# International Commission for the Northwest Atlantic Fisheries

Serial No. 4099
(B.d. 76)

ICNAF Summ. Doc. 77/VI/1

ANNUAL MEETING - JUNE 1977

## Report of Standing Committee on Research and Statistics (STACRES)[2]

Ninth Special Commission Meeting - December 1976

CONTENTS



[1] Executive Secretary, ICNAF, P. O. Box 638, Dartmouth, Nova Scotia, Canada B2Y 3Y9.
[2] Proceedings No. 1 of the Ninth Special Commission Meeting, Tenerife, Spain, December 1976.

Publ. in ICNAF Redbook 1977: 5-32

# REPORT OF STANDING COMMITTEE ON RESEARCH AND STATISTICS (STACRES)

Ninth Special Commission Meeting - December 1976

Chairman: M. D. Grosslein Rapporteur: V. M. Hodder

STACRES met at Puerto de la Cruz, Tenerife, Canary Islands, Spain, during 24 November-2 December 1976 to consider the Commission's request for a review of conservation measures for the northern deepwater prawn (*Pandalus borealis*) in Subarea 1, silver hake in Subarea 4 and mackerel in Subareas 3 to 5 and Statistical Area 6. A further meeting was held on 6 December 1976 to deal with "other business" items and to give final approval to its report. Representatives were present at one or more sessions from Bulgaria, Canada, Cuba, Denmark, Federal Republic of Germany, German Democratic Republic, Japan, Norway, Poland, Spain, Union of Soviet Socialist Republics, United Kingdom, and United States of America, and observers from FAO and ICES.

*Ad hoc* Working Groups on Shrimp (convened by E. C. Lopez-Veiga), Silver Hake (convened by V. C. Anthony) and Mackerel (convened by A. T. Pinhorn) were assigned the tasks of considering the above-mentioned conservation measures, and their reports, as approved by STACRES, are given in Appendices I, II and III. Brief summaries of these reports, together with other matters considered by STACRES, are given below.

## 1. Summary of Recent Catches and TACs

A listing of recent nominal catches and total allowable catches (TACs) by species and stock area is presented in Table 1. The preliminary 1976 nominal catches are estimated from data reported for approximately the first three-quarters of the year with projections for the remaining months of 1976. Advice on TAC levels for 1977 is given in the last column of the Table.

Table 1. Nominal catches (1972-76) and TACs (1973-76) for stocks deferred from June 1976 Annual Meeting, with TACs as recommended by STACRES for 1977 in parentheses.

| Species | Stock area | Nominal catches (000 tons) 1972 | 1973 | 1974 | 1975 | 1976[1] | TACs (000 tons) 1973 | 1974 | 1975 | 1976 | 1977[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Shrimp[3] | 1(offshore)[4] | 2 (10) | 5 (13) | 12 (22) | 28 (38) | 41 (48) | - | - | - | - | (40) |
| Silver hake | 4VWX | 114 | 299 | 96 | 116 | 90+ | - | 100 | 120 | 100 | (70) |
| Mackerel | 3+4 | 22 | 38 | 45 | 36 | 30 | - | 55 | 70 | 56 | (105-133)[5] |
| | 5+6 | 387 | 381 | 295 | 251 | 205 | 450 | 304 | 285 | 254 | |

[1] Preliminary estimated nominal catches.
[2] TACs recommended by STACRES.
[3] Northern deepwater prawn (*Pandalus borealis*).
[4] Catches in parentheses are total catches (inshore + offshore).
[5] TAC options were not agreed to by USSR and Bulgarian scientists who proposed 180,000 tons.

## 2. Shrimp in Subarea 1

Considerable new information was presented on the general biology of the northern deepwater prawn (= shrimp), including age and growth, reproduction, distribution and mortality rates. An important feature of the life history of this species is that the females are exposed to one full year of fishing mortality before they produce eggs. In addition, it is possible that natural mortality may be very high after the first spawning of females, in which case the stock-recruitment relationship may be a critical factor in the stability of this stock. However, ageing is done by length frequency analysis and the growth of mature females is thought to be slow. Therefore, the growth and mortality estimates are very uncertain, and the assessment must thus be viewed as a first approximation.

The estimated total catch for 1976 is 48,000 tons (41,000 tons from offshore fishing grounds), based on reported catches for about three-quarters of the year and projections for the remaining months. Five independent estimates were made of the size of the fishable stock (part of age-group 4 plus older ages) for the whole or for parts of the West Greenland area. Taking into account all of the factors affecting the accuracy of these estimates which were based on research and commercial trawl catches, the Working Group concluded that 100,000 tons is a reasonable minimum estimate of the offshore fishable stock size in 1976 for the whole of the West Greenland area.

A model was used to estimate allowable removals, using assumed values of natural mortality (after first spawning), the duration of time between recruitment to the fishery and first egg production, fishing mortality, and the ratio of spawning stock to virgin spawning stock. It was concluded that the spawning stock should be maintained at a level above 50% of the virgin spawning stock size. Accordingly the recommended TAC for 1977 is 40,000 tons, including all discards. Although there was no new data on mesh selection, STACRES reiterates its recommendation of the June 1976 Annual Meeting that a minimum mesh size of 40 mm (stretched, nylon) be adopted.

Consideration was also given to possible closed areas and partitioning of the TAC by smaller areas. Knowledge of the inter-relationships between the various fishing grounds is insufficient to recommend specific measures for the whole region. However, since the area outside Disko Bay is believed to be the source of larval and adult shrimp for the Disko Bay fishery, STACRES recommends that offshore catches outside the Disko Bay area, between 68°00'N and 69°30'N latitude east of 59°W longitude, be restricted to 3,200 tons annually.

The uncertainties surrounding the population dynamics of this species make it very important to continue the intensive sampling and reporting of catches, by-catches and discards for the shrimp fisheries in Subarea 1.

3. Silver Hake in Divisions 4V, 4W and 4X

A major obstacle to the proper assessment of this stock continues to be the lack of agreement on ageing. The latest silver hake ageing workshop scheduled for October 1976 could not be held, and STACRES again

recommends

*that a silver hake ageing workshop be held at St. Andrews, Canada, in early March 1977 with Mr. J. J. Hunt as Convener.*

STACRES requested that representatives attend from Bulgaria, Canada, Cuba, USSR, USA and other countries with silver hake fisheries, and that the participants be the persons who are directly engaged in the ageing of silver hake.

Three assessments were examined based on a range of partial recruitment and mortality rates as well as different length-at-age data. The resulting estimates of allowable catches in 1977 for $F_{0.1}$ levels were 64,000, 67,000 and 79,000 tons. However, these assessments did not allow for the effects of the 60-mm manila (55-mm synthetic) mesh restriction to be imposed in April 1977 (1976 Annu. Meet. Proc. No. 8, App I). The available data on mesh selection were considered inadequate for precise estimates of the effects of the mesh size on different age-groups. However, the direction of the effects can be predicted and some first approximations were calculated. The increased mesh size will increase the mean age of recruitment of silver hake, resulting in an increase in $F_{0.1}$ and a reduction in fishing mortality on fish less than 28 cm in length. Canadian length-at-age data suggest that, if the mesh size corresponds to a mean age of recruitment of about 24 months, the partial recruitment of age 2 fish may be 75% while age 1 fish will be effectively excluded from the catches. USSR length-at-age data suggest that the increased mesh size might result in partial recruitment factors of 0% for ages 1 and 2, 50% for age 3 and 67% for age 4 fish.

If traditional patterns of fishing mortality were to continue in 1977, the recommended TAC associated with $F_{0.1}$ would be 70,000 tons, the average of the three estimated catch levels. An estimate of the effect of the increased mesh size suggests that the catch corresponding to $F_{0.1}$ with the new pattern of fishing mortality might be as much as 12,000 tons less, and a catch of 58,000 tons would be recommended. If a catch of 70,000 tons is taken in 1977 with the increased mesh size, $F_{0.1}$ will be exceeded but the spawning stock is expected to increase slightly. Thus, a 1977 TAC of 70,000 tons appears to pose no threat to the spawning stock, and the beneficial effects of the mesh size restrictions will be visible within 2-3 years.

Data on by-catches in the USSR, Bulgarian and Cuban fisheries in Subarea 4 were reviewed but were not considered adequate to estimate the full magnitude of the by-catch problem in fishing for silver hake with bottom trawls because of area and seasonal limitations in the coverage. Several areas on the Scotian Shelf were identified and ranked in order of their potential importance for by-catch based on the distribution of various fish species in relation to the distribution of the silver hake bottom trawl fishing grounds. In particular, areas and depths were delineated where potential by-catch of haddock would occur.

4. Mackerel in Subareas 3 to 5 and Statistical Area 6

After extensive analysis of a considerable body of new data on the mackerel stock, including results from both research vessel surveys and commercial catch data, the Working Group agreed on two options

which represent a range of parameters based on the most up-to-date estimates calculated at this meeting. A summary of the results of these options is given in Table 2. There were differences in the parameters used for the two options with respect to fishing mortality at age 3+ in 1976, size of the 1975 year-class at age 1 and partial recruitment values for ages 1 and 2. There was disagreement about the reliability of the USSR age-length keys for the first quarter of 1976 from Subarea 5 and Stat. Area 6. This disagreement could not be resolved in the Working Group, but it was provisionally agreed to pool the Polish and USSR age-length keys.

Table 2. Mackerel in Subareas 3 to 5 and Statistical Area 6: projections of catch in 1977 and spawning stock size in 1977 and 1978 for the various parameters of Options 1 and 2.

| | Parameters | Option 1 | Option 2 |
|---|---|---|---|
| Fishing mortality | $F_{76}$ (3+) | 0.6 | 0.75 |
| Partial recruitment (%) | F (age 1) | 10 | 14 |
| | F (age 2) | 67 | 53 |
| | F (age 3+) | 100 | 100 |
| Recruitment at age 1 ($10^6$) | 1974 year-class | 2,150 | 2,150 |
| | 1975 year-class | 1,250 | 750 |
| | 1976 year-class | 1,500 | 1,500 |
| 1977 projections | Spawning stock (000 tons) | 475 | 381 |
| | F (age 3+) | 0.35 | 0.35 |
| | Catch (000 tons) | 133 | 105 |
| 1978 projections | Spawning stock (000 tons) | 485 | 392 |

Both options indicate that the fishing mortality estimates (age 3+ fish) in 1976 are higher than previously recorded in the fishery. Fishing at $F_{0.1}$ = 0.35 in 1977 will result in a catch of 133,000 tons under Option 1 and 105,000 tons under Option 2. The predicted catch under either option will allow for some increase in spawning stock size from 1977 to 1978.

Calculations of the possible effects of adopting either Option 1 or Option 2, given that the underlying assumptions of the other option were in fact true, are given in Table 3. Specifically, if Option 2 were adopted but the assumptions of Option 1 were in fact true, there would be a reduction in fishing mortality in 1977 and a 6% increase in the spawning stock estimated for 1978. On the other hand, if Option 1 were adopted but the assumptions of Option 2 were true, fishing mortality would increase in 1977 above the $F_{0.1}$ level and a 16% decrease in spawning stock size would be projected for 1978.

Table 3. Possible effects of adopting either of the two options under the two sets of conditions indicated in the heading.

| | Effect if assumptions of options are correct | | | Effect if assumptions of alternative option are correct | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Option | TAC in 1977 (tons) | F in 1977 | Spawning stock in 1978 (000 tons) | Catch in 1977 (tons) | F in 1977 | Catch in 1978[1] (tons) | Cumulative 1977 and 1978 catch (tons) | Spawning stock in 1978 (000 tons) | % change in spawning stock by weight |
| 1 | 133,000 | 0.36 | 485 | 105,000 | 0.26 | 141,000 | 246,000 | 513 | +6 |
| 2 | 105,000 | 0.35 | 392 | 133,000 | 0.46 | 87,000 | 220,000 | 328 | -16 |

[1] Represents the catch of age 2 and older mackerel.

