A paper prepared for the

Economic Council of Canada

[redacted]

Un document préparé pour le

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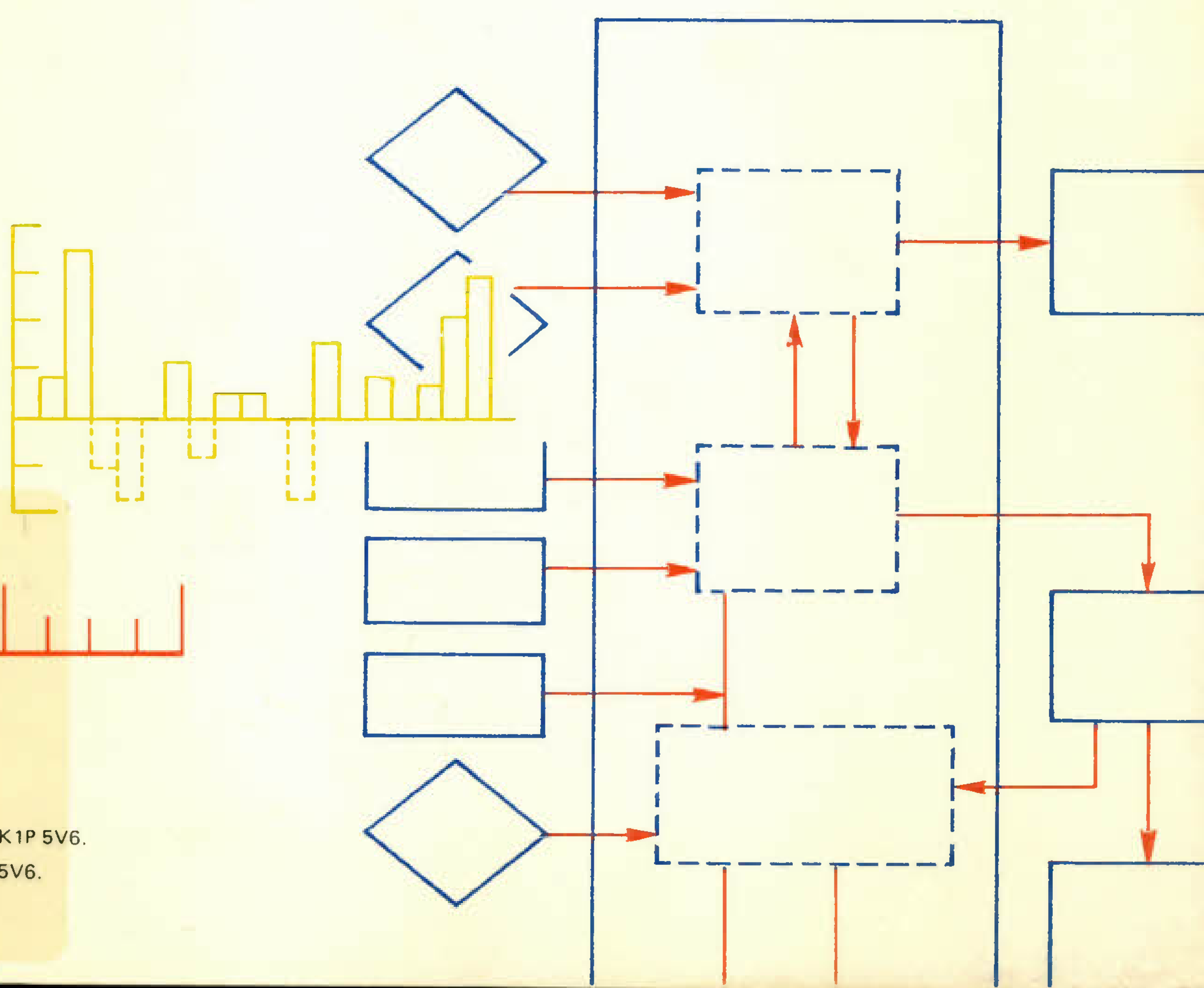

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DISCUSSION PAPER NO. 180

The Relative Productivity and Cost-Effectiveness of Various Fishing Techniques in the Newfoundland Groundfishery

by
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The findings of this Dicussion Paper are the personal responsibility of the authors and, as such, have not been endorsed by Members of the Economic Council of Canada.

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October 1980

ISSN 0225-8013

Acknowledgements

The authors of this study are especially indebted to Mr. Kenneth A. Carew for his assistance.

There are many officials in the Federal Department of Fisheries and Oceans, and the Newfoundland Department of Fisheries, who generously provided us with information and with judgments based on their extensive experience. We thank them all.

In particular, we express our deep gratitude to Dr. D. Pepper of the Department of Fisheries and Oceans, without whose cooperation and assistance this study would not have been possible.

We would also like to thank President M.O. Morgan, of Memorial University of Newfoundland, who arranged for auxiliary funding for the project of which this paper is part.

We would also like to thank Ms. Blanca Skoda and Ms. Linda Sturge for research assistance, and Mrs. Marie Dunne and Ms. Yvonne Raymond for typing the manuscript.

In addition to the above, we are indebted to the late D.G. Alexander, S.D. Antler, P. Copes, L. Copithorne, G.K. Goundrey, G. Munro and C.H. Pye for helpful comments on an earlier draft.

Finally, the authors accept full responsibility for all errors remaining in the text and for all interpretations and conclusions included in the study.

Résumé

La présente étude se fonde sur une analyse de régression de la productivité physique de plus de trente combinaisons de bateaux et d'agrès utilisés dans la pêche de fond à Terre-Neuve.

Les auteurs se servent de divers taux estimés de productivité physique, conjointement avec des données sur les coûts et prix unitaires en 1978, afin de déterminer, à l'aide de différentes combinaisons de bateaux et d'agrès, la valeur totale et le coût social global qu'engagerait la pêche des poissons de fond pris à Terre-Neuve en 1978.

Les résultats indiquent que les manets (ou araignées) et les palangriers moyens et grands ne constituent pas des méthodes efficaces, du point de vue du coût, pour la pêche de fond à Terre-Neuve.

En outre, les petits bateaux et palangriers convenablement équipés ne sont pas moins économiques que les chalutiers. Les coûts supplémentaires qu'entraîne l'usage des chalutiers compensent pour la main-d'oeuvre additionnelle nécessaire dans la pêche côtière lorsque toute la main-d'oeuvre est évaluée à son salaire industriel prévu. Les coûts et revenus réels de la pêche ne constituent donc pas des éléments cruciaux dans la décision d'encourager ou non la pêche côtière. L'emploi, les facteurs sociaux et les coûts des installation portuaires et des usines constituent des facteurs plus importants.

Bien que le secteur côtier exige un nombre considérablement plus élevé de pêcheurs que le secteur hauturier, la différence en années-hommes nécessaires est beaucoup moins marquée en raison du caractère saisonnier de la pêche côtière. Même si le secteur côtier croissait en importance, il ne faudrait pas s'attendre à ce que le chômage à Terre-Neuve s'en trouve considérablement réduit.

Le rapport en arrive à une conclusion assez frappante : aucune combinaison de bateaux et d'agrès n'aurait pu prendre le poisson de fond pêché en 1978 sans encourir de fortes pertes économiques et exiger des subventions d'une source quelconque.

Abstract

This study is based on a regression analysis of the physical productivity of more than thirty different vessel and gear combinations used in the Newfoundland groundfishery.

The authors use the estimated physical productivities, along with 1978 unit cost and price data, to determine the total value and total social cost that would be involved in gathering the 1978 Newfoundland groundfish harvest with a variety gear and vessel combinations.

The results of the study show that gillnets and intermediate and large longliners are not cost-effective methods of prosecuting the Newfoundland groundfishery.

In addition, when small boats and small longliners are suitably equipped, they are no less economical than trawlers. The additional capital costs associated with trawlers balance the extra labor required in the inshore fishery when all labor is valued at its expected industrial wage. The actual harvesting costs and revenues are therefore not the crucial elements in deciding whether the inshore fishery should be encouraged. More important considerations are employment, social factors, and the costs of harbour and plant facilities.

While the inshore fishery requires substantially more fishermen than does the offshore sector, because of the seasonal character of the inshore fishery the difference in required man-years is not nearly as great. Even if the inshore fishery is expanded, the harvesting sector cannot be expected to have a substantial impact on Newfoundland's unemployment problem.

A striking conclusion of the report is that there was no combination of vessels and gear which could have taken the 1978 groundfish catch without large economic losses, losses which would have to be subsidized from some source.

Table of Contents

EXTENDED APPENDICES[1]

1 Because the extended appendices are voluminous and technical they are not given general distribution, but are available on request, either from the Economic Council or from the authors. In addition the appendices are on deposit with libraries in the following institutions:

(1) National Library

(2) Newfoundland Department of Fisheries

(3) Newfoundland House of Assembly

(4) Department of Fisheries and Oceans in St. John's, Halifax, Ottawa.

(5) Department of Regional Economic Expansion in St. John's, Moncton, Ottawa.

(6) Memorial University of Newfoundland and Labrador

(7) Simon Fraser University, Vancouver.

(8) Dalhousie University, Halifax.

(9) University of British Columbia.

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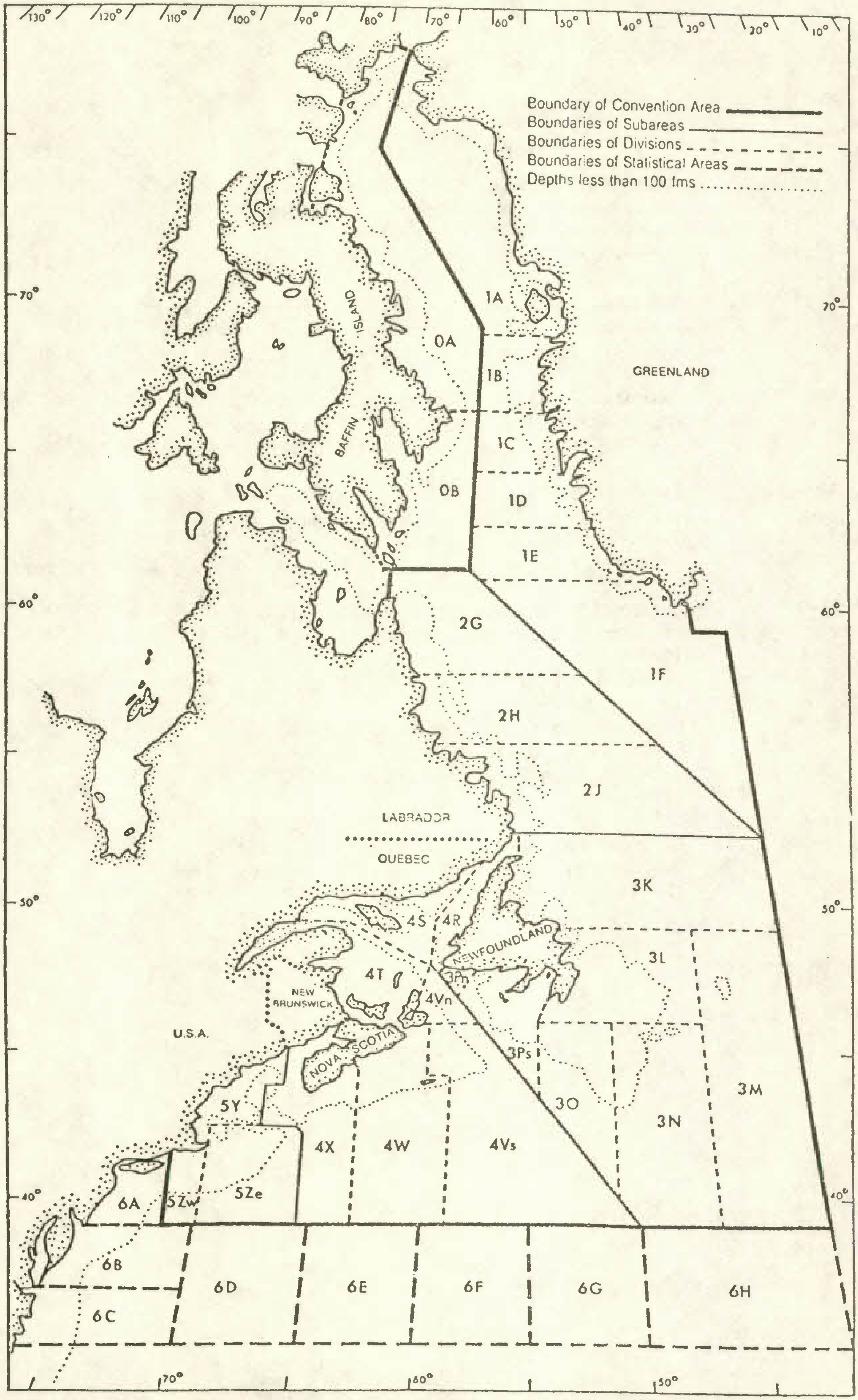
Map Showing ICNAF Fishing Divisions



I. Introduction

With the extension of direct Canadian control over ocean fisheries to a limit of two hundred miles from its coast, effective January 1, 1977, large increases in fish catches have generally been foreseen for Canadian vessels. Regarding specifically the waters off the coast of Newfoundland, Canada's Department of Fisheries and Oceans has prepared projections showing enormously increased cod catches (the "northern cod") and modest to substantial increases in the catch of other species resulting from the changed situation.[1] Major political decisions are being made concerning the distribution of the expanded catch: foreign versus Canadian; Newfoundland versus the Maritime Provinces and Quebec; and Newfoundland inshore versus offshore harvesting sectors. The first of these topics (essentially the question of extended fisheries jurisdiction) is the subject of Gordon Munro's book, published for its Newfoundland Reference by the Economic Council of Canada.[2] The second topic (whether the fish caught off Newfoundland's coast will be landed in Newfoundland or elsewhere in Canada) is one element of the debate over whether the Federal government should license freezer trawlers for use in the waters in which the northern cod stock is found. The third topic (whether or not there should be a sizeable inshore catch in Newfoundland) has been a major concern of the provincial government of Newfoundland.

This study is an economic analysis of some of the factors that are relevant to the inshore/offshore controversy. Perhaps even more important

[1] Fisheries and Marine Services (1977). Atlantic Coast Resource Prospects-1978 to 1985. Ottawa: Department of Fisheries and the Environment.

[2] Munro, G. (1980). A Promise of Abundance: Extended Fisheries Jurisdiction and the Newfoundland Economy. Ottawa: Economic Council of Canada.

than its relevance to that specific controversy, the study constitutes a detailed and broad-ranged productivity and economic analysis of the Newfoundland fish harvesting industry. Equipment used in the industry and considered in the study ranges from small inshore motor and trap boats to eight hundred ton wetfish trawlers; from handlines, longlines, and gillnets to bottom and midwater otter trawls. The study begins with a productivity analysis showing the relative catch per day that can be expected from different gear-vessel combinations. The study then draws on extensive cost and revenue data to determine the economic implications of using alternative gear-vessel combinations.

The economic effects of Extended Fisheries Jurisdiction (EFJ, the formal name for the two-hundred mile limit) are expected to arise primarily from the expanded Canadian cod fishery. One characteristic of the offshore fishery is that it includes large by-catches of several groundfish species. This study, therefore, focusses on the groundfishery, particularly on the groundfishery of Newfoundland. It is assumed that, although there now may be excess capacity in the Newfoundland groundfishery (i.e., too many boats), ultimately new vessels will have to be constructed and these vessels will largely be confined to the prosecution of the groundfishery. Therefore, only economic conditions relating to the groundfishery are included in this study; catch of other species is ignored.

In summary, our objectives in preparing this study are to:

a. evaluate the income and employment potential of the Newfoundland groundfishery;

b. evaluate the assumptions of Setting a Course,[3] the provincial government's primary study of the fishery;

c. introduce new and original data into the analysis of the Newfoundland groundfishery;

d. quantify the economic consequences of the use of specific gear and vessel types;

e. evaluate the economic implications of policies favoring either the inshore or offshore cod fishery; and

f. illustrate the need for the gathering and quick release of fisheries data by the federal government and emphasize the need for continuing research into the economics of the Newfoundland fishery.

Method of Analysis

The expression "relative productivity" is used throughout this study to indicate average differences in fish catching power between alternative gear and vessel combinations. As an example, within the small boat class of vessels we determine that, with the number of pounds of fish caught per day per vessel with handlines assigned a value of 1.00, gillnets have a relative productivity of 1.48 and cod traps a relative productivity of 2.97. On the average, therefore, operators of these vessels can expect, for each day fishing, to catch about twice as much groundfish with cod traps as they can with gillnets. The relative productivities are estimated from

[3] Newfoundland Department of Fisheries (1978b).

a multivariate regression analysis based upon nearly four thousand observations for the period from 1973 to 1978. Each observation represents the total catch (in metric tons) and total effort (in days fishing) of vessels in a given class, with a given type of gear, in a specific fishing division, catching a particular main species, during a given month. Most of these data were obtained from published documents of the International Commission for the Northwest Atlantic Fishery (ICNAF). This basic source was augmented by public data provided by the Department of Fisheries and Oceans and by a special survey of the results of perhaps five thousand trips by small boat fishermen. The study reports the relative productivities of thirty-three gear-vessel combinations. In addition to relative productivities, the regression analysis provides estimates of the average catch per day fishing over the sample period of each gear-vessel combination.

