Distribution and Abundance of the Ocean Quahaug *(Arctica islandica)* and Stimpson's Surf Clam *(Spisula polynyma)* Resource on the Scotian Shelf

T.W. Rowell [1] and D.R. Chaisson [2]

[1] Fisheries Research Branch
Scotia-Fundy Region
Halifax Fisheries Research Laboratory
Department of Fisheries and Oceans
Halifax, N.S. B3J 2S7

[2] Bio-Atlantech Ltd.
P.O. Box 2907 D.E.P.S.
Dartmouth, N.S. B3Y 4Y2

Supported by

Fisheries Development Branch
Scotia-Fundy Region
Department of Fisheries and Oceans
Halifax, N.S. B3J 2S7

June 1983

Canadian Industry Report of Fisheries and Aquatic Sciences 142

Gouvernement du Canada
Pêches et Océans

Government of Canada
Fisheries and Oceans

Rapport canadien à l'industrie sur les sciences halieutiques et aquatiques

Ces rapports contiennent les résultats des recherches et des progrès qui peuvent être utiles à l'industrie pour des applications soit immédiates, soit futures. Ils sont préparés à l'intention principalement des membres des secteurs primaire et secondaire de l'industrie des pêches et de la mer. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du Ministère des Pêches et des Océans, notamment gestion des pêches, techniques et développement, sciences océaniques et environnements aquatiques, au Canada.

Les Rapports destinés à l'industrie peuvent être considérés comme des publications complètes. Le titre exact paraît au haut du résumé de chaque rapport, qui sera publié dans la revue *Aquatic Sciences and Fisheries Abstracts* et qui figurera dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros de 1 à 91 de cette série ont été publiés à titre de rapports sur les travaux de la Direction du développement industriel, de rapports techniques de la Direction du développement industriel, et de rapports techniques de la Direction des services aux pêcheurs. Les numéros 92 à 110 ont été publiés à titre de Rapports à l'industrie du Service des pêches et de la mer, Ministère des Pêches et de l'Environnement. Le nom de la série a été changé à partir du rapport numéro 111.

La page couverture porte le nom de l'établissement auteur où l'on peut se procurer les rapports sous couverture cartonnée.

Canadian Industry Report of Fisheries and Aquatic Sciences

These reports contain the results of research and development that are useful to industry for either immediate or future application. Industry Reports are directed primarily towards individuals in the primary and secondary sectors of the fishing and marine industries. No restriction is placed on subject matter and the series reflects the board interests and policies of the Department of Fisheries and Oceans, namely, fisheries management, technology and development, ocean sciences, and aquatic environments relevent to Canada.

Industry Reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report will be abstracted in *Aquatic Sciences and Fisheries Abstracts* and will be indexed annually in the Department's index to scientific and technical publications.

Numbers 1-91 in this series were issued as Project Reports of the Industrial Development Branch, Technical Reports of the Industrial Development Branch, and Technical Reports of the Fisherman's Service Branch. Numbers 92-110 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Industry Reports. The current series name was changed with report number 111.

Details on the availability of Industry Reports in hard copy may be obtained from the issuing establishment on the front cover.

Canadian Industry Report of

Fisheries and Aquatic Sciences 142

June 1983

DISTRIBUTION AND ABUNDANCE OF THE OCEAN QUAHAUG (ARCTICA ISLANDICA) AND STIMPSON'S SURF CLAM (SPISULA POLYNYMA) RESOURCE ON THE SCOTIAN SHELF

by

T.W. Rowell[1] and D.R. Chaisson[2]

[1] Fisheries Research Branch
Scotia-Fundy Region
Halifax Fisheries Research Laboratory
Department of Fisheries and Oceans
Halifax, N.S. B3J 2S7

[2] Bio-Atlantech Ltd.
P.O. Box 2907 D.E.P.S.
Dartmouth, N.S. B2Y 4Y2

Supported by

Fisheries Development Branch
Scotia-Fundy Region
Department of Fisheries and Oceans
Halifax, N.S. B3J 2S7

Cat. No. Fs 97-14/142 ISSN 0704-3694

Correct citation for this publication:

Rowell, T.W. and D.R. Chaisson. 1983. Distribution and abundance of the ocean quahaug (Arctica islandica) and Stimpson's surf clam (Spisula polynyma) resource on the Scotian Shelf. Can. Ind. Rep. Fish. Aquat. Sci. 142: v + 75 p.

CONTENTS

ABSTRACT

Rowell, T.W. and D.R. Chaisson. 1983. Distribution and abundance of the ocean quahaug (Arctica islandica) and Stimpson's surf clam (Spisula polynyma) resource on the Scotian Shelf. Can. Ind. Rep. Fish. Aquat. Sci. 142: v + 75 p.

During 1980 to 1982, an assessment of underutilized clam resources using hydraulic dredges was conducted along the south shore of Nova Scotia between St. Mary's Bay and St. Margaret's Bay and on the offshore banks of the Scotian Shelf. Distribution and minimum biomass were determined for the principal target species, the ocean quahaug (Arctica islandica) and the Stimpson's surf clam (Spisula polynyma). Maximum sustainable yield (MSY) for populations of the ocean quahaug in the inshore area is estimated at 322 t to 1,767 t.[1] No significant concentrations of Stimpson's surf clam were found in the inshore areas. The offshore areas of Sable Island and Western Banks were found to have the highest concentrations of ocean quahaugs and Banquereau Bank the greatest concentrations of the surf clam. Those areas with greatest clam densities on Western and Sable Island Banks are estimated to have a MSY for the ocean quahaug of 2,803 t to 12,601 t[1] while those on Banquereau Bank are estimated to have a MSY for the surf clam of 23,960 t to 87,892 t.[1]

Key words: Distribution, abundance, ocean quahaug, Stimpson's surf clam, and Scotian Shelf.

---

[1]Range of MSY value based on 90% confidence limits of the minimum biomass estimates.

RÉSUMÉ

Rowell, T.W. and D.R. Chaisson. 1983. Distribution and abundance of the ocean quahaug (*Arctica islandica*) and Stimpson's surf clam (*Spisula polynyma*) resource on the Scotian Shelf. Can. Ind. Rep. Fish. Aquat. Sci. 142: v + 75 p.

Durant les années 1980 à 1982, on a fait, au moyen de drague hydraulique, l'évaluation des ressources de palourdes sous-utilisées de la côte sud de la Nouvelle-Écosse entre St. Mary's Bay et St. Margaret's Bay. On a aussi étudié les bancs du large sur le plateau continental. La distribution et la biomasse minimale furent déterminées pour les deux espèces qui faisaient le but de l'étude, soit la palourde de mer (Arctica islandica) et la palourde de Stimpson (Spisula polynyma). Le rendement maximal soutenu (RMS) pour les populations de palourdes de mer dans les régions côtières est estimé entre 322 et 1,767 t.[1] Aucune concentration significative depalourde de Stimpson ne fut trouvée dans les régions côtières. Les régions de l'Ile de Sable et du banc Western contiennent les plus grandes concentrations de palourdes de mer, et le banc Banquereau contient les plus grandes concentrations de palourdes de Stimpson. On a estimé que les régions du banc Western et de l'Ile de Sable contenant les plus hautes densités de palourdes de mer ont un RMS de 2,803 t et 12,601 t.[1] On a estimé que les régions à haute densités du banc Banquereau ont un RMS de palourdes de Stimpson de 23,960 t et 87,892 t.[1]

---

[1]Valeurs limites des RMS à un niveau de confiance de 90% des estimés minimaux de la biomasse.

INTRODUCTION

This report summarizes recent surveys of ocean quahaug (Arctica islandica) and Stimpson's surf clam (Spisula polynyma) on the Scotian Shelf. The surveys, conducted by the Molluscan Section of the Fisheries Research Branch, were supported by the Fisheries Development Branch.

The ocean quahaug A. islandica (Fig. 1a) is known to occur along the east coast of North America from the Arctic Ocean to Cape Hatteras (Bousfield 1960). Catches have been recorded from as shallow as 4 m in the present survey to as deep as 256 m on the continental shelf (Merrill and Ropes 1969). The distribution of the ocean quahaug is best known for U.S. waters (Parker 1965; 1966; Parker and McRae 1970; Merrill and Ropes 1969; Loesch and Ropes 1977; Fogarty 1981). In Canadian waters, its distribution has been less well understood despite a number of limited surveys. Medcof (1957) established the presence of quahaugs in Medway and Shag Harbours, N.S.; McPhail and Medcof (1959) conducted explorations in the Northumberland Strait; and Chandler (1983, in press) conducted a survey in several areas off southwestern Nova Scotia.

In 1943, in response to the U.S. Wartime Food Production Program, a small ocean quahaug fishery was established off Rhode Island which peaked in 1946 at 682 t of meat (Merrill and Ropes 1969). Competition from the surf clam fishery for a limited clam meat market following the war led to a decline in the quahaug fishery. In the past several years, however, the quahaug fishery has been revitalized. This is due mainly to decreased landings of surf clams following an anoxic event in 1976 which greatly reduced the harvestable stocks off the New York and New Jersey coasts. Increased consumer acceptance and development of new quahaug products were also factors. U.S. catches of ocean quahaugs rose to 16,329 t of shucked meat in 1981 from just 771 t in 1970 (Mid-Atlantic Fishery Management Council[2] 1982, unpub. report).

The principal fishery in the U.S. is located off the mid-Atlantic states, with most of the approximately 100 vessels operating between New York and Virginia. These vessels range in size from 25 GT to more than 100 GT (Fig. 2) with approximately 41% of the fleet over 75 GT (Ropes 1982). Fishing is by hydraulic dredge (details of the operation are explained under "Materials - Inshore Surveys"). The average cutting width or bottom area covered by dredges in the U.S. fishery is 152.4 cm, although there are dredges as wide as 508.0 cm in operation (Mid-Atlantic Fishery Council 1982, unpub. report).

---

[2]Mid-Atlantic Fishery Management Council, Room 2115, Federal Building, 300 South New Street, Dover, Del. 19901-6790

Fig. 1a. The ocean quahaug *Arctica islandica*.

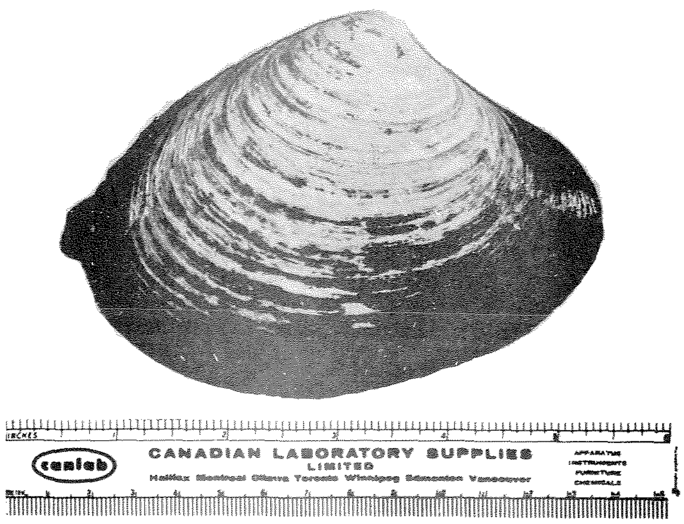


Fig. 1b. The Stimpson's surf clam *Spisula polynyma*.

S. solidissima for 1981 were 21,000 t of meat. In 1980, an estimated 90 t of *S. solidissima* meat were landed in the Maritime Provinces (Statistics Division, unpub. data). Most of these landings were harvested from intertidal or shallow near-shore areas for domestic consumption. Because of the limited depth range of *S. solidissima* in Maritime waters, it is considered unlikely that stocks are as abundant as in more southern waters.

S. polynyma, commonly known as the Stimpson's surf clam or pink neck clam (Fig. 1b), inhabits both the Atlantic and Pacific continental shelves. Bousfield (1960) states the general Atlantic distribution to be on sandy bottom from low water to 110 m with a range extending from Baffin Island to Rhode Island. However, Chamberlin and Sterns (1963) found no substantiated records of the species north of the Strait of Belle Isle. A U.S. fisheries survey on Middle Bank, Massachusetts Bay, produced catches of up to four bushels per standard four-minute tow (*Delaware II*,[4] Cruise Report 71-1). However, *S. polynyma* is not found in commercial quantities on the U.S. east coast and there have been no reported landings or commercial concentrations reported for Canadian waters. Hughes et al. (1977) reported commercial quantities of *S. polynyma* off the Alaska Peninsula and, as part of their survey of product quality, found the flavour and texture of the meat to be excellent.

With North American consumption of clams increasing, aided by the development of new products, and with declines in the availability of traditional species, there appears the possibility of developing an ocean quahaug or Stimpson's surf clam fishery in the Maritimes.

Consequently, a major survey was initiated to determine the distribution and abundance of ocean quahaugs, surf clams, and other underutilized shellfish resources off N.S. Between 1980-1982, areas between St. Mary's Bay and St. Margaret's Bay on the south shore of N.S. (Fig. 3) and 12 major banks on the Scotian Shelf (Fig. 4) were surveyed.

MATERIALS AND METHODS

MATERIALS

Inshore Surveys

Inshore surveys were conducted in 1980 from the 11.6 m vessel *Gary and Renee II*. This chartered vessel was equipped with a double-drum hydraulic winch of 2 t lifting capacity and had a 7.6 cm tubular steel A-frame from which the dredge was

---

[4]United States Department of Commerce, National Marine Fisheries Service, Woods Hole, Ma. 02543

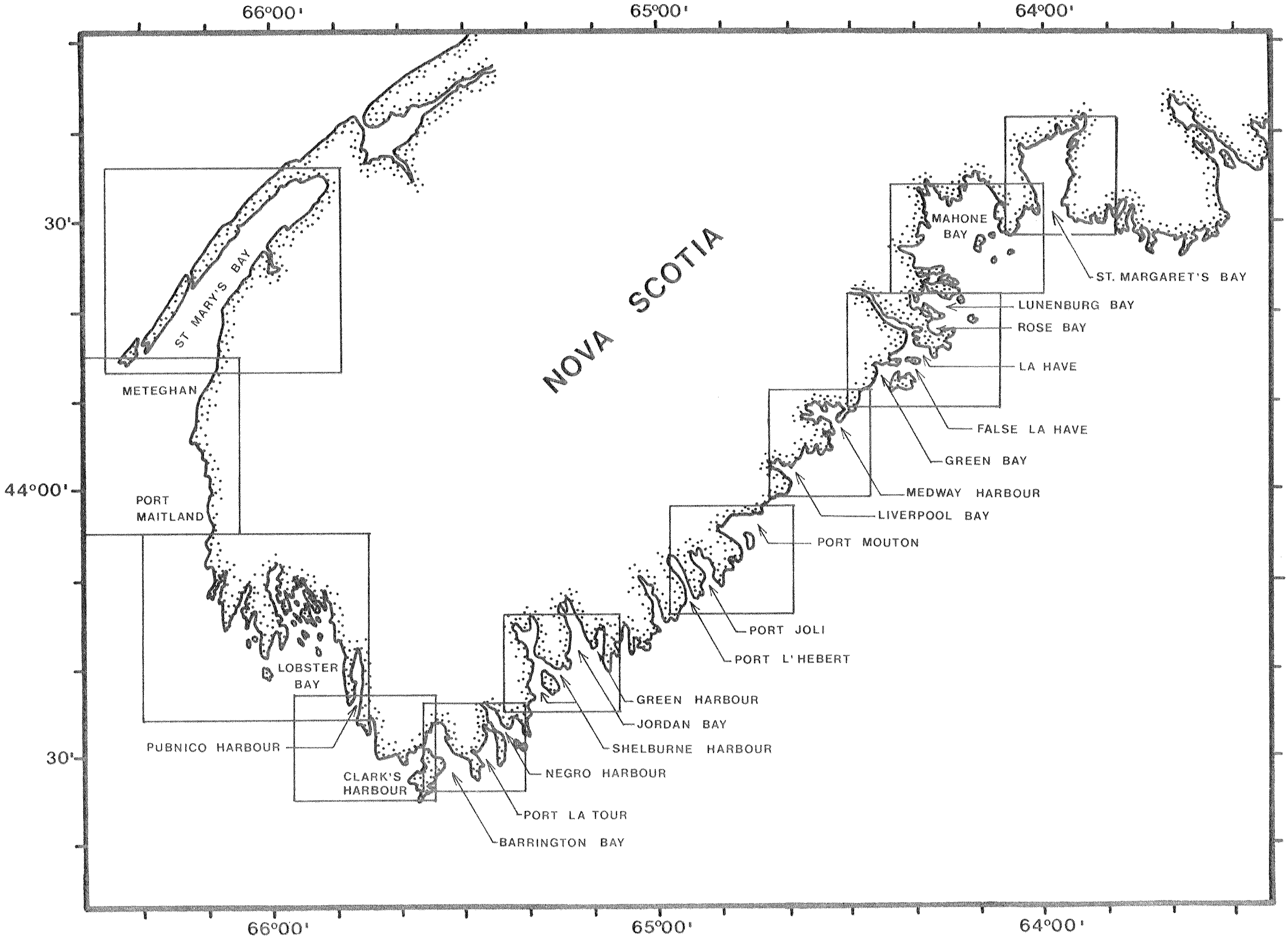


Fig. 3. Inshore areas of southwestern Nova Scotia surveyed from 1980 to 1982. Boxed areas are enlarged in Figures 7 to 17.

