Scientific Excellence • Resource Protection & Conservation • Benefits for Canadians
Excellence scientifique • Protection et conservation des ressources • Bénéfices aux Canadiens

RANKING HARBOURS IN THE MARITIME PROVINCES OF CANADA FOR POTENTIAL TO CONTAMINATE AMERICAN LOBSTER *(Homarus americanus)* WITH POLYCYCLIC AROMATIC HYDROCARBONS

Nicholas J. Prouse

Physical and Chemical Sciences Branch
Scotia-Fundy Region
Department of Fisheries and Oceans
P.O. Box 550
Dartmouth, Nova Scotia
Canada B3J 2S7

1994

Canadian Technical Report of
Fisheries and Aquatic Sciences
1960

Fisheries and Oceans Pêches et Océans

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

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

Numbers 1–456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457–714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715–924 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. 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, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annual des publications scientifiques et techniques du Ministère.

Les numéros 1 à 456 de cette série ont été publiés à titre de rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Technical Report of

Fisheries and Aquatic Sciences 1960

1994

RANKING HARBOURS IN THE MARITIME PROVINCES OF CANADA FOR POTENTIAL TO CONTAMINATE AMERICAN LOBSTER (*Homarus americanus*) WITH POLYCYCLIC AROMATIC HYDROCARBONS

by

Nicholas J. Prouse

Marine Chemistry Division
Physical and Chemical Sciences Branch
Scotia-Fundy Region
Department of Fisheries and Oceans
P.O. Box 550
Halifax, Nova Scotia B3J 2S7
Canada

Cat. No. Fs 97-6/1960E ISSN 0706-6457

Correct citation for this publication:

Prouse, N.J. 1994. Ranking harbours in the Maritime Provinces of Canada for potential to contaminate American lobster (*Homarus americanus*) with polycyclic aromatic hydrocarbons. Can. Tech. Rep. Fish. Aquat. Sci. 1960: v + 50 p.

TABLE OF CONTENTS

ABSTRACT

Prouse, N.J. 1994. Ranking harbours in the Maritime Provinces of Canada for potential to contaminate American lobster (*Homarus americanus*) with polycyclic aromatic hydrocarbons. Can. Tech. Rep. Fish. Aquat. Sci. 1960: v + 50 p.

The size of the lobster fishery within selected harbours in the Maritime Provinces of Canada was determined. Sources of polycyclic aromatic hydrocarbon (PAH) contamination in each harbour were evaluated by assessing point sources, population, industrial and commercial activity, international and domestic ship traffic, and number of commercial fishing vessels. Harbours were ranked based on these with Sydney the highest potential for PAH contamination, followed by Halifax, Saint John, Pictou, Port Hawkesbury (Ship Harbour), Dalhousie, Liverpool, Shelburne, Lunenburg, Clark's Harbour, Blacks Harbour, Pubnico, Lockeport, and Arichat, in order.

Lobster contamination with PAHs is reviewed. Present data on concentrations of PAHs and other contaminants in harbours and their biota, actual areas fished, and potential problems are reviewed for each harbour.

RÉSUMÉ

Prouse, N.J. 1994. Ranking harbours in the Maritime Provinces of Canada for potential to contaminate American lobster (*Homarus americanus*) with polycyclic aromatic hydrocarbons. Can. Tech. Rep. Fish. Aquat. Sci. 1960: v + 50 p.

On a déterminé l'ampleur des pêcheries de homard dans certains ports des provinces Maritimes du Canada. On a aussi cherché à cerner les sources de contamination par les hydrocarbures aromatiques polycycliques (HAPs) dans chacun de ces ports, en évaluant les sources ponctuelles de contamination, la population, l'activitié industrielle et commerciale, le trafic maritime international et intérieur, et le nombre de bateaux de pêche commerciale. Les ports ont été classés en fonction de ces éléments. Il est apparu que Sydney présentait le plus grand risque de contamination par les HAPs, suivi, dans l'ordre, par Halifax, Saint John, Pictou, Port Hawkesbury (Ship Harbour), Dalhousie, Liverpool, Shelburne, Lunenburg, Clark's Harbour, Blacks Harbour, Pubnico, Lockeport et Arichat.

On étudie ici la contamination du homard par les HAPs, en examinant pour chaque port les données actuelles sur les concentrations de HAPs et autres contaminants dans le port et dans sa biote, les zones où la pêche est pratiquée et les problèmes possibles.

1. INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) comprise a suite of contaminants that enter the marine environment through natural, e.g. forest fires, volcanoes, and anthropogenic sources, e.g. industrial activities. PAHs, including carcinogenic compounds, bioaccumulate in the tissues of exposed American lobsters (*Homarus americanus*). High PAH concentrations in lobster tissues necessitated the closure of the lobster fishery in the South Arm of Sydney Harbour, Nova Scotia, in 1982. Elevated PAH concentrations, although well below those recorded in Sydney Harbour, also have been observed in lobsters from Halifax Harbour, Nova Scotia (Uthe et al. 1989; Prouse 1991).

PAH concentrations in lobsters from other harbours in the Maritime Provinces of Canada (New Brunswick, Nova Scotia, and Prince Edward Island) have not been systematically assessed. Sources of PAHs to selected harbours were estimated to determine if there might be a reason for concern. This was done by evaluating the adjacent industrial and commercial activity, harbour uses, the surrounding population, and PAH point sources. Areas of lobster fishing and the number of permanent lobster holding facilities within each harbour were also determined.

This report details the extent of lobster fishing in each harbour area, possible PAH sources to the harbour, and the harbour's relative rank with respect to the potential for PAH contamination of its lobster fishery.

2. SELECTION OF HARBOURS

This report examines only those harbours in the Maritime Provinces with a surrounding population > 500. Navigational charts (Canadian Hydrographic Service) were used to define each harbour area. Harbours (Figure 1. Note: all Figures are in Appendix 1) selected for study were: (in Nova Scotia) 1. Digby; 2. Yarmouth; 3. Pubnico; 4. Clark's Harbour; 5. Shelburne; 6. Lockeport; 7. Liverpool; 8. Lunenburg; 9. Halifax; 10. Sheet Harbour; 11. Canso; 12. Arichat; 13. Port Hawkesbury (Ship Harbour); 14. Sydney; 15. Pictou; (in New Brunswick) 16. Saint John; 17. Blacks Harbour; 18. North Head, Grand Manan Island; 19. Dalhousie; 20. Bathurst; (in Prince Edward Island), 21. Charlottetown; and 22. Summerside. Belledune Harbour, New Brunswick, was closed to lobster fishing in 1980 due to the presence of cadmium in its lobsters and was not further assessed in this study. All harbours examined are closed for harvesting of bivalve shellfish, e.g. clams and mussels, because of bacteriological contamination.

3. HARBOURS WITH LOBSTER FISHING

Local Fishery Officers determined the magnitude and location of lobster fishing and lobster holding facilities in each harbour. Brief descriptions (see Table 1. Note: all Tables are in Appendix 2) of intraharbour lobster fishing and holdings for each location follow:

Digby Harbour

No lobster fishing is carried out within Digby Harbour. There is moderate fishing outside Digby in Annapolis Basin. No lobster holding facilities are present.

Yarmouth Harbour

There is no lobster fishing in either Yarmouth Harbour or Yarmouth Sound. There is lobster fishing in the approaches to Yarmouth Sound. No lobster holding facilities are present.

Pubnico Harbour

Twenty-four vessels fish up to 4000 traps in outer Pubnico Harbour, but not near any wharves. Lobsters are held near the government wharf in Lower West Pubnico.

Clark's Harbour

About 30 boats fish 625 traps in Clark's Harbour. There are two lobster holding pounds.

Shelburne Harbour

Up to 1300 traps are fished by 11 boats within Shelburne Harbour from the shipyard out to Gunning Cove (ca. 5 km outside Shelburne). Four holding facilities are located in the harbour.

Lockeport Harbour

Three boats fish 150 traps immediately outside the breakwater and several more fish outside the harbour proper. Lobsters are held in two pounds within the harbour.

Liverpool Harbour

A total of 8 vessels fish 600 traps within Liverpool Bay. There are no holding facilities in the harbour.

Lunenburg Harbour

There is no lobster fishing within the inner harbour. Three boats fish ca. 250 traps just inside the harbour limit. There are no lobster holding facilities in this area.

Halifax Harbour

Three fishermen fish approximately 300 traps within the inner harbour while upwards of 65 boats fish up to 7200 traps in the outer harbour. There are four lobster holding facilities located in Halifax Harbour.

Sheet Harbour

Lobster traps are set only at the mouth of Sheet Harbour inlet outside the harbour. There are no lobster holding facilities.

Canso Harbour

There is no lobster fishing within the harbour, only outside. There are no lobster holding facilities.

Arichat Harbour

Four vessels fish 36 traps within the harbour. There is one lobster pound.

Port Hawkesbury (Ship Harbour)

Thirty traps are fished by five fishermen in Ship Harbour, where Port Hawkesbury and Point Tupper are located. There are no lobster holding facilities in this area.

Sydney Harbour

The South Arm is closed to lobster fishing. There is extensive lobster fishing (ca. 4250 traps) by 52 boats elsewhere in Sydney Harbour. There are two lobster holding facilities located in the harbour.

Pictou Harbour

There is limited lobster fishing within the inner harbour (with up to 24 traps set per day). Over 20 boats set several hundred traps on each side of the outer harbour. Five Native fishermen set traps much of the year in three areas of the harbour. There is one holding pound at the Pictou government wharf.

Saint John Harbour

There is no lobster fishing in the inner harbour, where most wharves and commercial/industrial activity are concentrated. Three fishers set up to 900 traps in the outer harbour and there is moderate lobster fishing carried out in the approaches to Saint John Harbour from Partridge Island to Lorneville. Lobster fishing is associated with the "depot", where dredged material from the inner harbour has been dumped for the past thirty years. There are no lobster holding facilities.

Dalhousie Harbour

Three fishermen fish 320 traps in the southwest area of the harbour into Eel Bay. A Native subsistence fishery fishes 50 traps from May to October in the same area. There are no lobster pounds.

North Head Harbour, Grand Manan Island

There is no lobster fishing or holding within the harbour.

Bathurst Harbour

There is no lobster fishing or holding within the harbour.

Blacks Harbour

Five boats fish 75 traps within and immediately outside the harbour. There are no lobster holding facilities within the harbour.

Charlottetown Harbour

There is no lobster fishing or holding facilities within the harbour. Traps are set beyond the harbour outside Blockhouse Point.

Summerside Harbour

Seven fishermen fish traps outside the harbour and occasionally set a maximum of 5 traps at the harbour limit. There is no lobster fishing or holding facilities within the harbour.

Thus, lobster fishing and holding does not occur within several harbours, i.e. Digby, Yarmouth, Sheet Harbour, Canso, North Head, Bathurst, Charlottetown, and Summerside. They will not be considered further. The potential for PAH contamination in the remaining harbours was examined. Of these harbours, Halifax Harbour has the largest annual lobster fishery (ca. $1,000,000.00), followed in descending order by Sydney Harbour, Clark's Harbour, Pubnico Harbour, Liverpool Harbour, Saint John Harbour, Pictou Harbour, Shelburne Harbour, Lunenburg Harbour, Lockeport Harbour, Dalhousie Harbour, Blacks Harbour, Arichat Harbour, and Port Hawkesbury (Ship Harbour). There are only small catches (< 2500 pounds a year. Note: The commercial lobster fishery in Canada deals in pounds - 0.454 kg) in the last four harbours.

4. DETERMINING THE POTENTIAL FOR PAH CONTAMINATION IN A HARBOUR

Uthe (1979), NRCC (1983), and Lavalin Environnement (1988) described PAH sources to the aquatic environment. Included are: 1. Diffuse sources, e.g. space heating, transportation, petroleum product spills, creosote-treated pilings; 2. Point sources, e.g. emissions from industries that pyrolyse fossil fuels such as petroleum refineries, steel mills; and 3. Secondary sources, e.g. release of PAHs from dumped dredged spoils and other waste dumps.

I used five criteria for evaluating potential PAH input to each harbour: 1. Point sources; 2. Surrounding human population; 3. Industrial and commercial activity; 4. International and domestic ship traffic; and, 5. The number of commercial fishing vessels (CFVs).

4.1. POINT SOURCES

Industrial processes that burn or pyrolyse organic matter can release PAHs. For example, coal coking at Sydney, Nova Scotia, resulted in discharges of coal tar to Sydney Harbour. As a result, high PAH concentrations occur in harbour sediments and lobsters (Matheson et al. 1983).

Currently there is "no single regional inventory for PAH source data" (O'Neill and Kieley 1992). However, potential PAH point sources to harbours in the Maritime Provinces have been identified by various authors and are listed in Table 2 (Uthe 1979; NRCC 1983; Eaton et al. 1984; Eaton et al. 1986; P. Lane and Associates Ltd. 1986; Lavalin Environnement 1988; O'Neill and Kieley 1992; Environment Canada, unpublished information).

4.2. POPULATION

The population surrounding the harbour was used as a criterion for ranking harbours due to the various potential PAH sources associated with human activity, including:

-space heating: combustion of wood and fossil fuels.

-transportation: engine fuel emissions, lubrication products, tire wear.

-open burning: land and grass clearing, municipal refuse.

-municipal effluents: treated and untreated sewage, runoff.

