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A Review of Stock Structure in the Gulf of Maine Area: A Workshop Report

by

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Abstract

A Workshop to review the stock structure of finfish and invertebrate species of commercial importance to Canada in the Gulf of Maine Area (NAFO Divisions 4X, 5Y and Subdivision 5Ze) was held in February 1986. The meeting was held in response to International Court of Justice decision which established a maritime boundary in the Gulf of Maine Area between Canada and the United States. For each species, authors reviewed the history of management and provided a detailed analysis of the biological evidence pertaining to stock structure based on previously published work and new data.

Résumé

Un atelier a été tenu en février 1986 afin d'examiner la structure des stocks d'espèces de poissons nageoires et d'invertébrés ayant une importance commerciale pour le Canada dans le golfe du Maine (divisions 4X et 5Y et subdivision 5Ze de l'OPANO). La rencontre a été tenue en réponse à la décision de la Cour internationale de justice établissant la frontière maritime entre le Canada et les Etats-Unis dans la région du golfe du Maine. Pour chaque espèce les auteurs ont examiné l'historique de la gestion et ont fourni une analyse détaillée des indications biologiques liées à la structure du stock d'après les travaux antérieurement publiés et les données nouvelles.

Introduction

This report summarizes the results of a workshop convened by the Steering Committe of CAFSAC on the stock structure of finfish and invertebrate species of commercial or potentially commercial importance to Canada in the Gulf of Maine Area (NAFO Divisions 4X, 5Y and Subdivision 5Ze). The meeting was held in response to the decision of the International Court of Justice, rendered on 12 October 1984 at The Haque, which produced a maritime boundary dividing a major portion of the continental shelf and superadjacent water column in the Gulf of Maine Area between Canada and the United States. The new boundary line (Fig. 1) awards to Canada 2359 square nautical miles or approximately 1/6 of Georges Bank which is 17,100 square nautical miles in area (≤200 fm) Halliday et. al. (1986). The decision thus provided both the opportunity and requirement to review the biological and administrative basis for management of finfish and invertebrate species in this area.

The meeting held in February, 1986 at the Bedford Institute of Oceanography was chaired by Mr. Dick Wells, Chairman of CAFSAC. Participants met in a plenary session on the first day to discuss the concept of stock and to review the circulation patterns in the Gulf of Maine area. Subsequently two working groups were convened one chaired by Dr. M. Sinclair and the other by Mr. D. Wells. For each species, authors reviewed the history of management area definition and provided a detailed critique of the biological evidence pertaining to stock structure based on previous published work and new data.

The present report comprises summaries of present knowledge for each species listed which has been extracted from papers presented at the Workshop. For the most part, these papers will appear elsewhere in the primary literature. Species summaries are grouped using the ecological dimensions of habitat and mobility to make it easier to define general patterns of stock structure across species groups should they exist.

The Definition of Stock

As might be expected a number of different although not mutually exclusive views were expressed on just what constitutes a sufficient definition of a stock. Traditionally, a stock has been defined as "a population of organism which, sharing a common gene pool, is sufficiently discrete to warrant consideration as a self-perpetuating system which can be managed" (Larkin 1972). A more precise definition proposed by Booke (1981) is that a (genotypic) stock is "a population of fish maintaining and sustaining Castle-Hardy-Weinberg equilibrium". If genotypic stock characterization is not possible then a phenotypic stock if often recognized using characteristics such as colour, growth rate or any other definable character difference.

In our discussions some participants stressed the importance of recognizing genotypic traits while others argued that phenotypic traits were more useful in defining a stock. Although no concensus was achieved or really expected, most participants adopted the view expressed by Gulland (1983) who stated that for fisheries management purposes the definition of a unit stock is an operational matter. That is, a group of organisms can be treated as a stock if possible differences within the group and interchanges with other groups can be ignored without making the conclusions reached invalid. In keeping with this approach authors examined the distribution of fishing, spawning areas, population parameters, morphological and genetic characteristics and tagging studies in reaching conclusions about stock structure.

Circulation and Potential for Ichthyoplankton Dispersal in the Gulf of Maine Area

The mean circulation of the Gulf of Maine, including Georges and Browns banks, is described to facilitate interpretation of ichthyoplankton distributions and delimitation of stock boundaries. The possibilities for regular exchange of gadid eggs and larvae between Georges Bank and Browns Bank, and between the banks off southwest Nova Scotia, by the mean circulation and wind effects, are also examined.

Georges Bank

Loder and Weight (1985) and Butman et al. (in press) have recently reviewed the mean circulation on Georges Bank. They note the residual (i.e. mean or resultant) flow is clockwise about Georges Bank, oriented parallel to local isobaths. There is seasonal variation in the strength of the mean flow, with a maximum in summer and fall, and a minimum in winter when the current speeds are also more variable. This seasonal periodicity in current speed is associated with the development of density gradients during summer due to the formation of a mixed area on the top of the bank and a stratified area surrounding it. On the southern flank of Georges Bank, the shelf-slope water front usually intersects the bottom at about the 100-m depth contour and can be interpreted as a somewhat leaky hydrodynamic barrier.

There is also spatial variability in the strength of the clockwise circulation about Georges Bank, both geographically and vertically. Due to the shape of the bank, there is an intensification of the current into a jet-like flow along the northern flank, which spreads out and slows down as it rounds the northeast peak of the bank. The strength of the mean flow decreases with depth, but retains the same general direction.

Observations of currents at selected locations have been made using moored current meters. In winter, mean currents along the southern flank are directed to the southwest at about 5 cm/s at mid-depth and 13-20 cm/s near the surface. At these speeds, a passive particle could be expected to make a complete circuit of the bank in about 2 months (at 60 m depth) . On the northern flank, near-surface flows in spring (April-May are about 20-30 cm/s, increasing to 30-40 cm/s in June and July. At mid-depth, mean current speeds in April-May are about 20 cm/s and up to 30 cm/s in August-September, while near-bottom speeds are about 10 cm/s. These high velocities are confined within a bank 10-20 km wide along the northern flank, with near-surface speeds falling to 25-30- cm/s further off the bank above the 200-m isobath.

Browns Bank

The general circulation in the Browns Bank-southwestern Nova Scotia area is similar to that of Georges Bank, although more complicated due to the greater variation of bathymetry. Based on seabed drifter experiments during the early 1960s, Lauzier (1967) suggested mean flow was from east to west around Cape Sable, N.S., then northwards along the coast towards the Bay of Fundy.

Recently, Smith (1983) examined the circulation off southwest Nova Scotia, including Browns Bank. He noted an upwelling circulation off Cape Sable, N.S. (of order 1-2 cm/s at the bottom), as well as a westward longshore coastal current and a clockwise gyre about Browns Bank. The southwestward coastal current was consistently found nearshore at depths shallower than 110 m with speeds of 4-10 cm/s. It has seasonal variations in speed, with the strongest flow (6-10 cm/s) occurring in winter and directed to the west. Weaker summer velocities result from variations in density and stratification, in particular associated with the tidally mixed region off Yarmouth.

A gyral circulation about Browns Bank was suggested by current meter data, satellite-tracked drogues and model studies similar to those conducted for Georges Bank (Smith 1983). These results implied a closed gyre, making relatively little contribution to water mass characteristics of the Gulf of Maine. However, further experiments on Browns Bank by Peter Smith (Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, pers. comm.) have altered these conclusions. The clockwise gyre about the bank was confirmed, but it was found to be "leaky" to the north. Near-surface currents on the eastern flank were oriented towards the cap of the bank, leading to retention, while they tended to be dispersive to the north off the western flank. Maximum currents occurred along the northern edge where the bottom slope was greatest, while currents on the cap were generally weak.

Gulf of Maine

Understanding of the circulation in the Gulf of Maine has, until recently, remained as described by Bigelow (1927), who decribed it as a large counterclockwise eddy. Greenberg (1983) has developed a 2-D numerical model which described the tidally-driven circulation in the Gulf of Maine and Bay of Fundy. The model is able to reproduce the general features of the clockwise circulations about both Georges and Browns banks, but produces the counterclockwise eddy in the Gulf of Maine only when forced by strong, variations of density in the Gulf that were not included in the model.

This effect of density on the circulation in the Gulf of Maine has been studied by Brooks (1985). He found a circulation patttern in spring somewhat similar to that of Bigelow (1927), except for two major differences: an anticlockwise gyre about Jordan Basin in the eastern Gulf near the mouth of the Bay of Fundy, and a counterclockwise recirculation of water about Georges Basin from the northern to the southern sides of the Northeast Channel. In the western Gulf of Maine, Brooks (1985) indicates two major flow paths: a nearshore flow which joins the jet-like current on the northern edge of Georges Bank. However, his findings clearly indicate flow is not continuous about the edge of the Gulf of Maine from Browns Bank to western Georges Bank. However, his findings clearly indicate flow is not continuous about the edge of the Gulf of Maine from Browns Bank to western Georges Bank. Brooks (1985) further suggests the clockwise eddy that is found off Penobscot Bay over Jeffrey's Bank may act to retain larval herring along the central coast of Maine, and interfere with an apparent southwestward "lobster flux" noted in tagging studies. A composite summary of the circulation based on the above discussions of Georges Bank, Browns Bank and the Gulf of Maine is presented in Fig. 2.

Wind Effects

While the residual circulation includes the general effect of winds on ocean currents, it cannot indicate the variable action of local wind on the near-surface water layers. Satellite-tracked drifters provide a means to estimate the path followed by passive particles, resulting from the combined effects of the mean circulation rather than remain in the wind-drift layer. Transport between banks would be more effective during strong winds, however, the frequency of storms of appropriate strength and direction is unknown.

Ichthyoplankton Dispersal

Transport of eggs and larvae between banks might occur if they were distributed near the surface during periods of sufficiently strong winds. Mean winds in spring may create a surface drift from Browns Bank to Georges Bank, with transit times calculated to be greater than 10 days, i.e. almost the entire egg stage duration for cod and haddock. Early stage eggs of these species have been sampled between banks; however, they can be expected to sink as they develop and so join the mean circulation rather than remain in the mid-drift layer. Transport between banks would be more effective during strong winds, however, the frequency of storms of appropriate strength and direction is unknown.

The potential of ichthyoplankton dispersal from Browns Bank northwards and from the western Scotian Shelf towards Browns Bank is higher, considering the direction of the residual current. Simple estimates using current velocities and egg development rates from the literature suggest eggs of cod and haddock from as far as LaHave Bank could be advected to Browns Bank. However, any circulation which retains eggs or larvae on the banks, even for short periods, would promote discreteness of spawning products. Further details of the residual circulation and ichthyoplankton dispersal in the Gulf of Maine can be found in Perry and Hurley (1986).

Species Summaries

1) Slope/Basin: relatively sedentary species

Argentine (*Argentina silus*)

Management units for argentine were established by ICNAF in 1974 as Div. 4VWX and Subarea 5. This conflicted with biological advice which indicated that argentine in Div. 4VWX + Subarea 5 should be managed as a unit and that the Subarea 4/5 line divided one of the major fishable concentrations in the area. Practical management considerations relating to the 2nd-tier TAC system in Subarea 5 were given greater weight than biological considerations.

There are no new data relevant to stock structure. Reconsideration of data (Halliday 1974) on which the 1974 advice was based largely reconfirms earlier conclusions. Clines in vertebral counts and parasite infestations along with widespread distribution of ripening fish suggested that there is a complex of stock units spread along the edge of the northwest Atlantic shelf, with limited mixing between adjacent units. Observations of significant differences in meristic and morphometric characters between widely separated, but arbitrarily chosen, points in the species distribution are consistent with this interpretation. Occurrence of spawning concentrations clearly identifies Emerald Basin and strongly suggests Georges Basin as spawning sites. There are unconfirmed reports of a third site in the vicinity of Banquereau. The existence of a minimum of three spawning populations with some limited mixing among these in the non-spawning season is also an interpretation consistent with available data.

