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A PRELIMINARY ASSESSMENT OF THE GEORGES BANK MULTISPECIES TRAWL-FISHERIES WITH SPECIAL REFERENCE TO HADDOCK AND YELLOWTAIL FLOUNDER

by

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SUMMARY

A simultaneous assessment of the impacts of fishery management options for cod, haddock, yellowtail flounder, and pollock was accomplished by extending single species methodology to the account for mixed-species harvests (by-catch) on Georges Bank. The purpose of the study was to investigate probable responses of these species under present conditions and a variety of simulated options, such as mesh increases, area closures, and effort reductions. Georges Bank was divided into three fishery areas according to recent analyses of research and commercial data. A series of simulations were performed to assess the effects of different options on haddock and yellowtail flounder, since the abundance of these two stocks are presently low relative to historical trends. In addition, linear programming was used to examine trawl effort allocation schemes in the three areas to meet a series of optimal fishing mortality goals. Implications of the results are discussed in terms of their effect on the multispecies fishery.

An Assessment of Management Options for the Georges Bank Multispecies Trawl-Fisheries with Special Reference to Haddock and Yellowtail Flounder

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INTRODUCTION

Nominal catches (total landings, live weight, excluding discards, all countries) of the major groundfish stocks of the Georges Bank demersal fishery, notably Atlantic cod, haddock, and yellowtail flounder, have declined in recent years (1980-1984) (Figure 1). Cod landings declined to about 41,000 mt in 1984 from a peak of 57,000 mt in 1982. Haddock landings peaked at 27,500 mt in 1980 and dwindled to about 12,000 mt in 1984. Catches of yellowtail flounder declined to about 6,000 mt in 1984 from their recent peak of 12,000 mt in 1982. Landings of pollock, another important component of the Georges Bank multispecies fishery, have trended downward from a peak of about 12,000 mt in 1980 to an average of about 9,500 mt since that time. Landings of the four species combined in 1984 (67,800 mt) were 19% less than in 1983 (83,200 mt) and 20% below the 1980-1984 average (85,100 mt).

Several dominant year classes supported the fisheries for each of these species during the mid-1970's through early 1980's. Stock assessment results suggest that cod and pollock will remain relatively abundant over the next several years due to above average recruitment, even though landings have been at or above historic levels. In contrast, haddock recruitment has been poor since 1979, and the 1984 year class appears to be one of the smallest on

record. Similarly, recruitment to the Georges Bank yellowtail flounder stock will be very poor through 1986 (Clark et al. 1984).

Recent assessments (Overholtz et al. 1983, Clark et al. 1984, Mayo and Clark 1984, and Serchuk pers. comm. 1985) have documented trends in each of these important species, but the complexity of the Georges Bank multispecies trawl fishery necessitates a more holistic approach if conflicting management advice for the stocks is to be avoided. Since much of the effort on Georges Bank is directed at a complex of species, an approach that deals with the simultaneous problem of differing relative abundances and distributions is needed.

This study investigates the probable responses of these four species under present conditions and under several options for combined management. A multispecies harvesting model that includes species distributions (3 areas) was constructed to evaluate technical interactions (e.g., by-catch) in these fisheries. The effects of present and projected trends in fishing effort, area closures, mesh regulations, and effort allocation schemes on the Georges Bank haddock and yellowtail flounder stocks are discussed in detail. In addition, linear programming was used to examine effort strategies for the three areas to meet target fishing mortality goals defined as standard biological reference points for fishery management (F_{max}, $F_{0.1}$). The implications of management actions for rehabilitating haddock and yellowtail flounder stocks, and the effects of these actions on the status of the other species are also addressed.

MANAGEMENT PERSPECTIVE

Initial efforts to manage the multispecies fishery in the area off the northeast USA began in 1974 when the International Commission for the Northwest Atlantic Fisheries (ICNAF) imposed a two-tier quota system on the total catch of finfish and squids. This quota system was based on an aggregate surplus production model (catch-effort) for all major stocks (Brown et al. 1979). The total quota was less than the sum of the individual species quotas for the stocks in the ICNAF area.

The passage of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1976, began a new era of control by regional fishery management councils of all the contiguous waters of the USA. Management of the multispecies groundfish fisheries by the New England Fishery Management Council (NEFMC) began in 1977 with the implementation of the Fishery Management Plan (FMP) for Atlantic groundfish (cod, haddock, and yellowtail flounder). This plan established a minimum trawl cod end mesh size of 130 mm (5-1/8 inches), seasonal area closures to protect spawning aggregations of haddock, and optimum yields (OY) that were the basis for catch quotas. Attempts to restrict harvests under this regime led to complicated economic allocation measures, such as quotas by vessel class, calendar quarter, and vessel trip.

Partly as a result of the complexity of the economic allocation measures, the NEFMC adopted an Interim Plan for Atlantic Groundfish on March 31, 1982. Management measures under this plan were limited to spawning area closures, minimum net mesh size regulations, and specified voluntary reporting of data. Additionally, it included minimum size provisions for the three species. Atlantic cod, haddock, and yellowtail flounder were to be managed

under this plan for a period of three years (1982-1984) during which the NEFMC was to develop a more comprehensive approach; the Atlantic Demersal Finfish Plan (ADF), now called the Northeast Multi-Species Fishery Management Plan (NMFMP).

The NMFMP plan is scheduled for implementation during 1986. It includes more species distributed over a wider area than the Interim Plan. Draft management measures include area closures, minimum fish sizes, and minimum mesh regulations. Objectives of the plan are to maintain or achieve target spawning stock biomasses for the major species (e.g., cod, haddock, yellowtail flounder, pollock, redfish, and about 10 other species).

HISTORICAL CATCH STATISTICS

Total landings of the four species (cod, haddock, yellowtail flounder, and pollock), hereafter referred to as the demersal complex (DC), from Georges Bank have fluctuated markedly during the period 1960-1984 (Figure 1). After reaching a peak of 215,000 mt in 1965, combined landings of DC species declined precipitously to a low of 43,000 mt in 1976. Record landings of haddock by distant water fleets in the mid-1960's, coupled with poor recruitment after 1965, led to the rapid decline in total overall catch. By 1972, cod and yellowtail flounder comprised over 78% of the total landings, while in the early 1960's they accounted for only about 25% of the total (Figures 1 and 2). Good haddock year classes in 1975 and 1978 resulted in increased landings from 1977-1981. In the late 1970's and early 1980's haddock accounted for about 30% of the total, but the percentage has since declined (Figures 1 and 2). The percentage of cod in the catch has increased steadily since 1965 and now comprises 60% of the total landings (Figure 2).

Improved recruitment of cod, haddock, and pollock during the late 1970's, brought about a rapid turnaround in USA landings after 1976 (Figure 3). Recent USA catches of the DC show an increased dependence on cod as yellowtail flounder and haddock have declined (Figure 3). Before 1967, haddock comprised from 55-71% of the USA total, but has averaged only about 15% since that time. Cod, on the other hand, has nearly replaced haddock in terms of percentage of USA landings and now accounts for about 59% of the total (Figure 4). Recent information suggests that cod abundance is now also declining.

FISHING EFFORT TRENDS

By-catch (i.e., catch of several additional species in fisheries targeted at others) is an important assessment and management consideration where species have concurrent distributions. Differing relative abundances and by-catch in directed fisheries may result in underfishing productive stocks while overexploiting ones in critical need of protection. During periods of high abundance, fishing effort can sometimes be successfully directed toward particular species with a minimum of by-catch, but typically landings in the New England trawl fisheries include several species (Murawski 1983b). For example, otter trawl fisheries in the Great South Channel of Georges Bank catch cod, haddock, pollock, winter flounder, white hake, and several other species. Catches would comprise several species and effort could not easily be assigned to a particular species based on percent of landings.

ICNAF and NAFO effort data summaries collected by NEFC port agents were utilized to examine temporal and spatial trends for the DC on Georges Bank. Distant water fleets from several countries accounted for a tremendous increase in demersal fishing effort in the late 1960's and early 1970's. Days fished increased from about 22 thousand in 1961 to a peak of 52 thousand in

1969 (Figure 5). As ICNAF regulations on demersal gear and quota restrictions were implemented in the mid-1970's, effort on Georges Bank declined steadily to about 21 thousand days fished in 1979 (Figure 5).

A more formal analysis was performed for the years 1979-1982 to follow recent changes in USA and Canadian effort associated with the entrance of new vessels into the fishery since the adoption of the MFCMA in 1976 (Figure 6). This analysis was accomplished as outlined in Murawski (1984). Briefly, landings and effort by gear and vessel class were obtained for the DC from NAFO statistical bulletins, and standardized on USA-class 3 stern trawlers by using the CPUE from this vessel class. Landings for Canadian vessels were not available by ton-class for 1982 so standardized days fished were estimated using total overall landings and catch per effort by the USA-class 3 vessels. The analysis showed that effort since 1979 has increased in each year from about 19.8 thousand days fished in 1979 to about 26 thousand in 1982 (Table 1). Trends in 1985 and 1986 were approximated by using the 1982 value of 26 thousand days, recognizing that this could be a conservative estimate.

TRENDS IN STOCK ABUNDANCE

Details of stock abundance, cohort strength and stock biomass for DC stocks are available in the aforementioned assessment documents. It was possible to reconstruct historic abundance and stock structure by utilizing a modified DeLury analysis applied to cod, haddock, and yellowtail flounder research and commercial data (Collie and Sissenwine 1983).

Cod numbers at age for 1977-1980 were estimated using Canadian fishery age compositions (percent by number: Hurley and O'Boyle 1985, Table 6). This information was converted to percent weight and used with landings data to estimate percent of total landings at age. Total numbers at age were derived

by dividing total landings at age by appropriate mean weights. Numbers landed during 1981-1983 and survey catch per tow for 1977-1983 were obtained from more recent studies (Serchuk pers. comm. 1985). Stock sizes for cod during the period 1977-1983 were estimated by using the modified DeLury analysis.

Numbers at age from research vessel surveys and catch at age from commercial samples (Overholtz et al. 1983) were used to estimate haddock stock size for the period 1964-1983 with the same method (Table 3).

Age compositions for Georges Bank yellowtail flounder were estimated by converting percent at age to total number (McBride and Clark 1983, Table 4). This information was combined with survey estimates of mean catch per tow at age and used to estimate stock sizes for this species from 1974-1983.

Identical procedures were followed for pollock, but the DeLury method proved inadequate for estimating stock sizes for this species. This was because survey catches are generally intermittent, very small, and obviously do not reflect trends in pollock abundance. The DeLury method utilizes both survey and commercial data bases and hence a proper fit cannot always be obtained when the two diverge to the extent encountered with pollock.

Since the DeLury method was inappropriate for pollock, VPA results for this stock were used instead (Mayo and Clark 1984). Data from 1980-1983 suggest that about 19% of the total pollock catch for the entire stock area came from Georges Bank (Mayo and Clark 1984,p. 25, Table 2) (Table 5). It was assumed that 19% of the total stock was available on Georges Bank each year and stock sizes for 1983 were decremented to reflect this availability (Table 5).

