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Prospectus on Future Research for the Flemish Cap Project

by

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INTRODUCTION

The *ad hoc* Working Group of the Flemish Cap Project met most recently 12 September 1981 during the 3rd Annual Meeting of the NAFO Scientific Council (SCS Doc. 81/IX/27). Past work on Flemish Cap was reviewed based on analysis of recently available data. It was noted that a high level of research activity was carried out on Flemish Cap in 1981 by both Canada and the USSR. As part of this meeting, progress and future research of the Flemish Cap Project was reviewed.

Several points were discussed regarding the future of the Flemish Cap Project. These pertained to several areas of concern which are summarized as follows: (i) the almost complete absence of cod eggs and larvae in the Canadian ichthyoplankton surveys in 1979, and 1980; (ii) the low level of cod stock biomass and the uncertainty about studying recruitment mechanisms when the stock is at such a low level; (iii) difficulties in studying the larval phase of redfish by itself, without a concurrent juvenile fish program, to determine the causes of fluctuations in year-class strength; (iv) the state of the oceanographic program following the failure and curtailment of the moored current meter program in 1979; and (v) the fact that Flemish Cap is in international waters where fishing effort has been high and where regulation and monitoring of catch and effort is poor.

Discussion of these points led to a general review of the project and the conclusion that, considering available resources, the project should concentrate on cod, as originally outlined (Redbook 1977, p. 81). However, it was generally concluded that under present circumstances, the original aims of the project could not be met. It was agreed that the Task Force Leader would draft, for consideration, terms of reference for future research of the Flemish Cap Project. (SCS Doc. 81/IX/27).

FLEMISH CAP ICHTHYOPLANKTON

Review of results collected to date indicated a virtual absence of cod eggs and larvae sampled on Flemish Cap during 1978 (SCR Doc. 80/VI/57; 62), 1979 (SCR Doc. 80/IX/150) and again in 1980 (SCR Doc. 81/IX/116). While these ichthyoplankton surveys indicate recruitment will be 'low', sample numbers of cod eggs and larvae are too low to analyze for causal relationships with respect to the environment and spawning stock size. The extremely low numbers of cod eggs and larvae raises several questions that cannot be immediately answered. For example, if the egg and larval surveys are representative of cod spawning on Flemish Cap, then they indicate there was little spawning activity for Flemish Cap cod during the last 3-4 years. The question becomes, then, what is state of stock-dependent egg production for cod on Flemish Cap? On the other hand, if the ichthyoplankton results are not representative of cod spawning the question becomes: how many cod eggs are being spawned, at what time(s) and is there a spawning concentration? Given the extremely low results from the ichthyoplankton surveys, the answers to either question must initially come from the cod stock itself; what is the spawning potential?

FLEMISH CAP COD

On Flemish Cap cod biomass has declined significantly since the early 1960's from around 250,000 tonnes to <50,000 tonnes in 1980, mostly as a result of increased fishing mortality (SCR Doc. 80/II/25; 81/II/12). Spawning stock, as numbers of fish 6 years and older (based on ~96% maturity, R. Wells, pers. comm.), reached a peak in 1964 and has declined to record low levels during the 1970's (Fig. 1). Stock size varied by a factor of 4 during the period 1959-68 and by a factor of 11 during the period 1972-80. During this same time recruitment, as age 4 cod (SCS Doc. 80/VI/9), has fluctuated widely,

