

Resource and Fishery Distributions in the Gulf of Maine Area in Relation to the Subarea 4/5 Boundary

R. G. Halliday, J. McGlade, R. Mohn, R. N. O'Boyle, and M. Sinclair¹
Department of Fisheries and Oceans, Fisheries Research Branch
P. O. Box 550, Halifax, Nova Scotia, Canada B3J 2S7

Abstract

A proposal to modify the NAFO statistical boundary between Subareas 4 and 5, making it correspond to the new maritime boundary between Canada and the USA in the Gulf of Maine Area, is evaluated. History of the Subarea 4/5 boundary, topography and oceanography of the Gulf of Maine Area, distributions and migrations of the exploited phases of commercial species, and the distributions of fisheries are reviewed. The effect of boundary changes on long-term series of commercial catch and fishing effort data is analysed. It is concluded that, on the basis of size of the geographic areas affected and on their historical importance to fisheries, the only practical way of implementing the proposed change is (i) to reassign small areas between Div. 5Y and Div. 4X, and (ii) to establish a new division of Subarea 4 from what is currently the northeastern part of Subdiv. 5Ze. This solution will result in disruptions to historical data series which are considered to be trivial, whereas some advantages could accrue from having an additional statistical area. A change in the boundary to correspond to the newly-defined jurisdictional areas for fisheries management is considered a necessary rationalization of the statistical system from an administrative point of view.

Introduction

At its June 1985 meeting, the NAFO Scientific Council noted the recent International Court of Justice (ICJ) decision regarding the maritime boundary between Canada and the USA in the Gulf of Maine Area (NAFO, 1985). The Council decided to consider the appropriate location of the NAFO Subarea 4/5 boundary, in light of this decision, at its September 1985 meeting. Subsequent to the June meeting of the Council, Canada put a proposal before the September 1985 meeting of the General Council (NAFO, MS 1985) to modify the Subarea 4/5 boundary. The proposal read "Given the establishment of the Maritime Boundary between Canada and the USA, it would be appropriate to adjust the 4/5 line to coincide with this boundary. This would facilitate reporting for all concerned. ..."

To support its considerations, the Scientific Council requested a review of relevant data based on the guidelines for boundary change approved by the Coordinating Working Party on Atlantic Fishery Statistics (CWP) (FAO, 1982), and which are given in Annex I of the June 1985 STACRES report (NAFO, 1985). This paper addresses that request. The main part of the paper addresses the advantages and disadvantages of changes in the light of administrative, biological, fishery and statistical considerations, and takes into account the possibilities of subdividing previous statistical areas rather than moving boundary lines to create completely new statistical areas. This meets working principles (a) to (d) of the CWP guidelines. The supporting documentation required under (e) of the CWP guidelines follows in the Appendix, with Section I giving a brief description of the topography and oceanography of the Gulf of Maine Area, Section II giving the distributions and migrations of the exploited phases of a comprehensive list of species, and Section III giving distributions of fisheries in the area and an analysis of the effects of boundary changes on long-term series of commercial catch and fishing effort data.

History of the Subarea 4/5 Boundary

¹ Authors in alphabetical order.

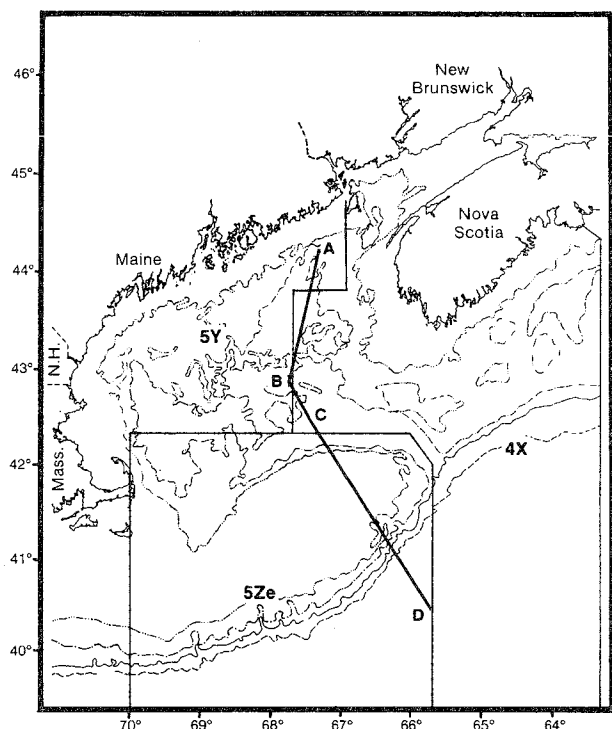


Fig. 1. The ICJ line in relation to NAFO boundaries in the Gulf of Maine Area.

The line between Subareas 4 and 5 in the present NAFO Convention (Fig. 1), which is identical to that contained in the ICNAF Convention established in 1949, is defined as follows: "beginning at the terminus of the international boundary between the United States of America and Canada in Grand Manan Channel, at a point at $44^{\circ} 46' 35.346''$ north latitude; $66^{\circ} 54' 11.253''$ west longitude; thence due south to the parallel of $43^{\circ} 50'$ north latitude; thence due west to the meridian of $67^{\circ} 40'$ west longitude; thence due south to the parallel of $42^{\circ} 20'$ north latitude; thence due east to a point in $66^{\circ} 00'$ west longitude; thence along a rhumb line in a southeasterly direction to a point at $42^{\circ} 00'$ north latitude and $65^{\circ} 40'$ west longitude; and thence due south to the parallel of $39^{\circ} 00'$ north latitude". The present Subarea 4/5 line is, therefore, almost identical to that of NACFI as modified by the USA in 1943 which, in itself, was in the same general location as the original NACFI line of 1932.

Although the location of the lines used is well documented by NACFI (1935) and by Rounsefell (1948), the reasons for the precise positions chosen is less so. It can be surmised with confidence that the contemporary results of haddock stock separation research (Huntsman and Needler, 1927; Needler, 1930) and preoccupation with biostatistical analysis of the haddock fisheries (Rounsefell, 1948) had a profound influence on the NACFI decision to run the boundary line between Browns and Georges Banks and up the middle of the Bay of Fundy.

Rounsefell's (1948) account of the development of fishery statistics concentrates on development of the unit area system designed to define discrete commercial fishing grounds. Rounsefell states that the 1936 modification to the NACFI line was to achieve a closer correspondence between it and the boundaries of the unit areas. Since, up to that point, these unit areas had been designed to describe the haddock fishery, it appears that haddock resource and fishery distributions continued to dominate thinking about boundaries. Rounsefell's account of the basis for the 1943 changes in the NACFI line is cryptic. He states "Placing the catches of the two sides of the Bay of Fundy in the same area is more logical than the former division". It appears, therefore, that this change was an administrative convenience.

It is quite clear from Rounsefell's (1948) paper, for example, that the intention in devising boundaries was for statistical purposes, and that the boundaries should separate biological stocks, and on a smaller scale, the major fishing grounds. The statistics were to be used to determine the population dynamics of the major species, and this knowledge was to be used for conservation purposes. NACFI was a purely scientific organization without fishery regulatory authority. ICNAF provided the first regulatory authority for high seas fisheries in the Gulf of Maine Area. The ICNAF Convention divided the Convention Area into subareas (ICNAF, 1951). These subareas were used to define the geographic areas of responsibility of subgroups within the ICNAF Commission called Panels. Panels were the basic organizational entities for consideration and recommendation of conservation measures. Utilization of the NACFI boundary in the Gulf of Maine Area as the dividing line between the responsibilities of Panels 4 and 5 destined it to be a major line of delimitation for conservation purposes.

The ICNAF Panel system for Subareas 4 and 5 became defunct in 1977 with extensions of coastal state jurisdiction. The Subarea 4/5 line continued to be used for some time by USA authorities, and continues to be used by Canadian authorities, for domestic regulatory purposes.

The New Maritime Boundary Between Canada and the USA

On 12 October 1984, the International Court of Justice in The Hague rendered its judgement on delimitation of the maritime boundary between the USA and Canada in the Gulf of Maine Area. The decision was that the boundary be defined by geodetic lines connecting the points with the following coordinates of latitude and longitude:

- | | | |
|----|-------------------------------|-------------------------------|
| A. | $44^{\circ} 11' 12''\text{N}$ | $67^{\circ} 16' 46''\text{W}$ |
| B. | $42^{\circ} 53' 14''\text{N}$ | $67^{\circ} 44' 35''\text{W}$ |

- C. 42° 31' 08"N 67° 28' 05"W
D. 40° 27' 05"N 65° 41' 59"W

This boundary originates in the northeastern corner of Div. 5Y, approximates the Div. 4X/5Y boundary at 67°40'W then cuts diagonally across the northeastern portion of Subdiv. 5Ze (Fig. 1). It ends over deep water within 1'59" of the Subdiv. 5Ze/Div. 4X boundary at 65°40'W.

Canadian and USA jurisdictional claims both originate at the land boundary terminus in the Grand Manan Channel, coincident with the terminus of the Subarea 4/5 line. These claims overlap until they reach Point A, where they cross (Fig. 2). The dispute referred to the ICJ involved only those parts of the claims of the two parties which were seaward of Point A. Thus, the Court's decision does not extend landward of Point A, and claims in that area remain unresolved. The ICJ was

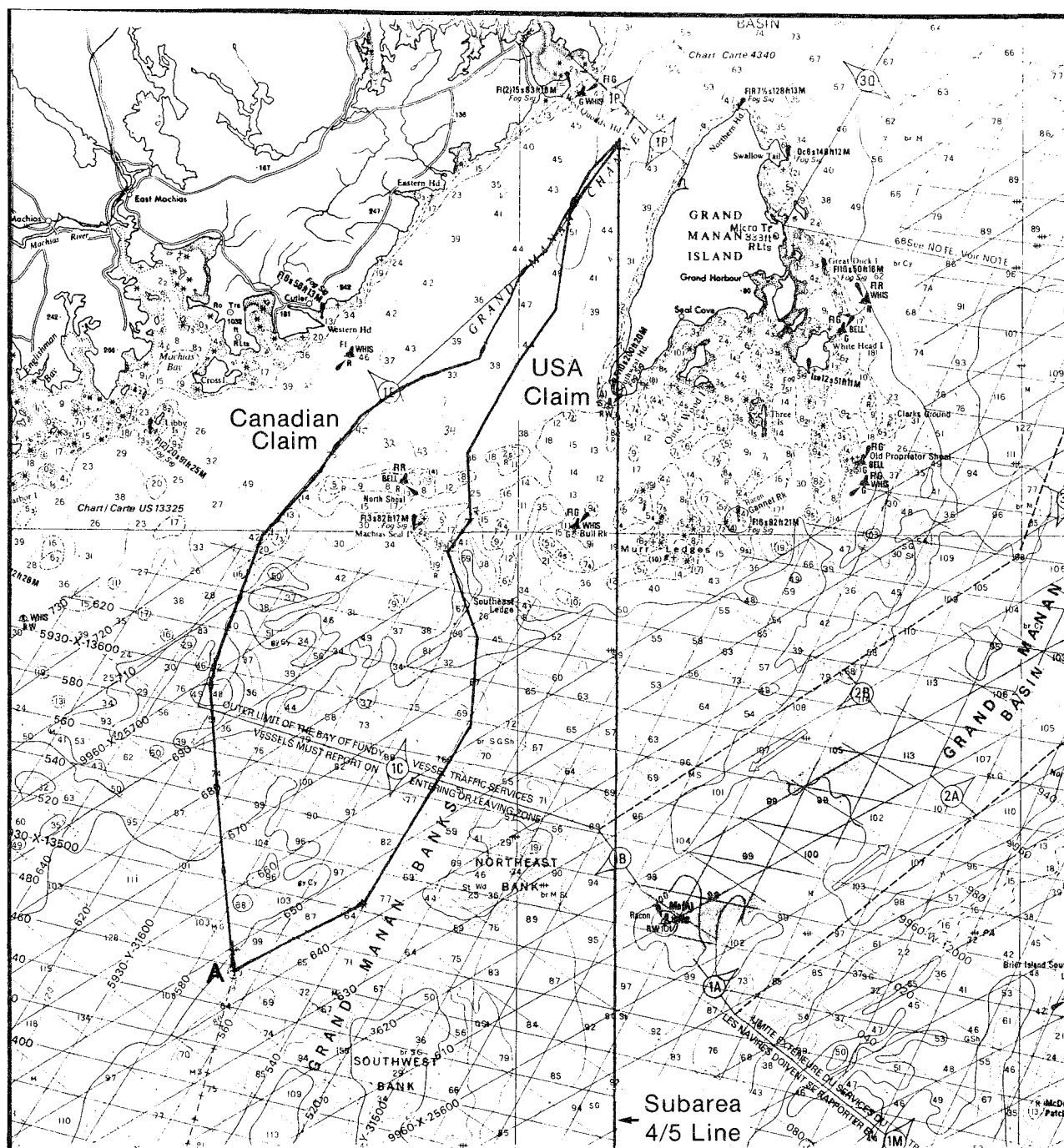


Fig. 2. Location of Point A, unresolved jurisdictional claims of Canada and USA landward of Point A, and the present Subarea 4/5 boundary line, in relation to bottom topography.

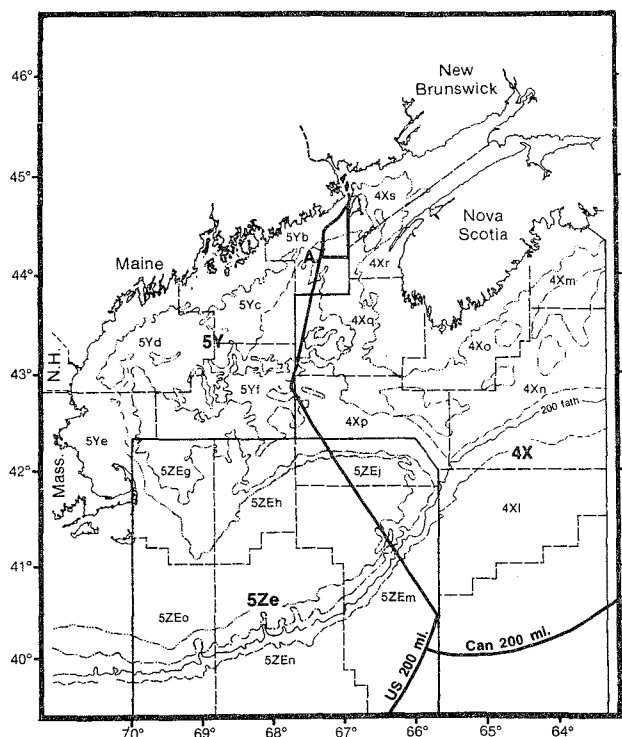


Fig. 3. Gulf of Maine Area showing NAFO divisions, Canada-USA unit areas, and the ICJ line with the two landward extensions from Point A used as examples in the analysis.

requested to terminate its decision within a triangle bounded by 40°N 67°W, 40°N 65°W, and 42°N 65°W. Point D lies within this triangle, but jurisdiction seaward of Point D also remains unresolved.

With regard to the unit area system (Fig. 3), which will be used subsequently in data analysis, the ICJ line transects six unit areas, 4Xp, 4Xq, 5Yb, 5Yf, 5Zj, and 5Zm. (These latter unit areas could, perhaps more correctly, be referred to as 5Zej and 5Zem as both are in Subdiv. 5Ze. However, for brevity, and as there is no danger of confusion, the terminology 5Zj and 5Zm is used here.) The unit areas shown in Fig. 3 are those currently in use by Canada which are closely similar, though not quite identical, to those defined by Rounsefell (1948) as applying from 1943 to the USA statistical system.

Canadian Proposal for Revision of Subarea 4/5 Boundary

The Canadian proposal to adjust the Subarea 4/5 boundary to coincide with the ICJ line (NAFO, MS 1985), although clear in that all areas to the east of the ICJ line would be in Subarea 4 and all areas to the west of it would be in Subarea 5, leaves open the question of precisely how this is to be accomplished, in addition to the question of the impact that adoption of such a proposal would have. Indeed, the impacts will depend to a significant degree on the precise changes to be

adopted. The following framework has been used for the evaluation of potential impacts of a change in the boundary.

It is necessary to connect Point A to the international land boundary terminus, the origin of the present Subarea 4/5 boundary as well as an agreed point in the jurisdictional claims of Canada and the USA. It is presumed that the connecting line will not proceed to the terminus in a direction taking it west or south of Point A. Thus, it is considered below for the purpose of providing illustrative examples of potential impacts that the "maximum" and "minimum" area of unit area 5Yb which would be reassigned from Div. 5Y to Div. 4X would be defined by the Canadian claim line (approximately a line due north from Point A) and by a line due east from Point A respectively (Fig. 3).