RECRUITMENT

Recruitment estimates for the 1983 and 1984 year classes of each species in the DC were developed by fitting regressions of survey catch per tow at age vs age 2 recruitment from population estimation methods. Estimates of recruitment at age 0 and 1 were developed for haddock and cod for the 1983 year class and age 0 for the 1984 year class. A mean of the age 0 and 1 estimate was used as a recruitment projection for 1985 and the value obtained from the age 0 projection for the 1984 year class was used as an estimate for recruitment in 1986.

The same procedure was attempted for yellowtail flounder, but survey catches at age 0 are typically very small and intermittent, hence they are statistically unreliable for estimating recruitment. A relationship between survey catch at age 1 and age 2 recruitment (r=.95) was developed and used to estimate recruitment for the 1983 year class at age 2 in 1985. Since no survey age 0 catch for the 1984 year class was available the estimate for the 1983 year class, 12 million fish were used as an estimate of age 2 recruitment for the 1984 year class in 1986. This is a reasonable procedure since recruitment of yellowtail flounder tends to follow patterns (Sissenwine 1976) and recent recruitment to the Georges Bank stock has been poor (Clark et al. 1984).

Pollock recruitment proved to be the most difficult of the four species to predict. As with yellowtail flounder, no reliable age 0 index is available, primarily because pollock are inshore during their early life history stages and hence unavailable to the offshore groundfish survey. A linear relatioinship between survey catch at age 1 and age 2 recruitment was

developed and used to estimate recruitment for the 1983 and 1984 year classes. An estimate of 48.4 million fish was obtained from this method and used as an estimate for the 1983 year class at age 2 in 1985. Since no predictor of the size of the 1984 year class was available, 48 million were used. It should be mentioned that these estimates are only slightly higher (48.4 vs 44.5) than those used for the 1983 year class by Mayo and Clark (1984).

MULTISPECIES ASSESSMENT

Model - Design and Structure

The multispecies (by-catch) nature of demersal fisheries makes it particularly difficult to assess responses and stock fluctuations by single species methods. If several species are caught concurrently, and each has different abundance levels, a method of simultaneous assessment is necessary. Several workers have investigated technological interactions with respect to quota and effort allocations or yield per recruit considerations (Brown et al. 1979, Murawski et al. 1983a,b, 1984, Overholtz 1985).

Our model is structured around management units defined in space and time that are reflective of species associations from previous studies of research vessel and commercial data (Murawski et al. 1983b, Overholtz and Tyler 1985). The model utilizes standardized fishing effort partitioned spatially, consistent with these results. The six statistical reporting areas on Georges Bank (521-526) were grouped into three potential management zones based on similarities in species composition of groundfish populations: Channel (521-522), Northeast Peak (523-524), and Shallow (525-526) (Figure 7).

Aggregate fishing mortality (F) for a species in this model is a linear summation of the fishing mortalities generated in each specific area by a

given amount of standardized effort. This is basically an extension of the relationship

$$F=qf$$

where

F is the instantaneous fishing mortality

q is the catchability coefficient

f is the standardized fishing effort.

This can be extended to the case where fisheries in several areas are operating on several species (Murawski 1984).

$$F_i = \sum_{j=1}^{3} q(ij)f(j)$$

where

i = species

j = area

In this analysis fishing mortality at age is assumed constant for fully-recruited ages. Catchability coefficients (qij) are species and area specific, reflecting differences in abundance, availability, and vulnerability to the fishing gear. The difference between the current and the aforementioned studies is that recruitment is dynamic so that annual influences of effort on stock abundance can be monitored. The other dynamic equations of the model were similar to those used in many common fishery models (Walters 1969; Sissenwine 1977). The Baranov catch equation was used to calculate annual yields, and age specific year class size was estimated for each species using survival rates from the negative exponential relationship (Beverton and Holt 1957). Natural mortality was assumed equal to 0.2 for each species. Fish were assumed to recruit to the fishery at age 2 and to the

spawning stock at age 3. Growth was assumed to follow an average pattern since only a two-year simulation was conducted. The model can be used to investigate a variety of management options such as effort allocation schemes, mesh regulations, and area closures.

Catchability coefficients by area were estimated using the ratio of landings by area, i.e., 521-522, 523-524, 525-526, and total effort to calculate standardized effort by area. The proportion of total landings by species was then used to divide F by area and area-species; specific q_{ij}'s were then calculated for each year. Mean q's (1980-1982) were then computed for the three areas and four species (Table 6). This method assumes that a species has the same catchability throughout a defined management unit.

The model produces estimates of catch, standing stocks, spawning stock biomass and overall fishing mortality by species for several sets of conditions. It was programmed in FORTRAN, accessing the Dynamic Model Processor (DMP; Overholtz and Hauser 1984) available on the NMFS VAX computer. The major driving variable in this model is fishing effort in standardized days, but changes in vulnerability and availability are also possible by changing partial recruitment vectors (age specific F) and by closing particular areas.

SIMULATION RESULTS

Results of simulations tend to confirm and extend earlier studies. Haddock and yellowtail flounder will continue their downward trends over the next several years under present patterns of effort and exploitation. Possible responses, under alternative management regimes, were investigated for several options of area closures, mesh changes, effort reductions, and

effort reallocations. These analyses focused primarily on haddock and secondarily on yellowtail flounder.

If the Northeast Peak (523-524) was closed to protect haddock from exploitation, Canadian effort would be removed from Georges Bank entirely and USA effort would be redistributed to the Channel (521-522) and Shallow (525-526) areas (Table 7). This would result in reductions of effort from the estimated 26 thousand days fished at present to about 20 thousand days fished. Catches would decline for all four species, but particularly for cod, haddock, and pollock (Table 7). This action would produce increases in fishable stock and spawning stock and reduce F for all the species (Table 7). Fishing mortality would nevertheless remain relatively high for haddock and above F_{max} for yellowtail flounder (Table 7).

Systematic reductions in effort for all areas on Georges Bank would result in dramatic short-term decreases in catch for all species in the DC. This simulation was useful as a guide for estimating the effort reductions necessary for meeting specific fishing mortality goals for the species. Unless effort was reduced by 40-60%, simultaneous F_{max} targets for cod and yellowtail flounder are unobtainable (Tables 8 and 9, Figure 8). Meeting $F_{0.1}$ fishing mortality goals for cod and haddock would require reductions of 60-70% in effort and even more for yellowtail flounder (Tables 8, 9, Figure 8).

Another model run simulated an increase in cod-end mesh size to six inches. Results indicated that with some overall reduction in catch in 1985, haddock catch in 1986 would then increase (Table 10). This occurred because haddock from the 1983 year class would add yield per recruit in 1985 and be caught in 1986 at age 3 at larger sizes. Increases in stock abundance, especially for haddock and yellowtail flounder, would also occur (Table 10).

This scenario is based on the assumption that knife-edge selection would occur for these species at age 3 with no discarding of younger fish. This assumption is probably unrealistic since length of tow and total catch per haul partially determine the selection characteristics of otter trawls. This change would have no impact on fishing mortality rates of fully recruited age groups (Table 10).

To ascertain the effect of potential fishery closures on the stock status of yellowtail flounder, a complete closure of the Shallow (525-526) area was simulated. This was accomplished by removing all effort from this area and reallocating it to the Channel (521-522) (70%), and the Northeast Peak (523-524) (30%). Results suggest that this would stabilize yellowtail flounder stock size at the beginning of 1985 and 1986 at about 10,000 mt. This area closure would also cause a 38% decline in yellowtail flounder F on Georges Bank, but would result in modest decreases in stock size of cod, haddock, and pollock (Table 11).

Simulation was also used to investigate the combined effects of systematic effort reductions and redistribution from the Northeast Peak (523-524). Effort was apportioned to the three areas according to the following percentages: Channel, 75%, Northeast Peak, 5%, and Shallow, 20%. Results of this scenario suggest only a slight improvement over the simple effort reduction situation (Table 12). A slight loss in short-term (1986) catch would correspondingly produce some gains in fishable stock and spawning stock biomass (Table 12).

The simultaneous effect of mesh increases (to 6") and area closures (Northeast Peak) were also simulated (Table 13). Again, this option resulted in decreased and reapportioned effort since Canadian effort would be

eliminated and USA effort would be transferred to the Channel and Shallow areas. This simulation suggests that catch would decrease by over 20% for each species in 1985, followed by smaller declines in 1986 (Table 13). Fishable stock and spawning stock biomass, however, would increase, especially for haddock and yellowtail flounder (Table 13). This option would stabilize the haddock stock at about 22,000 mt in both years and result in a spawning stock of about 22,000 mt in 1986, a 46% increase over present conditions (Table 13). Yellowtail flounder stock biomass would also increase and F for all species would decline (Table 13).

If effort and mesh size were changed concurrently, yellowtail flounder fishable stock and spawning stock biomass would exhibit the highest relative increase of the four species (Table 14). The combined effect of these two measures results in similar F levels as in the effort reduction scheme alone, but larger overall increases in stock size for all the species (Table 14).

Finally, all three measures were evaluated simultaneously. The first option was a systematic effort reduction with a mesh increase to 6" and closure of the Shallow area. As expected this scheme was most beneficial to the yellowtail flounder stock. This option results in larger stock increases and reductions in fishing mortality than would occur if the options were utilized singly (Tables 8, 9, 10, and 15). The second 3-way option was the same as the above except the Northeast Peak was closed instead of the Shallow area. This resulted in greater increases in fishable stock and spawning stock biomass for cod, haddock, and pollock as well as lower F's than occurred in the other 3-way option (Tables 15 and 16). All species would benefit to a greater extent from this option because of the overall reduction in effort

(Table 16). The status of yellowtail flounder, however, would not improve as much as in the 3-way option closing the Shallow area (Table 16).

The effect of all options on conditions in 1986 are summarized in Table 17 to give a clearer interpretation of the impacts of each measure. Results are expressed as percentage difference from Option 1, the present effort and mesh conditions. In general, Options 6-10 result in the greatest overall percent change for all four species in aggregate. Some exceptions are Option 3 for cod, yellowtail flounder, and pollock, and Option 4 for haddock (Table 17). Haddock and yellowtail flounder status improved markedly by increasing codend mesh from 5.5" to 6", and also from reductions in total effort (Table 17). The greatest overall positive changes in spawning stock and corresponding reductions in F occur with Options 9-10 (Table 17).

If 1986 catch and spawning stock are plotted concurrently the percent change or trade-off between the two is more clearly illustrated (Figure 9). It is apparent that few options produce any simultaneous positive trends in catch and spawning stock except Option 4 for cod and haddock. This is due to the relatively poor recruitment prospects for most species (Figure 9). Few of the other options are feasible without some reduction in catch of the four species. Increases in spawning stock can be accomplished for haddock and yellowtail flounder without reducing catch in 1986, but this would result in reduced cod and pollock catch (Figure 9). Option 4 appears to be the least disruptive over the two-year period because it results in positive increases in spawning stock for cod, haddock, and yellowtail flounder without reductions in catch (Figure 9). Option 10 would severely reduce cod and pollock catches, but would help to stabilize haddock and yellowtail flounder spawning stocks.