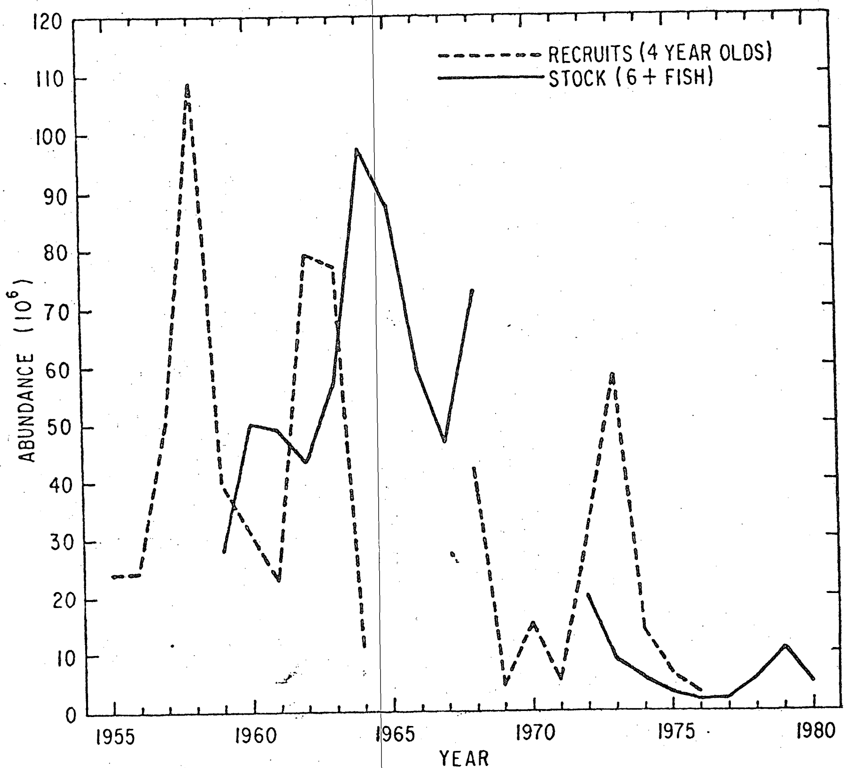

Figure 1. Fluctuations in stock size and recruitment for Flemish Cap cod.

varying by a factor of 10 during the period 1955-64 and by a factor of 20 during the period 1968-76. Over the entire time, estimates of stock size and recruitment have fluctuated by approximately 50 fold. The noticeable trend is the order of magnitude reduction in stock size from the 1960's to the 1970's. Unfortunately data are missing for 1969-71, but by 1972 there had been a definite reduction in this stock compared to earlier years. Stock size has not fluctuated irregularly during the 1970's but has appeared as a continuing decline, up to 1978 and 1979 at which point the 1973 year-class approached and reached age 6. By 1980 stock size was again decreasing.

Decreasing stock biomass (age 3+) since the mid-1960's has been related to increasing fishing mortality (SCR Doc. 81/II/12). Similarly, a decrease in the spawning stock size (age 6+) is associated with higher fishing effort, which has risen steadily since 1974 (Fig. 2). Under conditions of heavy fishing the stock has declined to record low levels. In a natural system it becomes inefficient, at some point, for predators to continue to exploit a

