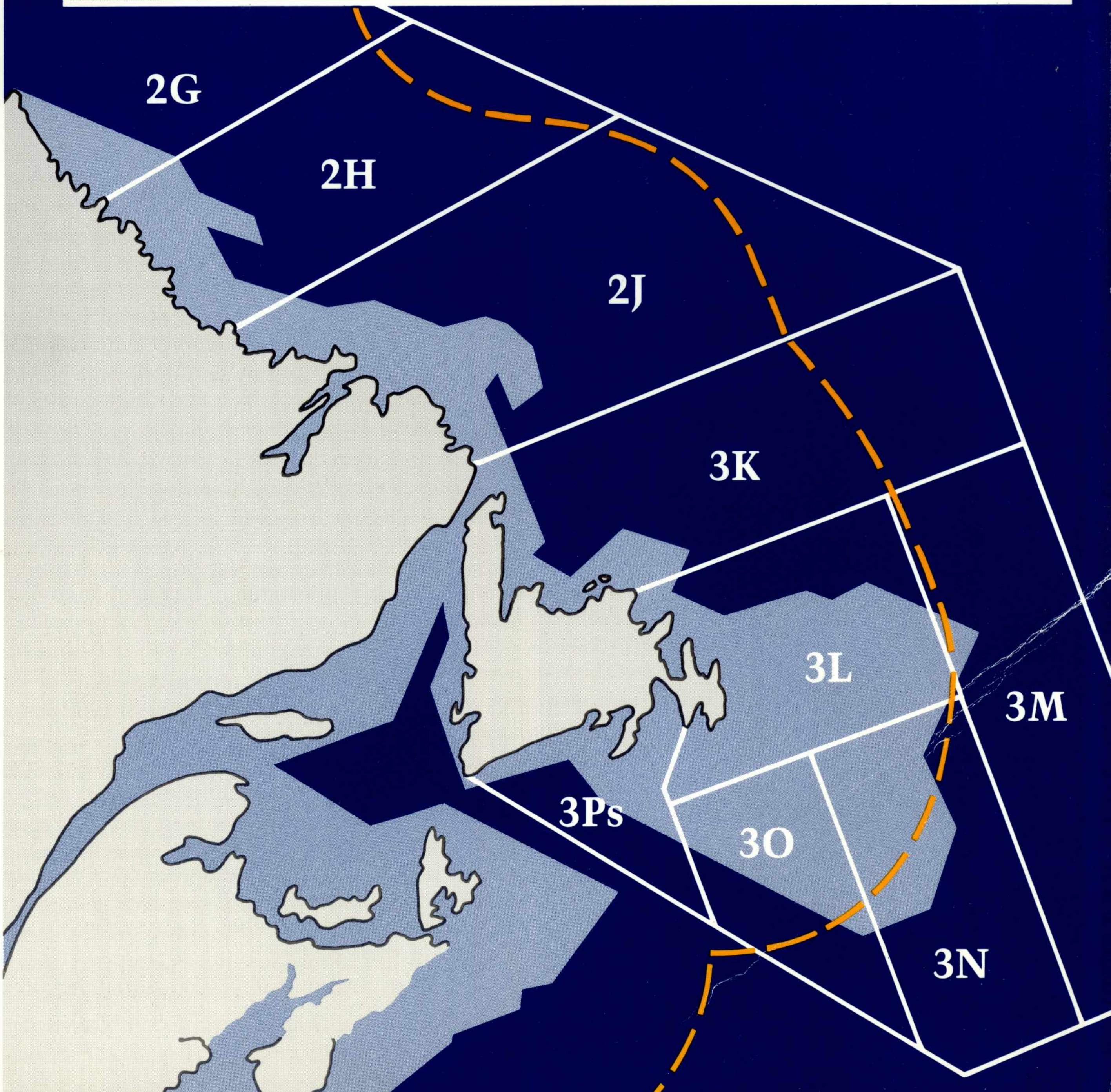
Independent Review Of The State Of The Northern Cod Stock

Prepared For
The Honourable Thomas E. Siddon

Submitted By
Dr. L. Harris



Independent Review of the State of the Northern Cod Stock

Final Report

Prepared for
The Honourable Thomas Siddon
Minister of Fisheries

Submitted by
Dr. Leslie Harris
Northern Cod Review Panel

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Table of Contents

CHAPTER IV

CHAPTER V

CHAPTER VI

CHAPTER VII

List of Figures

List of Tables

List of Maps

EXECUTIVE SUMMARY

Northern cod, that is the cod stock(s) inhabiting NAFO statistical divisions 2J, 3K, and 3L and spilling over into divisions 2GH and 3NO, has been exploited by fishermen since c. 1481. Though patterns of exploitation have varied, these stocks were, through four centuries at least, the economic foundation for the growth of a settled community along the east and northeast coast of Newfoundland and the coast of Labrador. Though supplemented by comparatively modest contributions from other marine species such as salmon, herring, seals, and whales, the cod stocks were the **raison d'etre** for the existence of Newfoundland as a colony, and subsequently as a Dominion, and contributed in a lesser way to the well-being of several Nova Scotian coastal communities.

Though there has been, throughout the past century, some economic diversification, it is true even today that the vast majority of the Newfoundland coastal communities that were built upon a foundation of cod are still utterly dependent upon that resource for their continued existence.

Although foreign fishing fleets and a smaller number of Newfoundland based vessels have, throughout the centuries concentrated their fishery upon the northern cod sub-groups that frequented for some part of each year the shallow offshore banks of what are now known as divisions 3LNO, the vast majority of Newfoundland fishermen were reliant upon the seasonal feeding migration that brought the codfish to shallow coastal waters where they were accessible to fixed gear deployed in traditional berths or on traditional near shore fishing grounds.

Though annual harvests fluctuated in accord with changing environmental conditions and to some extent with the vagaries of the international market, the northern cod stock(s) yielded, in the century prior to 1950, for example, an annual production varying about an average of some 250,000 tons. In general, the harvest level gradually moved upward as populations grew and fishing effort increased. Nevertheless, except for environmentally induced disruptions of migratory patterns that resulted in localized failures of the fishery, sometimes for a number of consecutive years, the overall historical record indicates that the stock(s) could sustain the fishing pressures imposed upon them without exhibiting any obvious sign of decreasing abundance.

By the middle of the twentieth century, however, new fishing technologies were being introduced at an increasingly rapid rate. Chief among them was the comparatively heavily powered vessel equipped with otter trawls that was capable of fishing in deeper waters than were heretofore accessible and of exploiting the large concentrations of fish that at the end of their autumn migrations were assembled for spawning in the outer shelf regions of the several offshore banks. Subsequently, inshore fishermen, too, began to acquire larger diesel powered vessels (the long-liner fleet) with extended range and seakeeping capacities, equipped with electronic navigational and fish finding instruments and with hydraulic net haulers that permitted utilization of long "fleets" of gillnets. This new fleet extended the "inshore" effort into deeper waters, upwards of fifty miles from shore. Did the fish thus made accessible to inshore gear constitute the older elements of the population that terminated their feeding migration in those deeper "middle-distance" waters? Or on the other hand, did they constitute discrete inshore spawning populations? This, regrettably, is still a matter for speculation. In any case, they represent elements of the northern cod spawning biomass that were, for the first time, subjected to intense fishing pressure.

Then came the burgeoning of offshore technology, with West Germany in the vanguard and other European nations quickly following and the notorious assault upon the spawning aggregations on the northern banks during the late 1960s and 1970s. With catches reaching 800,000 tons in the peak year of 1968, the predictable result was a collapse of the stock with inshore landings falling to figures lower than any recorded in the previous centuries.

The Law of the Sea Convention, though still unratified in 1977, prompted Canada in that year to declare a two hundred mile management zone. This provided the opportunity to begin the process of rebuilding depleted stocks and of establishing fishing strategies that would ensure continuing long-term viability for both an inshore and offshore fishery. With the objective of building spawning stocks to a biomass capable of sustaining a harvest at historical levels, the Department of Fisheries and Oceans (DFO) adopted a management strategy designated as $F_{0.1}$ which would have permitted annual fish landings of approximately 20% of the exploitable biomass.

During the next seven years the euphoria that had been engendered by the declaration of the exclusive economic zone was reinforced by the steady growth of the stock, by continually improving catches, and by the belief that the $F_{0.1}$ objective was, indeed, being met. In those circumstances, scientists, lulled by false data signals and, to some extent, overconfident of the validity of their predictions, failed to recognize the statistical inadequacies in their bulk biomass model and failed to properly acknowledge and recognize the high risk involved with state-of-stock advice based on relatively short and unreliable data series. Furthermore, the Panel is concerned that weaknesses in scientific management and the peer review process permitted this to happen.

Such blunt criticism is, of course, itself the product of hindsight. In fairness, we must recognize the simple enormity of the task of taking a census of fish populations over so vast a territory. We must recognize as well that DFO scientists had to do the best they could with short data series since longer ones were simply not available to them. As well, they had to contend with misreporting of catches, bycatches, and discard rates and other significant inaccuracies in the commercial catch data; with their own inability to modify certain research vessel data to account for changes in the time of the survey and for fluctuating environmental conditions; with unanticipated changes in recruitment levels; and with a substantial number of lesser variables whose consequences are easier to identify in retrospect than they were to forecast. Nevertheless, it is possible that if there had not been such a strong emotional and intellectual commitment to the notion that the $F_{0.1}$ strategy was working, the open and increasing scepticism of inshore fishermen might have been recognized as a warning flag demanding more careful attention to areas of recognized weakness in the assessment process.

In any event, by the late autumn of 1988, it was apparent that the more sophisticated analytical methodologies recently adopted and the acquisition of two additional years of data combined to indicate that the actual fishing mortality rates since 1977 had in fact been at least double those projected in the $F_{0.1}$ strategy. That the population did, in spite of this relatively intense fishing, continue, at least until 1984, to show substantial growth was, for the most part, attributable to good earlier recruitment. Now, however, it was apparent that the more recent trend in recruitment was definitely downward. Thus, it is apparent that, even though there is not an immediate threat to the survival of the northern cod stock, recent catch levels simply cannot be maintained without causing a significant and potentially very serious decline in the exploitable and spawning biomass.

On the positive side, the Panel is persuaded that the current modelling methodology employed by DFO scientists is superior to that previously used. Further, the Panel is reasonably confident that the range of fishing mortalities provided by that methodology are in the right domain. This position is supported by results obtained when the data are subjected to a number of independent analytical techniques.

Nevertheless, the data themselves are still to some considerable degree unreliable or, at least, subject to strong suspicion of unreliability; and, this stricture applies, though perhaps not with equal force, to both the Research Vessel (RV) data and the commercial catch per unit of effort (CPUE) data. The former, it is believed, might be improved through increased sampling effort, by appropriate correction for time of survey, and for environmental variability. The latter are, perhaps, distorted by underestimation of the significance of technological changes in catching effectiveness when fishing is conducted primarily upon spawning or other aggregations.

In light of this, the Panel would emphasize that a vital aspect of management strategy must be the improvement of the quality of data used in assessment and the establishment of additional independent indices of abundance including an inshore CPUE index, and the incorporation into the assessment process of such additional elements as acoustic survey data and environmental indices of availability and abundance. Further, DFO should expand its computing power to remove current restrictions on timely data processing and should include in the scientific assessment process a rigorous peer review by other scientists drawn from the university or industrial communities, for example, and who are not directly involved in departmental processes.

The Panel would also urge DFO not to place too much reliance upon mathematical models alone to solve the problems of the northern cod assessment. Good mathematical models are of course a central part of the assessment process, but they cannot compensate for inadequate or missing data. There is a need to develop appropriate models and to collect the appropriate data with sufficient precision and accuracy. In such modelling a danger to be avoided is the tendency to forget the distinctions between convenient mathematical abstractions, for example, constant catchability rates and the living fish whose behaviour may well be in response to varying environments.

Thus, the Panel believes that more sophisticated modelling, combined with a broader and deeper understanding of the biology of the animals involved and of the physical environment in which they function, is essential to the proper management of the ecosystem of which northern cod is but one element. Indeed, the Panel sees as necessary a long-term goal of a properly integrated systems approach to stock management.

In the meantime, it would appear to be imperative that a very considerable research effort should be mounted and that, in the management of that effort, DFO should ensure that all its best resources are brought to bear through planned collaborative approaches to a hierarchy of particular problems that are cooperatively identified as demanding early resolution. Beyond this, the Panel would urge DFO to mobilize the resources of the broader scientific community as well as those of the fishing industry to address the enormously important scientific challenges facing Canadians in respect of their oceans and the life systems within them. The Panel, of course, is not unaware that DFO has already, in response to our Interim Report, committed considerable additional resources to its research efforts and that in taking such action has given consideration to the appropriate reallocation of existing resources.

In short, both the management of the scientific effort and the management of the fish stocks must be set in the context of clearly enunciated sets of biological, economic and social goals and objectives. Our intrusion into the natural domain can be justified only in terms of human reliance upon the resources that the oceans afford. At the same time, all such intrusions must be sensitive to necessities of the environment and to our obligations to protect and conserve. Because the technology we control gives us the power to be utterly destructive, we must be all the more aware of the heavy moral responsibilities we bear. Among those responsibilities is that of seeking and acquiring the knowledge that is within our grasp and that will alone enable us to manage as we ought. We can only pray for the wisdom to use our knowledge wisely.

In the opinion of the Panel, the beginning of wisdom is acceptance of the proposition that the fishery based upon the northern cod stock(s) will not be saved unless the spawning biomass is permitted to grow. This implies the urgent necessity to reduce the rate of fishing mortality from its current value of 0.45 or higher to a value below 0.30. Even if such a reduction were to be achieved, the pace of recovery would probably be still very slow and, perhaps, of such a marginal nature that natural environmental fluctuations might at any time tip the balance in the other direction. Thus, the Panel believes that the rate should, as soon as it is feasible, be reduced to 0.20 and that this should be the goal of DFO management strategy for the foreseeable future.

In the meantime, every reasonable effort must be directed to whatever tactics are available to encourage the survival of cod to increase the spawning population. This implies the rigid enforcement of regulations respecting gear types, fishing areas, allocations, bycatches, discards, etc. and the implementation of policies specifically aimed at a very considerable reduction in mortality of two, three, four, and five year old cod. It implies as well a very determined effort to restrict or eliminate the actual catch of cod by foreign vessels operating under Canadian licence within the two hundred mile zone and a determined Government of Canada initiative either to bring the entire Canadian shelf under Canadian management or to reach an effective international agreement that will curb the irresponsible and destructive activities of certain countries fishing the "Nose" and "Tail" of the Bank.

In respect of both foreign and domestic fisheries, the Panel would urge consideration of the dangers of compartmentalization. Indeed, if the case for an integrated approach to science is well made, so will be the case for a similar approach to management. That is to say, we cannot contemplate a crab fishery, a capelin fishery, or a shrimp fishery, for example, that does not impact upon cod population and biomass, either directly or through bycatch possibilities, or indirectly through weight-at-age or density dependent, or other analogous relationships. In this context, foreign licences to take allegedly underutilized species should be carefully examined. By the same token, it is incumbent upon DFO to undertake a serious study of predator-prey relationships within the northwest Atlantic ecosystem with a view both to expanding essential knowledge and of refining management objectives. At the very least, we should know, for example, how many harp seals there currently are and, in terms of their bioenergetics, what their current tax upon the system may be. In a similar vein, the status of the capelin and shrimp stocks may be of enormous importance to the long-term health of the cod populations and, through weight-at-age relationships, for example, may not be entirely without significance to the process of cod biomass assessment.

In conclusion, the Panel having concluded that the population, the biomass, the spawning population, and the spawning biomass of northern cod are all currently in decline and that the fishing mortality rate is currently at the level of 0.45 or higher would stress the following recommendations:

- that in respect of the northern cod stock(s) and as a matter of urgency there should be an immediate reduction of fishing mortality to the level of at least 0.30 and, at the earliest feasible date, to the level of 0.20;

- that DFO must establish regulations to limit fishing mortalities imposed during the spawning period proportionally with the general reduction in total fishing mortality and should explore with the affected sectors of the fishing industry whether this objective can be best achieved through a straight reduction in the winter catch (i.e. during the spawning period) or through a combination of seasonal closure coupled with a catch reduction proportional to the reduction of the TAC during the remainder of the spawning period;

- that DFO should for both biological and economic reasons examine immediately the selectivity of traps, small and large trawlers, gillnetters, and other gear types with the intent of improving the yield in cod fisheries; the goal should be to eliminate the harvest of two, three, four, and five year olds and to reduce the bycatch of these year classes;

- that DFO review its management structures and approaches with the end of establishing a more focused and coordinated approach to the management of the northern cod stocks;

- that while we must work assiduously to refine our mathematical modelling techniques, it is also urgently important to acquire, through research, a more profound biological and general environmental knowledge of the system we seek to manage;

- that, in particular, we must address the problems of stock discrimination and of migratory and distributional patterns and adjust our fishing effort to bear with proportionate weight upon the several stock components;

- that we must convince the domestic and foreign fishermen that conservation is a matter of the utmost importance and that violations of appropriate regulations will not be tolerated;

- that the Government of Canada must be convinced of the imperative necessity of regulating, through agreement or otherwise, foreign fishing pressure upon northern cod;

- that predator-prey relationships be accepted as a matter of considerable importance and that, in particular, a seal census be initiated as a matter of urgency;

- that the management of DFO science be reorganized to recognize the necessity for the clarification of goals and priorities and for the appropriate integration of services and facilities and expertise to serve established priorities;

- that the DFO assessment process be submitted to peer review by independent scientists and that DFO should seek to involve the broader scientific community in its overall research programme;

- that the Government of Canada and the relevant provincial governments be encouraged while recognizing the importance of conservation to identify in unequivocal terms the socio-economic and cultural objectives of the Atlantic coast fisheries and so to coordinate their respective areas of jurisdiction to improve the collection of objective biological and economic data and to obviate conflict in terms of stock management;

- that the principles of adjacency and of essential needs be adopted as a fundamental premise underlying quota allocations.

CHAPTER I

Introduction

1.1.0 General Background

Under the Canadian Constitution, the Federal Government has authority over and management responsibility for both coastal and inland fisheries in all provinces and territories. This confers upon the Minister of Fisheries and Oceans the mandate to exercise licensing authority to individuals, to corporate entities, and to other parties permitting the exploitation of specified stocks or species of fish, for specified periods of time, in accordance with such conditions both general and particular as are deemed appropriate to the circumstances. It also confers upon the Minister the obligation of responsibility for the welfare of the stocks, for their proper management and conservation.

In respect of the marine fisheries on the east coast the role of the Minister was prior to 1977 clearly circumscribed by the exigencies of a situation in which international fishing fleets had ready access to the stocks beyond the narrow strip of territorial sea that international law allowed. Nations such as Great Britain, France, Spain, and Portugal who had traditionally fished waters of the Northwest Atlantic were joined by numerous others including East and West Germans, Russians, Poles, Rumanians, Danes, Norwegians, Cubans, and Japanese as fish became an increasingly valuable commodity, as domestic fisheries were depleted by overfishing, and as technological advance permitted access to hitherto inaccessible resources in distant waters. An attempt to introduce some element of order into this fishery was made through the establishment of the International Commission for Northwest Atlantic Fisheries (ICNAF) whose regulatory and management functions covered stocks beyond the twelve mile coastal limit. **As an agency for conservation, however, ICNAF was a total failure.** It did, perhaps, succeed in obviating direct international conflicts, but it did so by setting catch quotas so high that they could not possibly be met and that threatened the very survival of the fisheries dependent on cod and haddock.

Fortunately, movement towards the Third United Nations Convention on the Law of the Sea was sufficiently promising that many coastal states including Canada took unilateral action in 1977 to establish fishing zones extending two hundred nautical miles out to sea. Some five years later in 1982 the Convention was adopted by an overwhelming majority of the United Nations Conference membership. It is expected that the ratification process will be completed in the next few years, at which time the provision that fishing zones "shall not extend beyond two hundred nautical miles from the baseline from which the breadth of the territorial sea is measured," will be formally confirmed as part of the Law of the Sea Treaty.

Regrettably, provisions for the management of stocks of fish that straddle the two hundred mile line but that are indigenous to the continental shelf of a coastal state are cumbersome requiring agreement among the international user group and leaving the concentrations of the stocks in question in limbo during the period of dispute resolution. Thus, in the case of the northern stock, the Canadian Government is left in a still invidious position in respect of its conservational and management mandate. For, setting aside the question of the Flemish Cap with its separate stocks, the two hundred mile line cuts through several important fish populations on the "Nose" and "Tail" of the Bank leaving the issue of their proper management very much in doubt.

Nevertheless, in October 1978 the Convention on Future Multilateral Cooperation in the Northwest Atlantic Fisheries was adopted and out of this came the Northwest Atlantic Fisheries Organization (NAFO) as the regulatory agency for the establishment and enforcement of fisheries regulations in the zone outside the two hundred mile Canadian limit. NAFO was composed of thirteen contracting parties including Canada, the USSR, the countries of the European Community, Japan, and Portugal.

NAFO agreed that Canada would manage the 2J3KL cod stock, even though it was recognized as a transboundary stock, on the grounds that only a small part of the stock was normally present outside the two hundred mile limit and that for only part of the year and because of the vital importance of that stock to the coastal state. Nevertheless, NAFO continued until 1986 through its Scientific Council to do the scientific assessments of 2J3KL stocks and, furthermore, continued, as it does at present, to establish quotas to be fished outside the two hundred mile limit. **However, NAFO like ICNAF before it is totally devoid of "teeth."** Its moral authority counts for less than nothing in the world of "realpolitik" and nations of the European Community, for example, may through the simple expedient of filing a protest against the TAC set by NAFO free themselves from any obligation to be bound by it. **In practice, such nations as Spain and Portugal habitually ignore scientific advice, flaunt their defiance of conservational strategies, and limit their catches only by the capacity of their fishing fleets.** As an example, we may cite the year 1986 in which Canada established a northern cod TAC of 266,000 tons, in which NAFO proposed a TAC for the European Community countries of approximately 36,000 tons to be taken from the "Nose" and "Tail" of the Bank, and in which those countries reported landings from those areas of approximately 100,000 tons.

In this context of international irresponsibility amounting in the eyes of most Newfoundland fishermen who addressed our Panel to outright piracy, the mandate of the Canadian Minister of Fisheries and Oceans cannot be executed properly. Even if it is impossible to attain international agreement under which the Canadian writ would run to embrace all the stocks of the Canadian

Continental Shelf, it should be possible to develop a cooperative approach to scientific assessment and to management that recognizes both the preponderant interest of the coastal state but as well the necessity to ensure the long-term survival of the stocks. Ideally, we believe that that control should be exercised by a single authority and that authority should be Canada.

Despite the difficulties arising from a divided jurisdiction, the declaration of 1977 provided to Canada an opportunity to begin the process of rebuilding depleted stocks and to establish a management regime based upon a solid scientific base that would ensure a viable fishery into the foreseeable future. Wisely, Canada's approach to this objective was to concentrate within its jurisdictional zone upon the active encouragement of long-term growth of the spawning stock. This overriding objective was sought through routine monitoring of stock population and biomass followed by careful regulation of the total allowable catch (TAC) in conformity with a strategy developed around the stated goal of a $F_{0.1}$ mortality which identified approximately 20% of the exploitable biomass for harvest each year. This strategy if effectively pursued should have guaranteed a healthy and steadily growing stock and a TAC that increased proportionally in successive years.

However, the management of any fishery is a difficult undertaking at the best of times as a wide range of varying conditions come into play, any or all of which have the potential of altering the hoped for results. These can include an unpredictable and highly variable physical environment, wide swings in the numbers of young fish annually recruited to the stock, extensive and incompletely known interactions among different species occupying similar territories, the misreporting of fish catches, unrecognized sources of natural mortality, uncertain reliability of data gathering methodologies, and the subsequent failures to submit available information to sufficiently sensitive and rigorous statistical models.

Despite those constraints, there was in the decade immediately following Canada's assumption of management rights a widespread belief that the $F_{0.1}$ harvest strategy was resulting in the recovery of the northern cod stocks that had been shamelessly overexploited in the decade of the 1960s. The TAC had increased progressively from 135,000 tons in 1978 to 266,000 tons from 1984-1988, and a major restructuring of the fishery had been carried out. With renewed confidence investors and fishermen alike began to believe that a resource that had been the backbone of the regional economy for five hundred years, with all the profound socio-cultural implications thereby entailed, could be so managed as to represent the best hope for an illimitable future.

Early in 1989, however, it became clear that there were serious discrepancies in the assessment figures. It now seemed that total stock size was significantly smaller than had been predicted from all previous estimates. The reasons for this altered view were variously ascribed but principally to the introduction of new and more sophisticated statistical modelling techniques and to the availability of data in an increasingly longer time series. The revised position was that while the stock had not declined relative to previous years, it had not grown at a sufficiently rapid rate to justify the TAC of a year earlier, i.e. 266,000 tons. In essence, the new calculations indicated that the previous estimate of fishing mortality had been too low with the consequence of offering a brighter view of stock growth than had been warranted. Consequently, it was recommended that if the $F_{0.1}$ strategy were indeed to be realized so as to encourage an increased growth rate in the spawning stock, the TAC would have to be reduced by one-half.

1.2.0 Composition of the Panel

The Minister of Fisheries and Oceans responded to this alarming advice by adopting the temporary expedient of reducing the TAC for 1989-1990 to 235,000 tons and by creating an independent review Panel to examine the situation.

The Panel was called into being on February 12, 1989 with membership as follows:

Dr. Leslie Harris
President and Vice-Chancellor
Memorial University of Newfoundland
St. John's, Newfoundland
(CHAIRMAN)

Dr. D. L. Alverson
President
Natural Resources Consultants
Seattle, Washington
U.S.A.

Dr. Robert O. Fournier
Professor of Oceanography and Associate Vice-President (Research)
Dalhousie University
Halifax, Nova Scotia

Mrs. Mary Lou Peters
Mary Lou Peters and Associates
St. John's, Newfoundland

Mr. J. G. Pope
Directorate of Fisheries Research
Fisheries Laboratory
Ministry of Agriculture, Fisheries and Food
Lowestoft
United Kingdom

Mr. Maxfield Short
Director
Inshore Sector of the Fishermen Food and Allied Workers Union
St. John's, Newfoundland

Mr. Frank D. Smith
President and Chief Executive Officer
NORDCO
St. John's, Newfoundland

1.3.0 Terms of Reference

The Terms of Reference provided to the Panel by the Honourable Tom Siddon, Minister of Fisheries and Oceans were as follows:

Independent Review of The State of the Northern Cod Stock

Terms of Reference

The panel will consider the scientific advice provided by the Department of Fisheries and Oceans since 1977 on the Northern cod stock and the current state and size of the stock, and make recommendations regarding stock assessment methods and means with a view to better forecasting the size, growth potential and behavior of the stock in future.

In fulfilling its mandate the panel will examine:

> **the definition of the Northern cod stock complex and the relationships over time between its components;**
>
> **the data used in assessing the abundance and growth potential of the stock and in forecasting catches;**
>
> **the methodologies used in Canada to assess the state of the Northern cod stock;**
>
> **possible causes of changes in the state of the stock, including natural phenomena, environmental factors, fishing practices within and beyond the 200-mile limit;**
>
> **approaches taken by other countries and by the Northwest Atlantic Fisheries Organization (NAFO)to the measurement of fish stocks; and**
>
> **explanations for the variance between the current and earlier scientific advice as to the overall state of the 2J3KL stock;**

and will recommend:

> **possible improvements in data collection, methodologies, and related research resources that would contribute to the achievement of greater certainty in forecasting the state of the stock in 1990 and in future years, including means of incorporating the monitoring of the inshore fishery into the stock assessment process.**

The panel will receive submissions from the public and hold public hearings.

The review panel will provide an initial report to the Minister of Fisheries and Oceans no later than May 15, 1989 on any new measures that might be needed in 1989 to ensure reliability of the scientific advice for the 1990 fishing season. The panel will provide further comprehensive advice by the end of 1989.

1.4.0 Work Methodologies

The Panel commenced its work with a review of current and historical documentation touching the northern cod stocks and the total ecosystem of which they constitute a part. In this context, the library and resources of the Northwest Atlantic Fisheries Centre were made available in a manner that reflected the generous spirit of cooperation with which the Director of the Centre and his scientific staff greeted the efforts of the Panel and which continued to the conclusion of the project. Indeed, the Panel cannot praise too warmly the efforts of Mr. M. C. Mercer and his colleagues to ensure its access to all available data sources and to all sources of particular expertise that might inform its deliberations and assist it in reaching valid conclusions. Thus, in the early days the Panel was not only provided with reams of documentation but was as well and upon request given oral briefings by members of the scientific staff of the Centre and by senior officials of the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC).

Further, because there was not time before presentation of its interim report to organize and to conduct public hearings, the Panel did seek through informal meetings the views of individuals and groups representing both inshore and offshore fishermen, the major fishing companies, the fishermen's union, and other special interest groups.

Nevertheless, in the limited time available before the May 15 deadline for submission of an interim report, it was necessary to concentrate attention upon the statistical methodologies and the mathematical models being employed by CAFSAC in assessing the state of the northern cod stock complex. In due course, members of the Panel became reasonably comfortable with their understanding of the source and nature of the errors that had led to earlier overestimates of stock abundance and confident that they had correctly identified the likeliest source of weakness or of deficiency in data being employed to tune the cohort analysis figures to project current abundance. Further, the Chairman and Dr. Alverson were able to spend some time at the Fisheries Laboratory, Lowestoft, of the British Ministry of Agriculture, Fisheries and Food and through the good offices of Mr. John G. Pope and his superiors, to use their computer facilities to check fishing mortality levels derived from available data by Canadian scientists using the ADAPT mathematical model against levels obtained by submitting the data to other models employed in other jurisdictions. Furthermore, they were able to generate certain risk analysis scenarios assuming different levels of fishing mortality and varying TACs which were a significant part of the interim report which was submitted to the Minister on May 15, 1989.

Following submission of the interim report, the Chairman accepted a number of invitations to present the Panel's tentative conclusions to interested and informed groups and organizations and to engage in dialogue in respect to them. This process provided opportunities for the clarification of issues, for the identification of questions of concern to the fishing industry, and for the dissemination of information to the public at large.

This process was continued in the more formal context of public hearings. Scheduled in two series, the first between June 21 and 24 at Clarenville, Marystown, Gander, and St. Anthony; the second between September 25 and October 4 at Makkovik, Cartwright, Port Hope Simpson, La Scie, Twillingate, Fogo, Bonavista, St. John's, and Halifax. In the course of those hearings some seventy-eight presentations were made to the Panel, a complete list of which is included in Appendix A.

The hearings were, in the main, characterized by lively discussion, a free exchange of information, and more particularly by the repeated and passionate outpourings of anger and frustration. From the northern coast of Labrador to the southern shore of the Avalon Peninsula the message of the inshore fishermen was clear and unequivocal. Their livelihood, their communities, their lifestyle, their heritage were all under attack. The resource upon which they and their fathers and grandfathers before them had built their lives and which they had regarded as preeminently theirs had been alienated from them. The great schools of migrating cod no longer came to shore. Despite vastly increased efforts and more and more substantial investments in boats and gear, their landings were in steady decline and as related to effort were only a minuscule fraction of what they once had been. Nor was any doubt expressed but that the decline precisely paralleled the growth of the offshore trawler fleets whose rapacious assaults upon the spawning concentrations represented the ultimate in destructive potential. And as if this were not enough the Canadian Government appeared to condone the depredation of foreign fleets, many elements of which fished under Canadian licence, and the ravages of an expanding herd of seals whose growth would be checked, presumably, only when it had exhausted its food supply.

Even this bleak tale failed to exhaust the catalogue of woes besetting the beleaguered inshore fixed gear fisherman. For when, they argued, a few fish did escape the nets of domestic and foreign trawlers and the maws of predacious seals, they were intercepted before they could reach shore by gillnets in the thousands deployed across the migration routes by a middle distance fleet owned, in part, by desperate inshore fishermen being forced further and further from the land and, in part, by government, an intrusion signifying to many fishermen a singularly poignant symbol of betrayal.

Has this presentation of the burden of the inshore argument in any way gilded the lily? Indeed, it has not, for the reportage pales in comparison with the force of the language used to convey the message so that the Panel might, like William Pitt, stand in astonishment at its own moderation.

Moving from evidences of anger to symptoms of frustration, we must note the oft repeated refrain, "we told them so, but they wouldn't listen." Over and over, the Panel was urged to recommend incorporation of inshore data into assessment equations. Over and over, the Panel was urged to consider the principle of adjacency. Over and over, it was urged to think upon the value of local knowledge and experience. Over and over, it was urged to find the means of involving fishermen in the process of decision making. **Over and over, it was urged in so many words to reflect upon the proposition that there are categories of knowledge that are not amenable to**

quantification and that, even if they cannot be incorporated into mathematical models, should not for that reason be scorned.

From the foregoing it will appear that the preponderant voice heard at the public hearings was that of the inshore fishermen. And that is, indeed, the case. Nevertheless, it should not be thought that the offshore trawler industry does not, as well, have its passionate and articulate spokesmen. Nor are such persons merely tools or agents of major corporate interests. For there are communities whose traditions are offshore and whose survival depends upon the maintenance of a viable trawling industry. From their perspective they are the truly endangered species. Already more highly regulated than any other branch of the fisheries, with their every action subject to the supervision of law and authority, they are as well the most consistently productive component of the entire fishing industry. And if they are very efficient fish killers they are also, because they function under such close governmental supervision, potentially efficient agents of conservation. Compelled by law and by self-interest and being responsive to an increasingly demanding market, they have long since abandoned their old ways of profligate destruction so that the current generation of trawler men have never witnessed the practices that still inspire the mythology in forming the inshore prejudice. And if they do fish upon spawning concentrations, they do so with the clear conviction that such a fishery is not of itself inimical to the viability of the stock. Supported by the weight of evidence provided by the international scientific community, they are persuaded that the real threat to a population is the killing of too many individuals so that not enough are left to constitute a viable spawning biomass. There is no magic in the date on which the killing occurs.

In addition to the scheduled public hearings, Panel members met on request with individuals and groups who, though unable to be present at public sessions, were yet desirous of making their views known or who wished to supplement the presentations they had already made in the public forum. These included officials from the Government of Newfoundland and Labrador, scientists from Memorial University of Newfoundland, officers of Fishery Products International Ltd., the Economic Council of Newfoundland and Labrador, a former member of the fisheries observer programme, and others.

1.5.0 Organization of the Report

In the meantime Panel members were busily engaged in attempting to read and digest the enormous volume of documentation that had been assembled for their consideration. Individual members of the Panel were assigned specific writing and research tasks and periodic meetings were held to debate issues, to share information, and to seek consensus in respect of critical issues. The overall structure of the report was collectively determined but the final task of collating and editing the several contributions of Panel members into a coherent final report was assumed by the Chairman who must, therefore, bear responsibility for the style of this presentation.

If the Panel were to make a single collective complaint, it would be the very tight time frame into which its work has had to fit. From the very beginning it has worked under extreme pressure, not only because of the enormously important issues upon which it is required to pronounce, but because of the great complexity of the questions with which it has been confronted. It is inconceivable that Panel members should have been able in the time at their disposal even to strip mine the wealth of published material touching its concerns or to address, in anything like comprehensive fashion, the range of environmental and socio-economic concerns that must inform any approach to a satisfactory resolution of the crucial questions before us. It has, therefore, tended rather to oversimplification than otherwise and has probably raised new questions where some might have expected it to provide answers. Perhaps its best hope is that in stressing certain fundamentals both in respect of principles to be observed and of gaps in our knowledge to be made good, we will have pointed a direction that will lead ultimately to the desired goal of a healthy stock of northern cod and a viable fishery based upon it.

1.6.0 Acknowledgements

The Chairman of the Panel would be remiss if he did not acknowledge the total commitment and the hard work of all Panel members who accepted his chairmanship with such good grace and in such a spirit of cooperation as to leave him with nothing but a most profound sense of gratitude. In particular, he wishes to acknowledge the outstanding contribution of Dr. D. L. Alverson whose breadth of knowledge, whose wide experience, whose former familiarity with the northern cod problem were all of enormous value to the Panel's deliberations and whose profoundly humane values so inform his science that working with him was a joy. The Chairman also is happy to acknowledge a great debt of gratitude to Mr. John G. Pope upon whose very special expertise in the domain of mathematical modelling the Panel placed its reliance and whose performance has not been disappointing. The Chairman and Dr. Alverson owe him a particular word of thanks for the warmth of his hospitality at his laboratory in Lowestoft. Indeed, they must in this context express their thanks, as well, to the Directorate of that Laboratory who permitted such generous access to their staff and facilities.

To all those people along the coast of Newfoundland and Labrador who participated in the public hearings the Panel expresses its gratitude and its admiration. The arrangements were in all cases excellent and the participation all that could be desired. To those with no previous exposure to rural Newfoundland the experience was both enlightening and moving. Perhaps it would not be inappropriate to single out for particular mention the splendid meal and superb hospitality provided by the Makkovik Women's Group and the very special courtesies extended to the Panel by Ms. Carol Burden at Port Hope Simpson.

To Mr. M. C. Mercer and his staff at the Northwest Atlantic Fisheries Centre the Panel is also deeply grateful. They have been unfailing in their cooperation and have given freely of their time and talents as they were called upon. There is not any sense in which more could have been expected and even in expressing its criticism the Panel does so with respect for their integrity as scientists and in full recognition of the great difficulties of the tasks confronting them. The Panel would also acknowledge with gratitude the assistance of Mr. C. A. Whalen and his staff.

The Chairman and members of the Panel involved with historical research would record as well their grateful appreciation of the work of Ms. Barbara Cox who assembled and compiled virtually all the statistical data in Chapter II, compiled the bibliography, and willingly and efficiently undertook literature searches and other useful tasks upon request. Her invaluable services were

made available to the Panel through the courtesy of Dr. Niall J. Gogan, Associate Vice-President (Research), Memorial University of Newfoundland who permitted her part-time secondment to the project.

Finally, the Chairman and members of the Panel must acknowledge the person of whose superb organizational skills they stand in awe. Mrs. Florence Parsons has been the secretariat. With total efficiency and unfailing good humour she has made all ways smooth, kept the Panel closely to what often appeared to be an impossible schedule, bargained, cajoled and browbeat as circumstances required, sublimated her fear of flying to advance the cause, and withal behaved as the perfect secretary.

CHAPTER II

Historical Overview

2.1.0 Introduction

The first humans to occupy the territories now known as the Province of Newfoundland and Labrador probably settled along the shores of the Strait of Bell Isle, for in the fecund waters of the Strait a fortuitous confluence of oceanographic and biological elements conspired to produce a profusion of marine life, fish, flesh, and fowl that promised a seemingly inexhaustible resource for those who could harvest its teeming abundance. Several millennia later, the first Europeans known to have inhabited any part of North America also chose for their settlement the region of the Straits and, perhaps, for similar reasons. Some five hundred years later still the stench of great trying pots signalled the presence at Red Bay and other adjacent harbours of Basque whalers also intent upon the exploitation of the riches to be wrested from those northern waters.

The coming of the Basques heralded the dawn of a new and different era. The native peoples who for some seven or eight thousand years had exacted a subsistence economy from their harsh environment were, with their primitive technology and their small numbers, incapable of diminishing to any appreciable degree the prolific life supported by the seas around them. But the Basques were a different kettle of fish; not in and of themselves, but because they represented the first wave of West European expansion that carried the flags of Europe to every corner of the earth and that brought newly burgeoning European technology to bear upon the exploitation of earth's resources wherever they might be found.

2.2.0 Evolution of the Fishery

Among those resources were the great stocks of northern cod whose seasonal migrations to the shallow waters of the near shore and of the offshore banks made them accessible to the technology of the age. And so the earlier adventurers with their visions of the fabled Northwest Passage, of magical spice islands, and mountains of gold were replaced by others whose more prosaic mission was the catching and curing of cod for sale in the markets of Europe.

There is some evidence suggesting that there were English voyages to the shores (or Banks) of Newfoundland as early as 1481. In any event, by the opening decade of the sixteenth century the fishing ports of northern Europe were rife with stories of fish so abundant that they impeded the progress of ships and that were to be caught by the simple expedient of lowering a basket over the side and drawing it up filled. In those circumstances, fishermen of Portugal, Spain, France, and England were prepared to place their vessels and their lives at hazard in braving twice each year the dangers of the western ocean passage.

Through the course of the sixteenth and seventeenth centuries there developed a substantial migratory fishery prosecuted on the banks and in the coastal waters of Newfoundland and Southern Labrador. For the nations of continental Europe, it was, by and large, a ship fishery in which the cod was taken back across the ocean each autumn in what we would now describe as "salt bulk" to be washed and sun dried in their own salubrious climates. The English alone, perhaps because they lacked a native source of cheap salt and perhaps because of somewhat damp autumnal weather, developed the practice of light salting and drying on the shores of Newfoundland. This, in turn, led to settlement. In the first instance winter crews were left behind in the fall — to cut timber and erect wharves, stages, flakes, and other structures of a standard fishing room; to serve as watchmen and caretakers or merely to hold good berths for the next season. In time some of these became attracted to the land and chose to stay to become land and property owners if, indeed, penniless ones; others opted for the comparative freedom of life in a new world. For a host of individual reasons Newfoundland, "the great ship moored near the fishing banks," became by slow evolution a crypto-colony with a settled population.

By the same token, the economic structures that had emerged in the age of transience were transformed into systems dependent upon resident fishermen; the dogma of the fishery as the great training school for English seamen became a meaningless shibboleth and the statutory injunctions against settlement came to be more honoured in the breach than in the observance. So the population grew and particularly during periods of war, notably the Seven Years' War (1756-1763) and the Napoleonic War (1792-1815), when market demand drove fish prices to unprecedented heights and when wartime conditions made the ocean passage more hazardous than heretofore. And as it grew, so did the peculiar nature of Newfoundland demography become established.

2.3.0 Cod and Demography

There are two significant characteristics of that demography that relate directly to cod as the *raison d'etre* for Newfoundland's existence as a distinct society. First there is the fact that the settlers' beachheads at the edge of the sea were tenuous. Unlike situations facing their counterparts to the south, the hostile land confronting those newcomers to the shores of Newfoundland daunted any budding anticipation of landward development and left them clinging to the barest margin of the sea facing eastward and looking to the continental shelf that lay submerged before them as their primary field of endeavour. The constraints of this environment precluded the kind of diversified production that allowed the development of a different society in New England and to a lesser extent in the Maritime provinces and determined the nature of the cultural and commercial patterns that were to control the lives and destinies of Newfoundlanders for centuries.

The central significance of this phenomenon should not escape us. The Newfoundlander did not clear the forest and plant fields; he did not stake claim to vast tracts of land; he did not often bother even to give names to prominent physical features of the landscape (excepting those that bordered the sea). Indeed, he hardly even thought of the land except as a convenient platform from which to exploit those underwater banks and shoals to which he did lay claim and whose every feature he knew and named as farmers did their field and pastures. Small wonder then that the typical Newfoundland fisherman should resent allegations and legal determinations purporting to show that his fields because they were covered by water were common property and that his reliance upon them as his only source of livelihood for four hundred years or so counted for less than nothing.

The second demographic characteristic of interest to us is that which relates to the fact that it was not sufficient for our early settlers merely to live beside the sea; it was crucially important to live beside the resource that the sea afforded. And that resource was not evenly distributed throughout coastal waters. Locations for settlement were those at which a precise combination of geographic, oceanographic, and biological elements came together, the essential conditions being the interaction of winds, tides, and currents, operating to keep plankton rich waters sufficient to attract concentrations of feeding fish within reasonable distance (given primitive technology) of an adequate haven with sufficient foreshore and a supply of fresh water. Look at the early and ultimately most successful settlements and we will see that they do not represent the best or most sheltered harbours, the best and most readily accessible supply of wood, the best and most accessible supply of arable land or of fresh water; rather they frequently offer only the barest modicum of shelter from the seas, only a modicum of passably good land, only the least amount of fresh water necessary to survival. What they have in common is easy accessibility, at a time before the invention of the internal combustion engine, to good fishing grounds. Thus, we see early successful settlements at Hibbs Hole but not at Avondale, at Bay de Verde but not at Holyrood, at Bonavista but not at Clarenville, at Greenspond but not at Valleyfield, at Fair Island but not in Indian Bay, at Fogo but not at Lewsiporte, and so on through the whole of the gazetteer of the coasts of Newfoundland and Labrador.

2.4.0 Northern Cod — The Socio-Economic Context

The settlement pattern dictated by the overriding importance of accessible fishing grounds has over the centuries created a unique set of problems for successive Newfoundland administrations. These include a relatively small population, thinly scattered in more than one thousand communities along ten thousand miles of coastline, often in the locations most difficult of access involving astronomical per unit cost for basic infrastructural services like roads, harbours, electricity, water, sewage, schools, and hospitals; and, all dependent upon a single seasonal resource that fluctuated in availability in tune with environmental fluctuations that were neither understood nor controllable.

Nevertheless, this demographic pattern, a nightmare to finance ministers and central planners, constituted the foundation of the Newfoundland socio-cultural experience and created lifestyles that have become the object of passionate adherence and that inform a political consciousness that has not grown weak with time but rather, in recent decades, has witnessed a virtual renaissance. The personal and social values of hardihood of endurance, of survival, of resilience, of neighbourliness, of sharing, of community, of independence have become the immutable elements of a mystique that might almost be described as the cult of the unique and distinctive Newfoundland. We have only to look to the political history of the past twenty-five years to recognize the old passions that were evoked in the face of a perceived threat to the social structure. A political party that had been deliberately identified as "Her Majesty's **Outport** Government" and that had been more popular than any that had ever before existed was swept from power by one whose name had, heretofore, been anathema to much of the rural community. The magic formula offered by the new dispersation was a commitment to turn the tide of centralization and to promote economic development in the context of "Newfoundland Culture," the preservation and conservation of the distinct Newfoundland society and lifestyle predicated upon the historic demographic pattern.

Nor can there be a doubt of the intimacy of the relationship between that distributional pattern and the accessibility of northern cod. The spread of settled population northward from very early centres on the Southern Shore and in Conception Bay to Trinity Bay, to Bonavista Bay, to Notre Dame Bay, to the Northern Peninsula (when the exigencies of imperial relations with France permitted), and to the coast of Labrador was, in part, a response to increased crowding of inshore fishing grounds and in part an aspect of the competitive urge to be first to occupy the headland areas to which the summer migration of cod came in greatest abundance. Through this process the whole of the east and northeast coast from Cape St. Mary's to Cape Chidley was by the beginning of the twentieth century dotted with fishing communities, though the coast of Labrador had retained some of the prototypical characteristics of the early transient West Country fishery to Newfoundland. That is to say, much of the Labrador fishery continued to be prosecuted by fishermen, whether "floaters" or "stationers," who maintained permanent residence in villages strung along the east and northeast coast of the island. In any case, roots had been sunk deep, or to use a more appropriate metaphor, holdfasts had been securely attached in hundreds of coves and harbours and bays which, as inhospitable as some might to the casual glance appear, had become the focal point of all those associations, both practical and emotional, that connote home and community. After three or four hundred years of occupancy even a barren, rock-strewn piece of foreshore becomes an infinitely valued piece of property, sanctified by the lives and the striving of a family through many generations. A house that is owned outright and that stands on the site once occupied by one's father, and his father and his father's father becomes a sacred property not to be lightly abandoned. An environment whether physical or social in which one has exclusively lived and moved and had one's being; a church in which generations of a single family have worshipped; a churchyard in which the bones of generations of ancestors have been laid; a seasonal round of work and relaxation made comfortable with time; are but some of the elements that together constitute a lifestyle fostering social and emotional security and not lightly to be forsaken.

Of course, there are none who doubt that the whole structure collapses when the fish, that is to say the cod, fail in their annual migration to appear in the shallow coastal waters where they have traditionally been accessible to the relatively unsophisticated technology of the inshore fisherman. For a year or two or three, poor catches may be endured. Traditionally in such times, the merchant offered credit or the government offered dole sufficient between them to obviate outright starvation. But in the end, either the fish returned or the community died. There was and is no middle ground. There was and is no other economic activity to which the dispossessed fisherman could turn. The limited agricultural and pastoral pursuits, the small sawmilling operations, and such like were supplements to and not replacements for the fishery. If the fish failed, the ultimate solution was to release the hold-fast and move in a few cases to urban centres within Newfoundland but more probably to "the Boston States" or latterly to the mecca of Southern Ontario. Nevertheless, the hold of the land was so strong that many refusing to irrevocably sever the connection with "home" became seasonal migrants seeking summer employment in the construction camps and mines and mills of Northern Canada and returning each winter to the place that had given them birth and in which they could find the psychological security their spirits craved. It is no accident of language that an average Newfoundlander will say not that "I come from ..." but rather "I belong to ..." (a particular community)

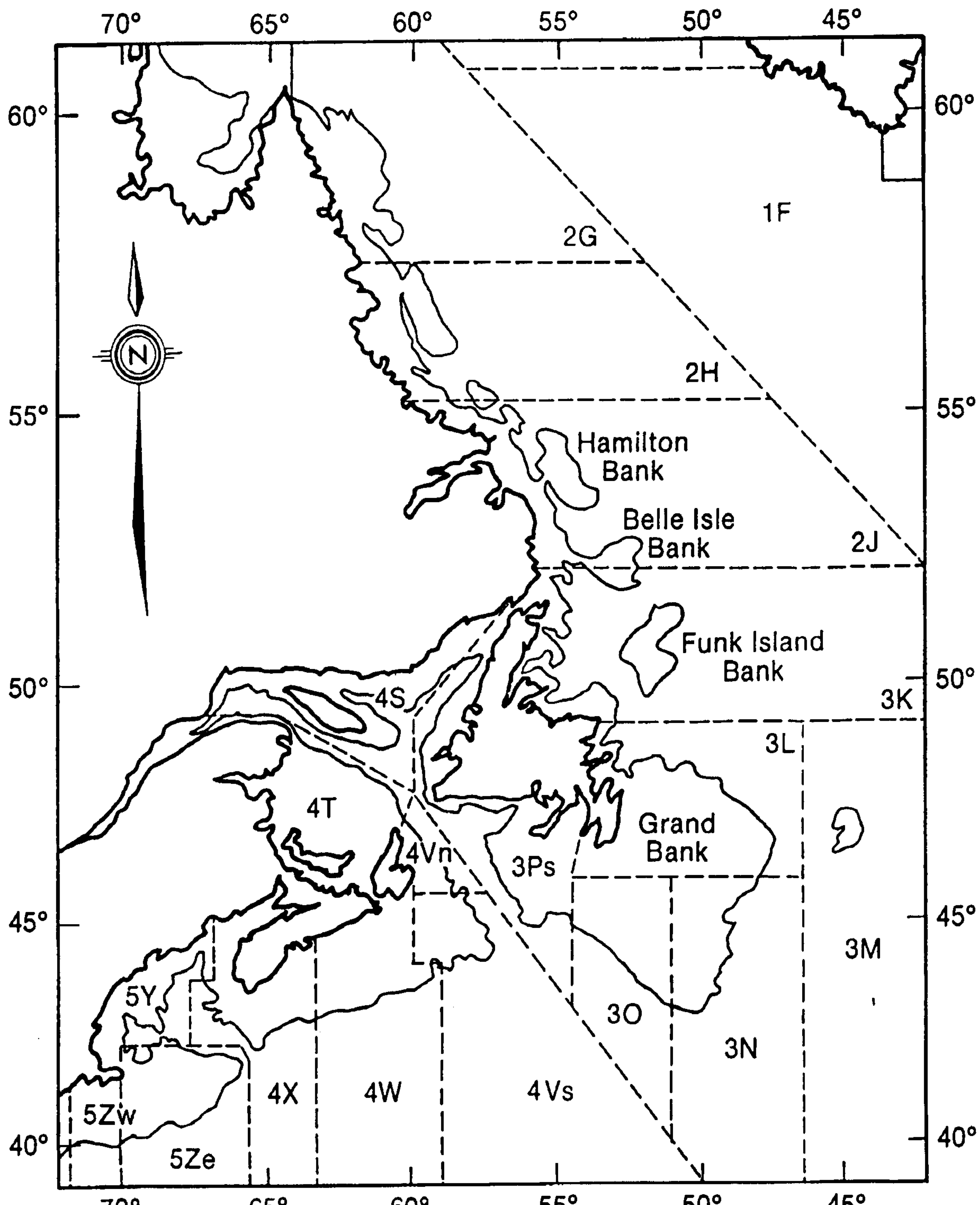
In short, if we contemplate, over the long-term, the demise of the northern cod stocks, we contemplate the death of communities along the whole east and northeast coast of Newfoundland as we have known them. For the vast majority of the communities in question, northern cod was their only reason for existence and northern cod remains the only substantial economic basis for their survival. And this is a simple statement of fact and not an argument pro or con.