LINEAR PROGRAMMING RESULTS

The previous results depended on assumptions of how effort was allocated among the three areas. An important aspect of the above studies is the examination of fishery strategies, relative to their effects on mortality rates of each stock. Obviously, it is vital to consider the feasibility of a series of mortality rate goals for each stock. Likewise, it is of interest to examine effort patterns necessary to attain these goals. These policies could be examined by trial and error, or by employing a mathematical optimization technique, such as linear programming (LP). For instance, effort could be reduced by trial and error and allocated such that $F_{0.1}$ is attained for one or more of the four species. This would not insure that effort is minimized nor that $F_{0.1}$ is obtained for each species. Further, since the attainment of specific F goals for haddock and yellowtail flounder will likely result in reductions in cod catch, a trial and error strategy may overly reduce catch.

Linear programming can be used to structure such problems so that effort can be calculated and allocated on an optimal basis. Several LP's were used to estimate effort for $F_{0.1}$ and F_{max} fishing mortality goals under 5.5 and 6" mesh regulations. The equations were configured similar to the following general example.

Minimize:

$X_1+X_2+X_3$

where

X's represent total standardized fishing effort by area

Subject to:

Cod $q_{11}X_1+q_{12}X_2+q_{13}X_3 \geq F_1$.

Haddock $q_{21}X_1+q_{22}X_2+q_{23}X_3 \geq F_2$.

Yellowtail flounder $q_{31}X_1+q_{32}X_2+q_{33}X_3 \geq F_3$.

where

q's are catchability constants by species and area

F's are fishing mortality constraints for each species.

Estimated effort from these runs was used in the model to assess changes in catch, spawning stock and F. In other runs, additional constraints were added to the LP's to insure that the Channel area received some effort. Pollock was eliminated from the analysis to simplify the equations and their solution.

Results of these studies suggest that major reductions in effort would be necessary to attain $F_{0.1}$ fishing mortality goals for Georges Bank. Under one such simulated option, effort would need to be reduced 71% and confined to the Northeast Peak (Table 18, Option 2). Under this option, catches of cod would decline 64% and 54% in 1985 and 1986, respectively. If an additional constraint requiring some effort in the Channel area is included, effort would be about 62% of the present figure and catches of cod would be about 10% higher (Table 18). These results suggest that target F's can be obtained for these species, but not without effort reduction and reallocations. The results of all the LP runs are displayed in Table 19. Overall they suggest that numerous options are available, but all entail some reduction and reallocation of effort in order to meet fishing mortality goals. At present, effort is too high even to meet F_{max} goals for the DC.

DISCUSSION

The Georges Bank multispecies trawl fishery can generally be categorized as suffering from chronic overexploitation at this time. Numerous studies have suggested that effort and F are too high at present and age at entry for most of the demersal species is below maximum Y/R (Overholtz et al. 1983, Murawski 1984, Clark et al. 1984, Serchuk et al. 1985, and Overholtz and Tyler 1985). The problem ranges from growth overfishing and general stock abundance declines to severe recruitment overfishing in some cases (Gabriel et al. 1984, Murawski 1984, and Overholtz et al. 1984).

Under present conditions the probability of recovery of the Georges Bank haddock spawning stock appears to be low (Overholtz et al. 1984). Fishing mortality is presently excessive and must be lowered if any significant long-term recovery of the stock is to occur (Overholtz et al. 1983, Overholtz et al. 1984). Haddock are codistributed with several species and hence are caught as one component in the Georges Bank demersal fishery. In order to reduce haddock mortality it will probably be necessary to reduce short-term catches of the other key species in the Demersal Complex.

Model results suggest that the mesh changes investigated in this study would not reduce fishing mortality enough, even though some short-term stockpiling of biomass and increased yield would occur by 1986. It appears that a restriction, like a long-term area closure or systematic reduction in effort, will be necessary to reduce F and increase or stabilize the spawning stock. For example, to reach an $F_{0.1}$ fishing mortality goal for haddock, effort would need to be reduced to about 10 thousand days or approximately 62%, given current conditions (Figure 8). This would result in significant decreases (25% or greater) in cod and pollock catches (Table 17).

Similar measures would be necessary to improve the status of yellowtail flounder, including possible closure of the Shallow area (Table 17). Since yellowtail flounder catches are highest in the Shallow and Northeast Peak areas, the most rapid improvement would result by controlling fishing activity there. Simulations suggest that concurrent increases in mesh and area closures would be beneficial to this stock. To reduce fishing mortality to acceptable levels (F_{max} or less) a significant reduction in effort would also be needed (Tables 9, 17, Figure 8).

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Table 1. Fishing effort (USA and Canada) in standardized days fished using USA OTB2-3 vessels, for 1979-1982, for Atlantic cod, haddock, yellowtail flounder, and pollock on Georges Bank.

1979[1]	19,768
1980	21,515
1981	23,809
1982	26,201

[1]from Murawski 1984.

Table 2. Stock size (millions) by age group from DeLury analysis with M = 0.2 for Georges Bank cod, 1977-1983.

Year	Age 2	3	4	5	6	7	8	9	10	11
1977	78.19	19.02	7.52	2.89	7.55	0.57	2.76	0.11	0.55	0.21
1978	3.15	46.49	11.42	3.49	2.30	5.32	0.10	0.36	0.06	1.02
1979	27.60	3.45	32.12	10.19	4.22	2.15	4.38	0.66	0.39	0.18
1980	19.04	20.14	2.83	17.74	3.98	2.37	0.47	1.52	0.10	0.29
1981	14.05	9.83	10.35	1.01	3.92	0.70	0.88	0.32	0.06	0.06
1982	39.94	14.87	11.66	7.09	0.71	6.32	0.74	0.84	0.24	1.08
1983		24.38	2.45	0.73	1.02	0.06	0.16	0.06	0.06	0.23

Table 3. Stock size (millions) by age group from DeLury analysis with M = 0.2 for Georges Bank haddock, 1964-1983.

Year	Age 2	3	4	5	6	7	8	9
1964	138.68	19.80	14.36	22.74	13.68	5.14	3.50	3.43
1965	363.37	99.23	11.86	7.07	10.68	5.70	2.01	1.97
1966	17.72	183.67	40.99	4.06	2.43	2.74	1.97	1.36
1967	2.38	7.81	59.15	16.44	1.46	1.23	0.92	0.56
1968	9.21	1.03	3.12	29.78	5.10	1.25	0.58	1.31
1969	0.16	3.32	0.37	0.90	11.63	2.78	0.72	1.39
1970	0.08	0.02	0.81	0.37	0.45	4.78	1.44	1.04
1971	5.71	0.56	0.04	0.76	0.71	1.24	3.21	2.20
1972	0.02	1.04	0.20	0.04	0.60	0.08	0.25	3.00
1973	6.70	0.02	1.31	0.24	0.02	0.24	0.16	2.83
1974	13.95	3.55	0.02	0.53	0.12	0.02	0.20	1.88
1975	4.36	6.68	1.00	0.02	0.04	0.02	0.02	0.64
1976	1.77	2.14	5.55	1.99	0.02	0.08	0.02	0.85
1977	79.65	1.44	1.55	2.75	0.86	0.02	0.12	0.94
1978	6.44	47.29	1.68	1.71	2.08	1.05	0.12	0.33
1979	2.30	4.27	25.33	0.64	0.88	1.41	0.04	0.04
1980	67.21	0.12	2.55	13.65	0.86	0.95	0.16	0.04
1981	8.33	26.73	1.35	0.66	5.97	1.36	1.32	0.47
1982	10.27	5.04	11.28	0.69	1.23	1.97	0.04	0.04
1983	0.70	5.83	1.03	5.14	0.37	0.20	0.56	0.32

Table 4. Stock size (millions) by age group from DeLury analysis with M = 0.2 for Georges Bank yellowtail flounder, 1974-1983.

Year	Age 2	3	4	5	6	7
1974	29.84	30.37	25.61	15.85	8.27	3.40
1975	38.13	18.57	14.28	10.68	4.64	2.39
1976	46.10	16.73	7.51	5.56	3.24	0.34
1977	4.36	22.32	4.78	1.18	1.17	0.34
1978	12.19	10.08	11.74	0.11	1.13	0.68
1979	48.70	10.33	6.91	4.78	1.44	0.11
1980	26.52	34.04	3.29	1.56	1.52	0.34
1981	12.81	23.72	21.64	5.66	2.80	1.76
1982	30.48	16.85	13.31	7.92	0.81	0.58
1983	26.21	15.49	10.43	4.47	0.82	0.11

Table 5. Stock size (millions) by age group from virtual population analysis with M = 0.2 for the Northwest Atlantic pollock stock, 1973-1983 (Mayo & Clark 1984).

Year	Age 2	3	4	5	6	7	8	9	10	11	12
1973	57.595	18.124	19.428	9.508	3.477	1.950	.909	.939	.833	.186	.073
1974	32.685	45.492	13.402	10.804	3.908	1.905	.886	.419	.361	.307	.167
1975	43.494	26.207	30.690	8.365	5.595	2.010	1.101	.355	.243	.185	.153
1976	52.834	35.301	18.443	17.553	5.149	3.096	1.147	.778	.241	.136	.280
1977	64.326	42.792	26.240	11.876	10.371	3.108	1.673	.707	.612	.168	.995
1978	51.964	52.636	32.758	17.907	7.537	5.854	1.558	.824	.423	.426	.928
1979	13.598	42.402	40.365	22.600	11.364	4.531	2.937	.685	.348	.210	.618
1980	26.874	10.923	31.446	27.333	14.973	7.215	3.064	2.002	.390	.218	.344
1981	57.120	21.676	7.418	21.270	16.653	9.117	4.824	2.188	1.405	.230	.549
1982	25.793	44.794	15.567	3.412	11.650	10.556	6.171	3.484	1.468	.974	.936
1983		10.845	31.283	10.435	2.154	7.354	6.664	3.896	2.199	.927	.615

Table 6. Catchability coefficients for species in the demersal complex for the Channel (CH), Northeast Peak (NP), and and Shallow (SH) areas of Georges Bank, expressed as mean values for 1980-1982.

Species	CH	NP	SH
Cod	.208	.208	.101
Haddock	.188	.343	.136
Yellowtail	.181	.448	1.233
Pollock	.153	.101	.027

Table 7. Simulated area closure of the Northeast Peak (523-524) of Georges Bank with relative comparison of changes in catch, stock size, spawning stock size, and F between present conditions (option 1) and area closure (option 2).

	Catch		Stock Size		Spawning Stock Size		F	
	85	86	85	86	85	86	85	86
Option 1								
Cod	37912	44443	129033	136201	91411	116552	.497	
Haddock	8092	6203	22741	15414	9289	15186	.582	
Yellowtail flounder	5742	4217	10455	7969	7508	7969	1.094	
Pollock	10146	11099	60338	63078	52618	55358	.305	
Option 2			20,000 Days Fished					
Cod	28460	36911	129033	148934	91411	129285	.352	
Haddock	5260	4964	22741	18724	9289	18496	.345	
Yellowtail flounder	5409	4198	10455	8368	7508	5621	.993	
Pollock	4198	9028	60338	65730	52618	58011	.228	
			% Change if Option 2 is Used					
Cod	-25.1	-16.9	-	+9.3	-	+10.9	-29.2	
Haddock	-35.0	-20.0	-	+21.5	-	+21.8	-40.7	
Yellowtail flounder	-5.8	-0.5	-	+5.0	-	+7.9	-8.9	
Pollock	-22.9	-18.7	-	+4.2	-	+4.8	-25.2	

Table 8. F_{max} and $F_{0.1}$ values for species in the Georges Bank demersal complex from various sources.