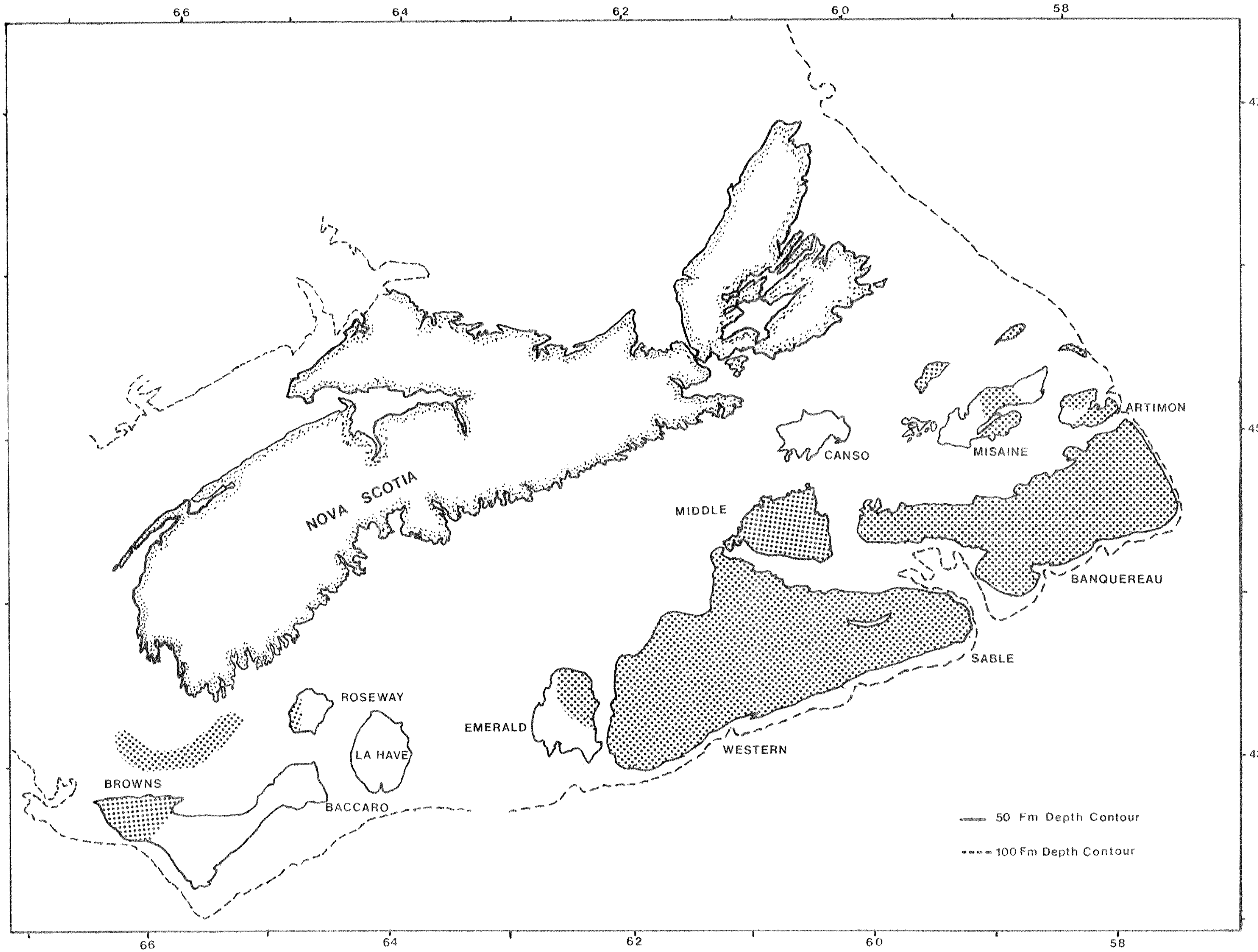


Fig. 4. Offshore areas of the Scotian Shelf surveyed from 1980 to 1982.

operated (Appendix 1). A single-cage hydraulic dredge, similar to that shown in Figure 5, with overall dimensions measuring 202 x 114 x 41 cm and a cutting blade width of 89 cm was used. The dredge was fitted with a 2.5 cm square steel mesh liner. Water was supplied to the dredge from an end suction centrifugal pump delivering 2,700 liters per minute at 45 psi through a 10.2 cm diameter hose. The pump was powered by a six-cylinder, 165 hp Chevrolet marine engine.

During 1981-1982, the 14.6 m vessel MV Sigma T from the Bedford Institute of Oceanography was used. The dredge operated during these surveys (Fig. 5) was slightly smaller than the one used in 1980, with overall dimensions of 198 x 101 x 38 cm and a cutting blade of 71.1 cm. Again, a 2.5 cm liner was used. An end suction centrifugal pump powered by a four-cylinder, 154 cubic inch, 30 hp Wisconsin engine provided water to the dredge. The dredge was operated from a 7.6 cm diameter steel boom and connected to a 2 t capacity double-drum hydraulic winch.

The major difference between the hydraulic dredge used for this survey and non-hydraulic or dry dredges, such as the conventional scallop dredge, is that in the hydraulic dredge, water is pumped at high pressure from the boat to the dredge. The water is forced through several small nozzles creating a jet spray. It is the high-pressure water jets which do the digging, with the dredge blade acting as a scoop collecting the exposed clams. During the inshore survey in which ocean quahaugs were virtually the only clam caught, a blade depth setting of 12.7 cm below the dredge cage worked well. Few quahaugs were damaged by the blade (indicating that it was set deep enough to cut under the quahaugs) and few quahaugs remained in the dredge track when examined by divers. Previous studies (Medcof and Caddy 1971) have shown this type of dredge system to be 95% efficient on sand bottom.

Offshore Surveys

The offshore surveys on the Scotian Shelf in 1980, 1981, and 1982 were conducted using the U.S. National Marine Fisheries Service research vessel Delaware II.[5]

The vessel was fitted with a hydraulic dredge similar in basic configuration to the type used in the commercial surf clam fishery in the U.S. The dredge differs from commercial gear in that a submersible pump is dredge mounted and powered electrically from the vessel (Crossen and Smolowitz 1980). The dredge measured 5.2 m in length with a 152.4 cm wide cutting blade and used 7,571 liters of water per minute. Cutting depth of the blade was set at 20.3 cm, and the dredge was fitted with a 5.1 cm square mesh steel liner.

---

[5]The use of this vessel and its specialized research dredge was made possible under a cooperative research agreement between Canada and the U.S. to investigate the biology and distribution of ocean quahaugs in northwest Atlantic waters.

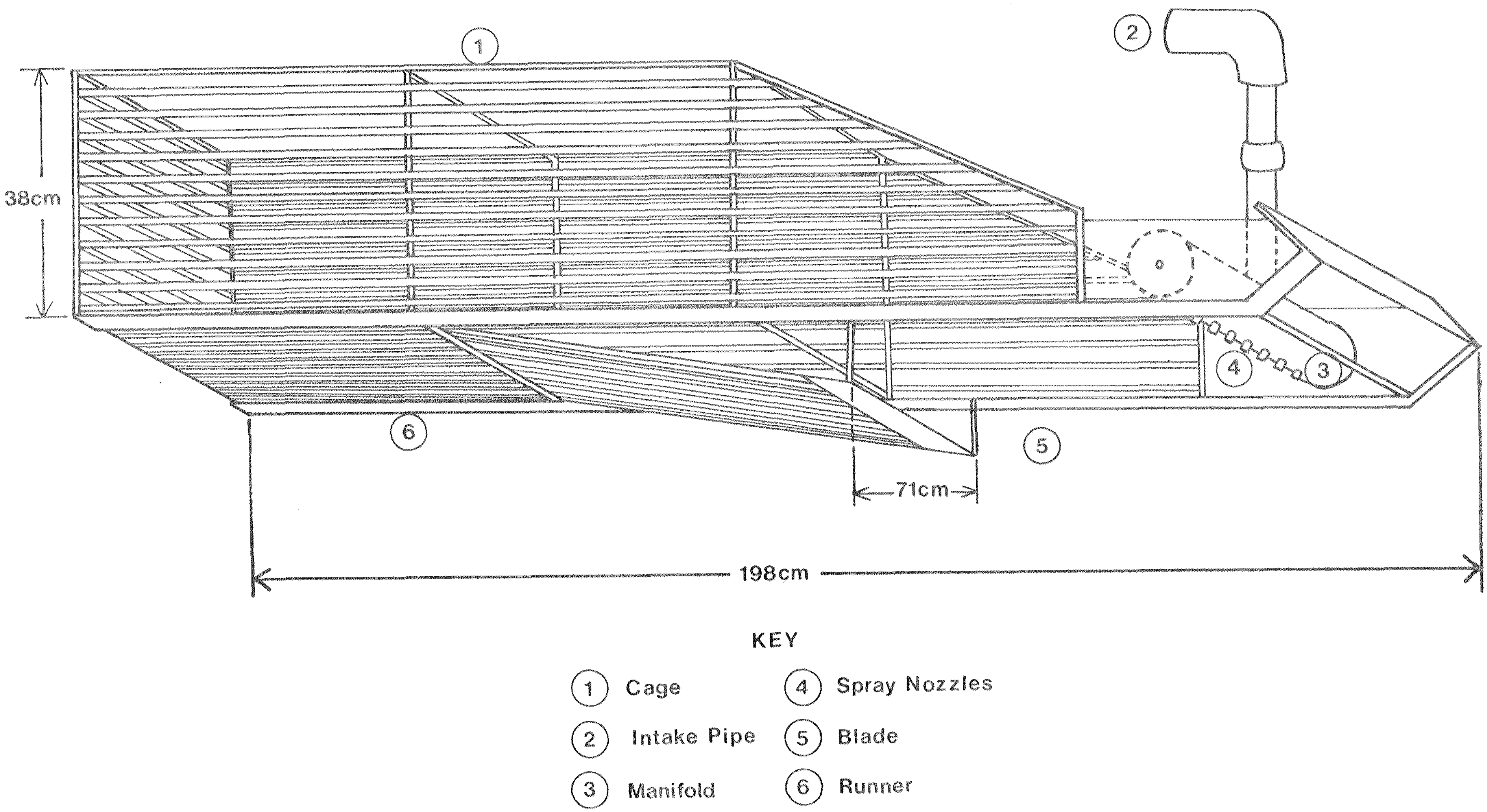


Fig. 5. Configuration and general dimensions of the hydraulic dredge used in the 1981 and 1982 inshore surveys.

METHODS

Inshore sampling areas were first identified on charts as to their suitability for dredging based on the smoothness of the bottom topography. Once areas were identified, transects were established along Loran C lines with stations spaced, where possible, at intervals of 1.1 km (the intersection of the x and y Loran lines). The distance between transects was 0.9 km. Due to the shape of the embayments and the actual bottom type encountered, this spacing was not always possible but served rather as a guide to provide a uniform distribution of sampling effort. Tows were made from 4 m to 41 m, the approximate maximum operating depth of the equipment.

Areas to be surveyed offshore were first identified according to the availability of suitable clam bottom sediment types as determined from surficial geology charts of the Scotian Shelf (Drapeau and King 1972; King 1970; MacLean and King 1971; MacLean et al. 1977).

To avoid undue stress on the dredge and equipment, 85 m was set as the approximate maximum working depth. Where areas were large enough for a systematic grid survey, sampling stations were established along Loran C lines (approx. 5 nm or 9.3 km apart) at intervals of 5 nm to 10 nm (9.3 km to 18.5 km).

Tows were made as deep as 92 m, although 99% were less than 85 m and 80% were less than 70 m. No tow was shallower than 29 m.

In both inshore and offshore surveys, the catch was sorted and the major clam species were separated and the volume of each was measured in bushels. For each clam species, up to one bushel was measured for length-frequency and the remaining clams counted. Length was taken as the maximum shell measurement in the anterior-posterior plane. Total weight per bushel was also obtained at selected stations on each bank, and samples were preserved for studies on reproduction and growth. The remaining catch was sorted with all other animals being identified and counted. The type of trash material (shell fragments, substrate) was noted and the volume recorded.

In order to determine quahaug densities in terms of numbers per square meter (no./m^2) and kilograms per square meter (kg/m^2), it was necessary to measure the tow distance. For the inshore surveys, a weighted line marked in 5 m intervals was payed out during the tow. By knowing the water depth and the rope length the distance covered by the dredge could be calculated using the following formula:

$$C = \sqrt{b^2 - a^2}$$

c = tow length
a = water depth
b = rope length

Divers were used on a limited number of tows to measure the dredge track and confirm that the computed tow lengths approximated the actual distance towed.

This method proved unreliable in areas with strong tidal currents (areas between St. Mary's Bay and Cape Sable Island).

In the offshore surveys, the highly precise navigational gear (doppler) found on the R/V Delaware II allowed tow distances to be easily measured by differences in the ship's doppler reading at the start and end of each tow.

In order to convert densities in no./m^2 to kg/m^2, the mean quahaug or surf clam length at each station was first determined and fitted to a length-weight regression. The resulting mean weight was then multiplied by the total number of animals in the catch to give an estimate of the total catch weight. The total catch weight was then divided by the number of square meters covered in each tow to give density in kg/m^2. Biomass estimates for individual areas and banks were calculated from the mean densities for each area multiplied by the total area. Biomass estimates for inshore locations are only for those areas outlined in Figures 7 to 17 and are not estimates of the entire bay or inlet shown. These outlined areas represent known towable bottom and were drawn based on information from actual tows, van Veen sediment analysis, and the vessel's echo sounder. For the offshore banks, total area represents only those depths less than 91.4 m. The boundaries for areas outlined in Figures 18, 19, and 23 as having the most significant concentrations were drawn so as to include only those stations with densities greater than 0.1 kg/m^2.

