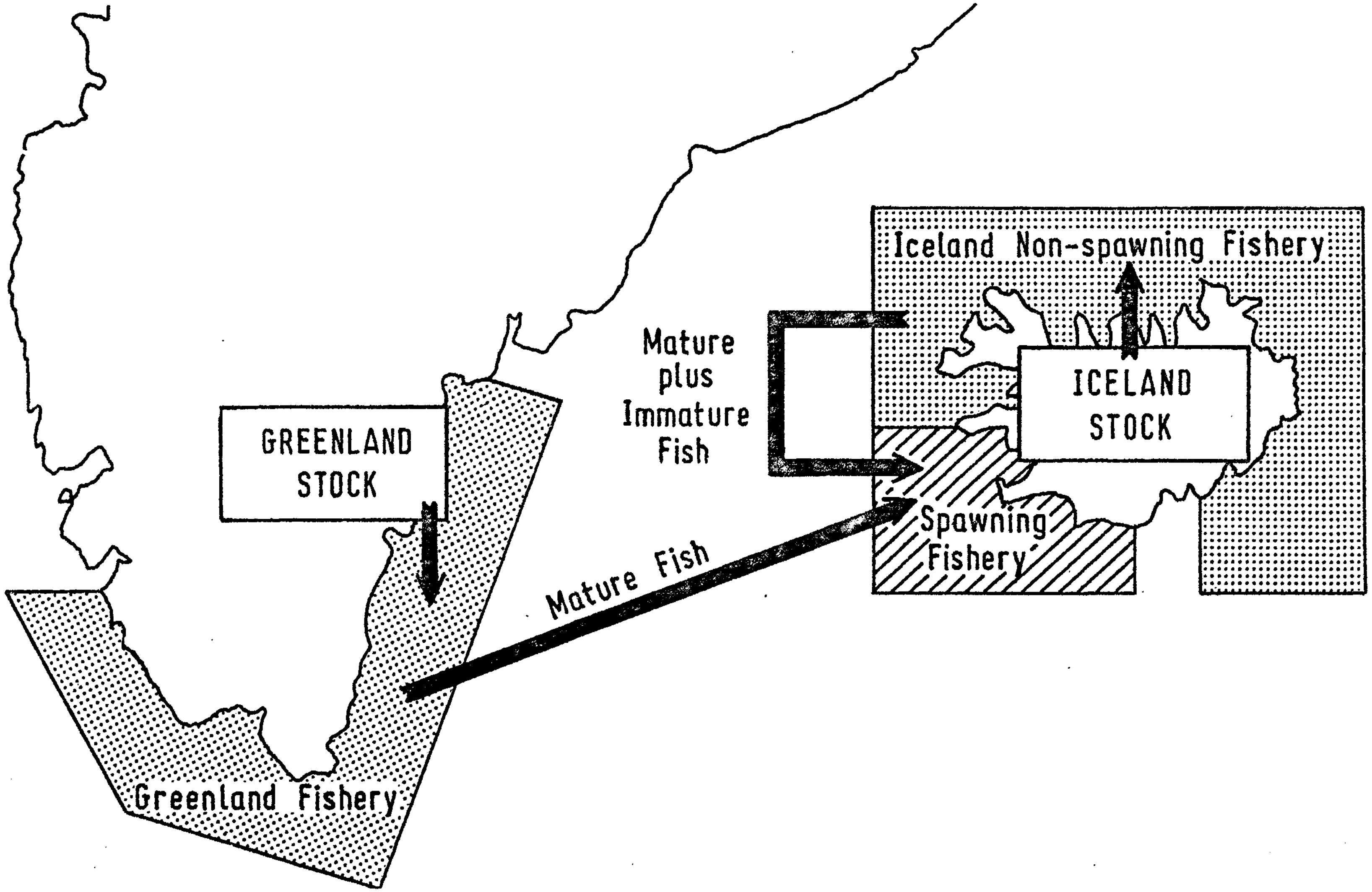

Figure 2 Diagrammatic representation of the inter-relationships between the fisheries at Iceland and the stocks which contribute to them.