Species	Mesh size (mm)	F_{max}	$F_{0.1}$
Atlantic cod[1]	140	0.259	0.155
	152	0.289	0.166
Haddock[2]	140	0.563	0.215
	152	0.688	0.235
Yellowtail[1] flounder	140	0.364	0.230
	152	0.400	0.247
Pollock[3]	140	0.490	0.250
	152		

[1]Murawski (1983) ICES 1983/D:12.

[2]Overholtz personal communication 1985.

[3]Mayo and Clark 1984.

Table 9. Simulated reductions in effort and corresponding catch and fishing mortality with present conditions (26,000 days fished) as starting point.

		CATCH WITH SYSTEMATIC REDUCTION IN EFFORT							
	%	Cod		Haddock		Yellowtail flounder		Pollock	
Effort	Decrease	85	86	85	86	85	86	85	86
26000	0	37912	44443	8092	6203	5742	4217	10146	11099
23400	10	34816	42232	7447	6007	5378	4195	9244	10329
19500	25	29914	38222	6420	5590	4765	4088	7847	9055
18200	30	28210	36680	6061	5414	4541	4027	7369	8596
15600	40	24687	33253	5316	4998	4061	3853	6395	7624
13000	50	21008	29325	4534	4488	3535	3596	5397	6576
10400	60	17166	24842	3713	3869	2956	3232	4372	5446
7800	70	13153	19739	2851	3129	2319	2732	3321	4229
		FISHING MORTALITY							
26000	0	.497		.581	F_{max}(.563)	1.094		.305	
23400	10	.448		.524		.984		.278	
19500	25	.373		.436		.820		.229	$F_{0.1}$(.250)
18200	30	.348		.407		.766		.214	
15600	40	.298	F_{max}(.259)	.349		.656		.183	
13000	50	.249		.291		.547		.154	
10400	60	.199	$F_{0.1}$(.155)	.233	$F_{0.1}$(.215)	.437	F_{max}(.364)	.123	
7800	70	.149		.175		.328		.093	

Table 10. Simulated increase in codend mesh size from 5½ inches to 6 inches and relative comparison of changes in catch, stock size, spawning stock size, and F between present conditions (option 1) and mesh change (option 2).

	Catch		Stock Size		Spawning Stock Size		F[1]	
	85	86	85	86	85	86	85	86
Option 1								
Cod	37912	44443	129033	136201	91411	116552	.497	
Haddock	8092	6203	22741	15414	9289	15186	.582	
Yellowtail flounder	5742	4217	10455	7969	7508	5022	1.094	
Pollock	10146	11099	60338	63078	52618	55358	.350	
Option 2			6" Mesh Regulation					
Cod	32736	45029	129033	145384	91411	125735	.497	
Haddock	3750	8405	22741	21051	9289	20823	.582	
Yellowtail flounder	4607	4173	10455	9748	7508	6801	1.094	
Pollock	10039	11006	60338	63239	52618	55519	.350	
			% Change if Option 2 is Used					
Cod	-13.7	+1.3	-	+6.7	-	+7.9	-	
Haddock	-53.7	+35.5	-	+36.6	-	+37.1	-	
Yellowtail flounder	-19.8	-1.0	-	+22.3	-	+35.4	-	
Pollock	-1.1	-0.8	-	+0.3	-	+0.3	-	

[1]F on fully recruited ages.

Table 11. Simulated area closure of Shallow (525-526) area of Georges Bank with relative comparison of changes in catch, stock size, spawning stock size and F between present conditions (option 1) and area closure (option 2).

	Catch		Stock Size		Spawning Stock Size		F	
	85	86	85	86	85	86	85	86
Option 1								
Cod	37912	44443	129033	136201	91411	116552	.497	
Haddock	8092	6203	22741	15414	9289	15186	.582	
Yellowtail flounder	5742	4217	10455	7969	7508	5022	1.094	
Pollock	10146	11099	60338	63078	52618	55358	.305	
Option 2			Close Areas 525-526					
Cod	40508	46106	129033	132705	91411	113056	.541	
Haddock	8391	6277	22741	15066	9289	14838	.610	
Yellowtail flounder	4164	3895	10455	9859	7508	6911	.679	
Pollock	11528	12198	60338	61504	52618	53784	.357	
			% Change if Option 2 is Used					
Cod	+6.9	+3.7	-	-2.6	-	-3.0	-3.0	
Haddock	+3.7	+1.2	-	-2.3	-	-2.3	+4.8	
Yellowtail flounder	-27.5	-7.6	-	+23.7	-	+37.6	-37.9	
Pollock	+13.6	+9.9	-	-3.5	-	-2.8	+17.1	

Table 12. Simulated combined effects of effort reduction and reallocation of effort to the three areas, on a Channel (75%), Northeast Peak (5%) and Shallow (20%) basis.

Effort	Percent Reduction in effort	CATCH											
		Cod			Haddock			Yellowtail flounder			Pollock		
		85	86		85	86		85	86		85	86	
26000	0	37162	43930		6966	5827		5608	4212		10636	11500	
19500	25	29290	37666		5477	5094		4639	4055		8239	9423	
15600	40	24155	32706		4510	4471		3946	3803		6722	7955	
13000	50	20545	28805		3832	3964		3429	3536		5676	6874	
		FISHING MORTALITY											
26000	0	.485			.482			1.052			.326		
19500	25	.364			.361			.789			.242		
15600	40	.291			.289			.631			.193		
13000	50	.243			.241			.526			.161		
		STOCK SIZE											
				CPI[1]			CPI			CPI			CPI
26000	0	129033	137211	0.0	22741	16728	0.0	10455	8130	0.0	60338	62519	0.0
19500	25	129033	147816	7.7	22741	18469	10.4	10455	9289	14.3	60338	65251	4.4
15600	40	129033	154738	12.8	22741	19602	17.2	10455	10120	24.5	60338	66980	7.1
13000	40	129033	159603	16.3	22741	20398	21.9	10455	10741	32.1	60338	68173	9.0
		SPAWNING STOCK SIZE											
				CPI			CPI			CPI			CPI
26000	0	91411	117562	0.0	9289	16500	0.0	7508	5182	0.0	52618	54800	0.0
19500	25	91411	128167	9.0	9289	18241	10.6	7508	6342	22.4	52618	57531	5.0
15600	40	91411	135089	14.9	9289	19374	17.4	7508	7173	38.4	52618	59261	8.1
13000	50	91411	139954	19.1	9289	20170	22.2	7508	7794	50.4	51618	60454	10.3

[1]CPI - Cumulative % increase in 1986 with each reduction in effort.

Table 13. Simulated mesh increase to 6", closure of the Northeast Peak area and relative comparisons of changes in catch, stock size and F between present conditions (option 1) and mesh-closure (option 2).

	Catch		Stock Size		Spawning Stock Size		F	
	85	86	85	86	85	86	85	86
Option 1								
Cod	37912	44443	129033	136201	91411	116552	.497	
Haddock	8092	6203	22741	15414	9289	15186	.582	
Yellowtail flounder	5742	4217	10455	7969	7509	5022	1.094	
Pollock	10146	11099	60338	63078	52618	55358	.305	
Option 2			20,000 Days Fished					
Cod	24715	36753	129033	155583	91411	135934	.352	
Haddock	2470	5883	22356	22356	9289	22128	.345	
Yellowtail flounder	4354	4103	10455	10021	7509	7074	.993	
Pollock	7738	8956	60338	65051	52618	58132	.230	
			% Change if Option 2 is Used					
Cod	-34.8	-17.3	-	+14.2	-	+16.6	-29.2	
Haddock	-69.5	-5.2	-	+45.0	-	+45.7	-40.7	
Yellowtail flounder	-24.2	-2.7	-	+25.8	-	+40.9	-8.9	
Pollock	-23.7	-19.3	-	+4.4	-	+5.0	-25.2	

Table 14. Simulated combined effects of reduction and mesh increase to 6" with catch, F, stock size and spawning stock size with present conditions (26,000 days fished) as starting point.

Effort	Percent Reduction in Effort	CATCH											
		Cod			Haddock			Yellowtail flounder			Pollock		
		85	86		85	86		85	86		85	86	
26000	0	32736	45029		3750	8405		4607	4173		10039	11006	
19500	25	25957	38150		2999	6968		3860	3914		7766	8983	
15600	40	21484	32917		2495	5937		3310	3622		6330	7565	
13000	50	18318	28878		2135	5165		2893	3343		5343	6526	
		FISHING MORTALITY											
26000		.497			.582			1.094			.305		
19500		.373			.436			.820			.229		
15600		.298			.349			.656			.183		
13000		.249			.291			.547			.153		
		STOCK SIZE											
				CPI[1]			CPI			CPI			CPI
26000		129033	145384	0.0	22741	21051	0.0	10455	9748	0.0	60338	63239	0.0
19500		129033	154000	5.9	22741	21815	3.6	10455	10559	8.3	60338	65819	4.1
15600		129033	159708	9.9	22741	22329	6.1	10455	11163	14.5	60338	67450	6.7
13000		129033	163758	12.6	22741	22699	7.8	10455	11625	19.3	60338	68572	8.4
		SPAWNING STOCK SIZE											
				CPI			CPI			CPI			CPI
26000		91410	125735	0.0	9289	20823	0.0	7508	6809	0.0	52618	55519	0.0
19500		91410	134350	6.9	9289	21587	3.7	7508	7612	11.8	52618	58100	4.7
15600		91410	140059	11.4	9289	22102	6.1	7508	8216	20.7	52618	59730	7.6
13000		91410	144109	14.6	9289	22471	7.9	7508	8678	27.4	52618	60853	9.6

[1]CPI - Cumulative % increase in 1986 with each reduction in effort.

Table 15. Simulated combined effects of effort reduction, mesh increase to 6" and closure of the Shallow area (525-526) with changes in catch, F stock size and spawning stock biomass (mt) with present conditions (26,000 days fished) as starting point.