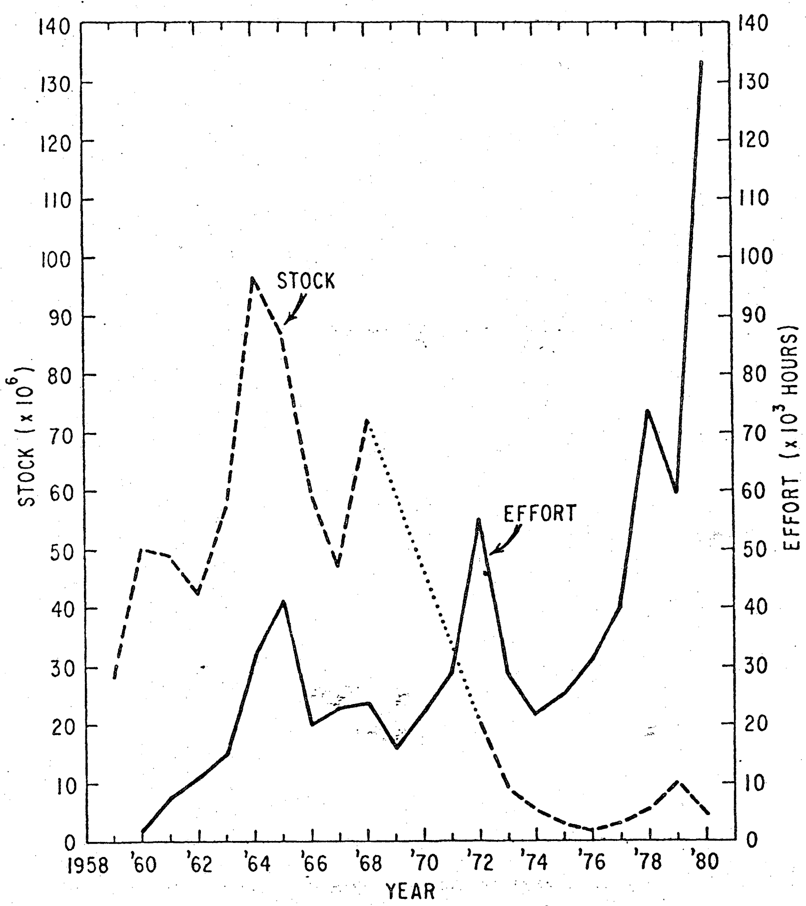

Figure 2: Standardized fishing effort (hr) and spawning stock size (age 6+) for Flemish Cap cod, 1960 to 1980.

particular prey item. The usual response is a switch in predator feeding strategies allowing prey recovery (Haber et al. 1976). Continued high predation, however, will keep prey numbers down. Theoretically, at least, this can lead to extinction. While it is doubtful we will experience extinction of Flemish Cap cod, the point is that continued high levels of fishing effort, whether specifically for cod or as a directed by-catch, would be expected to keep cod abundance at very low levels.

Recruitment in earlier years on Flemish Cap was lowest during 1964, concurrent with the largest estimate of spawning stock size as reported here (Fig. 1). The highest level of recruitment came from 1958, but unfortunately there is no stock estimate available from VPA assessments for that year. Recruitment has been low since 1969 with the exception of 1972 and especially 1973 year-classes. Overall, recruitment has fluctuated widely from year to year the only apparent trend being low and declining recruitment from 1973-1976.

The declining stock abundance in the 1970's has been accompanied by a substantial reduction in the age base of the cod stock, and hence a reduction in spawning potential. For example, comparing 1980, the most recent year for which data are available, with 1973, a year of low stock size that produced the last good year-class, we see age 3+ abundance in 1980 was 48% of that in 1973, age 6+ abundance 55%, while age 8+ abundance was only 6% (SCR Doc. 81/II/12). In addition, an estimate of spawning potential in 1980 was only about 31% of that in 1973. Spawning potential here was based on estimates of percent mature and percent spawning at age (R. Wells, pers. comm.), weights at age (SCR Doc. 81/II/12) and a general weight-fecundity estimate determined for cod stocks from the Grand Banks (May 1966). So, while spawning stock size (as age 6+ fish) in 1980 was 55% of that in 1973, spawning potential was only 33% based on this fecundity estimate. During this period, 1974-1980, spawning potential ranged from 24%-67% compared to 1973. If 1973 was considered to be a year of low stock size then it is obvious that in recent years the spawning potential of Flemish Cap cod has reached an all time low.

STOCK-RECRUITMENT RELATIONSHIPS

As a background for discussion, we should consider general stock and recruitment relationships and possible scenarios of response. The underlying question is the nature, if any, of a stock-recruit relationship; either there is a relationship and recruitment is some function of stock size, or there is no clear, simple relationship and recruitment appears to fluctuate as a random event with respect to stock size. We are talking about three components, where Recruitment = f (Stock, Survival).

Fish stocks can be characterized in non-stressed conditions with constant fishing pressure by a stock size that fluctuates about a long-term mean; overall there would be no trends. In this sense the population, or system, is stable over many years (Garrod 1973; Walters et al. 1980; Cushing 1981). Associated with this stable but fluctuating stock size is fluctuatng recruitment Under these conditions it is assumed that any year-class or groups of year-classes have a minimum egg production necessary to ensure its replacement over the long-term (Garrod 1973). Under these 'normal' conditions the relevant question to fisheries research is determining what factors result in good and poor year-classes. In this regard much attention has focused on pre-recruit survival as affected by success of first feeding, ocean climate variation, and other factors.