With the physical productivities computed, economic considerations are then introduced into the analysis. For each gear-vessel combination used in 1978, catch, price, and detailed cost data are used to compute the "normalized social economic surplus" (which is the total revenue from selling the fish minus the total costs incurred by vessels in that category catching the given volume of fish, all divided by the total revenue) generated from fishing activity in 1978.

Several types of analysis are included in the study. First, we note the actual catch of groundfish by species taken in 1978 by vessels of a certain class with specific types of gear. For this aggregate catch, estimates are made of the total revenue received by vessel operators and the total amount of effort (in days fishing) required. This catch, divided by the estimated catch per day fished, yields an estimate of the average number of days fishing required for all vessels of that type to catch this aggregate quantity of fish with the specified gear. The revenue and effort calculations are repeated for each species and for each gear type used on the specified class of vessel in 1978.

With the estimated effort as a base, and a reasonable number of days fishing per vessel per season assumed, we obtain an estimate of the minimum number of vessels required to catch the volume of fish that actually was caught in 1978. The cost of operating that number of vessels with the requisite equipment is then computed. Here we use a variety of data sources, most of which have not been previously used in analyses of this kind. Labor is evaluated at an opportunity cost (measured as the expected industrial wage), fixed non-capital and operating costs of the vessels are obtained from unpublished surveys of the Department of Fisheries and Oceans, engine and hull costs are obtained from the records of the Fisheries Loan Board and from estimates prepared by the Marystown shipyard, and gear costs are obtained from a survey of fishing equipment suppliers in St. John's and from trawler operators. The sum of these costs is the minimum total social cost of catching the volume of fish that actually was caught in 1978 with the actual distribution of gear used on particular classes of vessels in that year.

Our costs and revenues are social rather than private. All subsidies are neglected. For instance, vessels and gear are evaluated at their full cost, the amount paid by the operators plus the amount of any subsidies.

The results of the economic analysis are summarized in a single statistic, the aggregate "economic surplus", more accurately termed the "normalized social economic surplus" per dollar of gross revenue. The economic surplus is computed by subtracting the total cost from the total revenue and normalizing the difference by dividing it by the total revenue. Thus the summary statistic is the economic surplus expressed as the number of dollars of surplus per dollar of revenue. If the surplus is negative and equal in magnitude to one, then the fishing operation is taking a loss of one dollar for every dollar of revenue (reflecting the assumptions that the workers could have sought alternative employment at an expected industrial wage and that the cost of the vessels could have been saved). Of course, subsidies paid to private operators may turn a deficit operation to profit and large, integrated harvesting-processing firms may, in addition to taking subsidies, use profitable processing operations to cross-subsidize the harvesting operations.

It should be clear that these computations also yield an estimated minimum number of vessels required to take the 1978 catch using existing technology. By assuming that the number of crewmen on a vessel of a given class is constant, the minimum number of fishermen required for the indicated harvesting operation can be determined.

Summarizing the first phase of the economic analysis, the economic implications of the groundfish catch taken by a particular class of vessel with the actual 1978 distribution of catch by gear are determined. These implications are summarized by the number of vessels and fishermen required and the economic surplus generated.

The second type of economic analysis involves simulations in which hypothetical distributions of catch by gear type are assumed to have been used to obtain the actual catch taken by vessels in the given class in 1978. The nature of the computations made in this analysis is the same as that which we previously described. To illustrate the nature of the results, the following table shows, for large longliners (65'), the normalized economic surplus, employment generated, and the required number of vessels computed from the first analysis ("1978 reconstruction") and from two examples from the second (using gillnets only and using a combination of longlines and bottom trawls).

Selected Results: Minimum Employment and Minimum Number of Vessels Required to Take the Catch Obtained in 1978 by Large Longliners Assuming Alternative Gear Combinations*

Gear	Economic Surplus	Employment	Number of Vessels
1978 Reconstruction	-1.30	220	44
Gillnets	-1.65	240	48
Longlines-Bottom Trawls	-1.02	205	41

*This table is based on Table 7, page 79.

In the third form of economic analysis, the entire Newfoundland 1978 catch of groundfish is hypothetically divided between different types of vessels using, generally, the most cost-effective types of gear. In this analysis, there is no restriction that the 1978 catch by vessel type be maintained. These simulated results allow for any reasonable distribution of the catch between different types of vessels. Among the most interesting cases studied are those where comparisons are made between an "inshore" option (where a large proportion, 80%, of cod is caught inshore) and an "offshore" option (where only 20% of cod is caught inshore). Once again, the nature of the computations is the same as that used in the 1978 reconstructions.

The above discussion refers to a number of technical terms which require amplification:

a. Vessel Classes --

We divide Newfoundland fishing vessels into six classes, roughly paralleling the tonnage classification scheme used by ICNAF.

Vessel Classes

Tonnage Class	Length	Tonnage	Description
Zero	18'-22' 22'-39'	< 10 < 10	motor boats trap boats
One	35'-45'	10-24.9	longliners (small)
Two	52'-55'	25-49.9	longliners (medium)
Three	65'	50-149.9	longliners (large)
Four	< 145'	150-499.9	trawlers (medium)
Five	> 145'	500-999.9	trawlers (large)

b. Gear Types --

The following table shows the gear types used in the economic analysis, along with those vessel classes with which each is employed.

Gear Types by Vessel Class

Tonnage Class:	0	1	2	3	4	5
Gear Type:						
Handlines	✓	✓	✓	-	-	-
Gillnets	✓	✓	✓	✓	-	-
Longlines	✓	✓	✓	✓	-	-
Cod Traps	✓	✓	✓	-	-	-
Bottom Trawls	-	✓	✓	✓	✓	✓
Midwater Trawls	-	-	-	-	✓	✓

There are numerous definitions of the inshore and offshore fisheries. Under the definition which we adopt, vessels of less than fifty tons constitute the inshore fishing fleet and larger vessels constitute the offshore fleet.

c. Species --

The following groundfish species are considered in this study:

Cod

Redfish (ocean perch)

Flatfish (including greysole, American plaice, turbot, and yellowtail flounder)

d. Prices --

Fish prices in Newfoundland are essentially those set as minima by the contract between the Newfoundland Fishermen Food and Allied Workers Union and members of the Fisheries Association of Newfoundland and Labrador. The contract sets minimum prices for species depending on the gear used to catch it, and fish size, grade and state. Most fish are stated to be "Grade A" so we have ignored this classification; it seems that fish buyers do not seriously attempt to grade fish within a gear classification. The "state", e.g., round or gutted head on, can be converted through the application of standard ratios to a basic form. We use the round state. The crucial determinants of fish prices are size and gear. Our average prices are generally based upon either the prices reported by fishermen in the Department of Fisheries and Oceans survey or upon a weighted average with union price scales applied to the actual distribution of fish size by gear type.

e. Cost Classifications --

For each simulation of fish catch by gear type, the following costs are computed:

Wage of skipper
Wage of crew
Fixed non-capital cost (e.g., insurance)
Fuel
Maintenance
Other operating costs
Engine and hull cost
Gear costs.

f. Cost-effective Gear-vessel Combination --

A gear-vessel combination is considered to be the most cost-effective combination in a class if it exhibits the highest normalized surplus of all gear-vessel combinations in the class. The concept of normalized surplus was defined above (page 6). The expression "cost-effective" is often used in this study in a relative sense, where one combination is considered to be more cost-effective than another if it has a higher normalized surplus than does the other.

Basic Assumptions

To fully incorporate the effects of time into the productivity analysis, we would require a time series of cross-sections in which micro-economic data are available for each individual vessel and its gear. For every vessel, for instance, we would have data concerning its age, structural characteristics, length, and horsepower as well as its catch, effort, crew size and types and details (such as mesh size and material for nets) of gear for every year that the vessel is engaged in the Newfoundland fishery. With such data, it would be possible to account for technological change over time, vessel and gear quality differences within seasons, and a host of related factors. Much of this data is simply not available, unfortunately, and most of the data that exists is either considered to be confidential by those with access to it or is not in a form that makes it readily available for research.

In addition, an ideal study of the productivity of the fishery would include data on fish populations by species and season organized in a fashion that isolates information concerning discrete fish stocks and fish migration patterns. Once again, unfortunately, the biologists have not advanced their field to the point where sufficiently reliable information of this kind is available.

The description of unavailable data given above makes the nature of our simplifying assumptions clear. Our sample is drawn for the years 1973-78, not a sufficiently long time to introduce substantial temporal effects into the analysis. Microeconomic data is available only to such a limited extent that it is virtually useless for our productivity study. With a few exceptions, therefore, we have omitted all consideration of the effects of time, particularly of time trends and of the effect of technological progress within a single type of gear. To the extent that new gear types are used more heavily in the later years of our short sample, we have accounted for technical change in that new equipment types are being substituted for old. Thus, our analysis will reflect the substitution of mid-water for bottom trawls. If mid-water trawl mesh material has changed over the period of the sample, however, our analysis will not isolate the effect of this change. If newer vessels in a tonnage class are larger or smaller or have other characteristics different from the older vessels in the class, the effects of these changes cannot be taken into account.

We therefore work within an essentially static framework. As referred to above, new gear types can be introduced over the period of the sample but changes in specific types cannot be introduced. Similarly, since we are working within the framework of a statistical analysis, we take no account of changes in vessels and gear which may be made in the future.

Experiments have been performed in Newfoundland waters with pair trawling. Since data are available from these experiments, we can and do take them into account and draw conclusions on the basis of our analysis. Freezer trawlers, however, were not used in Newfoundland waters during our sample period and we therefore have nothing to say about their productivity or cost-effectiveness relative to the vessels included in the study.

In the absence of satisfactory biological information, we are severely restricted in our ability to evaluate the effects of varying fish populations on productivity. We use time variables to represent years and therefore have available a proxy, though a weak one, for temporal population effects. Within years, we use specific variables to indicate monthly fluctuations and fishing areas. These population variables permit us to account in a limited way for time and space fluctuations. Although the sample is quite large, the number of explanatory variables is also large so that attempts to determine productivities specific to a combination of main species, year, month, fishing division, and gear type are either impossible or would yield statistical results of such poor quality as to be virtually useless. Were microeconomic data available, this problem would disappear.

Our survey of the 1978 operations of small boats presents us with sufficient data to permit a more detailed analysis of the productivity of these vessels than is possible for the larger vessels. The results of this analysis are presented in the Appendix to Chapter II.

Another temporal problem, one related to within year changes, arises from the switching of gear types by fishermen. The basic assumption which we have made, in response to the factors outlined above, is that the relative productivities among gear-vessel combinations do not change over time and space. In one case this assumption becomes untenable. Cod traps are only useful for a relatively small part of the fishing season; outside of the peak season their productivity falls dramatically. We therefore assume that cod traps can be used only during the peak season and that other gear types must be used for the remainder of the year.

We also recognize, of course, that gillnets, for example, will not be used on the northeast coast during those parts of the year when the ports are closed because of ice. But as the fishing season progresses, it is possible that the relative productivity of different gear types vary. Obviously this is true on the northeast coast when cod traps are used for only four to six weeks and gillnets are preferred both before and after the peak trap season. However, except for the dramatic change into and out of cod traps, fishermen are rather consistent in their use of groundfish gear. Longlines, for instance, are rarely used on the northeast coast and gillnets are absent from the southwest coast.

Since our relative productivities are based upon a statistical analysis of historical data, it is impossible for us to draw conclusions concerning changing relative productivities between gear types within geographical areas over the year if, in fact, alternative types of gear are not used in the same regions at the same time. The problem is most clearly illustrated in the Appendix to Chapter II where, despite the fact that the data for small boats includes the results of nearly four thousand fishing days, there are very few examples of overlap where month-by-month estimates can be made of relative productivities between specific pairs of gear types. If the appropriate data does not exist then it cannot be analyzed.

One might argue that the government could stimulate experiments whereby such pairwise comparisons could be made. Suitable data might be generated in this way (as in the case, referred to earlier, of pair trawlers) but an important caution is necessary. A few vessel operators chosen by the government to conduct an experiment may perform much better than they would under normal circumstances.

It should be clear, therefore, that in addition to limits on our work being imposed because suitable data are unavailable, other limits are imposed by the very nature of the fishery.

While the economic analysis is performed for data from 1978, we recognize that one result of EFJ is that fish populations should increase in the near future. Our assumption that relative productivities do not change over time and space does not mean that absolute productivities are subject to the same constraint. Obviously, if fish populations increase, the catch per unit effort of all types of equipment will increase. Our assumption is restrictive only in that, as catch per unit effort increases with rising fish populations, the relative productivities between gear-vessel combinations remain unchanged.

Time introduces other considerations that must be assumed away. Prices play a crucial role in the economic analysis and the difference in relative prices, for instance, between the price paid for cod trap fish and that for longline fish, are substantial. It is possible that, if there were major changes in the distribution of fishing gear actually used in Newfoundland, the price structure would also change in response to perceived fish quality changes. For instance, longline fish prices are substantially higher than trap fish prices. Since traps are used at the height of the summer season and presumably the low price of trap fish reflects their poor quality, the question arises of whether the poor quality is inherent in the use of traps or because inferior fish are being caught. If the latter were true, then catching the same fish with longlines would result in a lowering of the current longline fish price. This change in price might alter our conclusions. We neglect this problem.

Another problem which we neglect, and again one which involves changes over time, is the question of overcrowding in a fishery. This problem is most likely to create difficulties in the analysis of gillnets, where it seems that the perceived low quality of netted fish results from the use of too many nets. Would the quality of gillnet fish rise if fewer nets were used, and how would this quality change affect our results? Once again, in the absence of suitable data, we must assume the questions away.

Several other characteristics of the fishery are also neglected, generally because of the absence of suitable data. We have not accounted for the effects on the analysis of social overhead capital. A fishery heavily oriented towards the inshore sector requires numerous wharves and breakwaters, usually paid for and owned by the federal government. Different types of facilities are required for an offshore fishery. In evaluating the cost-effectiveness of the inshore relative to the offshore fishery, relative social overhead capital requirements should be taken into account. This analysis would, however, require a separate research project and it is therefore neglected.

In addition, non-groundfish operations are not considered. We argued at the start of this introduction that it is reasonable to focus on groundfish operations alone. It should also be noted that the potential of non-groundfish catches could alter our evaluation of alternative types of vessels.

Perhaps one of our most critical assumptions is that concerning the choice of the opportunity cost of labor. We assume throughout the economic analysis that the opportunity cost of a fisherman is the wage he could expect to earn if he were to enter the manufacturing sector of the Newfoundland economy. Critics of this assumption might argue that many Newfoundland fishermen do not have the option of entering the manufacturing industry, that that sector of the Newfoundland economy is too small and too geographically concentrated to offer a real alternative to the fishery.

At first glance it might seem that the entire problem could be avoided by using the actual wages of labor rather than the opportunity costs. This option is proscribed, however, by our consideration of social rather than private costs. Once we decide to base our computations on costs net of subsidies, we must be consistent in orienting our cost calculations towards social considerations and these are best reflected in opportunity costs. The question remains: what is the most appropriate opportunity cost?

Once again it is necessary to recall that we are generally neglecting spatial effects throughout the study. The opportunity cost of a fishermen in St. John's is no doubt different from that of a fisherman on the northeast coast. Since we are aggregating over the entire fishery of Newfoundland and Labrador, we must decide on a single appropriate opportunity cost.

It should be clear that by suitably juggling our choice of opportunity cost, we can achieve almost any desired result. For instance, it is obvious from our analysis that there is a clear trade-off between the labor intensive inshore fishery (where the cost of capital is low) and the capital intensive offshore fishery (where relatively few fishermen are required). If we were to assume a zero opportunity cost of labor, then the inshore fishery, with its low capital costs, must be cost-effective. With jiggers costing about twenty-five dollars, and labor evaluated at zero opportunity cost, it seems obvious under these extreme assumptions that the optimal Newfoundland fishery would involve a large number of inshore fishermen equipped with rafts, much less dories. Such a scenario seems ridiculous, but it could easily result from a poor choice of opportunity cost.

A reader, desiring to test the effects on our results of the choice of alternative opportunity costs, can recompute the economic surplus for any particular case (using the worksheets at the end of the study) and draw the appropriate conclusions. Since, in the absence of a detailed spatial dimension in our study, it is impossible to provide region-specific cost estimates, we believe that our choice of opportunity cost is a reasonable one.

Results

Two questions concerning productivity can be answered directly from the results of the regression analysis. First, how much more fish can be caught with one gear-vessel combination than with another *if* both are used at the same time, in the same place, to catch the same species? Second, how many tons of fish of a specific species can a particular gear-vessel combination catch in a day of fishing at a particular time in a particular place?

The table of relative physical productivities on page 21 summarizes the answers to the first question for a broad selection of the gear-vessel combinations included in the analysis. The table graphically illustrates the anticipated rise in productivities with increased vessel size as well as the often dramatic variations in productivity obtained with different gear types mounted on similar vessels.