2.5.0 Northern Cod — Historical Landings

Let us now examine the nature and extent of the economic base as it has been exploited over the years.

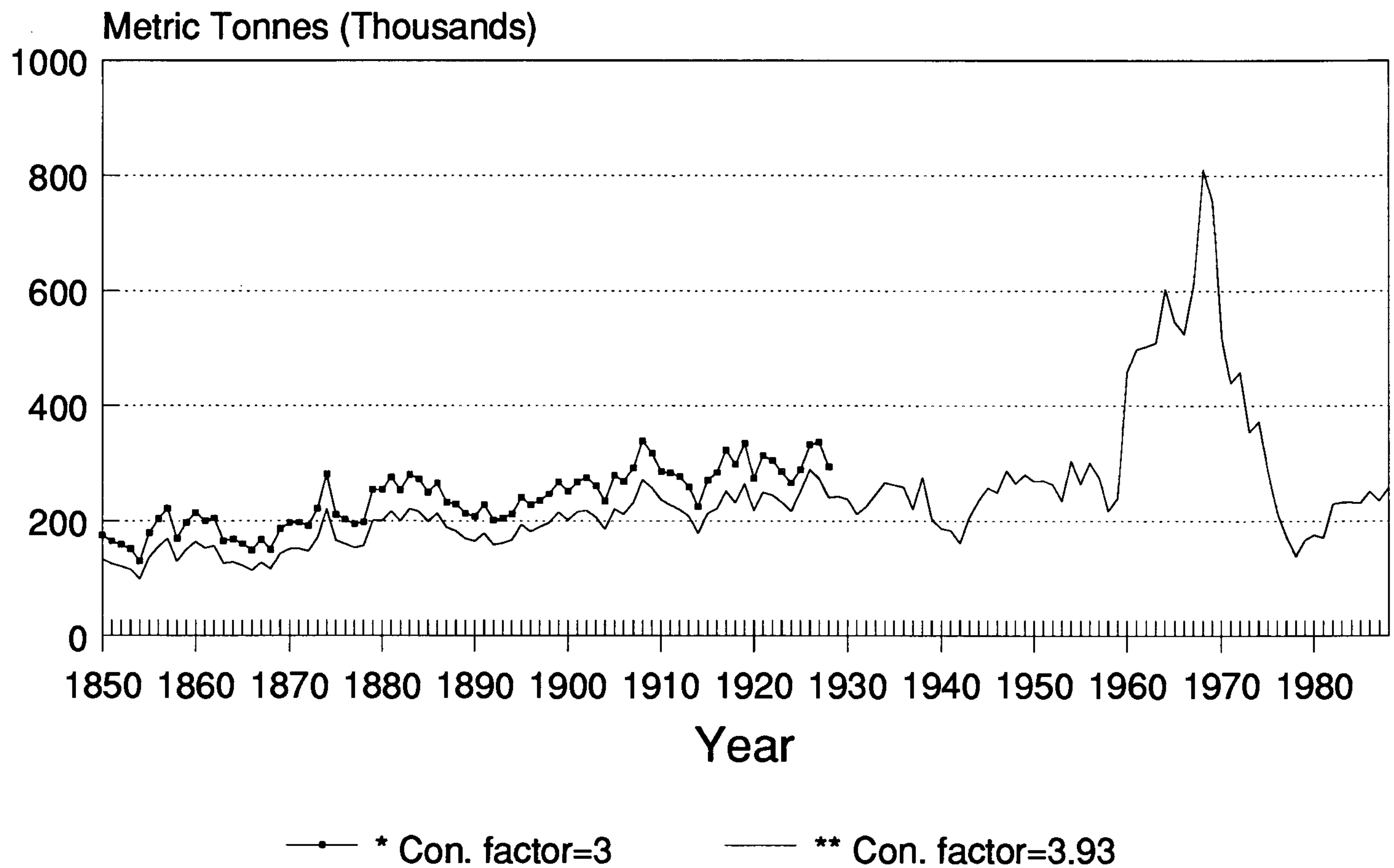
Figure 1 is an attempt to reconstruct from available data historic landings of northern cod from waters that are now designated as management zones 2J, 3K, and 3L. We cannot, of course, be certain of the absolute accuracy of the figures cited for a number of reasons that will appear. An attempt has, however, been made to reconcile the difference in statistical treatment that appear in the several sources that have been used. In consequence, what emerges is probably sufficiently close to reality as to provide a reasonably sound basis for our conclusions.

Landings in the 2J3KL (see **Figure 2**) area prior to 1952 are estimated from data provided in Part 4, *Second Annual Report of the International Commission for the Northwest Atlantic Fisheries* (often cited as Volume 1, *ICNAF Statistical Reports*, 1951). The historical data presented by ICNAF were, in turn, derived from "Statistics of the Catch of Cod off the East Coast of North America to 1926" by Oscar E. Sette, U. S. Bureau of Fisheries Document No. 1034, supplemented to 1928 by R. H. Fiedler and R. A. Power of the U. S. Bureau of Fisheries. ICNAF data presented



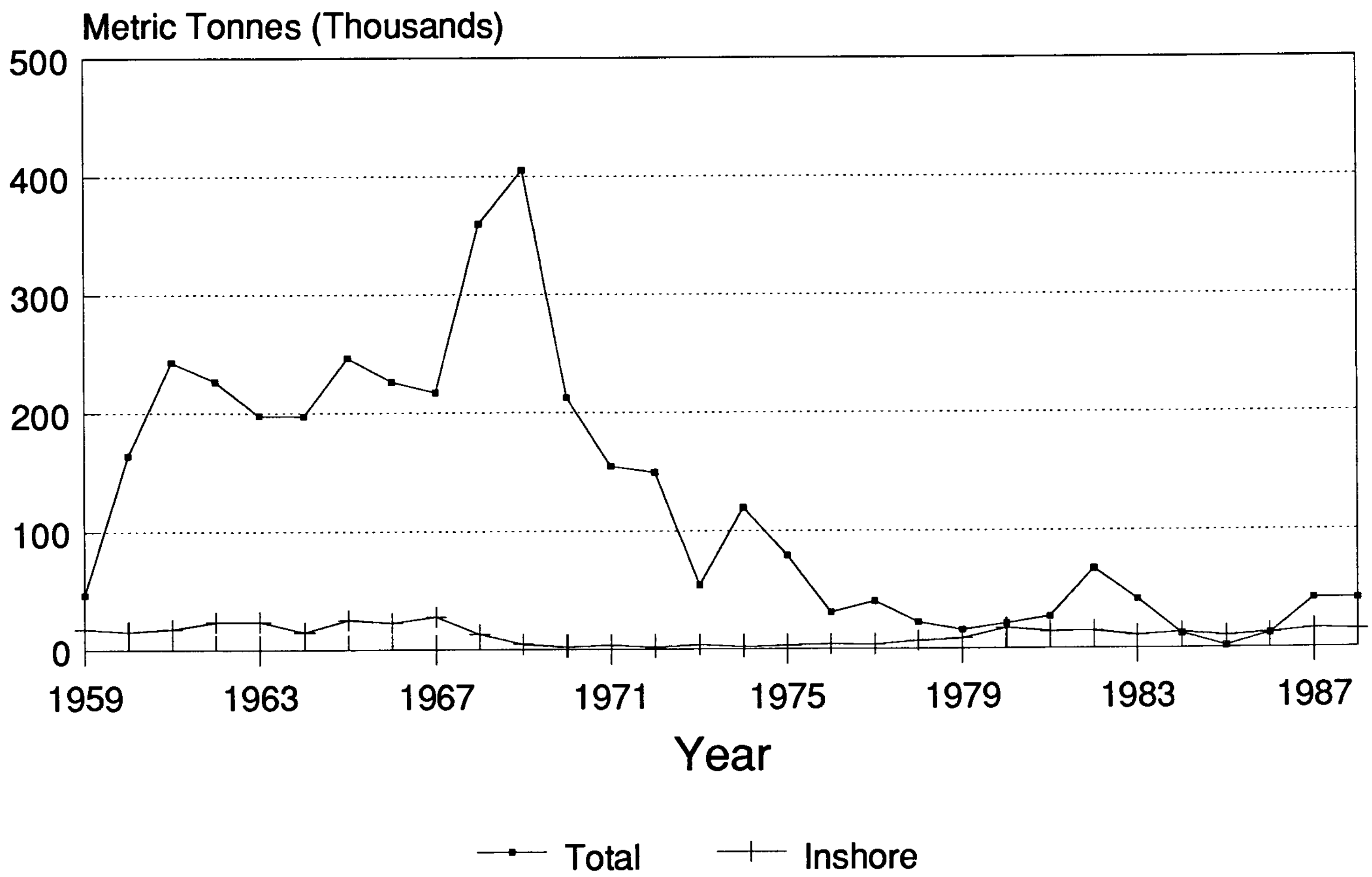
Map showing 2J3KL divisions

Figure 1: Cod Landings 2J3KL
1850-1987



* NF Dry to Fresh Conversion Factor=3
**NF Dry to Fresh Conversion Factor=3.93

Figure 2: Historical Catches of Cod
Division 2J



for the period 1929-1951 were obtained from reports of the Newfoundland Fisheries Research Station. Actual landings covering the period 1952 to 1987 are available for the 2J3KL area from ICNAF Statistical Bulletins (Vols. 2-28) and NAFO Statistical Bulletins (commencing with Vol. 29).

Historical reviews of the period prior to 1951 either cite the ICNAF statistics or Sette's U. S. Bureau of Fisheries Document No. 1034, or they present data that correlate closely with these sources. Therefore, these statistics would appear to be the best available data from which to calculate total landings in the 2J3KL area.

In making such a calculation, however, we must be aware that for the historical period prior to 1952 the data we have refers to total Newfoundland landings. To derive from those figures the 2J, 3K and 3L landings, we must determine what percentage of the total came from those zones, and we have estimated that figure to be in the order of 74%.

The rationale for such an estimate derives from the record of actual landings in the 2J, 3KL areas between 1953 and 1961 as reported in ICNAF Statistical Bulletins 3-11. Yearly percentages for the period in question range from a high of 80% in 1953 to a low of 68.1% in 1958 and it will, therefore, be apparent that the assignment of any fixed number will result in overestimations for some years and underestimations for others.

However, it should be noted that for the first four years, 1953 up to and including 1956, the percentage of cod landings attributable to the 2J3KL area were consistently above 75% while for the years 1957 to 1961 they were consistently below. Since it would appear that the earlier years of the nine-year period analyzed are more representative of the 1850 to 1952 historical period, it follows that taking 74% of total landings will probably provide a conservative estimate of the 2J3KL landings prior to 1953.

To provide a complete estimate of 2J3KL landings, landings by Canada (other than Newfoundland) as well as landings by other countries have to be taken into account. Unfortunately, the historical data for Canada (other than Newfoundland) are available only from 1869; for France from 1874; and for Portugal from 1896. Spanish landings are not reported by ICNAF until 1951. For the data that are available, once again, estimates of the portion attributable to the 2J3KL area have been based on a fixed percentage determined by obtaining the average of actual landings reported in the 2J3KL area over the years 1953 to 1961. Canadian (other than Newfoundland) 2J3KL landings have been calculated on the basis of 5.5% of total reported landings for the period 1869 to 1952; French 2J3KL landings have been calculated on the basis of 38% of total reported landings for the period 1874 to 1952; and Portuguese 2J3KL landings have been calculated on the basis of 30% of total reported landings for the period 1896 to 1952. For the period 1953 to 1987, as indicated above, the graph combines actual reported landings by all countries in the 2J3KL area.

To add to the difficulty encountered in providing a reasonably accurate assessment of total 2J3KL landings in the years prior to 1953, a number of estimates which were included in the total landings presented in the ICNAF statistics have to be assessed. The landings reported to 1928 by Oscar E. Sette *et al.* were converted from exports of dried fish (quintals) to landed pounds of fresh round cod by multiplying by a factor of 3. He also included an estimate to cover Newfoundland consumption. The landings from 1929 to 1951 reported by the Newfoundland Fisheries Research Station were reported in thousand pounds fresh fish, head on and eviscerated. ICNAF converted these data to round fresh weights by using 1.20 as a conversion factor.

While the factor of 1.20 used to convert the landings reported from 1929 to 1951 appears reasonable, the factor of 3 used to convert exports of dried fish to landed pounds of fresh round cod from 1850 to 1928 seems rather low. An additional set of computations have, therefore, been used to show on the graph the result of using a factor of 3.93 (440 pounds fresh to 112 pounds dried) to convert to landed pounds of fresh round fish. The amount factored in for domestic consumption, on the other hand, could be a little high. Sette assumes a consumption rate of 3 quintals of dried cod (336 pounds) per family per year or 97.78 pounds of dried fish per person per year. The graph from 1929 certainly seems to suggest that the combined estimates of domestic consumption and the 3.93 dried to fresh conversion rate are on the high side.

Nevertheless, we must also note that DFO has used a conversion factor of 4.88 per quintal of salted dried fish in some of their catch calculations while the ICNAF statistics are based on a conversion factor of 3.0. If indeed 4.88 were the appropriate figure, the graph for the period 1850-1949, at least, would shift upwards. The same pattern of fluctuation would, of course, remain.

Setting aside the inescapable imprecision in these data, we may, nevertheless, express a reasonable confidence in the general pattern. And that pattern shows that, even if we take the higher graph line representing the most optimistic conversion factors, the 2J3KL stock(s) of cod prior to 1959 sustained an annual production that in the peak years did not reach 350,000 tons and that on average was not in excess of 250,000 tons. The significant technological innovations introduced in the late fifties and early sixties of the twentieth century produced landings that in its peak year exceeded 800,000 tons, but that effort precipitated a crash to levels as low as any recorded in the previous century.

It is clearly not possible from this superficial examination of historical data to arrive at a firm conclusion in respect of the sustainable yield from the 2J, 3K and 3L stock(s). What does appear, however, to be a reasonable proposition is that an annual reported harvest of 300,000 tons was a sustainable figure in the years between 1902 and 1958, while harvests in excess of 600,000 could not be sustained during the later 1960s and early 1970s as was clearly evident from the notable and rapid decline in both catches and estimated stock size.

2.5.1 Limits of Growth

It is, perhaps, sometimes appropriate to state the obvious. And it is obvious that even in its virgin state, before the intrusion of any fishermen, the numbers of cod did not grow infinitely. Within any particular ocean regime, finite limits to growth are, in fact, set by combinations of biological and physical conditions that determine the life-sustaining capacities of the whole and that determine as well the success or failure of the individual species within the complex of interrelated species inhabiting a particular ecosystem. If this were not so, John Cabot might have walked ashore from the Matthew on the backs of densely packed cod and even in modern times, cod would, for example, be abundant in the 2GH management zones from which no significant numbers have been taken in the past twenty years or more.

There is, therefore, a finite biomass of codfish that the 2J, 3KL region of the northwest Atlantic will support. Clearly, the largest size of that biomass will be attained when all environmental conditions are at their optimum. Fluctuation in the biomass will occur with the vagaries of wind and current, with changes in temperature regimes, with increases or decreases in salinity, with the success or failure of other species, with the incidence of naturally arising or induced pathologies, with levels of natural or introduced pollution, or with any one of dozens of other causes. For the life that the ocean system supports is a complex and intricate web constantly seeking but never achieving an equilibrium.

The intrusions of fishermen who selectively remove particular species may disturb the natural balance in a most profound way. Indeed, the perturbation thus created may lead to total annihilation of species. Man's history in the terrestrial regions and in respect of marine mammals is replete with such instances. Fortunately, the cod and other marine species of which we have become major predators have heretofore shown sufficient resilience as to survive the worst excesses of our rapacity. But we cannot assume that it will be always so. If we continue to insist upon walking the very edge of the precipice, the laws of chance ordain that we daily walk in greater danger of falling over. The oft-repeated story of our assault upon the haddock stocks ought to be an instructive parable. In the case of northern cod, the madness in which we indulged in the decade 1964-1974 ought to stand as a great warning beacon that we should never forget.

Nor should we fail to observe that even if we were capable of bringing our science to a state of perfection and establishing the optimum yield with great precision, we would still be dealing with an ephemeral number that would hold only so long as all other conditions remained equal. Thus, even subtle changes in the oceanographic regime could lead to either an increased or diminished capacity of the system to sustain life and by the same token would weaken or strengthen the capacities of individual species to be fruitful and multiply. It need, for example, hardly be argued that an adequate and accessible food supply is a necessary condition to the optimum growth of any animal and that growth rates and weight-at-age are critical determinants of biomass. In consequence, any changing environmental conditions that reduce the abundance of dominant prey species to less than the optimum demands of its predator species will result in a reduced biomass. In this context, recent experiences in the Barents Sea respecting the cod-capelin relationship clearly demonstrate the point. Heavy exploitation of capelin, limiting the food supply available to cod, led to reduced weight-at-age among the latter and, consequently, a substantially reduced biomass.

What is true for cod-capelin may also be true for other similar relationships. Thus the introduction of a crab fishery or a shrimp fishery will, since both crab and shrimp are food for cod, carry with it the potential for reducing the food supply available to cod below the optimum level with the inevitable result of a reduced biomass. Conversely, however, we should also note that exploitation of cod may reduce predation levels on their prey species and, perhaps, ensure the survival of such species. The same argument can obviously be applied *pari-passu* to a great many other sets of circumstances. An environmental change that results in declining production of planktonic forms upon which capelin feed will result in a declining capelin biomass; the multiplication of seals that feed upon shrimp and capelin will even if seals eat no cod at all still have the potential for reducing the cod biomass.

But one need not belabour the point. The long and the short of it is that we are dealing with a system and no individual species within that system can be treated in isolation. Whether we are primarily concerned with the scientific assessment of stock abundance, the setting of TACs, the introduction of new fisheries, or any other matter of that nature, we must be continuously aware that significant tinkering with any part of the system can set up reverberations that may echo throughout the whole. Nevertheless, we should also be aware that the system while incredibly complex is not nearly so fragile as may sometimes be supposed. In fact, most ecosystems are subject to major annual and seasonal events that precipitate large changes and force such systems into a continual state of adjustment. Minor tinkering by humans may, in such a context, be frequently lost in the scale of other events.

2.5.2 Fixed and Mobile Gear

We may note as well that the introduction of new styles and methods of fishing and of new technologies that increase the overall fishing mortality on a stock may have far-reaching reverberative effects on resource productivity and upon the fisheries that have traditionally exploited that stock. In the case before us that fishery was predominantly an inshore fishery. That is to say, it was a fishery conducted in shallow water with essentially passive gear. The availability of fish to that gear was dependent upon the constancy of recurring patterns of stock migrations. Codtraps were set, year after year, in the same berths; long-line trawls were set around the same rocks and shoals; hand-lines or jiggers were used on spots of ground precisely determined by traditional "marks" giving exact navigational coordinates. Even the offshore fishery on the Grand Banks was of a similar nature for it, too, was dependent upon fish that was accessible only when its seasonal migration brought it to the shallower regions of the Banks and to such traditional ground as the Virgin Rocks, the Southeast Shoal, the Thirty Fathom Gravels, and so on.

It is true that a passive gear fishery was peculiarly susceptible to the variability of oceanographic conditions and to fluctuations in the overall or local abundance of prey species such as capelin. This is apparent from an examination of **Figure 1** which exhibits a steady progression of peaks and valleys, some of which may be attributable to variability of effort deriving from conditions of war, or market depression, or other socio-economic phenomena, but which in the main signify disruptions of normal migratory patterns in response to changing environmental conditions as well as variable year-class success.

Notwithstanding those year to year fluctuations, the fixed gear fishery produced landings of northern cod that, from the beginning of the twentieth century until the introduction of the deep-sea trawler fleets, rarely fell below 225,000 tons or, if we use the 3.0 conversion factor, below 200,000 tons. In that context, it is instructive to examine the patterns that emerge after 1950 or thereabouts when large otter trawlers and factory freezer trawlers entered the fishery in a major way. Though the charts differentiate between inshore and offshore landings, the real distinction is between the production of fixed gear set in shallow waters and mobile gear deployed in deeper water and particularly upon spawning concentrations heretofore inaccessible.

Figures 2, 3, and **4** show, respectively, inshore and offshore (fixed and mobile gear) landings in the 2J, 3KL zones since 1954 while **Figure 5** is a combination of these three and hence represents the entire northern cod stock(s). Even a cursory examination of these graphs will lead to certain inescapable conclusions. It may be noted, for example, that the rapid expansion of the trawler fleet in the mid-1950s led to significant increases in total catches taken from 2J3KL as a whole and, in particular, from divisions 2J and 3L. Second, it appears that the excessively high landings during the period 1967-1970 subsequently led to declining catches in both the inshore and offshore fisheries. Finally, the graphs strongly suggest that the inshore and offshore fisheries, at least in part, compete with each other for a common resource and that large catches offshore reduce the level of inshore landings. Indeed, the impact of the offshore fishery upon the traditional inshore fixed gear fishery may be significantly greater than the graphs indicate. For, the line indicating inshore landings includes not only the production of the codtrap and traditional near shore hook and line, jigger, and cod net fisheries but as well the landings of the steadily growing fleet of larger and more seaworthy gillnetters, and latterly of small otter trawlers that have steadily moved the "inshore" fishery further and further off shore. That is to say, it has been only through the extensive capitalization of the inshore fishery and a major transfer of effort to tap elements of the cod population that had been previously inaccessible to fixed gear deployed in near shore waters that the inshore fishery has even come close to landing its total allowance which even now represents no more that 44% of the northern cod TAC. The increase of the fleet of 35 ft. to 65 ft. vessels directing their efforts to more and more distant waters has been most pronounced in the 3L zone, less so in 3K, and much less significant in 2J. This fact is clearly reflected in **Figures 2, 3** and **4** which show that inshore landings are lowest in 2J, somewhat higher in 3K and highest in 3L.

2.5.3 Inshore Catch by Gear Type

We can complete the historical picture, insofar as our data will allow, by recording the inshore catch by gear type for the period 1969 to 1988. **Tables 1, 2,** and **3** provide these data for the 2J, 3K, and 3L regions respectively, while **Table 4** gives the combined figures. While the data cannot be used as an index of abundance since they are not in any way adjusted for effort, they are nevertheless interesting in that they show: (1) that the gillnet and long line catches fluctuate almost as widely as trap catches, and (2) that there does not appear to be any directly discernible relationship between, for example, the gillnet and codtrap catches. That is to say, high gillnet catches are not reflected in a reduced yield from cod traps. This may imply that the gillnets by selecting older, that is larger fish, may take those fish that would not, in any case, migrate all the way to the near inshore, or that the mortality on the stock imposed by the gillnet fishery was relatively small and, hence, did not significantly affect trap landings. It would, however, be foolhardy to draw such conclusions from the insufficient evidence before us. A more reasonable proposition is that the success or failure of the inshore fishery, whatever the gear type employed, is contingent upon prevailing environmental conditions, the intensity of the offshore fishery coupled with the success or failure of year-class survival which in turn is responsive to the size of the spawning biomass which is itself, in large part, a function of the number of fish permitted

Figure 3: Historical Catches of Cod
Division 3K

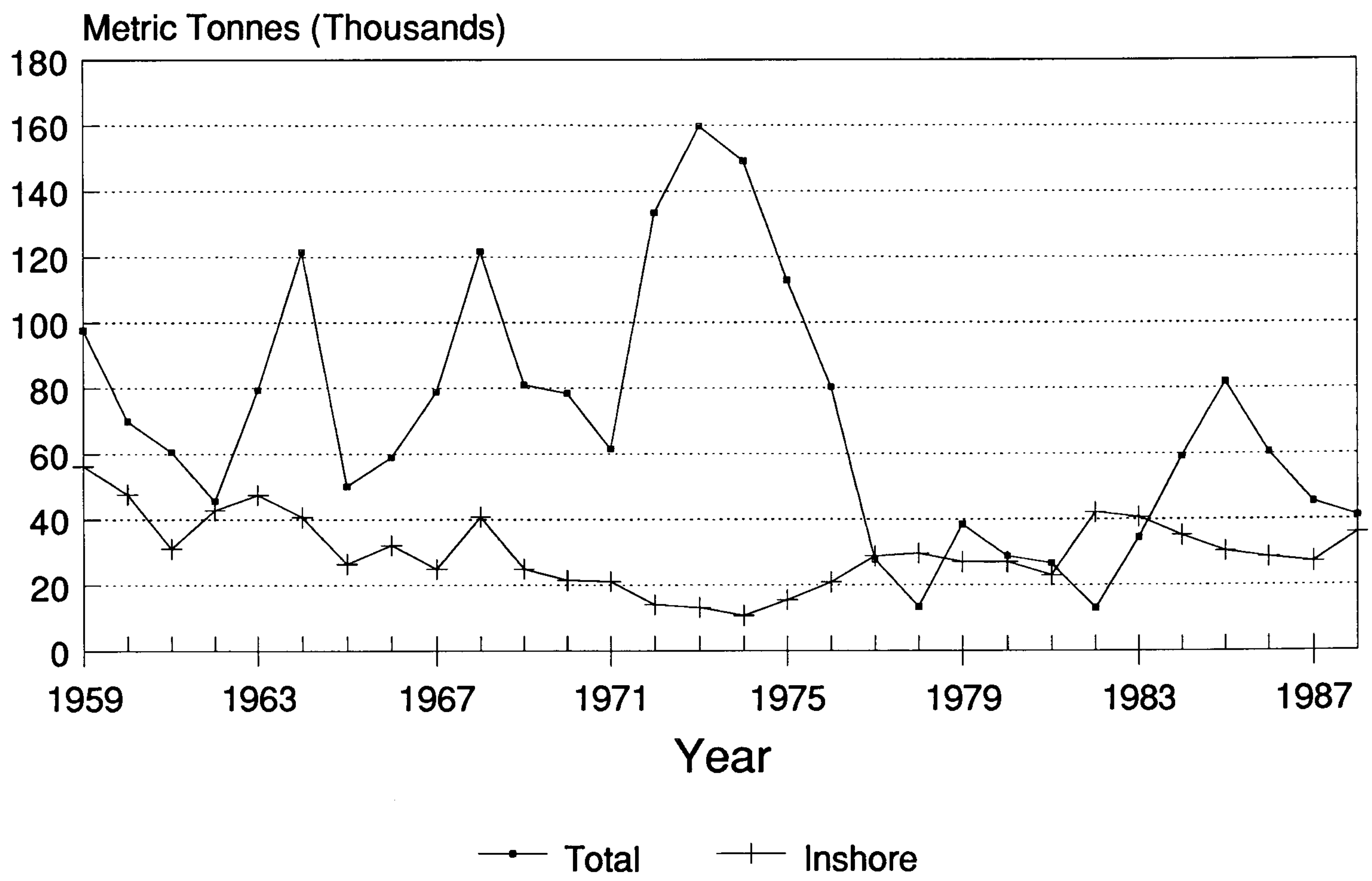


Figure 4: Historical Catches of Cod
Division 3L

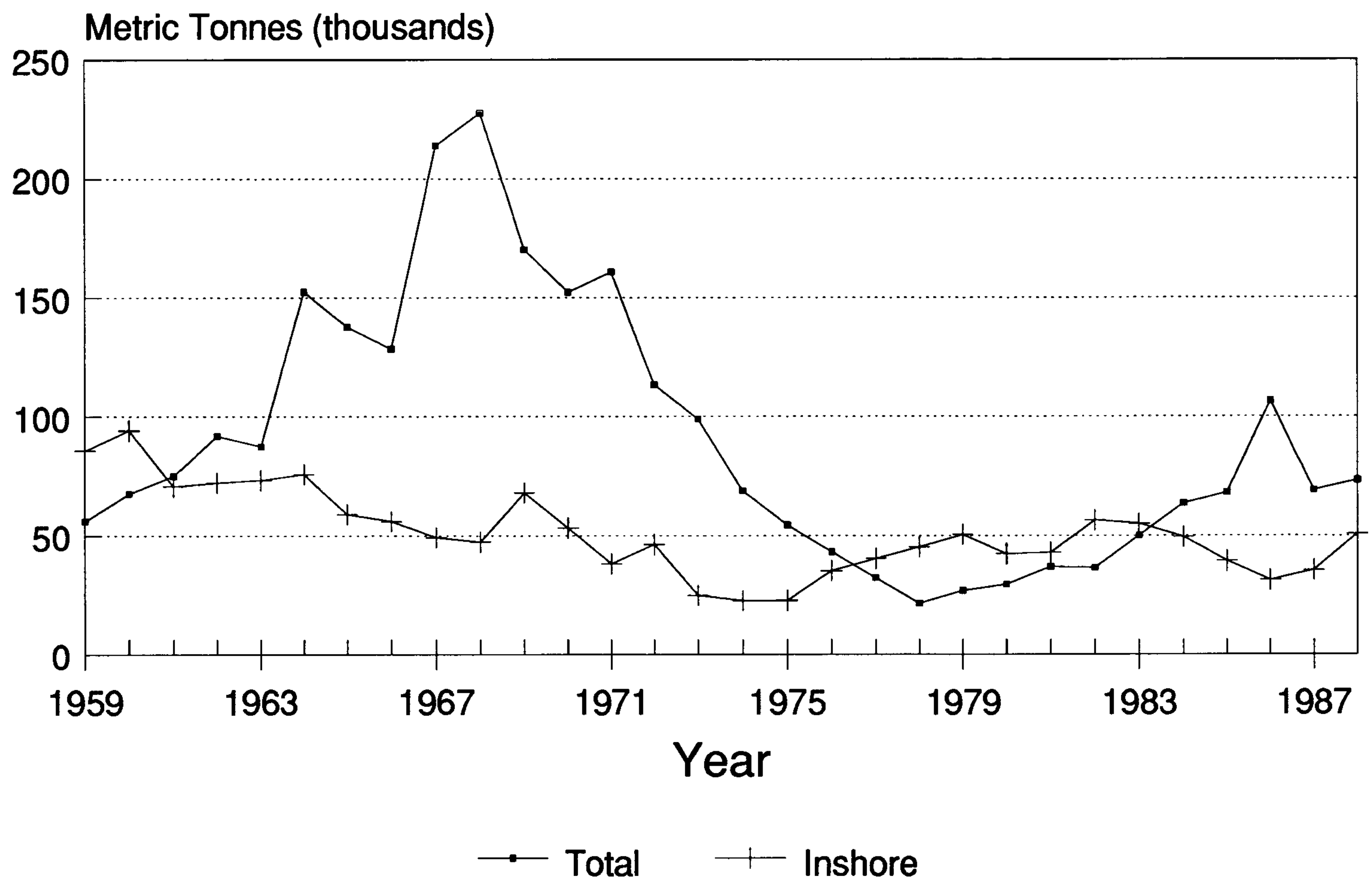


Figure 5: Historical Catches of Cod
Division 2J3KL

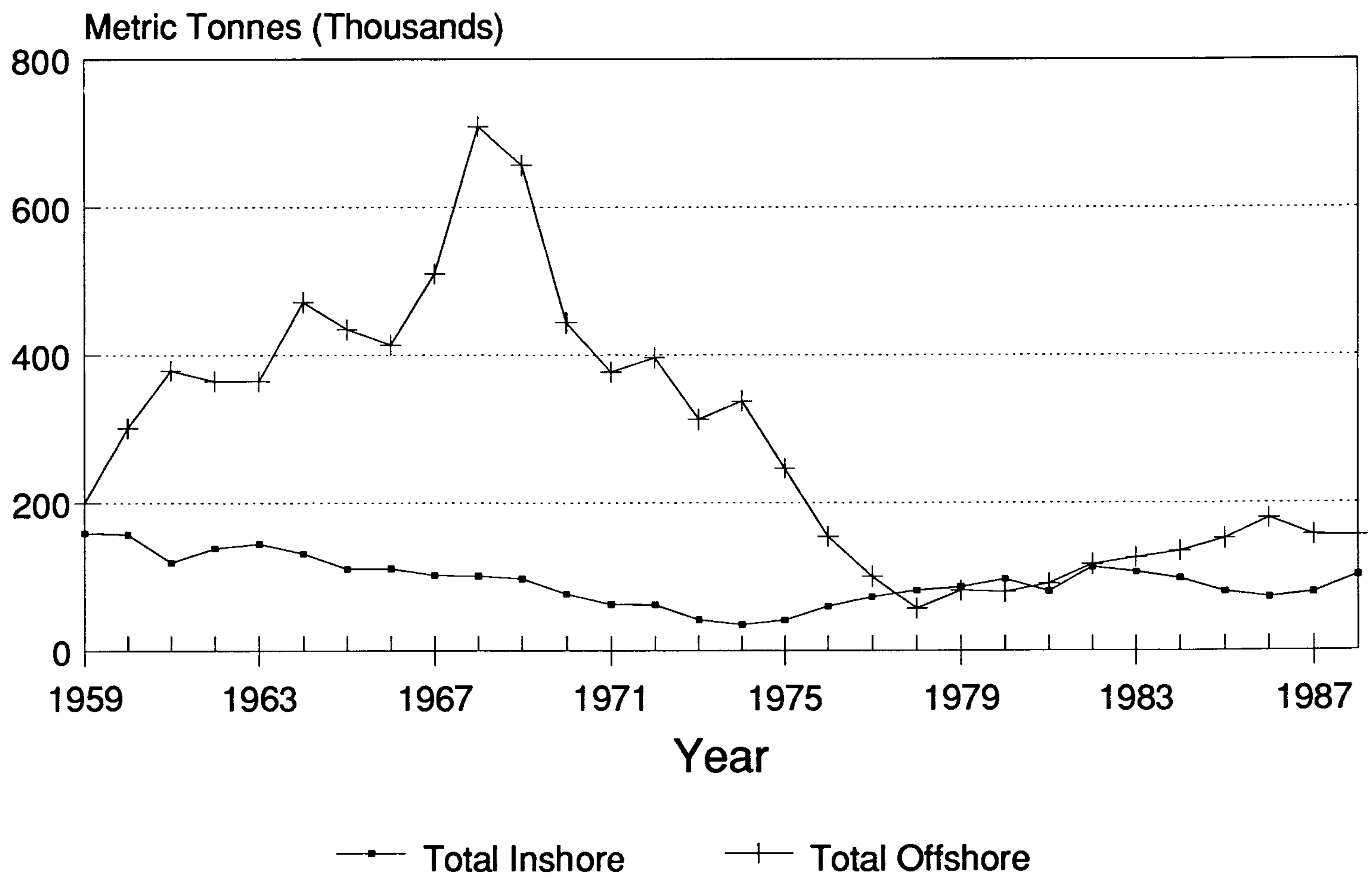


Table 1
Inshore Catches by Gear Type (MT) — Area 2J

Year	Trap	Gillnet	Longline	Handline	*Misc
1969	2,142	1,619	72	278	217
1970	416	317	0	237	993
1971	1,577	707	18	488	523
1972	655	197	47	314	511
1973	1,432	1,196	35	239	717
1974	66	1,520	12	183	23
1975	678	2,269	0	54	-
1976	1,383	2,426	6	36	-
1977	1,466	1,895	37	125	-
1978	3,046	3,202	55	335	-
1979	1,333	5,663	175	1,274	-
1980	4,679	11,414	204	913	-
1981	3,893	10,105	72	181	-
1982	4,464	9,121	114	730	-
1983	3,870	4,854	837	1,182	-
1984	5,618	6,116	379	1,037	-
1985	4,973	2,990	252	1,994	-
1986	4,340	7,607	58	562	-
1987	5,010	9,525	216	1,388	-
1988	6,615	6,607	265	1,774	-

* Represents catches which are not specified by gear type.

Table 2
Inshore Catches by Gear Type (MT) — Area 3K

Year	Trap	Gillnet	Longline	Handline	*Misc
1969	9,058	9,713	1,894	1,975	2,283
1970	6,494	10,843	1,146	1,416	1,613
1971	8,019	9,384	1,356	2,133	219
1972	3,801	7,093	459	1,941	760
1973	3,143	5,695	1,067	2,181	1,104
1974	3,415	4,571	526	2,112	123
1975	4,662	8,495	565	1,646	150
1976	7,056	10,638	718	2,439	28
1977	11,501	11,611	1,294	4,412	-
1978	11,329	11,445	3,647	3,202	-
1979	3,532	11,474	8,407	3,605	-
1980	12,732	13,549	8,059	2,675	-
1981	3,952	10,679	6,360	2,011	-
1982	16,415	17,571	6,101	2,054	-
1983	10,490	18,305	2,558	9,328	-
1984	9,872	14,325	2,396	8,403	147
1985	13,310	8,082	2,352	6,624	-
1986	14,803	7,636	1,416	4,684	-
1987	11,258	10,101	1,479	4,303	-
1988	18,189	12,488	852	4,436	-

* Represents catches which are not specified by gear type.

Table 3
Inshore Catches by Gear Type (MT) — Area 3L

Year	Trap	Gillnet	Longline	Handline	*Misc
1969	42,533	11,623	3,104	8,492	2,221
1970	31,835	10,603	1,768	5,716	3,191
1971	15,832	13,648	3,409	4,552	674
1972	28,021	10,403	1,794	4,706	1,349
1973	12,123	6,250	1,981	2,686	1,799
1974	12,157	5,344	1,460	3,636	32
1975	10,390	7,529	1,641	3,112	23
1976	18,404	9,057	2,904	4,835	9
1977	20,987	8,852	3,591	6,851	1
1978	23,218	9,023	5,114	7,839	-
1979	20,785	13,488	7,022	9,064	-
1980	12,871	11,231	9,394	8,802	-
1981	10,177	13,579	11,419	7,646	-
1982	24,248	20,295	5,693	6,243	-
1983	25,690	16,446	3,832	9,031	-
1984	22,996	14,897	3,804	7,387	344
1985	21,594	8,760	3,245	5,707	-
1986	15,783	8,932	2,437	4,111	-
1987	11,386	17,446	2,083	4,552	-
1988	25,617	14,843	2,261	7,978	-

* Represents catches which are not specified by gear type.

Table 4
Inshore Catches by Gear Type (MT) — Area 2J3KL

Year	Trap	Gillnet	Longline	Handline	*Misc
1969	53,733	22,955	5,070	10,745	4,721
1970	38,745	21,763	2,914	7,369	5,797
1971	25,428	23,739	4,783	7,173	1,416
1972	32,477	17,693	2,300	6,961	2,620
1973	16,698	13,141	3,083	5,106	3,620
1974	15,638	11,435	1,998	5,931	178
1975	15,730	18,293	2,206	4,812	173
1976	26,843	22,121	3,628	7,310	37
1977	33,954	22,358	4,922	11,388	1
1978	37,593	23,670	8,816	11,376	-
1979	25,650	30,625	15,604	13,943	-
1980	30,282	36,194	17,657	12,390	-
1981	18,022	34,363	17,851	9,838	-
1982	45,127	46,987	11,908	9,027	-
1983	40,050	39,605	7,227	19,541	-
1984	38,486	35,338	6,579	16,827	491
1985	39,877	19,832	5,849	14,325	-
1986	34,926	24,175	3,911	9,357	-
1987	27,654	37,072	3,778	10,243	-
1988	50,421	33,938	3,378	14,188	-

* Represents catches which are not specified by gear type.

to survive the total fishing effort. Since fish that escape the efforts of all classes of fishermen tend to congregate in spawning concentrations during the winter months, it is obvious that an important key to a healthy spawning biomass is the establishment of appropriate harvest rates and modes of operation that allow an adequate number of fish to survive to spawn.

2.6.0 Total Fishing Pressure Upon Northern Cod

Having assessed as accurately as possible, given the imperfect nature of our data, the historical indications of fishing pressure that the northern cod stock can sustain, let us now briefly examine the pressures that are in fact currently exerted upon it. The current TAC of 235,000 tons gives us a starting point. To that number we must add bycatches both licit and illicit, underreporting, discards both within and beyond the legal limits, and foreign catches of 2J3KL cod beyond the two hundred mile economic zone. Furthermore, in converting numbers of animals to tonnages, we must be aware of the profound effects that may be induced by changing weight-at-age as a function of disrupted food supplies or density dependent factors.

2.6.1 Northern Cod and Foreign Fishing

In some respects, the easiest of those elements to estimate is that reflecting the foreign fishing effort.

It is currently accepted that the stock complex which supplies the cod fishery in the 2J3KL area is a transborder stock which overlaps with NAFO divisions 2GH and 3NO. In addition, portions of the 2J3KL area fall outside the two hundred mile Canadian management zone and under the jurisdiction of NAFO. Areas of particular interest with respect to the 2J3KL stock complex outside the two hundred mile zone include the "Nose" (NAFO Division 3L) and "Tail" (NAFO Division 3NO) of the Grand Bank. To be comprehensive, therefore, a study of fishing pressure on the 2J3KL stock by countries other than Canada must include an assessment of pressure from international fishing in the 2J3KL area both inside and outside the two hundred mile Canadian management zone as well as in the immediate areas (2GH and 3NO) that border 2J3KL.

An important consideration in any comprehensive study of international fishing pressure on the 2J3KL cod stock is bycatch of cod (both actual and potential) by countries which have been allocated quotas of other fish species in the areas indicated above. The current policy is that a maximum of 10% bycatch of cod is permissible. This applies both inside and outside the two hundred mile zone. However, if a country has a cod allocation for the particular area in which the bycatch of cod is taken, then the bycatch is counted towards fulfilment of its cod allocation.

Tables 5, 6, and **7** calculate total foreign pressure (including maximum potential bycatch where applicable) on the 2J3KL cod stock on a country-by-country basis for the years 1985 through 1987, the last year for which complete data are available. The tables also include for comparison purposes the total nominal catch (by area) reported by each country. (The word "nominal" refers to the live weight equivalent of reported landings.)

For 1985, the total pressure on the stock complex by countries other than Canada was estimated at a maximum of 54,882 metric tons (cod allocations of 13,000 - 2GH; 16,200 - 2J3KL; 16,345 - 3NO; plus potential bycatches of 9,337). However, the total nominal catch reported by countries other than Canada for 1985 was 63,150 metric tons (2GH - 318; 2J3KL - 44,199; 3NO - 18,633). These statistics show that although allocations of 13,000 metric tons were issued in 2GH, the reported catch in that area amounted to only 318 metric tons while reported catches in 2J3KL were more than double those allocated.

This situation repeated itself in 1986 with an increase in the volume of fishing over established allocations in both 2J3KL and 3NO. Although allocations in 2J3KL were reduced from 16,200 metric tons to 9,500 metric tons, reported foreign catches in that area increased to 66,583 from the 44,199 reported in 1985, resulting in catches over seven times those allocated. The maximum pressure on the stock calculated for 1986 at 45,432.5 metric tons, therefore, was only half the level of catches reported for that year.

In 1987, the latest year in which nominal catches are available, total nominal catches were reported at 58,440 metric tons as compared with total calculated pressure on the stock of 49,795. Although the picture of international fishing in excess of allocations was not as bleak as presented the previous year, the situation with respect to excess fishing in the 2J3KL area itself was still severe. A total nominal catch of 36,653 metric tons was reported, representing catches nearly four times as great as those allocated.

The data incorporated into these tables have been compiled from Foreign Allocation Tables provided by Department of Fisheries and Oceans (DFO) staff for the years 1985 to 1989. Initial allocations for 1989 (all species) show a reduction in total allocation for each country with the exception of France whose total initial allocation is listed as 26,615 metric tons (all species) up from 23,490 metric tons in 1988. However, these allocations have yet to be finalized. The statistics representing total nominal catches for the years 1985 to 1987 are taken from NAFO SCS Doc. 89/07, Serial No. N1584.

Assuming that reporting is accurate, we can be certain that to calculate the total pressure upon the northern cod stock from the combined Canadian TAC and the reported foreign effort, we must add to the Canadian TAC a figure ranging up to 100,000 (cf. **Table 6** for 1986). Nor can we safely assume that reported foreign landings represent the absolute truth. Even in respect of vessels carrying Canadian observers, we have been informed by what seem to be reliable sources that underreporting of up to 25% is not at all uncommon, and if that should be the case for vessels under observation, we might well suppose that similar or larger "errors" will occur in reported figures from vessels fishing outside the two hundred mile limit.

2.6.2 Other Sources of Fishing Mortality

Other sources of unrecorded fishing mortality include discarded bycatches of fisheries directed to other species such as capelin or shrimp, discards in excess of legal limits by domestic and foreign deep-sea trawlers within the two hundred mile zone, discards of small fish from inshore draggers and from codtraps, discards of spoiled fish from irregularly attended gillnets, and fish

FOREIGN FISHING PRESSURE ON NORTHERN COD STOCK

YEAR: 1985

Country Catch)	**Total Cod Allocation**	**Total Potential Cod By-Catch**	**Total Pressure from Allocations on 2GH, 2J3KL, 3NO Cod**	**Actual Pressure on 2GH, 2J3KL, 3NO Cod (Reported)**
Cuba	-	1,270	1,270	126
EEC (Germany)	13,125	260	13,385	22,684
EEC (Portugal)	9,015	210	9,225	9,421
EEC (France)	1,995	-	1,995	880
EEC (Spain)	10,780	400	11,180	24,320
EEC (U.K.)	1,130	-	1,130	0
Faroes	2,500	350	2,850	294
GDR	500	680	1,180	70
Japan	-	2,350	2,350	64
Norway	2,000	-	2,000	1,178
Poland	500	325	825	20
USSR	4,000	3,492.5	7,492.5	4,093
USA	-	-	-	84
Non-Members	-	-	-	3
TOTALS	**45,545**	**9,337.5**	**54,882.5**	**63,237**

TOTALS BY SECTOR	**TOTAL ALLOCATION**	**TOTAL REPORTED CATCH**
2GH	13,000	318
2J3KL	16,200	44,199
3NO	16,345	18,720

FOREIGN FISHING PRESSURE ON NORTHERN COD STOCK

YEAR: 1986

Country Catch)	Total Cod Allocation	Total Potential Cod By-Catch	Total Pressure from Allocations on 2GH, 2J3KL, 3NO Cod	Actual Pressure on 2GH, 2J3KL, 3NO Cod (Reported)
Cuba	-	1,270	1,270	46
EEC (Germany)	13,125	260	13,385	7,420
EEC (Portugal)	1,315	-	1,315	37,353
EEC (France)	1,745	30	1,775	1,724
EEC (Spain)	10,780	-	10,780	45,244
EEC (U.K.)	1,130	-	1,130	821
Faroes	3,000	450	3,450	148
GDR	500	650	1,150	8
Japan	-	2,550	2,550	172
Norway	2,500	-	2,500	4,384
Poland	500	325	825	2
USSR	1,500	3,802.5	5,302.5	1,327
USA	-	-	-	315
Non-Members	-	-	-	337
TOTALS	**36,095**	**9,337.5**	**45,432.5**	**99,301**

TOTALS BY SECTOR	TOTAL ALLOCATION	TOTAL REPORTED CATCH
2GH	13,000	149
2J3KL	9,500	66,583
3NO	13,595	32,569

FOREIGN FISHING PRESSURE ON NORTHERN COD STOCK

YEAR: 1987

Country Catch)	**Total Cod Allocation**	**Total Potential Cod By-Catch**	**Total Pressure from Allocations on 2GH, 2J3KL, 3NO Cod**	**Actual Pressure on 2GH, 2J3KL, 3NO Cod (Reported)**
Cuba	-	1,307.5	1,307.5	0
EEC (Germany)	13,125	-	13,125	7,463
EEC (Portugal)	1,315	-	1,315	17,728
EEC (France)	4,995	-	4,995	3,893
EEC (Spain)	10,780	-	10,780	27,490
EEC (U.K.)	1,130	-	1,130	822
Faroes	2,500	150	2,650	19
GDR	500	750	1,250	32
Japan	-	2,630	2,630	137
Norway	2,000	300	2,300	0
Poland	500	395	895	1
USSR	2,000	5,417.5	7,417.5	855
USA	-	-	-	217
Non-Members	-	-	-	-
TOTALS	**38,845**	**10,950**	**49,795**	**58,657**

TOTALS BY SECTOR	**TOTAL ALLOCATION**	**TOTAL REPORTED CATCH**
2GH	15,000	123
2J3KL	9,500	35,653
3NO	14,345	22,881

taken in "ghost nets." Given the state of our current knowledge, it is, of course, impossible to assign any precise numeric values to any of those sources of unrecorded mortality to which we have referred. It would not, however, be wildly impossible to suggest that the aggregate number might well equal 30,000 tons. If that figure is even close to the truth, we can see that the total pressure upon northern cod is of the order of 365,000 tons which is a larger number than the stock historically sustained and probably a larger number than the existing spawning biomass can continue to provide.

2.7.0 Northern Cod — The Economic Impact

Although the primary purpose of this review must be to assess the state of the northern cod stock and of the science underlying the management decisions made in respect of it, it is difficult, if not impossible, to do so in a socio-economic vacuum. Thus, we have already referred to the overriding significance of northern cod as the base of the economy of the east and northeast coast of Newfoundland and of the coast of Labrador.

This fact will be made more apparent when we realize that 63% of all the Province's fishermen and 69% of the fish plant workers are residents in communities contiguous with the 2J3KL zones. In actual numbers, this means approximately 8,100 full-time fishermen, 8,200 part-time fishermen, and 18,600 plant workers for a total contribution to employment of 34,900 which does not include deep-sea fishermen and plant workers from south coast communities that also depend, in part, upon access to northern cod.

In a province in which the unemployment rate is in excess of 16%, some 35,000 jobs is a matter of very great consequence and completely overshadows the fact that the fishery, as a whole, contributes only 6% to the gross provincial product.

We must also note the historical basis of the Nova Scotian claim of access to northern cod. It is, of course, true that Nova Scotian deep-sea fishermen and particularly those of Lunenburg were a significant presence on the southern Grand Banks in the first half of the twentieth century. In respect of northern cod, their efforts were, however, restricted to the 3NO and 3L zones as we now identify them, and it has only been in the post-1977 era that trawlers from Nova Scotian ports have ventured into the 2J3K areas.

In any case, the Nova Scotian fishery, being much more diversified than that of Newfoundland, is much less dependent upon groundfish which accounts for only half the recorded landings, northern cod representing no more than 15% of the total or only 7.5% of all landings. In fact, more than 90% of all the jobs generated by northern cod are in Newfoundland.