For fish stocks to remain stable about a long-term mean implies compensatory mechanisms. As stock size increases or decreases there is a compensating response which tends to offset the trend. Two mechanisms have been proposed: a survival response or a growth response (Walters et al. 1980). In the first, compensative responses occur as a result of changes in survival rate during prerecruit stages, mostly during the larval phase. This functions as a result of density-dependent processes of competition and predation, overlain by density-independent factors of their environment. Thus, as stock size decreases, survival rate would be expected to increase, and to decrease at large sizes. While compensation is not well demonstrated it has been shown for North Sea plaice (Beverton 1962), Downs herring (Burd and Parnell 1973), while some examples exist from freshwater (Backiel and LeCren 1967). In general, this relationship may hold as well for Flemish Cap cod where survival increases at decreasing stock size (Fig. 3a). In this case survival is expressed by the ratio of recruit per unit stock. It is assumed here that fecundity and age at maturity have not changed. While the large increase in survival sketched in Fig. 3 is based on one data point, inclusion of recruitment from 1958 might add a second observation in this region of the graph. Recruitment in 1958 was the largest on record for Flemish Cap (Fig. 1), however, there is no stock size data available for that year. In 1959 spawning stock size was approximately 28×10^6 (Fig. 1). If spawning stock size in 1958 was $<20 \times 10^6$ then it would give a second observation in this region of the graph in Figure 3.

In the second case, a growth response, prerecruit survival is solely density-independent and compensatory responses are generated through increased growth rates leading to earlier age at maturity and increased fecundity at age (Walter et al. 1980). Attention thus shifts from survival during the larval phase to a population response examining: 1) the relationship between body weight and fecundity; and 2) rates of growth in relation to density. Substantial

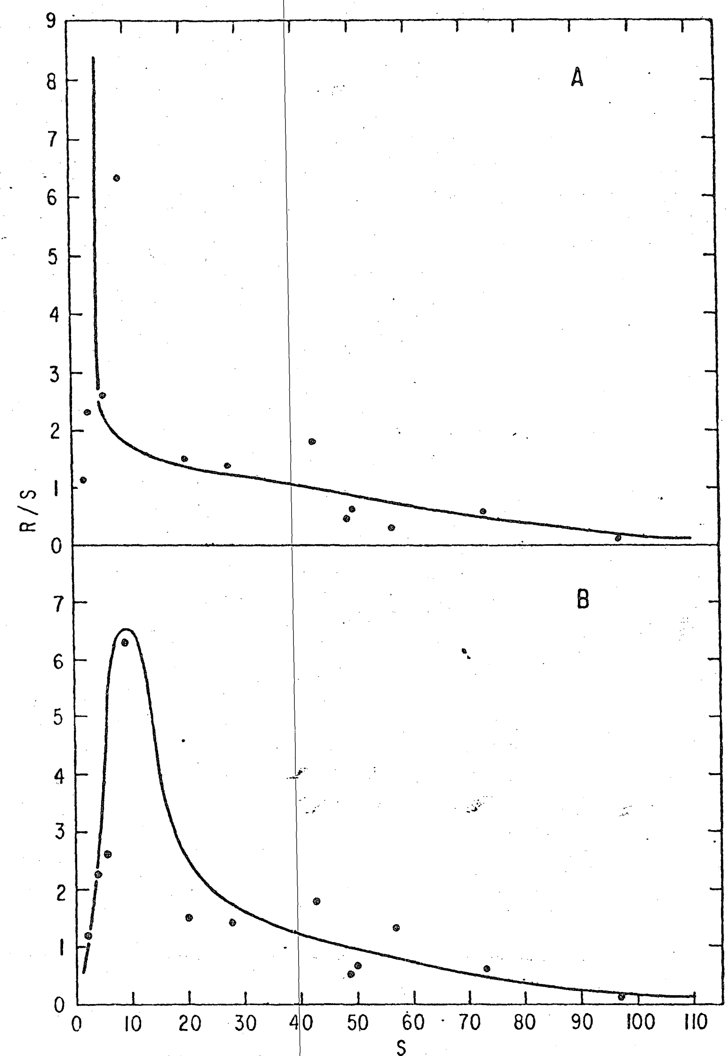

Figure 3: Estimates of survival, as recruit per unit stock, versus stock size: A - a simple hyperbolic eelationship; B - a line drawn sequentially through the same data points.