Argentine occur in dense concentrations in the Fundian Channel, along the edge of the Scotian Shelf and occasionally on the eastern edge of Georges Bank north of Corsair Canyon (Almeida et al. 1984, Scott 1976, Sinclair 1981). Thus fishable concentrations apparently occur only in Canadian waters. Not enough is known about argentine stock structure and patterns of movement to justify definition of "best" lines for the geographic separation of unit stocks within the species range. There are no obvious discontinuities in the distribution of argentine along the edge of the shelf. The only line which could be justified based on present knowledge is one which puts the Georges Basin and Emerald Basin spawning locations into separate management units. Approximately half of the resource occurs in each of these geographic regions. Total yield potential of the species in the Northwest Atlantic may be about 10,000 t.

Redfish (*Sebastes* sp.)

At present redfish in the Gulf of Maine Area are assigned to two management units. Those in Division 4X belonging to the 4VWX unit while those in Division 5Y and Subdivision 5Ze are managed as the Subarea 5. In 1973 the Assessment Subcommittee of ICNAF reported that "redfish quotas should be applied in 1974 to stocks in Divisions 3LN, 3Ø, 3P, 4VWX, and 5YZ in order to prevent over-exploitation which could result from a diversion of effort from fisheries on the currently regulated species". The 4VWX redfish management unit continues to be regulated by Canada through TACs set at levels recommended by CAFSAC. The fishery in Subarea 5 has not been regulated by TACs since 1976.

Investigations of redfish stock structure in the Northwest Atlantic were initiated by ICNAF as early as 1953. Early views were that Subarea 4 redfish differed from those of adjacent areas based on parasite levels, meristics and growth rates (Martin 1953). Also, on the basis of parasite infestation rates, it was concluded that redfish do not migrate from Subarea 5 and that in general they are relatively sedentary. In the early 1960s, scientific views appear to have favoured combining Subarea 4 and Subarea 5 redfish into a single non-migratory stock, although it was allowed that within this large stock there may be highly localized groups which varied in such attributes as maturity stage and parasite infestation rates (Wise and Jensen 1960; Mead and Sindermann 1961; Sindermann 1961; Perlmutter 1953; Kelly *et al*. 1961). The view that Gulf of Maine redfish may be somewhat separate from Division 4VWX redfish was supported by larval distribution patterns and the available knowledge on currents which would tend to concentrate large numbers of larvae over the south and central parts of the Gulf of Maine. It was also postulated that some larvae would nevertheless be transported into the Gulf of Maine from the Scotian Shelf by the westerly currents around Cape Sable Island (Kelly and Barker 1961).

In 1962 the ICNAF Working Group of Scientists on Fishery Assessment in Relation to Regulation Problems again presented evidence favouring the separation of Subarea 4 and 5 redfish based on differential responses to fishing pressure. Calculations of total mortality rates indicated that for both areas only small changes in Z were associated with large changes in effort. This led to the hypothesis that within each general area redfish are made up of a number of small self-contained stock units and that each of these were exploited in succession thus buffering the effects of increasing effort. The decision to separate the redfish in Subarea 5 and Divisions 4VWX appears to have been finalized in 1973 when separate catch quotas were recommended for Divisions 5YZ and Divisions 4VWX. The choice of dividing lines between these two management units was, however, contrary to the recommendation of ICNAF in 1961 which stated that for halibut and redfish it would be advantageous not to divide stocks by using deep channels as boundaries since these represent areas of greatest concentration.

Annual estimates (1970-1985) of redfish biomass from surveys in both the Gulf of Maine Area and on the Scotian Shelf indicate aggregations of redfish which are persistent in both space and time. The Gulf of Maine Basin contains one aggregation which is spatially separated from an adjacent concentration on the Scotian Shelf by an area of redfish poor waters in a line from Cape Sable Island across Browns Bank to the Fundian Channel. Larvae released by these aggregations may become widely dispersed depending in part on the hydrodynamic features of the area of release. It is believed that such features operating in the Gulf of Maine, Bay of Fundy, Browns Bank, Georges Bank Area would tend to retain larvae within these general areas, but there is no conclusive evidence to support this. The distribution of juvenile redfish indicates that settlement and resident areas are not necessarily the same suggesting some migration to areas of concentration. The genetic structure of redfish aggregations is not known.

Given the uncertainty about the source and maintenance of the observed redfish aggregations in the Gulf of Maine Basin it is not possible to draw firm conclusions about stock structure. However, given the persistent nature of these concentrations they may usefully be considered as distinct for management purposes.

Red Crab (Geryon quinquedens)

Red crab constitutes a new Canadian fishery on the continental slope and management areas have yet to be defined. Since 1984 a Canadian fishery has been prosecuted by two vessels on the edge of the Scotian Shelf between Western and Emerald banks. Catches were 118 t and 468 t in 1984 and 1985, respectively. However, the fishery is still exploratory; the exploited area may eventually incorporate red crab grounds south to the ICJ line. There are no restrictions on the fishing season or numbers of traps used. The provisional TAC of 1,300 t is based on a 50% exploitation rate of the commercial biomass for the Scotian Shelf edge from the Fundian Channel to the Gully east of Sable Island. The major known Canadian commercial grounds are on the Scotian Shelf edge (500 to 860 m) between Western and Emerald banks, although proven concentrations extend along the Shelf edge to the Fundian Channel.

Resource distribution, as assessed by research surveys and commercial fishing patterns, suggests that northeastern Georges Bank forms a broad natural boundary between U.S. and Canadian red crab grounds (Wigley et al., 1975; Stone & Bailey, 1980; Gerrior, 1981). Given the restricted and patchy distribution of commercial concentrations of red crab in Canadian waters, subdivision of the Scotian Slope and Georges Bank by biologically based boundaries appears not to be of practical benefit. Red crab in Canadian waters is at the northern limit of its distribution.

There is a paucity of biological information relevant to stock definition for deep-sea red crab. The species is distributed predominantly along the edge of the Scotian Shelf and continental slope to Argentina; concentrations are most dense from approximately 300 to 1,000 m at temperatures of 5° to 8°C (Gerrior 1981). There is evidence for seasonal migrations up and down the slope. Tagging studies have indicated little movement by adults along the continental slope of the U.S. (Gerrior 1981; Lux et al., 1982). Larval development times are temperature dependent and may exceed 80 d. Given this and their behavior, red crab larvae have the potential to be transported for considerable distances (900 km). An existing recruitment model predicts a continuum of genetic mixing amongst the adult populations of the mid-Atlantic Bight (Kelly et al., 1982). Thus, given the northeastern flow of the Gulf Stream, recruitment to Canadian grounds may well depend on egg production in U.S. waters.

ii) Slope/Basin: mobile

Atlantic Halibut (Hippoglossus hippoglossus)

No management units have been established for Atlantic halibut in the Gulf of Maine Area. The halibut fishery was initiated in the Massachusetts Bay-Cape Cod area in the 1820s in response to a demand from the Boston market. These local aggregations were sufficiently depleted by the 1830s to initiate the offshore halibut fisheries and their expansion into more northern waters. By the 1860s the halibut fishery had spread across the Scotian Shelf onto the Grand Banks and the west Greenland Banks. The 1870s and 1880s saw the fishery moving into the Gulf of St. Lawrence and as far away as Iceland. Catches of halibut by Canadian fishermen have fluctuated between 2000 and 4000 t since 1910. Catches in Divisions 4VWX have ranged between 1500 and 2000 t since the early 1960s while in Subarea 5 catches have ranged from less than 100 t to slightly over 500 t.

There are no data which reflect directly on stock structure in the Gulf of Maine Area. Distribution data on halibut indicate that the species ranges from as far north as Disko Bay, Greenland to a southern limit off New Jersey. Within this range some indication of the fine scale distributional patterns is given by the results of seasonal surveys. In 4VWX, halibut biomass is relatively evenly distributed in waters of moderate depths (90-180 m) during the summer months with some concentration occurring during the spring and fall surveys. Halibut tend to overwinter in deeper waters and spend summer months in shallower waters. In addition to these seasonal movements, tagging studies indicate that halibut are highly mobile, frequently moving hundreds of kilometers. Spawning occurs between February and May in water ranging from about 700 to 1000 m. Larvae tend to display a generally shoreward movement during the pelagic stage which lasts until they reach lengths of approximately 50 mm. After settling, the juveniles begin to inhabit deeper waters with increasing age. These characteristics could facilitate wide spread dispersal.

iii) Slope/Basin/Bank: mobile

Lobster (Homarus americanus)

The Canadian inshore lobster fishery has been managed on the basis of Lobster Fishing Areas (LFAs) since 1899. Though minor modifications have taken place, the basic structure of the present LFA system has been in place since the late 1920s (LFA 2 established around Grand Manan in 1978; LFA 4 divided into LFA 4a and 4b in 1980). The five Canadian LFAs within the Gulf of Maine Area have a common minimum size for lobsters (81 mm carapace length), and protection of egg bearing females, but slightly different seasons, trap limits and vessel size restrictions.

The Canadian offshore lobster fishery, established in 1971, is restricted to a boundary line 50 nautical miles (92 km) from shore. This restriction was designed to minimize conflict with the inshore fleet, which in the early 1970s fished within 10 nautical miles (18 km) of shore. Since 1972, inshore effort has expanded outward and now extends out to the offshore boundary line. Browns Bank was closed to lobstering in 1979 to protect the brood stock.

A quota, trap limit and 3-month closed season (dropped in 1985) was instituted in 1977 on six offshore vessels fishing NAFO Div. 4X. Two additional vessels were limited to NAFO Sub. Div. 5Ze with no quota or closed season. The quota was extended to 5Ze in 1985, following the ICJ decision.

The American inshore fishery, within 12 nautical miles (21 km), is managed by the contiguous states; federal management jurisdiction lies beyond 12 nautical miles. Both American jurisdictions have the the same minimum size (81 mm carapace length) and prohibition on the possession of berried females as Canada. There is however no restrictions on entry, season, gear type (trap and trawl) or number. Additionally Maine regulations protect lobsters over 127 mm carapace length and all reproductively mature females bearing a "V" notched tail, whether egg bearing or not at the time of capture.

Fisheries and Oceans management from the 1950s through the early 1970s was based on the assumption that lobsters were non-migratory whereas in the 1970s it was based on the assumption that there may be a recruitment relationship between inshore and offshore lobster stocks. More recently it has been suggested that the Gulf of Maine Area should be considered a single population based on adult movement data and hypothesized larval drift (Harding et. al 1983).

Adult lobsters are distributed throughout the Gulf of Maine Area but densities are greater in certain areas (Fogarty et. al. 1982; Pezzack 1984; Pezzack and Duggan 1985). Lobsters move seasonally, concentrating in deeper waters during winter and in coastal regions, the shelf edge and shallow banks in late summer and early fall (Campbell 1986; Pezzack and Duggan, 1985, 1986; Cooper and Uzmann 1971). The movement appears to be regulated by temperature. Commercial concentrations are found along the coast (40 m), in some deep basins (Georges, Crowell, Grand Manan) and on the offshore banks (Browns, German and Georges) and outer shelf.

Adult size frequencies vary markedly between management areas (Stasko and Pye 1980; Pezzack and Duggan 1983, 1985); this could be due to long periods of high exploitation on inshore grounds (smaller mean size), and/or increased movement to deeper water with increasing size.

Morphometric and electrophoretic differences of adults have been observed between inshore and offshore areas off southern New England, but little data are available for the Gulf of Maine Area (Barlow 1969; Tracey et al. 1975).

Thousands of lobsters, tagged with sphyrion tags (retained through the molt) in the Gulf of Maine Area, demonstrate a complex movement pattern (Campbell 1984; Campbell and Stasko 1985, 1986; Pezzack and Duggan 1986 which may be summarized as follows:

(a) most lobsters are recaptured within 30-50 km of release sites, some after more than 2 years at large;
(b) immature animals (60-94 mm CL), move an average of 10.5 km, whereas mature animals (>95 mm CL) move an average of 41.9 km and are capable of moving several hundred km;
(c) some lobsters make long distance (>100 km) annual migrations, returning to initial tagging areas;
(d) long distant movement (>30 km) of Bay of Fundy lobsters is predominantly southwestward along the Maine and Massachusetts coast; smaller numbers move to the offshore grounds, and the inshore grounds of SW Nova Scotia;
(e) some exchange of tagged lobsters occurs between inshore and offshore SW Nova Scotia concentrations;
(f) lobsters tagged on offshore banks are rarely reported inshore, and none have been reported from Grand Manan or the Bay of Fundy;
(g) lobsters released in Jordon Basin tend to move shoreward to Maine and SW Nova Scotia; lobsters released in Crowell Basin moved southwest to Georges Bank; and
(h) Gulf of Maine Area lobsters have not been reported from east of Cape Sable Island.