In addition to the above calculations, the general implications of the present level of spawning stock biomass in relation to historical trends were discussed. It was pointed out that, although the level of the present spawning stock biomass is in the same range as that which produced the moderate 1966 year-class and the large 1967 year-class, the mean age of the spawning stock at present is 3.2 years compared with a mean age of 4.5 years in 1966 and 4.2 years in 1967. Since fecundity is related to the weight of individuals, this implies a significantly reduced egg production from the present spawning biomass, although recent work in the Gulf of St. Lawrence has indicated that the number of eggs may be more related to the production (growth rate × biomass) of the stock than to the biomass. It was also pointed out that the numbers of ages 4 and 5 fish are expected to in-

crease in 1978 under both options, thus causing a slight increase in the size and mean age of the spawning biomass. The estimates of spawning stock size in 1978 are heavily dependent on the estimates of the recruiting year-classes used in the assessments. Although it was not possible to evaluate precisely the effects of the various factors on recruitment success and spawning, it was agreed that the present level and condition of the spawning biomass is reason for concern (see Appendix III, Fig. 1).

STACRES notes that, in view of the concern regarding any future reduction in the size of the spawning stock, the projected catch of 105,000 tons would clearly be the more prudent choice, since an increase in spawning stock would be more probable. Furthermore, it was noted that the estimated cumulative catch in 1977 and 1978 would be greater under Option 2 than under Option 1 if, in fact, the assumptions of the other option were true (Table 3). However, in view of the uncertainty regarding factors controlling spawning success and the fact that the spawning stock is expected to increase under both options (given that the assumptions for the adopted option are, in fact, true), STACRES was unable to make a clear choice between the two options. Therefore, with the exception of USSR and Bulgarian scientists, STACRES advises that the TAC in 1977 be in the range of 105,000-133,000 tons associated with Options 1 and 2.

The two paragraphs and the table which follow is an exact copy of the part of the Working Group Report (App. III) which presents the views of USSR and Bulgarian scientists on the mackerel assessment:

"However, in the opinion of the USSR scientists, the pooling of age-length keys for 1976 was done without sound scientific evidence because some factors which could be the reason for the differences were not taken into account. For example, the areas fished by Polish and USSR fishing fleets, and consequently the sampling areas, were considerably different. A possibility of the existence of some differences in age-reading techniques should not be completely excluded. In this particular case, the doubts can be eliminated only by the joint work of experts of these countries. The mechanical pooling of "keys" resulted in a 50% decrease in the estimated 1973 year-class abundance at age 1 in comparison with the value obtained when using separate age-length keys (Res. Doc. 76/XII/169). The mackerel stock size in 1977 to a great extent depends on 1974 and 1975 year-class abundance. The estimation of these year-classes based on US bottom trawling surveys, in the opinion of the USSR scientists, failed to be scientifically justified because its procedure does not allow reliable information to be obtained on mackerel, whose distribution is extremely unequal and to a great extent depends on environmental factors. The US bottom trawling surveys, conducted in 1969, vividly showed to what extent the results could be distorted due to the above-mentioned reasons. Thus, the estimates of year-class strength run with abundance indices of these surveys are subject to very substantial errors. The commercial data of all countries fishing for mackerel evidently indicate a high abundance of the 1974 year-class. The estimates of this year-class used in the calculations are apparently extremely under-estimated in the opinion of the USSR scientists.

"The abundance of the 1975 year-class using trawling survey data ranges from 750 to 1,250 million fish. The Soviet scientists are of the strong opinion that, until more reliable information becomes available, a more valid approach is associated with estimation of the above-mentioned year-class as a mean value of the abundance of age 1 fish in 1969-74, i.e. 2,765 million fish (Res. Doc. 76/XII/169). The estimation of F for 1976 is 0.6. This figure obtained in Res. Doc. 76/XII/169 using commercial data is slightly over-estimated. Based on scientific evidence presented in Res. Doc. 76/XII/169 (and also on the very similar evidence presented in Res. Doc. 76/XII/135)[1], the USSR scientists consider it possible to recommend a TAC at the level of 180,000 tons. This catch and the resultant stock size are presented in the following table of catch and stock size predictions (from Res. Doc. 76/XII/169)."

| Mackerel in SA 3-6 | 1976 | 1977 | 1978 |
|---|---|---|---|
| Spawning stock (000 tons) | 635.9 | 604.1 | 743.0 |
| F (age 3+) | 0.60 | 0.35 | 0.35 |
| Catch (000 tons) | 252.2 | 183.7 | 218.5 |
| Partial recruitment - F (age 1) = F (age 3+) × 0.05<br>- F (age 2) = F (age 3+) × 0.60 | | | |
| Recruitment - 1975 year-class = 2765.4 million fish<br>1976 year-class = 2624.0 million fish | | | |

[1] This statement in parentheses was added by STACRES.

5. Other Business

a) Statistical and Sampling Requirements

STACRES noted the discussions which took place at the 1976 Annual Meeting on the need for more detailed reporting of sampling data and also that a small group of experts (one nominee from each of Canada, USSR, USA and the Secretariat) is scheduled to meet at the Office of the Secretariat before the 1977 Annual Meeting to specify the requirements and costs of implementing a detailed base of sampling data. Pending the completion of this study, STACRES noted the immediate need for more detailed age-length keys for mackerel, and accordingly

recommends

*that the usual requirements for the submission of 1976 sampling data for the April 1977 Meeting of the Assessments Subcommittee include the request that member countries provide individual age-length keys for individual samples of mackerel.*

STACRES was informed that the CWP Secretary and the Assistant Executive Secretary have made the necessary adjustments to the STATLANT 21 Form and the instructions for completing the form, preparatory to the implementation of the Commission's Resolution regarding the reporting of catch and effort data by 30 × 30 minute unit areas and twice-monthly time periods (1976 Annu. Meet. Proc. No. 18, App. I). It was noted that the Secretariat has already provided member countries with advance information on the implementation of the new system for reporting 1976 data through the Circular Letter series. STACRES urges that member countries pay particular attention to completing the new STATLANT 21B forms in accordance with the revised requirements.

b) Progress Report on Herring Tagging Program

A brief review of the 1976 herring tagging program in Subarea 5 was presented by the USA representative. More than 29,000 herring were tagged on Georges Bank in October through the cooperation of Canadian, USSR and USA scientists and utilizing the USSR purse seiner *Ubileiniy* and the USSR *R/V Belogorsk* as the support vessel. Although practical problems were encountered in conducting the tagging operations offshore, the research teams nearly reached their goal of tagging 30,000 herring. Tagging was also carried out on Jeffrey's Ledge (Div. 5Y) in October but only 10,693 herring were tagged in relation to the goal of 30,000 because of rough seas during much of the period assigned to the operation. Finally it was noted that herring tagging along the coast of Maine was in progress with 21,000 fish tagged up to 19 October, the goal for this area being 25,000 tagged herring. The coordinator of the ICNAF herring tagging program (W. T. Stobo, Canada) reported on progress of tagging in Subarea 4, noting that goals had been reached, or nearly so, in a number of tagging operations there.

STACRES was pleased with the progress of the tagging program to date and noted that there was a good possibility that most of the tagging operations planned for 1976 and 1977 could be completed. In particular, it was noted that returns from herring tagged in the winter and spring in Div. 6A or Subdiv. 5Zw would be especially important for determining the possible extent of mixing of these fish with stocks to the north and east. Attention was drawn to the fact that vessel support for the tagging of 30,000 herring in April 1977 in this area had not yet been arranged. The USSR representative indicated that a Soviet purse seiner and a support vessel could be made available for this offshore tagging operation in Div. 6A or Subdiv. 5Zw during the period of 15 April-15 May 1977. Assuming, therefore, that herring can be located and successfully tagged during this period, the outlook for completing this very important part of the tagging program appear encouraging.

STACRES recommends that the proposed 1977 tagging operations be completed in so far as possible, including the seeding experiments and the complete reporting of all recaptures as outlined in *Redbook* 1976, pages 153-155, and in Circular Letter 76/40. STACRES noted that, in order to obtain the maximum information from the tagging experiments, it will be necessary to have tag recaptures from all offshore and inshore fishing grounds throughout the year.

c) Steering and Publications

A meeting of the Steering and Publications Subcommittee was held on 5 December 1976 to consider the scheduling of the next meeting of the Assessments Subcommittee and the matter of selecting papers from research documents presented to this Special Meeting for possible publication in the *Selected Papers* series.

STACRES noted its decision at the 1976 Annual Meeting that the Assessments Subcommittee meet for 10 days in the last half of April 1977 at ICNAF Headquarters in Dartmouth, Canada, and agreed that the period of 19-29 April would be appropriate if the Commission holds its next Annual

Meeting during the usual period in June. Should the time of the 1977 Annual Meeting be changed, the time of the Assessments Subcommittee Meeting could be adjusted accordingly, if required.

STACRES noted that much data on the biology and size of the shrimp stocks in Subarea 1 and on the status of the fishery were submitted as research documents to this Special Meeting, and considered it desirable that these reports be published in a single volume of the *Selected Papers* series after appropriate revision and editing. It was noted that a number of the Danish papers might be condensed and/or integrated into a smaller set to avoid as much repetition as possible. STACRES was informed that the Secretariat would be unable to cope with the additional editorial work represented by this special volume and agreed that an ICNAF scientist familiar with shrimp biology be requested to serve as editor. The Chairman of STACRES agreed to seek an appropriate editor for the task. It was also noted that, in order for the shrimp papers to be ready for the next issue of *Selected Papers*, the final revised drafts of the papers must be in the hands of the editor no later than 30 June 1977, but preferably earlier. During the early months of 1977, the editor will communicate with the authors regarding the suggested revisions of their papers. Regarding the selection of other papers (i.e. mackerel and silver hake) for possible publication, STACRES agreed that these be referred to the Steering and Publications Subcommittee for consideration at the 1977 Annual Meeting.

6. Future Research and Status of STACRES

Concern was expressed by some members of STACRES because of the uncertainty about the future of coordinated research programs and the role of STACRES itself. In addition to the herring tagging program, there are, for example, two other coordinated research programs on herring where continuity with past work is important, namely the autumn larval herring surveys and the spring trawl surveys for juvenile herring. Both of these surveys have been going on for some time with the resultant development of a time series of data which represent some significant potential for monitoring and evaluating factors related to spawning success and the recovery of the herring stocks. In a more general sense, it was noted that progress in understanding the natural factors controlling fish production (e.g. testing hypotheses on factors controlling year-class success) would require well coordinated research programs conducted on a broad scale on both biological and physical environmental factors, as outlined by the Environmental Working Group (*Redbook* 1976, pages 141-151). Consequently, STACRES again strongly endorses the view that there be continued international cooperation in research and that STACRES and its Subcommittees can continue to be an effective forum for the formulation and conduct of research in the Northwest Atlantic.

7. Adjournment

The Chairman expressed his appreciation for the efforts of the Working Group conveners and participants in completing their tasks and thanked the STACRES representatives for their cooperation.

# APPENDIX I. REPORT OF *AD HOC* WORKING GROUP ON SHRIMP IN SUBAREA 1

Convener: E. C. Lopez-Veiga

The *ad hoc* Working Group on Shrimp met during 24-27 November 1976 to assess the status of the offshore shrimp stocks in Subarea 1. Scientists attended from Canada, Denmark (Greenland and Faroese laboratories), Japan, Norway, Spain and USSR. At the June 1976 Annual Meeting, STACRES recommended that the total allowable catch (TAC) from the offshore fishing grounds should not exceed 26,000 tons annually, including all discards, but the Commission decided to defer the setting of the TAC and allocations for 1977 to this Special Meeting when new information would be available. Consequently, the Working Group reviewed a considerable amount of new information relating to both the general biology of the species and stock size estimates: Res. Doc. 76/XII/149, 150, 151, 152, 154, 155, 156, 166, 168, 172 and several working papers.