South of Point A, the ICJ line cuts off small portions of 4Xq and 4Xp, and of 5Yf, which would become parts of Subarea 5 and Subarea 4 respectively. The ICJ line then cuts off large portions of 5Zj and 5Zm which would become part of Subarea 4. In keeping with CWP working principle (c), it is necessary to consider whether these reassigned areas are large and important enough to merit creation of new divisions or subdivisions to maintain statistical continuity, or whether they become part of adjacent divisions or subdivisions within their new subarea.

Finally, the course of the proposed subarea boundary seaward of Point D will have to be decided upon. The proximity of Point D to the present Subarea 4/5 boundary suggests that the ICJ line could be joined in some fashion to the present boundary at 65°40'W and thence run due south to 39°00'N. The ICJ line south of about 41°00'N lies over depths greater than 1000 fm and Point D is well off the continental shelf. Thus, any solution adopted which involves only that area south of 41°00'N cannot affect historical fishery records in a significant way, with the possible exception of those for large pelagic species. If the ICJ line is joined to the present Subarea 4/5 line in the immediate proximity of Point D, statistics for these species will not be significantly affected either.

With regard to the application of CWP working principle (c), the practicalities of the two possible courses of action, i.e. creation of new statistical units or simple transfer of part of one existing area to another, becomes clear from inspection of the areas involved (Table 1) and the general distribution of fisheries (Fig. 4 and 5). The areas of the portions of present divisions or subdivisions which would be reassigned as to subarea under the Canadian proposal are mostly small: 40 n. mi² from 5Yf, 161 n. mi² from 4Xp, 193 n. mi² from 4Xq, and about 350–700 n. mi² from 5Yb. These areas represent 0.3–5.5% of the divisions to which they presently belong, which are average-sized

TABLE 1. Sizes of areas proposed for reassignment in relation to sizes of present statistical areas in the Gulf of Maine Area.

Parameter	Div. 4X ^a		Div. 5Y ^a		Subdiv. 5Z ^a	
	4Xq	4Xp	5Yb	5Yf	5Zj	5Zm
A. Surface area (n. mi ²)	3,414	3,192	1,624	3,689	2,063	3,000
B. Area to be reassigned (n. mi ²)	193	161	357–726 ^b	40	1,435	924
C. B as % of A	5.7	5.0	22.0–44.7 ^b	1.1	69.6	30.8
D. B as % of Div. or Subdiv. area	1.1	0.9	2.7–5.5 ^b	0.3	8.4	5.4
E. Total reassigned area (n. mi ²)	354		397–766 ^b		2,359	
F. E as % of Div. or Subdiv. area	2.0		3.0–5.8 ^b		13.8	

^a Surface areas: Div. 4X (<200 fm) = 18,200 n. mi²; Div. 5Y = 13,200 n. mi²; Subdiv. 5Ze (<200 fm) = 17,100 n. mi².

^b Minimum and maximum values based on a line running east from Point A and on the Canadian jurisdictional claim line respectively (see text).

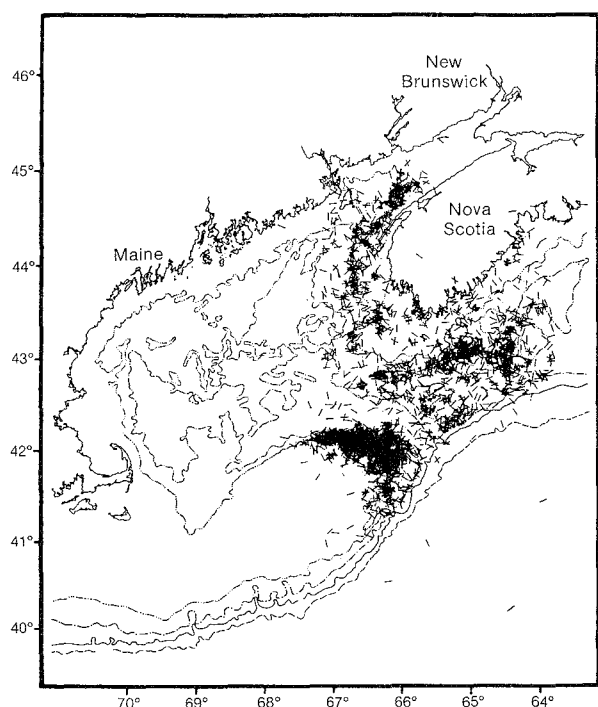


Fig. 4. Canadian surveillance sightings of Canadian vessels in the Gulf of Maine Area.

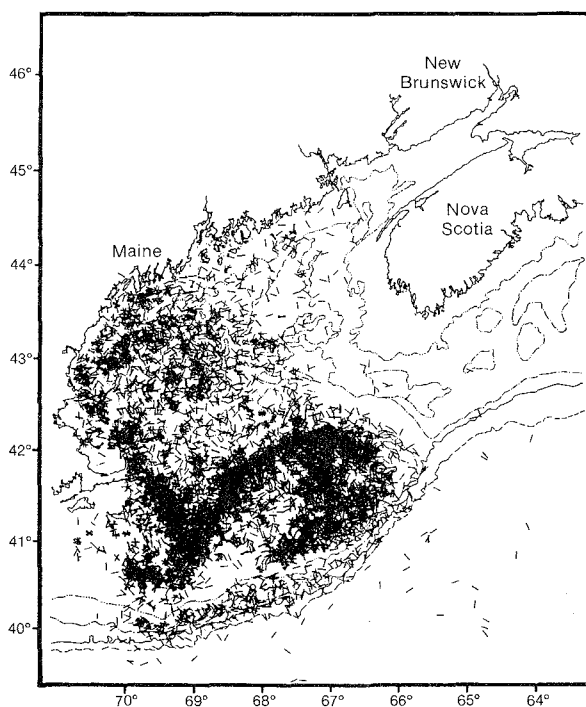


Fig. 5. USA surveillance sightings of USA vessels in the Gulf of Maine Area.

NAFO divisions. Indeed, these areas are small in relation to the size of the unit areas used by Canada and the USA as the minimum geographical unit for offshore fisheries data collection. Even using a 10' quadrangle collection system, only three such quadrangles would fit in the (minimum) part of 5Yb reassigned, one in each of 4Xp and 4Xq, and none in 5Yf. These areas are clearly too small to be established as divisions or subdivisions in the NAFO statistical grid. The Canadian proposal can only be implemented in a practical way by reassignment of these areas to become parts of the adjacent divisions of their new subarea. Thus, these parts of Div. 5Y reassigned would become integral parts of Div. 4X and *vice versa*.

The area of Subdiv. 5Ze proposed for reassignment is substantially larger. Together, the parts of 5Zj and 5Zm reassigned are about 2,400 n. mi² which is about 14% of Subdiv. 5Ze. (All area comparisons are based on the areas which are shallower than 200 fm, i.e. the presently fished areas). This is about the size of a unit area and on the small end of the size scale of present NAFO divisions and subdivisions. It is intermediate in area between Subdiv. 3Pn and 4Vn, however, which indicates that it is a practical size to allow for the collection of separate statistics. Figures 4 and 5 indicate that the area in question on Northeast Georges Bank is one of the most intensely fished parts of the Gulf of Maine Area. It is clear, therefore, that reassign-

ment of this area to Subarea 4 as an integral part of Div. 4X would create a major discontinuity in the statistical records for both areas. (These same figures, on the other hand, suggest that the other areas discussed above are not the focal points of intense fishing.) Thus, the northeastern part of Georges Bank clearly needs to be identified separately from Div. 4X to maintain continuity of statistics, and it is of sufficient size for establishment of a separate division or subdivision of Subarea 4 to be practical.

These considerations simplify the assessment of the impact of adopting the Canadian proposal. This now amounts to examining the effect of transferring four small areas between Div. 4X and 5Y on historical statistical series, and of creating a new division or subdivision in Subarea 4 from what is presently the northeastern portion of Subdiv. 5Ze, and to assessing the advantages and disadvantages arising from such actions.

Impacts of Adopting the Canadian Proposal

Administrative considerations

The present Subarea 4/5 line acquired much of its administrative significance through its embodiment in the ICNAF Convention as a boundary between the jurisdiction of Panels. The ICJ line has become the primary jurisdictional boundary in the Gulf of Maine Area, delimiting the administrative regimes of the USA and Canada.

The utilization of statistics on fishing operations and catch is ubiquitous in the administration of fisheries. As matters now stand, it is not possible to generate separate statistics on fishing operations in USA and Canadian waters of the Gulf of Maine Area directly from NAFO statistics. However, as these areas pertain to the separate jurisdictions for fisheries, the demand for separate statistics is axiomatic.

Biological considerations

The principal biological consideration in locating statistical lines is to place lines between stocks of the primary species so that statistics for areas contained within the lines relate to biological units. The key issue here, then, is whether the changes in lines proposed improve or worsen the position of statistical lines in relation to perceived stock boundaries.

In the case of the northeastern part of Subdiv. 5Ze, since a statistical line is to be added given a new statistical area, the correspondence of the statistical grid with biological divisions cannot be worsened. In fact, opportunities are created for defining resource and management units in more detail than before. The distributional data in Appendix Section II and associated

figures suggest the possibility of benefits in more closely defining concentrations of pollock, argentine, redfish, cusk and scallops.

In the central part of the area (4Xp, 4Xq and 5Yf), the lines in question run across deep water. This area is not inhabited by shallow water species such as winter flounder, yellowtail flounder, haddock, red hake and scallops, and species such as cod, pollock and *IIIex* are not common there. The area is of some importance to redfish, lobster, argentine, silver hake, white hake, cusk, American plaice, witch flounder, angler and dogfish. There is no indication for any of these species, from the data in Appendix Section II that the changes in lines proposed would relocate significant proportions of major concentrations from one subarea to the other. Given the small size of the areas involved, this conclusion is not surprising.

In 5Yb, the line from Point B to Point A runs through deep water, but any line from Point A to the land boundary terminus must cross shallow water regions. The deeper area appears to be relatively significant in terms of the distribution of white hake and witch flounder, but not for the other deep water species such as redfish, silver hake, cusk and argentine. The line landward from Point A will cross areas of some local importance to the distribution of cod, pollock, haddock and herring, and also to lobster and small scallop stocks. In relation to the overall distribution of stocks of these finfish species, the proportion of the stock, or stock complex, occurring within the area in question is small, and, in relation to management areas in use for the finfish, the area involved in relocation is again a small part of the total involved. For localized resources such as scallops and lobster, the small areas being dealt with here are of potential importance. However, it is also true that the scale of the NAFO statistical grid is too coarse to be of value in their management. These resources are managed based on geographic units other than the NAFO system, e.g. statistical districts defined on the basis of lengths of coastline.

Fishery considerations

One of the key concerns about moving statistical grid lines is the potential disruption of historical data series on catches and fishing activity which would create difficulties for stock assessment and related management efforts. In considering fishery distributions, then, the important issue is whether major parts of fisheries which have been in one NAFO division would be relocated into another division as a result of changing the position of statistical lines.

It has been concluded above that the northeastern sector of Subdiv. 5Ze has been the focus of major fishing activity (see Fig. 4 and 5), but that it would be practical to deal with this situation by creating a new statistical division or subdivision. Attention can be

focused, therefore, on the areas north of Subdiv. 5Ze (Appendix Section III).

The central basin areas (4Xp, 4Xq and 5Yf) are areas of generally low fishing activity (Fig. 4 and 5). There were some restrictions on fishing areas during the period to which Fig. 4 and 5 applies (Fig. 6), but these do not invalidate this conclusion. The Canadian groundfish fishery, which has concentrated on haddock, cod and pollock, has been prosecuted in shallower, more eastern areas. The USA fisheries for redfish and silver hake have been conducted primarily in more western parts of the basin. Herring and scallop fisheries are shallow water fisheries, and the areas in question are of no importance. Although the lobster resource extends into these areas, the Canadian fishery, at least, has historically been conducted further to the east.

In 5Yb, there has been Canadian groundfish fishing by the small-vessel fleet on the Grand Manan Banks. In recent years, a small scallop fishery has occurred on these banks and in coastal Grand Manan Island waters. These banks have also, in some years, supported substantial Canadian herring purse seine fisheries. The fleets prosecuting these fisheries are wide ranging (with the exception of some local scallop druggers), and the fisheries tend to be extensions of larger fisheries undertaken in adjacent Div. 4X.

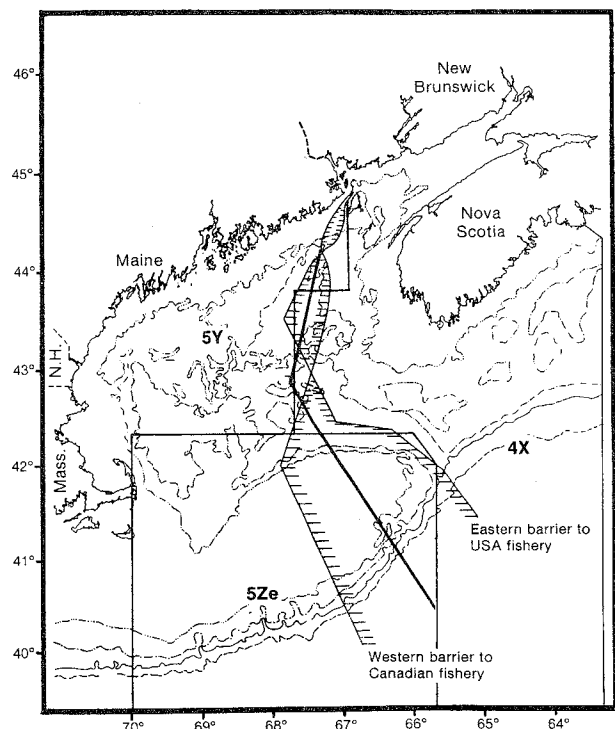


Fig. 6. Limits of fishing for national fleets as agreed by Canada and USA, subsequent to termination of reciprocal fishing agreements and prior to the ICJ decision on jurisdiction in the Gulf of Maine Area.

Statistical considerations

Creation of a new statistical division or subdivision from the northeast sector of Subdiv. 5Ze, by permitting more detailed description of fishing activities, could confer advantages. Moving lines, as will be necessary in more northern areas if the Canadian proposal is followed, runs the risk of disrupting historical data series. The important issue, then, is how much of a disruption might result.

Based on the resource and fishery distribution data presented above, commercial catches from the areas to be reassigned would be expected to be low and to be a small proportion of the total in Div. 4X or Div. 5Y. To obtain an estimate of the quantities which may be involved in the case of groundfish, a method was developed to prorate commercial catches for larger areas based on research vessel bottom trawl survey data (Appendix Section III). The key assumption of the method is that commercial catches within unit areas are distributed in proportion to resource abundance as described by surveys. These calculations (Tables 2 and 3) confirm that the catches likely to be reassigned from one division to another are small. The largest estimates are for pollock involving transfer of about 500 tons from Div. 4X to Div. 5Y, and 140 tons from Div. 5Y to Div. 4X. In both cases the amount transferred is about 3% of the division total.

The calculations for groundfish include 5Yb. In the case of Canada, since essentially all of its Div. 5Y groundfish catch has come from 5Yb, the impact on the statistics from that fleet is large. However, since the

TABLE 2. Proportion of the resource estimated to be in the reassigned area as a percentage of the total resource in each relevant unit area of Div. 4X and 5Y, for 18 species items.

Species	Resource by unit area (%)			
	4Xp	4Xq	5Yb ^a	5Yf ^b
American angler	14	14	40	—
American plaice	11	16	29	—
Atlantic argentine	5	3	53	—
Atlantic cod	2	2	35	—
Atlantic halibut	0	0	12	—
Atlantic redfish	9	20	42	—
Cusk	3	8	45	—
Haddock	2	1	45	—
Pollock	6	11	50	—
Red hake	1	4	30	—
Silver hake	15	16	38	—
Skates	6	10	37	—
Spiny dogfish	8	8	46	—
White hake	24	21	32	—
Winter flounder	0	0	22	—
Witch flounder	6	7	40	—
Wolffishes	1	1	74	—
Yellowtail flounder	0	0	0	—
Reassigned area as % of unit area (Table 1)	5	6	45	1

^a Example here refers to maximum area as defined in Table 1.

^b Too small to calculate.

TABLE 3. Average annual catches of various groundfish species by Canada and USA in Div. 4X and 5Y during 1968-78, and estimated amounts taken in parts of these Divisions proposed for relocation, as weights (tons) and as percentages of total catch in the Divisions, based on resource distributions in Table 2 (+ indicates less than one-half the unit used).