increases in growth rate of lake trout have been reported during population declines, together with a drop in female age at maturity (Walters et al. 1980). Changes in fecundity of marine fish with stock size has been discussed by Bagenal (1973) and, while data are lacking, the concept is supported. Changes in fecundity with improved feeding conditions, which might reflect density-dependent processes, have been reported for a number of species (see Ware 1980).

Survival and growth responses are synonomous with the concepts of density-dependent and stock-dependent processes as discussed by Harris (1975) and Ware (1980). The important point is that fecundity is not a constant, as so often treated in stock and recruitment studies. Changes in fecundity will have a direct effect on our estimates of stock (as number of eggs spawned) and eventual recruitment. In addition, this effect should be more pronounced at both extremes of stock size. To date, our study on Flemish Cap has focused on a survival response during the larval phase and most specifically on environmental effects and food availability affecting growth and survival in fish larvae. This has been considered one of the most important areas of fisheries research.

Unfortunately, stock size does not always remain stable about a long-term mean. Many of the world's fisheries have suffered severe declines (eg. Parish 1973; Saville 1978) and have been highlighted by the collapse of herring, sardine and anchovy fisheries. Declines have clearly been related to fishing mortality, but the extent to which this causes a collapse remains obscure. Fishing pressure, environmental changes or a combination of both may precipitate the declines (Clark 1974). Associated with these declines is the possibility of depensatory mechansims which may result in increased relative mortality rates at low stock levels (Ricker 1954; Larkin et al. 1964; Clark 1974; Walters et al. 1980; Cushing 1981). Below some critical point, recruitment falls off catastrophically due to reduced survival. Ultimately this results in extinction, or less drastically may result in a lower, stable equilibrium (Radovich 1962; Walters et al. 1980). This critical point is the minimum level of egg production below which a stock will be unable to replace itself. Under these 'non-normal' conditions, at very low levels of stock size, the question becomes not "how large is recruitment per stock size?", but "can that stock produce enough eggs to overcome environmental variability ...?" (Garrod 1973). We would no longer be considering causes affecting recruitment but the very survival of that particular stock. Admittedly there is little evidence of depensatory mortality, evidenced only by the fact that spawning stocks have ceased to exist (eg. Georges Bank herring, California sardine). Due to the apparent rapidity with which stocks move through a phase of depensation it may be very difficult to collect sufficient data to demonstrate its existance (Walters et al. 1980). Nevertheless, all concepts of stock-recruit curves incorporate an ascending limb where recruitment is proportional to stock size. At this point of a stock-recruit relationship the question of replacement becomes the dominant concern.

The stock-recruit data for Flemish Cap cod is characteristic of many in its high variability. In general, it conforms to that of gadoid species in that it would fit a dome-shaped recruitment curve (Fig. 4) (cf. Cushing and Harris 1973). While stock size was relatively high during the 1960's it was low during 1972-76, with the only strong year-class during this period being 1973. Especially apparent are values from 1974-76 that lie along the lower limb of the curve, where low stock is linearly related to low recruitment as some slope tangent to the curve. There is no clear indication from these data that depensatory mortality is occurring. However, in a plot of survival versus stock size a better representation of the data in Fig. 3a may be as drawn in Fig. 3b. Here survival would be an increasing function of decreasing stock to a point, after which the relationship falls off and survival becomes a decreasing function at these low stock densities. If true this may indicate depensatory mortality in Flemish Cap cod.