## 1. General Information on Biology

The spawning of shrimp in the West Greenland area ends in September and the berried (ovigerous) period extends generally from August to April-May, which is considered to be a relatively long period compared with that for other areas. It seems that some of the females which have spawned do not become berried for spawning in the following year. In some areas, at least, most of the berried females develop eggs for a new spawning to take place about four months after the eggs have hatched. Since ecdysis cannot occur in the berried animals, their growth is very small, and this could lead to an accumulation of several age-groups around the last mode in a length-frequency diagram. Only those relatively few females which do not develop roe within a season can be expected to grow. *Pandalus borealis* is a protandric hermaphrodite, and, since the females enter the exploited phase of their life before any spawning occurs, they are exposed to fishing mortality for a full year before they make their first contribution to the production of larvae. This point is important with regard to the stock-recruitment relationship.

This species shows a strong diurnal variation in the catches due to vertical migration off the bottom during the night with the greatest concentrations on the bottom during the day at noon. The diurnal variation is most pronounced when the variation in light intensity is maximum. Underwater observations made by USSR during July-October 1976 (Res. Doc. 76/XII/156) show that the density of shrimp concentrations in the near-bottom 10-m layer was considerably higher in the daytime than at night. Transitional individuals (i.e. changing from male to female) constituted 92.5% in the pelagic trawl catches with only 7.5% females, whereas in the bottom trawl catches 42% were transitionals and 58% were females. The size composition was the same in the bottom and pelagic trawl catches during the period when the observations were made.

## 2. Fishery Trends

The estimated total catch of shrimp in Subarea 1 for 1976, based on reported landings for about three-quarters of the year and projections for the remaining months, is 48,360 tons, of which 41,060 tons were taken in the offshore areas. The breakdown of the offshore catch by country is as follows: Denmark (13,500 tons), France (1,100 tons), Japan (<100 tons), Norway (12,000 tons), Spain (7,860 tons) and USSR (6,500 tons). The recent rapid development of the offshore fishery is demonstrated by the following nominal catch figures for Subarea 1:

| Fishing areas | Nominal catches (000 tons) | | | | |
|---|---|---|---|---|---|
| | 1972 | 1973 | 1974 | 1975 | 1976[1] |
| Inshore grounds | 8 | 8 | 10 | 10 | 7 |
| Offshore grounds | 2 | 5 | 12 | 28 | 41 |
| Total | 10 | 13 | 22 | 38 | 48 |

[1] Preliminary data

## 3. Mortality Estimates (Res. Doc. 76/XII/168)

Using a method developed by the Danish scientist, K. P. Andersen, to estimate growth and mortality parameters directly from length composition data, total mortality coeficients (Z) of 1.5 and higher have to be assumed for the female group in order to obtain estimates of growth parameters which seem reasonable. These values compare well with those estimated for the same species in Norwegian fjords (Z = 1.8) by other methods. However, the lack of adequate data at present makes it impossible to judge with any certainty if the growth described by the model is realistic.

The method mentioned above was applied only to those length groups greater than 29 cm lateral carapace length from the length frequency samples of the catches. Doubt was expressed as to the applicability of the method to the female group, as the method would not apply if there is nil growth (in terms of carapace length) or if there is a strong dominance of one age-group. If, however, the mode and distribution mentioned always represents only one age-group, a high natural mortality rate (including migration out of the exploited area) would have to be assumed for that group, since it is followed only by very small groups in the length frequencies.

4. Fishable Stock Size Estimates

Several estimates of the fishable stock size in 1976, relating to the whole of the offshore West Greenland area or to parts of it, were presented, most being based on the area swept method. The Working Group also reviewed several papers on this subject which were presented to the April 1976 Meeting of the Assessments Subcommittee. Estimates of the fishable stock size, i. e. the stock size of length groups (mainly age-group 4 and older) represented in the commercial catches, were as follows:

a) A Danish research vessel cruise in Div. 1B gave a fishable stock size of 54,000 tons for July 1976, including corrections for diurnal variation (Res. Doc. 76/XII/150).

b) Observations from Spanish commercial vessels during October 1976 for a part of Div. 1B, including only the main fishing grounds, gave an estimate for the fishable stock size of 42,000 tons (Res. Doc. 76/XII/166).

c) Stock size estimates obtained using CPUE data of Norwegian trawlers in 1976 ranged from 99,000 to 127,000 tons (Res. Doc. 76/XII/155). The Norwegian CPUE data for 1975 gave stock size estimates which were similar to those based on the CPUE of Faroese trawlers for 1975 (Res. Doc. 76/VI/15).

d) An estimate of 124,000 tons for the fishable stock was obtained for part of Div. 1B (southwest of Store Hellefiske Bank and Holsteinborg Deep) where the Norwegian *M/S Pero* worked during May 1976 (Res. Doc. 76/XII/155).

e) USSR investigations in July-October 1976, based on instrumented trawl survey and underwater observations, which avoids many of the causes of under-estimation by the swept area method as it takes into account the vertical distribution of shrimp within the water column, gave an estimate of the fishable stock size of 184,000 tons for Div. 1B (Res. Doc. 76/XII/156).

The swept area method basically implies that the stock size estimates are minimum estimates for the following reasons: (i) it is assumed that the trawl effectively catches every shrimp in the volume of water swept, but this is hardly the case; (ii) the method does not take into account the fact that the vertical distribution of shrimp may exceed the height of the trawl headline, but the results of the Danish survey does to some extent take into account the diurnal variation with corrections to the actual catches; and (iii) some significant escapement may occur under the footrope as some of the trawls used have the footrope about 1 m off the bottom.

The swept area method could, on the other hand, lead to severe over-estimates if the actual catches used are higher than those which would have been obtained in the other parts of the areas to which the observations are extrapolated. This bias occurs when the actual catches used are those from the commercial fishery which tends to concentrate in areas where catch rates are highest, and when these catches are extrapolated to the overall area of distribution. Indeed, there was great variation in abundance of shrimp in 1976, not only between areas but also between times of the year within areas. For example, in an area where catch rates were very high at the start of the fishing season (April-May), the Danish survey showed the nearly complete absence of shrimp later in the year. A critical factor in using the swept area method with commercial data involves, therefore, the assumptions made about the size of the areas with shrimp concentrations, as the stock size estimates would increase substantially if all areas with suitable depths for shrimp were included in the calculations. It should also be noted that discards have not been included in the Norwegian, Spanish and Faroese CPUE values used in the calculations from which the fishable stock size estimates were obtained: Norwegian observations indicated a discard rate of 9.1% by weight, and Spanish observations showed discards of 6.2% in October with the suggestion that this figure could have been higher in the summer months.

After considerable discussion, the Working Group agreed that 100,000 is a reasonable minimum estimate of the fishable stock size (offshore component) for West Greenland in 1976.

5. Allowable Removals

In general production models, it is assumed that the maximum yield is obtained when the fishable

stock biomass is reduced to 50% of that of the virgin stock. In reducing the virgin fishable stock size by 50%, the spawning stock may, however, be reduced by a much higher percentage, depending on the relationship between age of recruitment to the fishery and the age of first spawning. In the case of shrimp, the Working Group concluded that a safer position would be to maintain the spawning (hatching) stock level at about 50% of the virgin spawning stock size. A method for calculating how much the fishery will reduce the spawning stock biomass is outlined in Res. Doc. 76/XII/172. The key parameters are the value of natural mortality ($M_1$) after first spawning (hatching) and the period (t) between the time of recruitment to the fishery and the time of first hatching. Table 1 presents the values of the ratio $S/S_o$, where S is the resultant spawning stock and $S_o$ the virgin spawning stock, for different values of F, $M_1$ and t. If $M_1 = 1.5$ and $t = 1.5$, an $F = 0.4$ will reduce the spawning stock to 50% of the virgin spawning stock, whereas if $M_1 = 1.0$ the spawning stock will be reduced to 46% of the virgin stock for the same fishing mortality.

Table 1. Ratio of spawning stock size to virgin spawning stock size ($S/S_o$) for a range of fishing mortality (F), two values of natural mortality after first spawning ($M_1$) and three values of the time (t) between recruitment to the fishery and first hatching.

| | t = 1.0 | | t = 1.5 | | t = 2.0 | |
|---|---|---|---|---|---|---|
| F | $M_1 = 1.5$ | $M_1 = 1.0$ | $M_1 = 1.5$ | $M_1 = 1.0$ | $M_1 = 1.5$ | $M_1 = 1.0$ |
| 0.1 | 0.88 | 0.86 | 0.84 | 0.82 | 0.80 | 0.78 |
| 0.2 | 0.78 | 0.74 | 0.70 | 0.67 | 0.64 | 0.61 |
| 0.3 | 0.69 | 0.64 | 0.59 | 0.55 | 0.51 | 0.48 |
| 0.4 | 0.61 | 0.56 | 0.50 | 0.46 | 0.41 | 0.38 |
| 0.5 | 0.54 | 0.49 | 0.42 | 0.38 | 0.33 | 0.30 |
| 0.6 | 0.49 | 0.43 | 0.36 | 0.32 | 0.27 | 0.24 |
| 0.7 | 0.43 | 0.38 | 0.31 | 0.27 | 0.22 | 0.19 |
| 0.8 | 0.39 | 0.34 | 0.26 | 0.23 | 0.17 | 0.15 |
| 0.9 | 0.35 | 0.30 | 0.22 | 0.19 | 0.14 | 0.12 |
| 1.0 | 0.31 | 0.27 | 0.19 | 0.16 | 0.11 | 0.10 |

Assuming a natural mortality of 1.5 after spawning (hatching) and a difference of 1.5 years between the age of recruitment to the fishery and the age of first spawning (hatching), the fishing mortality which would lead to a 50% reduction of the spawning is therefore 0.4. With a mean annual fishable stock biomass of at least 100,000 tons, this fishing mortality would correspond to a catch of 40,000 tons. Therefore, the Working Group recommends that the level of catch for 1977 should not, in any case, exceed 40,000 tons, including all discards, from the offshore grounds.

The Working Group stresses that the present knowledge about the stability of the size of the offshore shrimp stocks is very limited. Observations indicate that on some of the grounds great variations can occur between months and years, and it is likely that the size of the total biomass of shrimp also fluctuates greatly. For example, cod, which is known to be one of the major predators on shrimp, is at present very scarce in Div. 1A and 1B where the greatest shrimp concentrations are found.

The Working Group also points out that the consequence of using high natural mortality values in the models, and the fact that the catch composition consists of only two modes, makes forecasting of potential shrimp yields extremely dependent upon a knowledge of recruitment to the fishable stock in the forecast year. Thus, the application of $F = 0.4$ and $M_1 = 1.5$ in the model will mean that only 15% of the female part of the 1976 fishable stock will be available to the 1977 fishery, whereas that component accounted for about one-half of the estimated mean annual fishable stock size in 1976. It would therefore seem proper to evaluate the situation at the beginning of each fishing season so that possible corrections to the management scheme can be made. The Working Group also stresses that, to ensure the highest possible long-term yield from the stock, the relative level of removal might be lower than the level described above, that is, in cases where the spawning stock has been reduced (by fishing and/or extreme environmental factors) to a level where recruitment would be too low to ensure a rebuilding to the high potential level if the relative level of removal is continued.

6. Mesh Size Regulation

There was no substantial new information on mesh selection, so the Working Group agreed that a minimum mesh size of 40 mm (stretched nylon), as recommended by STACRES at the 1976 Annual Meeting, should be adopted.

7. Closed Area Regulation

Although there seems to be an indication that the mean size of shrimp is smaller on the shallower parts of the grounds, there is not at present enough information on the delineation of particular nursery grounds. The Working Group agreed that such measures should be considered when more information becomes available.

8. TAC Breakdown by Area

The Working Group had a lengthy discussion about the desirability and feasibility of breaking down the TAC by areas. The desirability of a breakdown is generally related to two considerations: (i) the inter-relationship between offshore and inshore areas, specifically in Disko Bay where an important local fishery has been established, and (ii) the inter-relationship between the various offshore grounds.

