This Report not to be cited without prior reference to the Council[x)]

International Council for the Exploration of the Sea

C.M.1971/F:3
Demersal Fish (Northern) Committee



# REPORT OF THE NORTH-EAST ARCTIC FISHERIES WORKING GROUP

Copenhagen, 1 - 5 February 1971

x) The General Secretary,
ICES,
Charlottenlund Slot,
DK-2920 Charlottenlund,
Denmark.

# REPORT OF THE NORTH-EAST ARCTIC FISHERIES WORKING GROUP

Copenhagen, February 1 - 5, 1971

## List of Contents



-o-o-o-

# Report of the Meeting of the North-East Arctic Fisheries Working Group

Copenhagen, February 1 - 5, 1971

## 1. Participants

| | | |
|---|---|---|
| Mr. D. J. Garrod | UK | Chairman |
| Dr. A. Schumacher | Germany | |
| Dr. A. I. Treschev | USSR | |
| Dr. V. P. Ponomarenko | USSR | |
| Mr. O. V. Bakurin | USSR | |
| Mr. A. Hylen | Norway | |
| Mr. B. W. Jones | UK | |
| Mr. J. Netzel | Poland | |
| Mr. J. Møller Christensen | ICES - Secretary, Liaison Committee. | |

The Group met to update previous assessments of the north-east Arctic cod and haddock fisheries in the light of the most recent data, and to prepare estimates of catches in 1971 and 1972 (C.Res.1970/2:4).

## 2. Status of the fisheries in 1969 and 1970

### a) Cod

Total nominal catches of cod, fishing effort and catch per unit effort are given in Tables 1-4. Provisional estimates of catch in 1970 indicate a fall from the high level of 1 200 000 tons in 1969 to 900 000 tons in 1970. This level of catch in 1970 is considerably greater than that estimated at the last meeting although the proportional decline (25%) between the two years corresponded to the expected change. This is reflected in a decline in both the USSR and UK estimates of stock abundance, overall fishing effort having remained close to the 1969 level. The character of the fishery changed slightly during 1970, however, being based primarily upon the 6 and 7 year old cod of the 1964 and 1963 year classes which contributed 70% of the catch by numbers. A proportion of these year classes migrated to the Norway coast to spawn for the first time in 1970 and the Norwegian catch per unit effort data for that area indicate that the availability of cod was relatively higher in 1970 than in 1969. This, combined with the development of mid-water trawling for cod at times when mature cod were returning to the Barents Sea and Bear Island has caused a relatively higher mortality on older fish than in former years.

It is evident that the major part of the discrepancy between the estimates of expected catch in 1970 (530 000 tons) compared to the actual catches is accounted for by an underestimate of the abundance of the 1963 and 1964 year classes. The Group believes that previous estimates of the abundance of the 1965-68 year classes may also have been too low though the most recent data confirm that they are still very poor.

### b) Haddock

Basic fishery statistics are given in Tables 5-7. Total catches have fallen from 130 000 tons in 1969 to 71 000 tons in 1970, with a corresponding decline in stock abundance. The fishing effort directed towards haddock also appears to have fallen slightly with the declining abundance of the stock. Following from the fishing effort estimated for 1970 the Group expected a catch of 81 000 tons. This corresponds well with the actual catch, the majority of the catch being made up of 6 year olds from the 1964 year class, and the 3 year olds from the 1967 year class.

3. Estimates of mortality

Revised estimates of fishing mortality (F) have been prepared by virtual population analysis. The initial values for F in 1970 necessary for this technique have been deduced from the examination of catch per unit effort data summarised in Table 8. The variation of F with age has been modified slightly from that given in the 1970 Report to take account of the change in the pattern of fishing, referred to in paragraph 2. These have been used in conjunction with an estimate of the age composition of the catches in 1970 also deduced from provisional data **for** one country (UK). The estimated age composition will not be exact but provide a firmer basis for the estimation of mortality than was available at the previous meeting, when estimates of F in 1969 had to be extrapolated from the catch composition of 1968 and the total catch in 1969.

The results of the analysis are summarised in Table 9. The analysis for cod shows the increase in F on 4-5 year olds of the 1964 and 1963 year classes in 1968 and the progression of increased F on the older age groups as these abundant year classes pass through the fishery.

The estimates for haddock also show the increase in fishing mortality in 1968 and 1969 with the slight decline expected in 1970 on the basis of the trend in fishing effort and catch per unit effort data for this fishery.

4. Recruitment

Estimates of recruitment for cod and haddock are given in Table 10 as millions of 3 year old fish in each year class since 1962, these being the year classes which will provide the catches in 1971 and 1972. These estimates are derived from virtual population analysis for the year classes 1962-65 and by estimates of relative year class strength in the international 0-group survey, and USSR young fish surveys for the year classes 1966-70, the estimates for 1969 and 1970 remaining very provisional. The regression relating the pre-recruit index of year class strength with subsequent actual numbers derived by the virtual population analysis has very wide confidence limits, as evidenced by the previous underestimate of the 1964 year class, so that the estimates of year classes not present in significant numbers in catches in 1970 (i.e. 1966 onwards) are very provisional and may do little more than indicate the order of magnitude of their abundance. However, these year classes will contribute to the catches in 1971-72 and so the lack of precision will therefore contribute a source of error, in estimates of future catches.

Revised estimates of recruitment for haddock correspond closely with previous estimates for the year classes 1962-64, but have been reduced slightly for the year classes 1965-67 on the basis of the virtual population analysis.

5. Estimates of future catches

a) Cod

Using the parameters described in the previous section, future catches have been estimated assuming four possible levels of fishing mortality in 1971:

(i) that F is reduced to a level close to that giving the maximum yield per recruit with the present pattern of the fishery, $F_{max} = 0.53$.

(ii) that F is reduced in 1971 to its 1967 level $F_{max} = 0.80$

(iii) that F remains at its present level $F_{max} = 1.10$

(iv) that F is increased to the level where F in the oldest age groups $(F_{max}) = 1.5$.

The same range of possibilities has also been applied to estimate catches in 1972, depending upon the level of fishing mortality in 1971. The estimates are summarised in Table 11.

An independent estimate of catches in 1971 has been derived by applying to the age composition of catches in 1970 a matrix of ratios defining the average percentage change in catches from a particular year class from one year to the next. This method assumes that the catch is determined primarily by fluctuations in recruitment; it does not take into account the effect on catches of changing levels of fishing mortality which have been particularly important in the north-east Arctic fisheries in the period 1965-70. This method confirms that if the 1970 level of fishing continues during 1971 a total landing of about 700 000 tons may be expected.

The estimates of catches in 1972 depend on the level of fishing in 1971 and in addition to the selected values given in Table 11, Figure 1 permits the expected catch in 1972 to be read off for any particular level of catch that may be achieved in 1971.

The new estimates of catches in 1971 are higher than those made previously, in 1970. This is almost entirely due to the upward adjustment of the abundance of the 1964 year class. Present evidence continues to indicate that the 1965-68 year classes are very poor so the overall prognosis of a decline in catches in 1971, and especially in 1972, remains valid. It is necessary to emphasize, however, that under the present circumstances where the yield is heavily dependent on one or two very large year classes, estimates of catch will be very sensitive to errors in the estimation of their abundance and these errors may be high. They would become less important in a fishery where the yield is distributed over a number of year classes of more uniform abundance because errors between year classes could be expected to compensate each other.

It should also be noted that the 1970 year class was very abundant at the 0-group stage. If this apparent abundance is correct, fish of that year class can be expected to be caught in significant quantities in 1973, and especially in 1974. The remainder of the stock is expected to be relatively weak by that time, so that regulation of the fishery on that year class could become more important than ever.

b) Haddock

Estimates of catches in 1971 have been prepared for four assumed levels of fishing mortality:

(i) that F is reduced to a level close to that giving the maximum yield per recruit, $F_{max} = 0.3$

(ii) that F is reduced in 1971 to the 1967 level of $F_{max} = 0.6$

(iii) that F remains at its present level $F_{max} = 0.8$

(iv) that F is increased in 1971 to a higher level, $F_{max} = 1.0$.

As for cod, this range of fishing mortality has also been applied to estimate catches in 1972, depending upon the level of fishing mortality in 1971. The estimates are summarised in Table 12 and Figure 2.