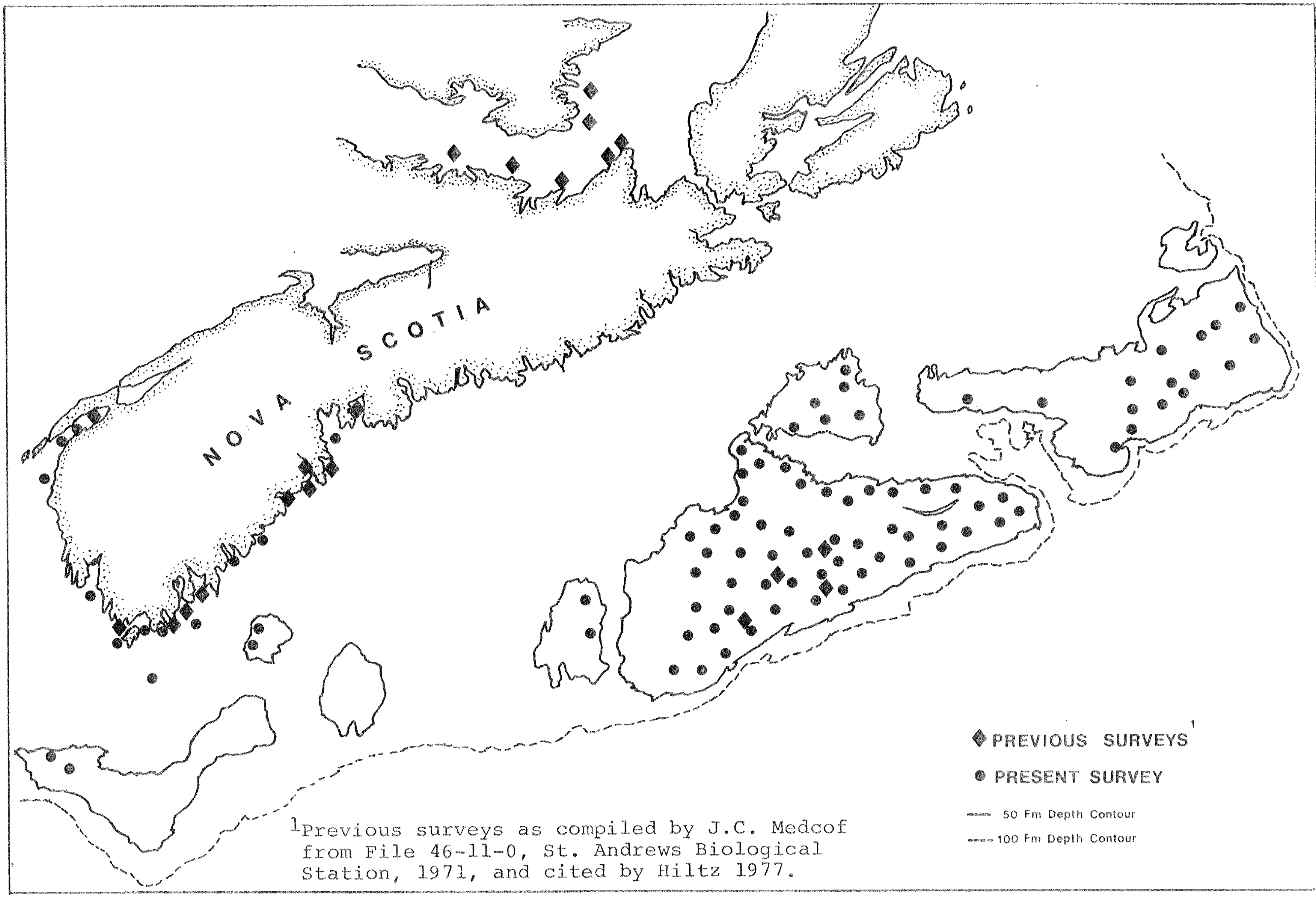
All areas were calculated using a Hewlett Parkard 9825 digitizer with a planometer program package.

Estimates for Maximum Sustainable Yield (MSY) were calculated using the formula $C_{max} = X M B_o$ (Gulland 1971) where M = instantaneous rate of natural mortality; B_o is the virgin stock size; and X, the proportion of B_o which may be harvested annually, is 0.5.

RESULTS

INSHORE AREAS

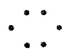
During the inshore survey, sampling was conducted at 321 stations. From this total, 30 were omitted from further analysis due to gear failure and another 52 comprised only van Veen sediment grab samples. Of the remaining 239 stations, 172 (72%) contained A. islandica. This was the only subtidal bivalve species of commercial importance encountered in significant numbers (Fig. 6). Densities varied greatly from area to area (Fig. 7 to 17), primarily in relation to differences in bottom sediment type. The greatest densities were usually found in sediment composed mainly of medium to very fine grain sand in the 0.25 mm to 0.149 mm size range. The maximum density recorded was 108 animals/m^2 (6.5 kg/m^2) close



[1]Previous surveys as compiled by J.C. Medcof from File 46-11-0, St. Andrews Biological Station, 1971, and cited by Hiltz 1977.

Fig. 6. Distribution of ocean quahaugs (*A. islandica*) on the Scotian Shelf and inshore areas of Nova Scotia as determined from the 1980 to 1982 and earlier surveys. Area of distribution shown approximates areal extent of surveys.

Key to Symbols in Figures 7-17

T	Trial stations (Liverpool Bay only)
GF	Gear failure
VV	van Veen sediment sample only
	Outline of area of towable bottom
R	Rocky bottom; identified by sounding, van Veen sampling, and/or dredging.
M	Mud bottom; stations where the dredge was rendered ineffective by filling completely with mud.
P	Indicates *Arctica* present but no density value available.

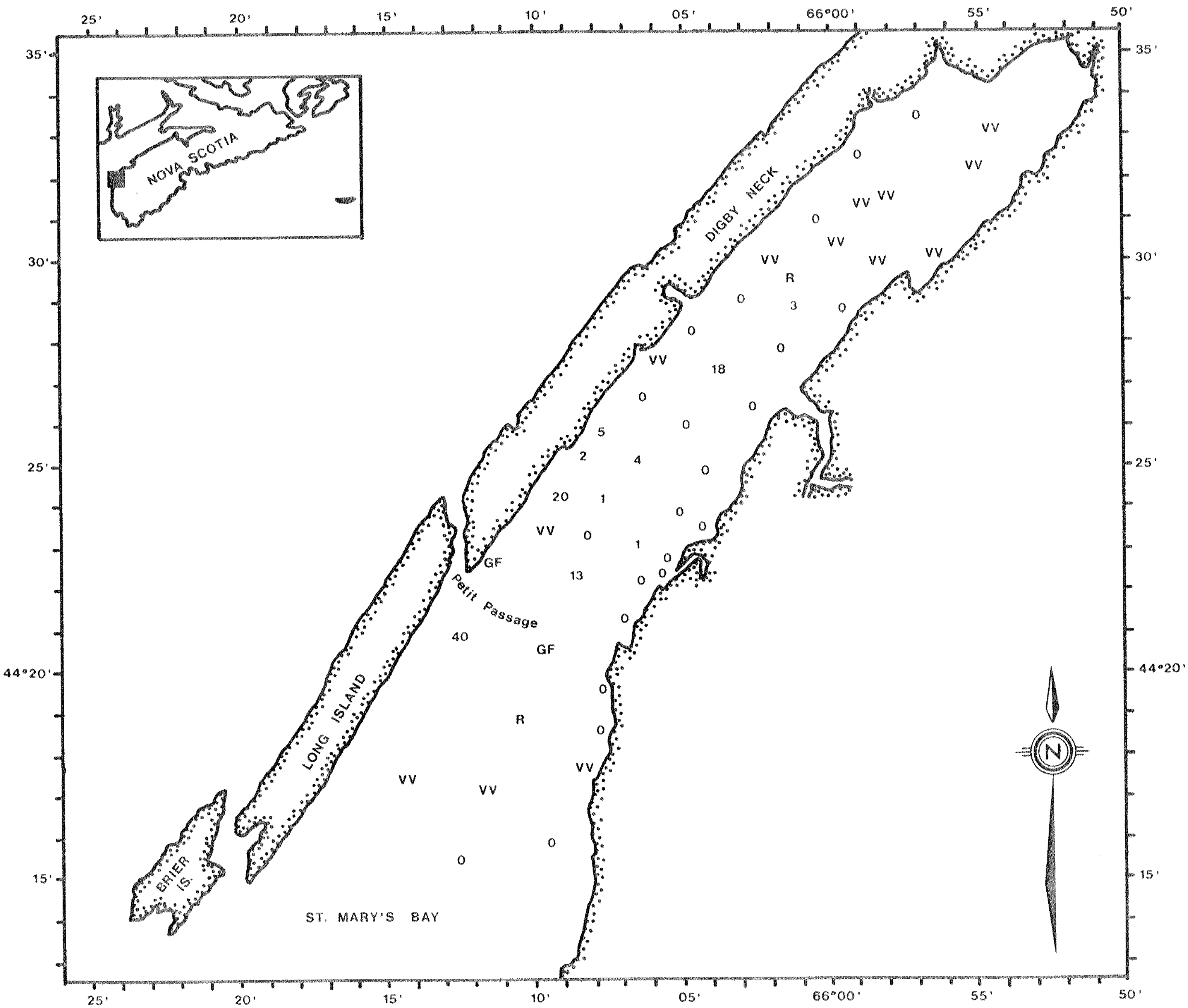


Fig. 7. St. Mary's Bay survey area showing station locations and number of quahaugs/ 3 min. tow. Due to strong tidal influence on dredge operation and distance estimation, no density or biomass estimates have been developed.

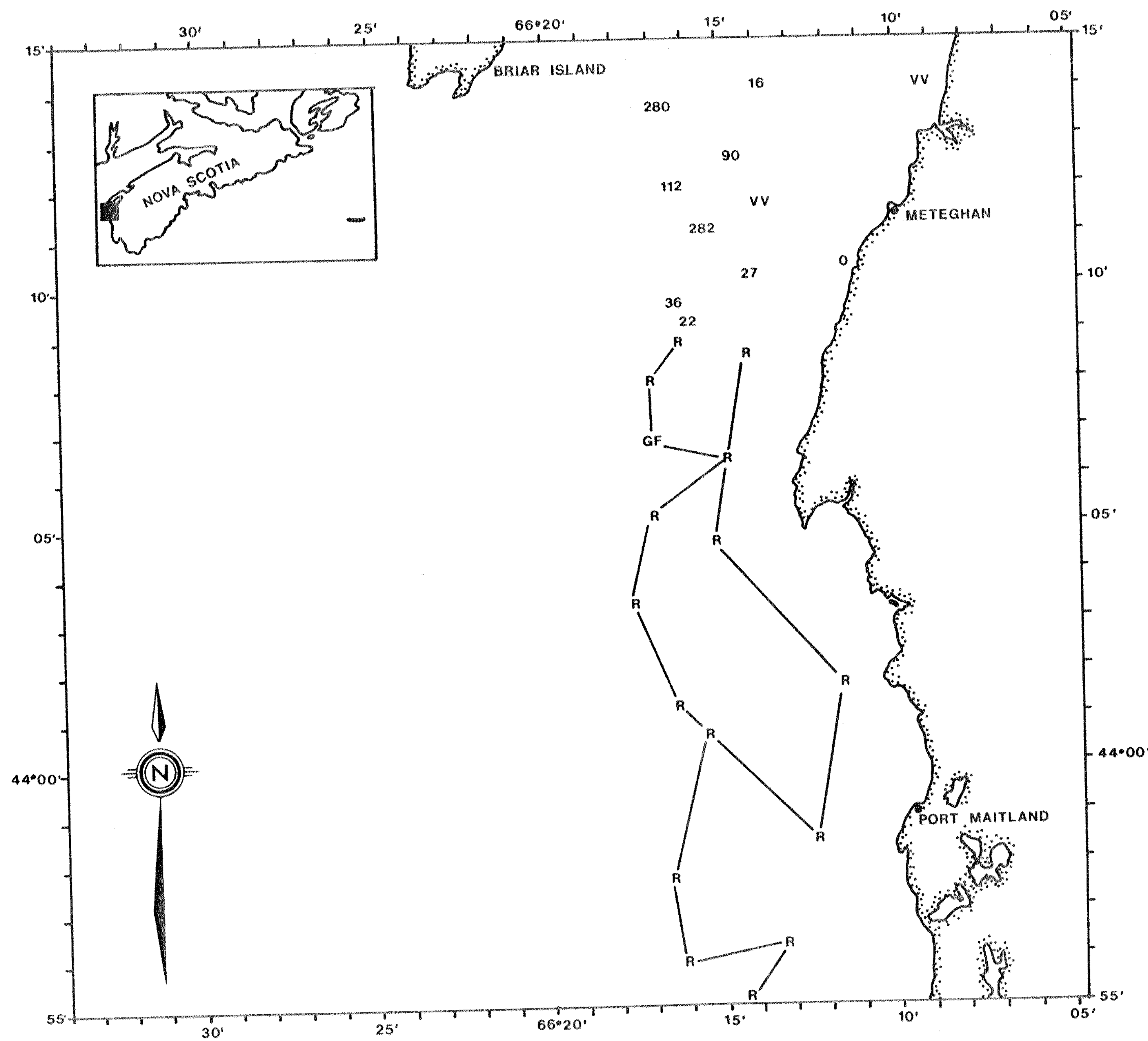


Fig. 8. Areas surveyed between Meteghan and Port Maitland showing vessel cruise track, station locations, and number of quahaugs/3 min. tow. Due to strong tidal influence on dredge operation and distance estimation, no density or biomass estimates have been developed.