2.7.1 Adjacency and "Vital Needs"

Without discounting the value of historical association and of practices ordained by custom, it is still apparent that we should draw a distinction between conditions of stock abundance when all reasonable expectations for access can be met and conditions of stock depletion when no need can be wholly satisfied. In the Newfoundland context, **it would seem altogether appropriate that first preference for access should in all cases go to the communities contiguous to the resource and whose survival is historically dependent upon it**. In such circumstance, it might well be appropriate to consider the adoption of a doctrine analogous to the "Hague Preferences," a component of the general agreement among nations of the European Economic Community (EEC) at the time of the implementation of the two hundred mile economic management zone. In the context of a general resolution developed to protect inshore fisheries, the EEC declared its willingness to take into account the "vital needs" of local communities particularly dependent on fishing and the industries allied thereto. The regions covered by the "Hague Preferences" were Greenland, Ireland, and the northern parts of the United Kingdoms.

2.8.0 Issues Arising from Historical Review

We may conclude this brief historical overview with an equally brief assessment of some, at least, of the significant problems that have emerged from our review of past conditions and practices. At the top of the list is the indisputable fact that the northern cod stock has not recovered from the heavy overfishing of the late sixties and early seventies of this century at the rate projected and confidently expected in the years immediately following the watershed year 1977. Along with this recognition has come the realization that the northern cod stock complex exhibits what appears to be a strong relationship between recruitment levels and size of the spawning biomass. Whether or not subsequent scientific investigation will explain this phenomenon either by way of confirming or exploding the hypothesis of the relation of recruitment to spawning stock size, the fact remains that our current state of knowledge dictates the absolute necessity of substantially increasing the size of the spawning biomass. Furthermore, until there is clear evidence that the noted relationship is invalid, it would seem prudent to adhere to the best scientific data available to us.

2.8.1 A More Holistic Approach to Management

Another lesson that may be derived from historical experience is that neither northern cod nor any other species can be understood, nor managed, in a vacuum. Northern cod as an individual species are yet part of an enormously complex system, and whether we address our concerns to scientific comprehension or to management strategies, we must do so from the systems perspective. The record would seem to indicate that in the past some excellent science and even good management tactics as relates to individual parts of the system have been less effective than they might have been because they were conceived and executed as if a vast, diverse and dynamic system could be segregated into watertight compartments.

2.8.2 The Danger of Overcapitalization

Another set of problems flow from the condition of near euphoria that followed upon the establishment of the two hundred mile economic zone and the confident projections of rapid stock recovery. In this context, brightening future prospects, encouraged by an actual stock growth of some magnitude during the late seventies and early eighties, led to large investments in boats and gear as well as in new and improved plants and processing facilities. This, in turn, placed heavier and heavier demands upon the stocks since the natural concomitant of larger investment is larger catches of fish to justify them. In an essentially open fishery, the tendency is for investment to outstrip the resource available to support it and, as well, a tendency to indulge in wishful thinking in respect of the general status of the stocks themselves. An unwillingness to recognize clear warning signs and to invent rationalization that discount them is not a phenomenon peculiar to the Canadian jurisdiction. Indeed, the present posture of Spain and Portugal, for example, in respect of transborder stocks on the "Nose" and "Tail" of the Grand Banks are clearly analogous.

Nor does the problem with overcapitalization end there. As fish stocks decline, catches may still be maintained by increased fishing effort brought about through improved technology, the use of larger vessels, the deployment of more gear, and other like strategies that by maintaining landings at or near historic levels mask the real problem. Indeed, in the context of steady improvement in boat design, in motive power, in range and seakeeping capacities, in gear design, in quality of materials used, in electronic navigational fish finding instruments, and in other numerous ways, the definition of a constant unit of effort is a problem of very considerable complexity.

Thus, overcapitalization in the harvesting sector tends not only to increase pressure upon the stocks but to conceal the true level of fishing mortality by encouraging an underestimation of the effort involved in the landing of a given quantity of fish and thereby suggesting interpretations of abundance that would justify higher TACs as opposed to a policy of conservation.

On the other hand, overcapitalization in the processing sector will not affect calculations of fishing mortality but may put political and social pressures upon government to adopt the most optimistic view of resource availability and where optional interpretations of abundance are available, to err on the side of overexploitation rather than on the side of conservation.

2.8.3 Federal-Provincial Relationship

These difficulties are compounded by the fact that management of the harvest is the prerogative of the federal authority while licensing within the processing sector is a provincial responsibility. It will not be difficult to believe that a failure of coordination between those two jurisdictions will continue to generate unfortunate situations that were better avoided. The management of conflict avoidance is clearly a matter of political will as may be made manifest in appropriate arrangements within an established constitutional framework. Perhaps the model of the Offshore Petroleum Board might be adapted to the requirements of the case, but, in any event, there can be no doubt **that Federal and Provincial Governments must agree upon a mechanism that permits and encourages communication between them and that ensures a rational decision making process that reconciles the basic objectives of both jurisdictions.**

2.8.4 Inshore Versus Offshore

Another area in which the arts of conflict avoidance must be practised emerges in the growing polarization of interests represented as inshore/offshore but which really represent differences between operators using, respectively, fixed and mobile harvesting gear or, to put the matter more simply still, between deep-sea trawlers and all others.

In all of the presentations made to our Panel whether in written or oral form no single issue appeared more frequently than this and none evoked more passionate protestations.

The inshore fixed gear fisherman seeing his landings annually decline or seeing them maintained only through an enormous increase in effort cannot help but be convinced that the deep-sea fleet whose catch rates remain high must be taking the fish that would otherwise be accessible to his gear. Within narrow limits he will accept explanations that involve varying temperature regimes, variations in available numbers of prey species, and other phenomena of a like nature. But as he examines the historical patterns or draws upon the accumulated community experience of the past, he will not accept the proposition that the universal decline both in population and in size of individual fish is or can be unrelated to offshore activities. We have seen no evidence that will persuade the average inshore fishermen that a trawler fleet equipped with the most sophisticated means of locating concentrations of fish wherever they may be; comprised of ships designed and powered to fish wherever such concentrations appear; and equipped with the most up-to-date gear technology that virtually guarantee the capacity to catch whatever may be found does not potentially represent the most destructive fishing machine yet devised by human ingenuity. Any argument to the contrary will be countered by anecdotal accounts of the fate of various populations, whether of redfish, haddock, flounder, or others, that after centuries of relative abundance succumbed in short order to the ravages of the modern trawler. Nor should we discount the emotional appeal of what we may call the "knee deep in spawn" argument that describes the modern trawler as mercilessly ripping through beds of spawning fish, disrupting behaviourial patterns, destroying habitat and killing not only the adults in the population but countless millions of potential young who will never have the opportunity of being hatched.

One may, of course, quite logically argue that the death of any female at anytime represents the loss not only of that individual but of all her potential to reproduce for all time to come; that the death of a gravid female is the same loss to the population whether she dies one month or one hour before spawning; that, in fact, the danger to survival of the species resides in the killing of too many adults and not in the date on which you choose to kill them.

Nevertheless, logic has little impact in the face of the emotion generated by images of large numbers of animals killed in the very act of procreation. Nor can we be absolutely certain that persistent and eventually violent disruption of spawning activity does not affect behaviour in a manner that might be inimical to fecundity or to the survival of the fertilized egg. In any event, it is a matter that must be addressed in the process of effecting a general resolution of the inshore/offshore conflict.

By the same token, we must address the counter charges levelled by trawlermen against inshore fishermen and particularly against those employing codtraps that their killing is concentrated upon juvenile fish, a practice that is neither economically nor biologically sound. In economic terms such fish are costly to process, provide low yields of marketable product and command very low prices. Biologically, the numbers of such animals that must be killed to produce a ton of product is extremely large while the killing before the attainment of sexual maturity means that none will live to reproduce their kind. As with the argument regarding fishing on the spawning grounds, there is an element of sound common sense in this position. It should nevertheless be borne in mind that having allowed substantial numbers of juvenile fish to survive to maturity and to constitute a viable spawning biomass, care must be taken to ensure that enough of them continue to live through several spawnings to ensure a continuing adequate supply of juveniles to sustain or enhance the population. To put the case bluntly, a process that enjoined the protection of all juveniles up to sexual maturity at, let us say, age seven years and then permitted a fishing mortality of 100% on fish aged seven or older would be a prime recipe for disaster. Simply put, while it would be desirable to restrict, in so far as possible, the killing of three, four, and possibly five year olds, the only way in which a viable spawning biomass can be sustained is through a general reduction of mortality of all age groups.

We are, of course, aware that there are many arguments pro and con both inshore and offshore positions that we have not addressed in large part because they do not impinge directly upon the problems of stock assessment. We should note, however, the specific argument that an offshore trawler fishery is necessary because of its capacity to take fish at any season of the year and in quantities required to satisfy market demands. By way of contrast, it is agreed, the inshore fishery traditionally proceeds in a cycle of glut and famine that virtually rules out the possibilities or orderly marketing. While realizing that such arguments, though appealing in their simplicity, may be countered by others that are not totally devoid of logic, we are constrained to admit that the trawling industry, though possessing the potential to be totally destructive, need not be more destructive than proper management permits it to be. To reiterate the oft repeated maxim, technology is a marvellous servant but a very poor master. If we are not prepared to curb our technological capacities in the interests of environmental integrity and in cognizance of human dimensions of all our activities, then we will obviously invite the inevitable disaster that we will undoubtedly deserve to have visited upon us.

2.8.5 Scientific Credibility

One final point must be made as we bring these introductory remarks to a conclusion. The entire fisheries community, harvesters and processors, individual fishermen and corporations, all alike have indicated a degree of disenchantment with the capacity of scientists to provide adequate advice and with the capacity of political managers to make appropriate decisions to preserve the northern cod stocks in such a state of health that they can continue to provide a sound economic base for the communities that have traditionally depended upon them. While recognizing that this crisis of credibility stems from promises now shown to have been illusory, we do not concede that the case is in any sense hopeless. On the contrary, it is gratifying to note that the DFO scientists themselves recognized their errors and some, at least, the sources of such errors. Moreover, without downplaying the significance and magnitude of mistakes that were made, we must reemphasize the incredible complexity of the problems, the short data sequences available for analysis and the psychological pressure operating to compel acceptance of evidence that appears to support ones own hypotheses and to discount warning signs that may be interpreted as aberrational elements deriving from temporary environmental disturbances. In hindsight the errors of the past stand out clearly, and we are certainly capable of devising systems that will obviate similar errors for the future. But it is not at all clear that at the time and under the circumstances in question any other group of scientists would have done much better. Nor should we forget that scientific knowledge advances, in part at least, through a process of disproof. What must, of course, be avoided is the use of hypotheses that have not been subjected to rigorous tests of proof or disproof as the foundation of management decisions that may have far reaching future effects of a negative nature.

This is not to say that in the absence of comprehensive knowledge, the world must stand still. It does mean that when our knowledge is deficient we should proceed with extreme caution, and if error is inevitable, we should at least attempt to ensure that our errors are on the right side of the ledger. At the same time, we should move as rapidly and as efficiently as circumstances permit to fill those gaps in our knowledge that inhibit our capacity to manage properly.

In short, we have no hesitation in asserting that the credibility of our scientific establishment must be firmly established. Apart from sound science, there is no other acceptable source of appropriate management advice. It may, indeed, be true that in the development of the current crisis, the warnings of fishermen predicated upon their intuition, their feelings, their observations, their conclusions derived from personal and community history ought to have been heeded. As events transpired, they were seen to be nearer the mark than were the overly optimistic projections of growth based upon a flawed assessment process. Indeed, even though such information may be difficult if not impossible to quantify, it should not for that reason be ignored. If a means is not currently at hand to integrate it within the modelling equation, at the very least, it should be reckoned as a guide to the interpretation of ambiguous or anomalous data. Those who have submitted themselves to the disciplines of history will be fully aware of the unreliability of folk memory and of the manner in which over the years fact becomes interwoven with myth and legend. Nevertheless, years of cumulative knowledge and experience will provide a substratum of fact and of wisdom to which even the most rigorous scientist should give heed. Good science is still the essential key to our problem, but until such time as we have absolutely perfected our techniques, we must remain willing to submit our uncertain data to every reasonable test to confirm or reject it.

And even when the credibility of our science is firmly and unequivocally established, we must ensure that the political process through which management decisions are taken is equally credible. We are involved with the manipulation of a vast and extremely complex natural system involving many hundreds of species and many billions of life forms. For that reason alone, we should proceed with extreme caution. But when we add to that the fact that there is also at stake the future of a province and the material and psychological well-being of a substantial part of its population, it is all the more incumbent upon us to permit no consideration of temporary political advantage to deflect us from the path of true conservation.

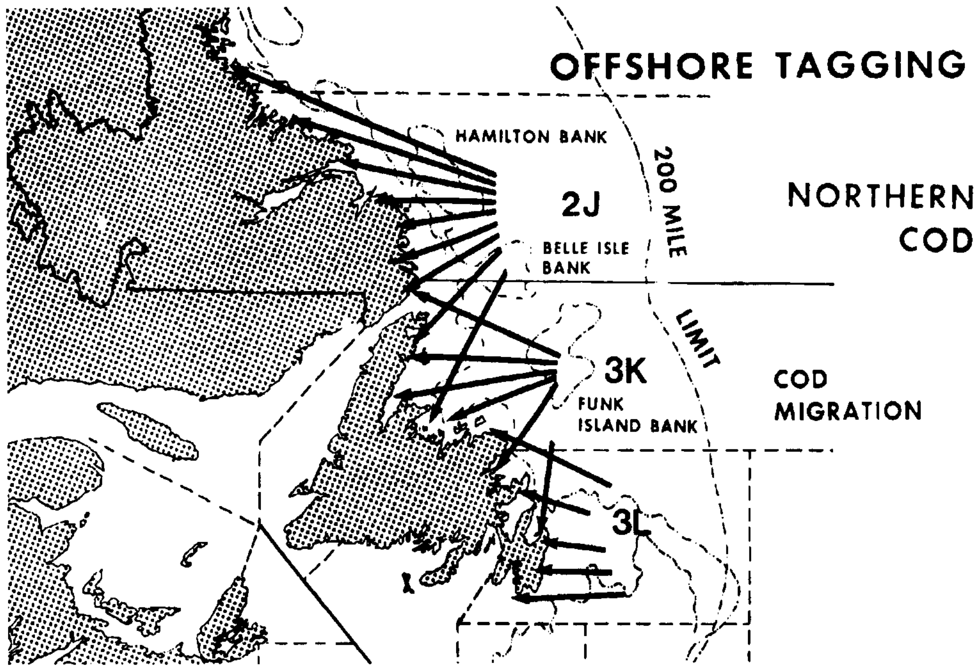
CHAPTER III

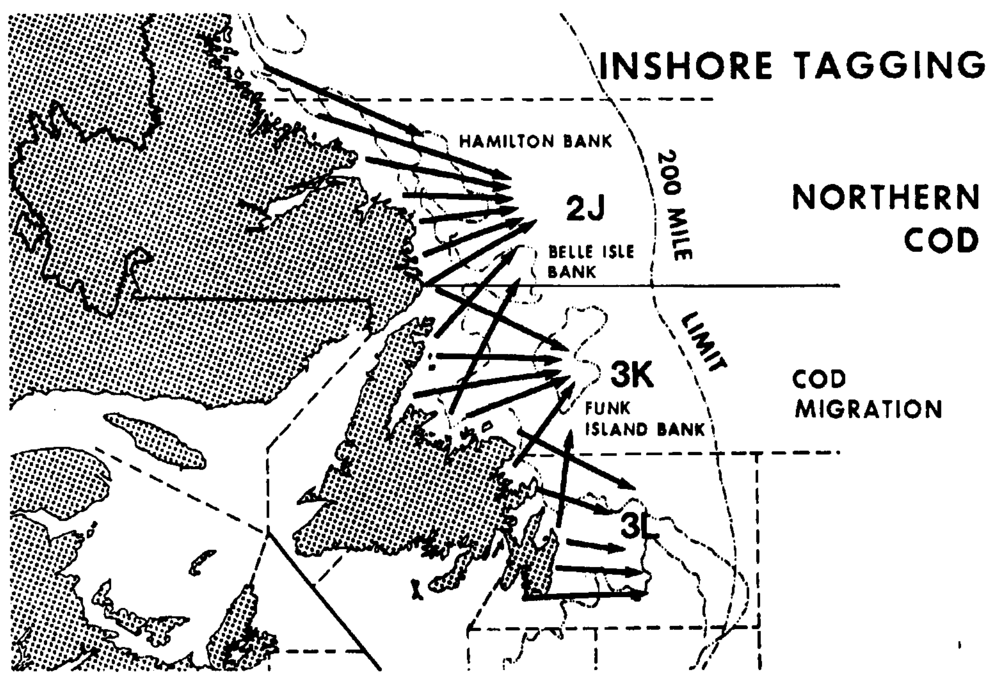
The Definition of the Northern Cod Stock Complex and the Relationship Over Time Between Its Components

3.1.0 Introduction

The Newfoundland—Labrador northern cod population within the Northwest Atlantic Fisheries Organization (NAFO statistical divisions designated as 2J, 3K, and 3L (2J3KL) constitute, by operational definition, a population of fish that is considered to be suitable for management as a unit and that has, indeed, been so managed since the early 1970s. This suggests a belief that the fish recruited to the several statistical divisions within the area have relatively small seepage in and out of the management area or that whatever seepage does occur is relatively consistent from year to year.

That some seepage does occur is, however, a point upon which fishermen, at least, have no difficulty in reaching agreement. Nor is there in the record any substantial scientific evidence to suggest that the line between 2GH and 2J, for example, represents any real separation of fish populations in those divisions. By the same token, the separation between statistical divisions 3L and 3NO may be seen as equally artificial. If, however, the interchanges that may occur between 2J and 2GH on the one hand and between 3L and 3NO on the other are consistent from year to year, the suitability of 2J3KL as a management unit need not be substantially impaired. Nevertheless, it must be clear that a better management plan might be implemented if all the fish belonging to the stock or stock complex were included in the management area.





Maps Showing Spawning Areas

3.2.0 What is Northern Cod?

Indeed, the best management plan for northern cod can only emerge in the context of full and accurate information concerning the nature of the population and of the territory it occupies. At present, our information is deficient. We do know or at least we believe strongly that the population consists of a complex of somewhat discrete subgroups that gather for spawning on the outer continental shelf and slope regions of the Hamilton Bank, Belle Isle Bank, Funk Island Bank, the Northern Grand Bank, and possibly at various inshore locations. But even here, the introduction of the word "possibly" indicates a gap in our knowledge. There is certainly strong presumptive evidence and some empirical evidence from tagging studies to suggest that some elements of the northern cod population do not regularly migrate to the spawning grounds of the outer continental shelf but rather remain to spawn in some of the deeper trenches that reach into the bays of the Newfoundland coast. Whether there are discretely separable groups, whether they recruit only from their own progeny, or whether they may be casual aggregations whose assemblage is variable and contingent upon environmental fluctuations are all moot points that clearly demand explication. It is unnecessary for us to repeat the discussions on this matter included in the Report of the Task Group on the Newfoundland Inshore Fishery (TGNIF), but it is important to reiterate the point that the possession of accurate information in this domain would have profound implications for overall management strategies as they impact separately upon inshore and offshore fishing operations.

To return to what we do know, we can state unequivocally that the summer distributions of the various subgroups do overlap in the coastal waters off Newfoundland and Labrador. We are further persuaded that both the offshore migration to spawning grounds and the inshore feeding migration are more or less replicated from year to year. Nevertheless, it should not be thought that a constant proportion of each spawning subgroup moves inshore each year to defined coastal waters nor that each of the major offshore spawning areas contribute equally or even proportionally to the inshore summer migration. Nor should it be presumed that the importance or relative size of the subgroups remains constant over time. There is, in fact, some empirical evidence that the proportion of spawning cod in 3L that moves to inshore areas of Newfoundland is less than that in either 2J or 3K.

What we do not know is whether or not the spawning subgroups constitute genetically separable stocks or whether their aggregations are fortuitous and dependent upon behaviourial patterns as modified by changing environmental circumstance. In any case, there is no evidence at present available to us to indicate that the 2J3KL cod population necessarily recruit young exclusively from the spawning stocks within the 2J3KL management divisions. On the other hand, there is some evidence that once a fish recruits to a particular spawning group it will retain its relationship with that group.

3.3.0 Appropriate Management Units

These matters clearly cry out for elucidation. The TGNIF before us recognized the problem and suggested that it would be prudent to consider each major offshore spawning subgroup as a potential management unit. Although the DFO has not followed this suggestion to its obvious conclusion, they have in recent years distributed the catch more evenly among 2J, 3K, and 3L by assigning one-third of the TAC to each of the management divisions. This we believe to be a wise precautionary policy designed to reduce the possibility of localized depletion of inshore fishing grounds. Indeed, there is some evidence to suggest an improvement in inshore landings in some sections of the northeast coast coincident with the reduction, under the one-third, one-third, one-third policy of offshore effort in 2J and 3K. For this reason, we must express concern with the recent decision to permit catch deficiencies in the northern zones to be made up by increasing the allowable catch in 3L.

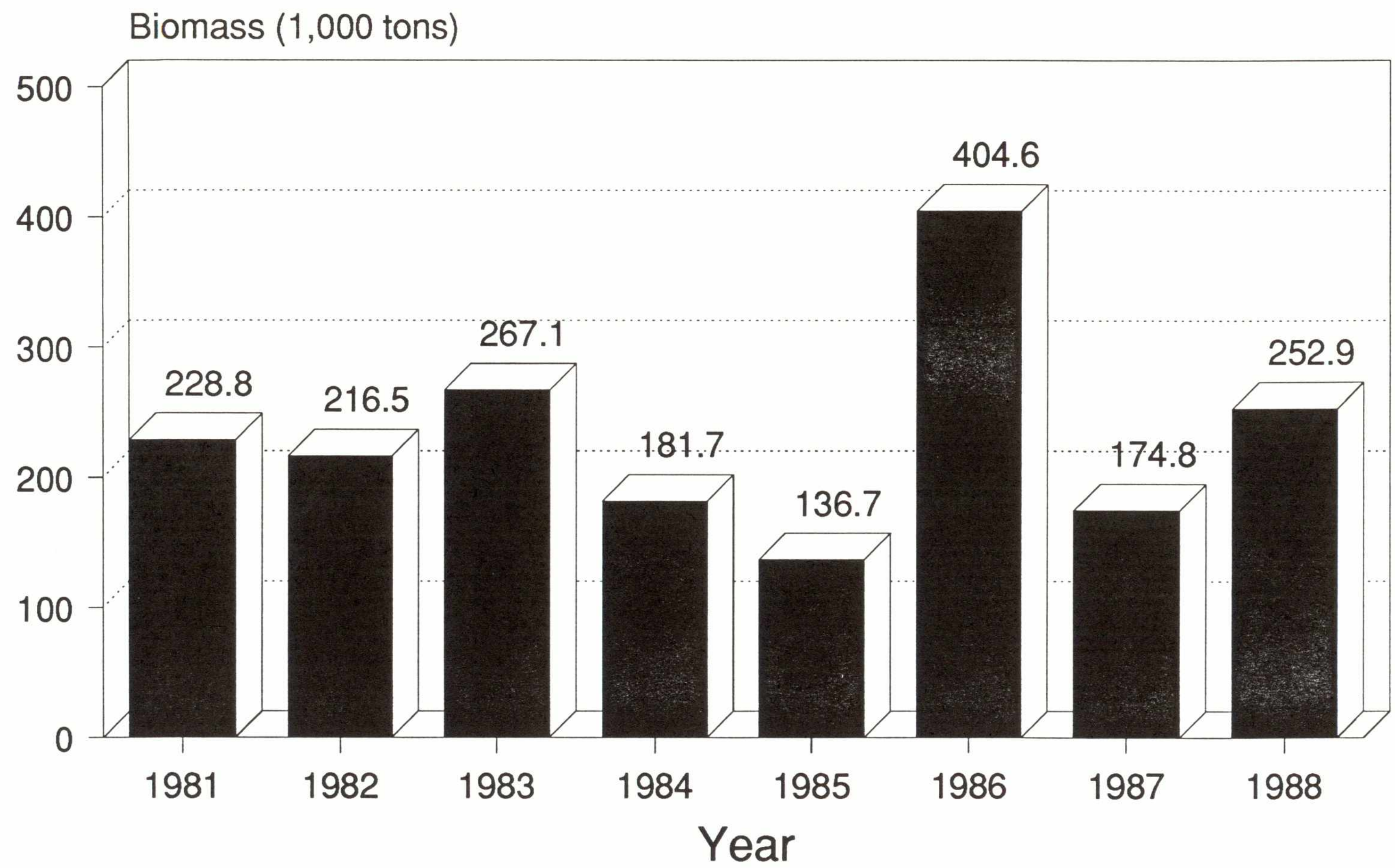
Indeed, we are persuaded that the current policy is nothing more than a desirable first step. In the long run, we must ensure that fishing effort is applied in direct relationship with the actual distribution of the exploitable biomass. We realize, of course, that the attainment of this highly desirable goal is contingent upon our capacity to acquire much more detailed information on the major spawning components of the stock, on the nature of inshore/offshore migrations, and on the levels of exploitation imposed upon each of the spawning subgroups.

Nor should we forget that our knowledge must be extended to encompass the important question raised by the TGNIF and to which we have alluded above and that refers to the potential existence of an inshore stock or stocks that is/are separate in a genetic and/or behaviourial sense from the offshore stocks. Tagging carried out in the last two years adds weight to other evidence, some of it admittedly anecdotal, suggesting that such inshore discrete or semi-discrete stock components do, in fact, exist. If that should indeed be the case then it is clear that we must inject a new element into all our calculations of population size and must, as well, be prepared for an appropriate modification of management strategy. Various impacts upon earlier and current calculations are possible depending upon what may be discovered in respect of the size and behaviour of any existing inshore stocks and the history of their exploitation. It is clear, however, that before anything can be done to identify such impacts, we must establish the facts.

In short, though our ignorance is regrettable, we really do not have any definitive answers in respect of the relationships among the several components of the northern cod stock complex over time. We do have access to anecdotal evidence derived from the observations of fishermen through the years, and we have the results of a few relatively modest tagging studies by fisheries scientists. But apart from speculation as to what may have occurred as the consequence of historical harvest patterns, we are principally dependent for our limited information upon gleanings from the Research Vessel (RV) estimated population trends by statistical division.

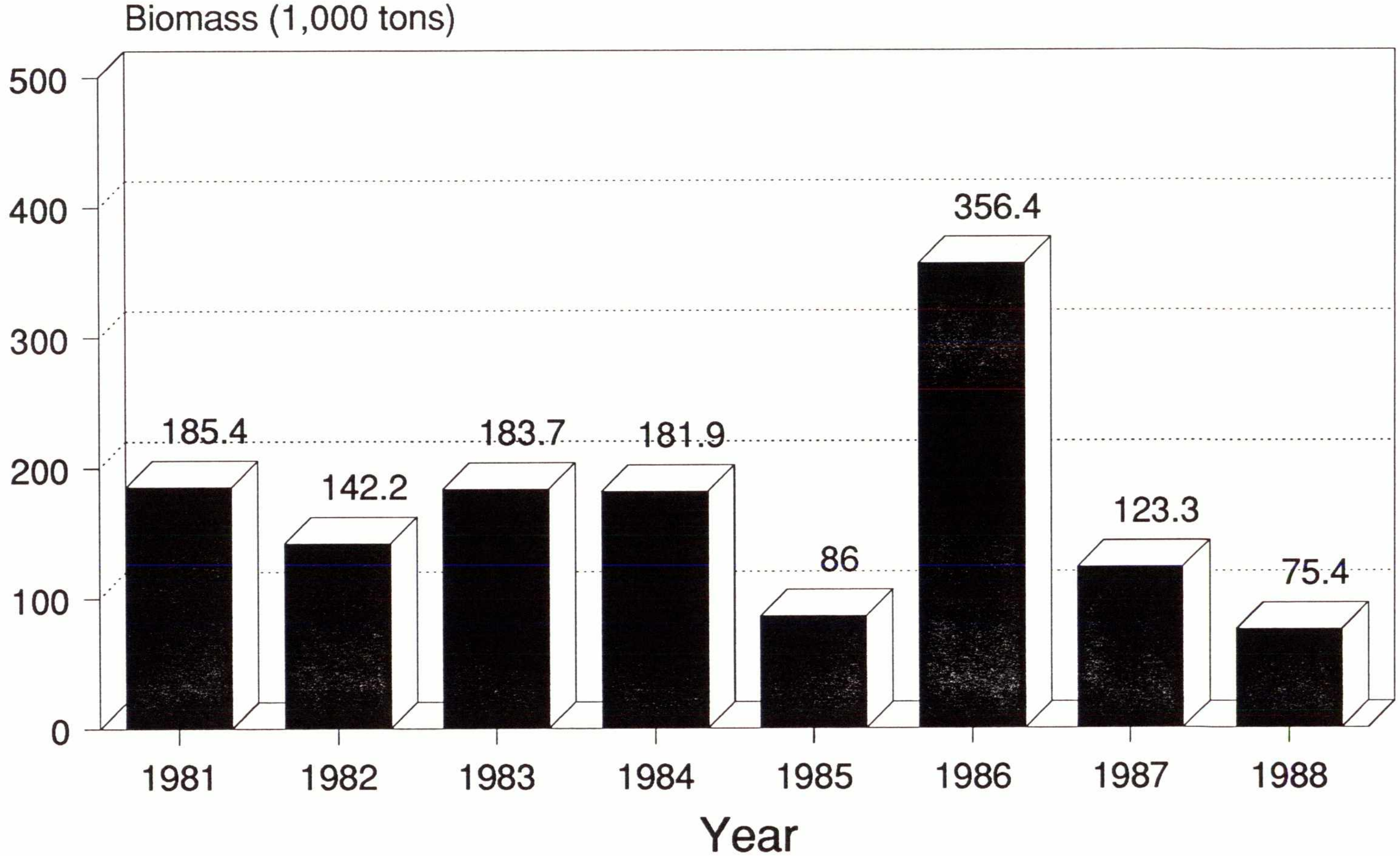
The RV population trends by statistical division but unadjusted for time and temperature data are provided in **Figures 6, 7,** and **8** and the summed trend in **Figure 9**. In these tables both 3K and 3L show rather stable or slightly declining numbers in recent years while the population in 2J seems to have been improving somewhat since 1985. However, the danger of overreliance upon such data is apparent in the fact that the graphs show that the vast majority of the northern cod population appears to have been located in division 2J during the period of the autumn survey of 1988. This situation is one that has obviously varied over time, is consistent with information provided from the experiences of fishermen operating in the 2J3K divisions, and may suggest a behaviourial or environmentally induced rather than a genetically driven pattern of migration. In

FIGURE 6: BIOMASS ESTIMATES OF COD FROM AUTUMN RESEARCH VESSEL SURVEYS IN NAFO DIVISION 2J



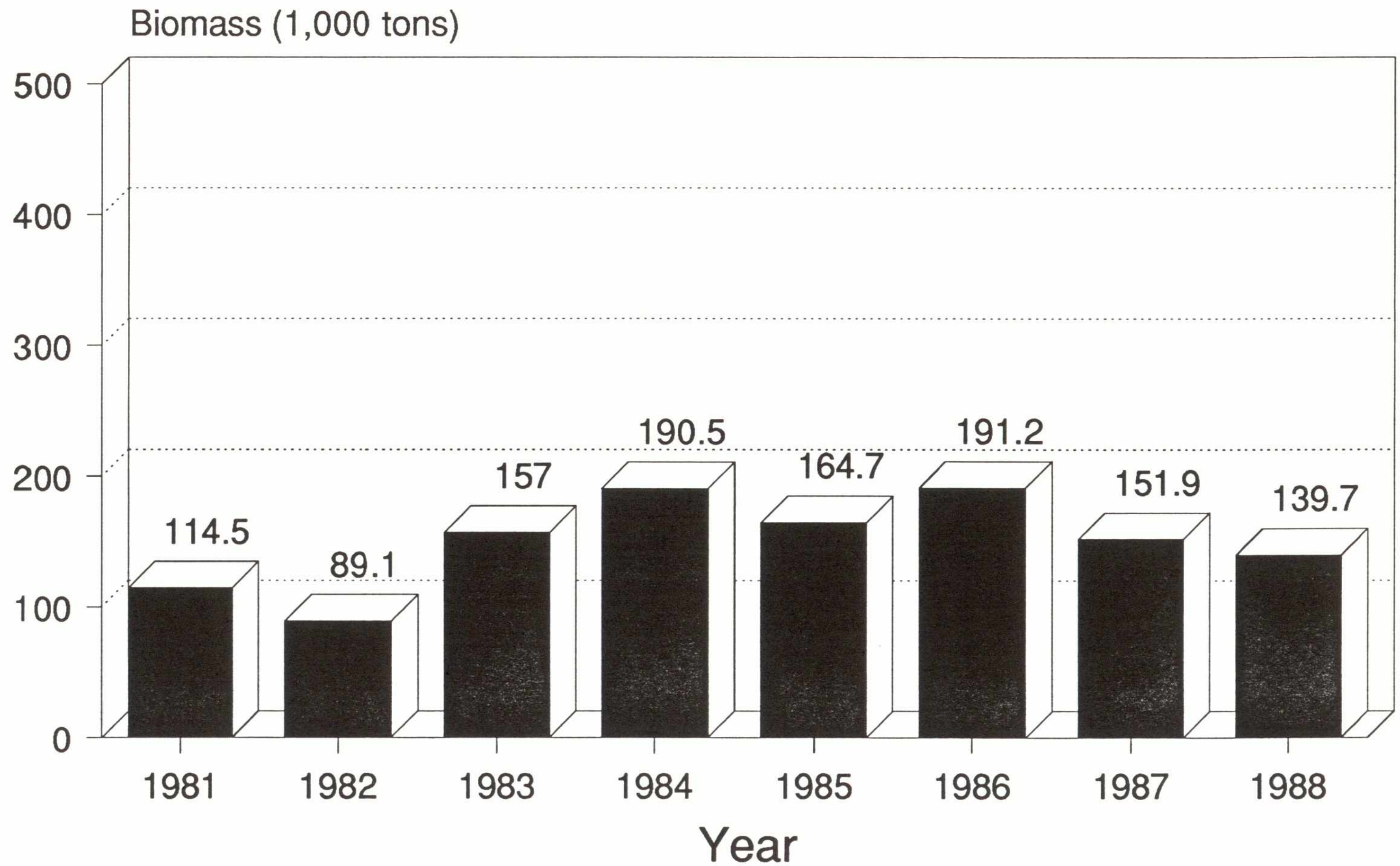
Source: Canadian Dept. of Fish. & Oceans

FIGURE 7: BIOMASS ESTIMATES OF COD FROM AUTUMN RESEARCH VESSEL SURVEYS IN NAFO DIVISION 3K



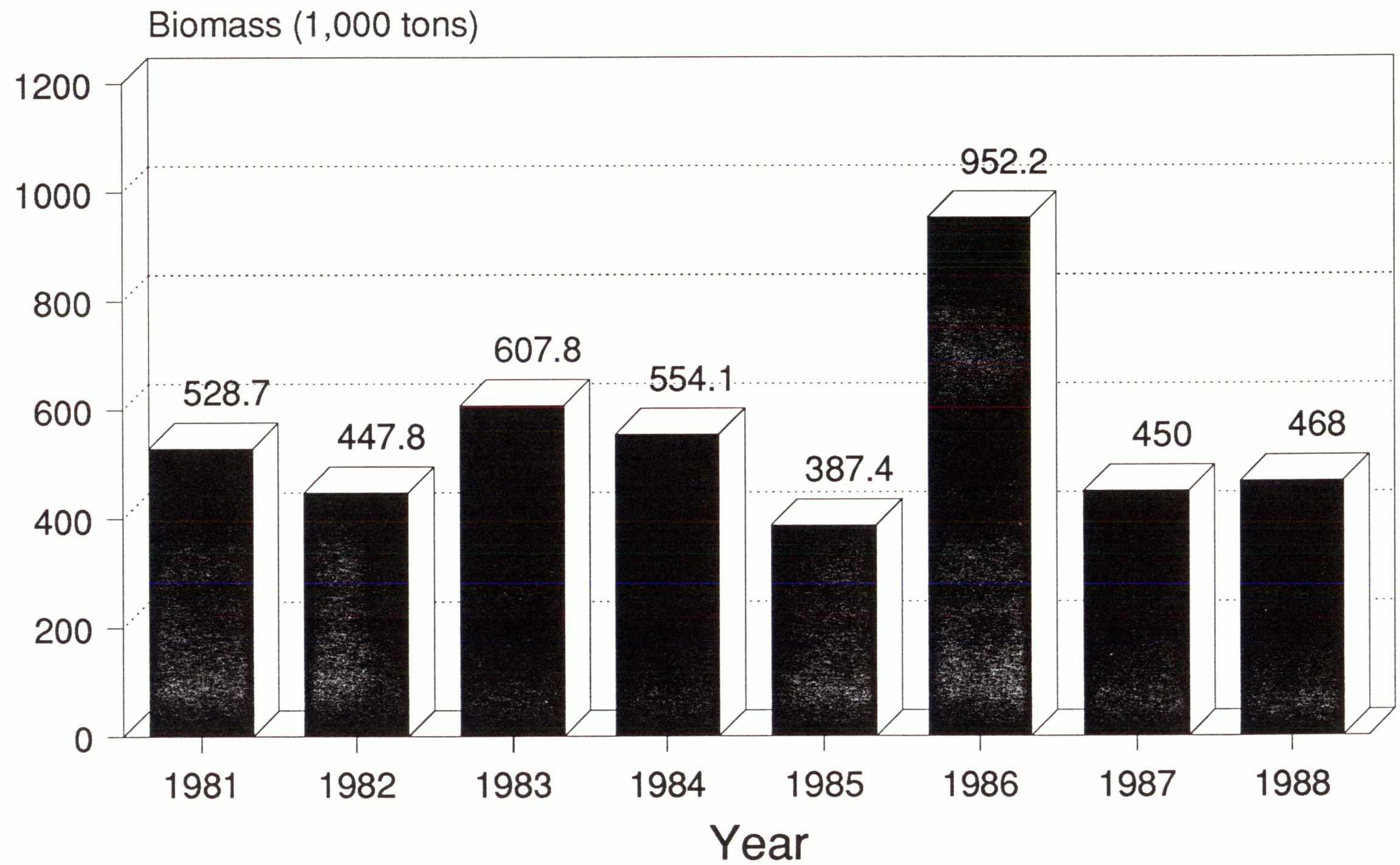
Source: Canadian Dept. of Fish. & Oceans

FIGURE 8: BIOMASS ESTIMATES OF COD FROM AUTUMN RESEARCH VESSEL SURVEYS IN NAFO DIVISION 3L



Source: Canadian Dept. of Fish. & Oceans

FIGURE 9: BIOMASS ESTIMATES OF COD FROM AUTUMN RESEARCH VESSEL SURVEYS IN NAFO DIVISIONS 2J, 3K AND 3L



Source: Canadian Dept. of Fish. & Oceans

any event, it constitutes another in the table of uncertainties that derive from our essential ignorance.

What, we must ask, do these estimates of changing stock size by statistical division really represent? Do they merely reflect differential responses of the various stock components to differing fishing pressures? Do they represent infinitely varying redistribution patterns of the population during its feeding migrations? Do they suggest the practical impossibility of management by statistical division? Or, do they suggest that it is possible or even desirable to draw other lines of demarcation on our map to replace those currently differentiating 2J from 3K and 3K from 3L?

Whatever may be the case, there can be no doubt but that the differential population trends within the several 2J3KL divisions are of great interest and concern because they impact directly and significantly upon our estimates of both population and fishing mortality (F) values. Certainly, the long-term catch history of northern cod clearly implies either an earlier inshore stock that has been much depleted if not exhausted: or, migration patterns that have changed dramatically over time: or, perhaps, a much smaller general population than even current estimates allow.

After this somewhat cursory review of available data associated with the nature of the northern cod stocks, we can conclude without hesitation that effective management for the future demands a broader and more comprehensive data base. **Specifically, we must know whether the stock is one or many; whether the separate spawning groups are genetically discrete or whether they may be differentiated by behaviour; whether behaviourial patterns are fixed and immutable or whether they are responsive to the imperatives of changing environmental conditions; how and from which source separate subgroups attract recruits; how and under what conditions interchanges among existing statistical divisions occur; whether migratory routes are fixed or variable; how patterns of inshore and offshore distribution are determined; how such patterns may be affected by varying temperature or salinity regimes, varying availability of prey species or varying presence or absence of predators; and, whether or not there exist discrete inshore spawning groups and, if so, what is the basis of their separateness and what is their current status.**

With this knowledge in hand, it will be possible to develop a management regime that will be able to make an appropriate allocation of catches by statistical division. For so long as our knowledge remains deficient, we must proceed with caution. At the very least we should enforce, without exception, the current policy of allocating one-third of the catch to each statistical division. However, as our knowledge increases we should be prepared to move quickly to make appropriate adjustments to the catch apportionment so that as our understanding grows so will our management practices become more effective.

CHAPTER IV

Data and Methods Used in the Assessment of the Northern Cod Stock(s)

4.1.0 Data Used

The Department of Fisheries and Oceans database used in stock assessment for division 2J3KL and which is the basis of the advice given to the Government of Canada involves:

A. Catch data for the inshore and offshore components of the fishery by gear and vessel classes as well as by divisions.

B. Catch per unit of effort (CPUE) data on the offshore fleet used to form a commercial fishing index of abundance.

C. The RV survey data which leads to swept area estimates of population numbers and biomass by age and CPUE numbers by depth strata and which includes samples of catch for age-weight information.

D. Age-length and age-weight samples of the commercial catch by years based on shore-based sampling of both inshore and offshore landings.

E. Commercial observer data related to discards and operational modes of the offshore fleet.

These databases constitute the underlying information used to develop estimates of population numbers and biomass, CPUE trends, recruitment patterns, and fishing mortality. The data are supplemented by various behavioral, ecological, and environmental observations that are useful in evaluating availability trends to sectors of the commercial fleet and fall research surveys. They may also be useful in forecasting long-term population trends, but this is less certain or needs considerable refinement. The data corrected to account for environmental influences have not as yet been used to adjust population estimates used in providing advice to the government, although some preliminary work of this character has been initiated.

Since we can never have total confidence in the absolute reliability of any of these data sets, it is important that as many independent sources of information as possible be employed so that in checking one against the other the closest possible approximation to reality can be attained. Thus, while the Panel is content that the data sets listed above are being used in an appropriate fashion, it was inclined to wonder why historical CPUE data for the inshore fleets, acoustic survey data and environmental indices of availability and abundance have not played a larger role in developing abundance estimates and resource forecasting.

4.2.0 The Methodologies Used

DFO scientists are currently using a retrospective population analysis [Virtual Population Analysis (VPA) or cohort analysis] to estimate population size and terminal fishing mortality. This method is rather simple conceptually in that it involves adding up the catch of a particular year-class over time and adjusting this number upwards to account for natural mortality. Let us explain in simple terms. Suppose, for example, we take all the young fish recruited to the stock in 1982 and which may be described as the 1982 year-class. By 1985, they would be three year olds and would be large enough to be caught. If we count the numbers of them caught in that year and add to that the numbers of four year olds caught in 1986, of five year olds caught in 1987, of six year olds caught in 1988, of seven year olds caught in 1989, and so on until no more fish of that year-class are caught; and if we add to that total the numbers from that same year-class that have died from natural causes, we will know how many fish there were in the 1982 class at the beginning. This is to say, by 1995 or there about we will know, if our counting was done correctly and if our estimate of natural mortality is correct and if there are no other fishing-induced mortalities other than those accounted for by the commercial catches, how many young fish were recruited to the stock in 1982. This in turn is to say that VPA or cohort analysis is, if the underlying assumptions are correct, an accurate method of **hindcasting**. Such hindcasting does not, of course, even if it is very precise tell us how many fish are alive in the ocean today. If we again take our 1982 year-class as an example, we know, if our data sets are reasonably accurate, how many of that class have already been caught or have already died from other causes; but, our knowledge of how many are still alive is only a "guesstimate." To make that "guesstimate," we use a calculated value for fishing mortality which we identify as F (an instantaneous fishing mortality rate) and which can be easily equated to the percentage of the total exploitable populations that is killed each year by fishing. At some future time, when all the 1982 year-class have been caught, we will know whether or not our "guesstimates" were correct. At that time, it will also be possible to determine whether the values we used to calculate the F value were correct and, if they were not, to modify the calculations appropriately for the future. It will be clear from the foregoing that the longer the period of time over which our data sets extend, the greater will be the chance of our getting the answers right.

In the meantime, in order that appropriate management advice may be offered, we must use our hindcasting abilities as a foundation from which to make reasonable forecasts. To do this, the basic VPA model is "tuned"[1] by employing RV and CPUE data. Each of these sources of tuning data has its strengths and each its weaknesses. These are discussed at some length in the TGNIF report and the arguments need not be duplicated here. Sufficient to say, the standardized RV survey takes trawl samples at various depths (strata) within each subarea at a randomly selected set of stations. The catch at each location and at each depth is sampled to provide information on age and weight. The sample data are then used to determine the age composition of the population as well as a "minimum" estimate of total numbers and of biomass of the fish in the subareas sampled.

The extrapolation from the "swept area" partial estimate of population size to a "minimum population estimate" is based on the area swept by the net divided into the total area being sampled and multiplied by the estimated average density. Independent estimates are made for the several strata tested and the sub area estimates are added to obtain the overall population index.

Inasmuch as the net may not capture all the fish within its path and inasmuch as the area surveyed may contribute only a portion of the total northern cod habitat, the estimates derived in this way cannot be taken as absolute but rather as an "index" of population trends. It is assumed that the index remains a reasonable constant proportion of the true population size over time. The surveys provide important information on the abundance of various age classes and whether they are larger or smaller than in past years.

By the same token, the CPUE data which are derived from measuring the commercial catch as related to hours of fishing effort (i.e. hours in which a trawl is actually on the bottom and being towed in a fishing mode) are also used to construct an index of population trends. The assumptions in this case are that there is a direct linear relationship between CPUE and population size or, if not, that the relationship of population size to CPUE is a known function.

Since annual behaviour pattern of cod may be influenced by various environmental or ecological factors, it is clear that the timing of the survey may be very important if, from year to year, like is to be compared with like. That is to say, it may be necessary, if greater precision is to be obtained, to correct or adjust the RV data in the context of conditions that may be changed from year to year. These might include such components as temperature, salinity, and abundance of the food supply. In the same respect, CPUE data may be impacted by advancing technology, changes in gear type or deployment, changes in management strategy, and differences in skill level or experience among fishing masters and others.

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1. "Tuning" is a collective name for a family of techniques in which known data such as historical population levels, age structure, etc. are used in conjunction with trends appearing in the indexes derived independently from the RV surveys and the commercial CPUE, to establish and estimate of the current population size. Essentially they use the good estimates of absolute population size that VPA provides for the past years to calibrate survey and CPUE indices of relative abundance. The calibrated (to absolute popultaion size) indices of abundance for current years are then used to replace the "guesstimates" of current population size in the VPA. Of course, such estimates of recent populations and size are only as good as the trends indicated by the survey and CPUE data.

The Panel was reasonably satisfied that the current analytical approaches used by the DFO scientists represented state-of-the-art methodology, but were concerned over (a) the absence of an estimate of cod losses due to bycatch losses, (b) the large variability in RV survey results, and (c) the utilization of the offshore CPUE data to tune the VPA/cohort model. **The Panel saw a need for an alternative independent measure of population trends.**

4.3.0 Approaches Taken by Other Countries and NAFO to the Measurement of Fish Stocks

In principle, the approaches used by scientists of other countries in measuring the size and trends in fish stocks are similar to those used by CAFSAC scientists. However, the degree of reliance on a single population estimate varies among species and among regions of the world. It is obviously desirable to have several independent indicators of population trends. CAFSAC scientists' population estimates are derived from their cohort analysis in conjunction with "tuning calibrations" that employ commercial CPUE and RV indices of abundance. Throughout the world cohort analyses are normally supplemented by independent estimates of population trends such as CPUE data, acoustic and RV surveys, egg and larva surveys and/or estimates derived from tagging studies.

In the past, the northern cod population estimates have been tuned using what is known as a bulk biomass method. This method uses the overall (all ages combined) catch rate estimates from vessel surveys and/or from commercial fishing vessels. These indices of biomass change were related to historical exploitable biomass estimated from the VPA. This relationship was then used to tune the population estimates for the most recent years so that the exploitable biomass showed an equivalent trend to the survey of CPUE index.

This approach was probably reasonably effective prior to 1978 when the international fishery was removing a large proportion of the stock and. hence, large year-to-year changes in the size of the biomass occurred. However, the method appears to have faltered during the period of extended jurisdiction. This may have been partly because of the slower rate of biomass change but was more likely affected by increasing levels of uncounted bycatch and systematic increases in the efficiency of the Canadian fleet — leading to an underestimate of fishing mortality and a corresponding overestimate of the rate of growth of the stock(s). Apart from the problems inherent with the data set, the bulk biomass approach has several fundamental drawbacks which have been recognized in recent years; e.g., the exploitable biomass estimated from the VPA can be distorted by using incorrect estimates of the exploitation pattern (the proportion of the full fishing mortality acting on each age of fish). This problem can be particularly difficult if this exploitation pattern changes through time. For these reasons, the method has been discouraged in working groups of the International Council for the Exploration of the Sea (ICES).

In the January 1989 CAFSAC northern cod assessment, a different approach was used to tune the VPA to the research vessel survey. The new method uses data from the research vessel survey on an age-by-age basis. The method minimizes the discrepancies between the VPA population estimates for each age and the equivalent survey age-specific indices of abundance. This more statistical approach enables the assumptions underlying the method to be carefully questioned by CAFSAC. The approach is broadly similar to those used currently in the ICES area.

The same adaptive framework programme was also used to tune the VPA to the commercial CPUE data. However, in this case the method used within the framework was one based upon relating VPA estimates of bulk biomass with the bulk biomass trend shown by the commercial vessels. Despite the more sophisticated statistical procedure used, this approach may still suffer from the faults noted for the earlier bulk biomass method. While there are certainly some valid statistical reasons for CAFSAC's choice of this approach, these may well be outweighed by its inherent problems.

Direct comparisons between the Newfoundland case and that obtaining in respect of other countries are not always necessarily useful. For example, the characteristics of many large-scale world fisheries which are undertaken with various gear types and different national fleet components may provide for a number of independent sets of CPUE trends and hence make possible multiple estimates of populations trends and age structure data. Furthermore, environmental factors in other ocean regions may have a much smaller impact on fish behaviour than in the Newfoundland region. Hence population trends and stock enumeration in these fisheries may be more easily accomplished than in Newfoundland and the results more easily interpreted. In other cases, the species of fish whose population is being assessed may be much more predictable or much better understood in terms of behaviour than is the case with northern cod.

In the ICES area VPAs are frequently tuned using the Lowestoft VPA tuning package. This is available at DFO laboratories. This package enables a quite wide family of age-based tuning methods to be applied; but, the currently preferred approach is the Laurec/Shepherd method. In recent years, there has been much active research into methodologies for tuning VPAs. ICES has provided a focus on this research through its Methods Working Group. This working group has been regularly attended by DFO scientists and the ADAPT framework, the Lowestoft tuning package, and a number of other methods have all been subjected to its scrutiny. As yet no clearly favourite method has emerged, but the broad principles on which better methods should be based have been agreed. Chief amongst these are that age desegregated data should be used and that detailed examination of how well the data fits together should be made.