These are similar to the estimates prepared for 1971 in the last Report with modifications caused by small adjustments to estimates of recruitment in the most recent year classes.

The estimates indicate that catches can be expected to decline to about 60 000 tons in 1971 at the present level of fishing, with proportionate changes for any different level of fishing mortality. The level has also been confirmed by the alternative method for estimation described for cod. By 1972 the recruitment from the 1967 and 1968 year classes is expected to offset removals so that catches will remain close to the 1971 catch level, given the same fishing mortality in both years. In the longer term there is a prospect of slightly improved catches when the stronger 1969 year class enters the fishery in significant numbers.

## 6. Changes in total stock size

Table 13 summarises recent changes in the total stock of 3 years ans older cod, with comparative information from earlier years. Stock size in 1968 was close to that of the early 1950's but the biomass was concentrated mainly in the two very strong year classes of 1963 and 1964: the strength of the stock was not widely distributed over a range of age groups as it was in former years. At the present time the total stock size is declining towards the level of the mid-1960's, with the annual harvest representing an increased proportion of the stock. However, this percentage cannot be directly related to the estimates of fishing mortality because although the stock existed as shown, the age groups were not all equally available to the fisheries.

## 7. The effects upon the cod fishery of the closure of fishing grounds

At an earlier meeting the Group concluded that the reduction of spawning stock size to relatively low levels may reduce the probability of strong year classes. With regard to the anticipated poor recruitment from the 1965-68 year classes, and in view of the high level of exploitation of recently strong year classes (1963, 1964) in 1968-70, the Group expects that the spawning stock will become considerably reduced in coming years. The Group has therefore discussed alternative methods of regulation (particularly the closure of fishing areas) that might be used in conjunction with a catch limitation in order to offset the anticipated decline in spawning stock.

In principle, the effects of closure of either fishing grounds or seasons might be estimated from a detailed knowledge of the distribution of catches, but in practice the Group concluded that this would not be meaningful because of uncertainty regarding the redeployment of fishing effort that would be displaced by a limited regulation. These uncertainties may be expressed in a number of alternative arrangements as follows:-

(i) Closure of all areas of the fishery closed throughout the year.

(ii) Closure of all areas of the fishery closed during the same season or at different seasons.

(iii) Closure of limited parts of the fishery closed throughout the year.

(iv) Closure of limited parts of the fishery closed during the same season or at different seasons.

In all cases except (i) it could be expected either that part of the displaced fishing effort would be diverted to other parts of the stock, or that a proportion of the fish surviving from a seasonal closure would be caught elsewhere at other times of the year. It is not possible to provide realistic estimates of the effects of such alternatives on either the catch or the stock size, but the interaction of fishing between different seasons or areas would tend to nullify the potential benefit.

In general, the effect of limited closures of either areas or seasons upon long-term total catches would be small at the present level of fishing mortality, with or without redeployment, though catches might be redistributed between areas and countries in a different way. However, the closure of Division IIa would reduce catches to a greater extent than the closure of Sub-area I or Division IIb because the fishery there exploits older fish and takes place at a time when the availability of cod is low in other areas.

The effect of closure upon the size of the spawning stock may be judged from its effect upon the number of fish surviving to spawn once or several times, regardless of the age at which fishing mortality occurs. Previous assessments have shown that a reduction in fishing mortality in the fishery as a whole, either by regulation of catch or by regulation of mesh sizes, will increase the number of older fish, and hence increase the spawning stock size by, in effect, reducing the fishing mortality on younger fish. Although the Group see no prospect of being able to determine precisely the effect of a particular closure regulation taken in isolation, calculations assuming no redeployment of fishing between areas can give a maximum estimate of potential benefit. Taking the weight of stock of 7 year old cod and older as an index of spawning stock size these calculations suggest that total closure of Sub-area I could give a fourfold increase in potential spawning stock for a given level of recruitment, and closure of either Divisions IIa or IIb could give a twofold increase. However, this calculation excludes the more uncertain benefits to recruitment that such an increase in spawning stock might have and its consequent effect in further increasing spawning stock size over a long period of years. Any increase in spawning stock size following a reduction in fishing mortality would also increase the number of cod spawning more than once, which may have an additional beneficial effect on the chances of good recruitment.

The Group does not believe that it will be able to add materially to these conclusions from further consideration of the problem without postulating a complex and hypothetical framework of alternative assumptions concerning the redeployment of fishing effort or the seasonal pattern of fishing mortality in different areas of the fishery.

## 8. Recommendations

At its present meeting the Group had available the estimates of the 1970 age composition of the catches of one country (UK) in addition to the provisional estimates of total international nominal catches in 1970. This has permitted estimates of catches in 1971 and 1972 to be based on more closely up-to-date information. (The previous estimates of catches in 1970 had to be based upon 1968 data, with the detail of stock composition in 1969 being completely unknown). This information on the age composition in the catches in the most recent years should improve the precision of the catch estimates, especially with regard to the abundance of year classes just entering the fisheries, and the Group therefore recommends:-

1. that all countries should make special efforts to provide data on the composition of landings for the year before the first for which catch estimates are required;

2. that, if data for the whole year are not complete, efforts be made to provide even incomplete data for all fisheries and particularly for important seasonal fisheries that take place in the first half of the year;

3. that data for each year be circulated to all members of the Group as soon as they are finalized.

Table 1. COD. Total nominal catch by fishing areas (metric tons).

| Year | Sub-area I | Division IIb | Division IIa | Total |
|---|---|---|---|---|
| 1960 | 380 962 | 94 599 | 155 116 | 630 677 |
| 1961 | 409 694 | 222 451 | 149 122 | 781 267 |
| 1962 | 548 621 | 222 611 | 138 396 | 909 628 |
| 1963 | 547 469 | 113 707 | 116 924 | 778 100 |
| 1964 | 202 566 | 126 029 | 108 803 | 437 398 |
| 1965 | 241 489 | 103 407 | 99 855 | 444 751 |
| 1966 | 292 244 | 56 568 | 134 664 | 483 476 |
| 1967 | 322 781 | 121 050 | 128 729 | 572 560 |
| 1968 | 642 449 | 268 908 | 162 472 | 1 073 829 |
| 1969 | 670 158 | 266 117 | 254 985 | 1 191 260 |
| 1970 x) | 546 488 | 123 980 | 228 438 | 898 906 |

x) Provisional figures.

Table 2. COD. Nominal catch (in metric tons) by countries (Sub-area I and Divisions IIa and IIb combined).

| Year | England | Germany | Norway | USSR | Others | Total | Coastal Cod Norway |
|---|---|---|---|---|---|---|---|
| 1960 | 141 175 | 9 472 | 231 997 | 213 400 | 34 633 | 630 677 | 43 092 |
| 1961 | 157 909 | 8 129 | 268 377 | 325 780 | 21 072 | 781 267 | 32 359 |
| 1962 | 174 914 | 6 503 | 225 615 | 476 760 | 25 836 | 909 628 | 29 596 |
| 1963 | 129 779 | 4 223 | 205 056 | 417 964 | 21 078 | 778 100 | 40 405 |
| 1964 | 94 549 | 3 202 | 149 878 | 180 550 | 9 219 | 437 398 | 46 100 |
| 1965 | 89 874 | 3 670 | 197 085 | 152 780 | 1 342 | 444 751 | 23 786 |
| 1966 | 103 012 | 4 284 | 203 792 | 169 300 | 3 088 | 483 476 | 27 800 |
| 1967 | 87 008 | 3 632 | 218 910 | 262 340 | 670 | 572 560 | 33 102 |
| 1968 | 140 054 | 1 073 | 255 611 | 676 758 | 333 | 1 073 829 | 47 212 |
| 1969 | 231 066 | 5 434 | 305 241 | 612 215 | 37 287 | 1 191 260 | 52 416 x) |
| 1970 x) | 177 141 | 9 385 | 358 126 | 320 000 | 34 254 | 898 906 | 49 000 |

x) Provisional figures.

Note: Landings for USSR exclude catches of coastal cod, provisionally estimated to be approximately 40 000 tons per year. The USSR is preparing statistics for this fishery.