Analysis of approximately 90 years annual landings from the Gulf of St. Lawrence to Maine supports the hypothesis that the Gulf of Maine Area lobsters are a distinct population from eastern Nova Scotia (Campbell and Mohn 1983; Harding et al. 1983).

The self-sustainability of major commercially fished lobster concentrations is not known. Evidence of some lobster interchange, based on movements of adults, throughout the Gulf of Maine Area suggests a single biological population. However, the population structure may be more complex and insufficient biological data exist to permit population delineation. Information is required on larval and juvenile distributions, the source of inter-stock size frequency differences and brood stock distributions.

Red Hake (Urophycis chuss)

Management units for red hake were established by ICNAF in 1973. southern New England-middle Atlantic and Georges Bank management units were divided by a line at 69° W. This dividing line was changed in 1974 to 70°W. Assessments of red hake stocks since 1974 by American workers have incorporated three management units; southern New England-middle Atlantic (SA6 and 5Zw), Georges Bank (5Ze) and Gulf of Maine (5Y), although the red hake stock in Div. 5Y was considered too small to warrant assessment. Based on fin ray counts, vertebral numbers, and otolith weights, Richter (1968) concluded that three or possibly four stocks existed in this area - Scotian Shelf, Georges Bank (possibly two stocks) and Hudson Canyon. Separation of the southern New England-middle Atlantic stock from Georges Bank was further supported by a difference in age composition of catches between these two areas (Richter 1970). Based on the distribution of red hake in U.S. research vessel catches , Anderson (1974a, b) concluded that red hake in Div. 5Y should be considered as separate stock.

There are no new data which would lead to a revision of the stocks currently defined in the Gulf of Maine Area, namely:

i) Scotian Shelf
ii) Georges Bank
iii) Southern New England-Middle Atlantic
iv) Gulf of Maine

Red hake catches reported from the Gulf of Maine Area are now relatively small at 2-3,000 t although catches as high as 50-60,000 t were reported in the early 1970s.

Silver Hake (Merluccius bilinearis)

TACs were first imposed on silver hake in 1973 for Subarea 5 stocks and in 1974 for Subarea 4. Four stocks were defined and the following management units were identified:

1. The Scotian Shelf (Div. 4VWX) stock,
2. The Gulf of Maine (Div. 5Y) stock,
3. The Georges Bank (Subdiv. 5Ze) stock, and
4. The southern New England-middle Atlantic stock (Subdiv. 5Zw and Statistical Area 6).

Morphometric and electrophoretic studies (Conover et al., 1961, Konstantinov and Noskov, 1966) suggested that there were two stocks in Subarea 5 and Statistical Area 6 with a boundary at about 69°-70°W. Differences in growth and zone formation of otoliths between silver hake caught in the Gulf of

Maine and south of Cape Cod suggested that there were two groups separated by an east-west boundary across Georges Bank (Nichy, 1969). ICNAF took a conservative approach to silver hake stock boundaries in the area and defined 3 stocks for Subarea 5 and Statistical Area 6 (Anon 1972a, 1973). The choice of the Subarea 4/5 line for a northeastern boundary of these groups was administratively convenient and corresponded to a discontinuity in fishing patterns. Based on silver hake distribution patterns from research vessel catches, it was proposed that for management purposes the Scotian Shelf population (Subarea 4) could be treated as a single unit separate from stocks along the USA coast. (Anon 1973, Halliday 1973).

The stock boundaries agreed to by ICNAF have been under regular review. Seasonal research vessel surveys have provided more detailed information on distribution, indicating that silver hake are scarce on the shoals of Georges Bank at all times of the year, supporting the concept of northern and southern groups (Anderson, 1974b). Also isoelectric focusing techniques applied to tissue samples from spawning fish from 5Zw and 5Y showed significant differences (Schenk, 1981). Tagging studies have not provided useful insights on stock structure (Noskov, 1970; Fritz, 1959, 1962, 1963; Almeida, 1985). Extensive collections of morphometric data have been used to confirm differences between northern and southern groups Almedia, 1985).

In Subarea 4, ichthyoplankton studies have confirmed the location of a major spawning stock in the central Scotian Shelf area around Sable Island Bank and the Scotian Gulf, and indicate that a small amount of spawning activity occurs on Browns Bank. This is consistent with biomass estimates from research vessel surveys and distribution of the commercial fishery which show that most silver hake occur in the central shelf area. Morphometric analyses suggest heterogeneity in stock structure in the central shelf area, but are not conclusive at this time (Waldron et al., 1982).

Spawning is protracted commencing in March and ending in November. However, the major spawning occurs from May to August. Spawning occurs in May-June in waters of southern New England and the middle Atlantic Bight. The main spawning area is the Nantucket Shoals and south of Martha's Vineyard and south to Cape Hatteras. Spawning on the southern slopes of Georges Bank occurs primarily during July and August. The northern and northwestern slopes of Georges Bank are secondary spawning areas. Spawning in the Gulf of Maine from Cape Cod to Grand Manan Island occurs from May to late October with peak spawning occurring during July and August. The largest spawning concentration in the Gulf of Maine occurs on the east side of Cape Cod to Cape Ann. Based upon data collected during the 1978-1980 Scotian Shelf Ichthyoplankton Program cruises, silver hake eggs are concentrated in the Emerald Bank area and on southern Browns Bank in May and June. Spawning in September to October was on Sable Island Bank with only low abundance of eggs in the Browns Bank area.

Overall, these more recent studies have not provided grounds for major modifications of the ICNAF management units. There is good evidence for a stock separation across Georges Bank of the eastern and southern slope fish from those on the northwestern slope. Whether there are discontinuities in the stock structure within the South Georges-Mid-Atlantic group remains unclear, but the original evidence for a separation of 70°W was not strong. There is a broad area encompassing eastern Georges Bank and the western Scotian Shelf in which silver hake are uncommon. Within this broad boundary area there may be some mixing of all three of the clearly identifiable silver hake stock groupings - the central Scotian Shelf, the Gulf of Maine Basin, and the South Georges-Mid-Atlantic groups.

Basin: relatively sedentary

Angler (Lophius americanus)

No management units for angler have been established. Distributional information derived from both USA and Canadian research vessel surveys conducted in Subareas 4 and 5 indicate that angler is an ubiquitous species. Angler are found from Newfoundland and the Gulf of St. Lawrence to as far south as Cape Canaveral. There is some evidence of seasonal movement between shallow and deep water but no evidence for or against long distance movements. There is no evidence of concentrations within the Scotian Shelf-Gulf of Maine Area large enough to attract directed fisheries and no discernible discontinuities in distribution between the two areas based on research vessel survey data.

Eggs are embedded in a sheet of gelatinous mucous and float at or near the surface. Larvae apparently occupy the top 25 m of the water column. Juveniles may settled to the bottom at lengths in excess of 55 mm, but there is no indication of the duration of the pelagic phase. Knowledge is insufficient to allow inferences to be made concerning stock structure in the Gulf of Maine Area.

Cusk (Brosme brosme)

There are no management units in effect for cusk in Subareas 4 and 5 because of its low market value and the absence of areas of sufficiently high concentrations to allow a directed fishery. Cusk are taken primarily as a by-catch with an average annual catch (1978-84) of about 5,000 t.

There have been no studies on the stock structure of cusk. Most of our information about this species comes from commercial landings and research vessel surveys. Scott (1971, 1976, 1982) found that cusk are captured in depths between 40 and 199 fathoms and show no definite trends in abundance with depth, temperature, or salinity along the Scotian Shelf. Cusk inhabit the southwestern portion of the Scotian Shelf at intermediate depths avoiding the shallow water of the banks and are virtually absent on the extreme northeastern part of the Shelf. United States autumn bottom trawl surveys place the largest concentration of cusk in the inner Gulf of Maine.

Commercial catches indicate the highest concentrations of cusk occur in Unit Area 4Xo in Canadian waters and Unit Area 5Yd in the American area. Because cusk prefer hard rocky bottoms (Bigelow and Schroeder 1953), they may be under represented in the trawl catches. Although cusk are known to spawn in late spring and early summer no discrete spawning grounds have been noted. Ripe fish have been found evenly distributed over the principle fishing areas (Oldham 1972).

Based on the distribution of cusk in commercial catches and research vessel surveys, two stocks of cusk might exist, one on the Scotian Shelf and the other in the inner Gulf of Maine. However, the available biological evidence is insufficient to justify the identification of separate stocks.

White Hake (Urophycis tenuis)

There are no management units for white hake in the Gulf of Maine Area. However, the 1979 Draft Fisheries Agreement between the USA and Canada recognized Div. 4VWX and Subarea 5 as separate management units.

Information on the stock structure of white hake in the Gulf of Maine Area is limited. No significant differences in meristic or morphometric characteristics have been found between fish collected on the Scotian Shelf and those collected in the Gulf of Maine (Musick 1969). However, Musick (1969) noted that research vessel survey data indicated a discontinuous distribution of white hake between the two areas. Tagging studies in Div. 4T indicate white hake from the area do not mix with populations from the Scotian Shelf or Gulf of Maine (Kohler 1971). White hake catches in the Gulf of Maine Area have averaged about 6,000 t over the last 15 years but recent catches (1981-84) have been higher at 9,000-10,000 t.

Witch Flounder (Glyptocephalus cynoglossus)

Witch flounder in the Gulf of Maine Area is a small resource with average annual removals (1979-83) of 1,000, 3,100 and 500 t in 5Ze, 5Y and 4X, respectively, in Canada and USA combined. Witch flounder resources in 4VWX are managed as a single unit stock along with American plaice and yellowtail flounders. There are currently no catch controls for witch flounder in Subarea 5.

Relatively few data are available which are relevant to a discussion of stock structure. Based on spring and fall survey catches by the United States, neither the resource distribution nor the distribution of spawning fish throughout the Gulf of Maine Area showed evidence of discontinuity (Neilson and Hurley, MS 1986). An unusually long (up to one year) larval pelagic stage (Markle 1975) seems to indicate possibilities for transport over long distances, thereby reducing the likelihood of discrete stocks. However, the lengths at age of 5Y fish were greater than those of Scotian Shelf fish (Neilson and Hurley, MS 1986). There are no morphological or tagging studies which bear on the question of stock structure in the Gulf of

Maine Area. In summary, insufficient data exists to allow conclusions to be drawn on the stock structure of witch flounder in the Gulf of Maine Area.

Shrimp (*Pandalus borealis*)

The shrimp fishery in the Gulf of Maine has been conducted primarily by the United States. Divisions 5Y and 5Ze are combined as one management area, with the majority of fishing occurring in 5Y - the southwestern corner of the Gulf of Maine by the USA. This fishery focuses on a concentration of larger animals inshore in the winter which is the result of a spawning migration of ovigerous females. Although managed as a single unit, individual states (Maine, New Hampshire, and Massachusetts) each enforce their own regulations.

Occasionally shrimp concentrations have appeared in Canadian waters and have been fished by Canadian trawlers. It appears that shrimp in the Gulf of Maine are members of one population which, with optimal environmental conditions, can extend their range from the southwestern corner of the Gulf of Maine into the Bay of Fundy. Occurrences of large concentrations of shrimp in the Bay of Fundy coincide with increased landings in the Gulf of Maine, thus supporting this view.

Biological data have not been collected for the purpose of defining stock structure and the above observations are based on shrimp research surveys and historical fishing patterns.

iv) Basin/Bank

American Plaice (*Hippoglossoides platessoides*)

American plaice in the Gulf of Maine Area constitute a significant resource, with average annual removals (1979-83) of 3,100, 10,100 and 600 t in 5Ze, 5Y and 4X, respectively, Canada and USA combined. American plaice resources in 4VWX are managed as a single unit along with witch and yellowtail flounders. There are currently no catch controls for American plaice in Subarea 5.