All of the methods mentioned above will give the correct answer when the data is exact but all will give answers which vary about the truth when the independent estimates of population trends are variable, which is often a fact of life.

In short, the choice of methodologies emphasized in stock assessment depends, in part, on the life history features of the fish being studied and, in part, upon the suitability of sampling and assessment schemes to particular species, and, in part, upon the availability of funds and facilities. **Although the CAFSAC methodology seems reasonable in light of the species involved and in view of the characteristics of the area and of the funds available, the independent estimates of population trends require much closer scrutiny.**

CHAPTER V

Stock Trends and Past and Current Scientific Advice

5.1.0 Possible Causes for Changes in Status of the Stocks

This is an interesting question in light of the fact that there may not have been a significant change in population biomass trends since 1984. At the outset, let us be clear that we understand the words we are using. Let us note, for example, that populations and population biomass are two quite different things. Population of itself refers simply to the number of fish with which we are concerned. Population biomass means the aggregated weight of all the fish. Thus, a population of 1000 fish weighting on average two kilograms each would constitute a population biomass of 2000 kilograms. That same biomass would exist if we had only 100 fish weighting on average 20 kilograms each. Thus, when we say that there has been no significant change in population biomass trends since 1984, we are not necessarily saying that there has been no change in the number of fish (average weight-at-age or age structure) in the population since that date. Indeed, the biomass trend alone may mask internal changes in the population age structure and thus be misleading or not very instructive about potential downstream population trends.

The DFO's current interpretation of stock status is that the northern cod stock increased between 1977 and 1984 and has subsequently stabilized and, depending on harvest strategies, may decline in the next several years. It should be noted, however, that a fisherman's perception of the state of the resource or exploitable biomass may differ from that of the scientists or from that of other competing fishermen, depending on when and where he/she takes the catch and on the abundance and distribution of different age groups in the population. That is, the overall population biomass may remain constant, but there may be sharp changes in the abundance or availability of different age groups in various geographic areas inhabited by the population.

Figure 10 graphs the population trends for the 2J3KL stock in numbers and biomass from 1976 to the present based on the DFO use of a terminal F (instantaneous mortality rate) of 0.436. As previously noted, the population biomass remains rather static between 1984 and 1988, although a slight decline is apparent. **However, a downward trend in number of fish in the population is more obvious and apparently reflects a decline in the number of younger age groups (three to five year olds) entering the population.** Both biomass and population numbers provide evidence of a healthy population growth between 1976 and 1984. The percentage of growth in the biomass, however, is greater than that for population numbers.

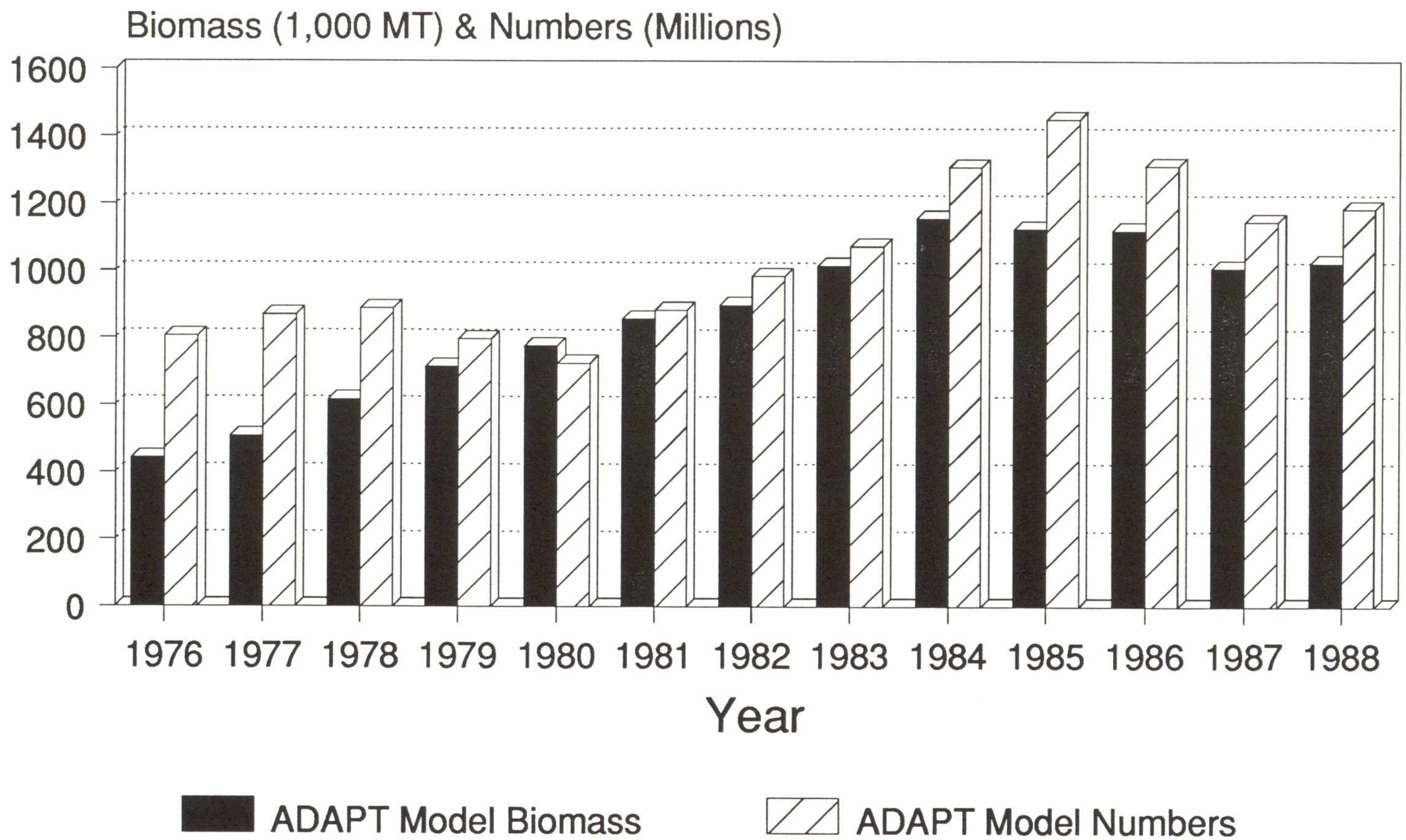
The rather stable level in the biomass since 1984 (as projected from the cohort study) is supported by the commercial catch index and the RV data (**Figure 11**). It also accords reasonably well with the trends in inshore catches during this same period. All this brings us to the view that **the state of the stock measured by the biomass trends does not support a conclusion that anything drastic or threatening has occurred to the northern cod stock to date.**

However, we are concerned that the decline in recruitment which is occurring (three to five years olds), coupled with the continued catch levels experienced during 1986, 1987 and 1988, could sharply erode the gains made in rebuilding the northern cod stock during the late 1970s and early 1980s.

Our concern is based on two observations. First, the ability of the population to maintain a rather static biomass in the past three years despite declining numbers of younger recruits is based on the relative good strength of six and seven year olds in the population during these years (**Figure 12**). The overall population numbers are down but the average age and size of the animals in the exploitable population is up. However, as the smaller year-classes become the backbone of the fishery, the population biomass (if subject to most recent catch levels) is likely to decline (**Figure 13**). Thus although the rather heavy fishing rates (F 0.4) which characterized the fishery between 1984 and the present did not lead to a significant decline in population biomass, this may have been only possible because recruitment was significantly better between 1981 and 1985 than it is likely to be over the next several years (**Figure14**). We do not believe that the 1985-1988 stock levels will be sustained if the current domestic and foreign fishing rates are maintained in the future.

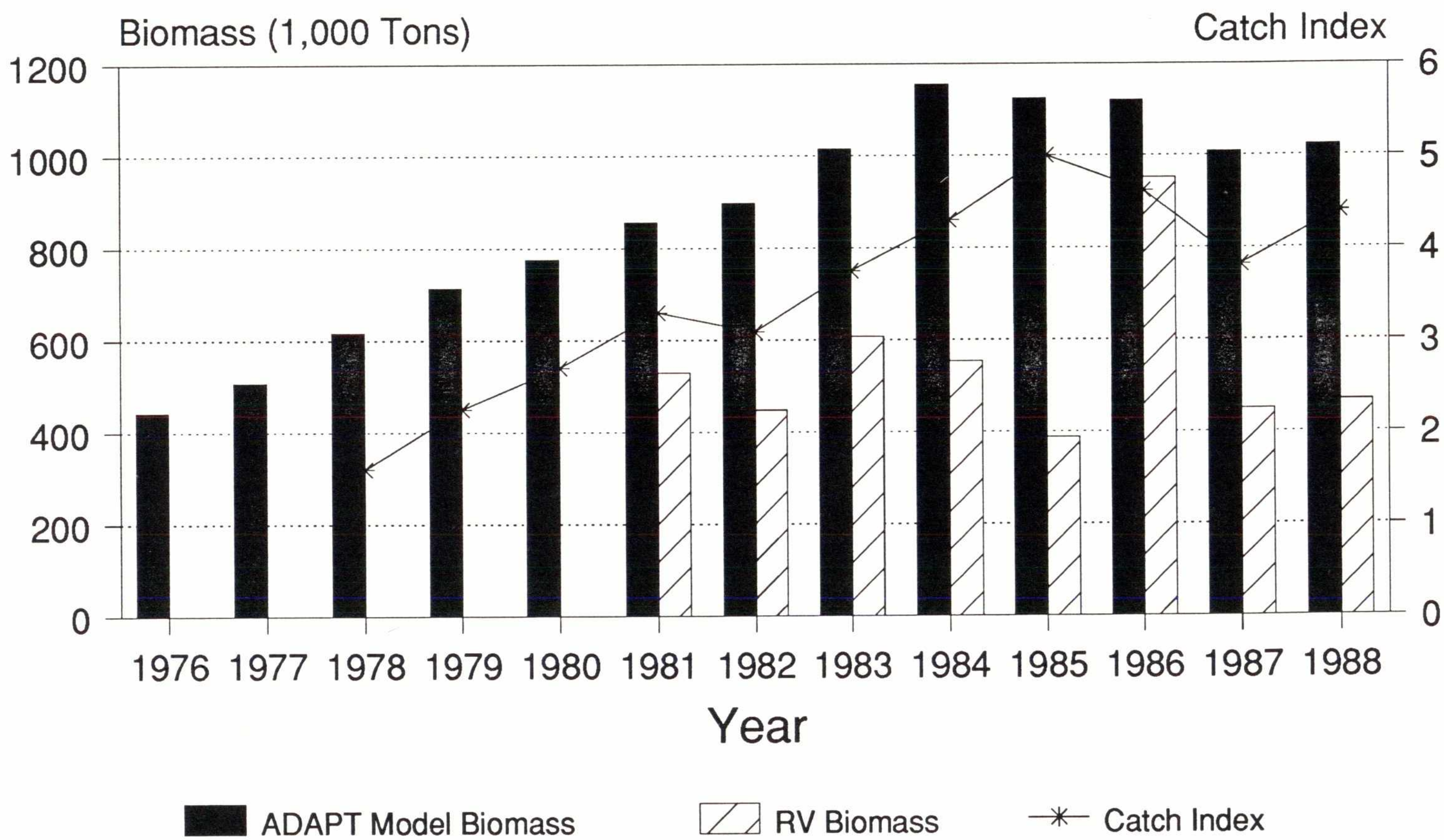
It is interesting to note that between 1984 and the present, the population biomass has been holding rather steady despite the fact that the percentage of young fish (five years and younger) in the catch has declined from 39% in 1984 to 25% in 1988. This relationship may have been affected by changes in the mesh size, the adoption by some fishermen of square mesh, etc., but the inshore catches (excluding traps) by age should not have been similarly biased. The big decline in younger fish in the catch occurs between 1986 and 1987 when the poor 1983 and 1984 year-classes entered the fishery. Looking at these data alone, we would have expected a decline in biomass but presumably the increased strength of earlier year-classes plus growth of individuals has, for the present, stabilized the biomass trend (**Figure 15**). The presumed stability of the population, of course, depends on the reliability of the recent estimate of F=0.44. **If the RVF value is closer to reality, then the population has probably declined in recent years.**

FIGURE 10: ADAPT MODEL BIOMASS AND ADAPT MODEL NUMBERS ESTIMATES OF AGE 3+ COD IN NAFO DIVISIONS 2J, 3K AND 3L



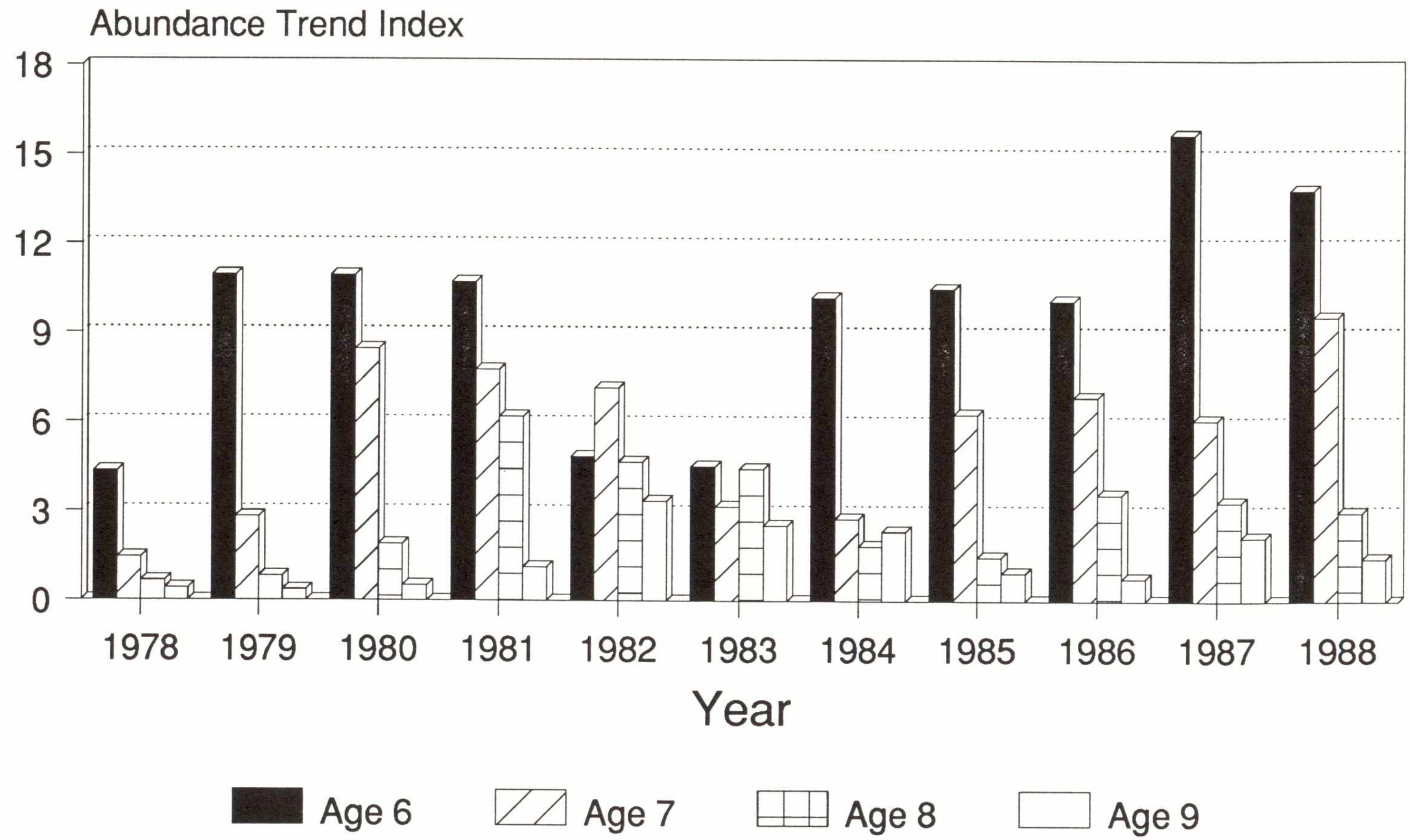
Source: Canadian Dept. of Fish. & Oceans

FIGURE 11: CATCH INDEX, RV BIOMASS, AND ADAPT MODEL BIOMASS ESTIMATES OF AGE 3+ COD IN NAFO DIVISIONS 2J,3K & 3L



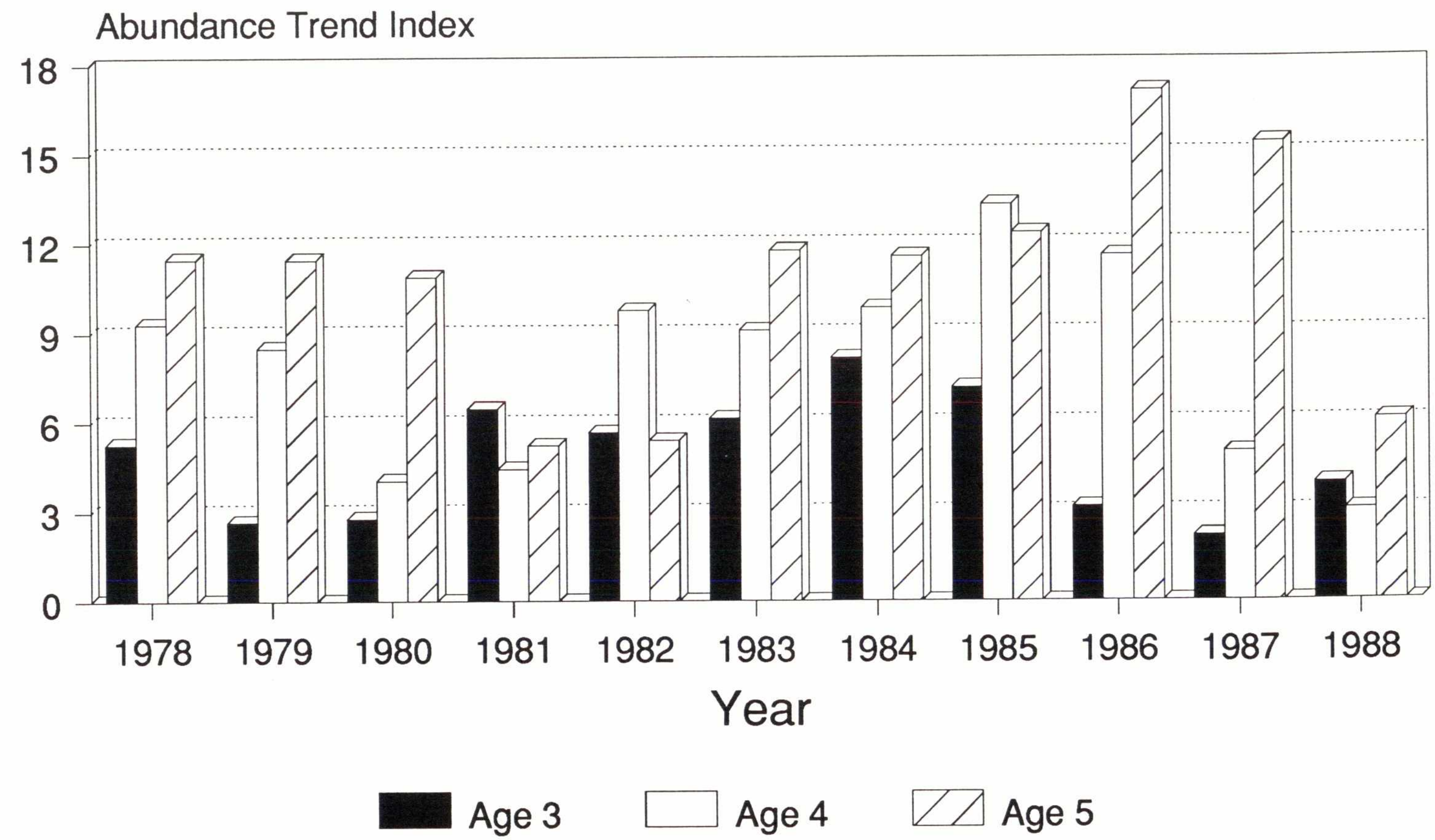
Source: Canadian Dept. of Fish. & Oceans

FIGURE 12: ABUNDANCE TRENDS OF AGE 6, 7, 8, AND 9 COD FROM NAFO DIVISIONS 2J, 3K, AND 3L



Source: Canadian Dept. of Fish. & Oceans

FIGURE 13: ABUNDANCE TRENDS OF AGE 3, 4, AND 5 COD FROM NAFO DIVISIONS 2J, 3K, AND 3L



Source: Canadian Dept. of Fish. & Oceans

FIGURE 14: OBSERVED RECRUITMENT FROM COHORT FOR COD IN NAFO DIVISIONS 2J, 3K, AND 3L

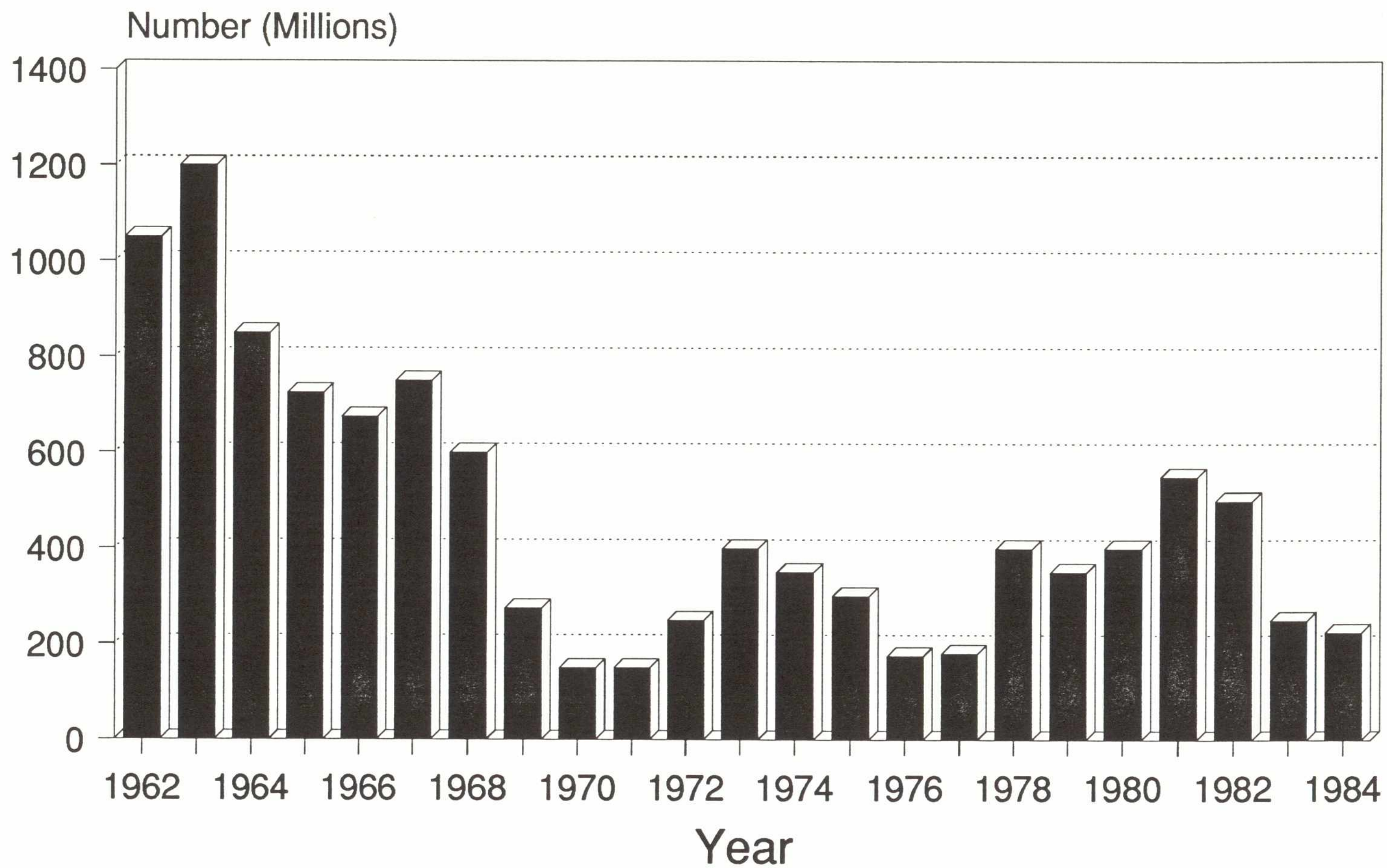
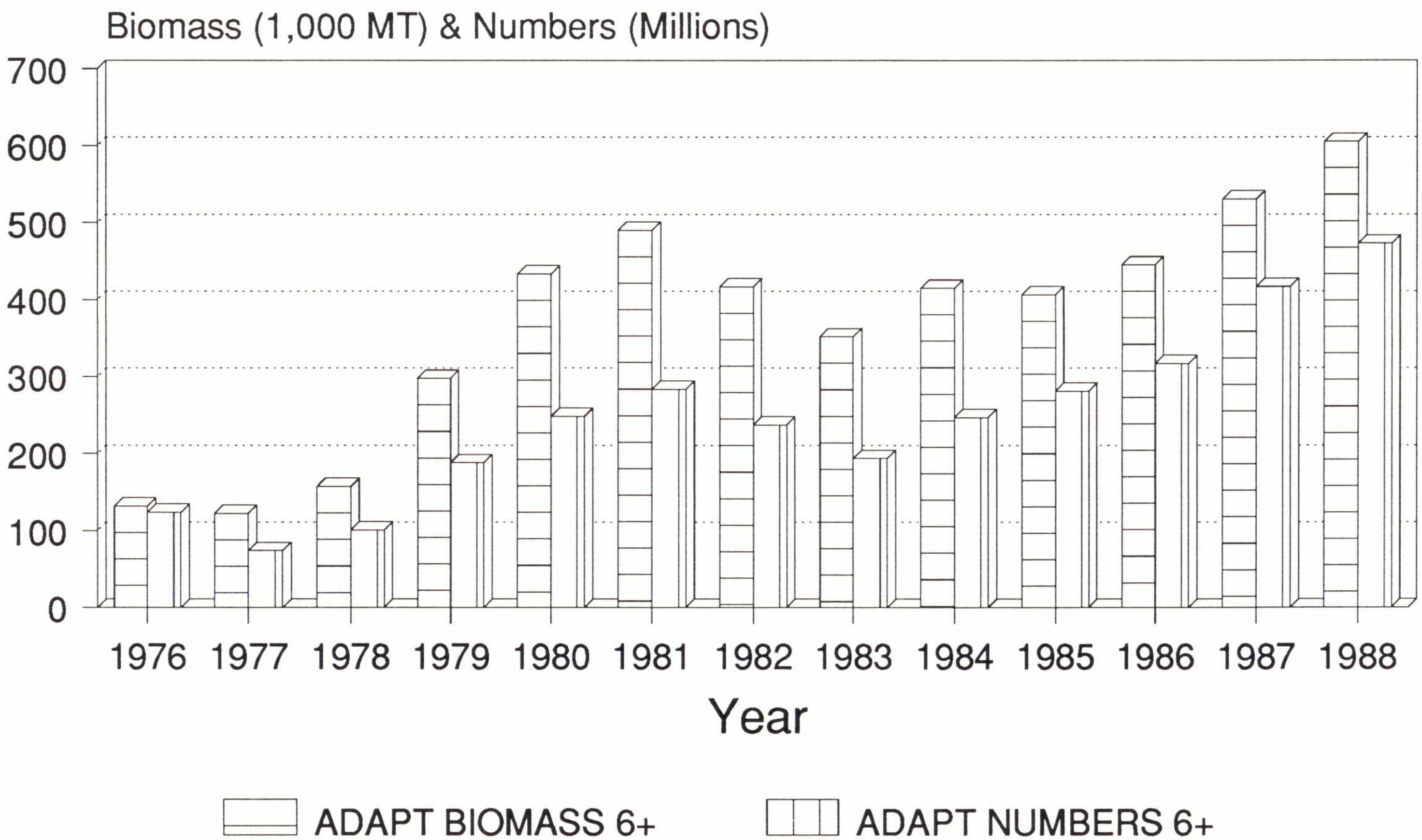


FIGURE 15: ADAPT MODEL BIOMASS AND ADAPT MODEL NUMBERS ESTIMATES OF AGE 6+ COD IN NAFO DIVISIONS 2J, 3K AND 3L



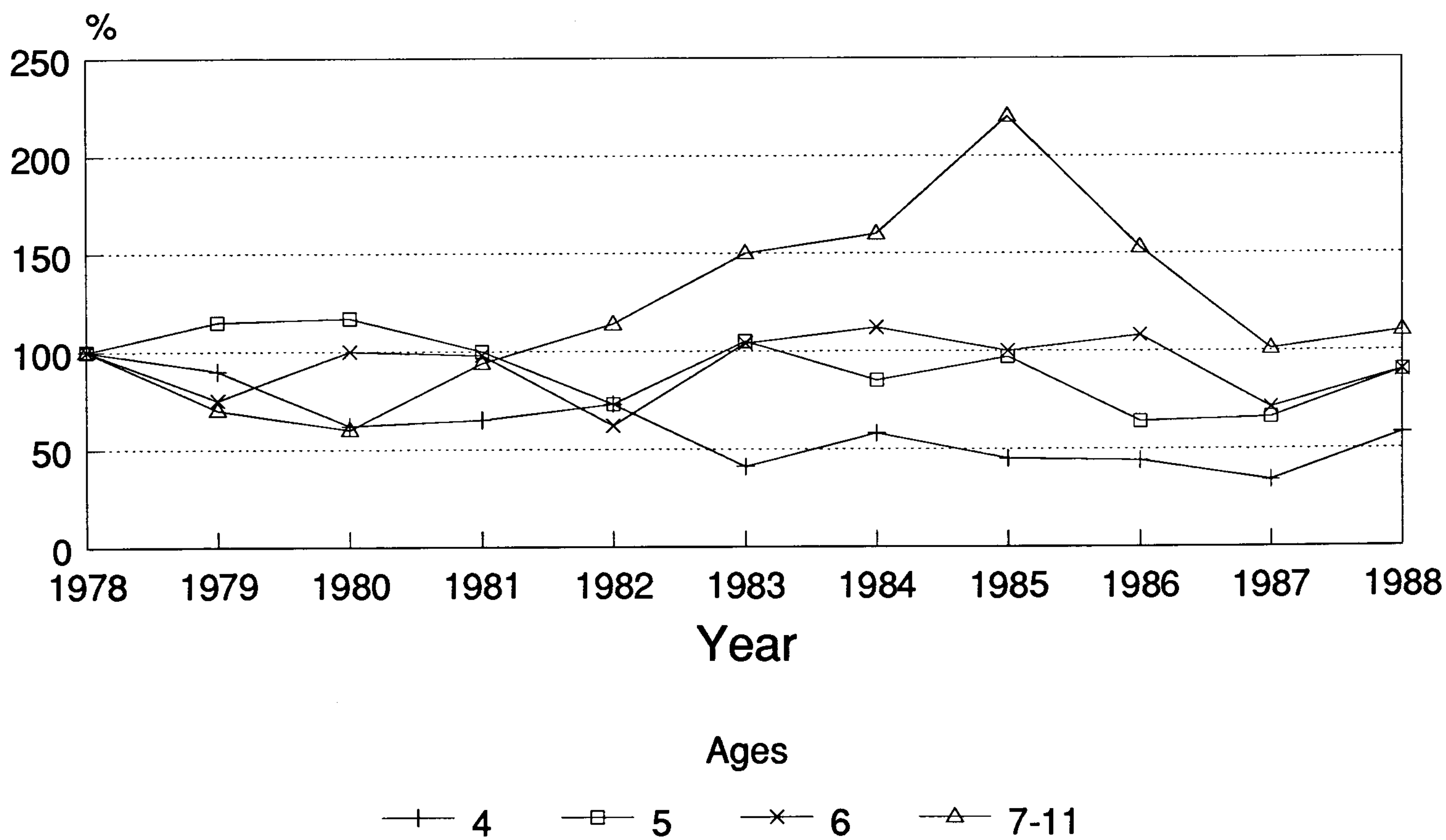
Source: Canadian Dept. of Fish. & Oceans

Changes in state of the stocks are a function of fishing levels, natural mortality, recruitment levels, and growth of the fish in the population. However, our perception of the stock's status may also be an artifact of the database and estimating procedure. For example, if a harvest of 150,000 metric tons is presumed to generate an annual mortality of 0.25, then the population estimate will be 150,000 metric tons divided by 0.25 or 600,000 metric tons. However, if the true value of the annual fishing mortality is only 0.15, then the actual population size would be 150,000 metric tons divided by 0.15 or 1,000,000 metric tons. If the current DFO assessment is correct, recruitment and growth of the fish in population during the late 1970s and early 1980s exceeded losses imposed on the stock by fishing and natural factors. Variation in the natural mortality and growth of the individuals in the population are limited by a complex set of interacting biological and physical/chemical environmental factors and ecological conditions. Although there is good qualitative evidence that these factors play an important role in the behaviour of northern cod, it is not clear to what extent they impact population trends and the data are, as yet, not very useful as an aid to adjusting stock estimates resulting from direct and indirect measurements of population trends.

In conclusion, the Panel notes that since 1976 there has been a general improved stock condition. This has occurred despite catches well in excess of the $F_{0.1}$ goal. Growth of the population appears to have been aided by recruitment levels that were considerably larger than those the stock is now experiencing. Fishing levels have obviously played a role in the exploitable population trend, and the aggregate catches taken from the stock complex in recent years has prevented growth of the stock complex since 1984. **The recent downturn in recruitment suggests that the recent catch level cannot be maintained without causing a significant decline in the exploitable and spawning biomasses.** Further, there are the unknown effects of the foreign fleets operating outside Canada's two hundred mile limit.

Up until the time Canada assumed responsibility for the two hundred mile fisheries zone, the main index of abundance of the northern cod was mostly provided by the catch per unit effort of foreign fishing vessels. From 1978 onward the CPUE series was based upon Canadian vessels. Only two years, 1978 and 1979, provided an overlap period between these two series of abundance indices. With the wisdom of hindsight, it is possible to see that the efficiency of the Canadian vessels increased quite sharply after these two earlier years. **Figure 16** shows trends in efficiency between 1978 and 1988. Taking the result of 1978 as 100%, the efficiency appears to have increased quite sharply between 1980 and 1985 but then has declined perhaps in response to the enterprise allocation regime. While the time series remained short, this increase in efficiency was interpreted as an increased stock size, and this error became apparent only as the longer time series of CPUE data became available and as the survey data series became available for use. If only the commercial CPUE data of 1978 - 1988 are used to tune the VPA then owing to the increases in efficiency, the estimate of terminal fishing mortality is lower than the final figure adopted by CAFSAC. If, however, the earlier years are progressively dropped from the VPA tuning then results compatible with the final CAFSAC estimate are obtained from the VPA tuning. The text table shows the progressive changes in estimates of fishing mortality on ages 7-11 obtained from tunings based upon shortened CPUE time series.

FIGURE 16: CHANGES IN EFFICIENCY, OFFSHORE EFFORT, FOR AGES 4, 5, 6 AND AGES 7-11 COMBINED



Estimated Fishing Mortality Ages 7-11
from Laurec/Shepherd Tuning Based upon Year Y
Up to 1988 Commercial CPUE Data Only

Year Y	78	79	80	81	82	83	84	85	86	87
Fishing Mortality 1988 ages 7-11	.34	.35	.38	.43	.48	.53	.55	.57	.45	.45

It is noticeable that the changes of efficiency figures (shown in **Figure 16**) bear out the contention of offshore fishermen that their catching efficiency has been reduced in the most recent years. However, despite this, the text table shows that an analysis based only upon the last two or three years of their data gives an estimate of fishing mortality in 1988 very similar to that finally adopted by CAFSAC.

5.2.0 Explanation for the Difference Between the Current and Earlier Scientific Advice as to the Overall State of the 2J3KL Stocks

The significant difference in the 1989 scientific advice from that of earlier years results in part from the addition of a new analytical method of handling the data inputs, in part from the changes in the state of stock which have occurred since 1986, and in part from a significant adjustment in the 1986 RV survey abundance estimates.

Firstly, the current method uses results of the prior year to obtain estimates of F for both commercial and RV data. The new model was employed in 1988 groundfish assessments and for the January 1989 northern cod assessment. A subsequent application of the old model to the complete data for purposes of comparison confirmed the belief that the new modelling technique was indeed the superior tool. Thus, part of the change in advice may be directly associated with the model used in the assessment analysis.

Secondly, the change in advice flows from two additional years of data which have been added to a reasonably short series of observations. **The two most recent years show a marked decline in recruitment over that observed in years prior to 1985 (re-visit Figures 12-14).**

Thirdly, the 1986 survey values which were incorporated into the earlier RV survey calibration have now been shown to be an artifact of resource availability, probably brought about by a change in the timing of the 1986 RV survey.

Finally, estimates of fish mortality during the period following Canada's developing the offshore fishery were biased by rapidly changing levels of efficiency resulting from both learning and technological change.

Although these points may seem simplistic, the Panel notes that the basis for the rather sharp change in the character of advice is rooted in recent changes in stock recruitment, an anomalous 1986 survey signal, high variability in the RV tuning data, and the abandonment of an analytical technique that proved statistically faulty in 1989. Whether or not the 1986 RV data should have been suspect and ignored or the bulk biomass model abandoned earlier is a value judgement which is easier to make in retrospect than it might have been in earlier years.

CHAPTER VI

Expanding Our Scientific Understanding

6.1.0 Introduction

In Chapters III through V, the Panel has addressed specific questions raised by the Minister in respect of the structure of the northern cod stock(s), the data and methods used by DFO and other scientists in carrying out assessments of stock abundance, factors influencing abundance trends, and the basis of past and current scientific advice given by DFO scientists. The responses to the questions posed by the Minister have, for the greater part, been based upon a review of the voluminous literature and statistics concerned with the northern cod and upon information provided in response to questions addressed to DFO and other knowledgeable scientists. Hence, they flow from and reflect the Panel's interpretation of data and information garnered from a wide variety of sources and are informed by the Panel's collective understanding of the subjects of concern.

Most of the questions raised by the Minister were concerned, directly or indirectly, with the database and methodologies used by DFO and other scientists in the formulation of scientific advice, but they also raise the more fundamental issue of the appropriate role for science in the formulation of management strategies. This is, indeed, a most important issue for, as has been frequently noted in fisheries literature, one of the important problems inhibiting effective management has been the failure of scientists and administrators to properly differentiate their respective roles of fisheries science and fisheries management. Gulland (1971), for example, makes the point that many problems arise because of "the comparison between the roles and methods of ... science and management" and goes on to explain that

"Management is a matter of making decisions and it is often as important to make a decision in time as to make precisely the best decision. Management has to resolve a wide range of political, social or economic problems. Science has to provide evidence on the likely results, within its field of competence, of possible management actions and so enable more rational decisions to be made.... Science advances by disprove rather than prove—a succession of hypotheses are put forward capable of explaining the observed facts and have to be abandoned or revised as further observations show them to be inadequate."

This scientific process, as Gulland describes it, is precisely what took place in the DFO northern cod stock analysis, although the question remains whether certain methodology and certain hypotheses should have been rejected sooner than, in fact, they were.

In this sense, it is important that the Panel, the scientific community, and the managers alike should acknowledge that the guidance provided did not produce the expected and desired results. It is, however, even more important from the Panel's perspective that the scientific community and the managers should clearly identify and understand factors which may have contributed to an underestimation of fishing mortality and to the inability of science at that time to predict correctly the likely consequences of past management decisions. It is, therefore, the goal of this chapter to examine scientific databases, methodologies and operational modes, and to suggest approaches that may lead to improved scientific advice.

Perhaps at the outset, we should note another of Gulland's dicta from the work cited above, that

> "It is a fallacy to think that scientists, given time, and perhaps money, can produce the complete answers to management problems, e.g. specifically the precise value of the maximum sustainable yield from a particular stock of fish and also the exact levels of fishing and of population abundance required to produce it."

We recognize that fish, the environment in which they live, and the fisheries that exploit them together constitute a highly complex and dynamic system consisting of a multiplicity of interactive functions producing results that may not be easily predictable and that may never be managed with absolute precision. Nevertheless, **we are convinced that greater attention to integrating information from the biological and oceanographic disciplines into the assessment process and better use of the available data sources can reduce the risk of future errors in estimating key population parameters.**

The achievement of these goals will depend in part on adequate funding and in part on the setting of appropriate priorities in the collection and analysis of needed information. We will, therefore, in the pages that follow outline and discuss areas of study and modes of operation that will, we hope, stir the imagination of the scientists responsible for the northern cod stock analysis and, perhaps, serve as a guide to the development of appropriate programmes of research. We recognize, however, the emphasis to be placed upon existing and potential new areas of study will change over time. Hence **it will be necessary to establish a process for the continual reappraisal of the importance of various work and its potential contribution to the overall scientific understanding of the population dynamics, behaviour, life history, and ecological relationships of the northern cod stock.**

6.2.0 The Management Unit

Atlantic cod between southern Labrador and southeastern Newfoundland within NAFO divisions 2J3KL have been managed more or less as a single stock complex since implementation of the total allowable catch strategy in 1973. The decision to treat the population as a single stock complex was based upon earlier information relating to distribution, migration patterns, spawning times and locations, and growth rates (Templeman 1962). However, it would appear that when the decision was taken, it was the general view that subsequent studies might identify a number of populations, stocks, or substocks within 2J3KL at which time management strategies could be appropriately modified. Nevertheless, "except that a recent attempt has been made to distribute the offshore catch in relation to biomass distribution in divisions 2J3KL, there have been no prior stock-specific management measures," (Alverson et al. 1987) since that date. That is to say, fish within statistical divisions 2J3KL have been managed as a stock unit over a period of sixteen years; and, over that time with the single exception noted in the TGNIF Report, no modification of basic management strategy has been deemed necessary.

The concept of a stock in fisheries management is used most frequently to denote a functional relationship rather than a discrimination on the basis of genetic differences. Thus, fisheries scientists and managers generally identify a stock as a population of fish which inhabit a particular region, behave similarly, and can be managed as a unit. That is, the response to fishery removals within any part of the unit area can be attributed to the population of the described stock.

The question we must address is the degree to which the 2J3KL stocks fits such a definition. Evidence of some differential behaviour among segments of the so-called northern cod stock surfaced soon after establishment of the St. John's laboratory. This led to the more contemporary concept that the 2J3KL population is comprised of several overlapping substocks, as described in Chapter III. Certain differential migration patterns and different wintering and feeding grounds have been described for these subgroups; however, intermingling between divisions is also apparent. Gene frequency studies also support the proposition that there is intermingling of cod in 2J and 3KL. However, differences have been found in cod taken from the shallow water of the northern Grand Banks and elsewhere. Further significant differences in meristic characteristics have been noted in fish taken from the southwestern Hamilton Bank and Funk Island Bank. Finally, returns from tagged fish released in inshore areas suggest that some part of the 2J3KL population may remain in some inshore bays throughout the year and, thus, further suggest behaviourial patterns for such fish that are dissimilar to patterns observed among other components of the cod populations in the region.

It is obvious from our review of the literature that a considerable amount of work has been undertaken since the establishment of the 2J3KL northern cod management unit in an attempt to better understand the behaviour and stock relationships within these statistical divisions. Yet, from the Panel's vantage point, no clear picture emerges, and from the information available, it is difficult to conclude that the population inhabiting the region meets either a functional or genetic concept of a "stock." Growth rates, meristic counts, genetic studies, and behaviour patterns appear to differ — particularly at the extremes of the 2J3KL geographic zone. At the same time, we must conclude that on the basis of the literature we have studied and the information we have been given, we are unable to say that the cod inhabiting the waters off eastern Newfoundland and Labrador can be easily differentiated into definably separate stocks.

This seeming paradox may result in part from the fragmentary character of past studies which may in turn be associated with inadequate funding levels. At the same time we must note an apparent lack of a comprehensive plan which would have addressed specific questions that would lead to a better understanding of (a) year to year behaviour of the noted subgroups, (b) the basis and origin of the recruitment to each of subgroups, and (c) the relative contribution of each group to different components of the fishery. **What is required is a comprehensive conceptual model of the recruitment mechanisms, distribution, behaviour, and the behavioral adaptations of the populations of the several subgroups to environmental changes. Expanded studies in these areas seem vital if we are to test the assumption that the 2J3KL population can be effectively managed as a stock unit; or, if we are to determine whether it is necessary or not to establish finer scale management units.**

6.3.0 Current and Alternative Measures of Abundance

The establishment of the annual TAC for northern cod has been in the past and is currently based on stock assessments rooted in VPA and/or cohort analysis adjusted or tuned to two independent measures of relative stock size. The latter as noted in Chapter III involve indices developed from RV surveys and CPUE from larger offshore trawlers. These two indices constitute the primary evidence of population trends.

Although these indices can provide important information regarding changes in population structure and trends, neither is completely reliable in that they are influenced by such variables as environmental change, operational changes in the fishery and/or surveys, and the introduction of new technology. These issues are also addressed in Chapter IV.

6.3.1 Possible Alternatives

The Panel feels strongly that **additional CPUE indices of change in abundance can and should be obtained from elements of the "inshore" fisheries such as gillnetters, small trawlers, and perhaps line trawl vessels. Further, index fishermen or highliner operators in both inshore and offshore fisheries could be used as an alternative and additional check on population CPUE trends.** This would be particularly useful if a time series covering the most recent years could be established.

Other alternatives that the Panel feels should be explored include hydroacoustic population enumeration and juvenile fish surveys. These may be useful for indexing recruitment levels but, in particular, to evaluate both the spatial and depth distribution patterns of the northern cod at several different times of the year.

6.4.0 Measurements of Fish Removals

Estimates of the rate of fishing are frequently based on a knowledge of the size of the exploitable population versus the size of the catch. The annual rate of death from fishing is calculated by dividing the exploitable biomass for a particular year by the reported catch. The accuracy of the estimated rate of fishing on the northern cod stock depends on (1) collecting accurate weights for all of the fish harvested or otherwise killed by both the inshore and offshore fisheries, and (2) how well the scientists can estimate the biomass of the exploitable population.

In the northern cod stock, estimates of the population size have (as previously discussed) relied on the VPA and/or cohort analysis which add the annual catches of various year-classes in the fishery to estimates of those dying from natural causes to develop a historical record of population trends. Errors in either the calculated total catch (or catch by year-classes) can lead to incorrect calculations of the vital parameters used to calculate population trends and thus the quality of advice given to managers.

The Panel was satisfied that recent commercial catch records from the various elements of the fishing fleets constituted a reasonably accurate record of fish caught and sold by fishermen to processors and/or caught and processed by company-owned vessels and subsequently reprocessed. What is not at all clear is the manner in which current estimates of total fish removals account for fish that are caught but not sold because of quality problems, that are discarded at sea because they are undersized, or that are discarded simply because they constitute prohibited species.

In accounting for the effects of fishing, it is clear that the reported catches of the different national and international fleets enter into the total aggregate catch figures. But, if the cohort or VPA models are to provide the most accurate answers possible, they must also properly account for non-recorded catch induced mortality including underreported catches and all discards to complete the calculation of total losses due to fishing. Although estimates of bycatch for large trawlers targeting on cod were available to the Panel, similar estimates for traps, small trawlers, gillnetters, and foreign fishing activities did not seem to be in hand. Further estimates of losses in fisheries not targeting on cod (e.g., shrimp, capelin, herring, and flatfish) were not available. Since the literature does not indicate that bycatch is accounted for in the process of cohort analysis, we have assumed that it has been ignored either because it is felt to be of little significance in the calculation of F or because it has been accounted for in the natural mortality estimate. The Panel is not persuaded that either of those justifications is adequate. In particular, if the latter is the case, we would have expected that the natural mortality estimate would have floated upward over time with the growth of the fishery complex.

During the course of meetings with elements of the fishing industry in Newfoundland and Labrador, the problem of bycatch was raised by almost every sector of the industry. Various estimates of losses of undersized fish and/or discards because of injury or loss of quality were noted for traps, gillnets, small trawlers, large trawlers, line gear, etc. Fishermen also noted cod bycatch problems in the directed shrimp, capelin, and herring fisheries. Estimates of loss of small fish in traps ranged from 2% to 10% by weight of retained catch while estimates for discards in gillnet fishing ranged from two to fifteen percent of the retained catch. In shrimp fishing, one captain noted losses in some shrimp tows of ten pounds of cod for every one pound of shrimp taken. Others, however, reported much lower cod bycatch rates during shrimp fisheries. Fishermen also noted cod bycatch losses were often high in the capelin and herring fisheries. The total magnitude of losses due to discards in the directed cod fishery and other fisheries as well as losses resulting from the inability to handle and process catches is, of course, highly speculative, but the Panel believes that this figure could easily exceed 30,000 metric tons.

In any case, **the Panel feels that the question of all fish caught and not sold for whatever reason and of all fish caught, sold, and not reported needs further investigation.** The magnitude of discard mortality in the Canadian inshore and offshore fisheries, in foreign fisheries targeting on 2J3KL cod, and in both domestic and foreign fisheries targeting on other species, together with underreporting or illegal fishing by both domestic and foreign vessels may constitute a substantial unaccounted fishing mortality and may have contributed to recent underestimates of fishing mortality.

6.5.0 Use of Oceanographic Data and Indices in Forecasting Stock Recruitment, Behaviour, and Availability

In the course of its public hearings as well as in oral and written submissions, the Panel was repeatedly alerted to the widely held belief that water temperature was an important controlling factor in some aspects of the northern cod life cycle and in respect of the availability or otherwise of fish to gear at specific times and locations. This view was shared by fishermen and scientists alike. Unfortunately, support for this contention rests for the most part on anecdotal or intuitive evidence. That in itself does not refute its potential validity, but it does put the burden of proof on the scientist to define such a relationship, if one in fact does exist. It also points to the need for greater general understanding of the broader role that oceanographic variability plays in respect of cod availability and equally the need for improved understanding by the user community of the array of significant interactions within the marine environment that are germane to their interests.

The marine environment is often complex and unpredictable. The forces which influence the location and intensity of ocean currents, the interplay of waters with different properties, all the unpredictability of seasonal change, or the biological suitability of one area relative to another are incompletely known. Oceanographers can easily enumerate suspected mechanisms, but difficulties arise when attempts are made to link a specific force to a particular result. Sometimes correlations are possible, but they are no guarantee of a causal relationship. More often it is the interplay of several factors simultaneously or in tandem that produce observed responses. In addition, one must be aware that events in the marine environment can and do occur at a variety of time and space scales. Water mixes over distances smaller than the smallest organism, or larger than the largest ocean basin. The intervals over which these events occur range from a fraction of a second to years.

Within this dynamic and unpredictable physical environment is a diverse array of organisms who also vary in time and space. Their number and variety reflect both the quality of that environment plus their ability to adjust to a changing world. Here, one must keep in mind that each species has unique environmental requirements so that in a group made up of several different species, a great deal of complexity exists at all stages in the food chain. Also, as with the physical processes mentioned above, delays can occur sometimes on the order of years between a particular event and the final result.