Table 1. COD. Total nominal catch by fishing areas (metric tons).

| Year | Sub-area I | Division IIb | Division IIa | Total |
|---|---|---|---|---|
| 1960 | 380 962 | 94 599 | 155 116 | 630 677 |
| 1961 | 409 694 | 222 451 | 149 122 | 781 267 |
| 1962 | 548 621 | 222 611 | 138 396 | 909 628 |
| 1963 | 547 469 | 113 707 | 116 924 | 778 100 |
| 1964 | 202 566 | 126 029 | 108 803 | 437 398 |
| 1965 | 241 489 | 103 407 | 99 855 | 444 751 |
| 1966 | 292 244 | 56 568 | 134 664 | 483 476 |
| 1967 | 322 781 | 121 050 | 128 729 | 572 560 |
| 1968 | 642 449 | 268 908 | 162 472 | 1 073 829 |
| 1969 | 670 158 | 266 117 | 254 985 | 1 191 260 |
| 1970x) | 546 488 | 123 980 | 228 438 | 898 906 |

x) Provisional figures.

Table 2. COD. Nominal catch (in metric tons) by countries (Sub-area I and Divisions IIa and IIb combined).

| Year | England | Germany | Norway | USSR | Others | Total | Coastal Cod Norway |
|---|---|---|---|---|---|---|---|
| 1960 | 141 175 | 9 472 | 231 997 | 213 400 | 34 633 | 630 677 | 43 092 |
| 1961 | 157 909 | 8 129 | 268 377 | 325 780 | 21 072 | 781 267 | 32 359 |
| 1962 | 174 914 | 6 503 | 225 615 | 476 760 | 25 836 | 909 628 | 29 596 |
| 1963 | 129 779 | 4 223 | 205 056 | 417 964 | 21 078 | 778 100 | 40 405 |
| 1964 | 94 549 | 3 202 | 149 878 | 180 550 | 9 219 | 437 398 | 46 100 |
| 1965 | 89 874 | 3 670 | 197 085 | 152 780 | 1 342 | 444 751 | 23 786 |
| 1966 | 103 012 | 4 284 | 203 792 | 169 300 | 3 088 | 483 476 | 27 800 |
| 1967 | 87 008 | 3 632 | 218 910 | 262 340 | 670 | 572 560 | 33 102 |
| 1968 | 140 054 | 1 073 | 255 611 | 676 758 | 333 | 1 073 829 | 47 212 |
| 1969 | 231 066 | 5 434 | 305 241 | 612 215 | 37 287 | 1 191 260 | 52 416x) |
| 1970x) | 177 141 | 9 385 | 358 126 | 320 000 | 34 254 | 898 906 | 49 000 |

x) Provisional figures.

Note: Landings for USSR exclude catches of coastal cod, provisionally estimated to be approximately 40 000 tons per year. The USSR is preparing statistics for this fishery.

Table 3. COD. Estimates of total international fishing effort in Sub-area I and Divisions IIa and IIb.

| Year | Sub-area I | | | | Division IIb | | | | Division IIa | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | National Effort | | Total International Effort | | National Effort | | Total International Effort | | National Effort | | Total International Effort | |
| | UK[1] | USSR[2] | UK units | USSR units | UK | USSR | UK units | USSR units | UK | Norway[3] | UK units | Norwegian units |
| 1960 | 95 | 43 | 512 | 91 | 42 | 11 | 97 | 34 | 39 | 10 | 232 | 26 |
| 1961 | 94 | 53 | 518 | 109 | 51 | 22 | 173 | 39 | 30 | 9 | 255 | 20 |
| 1962 | 93 | 61 | 590 | 94 | 51 | 16 | 168 | 29 | 34 | 10 | 210 | 21 |
| 1963 | 78 | 62 | 635 | 91 | 45 | 9 | 120 | 22 | 29 | 7 | 176 | 19 |
| 1964 | 42 | 30 | 351 | 55 | 49 | 17 | 136 | 32 | 36 | 6 | 157 | 17 |
| 1965 | 42 | 25 | 367 | 62 | 37 | 11 | 95 | 4 | 33 | 5 | 150 | 16 |
| 1966 | 63 | 33 | 387 | 69 | 23 | 16 | 71 | 29 | 46 | 5 | 199 | 15 |
| 1967 | 51 | 30 | 395 | 61 | 10 | 12 | 110 | 13 | 50 | 5 | 261 | 22 |
| 1968 | 86 | 45 | 584 | 67 | 9 | 24 | 151 | 26 | 52 | 6 | 288 | 15 |
| 1969 | 115 | 45 | 593 | 72 | 24 | 19 | 197 | 26 | 73 | 5 | 272 | 18 |
| 1970 | 122 | 35 | 573 | 77 | 24 | 15 | 122 | 27 | 55 | 5 | 346 | 14 |

1) Hours fishing x average tonnage x $10^{-6}$ = millions of ton-hours.

2) Hours fishing (catch/catch per hour fishing) x $10^{-4}$

3) Number of men fishing at Lofoten x $10^{-3}$.

Table 4. COD. Catch per unit effort (metric tons, round fresh).

| Year | Sub-area I | | Division IIb | | Division IIa | |
|---|---|---|---|---|---|---|
| | UK 1) | USSR 2) | UK | USSR | UK | Norway 3) |
| 1960 | 0.075 | 0.42 | 0.105 | 0.31 | 0.067 | 3.0 |
| 1961 | 0.079 | 0.38 | 0.129 | 0.44 | 0.058 | 3.7 |
| 1962 | 0.092 | 0.59 | 0.133 | 0.74 | 0.066 | 4.0 |
| 1963 | 0.085 | 0.60 | 0.098 | 0.55 | 0.066 | 3.1 |
| 1964 | 0.058 | 0.37 | 0.092 | 0.39 | 0.070 | 4.8 |
| 1965 | 0.066 | 0.39 | 0.109 | 0.49 | 0.066 | 2.9 |
| 1966 | 0.074 | 0.42 | 0.078 | 0.19 | 0.067 | 4.0 |
| 1967 | 0.081 | 0.53 | 0.106 | 0.87 | 0.052 | 3.5 |
| 1968 | 0.110 | 1.09 | 0.173 | 1.21 | 0.056 | 5.1 |
| 1969 | 0.113 | 1.00 | 0.135 | 1.17 | 0.094 | 5.9 |
| 1970 | 0.100 | 0.80 | 0.100 | 0.80 | 0.030 | 6.4 |

1) UK data - tons per 100 ton-hours fishing

2) USSR data - tons per hour fishing

3) Norwegian data - tons per gill net boat week at Lofoten.

Table 5. HADDOCK. Total nominal catch by fishing areas (metric tons).

| Year | Sub-area I | Division IIb | Division IIa | Total |
|---|---|---|---|---|
| 1960 | 125 675 | 1 854 | 27 925 | 155 454 |
| 1961 | 165 165 | 2 427 | 25 642 | 193 234 |
| 1962 | 160 972 | 1 727 | 25 189 | 187 888 |
| 1963 | 124 774 | 939 | 21 031 | 146 744 |
| 1964 | 79 056 | 1 109 | 18 735 | 98 900 |
| 1965 | 98 505 | 939 | 18 640 | 118 079 |
| 1966 | 124 115 | 1 614 | 34 892 | 160 621 |
| 1967 | 108 066 | 440 | 27 980 | 136 486 |
| 1968 | 140 970 | 725 | 40 031 | 181 726 |
| 1969 | 88 960 | 1 341 | 40 208 | 130 509 |
| 1970x) | 41 519 | 428 | 29 613 | 71 560 |

x) Provisional figures.