With reference to (i) above, it has been documented that some of the southernmost inshore fisheries are greatly dependent upon the inflow of adult shrimp from coastal and offshore areas, and there are also indications of an inflow of adult shrimp to the Disko Bay area from the offshore grounds. Furthermore, the recruitment to nursery grounds and subsequently to the exploited stock of Disko Bay is assumed to be dependent upon the supply of larvae from the offshore spawning stock. Lacking detailed knowledge, especially above larval drift, the Working Group considers that, if the Commission wishes to take precautionary action to maintain the established Disko Bay fishery and to take into account the possible inter-relationship between Disko Bay and the offshore grounds, such action should be to ensure that an area adjacent to Disko Bay be fished at a relatively low level of exploitation. Such an area could probably be defined as between latitudes 68°N and 69°30'N, east of 59°W longitude. The lowest of the fishable stock size estimates for that area, based on the size of a part of the area covered by the Spanish fleet in 1975, is about 8,000 tons. A fishery of not more than 40% of that minimum stock size, i.e. a catch of not more than 3,200 tons annually within the defined area, should therefore ensure that the stock is fished at a level not higher than, and possibly well below, that which corresponds to $F = 0.4$ under the general assumption underlying the suggested overall removal of 40,000 tons. Should the Commission wish to consider such precautionary action, the Working Group recommends that annual catches in the offshore area adjacent to Disko Bay, between latitudes 68°N and 69°30'N east of 59°W longitude, not exceed 3,200 tons, this figure being adjusted in the light of future new evidence about the inter-relationship between fishing grounds.

With reference to (ii) above, the inter-relationships between offshore grounds is presently unknown, although the general assumption is that larval drift is in a northward direction such as is observed for the drift of fish larvae. However, the movement of the adult stock between grounds is at present unknown, although the fishery trend in Div. 1B during 1976 suggests a northward movement of shrimp concentrations in that year. It would therefore seem desirable to ensure that the spawning stocks of the more southerly grounds are not reduced to a level below the mean level for the offshore grounds as a whole. In this connection, it was pointed out that, if the overall TAC is not broken down by areas, there is a risk that local stocks (including important spawning stocks) may be heavily exploited in areas where such stocks concentrate, for example, due to environmental conditions or to possible schooling behaviour.

Variation in catch per unit effort has been observed between fishing grounds. If the TAC is not broken down by areas, it seems most likely that fishing activity on the grounds with the highest CPUE would continue until catch rates corresponding to or lower than those on the other grounds are achieved. However, it is not certain that a unit of fishing activity in one area exerts the same fishing mortality in that area as it would in other areas. Thus, if good fishing in an area is due to a relatively greater degree of concentration than in other areas, there could be a high level of F in that region. Under such circumstances, it would also seem desirable to distribute a part of the fishing effort to less important areas (in terms of larval production and larval drift) by a breakdown of the TAC.

It was pointed out that, if the TAC is broken down by area without having good data for doing so, there is the risk of forcing the fleet to over-exploit some components of the stock compared with others. Without an area breakdown, there is the chance that, if a certain component of the stock is fished too heavily, the CPUE will decrease and the fleet will move to other areas. It was also pointed out that it could be dangerous to base an area breakdown of the TAC on data for one or two years only, because the shrimp distribution may change from year to year. Possible seasonal variation in shrimp distribution will also make it difficult to determine the most appropriate breakdown.

In view of the above-mentioned arguments for and against a breakdown of the TAC, the Working Group was not able to advise on any specific scheme for allocating the TAC by area, except for the aforesaid advice concerning the area adjacent to Disko Bay.

9. By-catches in the Shrimp Fishery

The Working Group noted that information on by-catches in the shrimp fishery had been collected during the research surveys and by observers on commercial vessels in 1976. Analysis of the material has not yet been completed but preliminary observations indicate that small redfish formed the major part of the by-catches in the 1976 fisheries while the very small quantities of cod in the offshore areas of Div. 1B at present do not cause problems in the shrimp fisheries there. The Working Group stressed the need for the continuous collection of data on by-catches in the shrimp fisheries.

10. Future Research

The present uncertainties about the assessment of the shrimp stocks are related mainly to : (i) areal and seasonal distribution and density of the stocks; (ii) the inter-relationship between grounds regarding the drift of larvae and migration of adult shrimp; and (iii) interpretation of the length compositions, especially of female shrimp, in terms of age and growth.

Items (i) and (ii) above can only be elucidated by establishing stratified surveys in the offshore areas similar to that carried out by Denmark in Div. 1B in 1976, and the Working Group strongly

recommends

*that stratified trawl surveys of the offshore shrimp grounds be part of the annual research program in Subarea 1.*

Item (iii) above requires the detailed study of shrimp samples, including possible alternatives to the present criteria (carapace length) for age and growth. The Working Group

recommends

*that detailed studies of shrimp samples be carried out, with special attention to characters usable to illustrate the age composition of female shrimp.*

The Working Group stressed the need for continuously sampling the commercial catches and for the reporting of catch and effort data, as well as discards, by small area and time units. The Working Group therefore

recommends

*that STACRES nominate a working group to study (i) a scheme for stratified surveys, (ii) a minimum sampling level for shrimp, and (iii) an adequate system of reporting catch and effort data, including discards, to be established for the 1977 fishing season.*

# APPENDIX II. REPORT OF *AD HOC* WORKING GROUP ON SILVER HAKE IN DIVISIONS 4VWX

Convener: V. C. Anthony

Rapporteur: M. D. Grosslein

The *ad hoc* Working Group on Silver Hake met during 24-29 November 1976 to further review the status of the silver hake stock in Div. 4VWX, a matter which was deferred by the Commission from the 1976 Annual Meeting. Representatives attended from Bulgaria, Canada, Cuba, USSR and USA. The Working Group reviewed all available new information on silver hake: Res. Doc. 76/XII/157, 158, 159, 160, 163, 164, 165 and several working papers.

## 1. Catch Statistics

The estimated total catch of silver hake in Div. 4VWX for 1976, based on reported landings for approximately three-quarters of the year and projections for the remaining months by most countries, is about 90,000 tons, slightly below the 1976 TAC of 100,000 tons. This is a reduction in catch from 1975 when 112,000 tons were taken, which was also slightly less than the 1975 TAC of 120,000 tons. The breakdown of the provisional 1976 catch by country is as follows: Bulgaria (2,151 tons), Canada (22 tons), Cuba (9,464 tons, Jan. to Aug.), Federal Republic of Germany (83 tons), USSR (77,614 tons) and USA (1 ton).

## 2. Review of the Age and Growth Problem

A major obstacle to the proper assessment of this silver hake stock continues to be the lack of agreement on ageing. Significant discrepancies still exist between Canadian age-at-length data (based on length frequency modal analysis) and USSR data (based on ageing whole otoliths) for young age-groups. Another special workshop (the third) had been planned for October 1976 at Woods Hole, USA, in order to resolve the problem, but it could not be held because USSR representatives were unable to attend.

Some further examination of the problem was possible, however, through USA-USSR exchange of whole otoliths and otolith sections (23 pairs of otoliths). The age readings of these specimens by USSR scientists were in very close agreement (nearly 100%) with the age readings previously done by USA scientists. The USSR representative noted, however, that there were biological discrepancies in relation to growth rate and time of sex maturation, but that these discrepancies could be explained by a single approach to the interpretation of annual rings. The Working Group again

recommends

*that a silver hake ageing workshop be held in the near future.*

New information on the length-at-age and growth of silver hake was presented in Res. Doc. 76/XII/164. USSR and Canadian research vessel samples of silver hake on the Scotian Shelf for 1970-75 were examined by modal analysis. The availability of length frequency data by 1-cm groupings and by sex facilitated a more precise analysis than is possible with commercial length frequency data reported by 2-cm length groups. A clear and consistent pattern of growth with differentiation between sexes at lengths greater than 25 cm was obtained. The length-at-age and growth estimates from these data support the earlier results of modal analysis of USSR commercial length samples. Von Bertalanffy growth curves were fitted to the data for each sex. The calculated asymptotic length for females (38 cm) is lower than some observed values. However, a related species, *Merluccius albidus*, sometimes occurs in the catches of silver hake and these larger specimens (>40 cm) may be mistaken for silver hake.

## 3. By-catches in the Silver Hake Fisheries

The Working Group reviewed a summary of by-catches by USSR scouting and fishing vessels engaged in the Subarea 4 silver hake fishery during 1970-76 (Res. Doc. 76/XII/158). Species composition of catches were reported for a total of 815 bottom trawl hauls (about 60% on scouting vessels) directed toward silver hake, the pooled catches being recorded by 30' × 30' unit areas covering about 80% of the silver hake fishing grounds. A total catch of 3,300 tons was recorded for all 815 hauls combined, of which only 4% represented species other than silver hake. Most of the by-catch consisted of herring, argentine, mackerel and redfish. Gadoids made up less than 1% of the total catch and were reported chiefly from the western part of Div. 4W. Surprise was expressed by some representatives that such consistently pure silver hake catches could be taken with bottom trawls, given the known occurrence of other species in these areas. It was stated that the low by-catch in this fishery was due to the fact that silver hake prefer warmer water than some other groundfish and also are found in deeper areas particularly in the winter.

The Working Group found it difficult to judge the significance of these results because data were not available by season, year or depth of hauls and because the types of haul (scouting *vs* commercial)

were not given separately for each 30' × 30' unit area. It was noted that about two-thirds of the hauls were made along the edge of the Scotian Shelf and most of the remainder in the Emerald Basin area. Only five hauls were reported for four 30' × 30' unit areas in the region to the west of Sable Island, where a major part of the summer fishery has occurred in some years. The available data were clearly not adequate for estimating by-catch in this region, as this is an area where significant quantities of other groundfish occur, including adult and juvenile cod and haddock, yellowtail flounder, winter flounder and American plaice, and where the potential for by-catch in the silver hake fishery with bottom trawls is higher than in other areas of the shelf.

Information on by-catch was also reported for the Bulgarian and Cuban fisheries in 1976. In July 1976, about 9% of the Cuban catches consisted of species under catch quota regulation other than silver hake and squid, and the figure was about 12% for the year to the end of August. The Bulgarian representative noted that, in July 1976, his country's vessels fishing for silver hake with pelagic trawls had less than 2% by-catch, composed chiefly of mackerel. He also noted that the by-catch would be somewhat higher if the vessels had fished for squid.

4. Distribution of Silver Hake Fishing Grounds and Silver Hake in Relation to Other Groundfish

The USSR scientists presented a brief description of the silver hake fishing grounds in Subarea 4, including a chart showing the geographic distribution of major silver hake concentrations. It was noted that 80% of the annual catch is taken at depths of 110-350 m in Div. 4W. Aggregations of silver hake sometimes break up a short time after fishing commences (4-5 days) and the fleet must search for new aggregations in other areas. These movements of silver hake are believed to be related to changes in water temperature. Commercial concentrations of mature silver hake are found chiefly in areas where the water temperature is 7 to 9°C. The schools often lie close to the bottom, sometimes only 5-10 m off the bottom, and, therefore, pelagic trawling could not entirely substitute for bottom trawling in the silver hake fishery.

The summer distribution of silver hake on the Scotian Shelf was described from Canadian research vessel data for 1970-74 (Res. Doc. 76/XII/164). They are distributed widely over the Shelf with the greatest concentrations in the Emerald Bank-Sable Island area. In general, larger silver hake (>24 cm) are found farther offshore than the smaller ones. Concentrations of adult fish were found in the west Sable Island area. Previous USSR studies showed this region to be a major spawning area.

General fish distribution in relation to hydrographic conditions on the Scotian Shelf was studied as a secondary objective on a Cuban research cruise in July 1976 (Res. Doc. 76/XII/165). It was suggested that temperature conditions and fish distribution may have been abnormal in 1976 compared with those of the early 1960's. However, examination of the hydrographic regime in 1970-74 (Res. Doc. 76/XII/163) suggested that the 1976 conditions were not greatly different from those of the early 1970's.