Effort	Percent Reduction in Effort	Cod 85	Cod 86	CPI	Haddock 85	Haddock 86	CPI	Yellowtail flounder 85	Yellowtail flounder 86	CPI	Pollock 85	Pollock 86	CPI
						CATCH							
26000	0	34918	46975		3882	8646		3391	3671		11404	12093	
19500	25	27810	40156		3114	7196		2738	3227		8863	9993	
15600	40	23081	34850		2595	6146		2292	2853		7246	8481	
13000	50	19718	30698		2224	5357		1970	2546		6127	7354	
						FISHING MORTALITY							
26000	0	.541			.610			.679			.354		
19500	25	.406			.457			.509			.265		
15600	40	.324			.366			.407			.214		
13000	50	.270			.305			.339			.179		
						STOCK SIZE							
26000	0	129033	142620	0.0	22741	20916	0.0	10455	11074	0.0	60338	61690	0.0
19500	25	129033	151640	6.3	22741	21698	3.7	10455	11796	6.5	60338	64573	4.7
15600	40	129033	157668	10.6	22741	22227	6.3	10455	12292	11.0	60338	66410	7.7
13000	50	129033	161966	13.6	22741	22608	8.1	10455	12652	14.3	60338	67682	9.7
						SPAWNING STOCK SIZE							
26000	0	91411	122971	0.0	9289	20688	0.0	7508	8127	0.0	52618	53970	0.0
19500	25	91411	131991	7.3	9289	21470	3.8	7508	8849	8.9	52618	56854	5.3
15600	40	91411	138019	12.2	9289	21999	6.3	7508	9345	15.0	52618	58691	8.8
13000	50	91411	142317	15.7	9289	22380	8.2	7508	9705	19.4	52618	59962	11.1

Table 16. Simulated combined effects of effort reduction, mesh change to 6" and closure of the Northeast Peak area (523-524) with changes in catch, F, stock size (mt), and spawning stock biomass (mt) with present conditions (26,000 days fished) to a starting point.

Effort	Percent reduction in effort	Cod 85	Cod 86	CPI	Haddock 85	Haddock 86	CPI	Yellowtail flounder 85	Yellowtail flounder 86	CPI	Pollock 85	Pollock 86	CPI
		CATCH											
20000	23	24715	36753		2470	5883		4354	4102		7738	8956	
19500	25	24194	36154		2417	5772		4288	4081		7562	8788	
15600	40	19973	31024		1994	4855		3716	3846		6161	7390	
13000	50	17000	27114		1697	4187		3271	3598		5198	6369	
		FISHING MORTALITY											
20000		.352			.345			.993			.228		
19500		.343			.336			.968			.222		
15600		.274			.269			.775			.180		
13000		.229			.224			.646			.148		
		STOCK SIZE											
20000		129033	155583	0.0	22741	22356	0.0	10455	10021	0.0	60338	65851	0.0
19500		129033	156248	0.4	22741	22409	0.2	10455	10093	0.7	60338	66051	0.3
15600		129033	161640	3.9	22741	22843	2.2	10455	10717	6.9	60338	67642	2.7
13000		129033	165446	6.3	22741	23149	3.5	10455	11206	11.8	60338	68737	4.4
		SPAWNING STOCK SIZE											
20000		91411	135934	0.0	9289	22128	0.0	7508	7074	0.0	52618	58132	0.0
19500		91411	136599	0.5	9289	22181	0.2	7508	7145	1.0	52618	58331	0.3
15600		91411	141991	4.5	9289	22615	2.2	7508	7770	9.8	52618	59923	3.1
13000		91411	145797	7.3	9289	22921	3.6	7508	8259	16.8	52618	61018	5.0

Table 17. Summary of results of all simulated options with relative comparison to present conditions (option 1) for catch, F, and spawning stock in 1986.

EFFECT OF OPTIONS ON CATCH IN 1986

	Cod	Change	Haddock	Change	Yellowtail	Change	Pollock	Change
1. Present effort, areas and mesh	44443	0.0	6203	0.0	4217	0.0	11099	0.0
2. Close 525-526, Redistribute effort	36911	-17.0	4964	-20.0	4198	- .5	9028	-18.7
3. Reduce effort 40%	33253	-25.2	4998	-19.4	3853	-8.6	7624	-31.3
4. Increase mesh to 6" for all areas	45029	+ 1.3	8405	+35.6	4173	-1.0	11006	- 0.8
5. Close 525-526	46106	+ 3.7	6277	+ 1.2	3895	-7.6	12198	+ 9.9
6. Reduce effort 40% and Reallocate away from 525-526	32706	-26.4	4471	-27.9	3803	-9.8	7955	-28.3
7. Increase mesh, close 525-526	36753	-17.3	5883	- 5.2	4103	-2.7	8956	-19.3
8. Reduce effort 40%, Change mesh	32917	-25.9	5937	- 4.3	3622	-14.1	7565	-31.8
9. Reduce effort, 40% Increase mesh to 6", Close 525-526	34880	-21.6	6146	- 1.0	2853	-32.4	8481	-23.6
10. Reduce effort, 40%, Increase mesh to 6", Close 525-526	31024	-30.2	4855	-21.7	3846	-8.8	7390	-33.4

EFFECT OF OPTIONS ON FISHING MORTALITY[1] IN 1986

	Cod	Change	Haddock	Change	Yellowtail	Change	Pollock	Change
1.	.497	0.0	.582	0.0	1.094	0.0	.305	0.0
2.	.352	-29.2	.345	-40.7	.993	- 9.2	.228	-25.2
3.	.298	-40.0	.349	-40.0	.656	-40.0	.183	-40.0
4.	.497	0.0	.582	0.0	1.094	0.0	.305	0.0
5.	.541	+ 8.9	.610	+ 4.8	.679	-37.9	.357	+17.1
6.	.291	-41.5	.289	-50.3	.631	-42.3	.193	-36.7
7.	.352	-29.2	.345	-40.7	.993	- 9.2	.230	-24.6
8.	.298	-40.0	.349	-40.0	.656	-40.0	.183	-40.0
9.	.324	-34.8	.366	-37.1	.407	-62.8	.214	-29.8
10.	.229	-53.9	.224	-61.5	.646	-41.0	.148	-51.5

[1]Fully recruited F.

EFFECT OF OPTIONS ON SPAWNING STOCK IN 1986

	Cod	Change	Haddock	Change	Yellowtail	Change	Pollock	Change
1.	116652	0.0	15186	0.0	5022	0.0	55358	0.0
2.	129285	+10.9	18496	+21.8	5421	+ 8.0	58011	+ 4.8
3.	134570	+15.3	18430	+21.4	7035	+40.1	59633	+ 7.7
4.	125735	+ 7.9	20825	+37.1	6801	+35.4	55519	+ 0.3
5.	113056	- 3.0	14838	- 2.3	6911	+37.6	53784	- 2.8
6.	135088	+15.9	19374	+27.6	7173	+42.8	59261	+ 7.1
7.	135934	+16.6	22128	+45.7	7074	+40.9	58132	+ 5.0
8.	140068	+20.2	22102	+45.5	8216	+63.6	59730	+ 7.9
9.	138019	+18.4	21999	+44.9	9345	+86.1	58601	+ 6.0
10.	141991	+21.8	22615	+48.9	7770	+54.7	59023	+ 8.3

Table 18. Linear programming of results for two examples of $F_{0.1}$ target fishing mortality goals with relative comparisons to present conditions (26,000 days fished, option 1). Option 3 has an additional constraint that provides for a fishery in the Channel area.

	Catch		Spawning stock		F		
	85	86	85	86	85	86	
Option 1	26,000 days fished						
Cod	37912	44443	91411	116552	.497		
Haddock	8092	6203	9289	15186	.582		
Yellowtail	5742	4217	7509	5022	1.094		
Pollock	10146	11099	52618	55358	.350		
Option 2	7,452 days fished (Area 2)						
Cod	13628	20366		149281	.155		(F0.1)
Haddock	4041	4127		19924	.256		=F0.1
Yellowtail	2354	2762		9087	.339		
Pollock	2720	3508		63825	.075		<F0.1
	% Change if option 2 is used						
Cod	-64.1	-54.2		+28.1	-68.8		
Haddock	-50.1	-33.5		+31.2	-56.0		
Yellowtail	-59.0	-34.5		+80.9	-69.0		
Pollock	-73.2	-68.4		+15.3	-78.6		
Option 3	9,826 days fished (.80 Area 1, .20 Area 2)						
Cod	17593	25359		143934	.204		=F0.1
Haddock	3458	3660		20608	.215		(F0.1)
Yellowtail	1696	2139		9877	.230		(F0.1)
Pollock	4931	6070		61302	.140		<F0.1
	% Change if option 3 is used						
Cod	-53.6	-42.9		+23.5	-59.0		
Haddock	-57.3	-41.0		+35.6	-63.1		
Yellowtail	-70.5	-49.3		+96.7	-79.0		
Pollock	-51.4	-45.3		+10.7	-60.0		

Table 19. Linear programming results for $F_{0.1}$ and F_{max} target fishing mortality goals with 5½" and 6" mesh.

	Effort	Areas fished	Cod	Haddock	Yellowtail	Pollock
5½"						
$F_{0.1}$	7,452	2	+	*	-	+
$F_{0.1}$ with other constraints	9,826	1,2	*	+	+	+
F_{max}	16,414	2	*	+	-	+
6"						
$F_{0.1}$	7,981	2	+	*	-	+
$F_{0.1}$ with constraints	11,047	1,2	*	+	+	+
F_{max}	20,058	2	-	+	-	+