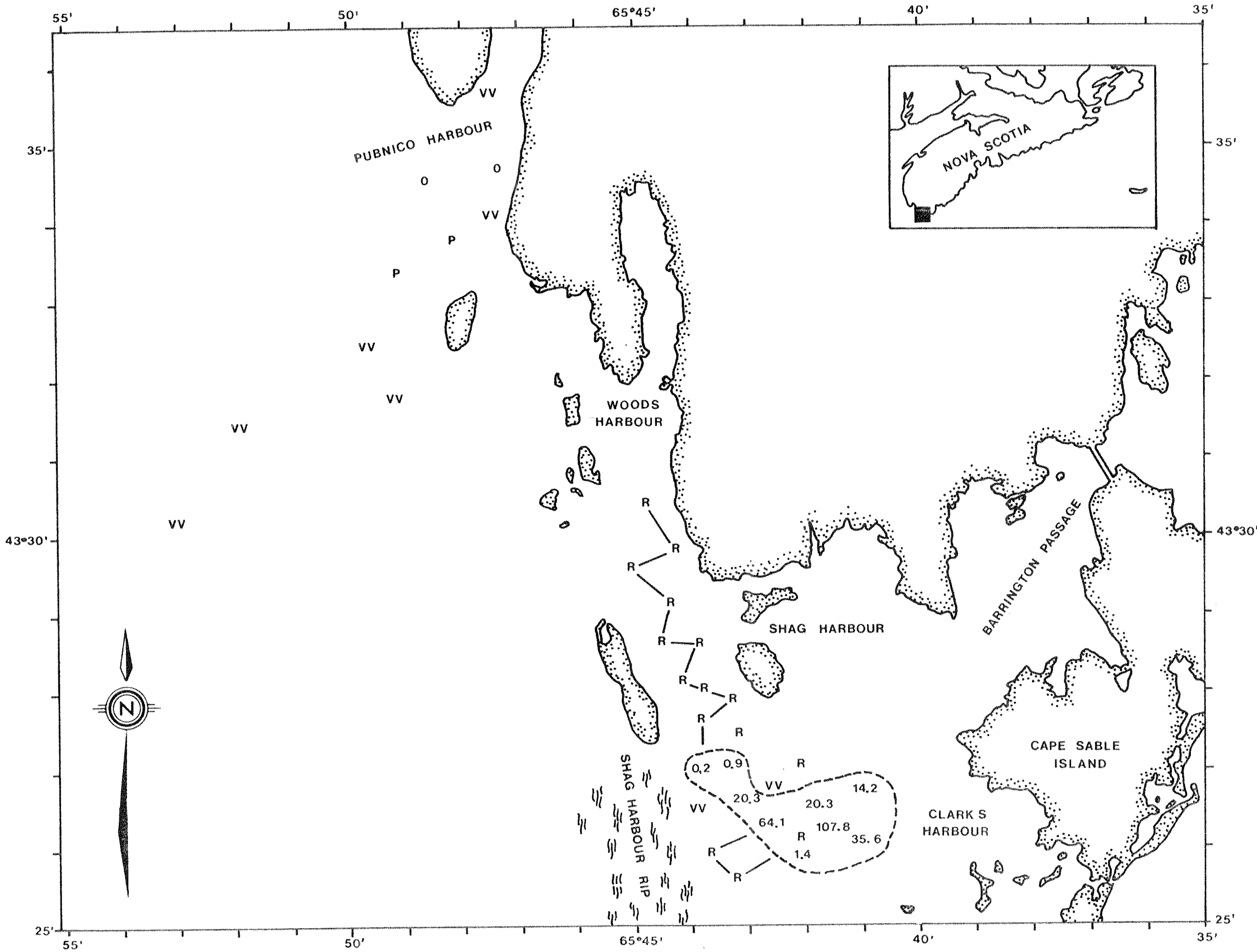


Fig. 10. Areas surveyed off Cape Sable Island showing vessel cruise track, station locations, and quahaug densities (no./m^2).

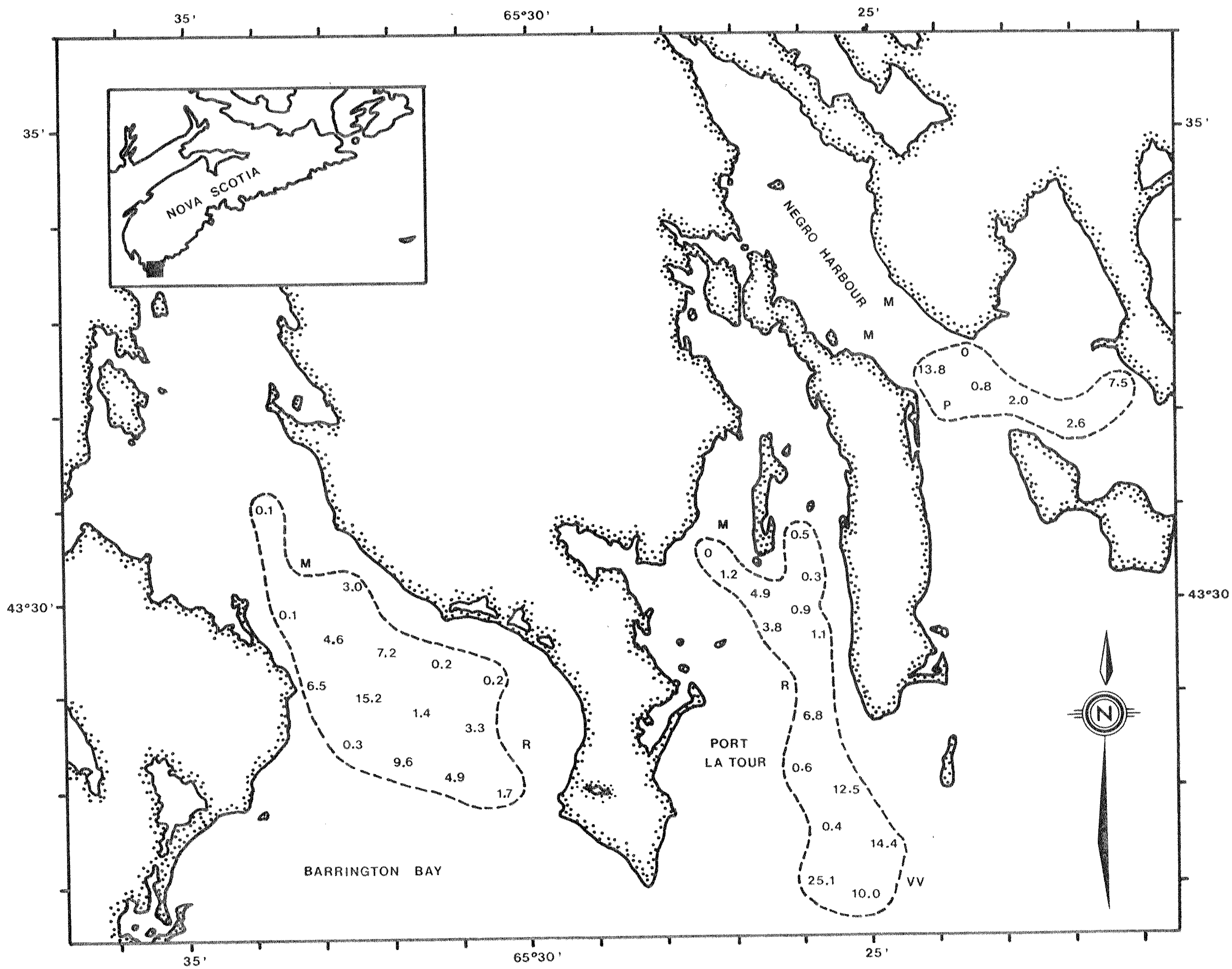


Fig. 11. Areas surveyed in Barrington Bay, Port La Tour, and Negro Harbour showing station locations and quahaug densities (no./m^2).

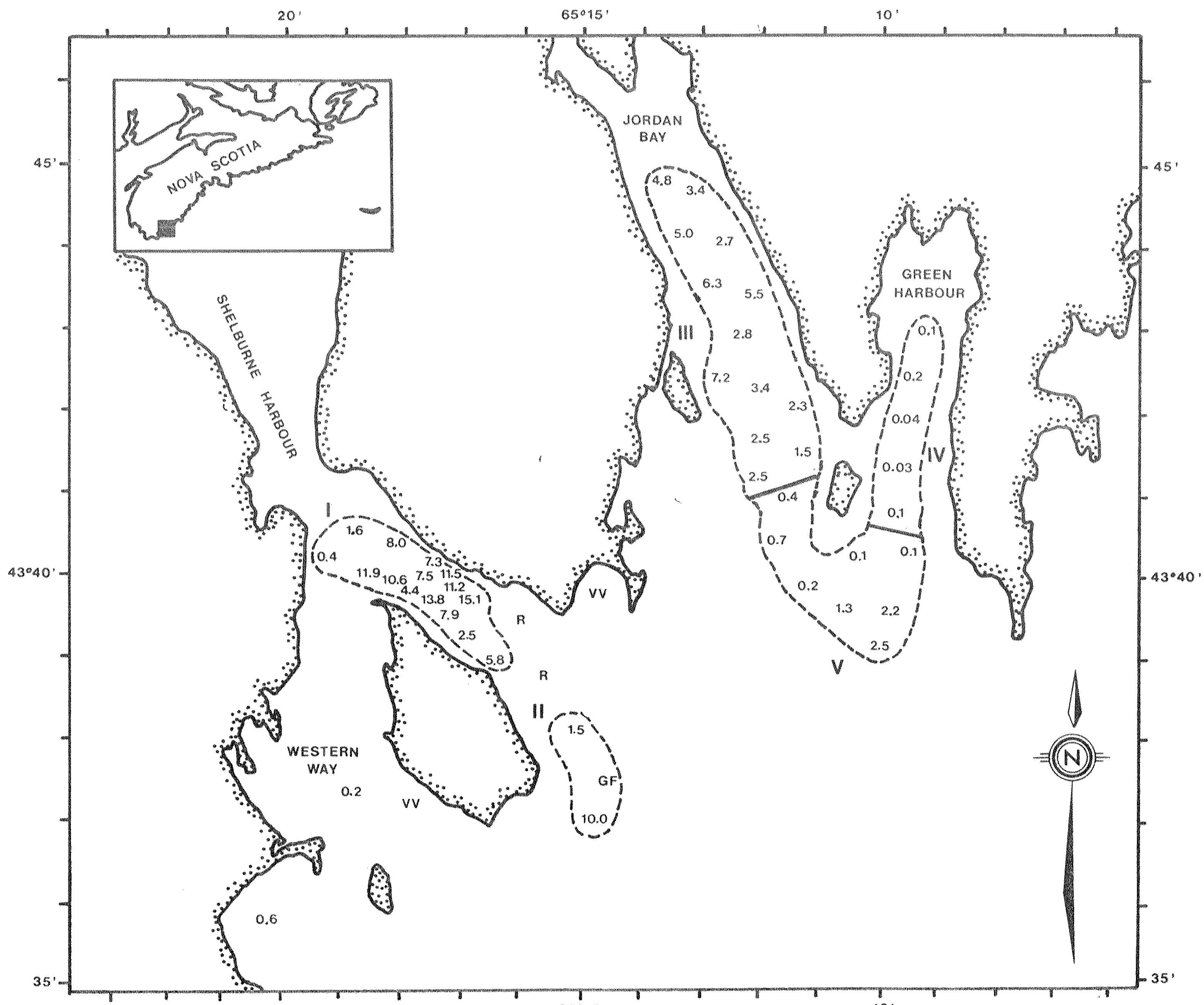


Fig. 12. Areas surveyed in Shelburne Harbour (I and II), Jordan Bay (III), Green Harbour (IV), and Jordan/Green outer area (V) showing station locations and quahaug densities (no./m^2).

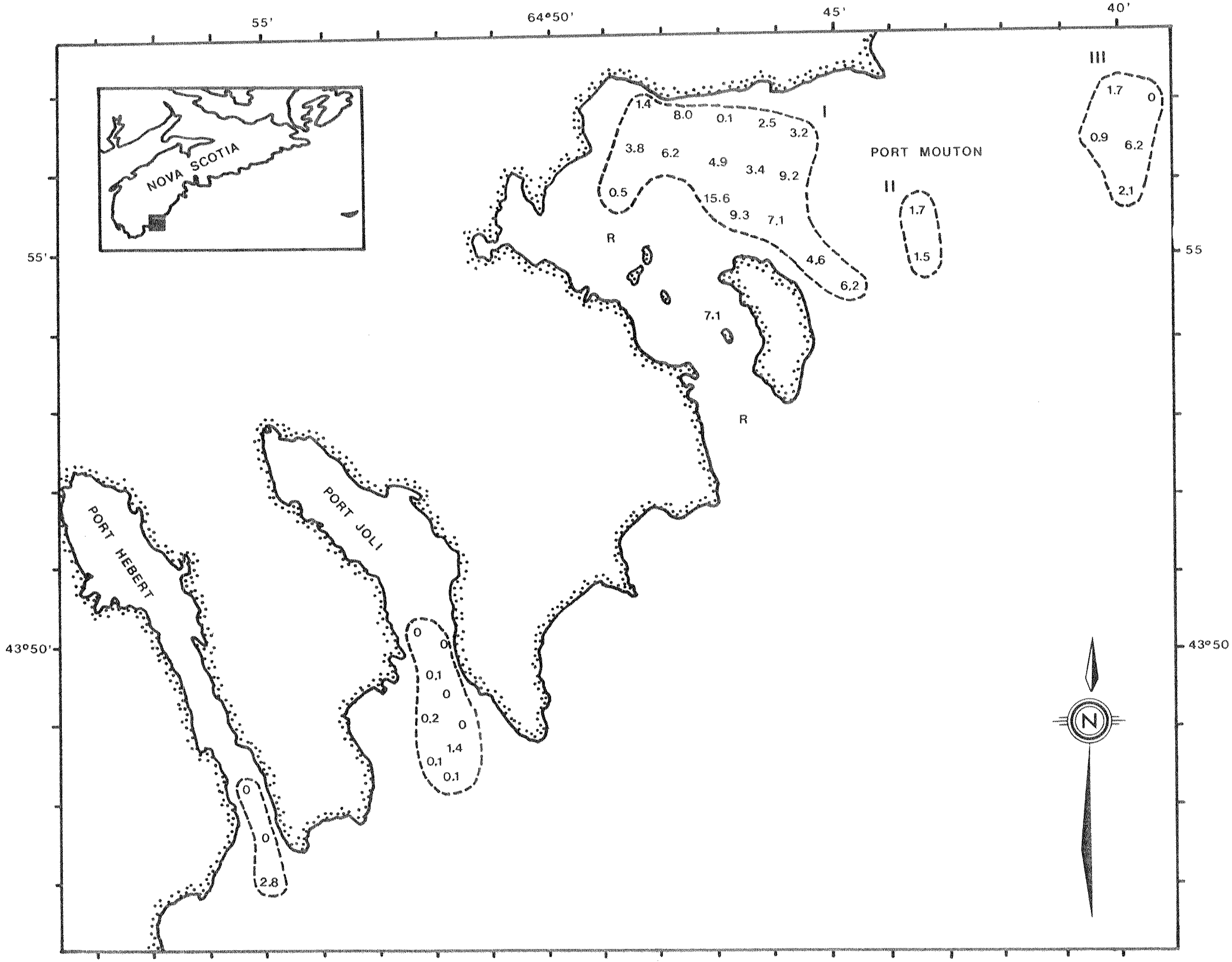


Fig. 13. Areas surveyed in Port Hebert, Port Joli, and Port Mouton showing station locations and quahaug densities (no./m^2).