The geographical and seasonal distribution of the silver hake fishery in relation to the distributions of other important groundfish species in Div. 4VWX were examined. Three primary areas were identified in which silver hake fishing with bottom trawl is concentrated: (a) the west bar of Sable Island in depths less than 100 m from July to November; (b) in the Scotian Gully north of Emerald, Western and Middle Banks and as far west as Emerald Basin in depths greater than 110 m from March to November; and (c) along the edge of the Continental Shelf from the eastern tip of Sable Island to the eastern tip of Browns Bank in depths of 110-350 m during January-August and November-December (Fig. 1). Knowledge of the distribution of other finfish species and squids (Res. Doc. 76/XII/159, 163) indicates that there could be potential by-catches in these areas as follows:

a) West bar of Sable Island Bank. In the months fished, concentrations of juvenile cod and haddock occur in this area. Also, there are resident populations of flatfish, particularly yellowtail flounder but also winter flounder and American plaice. Juvenile Atlantic halibut also occur there in summer as do species of lesser commercial importance such as thorny and eyed skates, sea raven and ocean pout. Squid (*Illex*) are also usually present in small quantities.

b) North of Emerald, Western and Middle Banks. In the shallowest parts of this area, cod and haddock can be caught, and this would be most likely at the beginning and end of the silver hake season when cod and haddock are concentrated in deeper water. Redfish are concentrated in this area throughout the year in depths greater than 140 m. Other species of commercial importance occurring in this area in lesser abundance are American plaice, pollock, white hake and squid.

c) The edge of the continental shelf. Commercial concentrations of redfish occur in the depth range fished for silver hake, particularly at the eastern and western ends of the area fished, and Atlantic argentine, common grenadier, cusk, longfin hake, white hake and thorny skate also occur in the area. Squid are abundant in summer, and haddock occur in the winter, to some degree, in the depths fished for silver hake in the Emerald, Western and LaHave Bank areas.

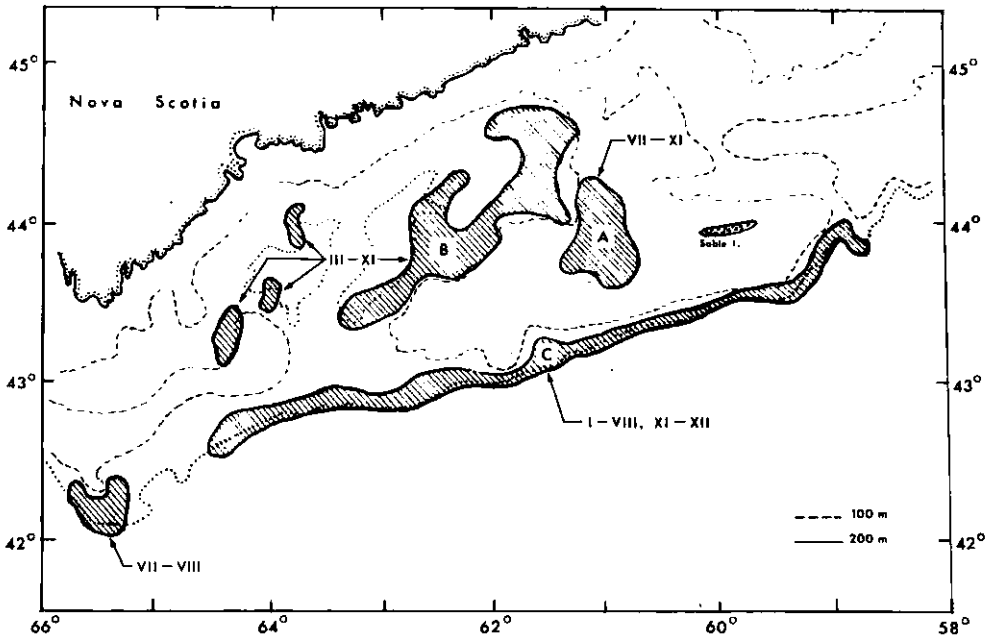


Fig. 1. Distribution of silver hake concentrations by season in Div. 4VWX, based on summed data of the USSR fishing fleet.

It is apparent that there are overlaps in the distributions of important commercial fish species in all of the major areas of silver hake fishing. Hence, there is the potential for by-catches to occur in bottom trawling for silver hake. The importance of the effects of such by-catches on the productivity of these stocks is contingent on the quantities caught and the state of the stocks in question. For stocks subject to minimum mesh size regulations (e.g. cod, haddock and flatfishes), by-catches in small-meshed gears result in some reduction in productivity. It has been demonstrated (*ICNAF Redbook* 1976, pages 86-87) that relatively small catches by weight can have very substantial effects under these circumstances. For some resources such as redfish, although not regulated by a minimum mesh size, small fish are avoided by some national fishing fleets for processing and marketing reasons. By-catches of small fish, such as redfish, reduce the productivity of the resources. They do represent a conflict of interest between fishermen of different nations, lesser allocations being available to those fishermen who wish to engage in directed fisheries for these species. There are other resources (e.g. squid) for which by-catches in small-meshed trawls do not represent a loss in potential yield if such by-catches are utilized. In such cases, and when the Commission has agreed that a particular nation should have an allocation of that resource, by-catches do not constitute a problem unless these result in the nation's total catch exceeding its allocation. nnn

In reviewing the information on fish distribution in relation to potential by-catch problems, the Working Group considered that their importance decreases from area (a) through area (b) to area (c) (see Fig. 1). Certain deeper parts of area (b) may present minor by-catch problems with the exception of redfish, but the central part of area (c) between approximately Western Bank and east of LaHave Bank is the area of silver hake fishing where overlaps of distribution with other important commercial species are the least. It was noted, however, that the northern limit of this fishing area is critically important, as haddock could be subject to potential by-catch problems, particularly in the winter when they are aggregated in pre-spawning and spawning concentrations. These aggregations can occur to a depth of 155 m (85 fath) in winter (November to March or April inclusive), depending on hydrological conditions. However, in summer (May to October inclusive), haddock occur in shallower areas, and fishing for silver hake along the edge of the continental shelf in depths as shallow as 120 m (65 fath) would avoid the main areas of haddock distribution.

5. The TAC Level for 1977

The Working Group reviewed assessments presented by Canada and USSR, both suggesting TACs for 1977 (Res. Doc. 76/XII/157, 160). Both assessments allowed for estimates of 1976 catch-at-age data not previously available, and one assessment utilized new research survey data. The age composition of the commercial catch was very different in the two assessments. The Canadian assessment used a modal length analysis from Canadian age-length keys, which indicated a large number of young silver hake in the catches. The catch composition, as determined by USSR age analysis, on the other hand,

was composed of a greater proportion of older individuals. The USSR assessment assumed M = 0.5 and the Canadian assessment used M = 0.4. The USSR assessment determined $F_{0.1} = 0.7$, whereas $F_{0.1} = 0.5$ was calculated in the Canadian assessment. Both assessments were revised to include the most recent estimate of the 1976 catch. This resulted in an increase of 42% in the estimated 1976 catch in the USSR assessment (Res. Doc. 76/XII/157) and an increase of 18% in the estimated catch in the Canadian assessment (Res. Doc. 76/XII/160).

The USSR assessment was recalculated following the procedure suggested by the author but correcting for uncertainties in the analysis. Partial recruitment values were determined from Anderson (Res. Doc. 76/VI/98) for ages 1, 2 and 3 as 0.035, 0.135 and 0.565 respectively. These were applied to an estimate of F for fully recruited age groups. The resulting values of F for ages 1, 2 and 3 and an F-value of 1.23 for age 4 and older were used to determine the stock size at the beginning of 1976 and 1977. The application of F = 0.7 ($F_{0.1}$ in USSR assessment) for fully recruited silver hake and M = 0.5 to the stock size at the beginning of 1977 gave a projected catch of 67,000 tons. In the Canadian assessment, the application of $F_{0.1} = 0.5$ and M = 0.4 to its stock size composition at the start of 1977 indicated a catch of 64,000 tons. Even though the two assessments were very different, the projected 1977 catches ranged only from 64,000 to 67,000 tons.

At the request of USSR and Bulgarian representatives, a third assessment was carried out on the assumption that full recruitment occurs at age 3 rather than age 4, using (a) USSR estimates of catch composition, (b) partial recruitment rates as originally proposed for ages 1 and 2 in the USSR assessment, (c) $F_{0.1} = 0.7$ for 1977, and (d) M = 0.5. The calculations in this assessment indicated a 1977 catch of 79,000 tons.

Initial TAC calculations in these three assessments did not allow for the likely effects of the 60-mm manila (55-mm synthetic) mesh regulation to be imposed in April 1977 (1976 Annu. Meet. Proc. No. 8, App. I). No analysis was available to demonstrate the effects of the mesh size on different age-groups, but some general conclusions can be made. A 55-mm (synthetic) minimum mesh size with a selection factor of 5.1 indicates a mean selection length of 28 cm (*ICNAF Redbook* 1976, page 61). According to Canadian growth curves for silver hake (Res. Doc. 76/XII/164), this mean selection length occurs at age 2.0 years. The length-at-age used in the USSR assessments (Res. Doc. 76/VI/57) indicates that 28 cm occurs at an age of about 3.0 years. The increased mesh size will increase the mean age of recruitment of silver hake, resulting in an increase in $F_{0.1}$ and a reduction in fishing mortality on fish less than 28 cm in length.

Yield calculations, based on Canadian length-at-age and natural mortality estimates, indicate that, if the mean age of recruitment is increased to 24 months, $F_{0.1}$ increases from 0.5 (15 months) to 0.65 (24 months). A similar increase in $F_{0.1}$ with increased mean age of recruitment would apply for USSR growth and mortality parameters. While calculations were not available, it was assumed, as a first approximation, that the USSR estimate of $F_{0.1}$ would increase from 0.7 to 0.9 in proportion to the Canadian estimates. Canadian length-at-age data suggest that, if the mesh size corresponds to a mean age of recruitment of about 24 months, the partial recruitment of age 2 fish may be 75%, while age 1 fish would be effectively excluded from the catches and age 3 and older fish would be fully recruited. The USSR length-at-age data, on the other hand, suggest that the mesh size might result in partial recruitment factors of 0% for ages 1 and 2, 50% for age 3 and 67% for age 4 fish.

To examine the sensivity of the calculations to the mean age of recruitment, projected catches were calculated for 1977 showing the effects of the 55-mm (synthetic) mesh size. These catches, together with those for no mesh size effects are given in Table 1 for all three assessments. Also given are the calculated long-term catches allowing for mesh size effects and based on median recruitment of $1.0 \times 10^9$ fish (Canadian) and $1.7 \times 10^9$ (USSR). A further calculation, based on Canadian data and using $1.0 \times 10^9$ as the year-class size of age 1 fish in 1976 and 1977, gave an estimated 1978 catch of 68,000 tons.

Table 1. Calculated catches for 1977 with and without the effects of a 55-mm (synthetic) mesh size beginning in 1977 and the long-term annual catch at $F_{0.1}$.

| | Assessment results for 1977 | | Long-term annual catch allowing for mesh size |
|---|---|---|---|
| Assessment | No mesh size effects | Possible mesh size effects | |
| Canadian | 64,000 | 51,000 | 92,000 |
| USSR | 67,000 | 67,000 | 92,000 |
| Third | 79,000 | 56,000 | 92,000 |
| Average | 70,000 | 58,000 | 92,000 |

If traditional patterns of fishing mortality were to continue in 1977, the TAC associated with $F_{0.1}$ would be recommended as 70,000 tons. It is impossible to accurately predict the effects of the mesh size restriction after its introduction in April 1977. However, the available information suggests that the TAC, corresponding to $F_{0.1}$ in 1977 with a new pattern of fishing mortality, might be as much as 12,000 tons less (Table 1). If a TAC corresponding to $F_{0.1}$ is required, a TAC of 58,000 tons must be recommended. However, the spawning stock is expected to increase slightly, even with a TAC of 77,000 tons in 1977, and the beneficial effects of the mesh size regulation will be visible within 2-3 years. The Working Group therefore advises that a TAC of 70,000 tons may be taken in 1977 with a probable increase in stock size even though $F_{0.1}$ will be exceeded.