PAHs can enter a harbour through discharges, runoff, and wet and dry deposition, where they become available to aquatic organisms. The amounts of PAHs entering the watershed should relate positively to its surrounding human population. For example, PAH concentrations in mussels and oysters at 234 mussel watch sites in 1990 correlated highly with population in the vicinity of the sample site (O'Connor 1992).

Table 3 gives the population surrounding each harbour (Statistics Canada 1986a & b). The amounts and prior treatment of sewage entering the harbour are included (Anon. 1987). Population was used as index of probable contaminant input.

4.3. INDUSTRIAL AND COMMERCIAL ACTIVITY

Industrial and commercial activity surrounding a harbour should relate positively to PAH input to it, viz:

-space heating.

-industrial effluents (often part of municipal effluents).

-combustion sources, e.g. welding, foundries, industrial boilers.

-power sources, e.g. internal combustion engines.

-point sources (included to give more weight to this factor).

Table 4 summarizes the major commercial and industrial activities, number of manufacturing and processing firms, and total employment with these firms for each harbour. This information was compiled from the directory of manufacturers for each province (New Brunswick Department of Economic Development and Tourism 1992; Nova Scotia Department of Economic Development 1992). Total employment was used as an index for the amount of industrial and commercial activity in each harbour to assess this factor.

4.4. INTERNATIONAL AND DOMESTIC SHIP TRAFFIC

Ships are a source of PAHs to the aquatic environment. The amount and kind of international and domestic shipping, i.e. the number of movements of commercial vessels in and out of each harbour, is recorded by Statistics Canada. This amount was used to indicate PAH input resulting from: 1. The number of wharves and their upkeep; 2. The frequency of oil spills or dumping of petroleum products; 3. The kinds of vessels and frequency, amount, and contaminant potential of products transported; and, 4. The combustion of fossil fuels.

4.4.1. Number of Wharves and Their Upkeep

Harbours require docking facilities. Most are constructed using pressure-treated creosoted wooden piles (personal communication, G. Frampton, Small Craft Harbours, DFO). Such piles are widely used to protect against wood-borers. Creosote, obtained by fractionating coal tar, contains high PAH concentrations (Uthe 1979). PAH contamination of sediment and biota, including lobsters, near creosoted wharves and in holding facilities (constructed with

creosote-treated timbers) has been documented (Eaton and Zitko 1978; Dunn and Fee 1979; McLeese 1983; Uthe et al. 1984). Contamination is greatest from freshly creosoted structures because of loss of surface creosote, particularly during the first year (Gibb 1978). Thus, it is probable that PAHs from this source sporadically increase as a result of pile replacement and other maintenance activities.

4.4.2. Crude Oil and Petroleum Product Spills

Petroleum products and wastes contain PAHs; some contain very high concentrations (Uthe 1979), e.g. used crankcase oil. Release to harbours occurs through accidental spills and intentional dumping, e.g. flushing bilge tanks or dumping used engine oil into sewerage.

The enormous and widespread use of petroleum products presents the greatest risk of spills. Environment Canada (1985) listed 510 spills, representing 1,396,460 litres in the Atlantic region during 1983. The largest spill was fuel #2 (which had the highest PAH content of API reference oils analyzed [Pancirov and Brown 1975]). Greater shipping in harbours could relate to frequency of oil spills or dumping of petroleum wastes. PAHs from such spills are rapidly taken up by marine organisms, e.g. PAHs were present in lobster digestive gland within 10 hours of a diesel oil spill (Williams et al. 1985).

4.4.3. Kinds of Shipping

The amount, type, and frequency of shipping could directly impact PAH input into a harbour, e.g. oil tankers would have a higher risk of spillage. The risk would increase with the amount and frequency of this shipping.

4.4.4. Combustion of Fossil Fuels

Small amounts of PAHs emitted to the atmosphere from combustion of fossil fuels by vessels could eventually enter the harbour.

Table 5 provides the number of vessel movements for international and domestic shipping for each harbour in 1991 (Statistics Canada 1992).

4.5. COMMERCIAL FISHING VESSELS

Commercial fishing vessels (CFVs) release PAHs, which should relate to the number of CFVs using a harbour. Table 6 lists the number and tonnage of Canadian CFVs as registered by port (DFO Statistics 1992, unpublished data).

5. RANKING THE POTENTIAL INPUTS OF PAHS INTO HARBOURS

The above criteria should relate to the amounts of PAHs entering a harbour. It is difficult to quantify the amount contributed by each individual source, for example, under Point Sources scoring was based only on the number and not the magnitude of each point source. This method has uncertainties and imprecisions that provide limited resolution; final rankings are relative rather than absolute. However they can still be used to examine priorities for attention in harbours in terms of PAH contamination of lobster.

Significant amounts of PAHs can originate from point sources and this criterion was given more weight by including it with industrial and commercial activity. Otherwise, the five criteria were given equal weight. Each criterion was scored (From 1 - 4 to span the range within a criterion.) and harbours ranked by their total score. The higher the score, the more likely that biota from the harbour are contaminated. The scoring was as follows:

1. Point Sources: 1 = no point source; 2 = one point source; 3 = two point sources; and, 4 = three or more point sources.

2. Population: 1 < 2500 inhabitants; 2 = 2500 - 5000; 3 = 5001 - 8000; and, 4 > 8000.

3. Industrial and Commercial Activity: 1 < 250 total employment; 2 = 251-500; 3 = 501-1000; and, 4 > 1000.

4. Ship Traffic: 1 = no registered movements; 2 < 100; 3 = 101-200; and, 4 > 200.

5. Number of Commercial Fishing Vessels (CFVs): 1 < 50 boats; 2 = 50-100; 3 = 101-150; and 4 > 150.

Table 7 gives individual criterion scores and their total for each harbour. Based on total score (in parentheses), harbours ranked, from worst (most likely to yield lobsters contaminated with PAH), Sydney Harbour, N.S., to best, Arichat Harbour, N.S., in descending order:

1. Sydney Harbour (19)

2. Halifax Harbour (18)

3. Saint John Harbour (17)

4. Pictou Harbour (15)

5. Port Hawkesbury (Ship Harbour) (14)

6. Dalhousie Harbour (14)

7. Liverpool Harbour (13)

8. Shelburne Harbour (13)

9. Lunenburg Harbour (11)

10. Clark's Harbour (9)

11. Blacks Harbour (7)

12. Pubnico Harbour (7)

13. Lockeport Harbour (7)

14. Arichat Harbour (6)

6. POSSIBLE PAH CONTAMINATION OF LOBSTERS IN RANKED HARBOURS

Certain harbours in the Maritime Provinces, i.e. Sydney and Halifax Harbours, are known to contain lobsters with elevated PAH concentrations. The present ranking, showing that other harbours, i.e. Saint John, N.B. and Pictou, N.S., scored almost as high, suggests they may contain contaminated lobsters.

Other investigations on contamination in these harbours confirm the ranking. Ocean dumping permit applications are a source of harbour contaminant data. Material dredged from harbours must contain concentrations of controlled substances below regulated limits of the Canadian Environmental Protection Act (CEPA 1988) for ocean disposal. Due to the need to dredge most harbours, there are data on contaminant concentrations in harbour sediments.

Oil and grease and PAH concentrations in harbour sediments indicate PAH contamination. Levy et al. (1988) examined concentrations of petroleum residues (non-polar aromatic hydrocarbons) in weathered harbour sediments. Harbours with major industrial activity had elevated sedimentary petroleum residues.

Lobsters and other benthic organisms living in contact with PAH-contaminated sediments are exposed to PAHs. Concentrations of nonalkylated PAHs in lipids of Baltic clams (*Macoma balthica*) and clam worms (*Nereis succinea*) were directly related to PAH concentrations in sediments collected from the same locations in Chesapeake Bay (Foster and Wright 1988).

Lobsters and crabs feeding on contaminated benthic invertebrates will themselves be contaminated. For example, diet accounted for most of the experimental cadmium uptake by *Cancer pagurus* (Davies et al. 1981).

Lobster digestive gland (hepatopancreas, tomalley) accumulates PAHs to much higher concentrations than other tissues (Dunn and Fee 1979; Uthe et al. 1984). Uptake can be rapid when lobsters are exposed to a PAH source, e.g. creosote (McLeese and Metcalf 1979). Unlike finned fish, lobsters do not metabolize PAHs, resulting in surprisingly high PAH concentrations in their fatty tissues (Uthe 1991).

Other factors must be considered in determining the extent of PAH contamination of harbour lobsters, i.e. the amount and location of lobster fishing within each harbour, hydrographic conditions, and additional PAH sources. The following is a description of each harbour, accompanied by an assessment of its potential for contaminating its lobster fishery.

6.1. SYDNEY HARBOUR

Sydney, with the highest score, ranks first for potential contamination of lobsters by PAHs. PAH contamination of Sydney Harbour is well documented (Hildebrand 1982; Matheson et al. 1983; Atwell et al. 1984; Kieley et al. 1988; Vandermeulen 1989). Operation of coal-coking facilities since 1899 resulted in high sedimentary PAH concentrations in South Arm. While Sydney Harbour receives PAHs from other sources, these are of minor importance compared to the coking oven discharges. The South Arm was closed to commercial lobster fishing in 1982. The closure line runs from South Bar to Point Edward (Figure 2). Outside the closed area, fifty-two boats fish over 4000 traps and catch ca. 8,000 pounds a day. Preferred fishing areas are the Northwest Arm up to the closure line and north of South Bar. Lobsters are heavily fished immediately outside the mouth of Sydney Harbour.

Elevated PAH concentrations in lobsters from South Arm were identified in 1980. A survey in 1982 confirmed the high PAH concentrations (Sirota et al. 1984). Benzo[*a*]pyrene concentrations in pooled digestive glands ranged 387-2240 $ng \cdot g^{-1}$ wet wt. with tail muscle concentrations ranging 8-43 $ng \cdot g^{-1}$ wet wt. in South Arm lobsters. Concentrations rapidly decreased seawards.

Sirota et al. (1984) concluded that PAH contamination of lobsters in the South Arm was a "stable and long term situation". This was corroborated by later studies (Uthe and Musial 1986; King et al. 1993). King et al. (1993) identified heterocyclic aromatic hydrocarbons (HACs) and other PAH compounds, e.g. the carcinogen benzo[*c*]phenanthrene, as contaminants in lobster digestive gland in their study of ca. 150 PAH compounds.

6.2. HALIFAX HARBOUR

Halifax Harbour serves the largest population in the Maritime Provinces and ranks second for potential PAH contamination. Numerous industries, including two oil refineries, significant commercial shipping, fishing, and naval activity potentially contribute to the contamination. Many scientific studies provide information on biological and chemical conditions in the harbour (Hargrave and Lawrence 1989). Recent work focused on the large

amount of raw sewage discharged into the harbour, its effects, and ways of dealing with it (Nicholls 1989).

Sediments in Halifax Harbour contain elevated contaminant concentrations. Buckley and Hargrave (1989) sampled 224 stations within the harbour and found sediments associated with "major sewage outfalls and industrial sources" enriched with organic carbon and heavy metals, particularly copper, lead, zinc, and mercury. Total sediment PAH concentrations at seven sites in the harbour ranged 510-25000 $ng \cdot g^{-1}$ (dry wt.) (Tay et al. 1992). These concentrations were lower than those in a previous survey (Environment Canada, unpublished data). Gearing et al. (1991) examined one core from the Northwest Arm and found PAH concentrations were similar to those measured by Tay et al. (1992) with a subsurface maximum of benzo[*a*]pyrene of 2600 $ng \cdot g^{-1}$ at 5-10 cm depth. Histopathological examination of liver from three winter flounder (*Pseudopleuronectes americanus*) from the harbour demonstrated hepatic lesions, suggestive of exposure to PAH-contaminated sediment (Tay et al. 1992).

Limited lobster fishing is plied in the inner harbour, near Georges Island and Dartmouth Cove, and in Northwest Arm and Bedford Basin (Figure 3). More intensive fishing occurs outside the inner harbour, mainly on shoals (Ducharme 1989). The value of the harbour lobster fishery exceeds one million dollars annually. The season extends from the last Monday in November until May 31, with most effort occurring during December and April.

Lobsters from the inner harbour (four sites) had benzo[*a*]pyrene concentrations ranging 29-310 $ng \cdot g^{-1}$ wet wt. in their digestive glands (Uthe et al. 1989; Prouse 1991).

6.3. SAINT JOHN HARBOUR

Saint John Harbour (Figure 4) is the second largest harbour in the Maritime Provinces for industrial activity and population. The harbour ranks third for potential PAH contamination. Concern over environmental quality and possible effects on fishing in the area have been noted (Hildebrand 1980; Lindsay and McIver 1983). Among the industries emitting a variety of toxic substances are a pulp and paper mill, an oil refinery, ship building and repair facilities, machine shops, two breweries, and an asphalt plant.

Toxic chemical surveys in Atlantic Canada showed Saint John Harbour sediments ranked sixth worst contaminated, after Sydney Harbour, St. John's Harbour, Nfld., St. Croix River Estuary, Port Aux Basques Harbour, Nfld., and Miramichi River Estuary (O'Neill 1988). Sediments near the docking facilities are frequently dredged to allow navigation and the spoils contain up to 1150 mg oil and grease $\cdot kg^{-1}$ dry wt. (Levy et al. 1988). Other contaminants, including PAHs and heavy metals, have been above or near the concentration of rejection for ocean dumping (Environment Canada, unpublished ocean dumping data). Sediment samples had total PAH concentrations (Σ18 compounds) in 1990 up to 4.23 $mg \cdot kg^{-1}$ dry wt., exceeding the ocean dumping guideline concentration set under the Canadian Environmental Protection Act - Part VI (CEPA 1988) of 2.5 $mg \cdot kg^{-1}$.