These figures, while interesting in themselves, must be used with great caution. Pairwise comparisons between gear-vessel combinations are valid only when the combinations are used under identical circumstances. Since large trawlers use midwater trawls in offshore waters to catch redfish while motor boats use handlines to catch cod in inshore waters, the fact that we have obtained a relative productivity between these combinations of 4.902 : 0.091, or 53.9, is not of much direct use in the economic analysis reported in this study. The relative productivity weights are useful for obtaining an aggregate annual effort figure for the Newfoundland groundfishery where the aggregation process involves the adding up of the amounts of effort expended by different gear-vessel

Relative Physical Productivities per Day Fishing per Vessel

Vessel Class / Gear Type	Motor and Trap Boats	Longliners Small	Longliners Medium	Longliners Large	Trawlers Medium	Trawlers Large
Handlines	.091	.261	.318	-	-	-
Gillnets	.135	.397	.517	.859	-	-
Longlines	.150	.375	.639	1.000	2.142	-
Cod Traps	.270	.553	.762	1.000	-	-
Bottom Trawls:						
Side Trawls	-	.611	.675	1.000	1.972	-
Stern Trawls	-	-	1.000	1.000	2.062	2.673
Pair Trawls	-	.446	.580	-	1.000	-
Midwater Trawls:						
Side Trawls	-	-	-	-	2.732	-
Stern Trawls	-	-	-	1.000	2.660	4.902

Notes: a) This table is based upon Table 3, page 47. See the notes to and discussion of Table 3 in the main text for explanations of these results.

b) This table consists of multiplicative relative productivity weights based upon an index of 1.000. Thus, on the average, fishermen will catch slightly more than twice as much (2.062) per vessel in a day of fishing when bottom trawls are mounted on medium-sized stern trawlers than when they are mounted on large longliners.

combinations. Rather than simply adding the effort figures (is one day fishing the same with handlines from motor boats and midwater trawls from 165' trawlers?), the effort figures are weighted by the numbers shown in the table. We perform this operation in another paper (Tsoa et al., 1980).

Of greater direct use in the current study is the answer to the second question, the average catch per vessel per day fishing obtained under specific conditions. We do not summarize these extensive results here, but the catch per unit effort figures generated by our regression analysis for specific cases of interest appear in the X_{ijk} column of each table in Appendices 4 and 5. These figures show the average catch per vessel per day fishing for a particular species, the average taken over all months and locations in which such fishing operations occurred over the entire sample period, 1973-78. Although the catch, cost and revenue data used in the economic analysis pertain solely to 1978, the catch per unit effort estimates that play so crucial a role in the economic analysis are affected by the fishing experience over the entire sample period. Except for the small boats, for which there is no total effort figure, we could have used the actual catch per unit effort for 1978. We have rejected this option in favor of using the regression results for fear that the experience of 1978 will not be maintained in the future. The high productivity of that year may, after all, have simply been the result of a fortuitous concatenation of weather, labor relations, fish populations and a host of other factors.

The table of "Social Economic Loss and Employment" consolidates a selection of the results of the economic analysis reported on in this study. The first sixteen lines of the table report selected results of the restricted analysis, the analysis in which alternative types of gear are assumed to obtain the catch actually obtained by vessels in a specific class in 1978. In these simulations, the "1978 reconstruction" reflects the actual distribution of gear used in 1978 and the remaining entries report hypothetical results that would be obtained had alternative gear distributions been employed. The remaining six lines of the table report a selection of the results of the extended analysis, an analysis where the total 1978 Newfoundland groundfish catch is assumed to have been caught by a variety of gear and vessel combinations.

The table shows the type of vessel and the gear combination used in the simulation, indicates whether the restricted or extended analysis is involved and, if the latter, whether the inshore option (80% of cod caught inshore) or the offshore option (20% of cod caught inshore) is involved, the economic loss in dollars per year per dollar of revenue resulting from the scenario, the employment generated by the scenario in men per year and, for the extended analysis, the equivalent man-years of labor generated.

The purpose of the restricted analysis is to determine the most cost-effective methods of catching fish with specific vessel classes. Thus, to take the case of class zero vessels (motor and trap boats), we find that the 1978 reconstruction implies that, with the distribution of gear actually used on small boats to obtain the 1978 catch, there is an implied required subsidy of $1.54 for every dollar of revenue obtained from the sale by these vessels of groundfish. The implied subsidy would fall to $1.49 if

Social Economic Loss and Employment

Gear-Vessel Combination	Analysis: Restricted	Analysis: Extended	Economic Loss (Dollars per dollar of revenue)	Employment (men per year)	Employment (man-year equivalents)
Motor and Trap Boats:					
1. 1978 Reconstruction	✓		1.54	7,993	-
2. Gillnets only	✓		1.49	7,908	-
3. Handlines only	✓		2.31	11,734	-
4. Cod traps - Longlines	✓		1.07	6,533	-
Small Longliners:					
5. 1978 Reconstruction	✓		1.50	1,456	-
6. Gillnets only	✓		1.57	1,504	-
7. Cod traps - Longlines	✓		.92	888	-
Medium Longliners:					
8. 1978 Reconstruction	✓		3.28	868	-
9. Gillnets only	✓		3.60	940	-
10. Gillnets - Longlines	✓		2.94	836	-
Large Longliners:					
11. 1978 Reconstruction	✓		1.34	220	-
12. Longlines - Bottom Trawls (stern)	✓		1.03	205	-
Medium Trawlers:					
13. 1978 Reconstruction	✓		1.40	299	-
14. Midwater/Bottom Trawls	✓		1.04	260	-

(continued)

Social Economic Loss and Employment (continued)

Gear-Vessel Combination	Analysis: Restricted	Analysis: Extended	Economic Loss (Dollars per dollar of revenue)	Employment (men per year)	Employment (man-year equivalents)
Large Trawlers:					
15. 1978 Reconstruction	✓		1.50	1,020	-
16. Midwater/Bottom Trawls	✓		1.37	975	-
Motor Boats and Medium Trawlers:					
17. Inshore Option (longlines)		✓	1.12	11,036	4,644
18. Inshore Option (handlines)		✓	1.78	16,876	6,279
Small Longliners and Medium Trawlers:					
19. Offshore Option (longlines)		✓	1.15	5,169	3,890
20. Inshore Option (longlines)		✓	1.15	9,262	4,147
Small and Large Longliners:					
21. Inshore Option (longlines)		✓	1.19	10,144	5,029
22. Inshore Option (longlines and cod traps)		✓	1.18	9,624	4,884

Notes:
a) This table presents selected results from Tables 7 (pages 78-80) and 12 (page 99).

b) For the distribution of gear types used in the 1978 reconstructions, see the appropriate tables in Appendix 4.

c) In the extended analysis, inshore fishermen are assumed to catch only cod.

d) For lines 17. to 22., gear types indicated in parentheses are those used in the inshore fishery.

only gillnets were used by these vessels, and would fall further to $1.07 if a suitable combination of cod traps and longlines were used. On the other hand, if all inshore fishermen on small boats were to jig for cod, and if the 1978 catch of groundfish by these vessels were maintained, then the implied subsidy would rise to $2.31. Similar results are reported for the remaining five vessel classes. The 1978 reconstructions for trawlers involve the use of bottom and midwater trawls in their actual 1978 proportion while the second entry for each of the trawler classes reports on simulated results obtained when it is assumed that all redfish are caught with midwater trawls rather than the smaller percentages of redfish that were actually caught with this gear.

Accompanying each estimate of the economic loss (or the negative "normalized social economic surplus" per dollar of revenue) is an estimate of the number of fishermen required during the year to obtain the 1978 catch with the given distribution of gear. For the extended analysis, we also convert these "men per year" figures to man-year equivalents, i.e., the number of men who would be required to perform the required work if the work could be evenly distributed throughout the year. To compute these figures, we assume that offshore fishermen are employed for the full year (with one month's vacation) and that inshore fishermen fish (catching groundfish and other species) for a total of ninety-five days per year (see the discussion on page 136), or about twenty-eight percent of the eleven-month working year of the offshore fishermen. The man-year equivalent employment therefore consists of the number of offshore fishermen required in the simulation plus twenty-eight percent of the number of inshore fishermen required. The range of variation when employment is measured in man-years is really quite small.

The economic surplus (or loss) figures are generally rather insensitive to minor errors in the data. In most cases, for instance, an error of one hundred thousand dollars or more in the estimate of total cost for all vessels in a particular simulation will have virtually no effect on the estimate of the surplus. The results are, however, sensitive to substantial changes in the assumed opportunity cost of labor, a problem to which we referred above. To add a few numbers to our earlier discussion, let us assume an opportunity cost of zero for labor, and use as illustrative examples the simulations referred to on lines 3. and 18. of the table of Social Economic Loss and Employment. To dramatize the effect of the zero opportunity cost assumption, we choose examples involving only handlines in the inshore fishery, this gear type being the most labor intensive. The economic surplus associated with the use of handlines on motor boats (the case of line 3.) rises from a low of -$2.31 to +$0.71 per dollar of fish sold. This change from an extreme loss to an equally extreme surplus (mathematically the surplus cannot exceed $1.00) is easy enough to account for since the labor intensive handline fishery has an exceedingly low capital cost. With labor costs assumed away, revenues become almost pure profit. Our earlier reference to an inshore fishery consisting only of men jigging from rafts describes a hypothetical (and ridiculous) situation that generates even lower capital costs and a higher surplus than the handline simulation of line 3.

For the extended analysis of line 18., the loss falls from a total of $1.78 per dollar of revenue when our estimate of the opportunity cost of labor is used to almost zero. Therefore, adopting the scenario of inshore fishermen, with zero opportunity cost, jigging for cod, and medium-sized trawlers, again employing labor with a zero opportunity cost, using an optimal distribution of gear, the fish harvesting sector would be at a "social" break-even point. With strong implications such as these resulting from a change in the assumption of the opportunity cost of labor, it is obviously only with great care that this figure should be manipulated.

While we do not summarize the figures here, Tables 7 and 12 also present estimates of the actual incomes from groundfish operations that accrue to Newfoundland fishermen for each of the scenarios included in the study. These figures are based upon the institutional structure prevalent in the Newfoundland fishery in 1978.

Conclusions

Our conclusions reflect on the relative economic efficiencies ("cost-effectiveness") of alternative gear-vessel combinations as well as on the desirability of certain government policies.

Concerning the choice of gear and vessel, it is clear from our results that gillnets, as their use is presently structured, are an inefficient fishing gear, as are handlines. Cod traps are effective over a very short season but, given their cost and the need for alternative equipment during the non-trap season, they are reasonably cost-effective but not dramatically more so than other techniques. They are more effective combined with longlines during the non-trap season than with the more usual gillnets. Longlining is a cost-effective method of cod fishing and trawling from even the smallest longliners is a very cost-effective technique where the physical state of the ocean bottom is such that trawling is feasible. Concerning the offshore sector, it seems that intermediate-sized trawlers would be more effective than they are if greater use were made of midwater trawls for redfish.

Concerning vessels, the capital cost grows so substantially as vessel size increases that there is virtually a direct trade-off between the use of cost-effective gear on small boats and trawlers. Large vessels are not in general more economical than small vessels. Small boats require many fishermen but involve low capital costs while trawlers require relatively few fishermen for a specified catch but large capital expenditures.

The economic surplus (actually loss) generated from the use of the optimal gear on small boats and small longliners is virtually the same as that for middle-sized trawlers, given a specified catch. We have doubts about the cost-effectiveness of the largest Newfoundland wetfish trawlers because of their huge cost but for statistical reasons mentioned in the text we hesitate to make any strong statements concerning these vessels.

We do not hesitate, however, to state that intermediate-sized longliners seem hopelessly expensive for the groundfishery. While their flexibility in pursuing groundfish and other species may make them desirable, the economic losses associated with their use in the groundfishery alone are far greater than those associated with the other types of vessels which we consider. One reason for their inefficiency seems to be that they are generally overloaded with electronic gear which requires extensive maintenance and drives the operating costs up. Perhaps these vessels could be more cost-effective if their auxiliary gear were more carefully chosen and the skippers were given special training. But the historical record of these vessels in the groundfishery is poor.

Large longliners are not much different in their cost-effectiveness than the small boats and trawlers. From the standpoint of the groundfishery they have no startling cost or productivity advantages. Once again, their versatility in catching non-groundfish species may make them desirable.

Our scenarios permit either a small inshore fishery accounting for twenty percent of the total cod caught or a large inshore fishery accounting for eighty percent of cod. On the assumption that both possibilities are feasible (and the latter is, in fact, the current situation), we find that the social economic loss is essentially the same regardless of which option is chosen.

Inclusion of social overhead capital in our calculations might have changed this result but the direction of any such change is purely speculative and we neglect it. Another characteristic of the fishery which has an economic effect on the inshore-offshore decision but which we neglect is the structure of fish plants throughout the island. Offshore operations require relatively few large plants while inshore operations have traditionally required substantial numbers of small plants which are inoperative for much of the year. The recently proposed Harbour Grace distribution center could alter these relationships considerably. Throughout the present study, considerations of fish plant economics are omitted.

Within the framework in which we are working, the decision between inshore and offshore options for cod depends on the government's evaluation of the relative labor requirements of each option. More fishermen would be required if there were to be a heavy emphasis on the inshore sector but, of course, the fishing season would be short for the inshore fishermen. In our table of Social Economic Loss and Employment, we present figures for both the men per year required for the fishery under alternative options and the man-year equivalents. While the inshore option substantially increases the number of fishermen per year, the increase in man-years is very modest.

While emphasis on the inshore option will serve to increase the part-year employment of Newfoundlanders by several thousand men, it is virtually impossible, without enormous economic losses, for the fish harvesting sector of the Newfoundland economy to have a serious effect on the unemployment problem of the province. Our analysis is based upon historical data for 1973-78 with particular emphasis on catch, cost, and revenue for 1978. It seems to us that, even with the dramatic increases in fish catches foreseen for the medium-term future, a substantial proportion of the thirty thousand unemployed Newfoundlanders will not be absorbed into the fish harvesting sector. Even a fishery with a large inshore sector consisting of motor boats and jiggers requires (for 1978 catch levels) no more than seventeen thousand fishermen, only about six thousand more than our hypothetical optimal fishery (see Table 6 for details). This handline fishery would require a subsidy of $1.78 per dollar of revenue from fish sales while the subsidy from the optimal fishery is "only" $1.12.

These last figures illustrate another conclusion of the study. We can conceive of no way in which the 1978 harvest could have been taken without extensive subsidies. We doubt very much that this situation will change in the foreseeable future without reductions in fishing effort so drastic as to be politically unfeasible. Unless fish populations rise dramatically, even more than currently seems to be expected, the harvesting sector will continue to take losses which must be financed either through government subsidies or through cross-subsidies of integrated harvesting-processing operations.

Finally, it should be very clear that we have been severely hampered by data restrictions and limitations in the state of the art in both economics and biology. The government must recognize the need for greater independent research in the fishery, must gather and release additional data, and must actively encourage research into the biological and economic aspects of the fishery.

Outline of the Study

In Chapter II we present the estimated equation used to determine the average catch per unit effort of various gear and vessel combinations as well as the relative catch productivities derived from the equation. The Appendix to Chapter II includes a more detailed regression analysis of the small boat fishery.

The economic analysis is presented in Chapter III. Section III.a explains the objectives and procedures of the analysis, Section III.b discusses the data, and Section III.c presents the results of the restricted analysis. The Appendix to Section III.c presents a comparison of our results with those obtained in the provincial government's Setting a Course. The extended analysis is presented in Section III.d

Conclusions and policy implications are presented in Chapter IV, followed by a list of references in Chapter V.

The main text is followed by four appendices. In Appendix 1, we present a complete table of relative productivities between gear-vessel combinations. This table is an elaboration of material originally presented in Chapter II. In Appendix 2, we further explain the method adopted in Chapter II, demonstrating the deficiencies of the conventional method of obtaining relative productivities. Appendix 3 consists of a table showing the details of the 1978 Newfoundland groundfish catch by gear type and vessel class.

Finally, Appendix 4 consists of worksheets showing the calculations used in the restricted analysis discussed in Section III.c and Appendix 5 presents similar worksheets for the calculations used in the extended analysis of Section III.d. Appendix 4 starts with a description and explanation of the calculations appearing in the last two appendices, along with details of the data sources and specific assumptions concerning the calculations.

II. Relative Productivity of Selected Gear and Vessel Combinations

II. a. Model

The purpose of this study is to compare the differential costs and revenues and the economic surpluses associated with particular gear-vessel combinations. To satisfy this objective requires that we first determine the appropriate amount of effort that must be expended when the fishing technique under consideration is used to catch the specified quantity of fish. We compare a wide variety of gear and vessel types and it is useful to standardize the effort required from each.