## APPENDIX III. REPORT OF *AD HOC* WORKING GROUP ON MACKEREL

Chairman: A. T. Pinhorn

Rapporteur: W. T. Stobo

The *ad hoc* Working Group on Mackerel met during 25 November-1 December 1976 to review the status of the mackerel stock in Subareas 3 to 5 and Statistical Area 6 in accordance with the Commission's request for further consideration at this Special Meeting. Representatives attended from Bulgaria, Canada, Cuba, Poland, USSR and USA. Research Documents 76/XII/135-148, 158, 161, 162, 167, 169-171 were reviewed.

### 1. Catch Statistics

Since reported catches of mackerel were not available for the whole of 1976, it was necessary to estimate the quantities that would be expected to be taken during the remaining months following the latest reports. Catch projections were provided by Canada, USSR and USA for the periods not covered in the monthly reports of these countries. For Bulgaria, Cuba, Federal Republic of Germany, German Democratic Republic, Poland and Romania, the projections were obtained by subtracting the reported overall total catch of finfish and squids in Subarea 5 and Stat. Area 6 from the second-tier TAC for each country and further reducing this value by each country's TAC for herring (assuming that this would be fully utilized) and also making some allowance for by-catch. For Bulgaria, German Democratic Republic and Poland, the estimated mackerel catch in the last quarter of the year was limited by the second-tier TAC and this is reflected in the estimates given in Table 1. However, Cuba, Federal Republic of Germany and Romania may be able to reach their mackerel TACs. For the remaining countries with small catches, estimates were assigned for by-catch on the basis of fishing patterns in 1975 and 1976.

Table 1. Estimated nominal catches of mackerel in 1976 by country, based on reported and projected catches.

| Country | Reported to date | Latest report | Estimated remainder | Total |
|---|---|---|---|---|
| Bulgaria | 12,736 | Aug | 504 | 13,240 |
| Canada | 9,555 | Oct | 945[1] | 10,500 |
| Cuba | 6,304 | Sep | 1,096 | 7,400 |
| France | - | - | 500[2] | 500 |
| FRG | 1,257 | Oct 15 | 143 | 1,400 |
| GDR | 32,122 | Aug | 4,898 | 37,020 |
| Italy | 530 | Sep | 50 | 580 |
| Japan | 40 | Sep | 10 | 50 |
| Poland | 36,639 | Sep | 16,601 | 53,240 |
| Romania | 2,818 | Feb | 385 | 3,200 |
| Spain | 132 | Jul | 18 | 150 |
| USSR | 101,812 | Oct | 2,908[1] | 104,720[3] |
| USA | 1,808 | Sep | 642[1] | 2,450 |
| Total | 205,750 | | 28,700 | 234,450 |

[1] Estimates provided by countries involved.
[2] Estimated inshore catch in Subarea 3 for the year.
[3] Estimated catch is 17,621 in SA 3+4 and 87,099 in SA 5+6.

For assessment purposes, the estimated total catch of mackerel in 1976 was rounded to 235,000 tons. This estimate represents a decline of about 20% in Subareas 3 and 4 and about 12% in Subarea 5 and Stat. Area 6 from 1975 levels of catch in these regions.

### 2. Biological Studies and Fishery Information

A first report was presented in which the catch levels of mackerel in the USA recreational fishery were estimated (Res. Doc. 76/XII/142). Catches as high as 32,000 tons (1970) have been taken in this fishery, but recent catches are similar to the much lower ones of the early 1960's. Information on USSR mackerel fisheries in terms of geographic location and by-catches (Res. Doc. 76/XII/158, 167) indicated that the range of mackerel distribution in Subarea 5 and Stat. Area 6 is from Chesapeake Bay to Georges Bank and that the by-catch in the mackerel fisheries with pelagic trawls was no more than 2%. Examination of the influence of environmental factors on recruitment (Res. Doc. 76/XII/139) indicates an inverse relationship with temperature in Stat. Area 6, which is opposite to that found in the Gulf of St. Lawrence (Res. Doc. 75/33); the possibility of offshore wind stress affecting recruitment showed no consistent relationship although poor year-classes seemed to be

associated with years of high wind stress. Laboratory experiments with mackerel (Res. Doc. 76/XII/143) indicated preferred temperatures of 7-13°C and the capability of maintaining swimming speeds in excess of 12 km/hr for periods up to 43 seconds.

3. Abundance Indices for 1976

The 1976 USA research vessel trawl surveys (Res. Doc. 76/XII/137) indicate a slight increase in mackerel abundance over that of 1975 but a substantial decrease in the number of age 1 mackerel in the spring surveys from 1975 to 1976. There is, however, considerable variability in these survey indices, and other papers were presented examining some of the factors involved (Res. Doc. 76/XII/138, 144, 170). Commercial catch per unit effort data (Res. Doc. 76/XII/169) for selected vessel categories showed an increase of 4% for GDR vessels, 50% for Bulgarian vessels, 8-12% for Polish vessels and a decrease of 4% for USSR vessels from catch per hour fished data. Interpretation of commercial catch per unit effort data, however, continues to be complicated by possible changes in efficiency and by possible continued accessibility of schooling species to fishing gear, even at low abundance levels.

4. Catch Composition

The age composition of the catches for the years 1968-75 were recalculated (Res. Doc. 76/XII/137) on the basis of data published in the ICNAF Sampling Yearbook and Statistical Bulletin. Substantial differences from the previously used age compositions were evident in some cases, due possibly to the use of provisional catch statistics and incomplete sampling data in preparing previous assessments. Estimates of the age composition of the catches for 1962-67 were also calculated from Canadian samples and other data sources (Res. Doc. 76/XII/137), but these were considered to be less reliable than those for recent years because of the small number of samples and the nature of the fisheries involved. The Working Group agreed that these recalculated age compositions of the catches for 1969-75 would be used in the present assessment (Table 2).

Table 2. Age compositions of mackerel catches from Subareas 3 to 5 and Stat. Area 6 for the years 1969 to 1976.

| Year class | Age composition of catch (millions of fish) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 |
| 1959 | 7.6 | 2.6 | | | | | | |
| 1960 | 2.0 | 3.5 | 6.9 | | | | | |
| 1961 | 2.8 | 9.3 | 7.8 | 5.4 | | | | |
| 1962 | 1.8 | 9.2 | 4.1 | 3.6 | 1.6 | | | |
| 1963 | 2.7 | 4.9 | 3.4 | 7.9 | 3.7 | 0.8 | | |
| 1964 | 5.2 | 6.6 | 8.5 | 4.1 | 4.0 | 2.4 | 1.0 | |
| 1965 | 59.9 | 25.8 | 33.1 | 23.2 | 10.6 | 6.3 | 2.2 | 0.6 |
| 1966 | 146.2 | 152.3 | 194.8 | 84.2 | 30.4 | 25.1 | 12.2 | 6.6 |
| 1967 | 238.5 | 488.0 | 535.1 | 376.5 | 192.2 | 105.9 | 49.6 | 16.5 |
| 1968 | 6.5 | 51.0 | 122.0 | 176.1 | 187.5 | 109.4 | 50.9 | 30.5 |
| 1969 | 3.6 | 180.9 | 281.7 | 247.0 | 227.5 | 111.8 | 66.6 | 30.6 |
| 1970 | | 4.5 | 71.4 | 82.7 | 277.6 | 99.3 | 57.6 | 31.5 |
| 1971 | | | 2.3 | 21.3 | 275.8 | 258.6 | 99.1 | 59.8 |
| 1972 | | | | 3.4 | 157.7 | 236.9 | 111.7 | 66.8 |
| 1973 | | | | | 3.9 | 93.8 | 423.7 | 257.9 |
| 1974 | | | | | | 2.0 | 367.1 | 367.3 |
| 1975 | | | | | | | 3.6 | 62.9 |
| Total | 476.8 | 938.6 | 1271.1 | 1035.4 | 1372.5 | 1052.3 | 1245.3 | 931.0 |
| $W_o$ (000 t)[1] | 131.8 | 230.6 | 373.0 | 409.7 | 419.3 | 339.6 | 287.1 | 235.0 |
| $W_c$ (000 t)[1] | 115.5 | 242.9 | 396.7 | 376.5 | 425.3 | 339.3 | 301.8 | 255.9 |
| $W_o/W_c$ | 1.141 | 0.949 | 0.940 | 1.088 | 0.986 | 1.001 | 0.951 | 0.918 |

[1] $W_o$ = observed weight, and $W_c$ = calculated weight using mean weight-at-age values from Table 4 of Res. Doc. 76/XII/137.

At the 1976 Annual Meeting, the Commission, in deferring a decision on the 1977 TAC for mackerel, requested that all countries participating in the fishery during 1976 submit data on individual samples to the Secretariat for examination and analysis at the present meeting. Such data for the Bulgarian and GDR fisheries were not available at the meeting for detailed analysis, and the reported age compositions of the catches were accepted as presented. The Working Group also agreed to accept

the Canadian (Res. Doc. 76/XII/162) and USSR (Res. Doc. 76/XII/169) age compositions for Subareas 3 and 4 as well as the Polish age compositions for Subarea 5 and Stat. Area 6. However, there was disagreement on the USSR age compositions for Subarea 5 and Stat. Area 6 in the first quarter of 1976 (Res. Doc. 76/XII/146). It was noted that the difference may have been due to the relatively small samples taken for the age/length key and to other reasons indicated by USSR scientists later in this report. A provisionally agreed solution was to pool the USSR and Polish age/length key data to obtain a quarterly age/length key for application to the USSR length compositions of the catch. (It was noted that the pooling of age/length key data of all countries may also need to be done for previous years in order to improve the estimates of the age compositions of the catches in Subarea 5 and Stat. Area 6). The 1976 age composition data were next prorated to the estimated 1976 catches of the various countries and then adjusted to 235,000 tons, the estimated total mackerel catch for 1976 (last column of Table 2).

5. Assessment Parameters

Several papers on the status of the mackerel stock were presented to the Working Group. Estimates of the minimum stock biomass based on egg surveys in Stat. Area 6 (Res. Doc. 76/XII/140) were discussed but they were considered to be of minimal value for the present assessment because of the large variability associated with the data. A modification of the surplus yield model (Res. Doc. 76/XII/145) was presented but this was not considered to have immediate applicability due to the need for testing the robustness of the model. The Working Group reviewed three assessment papers (Res. Doc. 76/XII/135, 137, 169) which implied 1977 catches in the range of 35,000-184,000 tons at the fishing mortality level of $F_{0.1}$. The information in these papers was used as the basis for deciding the parameters for additional calculations. The Working Group agreed on two sets of assessment parameters which are referred to below as Option 1 and Option 2.

a) Fishing Mortality

Regression of distant water fleet effort data against fishing mortality estimates from cohort analysis gave 1976 values of F in the range of 0.47-0.55. A fishing effort index was also calculated by dividing the international catch by the smoothed mean of the log transformed values of the spring survey abundance index (Res. Doc. 76/XII/169). This fishing effort index was then regressed against cohort analysis estimates of fishing mortality which resulted in a value of 0.43 for F in 1976. After considering these various estimates, the Working Group agreed to use $F_{76} = 0.6$ (near the upper end of the range of estimates) as the value for Option 1.

Another estimate of 1976 fishing mortality was obtained by smoothing the re-transformed spring survey catch-per-effort values (Res. Doc. 76/XII/137) using an exponential curve and by dividing these into the international catch to determine a fishing effort index. Cohort analyses using three starting values of F (0.6, 0.7 and 0.8) provided mean fishing mortalities on age 3 and older fish for the years 1968 to 1974. The fishing effort index was then regressed against the mean fishing mortalities for these years, resulting in a range of 0.62-0.67 for F in 1976. Also, the 1975 fishing mortality estimates and stock sizes from these cohort analyses were used to estimate the stock size at the beginning of 1976. With a knowledge of both the 1976 stock size and catch, the fishing mortality in 1976 was estimated to be in the range of 0.85-1.00. These two sets of estimates were then averaged, giving a range of 0.73-0.84 for F. The Working Group agreed to use $F_{76} = 0.75$ (near the lower end of the range) as the value for Option 2.