Available data relevant to a discussion of stock structure are somewhat contradictory. Based on spring and fall survey catches by the United States, the distribution of the resource within the Gulf of Maine Area shows little evidence of discontinuity. However, the distribution and timing of occurrence of eggs suggest that separate spawning groups occur on Georges and Browns banks, and that their reproductive products do not mix (Neilson and Hurley, MS 1986). In addition, the lengths at age of 5Y American plaice were greater than those of 4X fish (Neilson and Hurley, MS 1986). There are no available data from tagging or morphometric studies.

In summary, although adult catches show little evidence of discontinuity throughout the Gulf of Maine Area, there are indications that separate spawning groups occur on Georges Bank and the Scotian Shelf.

Jonah Crab (Cancer borealis)

There has been no directed Canadian fishery for Jonah crab since August 1984. However, since the mid 1960s occasional landings have occurred as by-catch to the offshore and inshore lobster fisheries on the Scotian Shelf and in the Bay of Fundy (1985 landings were approximately 10 t).

In 1984 the Jonah crab fishery on the Scotian Shelf reported reasonable success overall (149 t was caught by three vessels) but failed to regain impetus following heavy gear losses in late June. The fishery was replaced by a directed red crab fishery, a species which had previously been a by-catch to Jonah crab.

Information on Jonah crab population biology and distribution is limited. A series of trawl surveys in the mid-Atlantic Bight showed Jonah crab to be contagiously distributed with maximum abundances related to depth and temperature (Haefner 1977). There is some evidence for limited seasonal movements. Commercial catch rates show that Jonah crab has a patchy distribution on the Scotian Shelf. There is no information on current catches of Jonah crab by U.S. vessels in the Gulf of Maine, although both Jonah crabs and rock crabs, Cancer irroratus, are probably subject to low-level exploitation, most likely as by-catch in the lobster fishery.

There are no tagging, electrophoretic or morphometric studies to discern adult Jonah crab movement patterns or to distinguish stocks. However, given that larval development times are in excess of 40 d, there may be considerable genetic exchange throughout the Gulf of Maine Area.

v) Bank: relatively sedentary

Ocean Quahog (Arctica islandica)

Ocean quahog has supported fisheries in the eastern U.S. for a long time and over the last decade has become a major source of clam meat. In 1985, the Fishery Conservation Zone catch quota was 22,300 t (meat weight), and the quota has been increased to 27,300 t for 1986. In eastern Canada, this species has historically supported only small inshore fisheries on the south shore of Nova Scotia and Prince Edward Island. However, the quahog resource is extensive. Exploratory surveys conducted between 1980 and 1983 by the Invertebrates and Marine Plants Division showed commercially harvestable concentrations on the Scotian Shelf and inshore areas along the south shore of Nova Scotia and also on Georges Bank east of 69°30'. Preliminary biomass estimates from these surveys (Chaisson and Rowell, 1985) were: 81,300 t inshore, 1.12×10^6 t in Sable Island Bank and Western Bank (i.e. 627,700 t in six areas of high density plus 496,900 t in the remainder of Sable Island and Western Bank), and 684,000 t in three areas (1,451 km^2) of high density on Georges Bank.

In the Gulf of Maine Area the species is not currently managed by Canada. In the eastern U.S., the original Surf Clam and Ocean Quahog

Management Plan for the Atlantic Fishery Conservation Zone was approved in 1977. There were five amendments approved between 1977 and 1985. Amendment 6 to the Fishery Management Plan for these two species (surf clam and ocean quahog) was adopted by the Mid-Atlantic Fishery Management Council in January 1986. This amendment includes the plans to separately manage Georges Bank area by establishing an optimum yield and a management regime for the area.

The earlier Fisheries Management Plan contained two management areas: the Mid-Atlantic area, and the New England area. The amendment divides the New England area with the Georges Bank area constituting the bank area east of 69°. The U.S. ocean quahog fishery on Georges Bank (and all of the New England area) is managed by an annual quota. There is also a large inshore quahog fishery (accounting for 88% of the 1979 landings) in New England territorial seas.

A. islandica is found in the boreal region of the north Atlantic Ocean. The eastern Atlantic distribution extends from the Arctic Ocean to European waters while in the western Atlantic distribution ranges from the Arctic Ocean to Cape Hatteras along the eastern coast of North America at depths from subtidal to 250 m. Within its western Atlantic range, quahog aggregations are discontinuous based on the availability of suitable sand to fine silt substrate for settlement. There is no relevant information on their external fertilization stage (when genetic exchange can occur) and the planktonic larval stage, to describe transport or exchange between aggregations. Post-larval settlement is usually permanent. Settled quahogs show growth rate differences among areas (Thompson et al., 1980). Georges Bank quahogs show faster growth rates and a higher proportion of younger animals than those on the Scotian Shelf. Longevity is in excess of 100 yr (shell length greater than 100 mm). Age at recruitment in most U.S. areas is approximately 17 yr, i.e. recruits are in excess of 60 mm shell length.

Although little is known about the determinants of the distribution of *A. islandica*, three harvestable aggregations have been identified in Canadian waters: i) offshore Scotian Shelf, with major high density areas on Sable Island Bank and Western Bank, ii) inshore aggregations along the south shore of Nova Scotia, and iii) high density area on the eastern tip of Georges Bank.

Sea scallops (*Placopecten magellanicus*)

The management areas for sea scallops are based more on fleets than on geographical areas. The "offshore" fleet (vessels greater than 19.8 m LOA) fishes mostly on Georges Bank but also fishes the Scotian Shelf and St. Pierre Bank. This fleet is managed as a unit and is regulated by a meat count. The Bay of Fundy fleet (vessels 14 to 19.8 m LOA) fishes in the Bay of Fundy and the approaches to the Bay of Fundy, the western Scotian Shelf, and to a limited degree Georges Bank. Except when fishing on Georges Bank, this fleet does not have a size limit on the catch and its catch on Georges Bank is limited to 2.9% of the offshore fleet's catch of the previous year.

The areas of sustained scallop aggregations in the Gulf of Maine Area (Georges Bank, Bay of Fundy, German/Lurcher and Browns Bank) may not represent stocks in the strict sense. The principle factor in the definition of management areas - to the extent that they exist - is the geographic distinctness of the aggregations rather than biological or reproductive isolation.

Georges Bank scallops may be discriminated from those on the Scotian Shelf to a greater degree than is possible for other aggregations. The larval distribution is discontinuous over the Northeast Channel (Trembley & Sinclair 1986) as is the adult distribution. The growth rate is also higher on Georges Bank than for scallops found on the Scotian Shelf (Posgay, 1981), and peak spawning occurs earlier (Sinclair et al. 1985). All of these observations suggest a degree of independence between Georges Bank and the Scotian Shelf. Electrophorectic studies conducted in the Gulf of Maine Area were inconclusive and the clustering linked aggregations which were geographically distant (Gartner-Kepkay and Zouros 1985). The adult concentration on Georges Bank is split by the ICJ line although the Canadian sector contains most of the area of high productivity east of the Great South Channel. Scallops are not considered to be highly mobile after the age of recruitment (Posgay 1981), and thus adult movement across the International Boundary is not believed to be large. The source of recruitment into these fished aggregations is unknown.

The areas of commercial aggregation on the Scotian Shelf and the Bay of Fundy are distinquishable in terms of geographic separation of the recruited animals and, to a lesser degree, in terms of different growth rates and time of spawning (Robert et al. 1985). As the use of yield-per-recruit analyses is becoming more widespread for scallops to identify growth overfishing, the differing growth rates among aggregations is important to the management process. Size limits that are appropriate for the fast-growing Georges Bank scallops would never be met by Browns Bank scallops.

Atlantic Surf Clam (*Spisula solidissima*)

In the eastern United States the Atlantic surf clam, *Spisula solidissima*, has supported major fisheries for several decades, and over the last decade it has become the foremost target species in the offshore clam fishery. *S. solidissima* in 1983 yielded an estimated 17,000 t of meat in the USA fishery. Market demands for this species has resulted in increasing catches to approximately 31,800 t in 1985. Small fisheries for *S. solidissima* in eastern Canada have been limited to inshore areas primarily in the Gulf of St. Lawrence. Exploratory offshore surveys conducted between 1980 and 1983 by the Invertebrates and Marine Plants Division showed only a low-density of this species on the eastern tip of Georges Bank. This species is rare on the Scotian Shelf.

In the Gulf of Maine Area, the species is not presently managed by Canada. In the eastern U.S. the original Surf Clam and Ocean Quahog

Management Plan for the Atlantic Fishery Conservation Zone was approved in 1977. There were five amendments approved between 1977 and 1985. Amendment 6 to the Fishery Mangement Plan (FMP) for these two species (surf clam and ocean quahog) was adopted by the Mid-Atlantic Fishery Management Council in January 1986. This amendment includes a plan to establish an optimum yield and a management regime for the Georges Bank Area. The earlier FMP contained two management areas: the Mid-Atlantic area, and the New England area. The amendment divides the New England area at 69° with the Georges Bank area constituting the Bank area east of 69°. On Georges Bank, the U.S. currently manages the fishery between 69° and the ICJ line, with an annual optimum yield of 250,000 to 300,000 bushels and a quarterly quota with a minimum size regulation.

The range of the Atlantic surf clam extends from the Gulf of St. Lawrence to the northern Gulf of Mexico. In the Canadian areas, the species is limited mainly to shallow waters and is found in patches along the coastline extending from the Gulf of Maine to the Gulf of St. Lawrence. In U.S. waters the species is found southward from Georges Bank and the Gulf of Maine from shoreline subtidal areas to offshore depths greater than 100 m (Roper, 1980). In the offshore areas, the eastern tip of Georges Bank appears to be a transition zone for this species, as reflected by the low catches in the Canadian surveys. Although there is an apparent discontinuity eastward of Georges Bank, it is noted that dead surf clam shell concentrations are reported on the Scotian Shelf.

Determinants of distribution for S. solidissima are poorly understood. The offshore discontinuity eastward of Georges Bank may relate to the generally colder bottom temperatures in the Scotian Shelf (Colton and Stoddard, 1973); as young clams become inactive at 4°C (Saila and Pratt, 1973). It is known that these clams are typically found in low-diversity, high energy habitats, in sediments ranging from fine to course sand (Franz, 1976). Nevertheless, there is little information on external fertilization, when genetic exchange can occur, planktonic larval transport or exchange between aggregations.

Stimpson's Surf Clam (Spisula polynyma)

The Stimpson's surf clam is similar to the economically valuable Spisula solidissima found in the eastern United States. Although the species has been found off Rhode Island (Chamberlin and Sterns, 1963) and is sometimes confused with S. solidissima, commercially harvestable densities of S. polynyma were unknown prior to 1980. Exploratory surveys conducted between 1980 and 1983 by the Invertebrates and Marine Plant Division showed commercially harvestable concentrations on the Scotian Shelf, particularly on Banquereau Bank (Chaisson and Rowell, 1985). Preliminary estimates of virgin biomass were 560,700 t (whole weight) for two areas of high density and 234,000 t for the remainder of Banquereau Bank. The surveys were not exhaustive and it was recognized that other areas of high density may well exist. As a result of these surveys, this species is thought to have commercial potential as a substitute for S. solidissima. A test fishery is currently underway to evaluate harvestability and market potentials for this species. *S. polynyma* is not presently managed.

In western North America, the species ranges from Arctic seas to Puget Sound and is also found off Japan, and in eastern North America from Arctic seas to Rhode Island. Determinants of distribution and stock structure are unknown. Stimpson's surf clams are found in deeper and colder waters than *S. solidissima* (Chamberlin and Sterns, 1963) and in sandy habitats (Bousfield, 1960). Canadian surveys have found harvestable concentrations on the Scotian Shelf but only low numbers on Georges Bank. There are no reported commercial concentrations of this species in U.S. waters.