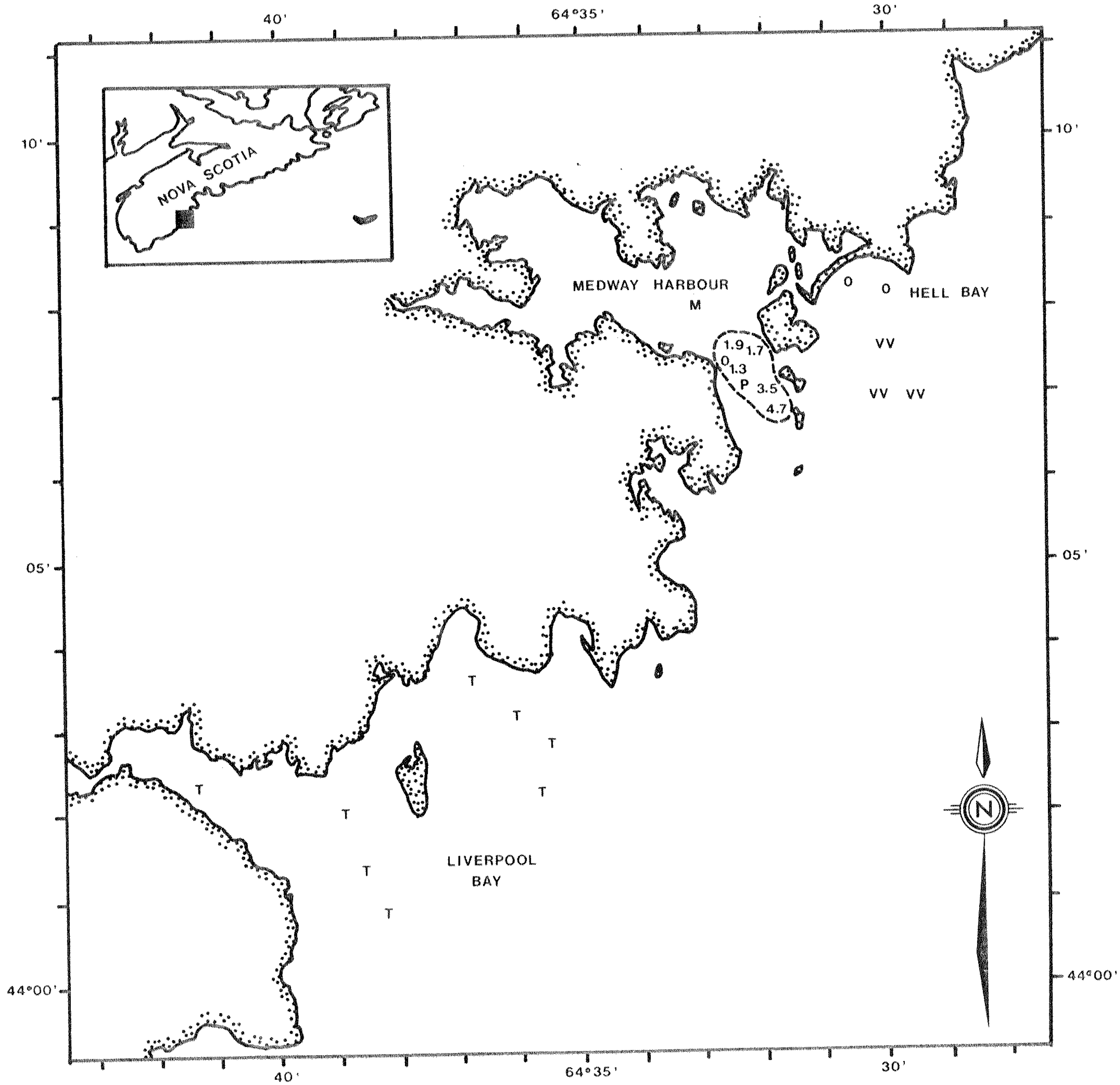


Fig. 14. Areas surveyed in Medway Harbour showing station locations and quahaug densities (no./m^2).

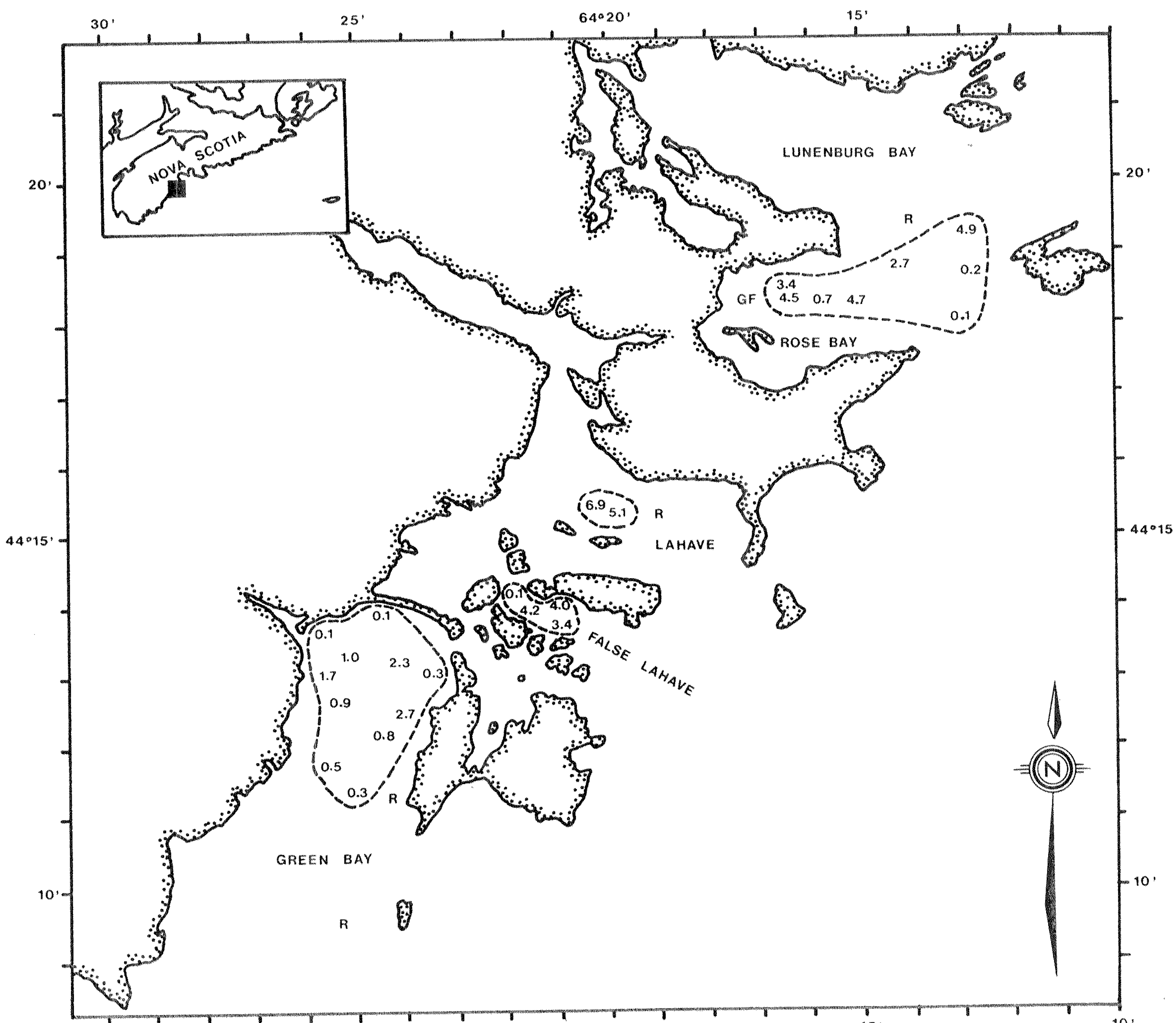


Fig. 15. Areas surveyed in Green Bay, False LaHave, LaHave, and Lunenburg Bay showing station locations and quahaug densities (no./m^2).

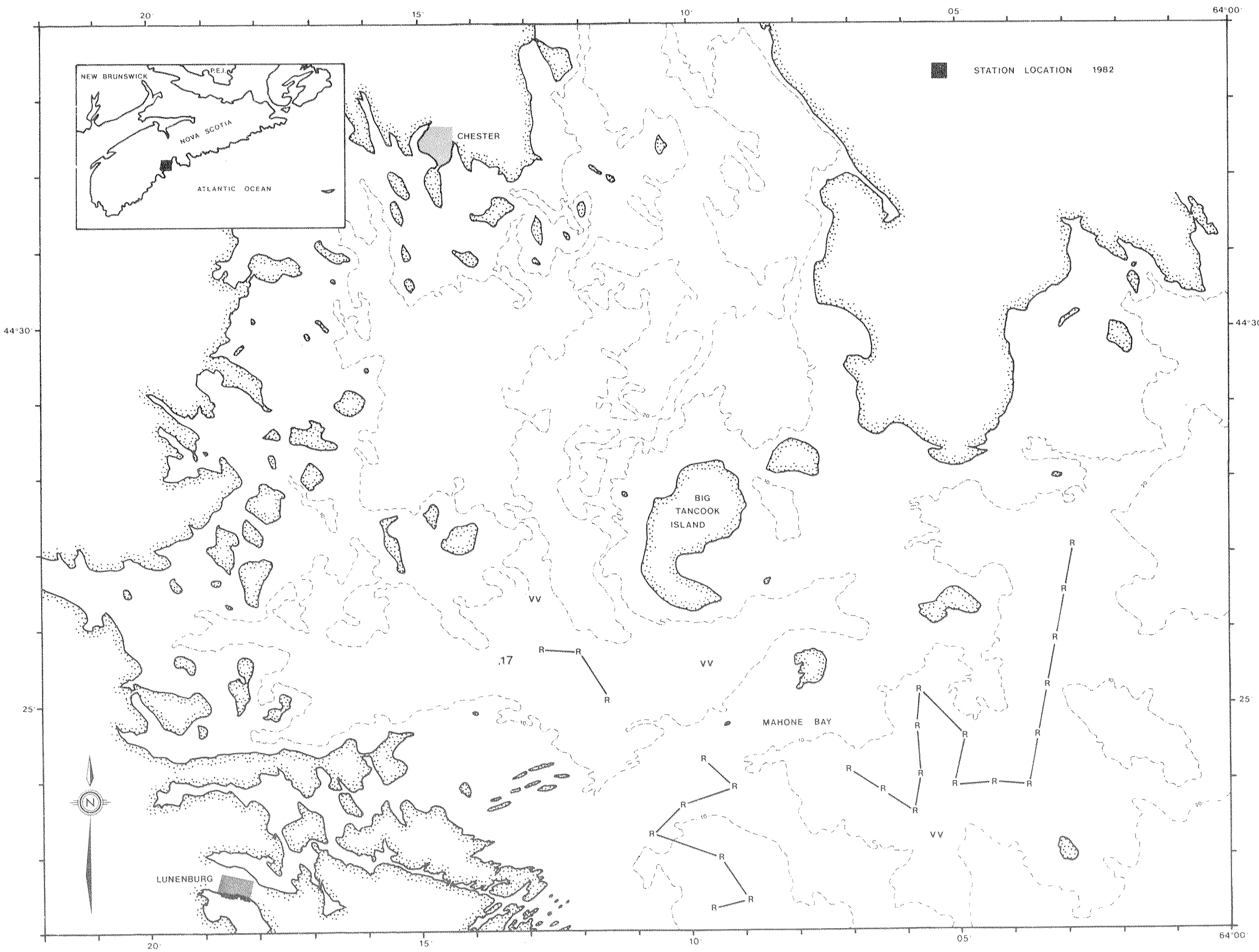


Fig. 16. Areas surveyed in Mahone Bay showing station locations and vessel cruise track.

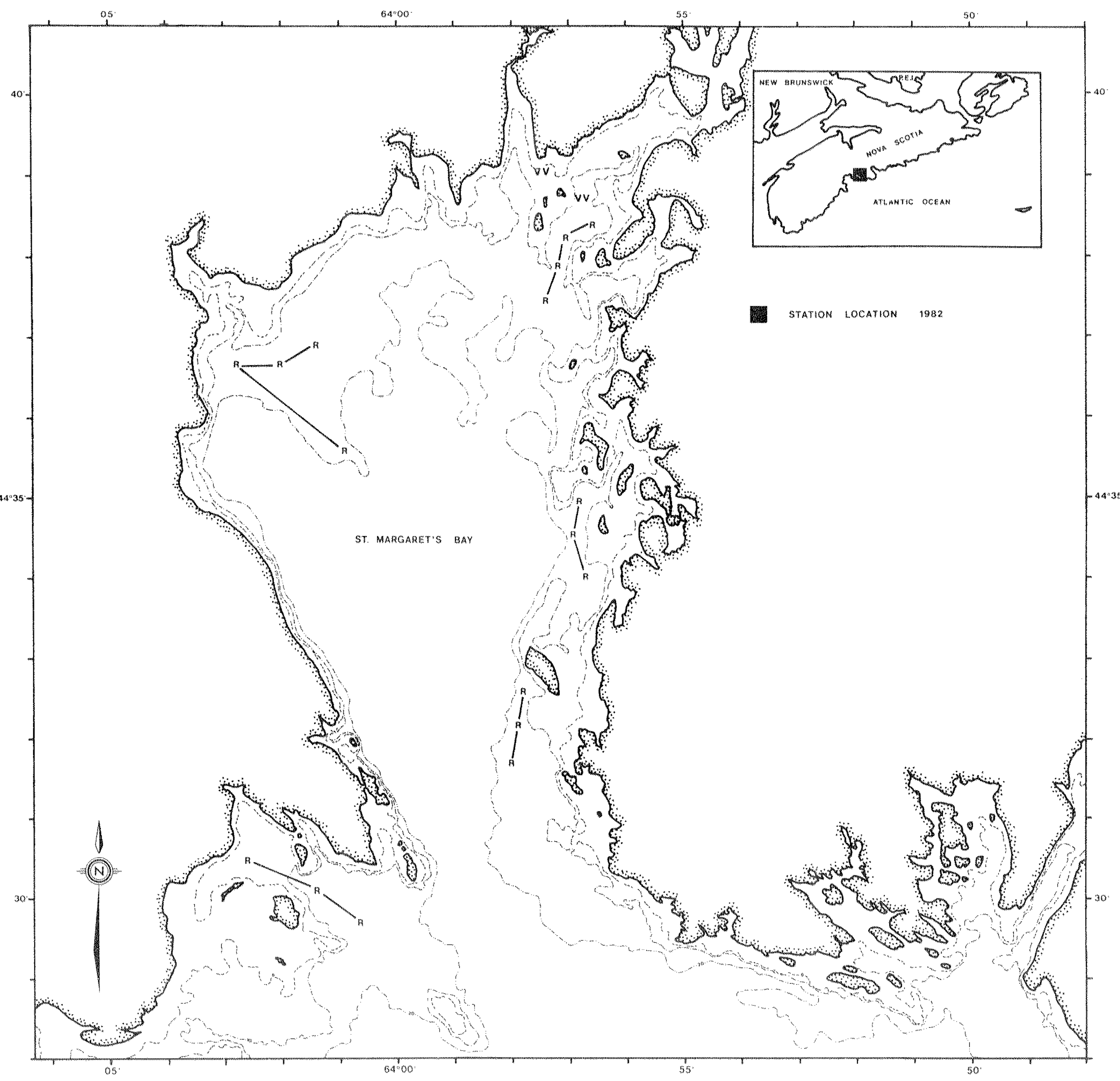


Fig. 17. Areas surveyed in St. Margaret's Bay showing station locations and vessel cruise track.

to Cape Sable; however, the maximum density for other areas was in the range of 15-25 animals/m^2 (1.0-1.5 kg/m^2). The range and mean densities and minimum biomass for the beds outlined in each area are summarized in Table 1. Estimates of MSY (Table 3) based on the total inshore biomass of 56,833 t and assuming natural mortality rates of 0.015 to 0.05, are 426 t to 1,421 t (322 t to 1,767 t when 90% confidence limits are applied to the biomass estimates).

OFFSHORE BANKS

A total of 250 dredge stations were completed during the offshore survey from 1980 to 1982 (Fig. 4). No dredge stations were completed on Misaine, Baccaro, or LaHave Banks because of rough bottom topography.

Two bivalve species of potential commercial importance were found on the Scotian Shelf - the ocean quahaug and the Stimpson's surf clam. Quahaugs were the more ubiquitous, being found on all major banks sampled and throughout all depths surveyed (Fig. 6). This species was found at 46% of all stations and was most abundant on Sable Island Bank where it was present in 90% of stations sampled (Fig. 18). It was also present in large numbers on Western Bank (Fig. 19). The maximum quahaug density at a sampling station was 8.3 animals/m^2 (0.408 kg/m^2) on Sable Island Bank.

Minimum biomass estimates for each offshore bank are presented in Table 2 and MSY estimates for _A. islandica_ and _S. polynyma_ are given in Tables 3 and 4 respectively.