Table 6. HADDOCK. Nominal catch (in metric tons) by countries (Sub-area I and Divisions IIa and IIb combined).

| Year | England | Germany | Norway | USSR | Others | Total | Coastal Haddock Norway |
|---|---|---|---|---|---|---|---|
| 1960 | 45 469 | 5 597 | 47 263 | 57 025 | 100 | 155 454 | 5 943 |
| 1961 | 39 625 | 6 304 | 60 862 | 85 345 | 1 098 | 193 234 | 4 031 |
| 1962 | 37 486 | 2 895 | 54 567 | 91 940 | 1 000 | 187 888 | 3 293 |
| 1963 | 19 809 | 2 554 | 59 955 | 63 526 | 900 | 146 744 | 4 285 |
| 1964 | 14 653 | 1 482 | 38 695 | 43 870 | 200 | 98 900 | 6 460 |
| 1965 | 14 314 | 1 568 | 60 447 | 41 750 | - | 118 079 | 6 217 |
| 1966 | 27 723 | 2 098 | 82 090 | 48 710 | - | 160 621 | 5 223 |
| 1967 | 24 158 | 1 705 | 51 954 | 57 346 | 1 323 | 136 486 | 3 181 |
| 1968 | 40 102 | 1 867 | 64 076 | 75 654 | 27 | 181 726 | 2 766 |
| 1969 | 37 234 | 1 490 | 67 549 | 24 211 | 27 | 130 509 | 2 120x) |
| 1970x) | 20 360 | 2 000 | 39 200 | 10 000 | - | 71 560 | 4 000 |

x) Provisional figures.

Table 7. HADDOCK. Catch per unit effort and estimated total international effort.

| Year | Catch per effort (UK) Kilos/100 ton-hours | | | Estimated total international effort in UK Units |
|---|---|---|---|---|
| | Sub-area | Divisions | | $\frac{\text{Total catch in tons} \times 10^{-6}}{\text{tons/100 ton-hours Sub-area I}}$ |
| | I | IIa | IIb | |
| 1960 | 33 | 34 | 2.8 | 4.7 |
| 1961 | 29 | 36 | 3.3 | 6.7 |
| 1962 | 23 | 42 | 2.5 | 8.2 |
| 1963 | 13 | 33 | 0.9 | 11.2 |
| 1964 | 18 | 18 | 1.6 | 5.5 |
| 1965 | 18 | 18 | 2.0 | 6.6 |
| 1966 | 17 | 34 | 2.8 | 9.4 |
| 1967 | 18 | 25 | 2.4 | 7.6 |
| 1968 | 19 | 50 | 1.0 | 9.6 |
| 1969 | 13 | 42 | 2.0 | 10.0 |
| 1970 | 10 | 30 | 1.0 | 7.2 |

Table 8. Estimate of fishing mortality used to commence virtual population analysis (VPA) needed to determine stock size in 1971.

| Age | Total Mortality Z English c.p.u.e. data | | Fishing Mortality F | | Value selected for 1970 VPA | |
|---|---|---|---|---|---|---|
| | 1968/69 | 1969/70 | 1968/69 | 1969/70 | F | % |
| **A. COD (M = 0.3)** | | | | | | |
| 3 | | | | | .06 | 5 |
| 4 | | | | | .17 | 15 |
| 5 | | | | | .28 | 25 |
| 5/6 | 0.58 | 0.44 | 0.28 | 0.24 | | |
| 6 | | | | | .56 | 50 |
| 6/7 | 0.59 | 1.01 | 0.29 | 0.71 | | |
| 7 | | | | | .73 | 65 |
| 7/8 | 1.04 | 0.97 | 0.74 | 0.67 | | |
| 8 | | | | | .90 | 80 |
| 8/9 | 1.33 | 1.74 | 1.03 | 1.44 | | |
| 9 | | | | | 1.12 | 100 |
| 9/10 | 1.63 | 1.24 | 1.33 | 0.94 | | |
| 10 | | | | | 1.12 | 100 |
| 10/11 | 1.23 | 1.04 | 0.93 | 0.74 | | |
| 11 | | | | | | |
| **B. HADDOCK (M = 0.2)** | | | | | | |
| 2 | | | | | .04 | 5 |
| 3 | | | | | .16 | 20 |
| 4 | | | | | .40 | 50 |
| 5 | | | | | .50 | 62 |
| 5/6 | .50 | .54 | .30 | .34 | | |
| 6 | | | | | .60 | 75 |
| 6/7 | .48 | 1.15 | .28 | .95 | | |
| 7 | | | | | .70 | 87 |
| 7/8 | 1.12 | .68 | .92 | .48 | | |
| 8 | | | | | .80 | 100 |
| 8/9 | .92 | 1.17 | .72 | .97 | | |
| 9 | | | | | .80 | 100 |
| 9/10 | .68 | 1.08 | .48 | .88 | | |
| 10 | | | | | .80 | 100 |
| 10/11 | .55 | .88 | .35 | .68 | | |
| 11 | | | | | | |

Table 9a. Fishing mortality 1967-70 estimated by virtual population analysis.

| Age \ Years | Cod (M = 0.3) 1967 | 1968 | 1969 | 1970x) | Haddock (M = 0.2) 1967 | 1968 | 1969 | 1970x) |
|---|---|---|---|---|---|---|---|---|
| 2 | .02 | .02 | .01 | .06 | <+ | + | .01 | .04 |
| 3 | .14 | .13 | .13 | .17 | .07 | .06 | .09 | .16 |
| 4 | .18 | .41 | .29 | .28 | .35 | .43 | .26 | .40 |
| 5 | .21 | .53 | .63 | .56 | .52 | .71 | .56 | .50 |
| 6 | .39 | .47 | 1.15 | .73 | .57 | .64 | .86 | .60 |
| 7 | .51 | .50 | 1.40 | .90 | .53 | .85 | .72 | .70 |
| 8 | .46 | .54 | 1.21 | 1.12 | .69 | .71 | .73 | .80 |
| 9 | .77 | .29 | .55 | 1.12 | .50 | .67 | .50 | .80 |
| 10 | .88 | .59 | .27 | 1.12 | .55 | 1.07 | - | - |
| 11 | .87 | .42 | - | - | .57 | .72 | - | - |
| 12 | .71 | 1.28 | - | - | - | - | - | - |

x) Estimated.

Table 9b. Mean weight at age data for cod and haddock used in the assessments in this Report. (The cod data have been revised, and these data are given here and have been used for the assessment for the years 1968 to 1972).

| Age | Mean Weight in Kilos: Cod | Haddock |
|---|---|---|
| 3 | 0.43 | 0.41 |
| 4 | 0.84 | .62 |
| 5 | 1.36 | .97 |
| 6 | 2.00 | 1.59 |
| 7 | 2.92 | 2.33 |
| 8 | 3.87 | 2.72 |
| 9 | 5.25 | 3.56 |
| 10 | 6.50 | 4.41 |
| 11 | 8.23 | 5.40 |
| 12 | 9.43 | 6.70 |
| 13 | 10.60 | - |
| 14 | 11.80 | - |
| 15 | 12.80 | - |

Table 10. Recruitment: million of 3 years old fish in each year class (Revised from 1970 Report).

| Year | Cod | Haddock |
|---|---|---|
| 1962 | 920 | 96 |
| 1963 | 2 194 | 220 |
| 1964 | 2 016 | 260 |
| 1965 | 217 | 12 |
| 1966 | (250) | 19 |
| 1967 | (400) | 95 |
| 1968 | (500) | (40) |
| 1969 | Average | (150) |
| 1970 | Very rich | Average |

Table 11. Estimates of nominal catch of cod ('000 tons) at selected levels of fishing mortality.

| 1970 | | 1971 | | 1972 | |
|---|---|---|---|---|---|
| F | Yield | F | Yield | F | Yield |
| 1.10 (present level) | 899 | 0.53(i) | 387 | 0.53 | 354 |
| | | | | 0.80 | 488 |
| | | | | 1.12 | 621 |
| | | | | 1.50 | 748 |
| | | 0.80(ii) | 531 | 0.53 | 302 |
| | | | | 0.80 | 418 |
| | | | | 1.12 | 534 |
| | | | | 1.50 | 644 |
| | | 1.10(iii) | 679 | 0.53 | 251 |
| | | | | 0.80 | 350 |
| | | | | 1.12 | 449 |
| | | | | 1.50 | 545 |
| | | 1.50(iv) | 818 | 0.53 | 204 |
| | | | | 0.80 | 285 |
| | | | | 1.12 | 366 |
| | | | | 1.50 | 447 |

(i) F reduced to a level close to that giving the maximum yield per recruit within the present pattern of the fishery.

(ii) F reduced in 1971 to its 1967 level.

(iii) F remains at its present level.

(iv) F increased to the level where F in the oldest age groups is 1.5 ($F_{max}$).