Winter Flounder (*Pseudopleuronectes americanus*)

Winter flounder in the Gulf of Maine Area constitute a significant resource, with average annual removals (1979-83) of 8,300, 2,400, and 1,100 t in 5Ze, 5Y, and 4X, respectively, Canada and USA combined. No management boundaries are currently in place in Subarea 5 or in 4VWX.

The case for separate stocks of winter flounder on Georges Bank and the Scotian Shelf seems unequivocal, although the stock structure in the western Gulf of Maine is less clear. Based on spring and fall survey catches by the United States, the distribution of the resource within the Gulf of Maine Area is not continuous. A clear demarcation occurs at the Northeast Channel, separating concentrations on Georges and Browns banks (Neilson and Hurley, 1986). The distribution of spawning fish also support the view that separate stocks occur on Georges and Browns banks, as do analyses of age and growth data. Meristic data indicate that Georges Bank fish are a different stock than that occurring in the vicinity of Cape Cod. Moreover, the occurrence of two separate stocks in the north and south of Cape Cod in the western Gulf of Maine was postulated by Lux (1970) on the basis of dorsal and annal fin ray counts. Results of tagging studies show that little exchange of winter flounder occurs between Georges Bank and inshore areas (Howe and Coates, 1975). This species is not known to undertake lengthy migrations.

In summary, sufficient information exists to postulate the occurrence of separate stocks in southern New England (one on either side of Cape Cod), Georges Bank, and the Scotian Shelf.

Yellowtail Flounder (*Limanda ferruginea*)

Yellowtail flounder in the Gulf of Maine Area constitute a significant resource, with average annual removals (1979-83) of 13,800, 2,300, and 300 t in 5Ze, 5Y, and 4X, respectively, Canada and USA combined. Existing management boundaries in Subarea 5 include 69°W longitude, which separates the Georges Bank yellowtail flounder resources from the stocks thought to occur in the vicinity of southern New England (between Nantucket Shoals and Long Island), and east of Cape Cod extending north to Cape Ann. Yellowtail flounder resources in 4VWX are managed as a single unit along with American plaice and witch flounder.

The case for separate stocks of yellowtail flounder on Georges Bank and the Scotian Shelf, specifically Browns Bank, seems unequivocal. However, the evidence for Georges Bank stocks being discrete from the southern New England and Cape Cod stocks is less complete and convincing. Based on spring and fall survey catches by the United States, the distribution of yellowtail flounder is discontinuous across the Northeast Channel, lending support to the view that the Scotian Shelf and Georges Bank populations do not intermingle to a large extent (Neilson et al., 1986). Spawning activity peaks in June in the Gulf of Maine and in June or July on the Scotian Shelf (Smith, 1985). Comparable data on spawning times and locations are not available for the other two postulated stocks. The lengths at age of Georges Bank yellowtail flounder were also greater than the corresponding values for Browns Bank fish (Scott, 1954; Jearld, 1983). The growth rate of the southern New England, Georges Bank, and Cape Cod stocks of yellowtail flounder also differ slightly from each other (Lux and Nichy, 1967). In addition to the available growth data, there are several studies which examined morphometric or meristic data (Scott, 1954; Lux, 1963; Berthome, 1974). However, while such investigations indicated that yellowtail flounder on Georges and Browns banks were separate stocks, there was conflicting results concerning the discreteness of the Georges Bank stock compared with the southern New England and Cape Cod stocks. While no tagging of the Browns Bank yellowtail flounder population has been attempted, marked Georges Bank yellowtail flounder have not been recovered across the Northeast Channel. However, tagged Georges Bank fish were occasionally recaptured in southern New England (Lux, 1963). Available data indicate that yellowtail flounder migrations are limited, usually less than 80 km and do not include movement between banks.

In conclusion, sufficient data exist to delimit the Nantucket Shoals, Cape Cod, and Georges Bank stocks, however, boundaries of the Scotian Shelf stock are largely unknown.

Cod (*Gadus morhua*)

Although Divisions 4X, 5Y, and 5Z were formally created by ICNAF in 1953, mesh regulations for cod initiated in 1957 were applied not on a divisional basis, but on a subarea basis. Management of separate Georges Bank (5Z) and Gulf of Maine (5Y) stocks was initiated in 1972 and was apparently modelled after an earlier interpretation of stock structure based largely on tagging results and parasite studies (Wise, 1963). Statistical convenience and analogies with earlier stock discrimination studies of haddock may also have played a part. The 1977 addition of Subarea 6 cod to the 5Z management unit did not appear to have a biological basis. In contrast, the 1971 decision to manage offshore cod in 4X as a separate stock from the inshore area was based on a number of tagging, meristic, and parasitological studies (Halliday, 1971). Reinterpretation of the same data, in conjunction with the realization that inshore and offshore catches in 4X could not be reliablly differentiated, resulted in a single assessment of all cod in the 4X area in 1984 (Campana and Simon, 1984). The current management units 4X, 5Y, and 5Z+6 accounted for catches of 25,000, 3,000, and 39,000 t respectively in 1984.

Fleet distribution, catch rates, and research vessel surveys (both Canadian and US) consistently identified persistent aggregations of juvenile and adult cod on Georges Bank, Browns Bank, the area between Digby Neck and Yarmouth, and the Maine coastline. These aggregations evidently retain some integrity, since morphological and population parameters differ between the areas (McGlade, unpublished). However, it appears unlikely that the aggregations are reproductively isolated, since tagging data, genetic indices, and ichthyoplankton distributions suggest mixing between these areas (Stobo, unpublished; Horne and McGlade, unpublished; Hurley and Campana; unpublished).

Although aggregations of cod appear to remain relatively discrete even as fish get older, no clear picture emerges as to the source of recruits for some of the aggregations. Georges Bank is clearly a major spawning area. Based on ichthyoplankton distributions, the Digby Neck to Yarmouth region is identified as a possible source of recruits to 4X, although few spawning fish have been reported from that area. Ichthyoplankton dispersal across the Fundian Channel may occur in both directions, but spawners in 4X apparently contribute most of the recruits to the Bay of Fundy region (Hurley and Campana, unpublished). The western Gulf of Maine was characterized by relatively low levels of cod eggs and larvae dispersed along the coastline. The western approaches to the Bay of Fundy and the region encircling Cape Cod may have been the primary centres of this dispersal.

Cod in 5Y appear to be relatively isolated from those in 4X and on Georges Bank, although they probably mix with cod along the coast to the north and south. Indeed, there is reason to believe that cod are homogeneously distributed along the coastline, with few apparent discontinuities north of Cape Cod. Such firm conclusions cannot yet be made for the 4X and Georges Bank fish. Despite the evidence of exchange between Georges Bank, Browns Bank, and the Bay of Fundy, enough segregation apparently occurs to maintain some group-specific characteristics of morphology and population dynamics. Exchange appears to be greatest between Browns Bank and the Bay of Fundy; thus these two aggregations of cod may not constitute separate stocks.

Haddock (*Melanogrammus aeglefinus*)

Haddock management units currently used by Canada are identical to those established by the International Commission for Northwest Atlantic

Fisheries (ICNAF) about 15 years ago. The three units used are Divisions 4VW, Division 4X, and Subarea 5; the same units recognized in the 1979 Draft Fisheries Agreement between the USA and Canada.

The USA in its Fishery Management Plan for Atlantic Groundfish effective March 1977, maintained the ICNAF management unit of Subarea 5, but in July 1978, amended the plan to establish Division 5Y and Division 5Z as separate management units for Total Allowable Catch (TAC) regulation. The Interim Management Plan for Atlantic Groundfish, which replaced the previous plan in March 1982, did not provide for TAC regulation and hence no management units were required for this purpose. The management unit defined for the purposes of the plan was specified as "All ... haddock ... in the Northwest Atlantic within the Jurisdiction of the United States."

Knowledge of the major features of haddock stock structure in the Gulf of Maine area preceded the establishment of a statistical grid and indeed, appears to have been a major determinant in establishing the location of the Subarea 4/5 dividing line. The importance and potential of the Gulf of Maine haddock stocks are indicated below.

	Catch		
Assessment Unit	Long-Term Sustainable	Maximum (yr)	1984 (% Can.)
4X[1]	20,000	37,092 (1966)[2]	19,690 (100)
5Ze[4]	47,000	150,000 (1965)[3]	10,269 (14)
5Y	5,000	7,270 (1980)[3]	4,400 (28)

1 - excludes 4Xs; 2 - since 1962; 3 - since 1906; 4 - Canadian fishing activity restricted to northeast part of Georges Bank

Haddock stock structure in the Gulf of Maine Area was evaluated by considering patterns of distribution at different life history stages, evidence for movement or migration (e.g. tagging) and similarities (or differences) in biological and population traits among previously defined aggregations. These aggregations were chosen on the basis of research vessel survey data and were ascribed to one of the currently defined unit stocks.

The review of new and previously reported work supports the currently held concept of a stock in 4X, ie. the existence of a haddock population which concentrates on the offshore banks (Browns, Roseway, LaHave, and Baccaro) during the winter; part of which migrates onshore (mouth of the Bay of Fundy and inshore southwest Nova Scotia) for the summer. That haddock on the offshore banks belong to a common stock was confirmed by the occurrence of large catches between the banks, the apparent existence of only one major spawning concentration in the Browns/Baccaro area and our inability to distinguish among these aggregations based on growth, length frequencies, meristics, time of spawning, length at maturity, and condition (Waiwood, unpublished). Historical and recent tagging studies (McCracken, 1956 and 1960; Halliday and McCracken, 1970; Stobo, unpublished), research vessel survey data and seasonal patterns of haddock-directed fishing effort are also consistent with the indicated pattern of seasonal migration. The apparent differences in growth, morphometrics, and condition between haddock on the offshore banks and in the mouth of the Bay of Fundy are consistent with the above hypothesis and reflected the importance of the inshore regions as rich summer feeding areas. Egg distributions based on recent Canadian ichthyoplankton surveys do not support earlier indications (Grosslein, 1962) of spawning in the Lurcher/German Bank area and it is concluded that these inshore aggregations are not self perpetuating.

There is no new evidence to support or refute the existence of a separate inshore stock along the southwest coast of Nova Scotia. The current view is that the stock, as defined by Needler (1930), may be extinct or at least not commercially significant.

Based on analysis of growth, length frequencies (Schuck and Arnold, 1951; Graham, 1952), length at maturity (Clark, 1959), distributions (egg, larval, juvenile, and adult), tagging and haddock-directed fishing effort (Stobo and O'Boyle, unpublished data), it is concluded that the Northeast Channel acts as a barrier to haddock movements between Georges and Browns banks. Although recent tagging studies demonstrate some movement of haddock from Baccaro to the northeast edge of Georges Bank, there were insufficient recoveries to draw conclusions about stock structure. No evidence is available to permit evaluation of the current view that the Georges Bank and Cape Cod stocks are discrete. However, U.S. survey data (Overholtz and Clark, pers. comm.) suggests significant continuity in haddock distribution at certain times of the year and the MARMAP data indicated little evidence for spawning in the Great South Channel in recent years. Hence it is concluded that the Georges Bank stock is discrete from the Browns Bank stock but may not be discrete from haddock in the Cape Cod (5Z-5Y) area.

Due to the current low level of the Bay of Fundy/Gulf of Maine stock, it was not possible to provide new information on its integrity. However, the extensive historical evidence (Needler, 1930) based on growth, length frequency, and tagging studies indicates that there is a discrete stock which overwinters in the Jeffrey's Ledge area and migrates northward along the coast of the Gulf of Maine and north shore of the Bay of Fundy in the summer. Tagging studies (Needler, 1930; McCracken, 1960) indicate some mixing with the Browns Bank/southwest Nova Scotia stock in the Bay of Fundy but little exchange with the Georges Bank or Cape Cod 'stocks'.

Pollock (*Pollachius virens*)

Management of pollock in the Northwest Atlantic began in 1973. In January of that year, a pre-emptive TAC of 50,000 t was placed on pollock in Division 4X and Subarea 5 at the International Commission of the North Atlantic Fisheries (ICNAF, 1973a). It was stated that the stock structure was not well known, but that one major spawning location on Jeffrey's Ledge (Divisions 5Y) had been located. In 1974, although no new information on the stock structure was forthcoming, it was considered prudent to treat pollock on the Scotian Shelf and the Gulf of Maine as a single stock (ICNAF, 1973b). Thus the management area was extended to Divisions 4V and 4W and the TAC was adjusted upward to 55,000 t. This management area consisting of Divisions 4V, 4W, 4X, and Subarea 5 has remained in effect until present.