Species	Canada			USA		
	Catch (tons)	Relocated (tons)	(%)	Catch (tons)	Relocated (tons)	(%)
Division 4X						
American angler	17	+	0.8	1	—	—
American plaice	467	14	3.0	36	2	4.8
Atlantic argentine	—	—	—	—	—	—
Atlantic cod	21,213	95	0.5	434	4	1.0
Atlantic halibut	442	—	—	3	—	—
Atlantic redfish	2,103	85	4.0	2,723	101	3.7
Cusk	3,698	42	1.1	32	1	3.4
Haddock	18,591	89	0.5	1,345	13	1.0
Pollock	14,465	459	3.2	395	18	4.7
Red hake	—	—	—	8	+	0.5
Silver hake	12	—	—	2	+	15.5
Skates	25	+	1.1	—	—	—
Spiny dogfish	—	—	—	—	—	—
White hake	2,609	63	2.4	49	5	10.1
Winter flounder	978	—	—	12	—	—
Witch flounder	494	3	0.6	31	1	2.8
Wolffishes	921	3	0.3	38	+	0.7
Yellowtail flounder	211	—	—	13	—	—
Division 5Y^a						
American angler	—	—	—	276	—	—
American plaice	4	1	29.0	2,058	3	0.1
Atlantic argentine	—	—	—	—	—	—
Atlantic cod	99	33	33.6	8,556	58	0.7
Atlantic halibut	1	—	—	33	+	0.7
Atlantic redfish	30	13	42.0	8,597	20	0.2
Cusk	2	+	22.5	716	2	0.3
Haddock	128	57	44.3	1,948	25	1.3
Pollock	213	106	49.5	4,524	31	0.7
Red hake	—	—	—	478	+	0.1
Silver hake	—	—	—	10,024	—	—
Skates	—	—	—	80	—	—
Spiny dogfish	—	—	—	—	—	—
White hake	12	4	32.0	2,031	11	0.6
Winter flounder	—	—	—	1,292	+	+
Witch flounder	8	3	40.0	1,218	13	1.1
Wolffishes	1	1	74.0	146	1	0.5
Yellowtail flounder	1	—	—	1,417	—	—

^a Maximum area, as defined in Table 1, used as an example.

total Canadian Div. 5Y catch is small, the overall impact of the transfer is not great. In the case of scallops, a similar situation applies. The maximum Canadian scallop catch from Div. 5Y (all from 5Yb) was 1,220 tons (round) in 1983, or 14% of the total Div. 5Y catch. In other years, the amount has been much smaller and the proportion trivial. In the case of herring, significant fisheries have periodically been prosecuted on the shoals south of Grand Manan Island and on the Grand Manan Banks. Annual catches of 25,000-30,000 tons have been documented as taken by Canadian purse seiners in 1972 and 1973 (Miller and Halliday, MS 1974; Miller and Iles, 1975). These catches were reported in the ICNAF Statistical Bulletin as Div. 4X catches although they occurred partly in Div. 5Y (Fig. 7). They were also counted as catches against allocations and

TACs for the Div. 4X stock and included in Div. 4X stock assessments. This reflected the view that the present Subarea 4/5 line was not well placed with regard to herring population structure and that the Grand Manan Banks catches should be associated with Div. 4X. While the validity of this view may well be open to challenge, the fact of the matter is, for herring, that a revised line which placed Grand Manan Banks in Div. 4X would more closely correspond to historical practice than does the present line.

Conclusions

The present Subarea 4/5 line has origins which can be traced back to the considerations of NACFI in

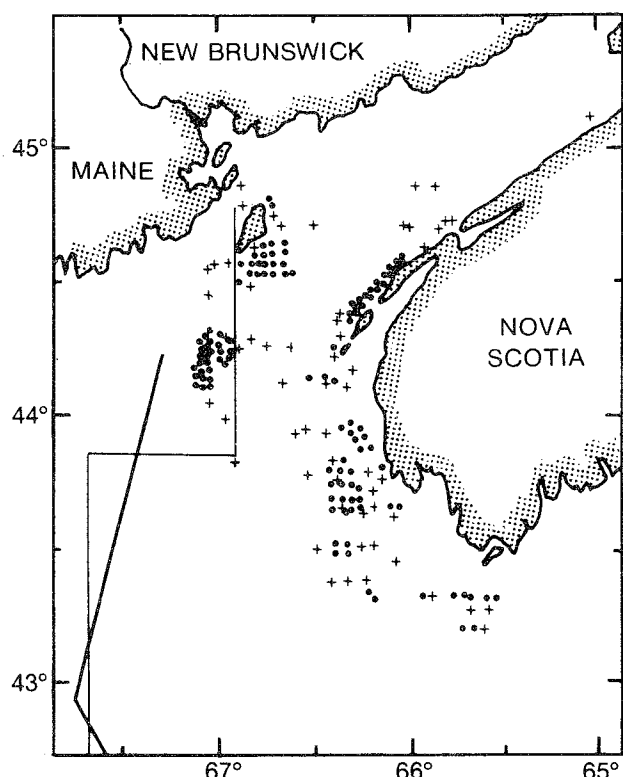


Fig. 7. Distribution of herring catches in 1972 and 1973 by the portion of the Canadian purse-seine fleet which provided log-records. (Each dot represents 1,000 tons, and each cross represents a catch less than 1,000 tons.)

the late 1920's and early 1930's. Offshore fisheries in those days were "banks" fisheries, and the precursor of the Subarea 4/5 line was one of a relatively small number used to divide the entire Northwest Atlantic into groups of major fishing banks.

When the first version of this line was drawn in 1932, biological knowledge of stock relationships of the major species in the area was largely confined to haddock. With embodiment of this line in the ICNAF Convention as the dividing line between the areas of regulatory responsibility of Panels, it took on a major role as a delimiter of management areas. The importance of the Subarea 4/5 line in historical management practices has stemmed, therefore, as much or more from its administrative usage as from its importance as a delimiter of biological populations.

The new jurisdictional situation in the Gulf of Maine Area divests the Subarea 4/5 line of its administrative importance and makes the ICJ line the primary administrative boundary in the area. It is clear that, for administrative purposes alone, statistics on fisheries will be required which relate directly to the two administrative regions (the Canadian and USA zones). The present statistical system does not provide these. It is also highly desirable that the solution to one problem does not create another, i.e. that the implementation of

the Canadian proposal does not create important discontinuities between past and future statistical series which have become the basis for stock assessment and fisheries management.

The ICJ line approximates the present Subarea 4/5 line in its northern part, but diverges in its southern part. To make the ICJ line the Subarea 4/5 boundary, the most practical adjustments are, for the northern part, to subsume the small parts of the present Subareas 4 and 5 that are cut off by the ICJ line into the adjacent divisions of these subareas. For the southern part, the northeast sector of the present Subdiv. 5Ze cut-off by the ICJ line is large enough to be established as a separate division or subdivision.

Based on resource and fishery distributions in the area, this solution to the proposed line change would result in disruptions to historical data series which are considered to be trivial. Some statistical advantages could accrue from having an additional statistical area which would allow a more detailed description and analysis of fisheries events in the Gulf of Maine Area.

Acknowledgements

Many persons on the staff of the Fisheries Research Branch, Scotia-Fundy Region, and several scientists from other Branches within the Department of Fisheries and Oceans, have contributed information on which this account is based. Permission to use the bottom-trawl survey data of the US National Marine Fisheries Service (Northeast Fisheries Center, Woods Hole, Mass.) is gratefully acknowledged.

References

- ANON. 1981. Atlas of tidal currents, Bay of Fundy and Gulf of Maine. Can. Hydrogr. Serv., Ottawa, 36 p.
- FAO. 1982. Guidelines concerning changes in boundaries of major fishing areas. *FAO Fish. Rep.*, **274**: 9.
- GREENBERG, D. A. 1983. Modeling the mean barotropic circulation in the Bay of Fundy and Gulf of Maine. *J. Phys. Oceanogr.*, **13**: 886-904.
- HUNTSMAN, A. G., and A. W. H. NEEDLER. 1927. Fluctuations in the haddock fishery of the Bay of Fundy. *Contrib. Can. Biol. Fish. N. S.*, **3**(18): 423-436.
- ICNAF. 1951. Report of the first annual meeting, with appendices. *ICNAF Ann. Rep.*, **1**: 53 p.
- MILLER, D. S., and R. G. HALLIDAY. MS 1974. An assessment of the 4X-4Wb herring stock. *ICNAF Res. Doc.*, No. 74, Serial No. 3159, 38 p.
- MILLER, D. S., and T. D. ILES. 1975. Catch statistics for the Bay of Fundy herring fisheries, 1963-1974. *Can. Fish. Mar. Serv. Tech. Rep.*, **594**: 75 p.
- NACFI. 1935. North American Council on Fishery Investigations. Proc. 1931-1933, No. 2, King's Printer, Ottawa, 40 p.
- NAFO. 1985. Report of Scientific Council, June 1985 Meeting. *NAFO Sci. Coun. Rep.*, 1985: 29-100.

- NAFO. MS 1985. Modifications to the Subarea 4-5 boundary. *NAFO GC Doc.*, No. 6, Serial No. N1046, 1 p.
- NEEDLER, A. W. H. 1930. The migrations of haddock and the interrelationships of haddock populations in North American waters. *Contrib. Can. Biol. Fish. N. S.*, 6(10): 241-313.
- ROUNSEFELL, G. A. 1948. Development of fishery statistics in the North Atlantic. *US Fish. Wildl. Serv. Spec. Sci. Rep.*,

47: 27 p.

- SINCLAIR, M., R. K. MOHN, G. ROBERT, and D. L. ROD-DICK. 1985. Considerations for the effective management of Atlantic scallops. *Can. Tech. Rep. Fish. Aquat. Sci.*, 1382: 120 p.
- STASKO, A. B., and P. W. PYE. MS 1980. Canadian offshore lobster fishery trends. *Can. Atl. Fish. Sci. adv. Committee, Res. Doc.*, No. 56: 11 p.

Appendix

I. Bottom Topography and Circulation in the Gulf of Maine Area

The physical geography of the Gulf of Maine Area is shown in Fig. A1. On the seaward side of the Gulf is a shallow rim which lies off the coasts of Nova Scotia and Massachusetts, between Cape Sable and Cape Cod. This rim is formed by a series of banks and shoals, pierced by a depression on either end of Georges Bank. The Northeast Channel (about 250 m deep) separates Georges Bank from Browns Bank and the shoal areas of southwestern Nova Scotia, and the Great South Channel (about 80 m deep) separates Georges Bank from Nantucket Shoals off southeastern Massachusetts. Georges Bank is a large, detached, oval-shaped bank, defined by the Great South Channel and the Northeast Channel and variously by either the 50 fm (91 m) or 100 fm (183 m) isobaths to the north and south. The Gulf of Maine itself has an average depth of 150 m. Its floor consists of a series of shallow basins, separated by low sills and flat-topped banks. The deepest of these basins is Georges Basin, which lies at the

western end of the Northeast Channel immediately north of Georges Bank and has a maximum depth of 206 fm (377 m).

The average surface circulation in the Gulf of Maine Area is shown in Fig. A2. The flow of the surface layer southwestward along the Nova Scotia coast splits into two as it approaches the Gulf of Maine Area. Part of the offshore component recirculates around Browns Bank in a clockwise direction, whereas the inshore component moves directly past Cape Sable, joining a generally northwestward flow along the eastern side of the Gulf of Maine Basin. Some of this water crosses the mouth of the Bay of Fundy, and some moves rapidly into the Bay on the Nova Scotia side and thence outward on the New Brunswick side before joining the general flow southwestward along the New England coast. The flow splits near Cape Cod, with part flowing around the Cape by way of the Great South Channel and continuing southwestward, whereas the remainder moves northeastward along the southern

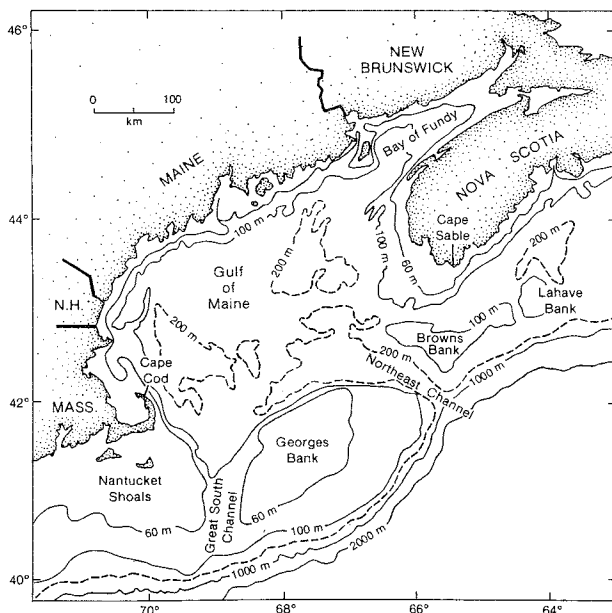


Fig. A1. Physical geography of the Gulf of Maine Area.

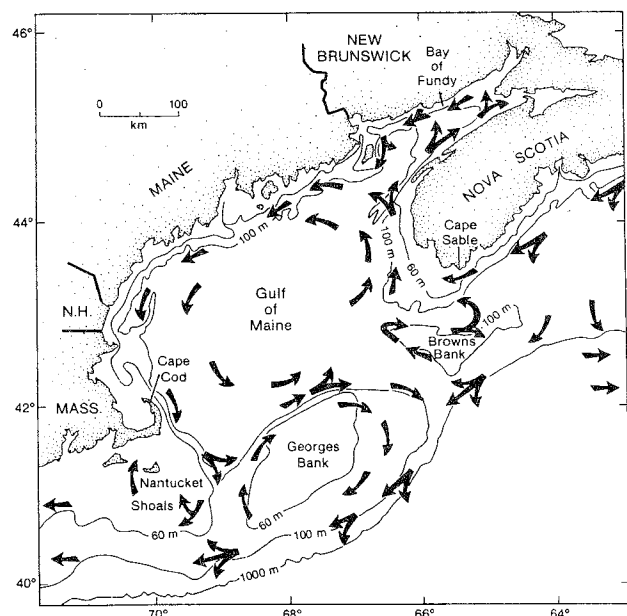


Fig. A2. Average surface circulation in the Gulf of Maine Area. (R. W. Trites, BIO, Dartmouth, N. S., Canada, pers. comm.)

side of the Gulf of Maine Basin and onto the northern flank of Georges Bank, where a relatively narrow, high-velocity jet develops. Here again the flow splits, with some moving back towards Nova Scotia and the rest curving southward and thence southwestward along the southern flank of Georges Bank.

At the southwestern part of Georges Bank, some of the flow turns northward in the eastern part of the Great South Channel and recirculates around the Bank, whereas the remainder crosses the Great South Channel in its progressive southwestward movement over the Shelf. The Nantucket Shoals form a "leaky" boundary between the western Gulf of Maine and the coastal shelf to the southwest. Most of the water flowing south and southwestward over the Shoals originates in the western Gulf of Maine and subsequently mixes with Nantucket Sound water and shelf water near the great South Channel before joining the general southwestward flow over the middle and outer parts of the continental shelf. Although the direction of the mean flow is nearly parallel to the bottom isobaths throughout much of the Gulf of Maine Area, there is a small but significant offshore surface flow along most of the outer edge of the continental shelf throughout the area. Also, there is a tendency for water to recirculate around the banks and basins, and thus a single

parcel of water may make more than one circuit of the Gulf of Maine or Georges Bank before continuing its southwestward journey.

Current speeds generally diminish with depth. In basins, the circulation and source of deep subsurface water usually differ appreciably from those of overlying waters. In basins like Emerald Basin on the central Scotian Shelf and Georges Basin, the deep water originates from offshore through subsurface penetration of Slope Water, whereas the upper water layer is part of the southward-moving Coastal Water. Computations of the mean annual influx into the Gulf of Maine through the Northeast Channel implies a replacement time of about 1 year for the deep water of the Gulf of Maine. The current pattern in the Gulf is not static and different pictures emerge, depending on season as well as depth.

In addition to the average circulation, the tidal circulation is also important in the Gulf of Maine Area, examples of which are shown in Fig. A3. The whole Bay of Fundy-Gulf of Maine-Georges Bank region forms a single tidal system. Based on a numerical model for this system, it appears that many of the persistent features of the observed mean flow are caused largely by the action of tides (Fig. A4). The clockwise gyre on Georges Bank, including the jet along the northern flank, and the gyres on Nantucket Shoals and Browns Bank, all bear a similarity to the average circulation pattern (Fig. A2).

II. Distribution of Fishery Resources in the Gulf of Maine Area

The distribution and migration of the exploited phases of the species fished in the Gulf of Maine Area are briefly described in this section. The distribution maps are composite interpretations of data from various sources, particularly from research vessel bottom-trawl surveys (for groundfish especially) and from commercial fisheries.