Table 12. Estimates of nominal catch of haddock ('000 tons) at selected levels of fishing mortality.

| 1970 | | 1971 | | 1972 | |
|---|---|---|---|---|---|
| F | Yield | F | Yield | F | Yield |
| 0.8 (present level) | 71.6 | 0.3(i) | 26.7 | 0.3 | 30.2 |
| | | | | 0.6 | 54.5 |
| | | | | 0.8 | 67.8 |
| | | | | 1.0 | 79.8 |
| | | 0.6(ii) | 48.3 | 0.3 | 25.0 |
| | | | | 0.6 | 45.2 |
| | | | | 0.8 | 56.4 |
| | | | | 1.0 | 66.5 |
| | | 0.8(iii) | 59.9 | 0.3 | 22.2 |
| | | | | 0.6 | 40.3 |
| | | | | 0.8 | 50.3 |
| | | | | 1.0 | 62.7 |
| | | 1.0(iv) | 70.2 | 0.3 | 19.8 |
| | | | | 0.6 | 36.0 |
| | | | | 0.8 | 44.9 |
| | | | | 1.0 | 53.2 |

(i) F reduced to a level close to that giving the maximum yield per recruit.

(ii) F reduced in 1971 to the 1967 level.

(iii) F remains at present level.

(iv) F increased in 1971 to a higher level.

Table 13. Summary of estimates of the size and yield of the cod stock

| (A) Year | (B) Stock Numbers 4+ Years Old (in millions) | (C) Recruits 3 years old (in millions) | (D) Total Stock Numbers (B) + (C) (in millions) | (E) Total Stock Weight (in 1000 tons) | (F) Yield (in '000 tons) | (G) Yield as % of Stock (F) ÷ (E) |
|---|---|---|---|---|---|---|
| 1950 | 1 818 | 833 | 2 651 | 4 473 | 732 | 16 |
| 1955 | 2 810 | 420 | 3 230 | 5 164 | 1 148 | 22 |
| 1960 | 1 387 | 1 068 | 2 455 | 2 804 | 631 | 23 |
| 1965 | 1 059 | 920 | 1 979 | 2 182 | 445 | 20 |
| 1966 | 1 295 | 2 194 | 3 489 | 2 936 | 483 | 16 |
| 1967 | 2 241 | 2 016 | 4 257 | 3 820 | 573 | 15 |
| 1968 | 3 044 | 217 | 3 261 | 4 042 | 1 074 | 27 |
| 1969 | 1 886 | 250 x) | 2 136 | 3 416 | 1 191 | 35 |
| 1970 x) | 1 086 | 400 | 1 486 | 2 422 | 899 | 37 |
| 1971 x) | 769 | 500 | 1 269 | 1 769 | 679 | 38 |

x) Estimated assuming F = 1.1 (present level).

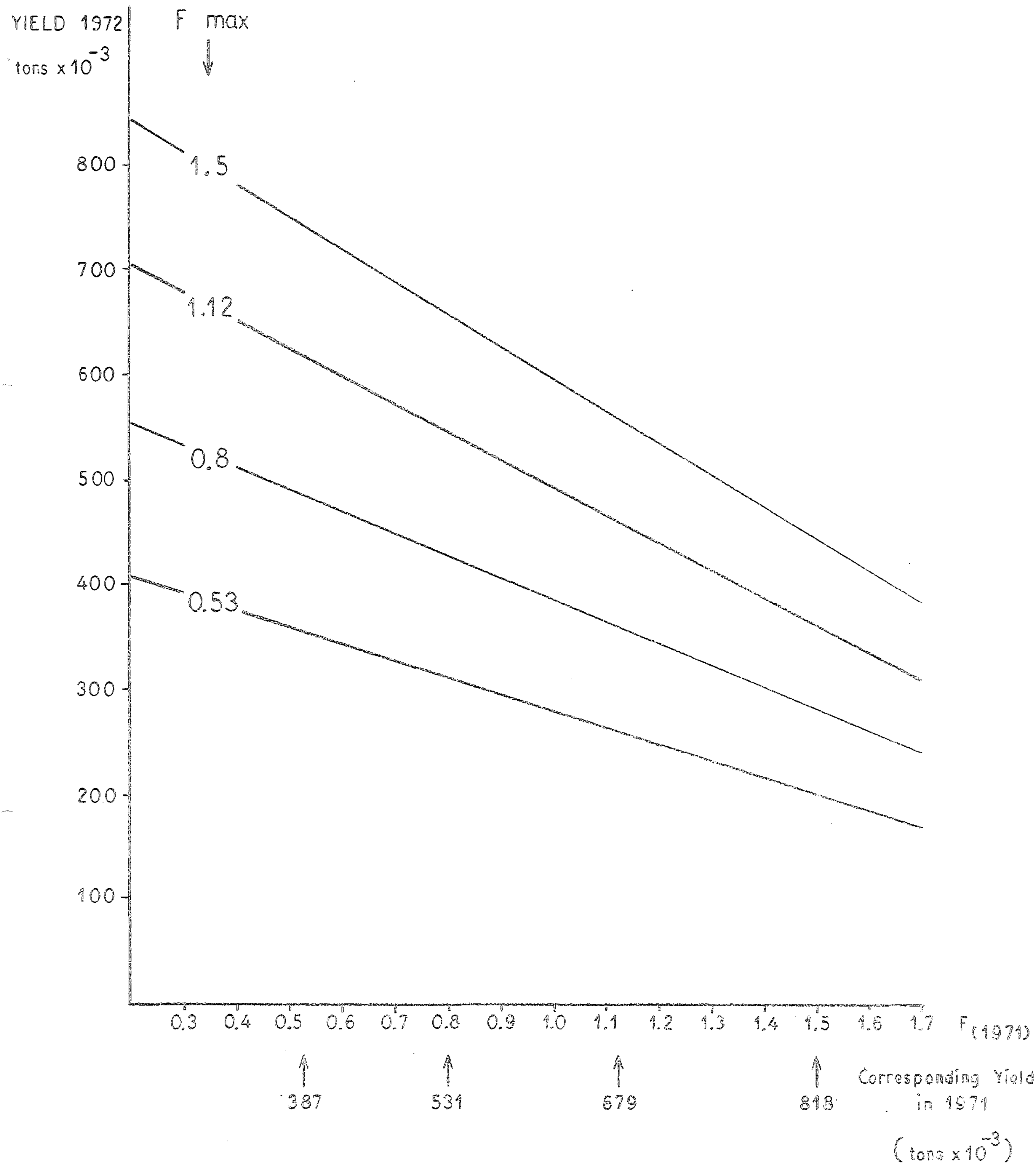


Figure 1. North-East Arctic Cod. Yield in 1972 at different levels of F in 1971 and 1972.