The largest concentrations of _A. islandica_ were found on Western and Sable Island Banks, and six areas of high density identified. For these six areas, having a total mean biomass of 438,908 t, a MSY of 3,292 t to 10,973 t was calculated for a range of natural mortality between 0.015 to 0.050. When 90% confidence intervals[6] are applied to the biomass estimates, a MSY of 2,803 t to 12,601 t is derived for these six areas. Biomass for the remaining area of Western-Sable Island Banks was 307,580 t; however, a mean density of only 0.026 kg/m^2 likely precludes any commercial potential for this area. Therefore, although MSY's have been calculated for this remaining area, they are of little significance in consideration of potential commercial harvest.

---

[6]For _A. islandica_, the range of MSY (C_{max}) within the 90% confidence limits may be calculated for any of the areas by adding the confidence interval to the mean biomass estimates to obtain maximum and minimum biomass values and then applying the model C_{max} 0.5 M B_o using the minimum natural mortality value (0.015) with the minimum biomass estimate and the maximum natural mortalities (0.05) with the maximum biomass estimate. For _S. polynyma_, the respective values are 0.15 and 0.30.

Table 1. A. islandica densities and the estimated minimum biomass for inshore areas (Fig. 7 to 17) surveyed.

Area	Mean no./m²	Range no./m²		Mean kg/m²	Range kg/m²		Area km²	Biomass t	±90% C.I.
St. Mary's Bay[a]	–	–	–	–	–	–	–	–	–
Lobster Bay	0.16	0	0.96	0.015	0	0.096	48	720	816
Pubnico Hbr.[b]	–	–	–	–	–	–	–	–	–
Clark's Hbr.	29.42	0.22	107.77	1.803	0.02	6.57	7	12,621	949
Barrington Bay	3.89	0.06	15.21	0.388	0.005	1.41	13	5,044	2,451
Port LaTour	5.49	0	25.07	0.341	0	1.04	11	3,751	1,657
Negro Hbr.	4.45	0	13.80	0.592	0	1.80	4	2,368	2,260
Shelburne I	7.96	0.40	15.06	0.811	0.04	1.54	6	4,866	1,289
Shelburne II	5.75	1.54	9.96	0.220	0.10	0.34	2	440	1,515
Jordan Bay	3.65	0.03	7.21	0.396	0.003	0.96	11	4,356	1,295
Green Hbr.	0.08	0.03	0.20	0.007	0.001	0.02	4	28	31
Jordan/Green	0.94	0.06	2.51	0.037	0.001	0.13	9	333	262
Port Hebert	0.94	0	2.82	0.067	0	0.20	1	67	195
Port Joli	0.20	0	1.41	0.023	0	0.16	3	69	97
Port Mouton I	5.36	0.10	15.57	0.307	0.004	0.67	12	3,684	1,165
Port Mouton II	1.57	1.47	1.66	0.095	0.08	0.11	1	95	95
Port Mouton III	2.17	0	6.20	0.050	0	0.11	3	150	116
Medway Hbr.	2.17	0	4.68	0.178	0	0.05	2	356	253
Green Bay	0.97	0.11	2.70	0.114	0.01	0.29	13	1,482	641
False LaHave	2.93	0.11	4.23	0.243	0.001	0.35	2	486	382
LaHave	5.95	5.05	6.85	0.585	0.47	0.70	1	585	726
Rose/Lunenburg	2.62	0.05	4.88	0.122	0.001	0.30	9	1,098	676
Mahone Bay									
St. Margaret's Bay	soundings made, but due to rough bottom no tows were made								
Total	4.33	0	107.77	0.353	0	1.80	161	56,833	42,980-70,686[c]

[a]No density or biomass estimates developed due to strong tidal influence on dredge operation and distance estimation. See Figure 7 and 8 for no./tow.
[b]Quahaugs present in densities too low to warrant biomass estimates.
[c]Range of biomass estimate within 90% confidence limits.

Table 2. Mean densities and minimum biomass with 90% confidence limits for *A. islandica* and *S. polynyma* surf clams in offshore areas.

Bank	Area km²	Species	Density kg/m²	Biomass t	±90% C.I.
Emerald	457	*Arctica*	0.006	2,742	6,041
Middle	2,304	*Arctica*	0.017	39,168	33,812
	2,304	*Spisula*	0.011	25,344	20,810
Western and Sable Island					
Area 1	109	*Arctica*	0.208	22,672	31,314
Area 2	654	*Arctica*	0.162	105,948	58,340
Area 3	381	*Arctica*	0.103	39,243	54,926
Area 4	191	*Arctica*	0.256	48,896	26,902
Area 5	968	*Arctica*	0.171	165,528	23,217
Area 6	149	*Arctica*	0.200	29,800	36,245
Total (1-6)	2,452	*Arctica*	0.179	438,908[a]	65,123
Remaining Area	11,830	*Arctica*	0.026	307,580	67,846
Total	14,282	*Arctica*	0.062	885,484[a]	172,207
	14,282	*Spisula*	0.003	42,846	13,644
Banquereau	9,182	*Arctica*	0.003	27,546	28,070
Area 1	1,589	*Spisula*	0.201	319,389	106,011
Area 2	709	*Spisula*	0.186	131,874	136,889
Total (1 & 2)	2,298	*Spisula*	0.197	452,706[a]	133,241
Remaining Area	6,884	*Spisula*	0.021	144,564	37,500
Total	9,182	*Spisula*	0.068	624,376[a]	200,170
Browns[b]	680	*Arctica*	0.001	680	1,772
	680	*Spisula*	0.027	18,360	34,426
Roseway[b]	100	*Arctica*	0.004	400	646
		Spisula	0.041	4,100	7,144

[a]Total biomass estimates for Western/Sable Areas 1 to 6 combined and Banquereau Areas 1 to 2 combined do not equate with total from individual area biomass calculations due to weighing of estimates based on no. of samples/area.

[b]Partial area only, see Fig. (4) for actual area surveyed.

Table 3. Estimates of maximum sustainable yield (MSY) in metric tons (t) for *A. islandica* at various rates of natural mortality (M) as derived from Gulland's (1971) model $C_{max} = X M B_o$. The model assumes that maximum surplus production occurs when the virgin stock is reduced to 50% of the original level (X = 0.5).

Bank	Area km^2	Biomass t	MSY (t) Mortality 0.015	0.020	0.025	0.035	0.043	0.050
Emerald	457	2,742	21	27	34	48	59	69
Middle	2,304	39,168	294	392	490	685	842	979
Western-Sable Island								
Area 1	109	22,672	170	227	283	397	487	567
2	654	105,948	795	1,059	1,324	1,854	2,278	2,649
3	381	39,243	294	392	491	687	844	981
4	191	48,896	367	489	611	856	1,051	1,222
5	968	165,528	1,241	1,655	2,069	2,897	3,559	4,138
6	149	29,800	224	298	373	582	641	745
Total (1-6)	2,452	438,908	3,292	4,389	5,486	7,681	9,437	10,973
Remaining Area	11,830	307,580	2,307	3,076	3,845	5,383	6,613	7,690
Total	14,282	885,484	6,641	8,855	11,069	15,496	19,038	22,137
Banquereau	9,182	27,546	207	275	344	482	592	689
Browns	680	680	5	7	9	12	15	17
Roseway	100	400	3	4	5	7	9	10
Inshore	161	56,833	426	568	710	995	1,222	1,421

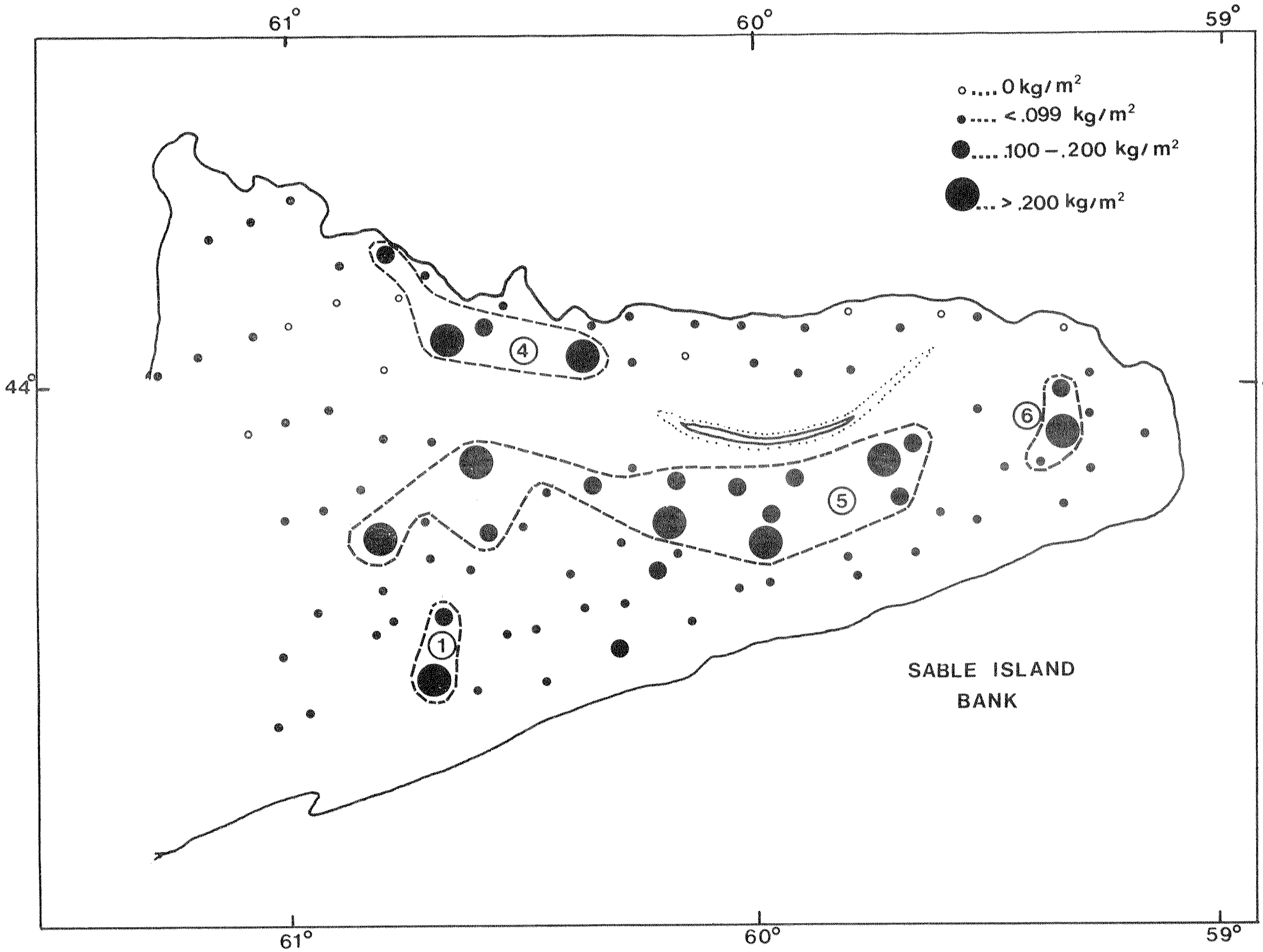


Fig. 18. Location of stations on Sable Island Bank in 1981-1982 showing densities (kg/m^2) of A. islandica and boundaries of areas having the most significant concentrations.

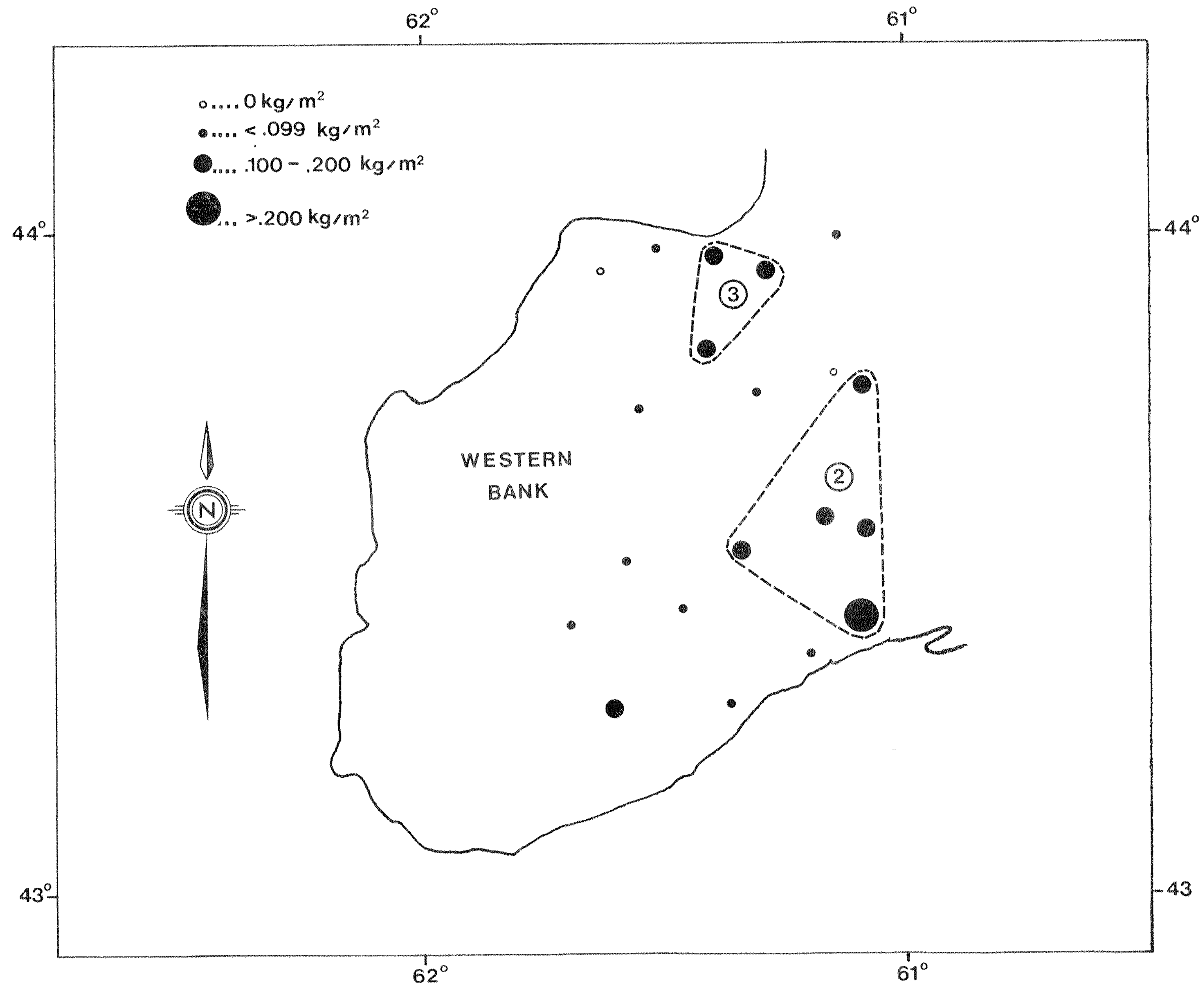


Fig. 19. Location of stations on Western Bank surveyed in 1981 showing densities (kg/m^2) of A. islandica and boundaries of areas having the most significant concentrations.