We estimate the relative productivity of different gear-vessel combinations with a descriptive model which relates the catch per unit effort of specific fishing techniques to some of the factors which affect this productivity. The most appropriate model for our purposes would involve cross-section analysis incorporating various aspects of fishing technique. For instance, with suitable micro data, we could obtain fairly large samples with observations on catch, effort, vessel length, vessel horsepower, trawl lengths, etc. While a consistent set of such data could be obtained from the federal Department of Fisheries and Oceans, problems of confidentiality arise and we have not pursued this approach.[4]

In the absence of suitable micro data, we obtain the productivity weights from a pooled sample of cross-section and time-series data for 1973-78.[5] The model which we use is:

[4] For an example of a study of this type, see Carlson (1970).

[5] For similar regression models, see Robson (1966) and Sissenwine and Bowman (1978).

$$(1) \quad ln\left(\frac{Q}{E}\right)_{ijkmst} = \alpha + \sum_i \sum_j \delta_{ij} T_{ij} + \sum_k \gamma_k R_k + \sum_s \beta_s S_s + \sum_m \eta_m M_m + \sum_t \xi_t Y_t$$

where:

$(Q/E)_{ijkmst}$ = Catch (in metric tons) of groundfish[6] per day fishing[7] for vessels of the i^{th} gear type and j^{th} tonnage class in the k^{th} ICNAF division, m^{th} month of the t^{th} year when the main species is the s^{th}.[8]

[6] When a particular gear-vessel combination is used to catch groundfish, there is usually a "main species" that dominates the catch with smaller bycatches of other species. It is possible that for each distribution of catch by species there is a different relative catchability associated with each gear-vessel combination. To simplify the analysis, we ignore the bycatch problem. In addition, while we permit the main species to affect catch per unit effort, we assume that changes in the main species will not alter the relative productivity of different gear-vessel combinations. We therefore avoid the use of cross-product dummy variables that would severely reduce the number of degrees of freedom in our estimating equation.

[7] Days fishing is the variable adopted throughout this paper to represent effort since the most consistent effort series is of this form.

[8] Division, month and year dummy variables are included to account for the effects of differences in the density of fish populations over time and space. The main species dummy variable is included for the reason indicated in footnote 6.

T_{ij} = Dummy variable representing the i^{th} gear type and j^{th} tonnage class.[9,10]

R_k = Dummy variable representing the k^{th} ICNAF division

S_s = Dummy variable representing the s^{th} main species.

M_m = Dummy variable representing the m^{th} month.

Y_t = Dummy variable representing the t^{th} year.[11]

The model (equation 1) permits the computation of average catch per unit effort figures controlling for the effects of varying fish population densities. It is the estimated catch per unit effort obtained from this equation that we use to compute the effort required for the economic analysis.

[9] All dummy variables are defined in a similar way. For instance T_{13} is a dummy variable that takes the value of one when the vessel of tonnage class 3 uses gear type 1 and the value zero otherwise. Gear types and tonnage classes are defined in Table 1 (page 45).

[10] We also experimented with the use of actual average tonnage of vessels in a gear type-tonnage class category for a particular year. There is, however, so little variation in the average tonnage figures over time that there is no observable gain from using actual tonnage. In addition, there are no reliable average tonnage figures available for vessels of less than fifty tons. We therefore adopt the more convenient dummy variable form.

[11] We attempted to use measures indicating the quality of the fishing year. Specifically, we experimented with functions of the moving average of annual catch. Since these experiments were unsuccessful, we adopt the simple expedient of using binary dummy variables to indicate years.

Switching our focus to the relative productivity between two gear types (net of changes in fish population densities and species), equation (1) implies:

$$(2)\qquad \frac{\left(\frac{Q}{E}\right)_{ijkmst}}{\left(\frac{Q}{E}\right)_{qrkmst}} = \frac{e^{\alpha}\, e^{\delta_{ij}}\, e^{\gamma_k}\, e^{\beta_s}\, e^{\eta_m}\, e^{\xi_t}}{e^{\alpha}\, e^{\delta_{qr}}\, e^{\gamma_k}\, e^{\beta_s}\, e^{\eta_m}\, e^{\xi_t}}$$

and, therefore,

$$(3)\qquad \frac{\left(\frac{Q}{E}\right)_{ij}}{\left(\frac{Q}{E}\right)_{qr}} = \frac{e^{\delta_{ij}}}{e^{\delta_{qr}}} = \theta_{ijqr}\,, \qquad \text{which is}$$

the desired relative productivity weight. By choosing a particular qr combination (i.e., gear type and tonnage class) as base, we obtain a set of unique weights which can be used to compare the productivity of one fishing technique with another. These comparisons are considered in Table 3 and in Appendices 1 and 2.

II. b. Data

The parameters of the regression equation are estimated from a sample of 3867 observations. The primary data source is the ICNAF Statistical Bulletin, published annually, which provides monthly fishing effort and catch data for specific gear types in each tonnage class by ICNAF division and main species. Effort data for vessels of ten to twenty-five tons are not published by ICNAF but were provided to us by the St. John's office of the Department of Fisheries and Oceans. In addition, we developed a set of equivalent values for vessels of less than ten tons by sampling the receipts issued by fish plants to the small boat operators. For ten widely dispersed locations in Newfoundland for 1978, we recorded data for all trips for all vessels selling fish in that location over a specified period of time. Where fishing activity was fairly limited, we recorded all fishing activity over the year. Where fishing activity was heavy, particularly during the peak summer months, we recorded observations for the middle two weeks of the peak months. This procedure permitted us to observe effort and catch data for the full range of gear types that were used by small boat operators in each of the locations sampled. The sampling procedure generated 3872 observations, each representing one day fishing for groundfish with a single gear type. In fact, four gear types were used with small boats: gillnets, cod traps, longlines, and handlines.[12]

II. c. Results

The results of the multivariate regression are highly satisfactory. The pooled sample of nearly four thousand observations results in an R^2 of 0.631, relatively high for this type of analysis. The estimated coefficients are of reasonable magnitude and most have very high t-statistics.

[12] The ICNAF data for 1973-76 were obtained on tape for vessels of 25 tons and over from Mr. V.M. Hodder of ICNAF. Through the efforts of Mr. L. Feltham of the St. John's office of Fisheries and Oceans, we were able to supplement the original tape with data for 1977 and 1978 and to incorporate effort data for 1975-78 for vessels of 10-25 tons onto the tape. Finally, data for vessels of less than 10 tons for 1978 were added through the sampling procedure described in the text. Mr. Eric Dunne of the St. John's office of Fisheries and Oceans kindly authorized the sampling process. In summary, the data used in the regression analysis relate to vessels of 25 tons and over for 1973-78, to vessels of 10-25 tons for 1975-78, and to vessels of less than ten tons for 1978 alone. In fact, although 3,872 daily observations were noted for the small boats, when aggregated to a monthly basis for consistency with the ICNAF data, the small boats data added only 38 observations to the sample. We also estimated a regression equation for the daily

(cont'd)

As anticipated, larger vessels with a particular gear type have higher catches per unit effort than smaller vessels.[13]

With redfish taken as datum, catch per unit effort is relatively low for cod and lower still for flatfish. That redfish catch productivity is high is not surprising since redfish were relatively under exploited in the late 1960's and early 1970's and high catch per unit effort is expected in such cases.

The winter fishery is reputed to be highly productive and our results support this contention. With summer months taken as datum, the months of January to March enter the equation with statistically significant positive coefficients, implying higher catch per effort as expected. Similarly, the fall months reflect relatively low productivity.

Spatial effects are relatively insignificant, according to our analysis, with catch productivity relatively high in the Gulf of St. Lawrence Division 4S and low in South Coast Division 3P. Otherwise, no regional effects are significant.

12 (cont'd)
small boat operations but, as might be expected with micro data, only about twenty percent of the variation in catch per unit effort was accounted for by the limited number of variables in the regression equation. Presumably skill differences among fishermen, weather conditions, quality of trap berths and similar variables must be considered at this level of disaggregation.

13 The only exception occurred with Danish seines of tonnage class one (10-25 tons). We suspect that in this case there are data problems in the computation of effort and in the final run, for which results are reported in Table 2, observations for this gear type and tonnage class were omitted.

The only statistically significant year effects are positive values in 1973 and 1978. The fishery in 1973, the first year of our sample, experienced low catches but very high net financial returns (Fisheries and Marine Services, 1976, p. 39). High returns with low catches suggest high prices and/or high catch per unit effort. The former is certainly true; our results suggest that the latter is true as well. 1978 is well known to have been a superb year. Thus, our results in this regard are reasonable.

Summarizing our multivariate regression results, spatial effects on catch per unit effort seem slight. Temporal effects are more important, with strong seasonality favoring the winter months and good fishing years standing out.

In the next section, we place considerable emphasis on the economics of the inshore fishery. In this context, it is of interest to compare the relative productivities of longliners equipped with various gear types. In particular, recent experiments have been performed concerning the feasibility of introducing pair trawling to the Newfoundland inshore groundfishery. Pair trawling is essentially a technique whereby two longliners pair up to pull a trawl. Almost all of our tonnage class one and two vessels are longliners;[14] these vessels are used with the following types of gear:

[14] In fact, there may be a few large trap boats grouped with the smaller longliners. We assume that any errors introduced from this source are small.

1) Bottom otter trawls
2) Gillnets
3) Longlines
4) Handlines
5) Cod traps
6) Pair trawls [15]

Using the highly inefficient handlines as a base, the following table shows the relative productivity of the various gear types that are used with longliners.

Relative Productivity: Tonnage Class One Vessels (10-25 Tons)

Handlines	1.00
Longlines	1.44
Gillnets	1.52
Pair Trawls	1.71
Cod Traps	2.12
Bottom Trawls [16]	2.34

There are two particularly interesting conclusions to be drawn from this table. First, we find that in this tonnage class, the pair trawl is more productive than longlines, gillnets and handlines, although it is less productive than bottom trawls and cod traps. Second, gillnets are

[15] In addition, Danish seines are used with these vessels. Since our results for this type of equipment are questionable, Danish seines are excluded both from this discussion and from the economic analysis later in the paper.

[16] It is possible that only vessels at the upper size limit of tonnage class 1 use bottom trawls, while handline activity is concentrated on the smaller vessels in this class. Therefore, the difference in productivity of 2.34 between these gear types may reflect primarily differences in vessel size rather than differences in gear type.

only about 6% more productive than are longlines. The second result suggests that the "gillnet revolution" of several years ago, in which gillnets were substituted for longlines because of increased productivity (but with a substantial loss in fish quality), was not an entirely beneficial process.

Several additional points need to be made regarding this comparison between gillnets and longlines. First, in this section of the paper, we have not included economic considerations in the analysis. Although we shall later base our conclusions on the differential costs and revenues associated with different gear types, here we are concerned only with physical characteristics. In fact, the economic analysis reinforces the case in favor of longlines over gillnets. Second, it is possible that when gillnets were first introduced they were highly productive but their productivity fell off when large numbers of them were used in relatively small inshore areas. We may be observing a "crowding" effect that could be eliminated, and gillnets restored to high productivity, if the number of gillnets were reduced. Finally, we assume that the relative catch productivities between gear types and tonnage classes do not change over time and space. To test this assumption, and particularly to test whether longlines are more productive than gillnets in certain seasons and less productive in others, we report the results of a regression analysis of vessels of tonnage class zero (motor boats and trap boats) in the Appendix to Chapter II. The results reported there support our assumption.

As a further comment on pair trawls, when vessels of tonnage class two are considered, then only handlines and gillnets are less efficient than pair trawls. Our evidence suggests that a very careful look must be taken at pair trawling before it is introduced into the Newfoundland groundfishery.

Finally, we note the relative productivities of the gear types used with small boats, again normalizing on handlines.

Relative Productivity: Tonnage Class Zero Vessels (Less than 10 Tons)

Handlines	1.00
Gillnets	1.48
Longlines	1.65
Cod Traps	2.97

Here the advantage of the cod traps is even more pronounced than in the case of tonnage class one vessels and the gillnets are not only no longer more productive than longlines but are actually eleven percent less productive than longlines.

TABLE 1

GEAR TYPES*

Code	Description
1.	Bottom Otter Trawls, Side
2.	Bottom Otter Trawls, Stern
3.	Midwater Otter Trawls, Side
4.	Midwater Otter Trawls, Stern
5.	Danish Seines
7.	Gillnets (set)
8.	Longlines (set)
10.	Handlines
11.	Cod Traps
12.	Bottom Pair Trawls

TONNAGE CLASSES

0.	< 10	tons	(motor boats and trap boats) 18'-22' 22'-39'
1.	10-24.9	tons	(small longliners) 35'-45'
2.	25-49.9	tons	(intermediate longliners) 52'-55'
3.	50-149.9	tons	(large longliners) 65'
4.	150-499.9	tons	(trawlers, 120'-129')
5.	≥ 500	tons	(trawlers, ≥145')

*Codes 6. and 9. are omitted from this table and the remainder of this paper. They indicate purse seines and longlines (drift), respectivity, gear that play no significant role in the Newfoundland groundfishery.

TABLE 2

Results of the Multivariate Regression Analysis**

$$\ln\left(\frac{Q}{E}\right)_{ijkmst} = \alpha + \sum_i \sum_j \delta_{ij} T_{ij} + \sum_k \gamma_k R_k + \sum_s \beta_s S_s + \sum_m \eta_m M_m + \sum_t \xi_t Y_t + \varepsilon_t$$

i.j	$\hat{\delta}_{ij}$	i.j	$\hat{\delta}_{ij}$	i.j	$\hat{\delta}_{ij}$	i.j	$\hat{\delta}_{ij}$	k	$\hat{\gamma}_k$	m	$\hat{\eta}_m$	t	$\hat{\xi}_t$
1.1	-.492 (.114)	5.2	-.162 (.062)	8.4	.762 (.386)	12.2	-.544 (.239)	3K	-.093 (.048)	JAN	.144 (.050)	73	.162 (.035)
1.2	-.392 (.056)	7.0	-2.003 (.239)	10.0	-2.400 (.239)			30	-.092 (.060)	FEB	.167 (.047)	76	.050 (.029)
1.4	.680 (.042)	7.1	-.922 (.055)	10.1	-1.345 (.091)	S	β_s	3Pn	-.097 (.039)	MAR	.153 (.046)	78	.122 (.030)
2.4	.724 (.056)	7.2	-.659 (.057)	10.2	-1.145 (.135)	*C	-.157 (.033)	3Ps	-.159 (.031)	APR	.066 (.039)		
2.5	.983 (.042)	7.3	-.152 (.098)	11.0	-1.311 (.387)	*F	-.320 (.033)	4R	.058 (.033)	OCT	-.174 (.039)		
3.4	1.005 (.139)	8.0	-1.894 (.158)	11.1	-.593 (.083)			4S	.194 (.064)	NOV	-.111 (.042)		
4.4	.978 (.078)	8.1	-.980 (.066)	11.2	-.272 (.089)								
4.5	1.588 (.059)	8.2	-.448 (.064)	12.1	-.807 (.189)								

* C = cod; F = flatfish

**

1) Standard errors are shown in parentheses.
2) The symbol "ij" represents vessels of gear type i, tonnage class j. Thus, i.j=12.1 represents bottom pair trawl vessels of 25-49.9 tons. See page 45 for descriptions.
3) All non-gear variables omitted from this table were statistically insignificant and were therefore omitted from the final regression calculations.

$\hat{\alpha}$ = 1.1

n = 3867

R^2 = 0.63

TABLE 3

Relative Productivity Weights Derived Directly from Table 2*

Gear Type - Tonnage Class (i.j)	Weight ($e^{\hat{\delta}_{ij}}$)	Gear Type - Tonnage Class (i.j)	Weight ($e^{\hat{\delta}_{ij}}$)
1.1	.611	7.3	.859
1.2	.675	8.0	.150
1.3	1.000	8.1	.375
1.4	1.972	8.2	.639
2.2	1.000	8.3	1.000
2.3	1.000	8.4	2.142
2.4	2.062	10.0	.091
2.5	2.673	10.1	.261
3.4	2.732	10.2	.318
4.3	1.000	11.0	.270
4.4	2.660	11.1	.553
4.5	4.902	11.2	.762
5.2	.850	11.3	1.000
5.3	1.000	12.1	.446
7.0	.135	12.2	.580
7.1	.397	12.4	1.000
7.2	.517		

* See page 45 for gear and vessel descriptions. The relative productivity weights are defined on page 38. Those gear types with weights equal to 1.000 collectively act as the "base" for computing the remaining weights. See the discussion on page 38 and the notes on page 48.

Notes to Table 3

1) The weights in Table 3 are normalized in terms of the results for gear types one, two, four, five, eight, and eleven in tonnage class three and gear type two, tonnage class two. There are numerous observations in the sample for these categories and their lack of significance in a regression equation including only binary variables in the regressor set suggests that they act as datum. They are, accordingly, treated as such.

2) There are very few observations for each of the following gear type-tonnage classes. They are therefore omitted from the final regression equation.

i.j	Number of Observations
1.5	2
3.2	1
3.3	1
7.4	1
12.3	2

3) Gear type-tonnage class 12.4 is represented by four observations and is statistically insignificant, suggesting that bottom pair trawlers of tonnage class four are no more productive than the tonnage class three vessels that establish the datum. This result seems reasonable. We suspect that the four observations were generated by an unsuccessful experiment. Two class-four vessels sharing a trawl would have to catch a huge quantity of fish per trawl to have a catch productivity comparable with a single class four trawler working alone.