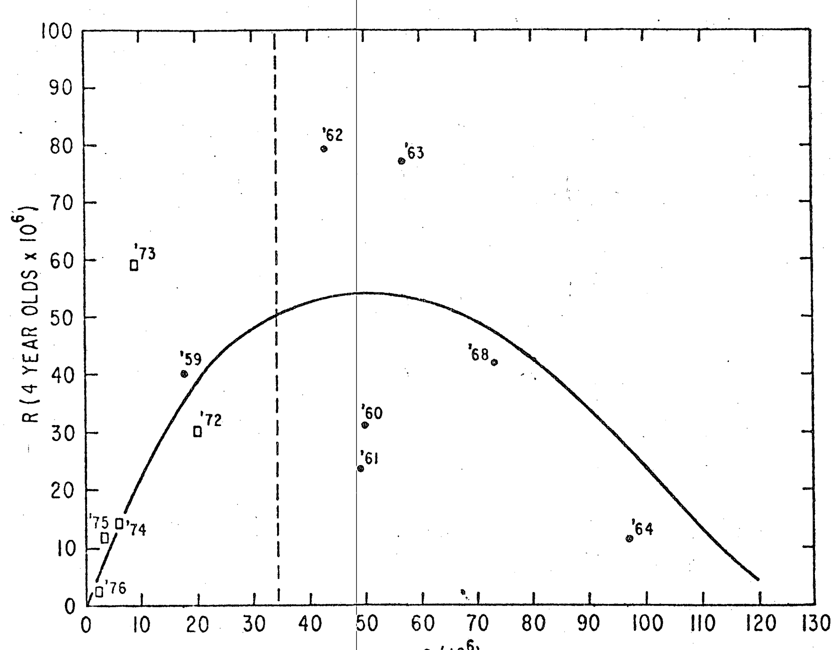

Figure 4: Stock-recruitment curve for Flemish Cap cod (closed circles - data from 1949 to 1964 and 1968; open squares - data from 1972 to 1976).

A similar trend was observed at low stock levels for Georges Bank haddock (Grosslein and Hennemuth 1973, Fig. 65). Declining stocks during the 1960's, under heavy fishing pressure, were accompanied by small recruitment during 1964-69. They suggested that "...the probability of good recruitment is reduced at such low stock levels" (Ibid 1973). Whether or not these observations result from depensation in both Flemish Cap cod and Georges Bank haddock, the point is that under heavy fishing recruitment was low at extremely low levels of stock size. If these stocks were on the ascending limb of a stock-recruit curve such observations would be expected.

FUTURE WORK

With the information at our disposal I think it is clear we are no longer dealing with a normal stock in a mid-size range. Overfishing has led to a significant reduction in spawning stock size, and there appears to be little gain in studying a cycle where too few adults produce too few recruits (Sharp 1980). Considering stock and recruitment relationships we appear to be at that point where pre-recruit survival would be at a maximum, and therefore non-limited by density-dependent processes. Under these conditions we would expect a stock growth response and would look for reduced age of maturity and increased fecundity at weight. The focus is no longer survival of pre-recruits but a stock response in egg production to maintain replacement. At this point we must address biological aspects of the spawning stock and pre-spawning process; is this population responding by producing more eggs?

At present we know very little about the ecology of the spawning stock. Early work indicated a spawning concentration in the southwest quadrant of Flemish Cap and peak spawning to occur in March (Mankevich and Prokhorov, 1963). Actual descriptions of a spawning curve are lacking. Available estimates for peak spawning indicate it does in fact occur in mid-March (Fig. 5), but this is based on three observations, all from the 1960's. What changes have occurred with regard to these early estimates, if any, under the present conditions?

Populations are expected to respond to low densities by accelerating growth. This can be inferred for Flemish Cap cod from increasing weights-at-age during recent years (SCR Doc. 81/II/12). Has increased growth resulted in reduced age at maturity and/or increased fecundity at weight? If it has this would drastically alter our estimates of stock size (as eggs produced annually). Given the extremely low results of cod eggs and larvae, the extremely low abundance of mature cod and increased growth rates, answer to these questions become central to the Flemish Cap Project.