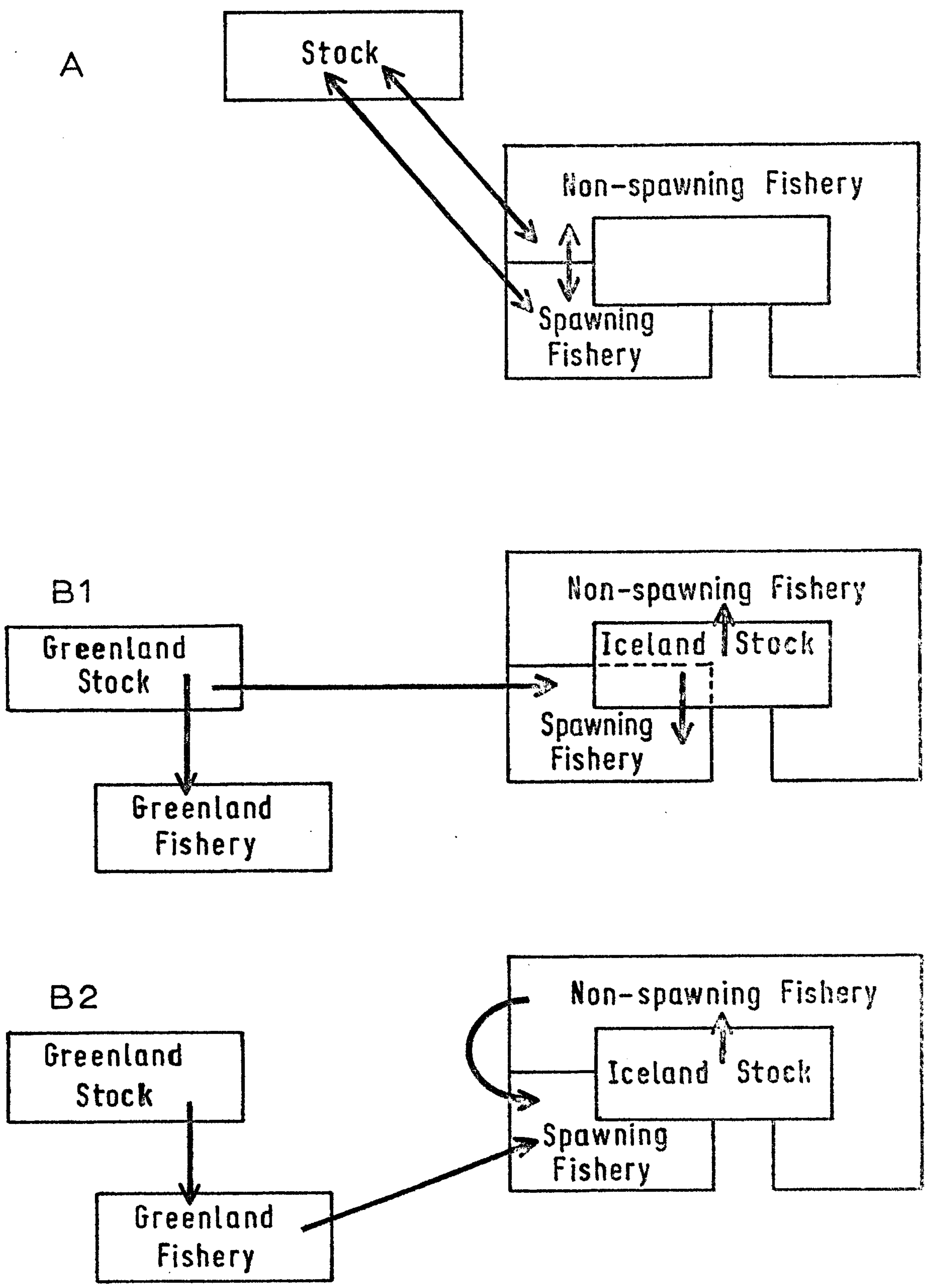

Figure 3 Diagrammatic representation of the assumptions made about the inter-relationships of stocks and the fisheries according to hypotheses A, B1 and B2.