In short, the marine environment in which the northern cod exists is one which contains considerable natural variability in the biological as well as physical sense. This variability is affected by different influences which can exert themselves singly or in complex interactions. One well known manifestation of this unpredictability is the 200 to 300 year long record of northern cod catch statistics. These data show wide variations from year to year well before sophisticated modern technology would have had any influence on fishing success. It is a safe conclusion that environmental variability played some part in these differences, but it will never be known for certain whether it influenced stock recruitment, animal behaviour, or simply availability —or possibly all three.

6.5.1 The Physical Environment

The regions of primary concern to the Panel are the NAFO subdivisions 2J, 3K, and 3L, which collectively approximate one million square kilometres. The geographic extent of this area is roughly from Harrisson Bank off the coast of Labrador to the northern tip of the Grand Banks in the south. Approximately 20% of the ocean in this area overlies continental shelf, upon which the various rich fishing banks are located. The topography of the shelf is marked by a distinct lack of uniformity: depths vary over a range of several hundred metres; some areas are scoured clean by icebergs while others are strewn with boulders; shelf width can vary from a few tens of kilometres to well over three hundred; and the ocean environment varies greatly across the shelves, as well as along them.

Water movement over the continental shelves of the 2J3KL region is generally southerly and occurs principally in the form of the Labrador current, which transports some of the coldest surface water in the North Atlantic. Although this current moves southward out of Baffin Bay, its origins are traceable back through a number of intermediaries to the Gulf Stream. This linkage points out that, even though far removed from the central North Atlantic, it remains subject to its large scale dynamics. Flowing southward the Labrador current separates into two distinct subunits which are identified by their positions relative to the continental shelf. Consequently, the inshore portion can be found close to the coast while the offshore component is normally near the shelf edge. The average position of each is reasonably well known, although it can vary within quite wide limits. One additional influence is the annual outflow from Hudson Bay of large quantities of fresh water derived from winter melt. The volume and timing of this outflow can influence characteristics of the Labrador Current.

Superimposed over this general southerly flow is a vertical water structure which has been described as reasonably typical of much of the east coast of North America. It is a distinct and, in a somewhat coarse sense, a predictable three-layered system which can also show considerable variability as to the exact location of each layer, their respective thicknesses, duration and perhaps most importantly their physical characteristics at important periods during the northern cod annual cycle.

The vertical structure of the waters in 2J3KL begin with a uppermost layer which extends to a depth of approximately 40 metres. During the warmest months temperatures can reach 10-12 degrees Celsius at the surface with a sharp gradient at the lower end, which marks the boundary to the layer below. The middle or intermediate layer begins with the aforementioned transition and extends to depths of 150 to 200 metres. Although temperatures in this layer have been observed below -1 degree Celsius, it can vary over a range of several degrees. Temperature is thought to be influenced by water entrained farther north with the added impact of localized cooling in any one winter. At that time, it and the surface layer become one, through the complementary processes of intense cooling from contact with the atmosphere followed by convective mixing. An especially severe winter could then lower the temperature of the intermediate layer relative to previous milder years.

The bottom layer comes about when waters from the deeper more oceanic areas move up and onto the continental shelf in the form of irregular intrusions. The result is a layer which is warmer and saltier than the one immediately above. When it is present it results in strongly contrasting biological environments over a very short vertical distance. Cod apparently find the characteristics of this bottom layer especially hospitable, given the fact that it is in these waters, at the shelf edge, that they winter over and spawn. These inshore-directed intrusions are governed by forces which are only now beginning to be understood. For the moment there is no clear indication as to seasonal variation.

6.5.2 Biological Considerations

Northern cod have grown and flourished on the Grand Banks and along the coast of Labrador for millennia. Their normal behaviour is to spawn on the outer slopes of the continental shelf at depths of approximately 300 to 400 metres and at water temperatures around 3 degrees Celsius. When eggs have been extruded and fertilized they float to the surface where they commence the earliest stages of maturation. Subsequent to spawning, the adults begin a migration to the west and south which should eventually take them inshore. It is widely presumed that the single most important motivating factor in this move is the desire to feed. From the standpoint of the fishing industry three events of major importance occur at this time. The first deals with the recruitment of new members to the population, the second concerns their migration to the coast, while the third is related to their availability to the fishermen. The physical environment can have an impact on all three.

There is a widely held, although unproven, belief that lack of tolerance for cold water by northern cod coupled with unpredictable changes in the Intermediate Layer have contributed to the observed variability in inshore cod availability. This has come to be referred to as the "thermal barrier". Some evidence does exist showing that temperatures do vary within the Intermediate Layer, although at its core it is normal to expect readings of less than -1 degree Celsius. Cod are believed to be inhibited in their movements by temperatures colder than -0.5 degrees Celsius. More important than the core temperature is the fact that the geographic extent of the Intermediate layer is also quite variable: it could extend well inshore or be observed far removed, it could be exceptionally thick or modestly narrow, or it could be in some extreme position for a brief period or for several months.

The practical result of such a thermal barrier, assuming from the fishery standpoint that its worst characteristics were displayed, would be to delay or even prevent inshore fish movement. The route that cod would follow might be deeper and more circuitous, as might the timing of the migration or even the final destination. Once inshore, the depth at which the fish feel comfortable might be deeper than previous years because the water overhead in the Intermediate Layer might be colder than normal. This would clearly have an impact on codtrap and gillnet fisheries which are used to fishing certain areas.

The survival of the fertilized egg and larva is decidedly a more complex matter than can be explained by the presence of a thermal barrier. It is an area of concern to all fishery biologists who readily acknowledge that physical factors play an important but as yet inadequately defined role in this process. The physical environment plays an important role in determining the success of an egg from the moment it is released on its own. But that same environment also strongly influences the myriad other organisms which coexist with the cod. Their success as either potential predators or potential sources of food is of equal importance but much less easily delimited. It should also be kept in mind that physical influences can be exerted during one year but might not show up in terms of their impact on the fishery until one or several years later. In other words, the concept of lags or delays adds a very important complicating factor to this whole issue.

6.5.3 The Use of Oceanographic Data for Forecasting

The physical characteristics of an environment are of fundamental importance to any organism attempting to grow and prosper there. Whether we consider bacteria in a laboratory dish, deer in a temperate forest, or vegetables in a summer garden plot they all require compatibility with their respective environments in order to flourish. In nature, normal variations in the physical environment include: available moisture, temperature, predators, nutrients, or any number of factors which can alter the success of the organism in question. When man vigorously intervenes, whether through agriculture, ranching or refined laboratory practice, it is with the express intention of maximizing the environment for the benefit of the organisms. This approach has been remarkably successful over the past 150 years culminating with our present enjoyment of the "Green Revolution". Without this control the present world population could not be fed with our present resources.

The approach used with fisheries today is not as devoid of environmental control as last century's buffalo hunt on the North American plains nor is it as regulated as modern ranching. Instead, modern population biologists attempt to understand how environmental factors exert their influence. **It is unlikely that this understanding will ever be translated into genuine control in the marine environment. Instead, greater understanding would be useful as a means of predicting or forecasting annual recruitment, availability or perhaps even location of animals important to the fishery. In other words this information would be extremely useful**

to manage the stocks by maximizing the available information and thereby minimizing unexpected findings which can threaten the fishery. Lack of information such as this has led to the crisis in which we are presently involved.

The question before us is whether or not it is possible under present circumstances to more accurately predict the vagaries of the fishery. It must be remembered that one's ability to predict anything is directly proportional to one's understanding of the factors which bring about change. With regard to the predictive role of oceanographic parameters in 2J3KL we have very little confidence at the present time for two reasons. Both the physical environment and the relationship between it and the organisms are insufficiently well defined to give confidence to most predictions.

In fairness to the scientists involved, attempts have been made to correlate various catch statistics with available temperature information. A positive correlation has been demonstrated between total inshore landings and water temperature during the summers of 1972-1979. This lends some support to the thermal barrier theory postulated above. However, it is hardly more than indicative since positive correlations simply demonstrate that the events being considered occurred simultaneously. Directed toward the future, the quality of the data is insufficient to give much guidance as to potential changes which might be expected from future variations in temperature.

Much of what we know about oceanographic conditions is based on hydrographic transects made over the past 50 years, current meter and thermistor moorings over the past 15 years, satellite observations, plus the output of numerical models. Although the above may sound impressive, it is a very large area to study, and consequently it has been greatly undersampled especially in terms of knowing the nuances of interannual variability. In oceanographic terms the available data provides very little in the way of spatial or temporal resolution.

An indication of some of the present needs would include a better understanding of the influence exerted on the southward flowing Labrador current and the resulting three layered structure by the following: continental shelf topography, climatic trends, local weather, Gulf Stream perturbations, cross-shelf intrusions, fresh water outflow from Hudson Bay, annual ice cover, and the possible influence of tidal forces. These are not presumed to be equally important, but at this point the rightful listing of priorities is not obvious. Ultimately, this improved understanding of the physical environment would be coupled with biological data which would in turn permit a deeper understanding of this complex system and with it possibly an improved ability to forecast.

In conclusion, it is apparent that the distribution, survival, and behaviour of the northern cod are influenced by a variety of oceanographic parameters and processes. These are, however, at present poorly understood. The above comments should not be interpreted by the reader as criticism of DFO by the Panel. It has been mentioned repeatedly that the environment occupied by the northern cod is large and exceedingly complex in oceanographic terms, and the number of scientists directed to this issue has been minimal. DFO has made staff and program changes over the past several years to attempt to come to terms with this deficiency. We believe this to be a positive sign but one unfortunately of limited value, given the magnitude of the problem. In our opinion there is a need to address the issue more directly through reorganization of personnel and altered priority setting as described in **Chapter VIII**. In addition we feel that the logistics are so enormous that the only approach which offers a reasonable possibility of success must include the employment of more refined technology (see **Chapter VIII) in order to gather the necessary data to refine our present inadequate picture of this natural system.**

6.6.0 Predator/Prey Relationships

Another issue with which the Panel was repeatedly confronted in the course of its public hearings was that concerning the growth of the seal herds and the possible impacts of that phenomenon upon the abundance of cod. Clearly and quite apart from fishermen's universal belief that seals are significant predators of cod and other valuable commercial species, the Panel must consider at least two important questions concerning those mammals. First, whether increased seal predation is sufficient to alter the natural mortality figures for cod which have been used in population assessment models; or, second, whether seal predation upon common prey species such as capelin and shrimp is capable of affecting the growth rates of cod and, therefore, of modifying the weight-at-age data relationship.

Seals are but one element in the equation. Indeed, there is a steadily growing school of thought suggesting that better scientific advice could be developed if predator/prey relationships and interspecies competition in general were more fully understood and if the means were found to integrate this kind of knowledge into an appropriate multispecies fisheries management mode. But even if this multispecies "wave of the future" approach is not yet a practical consideration, we cannot ignore the reality that a major fluctuation in the numbers of certain predator or prey species must result in accommodations elsewhere in the ecosystem.

If we accept this position then it should follow that the most appropriate approach to an accurate assessment of northern cod stocks would be against a background of interspecies relationships, among such relationships that between cod and capelin, between capelin and seal, and between seal and cod are particularly important.

6.6.1 Cod/Capelin

In the long list of things that may be found in cod stomachs, a relatively few animals appear consistently to constitute the bulk of their diet. Among those, capelin is known to be the most significant, although, it will be clear that the degree of reliance upon capelin will be dependent upon the extent to which capelin and cod overlap in the water column and upon the area and time of year in which predation is taking place.

In any event, recognition of the fact that capelin are a most important prey species for cod and other fishes, for seals and other marine mammals, and for sea birds has contributed to the current conservative strategy for capelin management under which the TAC is set at 10% of the estimated spawning biomass. We should not forget, however, that in this case the cause of conservation is supported by limited markets which result in a lower rather than a higher TAC. Should additional market opportunities arise, we can surmise that industry will demand a higher rate of capelin exploitation. And yet, **we are persuaded on the basis of current knowledge that a large**

capelin population may be an essential precondition of a large cod population. Until we are convinced that we have an adequate understanding of cod/capelin interaction, we should err, if at all, on the side of underexploitation of capelin rather than on the other side.

In this context, recent experiences in the Barents Sea fishery are instructive. Preliminary studies there indicate that current dramatic decreases in cod growth and, indeed, the disappearance of some year-classes altogether may well be the consequence of a reduction in capelin abundance brought about by overfishing. And, even if it may be argued that the situation in the Barents Sea with its different environment, its smaller selection of alternate prey species, and its vastly higher exploitation rates cannot be properly compared with the situation in 2J3KL, we must take from the example a salutary warning **that substantially increased pressure upon the capelin stocks may produce deleterious results.**

Studies undertaken to date give no indication that cod in 2J3KL would turn in a significant way to other prey to compensate for a scarcity of capelin. We should note, however, that our data are limited both in quantity and over time. For the period prior to 1977, we must rely upon information provided by foreign countries and particularly by Russia. Furthermore, because of differences in approach it is difficult to compare such data with that collected by Canada in the 1980s.

We do know that capelin stocks declined most dramatically in the late 1970s possibly as the result of a succession of poor year-classes environmentally induced. But, at the same time and because of foreign overfishing cod populations were also very low. Subsequent to that period, both capelin and cod populations have made significant recoveries. Thus, in the brief few years of active Canadian research, there has not been an occasion to test properly the hypothesis that the growth of cod is adversely affected by low abundance of capelin.

At present capelin stocks appear to be very healthy at least in the context of the very brief time series of abundance data we possess. Fortuitously, that situation coincides with limited market demand. The result has been that there has been no great pressure to analyze the data being assembled or to address as a matter of urgency such difficult questions as relate to the competitive demands of fishermen, fish, seals, whales, and seabirds for a common prey species. But, considering the vagaries of the market and the history of wild fluctuations in the strength of year-classes of capelin, we should not permit the easy stability of the present situation to lure us into a false sense of security.

In this context, it is important to note that the Cod-Capelin Working Group, first established within the Newfoundland Region of the Department of Fisheries and Oceans in 1986, has recently appeared to have picked up the pace of its activity. And, indeed, it is important that the Group be encouraged and provided with the necessary time and resources to follow through on "reviewing potential hypotheses regarding interactions between the two species and evaluating the adequacy of existing data bases and data collection for testing these hypotheses" (Cod-Capelin Working Group - Preliminary Report, 1986). **It would be appropriate to provide the resources to permit the concurrent examination of cod-capelin interactions during an extended annual survey period.**

This implies the use of two vessels, since cod and capelin surveys cannot be simultaneously conducted from one, to track spring migration inshore of both species and, in the process, to find answers to several important behaviourial questions. The simultaneous study of predator and prey species in the context of a process that is so important to our understanding of the mechanisms that affect the availability of cod at specific inshore locations could be the first of what might become a succession of multispecies approaches to research. Nor, as such studies develop should we ignore the possibility of fruitful cooperation with other nations whose interests in capelin and in capelin-cod interactions are as profound as ours must be. Recent visits to St. John's of Norwegian and Icelandic scientists seeking interaction with DFO scientists and particularly with the Cod-Capelin Working Group confirm the interest and point the way to what should be a continuing dialogue, regular exchanges of data and of ideas, and a concerted approach to the enhancement of scientific understanding. Such informal dialogue between small working groups and even individual scientists would supplement such formal processes as are represented by larger conferences such as those convened under the aegis of ICES.

6.6.2 Seal/Capelin

The scientific problem arising from predator/prey dynamics as they impact upon northern cod and capelin stocks are compounded by the role of marine mammals in general and by the particular role of the great harp seal herds. For while cod may be the most important predator of capelin, the harp seal is known also to be a significant competitor for that same source of food. While it is known that seals are opportunistic feeders and will as circumstances offer take herring, crustaceans (especially shrimp), and a broad range of other pelagic and demersal species, most authorities agree that capelin is their major prey. Unhappily, we do not have precise data concerning the weight of food that a seal will daily or annually consume. Estimates based on experiences with animals in captivity suggest figures ranging about 6% of body weight per day.

It is clearly evident that further study is required. In the meantime, it is also evident that a herd of several million animals possibly consuming 6% of its biomass daily does require fish of whatever species that must be measured in millions of tons. If, indeed, a considerable portion of this total should be capelin, the obvious question that must be asked is to what limit the herd can grow before its appetite precipitates a collapse of capelin stocks. A secondary question is whether the herd will itself decline as capelin become less abundant or will the seals in the absence or scarcity of capelin concentrate more heavily upon other prey species. And, finally, we must ask how either of those possible developments would impact upon the cod stocks.

In order that these questions and others that will occur to the thoughtful reader may be properly addressed, **we might suggest that the Cod-Capelin Working Group should expand its horizons or have its mandate expanded to include seals and other significant predators of capelin. Again, a systems approach is indicated.**

6.6.3 Cod/Seal

Throughout all sectors of the industry, there are strong convictions that the harp seal is a significant predator of cod. Many fishermen cite personal experiences of cutting open seal stomachs and finding whole cod and turbot. Offshore fishing captains have noted that seals target the "gut" of the cod (FPI, 1989). Inshore fishermen have observed cod in their nets with the stomachs partly torn out. Sealers make reference to having seen cod with parts of their stomachs gone lying on the ice next to seals. In light of this anecdotal evidence, it has been suggested that the practice of eating only cod stomachs may serve to mask the degree of seal predation on cod by confusing the issue of seal stomach contents. In any event, recognizing the limitations of available scientific evidence, the Panel is convinced that seal predation is a matter for concern and clearly unresolved. Thus in the view of the Panel, it is particularly important that appropriate and accurate data be assembled as soon as possible.

A question that is equally as important as what seals eat is how many seals there are. Again, we simply do not know. Fishermen have told us repeatedly that seals are now more numerous along the northeast coast than at any previous time in memory, that they are arriving in coastal waters earlier and departing later then heretofore. In short, we encounter no witnesses who did not believe that there had been a virtual explosion of numbers and none who were not convinced that the matter of cod-seal interaction demanded urgent evaluation. For, quite apart from actual predation, fishermen repeatedly informed the Panel that the appearance of seals on cod fishing grounds invariably meant the total disappearance of the cod.

The Panel agrees that we should possess accurate information including valid population statistics. Moreover, the time for a census is now opportune. Sufficient time has now elapsed for the earliest survivors of the offshore hunt that was abandoned in 1983 to have matured and whelped. A count now would not only provide the information we currently need but would permit the testing of certain hypotheses concerning such matters as fertility rates and rates of natural mortality.

Owing to the low harvest rate in recent years, population assessments based upon tag returns is not feasible and methods of directly counting pup production are likely to be more effective. The likeliest approach of all would be through direct aerial survey, a technique for which DFO appears to be very well prepared. Scientists have already examined photographic systems for those providing the best visibility of seal pups on ice, have evaluated a variety of sensor combinations, looked at the influence of flying altitudes, and studied the ice properties of seal habitats. **We strongly recommend, therefore, that funds to support the survey be approved.**

Only when we posses firm estimates of the present population size and of its rate of increase will we be able to consider the quantity of fish consumed by seals and whether or not adjustments are necessary to protect commercial fisheries. Nevertheless, to get accurate answers to such questions, we must combine population studies with dietary and feeding research as related to the behaviourial patterns exhibited by the animals over the large geographic area they inhabit and throughout their seasonal migrations. In addition to recommending that **the Department of Fisheries and Oceans Collector Program be more extensive geographically and seasonally, we recommend that observers on commercial fisheries vessels be required to record seal**

sightings, to record evidence of seal attacks on cod, and to obtain samples of seals as required by scientists.

Furthermore, since rapid digestion inhibits accurate estimation from examinations of stomach contents alone, **we suggest that carefully controlled studies of animals in captivity might be commissioned or undertaken.** To this end, it should be possible to establish an appropriate programme in cooperation with a university laboratory.

In whatever way the research is organized, it is clearly imperative that our knowledge base be expanded. It is also important that we give careful consideration to the question of how long a system predicated upon an annual and controlled harvest of commercially valuable marine species can remain viable if all the major components of the system but one are subject to TACs, and that one is subject to no control at all. In any event, before any action is taken, it would be preferable to address the underlying policy concerning the management of seals and other marine mammals.

Although this discussion has centred around the harp seal, we should not ignore the fact that there are hooded seal herds as well. While these herds are not as large as those of the harps, they tend to fish in deeper water and are known to feed on larger fish including demersal species. It has been suggested that cod could very well be one of these fish and based on individual body weights, hooded seals would, in all probability, consume more food per animal than harp seals.

6.7.0 Fishing on Spawning Stocks and Groups

During the course of the Panel's public hearings, a number of questions were raised regarding the impact of offshore fishing on spawning groups and aggregations and upon the spawning grounds themselves. The often passionate protestations left no doubt of the strong convictions held by many fishermen that fishing on spawning populations is "destructive" and is the largest contributor to the decline of the northern cod stock. Such convictions are often shared by fishermen everywhere and, since the questions put to the Panel are hardy perennials among fishermen, they bear some discussion.

It is not inappropriate to note at the outset that many of the world's major fisheries are conducted just prior to or during times of spawning. These include capelin, herring, salmon and the flounder fisheries, as well as fisheries for most cod-like species. For most of these management strategies involve controlling the level of fishing to insure that an adequate spawning stock is maintained. If a spawner/recruitment correlation is clearly known then knowledge of that relationship is used to establish catch levels.

However, when the available quota of a particular species can be taken throughout the year, fishermen tend to regulate their activities to times and locations that take advantage of fish aggregations, or of other behaviourial characteristics of the target species; that respond to market demands; or that merely suit their own particular convenience. In the case of northern cod, inshore fishermen catch them when they congregate inshore on their feeding migration. If the situation were reversed and cod moved inshore to spawn and offshore to feed, it is certain that the inshore fishery would be a spawning fishery just, in fact, as is the capelin fishery. And, in a strict mathematical sense that would make no difference to the survival of the species. For, assuming a target fishing rate, it does not matter in terms of the spawner stock at what time of the year the harvest mortality is imposed. If other factors are not of concern, the goal of preserving the stock will be realized by maintaining a desired level of spawning population with the appropriate age structure within that population. The important fact is the number of fish that are killed, or rather the number that are spared, and not the date on which the killing occurs.

There are, of course, good and valid fishing regulations which prohibit certain fisheries during the spawning period, but such regulations are frequently based on other important management goals. For example, fishing salmon on their spawning grounds is generally prohibited because such activity would disrupt or damage or perhaps destroy the spawning habitat. By the same token, for species whose eggs are deposited in bottom sediments or attached to plants or adhere to rocks, shells, etc., the prohibition of fishing in areas and/or with gear types that may alter or destroy the spawning habitat is desirable. In other cases, fishing during spawning periods may be prohibited because the general biological and physiological, and/or market condition of the fish at that time may produce a poor quality product providing lower yields or lower market values. On the other hand, in the case of species like capelin, lumpfish, or sturgeon, for example, the maximum value occurs during the spawning period because the valuable product is the roe. Even in the case of salmon, though they are not fished on the spawning grounds, it is frequently argued that better management is possible if the fish are taken when they congregate to enter the spawning streams since at that time fishing effort can be more effectively distributed proportional to spawning stock size. In fact, Newfoundland fishermen take salmon just prior to spawning, intercepting them as they approach the spawning rivers. **For cod there is no recorded evidence that fishing during spawning periods affects the spawning habitat in a negative manner or that fishing in other periods of the year will result in better survival of the spawned eggs. Thus, there is little if any substantiated evidence supporting the claim that fishing by trawls during the spawning season damages survival of the spawning products or that such removals are more damaging than taking fish during other periods of the year.**

Nevertheless, we cannot leave this subject without injecting a cautionary note. The state of our current knowledge is such that we cannot easily answer the question whether intense fishing on spawning cod populations disturbs either the mating behaviour or the spawning success of the aggregate. Nor can we be sure that fishing on large spawning aggregates will not lead to localized depletions so that overfishing of particular spawning groups may lead directly, in the short term, to shortages of fish in particular inshore areas. The longer term impacts are, however, speculative because we are not sure of the year-to-year integrity of spawning aggregates or of the relative contribution such spawning groups may have to the northern cod recruitment. That is to say, we cannot give anything like a definitive answer until we know a great deal more about the nature of the spawning subgroups, their aggregational patterns from year to year, the manner in which recruitment to such groups is affected, and the nature of their feeding and spawning migrations. **Once again, further study is indicated and, in light of the strongly held public perceptions, should be treated as a matter of some urgency.**

6.8.0 Integrating Data in the Assessment Process

The assessment of population trends in fish stocks requires that we assemble information on the magnitude of catches, that we identify trends in CPUE, that we possess knowledge of fish behaviour, that we understand their recruitment patterns, and that we have access at appropriate times to independent RV surveys of stock sizes. In the assessment of most fish stocks, we seek to determine the numbers of fish at various ages in the population and to make estimates of mortalities imposed on each age class. From these data it is possible to make judgements concerning the current state of the stock relative to such management objectives as the level of fishing mortality and the proper estimation of future catches. It is clearly imperative that if there is to be effective management these stock parameters must be calculated with the greatest accuracy and precision possible given the available data.

Population estimates for past years can be made by using retrospective population analysis (virtual population analysis or cohort analysis) given only a sufficient time series of total catch-at-age data. Furthermore, such estimates are not subject to large errors. If underlying assumptions such, for example, as that identifying the level of natural mortality are correct, the only remaining concerns are subject to an usually modest lack of precision owing to catch sampling errors; the possibility of bias deriving from systematic under- or oversampling of any catch-at-age data; and other systematic error reflecting faulty estimation of the most recent estimate of the number in the equivalent year-class of fish. The magnitude of this particular error, however, converges backward through time. Thus an overestimation of the numbers of ten-year-old fish in 1988 will cause a smaller overestimation in the numbers of five-year-old fish in 1983 and a still smaller overestimation of two-year-old fish in 1980. These caveats apart, given adequate sampling of catch-at-age data in all years, it is possible using retrospective population analysis alone to acquire good estimates of absolute populations and mortality rates in years sometime in the past. Put simply, when you have caught the lot and estimated losses owing to natural mortality, you know how many there once were.

Unfortunately those methods do not in themselves provide information on the current stock size. That figure must be estimated by making use of additional data relating to the relative abundance of fish in different years or to the relative level of fishing intensity. Hence data sets such as commercial catch per unit of effort or research survey catch rates or commercial effort data are used to "tune" the retrospective population analysis. In this way, accurate estimates of absolute population and mortality rate made in the past can be used to calibrate the most recent data, and the results from these calculations can then be used to provide estimates of current stock size. Although the basic intention of all methods of tuning VPAs are essentially the same, the various methods differ in their detail. The search for the best method is an active area of research in fisheries population analysis. At present, no method is a clear favourite, but an understanding of what constitutes a reasonable method is emerging.

In the case of the northern cod the tuning methods used previous to 1988 were based upon the use of bulk biomass models. Thus, the VPA was used to estimate the exploitable biomass of the stock each year, and this was correlated with the CPUE or survey catch rate for all ages combined. The level of fishing mortality and hence of population size which gave the best correlation was then adopted. Such bulk biomass methods have in recent years become less highly regarded in fisheries population dynamic circles because they can be subject to biases due to changing exploitation patterns and because they do not explicitly consider the age structure of the fish stock.

In the 1989 CAFSAC assessment the ADAPT method was used to assess the northern cod. This should be viewed as a tool box of methods rather than as a single method. It was used to provide an age-desegregated assessment based upon the survey catch rate data and a bulk biomass interpretation of the CPUE data. This latter choice was made because offshore catch-at-age data forms a substantial part of the total catch-at-age data in some ages. It was feared that this might cause spurious correlations to disturb the tuning process. In both cases the tuning was achieved by minimizing an objective function of the sum of squares of the difference between the natural logarithm of the observed abundance estimate and its predicted value. The use of the logarithmic transformation in the case of the age-aggregated CPUE data is the most obvious difference between this analysis and past analyses. In both analyses a careful study of the residuals was made to check for divergences from the assumed statistical model. The model was also used to make a series of alternative fits using various variations in the data sets.

Methods used by this Panel to check the CAFSAC results were the Laurec-Shepherd method, the extended survivors analysis, and the Cagean method. The former two are age-desegregated methods which fit to logarithmic transformations of the CPUE and research vessel data while the latter is an example of a fully integrated method in which both the tuning data and the catch-at-age data are fitted to a more restrictive model than the retrospective population analysis. Results from these methods bracketed the results from ADAPT.

6.8.1Alternatives to ADAPT

A number of different methods have been developed for tuning VPAs. A recent ICES study group (Anon 1988) attempted trials of a number of these on different artificial data sets. The point of adopting artificial data sets is that it was then possible to know how well different methods managed to recover the true population structure. In these trials the ad hoc tuning methods such as the Laurec-Shepherd and extended survivors analysis performed well. Methods like ADAPT and Cagean generally performed less well, but this may have been because the trials were run to a tight time schedule and did not favour methods, such as ADAPT and Cagean that require detailed operator inspections of diagnostic material. A reasonable approach for the future would be to continue with the ADAPT method as used for the research survey (e.g., age desegregated). It would also seem reasonable to experiment with a similar approach for the CPUE data. The fear of correlation between the observed CPUE at age and the estimated values based upon catch-at-age data seems less than the risk of using an inappropriate choice of exploitation pattern for the most recent years. This, however, might well be a point worth checking with artificial data simulated to have the main features of the northern cod.

In addition to the use of the ADAPT method, we would advocate the parallel running of a simple ad hoc method such as the Laurec-Shepherd. This will be valuable as a cross-check on the results of ADAPT. Divergences between the two models would indicate the need to question with particular care the various assumptions made in the different models.

6.9.0 Optimal Use of Scientific Capabilities and Facilities

In our introduction to this chapter we noted the fallacy in assuming that given enough money scientists can provide complete, exact, and timely answers to questions important to fishery managers. The quality of the scientific advice given will, nevertheless, in part be dependent on the qualifications and skills of the scientists, the tools available to carry out their work, funds available to collect and analyze data, the working environment, and the manner in which the technical skills are organized to produce advice needed.

Over the past several decades skilled mathematicians, statisticians, and modellers have increasingly become the dominant skilled professionals involved in population dynamics. This was an essential step in moving fishery science from the descriptive and qualitative aspects of ichthyology to quantitative needs of stock assessments. In many of the world's national fishery laboratories, population dynamics has become the paramount discipline, and frequently greater emphasis is placed on improving the quality of models and mathematical handling of data than on developing an adequate understanding of the response of the population or its elements to environmental facts, life history, and behavioral aspects of the species involved or operational characteristics of the fisheries which may influence the nature of the data used in population assessment. This is unfortunate and has probably contributed to the inability to attain greater certainty in scientific advice. The Panel, of course, respects and supports the importance of mathematical skills in population assessment but encourages renewed efforts to understand the biological, environmental, and fishing operational facts which may be important in the interpretation of tuning of the models.

In the work of the TGNIF they reported that "the scientist involved demonstrated a good understanding of the technical aspects of approaches to stock assessment and the underlying assumptions of the strengths and weaknesses of various assessment models." The Panel's interviews with scientists at the St. John's Fishery Centre have led to a similar conclusion, although many Panel members questioned whether the stock assessment group was taking advantage of data and information generated by other disciplines within the centre. This concern was also apparent among the TGNIF members who noted that "the formulation of a modelling group should improve the stock assessment activities, but care should be taken to insure effective intra-centre communication between the modelling group and oceanographic and behaviour disciplines." Although some progress along these lines may have occurred over the past two years, the Panel repeats the findings of the TGNIF that **"These disciplines should be an integral part of the stock assessment process and should work from a common and shared database."**

The general laboratory facilities at the St. John's Northwest Atlantic Fisheries Centre are of excellent quality. However, the Panel was surprised to note that in many instances the scientists were unable to access computer facilities in a timely manner because of a shortage of data processing capacity. Correction of this deficiency is essential.

It was also the Panel's view that the electronic and trawl monitoring devices on board the centre's offshore research vessel were not state-of-the -art equipment. No trawl mensuration system was available and certain commonly used computer plot and navigation devices were not available.

A great deal of concern was raised by sectors of the fishing industry regarding whether or not the data collected by observers on the offshore fleet were being adequately analyzed and used by DFO scientists. Investigation of this matter made it apparent that DFO scientists did place considerable value on the observer database but indicated that analyses of the observer data were delayed because of the shortage of people to enter and analyze the data. The Panel sees the observer program as an essential new data source that can provide information on bycatch and which can be used to sample the age structure of the actual versus the landed catch, to collect life history data, and to note operational or technological changes in the various fleet elements.

The Panel believes that there is a great need to insure not only that observer data is quickly entered into the databases, but also that the use of this program to collect information on other fishing sectors is considered. Current stock assessment relies too heavily on the RV and offshore CPUE data from the larger trawlers. **Collection of CPUE data and information gained from an observer program involving smaller trawlers and gillnetters and perhaps line vessels would substantially augment the current database used in stock assessment.** This database might also be improved if there were a pooling of provincial and federal data sources.

CHAPTER VII

Management: Goals, Objectives, and Operational Modes

7.1.0 Introduction

The need to constrain the harvest of fisheries to ensure the maintenance of an adequate spawning population has been recognized by resource managers since before the birth of Christ. It has, however, been only during this century that scientists have developed means to assess population trends in quantitative terms and to suggest harvest strategies which can both maximize potential yield from fish stocks and maintain spawning populations at a level adequate to provide long-term productivity of the exploited resources.

During 1950 and 1960, most government fisheries bodies managed fisheries on the basis of achieving the "maximum sustainable yield" or MSY. The concept was based on the assumption that the exploitable population of each stock had an optimum size which, if maintained, would produce yields, surplus to that needed to maintain the optimum stock size, that were greater than would be produced at any other stock size. Although this management strategy found many advocates, empirical data suggested that MSY was easier to understand as a theoretical basis for management than it was to apply in the real world. Hence, managers frequently turned to the alternative management goal of maximizing the yield from a given number of recruits.

The latter objective is tantamount to the wise use of whatever production nature provides, the goal being to establish a fishing rate at a level which will provide the highest weight yield per given number of recruits to the fishery. In order to achieve this goal, scientists needed to document carefully the growth and natural mortality rates and age of the fish entering the fishery. Possessing this information, the manager could either adjust the age of entry of the fish into the fishery through a fish- or mesh-size limit or adjust the rate of fishing to ensure that the fishery took maximum advantage of the increase in yield that results from the growth of the individuals in a year-class in excess of losses due to natural mortality.

During the 1970s and 1980s, the biological management goals of MSY and the maximizing of yield per recruit became intertwined with a variety of socio-economic goals and MEY (maximum economic yield) and OY (optimum yield) surfaced as alternative goals of fishery management. In reality, although biological goals and objectives have been frequently noted as the bases for setting size limits, seasons, gear limitations, and area restriction, socio-economic pressure from various elements of industries have historically played and continues to play important roles in the management processes. **Unfortunately, socio-economic goals seldom surface as specific national management options and, hence, are not subject to the normal quantitative evaluations of the consequences of such goals to the nation's overall biological, socio-economic, and ecological interests. This may be particularly true in the management of fisheries off Newfoundland and Labrador where a variety of allocation strategies already exist.**

7.2.0 Conservation: Goals and Objectives Since 1977

Since Canada's declaration of its two hundred mile limit (1977), the managers of the 2J3KL cod stock(s) off Newfoundland have been directly concerned with making effective use of the cod recruited to the fishery, while at the same time establishing a fishing rate which would provide for growth in both the exploitable and spawning population. In attempting to achieve this goal, Canadian managers had to establish a fishing level that allowed for a reasonable margin of biological safety. Hence, in consultation with their scientific advisors, they chose a level of fishing effort that would lead to an annual harvest rate of about 18% or an instantaneous rate of fishing (F) of about 0.2. This level of fishing was consistent with the frequently noted management goal of $F_{0.1}$ which implied that an additional unit of standard effort entering the fishery would increase the total catch by about one-tenth of the catch deriving from the first unit of effort to enter the fishery in its virgin state. Although the concept seems somewhat complicated, in practical terms it meant a harvest of northern cod sufficiently low as to allow the stock to increase steadily provided only that average expected recruitment levels were maintained.

It is important to notice that $F_{0.1}$ is a sensible but arbitrary biological reference point. It offers an approximate solution to the problem of how best to maximize the profitability of the fishery, without the necessity of constructing a complex and sophisticated economic model which would calculate what level of fishing effort by what types of fishing boat would achieve this objective. Such a model and the appropriate analysis associated with it would require a large study conducted over a number of years. The $F_{0.1}$ fishing level can, by way of contrast, be calculated in a few minutes.

The calculation of yields expected from a projected number of recruits is rather straightforward, provided reasonably accurate estimates are available for the growth and natural death rates of cohort populations and provided that the pattern of exploitation is known. **Table 8** shows a work sheet calculating the yield per recruit for the northern cod if the fishing mortality were 0.3 and under particular assumptions about growth and mortality rates. It also shows the calculation of

Table 8

M = .2 F = .3

Age	PR	AV. WT.	STOCK NO.	AV. STOCK	YIELD	
4	.18	.55	.10	485.71	26.23	
5	.48	.88	775.69	577.58	83.17	
6	.74	1.23	549.91	551.80	122.50	
7	1	1.66	360.60	471.05	141.32	471.05
8	1	2.12	218.71	364.38	109.46	364.88
9	1	2.64	132.66	275.59	82.68	275.59
10	1	3.18	80.46	201.35	60.40	201.35
11	1	3.73	48.80	143.25	42.97	143.25
12	1	4.15	29.60	96.67	29.00	96.67
13	1	4.71	17.95	66.54	19.96	66.54
14	1	5.54	10.89	47.47	14.24	47.47
15	1	6.11	6.60	31.76	9.53	31.76
16	1	5.03	4.01	18.38	5.51	18.38
17	1	6.44	2.43	12.31	3.69	12.31
18	1	6.07	1.47	7.04	2.11	7.04
19	1	6.61	.89	4.65	1.39	4.65
20	1	7.19	.54	7.79	2.34	7.80
Total	kg per 1000 recruits			3363.81	756.52	1748.73
	kg per recruit			3.36	.76	1.75

the spawning biomass per recruit. **Figure 17** shows the results of calculating these figures for a series of levels of fishing mortality rate. It will be seen that the curve showing the yield per recruit first increases, reaches a maximum, and then declines slowly. The spawning stock per recruit, however, decreases in a progressive fashion toward zero. This is, of course, to be expected, since as fishing increases, the chances of an individual fish being able to live long enough to spawn is bound to decline.

The yield per recruit curve provides data on total yield that can be expected at given fishing rates and ages of entry, and the spawning stock per recruit can be thought of as being equivalent to the relative number of spawnings that result from a given number of recruits subject to a range of fishing mortality rates. If, of course, a new level of fishing mortality rates is applied, the yield and the spawning stock gradually moves between the old and the new equilibrium positions as recruits are subjected to the new mortality rates. This means that if fishing effort is increased, there is a short-term increase in yield which is paid for by a reduction in stock size. This short-term gain is not sustained, however. Similarly, a decrease in fishing mortality or an increase in age of first capture leads to short-term loss while the stock size builds up to a new level. A simple analogy is a bank deposit account which pays a fixed interest rate. If you take only the interest

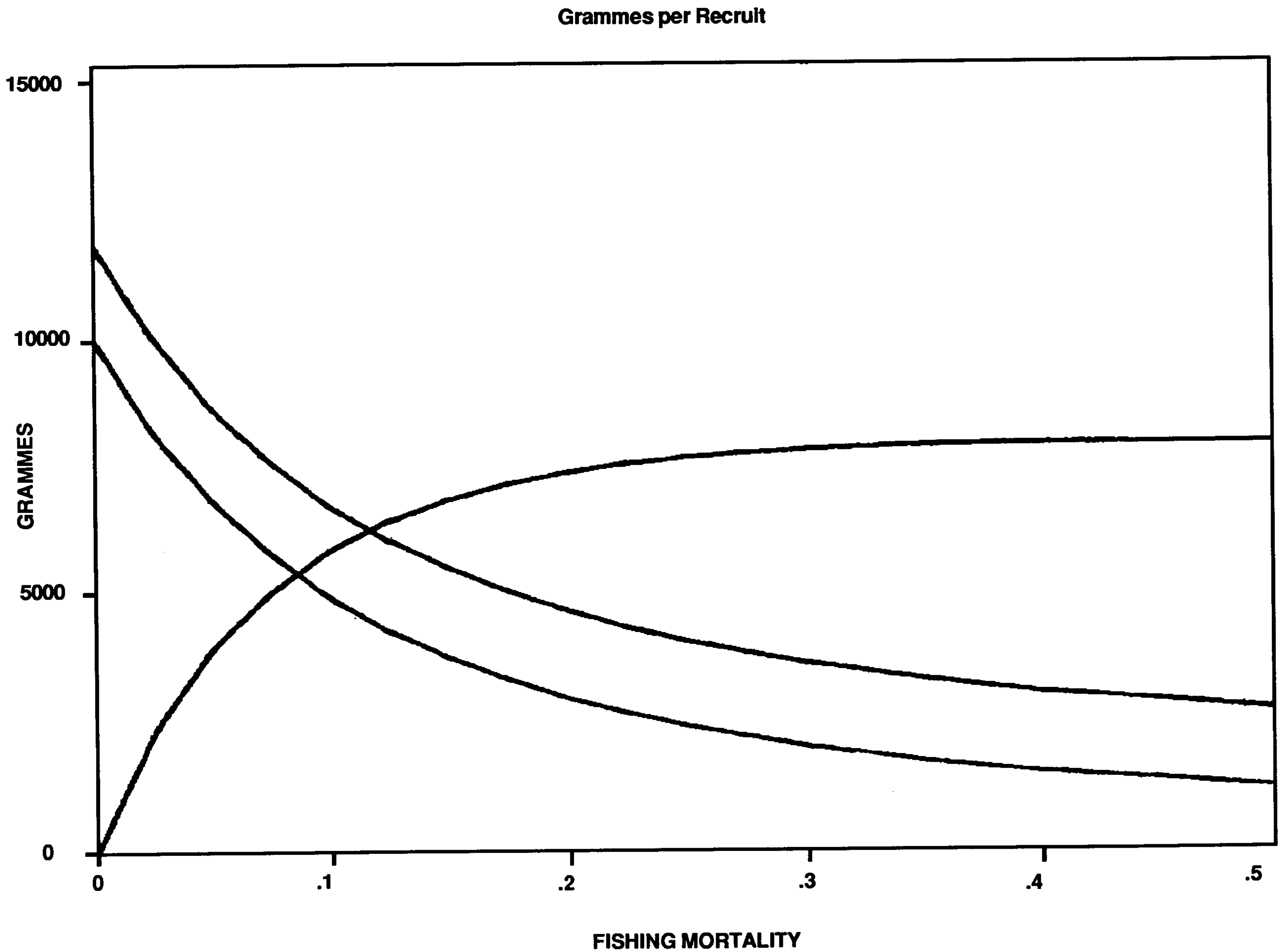


Figure 17

Ex.Biomass, SS. Biomass and Yield * 10 for 2J3KL each year, then the capital remains untouched and the level of interest remains constant. If, however, you annually remove some of the capital as well as the interest, you are initially able to spend more money from the account, but as the capital diminishes, so does the interest. Thus, to maintain your spending power, you will be required to take each year more and more of the capital until, in the end both capital and interest are totally exhausted.

In the northern cod example we can see that the maximum yield per recruit would occur when fishing mortality was about 0.4. However, we can also see that a substantial proportion of this yield could be achieved at considerably lower levels of fishing mortality. If the costs of fishing are roughly proportional to the level of fishing mortality, then fishing at a lower level of fishing mortality should substantially increase the profitability of the fishery and also increases the size of the spawning stock and the catch rate of those fishing boats remaining in the fishery after the stock has adjusted to the new level.

The simple calculations provided in **Figure 16** and shown in **Figure17** assume that the parameters adopted in the calculations are not subject to such biological feedback mechanisms as density-dependent growth or natural mortality rates or stock/recruitment relationships. For example, as stock sizes increase with diminishing fishing mortality, it is possible that growth rates might slow because of increased competition for food resources. This process is described as density-dependent growth. Furthermore, since cod is a fish-eating species and on occasion cannibalistic, if fishing mortality were decreased then the larger stock size of bigger fish might increase the natural mortality rate on smaller fish. This would give rise to a density-dependent natural mortality rate. Finally, as the fishing mortality increases, we have seen that the size of the spawning stock decreases, and it is possible that the number of young fish recruiting to the fishery could be altered. Such a relationship between the spawning stock size and the numbers of recruits has traditionally been referred to as a stock/recruitment relationship.

Of these three feedback mechanisms, the last is potentially the most important. This is clearly so since the stock/recruitment relationship implies the commercial loss of the fish stock if fishing continues at too high a level for the spawning stock to reproduce itself. An example of this in process may be seen in the George's Bank haddock fishery.

There are also some indications that density-dependent growth may affect the northern cod. This is the subject of study currently being conducted by DFO. If it is found to be the case, then the levels of F_{max} and $F_{0.1}$ may prove to occur at somewhat higher levels of fishing mortality than have been assumed in our calculations.

In respect of density dependent natural mortality rates, studies of the feeding behaviour of the northern cod have not so far shown any indication of heavy cannibalism. DFO scientists have, nevertheless, taken part in cooperative studies of predation mechanisms in the North Sea and elsewhere conducted in an ICES Working Group and are well aware of this feedback and how it can be modelled. They are, therefore, well prepared to take appropriate steps should it prove to be more important at some future stock state of the northern cod.

The stock/recruitment relationship of the northern cod has also been studied by DFO scientists Evans and Rice in 1988, and these studies do indicate a surprisingly strong stock/recruitment relationship. **Figure 18** shows the plot of the number of recruits to each year-class of fish related to the size of the spawning stock from which they come. Superficially, this relationship appears to be linear, but this is not possible, since it would imply that without fishing, the Northwest Atlantic would be filled with solidly packed cod. Since neither logic nor historical evidence admits this possibility, there must be some downward curvature at higher stock sizes. Indeed, a simple log regression does indicate some such curvature. **Figure 19** shows a fitted relationship, which, while neither as sophisticated nor as appropriate as the probabilistic fitting procedure adopted by Evans and Rice, may be much simpler for the lay reader to comprehend. The picture is quite clear and shows, even though there must be finite limits to growth, that as the numbers of spawning fish increases so too does the number of young fish entering the fishery at least up to much higher spawning stock sizes than the current level.

It is, however, important to notice that the decline in spawning stock has occurred systematically through time, and it is quite possible that at least some of the apparent relationship is owing to other processes that were operating in the same time period. It is possible, for example, that recruitment figures for the earlier years when the fishery was international were artificially inflated by the overreporting of catches from the northern cod. Such overreporting might have occurred as a consequence of accident or inadvertence deriving from poor statistical systems, or it might have been done deliberately in order to establish an apparently higher historic performance prior to the allocation of quotas. Another possibility is that long-term deterioration in the environment might have reduced recruitment systematically through time. These are at least some of the reasons why the relationship as it currently appears may be misleading; but, the risks of being misled by what we see are, in this case, far less than the risks of ignoring it or of refusing to see it at all because of an assumed improbability. **In consequence and since no one has to date offered a conclusive alternative explanation, the Panel is of the firm opinion that we should accept the stock/recruitment relationship as it appears until such time as it is disproven and that the management of the northern cod should, therefore, be based upon consideration of the spawning stock size rather than on consideration of the yield-per-recruit curve.**

This is a very important point for it is our knowledge of the spawning stock/recruitment relationship that allows us to gauge the impact of various fishing mortalities on the northern cod and to assess the consequence of past exploitation levels. If we use the spawning stock-per- recruit results shown in **Figure 17** then we can examine replacement lines. These are lines that link the number of recruits to the subsequent spawning stock size, i.e., spawning stock biomass = spawning stock per recruit x recruits. Such replacement lines are shown in **Figure 19** and indicate that a fishing mortality of 0.5 or over would probably deplete the spawning stock to levels giving low recruit numbers and, on the analogy of our banking account, would eventually exhaust the whole resource. A fishing mortality of between 0.3 and 0.4 would keep the spawning stock more or less at a constant level while lower levels of fishing mortality would eventually lead to higher spawning stock and, consequently, much higher recruitment levels than is currently the case. This in turn would lead to enhanced yield.

