Gulf of Maine Area lobster management areas and suggestions on stock structure

By

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Abstract

Gulf of Maine Area lobster management areas and the history of the Canadian lobster fishing districts are presented. Lobster stock structure within the Gulf of Maine Area is examined through a review of the literature on lobster distribution; larval, electrophoresis, morphometric, parasite and tagging studies; and landing trends. Electrophoretic and morphometric studies do not have sufficient coverage of the Gulf of Maine Area to allow stock determination. Few lobster larval studies have been done in the Gulf of Maine Area, and the lack of data on larval behavior and water movements makes the results difficult to interpret. Tagging data presents a complex picture of localized and long-distance movement, with strong linkage between some areas and little between others. The data available suggest that at the present time neither a single nor multiple stock structure hypothesis can be proven for the Gulf of Maine.

Résumé

Le présent document décrit les zones de gestion du homard du golfe du Maine et fait l'historique des arrondissements de pêche du homard du Canada. On y examine la structure du stock de homard dans le golfe du Maine, au moyen d'une revue d'une part des documents existants sur la répartition du homard, d'autre part des études électrophorétiques et morphométriques ainsi que des études sur les larves, les parasites et l'étiquetage, et enfin des tendances en matière de débarquements. Les études électrophorétiques et morphométriques ne présentent pas de données suffisantes sur la région du golfe du Maine pour permettre de définir les stocks. Par ailleurs, peu d'études sur les larves de homard ont été effectuées dans cette région; de plus, leurs résultats sont difficiles à interpréter, du fait de l'insuffisance de données sur le comportement des larves et sur leur mouvement. Les données sur l'étiquetage présentent un tableau complexe des mouvements localisés et des mouvements à longue distance, les liens étant très nets entre certains secteurs et faibles entre certains autres. Compte tenu des renseignements dont on dispose actuellement, il apparaît impossible d'établir si le homard du golfe du Maine provient d'un stock unique ou multiple.

HISTORY OF MANAGEMENT AREAS

The Canadian lobster districts were established in the early 1900's, though the concept originated in 1877 when the first sectional closed seasons were applied (DeWolf 1974). These were implemented to reduce the sale of low-quality, soft-shelled lobsters during the summer molting season. The closed season was extended from 1 mo to 8 mo in 1879 to reduce exploitation rates (DeWolf 1974).

The present Lobster Fishing District (LFD) system originated in 1900, following the recommendations of the 1899 Royal Commission, chaired by E.E. Prince. Two LFD's were established in the Gulf of Maine Area (Fig. 1a): LFD 1 - Charlotte, Yarmouth, and Shelburne Counties; and LFD 2- the remaining area of the Bay of Fundy. The division into two LFD's was based in part on the belief that the Bay of Fundy was suboptimal for lobster growth and reproduction. A larger size limit was instituted to maximize the financial returns to the fishermen on the "...few lobsters which reached the adult stage or that immigrated from other waters" (McLean Commission 1928). Various changes were made in LFD boundaries, seasons, and lobster size limits between 1900 and 1928; little has changed since (compare Fig. 1b and c). There was the establishment of a separate Bay of Fundy LFD for Grand Manan in 1978, and the division of LFD 4 into 4A and 4B in 1980. As well, an offshore lobster fishery with a separate district was established in 1971 (Fig. 1c) to provide employment for displaced swordfish vessels (Stasko and Pye 1980a; Pezzack and Duggan 1985).

The Offshore LFD "A" was defined as the area beyond a line drawn 50 naut. mi. (92 km) from shore, extending from the Laurentian Channel in the north to a point near the mouth of the Bay of Fundy. The fishery was restricted to beyond 50 naut. mi. from shore to provide a solid separation between the offshore and inshore fisheries which at the time seldom fished more than 18 km from shore (Wilder unpubl. MS). Initially it was believed that commercial stocks did not exist on the outer Scotian Shelf, hence all offshore lobster fishing would occur on Georges Bank. However, by 1972 commercial quantities were found in the Browns Bank area (Fig. 2). The line runs along the southern edge of Browns Bank and divides this Bank's lobster concentration between inshore and offshore fisheries (Pezzack 1983; 1984). The majority of the Canadian offshore lobster catch in Div. 4X occurs within 10-20 km of the boundary line. A wide "no-man's land" existed between the inshore and offshore fisheries in the early 1970's, not fished by Canadian fishermen but occasionally fished by American vessels (German Bank in 1972) (Wilder unpubl. MS). The offshore boundary line was deemed by some to possibly be too restrictive and could be modified to better reflect lobster distribution in the offshore areas (Wilder unpubl. MS). By the mid to late 1970's inshore effort had extended to the offshore boundary line and the inshore/offshore fisheries conflict prevented any shoreward extention of the boundary line.

An area enclosing all of Browns Bank (4800 km^2) (Fig. 1c) was closed to lobster fishing in 1979. The closure was based on the hypothesis that Browns Bank was an important source of larvae for the coastal regions and that a closure would prevent depletion of the brood stock resident to Browns Bank. The usefulness of the closure zone is presently under study.

The offshore lobster fishery was controversial from the beginning. Inshore fishermen feared the large offshore vessels would remove lobsters important to inshore recruitment. They also resented the presence of processor-owned vessels , no closed season, and no trap limit. Pressure on the government to close or restrict the offshore fishery peaked in 1976 following declining inshore, and record high offshore, catches.

The Offshore LFD was subdivided into Div. 4X and 5Ze fisheries in 1977 (Fig. 3); a quota was placed on Div. 4X and two vessels were restricted to Div. 5Ze (Pezzack and Duggan 1985). The quota was extended to the entire offshore area (Div. 4W, 4X, 5Ze, 5Y) in 1985, but two vessels were still restricted to Div. 5Ze.

Prior to 1986 the Gulf of Maine Area was divided into nine lobster management units: the four Canadian inshore LFD's 1-4A; Offshore LFD "A" (subdivided into Div. 4X and 5Ze for some vessel regulations); the three American State waters within 12 naut. mi. of the coasts of Maine, New Hampshire, and Massachusetts; and the American, federally controlled, offshore lobster fishery. The Canadian LFD's were defined as lengths of coast only, with no seaward boundaries. This led to disputes in the Bay of Fundy when fishermen from different LFD's began to overlap. Effective January 1986, Lobster Fishing Areas (LFA's) were defined as bounded areas; the numbering system was changed (Fig. 4). These districts may yet be modified by removing the present buffer zones (LFA's 37, 39) between LFA's 34-36 and 38.

Canadian LFA's within the Gulf of Maine Area have a common minimum size (81 mm) for lobsters and protection of egg-bearing females, but slightly different seasons, trap limits, and vessel size restrictions. The American inshore fishery is managed by the contiguous states; the offshore fishery is managed by the federal government. Both fisheries have the same minimum size and restrictions on the possession of berried females as Canada, but place no restrictions on entry, season, gear type (trap and trawl), or number. Maine, in addition, protects lobsters over 127 mm CL and all

reproductively mature females bearing a "V" notched tail whether egg bearing or not at the time of capture ("V" notch applied by fishermen and state officials to egg-bearing lobsters).

BIOLOGICAL BASIS FOR DEFINITION OF UNIT STOCKS

The geographic distinctness of lobster stocks in the Gulf of Maine Area has been under debate for years. Certain DFO policies, from the 1950's through the early 1970's, reflected the belief that lobsters were non-migratory, (Wilder 1963;1974; Wilder and Murray 1958). Saila and Flowers (1968; 1969) suggest that offshore and inshore lobsters were distinct; however, Cooper and Uzmann (1971) clearly show that offshore lobsters were capable of long-distance movements. Recently Campbell and Mohn (1983), Campbell *et al.* (1984), Campbell and Stasko (1985), Stasko and Campbell (1980), and Harding *et al.* (1983) suggest that the Gulf of Maine Area should be considered a single population. The hypothesis is based on the observed capacity of lobsters to make long-distance movements, the potential for exchange of larvae throughout the area during the 30-80 d larval period and the observation that the landings within the Gulf of Maine Area have fluctuated coherently (Campbell and Mohn 1983).

The large geographic area, the widespread distribution of lobsters, and the large number of jurisdictions within the Gulf of Maine Area have made extensive studies of the stock question difficult. Many biological studies are confined to a single state's waters or one or two LFD's, with little or no coordination between areas. Some inference on stock structure may be drawn from available data on lobster distribution, lobster movement, electrophoretic and morphometric differences, parasite distribution, and analysis of catch trends.