A survey of the dump site (where some lobster fishing occurs) showed a limited biomass of benthic organisms compared with two adjacent control sites (Yurick 1982). Heavy metals, PCBs, and PAHs were elevated in sediments collected at the site but were not at concentrations that would limit numbers and diversity of benthic fauna (Yurick 1982). Insufficient biomass was collected in the survey to allow measurement of contaminants.

6.4. PICTOU HARBOUR

Pictou Harbour (Figure 5) ranks fourth for PAH contamination. The area (including East River, Middle River, and West River) has a population of ca. 30,000. The area has much industrial activity and some intraharbour lobster fishing.

There are 55 manufacturing and processing firms employing 3979 persons in the area, which scores fourth highest for industrial activity. Tire, asphalt, chlor-alkali plants, foundries, and the Trenton coal-fired electric power plant are possible sources of PAH. Other contaminants are released from pulp and paper, paint, shipbuilding and repair, and coal mining industries. Wastes from the pulp and paper mill and tire plant are discharged to Boat Harbour to undergo settling and aeration before disposal into the mouth of Pictou Harbour. The Pictou Road-Pictou Harbour area has low flushing capacity, which could result in a buildup of effluent concentration from the Boat Harbour outfall (Krauel 1969).

The lobster fishing season is May 1-June 30. Intensive fishing begins at the mouth of Pictou Harbour (Figure 5): the first area extends outward around Mackenzie Head and eastward along the south shore; the second from Pictou Road north around Logan Point. Three boats set a total of 30 traps (1-1.5 pounds·trap^{-1}·day^{-1}) during the season in the first area and several hundred are set by 20 boats in the second with a yield of 0.5-2 pounds·trap^{-1}·day^{-1}. Limited fishing is carried out in three areas within the harbour: one boat occasionally sets 6 traps (0.5-1 pound·trap^{-1}·day^{-1}) near the coal pier off Pictou Landing, one boat sets 6 traps (0.75-1 pound·trap^{-1}·day^{-1}) for half of the season off the Pictou government wharf, and one boat sets 12 traps (1 pound·trap^{-1}·day^{-1}) along the causeway for most of the season. Annual total catch within the harbour is estimated at 2000 pounds.

There are two wharves in the harbour where lobsters are landed, Pictou waterfront and Pictou Landing. Thirteen fishing boats use both and landed a value of $274,000 of lobsters in 1989 (DFO Statistics, unpublished data). Most are lobsters taken from Pictou Road or outside the harbour. For example, Chance Harbour has 13 fishing boats which landed $317,500 value the same year (DFO Statistics, unpublished data).

Five members of the Pictou Landing Band carry out subsistence fishing with no season. They fish at the harbour mouth and off Pictou Landing. The fishery officer described their total catch as insignificant compared with the commercial catch.

Data from the 1980s (Environment Canada, unpublished ocean dumping data) showed sedimentary concentrations of some contaminants, including cadmium, PCBs, and hydrocarbons, exceeded the ocean dumping guidelines at dredge sites in the channel between Trenton and Abercrombie and near a wharf in Pictou. Measurements of sediment cores from five sites in Pictou Harbour were at or near the detection limit for PAHs, PCBs, and total organic halogens (Painter and Stewart 1992).

Two studies have measured contaminants in biota from the Pictou area. Zenon (1989) found volatile organic compounds, PAH, and pesticides below or near the limits of detection in mussels collected from Pictou town and the causeway. Metal concentrations were also low. Low concentrations of dioxins and furans were detected in clam, mussel, crab, and lobster tissues sampled from Pictou Road and the Boat Harbour outfall (DFO 1989, cited in Painter and Stewart 1992).

Since 1989, Environment Canada has coordinated an environmental study to address public concerns about pollution in Pictou Harbour and adjacent sections of the Northumberland Strait. The final report (Anon. 1992) identified gaps in the assessment of environmental quality. The Report recommends ongoing study of contaminants in commercial fish and shellfish from the Pictou Harbour area.

6.5. PORT HAWKESBURY (SHIP HARBOUR)

Port Hawkesbury, along with Point Tupper, is located on Ship Harbour (Figure 6) and is an industrial and shipping centre for the Strait of Canso area and ranks fifth for PAH contamination. A pulp and paper mill, a coal-fired electric power plant, oil storage facilities, and an oil refinery (now closed) are located in the area. In 1993, the refinery at Point Tupper became a terminal for supertankers, with facilities to store, blend, and transfer crude and refined oils to smaller vessels.

Dredge spoils from Port Hawkesbury contained 4160 $mg \cdot kg^{-1}$ oil and grease in one sample (OceanChem 1985). Levy et al. (1988) reported concentrations of petroleum residues in sediments collected from the Port Hawkesbury and Point Tupper area ranged up to 247.0 $mg \cdot kg^{-1}$. Total PAH concentrations outside Ship Harbour, in Strait of Canso sediments in 1987 ranged 0.039-2.94 $mg \cdot kg^{-1}$ dry weight, which were considered low (O'Neill and Kieley 1992).

Major industries are situated on the Strait of Canso, not in the actual harbour. Lobster fishing in Ship Harbour yields only 750 pounds annually from a few scattered pots, away from major contaminant sources. The likelihood of these lobsters being contaminated with PAHs is low. However, lobsters caught near industrial sites, e.g. the pulp and paper mill and ocean terminal, warrant study.

6.6. DALHOUSIE HARBOUR

Dalhousie Harbour (Figure 7) also ranks fifth (with Port Hawkesbury) for PAH contamination. A number of industrial activities, including a pulp and paper mill, an electric power plant, a chlor-alkali plant, and ore-loading facilities, are centred at this port.

Concern over contaminant inputs and concentrations around Dalhousie have been documented. Effluent from the chlor-alkali plant had elevated mercury concentrations in the past (Hildebrand 1984). High emissions of sulphur (SO_2) and heavy metals from the coal- and oil-fired electric power plant station on Eel Bay (Figure 7) have been reported (Hildebrand 1984).

Heavy metals and organics were measured in lobster collected from Eel Bay (Matheson and Bradshaw 1985). Lead and mercury concentrations in muscle homogenate (tail and claw) were elevated compared with lobster sampled from other areas in the Bay, but well below concentrations of concern. These concentrations probably resulted from industrial activities in the Dalhousie area. PCB content was near background. PAHs were not measured. The study concluded that contaminants in Chaleur Bay, including Eel Bay, were not at problematic concentrations.

Levy et al. (1988) reported petroleum residues in sediment were 5-28 $mg \cdot kg^{-1}$, above the 10 $mg \cdot kg^{-1}$ limit for ocean dumping. The harbour is frequently dredged to accommodate shipping.

Lobster fishing in Dalhousie Harbour is minimal and confined to Eel Bay, near the electric power plant.

6.7. LIVERPOOL HARBOUR

Liverpool Harbour (Figure 8) ranks sixth (with Shelburne) for possible PAH contamination. Its major industries are a pulp and paper mill at Brooklyn, which discharges its effluent into Liverpool Bay, a fish processing plant, and a machine and metal shop.

Sediments near wharves in Liverpool and Brooklyn contained 0.4-11.8 mg total PAH $\cdot kg^{-1}$ dry wt. (OceanChem 1985; Environment Canada, unpublished ocean dumping data). Oil and grease and cadmium concentrations were also elevated. There is lobster fishing only in outer Liverpool Bay, away from this dockage.

6.8. SHELBURNE HARBOUR

Industries involved with fishing are important to Shelburne Harbour (Figure 9), which ranks sixth (with Liverpool) for PAH contamination. The harbour supports 197 fishing vessels and commercial shipping is moderate with 110 vessel movements registered in 1992.

Annual lobster catch within Shelburne Harbour (out to Gunning Cove) is ca. 14000 pounds. Gunning Cove has a lobster pound. Cadmium concentrations in sediment near the public wharf in Gunning Cove exceed the ocean dumping regulatory limit and oil and grease concentrations, indicative of PAH, ranged up to 2875 $mg \cdot kg^{-1}$, well above the 10 $mg \cdot kg^{-1}$ limit for ocean dumping (OceanChem 1985). Lobsters from Gunning Cove warrent study. Contaminant concentrations are not available for other areas of the harbour.

6.9. LUNENBURG HARBOUR

Lunenburg Harbour (Figure 10) has activities based on fishing, fish products, and ship building and repair. There is some commercial shipping and 88 CFVs use the harbour. Lunenburg Harbour ranks seventh for PAH contamination.

Sediments off wharves in the inner harbour often contained elevated contaminant concentrations. Mercury in sediments collected near the Fishermens Wharf in 1988 was near the allowable limit of 0.75 $mg \cdot kg^{-1}$ and lead and zinc were 2-3 times background concentrations (Environment Canada, unpublished ocean dumping data). Sediments sampled the same year from another site near wharves had cadmium concentrations above the allowable dumping limit and high concentrations of oil and grease, zinc, lead, and copper. Petroleum residue concentrations ranged 1.4-72.7 $mg \cdot kg^{-1}$ for inner and outer harbour (Levy et al. 1988).

There is no lobster fishing in the inner harbour. Several fishermen set traps in the outer harbour, at the harbour limit; three boats set 75-250 $traps \cdot day^{-1}$ in this area and catch ca. 1.5 $pounds \cdot trap^{-1} \cdot day^{-1}$. This is adjacent to a dredged channel and within 1500 m of highly contaminated sediment sampled off the wharves in the inner harbour.

6.10. CLARK'S HARBOUR

The economy of Clark's Harbour (Figure 11) is based on fishing and fish processing and the harbour ranks eighth for potential PAH contamination.

Clark's Harbour was identified as a "problem" harbour in a compilation of data concerning dredging and ocean disposal of dredged material (OceanChem 1985). Cadmium concentrations in sediment near the government wharf exceeded the allowable limit of 0.6 $mg \cdot kg^{-1}$ for ocean dumping. The source for cadmium could not be attributed to any harbour activity. PCBs were also elevated (>0.2 $\mu g \cdot g^{-1}$). The source for PCBs has been attributed to fish processing plants in the harbour. High PCB concentrations (up to 75 $\mu g \cdot g^{-1}$ dry wt.) were found in sediment near the outfall of a herring plant (Wiltshire 1978).

Ship traffic and harbour activity can explain the elevated concentrations of PAHs and petroleum residues that have been documented in harbour sediments. Total PAHs in harbour sediments ranged 0.3-6.6 $mg \cdot kg^{-1}$ dry wt., above the screening concentration of 2.5 $mg \cdot kg^{-1}$ dry wt. for ocean dumping (OceanChem 1985). Oil and grease have also exceeded the 10 $mg \cdot kg^{-1}$

limit for ocean dumping (Environment Canada, unpublished ocean dumping data). Wharves used by the fishing vessels are constructed of creosoted piles and cribwork and have an estimated area of 3200 m^2 (personal communication, L. Avery, Small Craft Harbours, DFO). Therefore, although Clark's Harbour ranks low for possible PAH contamination, the evidence suggests that a limited contamination problem might be present.

6.11. BLACKS HARBOUR

Blacks Harbour is a fishing port on the Bay of Fundy (Figure 12). A fish meal plant releases effluent, which has caused severe oxygen depletion within the harbour (Wildish and Zitko 1991). This effluent is diluted by strong tidal currents at the mouth of the harbour and any contaminants dispersed. Lobster fishing in this area, at 2000 pounds a season, is minimal. Blacks Harbour has a low ranking (ninth with Pubnico and Lockeport Harbours) for PAH contamination. This and the small annual catch suggest low potential for PAH contamination in lobsters.

6.12. PUBNICO HARBOUR

Fishing is the primary activity in the Pubnico Harbour area, e.g. Lower West Pubnico (Figure 13) has four fish processing plants employing 205 persons and is the home port for 141 CFVs. Pubnico Harbour ranks ninth for potential PAH contamination. Only data for Lower West Pubnico was used in this assessment.

Levy et al. (1988) found elevated sedimentary concentrations of petroleum residues ranging 2.6-219.0 $mg \cdot kg^{-1}$ near Lower West Pubnico. Sediments from near fish plants on the east side of Pubnico Harbour, at Middle East Pubnico and Lower East Pubnico, had elevated PCB concentrations, possibly as the result of leakage from vessels or plant equipment (Wiltshire 1978).

Lobsters are fished away from the communities in Pubnico Harbour and there should be a minimal problem with PAH contamination.

6.13. LOCKEPORT HARBOUR

Lockeport (Figure 14) is a small fishing port, population 1200, ranking ninth, along with Blacks Harbour and Pubnico Harbour, for PAH contamination. A fish processing plant employs 92 people, but there are no industries which discharge PAHs into the harbour. However, 120 fishing boats require docking in Lockeport Harbour. The inner harbour is formed by north and south rock mound breakwaters surrounding creosoted piling wharves. These docking facilities have an estimated area of 2800 m^2 (personal communication, L. Avery, Small Craft Harbours, DFO).