4) There are no observations for the gear type-tonnage classes that appear in neither the body of Table 3 nor the notes.

Appendix to Chapter II

The productivity results shown in Table 2 do not take into account the variations in the relative productivity between two gear types that may occur from one month to another and from one ICNAF division to another. The productivity analysis reported there is of a nature that yields only a single (average) relative productivity measure between gear types.

To investigate the possible effects of spatial and seasonal elements on the relative productivities of gear types used on tonnage class zero vessels (small boats), we reestimate equation (1) with the addition of cross-product terms for gear type, month and fishing division. The regression is run only for tonnage class zero vessels because much more data are available for this class than for the others. Data (3872 observations) for tonnage class zero vessels for 1978 (with cod accounting for more than 97% of the catch) are used in this regression, and all relevant gear types - cod traps, gillnets, longlines, and handlines - are included. Our primary interest is the comparison of gillnet and longline productivity. The revised equation is:

$$\text{(1')} \qquad \ell n \frac{Q}{E} = \alpha_o + \sum_g \alpha_g GT_g + \sum_k \gamma_k R_k + \sum_m \eta_m M_m + \sum_g \sum_k \sum_m \phi_{gkm} GT_g R_k M_m ,$$

where: Q/E = catch per unit effort

GT = binary dummy variable representing specific gear types

R = binary dummy variable representing ICNAF fishing division

M = binary dummy variable representing month

The results of equation (1') should be compared with those on page 45 above. The table on page 45 shows the relative productivity of various gear types as derived from the results of equation (1) and demonstrates that longlines are somewhat more productive than gillnets. We show later in this study (Table 7) that when economic considerations are taken into account, the cost-effectiveness of longlines is far superior to that of gillnets. We now present evidence to demonstrate that the introduction of explicit spatial and seasonal effects do not substantially change our results.

Table 4 shows the regression results when equation (1') is fit for small boats (i.e., motor boats and trap boats) and when the cross-product terms referred to above are included in the equation.

Gillnets are taken as the datum. Longlines are clearly more productive than gillnets and cod traps are more productive still. These basic results agree with those of the table on page 45. Catches are significantly higher, on the average, in January and March than in the remaining months. It should be noted, however, that only longlines are used by fishermen during these months. In addition, there are statistically significant coefficients only for divisions 3Pn and 3K, with productivity higher in the former and lower in the latter than in other areas. It also should be noted that only longlines, and not gillnets, are used in division 3Pn. Several gear types are used in division 3K. Clearly, the increased productivities during the winter months and in division 3Pn reflect the effects of both fish populations and the use of longlines. We attribute, however, the full effect of these variables to fish population, thus biasing our results against longlines. Despite this bias, the evidence shows overwhelmingly that longlines are more productive than gillnets when these types of gear are used with small boats.

It is very difficult to obtain direct pair-wise comparisons of productivity between gillnets and longlines because these gear types are rarely used in the same ICNAF division, much less in the same month in the same division. There are, however, four month/division combinations where both gillnets and longlines are used: divisions 3K and 3L in August; and divisions 3L and 3Ps in July. It is clear from Table 5, where catch per day fishing is shown, that in each case the longlines are substantially more productive than gillnets. This result is most interesting because there is a heavy emphasis on gillnets in division 3L (which includes the Avalon Peninsula). Our initial results, which showed longlines as being more productive than gillnets, are, if there is any change at all, strengthened by the results reported here.

TABLE 4

Parameter Estimates Computed from Equation (1') for Small Boats*

Intercept	6.061
Longlines	.468
Cod Traps	1.132
January	.522
March	.195
DV3K	- .462
DV3Pn	.280
GN2JJul	- .451
GN3LJul	.435
LL3LJun	.515
LL3LJul	.899
LL3PnMay	- .640
LL3PnJul	-1.520
LL3PnAug	-1.116
LL3PnOct	- .618
LL3PnNov	- .162
LL3PsOct	.723
HL2JJul	- .439
HL2JSep	- .639
HL3LJun	.607
HL3LAug	.350
HL3LOct	1.233
HL3PnJul	-2.018
CT3KJul	.284

$R^2 = 0.49$

Definitions of Symbols

DV = ICNAF Division
GN = Gillnets
LL = Longlines
HL = Handlines
CT = Cod Traps

As an example, the entry "HL3PnJul -2.018" means that the estimated coefficient in equation (1') for the cross-product term for handlines in division 3Pn in July is -2.018.

*All estimates shown are significant at the 5% level.

TABLE 5

Catch Per Unit Effort for Small Boats by Fishing Division, Month, and Gear Type for 1978

Gear Type	2J	3K	3L	3Pn	3Ps	Month
Gillnets	-	-	-	-	-	January
Longlines	-	-	-	1527 (40)	-	
Handlines	-	-	-	-	-	
Cod Traps	-	-	-	-	-	
Gillnets	-	-	-	-	-	February
Longlines	-	-	-	906 (31)	-	
Handlines	-	-	-	-	-	
Cod Traps	-	-	-	-	-	
Gillnets	-	-	-	-	-	March
Longlines	-	-	-	1101 (148)	-	
Handlines	-	-	-	-	-	
Cod Traps	-	-	-	-	-	
Gillnets	-	-	-	-	429 (1)	April
Longlines	-	-	685 (1)	906 (289)	-	
Handlines	-	-	-	-	-	
Cod Traps	-	-	-	-	-	
Gillnets	-	-	429 (10)	-	429 (6)	May
Longlines	-	-	-	478 (281)	-	
Handlines	-	-	429 (3)	-	429 (1)	
Cod Traps	-	-	-	-	-	
Gillnets	-	-	429 (150)	-	-	June
Longlines	-	-	1146 (20)	-	-	
Handlines	-	-	786 (11)	-	-	
Cod Traps	-	-	1330 (171)	-	-	

TABLE 5 (cont'd)

Gear Type	2J	3K	3L	3Pn	3Ps	Month
Gillnets	273 (30)	270 (48)	662 (404)	-	429 (4)	
Longlines	-	-	1682 (49)	198 (65)	685 (20)	July
Handlines	276 (47)	270 (43)	429 (2)	75 (5)	429 (33)	
Cod Traps	-	1113 (195)	1330 (267)	-	-	
Gillnets	429 (19)	270 (1)	429 (11)	-	-	
Longlines	-	431 (97)	684 (318)	296 (57)	685 (27)	August
Handlines	429 (124)	270 (33)	608 (62)	-	-	
Cod Traps	-	838 (4)	1330 (31)	-	-	
Gillnets	429 (10)	-		-	-	
Longlines	-	-	684 (181)	-	-	September
Handlines	226 (30)	-	-	-	-	
Cod Traps	-	-	-	-	-	
Gillnets	-	-	-	-	-	
Longlines	-	431 (5)	684 (46)	488 (172)	1411 (10)	October
Handlines	-	270 (2)	1471 (18)	-	-	
Cod Traps	-	-	-	-	-	
Gillnets	-	-	-	-	-	
Longlines	-	-	-	770 (175)	685 (2)	November
Handlines	-	-	429 (1)	-	-	
Cod Traps	-	-	-	-	-	
Gillnets	-	-	-	-	-	
Longlines	-	-	-	906 (62)	-	December
Handlines	-	-	-	-	-	
Cod Traps	-	-	-	-	-	

a) - = No observations

b) (...) = Number of observations

c) Main entry = Catch per day fishing per vessel (in pounds)

d) These results are computed from the estimates of equation (1').

III. Economic Analysis

III. a. Objectives and Procedures

In this section, we present the surplus of revenues over costs obtained when given quantities of groundfish are caught by alternative fishing techniques.[17] Our basic procedure is to take an assumed fish catch and, applying the estimated parameters obtained from the relative productivity regression reported in the previous section, determine the total effort (in days fishing) required to obtain that catch using different techniques. The total revenue is determined by evaluating the catch at the unit price appropriate to the gear type. Total costs are the sum of the fixed non-capital and non-labor operating costs associated with the specific gear-vessel type combination, gear and vessel capital costs amortized over the expected life of the equipment at a real interest rate of three percent (to abstract from inflationary effects), and labor evaluated at its opportunity cost.

All gear and vessel capital costs are valued at suppliers' prices so that costs are not affected by any subsidies. In essence, we determine the surplus in terms of social rather than private costs. The surplus, so conceived, provides a basis for determining the cost-effectiveness of various fishing techniques and therefore suggests preferable methods which can be

[17] For studies concerned with problems similar to those faced in this paper, but substantially different in detail, see Bell (1970), Cleary (1970), Green and Broadhead (1965), Noetzel and Norton (1969), and Urion (1977). Cleary's analysis includes a consideration of Newfoundland vessels based upon Proskie's data.

encouraged by licensing, quota, subsidy or tax programs. In the inshore/offshore comparisons, it should be noted that we have made no attempt to calculate the value of the social overhead capital required to provide the necessary infrastructure for the desired techniques. If, as Copes (1964, 1969) has maintained, the social overheads are far higher in the inshore than in the offshore fisheries, then the results presented below, in the extended analysis, are biased in favor of the inshore techniques.

In addition, we make no attempt to incorporate into the calculations the implications for the processing sector of alternative harvesting technologies. It is sometimes claimed (Munro, 1980) that the inshore fishery, being predominantly seasonal, requires investment in processing capacity which remains unused much of the year. The cost of installing and maintaining this excess capacity, so the argument goes, must be allocated to the inshore fishery since it is only because of the peak-load problem induced by the seasonal inshore catch that the additional capacity is required. Our neglect of these costs is again a source of bias in favor of the inshore fishery.

Three variables, with two degrees of freedom, play key roles in the calculations. These are catch by species, the number of vessels used, and the number of days fishing per vessel per year. We take the number of days fishing per vessel per year as given, determined by weather conditions and fish migration patterns. From the relative productivity equation, we have a relationship between the catch and effort, and with the length of season determined, we can arbitrarily peg either the catch or the number of vessels and use the productivity equation to determine the other. We have pegged catch rather than the number of vessels for the following reason.

Our fundamental problem is to evaluate the cost-effectiveness of alternative fishing techniques. The methods used in this paper are essentially static, preventing effective incorporation of fish population constraints into the analysis. If we were to hold the number of vessels constant and solve for the resulting catch, the more productive techniques might generate catches considerably in excess of the actual 1978 catch. For us to accept this result, implies that we believe that the fish population constraint is not effective; that is, that the fish were there to be caught in 1978 but that they were not caught because of the particular types of equipment that fishermen were using. This conclusion might be valid but we have no evidence on the subject. Alternatively, by holding catch constant and determining the required number of vessels, we avoid problems arising from our neglect of limited fish populations.

In the restricted analysis presented below, the actual 1978 catch by species by vessel type is taken as a datum and the actual surplus generated by taking that catch with the mix of gear types actually used is compared with the hypothetical surplus that would have been generated by taking that catch with alternative gear types mounted on the same type of vessel.[18]

[18] We base these calculations on the actual 1978 catch and on the gear types used in that year. The effort figures utilized in making the calculations are not the actual effort figures but rather those implied by the results of the relative productivity equation. We use the estimated rather than the actual effort figures for two reasons. First, we compare the actual distribution of catch by gear type with hypothetical distributions for which, of course, there are no actual effort figures. To keep the two sets of results comparable, effort derived from a single source is required. Second, although we are basing the analysis on 1978 catches, costs, and revenues, we want to abstract from the analysis any aberrations concerning fishing techniques which are unique to that year.

The coverage of this analysis is fairly complete, with a substantial number of gear options being considered.

In the extended analysis, the restriction on the catch by vessel type is removed and the entire 1978 groundfish catch is reassigned to alternative combinations of types of vessels. There are, of course, an infinity of interesting combinations of catch distributions by gear and vessel type that can be considered.[19] In the absence of an optimizing procedure, we must severely limit the number of options considered. Using the results of the restricted analysis, we determine those techniques which generate the highest surplus. In the extended analysis, we use the more efficient techniques to compute the surplus for a variety of inshore/offshore distributions.

We present in Appendices 4 and 5,[20] one table for each distribution of the assumed catch by a particular gear-vessel combination. First, special assumptions relating to the case under examination are listed. Second, revenues and required effort are shown with catch, catch per unit effort, required effort, unit price, and revenue, each indicated

[19] There are, of course, some restrictions concerning vessel type. Unless we assume that all the offshore fish migrate inshore (a poor assumption for cod and a ridiculous one for redfish), it is senseless for us to assign the entire catch to the inshore fishery.

[20] The symbols used in these tables are explained in Table A4-1.

by species and by gear type. Below this subtable appear figures for total required effort and total revenue generated by the particular distribution of gear types considered, as well as a computation of the number of vessels required.

Third, costs are indicated, with unit and total labor costs, fixed non-capital costs (e.g., marine insurance), operating costs (subdivided into fuel, vessel maintenance, and miscellaneous categories), and capital costs of gear and vessels each specified. The sum of all costs (i.e., the total annual cost of obtaining the specified catch with the indicated technique) appears below the individual costs.

Fourth, the surplus (i.e., the difference between revenues and costs, divided by revenues) is computed with three treatments of vessel (but not gear) capital costs for the smaller vessels and two treatments for the larger vessels. In the first instance, the full vessel cost is amortized and the resulting figure is included with annual costs. Implicitly, the assumption made is that new vessels are to be built and the full cost is to be charged to the groundfishery. In the second case, capital costs for vessels are excluded entirely. The total cost in this case presupposes a situation where there are laid up fishery vessels which have zero opportunity cost. We assume throughout that vessels below fifty tons are used for the mixed groundfish-pelagic-invertebrate fishery while larger vessels are used solely for the groundfishery. Therefore, for the smaller vessels, we amortize the vessels in a third way, attributing sixty-five percent of the capital costs to the groundfishery, this being the percentage of the fishing effort of these vessels which we assume is devoted to the groundfishery.[21]

[21] Evaluating the catch of high priced species such as lobster and salmon is extraordinarily difficult since inshore fishermen often (cont'd)

In addition to the two or three figures for the surplus[22], we include under the general rubric "summary statistics" the employment that results from using the specified technique, the number of vessels required, the private cost of labor under current institutional arrangements, and the total catch which forms the basis of the calculations.

III.b. Data

III.b.1 Revenues

The contract between the Newfoundland Fishermen, Food, and Allied Workers Union and the Newfoundland fish processors specifies minimum prices per pound for fish by species, size, and quality by gear type. In fact, for unionized locations, these prices tend to be the actual prices as well. In nonunionized locations, prices vary with season

21 (cont'd)
sell the catch locally and report neither the full catch nor their full income from it. We rather arbitrarily assume that sixty-five percent of the inshore fisherman's effort is dedicated to the groundfishery. This figure seems reasonable; we have not seen any convincing evidence to the contrary.

22 The surplus can be presented in dollar terms or normalized in a number of ways. For instance, a negative surplus is the value of subsidies required to maintain the industry at a break-even point (again assuming that labor is paid its opportunity cost and ignoring social overheads). Alternative normalization schemes include dividing the surplus by total revenue, employment, capital cost, or effort. The choice of normalization procedure is affected by the objectives of the analyst. If the goal of the analysis is the minimization of required subsidies per worker, then dividing by employment is appropriate. If the goal is a maximum return to capital, then division by capital cost is appropriate. If the goal is minimization of the

(cont'd)

but their average is in line with the union scale. Our prices of landed fish are on a metric ton round weight basis[23] computed as the average price actually paid by the fish processors. Size and quality differentials in prices which are attributable to gear type are therefore built into the figures. The source of these data is the federal Department of Fisheries and Oceans which receives copies of the receipts issued by the fish processors. We assume that the size and quality characteristics of the fish caught by different gear types in 1978 are typical and that there are no particular aberrations introduced by the use of data for this year.

A serious problem arises in the case of the larger, plant-owned vessels. These vessels are part of integrated fish harvesting-processing operations and the prices attributed to landed fish are mere bookkeeping devices devoid of any real economic meaning.[24] All vessels of one hundred fifty tons and over in Newfoundland are owned by processing companies as are about half of the vessels between fifty and one hundred fifty tons. We therefore use, as proxies for the price of fish landed

22 (cont'd)
subsidy for the output produced, then division by total revenue is appropriate. Since we are not formally optimizing with respect to anything, our choice is arbitrary. We present figures for the surplus normalized by dollar of revenue but present sufficient information in the appendices to permit readers to renormalize as desired.

23 Round weight refers to fish that have not been gutted. When fish are landed in a dressed (i.e., gutted) state, there are standard conversion factors to determine the equivalent round weight.

24 Apparently there are a wide range of practices in the industry, including setting a book price that permits the trawler to fully recover its costs and, alternatively, not evaluating the landed
(cont'd)

from larger vessels, the unit prices received by the operators of the largest fully independent vessels (i.e., twenty-five to fifty tons) for flatfish and cod caught with bottom trawls. These figures are $254 and $296 per metric ton, respectively. No substantial redfish catches are made with the smaller vessels so an alternative assumption must be made to obtain redfish prices. The union contract specifies (1978) prices of seven cents per pound for small and ten cents per pound for large redfish. For want of an accurate ratio, we assume that redfish caught by trawlers are equally distributed between large and small fish with the resulting unit price being $188 per metric ton.[25]

III.b.2. Catch

Catch data are obtained as discussed in Section II.b. These data are listed in detail in the tables of Appendix 3, all figures are in units of metric tons round weight.