The Stimpson's surf clam was found on all banks but Emerald (Fig. 20). It occurred at 42% of all stations and was most abundant on Banquereau Bank where it was found at 92% of the stations. Generally, surf clams outranked ocean quahaugs as the major bivalve species in areas north of Sable Island Bank; however, the largest single catch in terms of numbers ($4.7/m^2$) was recorded on Roseway Bank. The largest single catch in terms of weight ($0.564\ kg/m^2$) was on Banquereau Bank. Biomass estimates for surf clams on each bank are given in Table 2. The bank having the greatest apparent potential for this species is Banquereau, particularly in Areas 1 and 2 as outlined in Figure 21. MSY estimates (Table 4) for the total biomass of 452,706 t in Areas 1 and 2, using mortality rates of 0.15-0.30, range from 33,953 t to 67,906 t (23,960 t to 87,892 t when 90% confidence limits are applied to the biomass estimates). The estimated biomass for the remaining area of Banquereau Bank was 144,564 t. However, the mean density of $0.021\ kg/m^2$ for this area would, as in the case of Western and Sable Island Banks, likely preclude any commercial potential.

DISCUSSION

Fogarty (1979) estimated the lower catch limit for a commercially exploited quahaug bed in Rhode Island Sound to be 100 kg per standard tow.[7] For comparison with our results this lower limit was converted to kg/m^2 using the following formula:

$$\text{Lower Catch Limit} = \frac{100\ \text{kg}}{\bar{X}\ \text{tow length} \times \text{dredge width}}$$

where, $\bar{X}$ tow length = 190 m and dredge width = 1.52 m. This gives an estimated lower limit for commercial exploitation of approximately $0.34\ kg/m^2$. Using this as a rough measure of commercial viability, seven of the areas listed in Table 1 had mean densities equal to or greater than $0.34\ kg/m^2$ while an additional four areas contained some stations with densities in excess of $0.34\ kg/m^2$.

Merrill and Ropes (1969) stated that most significant ocean quahaug beds in the U.S. are located between 25 m and 61 m. In our survey, only 19% (33 tows) of all inshore stations were at depths greater than 25 m. On areas of good bottom, densities for these stations were as high as 25 animals/m^2 ($1.8\ kg/m^2$). Stations 25 m or deeper were seldom sampled during the survey due to a generally rougher bottom topography. Once outside the relatively shallow depths and fine sediments associated with most embayments of southwestern N.S., quahaug habitat is less

---

[7] Standard tows were of four minutes duration, with the distance covered measured by differences in Loran C coordinates recorded at the start and end of each tow.

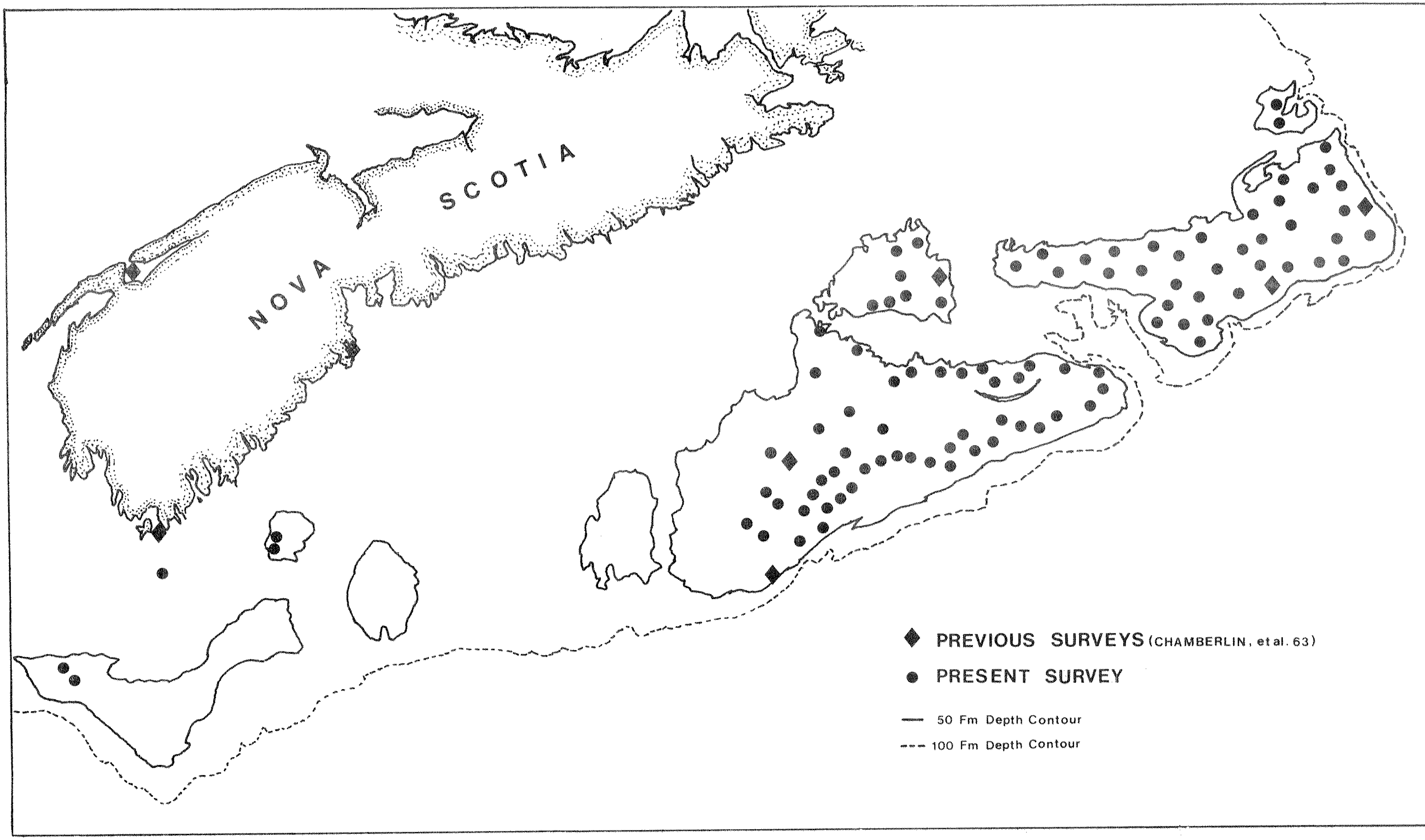


Fig. 20. Distribution of Stimpson's surf clam (S. polynyma) on the Scotian Shelf and inshore areas of Nova Scotia as determined by the 1980-1982 and previous surveys.

Table 4. Estimates of maximum sustainable yield (MSY) in metric tons (t) for *S. polynyma* at various rates of natural mortality (M) as derived from Gulland's (1971) model. $C_{max} = X M B_o$. The model assumes that maximum surplus production occurs when the virgin stock is reduced to 50% of the original level (X = 0.5).

Bank	Area km²	Biomass t	MSY (t) Mortality 0.15	0.20	0.24	0.25	0.30
Middle	2,304	25,344	1,901	2,534	3,041	3,168	3,802
Western-Sable	14,282	42,846	3,213	4,285	5,142	5,356	6,427
Banquereau							
Area 1	1,589	319,389	23,954	31,939	38,327	39,924	47,908
2	709	131,874	9,891	13,187	15,825	16,484	19,781
Total (1 & 2)	2,298	452,706	33,953	45,271	54,325	56,588	67,906
Remaining Area	6,884	144,564	10,842	14,456	17,348	18,071	21,685
Total	9,182	624,376	46,828	62,438	74,925	78,047	93,656
Browns	680	18,360	1,377	1,836	2,203	2,295	2,754
Roseway	100	4,100	308	410	492	513	615

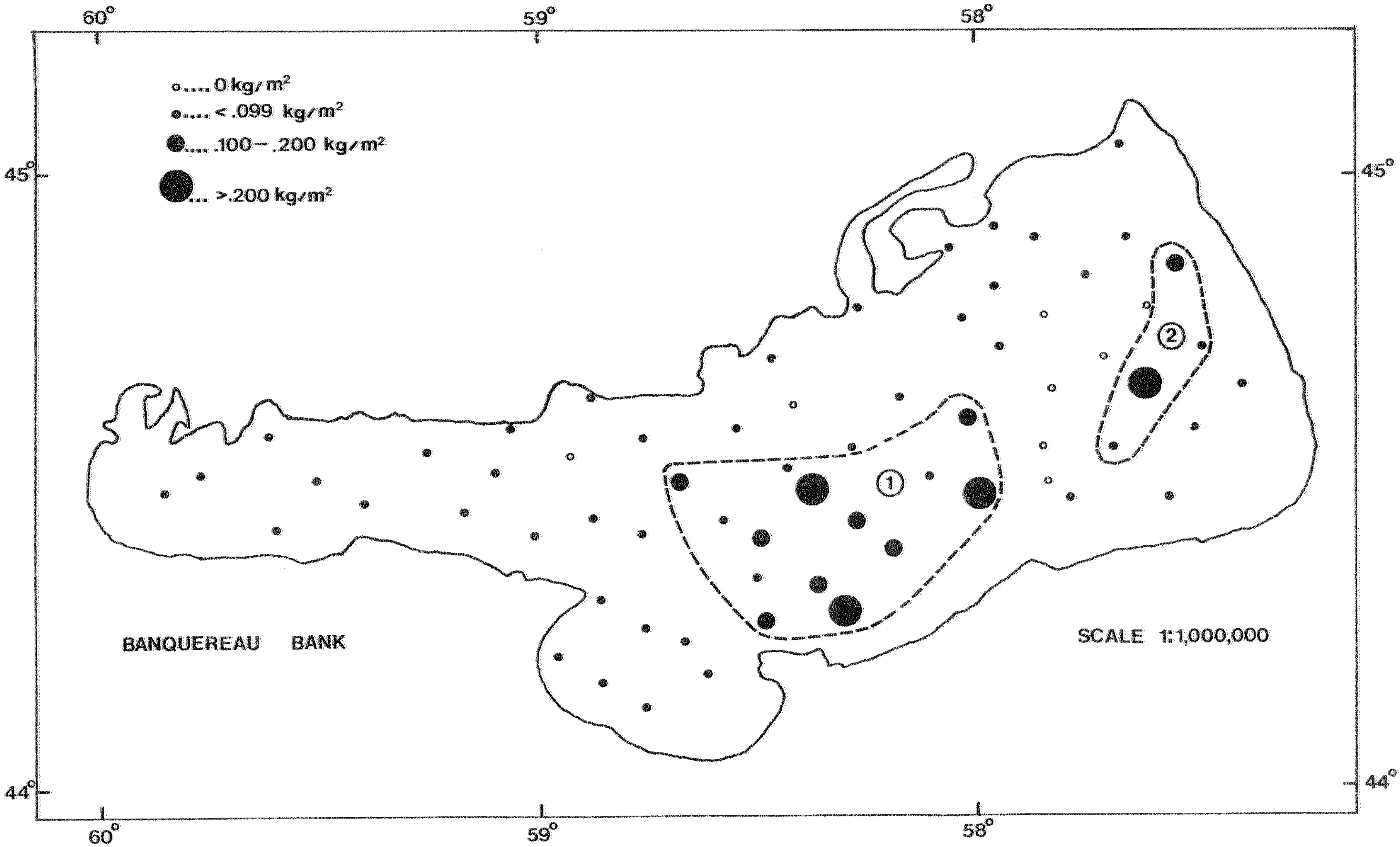


Fig. 21. Location of stations on Banquereau Bank surveyed in 1981 to 1982 showing densities (kg/m^2) of S. polynyma and boundaries of areas having the most significant concentrations.

than ideal, with sediments composed primarily of gravel and rock. The areas (Fig. 7 to 17) for which biomass estimates are given represent a total of only 161 km^2. Although small in area, the inshore location of these beds offers several advantages. They are, for the most part, within a few kilometers of a fishing port (thus reducing vessel steaming time); and, being located in relatively shallow and sheltered harbours, they should be fishable even in moderately inclement weather.

Growth studies on quahaugs from the survey area and from studies in the U.S. indicate that the ocean quahaug is an extremely long-lived (100 years plus) and slow-growing animal (Thompson et al. 1980; Murawski et al. 1980). Serchuk and Murawski (1980) suggest that 6.7% to 13.5% (mortality rates of 0.027 to 0.02 respectively) of the quahaug population off the U.S. Mid-Atlantic Bight live to 100 years. From age analysis of 450 quahaugs and length frequency information from the inshore survey, we estimate the percentage of the population living to 100 years at 1.3% ($M = 0.043$). These estimates of natural mortality are within the range used in developing our estimates of MSY. Although densities of ocean quahaug on the offshore shelf areas were considerably less than densities found inshore, the species was present over large areas. The development of an offshore fishery will be dependent on the overall economics of harvesting quahaugs at the densities found.

Growth and age studies of Stimpson's surf clams from this survey are not yet complete. However, information on the growth of this species is available from studies of populations on the Alaskan coast (Feder et al. 1976; Hughes and Bourne 1981). In both studies, growth rates were determined by counting shell annuli. Feder et al. (1976) indicate that Alaskan clams attained a maximum length of 151 mm at the age of 16. Hughes and Bourne (1981) determined maximum length between 129 mm and 148 mm and a maximum observed age of 25. Using the growth curve developed by Feder et al. (1976) for Alaskan clams and the length frequency data for clams from Banquereau Bank, a natural mortality rate of 0.245 was calculated. This compares favourably with the natural mortality rate of 0.19 for _S. polynyma_ in Alaskan waters (Hughes and Bourne 1981) and those for _S. solidissima_ of 0.200 (Caddy and Billard 1976) and 0.300 (Bernier and Poirier 1979) in Canadian waters and 0.260 in the Mid-Atlantic Bight area of the U.S. (Chang et al. 1976).

The dramatic increase in ocean quahaug landings in the U.S. resulted in part from a need to maintain clam meat production following the previously mentioned decline in surf clam stocks in 1976. If surf clams regain their former abundance, the demand for ocean quahaugs may again decrease unless the overall market for clam products increases. A possible substitute for the U.S. surf clam, _S. solidissima_, may be the Stimpson's surf clam, _S. polynyma_.

Stimpson's surf clams have several advantages over ocean quahaugs in terms of potential for commercial development. They have a much faster growth rate, resulting in a considerably higher MSY for a particular level of biomass. In addition, they should demand a higher price per pound, similar to that paid for S. solidissima in the U.S. market. Current (1982) U.S. prices for quahaugs and the surf clam, S. solidissima, are approximately $0.61/kg and $1.12/kg of meat respectively. Again, the development of a fishery for S. polynyma will depend on the economics of harvesting these clams at the densities available.

ACKNOWLEDGEMENTS

The authors wish to thank Mr. T. Amaratunga of the Invertebrates and Marine Plants Division for his input to the planning and early development of the project, Mr. T. Azarovitz of the U.S. National Marine Fisheries Service for his cooperation and assistance in carrying out the offshore surveys, and the staff of Bio-Atlantech who participated in the field sampling and data analysis.

REFERENCES

Bernier, L. and L. Poirier. 1979. Evaluation sommaire du stocks des mactres de l'Atlantique, Spisula solidissima Dillwyn, des Iles-de-la-Madeleine, M.I.C., Dir. gén. Peches marit., Dir. Rech., Can. Inf. 92, 42 p.

Bousfield, E.L. 1960. Canadian Atlantic sea shells. Nat. Mus. of Can., Ottawa, Ont., 72 p.

Caddy, J.F., R.A. Chandler, and D.G. Wilder. 1974. Biology and commercial potential of several underexploited molluscs and crustaceans on the Atlantic coast of Canada. A paper presented to the Federal-Provincial Fisheries Committee Meeting on Utilization of Atlantic Resources, Montreal, P.Q. Feb. 5-7, 1974, 30 p.