Lobster Distribution

Adult

Lobsters are distributed throughout the Gulf of Maine Area (Fogarty *et al.* 1982; Pezzack 1984), but commercial fishing is restricted to areas of high concentrations. A review of both Canadian and American research surveys (trawling and trapping) and fishing effort distribution indicates a non-uniform distribution which varies seasonally. Groundfish trawl surveys by DFO and NMFS show lobsters are distributed in low numbers throughout the Gulf of Maine Area (Pezzack 1984; Fogarty *et al.* 1982). Major winter-spring concentrations occur in Georges Basin, on the slope of Browns and Georges Bank, and in the deep water at the mouth of the Bay of Fundy. Summer-fall concentrations occur on Browns and Georges Bank. Submersible surveys (Uzmann pers. comm.) reveal that lobsters occur in low numbers between Browns and Georges Banks in summer.

Canadian offshore lobster fishery logs (Fig. 2) indicate lobster concentrations along the upper slope of the Scotian Shelf and Georges Bank and in the deep water of the Northeast Channel in winter and early spring. Lobsters are fished in shallower waters of the banks (where regulation and gear conflict restrictions allow) in summer and early fall. Effort shifts in late fall to Crowell and Georges Basin and the deeper water along the upper shelf southeast of Browns Bank. Crowell and Georges Basin were heavily fished by American vessels prior to the 1984 International Court of Justice (ICJ) decision.

Lobster movements are believed to be controlled in part by temperature (Uzmann *et al.* 1977; Campbell 1986). Shifts in bottom temperature distribution or in the timing of seasonal temperature changes can result in shifts in the distribution of major lobster concentrations. Seasonal and year-to-year changes in the relative availability of lobsters in the various offshore areas suggest the center of abundance varies over time (Pezzack and Duggan 1985). NMFS trawl surveys indicate that Gulf of Maine and Scotian Shelf lobster biomass levels may have been much lower during the mid 1960's than today (Fogarty *et al.* 1982). Bottom temperatures in the Gulf of Maine Area were at a 20 yr low in the mid 1960's (Mountain 1982). Catches increased at this time in the inshore region from Massachusetts to Long Island Sound, which Grosslein and Azarovitz (1982) suggest was do to a shift in distribution.

Little is known about the distribution of the inshore lobster fishing effort beyond the immediate coastal area. Recently, inshore lobster fishing effort off southwestern Nova Scotia was surveyed using aerial survey techniques (Sharp and Duggan 1985). Spring effort was high within 10 km to 20 km of the coast, corresponding closely to the 20-fm contour. A second, smaller peak occurred in the "middle grounds" 70 to 90 km from the coast, north and west of Browns Bank, just inside the offshore boundary line (60-100 fm). Fishing is also known to occur on German Bank and just inside the offshore line above Crowell Basin. Summer and fall trapping surveys (Pezzack 1983) observed the highest catches on Browns and German Bank and low catches in the area between. The limited available data suggest some discontinuity in the distribution of lobsters between inshore and offshore regions north of Browns Bank.

The size-frequency distribution of lobsters varies dramatically between certain coastal and offshore areas

(Fig. 5). Size differences were originally used to argue stock separation (Wilder 1974). More recently, the high percentage of large, mature lobsters (>95 mm CL) offshore and the large number of small, immature lobsters (60-94 mm CL) inshore, led Stasko (1978) to hypothesize that inshore lobsters matured and moved offshore. Prior to 1900, inshore mean sizes of Maine, New Brunswick, and Nova Scotia lobsters were equivalent to the present offshore fishery (Rathbun 1882; Venning 1910). Heavy exploitation in the southern New England offshore fishery resulted in a similar decline in mean size between 1955 and 1965 (Skud 1969). The larger size groups were replaced by smaller lobsters, uncommon during the early fishery. The present small size of inshore lobster could be due to exploitation rates between 50 and 90% and not to a hypothesized offshore movement of larger animals. Commercial concentrations of large, mature lobsters have recently been found inshore in the deep water off Grand Manan (Campbell and Duggan 1980) and German Bank.

Offshore grounds of Browns and Georges Banks have been fished since the early 1970's with no decline in mean size (Pezzack and Duggan 1985). The absence of small lobsters in Canadian offshore catches may be due in part to regulations restricting vessels to deeper shelf water, away from the shoal areas where small lobsters have been caught (unpubl. data); trap selectivity, and behavioral and mobility differences between large and small lobsters.

Distinct and persistent geographic size-frequency differences have been noted within the Canadian offshore areas since 1972 (Stasko and Pye 1980; Pezzack and Duggan 1985). The largest mean sizes were found on the outer slope of the Scotian Shelf and Georges Bank; the smallest in Crowell Basin; and intermediate sizes on German Bank and west of Browns Bank (Fig. 5). Stasko and Pye (1980) hypothesized that this was due to differential size migration; coastal lobsters migrated out to Crowell Basin, then proceeded to southwestern Browns Bank, and finally to the outer shelf southeast of Browns Bank. To date, tagging and size-frequency data from the grounds between the coast and offshore do not support this hypothesis. Howard (1980) suggests that substrata and available shelter size determine local size frequencies in *Homarus gammarus*.

The presence of large numbers of berried female lobsters offshore and the apparent low numbers inshore has lead to the suggestion that inshore recruitment is from Browns (Stasko 1978) or Georges Banks (Harding *et al.* 1983). Campbell and Pezzack (1986) reviewed the data and suggest that the frequency of berried females inshore is greater than previously thought.

Larval studies

Lobster larvae enter the plankton in the late spring/early summer, when surface waters attain approximately 12.5°C (Harding *et al.* 1983). The duration of the larval stage is a function of ambient water temperatures (Templeman 1936; MacKenzie 1985). Stage 4 animals are good swimmers, capable of moving approximately 11 cm/sec (Ennis and Cobb pers. comm.). The physiological or environmental cue to bottom seeking in this stage is yet unknown.

Although definitive studies were not available, it had been assumed for years that lobster larvae were neustonic (Templeman 1936; Scarratt 1964; Stasko 1978; Harding *et al.* 1982; 1983). Recently, Harding and Pringle (unpubl. data) observed that Browns Bank larvae exhibit stage-differentiated, vertical migration. Stage I occurred in the upper 10 m during the dark period, descending to 30 m during the light period. Stage IV larvae tend to remain in the upper 10 m day and night. Little is yet known about Stages II and III diurnal vertical distribution. The few collected by Harding and Pringle suggest that Stage II larvae tend to follow a Stage I vertical distribution; Stage III's, to follow a Stage IV distribution.

Two working hypotheses have been developed to explore lobster larval recruitment in the Gulf of Maine. First, that lobster larvae are passive drifters, carried by the residual currents. Stasko and Gordon (1983) and Harding *et al.* (1983) suggest that the offshore banks (Browns and Georges Banks) are the major source of recruitment to the inshore stocks. Supporting evidence was: 1) insufficient brood stock in the inshore grounds to support the annual fishing mortalities; 2) drift-bottle experiments which indicated water movement from the offshore banks to southwestern Nova Scotia and the American coast; 3) the bulk of the animals captured in the inshore fishery in LFD 4A are juveniles, while the offshore catch is dominated by large mature animals and very few juveniles. The corollary to this hypothesis is that the Gulf of Maine Area should be considered as one population.

The second hypothesis is that larvae are retained on offshore banks. For example, given the local gyres on Browns and Georges Banks and the larval diurnal distribution patterns, larvae may not be swept northward to the coast. Recent analysis of ovigerous female distribution and numbers suggest that they are more abundant in inshore areas than previously thought (Campbell and Pezzack 1986). The data indicate that coastal southwestern Nova Scotia and the Bay of Fundy produce 25 to 42% of the total egg production, while Browns and Georges Banks account for 18 to 25% and 29 to 40% respectively. The corollary to the retention

hypothesis is that several independent stocks could exist in the Gulf of Maine Area.

Research is under way on both larval and brood stock distribution and brood stock size. These data will permit a better estimation of the source of recruitment within the Gulf of Maine.