III.b.3. Costs

Until recently, the only detailed cost figures available for the Newfoundland fishery were those gathered by a federal government survey that was performed annually until 1968 (Proskie, 1971). More recent figures appear in Setting a Course (Newfoundland Department of Fisheries,

24 (cont'd)
fish at all. The most appropriate prices for our purposes could be obtained by determining the distribution of fish by size and quantity (by species and gear of course) and applying the union price scale. In the absence of the requisite detail, our estimates seem quite reasonable.

25 After completing this study, we received the requisite data from the St. John's office of the Department of Fisheries and Oceans. In fact, between two-thirds and three-quarters of the redfish caught are "large". A more accurate unit price would therefore approach $200 per metric ton. Our results would not be substantially affected if we used the higher figure.

1978b, vol. III, Appendix VIII), but these figures are largely based upon the Kellogg Report (Newfoundland Department of Fisheries, 1978a), a consultants' report often quite vague concerning data sources.

Following the disastrous 1975 fishing season, the federal government instituted a Temporary Assistance Program, requiring participants to file cost statements with the Department of Fisheries and Oceans. During the same period, the Department ran a carefully audited survey of independent fishermen. The Department of Fisheries and Oceans, in response to a request from the Economic Council of Canada, made summaries of these data (in a form which ensured the necessary confidentiality) available to us. These figures are our primary source of cost data for the operating and fixed non-capital costs. The survey figures consist of annual costs for vessels of a given type averaged over all Newfoundland fishing regions.

We supplement these data with estimates of capital and labor costs. To obtain capital costs, we first obtained detailed descriptions of the gears and vessels used in the Newfoundland fishery from officials of the federal Department of Fisheries and Oceans. We then approached a variety of fishing equipment suppliers, shipyards, and fish processing companies to obtain estimates for material and labor costs associated with our specifications. After excluding obvious outliers, we obtained average figures for the full cost of engine and hull (with electronic equipment) on the one hand, and gear on the other. Estimated gear and vessel lives were also obtained from both government officials and individuals in the industry.[26]

[26] Most of the individuals in private industry whom we approached for information were exceedingly helpful but equally shy, requesting in the strongest terms that neither they nor their companies be mentioned in our report.

Finally, we present two sets of labor costs. The private costs of labor are included with the summary statistics but are not used in the calculation of the surplus. The private costs of labor are based, for the plant owned vessels, on the union contract and, for the independent operators, on data included in the cost survey referred to above.[27] The labor figures used in the calculations are based upon the average expected income of hourly workers in Newfoundland for 1978, with premiums of ten percent for skippers of independent vessels and fifty percent for skippers of plant-owned vessels.[28] Crew sizes are obtained from the ICNAF List of Fishing Vessels for larger vessels and from the cost survey for the smaller vessels.

[27] For plant-owned vessels the figures are \$28 per day at sea and 37% of the value of the catch for stern trawlers and \$28 per day and 47% for side trawlers. The catch is to be evaluated at union prices. For independent vessels, the survey indicates that crew plus skipper shares amount to approximately two-thirds of the value of the catch for vessels in tonnage classes one and two, and three-quarters of the catch for tonnage class zero.

[28] The percentage premiums, but not the actual opportunity costs, are those used in Setting A Course. We calculate the opportunity cost of a crew member in the following way:

a. Average weekly earnings in Newfoundland, industrial composite for 1978 were \$248. This figure is calculated as the average of monthly data from Statistics Canada document 72-202.

b. The average unemployment rate in Newfoundland in 1978 was 16.4% (Statistics Canada 71-201).

c. We therefore assume that the average Newfoundland fisherman can expect to earn \$248 per week when working and can expect to be unemployed 16.4% of the time. Thus, expected annual earnings equal:

$$(1. - 0.164)\ 248 \times 52, \text{ or } \$10{,}781.$$

(cont'd)

28 (cont'd)

d. Since we assume that 65% of a fisherman's activity in the inshore fishery is devoted to the catching of groundfish, the equivalent opportunity cost for a crewman is $7008 per year and, adding ten percent, for a skipper is $7709. For a crewman on a company owned vessel the opportunity cost is $10,781 and for a skipper, the opportunity cost is $16,172.

c. Restricted Analysis: Determination of the Economic Surplus and Employment when the Actual 1978 Newfoundland Groundfish Catch by Vessel Type is Allocated to Alternative Gear Types

The restricted analysis on which we report here compares the economic surplus, employment and other economic consequences of redistributing the 1978 groundfish catch by gear type[29] to a number of hypothetical alternative gear combinations,[30] for each of six vessel-tonnage classes. The details of this analysis are presented in a series of worksheets in Appendix 4. The worksheets are complicated and, while they all follow the same general outline, they differ considerably in detail. A detailed description or analysis of each table would be voluminous and difficult to read. The details are presented, therefore, only for the first of the numerous worksheets shown in Appendices 4 and 5, that applicable to the reconstruction of the 1978 catch by tonnage class zero vessels in Table A4-3. This "guided tour" is presented in Table A4-2. Careful observation of the worksheets in conjunction with the tour of Table A4-3 should enable a reader to recreate our figures. The symbols on the worksheets are defined in Table A4-1.

[29] Gear types that produced only relatively small shares of the catch are omitted from our reconstruction of the 1978 catch experience. Details of the omitted portions of the catch can be determined from the tables in Appendix 3.

[30] Whenever it is reasonable to do so, we limit our attention to cases in which a single gear type is employed on a given type of vessel. It is not always possible to restrict our attention in this way. For instance, cod traps are used only during the peak summer months and it is not useful to hypothesize a situation in which traps are used all year, or in which they are used to catch species other than cod.

A summary of the results of the restricted analysis is presented in Table 7 (page 78). For each tonnage class, the first line of the summary table shows the normalized surplus (S_{j1}, S_{j2}, and S_{j3}), the employment generated, the number of vessels required, the catch, and the private cost (actual income) of labor for the reconstruction of the actual gear type distribution used to obtain the 1978 catch by vessels in the tonnage class indicated. Subsequent lines present these summary statistics for alternative gear combinations that could have been used to obtain the catch actually obtained by vessels in this tonnage class. Most of the examples are limited to the effects of using a single kind of gear. For instance, line "b" for tonnage class zero shows the summary statistics implied when the entire 1978 catch of tonnage class zero vessels is assumed to be obtained with gillnets. In line "c", the entire catch is assumed to be taken by longlines. It is more likely, in fact, that tonnage class zero vessels would use gillnets for flatfish and longlines for cod rather than longlines for all species. This case is presented in line "e". We also present an example of the combined use of longlines and cod traps on tonnage class zero vessels. This example is included because cod traps have a much higher catch per unit effort than longlines but they can only be used for part of the season.

The most striking result shown in the table is that the surplus is always negative, implying that there is no combination of gear types that would have permitted vessels in any tonnage class to obtain their 1978 catch and earn a profit if there were no subsidies and workers were paid their opportunity cost.[31]

[31] According to the reconstruction, inshore workers receive less and offshore workers receive more from the groundfishery than their opportunity costs. Note that even if the wage payments to trawlermen were brought down to their opportunity costs, the offshore harvesting operations would not be profitable without subsidies.

That all the surpluses are negative is not really surprising. Entry to the Newfoundland inshore groundfishery remains virtually free and one expects economic rents to be fully dissipated in such an open-access fishery. Until the declaration of EFJ, the situation was not much better in the offshore fishery. If the government pays subsidies to a zero-rent fishery, then fishermen will enter the industry until rents (including subsidies) are again dissipated. In this event, rents net of subsidies would be negative.

Our results suggest that, with fish population densities as they existed in 1978, there are no combinations of vessels and gear that would have generated a positive surplus in the absence of subsidies. With the increase in population densities that underlie the 1985 allowable catch projections, there would be an increase in the catch per unit effort for each gear-vessel combination and productivity may rise sufficiently to generate a positive surplus.

We should not lose track of our objective. We are attempting here to identify the most cost-effective techniques of fishing and our interest in the profitability of the fishery is incidental. On the assumption that the relative productivity weights shown on Tables 3 and A1-1 remain unchanged when the absolute levels of catch per unit effort rise with EFJ, our conclusions concerning the cost-effectiveness of alternative fishing techniques will remain valid (subject, of course, to the condition that relative prices and costs remain unchanged).

Considering first the inshore fishery (vessels in tonnage classes zero to two), it is clear that vessels in tonnage class two (intermediate-sized longliners) are considerably less cost-effective than are the smaller inshore vessels. This suggests that the longliner "revolution" of the late 1960's might have been a mistake. The vessels in this tonnage class are so inefficient that we omit them from further consideration in the analysis.

Handlining is consistently the least cost-effective method of fishing. The encouragement of a handlining inshore fishery would create substantial employment, but the labor costs would be so high that far higher subsidies would be required than for any other fishing technique. It seems to us that there is little virtue in pursuing this approach to the fishery.[32]

Similarly, our results suggest that gillnetting is an expensive fishery for all vessel classes. On pages 42-43 we noted that catch per unit effort for gillnets is low. It is clear from Table 7 that economic considerations do not improve the effectiveness of gillnets.

It is apparent from Appendix 3 that the inshore fishery is dominated by codtraps (about 50,000 metric tons), with substantial contributions from gillnets (about 34,000 metric tons), longlines (about 24,000 metric tons) and with smaller catches obtained with other types of gear. According to Table 7, the longlines are quite efficient while the gillnets are not. The high negative surpluses shown for the 1978 reconstructions for each type of vessel imply poor cost-effectiveness for the mixed gillnet and cod trap fishery.[33] These results strongly suggest the desirability of a change in the gear mix used in the inshore fishery.

[32] In fact, although 18% of small boat cod is caught with handlines, this technique dominates no aspect of the professional fishery. Handliners are primarily moonlighters as well as fishermen during slack periods (e.g., fishermen jigging for cod in the afternoon while waiting for evening squid).

[33] Cod traps have high catch per unit effort but the price of trap fish is low and trapboats are substantially more expensive than motorboats. The economic factors counterbalance the productivity factor. It is clear from the following table that gillnets, and not cod traps, are responsible for the high negative surplus generated by the inshore fishery.

The adoption of longlines as the dominant instrument of the inshore fishery (keeping unchanged the total catch of each vessel class) would permit a substantial fall in the negative surplus,[34] at the cost of a relatively small reduction in employment. The following table shows the relevant figures.

TABLE 6

1978 Catch by Selected Actual and Hypothetical Gear Combinations (Inshore)

Vessel Class	Gear Type	Surplus (S_{jl})	Employment
0	1978 Reconstruction	-1.54	7993
0	Longlines	-0.93	7072
1	1978 Reconstruction	-1.50	1456
1	Longlines	-1.11	1584
1	Longlines-Codtraps	-.92	888
1	Side Trawls	-.81	976

A mix of longlines and cod traps with small longliners (tonnage class 1) reduces the negative surplus by an even greater extent. There is, however, a corresponding drop in employment because of the increased productivity of cod traps. Use of cod traps with small longliners reduces the required subsidy but a straight longline inshore fishery is preferable from the point of view of employment to a mixed longline-trap cod fishery.

[34] Throughout this discussion, surpluses are defined as S_{jl}, i.e., in terms of the amortization of the complete vessel cost.

An even more dramatic reduction of the negative surplus occurs when side trawls replace both longlines and cod traps on longliners. Introduction of trawls on a large scale would constitute a revolutionary change in the inshore fishery. We are hesitant to recommend a sudden switch to inshore trawling for this and three additional reasons:

1) Employment would be low;

2) Since trawls interfere with gillnets, a change from gillnets to trawls must be sudden. Trawling could be introduced gradually by area but within the area where it is introduced gillnetting would die a sudden death.

3) In certain areas of Newfoundland, particularly the Northeast Coast, the rocky ocean bottom may make the use of bottom trawls impractical.

A warning concerning our revenue data is in order. The prices obtained by inshore fishermen for fish caught by gillnets, cod traps, longlines, etc. vary considerably among techniques. Cod trap fish tend to be small and rather soft, and therefore sell at a relatively low price. If longlines were to replace traps, the average quality of the fish caught by longlines might drop because some of the smaller fish that would otherwise be caught in traps might now be caught by longlines. This change in fish quality would induce a drop in the price of longline fish. The difference in the surpluses would then be less pronounced than they appear in this report.

A second omission that may be of importance is our neglect in the analysis of spatial elements. In some regions of Newfoundland the longline fishery continues to be pursued; in others the longlines have been almost totally displaced by gillnets. It is possible that, while longlines are highly effective where they are used, they would be less effective where gillnets have been adopted. We avoid testing this hypothesis, partly because the spatial elements in the regression study are relatively unimportant but also because to test it would require the inclusion of a large number of cross-product terms in the regression equation (Equation 1). We are unwilling to introduce these cross-product terms because of the loss in degrees of freedom that would ensue.

Turning now to the offshore sector, the negative surplus for the 1978 reconstruction of this sector is slightly less than that for the inshore sector. The surplus grows increasingly negative with vessel size, suggesting that the additional catch productivity of larger vessels is insufficient to offset the increased capital costs associated with them, and this situation may worsen as energy costs rise.

For the large longliners (tonnage class three)[35], employment and negative surplus are high for gillnets and in the 1978 reconstruction, low for the trawls and lower still for longlines. Here we have a situation, however, where several of our single gear examples are unfeasible. For instance, Table A3-4 shows that longlines are used only for cod, gillnets for flatfish and cod, and trawls primarily for cod. To recommend a switch to longlines for all species makes no sense, despite the apparently favorable results shown on Table 7, since longlines are inappropriate for any species

[35] The tonnage class three figures are valid for wooden vessels. Vessels in this class in actual use in Newfoundland include two broad groups: first, wooden longliners owned by independent fishermen; and second, steel vessels owned by fish processing companies. The catch per unit effort for both sets of vessels are approximately equal but the vessel costs of the steel vessels are substantially higher than for the wooden vessels. Because of confidentiality problems, we were required to use only the costs of the wooden vessels. This restriction is probably not a disadvantage; with equal catch per unit effort and higher costs, the steel vessels can hardly be cost-effective.

but cod. An appropriate gear combination for these vessels would involve the use of trawls (preferably stern) for flatfish and longlines for cod. Acceptance of this combination of gear types would require the phasing out of cod traps and gillnets.

For tonnage class four vessels, we restrict the analysis to side trawlers because of data confidentiality problems affecting stern trawlers. Our results imply that emphasizing midwater trawls for redfish and bottom trawls for cod and flatfish is more cost-effective than the current mix which maintains a fairly high catch of redfish with bottom trawls.[36]

Finally, for the largest Newfoundland vessels (tonnage class five), an increased emphasis on the use of midwater trawls for redfish seems desirable.

Some qualifications must be made regarding the tonnage class five results. In every case reported on Table 7, we estimate the number of vessels required. For the 1978 reconstruction, this figure should be close to the actual number of vessels registered[37] unless there are a fair number

[36] The examples which we consider for the trawlers involve the current distribution of catch by gear and the extreme case where all redfish are caught with midwater trawls and flatfish and cod are caught with bottom trawls. This second, hypothetical, example is a limiting case which is clearly impractical because of bycatches. The thrust of our argument, however, is that an increase in midwater trawling seems desirable.

[37] Our figures for the number of registered vessels in Newfoundland were obtained from officials of the Department of Fisheries and Oceans in St. John's. These figures should be accurate. The inshore figures were obtained by a direct count of registration certificates; the offshore figures were obtained from a computerized listing maintained by the Department.

of registered vessels in the class which are not engaged actively in the fishery. For tonnage classes two, three, and four, our vessel estimates for the 1978 reconstruction are very close to the actual figures. For tonnage classes zero and one our vessel requirements are far lower than the number of registered vessels in these classes, only one-third for the small boats and two-thirds for the small longliners. This result suggests either that the extra vessels are registered but are not used in the fishery, or that they are used only casually (for a few days per year), or, in the case of the tonnage class zero vessels, that there are many vessel operators who are far less efficient on the average than those included in our sample of small boat operators.

The tonnage class five vessels provide the only case where we overestimate the number of vessels. This overestimate, of 31%, arises from the catch per unit effort estimates obtained from equation (1). Given the actual tonnage class five catch, the catch per unit effort estimate implies a required effort about thirty percent greater than the actual effort reported for 1978 to the Department of Fisheries and Oceans by the tonnage class five vessel operators. Equation (1) underestimates the catch per unit effort of these vessels for that year. The high catch per unit effort of the tonnage class five vessels for 1978 may reflect either of two possibilities. In the first instance, 1978 may have simply been a particularly good year for these vessels. In this case, the 1978 results cannot be expected tc continue and the analysis presented here is appropriate. In the second instance, there may have been a structural change in 1978 (perhaps in response to increased fish population densities). If such a structural change has indeed occurred, then our results are in fact biased against the tonnage class five trawlers. In effect, the results reported below would then underestimate the cost-effectiveness of the offshore sector.