Groundfish species

Atlantic cod (Fig. A5). Coastal cod do not perform extensive migrations but form many localized stocks among which there is limited mixing. A discontinuity has been identified between Gulf of Maine and Cape Cod-South Channel cod, and the cod in these areas are recognized as separate stocks. The most southern group of coastal cod, called New Jersey cod, spend the summer in the Cape Cod-Nantucket Shoals area, mixed with local cod, but, in contrast to other coastal cod, migrate quite extensively to overwinter in more southerly USA waters, particularly along the coast of New Jersey. Offshore cod are quite separate from inshore cod, although there is evidence of some contri-

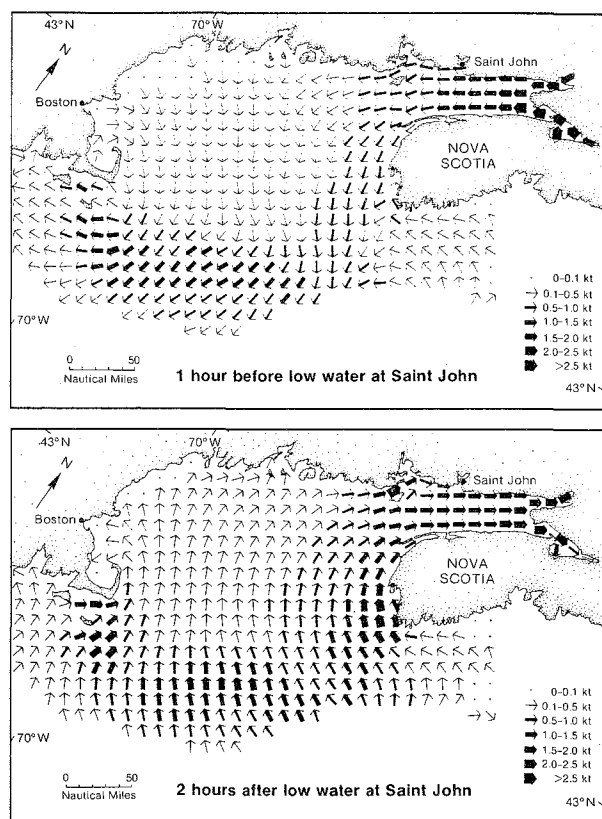


Fig. A3. Strength and pattern of tidal currents in the Gulf of Maine Area. (Data from Anon., 1981).

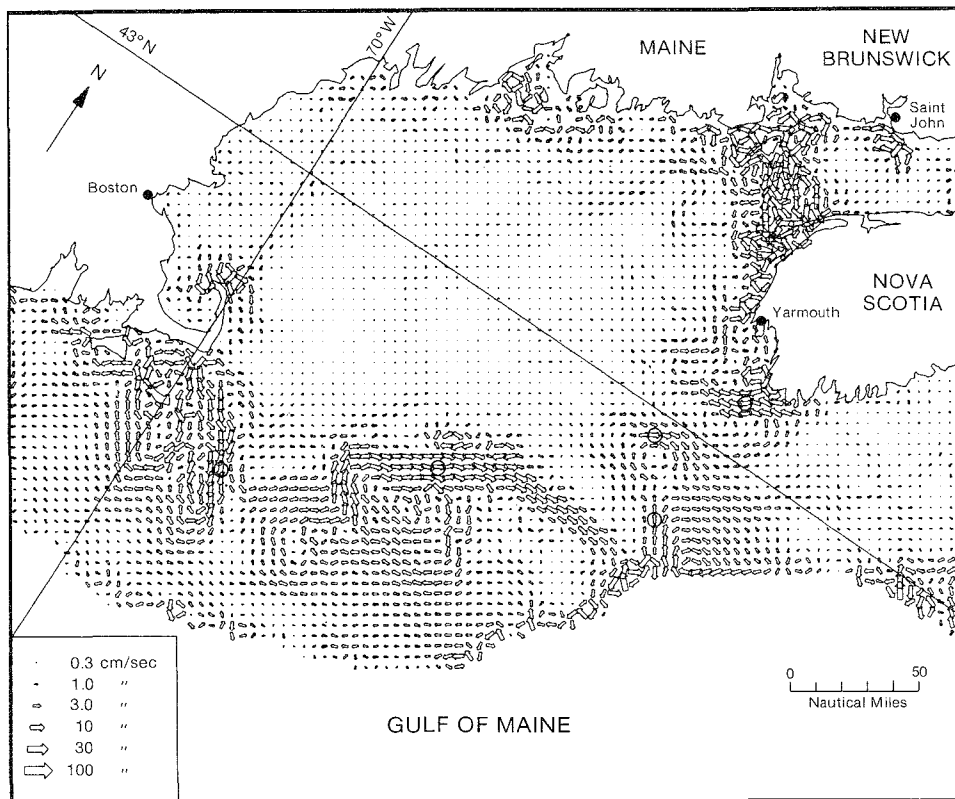


Fig. A4. Tidally-driven residual currents in the Gulf of Maine Area, showing clockwise gyre on Georges Bank with strongest current along its northern edge. (From Greenberg, 1983.)

bution to stocks in southwestern Nova Scotia coastal waters from the offshore banks. This does not appear to be a seasonal migratory movement but more of a drift of non-returning individuals, and it is unlikely to be sufficiently extensive to be significant to management. A more important interrelationship exists for Georges Bank and Browns Bank cod, between which there are quite extensive, apparently seasonal, movements.

There is extensive spawning of cod in many coastal regions, supporting the concept that these areas contain a complex of inshore cod stocks. A major spawning area of cod also exists on the northern part of Georges Bank. There is some evidence of spawning on Browns Bank, although this is fragmentary. Thus, the past conclusion that there is a spawning stock or stocks inhabiting the offshore banks of Div. 4X needs to be reexamined.

Haddock (Fig. A6). Available evidence indicates the presence of distinct haddock populations in Div. 4X, on the eastern end of Georges Bank, and in the Nantucket Shoals-western Gulf of Maine area. Egg and larval surveys have defined concentrations of spawning products in these three areas during the March-May period. These correspond to the closed areas defined for management purposes. Tagging studies have shown that there is little migration of adults

between Georges Bank and the Gulf of Maine. Historical tagging studies have also shown little movement between the Georges Bank and Browns Bank populations. The primary migrations involve northern movements by coastal Maine and Browns Bank populations, which bring these into the western and eastern sides of the Bay of Fundy respectively in summer, with a return movement in autumn.

Pollock (Fig. A7). This species occurs from Newfoundland to New Jersey but is most abundant in the Gulf of Maine Area. Spawning occurs in winter, in areas surrounding shoals, throughout the Scotian Shelf and Gulf of Maine, but it is not clear how temporally discrete these spawning aggregations are. Juvenile pollock appear in inshore waters of Massachusetts, Maine, New Brunswick and Nova Scotia during the summer, and migrate offshore with the onset of winter. The extent of trans-shelf migrations is unknown. However, it would appear from recent work on the stock structure of pollock in this area that some discreteness between those of the Scotian Shelf and the Northeast Peak of Georges Bank and those of the inner Gulf of Maine does exist.

Yellowtail flounder (Fig. A8). In the Gulf of Maine Area, there appear to be four relatively discrete aggregations of yellowtail flounder: (i) on southern Georges Bank, (ii) in the Nantucket Shoals area, (iii) in the Cape

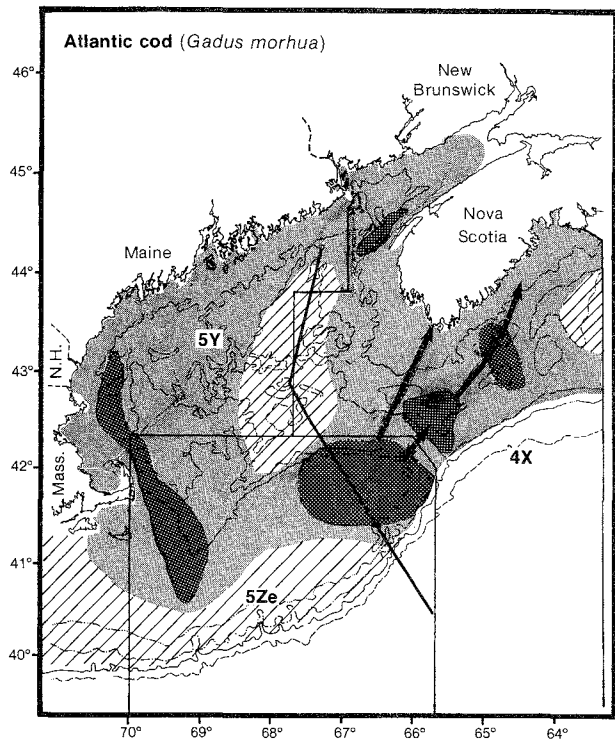


Fig. A5. Resource distribution of cod in the Gulf of Maine Area.

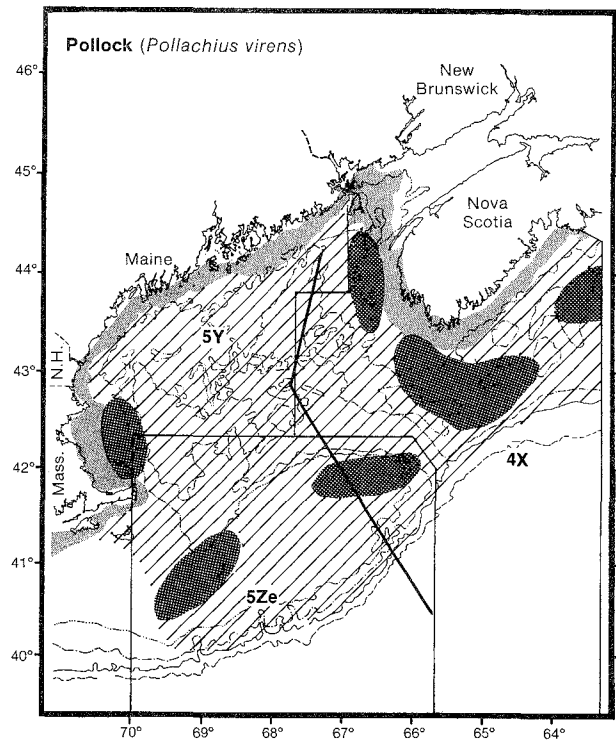


Fig. A7. Resource distribution of pollock in the Gulf of Maine Area.

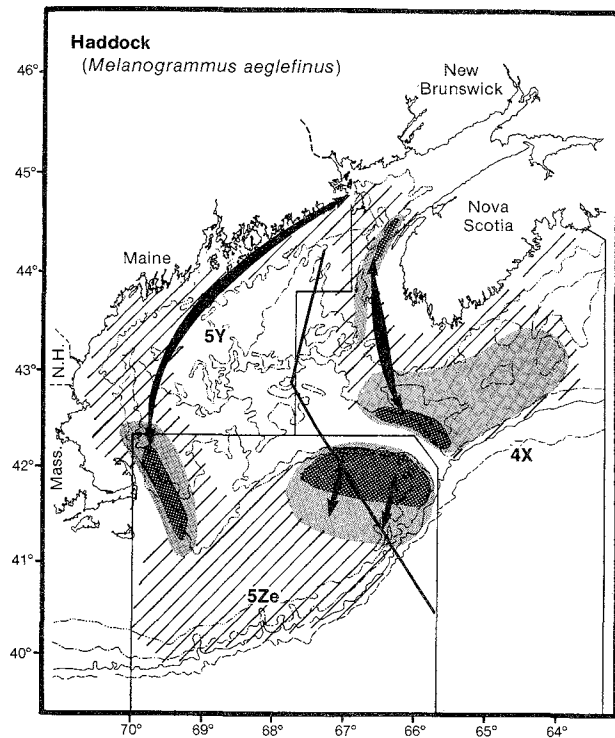


Fig. A6. Resource distribution and migration of haddock in the Gulf of Maine Area.

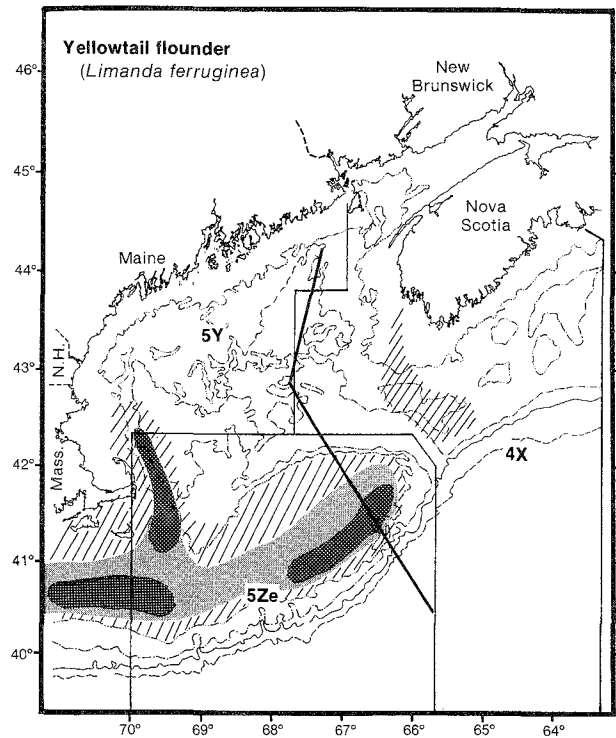


Fig. A8. Resource distribution of yellowtail flounder in the Gulf of Maine Area.

Cod area, and (iv) on Browns Bank. The Nantucket Shoals stock extends southwestward to the Middle Atlantic Bight. The Georges Bank stock is concentrated on the southern part of the bank and does not occur in strength on the northern and eastern parts. The Cape Cod and particularly the Browns Bank stocks are small. Movement of yellowtail flounder among these aggregations is limited.

Atlantic redfish (Fig. A9). Redfish is a deepwater species, occurring in basins and along the shelf edge in depths of 150–700 m (80–275 fm). It occurs throughout the Gulf of Maine Basin, and highest commercial catches have been obtained in its central part in the vicinity of Cashes Ledge, Fippinies Ledge and Jeffreys Bank. The southern limit of distribution appears to be the northwestern edge of Georges Bank from the Great South Channel to the western Fundian Channel. Very few redfish are found around the Northeast Peak of Georges Bank and the Southeast Peak of Browns Bank. Rather, they occur in commercial quantities along the outer edge of the Scotian Shelf and in the basins between the offshore Scotian banks and the coastal region.

Redfish move into deeper water as they grow larger, but there is no evidence for extensive seasonal migration or of long-distance movement of adults. This sedentary habit, combined with internal egg fertilization and release of young at the larval stage, which greatly reduces the length of time that the early life-history stages are subject to dispersion by currents, may indicate that redfish form many highly localized populations.

There is an area defined by German Bank and Browns Bank, the eastern Fundian Channel and Georges Bank where redfish are scarce. These relatively shallow water areas may serve as a partial barrier between redfish in the Gulf of Maine Basin and those on the Scotian Shelf to the east of Browns Bank. In this case, the Gulf of Maine Basin (i.e. Subarea 5 and the western part of Div. 4X) may contain a semi-isolated stock complex.

White hake (Fig. A10). This species is common on muddy bottom. Juveniles are found in shallow areas, whereas adults occur in depths of 110 m and more. The adults move into shoal areas for spawning in late winter and spring, and there appears to be some inshore movement in autumn. The stock structure of this species is unknown. Largest concentrations of white hake occur in the deeper waters of the Gulf of Maine Basin and in the inner areas, especially at the mouth of the Bay of Fundy. Populations in these areas may thus be distinct from those further to the east.

Cusk (Fig. A11). This is a deepwater species which is found throughout the Gulf of Maine at depths

exceeding 150 m. Spawning occurs in spring and early summer. There have been no studies on the stock structure of cusk, but it would appear from surveys that the species is distributed fairly evenly, except for areas of high concentration in the inner part of the Gulf of Maine.

Atlantic argentine (Fig. A12). This is a shelf-edge species with a predominantly temperate distribution pattern. The available evidence indicates that there is not much mixing of populations along the edge of the shelf, but there are short migrations associated with spawning. In addition to the known spawning population associated with Emerald Basin, spawning also appears to occur in the Fundian Channel. There could prove to be other spawning locations, however, and firm divisions among spawning stocks cannot be drawn with present knowledge.

Although argentine have been recorded as far south as New Jersey, the southern limit of fishable concentrations is the northeastern edge of Georges Bank. The densest concentrations of argentine occur in the northern Fundian Channel along the southwestern slope of Browns Bank, extending eastward around the southern tip of Browns Bank and along the edge of the Scotian Shelf. They occur throughout the Gulf of Maine but sparsely, except along the western slope of German Bank.

Silver hake (Fig. A13). This species, although widely distributed, ranging from Newfoundland to South Carolina, is most abundant off the New England coast and in the central Scotian Shelf area. It overwinters along the outer continental shelf and slope and in deeper waters of the Gulf of Maine and moves to shallower waters during March to November to spawn. The major spawning grounds for silver hake include the coastal area of the Gulf of Maine, southern and southeastern Georges Bank, and further north on the Scotian Shelf. The most recent studies on stock structure indicate that there are two stocks in the Gulf of Maine Area, divided by a line from east to west across Georges Bank: the southern stock thus occupies the southern half of Georges Bank and the shelf as far south as Cape Hatteras, and the northern stock occupies the northern part of Georges Bank, the inner part of the Gulf of Maine, and the southwestern slope of Browns Bank. The dividing line between the northern stock and the central Scotian Shelf stock probably lies to the east of Browns Bank.