Electophoresis

Three electrophoretic studies undertaken in the northwestern Atlantic were designed to study lobster population structure. Barlow (1969) did electrophoretic work on lobsters from coastal Nova Scotia, Maine, New York, and Magdalen Islands, and offshore lobsters from southern Georges Bank and the slope off southern New England. Barlow (1969) concluded, from the examination of heart proteins and esterases, that the offshore lobsters were a separate population from coastal Maine or Nova Scotia, and that coastal Nova Scotia lobsters were separate from those of coastal Maine. Tracy *et al.* (1975) examined lobsters from eight sites from Prince Edward Island to Massachusetts and the offshore canyons of southern Georges. They found a low level of genetic variability. Gulf of St. Lawrence lobsters were distinct from east coast of Nova Scotia and Gulf of Maine Area lobsters at the malic enzyme locus. They also concluded that the observed difference at this locus between lobsters from offshore canyons and coastal New England was sufficient to support the hypothesis of separate inshore and offshore populations. Odense and Annand (1978) found no significant differences in loci between lobsters from southeastern coastal Nova Scotia (Liverpool, N.S.) and the slopes southeast of Browns Bank. They did not, however, examine the malic enzyme. Glycerol phosphate dehydrogenase showed some indications of differences between inshore and offshore lobsters, but was not sampled in all animals and thus not used in the final analysis.

Large decapod crustaceans generally show low genetic variability (Hedgecock *et al.* 1977). Lobsters, being generalists, may adapt to environmental differences through phenotypic plasticity rather than genetic variability (Nelson and Hedgecock 1980). Hedgecock *et al.* (1977) found genetic divergence between *H. americanus* and *H. gammarus* to be small and speculated that they had been isolated only since the Pleistocene.

The low observed genetic variablility of lobsters suggests that electrophoretic studies may be of little use in delineating stocks within the Gulf of Maine Area.

Morphometrics

Morphometric studies encompassing the entire Gulf of Maine Area have not been undertaken. Saila and Flowers (1969) examined inshore lobsters from Boothbay Harbor, Maine, to Narragansett Bay, Rhode Island, and offshore lobsters from Vetch Canyon (southern Georges Bank) to Hudson Canyon. They found significant differences between southern New England inshore and offshore lobsters, and indications of differences within geographically separated inshore and offshore areas. Rodgers *et al.* (1968) observed Stage I larvae from offshore regions south of Rhode Island to be significantly larger than those from coastal areas. Later stages showed no significant differences. Aiken (1971) observed morphometric and colour differences between two groups of lobsters off southwestern Nova Scotia which the fishermen refer to as "native" and "school" lobsters. Aiken suggested that the "school" lobsters which appeared in late spring, were from further offshore and migrated shoreward in the spring.

Campbell and Mohn (1982) found statistically significant morphometric differences between southern Gulf of St. Lawrence, eastern shore of Nova Scotia, southwestern Nova Scotia-Bay of Fundy, and offshore regions of the Gulf of Maine Area; but considerable overlap existed. They concluded that at least two main groups existed: Northumberland Strait to Cape Breton and southeast Nova Scotia to the Bay of Fundy, possibly including the offshore regions off southwestern Nova Scotia.

Morphometric differences between areas may be either due to separate populations or the result of phenotypic plasticity. Morphometric differences are inconclusive on their own and should be followed by experimental studies.

Morphometric studies show promise in delineating stocks, but a large-scale program encompassing the entire Gulf of Maine, Scotian Shelf, and Georges Bank would be required.

Parasites

Geographic distribution of lobster parasites has not been extensively used to delineate lobster populations. Uzmann (1970) found that a larval nematode, *Ascarophis* sp., was almost exclusively found in offshore lobsters and a juvenile acanthocephalan, *Corynosoma* sp., exclusively in coastal lobsters. Wilder (1974) reported a species of gooseneck barnacle found on offshore lobsters in Lydonia Canyon on Georges Bank but absent from coastal lobsters off southwestern Nova Scotia.

Interpretation of parasite distributions requires knowledge of parasite life history and secondary host, as well as environmental requirements. The presence of short-lived stages or external epifauna which would be shed with each molt cannot be used to define the origin of the lobster but may be used to examine seasonal movements. Uzmann (1970) suggests that infection by

Ascarophis sp. and *Corynosoma* sp. are consistent enough to permit estimations of relative abundance of offshore and coastal lobsters in areas of seasonal stock overlap.

Tagging Studies

The study of lobster movement patterns has influenced concepts on lobster population structure (Wilder 1974). Lobster tagging is used to detect seasonal and longer-term movements which, as with parasites, only yield indirect evidence of population discreteness. Early studies used carapace and body tags, which were lost at molt, to measure exploitation rates (Stasko 1980). Sphyrion tags (Scarratt and Elson 1965) are retained through the molt and thus permit long-term movement studies. Between 1968-1985 over 50,000 Canadian and 12,000 American tagged lobsters were released in the Gulf of Maine Area.

Fisherman cooperation is required in tagging studies; thus one must be aware of bias which can lead to incorrect conclusions. Fishing effort and catches are not uniformly distributed spatially or temporally. Closed seasons and areas, and areas of low lobster density, will have fewer returns. Lobsters which move into coastal areas during the summer when the Canadian inshore lobster fishery is closed could go undetected if the outward migration occurs before the fall season opens. Rarely do all fishermen of a district return all recaptured tags. Lack of tag returns cannot automatically be interpreted as a lack of captured tagged lobsters without subsidiary information. The problem is complicated in the Gulf of Maine Area with American (federal and state) and Canadian tagged lobsters moving between national fisheries. Bias in the return rate is difficult to quantify, and our knowledge of potential bias is usually based on hearsay and comments from other fishermen.

Until recently, tagging studies gave only a single recapture site; round trip migrations, if they occurred, could not be detected. Recent studies by Pezzack and Duggan (1986), and Campbell (1986) used multiple recapture data of berried females to study movements over extended periods.

Tag returns show movement in a single time period but cannot show the potential interannual variation or long-term changes in movement patterns in response to environmental changes. Some of the variation or scatter in returns over several years may be due to interannual changes in movement patterns resulting from shifts in warm and cold bottom water distribution.

The tagging studies are numerous, and detailed examination is beyond the scope of this paper. Reviews of early work are given by Stasko (1980) and Krouse (1980). Major recent tagging programs using sphyrion tags include those by Uzmann *et al.* (1977) on Georges Bank, Campbell (1982) off Port Maitland, N.S., Campbell and Stasko (1985) off southwestern Nova Scotia, Campbell (1984) in the upper reaches of the Bay of Fundy, and Campbell and Stasko (1986) near Grand Manan and the lower Bay of Fundy. Recent unpublished studies include tagging programs in the Browns Bank-Crowell Basin area (Pezzack) and Crowell-Jordon Basin area (Meyer and Uzmann). In all cases the majority of movement was local (within 50 km), but a proportion of the animals undertook long-distance movements.

Immature lobsters (60-94 mm CL) in the Bay of Fundy (Campbell and Stasko 1986) move an average of 10.5 km from the release site. Mature lobsters (>95 mm CL) move an average of 41.9 km, but are capable of longer-distance movement, with displacements of several hundred kilometres observed. Some lobsters do not move. They were recaptured close to the original tagging site after several years (Campbell *et al.* 1984; Campbell and Stasko 1985; Krouse 1981; Pezzack unpubl. data). Results from Browns Bank (Pezzack and Duggan 1986) show mature lobsters are capable of migrating several hundred kilometres but returning to the same deep-water slope site off Browns. These return movements have been observed over 1-yr periods, but some data show lobsters migrating over 100 km in 6 mo and 2-3 yr later being caught near the original release site. Multiple recaptures also show that some lobsters undertake only short migrations up and down the slope, not far from the shelf break.

Saila and Flowers (1968) released berried females caught in offshore canyons, into Narragansett Bay, R.I. The lobsters tended to return to the offshore canyons. Similar releases in southwestern Nova Scotia during 1975-76 and 1983-84 (Pezzack and Duggan unpubl. data) produced similar results. Recovery rates from the most recent releases are over 25%, with 98% of these lobsters recaptured offshore. Saila and Flowers (1968) would suggest that these lobsters were returning to a home region.

The vast majority of lobsters tagged in the offshore regions remain offshore. None of the lobsters tagged on Georges Bank, by Uzmann *et al.*. (1977), were reported in coastal waters north of Cape Cod, though lobsters tagged off southern New England did show seasonal migration from the slope to the coast. None of the lobsters from the numerous offshore tagging studies were recaptured in the Grand Manan-Bay of Fundy region, even though mature lobsters are common in the Bay of Fundy fishery. There were some inshore recoveries off southwestern Nova Scotia from the 1975 release on Browns Bank, but larger releases in 1982-85 have produced fewer inshore returns (it is believed that low return rates off southwestern Nova Scotia are due in part to poor fishermen / Department relations in this

area). No lobsters from the 1975 tag releases off southwestern Nova Scotia or on Browns Bank were returned from the Maine coastal region, and to date only two (.05% of returns) of the recoveries from the 1982-84 Browns Bank area releases have come from the Maine coast.