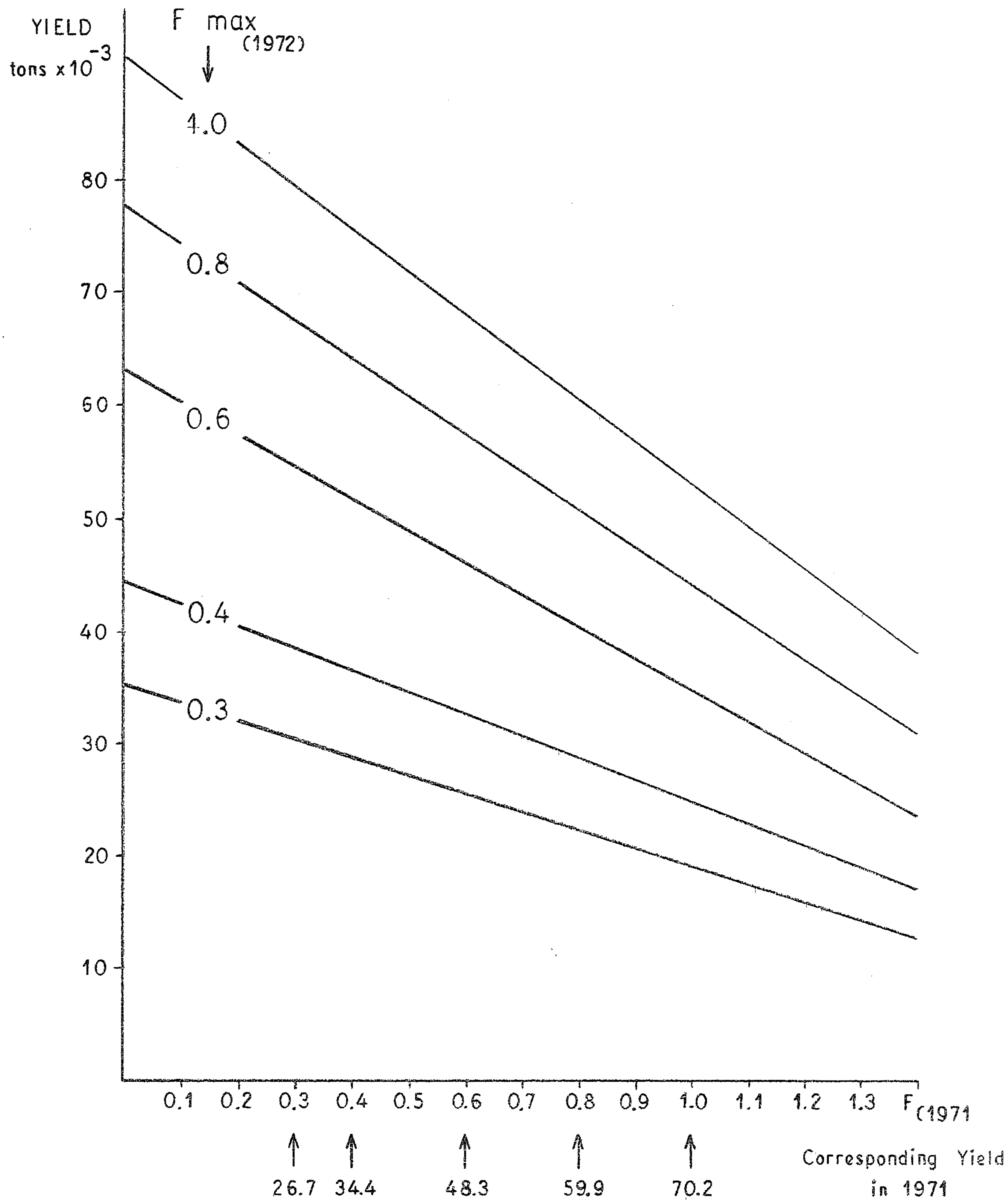


Figure 2. North-East Arctic Haddock. Yield in 1972 at different levels of F in 1971 and 1972.

This paper not to be cited without prior reference to the Council[x)]

International Council for the
Exploration of the Sea

C.M.1971/Supplement to F:3
Demersal Fish (Northern) Committee

SUPPLEMENT AND ANNEX TO REPORT OF THE NORTH-EAST ARCTIC FISHERIES WORKING GROUP

---

1. Supplement to replace paragraphs 7 on pages 4 and 5 of the Report.

2. Annex describing data and methods used to estimate the catch associated with particular levels of fishing mortality in the following years.

---

x) The General Secretary,
ICES,
Charlottenlund Slot,
2920 Charlottenlund
Denmark.

SUPPLEMENT

to replace para.7 on p. 4 and 5 of the Report.

7. The effects upon the cod fishery of the closure of fishing grounds

At an earlier meeting the Group concluded that the reduction of spawning stock size to relatively low levels may reduce the probability of strong year classes. With regard to the anticipated poor recruitment from the 1965-1968 year classes, and in view of the high level of exploitation of recent strong year classes (1963, 1964) in 1968 to 1970, the Group expects that the spawning stock will become considerably reduced in coming years. The Group has therefore discussed alternative methods of regulation (particularly the closure of fishing areas) that might be used in conjunction with a catch limitation in order to offset the anticipated decline in spawning stock.

Leaving aside the complexity of closures within major areas of the total fisheries four basic combinations of closure might be considered.

1. Closure of all areas of the fishery, closed throughout the year.

2. Closure of all areas of the fishery, (a) closed during the same season or (b) closed at different seasons.

3. Closure of major area(s) of the fishery, closed throughout the year.

4. Closure of major area(s) of the fishery, (a) closed during the same season, or (b) closed at different seasons.

In principle the effects of any of these combinations might be estimated from a detailed knowledge of the distribution of catches, provided fishing effort directly affected by a regulation were not redeployed in other parts of the fishery. However, the Group considers, that in all cases except 1 and 2(a) it could be expected that part of the displaced effort would be diverted to other parts of the same stock. These adjustments of the fishery to such a regulation would tend to nullify the potential benefits and prevent realistic estimation of its effect upon total catch or spawning stock size.

In general the effect of limited closures of either areas or seasons upon Long-term total catches would be small at the present level of fishing mortality, with or without redeployment, though catches might be redistributed between areas and countries in a different way. However, the closure of Division IIa would reduce catches to a greater extent than the closure of Sub-area 1 or Division IIb because the fishery in Division IIa exploits older fish and takes place at a time when availability of cod is low in other areas.

The effect of closure upon the size of the spawning stock may be judged from its effect upon the number of fish surviving to spawn once or several times, regardless of the age at which fishing mortality occurs. Previous assessments have shown that a reduction in fishing mortality in the fishery as a whole either by regulation of catches, or by the regulation of mesh sizes will increase the number of older fish, and hence increase spawning stock size by increasing survival at restricted, or overall age groups. A closure might be selective to protect particular

Supplement (ctd.)

age groups but it would contribute towards the same general effect. The Group sees no prospect of being able to determine precisely the effect of a particular closure regulation taken in isolation in this respect, but, calculations assuming no redeployment of fishing between areas can give a maximum estimate of the potential benefit that might be obtained by very broad closures. Taking the weight of stock of 7 year old cod and older as an index of spawning stock size these calculations suggest that total closure of Sub-area 1 could give a fourfold increase in the potential spawning stock from a given level of recruitment, and closure of either Division IIa or IIb could give a twofold increase.[1)] However, these calculations exclude the uncertain benefits to recruitment that such an increase in spawning stock might have, and its consequent effect in further increasing spawning stock size over a long period of years. Any increase in spawning stock size following a reduction in fishing mortality would also increase the number of cod spawning more than once, which may have an additional beneficial effect on the chances of good recruitment.

The Group does not believe that it will be able to add materially to these conclusions from further consideration of the problem without postulating a complex framework of alternative assumptions concerning the redeployment of fishing effort.

---

1) The effects of a closure of all areas of the fishery for the same limited period of time has not been calculated but it is unlikely to exceed the maximum benefits to be obtained by total closure of one of the areas of the fishery throughout the year.

# A N N E X

## Data and Methods used to estimate the catch associated with particular Levels of Fishing Mortality in the following Year

### Objective

1 A To estimate in absolute numbers the stock of fish per age-group at the end of the final year of fishing, i.e. the beginning of the first year for which catch estimates are required.

B To estimate the catch itself by application to the stock of the appropriate levels of fishing mortality.

### Estimation of absolute numbers

2 Data

A National fishery statistics of total catch, by species in round fresh weight in tons, and fishing effort, summarized by Subarea 1 and Divisions IIa and IIb separately on an annual basis. Comparable summaries by months are available within the national recording systems but they have not been used as a primary source of data in calculating catch estimates.

B Estimates of the composition of national catches as the number of fish landed per age-group within Subarea 1, and Divisions IIa and IIb separately. The length composition of catches is available within national statistics on a monthly basis but since the sampling system of some countries is designed only to provide a length to age conversion on an annual basis, the age composition of catches of the total international fishery is only available for the whole year. However, as with the catch statistics, monthly data are mainly used for reference and interpretation.

3 These data provide the basis for derivation of catch per unit effort, or per mille age and length distributions as required. Comparisons of mean weight and age of national catches in the same area of the fishery reveal any anomalous results which need to be checked back to the basic data.