For both options, the catch projections for 1977 were made on the basis of $F_{0.1} = 0.35$.

b) Recruitment Estimates

For the 1974 year-class, the regression of catch-per-tow in numbers of age-group 0 from autumn surveys and age-group 1 from spring surveys against estimates of year-class size at age 1 from three cohort analyses (with terminal F's of 0.6, 0.7 and 0.8) gave a range of 2,000-2,300 million fish at age 1. An estimate of the 1974 year-class at age 1 from cohort analysis (with $F_{76} = 0.6$) is 2,300 million fish. Considering the variance associated with these estimates of year-class size, the Working Group agreed to use 2,150 million fish as the size of the 1974 year-class at age 1 for both options.

With regard to the 1975 year-class, research survey abundance indices indicate its size to be in the range of 851-934 million fish from spring surveys and 548-568 million fish from autumn surveys. The possibility of this year-class being poor is also indicated from information on various environmental factors, although these are not consistent. The Working Group agreed to use for Option 2 the 1975 year-class size of 750 million fish, the approximate mean of the estimates from both surveys. However, it was recognized that the variance associated with research vessel survey data may cause large fluctuations in estimates of year-class size. Estimates, derived from the regression of the log-transformed mean of spring survey abundance indices against estimates of year-class size at age 1 from cohort analyses, suggest that this year-class

at age 1 may be larger than that indicated above for Option 2. Consequently, the Working Group agreed to 1,250 million fish as the size of the 1975 year-class at age 1 for use in Option 1.

For the 1976 year-class, the only information available is from the 1976 autumn suvey which suggests a level of 1,400 million fish. However, 1,500 million fish is about the median value for the sizes of the 1968-73 year-classes at age 1, and it was decided to use this value for both options.

c) Partial Recruitment

The Working Group considered that age 3 and older fish are fully recruited to the fishery and agreed to the following partial recruitment factors for 1976, calculated as the proportion of the fishing mortality of age-groups 1 and 2 in 1976 to the fishing mortality of age 3 and older fish, using the observed catch-at-age data and the estimated year-class size for 1976. These partial recruitment factors were then used for the 1977 projections.

| | 1976 partial recruitment (%) | |
|---|---|---|
| | Option 1 | Option 2 |
| Age 1 | 10 | 14 |
| Age 2 | 67 | 53 |

6. Results of Assessments

The summarized results of the assessments for the two options are given in Table 3, and the calculated fishing mortalities and stock sizes for 1959-76 are listed in Tables 4 and 5 for Options 1 and 2 respectively. The results of both options indicate that the fishing mortality estimates for age 3 and older fish in 1976 are higher than previously recorded for the mackerel fishery. Fishing at $F_{0.1}$ = 0.35 in 1977 will result in a catch of 133,000 tons under Option 1 and 105,000 tons under Option 2. It is noted that the predicted catch under either option will allow for some increase in spawning stock size from 1977 to 1978.

Table 3. Mackerel in Subareas 3 to 5 and Statistical Area 6: projections of catch in 1977 and spawning stock size in 1977 and 1978 for the various parameters of Options 1 and 2.

| | Parameters | Option 1 | Option 2 |
|---|---|---|---|
| Fishing mortality | $F_{76}$ (3+) | 0.6 | 0.75 |
| Partial recruitment (%) | F (age 1) | 10 | 14 |
| | F (age 2) | 67 | 53 |
| | F (age 3+) | 100 | 100 |
| Recruitment at age 1 ($10^6$) | 1974 year-class | 2,150 | 2,150 |
| | 1975 year-class | 1,250 | 750 |
| | 1976 year-class | 1,500 | 1,500 |
| 1977 projections | Spawning stock (000 tons) | 475 | 381 |
| | F (age 3+) | 0.35 | 0.35 |
| | Catch (000 tons) | 133 | 105 |
| 1978 projections | Spawning stock (000 tons) | 485 | 392 |

However, in the opinion of the USSR scientists, the pooling of age-length keys for 1976 was done without sound scientific evidence because some factors which could be the reason for the differences were not taken into account. For example, the areas fished by Polish and USSR fishing fleets, and consequently the sampling areas, were considerably different. A possibility of the existence of some differences in age-reading techniques should not be completely excluded. In this particular case, the doubts can be eliminated only by the joint work of experts of these countries. The mechanical pooling of "keys" resulted in a 50% decrease in the estimated 1973 year-class abundance at age 1 in comparison with the value obtained when using separate age-length keys (Res. Doc. 76/XII/169). The mackerel stock size in 1977 to a great extent depends on 1974 and 1975 year-class abundance. The estimation of these year-classes based on US bottom trawling surveys, in the opinion of the USSR scientists, failed to be scientifically justified because its procedure does not allow

reliable information to be obtained on mackerel, whose distribution is extremely unequal and to a great extent depends on environmental factors. The US bottom trawling surveys, conducted in 1969, vividly showed to what extent the results could be distorted due to the above-mentioned reasons. Thus, the estimates of year-class strength run with abundance indices of these surveys are subject to very substantial errors. The commercial data of all countries fishing for mackerel evidently indicate a high abundance of the 1974 year-class. The estimates of this year-class used in the calculations are apparently extremely under-estimated in the opinion of the USSR scientists.

Table 4. Results of mackerel assessment for Subarea 3 to 5 and Stat. Area 6 stock, using the parameters specified in the text for Option 1 (with F = 0.60 in 1976).

| Year class | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Fishing mortality | | | | | |
| 1959 | 0.296 | (0.172)[1] | | | | | | | | |
| 1960 | 0.033 | 0.082 | (0.254)[1] | | | | | | | |
| 1961 | 0.036 | 0.180 | 0.252 | (0.308)[1] | | | | | | |
| 1962 | 0.041 | 0.337 | 0.276 | 0.473 | (0.443)[1] | | | | | |
| 1963 | 0.049 | 0.131 | 0.141 | 0.645 | 0.849 | (0.485)[1] | | | | |
| 1964 | 0.068 | 0.129 | 0.273 | 0.228 | 0.412 | 0.532 | (0.492)[1] | | | |
| 1965 | 0.223 | 0.157 | 0.349 | 0.503 | 0.515 | 0.778 | 0.810 | 0.600 | 0.350 | |
| 1966 | 0.118 | 0.193 | 0.458 | 0.413 | 0.287 | 0.463 | 0.489 | 0.600 | 0.350 | |
| 1967 | 0.054 | 0.168 | 0.315 | 0.434 | 0.469 | 0.558 | 0.708 | 0.600 | 0.350 | |
| 1968 | 0.002 | 0.026 | 0.089 | 0.199 | 0.382 | 0.455 | 0.450 | 0.600 | 0.350 | |
| 1969 | | 0.071 | 0.168 | 0.244 | 0.420 | 0.425 | 0.555 | 0.600 | 0.350 | |
| 1970 | | | 0.051 | 0.085 | 0.519 | 0.399 | 0.484 | 0.600 | 0.350 | |
| 1971 | | | | 0.014 | 0.281 | 0.529 | 0.447 | 0.600 | 0.350 | |
| 1972 | | | | | 0.165 | 0.451 | 0.451 | 0.600 | 0.350 | |
| 1973 | | | | | | 0.057 | 0.444 | 0.600 | 0.350 | |
| 1974 | | | | | | | 0.219 | 0.399 | 0.350 | |
| 1975 | | | | | | | | 0.060 | 0.235 | |
| 1976 | | | | | | | | | 0.035 | |
| F (age 3+) | 0.125 | 0.172 | 0.254 | 0.308 | 0.443 | 0.485 | 0.492 | 0.600 | 0.350 | |
| | | | | | Stock size (age 1 and older) | | | | | |
| 1959 | 34.4 | 19.0 | | | | | | | | |
| 1960 | 72.3 | 51.8 | 35.4 | | | | | | | |
| 1961 | 91.9 | 66.7 | 40.6 | 23.4 | | | | | | |
| 1962 | 52.5 | 37.3 | 19.7 | 11.1 | 5.1 | | | | | |
| 1963 | 65.5 | 46.2 | 30.0 | 19.3 | 7.5 | 2.4 | | | | |
| 1964 | 91.8 | 63.6 | 41.4 | 23.4 | 13.8 | 6.8 | 2.9 | | | |
| 1965 | 348.0 | 206.2 | 130.6 | 68.2 | 30.6 | 13.5 | 4.6 | 1.5 | | |
| 1966 | 1531.7 | 1008.8 | 616.3 | 288.9 | 141.5 | 78.7 | 36.7 | 16.7 | 7.4 | 3.9 |
| 1967 | 5233.2 | 3671.5 | 2299.9 | 1243.3 | 597.0 | 276.8 | 113.9 | 41.7 | 17.0 | 8.9 |
| 1968 | 3129.3 | 2312.6 | 1669.3 | 1131.7 | 686.8 | 347.4 | 163.2 | 77.1 | 31.3 | 16.3 |
| 1969 | | 3071.0 | 2119.3 | 1327.6 | 770.9 | 375.3 | 181.8 | 77.3 | 31.4 | 16.4 |
| 1970 | | | 1663.1 | 1170.6 | 796.0 | 350.8 | 174.4 | 79.6 | 32.4 | 16.9 |
| 1971 | | | | 1789.8 | 1307.6 | 731.3 | 319.2 | 151.2 | 61.5 | 32.1 |
| 1972 | | | | | 1206.5 | 758.1 | 357.7 | 168.8 | 68.6 | 35.8 |
| 1973 | | | | | | 1961.3 | 1372.2 | 651.9 | 265.0 | 138.3 |
| 1974 | | | | | | | (2150.0)[2] | 1279.5 | 636.0 | 332.0 |
| 1975 | | | | | | | | (1250.0)[2] | 872.1 | 510.8 |
| 1976 | | | | | | | | | (1500.0)[2] | 1073.0 |
| Total ($10^6$) | 10650.6 | 10553.7 | 8665.6 | 7097.3 | 5563.0 | 4902.4 | 4876.6 | 3795.3 | 3522.7 | |
| Wt. (000 t)[3] | 2250.9 | 2172.0 | 2084.6 | 2063.8 | 1518.7 | 1195.2 | 960.6 | 745.3 | 692.9 | |
| | | | | | Spawning stock (50% age 2, 100% age 3 and older) | | | | | |
| Total ($10^6$) | 4904.7 | 5326.4 | 5942.8 | 4722.2 | 3703.0 | 2562.0 | 2040.5 | 1905.6 | 1586.6 | 1647.9 |
| Wt. (000 t)[3] | 1389.2 | 1703.1 | 1761.8 | 1767.4 | 1292.8 | 942.3 | 652.1 | 533.5 | 474.1 | 483.3 |

[1] Mean F for age 3+ assumed.
[2] Estimated year-class size at age 1.
[3] Adjusted according to correction factors (ratio of observed to calculated weights) in Table 2.