Results of the recent American tagging program (Meyer and Uzmann unpubl. data) in Crowell and Jordon Basins show lobsters moving to inshore southwestern Nova Scotia and Maine from Jordon Basin, while Crowell Basin lobsters moved predominantly to southern Georges Bank and Georges Basin. Canadian releases in Crowell Basin showed similar movement patterns. Few of the Canadian or American tagged Crowell Basin lobsters were recovered in adjacent Browns Bank grounds, and vice versa. Crowell and Jordon Basins are separated by Truxton Swell, a rocky rise of glacial origin. A lower rocky rise, Sewell Ridge, separates the Crowell and Browns Bank lobster grounds .

Lobsters tagged in the Bay of Fundy (Grand Manan, Chance Harbour, and Alma) are recovered in large and small numbers along the American and southwestern Nova Scotia coasts respectively (Campbell and Stasko 1986). Lobsters released at the head of the Bay of Fundy showed returns from the American coast, but not from the offshore region (Campbell 1984).

There have been no recoveries of Gulf of Maine Area tagged lobsters east of Cape Sable Island, supporting the idea that the eastern shore of Nova Scotia represents a distinct stock.

Movement patterns indicate that exchange occurs between distant areas within the Gulf of Maine Area, but the data do not permit a quantification of the interaction. Hence, the impact of movement on population structure and recruitment cannot be determined. Movement patterns and interrelationships may vary with environmental conditions and water temperature patterns.

The hypothesis that the Gulf of Maine Area represents a single population is based to a large extent on the observed long-distance movements of lobsters from Grand Manan (Campbell and Stasko 1986). Recent data indicate that though long-distance movements occur between some regions they appear lacking between others. The American study in the central Gulf of Maine Area suggests a division between north and south. The low level of offshore returns in the northern Gulf of Maine Area and inshore returns in the offshore areas tend to supports this. The tagging data reveal complex movement patterns with potential relationships between distant regions of the Gulf of Maine Area. Further work is required to establish population structure.

FISHERY LANDING TRENDS

Campbell and Mohn (1983) and Harding *et al.* (1983) attempted to describe population structure through analysis of long-term catch trends. Their conclusion for the Gulf of Maine Area is that the coasts of Maine, Bay of Fundy, and southwestern Nova Scotia represent a separate population from the east coast of Nova Scotia. The time series for the offshore fishery was too short for comparison with inshore areas. Other authors have related catch to sea surface temperature (Flowers and Saila 1972; Dow 1977) and river discharge (Sutcliffe 1973) which can act over large areas and could result in a similar trend in catch over an area encompassing several stock areas.

The conclusion that the southern and eastern coast of Nova Scotia are distinct from the Gulf of Maine Area agrees with tagging data and is supported by oceanographic observations. Within the Gulf of Maine Area, environmental and economic variables may have a levelling effect which may show unrelated stocks with the same landings response.

SUMMARY

1) DFO's policy in the 1950's through the early 1970's reflected the concept that lobsters were non-migratory. Policy in the late 1970's reflected a hypothesized connection between inshore and offshore lobster areas. More recently some scientists have suggested that the Gulf of Maine Area should be considered a single population based on movement data.

2) Adult lobsters are distributed throughout the Gulf of Maine Area, but commercial concentrations move seasonally from deeper waters during winter and spring, to the shelf edge and shallow banks in summer and fall. The movement appears, in part, to be regulated by temperature.

3) Adult size frequencies vary markedly between management areas; this may be due to the long period of higher exploitation rates on inshore grounds (smaller mean size) and/or increased movement offshore with size.

4) The planktonic duration of lobster larvae is, in part, a function of water temperature. Hypotheses involving passive northward drift from offshore banks to coastal areas must be reassessed in light of stage differential in diurnal vertical migration and gyres on the offshore banks which could retain larvae.

5) Morphometric and electophoretic differences between adults have been observed between inshore and

offshore areas off southern New England, but little data are available for the Gulf of Maine Area.

6) Thousands of lobsters tagged with sphyrion tags (retained through the molt), in the Gulf of Maine Area, demonstrate a complex movement pattern:

a) Immature animals (60-94 mm CL) moved an average of 10.5 km, while mature animals (>95 mm CL) move an average of 41.9 km and are capable of moving several hundred kilometres. b) Some lobsters were observed to make long-distance (>100 km) annual migrations, returning to the initial tagging area. c) Long-distance movement of Bay of Fundy lobsters is predominantly along the coast of Maine to Massachusetts, in smaller numbers on the offshore grounds, and rarely on the inshore grounds of southwestern Nova Scotia. d) Lobsters tagged on offshore banks are rarely reported inshore, and none have been reported from Grand Manan or the Bay of Fundy. e) Lobsters released in Jordon Basin tend to move shoreward to Maine and southwestern Nova Scotia; lobsters released in Crowell Basin moved southwest to Georges Bank. f) Gulf of Maine Area lobsters have not been reported from east of Cape Sable Island.

7) Analyses of annual landings from the Gulf of St.Lawrence to Maine support the hypothesis that the Gulf of Maine Area is distinct from eastern Nova Scotia.

STOCK STRUCTURE: CONCLUSIONS

It may be premature to conclude that the Gulf of Maine is a single stock. Lobsters are distributed throughout the Gulf of Maine, and along the edge of the continental shelf, but commercial concentrations are centered in several specific areas (Fig 6). Morphometric and electrophoretic data suggest some isolation, notably between inshore and offshore lobsters off southern New England; but insufficient data exist to determine if a similar pattern occurs within the Gulf of Maine Area. Tagging data show extensive movement between some concentrations, but little between others. Even low rates of exchange may result in genetic mixing, but the importance to local population size or recruitment is unknown. Larval data are inconclusive at this time. The long larval period affords the opportunity for long-distance movement, but gyres on the offshore banks combined with larval behavior may retain larvae on the banks where hatching occurs. Few juveniles are caught in the commercial offshore catches, but data suggest they are present on the offshore banks. The presence of juvenile nursery areas on offshore banks would raise the possibility that offshore areas are not dependent on outside recruitment.

Cross-border movements are common in the Gulf of Maine Area and on eastern Georges Bank. Summer migrations from the slope of Georges Bank to Georges Shoal (Uzmann *et al.* 1977) suggest that lobsters from the Canadian section of Georges Bank may move to American waters to mate and hatch their eggs, and that lobsters recruited to the Canadian fishery originate from larvae settling in these same shoal areas.

Though an understanding of population structure may aid in managing the fisheries, management units based on a phenotypic and/or genetic stock area are not always meaningful. The Cape Breton snow crab fishery clearly illustrates the potential problems. Different parts of a single biological population responded differently to the same management regime, with one area collapsing while others continued to prosper (Davidson *et al.* 1985). Management areas must consider intrastock factors such as growth, movement, and recruitment patterns.

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REFERENCES

Aiken, D.E. 1971. "School lobsters" from southern Nova Scotia. Fish. Res. Board Can. MS Rep. 1141, 19 p.

Barlow, J.II. 1969. Studies of molecular polymorphism in American lobsters (*Homarus americanus*). Ph.D. Thesis, University of Maine, Orono, Maine, 181 p.

Campbell, A. 1982. Movements of tagged lobsters released off Port Maitland, Nova Scotia, 1944-80. Can. Tech. Rep. Fish. Aquat. Sci. 1136: 41 p.

Campbell, A. 1984. Aspects of lobster biology and fishery in the upper reaches of the Bay of Fundy. In Can. Tech. Rep. Fish. Aquat. Sci. 1256: 469-489.

Campbell, A. and D.R. Duggan. 1980. Review of the Grand Manan lobster fishery with an analysis of recent catch and effort trends. Can. Tech. Rep. Fish. Aquatic Sci. 997: 20 p.

Campbell, A. 1986. Migratory movements of ovigerous lobsters, *Homarus americanus* , tagged off Grand Manan, Canada. Can. J. Fish. Aquat. Sci.: (in press).

Campbell, A., D.E. Graham, H.J. MacNichol and A.M. Williamson. 1984. Movements of tagged lobsters released on the continental shelf from Georges Bank to Baccaro Bank 1971-73. Can. Tech. Rep. Fish. Aquat. Sci. 1288: 16 p.

Campbell, A. and R.K. Mohn. 1982. Quest for lobster stock boundaries in the Canadian Maritimes. Northw. Atl. Fish. Org. Res. Doc. 82/IX/107, N615, p 45.