A first step in discussing stock structure is to look at differentiation in the large scale. Based on a time series analysis (Nicolis and Nicolis, 1984) of monthly catch data for Divisions 4V, 4W, 4X, 5Y, 5Ze, and 5Zw, we can discern temporal trends in the catch figures of the same time period. Much of the annual variability is thought to represent seasonal trends in various gears, but it is the large scale events that demonstrate the underlying temporal lags that occur from one end of the management area to the other. Overall the most striking differences in catch and indirectly abundance exists between the Scotian Shelf (Divisions 4VW) and Division 4X and Subarea 5.

These broad scale differences also show up in other aspects of the commercial fishery, differences occurring in average catch rates and weights at age in Divisions 4VW and Division 4X + Subarea 5. These differences represent seasonal and spatial trends by the various gear in each area, but even between the same gears there are obvious signs of variation.

Looking at the Canadian research vessel survey data, we see that the spatial distribution of catch rates by season shows non-contiguous areas of high concentrations especially during the fall and spring. Corroborative evidence from pollock surveys conducted in December from 1981-1985 suggests that these aggregations are in fact made up of ripe and in some year "running" fish (McGlade pers. comm., McGlade 1983). Similarly, aggregations picked up by the U.S.A. research vessel surveys represent pre-spawning aggregations, in particular on Jeffrey's Ledge, Cashes Ledge, the Great South Channel, and the northeast peak of Georges Bank.

The presence of spawning aggregations can also be ascertained from the spatial distribution of early life history stages. In fact the accumulated evidence from the Scotian Shelf Ichthyoplankton Program (Hurley, pers. comm.), and the Marine Resources Monitoring Assessment and Prediction Program (Grosslein, pers. comm.), together with preliminary data from the Bay of Fundy herring larval surveys (Iles, pers. comm.) suggest that spawning occurs in the following areas: The Gully, Middle Ground, Western Bank, Emerald Bank and Emerald Basin, inshore along the southwestern coast of Nova Scotia, LaHave Bank, Baccaro and Browns banks, St. Mary's Bay, the northeast peak of Georges Bank, Jeffrey's Ledge, Cashes Ledge, and the Great South Channel. The Bay of Fundy does not appear to be a spawning area *per se*, but rather an area of "spill-over" in the presence of large year-classes. There is no evidence to support the idea of spawning aggregates in the upper part of the Gulf of Maine adjacent to the Bay of Fundy.

These distributions provide not only a good indication of spawning activity but also suggests that eggs and larvae are relying upon a mechanism to maintain their spatial contiguity as they appear to have overcome the dynamics of an along shelf current system for periods of at least 2 weeks and potentially up to 3 months (McGlade, in press).

Although the results from tagging operations are still considered preliminary (Stobo, pers. comm.), there is no doubt that the large majority of fish tagged in inshore Nova Scotia waters range only as far as the northeastern portion of Georges Bank, and do not to any large extent cross the Gulf of Maine. However, the intermixing with offshore juveniles and adults and the relationship of these inshore groups to offshore spawning aggregates is still open to question, because fish tagged as 0 and 1 year olds are only just becoming sexually mature. Preliminary returns for pollock tagged as juveniles in coastal areas suggests a shelf-wide dispersal followed by aggregation in areas considered to be spawning grounds.

Overall the presence of these numerous spawning aggregates tends to support the idea of a large resource made up of sub-stocks. In order to further characterize these spawning aggregations, collections of pollock were analysed for intra-sample and inter-sample differences by traditional methods including electrophoresis, meristics, and morphometrics. Essentially three areas were sampled: Emerald Basin, Browns Bank, and Jeffrey's Ledge. Electrophoretic analysis of 28 enzyme systems produced consistent scores for 20, but of these only 9 were polymorphic or tissue specific, and none showed significant differences between Emerald Basin and Jeffrey's Ledge. The results from the multivariate analyses of the meristic data showed a clear separation of the three areas: these differences were maintained in the age by age analysis only between the Scotian Shelf as a whole and the Gulf of Maine. Similarly, differences in the morphometric data showed a distinction between these two areas. The maturity ogives and growth curves for these two areas, were not significantly different. In conclusion, the sample differences between continguous areas is such that the Scotian Shelf and inner Gulf of Maine are considered distinct in the sense that on average, individuals from either area can be consistently discriminated. Currently there is little evidence to readily assess the discreteness of Western Scotian Shelf and the Georges Bank areas and as such the stock-structure of these areas remains unresolved.

Alewives (*Alosa pseudoharengus*) and Blueback Herring (*A. aestivalis*)

Commercial fisheries for anadromous alewives and blueback herring, collectively referred to as gaspereau in Canada and river herring in the United States, occur in marine, estuarine, and freshwater environments in the Gulf of Maine Area. In the marine context, management of these species was non-existent until the mid-1970s because there were no domestic, directed fisheries. NAFO Statistical Areas are not structured in any way relevant to the biology of these species and can be considered marine management areas only insofar as they provide administrative limits for the collection of catch statistics. In Division 4X, the NAFO catch statistics for gaspereau represent the sum of estuarine and freshwater catches from the coastal Fishery Statistical Districts, excluding the four inland districts of the Saint John River. The boundaries of these districts were presumably also set for administrative convenience (many follow county lines) and are biologically meaningless. In Division 5Y, freshwater catch statistics are obtained for individual river systems and then summarized by coastal county.

Marine exploitation of alewives and blueback herring in the Gulf of Maine area is and has been negligable relative to freshwater exploitation with the exception of the period between the late 1960s and 1970s when eastern block fishing fleets harvested large quantities (1969-1975 mean of 3,530 t) from Subdivision 5Ze and 5Zw.

The unit stock for anadromous species exploited in freshwater is preferably based on the biological population within a river because of their ability to home to a parent stream or even to a natal tributary. Homing by alewives is implied by numerous successful restockings of barren streams and by studies of interpopulation variation in morphometrics and meristics. Alewives can select the "home" water when given a choice. Tagging studies have shown that both alewives and blueback herring can home with good accuracy to natal streams within the Saint John River system. Each major tributary can be considered to host a distinct population of a species. Smaller streams presumably contain a single population of a species. Where alewives and blueback herring cohabit, the unit stock will usually include both species because both enter freshwater within a short time of each other, both may be widely distributed throughout the river system and a distinction between species is not made by fishermen or catch statistics.

Alewives and blueback herring undertake extensive seasonal migrations along the Atlantic coast much as do American shad. Blueback herring may not migrate as far north or south from their home rivers as do alewives. Within the Gulf of Maine Area, marine fisheries are believed to harvest fish of mixed origins but the degree of intermixing is unknown.

American Shad (*Alosa sapidissima*)

The American shad is a large, anadromous clupeid. Shad spawn during spring in rivers from Florida to Quebec and after spending the first summer in fresh water, juveniles migrate to sea where they live 4 to 5 yrs, reaching maturity at a mean size of 40 cm FL and 1 kg (Walburg and Nichols, 1967). The major body of shad migrates between Virginia and the Bay of

Fundy, annually, homing to their natal rivers for reproduction (Talbot and Sykes, 1958; Leggett and Whitney, 1972).

Because of its biology, shad have been managed on a river basin, state-province, or ocean region basis (Walburg and Nichols, 1967). Both river and ocean fisheries exist in the Gulf of Maine-Bay of Fundy region for the last 200 yrs (Dadswell et al., 1983). There are fisheries with management regimes for three spring-river runs (Saint John, Shubenacadie, Annapolis) and for four ocean, summer-fall runs (Minas Basin, Cumberland Basin, Shepody Bay, Saint John Harbour) (Dadswell et al., 1984). Elsewhere in the ocean there is no management. Landings in all fisheries have declined to historical lows. Decline at first was because of low shad abundance, but now abundance is increasing and landings remain low because of reduced demand (Dadswell et al., 1984).

Tagging, merisitic and morphometric, otolith characteristics, and parasite studies indicate shad aggregations in the Gulf of Maine-Bay of Fundy region are a heterogeneous mixture of populations from all Altantic Coast rivers (Dadswell et al., in press). There are two aggregations in this region: a "summer" aggregation, consisting of 60-80% U.S.A. river shad, migrates completely around the Gulf of Maine-Bay of Fundy between May and November; a "winter" aggregation, consistng of Canadian (50%) and northern U.S.A. shad (50%), remains on the western Gulf of Maine and on the Scotian Shelf during winter. Some Canadian and northern American shad leave the summer group and remain with the winter group. There is also a reciprocal exchange with northern shad migrating south as far as Virginia (Melvin et al., 1986).

Spatial and chronological separation between the summer and winter aggregations would permit statistical and management unit separation for shad taken at sea in the Gulf of Maine region. However, for biological reasons and because shad mix extensively while at sea, management would best be by river basin or as a single, east coast unit stock.

Bluefin Tuna (Thunnus thynnus)

Atlantic bluefin tuna fisheries are regulated by agreement through the International Commission for the Conservation of Atlantic Tunas (ICCAT). Catches of bluefin tuna in the western Atlantic in the past 15 years have ranged from 6,900 t in 1971 to 1,400 t in 1982. Canadian fisheries for bluefin are described in Hurley and Iles (1980). Measures were taken in 1974 to eliminate catches of 1-year-old bluefin and to limit any increase in fishing mortality throughout the Atlantic. In 1981, further measures were taken in the west Atlantic to reduce the catch to the minimum level required to monitor stock abundance. This level was set at 1,160 t in 1982 and increased to 2,660 t in 1983 where it has remained.

Atlantic bluefin tuna are highly migratory, ranging from Newfoundland to Brazil in the western Atlantic. The only known spawning areas are located in the Gulf of Mexico and Straits of Florida and in the

Mediterranean Sea (Richards, 1976). A number of studies on stock structure have been conducted, with inconclusive results. Since 1981, ICCAT has provided advice based on the assumption that two stocks of bluefin tuna exist. One in the eastern Atlantic and the other in the western Atlantic. This view is based largely upon a population decline in the west which has not been observed in the east.

Dogfish (*Squalus acanthias*)

No management areas have been defined for dogfish in the northwest Atlantic. There is currently no directed fishery in Canada; however, about 5,000 t are taken in a directed fishery in U.S. waters.

A number of tagging studies have been conducted in the north Atlantic (see Templeman, 1984; Jensen, 1969); however, the small number of tag returns limits the inferences that can be drawn about stock structure. These tagging studies suggest that dogfish in the northwest Atlantic comprise a single migratory group that mixes to some extent with northeastern Atlantic populations. Both tagging and research vessel surveys indicate that the northwest Atlantic population migrates to the Gulf of Maine and more northern waters in spring and moves south to the Mid-Atlantic Bight in summer and fall. The considerable amount of gene flow suggested by tagging studies is also supported by electrophorectic data. Samples taken from the Scotian Shelf and the Gulf of Maine indicate no genetic differentiation between them.

Available data suggest that dogfish in the northwest Atlantic comprise a single migratory stock.

Herring (*Clupea harengus*)

The history of the management area definition for herring is the result of the interaction of two initiatives, that by Canada to extend her management jurisdiction to the maximum possible extent beginning in the early 1960s, and that by both Canada and the USA to insist on effective conservation measures to prevent overexploitation of the resource by "foreign" effort to redeem a situation that became critical by the late 1960s. This latter initiative, by necessity, was exercised through the International Commission for the Northwest Atlantic Fisheries and was thus constrained by the terms of the treaty that governed its activities and set out the administrative procedures to be followed by the contracting governments. In particular, the administrative areas, divisions, sub-divisions, and subareas had to serve as the basis for both statistical collection and management proposals as far as was biologically appropriate.