Red hake (Fig. A14). This species is found throughout the area from the Scotian Shelf to North Carolina but occurs in greatest numbers from Georges Bank to New Jersey. During winter, red hake are found in the deeper waters of the Gulf of Maine and along the slope and outer continental shelf of Georges Bank, whereas, from May to November, they migrate into

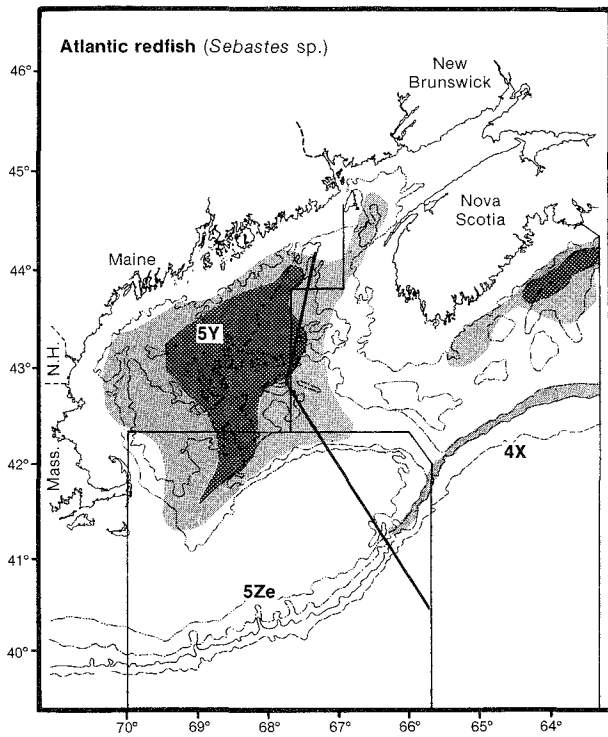


Fig. A9. Resource distribution of redfish in the Gulf of Maine Area.

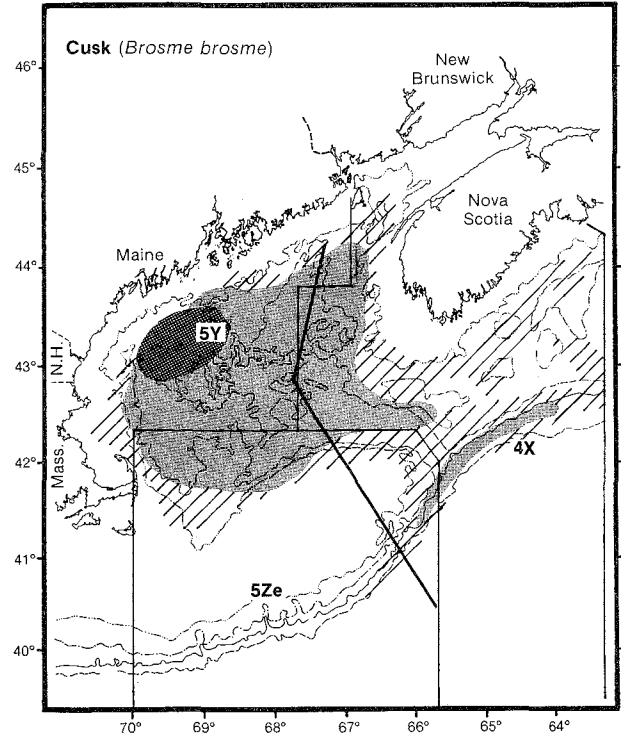


Fig. A11. Resource distribution of cusk in the Gulf of Maine Area.

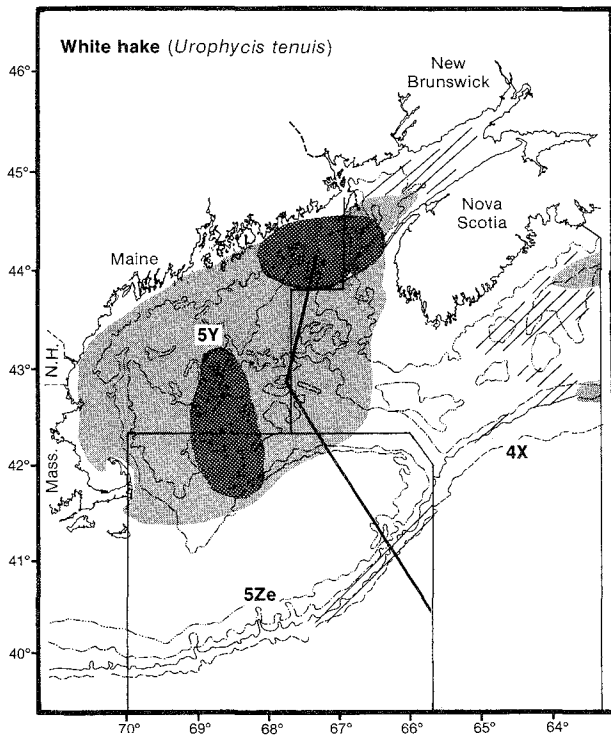


Fig. A10. Resource distribution of white hake in the Gulf of Maine Area.

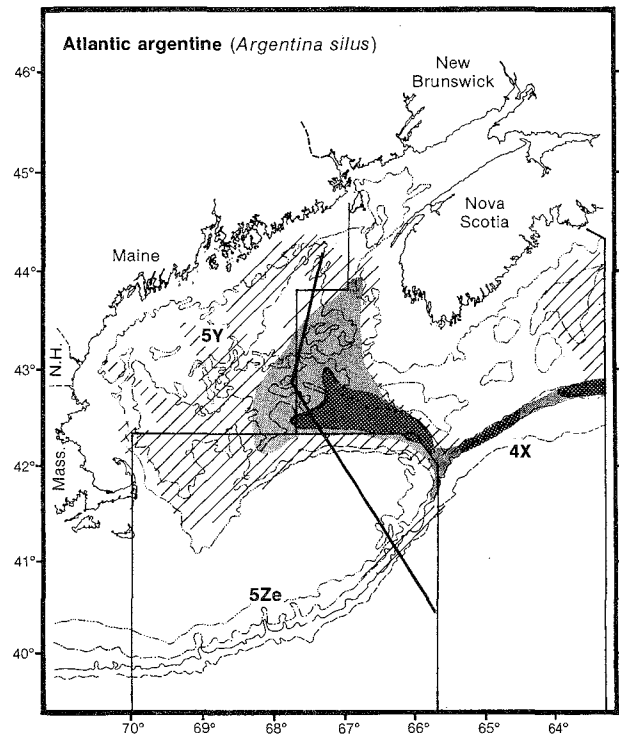


Fig. A12. Resource distribution of argentine in the Gulf of Maine Area.

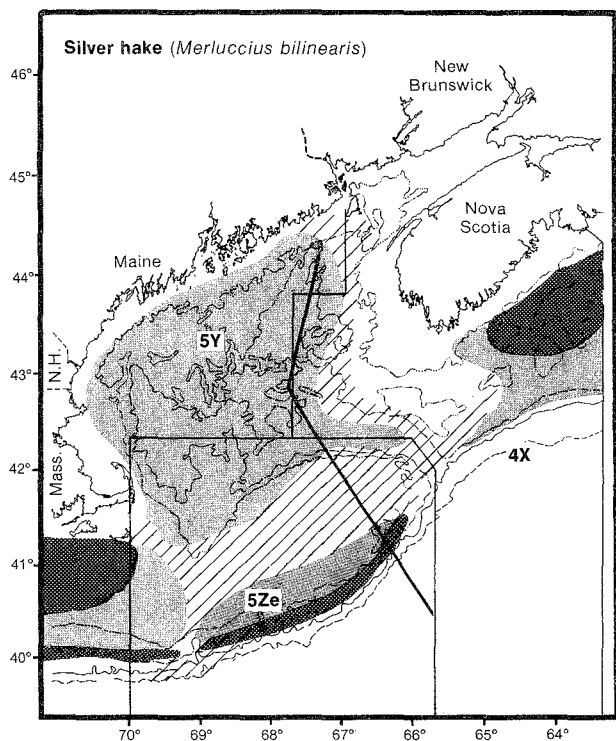


Fig. A13. Resource distribution of silver hake in the Gulf of Maine Area.

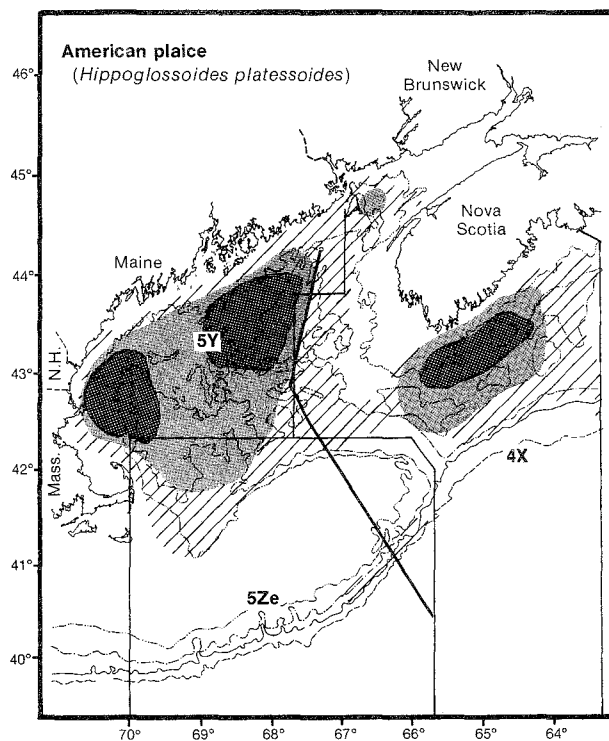


Fig. A15. Resource distribution of American plaice in the Gulf of Maine Area.

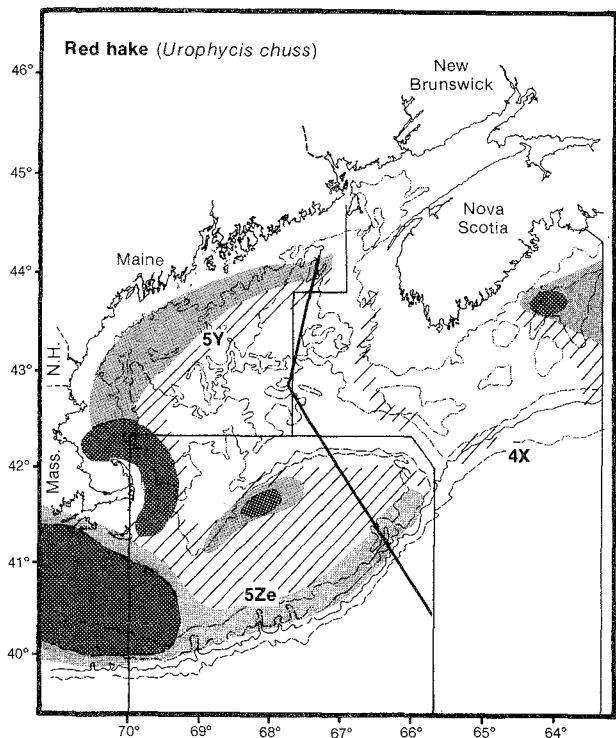


Fig. A14. Resource distribution of red hake in the Gulf of Maine Area.

shallower and inshore waters to spawn. A peculiarity of juveniles, which is pertinent to their survival, is the fact that they often reside within live sea scallops, appar-

ently using this behavioral characteristic as protection against predation. The stock structure of red hake is not well understood. However, from earlier studies by USSR scientists and from distribution of research-vessel catches, it would appear that there is a north-south discontinuity separating the red hake in the inner Gulf of Maine and those on the southern portion of Georges Bank. Larval distributions indicate that there is no discontinuity between Browns Bank and Georges Bank, but rather one which occurs to the east of Browns Bank.

American plaice (Fig. A15). Stock structure has not been defined. Groundfish survey information indicates that American plaice are concentrated in the deep waters of the inner Gulf of Maine.

Witch flounder (Fig. A16). As with American plaice, stock delineation has not been resolved. The species is ubiquitous in the inner Gulf of Maine, predominantly in the moderately deep areas.

Winter flounder (Fig. A17). Movements of this species are localized. In the southern part of their range, they migrate during winter to estuaries, embayments and salt-water ponds to spawn and move from these locations to deeper water during summer. In colder Canadian waters, spawning is later and the summer is spent inshore with movement to deeper, warmer water in winter months. There is evidence that winter

flounder tend to return to the same spawning locations in consecutive years. Restricted movement and differences in meristic and morphometric characteristics may indicate that relatively discrete local groups exist. It is primarily a shallow coastal species, but a substantial resource also occurs on the shallows of Georges Bank.

American angler (Fig. A18). This species is demersal and is found in a wide range of depths from the Gulf of St. Lawrence to North Carolina. It spawns in inshore waters from June to September, producing sheets of eggs connected by a mucous film that is up to 12 m long. The stock structure of this species is unknown. It is broadly distributed throughout Div. 4X and 5Y and Subdiv. 5Ze, with concentrations in the inner Gulf of Maine and mouth of the Bay of Fundy.

Spiny dogfish (Fig. A19). This species is a long-lived and slow-growing one whose reproductive capacity is limited by late maturity, a long gestation period, and low fecundity. Distributed in the western North Atlantic from Florida to Newfoundland, spiny dogfish are highly migratory and travel in schools which segregate by size and by sex as they mature. The species is distributed across the continental shelf and undergoes a seasonal migration, occupying the northern inshore portions of the range during the summer and the southern offshore portions of the range during the winter months. Reproduction occurs in southern waters. In the Northwest Atlantic, spiny dogfish probably comprise one stock, with migrations becoming more extensive as the fish grow to maturity.

Other groundfish. Other species of less commercial importance in the Gulf of Maine Area are skates (*Raja* sp.), tilefish (*Lopholatilus chamaeleonticeps*), summer flounder (*Paralichthys dentatus*), and windowpane flounder (*Scophthalmus aquosus*).

Pelagic species

Atlantic herring (Fig. A20). This species is highly migratory. During the summer-feeding phase of the adult annual migration, herring are aggregated in only three areas in significant concentration: along the fringes of Georges Bank, off Southwest Nova Scotia, and south of Grand Manan Island. Spawning occurs during mid-summer to mid-autumn at several well-defined locations. Subsequent to summer feeding and spawning, adult herring migrate to two overwintering areas: off Cape Breton and southwest of Cape Cod. The migration routes between the summer and winter distributional areas are not well described. Juveniles are distributed in coastal waters from western Maine to Southwest Nova Scotia.

Atlantic mackerel (Fig. A21). Tagging studies and other biological research have shown that the mackerel population in the NAFO Area is comprised of

northern (spawning in the Gulf of St. Lawrence) and southern (spawning in the Middle Atlantic Bight-Gulf of Maine region) contingents. The relative size of the two contingents has not been satisfactorily determined. Both contingents overwinter in Subarea 5 and 6 (mainly Subdiv. 5Zw and Subarea 6). It is not known what proportion of the northern contingent remains in Subarea 4, although it appears to be small. Only a minor portion of the southern contingent appears to move farther north than Subdiv. 5Ze during the summer-feeding period.

Swordfish (Fig. A22). This highly migratory species occurs in all world oceans between 45°N and 45°S. In the Northwest Atlantic, swordfish spawn in the Caribbean Sea, and their occurrence in Canadian waters in warmer months is a feeding phase. Migration patterns are not known but dispersal of juveniles by the Gulf Stream and movement of larger fish into continental shelf waters directly from warm Gulf Stream waters are the favoured hypotheses rather than an along-shelf migration. The above suggests that swordfish in the Northwest Atlantic, and possibly in a broader area, belong to a single stock or stock complex. Superimposed on this broad pattern is what appears to be a localization of distribution. The same groups of fish seem to occur in the same fishing areas each year, i.e. there appears to be a degree of "homing" on northern feeding grounds.

Other pelagic species. Species of less commercial importance in the Gulf of Maine Area include: bluefin tuna (*Thunnus thynnus*), large pelagic sharks such as the porbeagle (*Lamna nasus*), Atlantic butterfish (*Peprilus triacanthus*), Atlantic saury (*Scomberesox saurus*), alewife (*Alosa pseudoharengus*), blueback shad (*Alosa aestivalis*), Atlantic salmon (*Salmo salar*), and American shad (*Alosa sapidissima*). All of these species are highly migratory, the Gulf of Maine Area providing only a small part of their distributional range (e.g. see Fig. A23 for migration pattern of American shad).

Invertebrate species

Sea scallop (Fig. A24). The stock structure of this species is not well understood. There are persistent patterns of aggregations of scallops in the Gulf of Maine Area. At commercial size (after age 3 or 4) scallops are not migratory and each area can be managed independently. However, the eggs and larvae spend approximately 2 months in the water column and may be carried considerable distances. It is not known if or how the parental stock size affects future recruitment, and, in particular, whether parent stock size in one area could affect recruitment in other areas. There exists an unfishable portion of the resource, in refugia, which represents an unknown factor in the recruitment process.