Caddy, J.F. and A.R. Billard. 1976. A first estimate of production of the bar clam Spisula solidissima. Can. Fish. Mar. Serv. Res. Dev. Tech. Rep. 648, 13 p.

Chamberlin, J.L. and F. Stearns. 1963. A geographic study of the clam Spisula polynyma (Stimpson). Serial Atlas of the Marine Environment, Folio 3. Am. Geo. Soc., 12 p.

Chandler, R.A. 1983. Ocean quahaug survey, south shore of Nova Scotia, 1971 to 1972. Can. Mar. Rep. Fish. Aquat. Sci. (in press).

Chang, S., J.W. Ropes, and A.S. Merrill. 1976. An evaluation of the surf clam population in the Middle Atlantic Bight. Int. Counc. Explor. Sea. Special Meeting on Population Assessment of Shellfish Stocks. U.S. Dept. Comm., Nat. Mar. Fish. Serv., Sandy Hook Lab. Ref. No. 76-1, 43 p.

Crossen, J.M. and R.J. Smolowitz. 1980. Power system requirements of an electro-hydraulic clam dredge. Mar. Tech., Proc. 16th Ann. Conf. Mar. Tech. Soc.: 433-438.

Drapeau, G. and L.H. King. 1972. Surficial geology of the Yarmouth Brown's Bank map-area. Information Canada, Ottawa, Ont., 6 p.

Feder, H.M., A.J. Paul, and J. Paul. 1976. Growth and size-weight relationships of the pinkneck clam Spisula polynyma in Hartney Bay, Prince William Sound, Alaska. Proc. Nat. Shell. Assoc. 66: 21-25.

Fogarty, M.J. 1979. Assessment of the ocean quahaug Arctica islandica resource in Rhode Island Sound and south of Martha's Vineyard, Ma. Final Report, Fish. Dev. Serv. Br., Nat. Mar. Fish. Serv., Gloucester, Ma., Contract No. 03-7-043-35119, 55 p.

Fogarty, M.J. 1981. Distribution and relative abundance of the ocean quahaug Arctica islandica in Rhode Island Sound and off Martha's Vineyard, Ma., J. Shell. Res. (1): 33-39.

Gulland, J.A. 1971. The fish resources of the ocean. Fishing News (Books) Ltd., Survey, England, 255 p.

Hiltz, L.L. 1977. The ocean clam (Arctica islandica). A literature review. Fish. Mar. Serv., Env. Can. Tech. Rep. 720, 177 p.

Hughes, S.E., R.W. Nelson, and R. Nelson. 1977. Initial assessments of the distribution, abundance, and quality of subtidal clams in the S.E. Bering Sea. Co-op. Indust.-Fed.-State of Alaska Study. U.S. Dept. Comm., Nat. Mar. Fish. Serv., Seattle Lab., 58 p.

King, L.H. 1970. Surficial geology of the Halifax-Sable Island map-area. Mar. Sci. Br., Dept. Energy, Mines, and Resources, Ottawa, Ont., 16 p.

Loesch, J.G. and J.W. Ropes. 1977. Assessment of surf clam stocks in nearshore waters along the Delmarva Peninsula and in the fishery south of Cape Henry. Proc. Nat. Shell. Assoc. 67: 29-34.

MacLean B. and L.H. King. 1971. Surficial geology of the Banquereau and Misaine Banks map-area. Information Canada, Ottawa, Ont., 19 p.

MacLean, B., G.B. Fader, and L.H. King. 1977. Surficial geology of Canso Bank and adjacent areas. Mar. Sci. Pap. 20 (also Geo. Surv. Can. Pap. 76-15), 11 p.

MacPhail, J.S. and J.C. Medcof. 1959. Ocean quahaug explorations. Trade News. Can. Dept. Fish. 11(12): 3-6.

Medcof, J.C. and J.S. MacPhail. 1955. Survey of bar clam resources of the Maritime Provinces. Bull. Fish. Res. Board Can. 102, 6 p.

Medcof, J.C. 1957. Search for ocean quahaugs in Port Medway, Nova Scotia. Fish. Res. Board Can. Orig. MS, St. Andrew's Biol. Stn. 1002, 7 p.

Medcof, J.C. and J.F. Caddy. 1971. Underwater observations on the performance of clam dredges of three types. Paper prepared for Gear and Behaviour Committee, Int. Counc. Explor. Sea, CM 1971/B:10, 5 p.

Mendelsohn, J.M., P.S. Parker, E.D. McRae. F.S. King, and A.H. Joyce. 1970. The ocean quahaug, a bountiful clam. Food Prod. Dev. 4(7), 3 p.

Merrill, A.S. and J.W. Ropes. 1969. The general distribution of the surf clam and ocean quahaug. Proc. Nat. Shell. Assoc. 59: 40-45.

Murawski, S.A., J.W. Ropes, and F.M. Serchuk. 1980. Growth studies of the ocean quahaug Arctica islandica. Int. Counc. Explor. Sea. CM 1980/K:38, 24 p.

Parker, P.S. 1965. Clam survey Ocean City, Maryland, to Cape Charles, Virginia. U.S. Fish. Wildl. Serv., Comm. Fish. Rev. 27(5): 56-64.

Parker, P.S. 1966. Ocean clam survey off U.S. middle Atlantic coast - 1963. U.S. Fish. Wildl. Serv., Comm. Fish Rev. 28(3): 1-9.

Parker, P.S. and E.D. McRae, Jr. 1970. The ocean quahaug, Arctica islandica, resource of the Northeast Atlantic. U.S. Dept. Comm., Nat. Mar. Fish. Serv., Fish. Indust. Res. 6(4): 185-195.

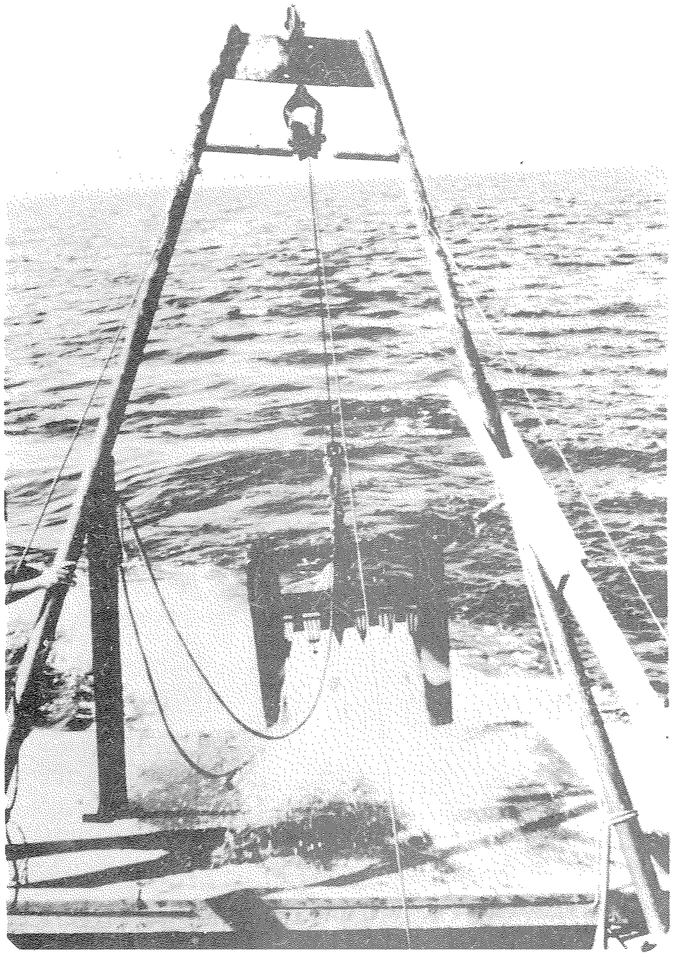
Ropes, J.W. 1980. Biological and fisheries data on the Atlantic surf clam Spisula solidissma (Dillwyn). U.S. Dept. Comm., Nat. Mar. Fish. Serv., Woods Hole Lab. Tech. Serv. Rept. 24, 88 p.

Ropes, J.W. 1982. The Atlantic coast surf clam fishery, 1965-1974. Mar. Fish. Rev. 44(8), 14 p.

Serchuk, F.M. and S.A. Murawski. 1980. Evaluation and status of ocean quahaug, _Arctica islandica_ (Linnaeus), populations off the middle Atlantic coast of the United States. U.S. Dept. Comm., Nat. Mar. Fish. Serv., Woods Hole Lab. Ref. No. 80-32, 7 p.

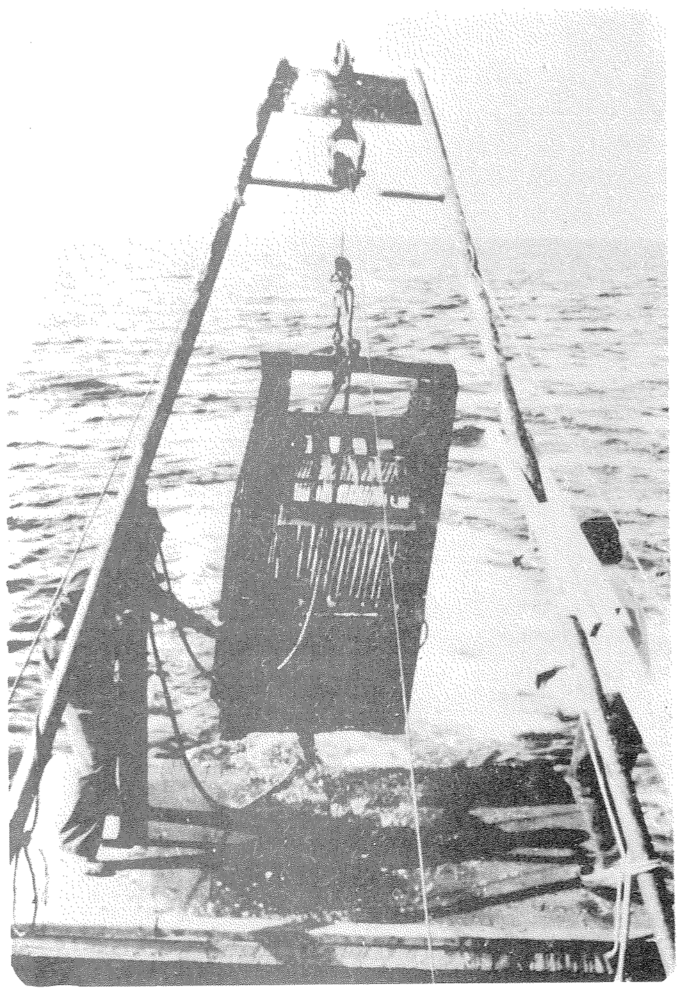
Thompson, I., D.S. Jones, and D. Dreibelbis. 1980. Annual internal growth banding and life history of the ocean quahaug _Arctica islandica_ (Mollusca:Bivalvia). Mar. Biol. 57: 25-34.

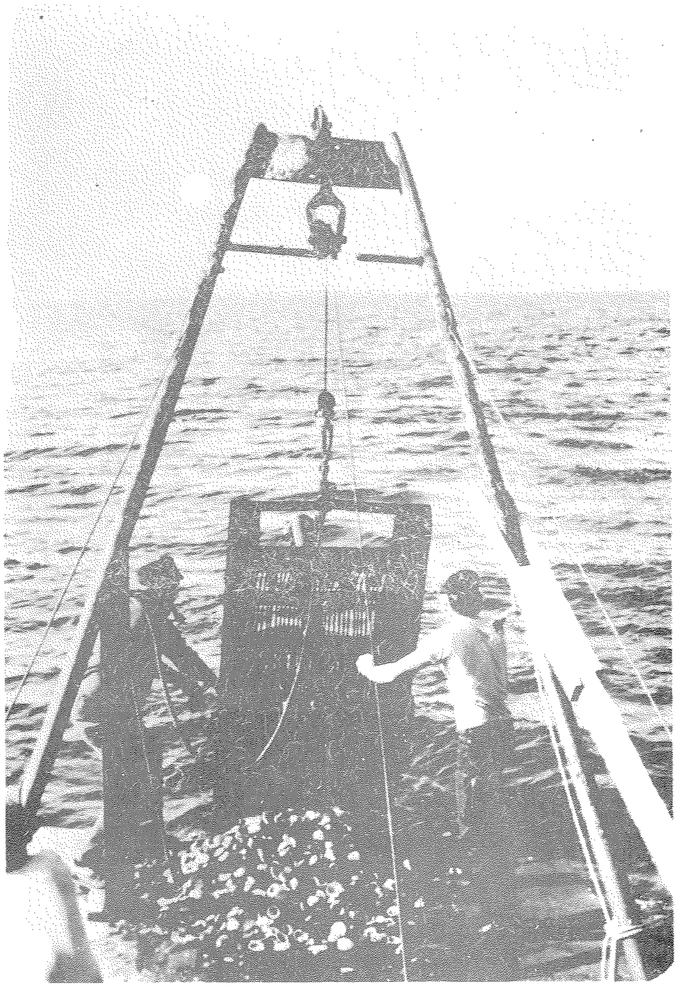
APPENDIX I



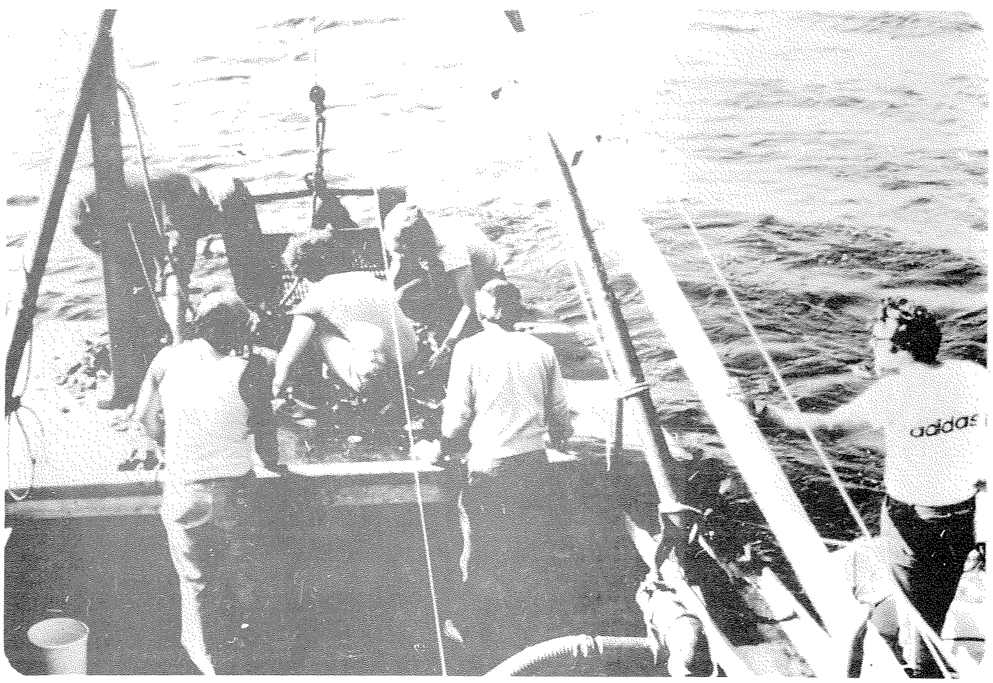
1. The dredge being hoisted onto the deck following completion of towing.

2. The dredge in dumping position.





3. The contents of the dredge being dumped onto the sorting platform.



4. Sorting of the dredge contents.