[1]
+ goal is attained
- goal not attained
* goal nearly attained

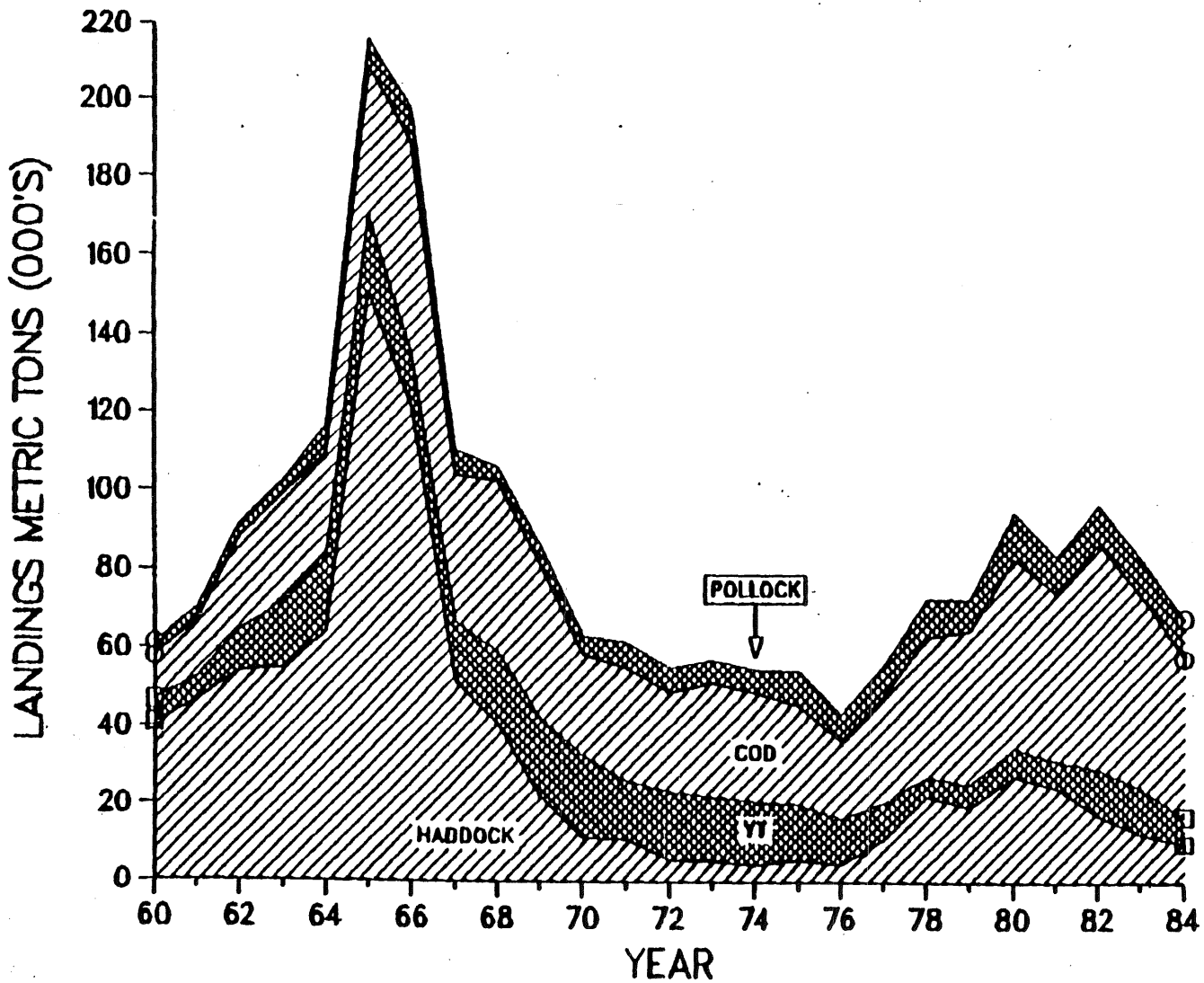

Figure 1. Total landings of haddock, cod, yellowtail flounder, and pollock by all countries on Georges Bank from 1960-1984.

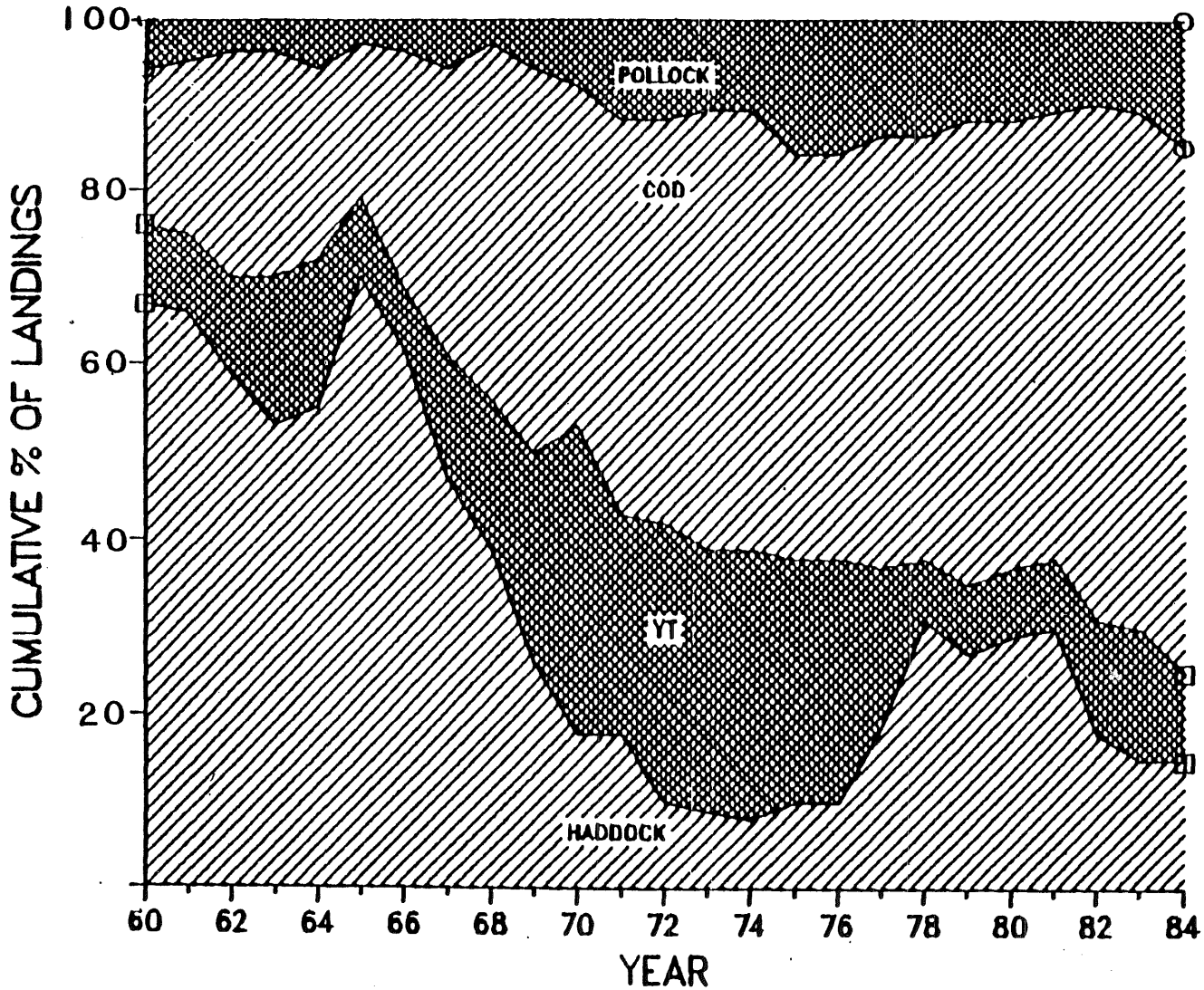

Figure 2. Total cumulative percent of landings of haddock, cod, yellowtail flounder, and pollock by all countries on Georges Bank from 1960-1984.

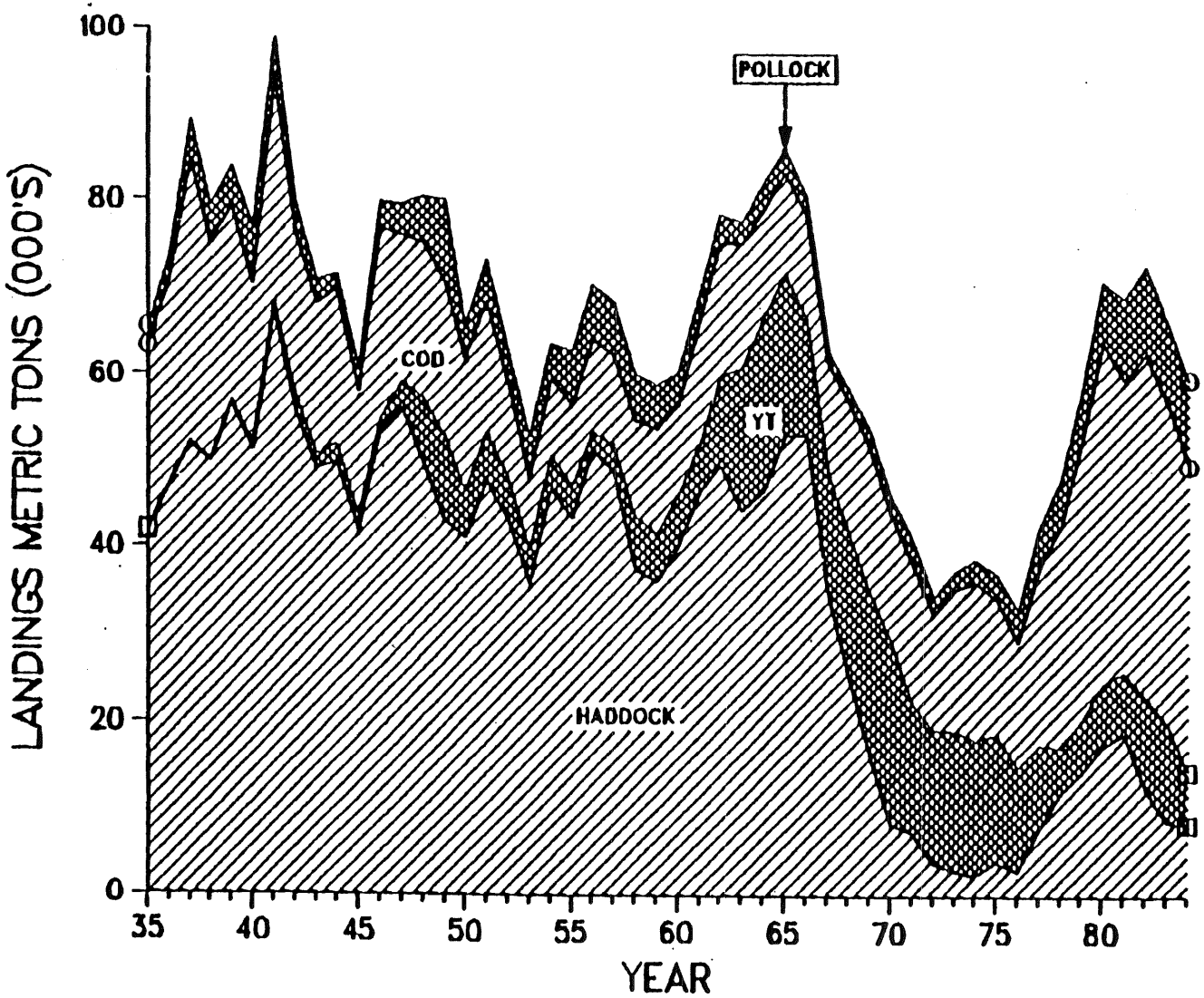

Figure 3. Total USA landings of haddock, cod, yellowtail flounder, and pollock on Georges Bank from 1935-1984.