The Panel feels this is a more compelling reason to reduce the level of fishing mortality than the $F_{0.1}$ argument which was predicated upon the maximization of profit. We do realize, of course, that the goal of maximizing profit may not be incompatible with the goal of increasing the spawning biomass and in that way ensuring the future. We must recognize, however, that stock

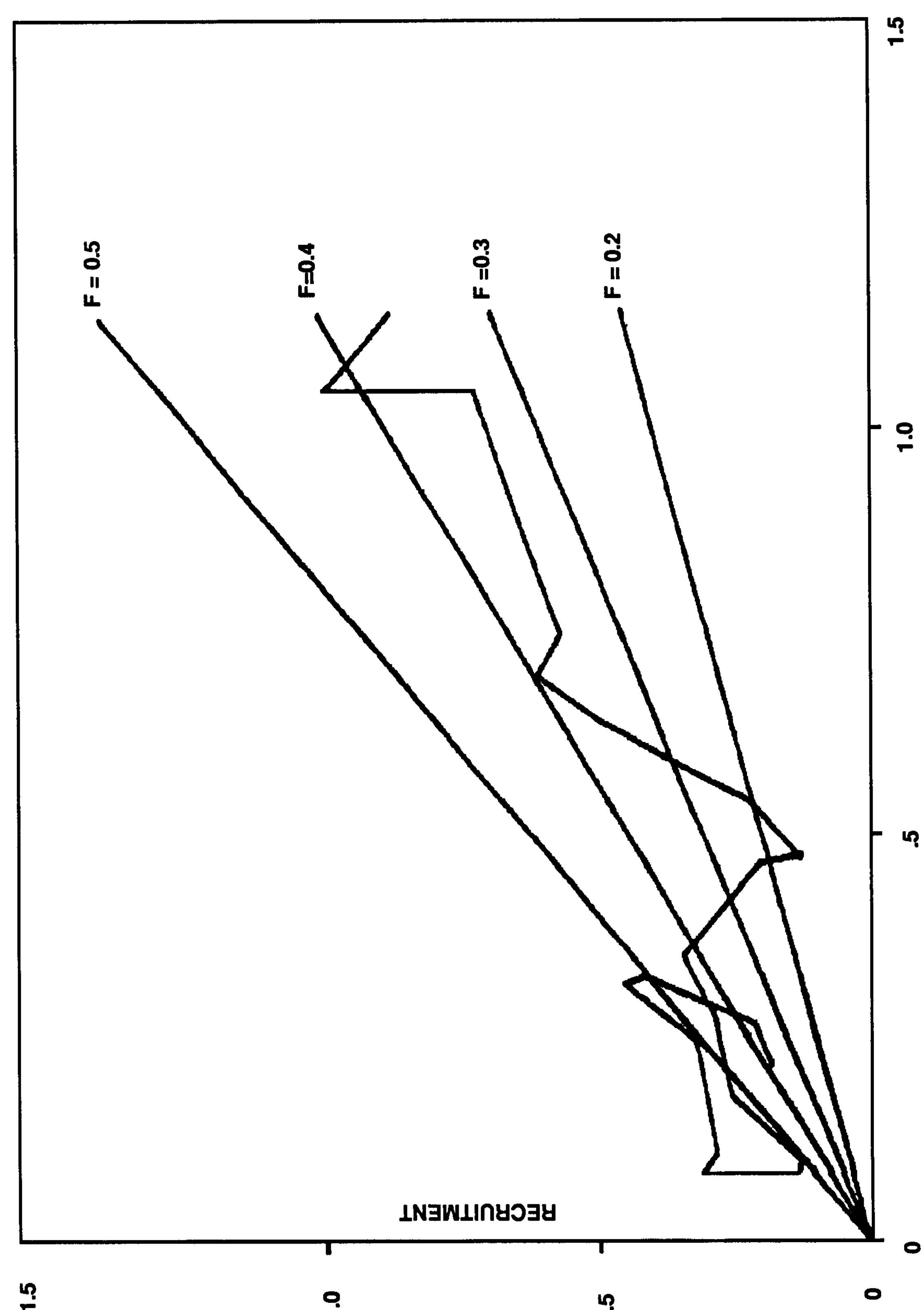


Figure 18

Stock Recruitment for the Northern Cod

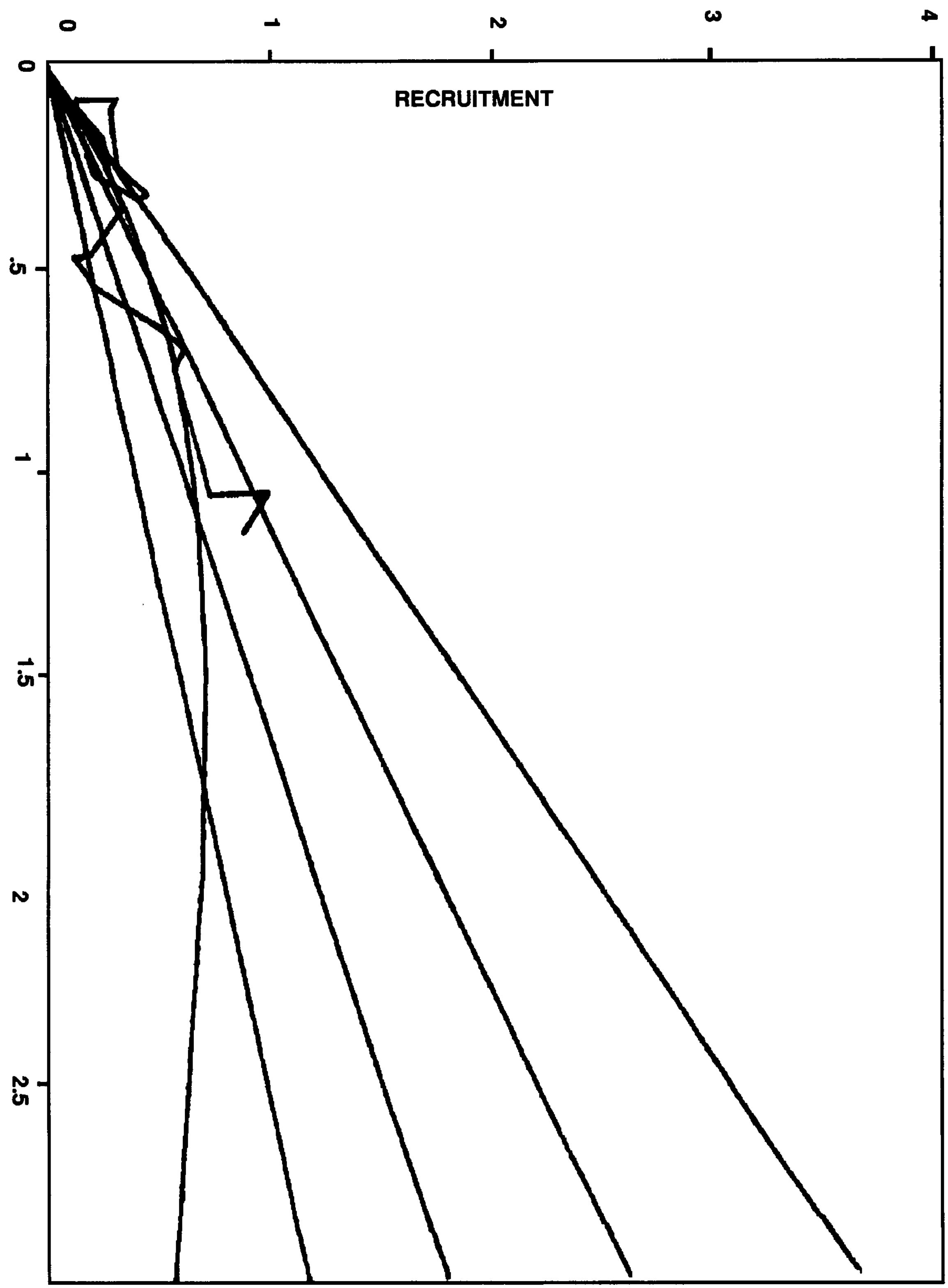


Figure 19

Stock/Recruitment for Northern Cod (Fitted) building or rebuilding is a long term project while profit taking has a more immediately urgent connotation. Nevertheless, we do not deny that the $F_{0.1}$ strategy was a conservative one and would have led to a significant growth in northern cod stock size if its goal had been achieved. Unfortunately, we did not have the capacity to monitor with sufficient accuracy either stock size changes or fishing rate and, in consequence, were unable to provide reliable scientific advice. With management decisions based upon faulty advice, fishing rates soared to well over $F = 0.4$, or more than double the desired level, and the spawning stock failed to grow as rapidly as had been anticipated. The net result is that current yields are much lower than might have been achieved had a lower rate of fishing mortality been maintained.

In any event, since our primary objective is to increase the size of the spawning stock and since that goal can only be achieved by reducing the fishing mortality rate, **the Panel believes that the $F_{0.1}$ concept should be discarded if only because it is difficult to explain and is rarely understood by fishermen or the non-scientific community in general. It should be replaced by the simple and easily understood strategy of establishing the fishing mortality rate at 0.2, a level designed to rebuild the spawning stock to a large biomass.**

7.3.0 Resource Allocation and the Management of Northern Cod

Although explicit policies or principles that might govern allocations among gear types, regions, or communities do not appear evident in provincial or national goals, one cannot escape the conclusion that resource allocation, in one form or another, has increasingly become a fishery management tool. In the northern cod fishery the inshore allowance, the special allocation to France, and the bycatch allocation to foreign trawlers are classic examples. It is significant to note that demands from user groups for special allocations almost always stem from competition for limited resources. That is to say, there is always a potential for conflict when fishing capacity is in excess of available biological yields.

Any potential solution of the conflicts thus engendered must relate to clearly defined management objectives as expressed in biological and conservational as well as in socio-economic terms. From the biological or ecological perspective it might be sufficient to apportion the TAC among the statistical management divisions in proportion to the contributions made to the biomasses by each spawning subgroup of the total population. This would beg the question of whether catches should be taken offshore or inshore except insofar as separate inshore spawning subgroups had been identified. Indeed, in such strictly biological context, the inshore versus offshore question might have no relevance at all. Nor, we should note, would such an ecological approach be inimical to a sectoral management strategy or even to a process of enterprise allocations. This latter approach if carried to its ultimate conclusion of an allocation for every individual fisherman would, of course, be an administrative and management nightmare. Nevertheless, if practised in a limited way, it would, for example, permit a more orderly harvest and that best suited to market conditions by permitting fishermen and fishing companies to apportion their catches to suit their particular requirements. It would, as well, indirectly regulate the amount of investment in boats, gear, and processing equipment and make such investment a direct function of the available resource. On the other hand, it would encourage underreporting of catches, high grading and other such practices, and would, in consequence, demand greatly increased surveillance and regulatory enforcement.

A strictly economic approach, that is an approach based on maximization of profit conceived in purely fiscal terms, would suggest that the harvest should be conducted in the most cost effective manner possible, that is, in the manner that would offer the lowest cost per pound of marketable product. This might mean an absolute reliance upon the codtrap, for example, which would appear to offer the highest yield per unit-of-effort at lowest cost of any gear type currently in use. That approach, however, would appear to be too superficial by far. In fact, it ignores the problem of seasonality of supply, the glut/famine syndrome, the vagaries of environmental changes that determine the availability of fish to fixed gear, the tendency to select juvenile fish, the demands of the market for regulated supply, and issues of quality. Such considerations may lead inescapably to the conclusion that an offshore fishery must be maintained if only to ensure consistency of supply of fresh product to the markets.

Indeed a variety of arguments, pro and con, may be advanced in respect of the several dominant gear types currently in use. However, inasmuch as the Panel has not analyzed in detail the relative merits of each, it is, perhaps, sufficient to note that many fishermen are disposed to see the gear they use as being superior and to see that of their competitors as detrimental to the goals of conservation or as producing fish of poor quality. Recognizing that there are significant differences among gear types, in respect of age and size selectivity, in bycatch rate, and in impact upon the environment, it is important that DFO should undertake appropriate studies to document such differences. This is particularly necessary if allocation among gear types is a strategy to be employed in the future management of the northern cod stock(s).

We have introduced those brief and to some extent superficial comments upon gear types for two reasons. First, because of strong representation made to us by fishermen and other interest groups and, second, because harvesting techniques do have implications for stock conservation and management. In the first case, the extreme position advocated by many inshore fishermen and others is a demand that there be no allocation of cod at all (other than a closely regulated bycatch) to otter trawlers. The Panel while unable to accept such an extreme demand is, nevertheless, agreed that **no reasonable effort should be spared to minimize the negative aspects of otter trawls and other gear types. Thus mesh size and configuration should be the object of careful study to determine those that minimize the capture of undersized fish**. In dealing with matters of this kind we should note that most, if not all, technological problems admit of technological solutions. The principle to be observed is that technology must not become our master. We must control technology through effective management decisions and through effective regulatory and enforcement regimes. The same argument applies **pari-passu** to all gear types. Thus, the ghost net problem may be simply obviated by the application of technology to ensure that all lost nets will be both findable and recoverable and by appropriate regulatory measures. In the case of codtraps, the problem of excess harvest of juvenile fish will be ameliorated when enough fish in the appropriate age groups survive to complete their migratory journeys to near shore waters at which time appropriate regulations of mesh size for trap bottoms and sides will give the desired result. This, of course, implies that mesh size in the "drying twine" at the back of the trap need not be changed from the traditional four inch or even from the more recently employed three and one half inch. The appropriate distribution of catch by age groups may require allocation of quotas or fishing effort by gear type. That such distribution should occur is clearly important. Since fishermen have traditionally been able to sell three year old fish, most gear types used in the regions are selective for cod of that age. Nevertheless, the proportions of such very small fish to total landings was, until quite recently, relatively low. In changing circumstances, with that proportion steadily increasing, the matter has become one of more serious concern. In northern cod, sexual maturity does not occur until about age seven, and hence it is important in terms of the needs of the spawning stock that fishing both prior to and after maturity must allow for a sufficient number of survivors to insure the future productivity of the stock. Inasmuch as the various gear types impact differently upon the different age groups, the management process must take such differences into account and promote harvesting patterns by age in such a manner as will but ensure the conservation of the resource. In addition to the potential impact of different gear types on survival of recruits to spawning age, the issue of maximizing the yield from available recruits must also be addressed.

At the same time, harvesting patterns must conform with the nature and seasonal distribution of the component parts of the stock complex. **Fishing and/or allocation strategies must be devised that will not permit localized depletion of spawning subgroups nor disruptions of migration patterns that negatively affect specific inshore areas.**

7.3.1 Inter-Regional Allocations: Adjacency

In general and notwithstanding the fact that marine resources have been determined constitutionally to be a common property resource, the principle of adjacency has been accepted by Canada and, indeed, by the international community. That is to say, those fishermen inhabiting the shoreline adjacent to northern cod stocks should have first claim upon the resource. Only when their patently obvious needs have been addressed should surplus stock be allocated to others.

Nevertheless, historical associations cannot be completely ignored. Thus, Nova Scotian fishermen who have traditionally fished the southern Grand Banks in the management divisions now designated as 3L and 3NO cannot and should not be denied access to those stocks though the allocation to Nova Scotia as a function of the 3L TAC should not, perhaps, exceed traditional Nova Scotian landings as a function of the total landings from the area. In respect of other provinces within the region, the principles of adjacency and of "vital needs" when considered with the current state of the stocks would seem to indicate that, for the time being, no part of the 2J3KL stocks should be available to them since there obviously are no fish surplus to the needs of the coastally adjacent communities and to the satisfaction of the legitimate Nova Scotian claim.

7.3.2 Inshore/Offshore

As we have indicated in section 7.3.0. above, the designations inshore and offshore are to some extent artificial distinctions since many inshore fishermen currently generate a substantial part of their landings from offshore fishing. The current allocations stem in part from socio-economic concerns. However, there may be sound biological argument for regional allocations that attempt to equalize levels of fishing mortality upon each of the several stocks or stock components with which management must be concerned. Similarly, there may be occasion to regulate gear types so as to apply appropriate mortalities upon the several age groupings that comprise the population. Apart from these considerations, the fundamental decisions must be predicated upon such strategies as will ensure, as a first priority, the conservation of the stock and the continuation of viable fisheries but that also address in the context of agreed social policy the "vital needs" of the community.

7.3.3 Domestic/Foreign

Given the near desperate state of the inshore fishery along the coast of Newfoundland and Labrador, the crisis of supply affecting both major offshore companies that fish 2J3KL cod, and the urgent necessity of reducing fishing mortality so as to commence the rebuilding of the stock, there should be no question of foreign allocations. Certainly, no part of the northern cod stock is surplus to Canadian requirements and just as certainly neither the primary interest nor the undoubted need of the adjacent coastal community can be disputed. In those circumstances, it is difficult to make the average Newfoundland fisherman understand what interests of state compel the Canadian Government to permit a large foreign fleet to continue fishing within the two hundred mile economic zone. For even if few units of that fleet are given a specific allocation of cod, the aggregate of the allowable bycatch alone looms very large in the eyes of Canadian trawlermen whose vessels are being tied up, of plant workers being consigned to the unemployment line, and of inshore fishermen whose nets are empty. Setting aside the issue of transborder stocks that are not appropriately discussed in this context, the **Panel believes that in the interests of consideration and of proper management and in the interest of protecting the clear rights of the coastal community, all foreign fishing within the two hundred mile zone should be terminated at the earliest possible date and that there should be an immediate reduction in the level of foreign fishing.**

7.3.4 Federal/Provincial Conflicting Goals

The foregoing discussion of foreign fishing within the Canadian zone is one example of conflicting Federal/Provincial goals. In this case, the goal of the province to maximize the economic value of the available resource represented by northern cod and other commercial species of fish is clearly in conflict with the Federal goal of using fishing concessions to further certain external relations objectives. Other potential sources of conflict derive from the fact that the Federal authority manages the resource and licences fishermen while the province licences processing facilities and processors and plays a critically important role in respect of the acquisition by fishermen of vessels and gear. Without appropriate coordination, it is not difficult to envision plants constructed or vessels financed to achieve certain political objectives without adequate reference to the availability of resources to justify the investment.

Other possible conflicts may arise when conservational goals are set by a Federal authority which has not consulted and which may not support the social goals identified by the province. Thus, the interests of one jurisdiction may be to maximize employment, those of the other to reduce the number of fishermen; the interests of one to decentralize processing in small plants supplied primarily by inshore fishermen, those of the other to promote the interests of large vertically integrated corporations. Whether or not such conflicts emerge as realities or remain as hypothetical possibilities, they clearly carry with them the potential to place intolerable pressures upon fish stocks inadequate to support them. What should never be **forgotten is that every fisherman issued with a fishing licence expects, as a right, access to sufficient fish to provide a livelihood; every processor who is given a plant licence expects access to sufficient fish to make the enterprise profitable; every new vessel built and every loan advanced for the purchase of fishing gear demands an increase in fish landings to justify the investments. The temptations to grant the licences or to approve the loans may be nearly irresistible. But, so may be the pressures subsequently generated to allocate the resources to justify the earlier decisions. The repercussions may be disastrous for the stocks.**

7.3.5 Further Entry into the Fishery of Additional Fishermen, Gear and Vessels

The forgoing discussion leads us directly to consideration of an issue raised with the Panel on many occasions both in public hearings and elsewhere; the issue of whether there are already too many fishermen, too many fishing vessels, too much fishing gear and too much processing capacity; and, if so, how this excess may be reduced to an appropriate level and maintained at that level. There can be no doubt that given the current state of the fish stocks, the first question, in all it parts, must be answered affirmatively.

This situation has arisen, in part, because of unrealistic forecasting of increasing stock abundance, in part, from a temporarily favourable combination of market conditions that encouraged unwarranted optimism for the future, and, in part, from the sad fact that fishing is the employment of last resort for a substantial number of individuals who would otherwise be unemployed. The other consideration is the socio-political reality that Newfoundland came into being as a fishing community and grew as such and that there is deeply ingrained in the psyche of every native born Newfoundlander, the belief that the right to fish is inalienable.

Nevertheless, we cannot escape the conclusion that a TAC that is finitely limited will be able to support a finite number of fishermen and employ a finite number of plant workers. It is true, of course, that a great deal depends upon social policy objectives and, for example, the kinds of income support programmes that governments are prepared to establish. Still the fact remains that there must come a time when, in the interest of conserving the fish stocks and eliminating biological waste, if for no other reason, no further fishing licences can be issued.

We believe, therefore, the further development of licensing policy should involve both levels of government acting in consultation with fishermen, and we would urge the view that objectives deriving from such a process should grow out of consideration of the following elements:

- the conservation of fish stocks
- the capability and economic viability of the commercial fishery
- the principle of equity in respect of access to the resource

- the need for sound administration, good data collection and proper law enforcement
- the concept of professional status for fishermen
- the orderly development of the fishing fleet
- the development of criteria for the establishment of priorities for the granting of licences
- the role of part-time fishermen
- the use of fishing gear compatible with orderly and efficient harvesting and with the principles of conservation.

7.3.6 Clarification of Goals for Future Management of Northern Cod

Frequently both fisheries managers and fisheries scientists suffer from ill-defined and often conflicting sets of management goals. This problem may, moreover, be compounded when more than one political jurisdiction is involved. In such cases, not only may objectives differ but even established goals may take on different meanings when seen from different perspectives. Thus, a national goal of improving the competitive position of the fishing industry may conflict with a provincial or regional goal designed to achieve a social objective such as enhanced job opportunities. All too often allocations among user groups are made on the basis of political expediency rather than on a clear understanding of established biological, ecological, social, or economic goals and objectives. Such ad hoc management decisions frequently destabilize the commercial fishery and scientific efforts to conserve the resource and to collect the data needed to assist government in making rational management decisions.

The current federal and provincial goals that relate to conservation of the nation's living ocean resources seem reasonably clear. However, those concerned with social and economic issues are vague, unclear, and seemingly in conflict. Such important policy issues as effort limitations, enterprise versus community allocations, and others of a like nature appear to be adrift in a sea of indecision.

Management goals must be clearly defined and they must be goals, moreover, to which both levels of government subscribe. Furthermore, they must be goals in the implementation of which Federal/Provincial collaboration is the accepted standard mode of procedure and not a sometime thing invoked only in the face of impending crisis. Only in the light of such clearly conceived and enunciated objectives will it be possible to establish the kind of fisheries management policies that are so critically important. This implies clear recognition by both sides of the powers, responsibilities, and interests of the other. **It also implies the creation of a permanent Federal-Provincial board or commission in the context of which information can be shared, management objectives clarified and coordinated, policy directions set, and strategies developed.**

7.4.0 New Management Alternatives — Introduction

In considering future management strategies, the Department of Fisheries and Oceans must take as its first and preeminent objective an increase of substantial proportion in the spawning stock size. The most obvious approach to achievement of this objective is through an overall reduction in the level of fishing mortality which implies a significant reduction in the TAC. At the same time, it will be important to so regulate and manage harvesting processes that more younger fish may survive to spawn and that the economic yield per recruit of harvested fish may be enhanced. Further, it will be necessary to impose stringent measures to control the problem of discards, to distribute the fishing effort so as to obviate the possibility of localized depletions, and to reduce or eliminate foreign fishing pressures upon northern cod.

7.4.1 Rebuilding the Spawning Stock

There can be no "quick fix" solution to the problem of rebuilding the spawning stock. That is to say, the prize of higher recruitment and a healthier fishery can only be won if we are prepared to allow more of the existing population to live and reproduce to increase the number of new recruits and more of those recruits to live to full maturity to further increase the spawning stock, and so on, until optimum spawning stock size has been attained.

This process will necessarily be a lengthy one as will be obvious if we reflect upon the simple fact that a northern cod takes seven years to mature and probably does not attain its maximum reproductive capacity for several years thereafter. Thus, even if it were possible to impose a total closure of the fishery, the miracle of recovery would not occur overnight. As it is, with a continuing fishery the time for recovery will be prolonged for a period whose duration will be dependent **inter alia** upon the rates of fishing mortality imposed both overall and upon the individual age groups.

In face of this situation and taking into account the social and economic as well as the biological exigencies of the case, it is not at all a simple proposition to establish the most appropriate management strategy. Modern theories of the economic management of fisheries (cf. Clark...Horwood, and Whittle) suggest that when a transition to a higher stock level is desirable, the transition should be made as rapidly as possible. This can imply that a particular fishery should be completely closed for a number of years until the biomass has attainted the desired level. If we were discussing the eel fishery, the lump fishery, or even the salmon fishery, this might be a viable proposition. But, we are rather discussing northern cod, and the social and economic consequences of a closure of that fishery would entail such enormous costs as would appear to totally invalidate the suggestion. For in Newfoundland there are simply no alternative resources to which fishermen might turn while they awaited recovery of cod stocks. On the other hand, if we maintain catch levels at or near present rates, we know that, at best, the process of recovery will be indefinitely prolonged; at worst, the stock will continue to decline.

Clearly, a compromise position must be attained. The stocks must be permitted to grow while catch levels are sufficient to prevent major social and economic dislocations. In short, we must get fishing mortality rates down to 0.2, and we must do so in stages if absolutely necessary but, in any case, as quickly as possible. Following the argument we have made above, even a sudden drop of 0.2 would mean a recovery period extending over a decade; a staged reduction, following the 50% or some analogous rule, would entail a proportionately larger recovery period.

7.4.2 Harvesting by Age Group

At the same time, there may be measures worth consideration as supplementary to a general reduction in fishing effort. These would include measures to increase the age of first capture by both inshore and offshore fishing gear.

Northern cod grows slowly, particularly in the more northerly parts of its range, and does not attain sexual maturity until about age seven. Since it is clear that there are not currently enough cod in the 7+ age groups to ensure an adequate level of recruitment for the future, we must act quickly to enhance that number. This implies that we must take all reasonable measures to reduce the mortality imposed upon younger fish so that more may survive to spawn.

In the recent Department of Fisheries and Oceans publication "The Science of Cod," the growth rates of fish from various grounds adjacent to the east coast of Newfoundland and Labrador are depicted in an instructive chart shown here as **Figure 20**. This figure shows not only that there are considerable differences in growth rate within the 2J3KL management area but, as well, that in all areas a substantial increase in growth occurs with age. Taking into account both growth rates and natural mortality, we are able to calculate the optimal time of harvest,though we should note that if our knowledge were precise, that optimal time might not be the same in all parts of the range. Setting aside that particular complication, **Figure 21** plots the expected biomass from a group of one thousand recruits entering the 2J3KL stock at age two.

The graph, based on a composite size at age for all 2J3KL harvested cod and on a 0.2 instantaneous mortality rate, shows that the growth of the individuals from a particular age group is in excess of losses owing to natural mortality until about age ten. For example, we may note that a particular group of fish if harvested at age five would constitute a catch 100% greater than if an equivalent mortality had been applied at age two. The economic gain would, of course, be far greater in consideration of the much higher monetary value of the larger fish. The total gain would, in fact, amount to several hundred percent.

Theoretically, the highest yield for a given number of cod would be achieved if they were all harvested at about ages seven to ten. We realize, of course, that current fishing methodologies do not allow for the harvest of a few age groups and that the effort required to achieve such a result would demand an increase in fleet size and significantly increased harvesting costs. Furthermore, it would significantly alter the nature of the fishing and would virtually eliminate much of the inshore fixed gear enterprise and a considerable portion of the catch currently taken by both inshore and offshore otter trawlers. Thus, as a matter of plain practicality, the fishery must begin by harvesting younger age groups and extend beyond age ten over the whole of the cod's life span. Nevertheless, insofar as it is practicable to do so, we must seek to maximize weight yield and economic benefit from the available harvest, and to do so we must be able to increase the age of cod entering the fishery.

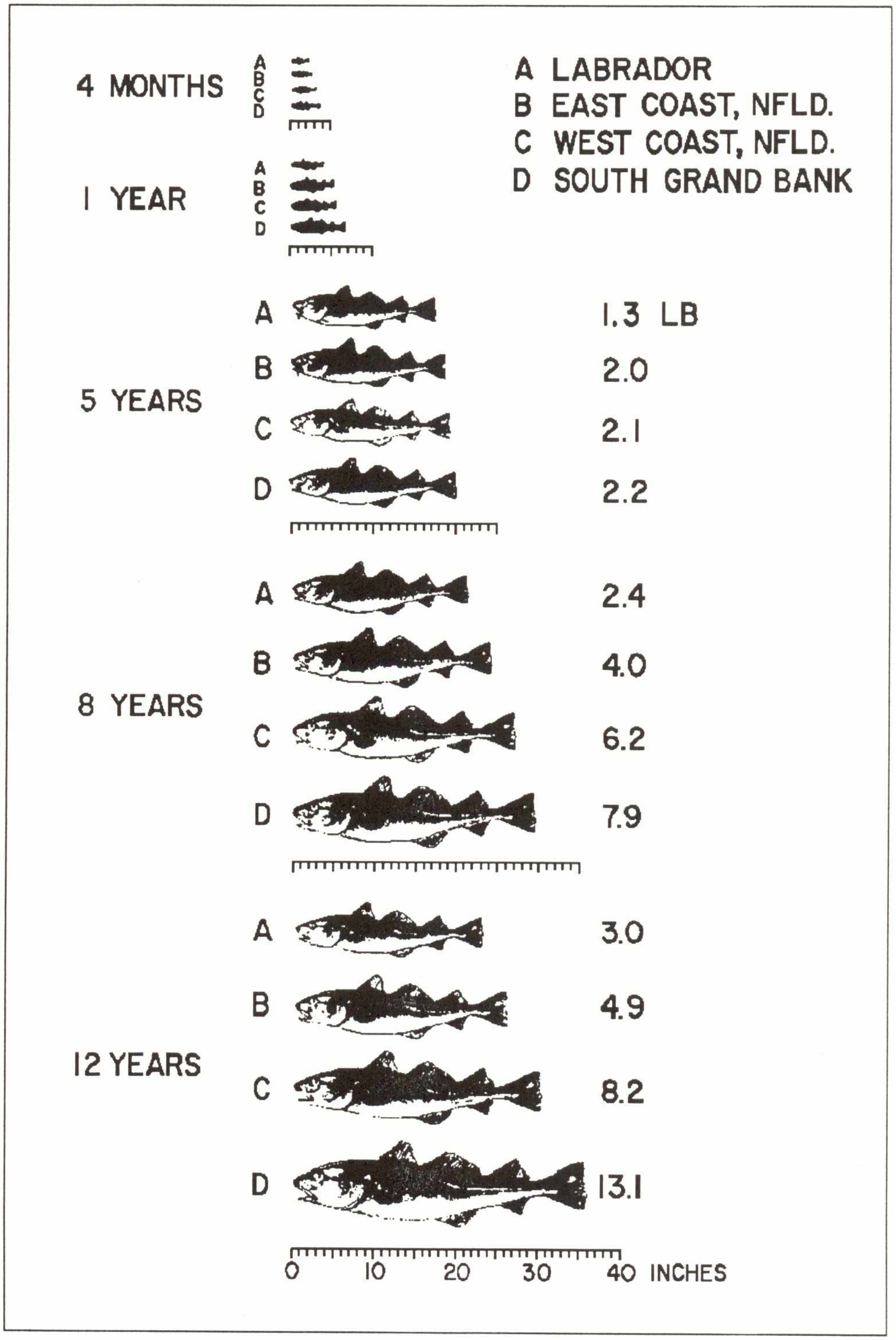
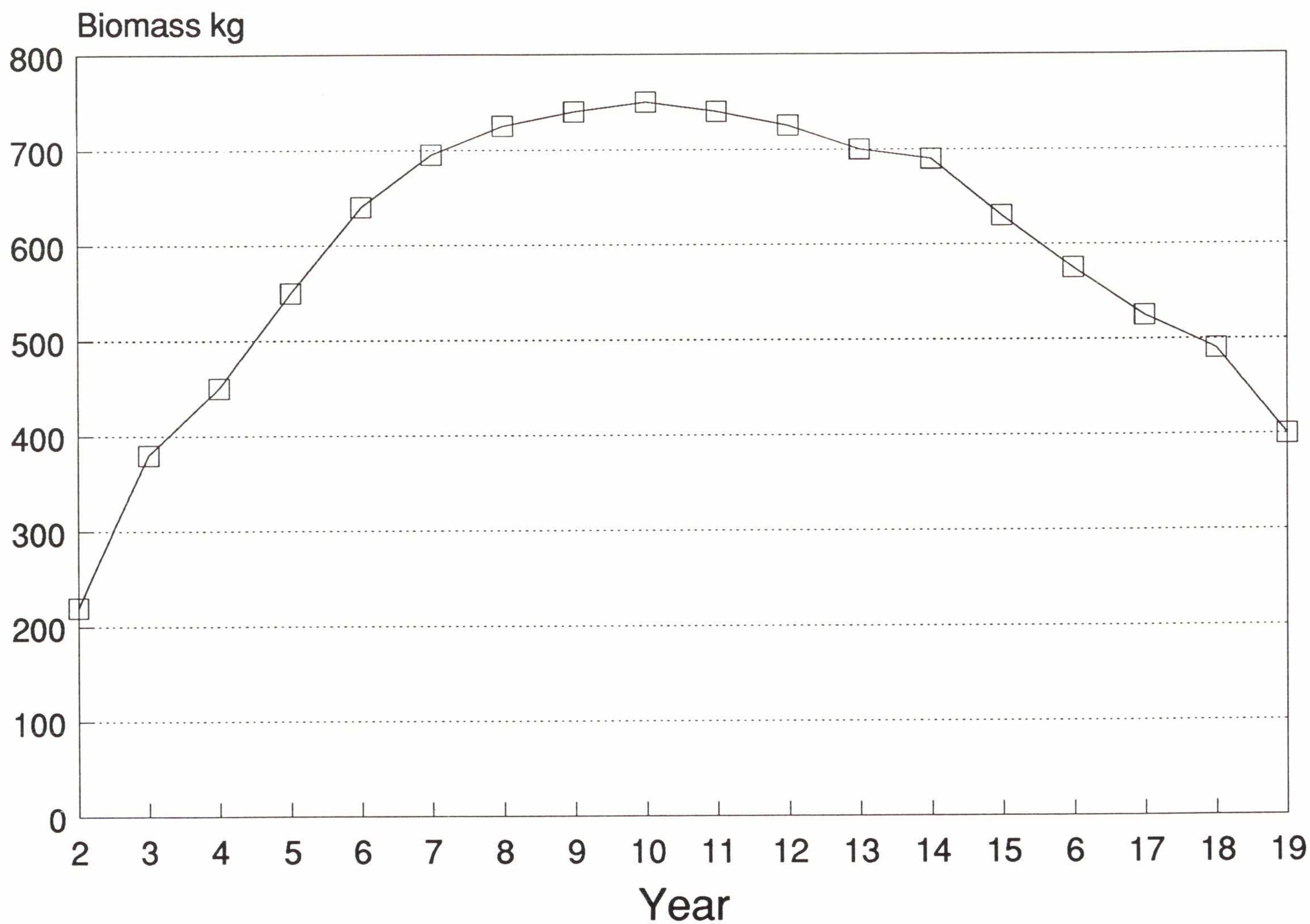


Figure 20

Graph Showing Cod Weights

FIGURE 21


Biomass kg
800
700
600
500
400
300
200
100
0
2 3 4 5 6 7 8 9 10 11 12 13 14 15 6 17 18 19
Year

The fact remains, however, that reduction in the mortality imposed upon three, four, and five year olds could not only encourage growth of the spawning biomass but could, as well, improve the overall yield through reduction in waste and through a subsequent increase in the biomass of these age groups at the time of harvest and the average value of the harvest. In this context, we cannot fail to note the repeated representations made to the Panel concerning the disproportionally high catch of three, four, and five year old fish taken by codtraps, by inshore draggers, by inshore hook and line fishermen, and by offshore otter trawlers.

In an ideal world, we might limit our harvest to a single age group. In the real world, we must at least work towards the goal of allowing all young cod up to age five to escape capture. This implies the regulation of mesh size and gear type and configuration to achieve such a purpose. The Panel is, of course, aware that in making such a suggestion it is presenting DFO with an array of problems that will be difficult of solution and that have far reaching implications. Nevertheless, it is possible to make fishing gear size selective. **And, given the overriding objective of permitting the most rapid possible growth of the spawning stocks, of maintaining economic yield at the highest levels consistent with that goal, and of ensuring the continued viability of an inshore fishery, it is important that guidelines respecting the desirable catch by age groups be established and that regulations be developed to satisfy the requirements of such guidelines.**

7.4.3 Discards and Bycatch

The Panel has, from the outset of its deliberations, been concerned that levels of both bycatch and discards have been insufficiently documented for assessment purposes. Certainly, the anecdotal evidence presented to the Panel suggests strongly that both bycatch and discard rates are higher than have been allowed in the calculations. In the face of the current situation the problem is all the more serious.

Nevertheless, the Panel is persuaded that such mortalities can and must be reduced. Appropriate strategies to achieve this purpose would include adaptations of gear technology, time and area fishing strategies, appropriate surveillance and enforcement, and, above all, the will to eliminate the problem. In this context, the critical issues must be resolutely addressed by both DFO and the fishing industry. The final objective should be the elimination of all discards. At the very least, they should be properly factored into all assessment equations and be accounted for as part of the established TAC.

7.4.4 Distribution of Fishing Mortality

We have already indicated our belief that sectoral allocation is a valuable management tool. However, it would appear that current sectoral divisions are rather crudely determined, being predicated upon inadequate knowledge of the nature, structure, and behaviourial patterns of the stocks. As our knowledge and understanding of these matters grow, so should our sectoral management strategies be refined with the objective of applying appropriate fishing pressure in direct proportion with the capacity of the several stock groups or subgroups to bear such pressures.

Furthermore, in accord with the proposal made in section **7.4.2.** above, fishing pressure should theoretically and practically where possible be applied appropriately by age group within sectors. The obvious consequence of failing to do so might well be localized stock depletion.

7.4.5 Foreign Fishing

Where Canada has the full authority to impose and enforce its conservational law and regulations, that is within the two hundred mile zone, there must be a determined effort to ensure full compliance by foreign vessels fishing under Canadian licence. This implies the strictest possible controls upon discards and bycatches as monitored by an effective observer corps and as enforced by an upgraded patrol and enforcement section fully supported by the courts. Ideally, given the current status of cod stocks, no bycatch of cod at all should be permitted, and if this is not deemed to be a viable proposition, it might conceivably be agreed that the need to conserve cod stocks outweigh our obligations to the international community to made underutilized stocks available to fishermen from other jurisdictions.

Perhaps we should emulate the judgement of Portia who ruled that Shylock, in execution of his bond, could indeed cut a pound of flesh from Antonio's breast provided that he did not spill one drop of blood. On that analogy, we might agree that foreign vessels could indeed take their silver hake or their grenadier provided that they took not a single cod in the process. And if that position is seen to be too extreme, we might, at the very least, order that any bycatch of cod taken by foreign vessels should be landed in Canadian ports.

With regard to foreign fleets fishing beyond the two hundred mile limit, Canada should and must redouble its efforts to gain through diplomacy, if possible, effective management rights over the entire northern cod stock complex. If diplomatic efforts should fail, other options should be considered including the unilateral declaration of management rights predicated upon the principle of adjacency. In the meantime, serious thought should be given to the possibility of participating in the rape of the "Nose" and "Tail" of the Bank. This would be to admit that the unwillingness of the European Community to behave in a responsible fashion has rendered NAFO useless as a regulatory agency. It might, however, if we were sufficiently aggressive in our approach, convince the European Community that the game was no longer worth the candle and that their best interests might be served by giving NAFO teeth. In any case, since European Community countries already take every fish they can possible catch on the "Nose" and "Tail", a Canadian fishery on those zones could not possibly harm the stocks more than they are already being harmed and would have the salutary effect of reducing the profitability of the European enterprise and, perhaps, sufficiently to make them repent of their intransigence.

CHAPTER VIII

Optimal Use of Scientific Facilities and Technical Capabilities

8.1.0 DFO Objectives

The Panel has repeatedly asked itself whether DFO has made the best use of its existing scientific facilities and capabilities in the conduct of its studies and management of northern cod. In addition, the Panel has wondered whether there were any evidence that with different objectives the present state of northern cod stocks might have been avoided.

Perhaps it would be instructive to review current objectives which are stated as follows in the Department's 1987-1988 Annual Report:

> "to undertake policies and programs in support of Canada's economic, ecological and scientific interests in the oceans and inland waters, and to provide for the conservation, development and sustained economic utilization of Canada's fisheries resources in marine and inland waters for those who derive their livelihood or benefit from these resources; and to coordinate the policies and programs of the government of Canada respecting oceans."

It should be noted that these objectives relate to the broad range of activities undertaken by DFO including science, resources management, and enforcement.

A further narrowing of the scientific objective is stated in the DFO management document entitled **Program Review and Evaluation (1988)** under the heading of "PURPOSE." It indicates that the Annual Program Review and Evaluation (PRE) exercises undertaken by the Science Branch (Newfoundland Region) are centred on the following:

(a)effectiveness, relevance, priority and effects of scientific projects and activities, taking into account governmental and departmental objectives and client needs;

(b)identification of changes to improve programme design and delivery, operational planning, and administrative effectiveness; and

(c)preliminary work planning for the new year.

Narrowing even further, the PRE document presents the mandate for the Groundfish Division of the Science Branch:

> "The Groundfish Division has a mandate to provide biological advice to support sound management of commercially and potentially commercially important groundfish species in the Newfoundland-Labrador area so as to yield maximum social and economic benefits for Canada. Such advice is provided to both national and international managers."

It would appear that all of the major concerns and issues felt by the Panel to be important plus many of those voiced at public hearings are embodied in these statements of purpose, although we have not been privy to any reports produced by the Newfoundland Branch dealing with maximising the social and economic benefits of the Newfoundland and Labrador fisheries.

8.1.1 Structure

The Science Branch, Newfoundland Region, consisted of 204 continuing full-time (CFT) positions in 1988. These are spread over the following divisions:

- Groundfish (60)
- Pelagic Fish, Shellfish, and Marine Mammals (40)
- Freshwater and Anaddromous Fish (30)
- Experimental Sciences (29)
- Oceanography, Hydrography, and Toxicology (25)
- Miscellaneous Others (21)

Within the Groundfish Division the 60 CFTs above were arrayed as follows:

- Division Head (3)
- Gadoids (16)

- Flatfish (13)
- Redfish (7)
- Canadian Port Sampling (7)
- Observer Programme Sampling (4)
- Fisheries Ecology (10)

Within the entire Science Branch, Newfoundland Region, resource assessment and related research constitute about 75% of research activities. The Groundfish Division is responsible for the provision of scientific advice on 24 stocks including northern cod.

8.1.2 The Planning Process

As we understand it, the planning process when developing the annual research programme employs the following sequential steps:

- national priorities are provided by Ottawa each year, usually in late October;
- specific research needs arising from recommendations initiated by CAFSAC and NAFO subcommittees or by the steering committee are added to the list of priorities;
- priorities and research recommendations are provided to line managers and individual scientists prior to each scientist/biologist developing, usually in late November, his/her specific research objectives for the coming year;
- an internal management committee then reviews work plans in December with two types of crosschecks employed:

  1) are all national priorities and research recommendations relevant to this region addressed in a meaningful way?

  2) are the specific objectives of different individuals, which should be complementary, clearly integrated (the same objectives would be expected to appear in two or more projects, indicating potential collaboration); and

- budgeting is carried out when the management committee is satisfied with the work plan integration for the entire research unit.

8.1.3 Apparent Shortcomings

The planning process outlined above provides a reasonably clear process for the articulation of national and regional goals and priorities into a coherently structured work plan for needed scientific research and for the provision of the fiscal and human resources required for its conduct. But, despite the clear description of the programme planning process, persistent questions remain. Why, for example, are there still such enormous gaps in our knowledge of the northern cod which is widely acknowledged to be fundamental to the economy of both Labrador and Newfoundland, which has been fished by us for five hundred years and which scientists have been studying for a century. Repeatedly in our public hearings and in private discussion with fishermen as well as with scientists, fundamental questions concerning the biology, the history, and the behaviour of the cod were raised and repeatedly we heard the response "we simply do not know." And, yet we also heard repeatedly, the assertion that only in the context of an improved understanding of the basic biology of the northern cod and of its physiological and behaviourial responses to various environmental stimuli could we expect to generate the best possible scientific advice upon which sound management practices could be based.

Despite the broad lacunae in our data and in our comprehension of the Northwest Atlantic ecosystem, DFO scientists must still provide to the managers the best advice of which they are capable. The world will simply not stand still while we await more perfect knowledge. But, knowing that our science is, in consequence, found to be inexact, we must be all the more careful in using the tools we do possess and the knowledge we do command to the best advantage and always with a determination to err, if err we must, on the side of prudent caution. Even though we have suggested elsewhere that the miscalculations of DFO scientists in respect of the growth of the northern cod stock up to 1988 might have been committed by any other scientific group given similar circumstances, we might also suggest that the problem might have been sooner identified had there been a greater appreciation of the weakness of our science and a greater commitment to caution.

We are, of course, not unappreciative of the fact that the gadoid section of the DFO Newfoundland Groundfish Division consists of only 16 scientists whose territory covers perhaps 150,000 square kilometres of ocean and that 75% of their effort must be directly concentrated upon stock assessment. There is little doubt that even if there were many more, the task of developing the data bases needed to improve significantly the quality of scientific advice would still be a formidable task. Furthermore, though the physical facilities at the White Hills are superb, the capacity to take scientists to sea where much of the biological and environmental research must be done is still limited; as is the capacity to process on shore in a timely fashion all the data that are currently accessible to say nothing of that which might be assembled.

These conditions obviously impose limitations upon what may be done. Nevertheless, the Panel is concerned with what might be described as the management of the scientific effort rather than with the quality of the science being done. That effort must, in the Panel's view, be increasingly concerned with the following significant issues:

- the development of such major research thrusts as must be initiated if the shortcomings of current data sets are to be evaluated and overcome;

- the evolution of models that integrate biological, environmental, and behaviourial elements into the assessment process;

- the encouragement of career advancement through contributions to the fisheries management process as well as through publications of scientific papers focused upon narrowly specialized disciplinary studies;

- the development of a process of peer review involving scientists external to the Department and prepared to provide an unequivocally independent perspective and to inject into the assessment process that healthy scepticism that is essential to scientific progress;

- the development among client groups of a high level of confidence in the DFO scientific establishment;

- the encouragement of the kinds of collaborative research that might bring to bear upon problems amenable to such an approach, the coordinated expertise of several different scientific disciplines.

This is a formidable list but one that the Panel believes to be worthy of serious consideration. In particular, attention might be directed to those approaches designed to obviate a situation in which research programmes properly focused and coordinated may, over time, drift into more or less segregated sets of disjointed studies that are, perhaps, driven more by the needs of individual scientists than by the necessity of serving the overall objective of the institution. It is true that such individual research programmes often interconnect and overlap, but this is not at all the same as if they were conceived as collaborative exercises in which the special possibilities of two or more disciplines were brought to bear upon different aspects of the same question.

This point is all the more important because the Panel believes that the proper exercise of the ministerial function in relation to northern cod involves more than simple assessment of population numbers, the establishment of a TAC, and appropriate enforcement. Management implies ongoing research of a nature determined by careful and sensitive assessment of the objectives of a fishery followed by careful and collective establishment of priorities. Furthermore, we believe that inasmuch as the northern cod is a resource of fundamental importance to the whole community, the entire applicable resources of the community should be mobilized to supplement the special capabilities of DFO science. The broad resources available within DFO itself can be drawn upon to develop collaborative teams to address significant problems from a multi-disciplinary perspective. Further, such teams can be augmented and supported by drawing upon particular expertise accessible at regional universities, Memorial University of Newfoundland and Dalhousie University, for example, or at other institutions, public or private, and including the corporate world. Such involvement must be deliberately sought since we can ill afford to miss any possibility of expanding our knowledge and of improving our chances of managing wisely.

We are not, of course, so naive as to assume that the significant advance in scientific knowledge will be attained except by true scientists, curiosity driven, and not by any means immune to the lure of high reputation that comes from personal achievement. The scientist as a team player is not an impossible concept, but the development of team approaches to problem solving that yet leaves space for individual recognition demands management of a high order. And, that is the kind of management to which we must aspire.

Perhaps it would be true to say that over the years our somewhat spotty knowledge of cod and of the system in which it exists is not so much the result of scientific failure as of failure to provide a clear management focus that would provide the necessary resources to researchers and at the same time promote the optimal utilization of those resources both human and material.

In this way, we can begin the process of restoring the high credibility of the science that must underlie proper management and which is a sine qua non to the ultimate success of our mission. At present, the basic client community, that is to say the fishermen, appear not only to distrust science but fail to understand its nature and its rationale, fail to see the relevance of particular research initiatives to their immediate problems, and fail to appreciate why their vast store of accumulated knowledge based on experience is not taken into account. To address this issue, means must be found to make them feel that they are both stake holders and participants in the process. There is clearly occasion for a community education programme and for the consideration of ways in which the inclusion of fishermen in the planning process can be made more effective.

In brief, the Panel is not disposed to denigrate in any way the high level of competence and of dedication displayed by DFO scientists. We are well aware of the limitations upon their resources and of the many constraints under which they seek to address a monumentally difficult set of problems. But, we do believe that there is room for major improvement in the planning process, in the need for greater measures of openness, in the development of improved educational programmes, in the establishment of better communications with client groups, and in the development of new science management techniques. In this context, we strongly recommend that DFO

1. Establish mechanisms for the external, independent scientific peer review throughout the scientific and stock management process;

2. Review its management structures and approaches with the end of establishing a more focused and coordinated approach to the management of the northern cod stocks;

3. Develop an ongoing programme that will open lines of communication through which appropriate information concerning the scientific process and management discussions may be communicated more effectively to client groups throughout the region and through which client groups may have more effective input.

8.2.0 Technology — Introduction

It is not the intention of the Panel to attempt a comprehensive discussion of the many technologies that are or may be applied to northern cod stock assessment or to the management of the fishery.

Rather, we propose a somewhat superficial identification of some of the significant ways in which technology, which has to a degree contributed to the problems we face, may be harnessed to redress the problems.

8.2.1 The Need for a More Technological Approach

There is no question that improved technology has reduced the risks associated with fishing and greatly improved the efficiency of the fishing fleets. It could be argued that these improvements in the detection and harvesting of northern cod have contributed to the present problem. During the period when trawling technology was going through vast improvement, the technology associated with management improved only marginally. To be sure, oceanographic and fisheries science has improved over time with better monitoring devices and new intellectual paradigms. However, the changes within the harvesting sector have by comparison been extraordinary.

Oceanographers and fishery scientists recognize that their discipline is observational rather than experimental and in such a dynamic environment the isolation of causative influences are often masked by the considerable background "noise."

Discrimination of important causative factors can be accomplished in several ways. Sophisticated mathematical models can be employed which permit a more incisive evaluation of existing data. Alternatively, more refined observation using the best available technology would greatly improve the possibility of identifying the essential variables. The most desirable approach would be one which employed both refined sensing capabilities as well as highly specialized software to help unravel the linkages hidden in very complex information.

The Panel believes that in order to more fully understand and manage the northern cod, it is imperative to explore fully the available technological alternatives. Advances appear daily in many related fields which have the potential for adaption to fishery-related problems, where a very pronounced need exists to monitor a particular species and its relationship with both its physical environment and other species. There is an overwhelming need to reduce the ambiguity and to improve our understanding of casual relationships. Coupled with a clearly defined and sharply focused management strategy, improvement in this area could reap some important benefits.

There is little evidence that the Department of Fisheries and Oceans, Science Branch in St. John's, has made a systematic effort to apply state-of-the-art technologies to either the annual assessment process or to ongoing management activities. This is not to say that new technologies are not in evidence. Rather, their use appears to be a random process resulting from independent, individual effort, rather than from any concerted effort.

The Panel is well aware that technology is not a panacea. Rather, it represents a more refined observational capability that limits the margin of error. For this reason, if for no other, the Panel believes that DFO has a requirement for a well defined policy, perhaps in venture with other departments, focused on the pursuit of new technologies as a means to extending and refining its fisheries management capabilities.

Technology will always be changing and improving within any scientific discipline simply as a reflection of the nuclei out of which that science emerged. However, gradual and sometimes undirected improvements are a far cry from the overt recognition of technological improvement as a cornerstone of a sophisticated management policy.

Some examples of potential new approaches are provided. No judgement is implied as to their relative usefulness, rather the following items demonstrate potential.

8.2.2 Fishing Gear Technology

The need to develop more selective fishing gear which minimize bycatch of undersized commercial species and the harvest of non-target species including marine mammals and sea birds has long been recognized as a desirable goal by fisheries managers, commercial fishing interests, and conservation groups.

Bycatch is not, of course, a problem that is unique to the fisheries of Canada's East Coast but rather is pervasive throughout the fisheries of the world. Nor can we doubt that solution of the problem would bring very significant gains in terms of conservation, the elimination of biological waste, and the more effective use of available fishing resources. In this context, it is somewhat surprising that Canada and other prominent fishing nations, with the possible exception of Japan, should have heretofore directed so little attention to the matter.

The issue must now, however, be addressed; and, if one contemplates traditional approaches we must anticipate, because of the growing intensity, complexity, and diversity of Canada's coastal fisheries, the commitment of substantial management resources and substantially increased costs for user groups. It may be possible, however, to consider technological solutions as more attractive and more cost effective alternatives.

Thus, the Panel urges the Government of Canada to establish a technology group whose focus should be to eliminate biological waste in directed fisheries and to minimize bycatch of non-targeted species. Such an operation could be contracted out to industry or developed as a component of DFO or other government laboratories. Two obvious projects for early attention might be the improvement of trawls, traps, and other gear types to eliminate entrapment of juvenile fish and the development of systems to locate lost gillnets or to prevent their continued fishing.

8.2.3 Fisheries Surveillance

An integral part of any overall fisheries management policy is the monitoring and policing of the harvesting process to ensure that conservation driven total allowable catch limits are maintained.

This surveillance becomes particularly difficult for the offshore fishery when considering the enormous area to be monitored and the prohibitive cost of one hundred percent coverage when utilizing conventional air and surface methods. A potential approach could be through the utilization of remote sensing techniques, including ground wave over the horizon high frequency radar and on-board transducers tracked by upcoming satellites such as Radarsat and M-Sat.

Early results from ongoing HF Radar experiments indicate that a sufficiently high resolution at three hundred kilometres distance may be obtainable, allowing for the continual monitoring of all vessel movements within Canada's territorial limits.

The launch of Radarsat will provide the first non-cloud restricted satellite images of the east coast of Canada and may well allow an ongoing cyclic monitoring of vessel traffic in the area.

It is also possible that M-Sat could be utilized to monitor with great accuracy the location and movements of all vessels engaged in the fishing process in the region. This would imply the installation of transducers on all such vessels and their integration with nonrational systems. In respect of vessels operating within the Canadian management zone such a regime could be improved by regulation and as a condition of licensing. For vessels operating outside the two hundred mile limit, international agreement would be necessary nor do we conceive that such agreement could be reasonably denied. Furthermore, it would be but a small step to add catch statistics to the transmissions so that Department of Fisheries and Oceans monitors could be provided with real-time catch results coupled with precise locational information. The scientific value of such data is obvious.