Campbell, A. and R.K. Mohn. 1983. Definition of American lobster stocks for the Canadian Maritimes by analysis of the fishery landing trends. Trans. Amer. Fish. Soc. 112: 744-759.

Campbell, A. and D.S. Pezzack. 1986. Relative egg production and abundance of berried lobsters, *Homarus americanus*, in the Bay of Fundy and off southwestern Nova Scotia. Can. J. Fish. Aquat. Sci.: (in press)

Campbell, A. and A.B. Stasko. 1985. Movements of tagged American lobsters, *Homarus americanus*, off Southwestern Nova Scotia. Can. J. Fish. Aquat. Sci. 42: 229-238.

Campbell, A. and A.B. Stasko. 1986. Movement of lobster *(Homarus americanus)*, tagged in the Bay of Fundy, Canada. Mar. Biol.: (in press).

Cooper, R.A. and J.R. Uzmann. 1971 Migration and growth of deep-sea lobsters, *Homarus americanus*. Science (Wash. D.C.) 171: 288-290.

Davidson, K., J. Roff, and R.W. Elner. 1985. Morphological, electrophoretic, and fecundity characteristics of Atlantic snow crab, *Chionoecetes opilio*, and implications for fisheries management. Can. J. Fish. Aquat. Sci. 42: 474-482.

DeWolf, A.G. 1974. The lobster fishery of the Maritime provences: economic effect of regulations. Bull. Fish. Res. Board Can. 187, 59 p.

Dow, R.L. 1977. Relationship of sea surface temperature to American and European lobster landings. J. Cons. Int. Explor. Mer 37: 186-190.

Flowers, J.M. and S.B. Saila. 1972. An analysis of temperature effects on the inshore lobster fishery. J. Fish. Res. Board Can. 29: 1221-1225.

Fogarty, M.J., R.A. Cooper, J.R. Uzmann, and T. Burns. 1982. Assessment of the U.S.A. offshore lobster (*Homarus americanus)* fishery. Int. Coun. Explor. Sea C.M. 1982/ K:14.

Grosslein, M.D. and T.R. Azarovitz. 1982. Fish Distribution. MESA New York Bight Atlas Monograph 15, New York Sea Grant Inst., N.Y.

Harding, G.C., W.P. Vass, and K.F. Drinkwater. 1982. Aspects of larval American lobster (Homarus americanus) ecology in St. Georges Bay, Nova Scotia. Can. J. Fish. Aquat. Sci. 39: 1117-1129.

Harding, G.C., K.F. Drinkwater, and W.P. Vass. 1983 Factors influencing the size of lobster stocks along the Atlantic coast of Nova Scotia, Gulf of St. Lawrence and Gulf of Maine: A new synthesis. Can. J. Fish. Aquat. Sci. 40: 168-184.

Hedgecock, D., K. Nelson, J. Simons, and R. Shleser. 1977. Genetic similarity of American and European species of lobster *Homarus*. Biol. Bull. 152: 41-50.

Howard, A.E. 1980. Substrate controls on the size composition of lobsters (*Homarus gammarus*) population. J. Cons. Int. Explor. Mer 39: 130-133.

Krouse, J.S. 1980. Summary of lobster, *Homarus americanus*, tagging studies in American waters (1898-1978). Can. Tech. Rep. Fish. Aquat. Sci. 932: 135-141.

Krouse, J.S. 1981. Movements, growth and mortality of American lobsters, *Homarus americanus*, tagged along the coast of Maine. NOAA Tech. Rep. NMFS SSRF-747, 12 p.

MacKenzie, B.R. 1985. Temperature considerations of larval lobster (*Homarus americanus* Milne Edwards) ecology in waters off Southwest Nova Scotia. MSc. Thesis, Dalhousie Univ., Halifax, Nova Scotia.

MacLean Commision. 1928. Report of the royal commission investigating the fisheries of the Maritime Provinces and the Magdelen Islands. King's Printer, Ottawa.

Mountain, D.G. 1982. Oceanographic conditions in NAFO Subareas 5 and 6 during 1970-79. Northw. Atl. Fish. Org. Sci. Coun. Studies 5: 95-100.

Nelson, K. and D. Hedgecock. 1980. Enzyme polymorphism and adaptive strategy in the Decapod crustacean. Amer. Nat. 116: 238-280.

Odense, P.H. and C. Annand. 1978. Isoenzyme systems of an inshore and offshore lobster population. Int. Coun. Explor. Sea Shellfish Comm. C.M.1978/K:15, 6 p.

Pezzack, D.S. 1983. Distribution of American lobster (*Homarus americanus)* in the midshore and offshore regions of S.W. Nova Scotia during October 1980, July 1981 and October 1981 trap surveys. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 83/67.

Pezzack, D.S. 1984. Lobster distribution on the Scotian Shelf and implications to the Jonah Crab fisheries. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 84/44.

Pezzack, D.S. and D.R. Duggan. 1983. The Canadian offshore lobster (*Homarus americanus*) fishery 1971-1982. Int. Coun. Explor. Sea Shellfish Comm. C.M.1983/K:34.

Pezzack, D.S. and D.R. Duggan. 1985. The Canadian offshore lobster fishery 1971-1984, catch history, stock condition and management options. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 85/89.

Pezzack, D.S. and D.R. Duggan. 1986. Migration and homing tendencies of offshore lobsters (*Homarus americanus*) on the Scotian Shelf. Can. J. Fish. Aquat. Sci.: (in press).

Rathbun, R. 1882. The lobster fishery. In G.B. Goode (ed), The fisheries and fishing industry of the United States.

Rodgers, B.A., J.S. Cobb and N. Marshall. 1968. Size comparisons of inshore and offshore larvae of the lobster, *Homarus americanus*, off southern New England. Proc. National Shellfish Assoc. 58: 78-81.

Saila, S.B. and J.M. Flowers. 1968. Movements and behaviour of berried female lobsters displaced from offshore areas to Narragansett Bay, Rhode Island. J. Cons. 31: 342-351.

Saila, S.B. and J.M. Flowers. 1969. Geographic morphometric variation in the American lobster. Syst. Zool. 18: 330-338.

Scarratt, D.J. 1964. Abundance and distribution of lobster larvae (*Homarus americanus*) in Northumberland Strait. J. Fish. Res. Board Can. 21: 661-680.

Scarratt, D.J. and P.F. Elson. 1965. Preliminary trials of a tag for salmon and lobsters. J. Fish. Res. Board Can. 22: 421-423.

Sharp, G.J. and R.E. Duggan. 1985. An aerial survey of near-shore and mid-shore lobster fishing distribution off southwestern Nova Scotia, spring and fall 1983-84. Can. MS Rep. Fish. Aquat. Sci. 1847, 37 p.

Skud, B.E. 1969. The effects of fishing on size composition and sex ratios of offshore lobster stocks. Fisk. Dir. Skr. Ser. Havunderes. 15: 295-309.

Stasko, A.B. 1978. Inshore-offshore S.W. Nova Scotia lobster stock interaction: A hypothesis. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 78/37, 10 p.

Stasko, A.B. 1980. Tagging and lobster movements in Canada. Can. Tech. Rep. Fish. Aquat. Sci. 932: 141-150.

Stasko, A.B. and Campbell, A. 1980. An overview of lobster life history and fishery in southwest Nova Scotia. Can. Tech. Rep. Fish. Aquat. Sci. 954: 208-224.

Stasko, A.B. and D.J. Gordon. 1983. Distribution and relative abundance of lobster larvae off southwestern Nova Scotia, 1977-1978. Can. Tech. Rep. Fish. Aquat. Sci. 1175: 23 p.

Stasko, A.B. and R.W. Pye. 1980. Geographic differences in Canadian offshore lobster. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 80/57, 12 p.

Sutcliffe, W.H. Jr. 1973. Correlations between seasonal river discharge and local landings of American lobster (*Homarus americanus*) and Atlantic halibut (*Hippoglossus hippoglossus*) in the Gulf of St. Lawrence. J. Fish. Res. Board Can. 30: 856-859.

Templeman, W. 1936. The influance of temperature, salinity, light and food conditions on the survival and growth of the larvae of the lobster (*Homarus americanus*). J. Biol. Board Can. 2:485-497.

Tracey, L., K. Nelson, D. Hedgecock, R.A. Shleser, and M.L. Pressick. 1975. Biochemical genetics of lobsters: Genetic variation and the structure of American lobster (*Homarus americanus*) populations. J. Fish. Res. Board Can. 32: 2091-2101.