Table 5. Results of mackerel assessment for Subarea 3 to 5 and Stat. Area 6 stock, using the parameters specified in the text for Option 2 (with F = 0.75 in 1976).

| Year class | Fishing mortality and stock size by year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 |
| | | | | | Fishing mortality | | | | | |
| 1959 | 0.299 | (0.174)[1] | | | | | | | | |
| 1960 | 0.033 | 0.083 | (0.260)[1] | | | | | | | |
| 1961 | 0.037 | 0.183 | 0.258 | (0.317)[1] | | | | | | |
| 1962 | 0.041 | 0.342 | 0.282 | 0.487 | (0.463)[1] | | | | | |
| 1963 | 0.050 | 0.133 | 0.143 | 0.656 | 0.882 | (0.522)[1] | | | | |
| 1964 | 0.069 | 0.131 | 0.279 | 0.236 | 0.431 | 0.573 | (0.557)[1] | | | |
| 1965 | 0.224 | 0.158 | 0.352 | 0.510 | 0.528 | 0.816 | 0.902 | 0.750 | 0.350 | |
| 1966 | 0.119 | 0.196 | 0.468 | 0.429 | 0.302 | 0.499 | 0.553 | 0.750 | 0.350 | |
| 1967 | 0.055 | 0.170 | 0.320 | 0.443 | 0.484 | 0.622 | 0.789 | 0.750 | 0.350 | |
| 1968 | 0.002 | 0.027 | 0.092 | 0.207 | 0.402 | 0.493 | 0.511 | 0.750 | 0.350 | |
| 1969 | | 0.073 | 0.172 | 0.252 | 0.440 | 0.456 | 0.626 | 0.750 | 0.350 | |
| 1970 | | | 0.053 | 0.089 | 0.546 | 0.431 | 0.549 | 0.750 | 0.350 | |
| 1971 | | | | 0.015 | 0.295 | 0.571 | 0.508 | 0.750 | 0.350 | |
| 1972 | | | | | 0.174 | 0.488 | 0.512 | 0.750 | 0.350 | |
| 1973 | | | | | | 0.063 | 0.505 | 0.750 | 0.350 | |
| 1974 | | | | | | | 0.219 | 0.399 | 0.350 | |
| 1975 | | | | | | | | 0.102 | 0.186 | |
| 1976 | | | | | | | | | 0.049 | |
| F (age 3+) | 0.126 | 0.174 | 0.260 | 0.317 | 0.463 | 0.522 | 0.557 | 0.750 | 0.350 | |
| | | | | | Stock size (age 1 and older) | | | | | |
| 1959 | 34.2 | 18.8 | | | | | | | | |
| 1960 | 71.0 | 50.9 | 34.7 | | | | | | | |
| 1961 | 90.5 | 64.6 | 39.9 | 22.8 | | | | | | |
| 1962 | 51.9 | 36.9 | 19.4 | 10.9 | 4.9 | | | | | |
| 1963 | 64.9 | 45.8 | 29.7 | 19.1 | 7.3 | 2.2 | | | | |
| 1964 | 90.2 | 62.3 | 40.5 | 22.7 | 13.3 | 6.4 | 2.7 | | | |
| 1965 | 346.1 | 204.9 | 129.6 | 67.5 | 30.0 | 13.1 | 4.3 | 1.3 | | |
| 1966 | 1511.5 | 993.9 | 605.2 | 280.7 | 135.5 | 74.2 | 33.4 | 14.2 | 5.5 | 2.9 |
| 1967 | 5182.8 | 3634.2 | 2272.3 | 1222.8 | 581.8 | 265.6 | 105.6 | 35.5 | 12.4 | 6.5 |
| 1968 | 3036.1 | 2243.6 | 1618.2 | 1093.8 | 658.7 | 326.6 | 147.8 | 65.7 | 23.0 | 12.0 |
| 1969 | | 3001.7 | 2068.0 | 1289.6 | 742.7 | 354.4 | 166.3 | 65.9 | 23.1 | 12.1 |
| 1970 | | | 1610.3 | 1131.5 | 767.1 | 329.3 | 158.5 | 67.8 | 23.7 | 12.4 |
| 1971 | | | | 1715.5 | 1252.6 | 690.5 | 289.0 | 128.8 | 45.1 | 23.5 |
| 1972 | | | | | 1145.1 | 712.6 | 324.0 | 143.9 | 50.4 | 26.3 |
| 1973 | | | | | | 1785.5 | 1242.0 | 555.4 | 194.4 | 101.5 |
| 1974 | | | | | | | (2150.0)[2] | 1279.5 | 636.0 | 332.0 |
| 1975 | | | | | | | | (750.0)[2] | 501.7 | 308.6 |
| 1976 | | | | | | | | | (1500.0)[2] | 1058.1 |
| Total ($10^6$) | 10479.2 | 10357.6 | 8467.8 | 6876.9 | 5339.0 | 4560.4 | 4623.6 | 3108.0 | 3015.3 | |
| Wt. (000 t)[3] | 2220.2 | 2137.0 | 2042.8 | 2007.5 | 1462.3 | 1122.8 | 890.8 | 637.9 | 567.2 | |
| | | | | | Spawning stock (50% age 2, 100% age 3 and older) | | | | | |
| Total ($10^6$) | 4851.7 | 6234.1 | 5823.5 | 4595.7 | 3567.6 | 2418.6 | 1852.6 | 1718.3 | 1264.5 | 1366.8 |
| Wt. (000 t)[3] | 1373.7 | 1680.0 | 1729.0 | 1722.4 | 1246.9 | 890.6 | 593.2 | 469.8 | 380.8 | 391.7 |

[1] Mean F for age 3+ assumed.
[2] Estimated year-class size at age 1.
[3] Adjusted according to correction factors (ratio of observed to calculated weights) in Table 2.

The abundance of the 1975 year-class using trawling survey data ranges from 750 to 1,250 million fish. The Soviet scientists are of the strong opinion that, until more reliable information becomes available, a more valid approach is associated with estimation of the above-mentioned year-class as a mean value of the abundance of age 1 fish in 1969-74, i.e. 2,765 million fish (Res. Doc. 76/XII/169). The estimation of F for 1976 is 0.6. This figure obtained in Res. Doc. 76/XII/169 using commercial data is slightly over-estimated. Based on scientific evidence presented in Res. Doc. 76/XII/169, the USSR scientists consider it possible to recommend a TAC at the level of 180,000 tons.

This catch and the resultant stock size are presented in the following table of catch and stock size predictions (from Res. Doc. 76/XII/169).

| Mackerel in SA 3-6 | 1976 | 1977 | 1978 |
|---|---|---|---|
| Spawning stock (000 tons) | 635.9 | 604.1 | 743.0 |
| F (age 3+) | 0.60 | 0.35 | 0.35 |
| Catch (000 tons) | 252.2 | 183.7 | 218.5 |
| Partial recruitment - F (age 1) = F (age 3+) × 0.05<br>- F (age 2) = F (age 3+) × 0.60 | | | |
| Recruitment - 1975 year-class = 2765.4 million fish<br>1976 year-class = 2624.0 million fish | | | |

7. Effect of Size Regulation

The Working Group noted that the minimum size regulation must be considered in setting the 1977 TAC for mackerel. However, the predicted catches under both options apparently do not require adjustments to take account of the size regulation, as the partial recruitment factors were calculated from the catch-at-age data for 1976 when the minimum size regulation was in effect and the effect of the regulation has been incorporated into the assessments under both options. If the estimated fishing mortality on age 1 mackerel in 1977 is correct, the quantity of these fish taken unavoidably in the catches could be within the tolerance allowed by the minimum size regulation on an annual basis.

8. Consequences of the Advice on the Mackerel TAC

In order to allow the Commission to evaluate the consequences of the action it may take in regard to the 1977 TAC for mackerel, the Working Group calculated the effects of catching the TAC under one option if the assumptions of the other option are correct. The resulting effects on the catch and fishing mortality in 1977 and on the catch and spawning stock in 1978 are indicated in the following table:

| | Effect if assumptions of options are correct | | | Effect if assumptions of alternative option are correct | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Option | TAC in 1977 (tons) | F in 1977 | Spawning stock in 1978 (000 tons) | Catch in 1977 (tons) | F in 1977 | Catch in 1978[1] (tons) | Cumulative 1977 and 1978 catch (tons) | Spawning stock in 1978 (000 tons) | % change in spawning stock by weight |
| 1 | 133,000 | 0.36 | 485 | 105,000 | 0.26 | 141,000 | 246,000 | 513 | +6 |
| 2 | 105,000 | 0.35 | 392 | 133,000 | 0.46 | 87,000 | 220,000 | 328 | -16 |

[1] Represents the catch of age 2 and older mackerel.

The fishing mortality (F) would decrease from 0.35 ($F_{0.1}$) expected under Option 1 to 0.26 in 1977 and the spawning stock in 1978 would increase by 6% from that expected under Option 1, if Option 2 is adopted but the assumptions of Option 1 are correct. Similarly, F would increase from 0.35 ($F_{0.1}$) expected under Option 2 to 0.46 in 1977 and the spawning stock in 1978 would decrease by 16% from that expected under Option 2, if Option 1 is adopted but the assumptions of Option 2 are correct.

In addition to the above calculations, the Working Group discussed the general implications of the present level of spawning stock biomass in relation to historical trends (Fig. 1). It was pointed out that, although the level of the present spawning biomass is in the same range as that which produced the moderate 1966 year-class and the large 1967 year-class, the mean age of the spawning stock at present is 3.2 years, compared with a mean age of 4.5 years in 1966 and 4.2 years in 1967. Since fecundity is related to the weight of individuals, a significantly reduced egg production from the present spawning biomass could be implied, although recent work in the Gulf of St. Lawrence has indicated that the number of eggs may be more related to the production (growth rate × biomass) of the stock than to the biomass. It was also pointed out that the numbers of ages 4 and 5 mackerel are expected to increase in 1978 under both options, thus causing a slight increase in the size and mean age of the spawning biomass. The estimates of the spawning stock in 1978 are greatly dependent on the estimates of recruiting year-classes used in the assessments. Although the Working Group could not evaluate the precise effects of the various factors on recruitment success and spawning, it did agree that the present level and condition of the spawning biomass is reason for concern.

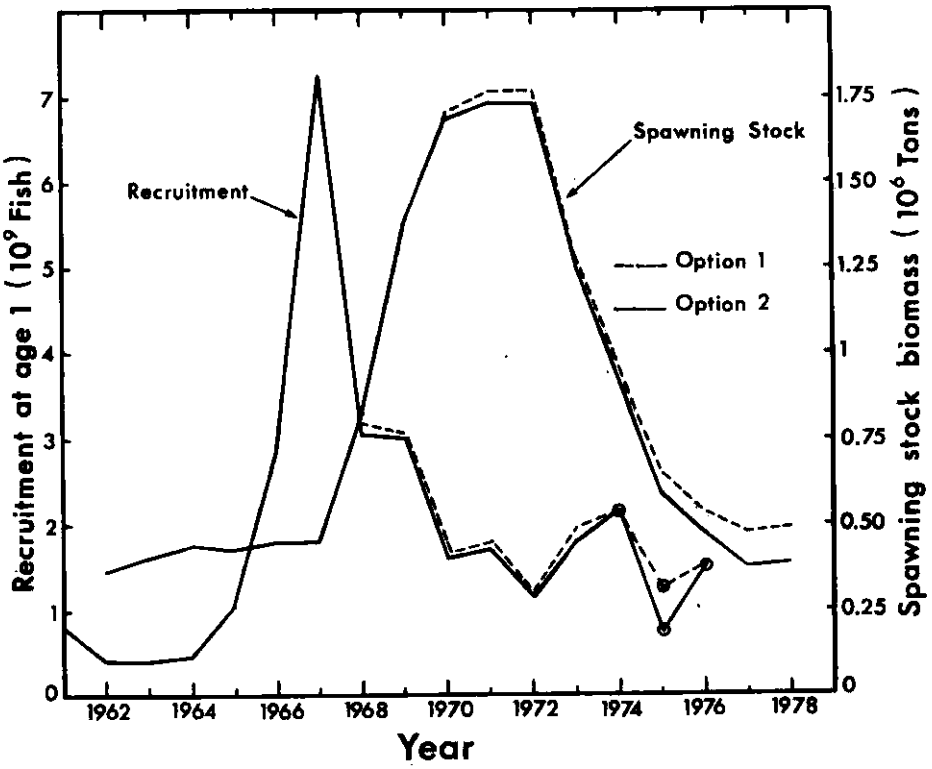


Fig. 1. Mackerel in Subareas 3 to 5 and Stat. Area 6: spawning stock biomass in 1962-78, and abundance at age 1 of the 1961-76 year-classes. (Open circles indicate estimated year-class sizes.)