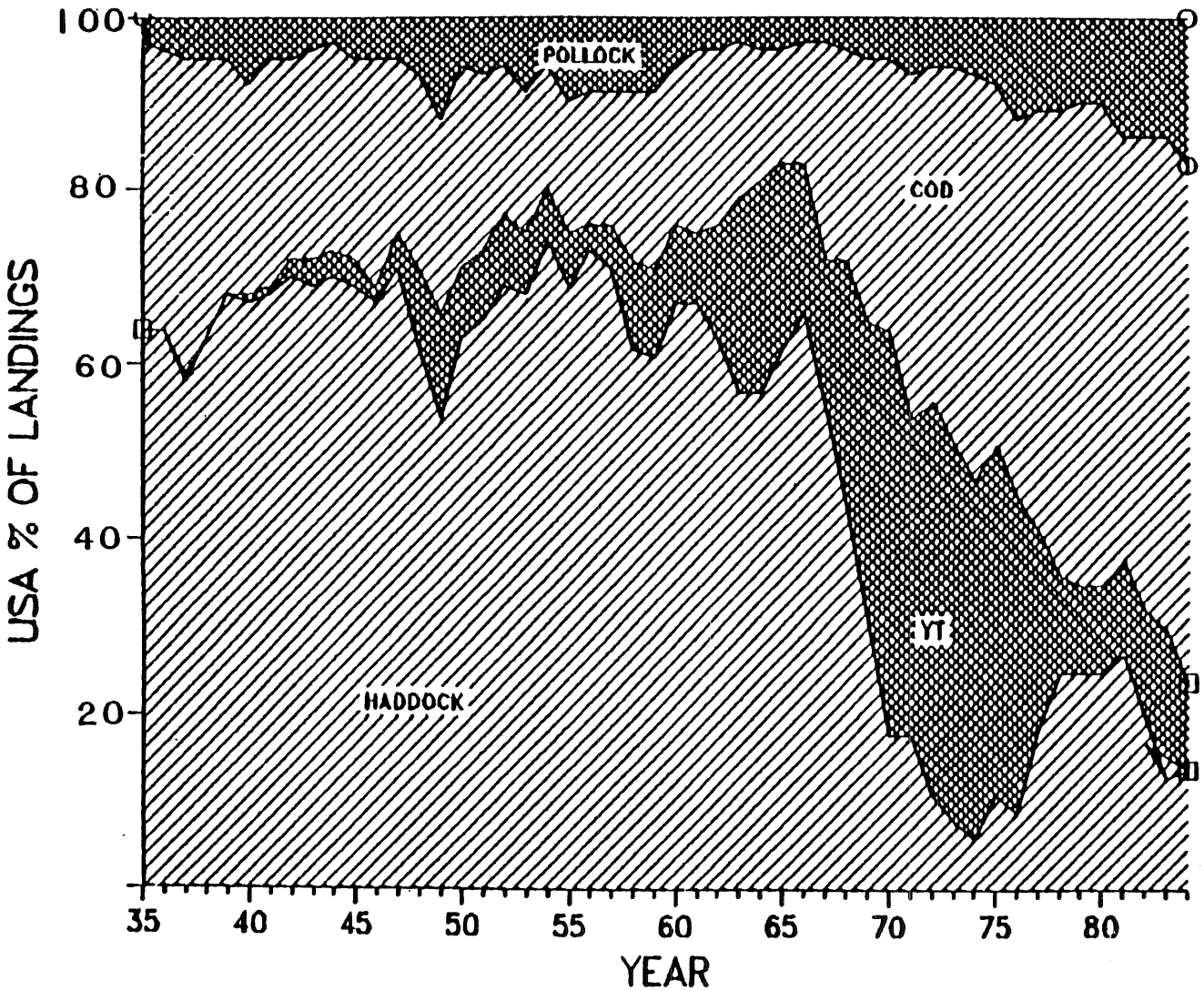

Figure 4. Total cumulative percent of USA landings of haddock, cod, yellowtail flounder and pollock on Georges Bank from 1935-1984.

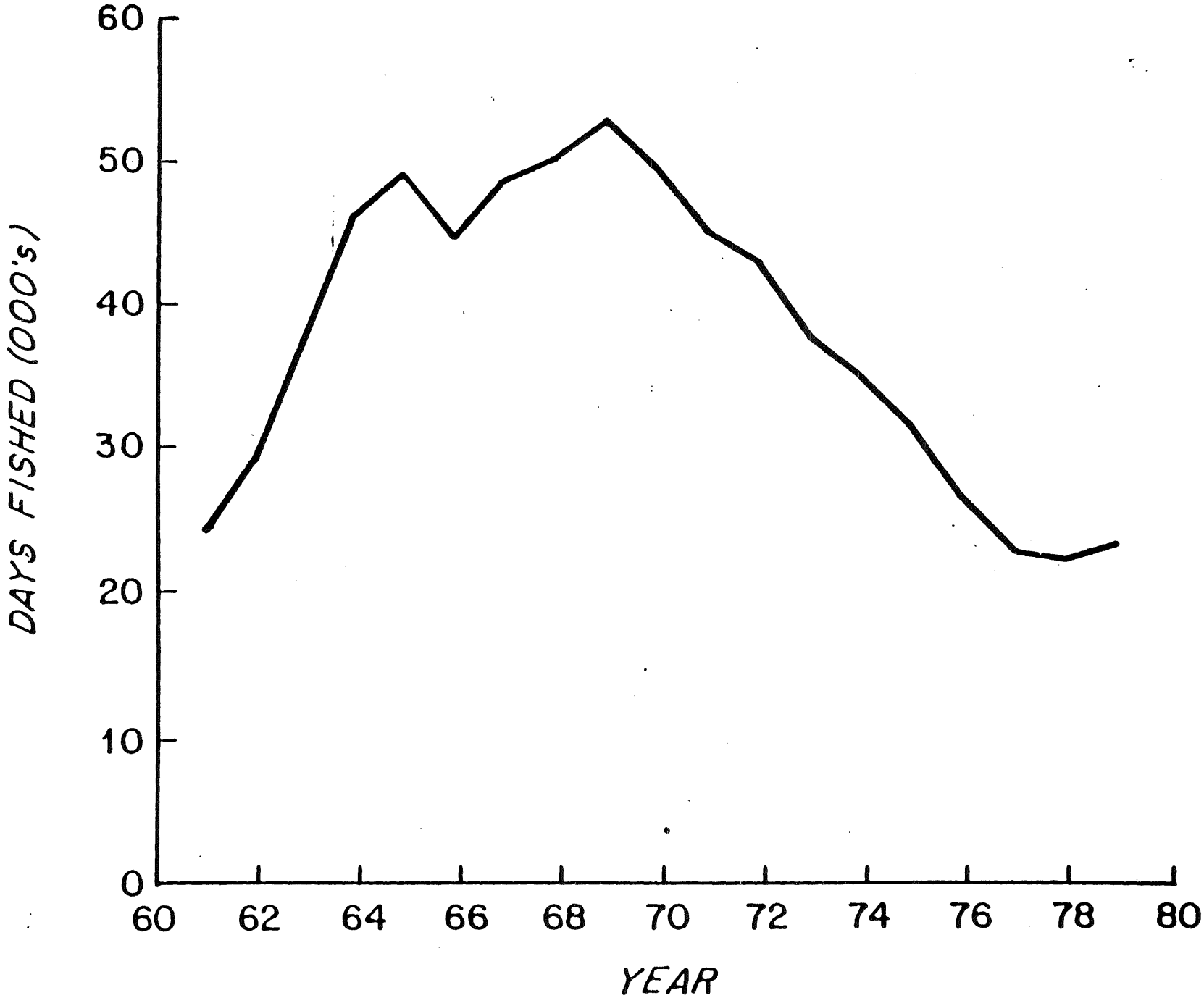

Figure 5. Unstandardized effort in thousands of days fished for the Georges Bank demersal fishery, all countries, for 1961-1979, expressed as 3-year moving mean (from Overholtz and Tyler 1985).

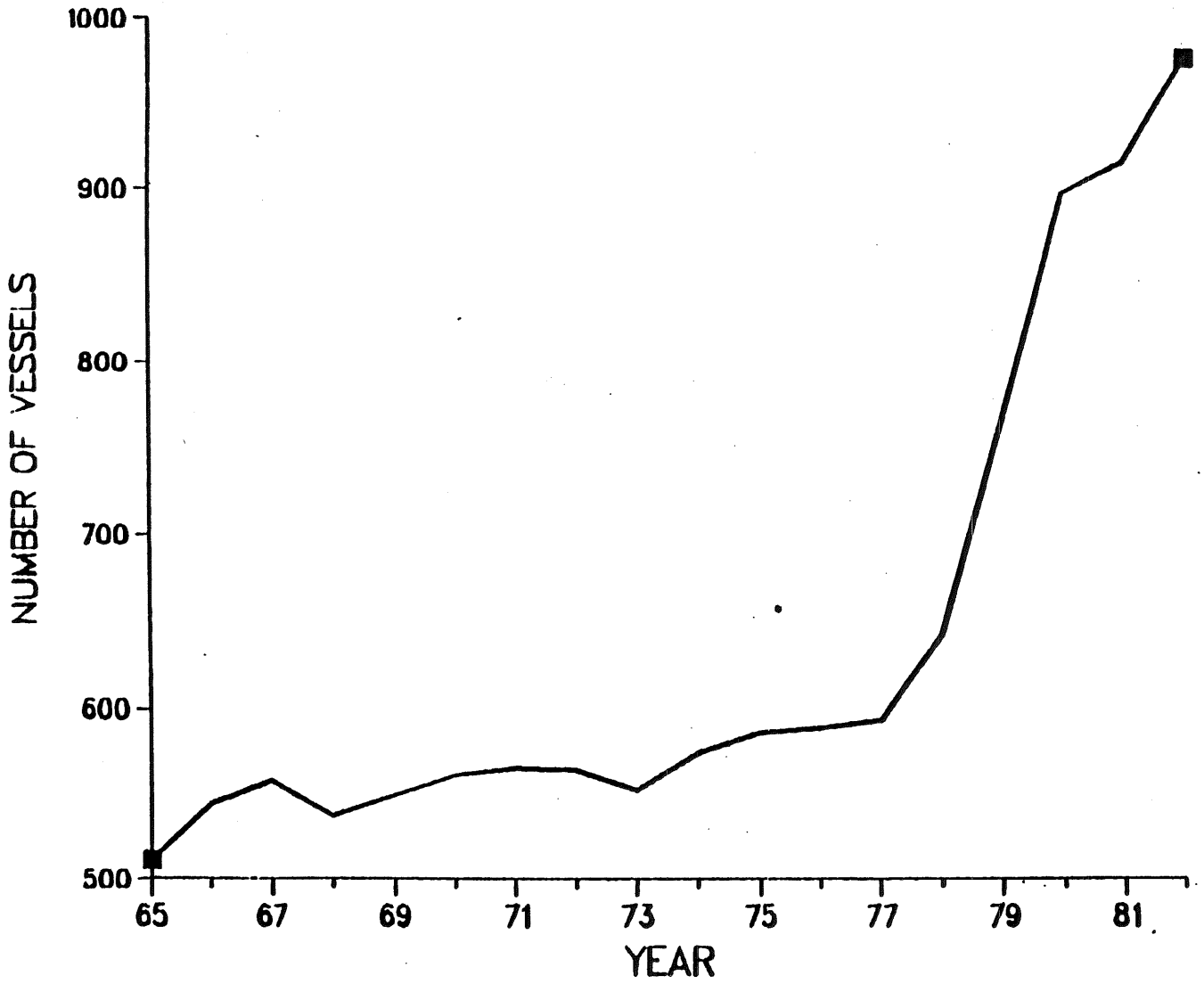

Figure 6. Number of vessels in the New England otter trawl fishery from 1965-1982 (from Status of the Fishery Resources off the N. USA for 1983).