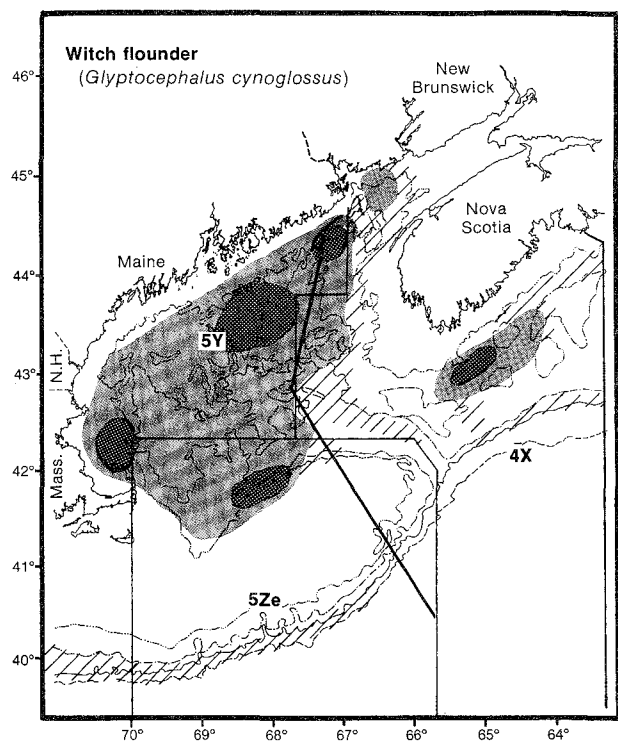


Fig. A16. Resource distribution of witch flounder in the Gulf of Maine Area.

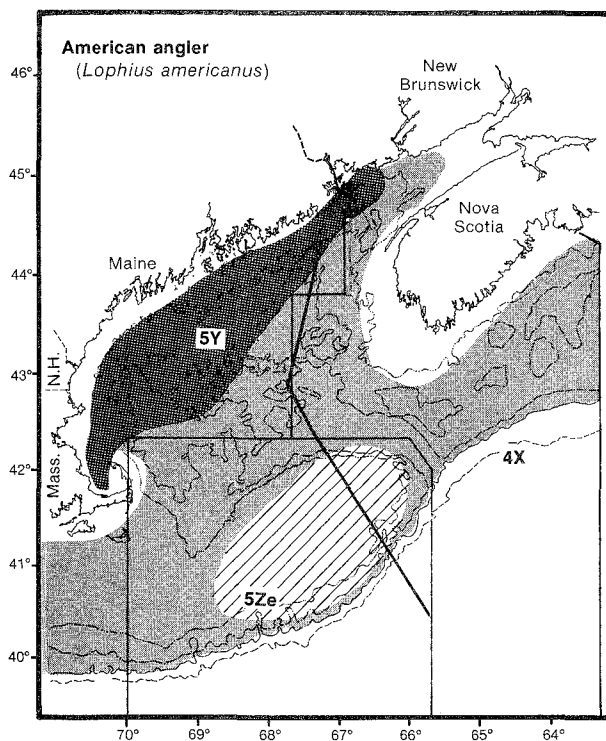


Fig. A18. Resource distribution of angler in the Gulf of Maine Area.

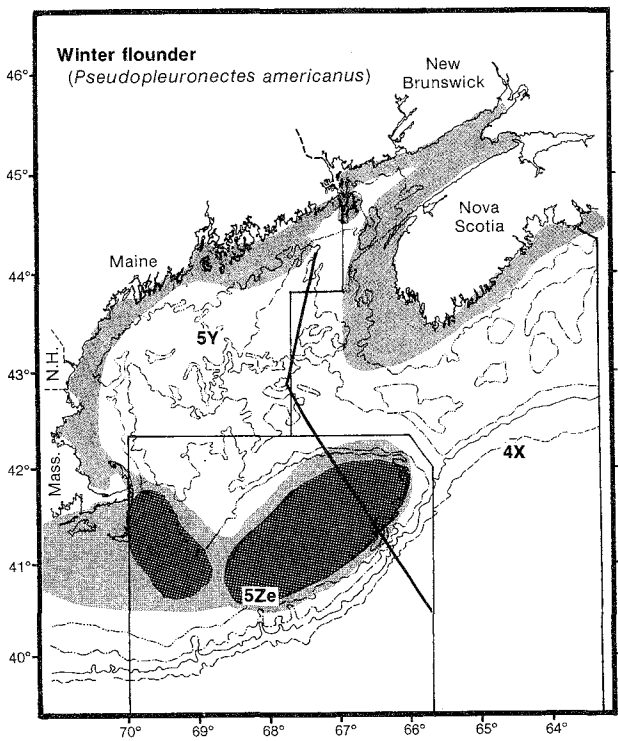


Fig. A17. Resource distribution of winter flounder in the Gulf of Maine Area.

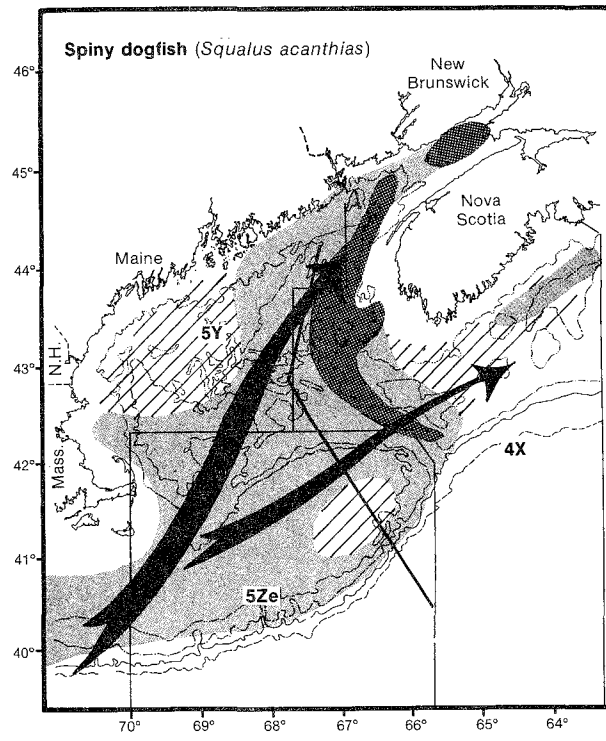


Fig. A19. Resource distribution (summer) and migration of spiny dogfish in the Gulf of Maine Area.

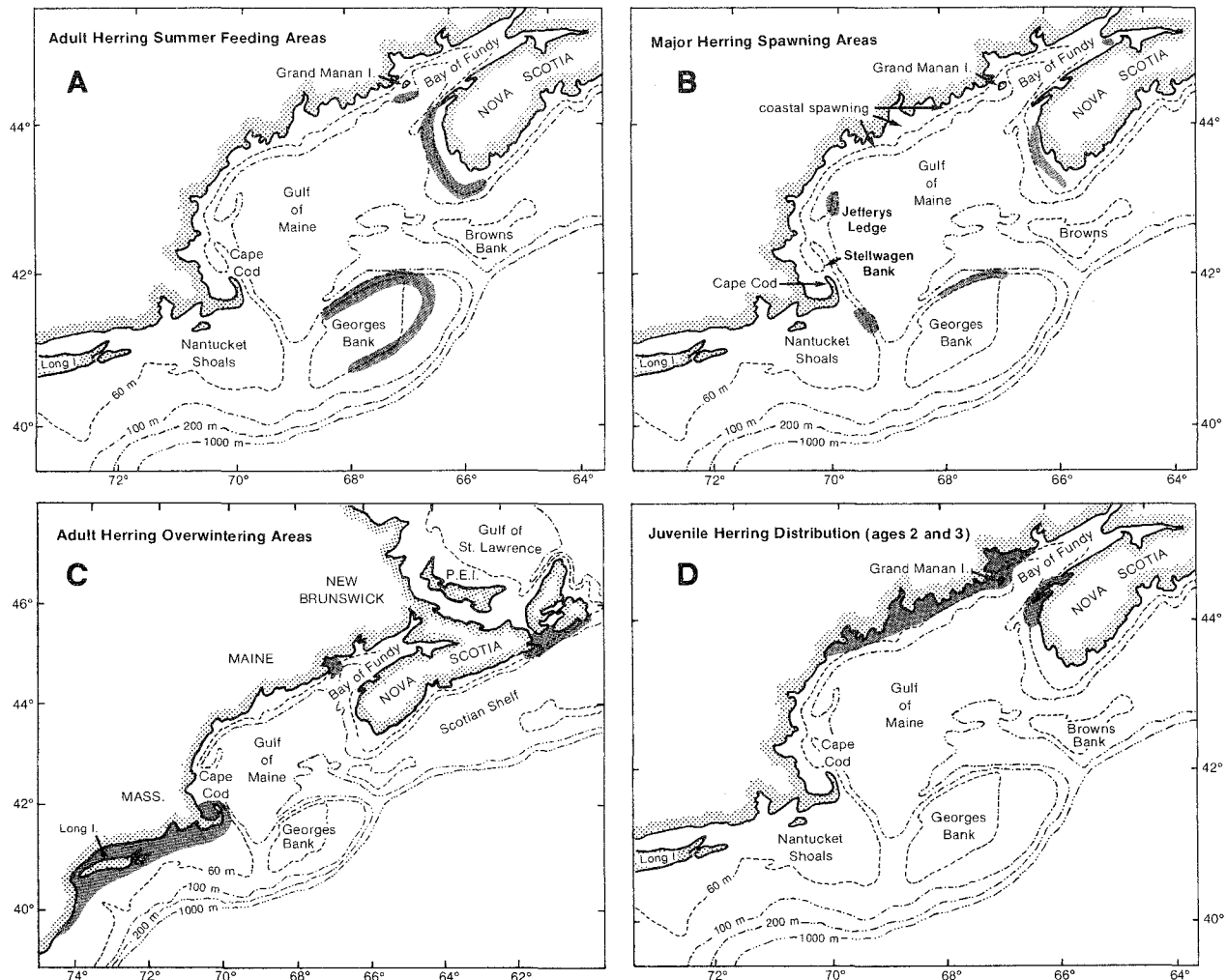


Fig. A20. Distribution of adult herring during (A) summer feeding, (B) spawning, and (C) overwintering, and of (D) juveniles (ages 2 and 3), in the Gulf of Maine Area.

American lobster (Fig. A25). Commercial quantities of offshore lobsters are found on Browns Bank and Georges Bank and, during the winter months, in the basins of the inner Gulf of Maine (Georges Basin and Crowell Basin). It appears that lobsters move out of these basins onto Browns Bank and possibly German Bank in the summer and autumn periods. Similarly, on Georges Bank, mature lobsters appear to migrate from the slope (100–500 m) where they spend the winter and spring to the shallow parts of the Bank (<100 m) in the summer and autumn. Lateral movements by large animals also occur along the slope in the form of long-distance nomadic wanderings with no apparent goal or return movement. Some mixing of lobsters occurs throughout the Gulf of Maine Area, but a clear account of stock structure and recruitment relationships has not yet been developed.

Long-finned squid (Fig. A26). This species is distributed from the Bay of Fundy and Browns Bank as far

south as the Gulf of Mexico, but fishable concentrations are generally limited to the area between Cape Hatteras and southern Georges Bank. Within the fishing areas, there is an overall decrease in abundance from south to north.

Long-finned squid undergoes seasonal migrations of up to 1,200 km, overwintering along the continental shelf edge and moving inshore in the Middle Atlantic and New England areas in the spring and summer. Spawning takes place inshore between May and October, resulting, in most years, in two cohorts from a major peak spawning in May and a smaller peak in October. Spawning occurs at 18–36 months of age, after which the squid are assumed to die. The life cycle is not fully understood, and it may be that two overlapping reproductive cycles are responsible for the extended spawning season and apparent variable age at spawning. It appears that there is only one stock of long-finned squid throughout its range.

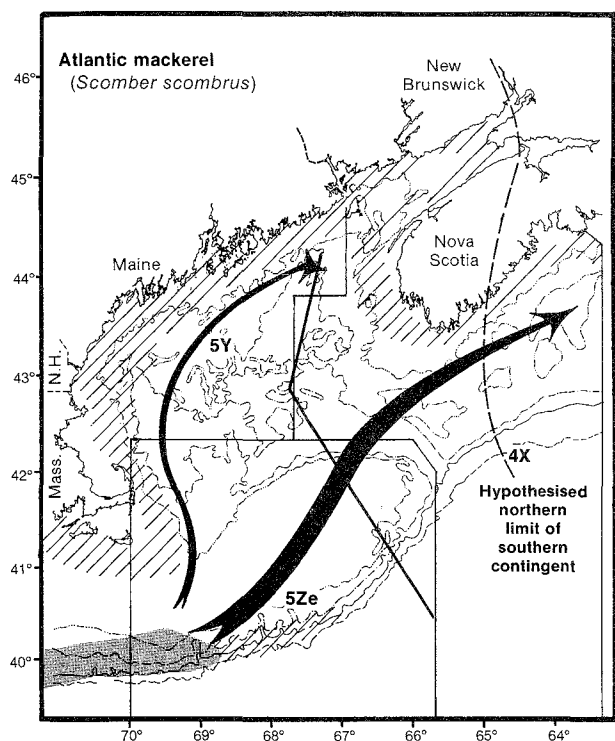


Fig. A21. Resource distribution and migration of mackerel in the Gulf of Maine Area.

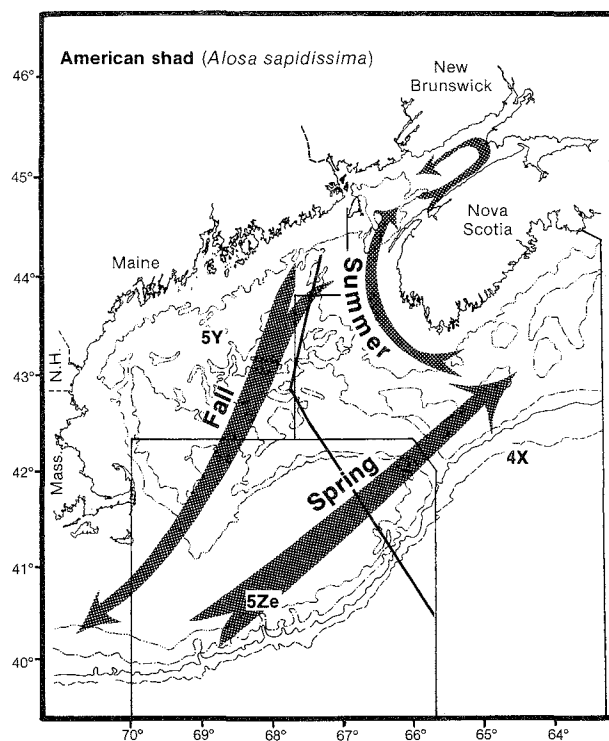


Fig. A23. Seasonal migrations of shad in the Gulf of Maine Area.

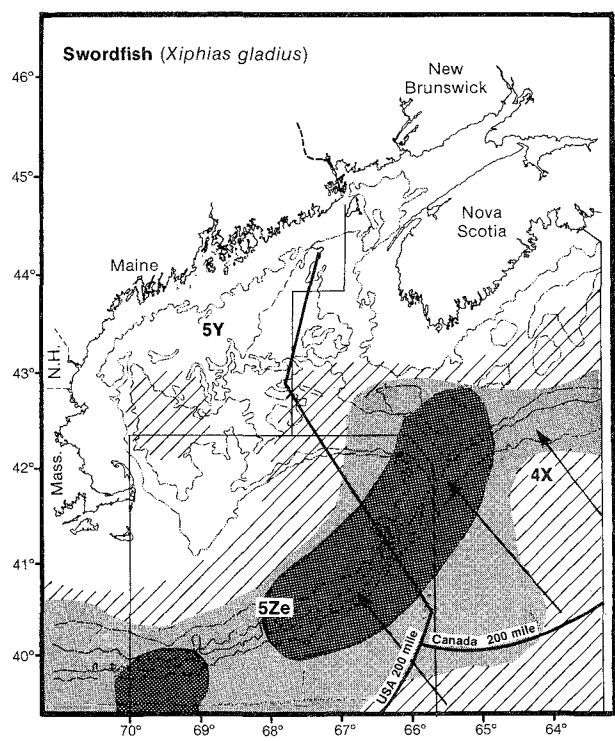


Fig. A22. Distribution of Canadian catches of swordfish. (Arrows indicate hypothesized migration route.)