Three questions had to be addressed. As a necessary preliminary, areas considered by Canada to be under national control were excluded from foreign control as far as possible - particularly the "closed areas" claimed unilaterally by Canada: the Bay of Fundy and the Gulf of St. Lawrence and the "12-mile" inshore territorial sea (Anon. 1971). This was achieved by establishing an area, one that enclosed the Gulf of St. Lawrence-Newfoundland complex in the north, that was demonstrated to be exploited only by Canadians and one that enclosed Bay of Fundy behind its closing line, with the provision that Canada would meet all ICNAF conservation and management criteria within the Bay of Fundy and report all catches against her allocation from the global TAC. The second question involved the Maine-New Brunswick juvenile fisheries, technically outside the Convention Area, because of the 3-mile limit but of obvious relevance to stock conservation as a whole. This was dealt with by joint and independent Canadian-USA management conservation action whose positive results proceded action by ICNAF and thus justified demands by Canada and the USA for international acceptance of proposals to limit catches on adults in "international" waters. The third question was the matching of ICNAF administrative areas to major spawning aggregations, that resulted in the acceptance of the "Three Adult Stock" situation of the "Nova Scotia", "Gulf of Maine", and "Georges Bank" stocks. The major spawning aggregation was the biological unit of both management and conservation and remains so. Subsequent modifications involved "fine-tuning" to define the northern boundary of the Nova Scotia stock on the Scotian Shelf and to deal with the juvenile fisheries of Maine and New Brunswick as a continguous entity considered separately from the "Nova Scotia" stock. Potential yields and catches of adult and juvenile herring stocks in the Gulf of Maine area are given below.

Assessment	Unit	Catch: Long-Term Potential	Catch: Maximum (yr) (since 1960)	Catch: 1984
Adult	4WX	100,000	178,000 (1970)	80,000
	5Y	50,000	43,000 (1972)	3,000
	5Z	150,000	373,600 (1968)	0
Juvenile	5Y	25,000	69,000 (1962)	?
	4Xs	25,000	79,000 (1968)	8,000

Recent tagging results, summarized by Stobo (1983), have supported the conclusion of the discreteness and integrity of the major spawning groups in the subareas. Movements of fish from areas of stock mixing at the entrance to the Bay of Fundy, and during the summer feeding season, was much more marked than, later in the season, from the spawning area containing the 4WX stock off southwest Nova Scotia. Movement to the north and east along the Nova Scotia coast was largely restricted to fish tagged in the 4WX spawning area itself, and in any case does not result in their movement outside Canadian waters in that direction. Movements of adults to and from the Georges Bank spawning area was indicated by fishing patterns and by biological sampling (Anon. 1972a) and was to the south and west, on that evidence. No tagging was conducted on Georges Bank during the period of the large fishery and it has been impossible to do so since its collapse, so that the possibility of small scale movement of Georges Bank fish to the north and east towards the Bay of Fundy cannot be excluded. That the entrance of the Bay of Fundy contained fish from groups spawning in the Gulf of Maine and in the Grand Manan area was demonstrated by the differential return of tagged fish to spawning fisheries in those areas.

The subsequent reduction of the Georges Bank stock (Anthony and Waring 1980), in contrast to the relative stability of the 4WX stock (Stephenson et al. 1985), even though the spawning grounds are well within the cruising range of adults (Stobo 1983), strongly supports the concept of biological distinctness that was the assumption on which the management regime was based (Anon. 1972a).

A large tagging experiment carried out in the 1950s (McKenzie and Tibbo 1958, McKenzie and Skud 1958) demonstrated large scale seasonal movement in and out of the Bay of Fundy along the Maine-New Brunswick coast. Sindermann (1957a, b), comparing parasite incidence, identified a juvenile stock boundary at Penobscot Bay; later comparison of the meristics of the same year-class of juveniles caught in the Nova Scotia and New Brunswick inshore fisheries, and over most of the season demonstrated clear cut differences across the Bay. Similarities in the meristic character between the New Brunswick juveniles and Georges Bank adults (Iles 1970) implied that the Sindermann boundary separated Georges Bank and Gulf of Maine juveniles to a degree at least. This hypothesis was tested by the analysis of mortality rates; these were found to be consistent with the hypothesis to an acceptable degree of precision, and it was agreed to as a working hypothesis (Anon. 1972b). The stock identity of a group of juveniles caught in an historical "early" fishery in the St. John area, on circumstantial evidence and as reported by fishermen, was thought to be different from the main body caught later in the season and could not be identified because the fishery had ceased to exist; these fish might have 4WX juveniles moving in from the north and east.

The stock picture for juveniles was (and is) complicated by the existence of "local" stocks throughout the area, the expanded distribution of large year-classes of the major stocks (as exemplified by the 1970 year-classes (Anon. 1972b) and the historical sporadic occurrence of large groups of juveniles along the Nova Scotia coast at places such as Liverpool Bay and Chedabucto Bay. It was assumed that these later originated in Canadian waters and are not relevant to the boundary issue.

The most important unknown is the extent to which the differential exploitation of adults, resulting in distributional gaps at certain spawning areas such as Georges Bank, has effected the distribution of juveniles. In particular, it is inherently more likely that geographical replacement, i.e. along the coast of Maine and New Brunswick, occurs at the juvenile stage, so that the current stock make up in the juvenile fisheries may be atypical.

The original management initiatives were directed towards an existing stock structure that no longer is found. In particular the largest of the three stocks has virtually disappeared and it is impossible to predict the pattern of possible recovery that might be expected in the 1980s and 1990s.

Mackerel (*Scomber scombrus*)

The mackerel stock complex is currently managed as a single stock over its entire distribution, ie. NAFO Subareas (SA) 3 to 6 (minor catches are occasionally made in Division 2J), although two main spawning populations are known to exist. Mackerel is a transboundary stock and it is presently managed independently by Canada and the USA.

The first stock assessment (Anderson, 1973) was reviewed by ICNAF in 1973. It dealt only with SA 5 and 6 as an international fishery had recently developed mostly in those areas. Based primarily on the work of Sette (1943, 1950), it was assumed that a single stock was being exploited. ICNAF discussed the stock structure of mackerel at several meetings in the following year and the Assessment Subcommittee report for the 1974 May-June meeting states that (Anon. 1974, p. 93):

> "Under the circumstances it might be most appropriate to include all mackerel within a single assessment ...".

This was done in the following year (Anderson, 1975; Anon. 1975) and the northwest Atlantic mackerel has since been assessed and managed as a single stock.

The management unit was revised in 1975 based on the results of tagging experiments showing that the northern population is exploited in the offshore winter fishery in SA 5 and 6. Furthermore, separate assessments for the two populations was not possible because the stock origin of the catches could not be determined.

Sette (1950) noted that the length frequencies of fish caught in summer off Nova Scotia were different from those caught during the same period off New England. He also noted that landings during the end of May-early June and late fall from southern New England appeared to show a mixture of these two length frequency groups. The persistence of these differences for several years, the absence of certain year-classes in one or the other region, combined with the known existence of two spawning areas (Sette, 1943 and 1950) lead him to suggest the existence of two distinct groups of mackerel in the northwest Atlantic. However, he was undecided on the question of whether these two groups comprised separate stocks.

Several authors (Anderson, 1975; Beckett, *et al*., 1974; MacKay, 1973; Moores, *et al*., 1975; Stobo and Hunt, 1974) have reviewed the two-population hypothesis proposed by Sette (1950) and all have accepted his conclusions. However, biochemical and meristic analysis (MacKay, 1967; MacKay and Garside, 1969) as well as parasitological studies (Isakov, 1976) did not show any differences between the two populations. MacKay and Garside (1969) concluded that there were sufficient exchanges between the two distinct populations to maintain relatively stable characteristics. Tagging studies (Beckett et al., 1974; MacKay, 1967; Parsons and Moores, 1974; Sette, 1950; Stobo, 1976) suggest that the two populations are probably mixed on overwintering grounds.

The Canadian fishery is mostly inshore during the summer. Catches generally follow the migration pattern described by Sette (1950) with annual variations on a general theme. Mackerel are first caught on the Scotian Shelf in May-June. The progression of catches can be followed from Yarmouth to Cape Breton, then into the Gulf of St. Lawrence in June-July. Catches in the northern part of the Gulf of St. Lawrence are usually in August-September. On the east coast of Newfoundland, the first signifcant catches are made in August and the fishery may extend into November. The distant water fleet fishery was carried out from Georges Bank southward, lasting from November to March. The domestic USA fishery is relatively small (3,000 t) and occurs mostly in the spring and summer. Mackerel is an important component of the sports fishery with catches estimated to range from 10-20,000 t (Anderson and Paciorkowski, 1980).

Methods of biochemical analysis have evolved considerably since the work of MacKay (1967) and MacKay and Garside (1969). Mackerel samples collected during spawning off New England and in the Gulf of St. Lawrence were analysed by isoelectric focusing. Of the 20 enzymes studied, 6 appear to be polymorphic, 11 did not show any variation, and 3 showed inconsistent variations. The cluster and principal component analyses of these data suggest some separation of the northern and southern areas although not statistically significant.

The earlier conclusions on mackerel stock structure in the Gulf of Maine Area are unaltered by more recent data. In the winter, a mixture of southern and northern groups is exploited if the fishery is prosecuted in SA 5 and 6. The extent of actual mixing on the fishing grounds is unknown and the two populations although occupying the same general area, may be geographically segregated. In the spring, the northern population leaves SA 5 and 6 to spawn in the Gulf of St. Lawrence. In the summer, the two populations are generally separated and the catches could probably be attributed to either population based on the area of capture.

Pelagic Sharks

At least six species of pelagic sharks occur in Canadian coastal waters (blue, *Prionace glauca*; mako, *Isurus oxyrhinchus*; porbeagle, *Lamna nasus*; white, *Carcharodon carcharias*; basking, *Cetorhinus maximus*; and Greenland, *Somniosus microcephalus*) and several other species of carcharinid sharks may occur in the warm waters associated with the Gulf

Stream. Reported pelagic shark commercial catches in the NAFO area rose from 75 t in 1960 to 8,407 t in 1964, declined to less than 1,000 t by 1970, and have since remained at that level. A recent study estimated that the total pelagic shark catch (ie. including recreational catches and discards) in the US Fisheries Council Zone (Atlantic Ocean excluding Gulf of Mexico) had reached 17,000 t in 1980. No management measures have been taken in the Gulf of Maine area, with the exception of Canada issuing shark licenses to a small number of pelagic longline vessels from Norway and the Faroe Islands. These vessels have been limited in their westward movement by a line approximately following the northern edge of the Fundian Channel. Such a line was necessary for administrative purposes to keep third party fishing out of the zone of disputed jurisdiction between USA and Canada prior to the ICJ decision.

Although information is limited, it appears that the stock units of all these sharks are much greater than the Gulf of Maine Area. By far the most abundant in Canadian waters, the blue shark has a worldwide distribution in tropical and temperate oceans (Casey, 1964). Tagging studies indicate that blue sharks are highly migratory and intermix throughout their range in the Atlantic Basin (Casey et al., 1984). Several species, particularly the mako shark and the carcharinids, are near the northern limit of their ranges in the Gulf of Maine Area, while the Greenland shark is near its southern limit.

Squids (Illex illecebrosus) and (Loligo pealei)

There are two management regimes in effect within the Gulf of Maine: that developed by NMFS and the mid-Atlantic and New England Fishery Management councils for U.S. waters, and that developed by Fisheries and Oceans in concert with NAFO for Canadian waters. Both regimes have evolved since extension of jurisdiction in 1977. Prior to this, management had been carried out under ICNAF. Fisheries in Canadian and U.S. waters have historically been well separated geographically, and there has been little fisheries activity by either nation or by third parties in the area of the ICJ line on Georges Bank.