Consolidating the results, the restricted analysis incorporating the full amortization of vessels suggests that the following are the most cost-effective techniques:

1)	Tonnage Class Zero (motor and trap boats)	--	Longlines (motor boats) or a combination of longlines and cod traps (trap boats)
2)	Tonnage Class One (small longliners)	--	Longlines, Bottom Trawls, or a combination of longlines and cod traps
3)	Tonnage Class Three (large longliners)	--	Trawls for flatfish and longlines and/or trawls for cod
4)	Tonnage Class Four (trawlers, <145')	--	Bottom trawls for cod and flatfish and midwater trawls for redfish

Gillnets and handlines are significantly less cost-effective with all vessel classes, as are tonnage class two (and perhaps five) vessels with all gear types.

In the above discussion, all vessel construction costs have been included in the computation of the economic surplus figures which are considered. We also present estimates of the surplus exclusive of vessel construction costs (S_{j2}). The S_{j2} figures might be useful in evaluating the consequences of reallocating the 1978 groundfish catch among the existing stock of vessels, since for this purpose vessel construction costs can be considered to be sunk costs, not reflecting opportunity cost.

It is clear from Table 7 that the exclusion of vessel construction costs reduces the size of the negative surplus, although in no case does the surplus become positive. In addition, the difference between the two surplus figures increases with vessel size, as the proportion of costs attributable to vessel construction increases. Thus, consideration of the lower negative surplus which results from excluding vessel construction costs could strengthen the argument, on efficiency grounds, in favor of the larger vessels. There are, however, no laid up vessels in Newfoundland in tonnage classes four and five and, as far as we know, there are none in tonnage class three as well. Since no excess capacity exists in the larger vessel classes, any increased utilization of these vessels requires new construction and the S_{j1} figure is the appropriate one. In other words, given the current situation in Newfoundland, the S_{j2} figures are irrelevant to the analysis of the offshore fishery.

Our calculations indicate, however, that there is substantial excess capacity in tonnage classes zero and one. While vessel construction costs for tonnage class zero vessels are so low that the difference in the results obtained from the two types of surplus calculations is negligible, there is a substantial difference between S_{j1} and S_{j2} for the small longliners of tonnage class one.

While this is true for tonnage class two vessels as well, these vessels remain quite inefficient relative to the other inshore vessels even when vessel construction costs are ignored.

In the next section of this paper, we consider the reallocation of the Newfoundland groundfish catch between the inshore and offshore sectors. These reallocations are examined with respect to the surplus, inclusive of vessel construction costs, because our main objective in this paper is the evaluation of the cost-effectiveness of alternative fishing technologies from a perspective which is independent of any contingencies associated with the existence of excess capacity in a particular vessel class -- excess capacity which might in any event be quickly eliminated through physical depreciation or with any expansion of the fishery.

However, when the economic consequences of these reallocations are considered, it should be recalled that the existence of excess capacity in the inshore fishery may, other things being equal, provide some advantage to the utilization of these surplus inshore vessels before the construction of new offshore vessels is begun.

TABLE 7

Summary of Results Obtained from the Restricted Analysis: Economic Returns and Employment[a]

CASE	Normalized Surplus[b] S_{j1}	S_{j2}	S_{j3}	EMPLOYMENT[b]	NUMBER OF VESSELS	CATCH	INCOME PER YEAR[g]
1) TC 0 (motor and trap boats)							
a) 1978 Reconstruction[c]	-1.54	-1.45	-1.51	7993	3465[e]	94800	2511
b) Gillnets	-1.49	-1.44	-1.47	7908	3954	94800	2628
c) Longlines	- .93	- .89	- .92	7072	3536	94800	3149
d) Handlines	-23.1	-2.25	-2.29	11734	5867	94800	1813
e) Gillnets-Longlines	-1.13	-1.09	-1.11	7128	3564	94800	3107
f) Cod Traps-Longlines	-1.07	- .99	-1.04	6533	2737	89300[f]	3003
1978 Registered Vessels[d]	-	-	-	-	15172	-	-
2) TC 1 (small longliners)							
a) 1978 Reconstruction[c]	-1.50	-1.08	-1.35	1456	364	25200	3150
b) Gillnets	-1.57	-1.14	-1.42	1504	376	25200	3082
c) Longlines	-1.26	- .84	-1.11	1584	396	25200	3178
d) Handlines	-2.31	-1.69	-2.09	2284	571	25200	2116
e) Bottom Otter Trawls (Side)	- .81	- .46	- .69	976	244	25200	4245
f) Gillnets-Longlines	-1.57	-1.15	-1.43	1552	388	25200	3147
g) Cod Traps-Longlines	- .92	- .57	- .80	888	222	16200[f]	3755
1978 Registered Vessels[d]	-	-	-	-	549	-	-
3) TC 2 (intermediate long-liners)							
a) 1978 Reconstruction[c]	-3.28	-1.86	-2.78	868	217	20600	.4288
b) Gillnets	-3.60	-2.09	-3.07	940	235	20600	4020
c) Longlines	-2.18	-1.04	-1.78	764	191	20600	5297
d) Handlines	-5.49	-3.12	-4.66	1536	384	20600	2556
e) Bottom Otter Trawls (Side)	-2.23	-1.06	-1.82	720	180	20600	5347
f) Gillnets-Longlines	-2.94	-1.66	-2.49	836	209	20600	4769
1978 Registered Vessels[d]	-	-	-	-	213	-	-

Cont'd ...

TABLE 7 (continued)

CASE	Normalized Surplus[b] S_{j1}	S_{j2}	S_{j3}	EMPLOYMENT[b]	NUMBER OF VESSELS	CATCH	INCOME PER YEAR[g]
4) TC 3 (large longliners)							
a) 1978 Reconstruction[c]	-1.34	- .48	-	220	44	10700	9059
b) Gillnets	-1.65	- .72	-	240	48	10700	8279
c) Longlines	- .87	- .15	-	205	41	10700	10663
d) Bottom Otter Trawls (Side)	-1.13	- .32	-	205	41	10700	9854
e) Bottom Otter Trawls (Stern)	-1.10	- .30	-	205	41	10700	9960
f) Longlines-Gillnets	-1.36	- .54	-	220	44	10700	9414
g) Longlines-Bottom Trawls (Stern)	-1.03	- .27	-	205	41	10700	10483
1978 Registered Vessels[d]	-	-	-	-	40	-	-
5) TC 4 (trawlers < 145')							
a) 1978 Reconstruction[c]	-1.40	- .65	-	299	23	23800	14071
b) Midwater/Bottom Trawls	-1.04	- .39	-	260	20	23800	15308
1978 Registered Vessels[d]	-	-	-	-	23	-	-

Cont'd ...

TABLE 7 (conclusion)

CASE	Normalized Surplus[b] S_{j1}	S_{j2}	S_{j3}	EMPLOYMENT[b]	NUMBER OF VESSELS	CATCH	INCOME PER YEAR[g]
6) TC 5 (trawlers >145')							
a) 1978 Reconstruction[c]	-1.50	- .48	-	1020	68	99600	16003
b) Midwater/Bottom Trawls	-1.37	- .40	-	975	65	99600	16419
1978 Registered Vessels[d]	-	-	-	-	52	-	-

[a]Figures shown here are the results of model simulations in which the actual 1978 Newfoundland groundfish catch by vessel type is assumed to be caught by a variety of alternative fishing techniques (see pages 66-77).

[b]Normalized surplus figures are in units of dollars of required subsidy per dollar of fishing revenue (see pages 59-60). Employment units are "men required per year" (but not "man-years" since most men do not fish for the full year).

[c]A "1978 Reconstruction" involves computing the surplus and employment when the actual 1978 catch allocation by gear type is used as the basis of the calculations.

[d]"1978 Registered Vessels" include only the number of vessels which use the gear types specified in the economic analysis. They do not include vessels which use purse seines, Danish seines, etc., as their main gear.

[e]Adding the auxiliary dories towed by trap boats, this figure increases from 3465 to 4528.

[f]Catch of cod only.

[g]Actual money income to fishermen for groundfish operations under 1978 institutional arrangements given catch by gear as indicated (see page 64).

Appendix to Section III.c

In their Appendix VIII, the authors of Setting a Course (hereafter referred to as SAC) present cost and revenue data for specific classes of vessels. The purpose of this note is to compare the SAC cost and revenue figures for intermediate-sized longliners and large wetfish trawlers with those presented in this study.

Since a much wider range of vessels is considered in the present work than in SAC, it is necessary to limit the scope of the comparison. In Table 8, we present vessel specifications from the two works under study. Among the longliners, the closest comparison is possible for vessels of tonnage class two, since all vessels in this class considered in the present study have a length close to the 55' considered in SAC.[38] We avoid comparing tonnage class one vessels with 45' longliners in SAC because 45' represents only the upper limit of the vessels included in our tonnage class one. Such a comparison would involve vessels that are on the average smaller in our study that in SAC. Finally, tonnage class three longliners are omitted from the comparison for the following reason. Ours is a study of the Newfoundland groundfishery, based upon historical data, but oriented with a view towards determining the desirable vessel-gear combinations to be used in the expanded groundfishery which is generally envisioned as a result of Canada's Extended Fisheries Jurisdiction. While tonnage class three vessels are involved in the groundfishery, well over half the catch taken by these vessels consists of pelagic species (in particular, herring). SAC is concerned with total fishing

[38] In fact, it is quite likely that SAC considers the length designation of 55' in a generic sense for vessels of approximately this length. Thus, it is likely that the populations of our tonnage class 2 vessels and of the 55 foot class in SAC are identical.

activity; we are concerned only with the groundfish component of the Newfoundland fishery. Because of the emphasis in the SAC data on non-groundfish species, we omit a direct comparison with SAC results for this vessel class as being inappropriate.

It is also clear from Table 8 that restrictions on the scope of SAC make it impossible to compare vessel tonnage classes zero and four with any equivalents in SAC.

Our remaining tonnage class, tonnage class five, is not quite comparable with the 171' vessel discussed in SAC. This vessel is highly productive -- for reasons unstated in SAC -- while our tonnage class five includes a wide range of vessels. In the interest of obtaining a comparison for the offshore fishery, however, we compare tonnage class five vessels with the 171' vessel of SAC.

Our results for tonnage class two are presented in Table 9 and for tonnage class five in Table 10. These tables should be self-explanatory. For each vessel class included in this comparison, parallel entries are made from SAC and our Appendix 4 for the number of vessels, landings, revenues, and costs by type. The source of each figure (where relevant) is given, as are any special assumptions or descriptions which are necessary to understand the figures. Each comparison ends with the computation of appropriate "surplus" statistics comparable with those presented in our Table 7.

For the inshore vessels, a surplus (S_{j1}) of minus forty-seven cents per dollar of revenue is generated in SAC, while a surplus (S_{j3}) of minus two dollars and seventy-six cents is generated in our study. These figures differ dramatically in magnitude and somewhat in definition; both differences require explanation.

TABLE 8

Vessel Specifications: Data Used in the Present Study

Tonnage Class	Description	Avg Length (feet)	Length Range (feet)	Avg HP	Avg Tonnage	Tonnage Range	Equivalent Length Range in SAC (feet)
0	Motor boats	19.2	18-22	40 (outboard)	--	< 10	x
0	Trap boats	28.6	22-39	50 (inboard)	--	< 10	x
1	Longliners 10-24.9 tons	40.2	35-45	137	17	10-24.8	45
2	Longliners 25-49.9 tons	54	52-55	307	37	34-42	55
3	Longliners 50-149.9 tons (wood)	65	65	443	72	57-83	65
4	Trawlers 150-499.9 tons	126	120-129	820	309	292-324	x
5	Trawlers 500-999.9 tons	154	149-165	1956	778	661-835	171

Notes:

1. Data source -- Fisheries Loan Board for tonnage classes 0-3 and interviews for tonnage classes 4 and 5.
2. We attempted in interviews to obtain data for steel tonnage class 3 vessels. For reasons which we do not understand, our sources declined to supply this information which, we believe, they had.
3. An "x" in the final column indicates that SAC did not consider this tonnage class.
4. An "--" indicates that we do not have the relevant information.
5. SAC uses data for the most productive of Newfoundland trawlers. We cannot, however, identify the vessel. Our records indicate that the only vessel in the Newfoundland fleet greater than 165' is the 195' Zaragoza.

SAC focusses on the total fishery operation of a vessel; groundfish and non-groundfish operations are therefore both included. We consider only groundfish operations and we assume that 65% of the vessels' total annual effort is devoted to the groundfishery. Our reported catch is therefore the result of only about 65% of the effort of the tonnage class two vessels and only 65% of labor and fixed vessel costs should therefore be included in the computations. The surplus figure which is relevant in this case (i.e., involving the amortization of only 65% of the vessel cost) is S_{j3}.[39] The figure S_{j3} from our analysis, therefore, should be compared with the S_{j1} figure (i.e., the surplus generated from the total fishing activity) in the SAC analysis.

The total costs per vessel computed in the two studies are almost the same (about $95,000) but it should be recalled that the figure for SAC covers all costs over the year while our figure covers only the costs attributed to the groundfishery. The distribution of costs by type, however, varies considerably between the two studies. In SAC the fixed and labor costs are considerably higher than ours but this differential is more than outweighed by our very high non-labor variable costs. These higher costs are important and they play a substantial role leading to our conclusion that tonnage class two vessels are highly cost inefficient for groundfish operations. Our data source indicates excessively high maintenance costs for these vessels. From interviews held with fishing vessel specialists, it seems that the actual maintenance costs on the hull of these vessels are not exorbitant but the vessels generally carry an excess of complicated electronic gear that involves heavy maintenance expenses. This element is omitted from consideration in SAC.

[39] See page 142 for precise definitions of the surplus statistics.

This explanation is also consistent with our observation that maintenance costs for tonnage class two vessels are surprisingly close to those for the larger tonnage class three vessels.[40]

The prime reason for the difference in results between the two studies, however, lies on the revenue side of the accounts. Revenues noted in SAC are fully two and one-half times as large as ours despite the fact that a lower unit price is used in SAC. The crucial determinant of the difference in revenues is that the authors of SAC assume a much higher catch per unit effort than that obtained from our productivity analysis. At first glance, one might attribute the difference to the large herring catches used in SAC. This explanation crumbles, however, when it is noted that less than a third of the catch of tonnage class two vessels is accounted for by non-groundfish species. It is most unlikely that the herring fishery is so productive that it can account for the observed difference in catch per unit effort.

A second factor that is more likely to account for the difference in efficiency is that only the most productive 45% of the vessels are considered in SAC while our catch per unit effort figures are determined from an econometric analysis of the results of all vessels for the period 1973-78. Presumably the selectivity of the authors of SAC in choosing their vessels accounts for the dramatic difference in the results of the two studies.

Turning now to the comparison of tonnage class five vessels with the 171' vessel, we once again find that the authors of SAC obtain much lower negative surpluses than do we. In this case, the negative surplus is one dollar and forty-nine cents per dollar of revenue in this study and only sixty-five cents in SAC

[40] See, for example, the maintenance costs noted in Tables A4-16 (p. 198) and A4-22 (p. 222).

Since both studies are here concerned with vessels that concentrate only on groundfish, there are no problems concerning the allocation of costs and the surplus figure S_{jl} is appropriate in both cases.

Our costs are somewhat lower than those in SAC but this differential is more than balanced by a catch noted in SAC of two and one-half times the catch noted in our work. Even considering that the authors of SAC use a lower average price than we do, the revenues noted in SAC are still twice those used in this study. Once again, as in the case of the tonnage class two vessels, SAC assumes a far higher catch per unit effort than do we. There are two possible explanations, complementary rather than contradictory.

The authors of SAC base their results on a single 171' vessel, a vessel which we have been unable to even identify. Presumably this vessel is highly productive. It is not at all clear that, even if the favorable results are typical of this vessel, they can be matched by other tonnage class five vessels. In other words, limiting the analysis to the results of a single vessel may be so restrictive that the results cannot be duplicated by other vessels and are therefore not of general interest.

On the other hand, we point out that the catch per unit effort figures for the tonnage class five vessels in this study seem to be low, requiring 30% more vessels to pursue the 1978 fishery than were actually registered. If we have actually underestimated the efficiency of the large vessels (a possibility, but not definitely established as fact), then this underestimate partially explains the differences in surplus noted for the two studies. It is highly unlikely, however, that the possible bias in this study against the tonnage class five vessels can be sufficiently large to explain the difference.

It seems to us that, given the fish population densities of 1977-78, the efficiency estimates in SAC are unduly optimistic.