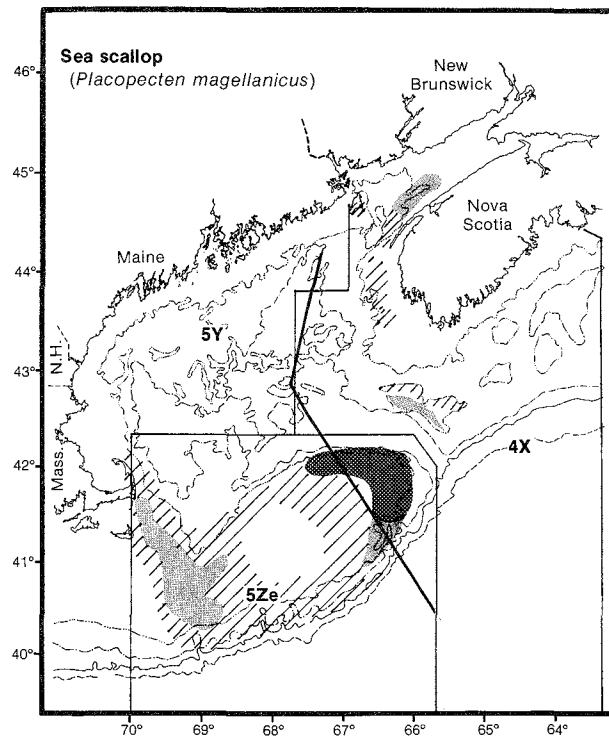


Fig. A24. Catch distribution of sea scallop in the Gulf of Maine Area.

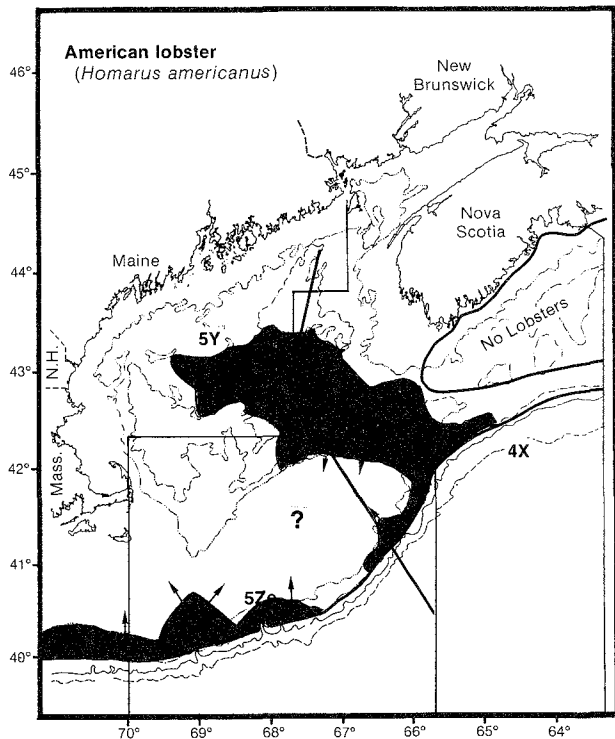


Fig. A25. Lobsters occur over the entire Gulf of Maine Area north and west of the demarcation lines. Heavy shading denotes distribution of known concentrations capable of supporting commercial trap fishery; light shading indicates hypothesized summer concentration in shallow water, with arrows suggesting direction of movement to shallow water.

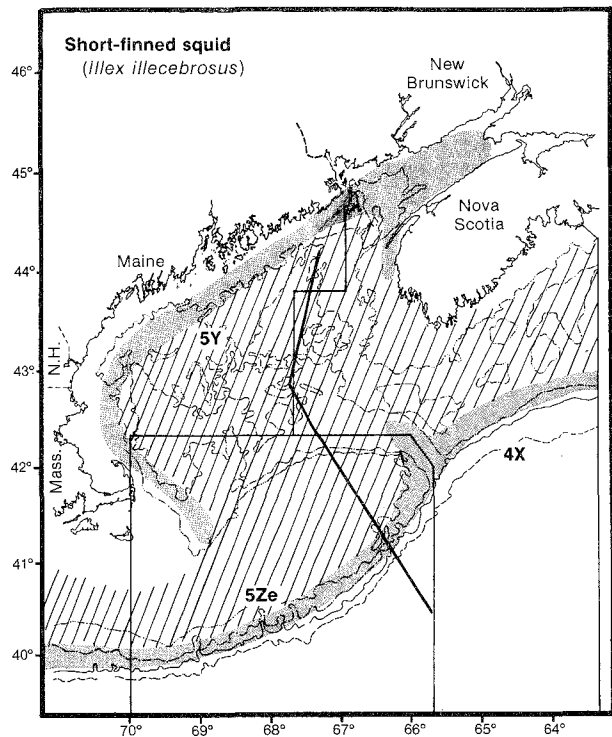


Fig. A27. Resource distribution of short-finned squid in the Gulf of Maine Area.

Short-finned squid (Fig. A27). This species is distributed from Greenland to Florida, with fishable concentrations from Newfoundland southward to Cape Hatteras. Within the fishing areas, abundance and distribution vary greatly both seasonally and annually.

The biology and life cycle of short-finned squid are very poorly understood, nothing being known of the spawning distribution and little being known of the early life stages and their distribution. Spawning is believed to take place pelagically in the Gulf Stream-Slope Water frontal zone somewhere to the south of Delaware Bay, most probably over the Blake Plateau. The period of spawning is protracted, extending from roughly December to June and generally resulting in two or more cohorts. The bulk of the population in most years has been made up of squid from the first cohort. Larvae and juveniles have been found over a distance of more than 1,500 km along the Gulf Stream-Slope Water frontal zone, and it appears that the Stream plays an important role in their transport to the areas off Georges Bank, the Scotian Shelf, and the Grand Bank. In late spring and summer, the rapidly growing juveniles migrate from the frontal zone to the areas of the continental shelf between Cape Hatteras and Newfoundland. There they grow rapidly and are found in fishable concentrations from roughly June to November. The squid leave the shelf areas in late autumn and apparently migrate several thousand kilometers southwestward to as yet unknown spawning areas. They are believed to live no more than 12-18

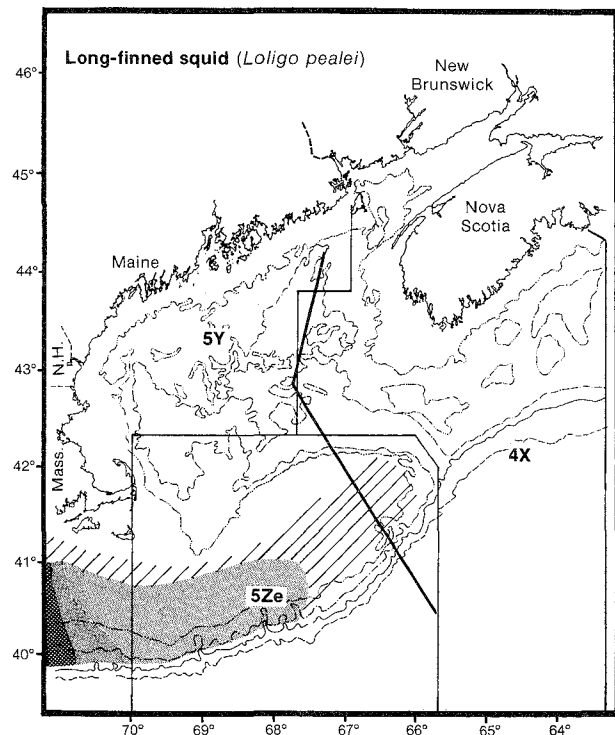


Fig. A26. Resource distribution of long-finned squid in the Gulf of Maine Area.

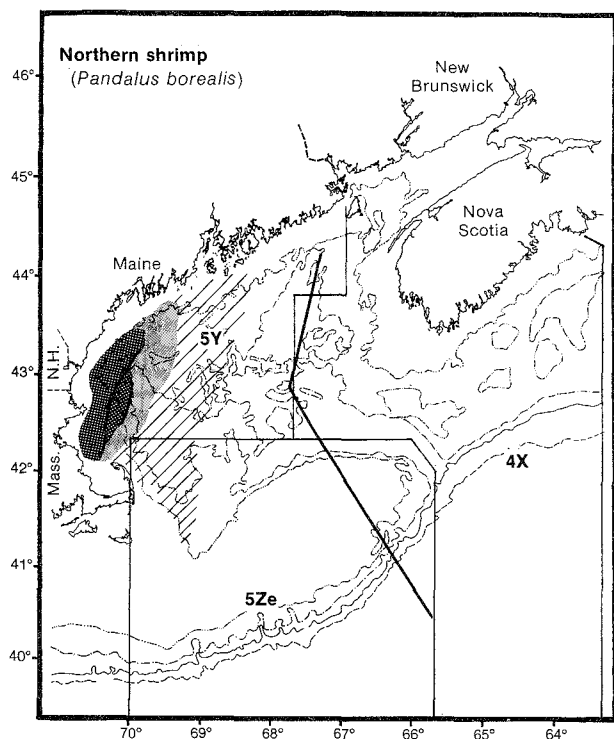


Fig. A28. Resource distribution of northern shrimp in the Gulf of Maine Area (1977-79).

months and to die after spawning. Hence, the adults of each generation are available only once to the fishery. Throughout its range, short-finned squid are believed to constitute a single stock.

Northern shrimp (Fig. A28). This species has a northern, cold-water distribution, and the Gulf of Maine represents the southern limit of fishable quantities. Therefore, warming trends are believed to seriously affect the ability of this species to survive in the Gulf of Maine, and this accounts to some degree for its variable abundance. During periods of high abundance, the distribution of northern shrimp extends beyond its normal limits eastward in the Gulf of Maine and into the Bay of Fundy. The stock structure is not well understood.

Other invertebrate species. Other species of less commercial importance in the Gulf of Maine Area include: red crab (*Geryon quinquedens*), Jonah crab (*Cancer borealis*), and ocean quahog (*Arctica islandica*).

III. Distribution of Fisheries and Effect of Boundary Changes on Long-term Series of Catch and Fishing Effort Data.

Introduction

The ICJ line transects three NAFO divisions (Div. 4X, 5Y and 5Z) and six unit areas of the NACFI system

(4Xp, 4Xq, 5Yb, 5Yf, 5Zj and 5Zm) (Fig. 3). If the proposal for modification of the statistical grid is dealt with by addition of a line across Georges Bank based on the ICJ line, thus creating an additional statistical area on the northeast part, there need be no concern about comparability with historical NAFO data series in this area. Although statistics on catch and fishing effort would be collected separately for two areas comprising the northeastern and southwestern parts of what is presently Subdiv. 5Ze, addition of statistics for the two areas would reconstitute the data for the historical area. Thus, the distribution of fishing in the present Subdiv. 5Ze is not an issue in relation to the present proposal, which would, in fact, result in more geographically detailed information on fisheries in the area being made available. The important concerns are, therefore, the implications to historical data series for Div. 4X and 5Y of moving the boundary between them.

The areas which are proposed for transfer between Div. 4X and 5Y are not large in terms of absolute area or as percentages of the area of these divisions (Table 1). Thus, the impact on historical fisheries data series would not be expected to be large, unless the fisheries proved to be highly localized in the areas to be reassigned.

Data from the NAFO statistical series are amalgamated by present statistical divisions and subdivisions and, hence, can give no insight into smaller-scale fishery distributions. Both Canadian and USA national statistical systems historically have used the "unit area" system as the smallest geographical unit recognized in data compilation. These areas are too large, however, to approximate the areas proposed for reassignment. In the Canadian statistical system, the original information on fishing areas of offshore vessels is collected through a logbook system. These logbooks often contain data on fishing location on a tow-by-tow basis. Some subsets of these data have been analyzed for particular (usually research) purposes and give insight into the areas fished. Operations of components of the Canadian fishing fleet also have been studied under a domestic observer program, which provides detailed information on location of fishing of these components. Finally, surveillance programs provide data on locations where fishing vessels have been observed. Both Canadian and USA surveillance data, based primarily on aerial reconnaissance, are available for several recent years in computer analyzable form. These data suffer from a number of limitations in relation to present purposes, however. In particular, surveillance observations are not random in relation to fleet distribution, and all vessels do not have the same probability of being observed. Designation of type of gear fished (which would allow some inference to be made regarding species or species group fished) and activity of vessel (i.e. fishing or in transit) are not comprehensive, also restricting value of the data for present purposes.

Logbook and observer data relate to components of the Canadian fleet, and surveillance data to components of both Canadian and USA fleets. No suitable data are available for fisheries by other countries, but no significant amount of fishing by third parties has taken place anywhere in the general vicinity of the Subarea 4/5 line since extensions of coastal state jurisdictions in 1977. The modifications to the proposed line cannot, therefore, have any implications in relation to third party statistics, at least for the last 9 years.

General distribution of fishing

Surveillance data give the most general account of fishing vessel activity in the whole Gulf of Maine Area. These data (for the 1979–84 period) indicate that the central part of the area adjacent to the Div. 4X/5Y boundary is an area of relatively low activity for both Canadian (Fig. 4) and USA (Fig. 5) fleets. During the period covered by these data, the USA fleet could not fish the eastern part of 5Yb, and the Canadian fleet could not fish the northwestern part of 4Xp (Fig. 6), as to do so would have placed them in waters subject to the undisputed claim of the other party. Taking these restrictions into account does not invalidate the inference from these data that the areas adjacent to the Div. 4X/5Y boundary have no general importance to the fisheries of the Gulf of Maine Area.

Groundfish fishing

The Canadian groundfish fleet which operates in the Gulf of Maine Area has three readily identifiable components: highly mobile large trawlers (≥ 150 GRT), and smaller trawlers and longliners which are more localized in their areas of fishing. Subsets of fishing log-records are available for the large trawlers and the longliners for the 1960–72 and 1973–77 periods (i.e. prior to restrictions on fishing areas resulting from jurisdictional claims). These data (Fig. A29–A32) indicate that, in 1960–72, the areas of Div. 4X and 5Y that are proposed for transfer were not important to the fishery, although in 1973–77 the southeastern part of 5Yb was fished more intensively. The impression is, however, that the fishing in 5Yb was an extension of the more extensive fishing being conducted in adjacent parts of Div. 4X. The data on which these plots are based are fairly comprehensive for the large trawlers but are scanty and hence less reliable for the longliners. Logbook data from the small trawlers for these periods are not adequate to produce comparable plots, but a special observer program provided quite extensive data on areas fished by these vessels during 1982 (Fig. A33). These data indicate that there is a component of the fishery which occurs in southeastern 5Yb on the Grand Manan Banks. The primary species in the Canadian groundfish fishery in this area are haddock, cod and pollock.

Herring fishing

Herring fisheries are characteristically highly localized on feeding, spawning and overwintering concentrations, as illustrated in Fig. A20. On Georges Bank, herring fishing concentrated along the northern edge, an area which is transected by the ICJ line. No fisheries have occurred over the deeper basin areas north of Georges Bank, however. At the northern end of the Subarea 4/5 boundary, the important fixed-gear (mainly weir) fisheries are shore-based and would not be affected by any line changes offshore. There have, however, been persistent fishing activities on the shoals around Grand Manan Island and on Grand Manan Banks. Catches of 25,000–30,000 tons were recorded by Canadian purse-seiners from fishing in this area in 1972 and 1973 (Fig. 7). The part of 5Yb which could be subject to reallocation to Div. 4X has, therefore, at least on occasion, been a focal point for important herring fisheries.

Invertebrate fishing

The major invertebrate fisheries in the area are specialized ones for scallops and lobsters. Fishing locations of the Canadian offshore scallop-dragger fleet can be described in detail from comprehensive log-record coverage. The data for 1983 (Fig. A34), used here as an example, indicate that fishing does not occur to any extent in the areas proposed for reassignment. A small amount of effort was expended on Grand Manan Banks (5Yb) by the offshore fleet in 1983. In addition, small boats, particularly those from Grand Manan Island, fished the shoals to the south of the island and as far as the Grand Manan Banks in most recent years (Fig. A35). The Canadian offshore lobster fishery in the 1973–79 period, which was largely prior to any restrictions due to jurisdictional claims on areas fished, did not occur in the areas proposed for reassignment (Fig. A36). The inshore lobster fishery extends south and west of Grand Manan Island in shoal waters as far as Machias Seal Island in Div. 5Y. There is also a deeper-water fishery in Grand Manan Basin, but this does not extend as far south and west as the present Subarea 4/5 boundary. The inshore fishery is managed not on the basis of NAFO divisions but by a specially defined Canadian “Lobster District No. 2”.