8.2.4 Stock Assessment

We have elsewhere in this report noted the relatively wide disparity between estimates of abundance as derived from commercial catch data and from the research vessel surveys. In fact, that disparity can on occasion approach one hundred percent. We have suggested that this disparity may, in part at least, result from an underestimate of the significance of improved technology among the commercial fleet and, in part, from the effects of commercial fishing preponderantly upon spawning concentrations which may in itself have influenced the effectiveness of the technology. Even if those reasons are valid, they probably do not comprise a complete explanation for the disparity which, however, must be accurately and fully explained if we are to arrive at an accurate calculation of F.

The single annual scientific assessment cruise of the research vessel may be adequate to the case through there is no proof to support that assertion. But that consideration apart, it is clearly important that DFO scientific personnel, whether restricted to one annual cruise or not, must have accessible to them the most technologically sophisticated equipment available. Apart from the obvious necessity to ensure as nearly as possible in respect of both the vessel and the fishing gear precisely similar conditions from experimental tow to experimental tow, it should be possible to use state-of-the-art hydroacoustic and net monitoring devices to improve both the quantity and quality of the data gathering exercise. Further, it should be possible to involve at least some of the commercial fleet in the scientific assessment activity. The Panel has been assured that commercial operators would not object to equipping some vessels with appropriate equipment, of taking scientists to sea, and of cooperating in the appropriate intercalibration of sampling equipment. **In short, given the paucity of ship resources available to DFO scientists, there**

would appear to be logic in the proposition of using commercial vessels, through agreement with their owners for scientific purposes.

In respect of stock discrimination, a problem which has been identified as an important one, a new approach, as yet untried with northern cod, is the application of DNA fingerprinting techniques as a means of unequivocal identification of an individual's stock affiliation. This approach, which is presently under development as part of the Ocean Production Enhancement Network (OPEN) Centre of Excellence, offers the possibility of reducing the ambiguity of stock discreteness plus the added advantage of providing some insight into stock migrations.

Some improvement is also warranted in the commercial side of stock assessment. The observer program is generally acknowledged as a very useful device, albeit one which appears to be underutilized. Greater use might be made of the accumulated data if the observers were to employ electronic logbooks which had the capability of telemetering the data to shore. In that way a "real time" assessment of commercial catch activity, CPUE information, and average fish size would be available to stock managers for inclusion into their models.

8.2.5 Environmental Observations

As indicated above, a major problem faced by fishery biologists is their inability to define convincingly the environmental factors which contribute to the observed changes in fish populations. Understanding relationships such as these would contribute greatly toward a better understanding of stock abundance and variability. Ultimately, it would put management on a much more secure footing and reduce the potential for unexpected oscillations. But most importantly, it might offer the possibility of eventual human intervention in order to protect and sustain these stocks for future generations.

Once again we draw attention to advanced technological approach which is in its earliest stage of development within the OPEN Centre of Excellence. The goals of that programme's participants would include the development, wherever possible, of a synoptic view of the organisms and their environment. This is expected to be accomplished through the use of remote data collection, using buoys, drifters, moored instrument packages, and both aircraft and satellites.

Once these data have been collected it will be transmitted back to shore where it will be processed immediately in computers equipped with specially written programmes specific for the site where the data was collected. In this way, a broad "real time" view of the environment can be created which can be related to the animals. Real-time measurements of water motion would be essential to continuously update the sampling strategy of vessels attempting to tract a particular assemblage of animals. Also, immediate analysis of results permits the design of future field work to proceed immediately.

8.2.6 Physiology and Behaviour

So much of what influences the behaviour of animals is tied to their genetically programmed ability to adapt to their physical environment. Animals are normally found in locations where they are the most comfortable or, conversely, they avoid inhospitable conditions. A better understanding of their actual preferences and aversions would permit greater insight into their distributional motivations.

Catching and releasing fish to which a "smart sensor" had been attached would permit a sophisticated tracking of the animal relative to, for example, temperature or depth. Smart sensors are very small packages which can contain devices capable of measuring some environmental variables and storing that information on a silicon chip. When the fish has been recovered, it would be possible to infer its migration route (from which it was tagged to where it was subsequently caught) and the kind of environment which it chose for itself. Information such as this would be extremely revealing and it could be useful.

8.2.7 Summary

This by no means comprehensive list of technologies has been presented solely as examples of existing hardware which could be employed as one component of an integrated and comprehensive programme to monitor and subsequently manage northern cod. The advisability of applying any or all of the above must, of course, await the establishment of clear goals and the careful choice of the most appropriate technology to best advance the possibility of success in each particular case.

What appears to be absent from the current DFO master plan is a generally acknowledged recognition that new, more efficient ways must be found to observe in appropriate detail a very large territory of great environmental complexity and to do so speedily enough to enable relevant conclusion to be drawn. The Panel believes that only by fully utilizing sophisticated modern technology can such a goal be obtained. We recognize that this suggestion is being advanced during a period of reduced government spending and limited manpower. But this is all the more reason why there is little choice but to find more efficient ways of doing things if improved management is a real goal. Surely a single four to five week cruise each year can no longer be considered to be adequate to serve the needs of the case. In short, **the Panel strongly recommends that DFO should mount a dedicated systematic effort to improve or expand relevant technologies for use in the annual assessment process and in ongoing management activities.**

8.3.0 Monitoring and Enforcing Laws and Regulations

We should not forget that neither good science, good laws, nor good regulations will achieve their objectives of ensuring the wise use of our marine resources unless they go hand in hand with the proper monitoring, surveillance, and control of the stocks and of those who exploit them. Thus, if the northern cod is truly the backbone of Canada's Atlantic Coast fishery, we must ask whether the resources allocated for its protection are adequate in consideration of the importance of the stock and the vast area in which the stock is found. In addressing this question, the Panel is aware that, in recent years, the role of management has become much more complicated as the fishery has been subjected to significant changes. For example, the geographical expansion of the inshore fishery far beyond its traditional sphere of operation has major implications for DFO monitoring. In particular, many inshore vessels now fishing 60-70 miles offshore are far beyond the range of the inshore patrol fleet whose small patrol vessels were designed as "day" boats with a limited range of approximately thirty miles from shore.

Nor is it merely in respect of range that the inshore fleet has changed. Other advances in applied technology have increased the abilities of the fleet to pursue fish to areas hitherto inaccessible, to find them, and to catch them more effectively. Meanwhile, the regulatory authority, while it is able to establish levels of horsepower for vessels of different classes, has no involvement with nor control over other technologies that are involved.

Furthermore, with changing expectations since 1977, more and more people have sought access to the fishery. The consequence has been the division of the quota into smaller and smaller units and among a variety of fleets. All of this has made policing more difficult. In addition, the level of effort has increased substantially not only in respect of the amount of gear deployed but in terms of time as well so that a fishery, once conducted during a portion of the year, has now been extended to occupy the entire year. All of these developments have tended to make the tasks of monitoring and controlling more difficult.

In another context, the fishery has changed to reflect a greater dependency on species other than the traditional groundfish. Thus, the multi-million dollar shrimp fishery in the north, while it might not be as visible as the crab fishery, for example, does put additional strain on the capabilities of the monitoring system. Then there is the capelin fishery which has become extremely important to certain sections of the industry and which, under its present industry directed marketing TAC, required an extraordinary amount of enforcement and places great demands upon fisheries staff demanding nearly all their attention during peak periods which last for at least two weeks each year.

Added to the foregoing is the presence of a large foreign fishing fleet, those fishing legally under restricted species licences inside the two hundred mile limit and those fishing outside the line and often tempted to cross it. The latter group offer particular frustrations for scientists attempting to make an accurate stock assessment of northern cod and as well for managers whose purpose is to keep unlicensed vessels outside the Canadian zone.

In short, it has become obvious to the Panel that resources for surveillance have not matched the changes that have taken place in the fishery over the years. One of the most evident examples of this is the lack of vessels to patrol the offshore.

Currently, there are only two patrol vessels, or one and one half if refitting time is considered to cover the offshore from Burgeo, along the south and east coasts of Newfoundland and as far north as Baffin Island including the NAFO area outside the two hundred mile limit. One of those vessels has to be dedicated to the "Nose" and "Tail" of the Banks since that area demands constant surveillance. Even so, the degree of visibility represented by this continuing patrol does not prevent all cases of foreign intrusion, and for the rest, a single vessel to patrol the whole of the northern cod area is little more than a token and, some might argue, a joke. However, taking into account the new fisheries in the north, the movement offshore of units of the inshore fleet, the Canadian inshore fleet itself, the foreign vessels legally fishing in the Canadian zone, and foreign vessels illegally inside the zone, the Panel sees an urgent need for additional vessels.

It is, of course, true that aircraft equipped with state of the art radar systems are enormously useful in locating and identifying vessels and must be considered one of our best deterrents to illegal activities. Nevertheless, aircraft crews are incapable of taking the kinds of actions that should follow from identification of illegal pursuits. They cannot, for example, board or arrest a vessel. In consequence, it is necessary that aircraft be supported by surface patrol vessels. Thus, while the Panel is supportive of the aircraft surveillance programme and would strongly encourage the use of additional new technologies that could be adopted to the purposes of electronic surveillance, we rather believe that increased surveillance will make even more necessary the deployment of additional offshore patrol vessels. Aircraft and particularly the helicopter have also demonstrated their usefulness in respect of inshore surveillance. Indeed, we can conceive of no more efficient means of maintaining a general surveillance over a large area and of directing the inshore patrol boats to specific situations needing on site investigation. The Panel would urge DFO to continue this valuable service and, indeed, to enhance it.

Apart from the shortage of physical resources to maintain proper surveillance and enforcement of regulations, the Panel is also concerned that the Department lacks personnel to implement in proper fashion programmes that have been well conceived. We have already referred to the need for people, time, and equipment to utilize more fully the data gathered for the purpose of scientific analyses through the observer programme. But this does not represent the full extent of the deficiency. It is, for example, not in our view appropriate that a new observer, after only a brief period of basic training, should be sent to sea unless accompanied, for a few days at least, by an experienced observer. Furthermore, experienced observers should be available to conduct regular audits or "spot checks" in the field. Again, additional personnel should be available on shore to check and analyze observers' written logs and so to identify developing trends that might indicate where additional patrols are required. In such ways, we believe the full potential of the observer programme might be realized and a well-conceived initiative made more cost-effective than it appears to be at present.

In the end, of course, not even the best surveillance and the most effective observer programme will obviate the necessity for other punitive forms of deterrence. When such situations do arise, there should be no doubt that the penalties imposed are sufficiently painful as to discourage repeat offenses. In this regard, we do not find the record of our courts impressive.

The penalties provided by law are not insubstantial. A maximum fine of $500,000 is provided for illegal entry by a foreign vessel into the Canadian zone and a maximum fine of $750,000 for illegal fishing in the zone. Additionally, fish and gear may be forfeited. In practice, penalties have not even approached those levels. We cannot escape the feeling that the violations of fishery regulations, the poaching of fish within the Canadian zone, and such like activities are regarded as mere peccadilloes; as if the whole matter of enforcement were a game in which a few tons of illicitly taken fish were of no greater significance than the crabapples stolen by naughty boys from a neighbour's tree. In the opinion of the Panel such attitudes must change. Canada must convince both her own fishermen and the international community that conservation and proper management are matters of vital concern. In no cases should the potential gain from defiance of regulations exceed the penalty for being apprehended in violation of them.

For the domestic fleet, maximum fines for violations such as incorrect mesh size, fishing in the wrong areas, exceeding the allowable discard limits, misreporting or underreporting catches, and the like are set at $5,000, though repeat offenders could have licences suspended and/or catch, gear, etc. forfeited. In practice, however, the tendency is definitely towards leniency. The message conveyed is that such offenses lack significance and are to be regarded as mere misdemeanours. That attitude must change. We must be convinced that the proper management of our marine resources is a vitally important matter demanding strict adherence to rules designed to ensure that a resource upon which we have depended for so long will survive our capacity to destroy it.

In this context, we are prone to support a proposition enunciated in a Fisheries and Oceans Research Advisory Council (FORAC) report in 1987 to the effect that "The economic consequences of dishonest reporting need to be greater than the economic gains of misreporting;" and, we are further of the opinion that the same argument should apply in regard to many of the more common offenses of which fishermen are guilty. There should be no doubt in anyone's mind that the privilege of receiving a commercial or sports licence carries with it an obligation to behave in a manner consistent with appropriate conservational strategies as defined in law and regulations.

By the same token, we are persuaded that managers who have for their guidance a set of admirably conceived goals and objectives should neither in the devising of regulations nor in their enforcement permit social, economic and political pressures that may be brought to bear upon them to be the occasions for deviation from the chosen path. The law, the agent of enforcement, and the giver of laws must all be equally credible in the eyes of the fishing community. It is obvious that any perceived movement away from our stated goals will, to the extent of that movement, diminish credibility. In short, we must clearly convey the message that we are seriously committed to our own rules and regulations. Thus, it is essential then that we adopt internal monitoring procedures to guarantee adherence to policy in order that any deviation from policy will be clearly documented to establish "a clear audit trail" for any who would question our accountability.

CHAPTER IX

Summary and Conclusions

An examination of the historical evidence for exploitation of the northern cod stocks, including both the 2J3KL stock(s) and those transboundary components found in 2GH and 3NO, indicate that prior to 1959 annual landings did not in peak years reach 350,000 tons and on average were not in excess of 250,000 tons. While it is clearly not possible on the basis of these data to reach firm conclusions in respect of a sustainable yield of northern cod, it would certainly appear reasonable to suppose that between 1902 and 1958, for example, a sustainable harvest of 300,000 tons was possible. It is equally clear from examinations of the record for the decades of the 1960s and 1970s that annual harvest in excess of 600,000 tons could not be sustained and precipitated a rapid decline in both catches and estimated stock size.

There are, obviously, limits to growth implicit in every natural system whose life sustaining capacity must of necessity be finite. In attempting to assess the capacity of any such system to sustain a relatively stable yield of a particular species such as northern cod, we must clearly contemplate not only the variability of naturally incurring phenomena on yield but, as well, the effect of human intrusions through, for example, the exploitation of other species. At present our knowledge is deficient in both respects. We neither comprehend fully the complexities of the natural world that northern cod inhabit nor realize the full impact of natural adjustments to human activities

While it is clearly imperative that we should expand our knowledge base as a matter of urgency; and that we should move to develop our management strategies in the context of a better understanding of cod within the Northwest Atlantic ecosystem, it is also clear that in the interim we must set harvesting goals that appear, in the light of historical experience, to be realistic.

In doing so we can, perhaps, take comfort from the proposition to be inferred from the historical record that the system is not a notably fragile one and that the northern cod appears to possess remarkable resilience. Thus, the gross overexploitation of the late 1960s and early 1970s did not result in the final collapse of the stock. Rather, following implementation of the new management regime in 1977, it demonstrated a reasonable growth pattern so that the exploitable biomass doubled during the decade following 1976, the year in which the stocks reached the lowest level of abundance of which we are aware.

Nevertheless since 1984 even though there has been no marked downturn in biomass, it would appear that growth has stopped and that weaker recruitment in more recent years may suggest population decline in years ahead. That is to say, losses from the current biomass as a result of fishing and natural mortality are exceeding gains made through recruitment and the growth within the population. While this does not suggest that a biological catastrophe has yet occurred, it does imply that current catch levels, if maintained, will place us on the road to stock depletion.

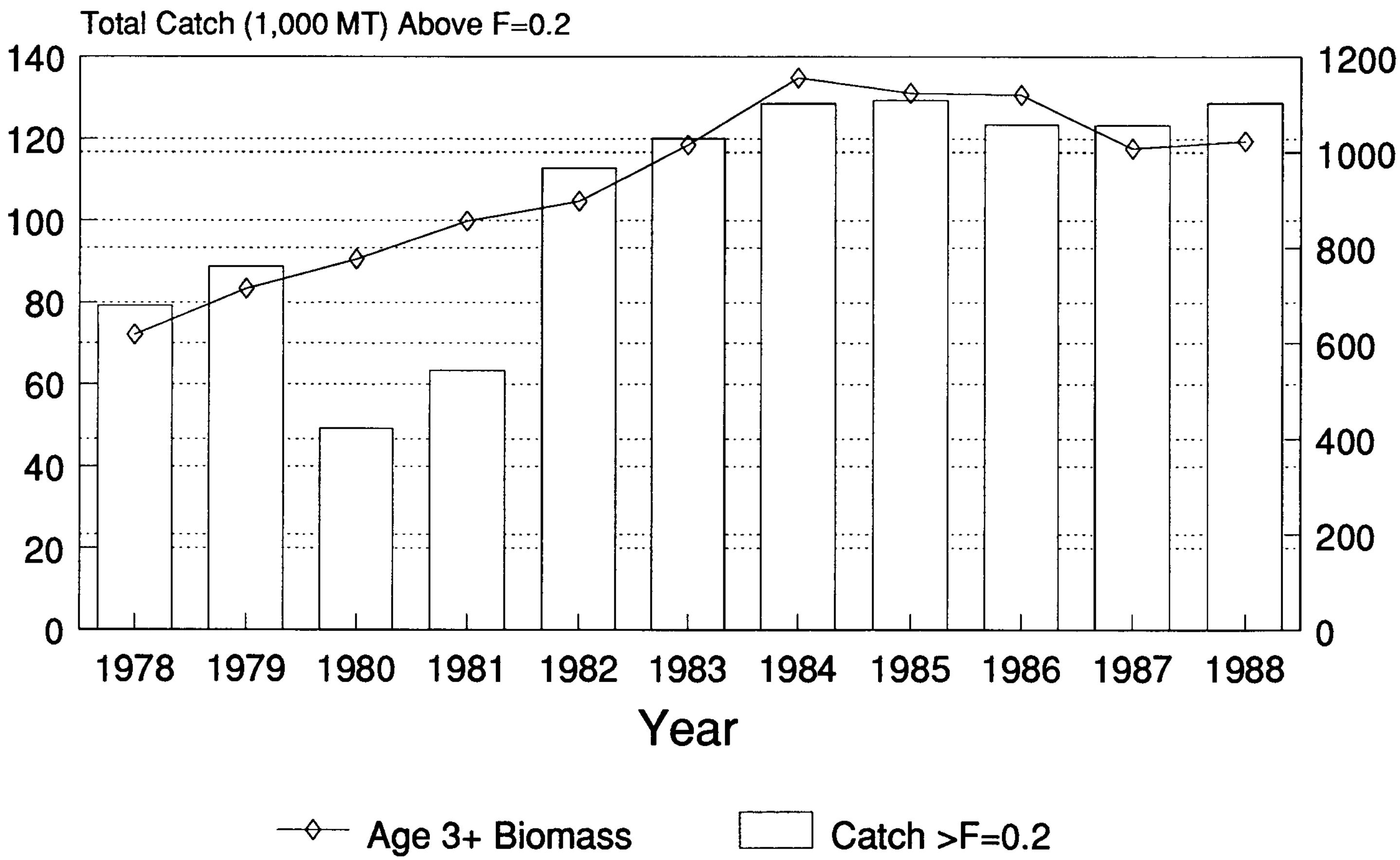
From this it will appear that in recent years the fisheries have taken a much larger percentage of the biomass than had been anticipated. That is to say, the fishing mortality imposed upon the exploitable biomass has been much greater than planned. The management strategy adopted in 1977 was that designated as $F_{0.1}$ which would have meant fishing at an instantaneous mortality rate of about 0.18. Instead fishing mortality was maintained at a level of at least 0.4 and possibly higher. At the same time, catches by foreign fleets outside the management zone consistently exceeded established quotas. Furthermore, the Panel believes that high discard rates and even high-grading of catches was a regular concomitant of the trawler fishery particularly in the earlier years of Canadian management and that underreporting of cod bycatches by both foreign and domestic fleets was a widely acknowledged practice. Furthermore, the Panel believes that fisheries such as those for shrimp and capelin destroy substantial and unreported numbers of juvenile cod and that the aggregate of these unreported losses may have elevated the deaths indirectly resulting from fishing.

Despite large harvest overruns and the additional sources of unrecorded mortality to which we have referred, the population continued to grow until 1984 as a result of several previous years of good recruitment. Unfortunately, such happily fortuitous circumstances no longer obtain. The evidence indicates that recent year-classes have been much smaller and further that, unless the spawning biomass can be rebuilt, they will continue to decline at an accelerating rate.

The magnitude of catch overruns in the years between 1976 and 1988 are shown in **Figure 22** where they are plotted against the population trend. As will be clear, the fish that ought to have lived to constitute an increasing spawning biomass for enhanced recruitment were instead caught, processed and sold.

In those circumstances, it is easy to point the finger of blame at DFO scientists. Infected like so many others by the post-1977 euphoria, they do not appear to have appreciated the full implications for cod mortality of new technologies and new fishing practices employed by both domestic and foreign fishermen. Confident of their belief that their database and analytical methods were sound and, hence, that the $F_{0.1}$ management strategy was indeed a functional reality they were prepared to accept the results of their assessment techniques and to set aside as

FIGURE 22: TOTAL CATCH ABOVE F=0.2 AND AGE 3+ BIOMASS OF COD IN IN NAFO DIVISIONS 2J, 3K, AND 3L



aberrational certain signs that might have been interpreted as pointing in another direction. Without benefit of hindsight they were predisposed to accept even when optional data interpretations were possible, those tending to support the validity of their mathematical models.

In fairness, of course, we must recognize that fisheries population dynamics is by nature a complex matter influenced by a wide variability in environmental, behaviourial, and general ecological elements that together constitute the ecological system. By analogy, we might conceive of a vast jigsaw puzzle made up of thousands of pieces each of which is likely to change its shape as we try to make it fit into a picture that also changes as we move along. In the view of the Panel, the methods used by DFO scientists to make the pieces fit were not notably faulty in concept but were based on tenuous conclusions and skimpy data sets. Simply put, the Department of Fisheries and Oceans population and estimates of stock trends could not be expected to have been more reliable than in fact they were, given the quality and quantity of available data and given the capacity of the system they were using to analyze the data they did possess.

This is but another way of saying that whereas cohort analysis (VPA) is a relatively accurate method only if the turning techniques are based upon reliable estimates of abundance and if all the catch components are identified. That is to say, the estimates are only as valid as the data sets used in the analysis.

In light of these considerations, it is clearly imperative that every effort be made to improve the quality and scope of data collected and that a rigorous regime be established for the checking and testing of data to uncover errors that will, if undetected, bias the assessment process. To this end, it is important that both the data and the conclusions derived from them be submitted to external peer review.

We are pleased to note that the ADAPT method used by CAFSAC is suited to inspections of data quality and that in most recent assessment exercises it has been used exhaustively to check the combined data sets used in the tuning. It has also been used to calculate the likely impact of such possible error sources as misreported discard rates.

Nevertheless, we cannot say that the Panel is entirely happy with the current situation. Certainly, the ADAPT model is an improvement upon the model used in previous years, but we are somewhat concerned that while the analytical process is being emphasized, insufficient attention is given to the quality of data inputs. Perhaps it is easier and, therefore, more tempting to seek answers through mathematical manipulations, whereas, the true solution may only become apparent when we have a more comprehensive knowledge of the biology and behaviourial characteristics of the species with which we are particularly concerned and of the ecosystem in which it functions. In any event, the principal issue currently before us is the reliability of the tuning indices that are being employed, and it would appear that neither the unadjusted RV data nor the commercial CPUE data are completely reliable. **We would, therefore, urge Department of Fisheries and Oceans scientists to make every reasonable effort to ensure that their commercial and RV data are producing reliable inputs and to make it a matter of priority to develop alternate independent estimates of stock trends.** We are convinced that **with appropriate and accurate data in hand, there is no shortage of acceptable models to which the data can be submitted.**

With regard to 1990 and subsequent years, the Panel is convinced that Canadian scientists must go well beyond this relatively simple prescription. A determined effort must be mounted not only to generate additional indices of abundance against which the RV and CPUE indices may be checked and challenged but, as well, to come to a more complete knowledge and understanding of the biological and behaviourial characteristics of the cod and of other animals with which it interacts and of the physical environment whose dynamic characteristics comprise some of the missing pieces of our jigsaw puzzle.

In the context of these general research and development objectives, the Panel has identified a number of specific areas of concern to which early attention should be directed. These include:

1. **Stock Definition.** Developing a better understanding of the stock components and the relationship of the major spawning aggregations to the inshore fishing grounds is an important area for further research. Such information could be most helpful in developing management strategies which more effectively distribute fishing mortality among the stock components thus reducing the possibility of localized depletion. Furthermore, since there are known wide variances in the weight-at-age data over the range of northern cod, it would appear that better definition of stock elements would lead to better stock assessment and management concepts related to maximizing the yield from available recruits.

2. **Data.** Current DFO stock assessment relies heavily upon tuning the VPA model using CPUE data from the offshore fleet and RV data. The Panel is strongly convinced that additional indices of abundance should be developed. Appropriate measures might include an index based upon bycatch rates, another based upon CPUE data from the small boat inshore fleet, and acoustical surveys. Further, an expansion of the observer programme to collect biological and bycatch data would seem highly desirable.

3. **Discards and Misreporting Bycatches.** Discards and misreported bycatches are not only significant in terms of natural mortality but may also, as has been indicated above, distort calculations of population and of fishing mortality. The Panel heard repeated testimony that foreign vessel bycatch figures were almost invariably underreported by as much as 25% and that discard rates, particularly by small domestic otter trawlers, to a lesser extent by deep-sea trawlers, and by inshore fishermen were far more significant than Department of Fisheries and Oceans calculations considered them to be. Not only is it imperative to reduce such waste to the absolute minimum that wise regulations and rigorous enforcement will permit, but we must also ensure that the information we record and use is as accurate as can be achieved.

4. **Foreign Fishing.** Foreign fishing both within and outside the Canadian management zone clearly affects the level of fishing mortality to which northern cod is subject, for we can by no means suppose that the drawing of an arbitrary line on a map in any way alters either the general biology or the behaviour of animals whose territory it bisects. Thus any proper management of the northern cod stock(s)must embrace all components of the stock(s). By the same token, the setting of a TAC and other management decisions ought, in logic, to be the responsibility of a single regulatory

> authority which, in the instant case, should be the Canadian Government. While we do not advocate lawlessness nor maintain that Canada should depart from the ways of negotiations, it is not, in the view of the Panel, at all unreasonable that Canada should vigorously pursue management rights that, at least in the morally prescriptive sense, are established both by adjacency and by the utter dependence of the coastal community upon the resource in question. The current Canadian strategy of confining its fishing activity to those portions of the shelf falling within the two hundred mile zone gives tacit consent to the proposition that the transborder stocks are in some degree different, that they fall exclusively under foreign jurisdiction, or even that they are subgroups of the stock in which Canadian fishermen have no legitimate interest.
>
> On the other hand, it is the opinion of the Panel that Canada has an **overriding** interest in them and should pursue every possible means of asserting that interest. Thus, in establishing the appropriate harvesting strategy the "Nose" and "Tail" of the Bank should be treated no differently then, for example, the Funk Island Bank. In short, the catching effort should be distributed proportionately in accord with the manner in which the stock itself is distributed throughout its range. Such an approach would be proper in biological terms but would also strengthen Canada's bargaining position **vis a vis** the international community.
>
> In respect of foreign vessels fishing under Canadian licence within the two hundred mile zone, no bycatch of cod, whether for processing or for discard should be permitted and violations of that proscription should be followed by cancellation of the licences in question.

The clear implication of the foregoing observations is that for the years 1990 and beyond, Canada must reevaluate both its management strategies and its tactics and must replace management through political expediency with management founded upon a solid scientific base. This suggests a substantially enhanced research effort. In the meantime, however, we must be absolutely clear **that failure to take appropriate steps to reduce current levels of fishing mortality will most probably lead to a significant continuing decline in the spawning population.** Thus, whatever management action is taken, the Panel recommends, in the strongest possible terms, **that the guiding principle must be the imperative necessity for an increase in the size of the spawning population.**

The achievement of this objective will, we believe, be a slow and difficult process and one that will regrettably continue to be fraught with uncertainties. For we must confess that we are not able to offer any absolutely firm categorical prescription. Nevertheless, the evidence before us strongly supports our belief that if the spawning population is to grow at a desirable rate, fishing mortality must be reduced to a value of 0.2 and should be continued at that level until such time as indisputable scientific evidence supports the application of a different rate. Under such a management regime, we believe that the exploitable biomass will increase to permit an optimal sustainable harvest that should not be less than 300,000 tons per year and might conceivably be higher. That we cannot presume to offer a firm figure is a function of the great complexity of the system with which we are dealing and, as well, of the fact that it is a system in flux. Nevertheless, the historical evidence alone provides a reasonably comfortable base for the number we have suggested.

If such a desirable situation is to be attained, the first and foremost consideration must be to reduce fishing mortality from its current level. We have already indicated that we accept the current CAFSAC estimate of fishing mortality at 0.44 as being most probably in the right domain. Still we are constrained to admit that higher or lower values are within the realm of possibility.

Table 9 shows various values of F as derived from several different analytical approaches. As will appear these values range from a low of 0.35 to a high of 0.62. We clearly incline rather towards the higher end of the range than toward the lower, but we cannot be so certain that we would offer only one course of action for consideration. Thus we have examined the Table 9consequences for the spawning stock and for annual TACs that would arise from various possible management decisions establishing different catch levels under assumed fishing mortality levels of 0.35, 0.45, and 0.55. Nevertheless, though we have acknowledged a range of possible F value, **we believe the true value to be at least 0.45.**

Table 9
F Values Predicted Using Various Analytical Approaches (average F 7-12)

CAFSAC ADAPT	0.44	
Methods using survey and offshore CPUE:		
Laurec/Sheppard	0.53	0.47
XSA	0.41	
Methods using survey only:		
Laurec/Shepard	0.62	0.56
XSA	0.48	
CAGEAN	0.57	
Method using offshore only:		
Laurec/Sheppard	0.43	0.39
XSA	0.35	
Average 1981-1988	0.46	
Inshore	0.50	

We have examined twelve possible management options using the different levels of fishing mortality as indicated. The first three of those (**Figures 23** through **25**) project the consequences of holding the assumed fishing mortality for 1988 constant over the next five years. **Figures 26** through **31** examine the spawning biomass and catch trends under various assumed reductions in the fishing mortality rate. The last three options (**Figures 32** through **34**) hold the catch constant at 200,000 metric tons and allow the fishing mortality rate to vary over time. In all those cases, and in any other that might be developed in similar fashion, it should be carefully noted that projections beyond three years are necessarily unreliable because of the uncertainties associated with year-class recruitment which cannot be anticipated.

From the Panel's perspective, none of the first three options which consider the consequences of continuing to fish at current rates will lead to the desired goal of increasing the size of the spawning biomass. Options B2 through C3 all lead to improved spawning stock levels but with the exception of option B1 which, perhaps unrealistically, assumes a current F value of 0.35, require that the catch be reduced significantly below the level set for 1989. Options C1 and option C3 also lead to significant increases in the spawning biomass but also require a substantial initial reduction in catch. If the final options, D1 through D3, which hold the catch constant at 200,000 metric tons, the only acceptable solution is that which assumes an F of 0.35 which is not an assumption we are prepared to accept as realistic.

Thus, the range of options presented in our interim report still stand. They should, however, be reexamined in the light of data collected in 1989. With that in mind, it should be noted that a 1990 TAC of 190,000 metric tons, as depicted in the C3 option (**Figure 31**) may not serve to reverse the trend of a declining spawning stock but may rather contribute to further decline. And yet, we cannot be unaware that the sudden reduction of catch levels designed to reduce F immediately to the desired value of 0.2 would precipitate social and economic repercussions of a particularly drastic nature. In consequence, we are still disposed to stand by the suggestion that the mortality be reduced to 0.3 as a staging point on the way to the lower figure that should be achieved at the earliest feasible date. The Panel would, of course, be very happy if its gloomy predictions were to be discounted by the results of the autumn 1989 survey. But in the likely event that the survey should confirm a continuing F value of 0.4 or higher, the Panel is strongly of the opinion that a lower TAC for 1991 will be imperative. In short, the decline in the spawning biomass cannot be permitted to continue, and it is our considered view that the decline will not be checked until the mortality rate has dropped below 0.3. Thus, as painful as it may be, the TAC should be reassessed annually with a view to further reductions if there is not good evidence of spawning stock recovery. For it should be clear that the longer the delay in facing the brutal reality, the harder and longer will be the road back.

But if the socio-economic imperatives appear to dictate somewhat higher TACs than biological necessities would indicate is desirable, there are certain management tactics that may serve as ameliorative. These include the strictest possible control upon cod discards by either domestic or foreign fleets; the close regulation of bycatches of cod and, indeed, the prohibition of such bycatch by foreign vessels within the Canadian management zone; the regulation of gear types to reduce mortality of juvenile cod; the strict enforcement of regulation through an expanded observer programme and close surveillance of domestic as well as foreign activities; and, the

FIGURE 23: OPTION A1--ESTIMATED CATCH & SPAWNING BIOMASS FOR COD IN NAFO DIVISIONS 2J, 3K, AND 3L

F=0.35 in 1988-1994.

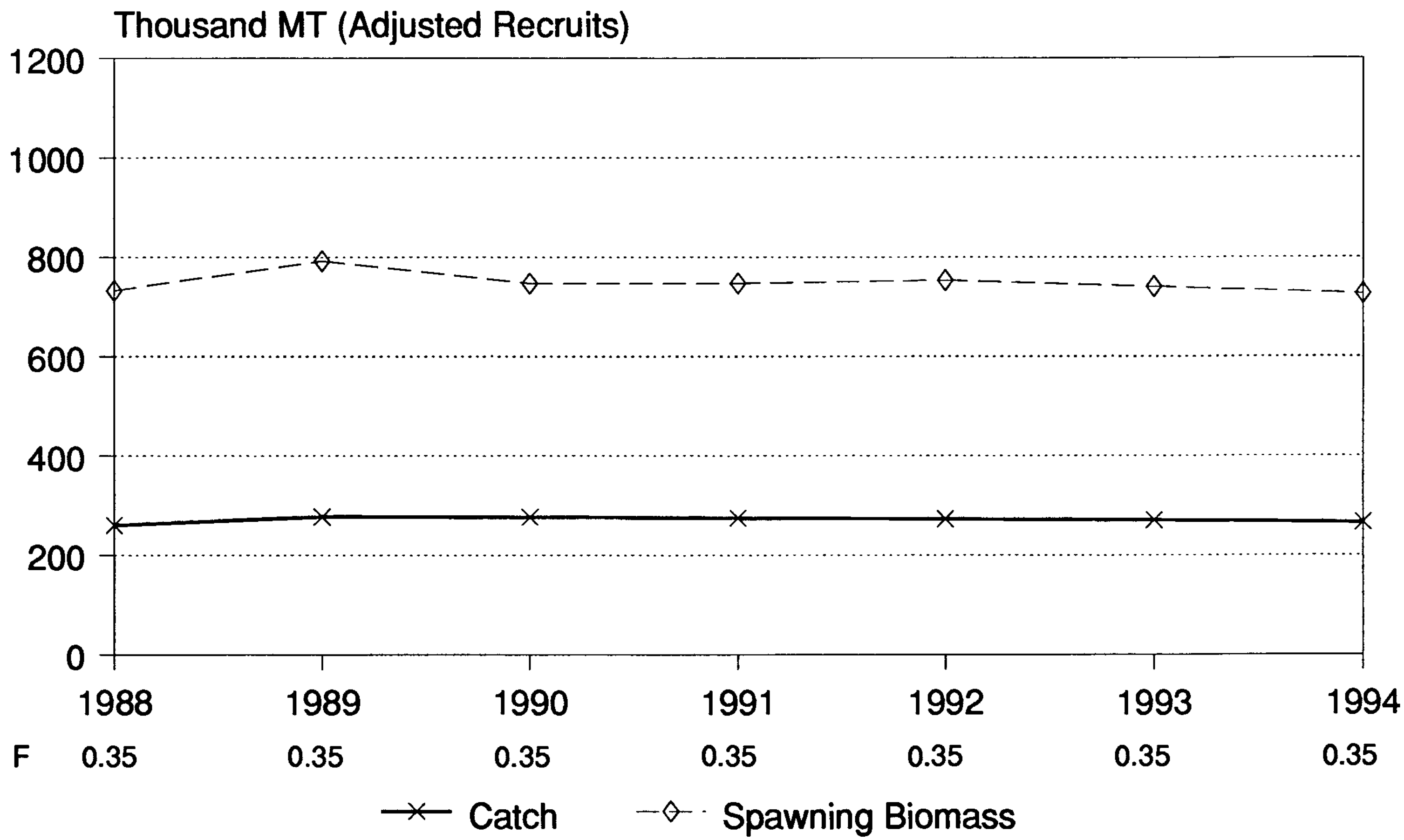


FIGURE 24: OPTION A2--ESTIMATED CATCH & SPAWNING BIOMASS FOR COD IN NAFO DIVISIONS 2J, 3K, AND 3L

F=0.45 in 1988-1994.

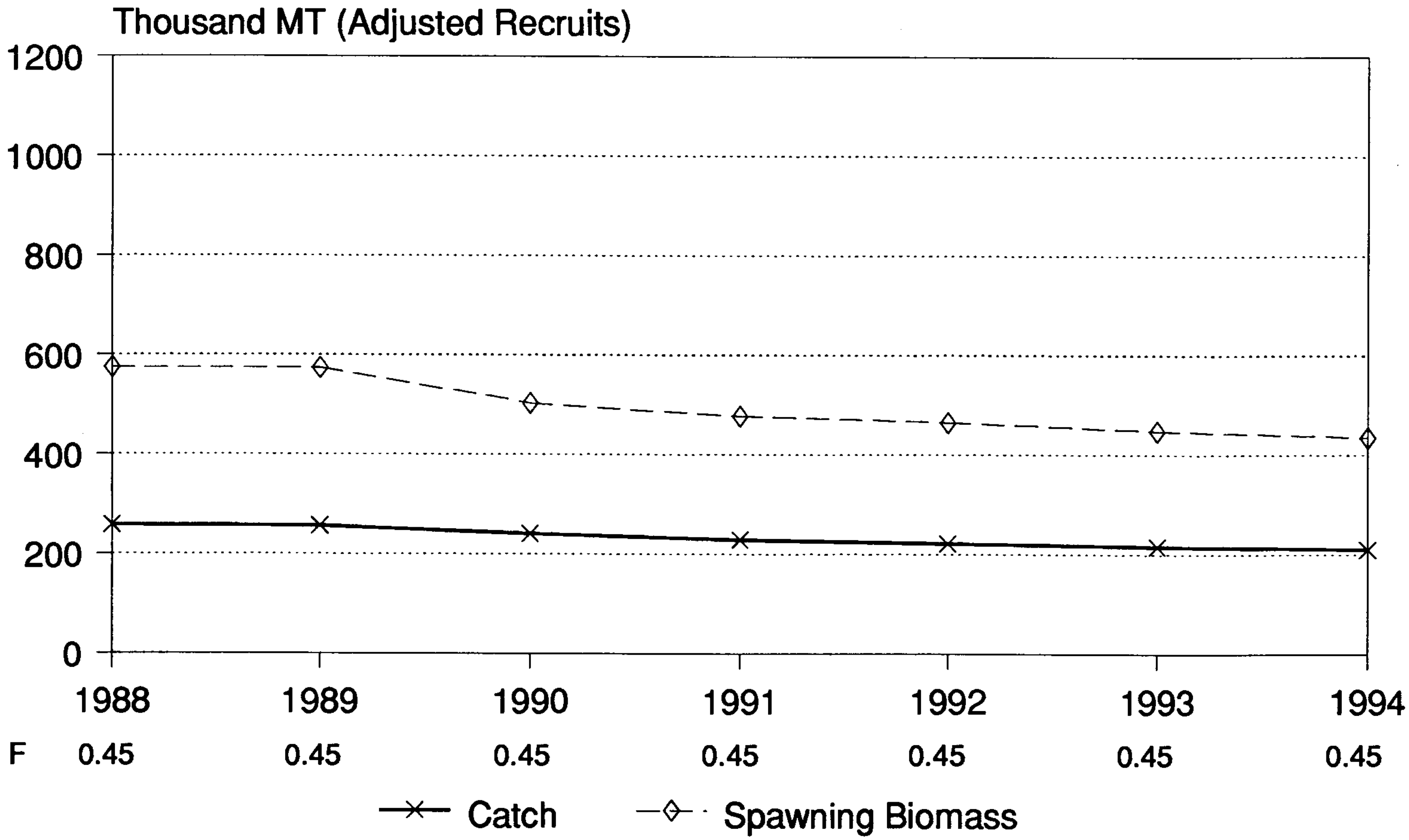


FIGURE 25: OPTION A3--ESTIMATED CATCH & SPAWNING BIOMASS FOR COD IN NAFO DIVISIONS 2J, 3K, AND 3L

F=0.55 in 1988-1994.

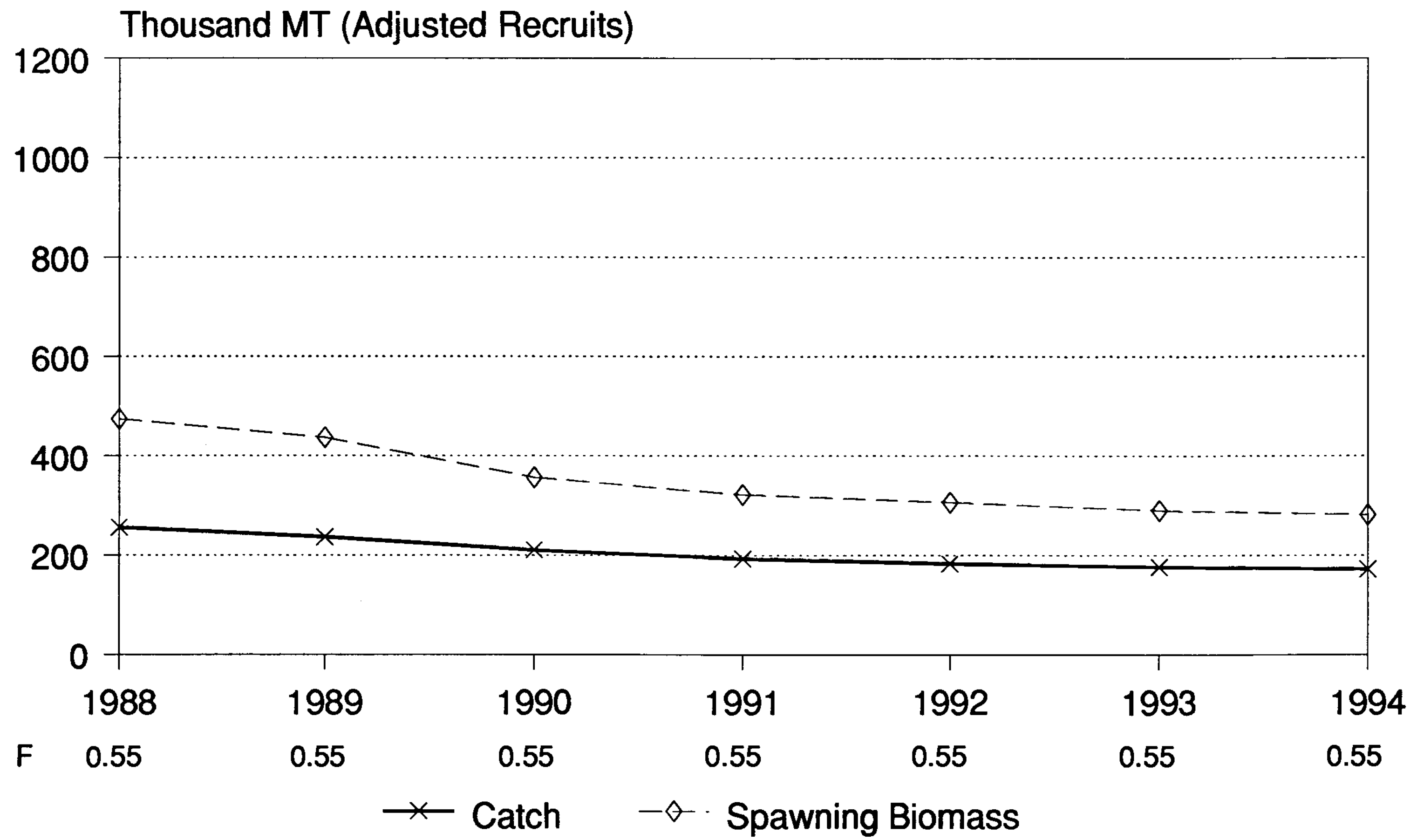


FIGURE 26: OPTION B1--ESTIMATED CATCH & SPAWNING BIOMASS FOR COD IN NAFO DIVISIONS 2J, 3K, AND 3L

F=0.35 in 1988, 0.235 in 1989, and 0.20 in 1990-1994.

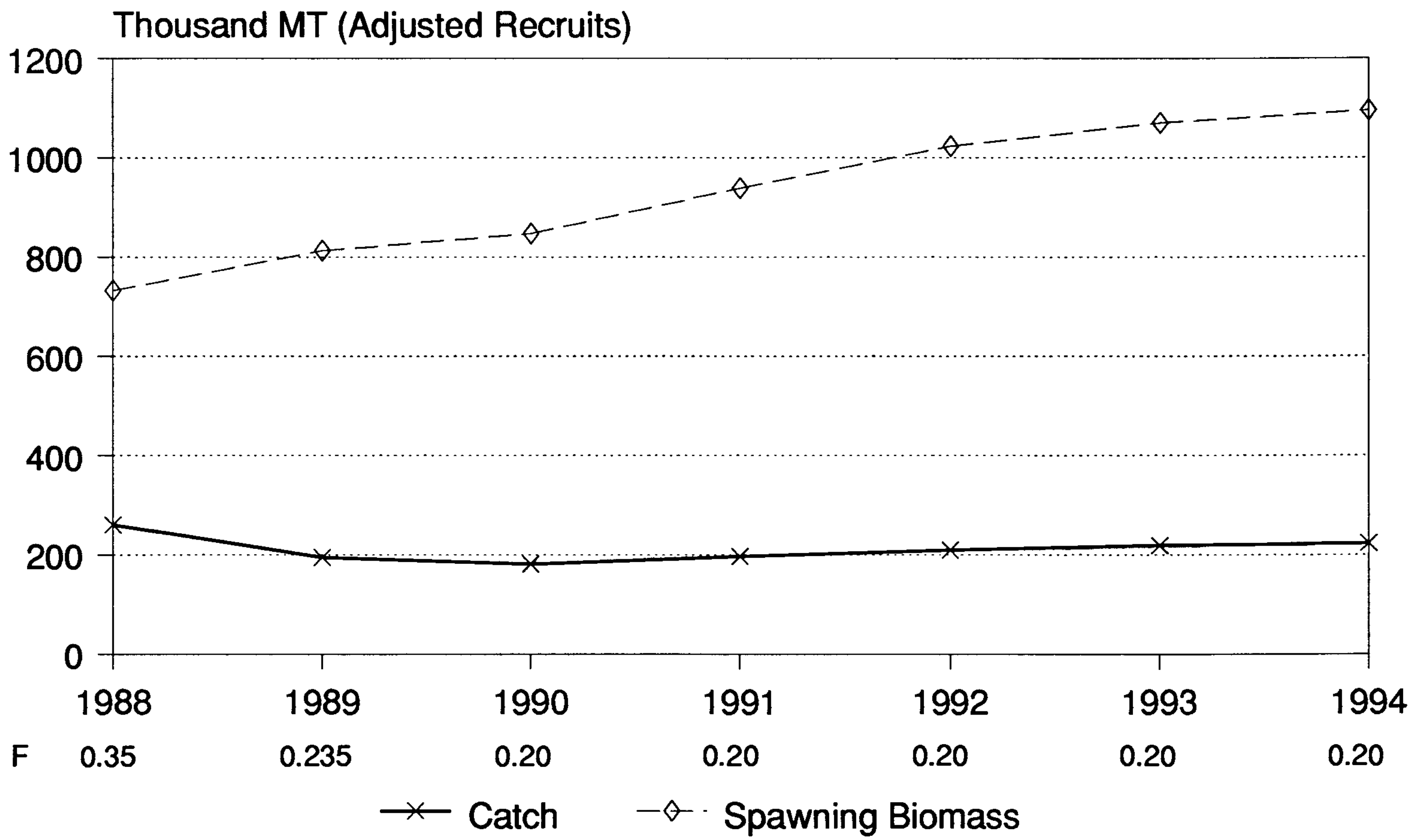


FIGURE 27: OPTION B2--ESTIMATED CATCH & SPAWNING BIOMASS FOR COD IN NAFO DIVISIONS 2J, 3K, AND 3L

F=0.45 in 1988, 0.32 in 1989, 0.26 in 1990, 0.23 in 1991, and 0.20 in 1992-1994.

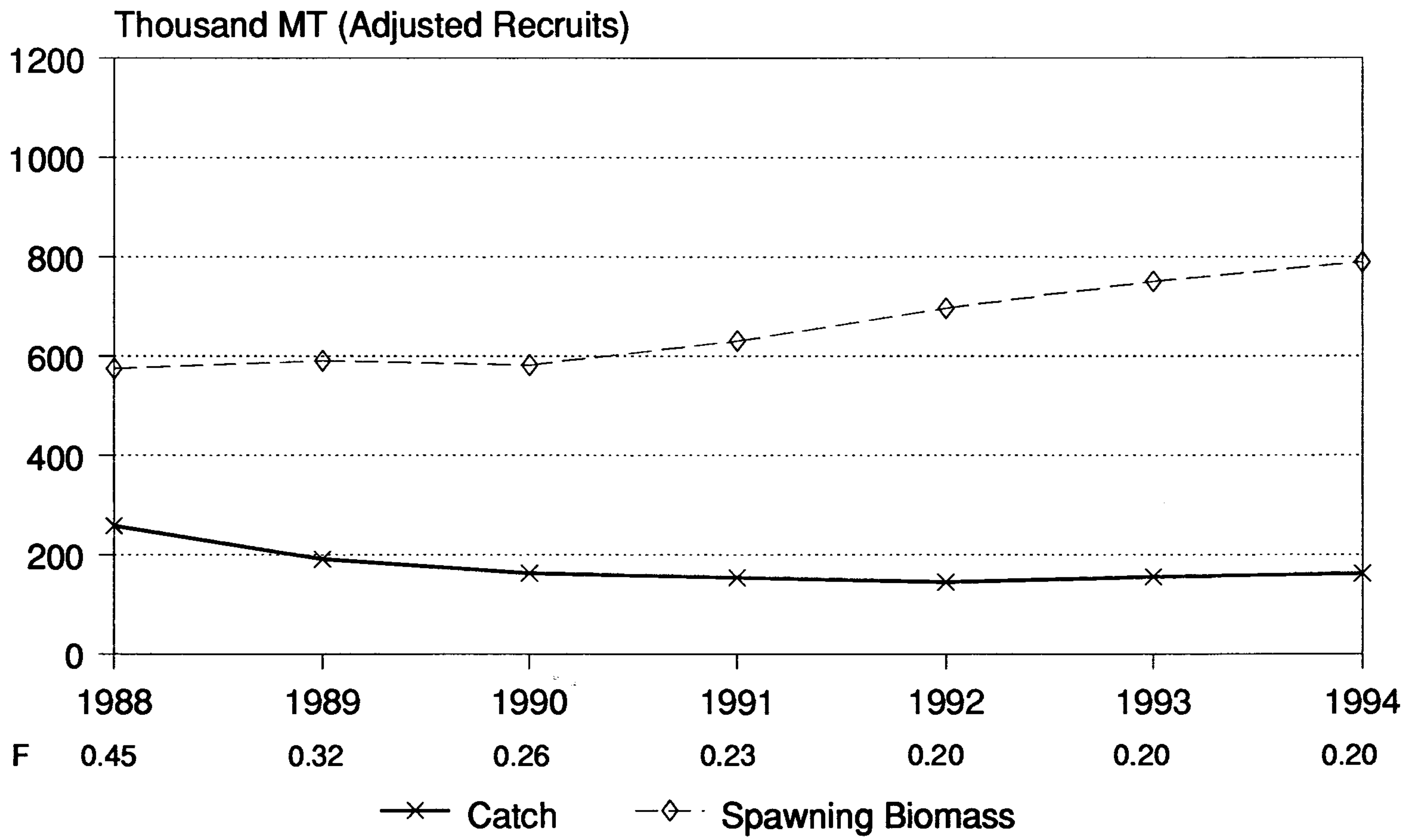


FIGURE 28: OPTION B3--ESTIMATED CATCH & SPAWNING BIOMASS FOR COD IN NAFO DIVISIONS 2J, 3K, AND 3L

F=0.55 in 1988, 0.415 in 1989, 0.32 in 1990, 0.26 in 1991,0.23 in 1992, and 0.20 in 1993 and 1994.