Uzmann, J.R. 1970. Use of parasites in identifying lobster stocks. Proc. Sec. Int. Cong. Parasitol. Abstr. 641. J. Parasitol. 56: 349.

Uzmann, J.R., R.A. Cooper, and K.J. Pecci. 1977. Migration and dispersion of tagged American lobsters, *Homarus americanus*, on the southern New England continental shelf. NOAA Tech. Rep. NMFS SSRF 705.

Venning, R.N. 1910. The marine and fisheries committee and lobster industry. A sessional Paper 22.

Wilder, D.G. 1963. Movements, growth and survival of marked and tagged lobsters liberated in Egmont Bay, Prince Edward Island. J. Fish. Res. Board Can. 20: 305-318.

Wilder, D.G. 1974. Inshore and offshore lobster stock. Fish. Res. Board Can. MS Rep. 1293: 14 p.

Wilder, D.G. and R.C. Murray. 1958. Do lobsters move offshore and onshore in the fall and spring? Fish. Res. Board Can., Atl. Prog. Rep. 69: 12-15.

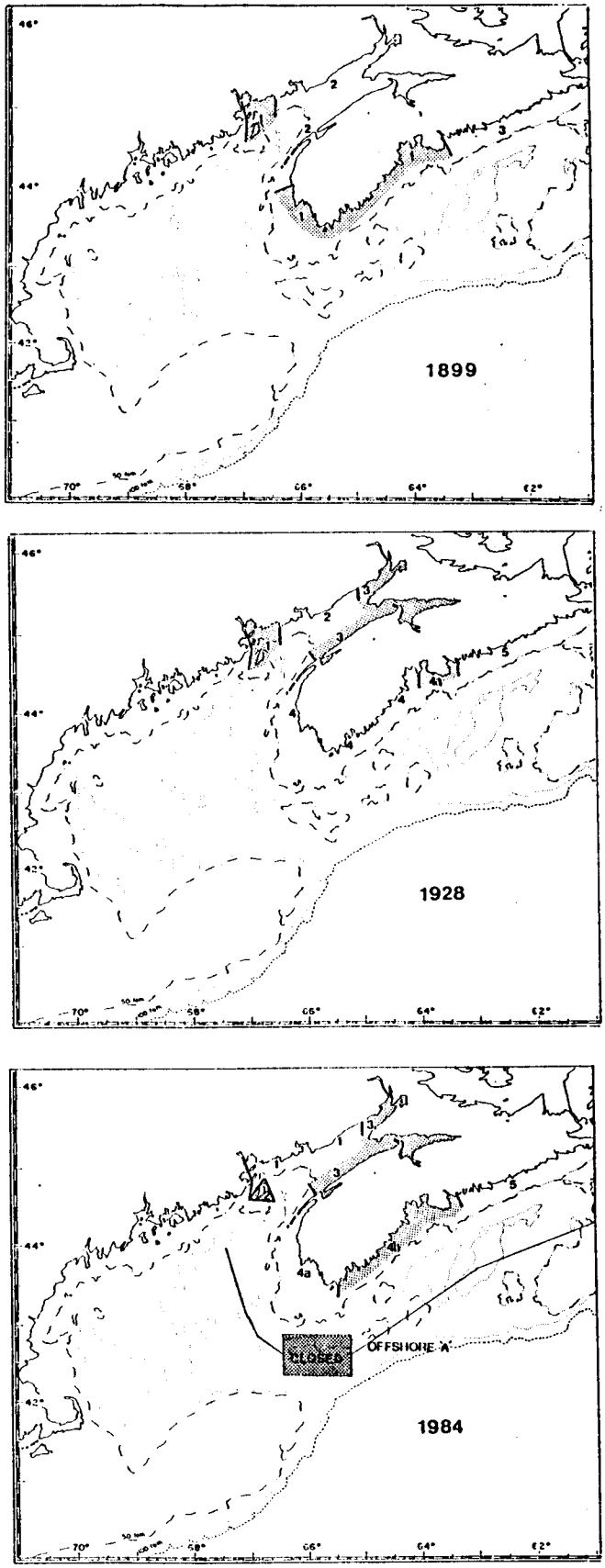


Figure 1. Canadian Lobster Fishing Districts (a) 1899, (b) 1928, (c) 1984.