Distribution of groundfish catches

It is clear from the fragmentary nature of the information which can be compiled on the distribution of fishing that a description of the detailed distribution of catches, based on direct observation, is not possible. It has already been demonstrated (Table 1) that the areas involved in proposed reassignments between Div. 4X and Div. 5Y (about 350 n. mi², or 2% of Div. 4X) and reciprocally between Div. 5Y and Div. 4X (about 400 n. mi², or 3% of Div. 5Y) are not large. Thus, catches from

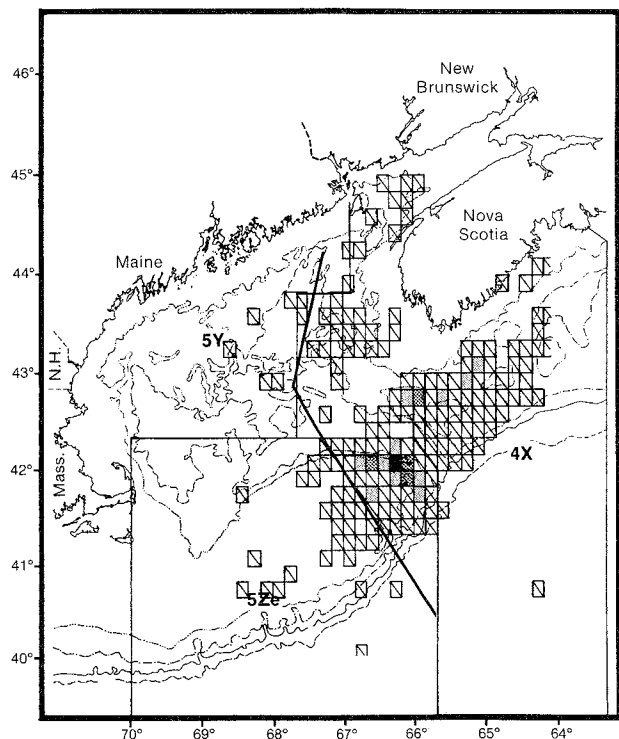


Fig. A29. Distribution of fishing effort by Canadian trawlers (≥ 150 GRT) in the Gulf of Maine Area, based on log-record information for 1960-72. (Heavier shading of 10' by 10' quadrangles indicates increasing levels of effort (hours fished), with oblique bars showing the lowest level.)

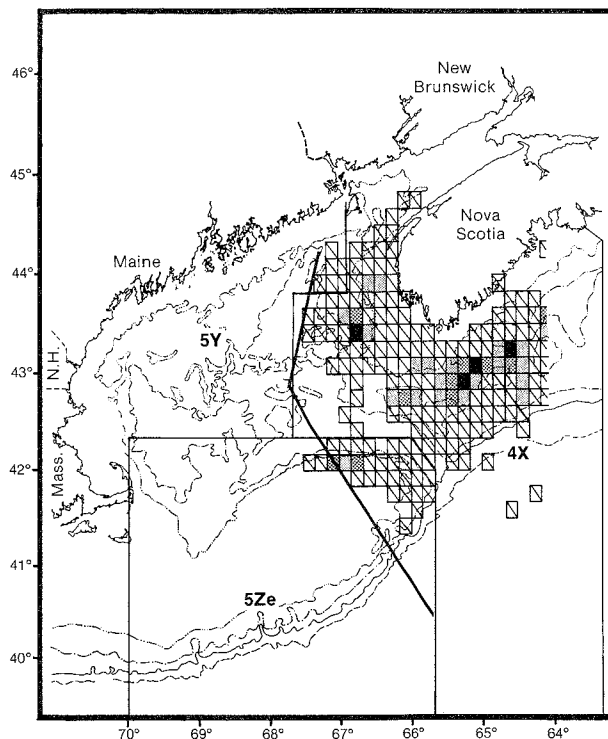


Fig. A31. Distribution of fishing effort by Canadian trawlers (≥ 150 GRT) in the Gulf of Maine Area, based on log-record information for 1973-77. (Heavier shading of 10' by 10' quadrangles indicates increasing levels of effort (hours fished), with oblique bars showing the lowest level.)

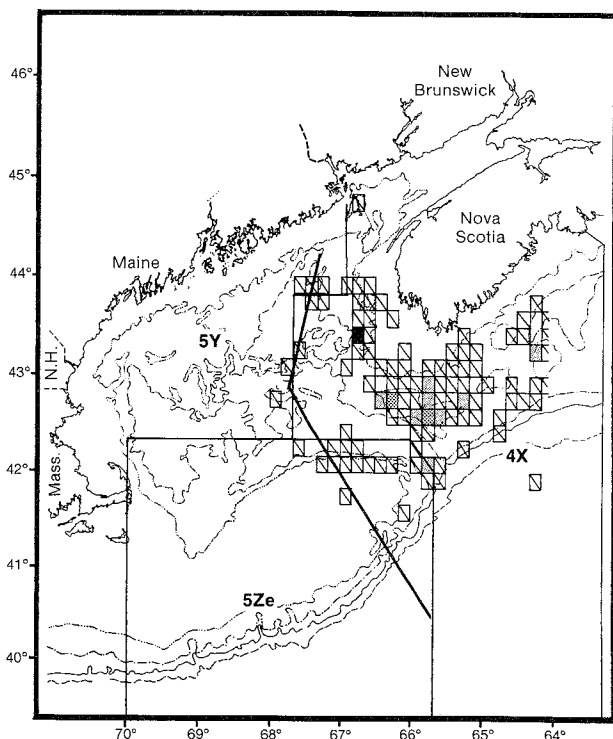


Fig. A30. Distribution of fishing effort by Canadian longliners in the Gulf of Maine Area, based on log-record information for 1960-72. (Heavier shading of 10' by 10' quadrangles indicates increasing levels of effort (number of hooks), with oblique bars showing the lowest level.)

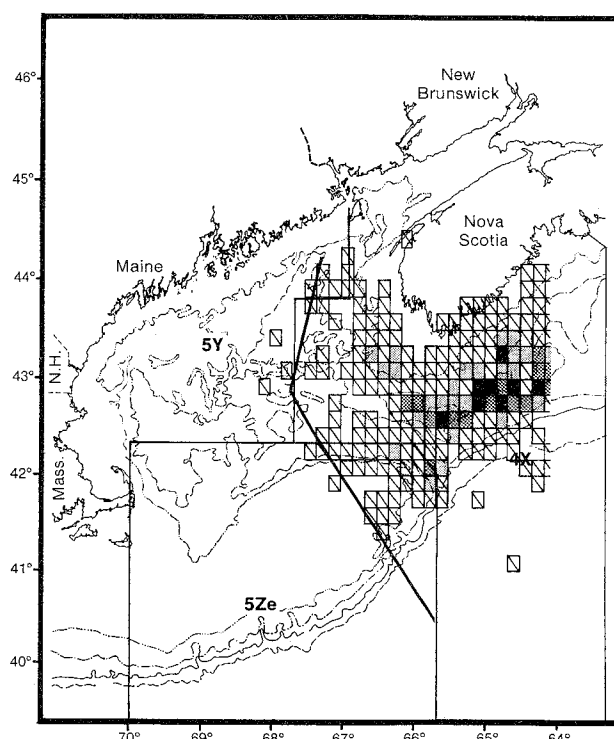


Fig. A32. Distribution of fishing effort by Canadian longliners in the Gulf of Maine Area, based on log-record information for 1973-77. (Heavier shading of 10' by 10' quadrangles indicates increasing levels of effort (number of hooks), with oblique bars showing the lowest level.)

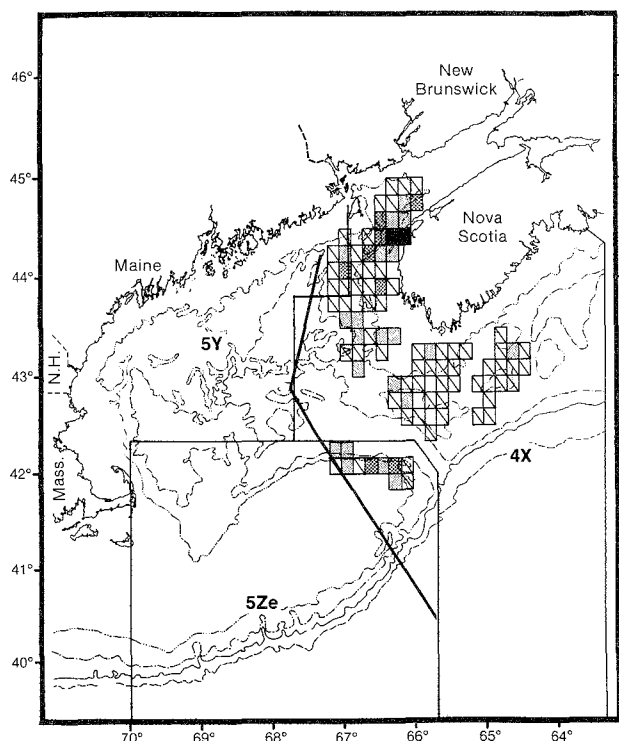


Fig. A33. Distribution of fishing effort by Canadian trawlers (<150 GRT) in the Gulf of Maine Area, as observed by the International Observer Program during 1982. (Heavier shading of $10' \times 10'$ quadrangles indicates increasing levels of effort (numbers of sets), with oblique lines showing the lowest level.)

these areas would not be expected to have been large. Knowledge of resource distributions allows some refinement to this inferential approach.

Bottom-trawl surveys have been conducted throughout most of the Gulf of Maine Area by the USA in spring and autumn and in Div. 4X by Canada in summer for a number of years. In the present analysis, data from all three series for the 1968–80 period (USA surveys) and the 1970–80 period (Canadian surveys) have been combined to provide an estimate of average resource distribution for each of the major groundfish species. A computer program was written which calculated the average abundance of each species in each $10' \times 10'$ quadrangle and then estimated the proportional abundance on either side of any defined line, based on the abundance in all quadrangles and parts of quadrangles on each side of the line.

Resource distribution tends to be quite closely proportional to area for 5Yb, in the particular case (i.e. maximum area relocated) shown in Table 2. In 4Xp and 4Xq, the areas proposed for reassignment are deep-water areas and, not surprisingly, tend to contain a higher proportion of deepwater resources, such as white hake, silver hake and redfish, and less cod and haddock than would be expected on the basis of area

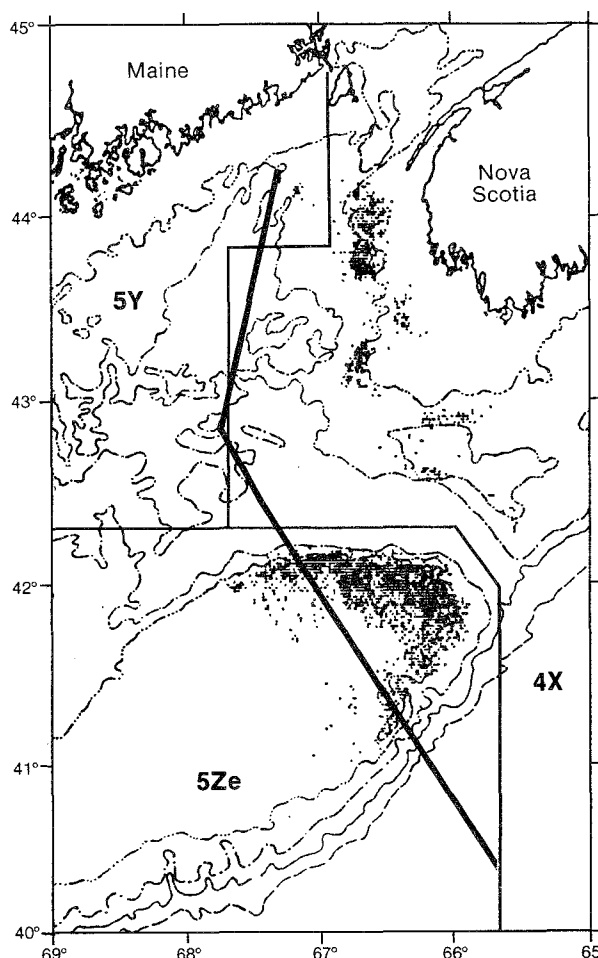


Fig. A34. Distribution of fishing by Canadian scallop draggers (>65 ft.), based on logbook data in 1983.

considerations only. If it is assumed that catch distribution has been proportional to resource distribution, the proportions of catch likely to be reassigned from 4Xp, 4Xq and 5Yf are small in most cases. Exceptions are the deepwater species already mentioned. However, NAFO statistics are summarized on a larger geographic scale, and it is necessary to estimate the impact of a line change on divisional catches.

To determine impacts on divisional catches, Canadian and USA catches by unit area were used, along with the data in Table 2, to estimate the proportion of the groundfish catch from the division as a whole which may have come from the area to be reassigned. Average catches for the 1968–78 period were used, and thus these are from the period prior to jurisdictionally-based restrictions on areas fished. An example of the calculations, the average Canadian redfish catch in 4Xp multiplied by 0.09 and the average catch in 4Xq multiplied by 0.20 (both proportions from Table 2) were summed and compared to the average Canadian

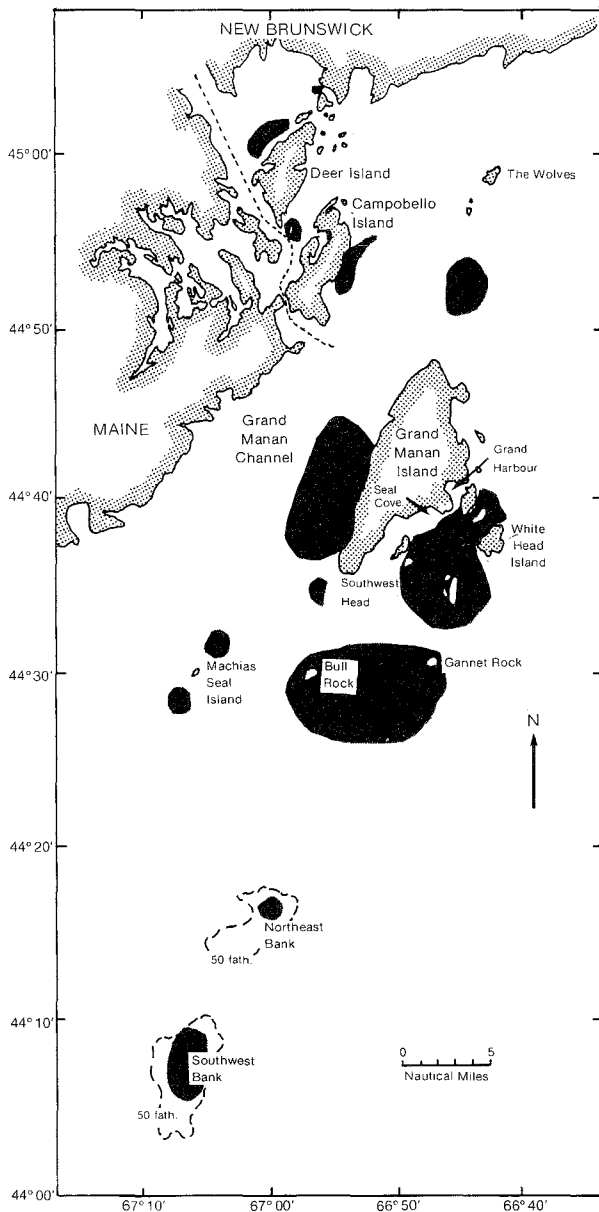


Fig. A35. Estimated locations of scallop-fishing grounds exploited by New Brunswick-based vessels, mainly from Grand Manan Island. (From Sinclair *et al.*, 1985.)

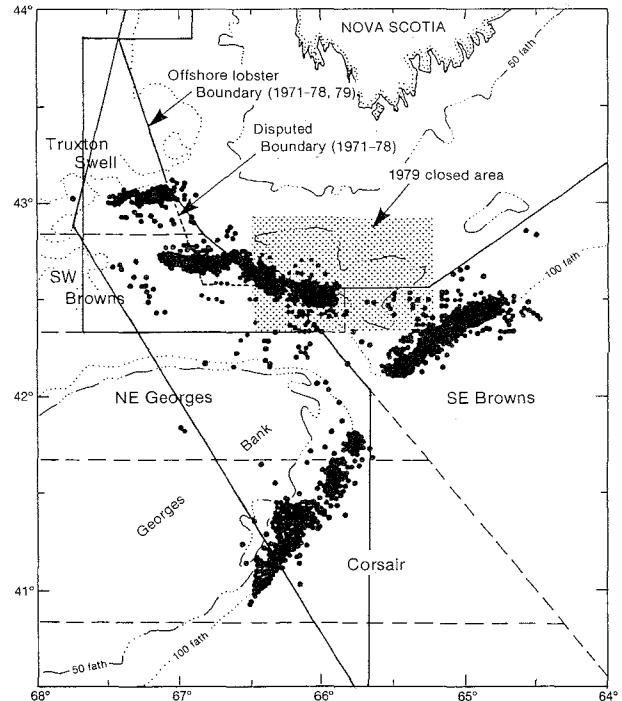


Fig. A36. Canadian offshore lobster-fishing areas in 1973-79 and the area closed in 1979. (From Stasko and Pye, MS 1980, with ICJ line and Subarea 4/5 line added.)

redfish catch from Div. 4X as a whole. The results support earlier conclusions that the impact of a line change is minor (Table 3).

In Div. 4X, the largest quantities involved in potential relocation are for pollock at less than 500 tons and from 3.0 to 3.5% of the catch. Redfish is next at about 200 tons and from 3.5 to 4.0% of the catch. In Div. 5Y, the largest quantity is about 140 tons of pollock which is about 3% of the catch. This is followed by cod and haddock at about 90 tons and 80 tons (1 and 4%) of the catches respectively. While percentages of Canadian Div. 5Y catches calculated to be relocated catches are high, the absolute amounts are trivial.