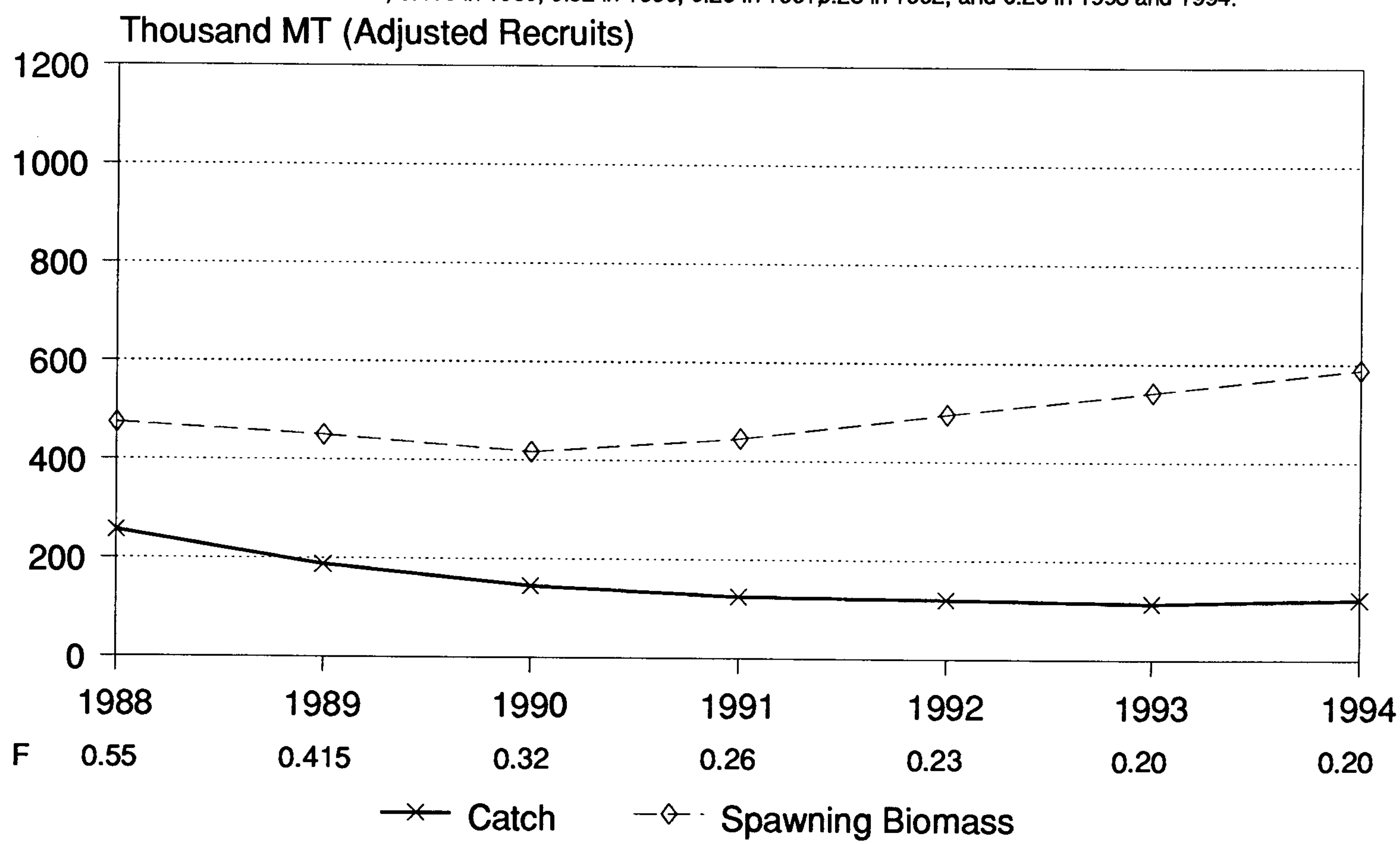


FIGURE 29: OPTION C1--ESTIMATED CATCH & SPAWNING BIOMASS FOR COD IN NAFO DIVISIONS 2J, 3K, AND 3L

F=0.35 in 1988 and 0.235 in 1989-1994.

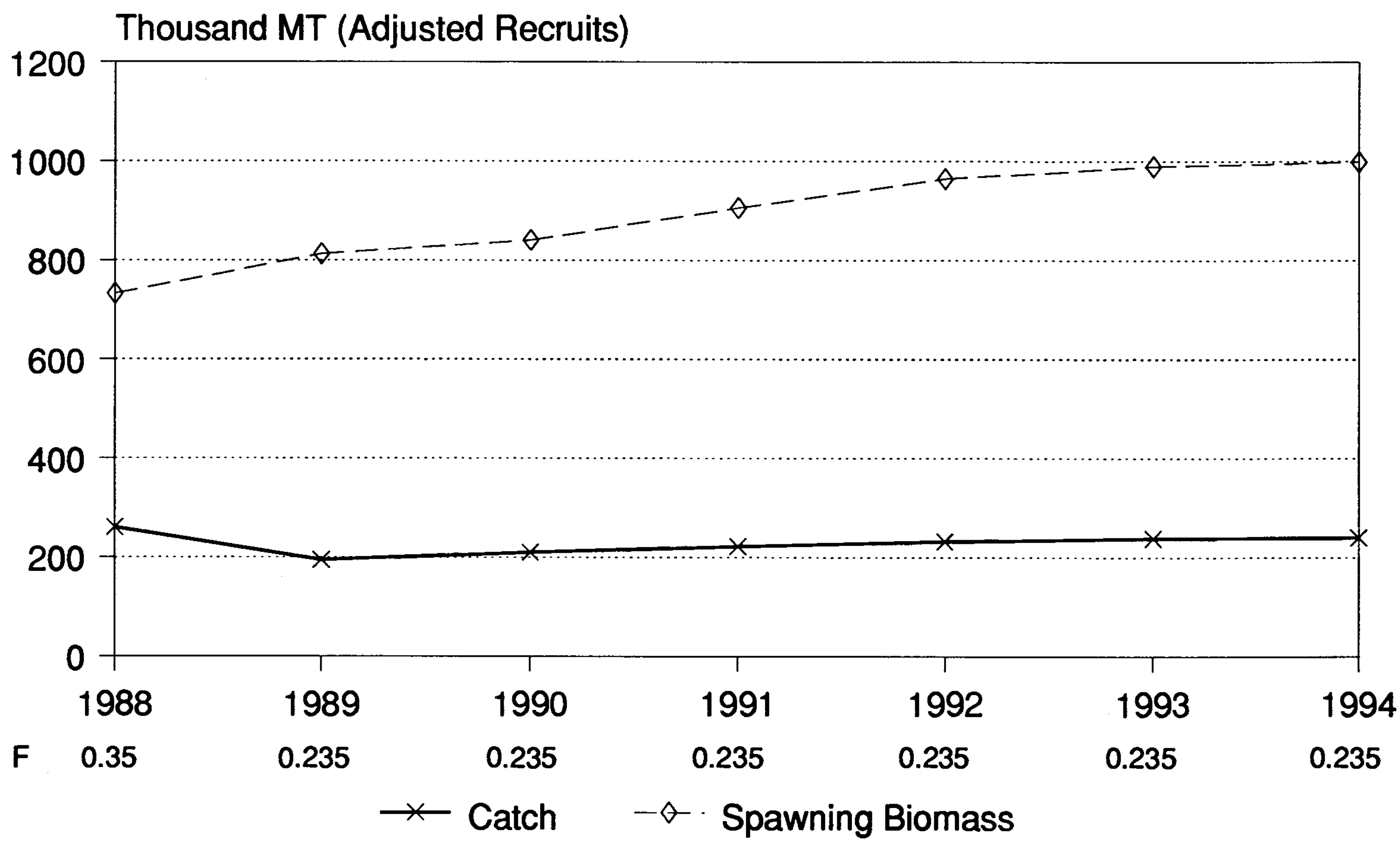


FIGURE 30: OPTION C2--ESTIMATED CATCH & SPAWNING BIOMASS FOR COD IN NAFO DIVISIONS 2J, 3K, AND 3L

F=0.45 in 1988 and 0.32 in 1989-1994.

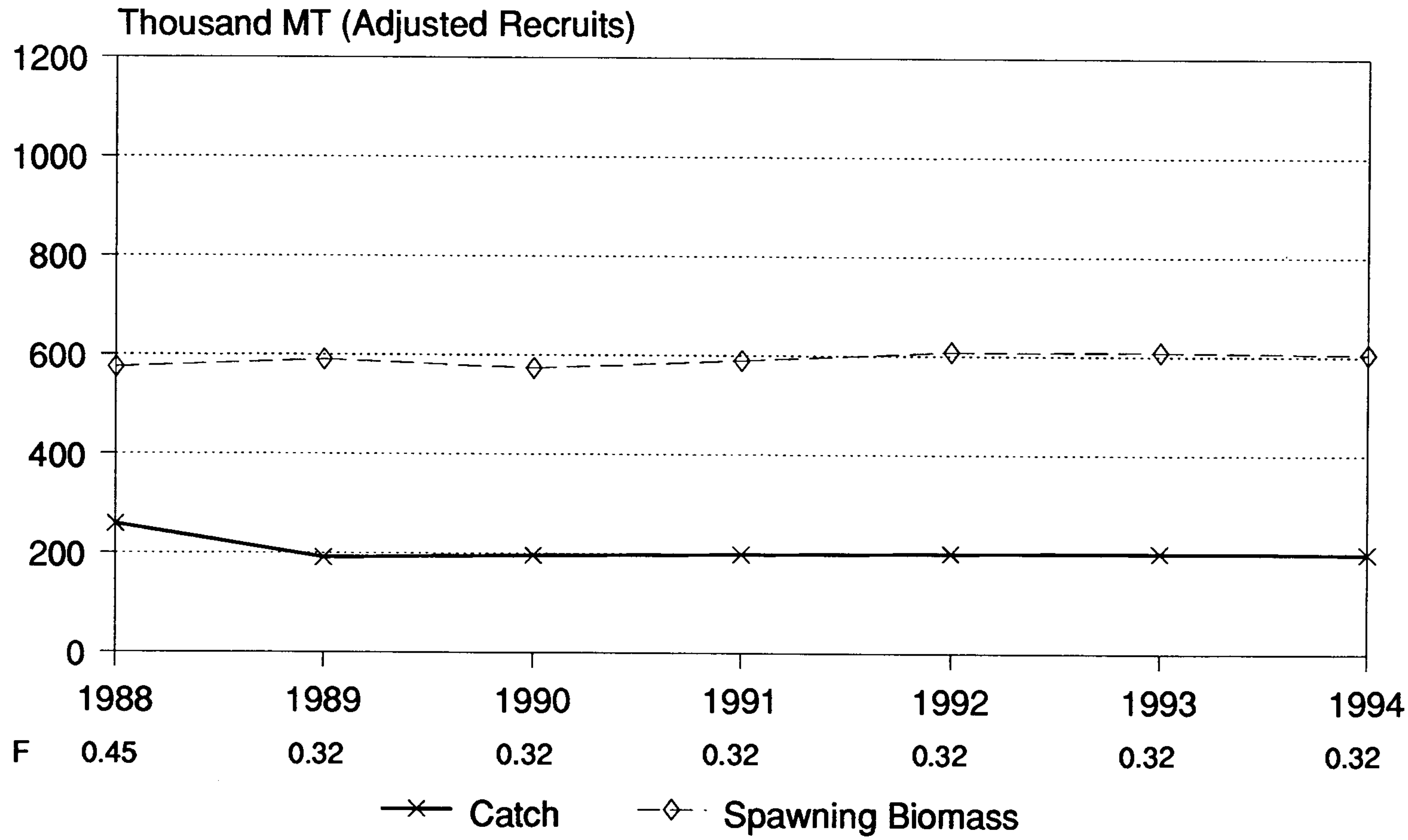


FIGURE 31: OPTION C3--ESTIMATED CATCH & SPAWNING BIOMASS FOR COD IN NAFO DIVISIONS 2J, 3K, AND 3L

F=0.55 in 1988 and 0.415 in 1989-1994.

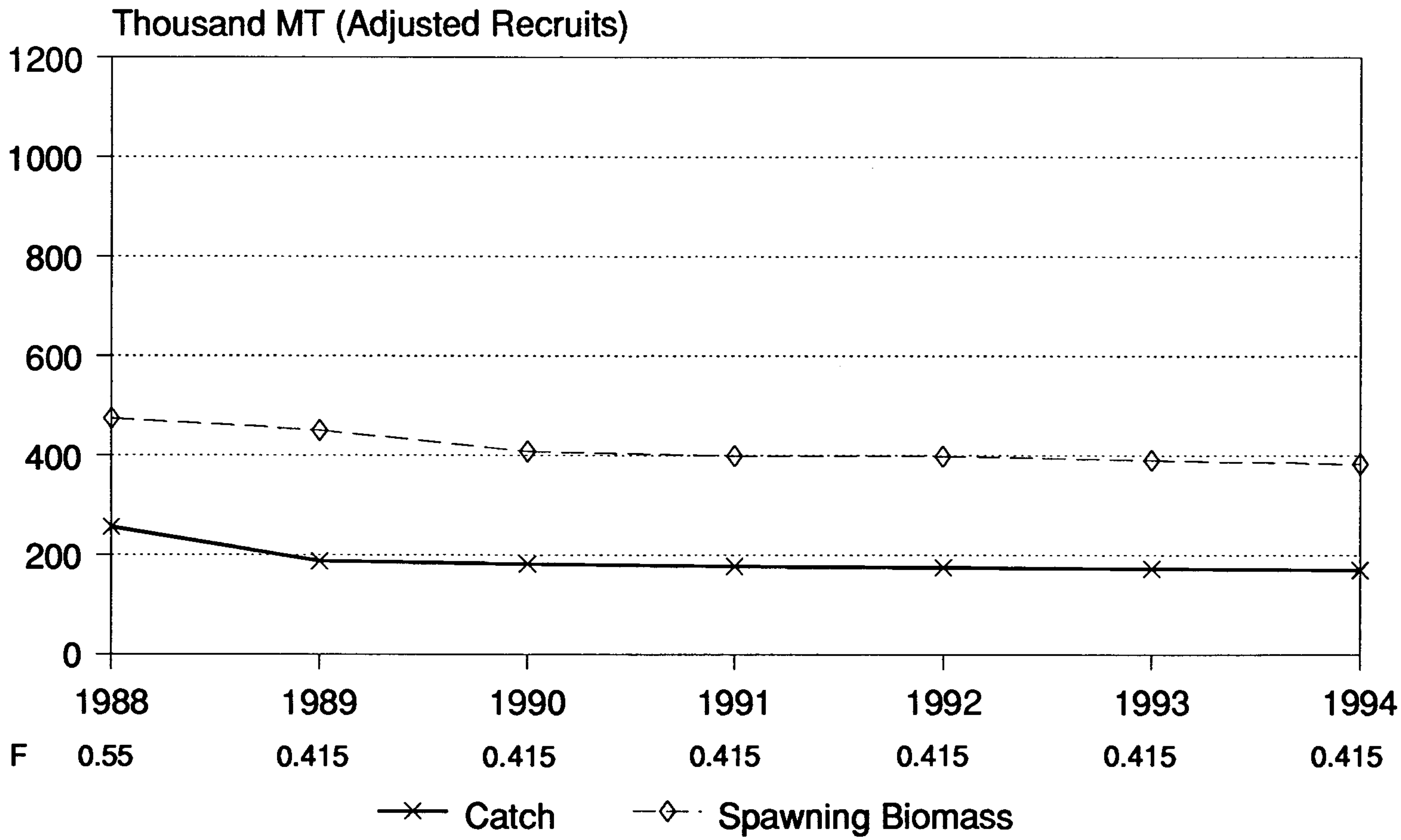


FIGURE 32: OPTION D1--ESTIMATED CATCH & SPAWNING BIOMASS FOR COD IN NAFO DIVISION 2J, 3K, AND 3L

F=0.35 in 1988, 0.245 in 1989, 0.225 in 1990, 0.21 in 1991, 0.195 in 1992, 0.185 in 1993, 0.18 in 1994.

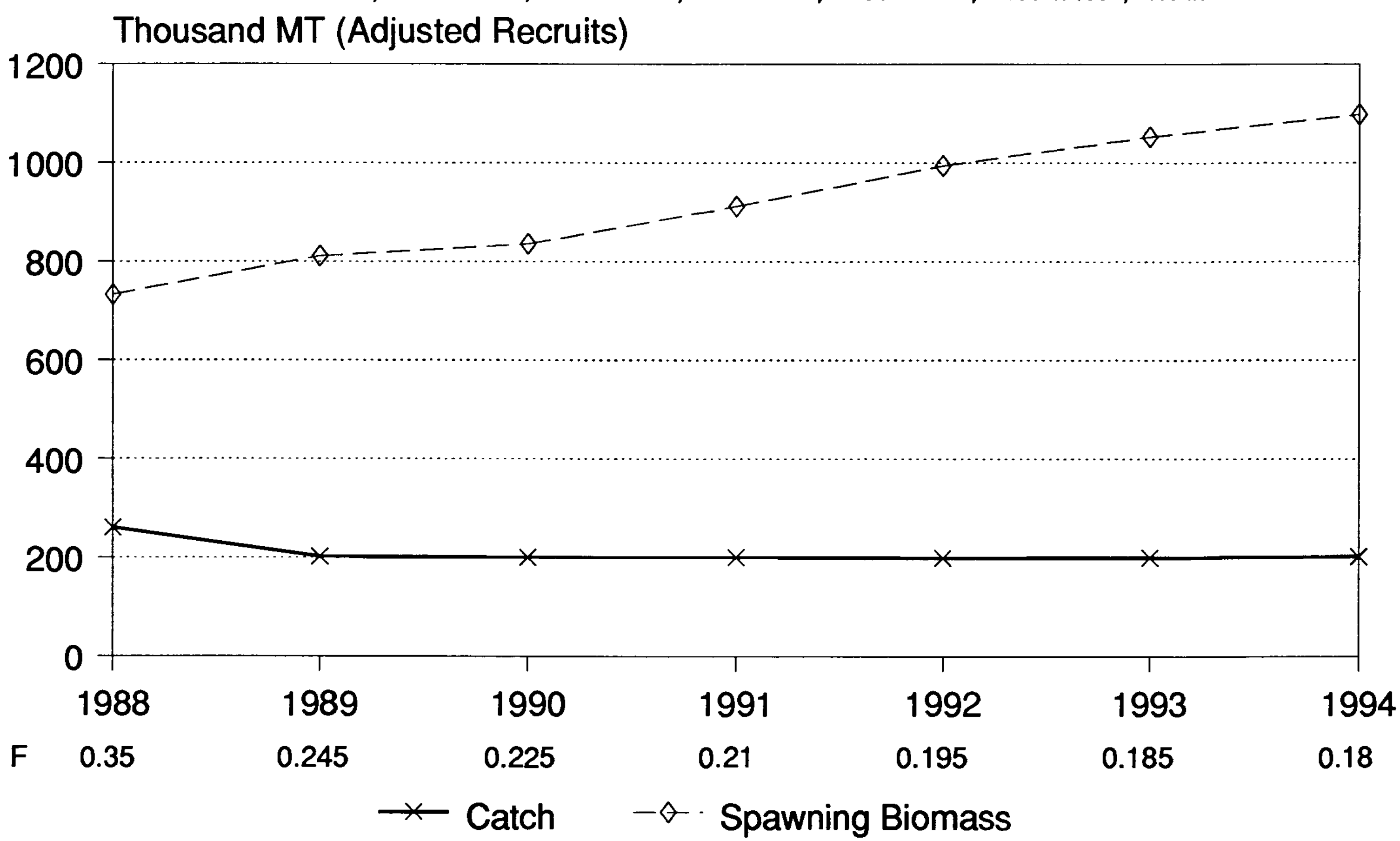


FIGURE 33: OPTION D2--ESTIMATED CATCH & SPAWNING BIOMASS FOR COD IN NAFO DIVISIONS 2J, 3K, AND 3L

F=0.45 in 1988, 0.34 in 1989, 0.335 in 1990, 0.33 in 1991,and 0.32 in 1992-1994.

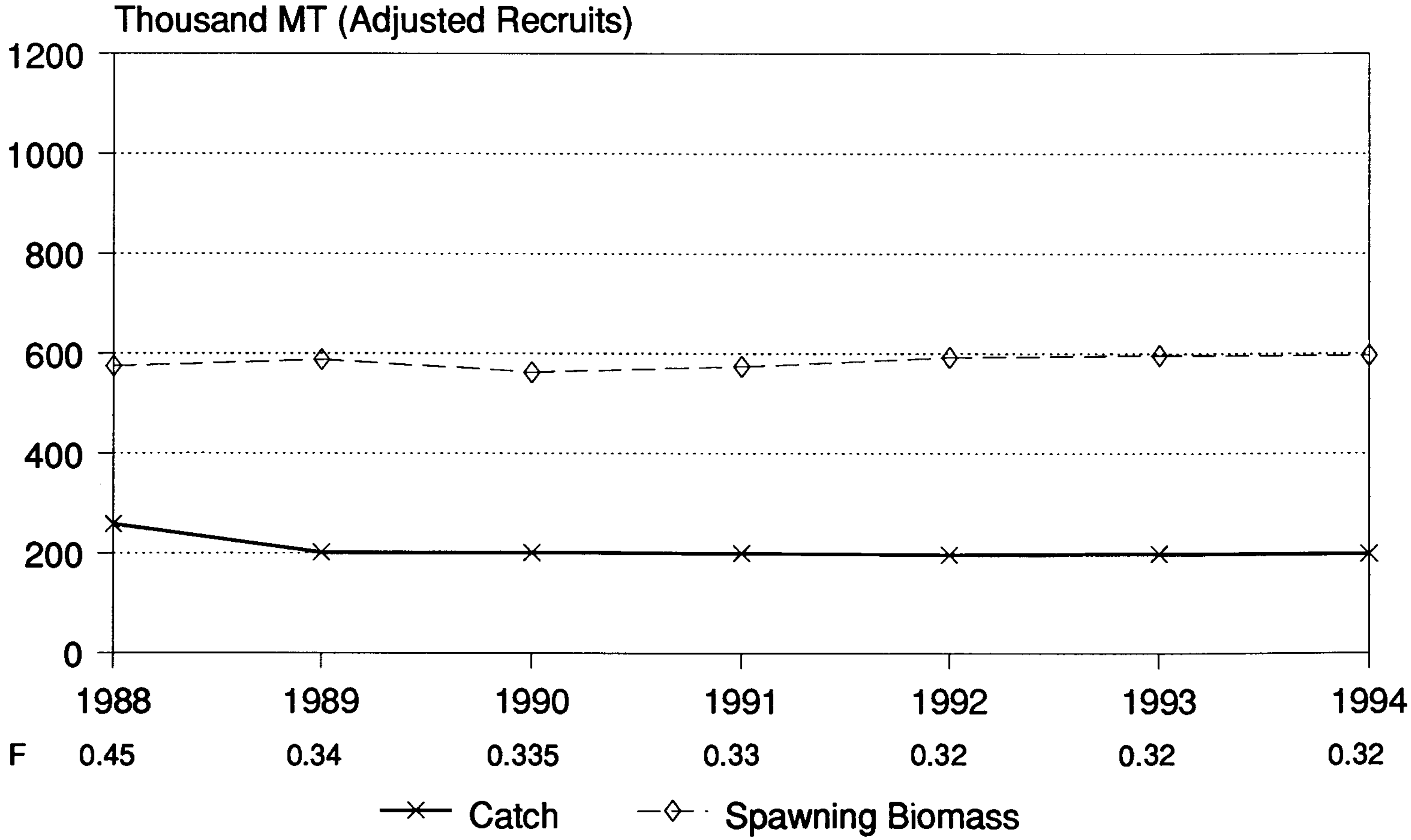
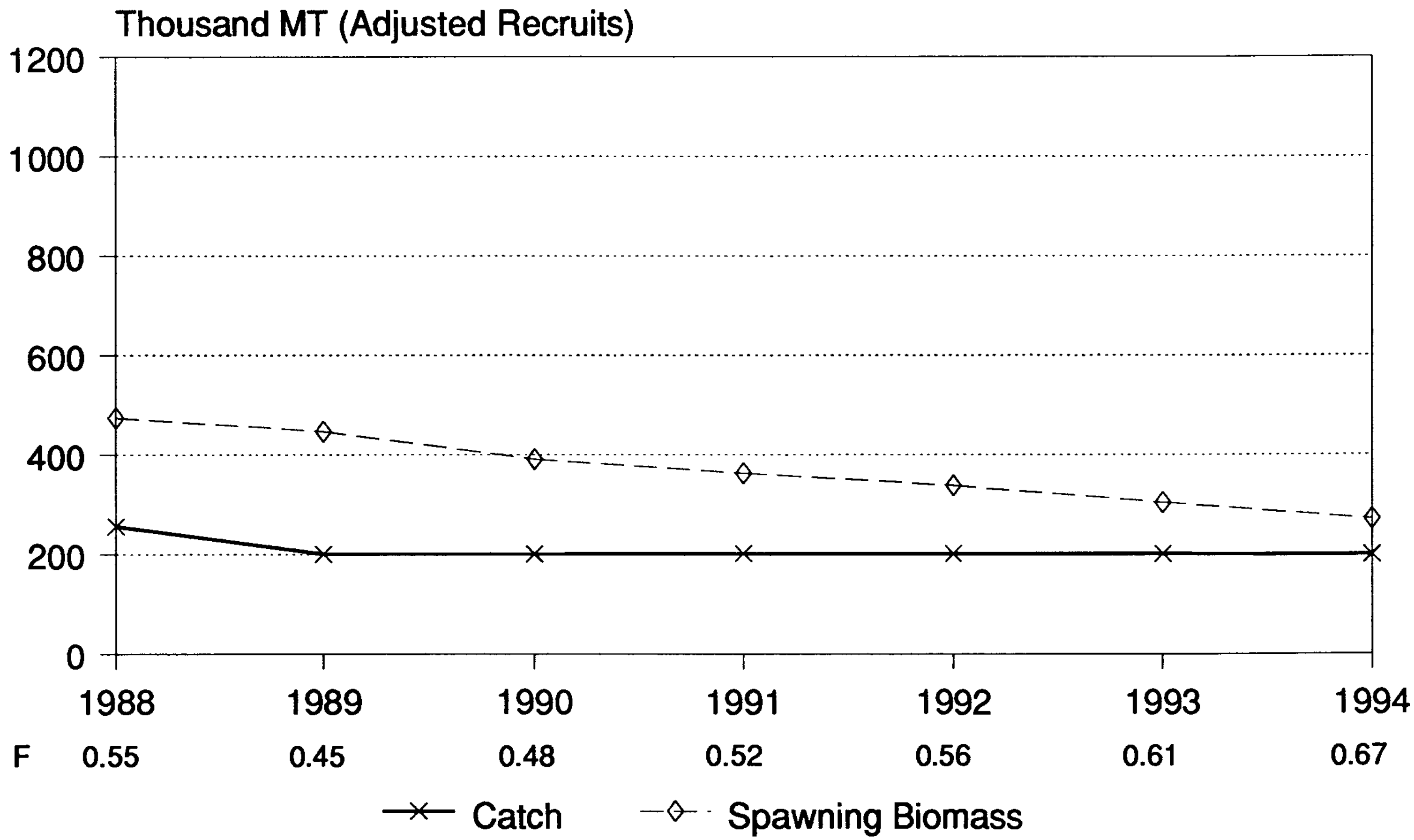


FIGURE 34: OPTION D3--ESTIMATED CATCH & SPAWNING BIOMASS FOR COD IN NAFO DIVISIONS 2J, 3K, AND 3L

F=0.55 in 1988, 0.45 in 1989, 0.48 in 1990, 0.52 in 1991, 0.56 in 1992, 0.61 in 1993, 0.67 in 1994.



requirement that domestic trawlers take some portion of the TAC in competition with foreign vessels on the "Nose" and "Tail" of the Bank.

Furthermore, the rate of growth of the spawning stock may be enhanced by appropriate distribution of the catch among age groups in order that the best combination of economic yield with biological growth may be attained. The Panel urges DFO scientists to pursue this goal with the utmost vigour. Furthermore, because the Panel is uncertain of the effects upon mating behaviour and spawning success of intense fishing during the spawning season, it proposes that there be a limit upon mortalities imposed during the spawning period proportionally with the general reduction in total fishing mortality. Whether this can best be achieved through a straight reduction in the winter catch (i.e. during the spawning period) or through a combination of seasonal closure coupled with a catch reduction proportional to the reduction of the TAC during the remainder of the spawning period is a matter that DFO should explore at the earliest possible date with affected sectors of the fishing industry. Nevertheless, in determining the most effective means of implementing such a policy, consideration should be given to the size of the various spawning aggregations and reduction in effort in respect of those aggregations should be proportional to their size.

In the end, though, we can but reiterate the central theme of this report. The conservation of the northern cod stock(s) and their management as an infinitely renewable resource is a matter of the most vital interest to the coastal communities of Atlantic Canada who have traditionally depended upon them and whose future well-being is inextricably tied to their vitality. Furthermore, it is the constitutional responsibility of the Government of Canada to ensure the survival of the stocks and to provide for their proper management and for their protection. For reasons that have been advanced elsewhere in this report, the management of the resource since 1977 has been less effective than is desirable. In consequence, though stocks did grow significantly in years immediately following the establishment of the Canadian economic zone, that pattern of growth has now been reversed and stocks are in decline. In the meantime, heavy capital investment in boats and gear and in processing facilities have placed heavier demands upon the stocks than they can currently bear. At the same time, the development of scientific understanding of the ecosystem has lagged behind our technological capacities to seek, to find and to kill. Nor have we been altogether successful in enunciating clear management objectives that recognize both the biological imperatives and the socio-economic requirements of the coastal community. This combination of circumstances has precipitated not only a crisis in respect of the continued health of the fish stocks but also in respect of the level of confidence that must be reposed in our scientists, our managers, and our political systems.

In this context, the time is ripe for a fresh start. Confidence must be restored: confidence in science which must remain the only sound basis for good advice; confidence in the political process which must establish social and economic objectives concomitant with scientific realities; and, confidence in the managers who direct the scientific programmes and implement proper functional strategies designed to achieve clearly established objectives.

But over and above all, we must exhibit both the will and the capacity to create conditions that will permit and encourage recovery of cod populations. This is not an impossible task though it is one that must entail some degree of hardship; for there is no alternative to a reduction of fishing mortality as the only prescription that will achieve growth of the spawning stock. Furthermore, it must entail a realistic assessment of the level to which the stock(s) can be rebuilt and of the sustainable yield that can be harvested. This in turn implies a realistic assessment of the numbers of fishermen and of fish processors who can be supported by the sustainable harvest and of the amount of capital investment that can be economically justified. We leave as an open question and one that demands a political answer the issue of whether the fishing should become the preserve of professional fishermen and plant workers, all of whom can earn from it an adequate living; or whether it should continue as at present a social relief mechanism, offering some measure of gainful employment and hence of dignity to a large number of participants most of whom will continue to require income supplementation.

We do not envy the politicians who must make such difficult choices. We do, however, insist that such choices must be made and that appropriate objectives must be clearly established. We also insist, that quite apart from social and economic concerns which understandably assume a dominant role, the Government of Canada has the unequivocal obligation of conserving one of the great living natural resources of the nation.

CHAPTER X

Recommendations

Management Actions

1. That the Panel strongly recommends that in respect of the northern cod stock(s) and as a matter of urgency there should be an immediate reduction of fishing mortality to the level of at least 0.3 and, at the earliest feasible date, to the level of 0.2.

2. That DFO must establish regulations to limit fishing mortalities imposed during the spawning period proportionally with the general reduction in total fishing mortality and should explore with the affected sectors of the fishing industry whether this objective can be best achieved through a straight reduction in the winter catch (i.e. during the spawning period) or through a combination of seasonal closure coupled with a catch reduction proportional to the reduction of the TAC during the remainder of the spawning period.

3. That DFO should for both biological and economic reasons examine immediately the selectivity of traps, small and large trawlers, gillnetters and other gear types with the intent of improving the yield in cod fisheries; the goal should be to eliminate harvest of two, three, four and five year olds and to reduce the bycatch of these year classes.

4. That DFO should reexamine current regulations requiring equal levels of effort in each of statistical divisions 2J, 3K and 3L with the objective of distributing fishing effort by large trawlers throughout the statistical divisions in the manner that is to the greatest degree possible relative to the distribution of the exploitable biomass.

International Issues

5. That Canada should seek international agreement to permit its management of all fish stocks indigenous to the Canadian Continental Shelf, and that extend beyond the two hundred mile economic zone; and, that failing achievement of this objective, Canada should take unilateral action to acquire management rights in accordance with provisions of the Law of the Sea Convention.

6. That the Government of Canada should reexamine its policies regarding the authorization of foreign fisheries within the Canadian economic management zone with the clear intention of eliminating any catch or bycatch of cod.

7. That Canada officially adopt a policy analogous to the Hague Preferences that would take into account in respect of stock allocations both the principle of contiguity and the "vital needs" of particular communities particularly dependent upon fishing and industries allied thereto.

Scientific Research

8. That DFO should develop means to estimate stock or relative stock trends beyond current RV and large trawler CPUE data and should place particular emphasis on establishing a CPUE index for elements of the inshore fishery, e.g. small trawlers, gillnetters, etc.

9. That DFO should expand scientific efforts to understand the integrity and interrelationship of spawning aggregations as they relate to recruitment and the distribution of spawning fish to feeding grounds and their availability to inshore fisheries. The goal should be to attain a clearer understanding of the effectiveness of current area management strategies as they relate to rebuilding the spawning stocks and potential gear/area or other allocational goals.

10. That DFO should examine in detail current and past stock recruitment relationships.

11. That DFO should undertake an in-depth analysis of cod bycatch losses in inshore and offshore target fisheries, as well as in other fisheries taking cod as a bycatch, including fish caught and not sold because of quality and/or operational problems; and estimate bycatch losses for each component of the Canadian and foreign directed cod fisheries, shrimp, capelin, and herring fisheries, and ground fisheries not targeting on cod.

12. That DFO should increase the RV sampling level in order to improve the level of precision of the estimate of minimum stock size and should, also, give consideration to RV surveys during other times of the year.

13. That DFO arrange, as a matter of urgency, for a harp and hooded seal census commencing with an aerial survey of pup production in the spring of 1990.

14. That DFO scientists should pay greater attention to the integration of information from the biological and oceanographic disciplines into the assessment process so that all available data may be employed to reduce the risk of future errors in estimating key population parameters.

15. That research be undertaken or commissioned to establish seal feeding patterns and consumption rates throughout the year.

16. That every reasonable effort be made to understand the cod-capelin-seal interactions and to incorporate appropriate data into cod population assessments.

17. That DFO should expand data collections to improve the knowledge of effort levels and factors influencing quality of data on inshore fisheries and landing records.

Technology

18. That DFO institute a dedicated systematic effort to improve and expand relevant technologies in the annual assessment process and in management activities; and that the Government of Canada investigate the use of satellite or other advanced technologies for purposes of surveillance; and that arrangements be imposed or negotiated as appropriate for fitting all vessels involved in the Canadian shelf fisheries with transducers for ease of monitoring their movements and location.

Goals

19. That the Government of Canada should carefully reexamine its biological, ecological, and socio-economic goals in respect of the fisheries to ensure that they are clearly defined, internally consistent, and attainable.

Institutional Arrangements and Procedures

20. That DFO review its management structures and approaches with the end of establishing a more focused and coordinated approach to the management of the northern cod stocks.

21. That DFO should expand the observer programme to include observation on the inshore sector of the fleet and to expand support services for analyzing observer data.

22. That the Government of Canada undertake the provision of additional patrol vessels for offshore surveillance to provide adequate on-site action in respect of violations reported by aircraft or by observers; and that helicopters be employed in conjunction with smaller patrol boats for inshore surveillance.

23. That the Government of Canada and the Government of Newfoundland and Labrador should jointly establish a Board or Commission in the context of which information can be shared, management objectives clarified and coordinated, policy directions set, and strategies developed.

24. That the Government of Canada should urge the appropriate authorities to treat violations of fisheries regulations aimed at conservation as serious offenses and to ensure that penalties imposed upon convicted violaters be sufficiently onerous as to fully offset any potential gain from violations.

25. That DFO should develop an educational programme and improve lines of communication through which appropriate information concerning the scientific process and management decisions may be communicated more effectively to client groups.

26. That DFO should establish a process for the regular reappraisal of various research activities and their potential contribution to the overall scientific understanding of the population dynamics, behaviour, life history, and ecological relationships of the northern cod stocks.

27. That DFO should ensure that when enterprise allocations are made, adequate surveillance must be maintained to guarantee accurate reporting of catches.

28. That DFO should review the process and methods by which scientific advice is developed within the Research Centre to ensure that the spectrum of scientific disciplines and skills available and applicable to state-of-stock analysis and interpretations are being utilized.

29. That DFO should resolve the ambiguities involved in the current designations of inshore and offshore and provide for the proper evaluation of the impact of various management strategies upon different harvesting areas and sectors of the industry by

(a) categorizing fishermen in terms of gear types employed;

(b) identifying catches taken by various elements of the fishing fleets by coding in terms of areas or subareas of capture.

Appendix A

Public Hearings:

Clarenville, June 21, 1989

Marystown, June 22, 1989

Gander, June 23, 1989

St. Anthony, June 24, 1989

Makkovik, September 25, 1989

Cartwright, September 26, 1989

Port Hope Simpson, September 26, 1989

La Scie, September 27, 1989

Twillingate, September 28, 1989

Fogo, September 29, 1989

Bonavista, September 30, 1989

Halifax, October 2, 1989

St. John's, October 3 and 4, 1989

Presentations to the Panel (Oral and Written)

Clarenville

June 21, 1989:

Mr. Earl Johnson
Chairman, Inshore Fishermen's Improvement Committee of Placentia, Bonavista and Trinity Bays

Dr. D.H. Steele
Biologist

Mr. Colin Cheater
Mayor, Town of Trepassey

Mr. Cabot Martin
President, Newfoundland Inshore Fisherman's Association

Mr. Keith Halleran
Trawlerman and Union Representation, Trepassey

Mr. Basis Croscup
Trepassey

Marystown

June 22, 1989:

Mr. Bernard Dooley
Deep Sea Trawlerman

Mr. Rex Matthews
Mayor, Town of Grand Bank

Mr. Ches Cribb
Vice-President, Deep Sea Sector, FFAW

Mr. Bernard Adams
Inshore Fisherman

Captain Bill Kelfoil
Fishery Products International Ltd.

Mr. Jerome Walsh
Mayor, Town of Marystown

Mr. Guy Hackett
Trawlerman, National Sea Products Ltd.

Mr. J.L. Edwards
Fisherman's Committee, Lawn

Mr. Cabot Martin
President, Newfoundland Inshore Fisherman's Association

Mr. Roger Simmons,
Member of Parliament, Burin-St. George's

Gander

June 23, 1989:

Mr. Calvin Buglar
Mayor, Town of Harbour Breton

Mr. John Windsor
Town Council, Gaultois

Mr. George Baker
Member of Parliament, Gander-Grand Falls

Mr. Wilfred Bartlett
Fishermen's Committee, Brighton, Green Bay

St. Anthony

June 24, 1989:

Mr. Trevor Taylor
2nd Vice-President, White Bay North Development Association

Ms. Maisie Groves
Co-ordinator, Southern Labrador Development Association

Mr. Charles Reardon
Plant Worker and Member, FFAW

Mr. Patrick J. Cabot
President, Newfoundland and Labrador Fixed Gear Fishermen's Association

Mr. Pierce Cull
Inshore Fisherman, St. Anthony Bight

Mr. Ray Elliott
Inshore Fisherman, St. Anthony

Dr. Peter Roberts
St. Anthony

Mr. Ralph Carrol
Director, White Bay Central Development Association

Mr. Samuel Caines and Ms. Janet Butt
On behalf of Inshore Fixed Gear Fishermen Trout River - Hawkes Bay

Makkovik

September 25, 1989:

Mr. Toby Andersen
Land Claims Director, Labrador Inuit Association

Ms. Kate Mitchell
Torngat Fish Co-op

Mr. Rupert McNeil
Chairman, Fishermen's Committee, Makkovik

Mr. William Andersen Sr.

Mr. Bert Winters

Mr. Ted Watkins

Mr. Wilfred Bartlett

Mr. Chesley Andersen

Mr. Ted Watkins

Cartwright

September 26, 1989:

Ms. Jessie Bird
Mayor, Cartwright Community Council

Mr. Mercer Davis
Senior Fisherman

Mr. Larry Parsons

Mr. John Martin
Fisherman

Ms. Patti Way
Fisherman's Wife

Mr. Max Mullins
Mr. Cylar Dyson
Gillnet Fisherman

Ms. Joanne Martin
Member, Cartwright Community Council

Mr. Bart Higgins

J.W. Hiscock Ltd.

Port Hope Simpson

September 26, 1989:

Mr. Danny Dumaresque
M.H.A. Eagle River

Mr. Don Simpson
Mayor, Port Hope Simpson

Mr. Roy Mangrove
Fisherman, St. Lewis

Mr. Earl Parr

Mr. Lloyd Hicks

Mr. Angus Moss

La Scie

September 27, 1989:

Mr. Job Halfyard
Fisheries Action Committee

Twillingate

September 28, 1989:

Mr. John Noel
Chairman, Regional Fisheries Committee

Mr. Cyril Dalley
Inshore Council, FFAW

Mr. Cabot Martin
President, Newfoundland Inshore Fisherman's Association

Mr. Michael Dwyer
Former River Guardian

Mr. Anstay
Fishermen's Committee

Mr. Winston Jennings
Co-ordinator, Twillingate - New World Island Development Association

Fogo

September 29, 1989:

Mr. Aubrey Cull
Fogo Island Co-op

Mr. Perry Collins
Fisherman

Mr. Peter Kane
Fogo Island Co-op

Mr. Gordon Waterman
Fishermen's Committee

Mr. Dorman Brown

Bonavista

September 30, 1989:

Dr. Chris Randell
Mr. Douglas Whiffen

Mr. Aubrey Gover
M.H.A., Bonavista South

Mr. John Rendell

Halifax

October 2, 1989:

Mr. Murray Coolican
Vice-President, Government Relations,
National Sea Products Ltd.

Mr. Owen Myers
Fisheries Information Services

St. John's

October 3, 1989:

Mr. Paul Moriarty
Mayor, Town of Harbour Grace

Mr. Victor L. Young
Chairman and Chief Executive Officer,
Fishery Products International Ltd.

Mr. John Robinson
NewPro Limited

Mr. Murray Coolican
Vice-President, Government Relations,
National Sea Products Ltd.

Trawler Captains
Fishery Products International Ltd.

St. John's

October 4, 1989:

Mr. Richard Cashin
President, Fishermen, Food and Allied Workers Union

Mr. Frank Chopin
Director of Fishing Technology,
Institute of Fisheries and Marine Technology

Mr. Shane Mahoney
Biologist

Mr. Tom Best
Petty Harbour Fishermen's Producers Co-operative Limited

Dr. D.H. Steele
Biologist

Mr. George Chafe
Inshore Fisherman

Mr. Charles Roberts
Longliner Operator

Mr. W.R. Moyse
President, Canadian Saltfish Corporation

Other Submissions to the Panel

February 20, 1989
Mr. Bernhard Nygaard
Carino Company Limited

March 20, 1989
Mr. H.M. Clarke
Executive Vice President, Harvesting and Marketing
Fishery Products International Limited

May 4, 1989
Mr. Murray Coolican
Vice-President Government Relations
National Sea Products Limited

June 8, 1989
Mr. David Connolly
Springdale

June 12, 1989
Mr. James E. McVicka
St. John's

October 4, 1989
Mr. Fred G. Earle
Earle Brothers Fisheries Ltd.

October 11, 1989
P.J. Murray
Portugal Cove

October 13, 1989
Independent Fish Producers Association

October 20, 1989
Mr. Michael Earle
Seals/Fishery Interactions Coordinator
Greenpeace International

October 23, 1989
Mr. Harry G. Benson
President, Beothuk Data Systems Ltd.,
Seawatch Division

October 24, 1989
Mr. Victor L. Young
Chairman and Chief Executive Officer
Fishery Products International Ltd.

November 6, 1989
Mr. Walter Carter, M.H.A.
Minister of Fisheries
Government of Newfoundland and Labrador

November 20, 1989
Seafood Producers Association of Nova Scotia

November 29, 1989
Dr. W.A. Montevecchi and Dr. D. Renouf
Department of Psychology
Memorial University of Newfoundland

Glossary of Technical Terms

1. **Age Length.** The length of a fish at a known age.

2. **Age Weight.** The weight of a fish at a known age.

3. **Background Noise.** Variations in environmental or biological parameters which bring about unexpected or abnormal value in a parameter and hence mask cause-and-effect relationships.

4. **Biomass.** The weight of a stock, stock complex, or population.

5. **Bycatch.** A catch of undersized fish, a species prohibited for retention, or undesirable and unwanted.

6. **Catch Per Unit Effort (CPUE).** The weight of the fish removed by a definable fishing gear over a specified time period.

7. **Cohort.** A group of animals born during the same year and general time period which are the young of a stock, stock complex, or population.

8. **Cohort Analysis:** A simplified form of retrospective analysis (see VPA).

9. **Disaggregated Data.** Data that has been selected on the basis of areas, age, length, or other defined criteria.

10. **DNA Fingerprinting.** A mechanism of detecting genetic differences through analysis of the complex protein structures within deoxyribonucleic acid material present in living tissue.

11. **Exclusive Economic Zone - EEZ.** The zone extending two hundred miles seaward from the Canadian coastal baseline which is under the jurisdiction of Canada.

12. **Exploitable Biomass.** The size of the population susceptible to fishing which, for northern cod, normally excludes a decreasing proportion of the younger age groups, e.g. 3, 4, and 5 year olds which are not fully recruited to the fishery.

13. **Exploitation.** Removals from fishery.

14. $F_{0.1}$ As used in this paper constitutes an annual fishing mortality of about 20% of the exploitable biomass.

15. **Fishing Mortality.** The mortality imposed on a stock, stock complex or population as a result of fishing. The value may be expressed as annual rate or compound interest rate (instantaneous rate).

16. **Green Revolution.** The recent success in agriculture which has over the past several decades greatly increased world crop production.

17. **HF Radar.** High frequency radar.

18. **Meristic Counts.** Count of numbers of fin rays, gill rakers, etc., which may differ between stocks, species, etc.

19. **Natural Mortality.** Death resulting from causes other than fishing. Normally expressed as the percentage of a population dying each year or a compound interest rate (instantaneous rate).

20. **Northern Cod Population.** The stock(s) of cod generally inhabiting NAFO Statistical Division 2J3KL, portions of which may extend beyond the two hundred mile fisheries zone of Canada and which are generally managed as a unit.

21. **Nose and Tail of the Banks.** Regions of the Grand Banks which extend seaward off the Canadian EEZ.

22. **Perturbation.** Variations in a parameter beyond that which might normally be expected.

23. **Population.** The aggregate of individuals of a stock or stock complex which inhabit a definable region.

24. **Population Index.** A measure of relative population size which is expected to vary proportionately to the true population size or which can be mathematically equated to the true population size.

25. **Recruitment.** The young of a population species entering into a population or fishery at a particular age. In the northern cod fishery, most recruitment occurs at ages 3, 4, and 5.

26. **Retrospective Analysis.** An analysis that bases its conclusions on known historical data.

27. **RV.** Research Vessel.

28. **Spawning Group.** A concentration of fish that spawns in definable area at known times of the year.

29. **Spawning Population.** The population of cod involved which are sexually mature and are involved in spawning.

30. **Stock.** A group of fish that have a common genetic make-up which inhabit a particular region and generally behave in a similar manner from year-to-year.

31. **Stock Complex.** Subgroups of a stock or multiple stocks that may comprise a population.

32. **Stock Status.** The size of a population in numbers or weight related to the historical levels and trends.

33. **Swept Area.** The area of seabed swept by the mouth of a trawl and generally measured from wing tip to wing tip.

34. **TAC.** Total allowable catch.

35. **Terminal Fishing Mortality.** The annual mortality rate acting on a year class in the last year for which catch-at-age data is available. It is the value used to indicate a VPA of cohort analysis.

36. **Thermal Barriers.** Areas in the ocean where temperature changes are rapid over short distances and, hence, which may constitute a barrier to the movement of some species.

37. **Tuning.** A collective name for a family of techniques in which known data such as historical population levels, age structure, etc. are used in conjunction with trends appearing in the indexes derived independently from the RV surveys and the commercial CPUE, to establish an estimate of the current population size. Essentially, they use good estimates of absolute population size that VPA provides for the past years to calibrate survey and CPUE indexes of relative abundance. The calibrated (to absolute population size) indexes of abundance for current years are then used to replace the guesstimates of current population size in the VPA. Of course, such estimates of recent populations and size are only as good as the trends indicated by the survey and CPUE data.

38. **VPA (Virtual Population Analysis).** A method of converting the total catch-at-age data into estimates of absolute population size and fishing mortality (see tuning).

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Table showing correlation between instantaneous rates of fishing ("F") and natural mortality ("m") and total yearly effect on stock.

Multiplicative analysis of commercial catch/effort data with the inclusion of a division/month interaction term in the model.

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Table of mean number of cod per tow from Autumn surveys in Division 3L with estimates for 1978-80 obtained from Spring 3L surveys.

Tables showing historical catches of cod from NAFO Divisions 2J3KL for the period 1959-1987.

Graph showing the relative biomass of age 3+ cod over the 1975-89 period for several North Atlantic stocks.

Tables showing management statistics for cod in the North East Arctic area of ICES, in the North Sea area of ICES, and for haddock in the North Sea area of ICES (from reports of ACFM on Fisheries Management and from reports of North Sea Haddock ACFM on Fisheries Management).

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