Levels of petroleum residues ranged 1.4-73.5 $mg \cdot g^{-1}$ in sediments from within and outside the breakwater of the inner harbour (Levy et al. 1988). In a review of ocean dumping

data, Lockeport was cited as a harbour with a potential contaminant problem: cadmium concentrations in sediments ranged 0.42-0.93 $mg \cdot g^{-1}$, frequently exceeding the ODCA limit of 0.6 $mg \cdot g^{-1}$ (OceanChem Ltd. 1985). PAH concentrations in sediment or biota have not been measured.

Three fishermen set a total of 150 traps just outside the rock breakwaters and catch 3000 pounds a season. Lobsters at this site could be exposed to PAHs from the docking facilities. However, creosoted wood has not recently been used for major wharf repair or replacement in the inner harbour (personal communication, F. Hills, Small Craft Harbours, DFO). Therefore, Lockeport Harbour ranks low for PAH contamination.

6.14. ARICHAT

A single fish processing plant (employing 200 persons), low population (900), and limited shipping and fishing activity, gives Arichat (Figure 15) the lowest ranking. Four fishermen scatter a few traps within the harbour and catches are described as poor to fair; fishing effort is concentrated outside the harbour and the area closed to shellfish harvesting.

The small number of lobsters taken from this harbour should have minimal likelihood of PAH contamination.

7. DISCUSSION AND CONCLUSIONS

The extent of the PAH problem for the two highest ranking harbours, Sydney and Halifax, has been documented by measuring PAH concentrations in sediments and lobsters. PAH concentrations in lobsters from Halifax Harbour are lower than concentrations found in Sydney Harbour animals. Studies of the next highest ranked harbours, Saint John and Pictou Harbours, should receive priority in the future. The rest, especially Blacks Harbour, Pubnico Harbour, Lockeport Harbour, and Arichat Harbour, rank low for PAH contamination and any PAH problem in lobsters should be minimal.

The use of creosoted wood in docking and other portside facilities has been problematic. In recent years creosote in pressure-treated lumber has been replaced by other agents. Chromated copper arsenate-treated (Wolmanized) timber is used because it is easy to handle and does not stain the sides of boats. There are indications that copper, chromium, and arsenic leach from Wolmanized timber, especially newly treated wood, in seawater and accumulate in sediments (Weis et al. 1993). These metals might pose another contaminant problem. Wharf construction with concrete is an alternative, but is expensive.

A high ranking for PAH contamination in a harbour also implies the presence of other toxic contaminants, e.g. trace metals and organics. Ocean dumping data from major harbours show, along with elevated PAH concentrations, elevated concentrations of heavy metals such as cadmium and mercury (Environment Canada, unpublished ocean dumping data). Sediments

from Sydney Harbour have high cadmium, mercury, lead, zinc, and PAH concentrations, resulting from steel and coking operations (Vandermeulen 1989). High concentrations of metals and hydrocarbons have been measured in sediments throughout Halifax Harbour (Buckley and Hargrave 1989) with concentrations increasing over time. Concentrations in Halifax Harbour are among the highest reported for similar marine coastal areas (Gearing et al. 1991). These contaminants could bioaccumulate in biota, e.g. PCBs and Cu concentrations exceeded background levels in the digestive glands of lobsters from Halifax Harbour (Uthe et al. 1989; Prouse 1991).

Other contaminants can affect the lobster fisheries in harbours. Operation of a lead smelter at Belledune Harbour on Chaleur Bay resulted in high cadmium concentrations in lobsters and forced the closure of this fishery in the harbour in 1980 (Uthe and Chou 1985). The Commonwealth of Massachusetts (Massachusetts Department of Public Health 1988) has issued a health advisory to avoid eating lobsters and other fishery products from Boston Harbour because of chemical and microbiological contamination. The advisory also cautioned against consuming digestive gland of lobsters from any location due to its high contaminant concentrations.

As long as lobsters are commercially fished in areas of known contamination, it is necessary to ensure that no significant contamination problems are present. Studies should focus on: 1. Classical contaminants in lobsters taken from suspect areas that have not been previously studied; and, 2. Hitherto unidentified contaminants in lobsters taken from seriously contaminated areas, such as Sydney and Halifax Harbours, both the sites of substantial lobster fisheries.

8. ACKNOWLEDGEMENTS

This work could not have been completed without the assistance of W. Halliday, I. Marshall, S. Nickerson, H. Williams, J. Forbes, P. Veno, W. Zinck, E. Samson, S. Frost, C. Burton, B. Newman, J. Race, W. Wells, R. Young, R. Roy, R. MacNair, J. Doucet, C. MacIsaac, E. Bernard, G. Nowlan, J. Kane, A. Ducharme, K. Tay, and R. Parker. Thanks are also extended to F. Kelly and A. Cosgrove who prepared the figures; D. Gordon and G. Harding who commented on the ranking method; and M. Kettle, M. Bewers, K. Kieley, and J. Uthe for their comments on the manuscript.

9. REFERENCES

Anon. 1992. Final Report, Pictou Harbour Environmental Action Plan. Submitted to Environment Canada, Conservation and Protection, Atlantic Region, Dartmouth, N.S. 21 p.

Anon. 1987. National Inventory of Municipal Waterworks and Wastewater Systems in Canada. 1986. Supply and Services Canada. Cat. No. E94-81/1987. vi + 419 p.

Atwell L., P. Hennigar, J. Kozak, M. Morin, and C. Oldreive. 1984. Ambient air polynuclear aromatic hydrocarbons study, Sydney, Nova Scotia. Environment Canada, Environmental Protection Service, Atlantic Region, Dartmouth, N.S. Surveillance Report EPS-5-AR-84-7. viii + 79 p.

Buckley, D.E., and B.T. Hargrave. 1989. Geochemical characteristics of surface sediments. p. 9-36. In: H.B. Nicholls [ed.]. Investigations of Marine Environmental Quality in Halifax Harbour. Can. Tech. Rep. Fish. Aquat. Sci. 1693.

Davies, I.M., G. Topping, W.C. Graham, C.R. Falconer, A.D. McIntosh, and D. Saward. 1981. Field and experimental studies on cadmium in the edible crab *Cancer pagurus*. Mar. Biol. 64: 291-297.

DFO. 1989 MS. Dioxin and furan residues in fish and shellfish from the vicinity of various pulp mills in the Maritimes. Unpublished analyses, DFO Gulf Region, Moncton, N.B. - cited in Painter and Stewart (1992).

Ducharme, A. 1989. The fisheries of Halifax Inlet. p. 19-21. In: Proceedings First Halifax Inlet Research Workshop, November 1, 1989, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, N.S.

Dunn, B.P., and J. Fee. 1979. Polycyclic aromatic hydrocarbon carcinogens in commercial seafoods. J. Fish. Res. Board Can. 36: 1469-1476.

Eaton, P.B., L.P. Hildebrand, and A.A. d'Entremont. 1986. Environmental Quality in the Atlantic Region 1985. Environment Canada, Environmental Protection Service, Atlantic Region, Dartmouth, N.S. xxviii + 241 p.

Eaton, P.B., J.F. Uthe, and G.R. Sirota. 1984. Coal and coal-based products. p. 109-120. In: R.C.H. Wilson and R.F. Addison [eds.]. Health of the Northwest Atlantic: A Report to the Interdepartmental Committee on Environmental Issues. Environment Canada, Department of Fisheries and Oceans, Department of Energy, Mines and Resources, Ottawa.

Eaton, P., and V. Zitko. 1978. Polycyclic aromatic hydrocarbons in marine sediments and shellfish near creosoted wharf structures in Eastern Canada. I.C.E.S. C.M. 1978/E:25.

Environment Canada. 1985. A summary of trends relating to spills of oil and hazardous materials in the Atlantic Region 1983. Environment Canada, Environmental Protection Service, Atlantic Region, Dartmouth, N.S. Surveillance Report EPS-5-AR-85-6. 76 p.

Foster, G.D., and D.A. Wright. 1988. Unsubstituted polynuclear aromatic hydrocarbons in sediments, clams, and clam worms from Chesapeake Bay. Mar. Poll. Bull. 19: 459-465.

Gearing, J.N., D.E. Buckley, and J.N. Smith. 1991. Hydrocarbon and metal contents in a sediment core from Halifax Harbour: a chronology of contamination. Can. J. Fish. Aquat. Sci. 48: 2344-2354.

Gibb, H. 1978. Coal tar, creosote and coal tar neutral oil. Fed. Regist. 43: 202. Oct. 18.

Hargrave, B.T., and D.J. Lawrence. 1989. Bibliography of Halifax Harbour and Bedford Basin. Appendix C. p. 72-83. In: H.B. Nicholls [ed.]. Investigations of Marine Environmental Quality in Halifax Harbour. Can. Tech. Rep. Fish. Aquat. Sci. 1693.

Hildebrand, L.P. 1984. An assessment of environmental quality in the Baie des Chaleurs. Environment Canada, Environmental Protection Service, Atlantic Region, Dartmouth, N.S. Surveillance Report EPS-5-AR-84-8. xii + 191 p.

Hildebrand, L.P. 1982. Environmental quality in Sydney and northeast industrial Cape Breton, Nova Scotia. Environment Canada, Environmental Protection Service, Atlantic Region, Dartmouth, N.S. Surveillance Report EPS-5-AR-82-3. viii + 89 p.

Hildebrand, L.P. 1980. An overview of environmental quality in Saint John Harbour, New Brunswick. Environment Canada, Environmental Protection Service, Atlantic Region, Halifax, N.S. Surveillance Report EPS-5-AR-81-1. vii + 59 p.

Kieley, K.M., P.A. Hennigar, R.A.F. Matheson, and W.R. Ernst. 1988. Polynuclear aromatic hydrocarbons and heterocyclic aromatic compounds in Sydney Harbour, Nova Scotia. A 1986 survey. Environment Canada, Environmental Protection Service, Atlantic Region, Dartmouth, N.S. Surveillance Report EPS-5-AR-88-7. vii + 41 p.

King, T.L., J.F. Uthe, and C.J. Musial. 1993. Polycyclic aromatic hydrocarbons in the digestive glands of the American lobster, *Homarus americanus*, captured in the proximity of a coal-coking plant. Bull. Environ. Contam. Toxicol. 50: 907-914.

Krauel, D.P. 1969. Tidal flushing of Pictou Harbour-Pictou Road, N.S. Fish. Res. Board Can. Tech. Rep. 146: xv + 28 p.

Lavalin Environnement. 1988. Inventory of polycyclic aromatic hydrocarbon sources in Quebec. Prepared for Environment Canada, Conservation and Protection, Quebec Region. File: 55526.

Levy, E.M., K. Lee, K.S. Saunders, and S.E. Cobanli. 1988. The distribution of petroleum residues in near-shore sediments from Atlantic Canada. Can. Tech. Rep. Fish. Aquat. Sci. 1612: iv + 169 p.

Lindsay, G., and A. McIver, [eds.]. 1983. Report on the Saint John Harbour Environs. (Proceedings of a workshop held on February 25 and 26, 1981, at the University of New Brunswick, Saint John, New Brunswick). Environment Canada, Environmental Protection Service, Dartmouth, N.S. Surveillance Report EPS-5-AR-83-8. viii + 177 p.

Massachusetts Department of Public Health. 1988. Health advisory for contaminants in fish and shellfish from Quincy Bay. Issued June 20, 1988. Executive Office of Human Services, Commonwealth of Massachussetts.

Matheson, R.A.F., and V.I. Bradshaw. 1985. The status of selected environmental contaminants in the Baie des Chaleurs ecosystem. Environment Canada, Environmental Protection Service, Atlantic Region, Dartmouth, N.S. Surveillance Report EPS-5-AR-85-3. ix + 65 p.

Matheson, R.A.F., G.L. Trider, W.R. Ernst, K.G. Hamilton, and P.A. Hennigar. 1983. Investigation of polynuclear aromatic hydrocarbon contamination of Sydney Harbour, Nova Scotia. Environment Canada, Environmental Protection Service, Atlantic Region, Dartmouth, N.S. Surveillance Report EPS-5-AR-83-6. viii + 86 p.

McLeese, D.W. 1983. The potential for exposure of lobsters to creosote during commercial storage in the Maritime Provinces of Canada. Can. Tech. Rep. Fish. Aquat. Sci. 1203: iv + 28 p.

McLeese, D.W., and C.D. Metcalfe. 1979. Toxicity of creosote to larval and adult lobster and *Crangon* and its accumulation in lobster hepatopancreas. Bull. Environ. Contam. Toxicol. 22: 796-799.

NRCC. 1983. Polycyclic aromatic hydrocarbons in the aquatic environment: formation, sources, fate and effects on aquatic biota. Associate Committee on Scientific Criteria for Environmental Quality, National Research Council of Canada, Ottawa, Canada. NRCC No. 18981. 209 p.

New Brunswick Department of Economic Development and Tourism. 1992. New Brunswick Directory of Products and Manufacturers 1992. Fredericton, N.B. 224 p.

Nicholls, H.B. [ed.]. 1989. Investigations of marine environmental quality in Halifax Harbour. Can. Tech. Rep. Fish. Aquat. Sci. 1693: v + 83 p.

Nova Scotia Department of Economic Development. 1992. Nova Scotia Directory of Manufacturers 1992-1993. Statistical Services Branch, Halifax, N.S. 165 p.

OceanChem Ltd. 1985. Ocean disposal of dredged materials from Atlantic Canadian harbours. 1. Small Craft Harbours, Scotia-Fundy Region. Report submitted to the Department of Fisheries and Oceans, Small Craft Harbours Branch, Scotia-Fundy Region.