TABLE 9

Cost and Revenue Comparison (Inshore Vessels)

Description	Tonnage Class 2 Vessels (25-49.9 ton longliners -- source of data: Table A4-16)	55' Vessels (source of data: Setting a Course, Appendix VIII, pp. 723-736)
Number of vessels	217	96 a. Vessels with landings in excess of 200 metric tons in 1977 b. 45% of the vessels in this class landed more than 200 metric tons in 1977.
Average landings	Cod : 60 metric tons Flatfish: 35 metric tons Redfish : .5 metric tons total = 95.5 metric tons	total = 268.6 metric tons 1978 ICNAF figures: Total catch by tonnage class 2 vessels: 36,750 m.t. Groundfish: 25,687 m.t. Herring : 10,434 m.t. Other : 639 m.t.
Days fishing (= days at sea)	62 (for groundfish)	65 (for all species)
Revenues		
Price per metric ton	Cod : $295 Flatfish: 226 Redfish : 217 (weighted average of prices received for fish caught with all gear.)	All species, all gear: $240
Average total revenue per vessel	$25,726 ($269 per ton average)	$64,464

TABLE 9 (cont'd)

Description	Tonnage Class 2 Vessels	55' Vessels
Costs		
Fixed Costs		
Vessel Cost	$218,975 (Average of vessels with range $176,000 - $437,000 is $336,884. 65% of the average figure is $218,975)	$251,615 (no source given)
Economic Life of Vessel	11 years	9 years
Capital Recovery Factor	.10808	.13246
Cost Per Year	$23,667	$33,327
Marine Insurance	991 (attributing 65% of figure on cost survey to groundfish)	2,516 (1% of cost of vessel)
Miscellaneous	-	500
TOTAL FIXED COSTS	$24,658	$36,343
Non-Labor Variable Costs		
Vessel Repair and Maintenance	$26,134 (cost survey attributes maintenance cost of $16,439 to 39 days at sea. We assume 62 days fishing. Figure shown here is 62/39 times cost survey figure)	$ 2,516 (1% of cost of vessel)

TABLE 9 (cont'd)

Description	Tonnage Class 2 Vessels	55' Vessels
Gear Replacement	$10,417 (average of four gear types with following economic lives: Cod Traps - 10 yrs. Longlines - 2 yrs. Gillnets - 2 yrs. Bottom Trawls - 1 yr.) Source: Survey of fishing gear supply firms.	$3,270 (each vessel assumed to carry $25,000 worth of gear. Replacement cost per year assumed to be 10% of stock financed with 9% short-term loan)
Fuel Cost	$ 2,404 (same source and computation as used in "vessel repair and maintenance cost")	$3,218 (90 gallons per day @ 55¢ per gallon)
Supplies, Bait & Ice	$ 4,316 (same source and computation as used in "vessel repair and maintenance cost")	$ 500 (allowance to cover incidental expenses)
TOTAL NON-LABOR VARIABLE COSTS	$43,271	$9,504
<u>Labor Costs</u>		
Crew Size (excluding skipper)	3	3
Deckhands' Wages	$21,024 [3 x .65 x 1978 average Newfoundland weekly wage x 52 x (1-0.164)]	$36,000 (3 x 1977 average Newfoundland weekly wage x 52)
Skipper	$ 7,709 (10% additional wage to skipper)	$13,200 (10% additional wage to skipper)

TABLE 9 (cont'd)

Description	Tonnage Class 2 Vessels	55' Vessels
TOTAL LABOR COST	\$28,733	\$49,200
TOTAL: ALL COSTS	\$96,662	\$95,047
Surplus	$S_{j3} = -2.76$ (differs slightly from the -\$2.78 figure in Table 7 because here only 65% of marine insurance is attributed; in Table 7, the full insurance figure is charged)	$S_{j1} = -.47$

TABLE 10

Cost and Revenue Comparison (Offshore Vessels)

Description	Tonnage Class 5 Vessels (500-999.9 tons -- source of data: Table A4-31)*	171' Groundfish Trawler (source of data: Setting a Course, Appendix VIII, pp. 723-736)
Number of vessels	68 (estimate is high because of low 1978 catch per unit effort estimate)	1 (analysis based upon best performance vessel)
Average landings	Cod : 296 metric tons Flatfish: 891 metric tons Redfish : 278 metric tons total = 1,465 metric tons	total = 3,852 metric tons
Days at sea	249	200
Days fishing	199	--
Revenues		
Price Per Metric Ton	Cod : $296 Flatfish: 254 Redfish : 188	$200 per metric ton
Average Total Revenue per Vessel	$366,194 ($250 per metric ton average)	$770,400

*Figures here may differ slightly from those in Table A4-31 because of rounding.

TABLE 10 (cont'd)

Description	Tonnage Class 5 Vessels	171' Groundfish Trawler
Costs		
Fixed Costs		
Vessel Cost	$5,550,000	$5,000,000
Economic Life of Vessel	20 years	18 years
Capital Recovery Factor	.06722	.09784
Cost Per Year	$373,071	$489,175
Marine Insurance	$ 31,797	$ 25,000 (.5% of cost of vessel)
Miscellaneous	-	$ 4,125 (source not given)
TOTAL FIXED COSTS	$404,868	$518,300
Non-Labor Variable Costs		
Vessel Repair and Maintenance	$111,078	$225,000 (4.5% of cost of vessel. Source: Canadian-Kellogg Report)
Gear Replacement	$ 61,456	Not considered
Fuel Cost	$124,686	$220,025 (6.9 metric tons per day per trawler)

TABLE 10 (cont'd)

Description	Tonnage Class 5 Vessels	171' Groundfish Trawler
Supplies, Bait & Ice	$ 43,761	$ 16,825 (4% of operating costs)
TOTAL NON-LABOR VARIABLE COSTS	$340,981	$461,850
Labor Costs		
Crew Size (excluding skipper)	14	13
Deckhand's Wages	$150,934 ($10,781 per man)	$260,000 ($20,000 per man)
Skipper	$ 16,172 (50% additional wage to skipper)	$ 30,000 (50% additional wage to skipper)
TOTAL LABOR COST	$167,106	$290,000
TOTAL: ALL COSTS	$912,955	$1,270,150
Surplus	$S_{j1} = -1.49$	$S_{j1} = -.65$

d. Extended Analysis: Determination of the Economic Surplus and Employment when the Actual 1978 Newfoundland Groundfish Catch is Allocated to Selected Gear and Vessel Combinations

In the previous section, we discussed the results of the restricted analysis, i.e., the reallocation of the 1978 catch within tonnage classes among alternative gear types. In this section, we consider the effects of alternative allocations of the 1978 Newfoundland groundfish catch among different vessel class combinations. In all simulations, the redfish and flatfish catch is allocated to the offshore sector. The cod catch is allocated in two different ways: in the first, twenty percent of the cod is caught inshore and eighty percent offshore; in the second, these percentages are reversed (as they are now). Table 11 shows the actual 1978 distribution of catch by tonnage class; Table 12 summarizes the results of the extended analysis.

The results of the restricted analysis are used to select the more economically efficient techniques for consideration here. The tonnage class five vessels are excluded for reasons cited earlier. Tonnage class two vessels are also excluded because they have a relatively high negative surplus for every gear type.

The vessel-gear combinations for which calculations are made in the extended analysis are:

1) Tonnage class zero vessels with longlines.

2) Tonnage class one vessels with longlines or with longlines and cod traps.

3) Tonnage class three vessels with trawls or with trawls and longlines.

4) Tonnage class four vessels with a combination of midwater and bottom otter trawls.

In addition, we present figures for tonnage class zero vessels using handlines. This example is presented to illustrate the enormous cost, shown most dramatically in the negative surplus appearing for case 8 in Table 12, involved in using the fishery to absorb large numbers of otherwise unemployed workers in Newfoundland.

All combinations of gear and vessel types considered are relatively cost-effective except for the handlines. Allocating eighty percent of the cod catch to small boats (less than ten tons) utilizing handlines, while using efficient offshore techniques, would generate seventeen thousand jobs in the primary fishery. Even using the highly inefficient labor-intensive handlines, therefore, generates only fifteen thousand seasonal inshore jobs. To obtain this level of employment, however, requires a subsidy (once again excluding social overhead and plant-connected costs) of $1.78 for every dollar of fish landed. This exceedingly high subsidy should be compared to that required for the other techniques considered. The highest subsidy required for the more efficient techniques is $1.19 per dollar landed value. The cost of handlining is exceedingly high.

The negative surplus associated with each of the relatively efficient techniques is in the range of $1.12 to $1.19. This range is very small; we believe that the analysis is sufficiently imprecise that these small differences are not too important. We note, however, that there is somewhat of a gain in employment from the large longliners relative to the trawlers, and this gain is at the cost of a somewhat larger subsidy. Thus this analysis provides no really strong support for the use of large longliners rather than trawlers in the offshore fishery.

We are left therefore with a comparison between vessels of tonnage classes zero and one on the one hand and the trawlers on the other.[41] Differences in the surpluses generated with these techniques are small but much larger employment is generated with a concentration of cod catch in the inshore fishery than with a concentration in the offshore fishery.

On grounds of efficiency alone, and at current energy prices, there is little or nothing to choose between these alternatives. If the choice of technique is to be made so as to increase employment in the harvesting sector as much as possible without incurring substantial additional costs, then our analysis suggests that the maximum possible percentage of cod be taken inshore with either small boats or small longliners mounting longlines, while the offshore catch is obtained from trawlers, with redfish caught with midwater trawls and cod and flatfish caught with bottom trawls.

When eighty percent of the cod catch is allocated to the inshore fleet and this catch is obtained from small boats of less than ten tons, while the offshore fish are caught by tonnage class four trawlers, a total employment of approximately eleven thousand fishermen is required and the negative surplus is as low as any we have obtained, $1.12 for each one dollar of landed fish.

[41] We are being intentionally imprecise in our use of the term "trawlers". The analysis favors tonnage class four side trawlers for the offshore fishery, although we have indicated earlier that it is possible that tonnage class five stern trawlers are, in fact, more cost-effective than our figures indicate. A similar result favoring tonnage class four over larger vessels is obtained by Green and Broadhead (1965) who, in their study of the tuna fishery, found that vessels over 500 tons (our tonnage class five) are, under a variety of criteria, less cost-effective than are smaller vessels.

The surplus rises marginally when small longliners replace motorboats, no doubt because of the increased cost of the vessel, while employment falls by more than seventeen hundred fishermen.

Our results indicate that small boats rather than longliners should dominate the inshore fishery and trawlers rather than large longliners the offshore fishery, with the allocation of catch between inshore and offshore depending on the importance which decision makers attach to the employment generated from harvesting operations.[42]

Detailed worksheets for the extended analysis are presented in Appendix 5.

[42] We emphasize that the unit of measurement of labor used throughout this study is "men per year", i.e., the number of fishermen who must be hired during a year to do the required work. This unit must be carefully distinguished from "man-years" which is the number of men required to do the work if the work could be evenly spaced out over the year.

TABLE 11

Distribution of 1978 Newfoundland Groundfish Catch by Tonnage Class of Vessel

Tonnage Class	Percentage of Total Groundfish Catch	Percentage of Cod Catch	Percentage of Redfish and Flatfish Catch
0	35	60	4
1	9	11	7
2	7	9	6
Total Inshore	51	80	17
3	4	5	3
4	9	2	15
5	36	13	65
Total Offshore	49	20	83

TABLE 12

Summary of Results Obtained from the Extended Analysis: Economic Returns and Employment**

Case	Percentage of Cod		Tonnage Class		Gear Type		S_{jl}	Employment		Number of Vessels		Total Catch (Metric Tons)		Annual Income Per Worker	
	Inshore	Offshore	Inshore	Offshore	Inshore	Offshore		Inshore	Offshore	Inshore	Offshore	Inshore	Offshore	Inshore	Offshore
1	20	80	1	4	Longlines	*Trawls	-1.15	1,776	3,393	444	261	30,000	244,700	$3,660	$14,814
2	80	20	1	4	Longlines	*Trawls	-1.15	7,104	2,158	1,776	166	120,000	154,700	3,660	14,158
3	20	80	0	4	Longlines	*Trawls	-1.14	2,220	3,393	1,100	261	30,000	244,700	3,213	14,814
4	80	20	0	4	Longlines	*Trawls	-1.12	8,878	2,158	4,439	166	120,000	154,700	3,213	14,158
5	20	80	1	3	Longlines	*Trawls	-1.19	1,776	4,690	444	938	30,000	244,700	3,660	9,447
6	80	20	1	3	Longlines	*Trawls	-1.19	7,104	3,040	1,776	608	120,000	154,700	3,660	8,653
7	20	80	0	4	Handlines	*Trawls	-1.31	3,680	3,393	1,840	261	30,000	244,700	1,859	14,814
8	80	20	0	4	Handlines	*Trawls	-1.78	14,718	2,158	7,359	166	120,000	154,700	1,859	14,158
9	20	80	1	4	Longlines & Cod Traps	*Trawls	-1.15	1,644	3,393	411	261	30,000	244,700	3,755	14,814
10	80	20	1	3	Longlines & Cod Traps	Longlines & *Trawls	-1.18	6,584	3,040	1,646	608	120,000	154,700	3,751	8,804

* Midwater trawls for redfish, bottom trawls for cod and flatfish (for tonnage class 4 vessels).
Bottom trawls (for tonnage class 3 vessels).

** Figures shown here are the results of model simulations in which the total 1978 Newfoundland groundfish catch is assumed to be caught by combinations of a variety of alternative fishing techniques. See explanatory notes to Table 7, page 78 and commentary on pages 94-97.

IV. Conclusions and Policy Implications

The main conclusions of this paper have been drawn in the previous two subsections; here we summarize them.

Longlines, or longlines combined with cod traps (the latter used only during the peak season), and trawls, are the most cost-effective techniques used in the Newfoundland groundfishery. We have found gillnets and pair trawls to be highly inefficient and handlines without merit as a component of the modern fishery. Cod traps are highly productive but, because of seasonal restrictions on their use, the low quality of fish obtained with this technique, and the relatively high cost of the equipment, traps do not add substantially to the cost-effectiveness of the industry.

We find that medium-sized longliners (tonnage class two) are not cost-effective in the groundfishery. These vessels are more productive than the small boats and smaller longliners (Table 2) but their costs are disproportionately larger. In addition, we have found that there is little advantage in using larger longliners (tonnage class three).

Ten years ago, much was heard in Newfoundland about the gillnet and longliner "revolutions". We conclude that however revolutionary the introduction of these types of gear might have been, their introduction seems to have been an inefficient way of modernizing the Newfoundland groundfishery. The authors of Setting a Course (Vol. Ia, pp.77 ff.) seem quite happy with the longliners (apparently those in tonnage classes two and three) and with trap boats (while recognizing that this fleet cannot be expanded significantly), and extremely unhappy with the small boats. We find that the increased range and productivity of the larger longliners are offset (and in the case of tonnage class two vessels more than offset) by their increased cost. We also find that the increased costs of using traps just balance their additional productivity, so that there is little or no gain in using cod traps rather than longlines. We therefore find it difficult to support the conclusions concerning fishing techniques stated in Setting a Course.

We emphasize, once again, that this study reports on an analysis of the Newfoundland groundfishery. With the increased harvests that are anticipated from Canada's declaration of a two-hundred mile resource control limit expected to be concentrated in groundfish, our analysis stresses the economics of using newly constructed vessels and gear in the groundfishery. Selected types of vessels and equipment currently used by fishermen may not be economical when used solely for groundfish but they may be more economically appealing when their versatility for fishing non-groundfish species is taken into account. In this paper we do not consider the economic (or productivity) implications of fishermen combining groundfish and non-groundfish operations.

A second point concerning our conclusions which should be noted is that our statistical work is based upon historical experience. We consider neither new types of vessels and gear which have not been used in the Newfoundland fishery before 1978 nor modifications of existing gear types that may be made in the future.

In terms of cost-effectiveness, there is little to choose between concentrating cod catches in the inshore or offshore sectors. The most efficient inshore and offshore techniques both require the same degree of subsidization. The increased cost of labor in the inshore sector is offset by the increased cost of gear and vessels in the offshore sector. For the purpose of increasing employment while maintaining the independence of the Newfoundland fishermen, a cost-effective decision can be made in favor of the inshore fishery. Once again we recall that this decision is made without regard to social overhead capital costs and costs associated with the establishment of small seasonal fish plants. These fixed facilities may weight the analysis in favor of concentrating the codfishery in the offshore sector but we have not made the necessary calculations and we remain totally agnostic on this point.

Even if the decision were made to emphasize the inshore fishery, it must be recognized that the employment generated in the fishery, for a catch at 1978 levels, cannot reasonably be expected to exceed eleven thousand men. Any greater employment would require increased subsidies. For instance, by using handlines, employment could be raised from eleven thousand to seventeen thousand men but the subsidy would have to rise from \$1.12 to \$1.78 per dollar revenue to cover capital, labor and non-labor operating costs of fishing activity. The harvesting sector of the Newfoundland fishery cannot reasonably be expected to generate sufficiently large employment to seriously help counteract Newfoundland's perennial unemployment problem.

It is interesting, of course, to speculate on the employment implications of the 1985 catch projections. Those projections are based upon the expectation of increased fish populations and these populations will, in turn, increase the catch per unit effort of various fishing techniques. The relative productivity weights obtained in this study should still be effective with the larger population densities but the actual catch per unit effort figures used in this analysis will not be appropriate. To expand this study to handle the projected 1985 catch, we must incorporate population dynamics into the productivity analysis. This expanded analysis will be the subject of a subsequent paper.

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