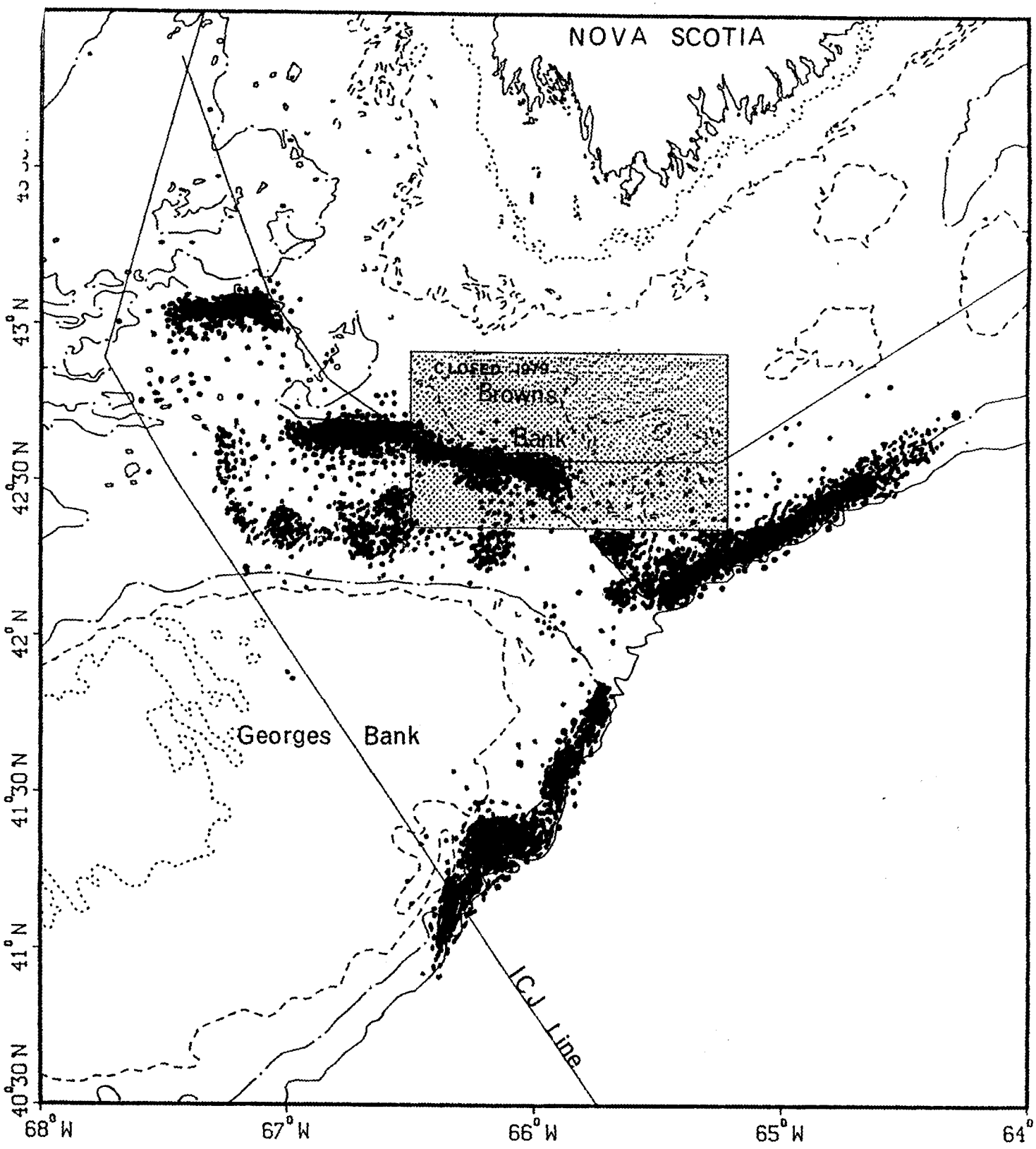
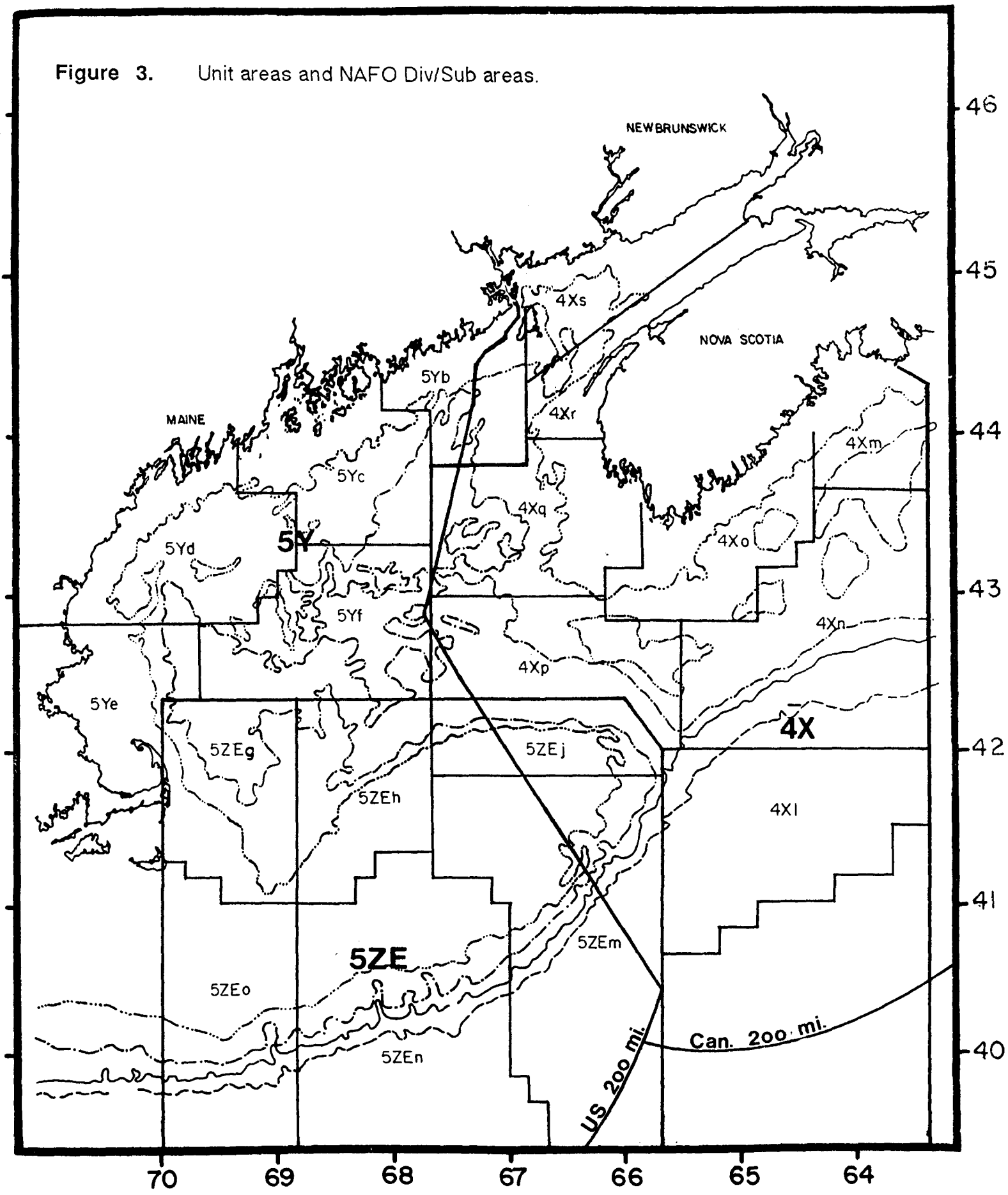
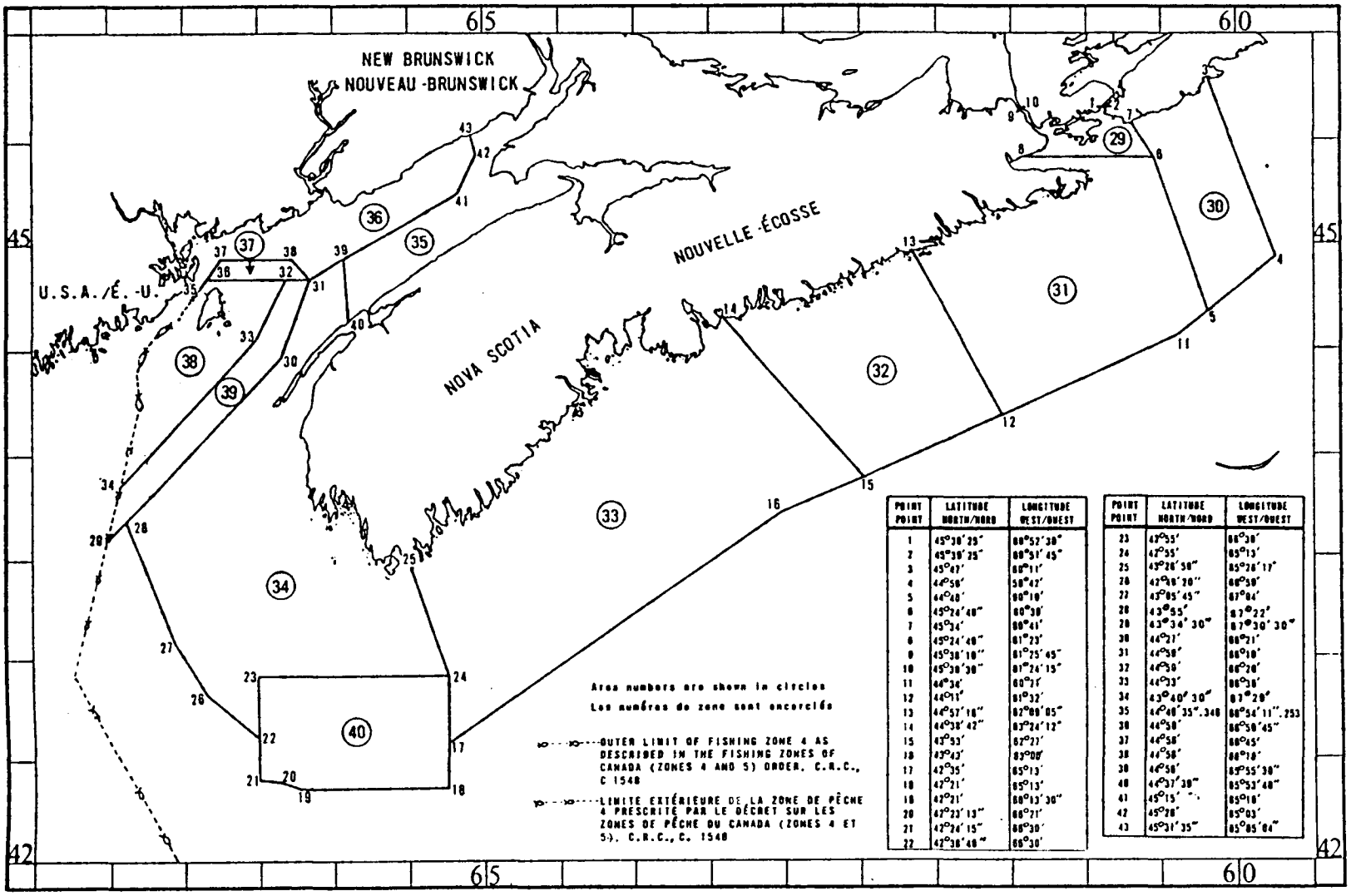


Figure 2. Canadian offshore lobster fishing area showing closed area (introduced in 1979) and approximate fishing locations 1971-1985 (based on fishermens logbook returns).

Figure 3. Unit areas and NAFO Div/Sub areas.





POINT POINT	LATITUDE NORTH/NORD	LONGITUDE WEST/OUEST
1	45°38'29"	60°52'38"
2	45°38'25"	60°51'45"
3	45°07'	60°11'
4	44°58'	58°42'
5	44°48'	60°10'
6	45°24'48"	60°38'
7	45°34'	60°41'
8	45°24'48"	61°25'
9	45°38'10"	61°25'45"
10	45°38'30"	61°24'15"
11	44°36'	60°21'
12	44°11'	61°32'
13	44°57'18"	62°09'05"
14	44°38'42"	63°24'12"
15	43°53'	67°27'
16	43°43'	63°08'
17	42°35'	65°13'
18	42°21'	65°13'
19	42°21'	66°13'30"
20	42°23'13"	66°21'
21	42°24'15"	66°30'
22	42°38'48"	66°30'

POINT POINT	LATITUDE NORTH/NORD	LONGITUDE WEST/OUEST
23	42°55'	66°30'
24	42°55'	65°13'
25	43°26'58"	65°26'17"
26	42°58'20"	66°58'
27	43°05'45"	67°04'
28	43°55'	67°22'
29	43°34'30"	67°30'30"
30	44°27'	66°21'
31	44°58'	64°10'
32	44°58'	66°20'
33	44°33'	66°38'
34	43°40'30"	67°29'
35	44°48'35".348	66°54'11".253
36	44°58'	66°58'45"
37	44°58'	66°45'
38	44°58'	64°10'
39	44°58'	63°55'30"
40	44°37'30"	65°53'40"
41	45°15'	65°10'
42	45°28'	65°03'
43	45°31'35"	65°05'04"

Figure 4. Canadian Lobster Fishing Areas 1986.