The short-finned squid (Illex illecebrosus) is seasonally distributed from Labrador to the Straits of Florida and possibly the Gulf of Mexico, with adults found in greatest concentrations in the central part of their range (Cape Hatteras to southern Newfoundland) (Clarke 1966, Lu 1973, Roper and Lu 1979, Squire 1957, Lange 1980, Lange and Sissenwine 1983, Almeida et al. 1984). Spawning is believed to occur over the Blake Plateau, and the Gulf Stream is known to play a major role in distribution of the early life stages (Rowell et al. 1985a, Rowell and Trites 1985, Trites and Rowell 1985, Hatanaka et al. 1985). The bulk of the population is believed to result from a protracted winter spawning, although evidence of secondary and tertiary modes in the length-frequency data from U.S. waters and the Scotian Shelf suggest some spring and summer spawning (Squire 1957, 1967, Amaratunga 1980, Dupouy 1981, Pouland et al. 1984, Rowell et al. 1985b, Mesnil 1977, Lange 1980). Having been transported northeastward with the

Gulf Stream, juveniles migrate shoreward to the feeding areas over the continental shelf (Lange and Sissenwine 1980, Rowell et al. 1985b, Almeida et al. 1984). In late fall, the adults appear to migrate in a southwestward direction, although long-distance tagging results are very limited (Amaratunga 1981, Dawe et al. 1981).

Reviews of size and maturity data, larval and juvenile distribution, the role of a major current system in transport, incidence of parasites, and limited tagging and electrophoretic studies, while not conclusive, suggest a single stock (Amaratunga 1981, Dawe et al. 1981, Romero and Amaratunga 1981, Dawe et al. 1984).

In U.S. waters, the long-finned squid (Loligo pealei) is managed under a regime developed by the NMFS in concert with the mid-Atlantic and New England Fishery Management councils. In Canadian waters, there is currently no management of this species, although the mechansim for such exists under NAFO. There has been no fishery for Loligo pealei in Canadian waters, and both research survey and commercial catch data suggest little prospect for a fishery on the Canadian side.

The long-finned squid is virtually absent from the Gulf of Maine during winter and spring and is present in only relatively low densities in autumn (Almeida et al. 1984, Lange and Sissenwine 1980). Although the distribution does extend as far north as the Bay of Fundy and southwestern areas of the Scotian Shelf, fishable concentrations are generally limited to the area between southern Georges Bank and Cape Hatteras (Tibbetts 1977, Stevenson 1951, Summers 1969, Lange and Sissenwine 1980, 1983).

Unlike I. illecebrosus, the long-finned squid does not appear to undergo major migrations or to be influenced by major current systems. Migration, over distances of up to 200 km, takes place annually between the overwintering area along the upper continental slope between western Georges Bank and Cape Hatteras and the shallower areas of the Shelf where spawning takes place in late spring and early summer (Lange and Sissenwine 1980, Summers 1971).

There have been no tagging experiments reported and little other work done on stock discrimination. Preliminary results of recently undertaken electrophoretic studies are reported to show no apparent difference between L. pealei taken inshore and those taken offshore (A.M.T. Lange, pers. comm.). Despite there being no conclusive evidence, this species is considered to be a single stock north of Cape Hatteras.

Swordfish (Xiphias gladius)

Management of the Canadian swordfish fishery is based upon the assumption of a single stock (or portion of a stock) fished throughout NAFO Statistical Areas 3, 4, 5, and 6. Prior to 1971, this fishery was unmanaged. From 1971-78 landings in the USA and Canada were regulated by mercury content restriction. In 1979 Canada introduced licensing and a quota (3,000 t in 1979 and 3,500 t in 1980) for Canadian vessels.

The stock structure is poorly understood. The species occurs widely throughouth the Atlantic from about 45°S to 45°N (Palko et al. 1981), with three areas of concentration; the western north Atlantic, south Atlantic, and eastern Atlantic (Conser et al. 1985). Although the ubiquitous occurrence and lack of clear dividing lines between areas of concentration suggest that interchange is possible and that there might be a single Atlantic stock, the weight of available evidence favours three stocks (Beardsley, 1977; Berkeley, 1983; Conser et al. 1985). Within the northwest Atlantic unit, the occurrence of larvae in the Caribbean and adjacent waters and the quiescent gonad state of fish captured north of 35° suggests migration between northern feeding areas and southern reproductive zones (Markle 1974, Beckett 1974). However, spatial and temporal variation of the larval distribution and summer feeding site tenacity indicated by tag returns suggest a more complex structure (Beckett, 1974).

Although the stock structure is not fully understood, it is clear that swordfish of the Gulf of Maine are part of a larger complex in the western North Atlantic.

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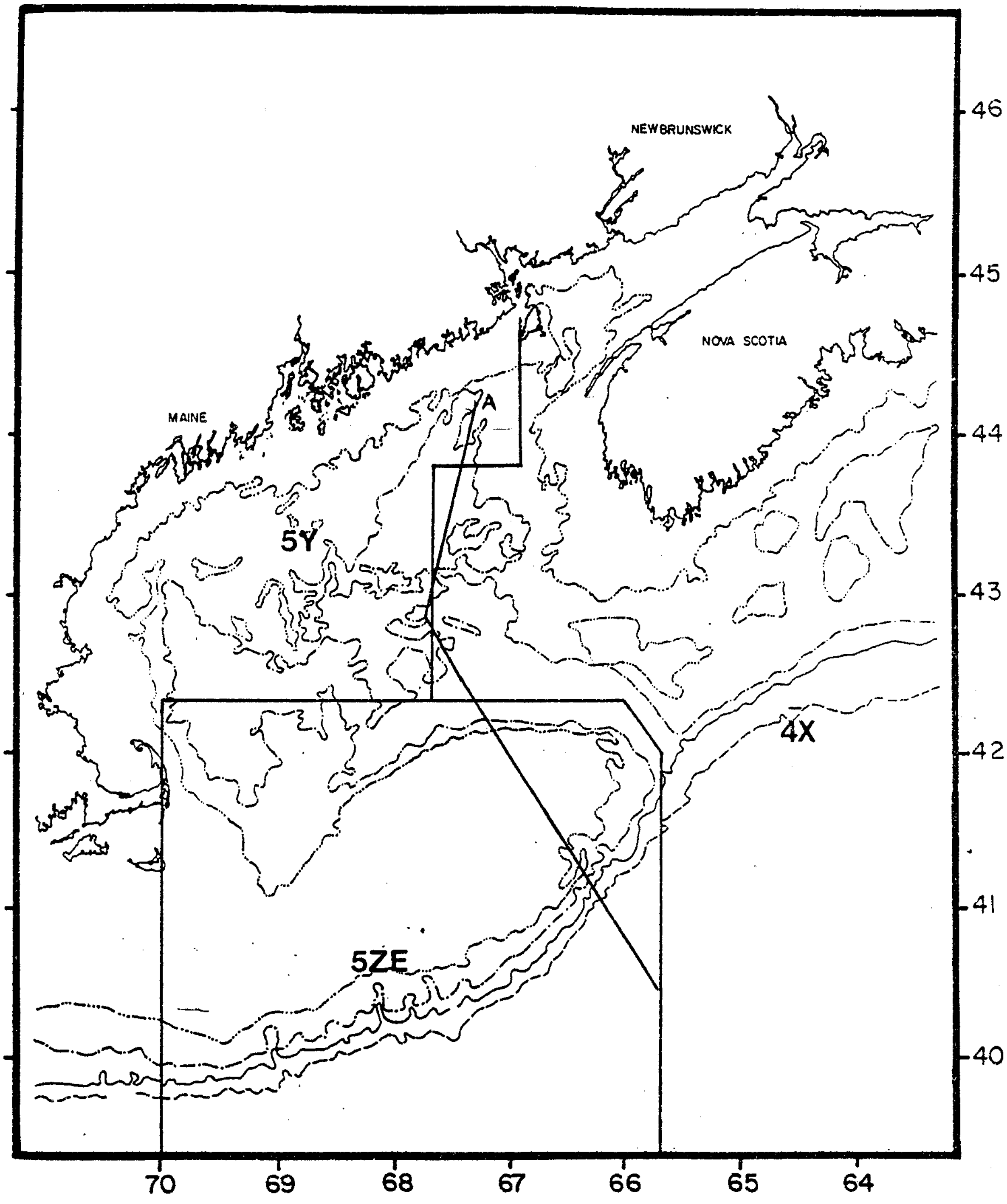

Fig.1 The ICJ line in relation to NAFO boundaries in the Gulf of Maine Area.

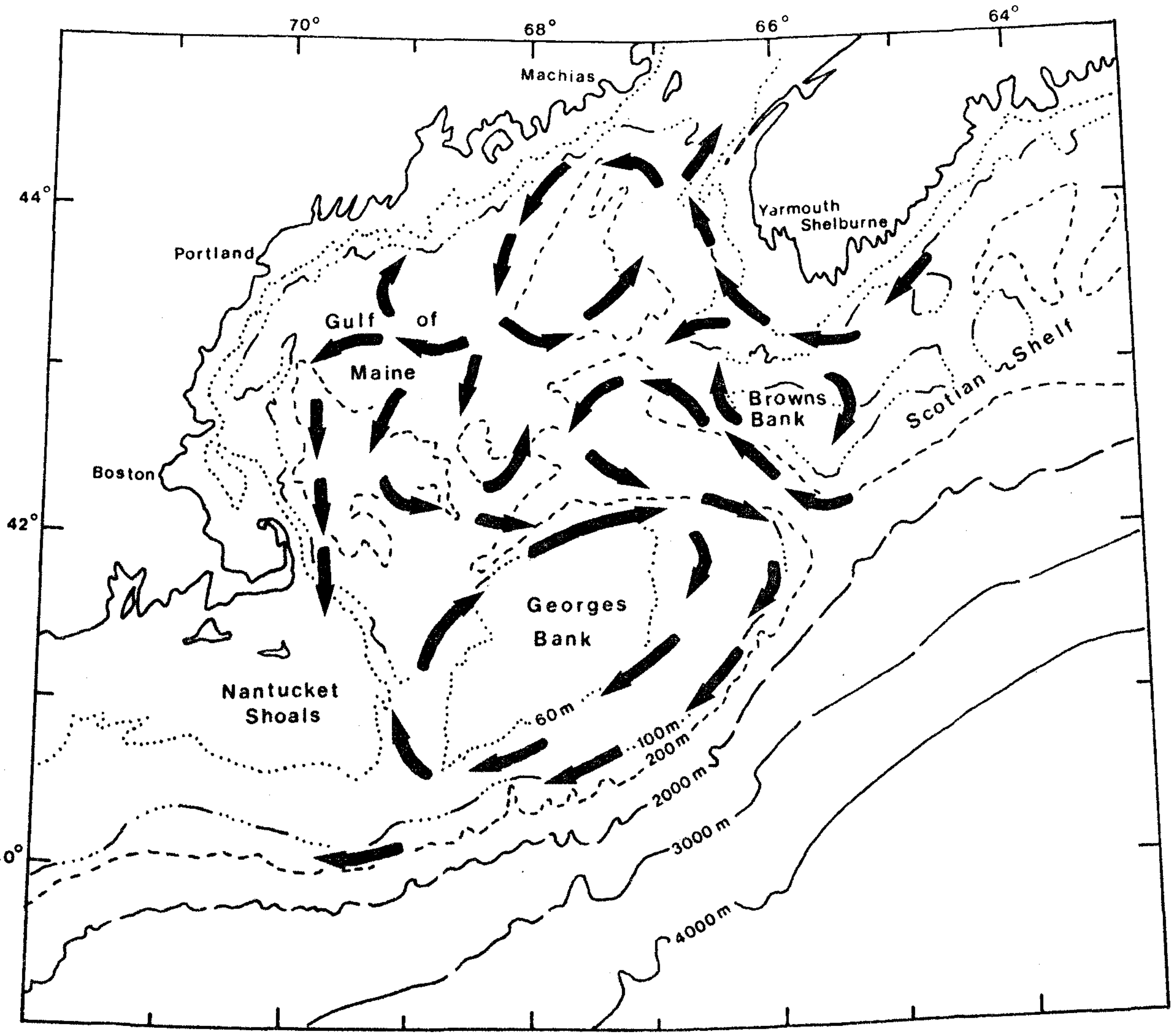

Fig. 2. Schematic representation of the spring circulation in the upper layers of the Gulf of Maine, Georges and Browns Banks, and southwest Nova Scotia; no current speeds are implied. Compiled from Brooks (1985), Smith (1983) and Butman et al. (In Press).