O'Connor, T.P. 1992. Recent trends in coastal environmental quality: results from the first five years of NOAA Mussels Watch Project. Coastal Monitoring Branch, NOAA, Rockville, MD. 46 p.

O'Neill, H.J. 1988. An assessment of Atlantic Region Water Quality Branch toxic chemical data 1980-1987. Environment Canada, Water Quality Branch, Atlantic Region, Moncton, N.B. Report IW/L-AR-WQB-88-140. vi + 80 p.

O'Neill, H.J., and K.M. Kieley. 1992. Polynuclear aromatic hydrocarbons: Atlantic Region data summary and review. Environment Canada, Conservation and Protection, Atlantic Region. Technical Report Series No. 92-01. xii + 64 p.

P. Lane and Associates Ltd. 1986. Risks to migratory birds: industrial point sources of toxic chemicals in Atlantic Canada. Prepared for Environment Canada, Canadian Wildlife Service, Atlantic Region, Sackville, N.B. Project No. E-135.

Painter, H.G., and P.L. Stewart. 1992. An assessment of the environmental quality of Pictou Harbour and surrounding watershed. Submitted to Environment Canada, Conservation and Protection, Dartmouth, N.S. vi + 49 p.

Pancirov, R.J., and R.A. Brown. 1975. Analytical methods for polynuclear aromatic hydrocarbons in crude oils, heating oils, and marine tissues. Proc. 1st Conference on Prevention and Control of Oil Pollution, Washington, DC. American Petroleum Institute. p. 103-113.

Prouse, N.J. 1991. Contaminants in Halifax Harbour lobster: summary of the 1989 surveys. p. 25-30. In: Proceedings Second Halifax Inlet Research Workshop, February 13, 1991, Department of Fisheries and Oceans, Bedford Institute of Oceanography, Dartmouth, N.S.

Sirota, G.R., J.F. Uthe, D.G. Robinson, and C.J. Musial. 1984. Polycyclic aromatic hydrocarbons in American lobster (*Homarus americanus*) and blue mussels (*Mytilus edulis*) collected in the area of Sydney Harbour, Nova Scotia. Can. MS Rep. Fish. Aquat. Sci. 1758: vi + 22 p.

Statistics Canada. 1992. Shipping in Canada, 1991. Cat. No. 54-205, Statistics Canada, Transportation Division. 154 p.

Statistics Canada. 1986a. Census divisions and subdivisions: Part 1, Nova Scotia profiles. Cat. No. 94-105. 72 p.

Statistics Canada. 1986b. Census divisions and subdivisions: Part 1, New Brunswick profiles. Cat. No. 94-107. 156 p.

Tay, K.L., K.G. Doe, S.J. Wade, D.A. Vaughan, R.E. Berrigan, and M.J. Moore. 1992. Sediment bioassessment in Halifax Harbour. Environ. Toxicol. Chem. 11: 1567-1581.

Uthe, J.F. 1991. Polycyclic aromatic hydrocarbons in the environment. Canadian Chemical News, Aug. 1991. p. 25-27.

Uthe, J.F., C.L. Chou, N.J. Prouse, and C.J. Musial. 1989. Heavy metal, polycyclic aromatic hydrocarbon, and polychlorinated biphenyl concentrations in American lobster (*Homarus americanus*) from Halifax Harbour. Appendix A. p. 64-68. In: H.B. Nicholls [ed.]. Investigations of Marine Environmental Quality in Halifax Harbour. Can. Tech. Rep. Fish. Aquat. Sci. 1693.

Uthe, J.F., and C.J. Musial. 1986. Polycyclic aromatic hydrocarbon contamination of American lobster, *Homarus americanus*, in the proximity of a coal-coking plant. Bull. Environ. Contam. Toxicol. 37: 730-738.

Uthe, J.F., and C.L. Chou. 1985. Cadmium in American lobster (*Homarus americanus*) from the area of Belledune Harbour, New Brunswick, Canada - A summary of five years study. Can. Tech. Rep. Fish. Aquat. Sci. 1342: vi + 20 p.

Uthe, J.F., D.W. McLeese, G.R. Sirota, and L.E. Burridge. 1984. Accumulation of polycyclic aromatic hydrocarbons by lobsters (*Homarus americanus*) held in a tidal pound. Can. Tech. Rep. Fish. Aquat. Sci. 1059: iii + 10 p.

Uthe, J.F. 1979. The environmental occurrence and health aspects of polycyclic aromatic hydrocarbons. Fish. Mar. Serv. Tech. Rep. 914: iii + 30 p.

Vandermeulen, J.H. 1989. PAH and heavy metal pollution of the Sydney Estuary: summary and review of studies to 1987. Can. Tech. Rep. Hydrogr. Ocean Sci. 108: ix + 48 p.

Weis, P., J.S. Weis, and T. Proctor. 1993. Copper, chromium, and arsenic in estuarine sediments adjacent to wood treated with chromated-copper-arsenate (CCA). Estuar. Coast. Shelf Sci. 36: 71-79.

Wildish, D.J., and V. Zitko. 1991. Chemical oceanographic conditions in Blacks Harbour, N.B., 1989-91. Can. MS Rep. Fish. Aquat. Sci. 2132: iii + 11 p.

Williams, U.P., J.W. Kiceniuk, and J.R. Botta. 1985. Polycyclic aromatic hydrocarbon accumulation and sensory evaluation of lobster (*Homarus americanus*) exposed to diesel oil at Arnold's Cove, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1402: iv + 13 p.

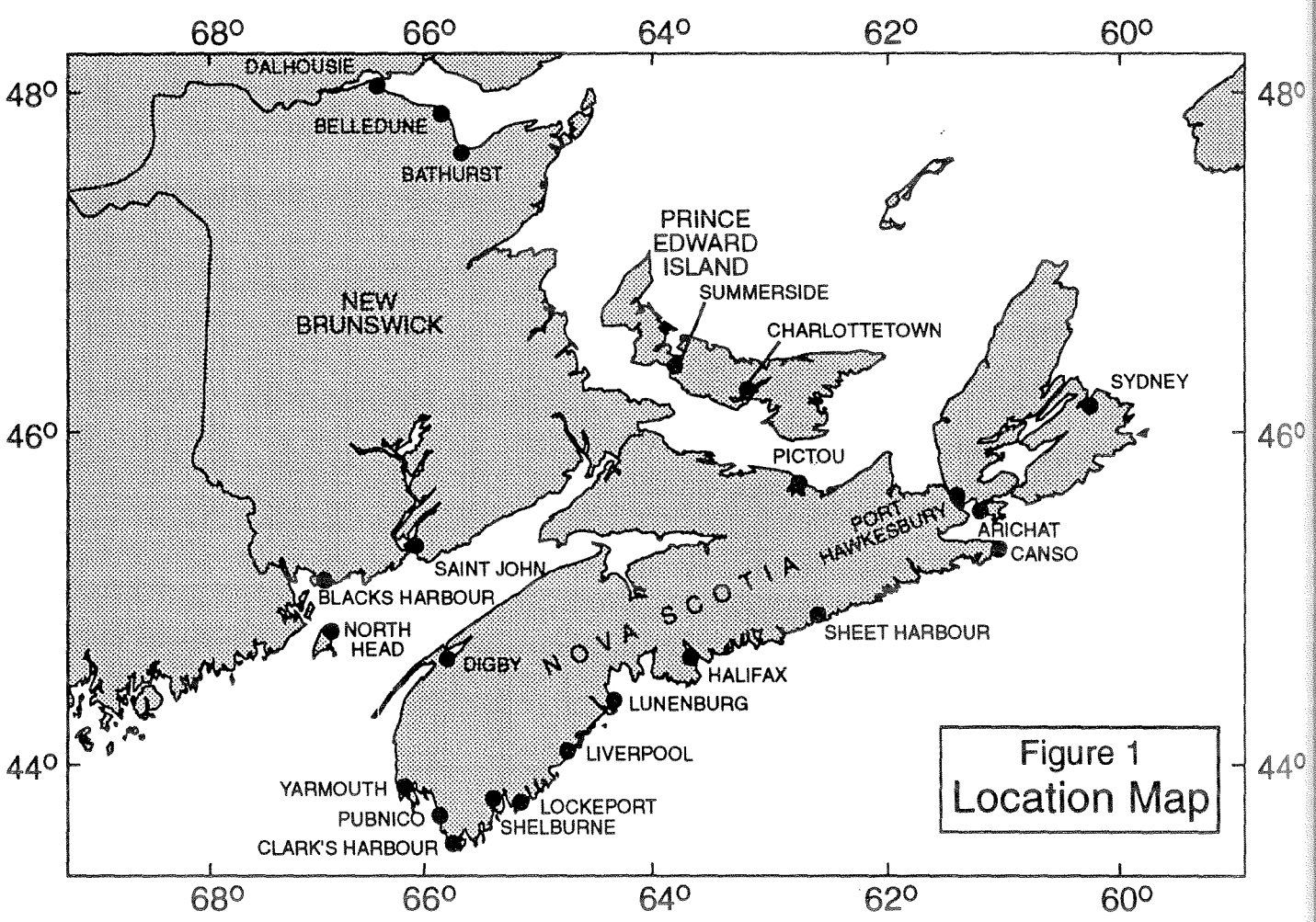
Wiltshire, J.F. 1978. Investigation of PCB contamination of marine sediments associated with fish plant operations in southern Nova Scotia. Department of Fisheries and the Environment, Environmental Protection Service, Atlantic Region, Halifax, N.S. Surveillance Report EPS-5-AR-78-8. iv + 43 p.

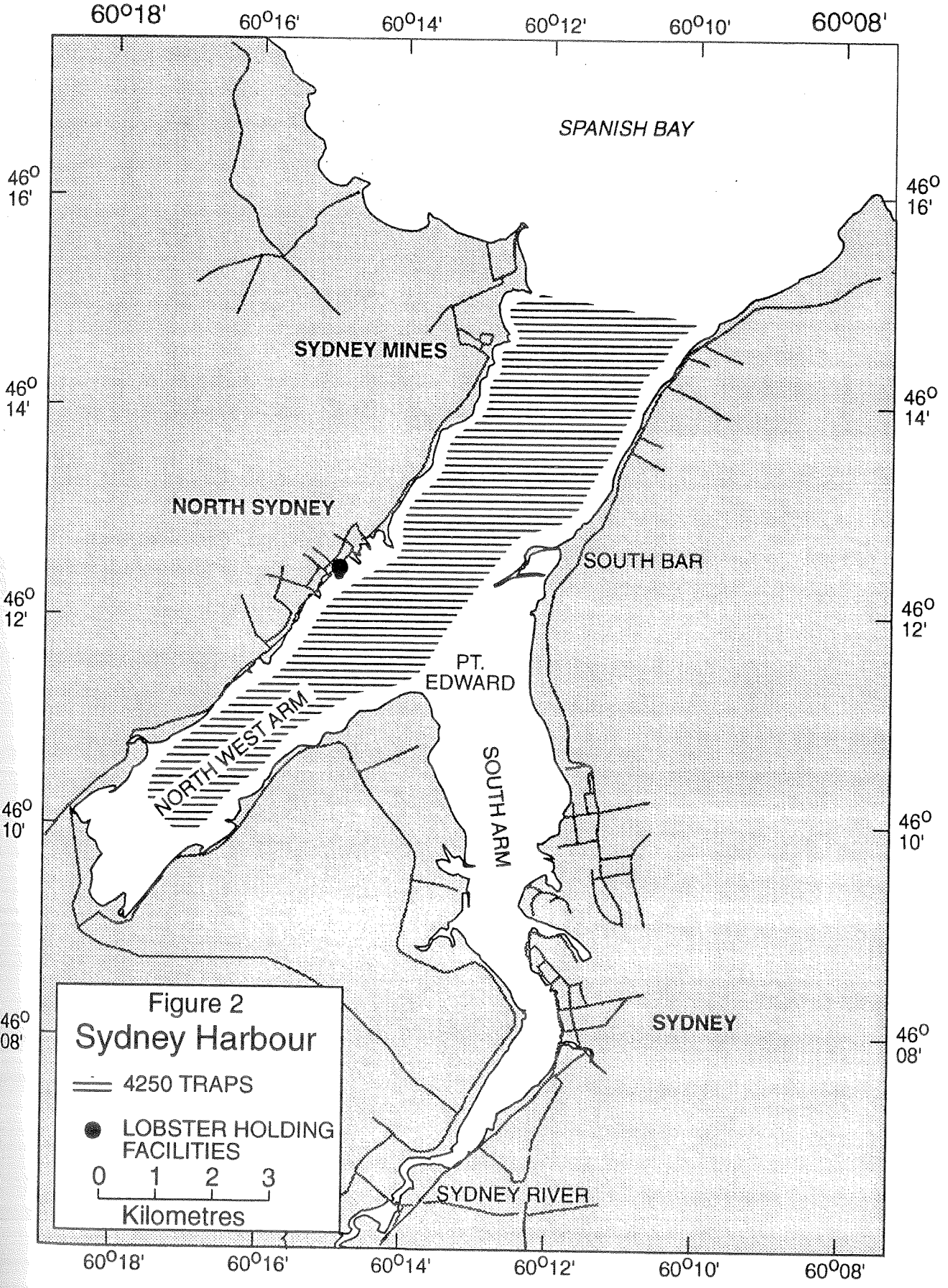
Yurick, D.B. 1982. An assessment of the Saint John harbour dump site. Report submitted to Department of Fisheries and Oceans, St. Andrews, New Brunswick. DSS File No. 08SC.FP706-1-CO28. ii + 24 p.