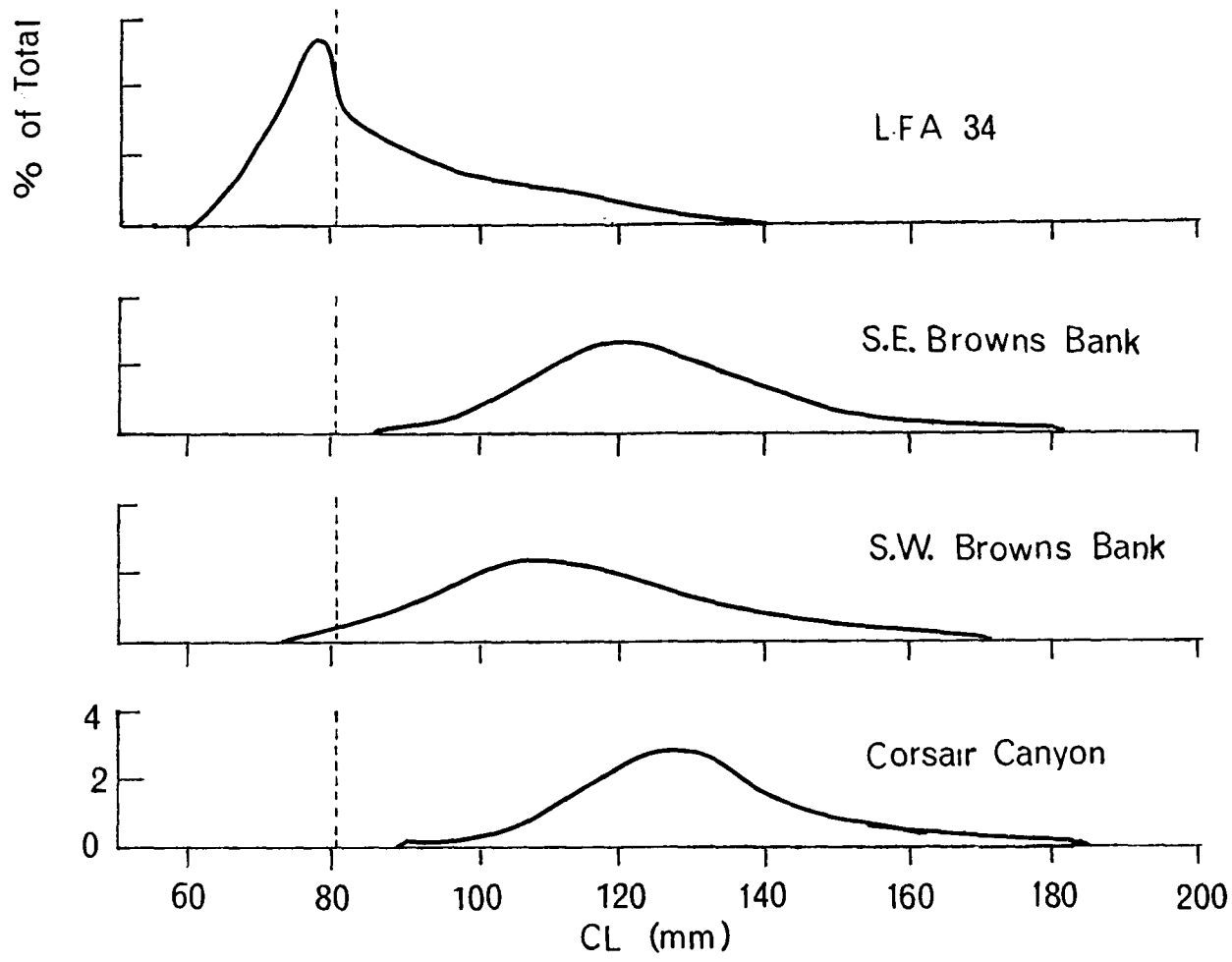


Figure 5. Trends in size frequency distributions of lobster catches from various LFA in the Gulf of Maine Area.

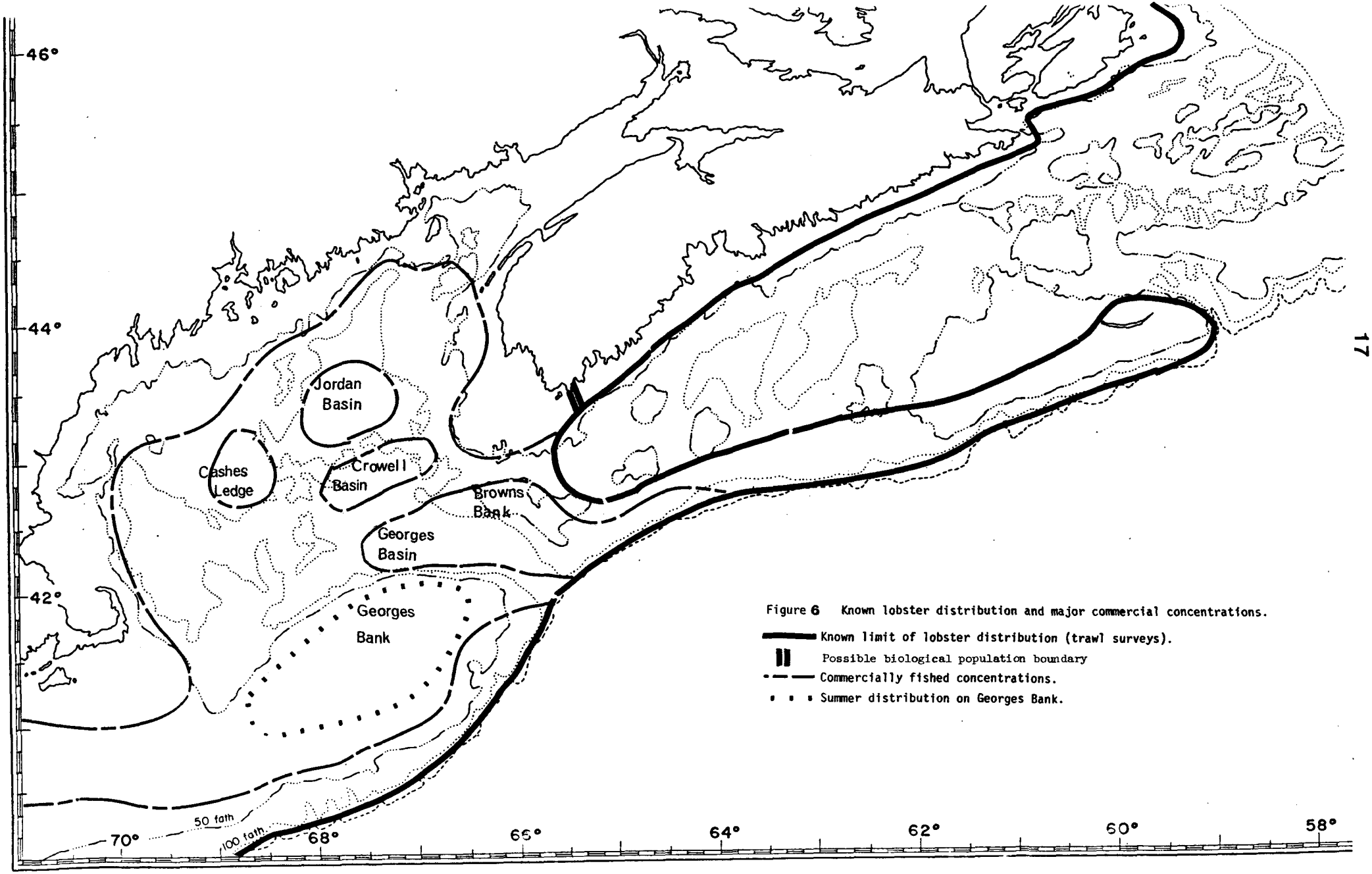


Figure 6 Known lobster distribution and major commercial concentrations.