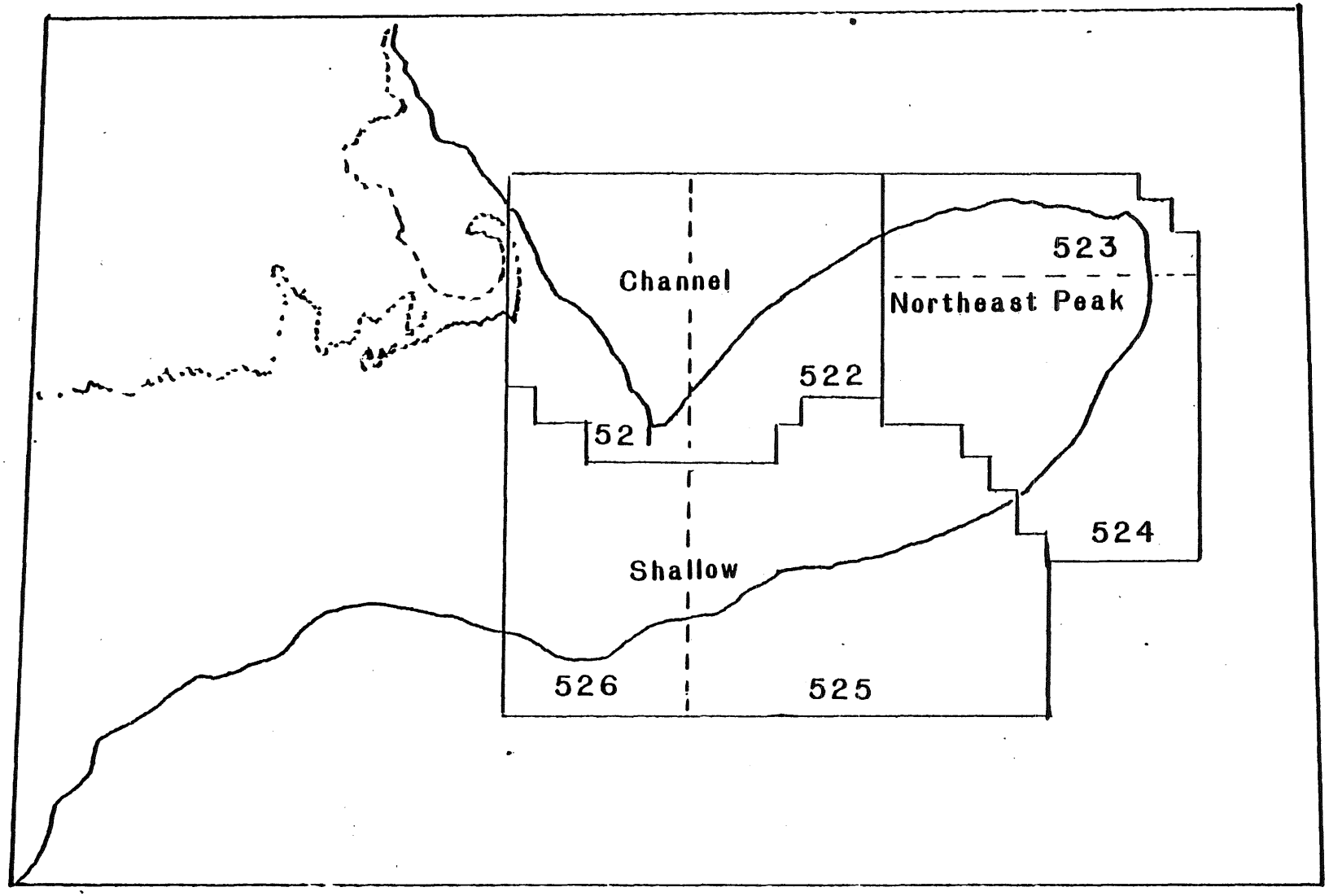

Figure 7. Spatial scheme of organization for the Georges Bank multispecies model with Channel (521-522), Northeast Peak (523-524), and Shallow (525-526) areas delineated.

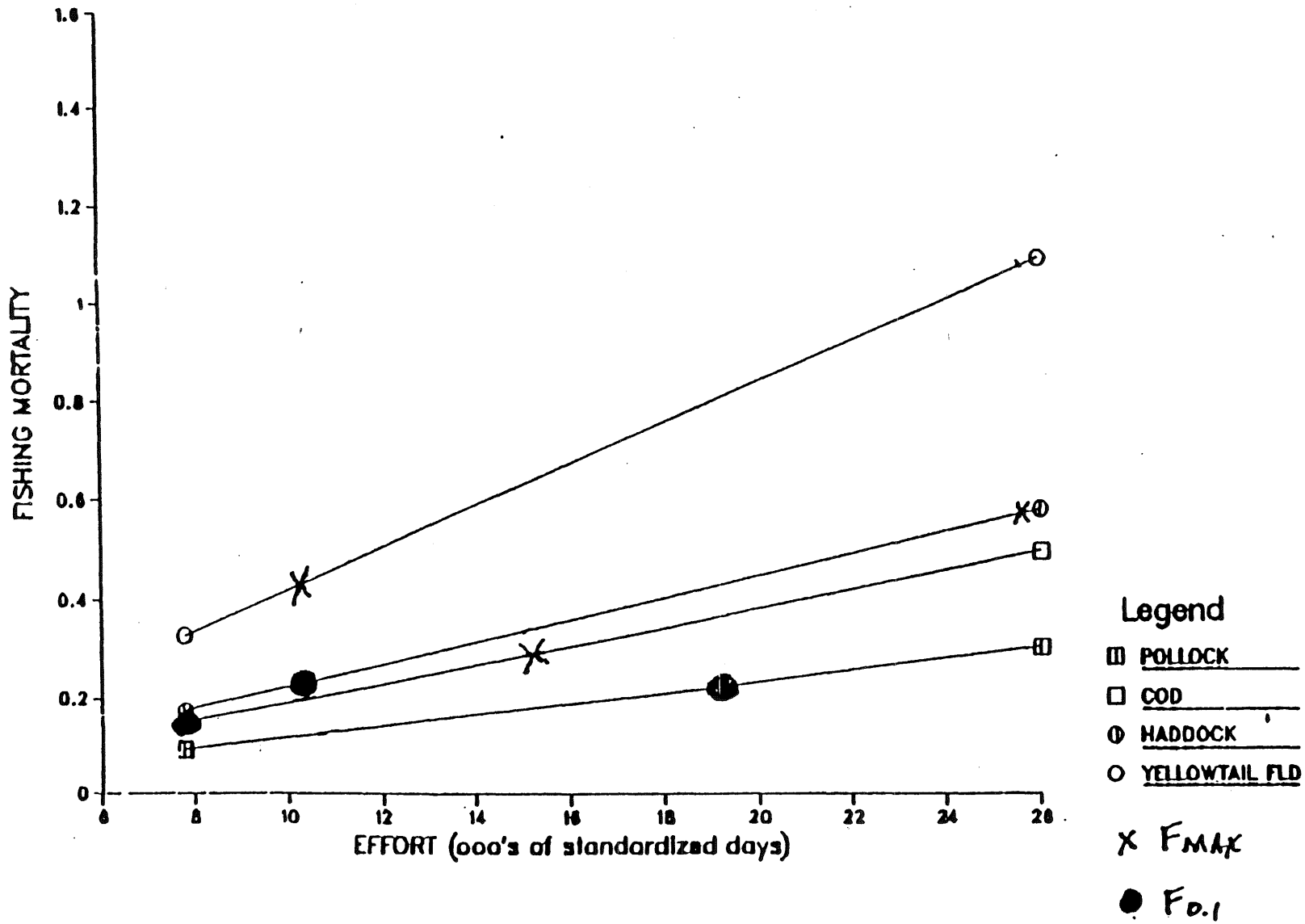

Figure 8. Results of simulation where effort was systematically reduced on the Georges Bank DC with various F_{max} and $F_{0.1}$ values for each species.

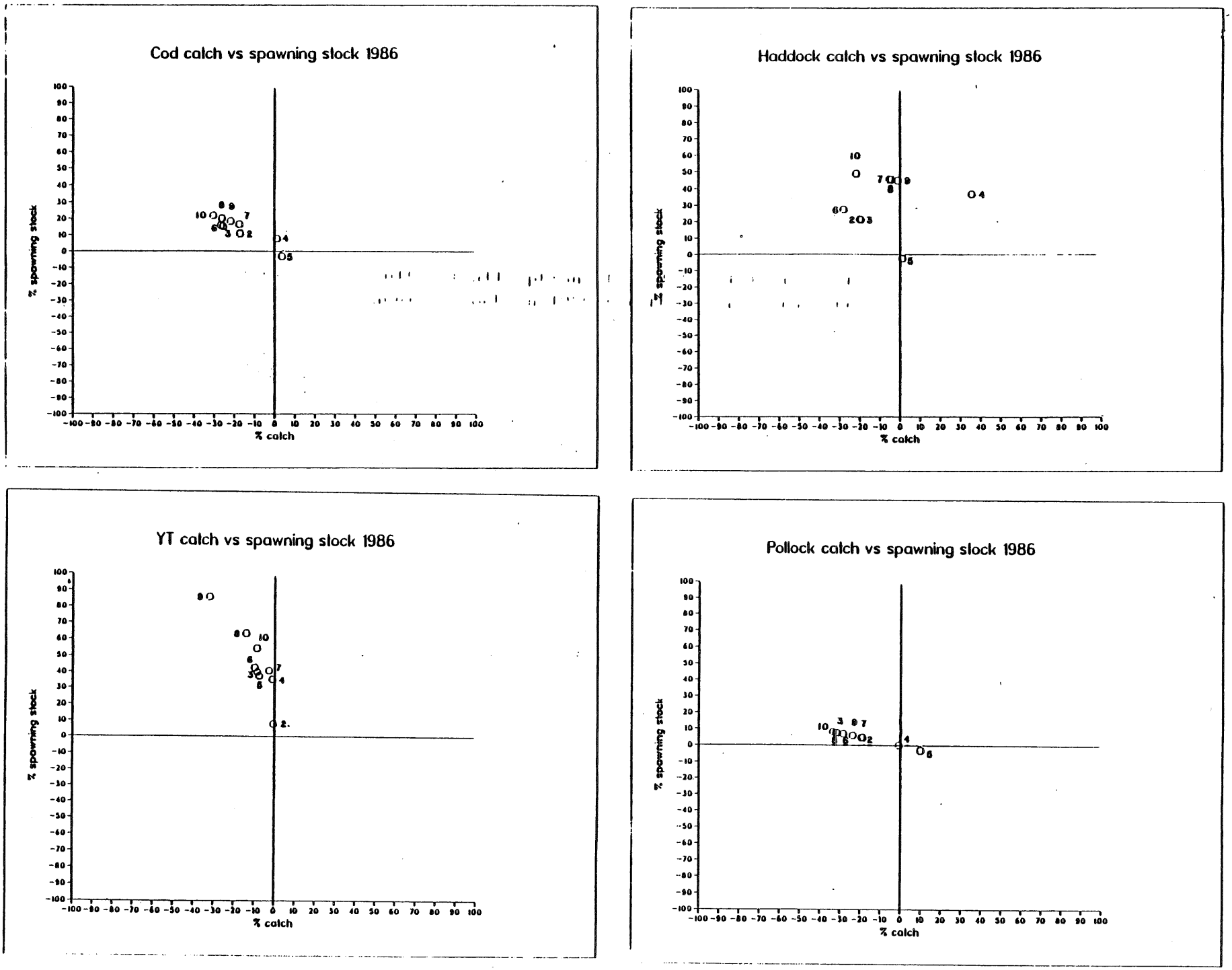

Figure 9. Results of all options (see Table 17) of catch vs spawning stock in 1986 for the Georges Bank DC.