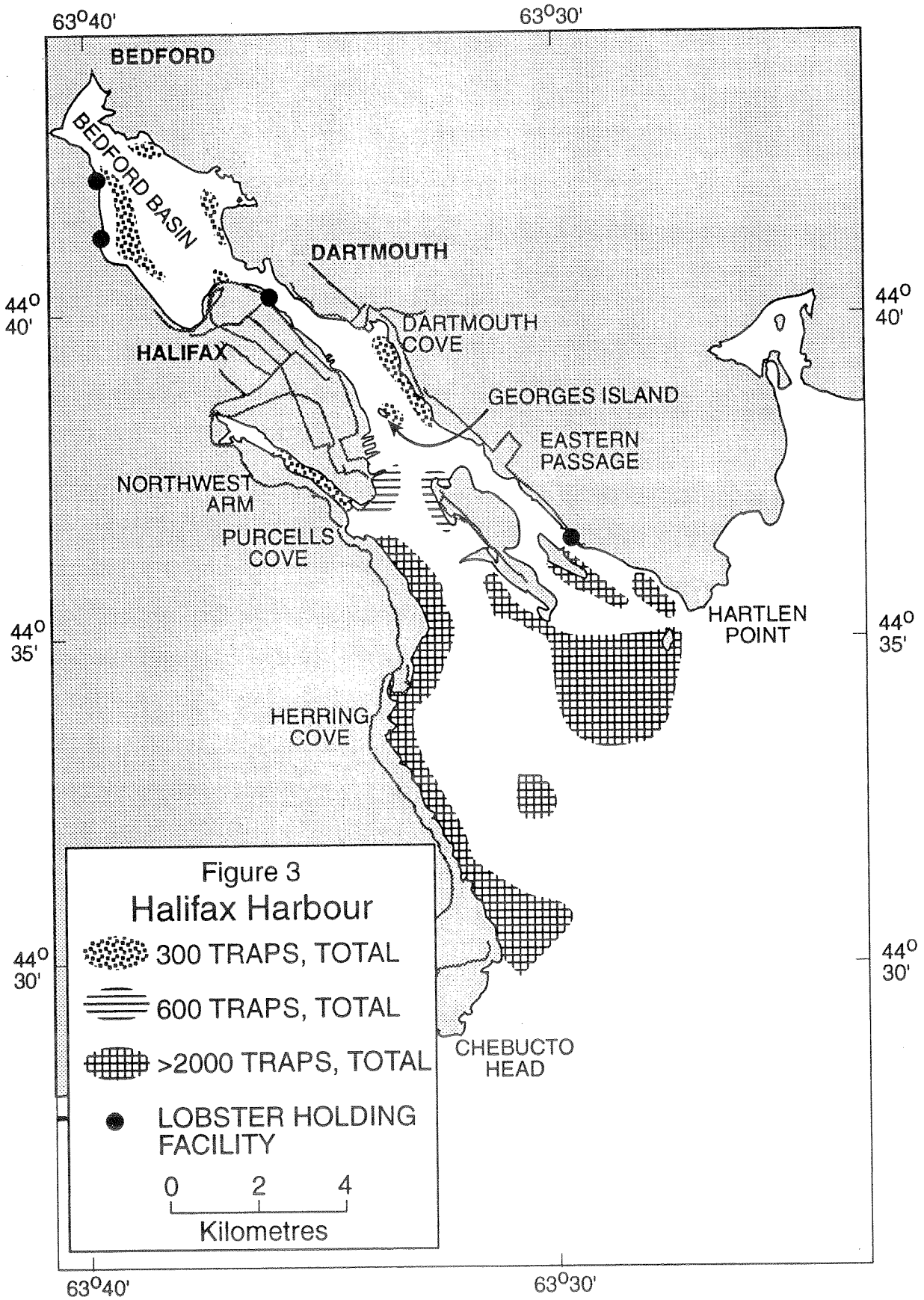
Zenon Environmental Inc. 1989. Analysis of shellfish for organic and inorganic contaminants. Prepared for Environment Canada, Conservation and Protection, Dartmouth, N.S. File No. AN893118.

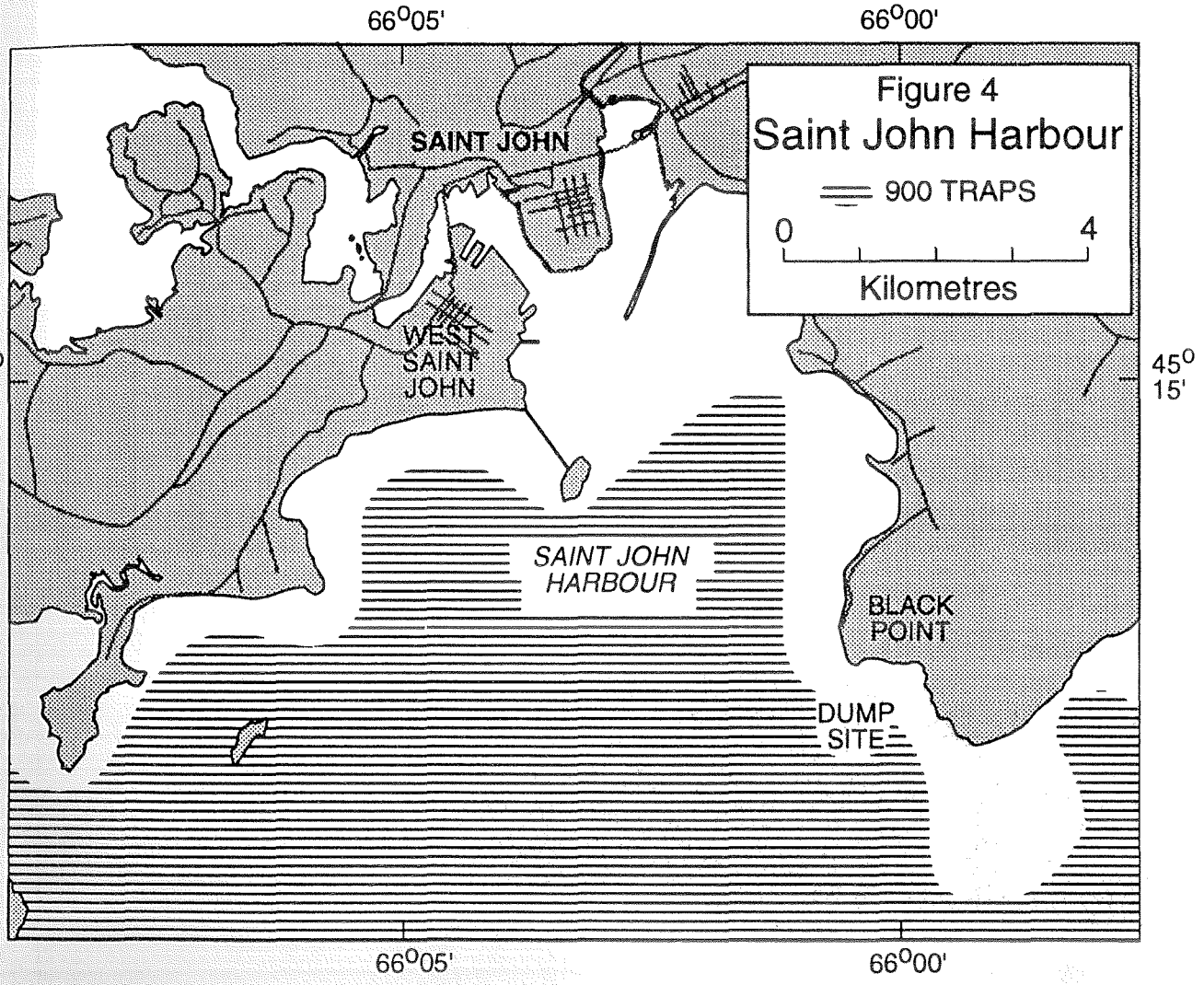
APPENDIX 1

FIGURES


68°
66°
64°
62°
60°
48°
46°
44°
DALHOUSIE
BELLEDUNE
BATHURST
NEW BRUNSWICK
PRINCE EDWARD ISLAND
SUMMERSIDE
CHARLOTTETOWN
SYDNEY
PICTOU
PORT HAWKESBURY
ARICHAT
CANSO
SAINT JOHN
BLACKS HARBOUR
NORTH HEAD
DIGBY
NOVA SCOTIA
SHEET HARBOUR
HALIFAX
LUNENBURG
LIVERPOOL
YARMOUTH
PUBNICO
CLARK'S HARBOUR
LOCKEPORT
SHELBURNE
Figure 1
Location Map


60°18'
60°16'
60°14'
60°12'
60°10'
60°08'
SPANISH BAY
46° 16'
SYDNEY MINES
46° 14'
NORTH SYDNEY
SOUTH BAR
46° 12'
PT. EDWARD
NORTH WEST ARM
SOUTH ARM
46° 10'
SYDNEY
46° 08'
Figure 2
Sydney Harbour
4250 TRAPS
LOBSTER HOLDING FACILITIES
0 1 2 3
Kilometres
SYDNEY RIVER


63°40'
63°30'
BEDFORD
BEDFORD BASIN
DARTMOUTH
44° 40'
DARTMOUTH COVE
HALIFAX
GEORGES ISLAND
EASTERN PASSAGE
NORTHWEST ARM
PURCELLS COVE
HARTLEN POINT
44° 35'
HERRING COVE
CHEBUCTO HEAD
44° 30'
Figure 3
Halifax Harbour
300 TRAPS, TOTAL
600 TRAPS, TOTAL
>2000 TRAPS, TOTAL
LOBSTER HOLDING FACILITY
0 2 4
Kilometres


66°05'
66°00'
44° 40'
45° 15'
44° 35'
44° 30'
SAINT JOHN
WEST SAINT JOHN
SAINT JOHN HARBOUR
BLACK POINT
DUMP SITE
Figure 4
Saint John Harbour
900 TRAPS
0
4
Kilometres