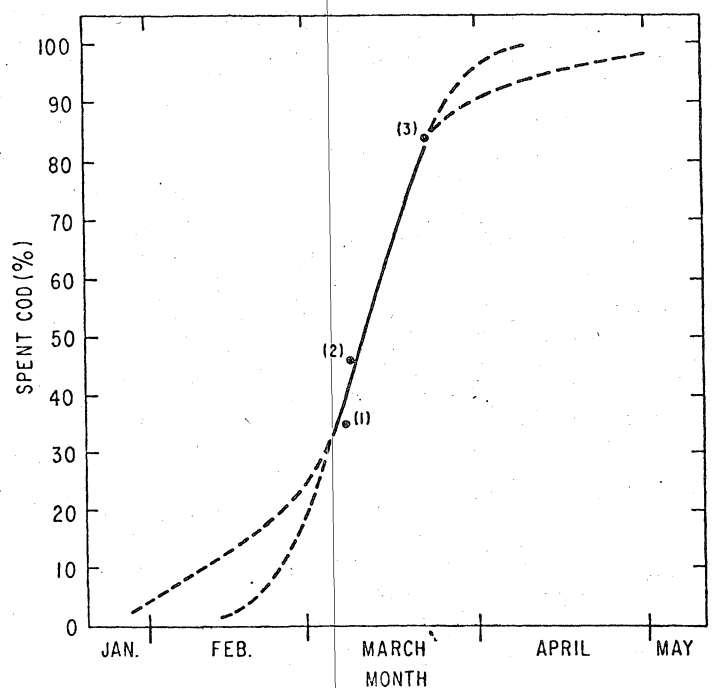

Figure 5: Spawning curve estimated for Flemish Cap cod based on three estimates: (1) Templeman (1969); (2) Dias (1969); (3) Templeman (1976).

Presently none of this information is available. Some data exists but have yet to be published, while in many cases the data have not been collected that would answer these questions (SCR Doc 80/IX/152). It is recommended, therefore, that future work on the Flemish Cap Project be directed to examine characteristics of the parent cod stock and the spawning processes, towards understanding the spawning potential at low stock densities. In light of the disappointing ichthyoplankton results it is imperative that we resolve questions such as: how many eggs are being spawned? where? and when?

To this end it is proposed that specific sampling be carried out during the February to April period of expected spawning in 1983. This work should be carried out as a joint venture between Canada and the USSR to examine abundance, distribution, maturity and fecundity of Flemish Cap cod, together with observations on age, weights, food and feeding, condition, and other relevant observations. Concurrent with this work, ichthyoplankton surveys measuring cod eggs and larvae should be carried out in a meaningful attempt to relate egg abundance estimates from ichthyoplankton surveys to fecundity and egg production estimates made on that spawning stock. This should consist of observations carried out during each of the three months, February, March and April, of 1983. This information should be made available to the Working Group at the first opportunity possible, preferably by September 1983, to aid in planning for any future work in 1984.

This outline forms a proposal for future research on Flemish Cap under present conditions of low stock size. However, serious questions could still be raised about the probability of success for this particular work. While observations can be carried out now for age at maturity, fecundity at weight and present growth rate, there is little historical data to compare with observations at higher stock densities. Under continued high fishing effort there is little chance of stock recovery, and there is the possibility that fishing mortality due to by-catch of the redfish fishery alone may be sufficiently high to limit any stock response. For a study such as this to be successful it will be necessary to monitor it from exploited to unexploited states with accurate measurements of stock, recruitment and biological characteristics of cod relating to egg production. It is therefore further recommended that all fishing effort for Flemish Cap cod cease as a prerequisite for creating conditions in which a meaningful study examining stock responses at low densities could be carried out. Without these conditions, there may be little value in a long-term program for Flemish Cap. As far as studying mechanism affecting survival in egg and larval stages, further work must await some degree of stock recovery in order that sufficient samples are present to continue this work as begun on redfish larvae.

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