4 N.B. Estimates of prospective catches for a given year t must necessarily be available early in a year if they are to be incorporated in the choice of an allowable catch in that year: the data are needed before national statistical returns of data for the previous year t - 1 are currently being completed. This means that the most recent data available to the Group relate to year t - 2 but not for the most recent completed year of fishing. This places a heavy constraint on accuracy when the fishery has shown substantial changes between years. Some guidance on fishing activity in year t - 1 has been obtained from provisional estimates of catch, but fishing effort data have not so far been available. So serious is the potential error that in this report, 1971, an attempt has been made to judge catches in year t - 1 from the age composition of catches of a single country most of whose data had been processed in time for the meeting. The estimate is made by extrapolation based on a conversion factor for each age-group as International catch age-group x/National catch of age-group x averaged over 10 years. The conversion matrix is stable for age-groups contributing the greatest part of the catch but shows increasing variability (though not trend) towards the extremes of the age distribution, where the variance of the basic sampling systems may be expected to be increased.

Appendix (ctd.)

5 Method of estimating stock size

The basic technique used is virtual population analysis (VPA) as described by Gulland (ICES, 1965). Briefly, the total population, N, of any age-group of a year-class may be determined from the total numbers of fish in that year class subsequently caught from it (the virtual population, V) and the exploitation rate, E, to which it is exposed. Thus for a given age-group in year n the total population $N_n = V_n/E_n$.

Similarly $N_{n+1} = V_{n+1}/E_{n+1}$ and

$$V_{n+1}/E_{n+1} = N_{n+1} = N_n e^{-Z_n} . \qquad (1)$$

The catch in numbers, C, during year n can be expressed in like terms:

$$C_n = N_n \frac{F_n}{Z_n} (1 - e^{-Z_n}) \qquad (2)$$

and taking the ratio of (1) and (2)

$$\frac{V_{n+1}}{E_{n+1} C_n} = \frac{N_n e^{-Z_n} Z_n}{N_n F_n (1-e^{-Z_n})} = \frac{e^{-(F_n + M)}(F_n + M)}{F_n(1 - e^{-(F_n + M)})}$$

where $Z_n = F_n + M$.

For each year class this expression can be solved for $F_n$ and $N_n$, given estimates of $C_n$; $V_{n+1}$ ($\Sigma C_{n+1} \ldots\ldots C_r$, where $C_r$ is the catch of the oldest age-group of that year class), M and $E_{n+1}$. The first three are directly available from data or previous research. However, an initial value $E_{n+1}$ must be assumed for the oldest age-group of a year class, and the computation must be solved through successively younger age-groups with appropriate modification of $E_{n+1}$. Thus $E_n$, the exploitation rate applicable to fish alive at the beginning of the year n, will be the sum of the proportion caught during that year and those caught later:

$$E_n = \frac{F_n}{Z_n} (1 - e^{-Z_n}) + E_{n+1} e^{-Z_n} .$$

$E_n$ is then entered as $E_{n+1}$ in the computation for the next youngest age-group. This series gives estimates of $F_n$ per age-group which can be used in conjunction with $C_n$ and M to estimate the number of fish dying during the year.

$$\frac{C_n Z_n}{F_n} = N_n(1 - e^{-Z_n}),$$

or the stock from which a catch was taken

$$N_n = \frac{C_n Z_n}{F_n(1 - e^{-Z_n})} .$$

Annex (ctd.)

6 The data required for the application of VPA are:

(i) the total numbers caught by age-group, which are obtained and updated from the most recent data;

(ii) an estimate of natural mortality, M;

(iii) an estimate of $E_{n+1}$ to which the stock has been fished in the last year of fishing (i.e. an appropriate level of F and hence Z).

7 Estimates of natural mortality for Arcto-Norwegian cod indicate this to be M = 0.3 as described elsewhere (ICES, 1965) and checked by Schumacher (per. comm.) by plotting F determined from VPA against estimated total fishing effort (see Figure 1). This value is consistent with previous estimates derived by regressing total mortality, Z, on fishing effort and has the added advantage that the variables are statistically independent. Moreover, for this stock the regression technique has the particular difficulty created by the combination of catch per unit effort data from three separate fisheries.

8. The estimate of F and hence F/Z (i.e. $E_n$) to which the stock has been subject in the last year of fishing cannot be determined explicitly by present methods, even from the ratios of catch per unit effort in the two most recent years. It has to be judged from that data in conjunction with the changes in total fishing effort evident from examination of the basic statistics. This is difficult, particularly so because a major part of the yield in any year is taken from age-groups that are not fully recruited to the fishery and which may be subject to discarding at sea so that catch per unit effort data offer no guidance at all.

The procedure adopted by this Group has been to inspect estimates of Z(from the natural logarithm of abundance t - 1/abundance t - 2) for the fully recruited age-groups to determine the direction and magnitude of change in Z, if any. This is examined for consistency with the available effort data. Having selected a trial value for F on these older age-groups, it has then been extrapolated to partially recruited age-groups on the basis of factors determined for past years for which the appropriate F can be determined with little error from VPA (Pope, 1971).

The values described above provide an initial estimate of F, and hence stock, for each age-group at the beginning of year t - 1. A best estimate is reached by a series of trial values of F and E to select that which is most closely consistent with the other evidence of changes in F in the most recent years.

9 In short, with the data and techniques currently available, the estimate of F and hence stock in year t - 1 has to be a carefully judged guess. The potential errors involved may not be significant for older age-groups which contribute a small proportion of the total catch and for which errors in the basic assumption to initiate VPA have little effect on estimates of the relevant year class strength. However, this source of error is crucial to the estimation of stock size of partially recruited age-groups. For example, since the catch of the Arcto-Norwegian cod in year t is heavily dependent upon 5-year-olds, it is essential to achieve good estimates of the absolute abundance of 4-year-olds in year t - 1, or 3-year-olds in t - 2. For these partially recruited age-groups the ratio F/M is relatively low, and, when the possibilities of discarding at sea are added, there is the real risk of significant error when estimates of F are used to derive stock size.

Annex (ctd).

10 The computations described provide estimates of stock size at the beginning of year t - 1. These are then further raised to the abundance of each year class at 3 years old through VPA on the historic record. These are then compared to the independent estimates of relative year class strength available from research surveys, thus checking that the data series are so far as possible consistent.

11 Estimates of future catch

At this point the Group has estimates of stock abundance per age-group at the beginning of year t - 1 and F during that year. The stock size is then updated to the beginning of year t as

$$N_t = N_{t-1} e^{-(F_{t-1} + M)}$$

for each age-group. Further basic information required for the computation of catches is the number of young fish that will recruit to the fishery for the first time in years t, t + 1, etc.,and the current weight at age.

12 Recruitment is estimated from international 0-group and USSR young fish surveys. The former give a single estimate for each year class prior to its first significant contribution to the fishery, and the latter gives four serial estimates so that the young fish surveys are potentially the more reliable source. USSR research has shown the mean abundance of a year class as 2- to 3-year-olds to give the best correlation with its later performance in the commercial fishery, and variance may be reduced by adjustments for the nutritional status of the young fish in particular years. Even so the confidence limits of the regression of recruitment from survey data on recruitment from VPA are very wide (± 100%) over the period for which the data cover all nursery areas (i.e. Bear Island and Barents Sea) 1957-1965. No doubt the precision will improve as the time period is extended.

13 The two forms of pre-recruit surveys have so far given results which are sufficiently comparable to indicate the relative magnitude of year classes, but at present there is a wide margin of error in estimates of the absolute abundance of newly recruiting year classes. The adequacy of this level of accuracy is to some extent conditional on the magnitude of the year class in question and of the stock it is entering. Errors on a large year class entering a small stock are more significant than the same proportional error on a small year class entering a large stock.

14 Weight at age is taken directly from recent observations rather than any theoretical fit based upon data collated over a series of years. This because, as USSR research has shown, the conditions encountered by young fish in this area, particularly the abundance of young from preceding year classes, may have a significant effect on the subsequent growth of the new group.

15 The assembly of data described involves the direct use of the most recent observations, objective calculation to derive estimates to simulate recent events in the fishery, and some careful judgement in areas where vital data are either inddequate or not available. Having compiled the parameters the future yield of each year class is then computed using the estimated abundance at the beginning of year t, the mortalities it would be subjected to under various assumptions concerning fishing effort, and the mean weight at age.

Annex (ctd.)

Thus the yield in year $t$ is given by

$$Y_{W_t} = \frac{\epsilon F_t}{\epsilon F_t + M} N_t (1 - e^{-\epsilon F_t + M}) \bar{W}_t ,$$

where in addition to the usual notation $\epsilon$ is the partial recruitment factor varying $0 \rightarrow 1$.