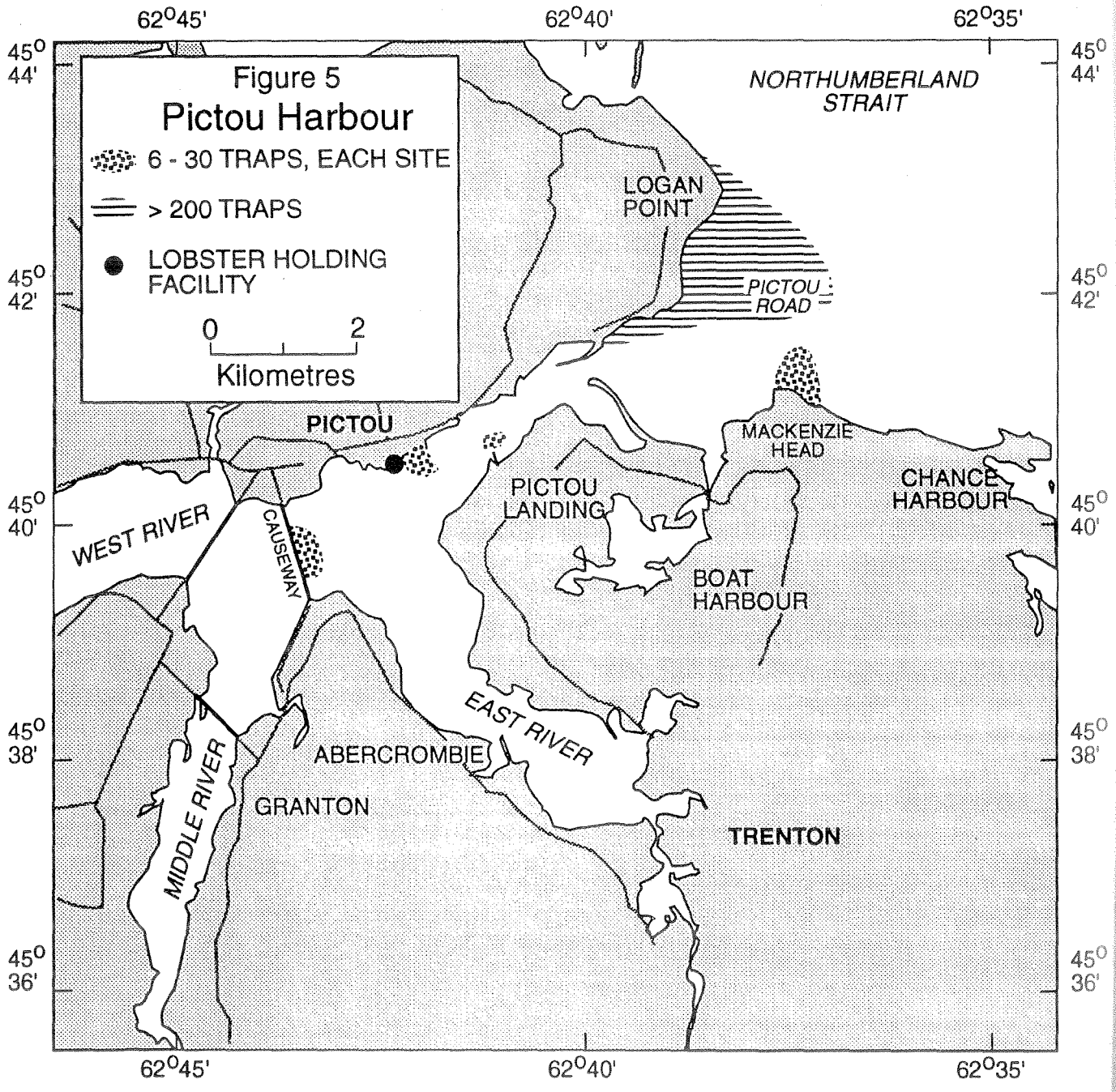
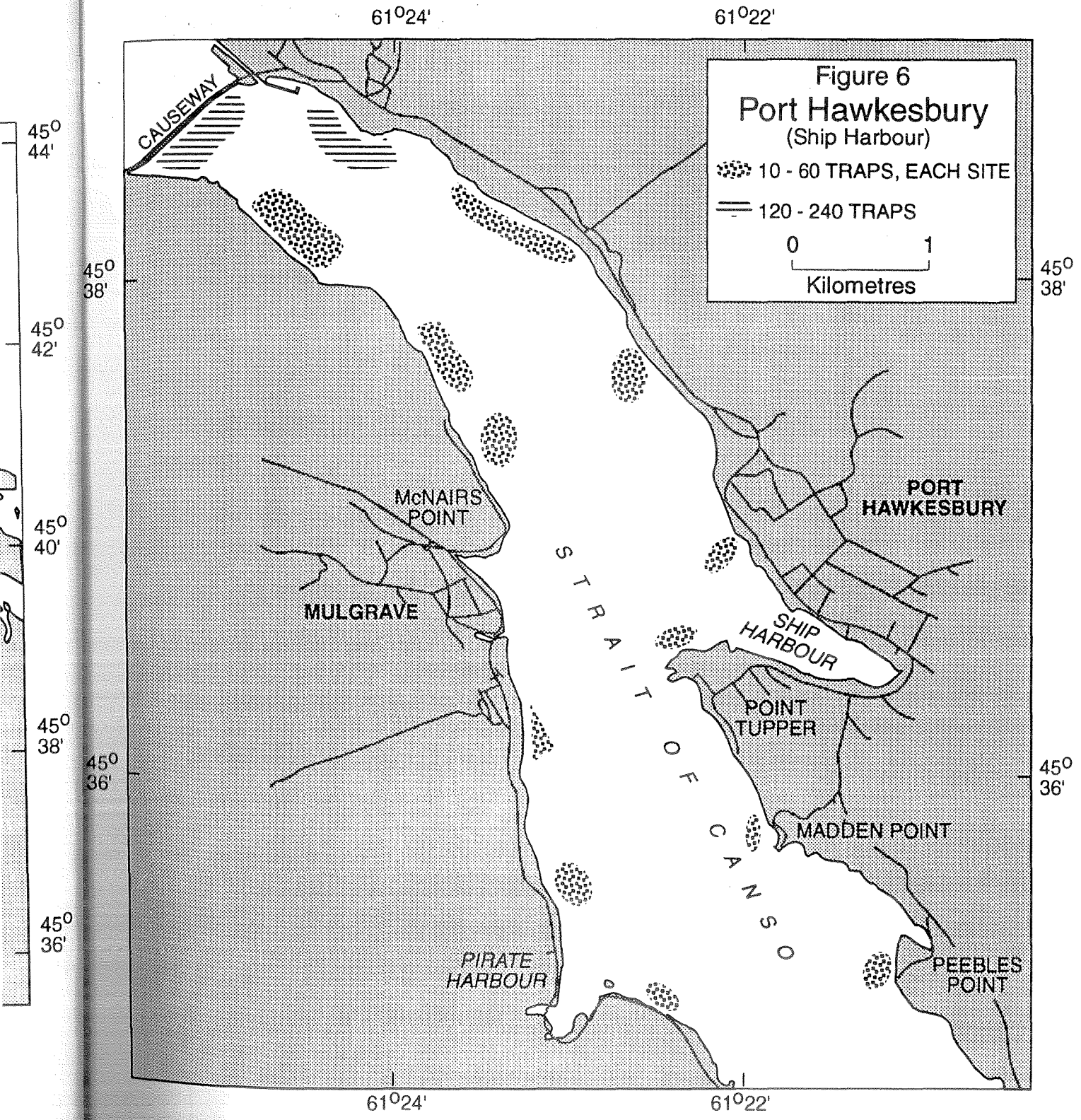
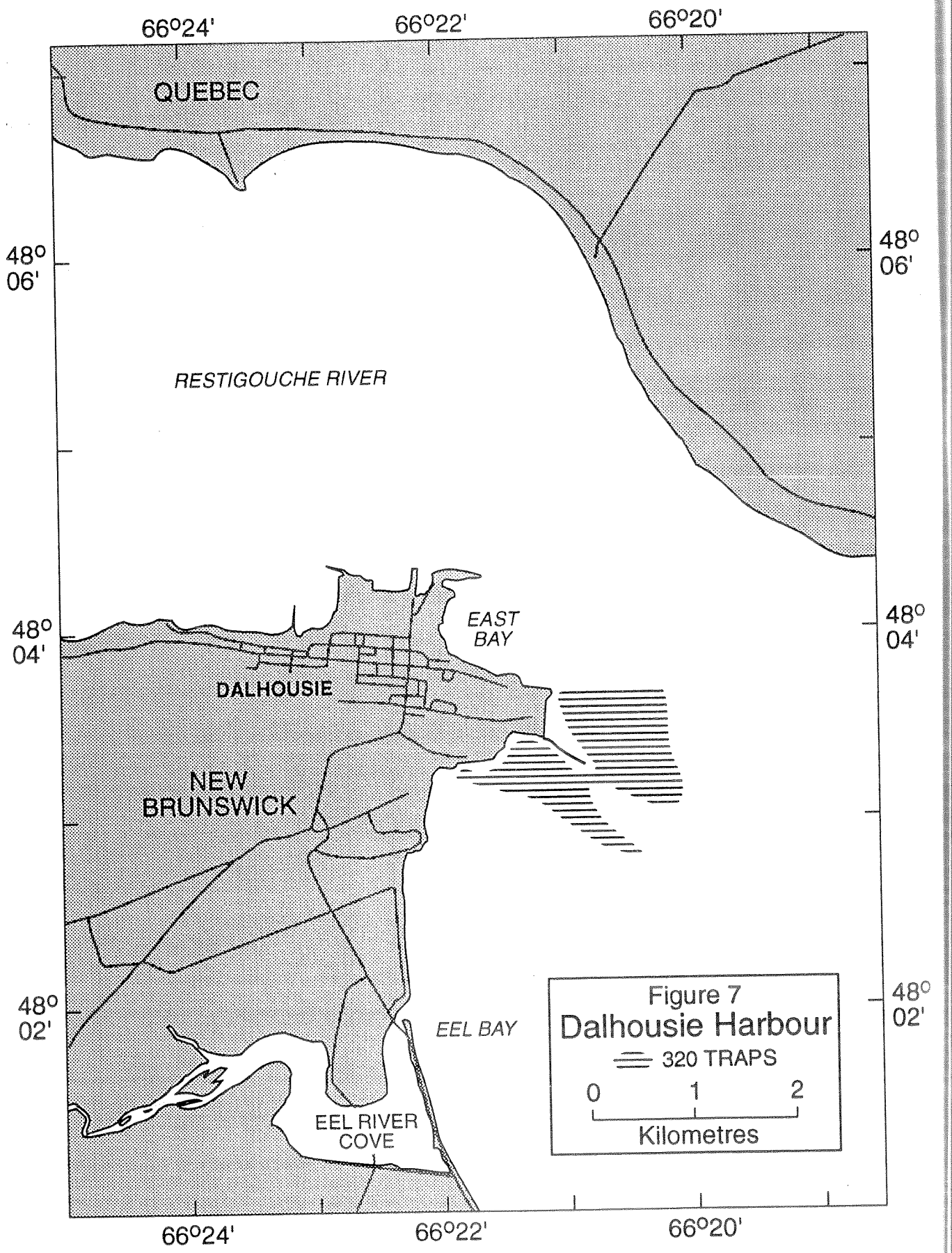
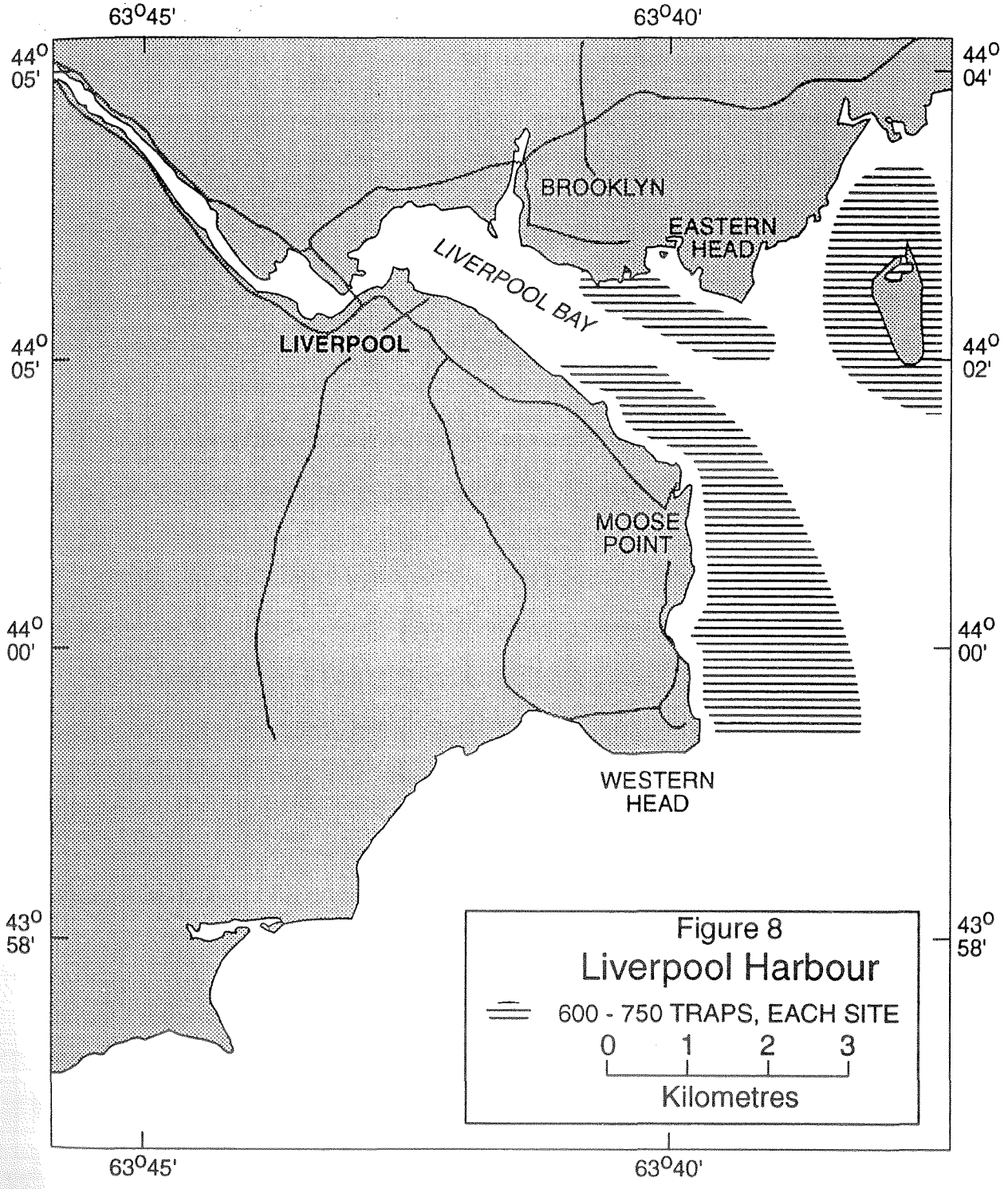
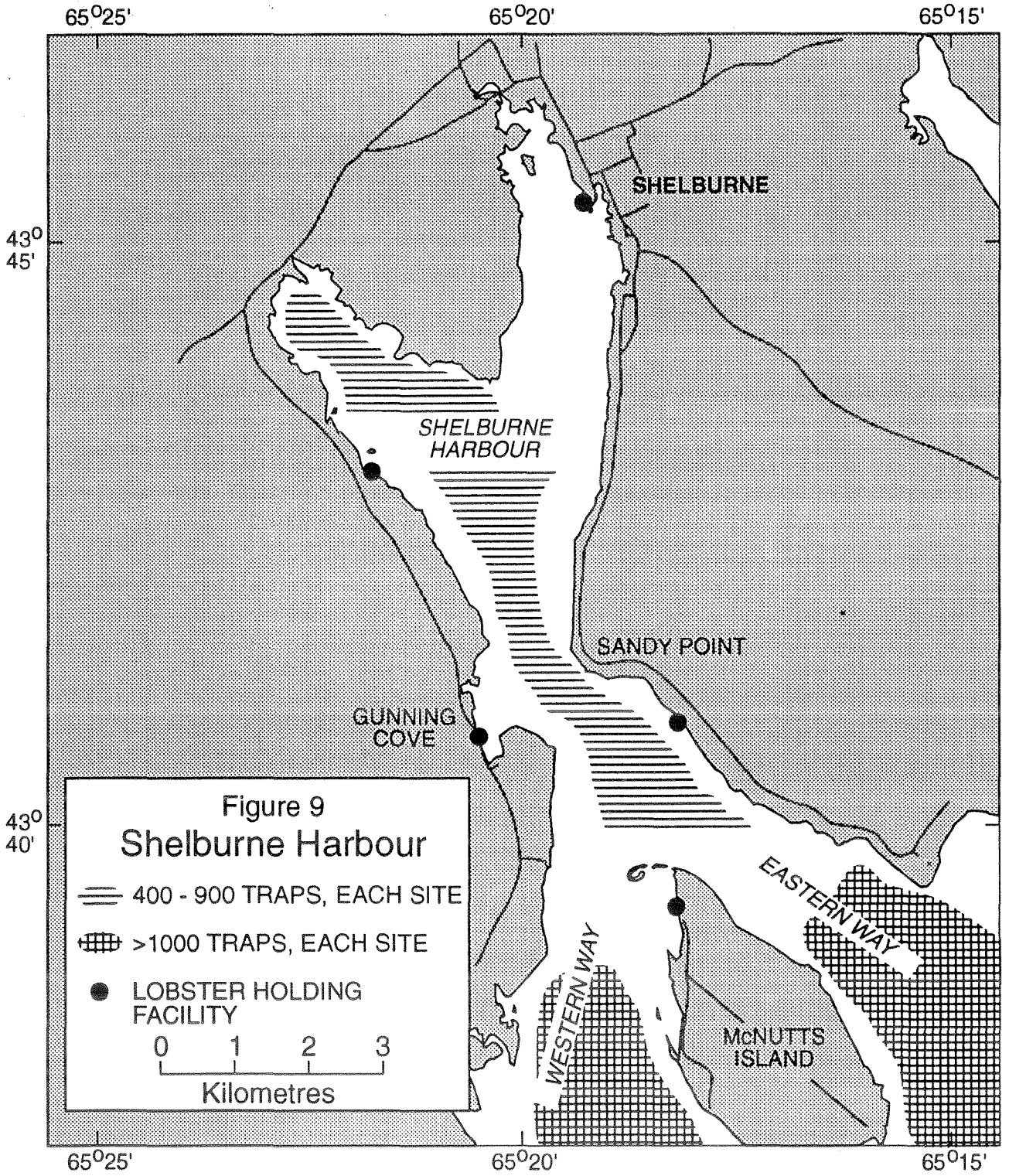