16 These computations will give the weight yield in year $t$ for any given mortality regime, and the survivors to year $t + 1$ at age $x + 1$. The procedure is then repeated with adjustment of fishing mortality, if appropriate, and the addition of new recruits.

17 The paragraphs above outline the procedures followed for computing prospective catches. There are, however, many other aspects of the biology and dynamics of the species which are held under review throughout, e.g. the determination of maximum sustained yield, size and structure of the spawning stock in relation to stock and recruitment problems. The computation of the catch levels is amenable to a high degree of mechanization and in taking advantage of this it becomes the more important to ensure that no fundamental changes in the biology or the character of the stock and its fisheries are overlooked.

## References

ICES, 1965. Report of the Meeting of the Arctic Fisheries Working Group in Hamburg, Jan. 18-23. Annex 1.

POPE, J. G., 1971. An investigation of the accuracy of virtual population analysis. ICNAF Res. Doc. (mimeo).

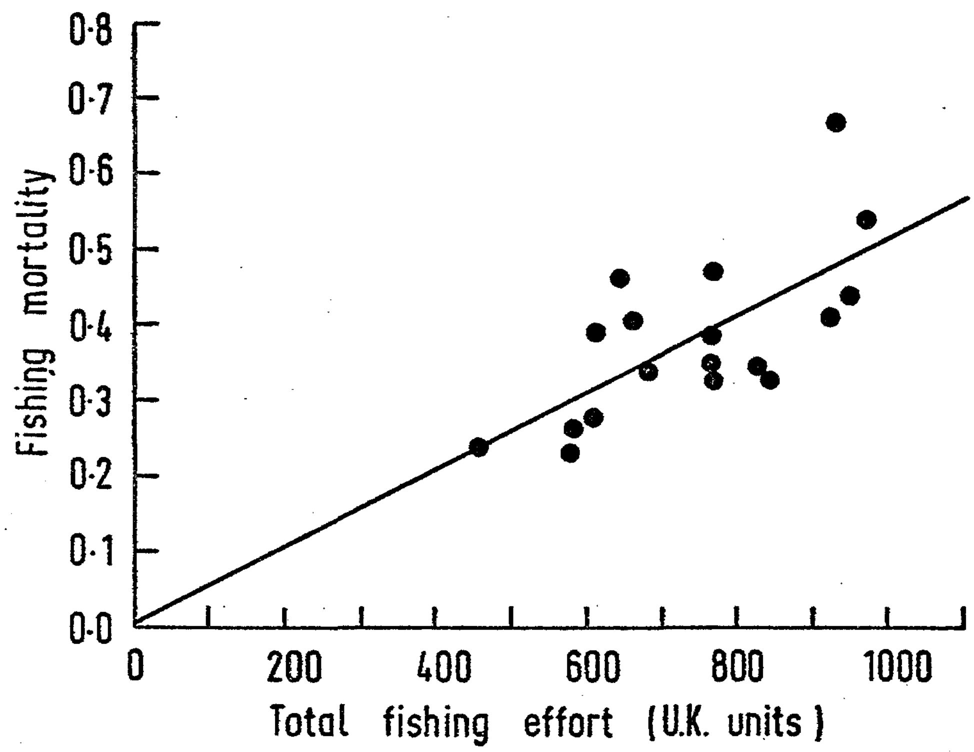
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0·0
Fishing mortality
0
200
400
600
800
1000
Total fishing effort (U.K. units)

Figure 1

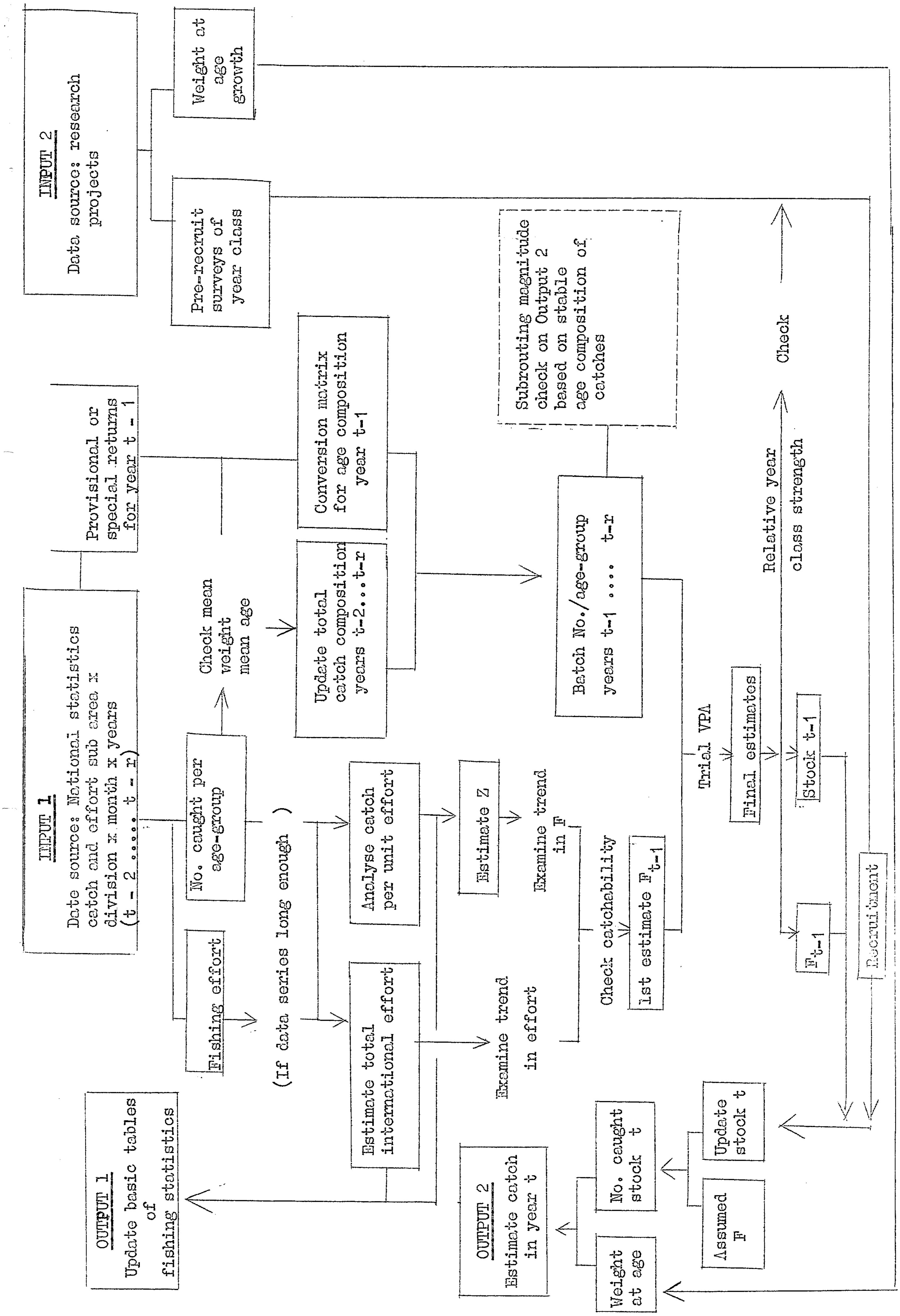
INPUT 2
Data source: research projects
Weight at age growth
Pre-recruit surveys of year class
Provisional or special returns for year t - 1
Conversion matrix for age composition year t-1
Subrouting magnitude check on Output 2 based on stable age composition of catches
Check
Relative year class strength
INPUT 1
Data source: National statistics catch and effort sub area x division x month x years (t - 2 ..... t - r)
Check mean weight mean age
Update total catch composition years t-2...t-r
Batch No./age-group years t-1 .... t-r
No. caught per age-group
Fishing effort
(If data series long enough)
Analyse catch per unit effort
Estimate total international effort
Estimate Z
Examine trend in F
Examine trend in effort
Check catchability
1st estimate $F_{t-1}$
Trial VPA
Final estimates
Stock t-1
$F_{t-1}$
Recruitment
OUTPUT 1
Update basic tables of fishing statistics
OUTPUT 2
Estimate catch in year t
No. caught stock t
Update stock t
Assumed F
Weight at age

Figure 2.