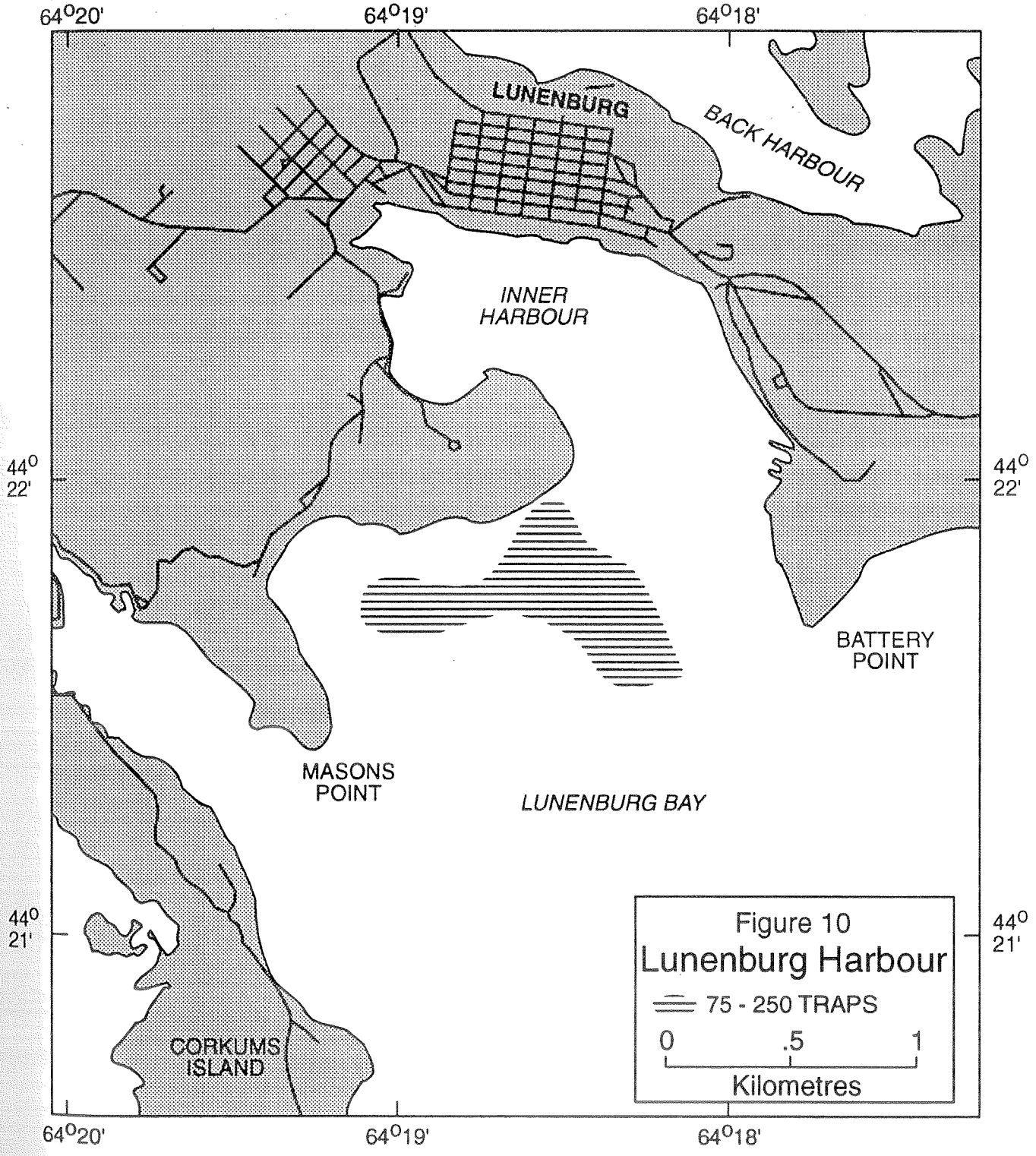
Figure 5
Pictou Harbour
6 - 30 TRAPS, EACH SITE
> 200 TRAPS
LOBSTER HOLDING FACILITY
0 2
Kilometres
62°45'
62°40'
62°35'
45° 44'
45° 42'
45° 40'
45° 38'
45° 36'
NORTHUMBERLAND STRAIT
LOGAN POINT
PICTOU ROAD
PICTOU
MACKENZIE HEAD
CHANCE HARBOUR
PICTOU LANDING
BOAT HARBOUR
WEST RIVER
CAUSEWAY
EAST RIVER
ABERCROMBIE
MIDDLE RIVER
GRANTON
TRENTON

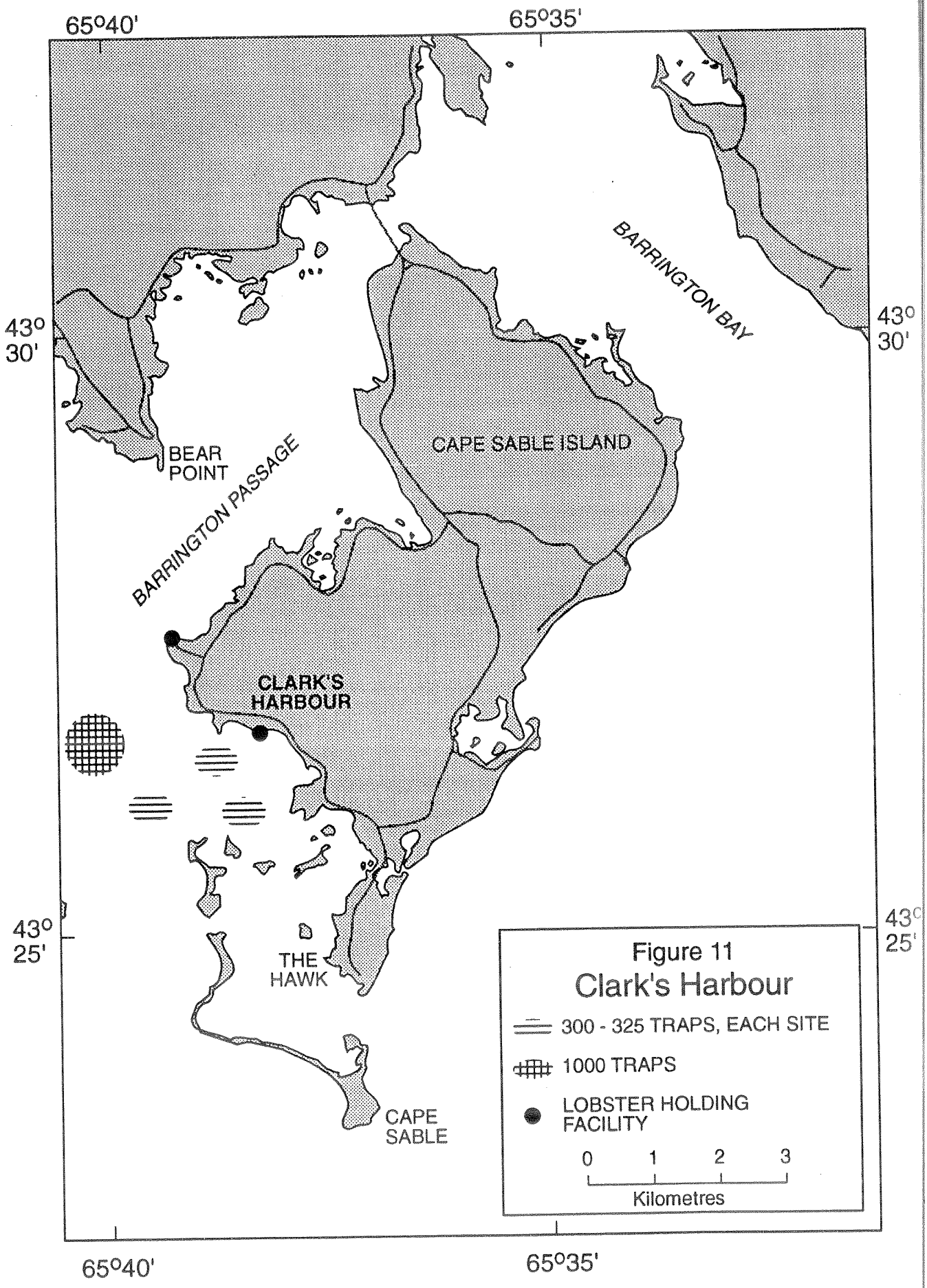

61°24'
61°22'
45° 44'
45° 38'
45° 42'
45° 40'
45° 38'
45° 36'
45° 36'
CAUSEWAY
Figure 6
Port Hawkesbury
(Ship Harbour)
10 - 60 TRAPS, EACH SITE
120 - 240 TRAPS
0
1
Kilometres
McNAIRS POINT
MULGRAVE
PORT HAWKESBURY
STRAIT OF CANSO
SHIP HARBOUR
POINT TUPPER
MADDEN POINT
PIRATE HARBOUR
PEEBLES POINT
61°24'
61°22'


66°24'
66°22'
66°20'
QUEBEC
48° 06'
RESTIGOUCHE RIVER
48° 04'
EAST BAY
DALHOUSIE
NEW BRUNSWICK
48° 02'
EEL BAY
EEL RIVER COVE
Figure 7
Dalhousie Harbour
320 TRAPS
0 1 2
Kilometres


63°45'
63°40'
44° 05'
44° 04'
BROOKLYN
EASTERN HEAD
LIVERPOOL BAY
LIVERPOOL
44° 05'
44° 02'
MOOSE POINT
44° 00'
44° 00'
WESTERN HEAD
43° 58'
43° 58'
Figure 8
Liverpool Harbour
600 - 750 TRAPS, EACH SITE
0 1 2 3
Kilometres
63°45'
63°40'


65°25'
65°20'
65°15'
43° 45'
43° 40'
SHELBURNE
SHELBURNE HARBOUR
SANDY POINT
GUNNING COVE
EASTERN WAY
WESTERN WAY
McNUTTS ISLAND
Figure 9
Shelburne Harbour
400 - 900 TRAPS, EACH SITE
>1000 TRAPS, EACH SITE
LOBSTER HOLDING FACILITY
0 1 2 3
Kilometres


64°20'
64°19'
64°18'
LUNENBURG
BACK HARBOUR
INNER HARBOUR
44° 22'
BATTERY POINT
MASONS POINT
LUNENBURG BAY
44° 21'
CORKUMS ISLAND
Figure 10
Lunenburg Harbour
75 - 250 TRAPS
0 .5 1
Kilometres


65°40'
65°35'
43°
30'
43°
25'
BARRINGTON BAY
BEAR
POINT
BARRINGTON PASSAGE
CAPE SABLE ISLAND
CLARK'S
HARBOUR
THE
HAWK
CAPE
SABLE
Figure 11
Clark's Harbour
300 - 325 TRAPS, EACH SITE
1000 TRAPS
LOBSTER HOLDING
FACILITY
0 1 2 3
Kilometres

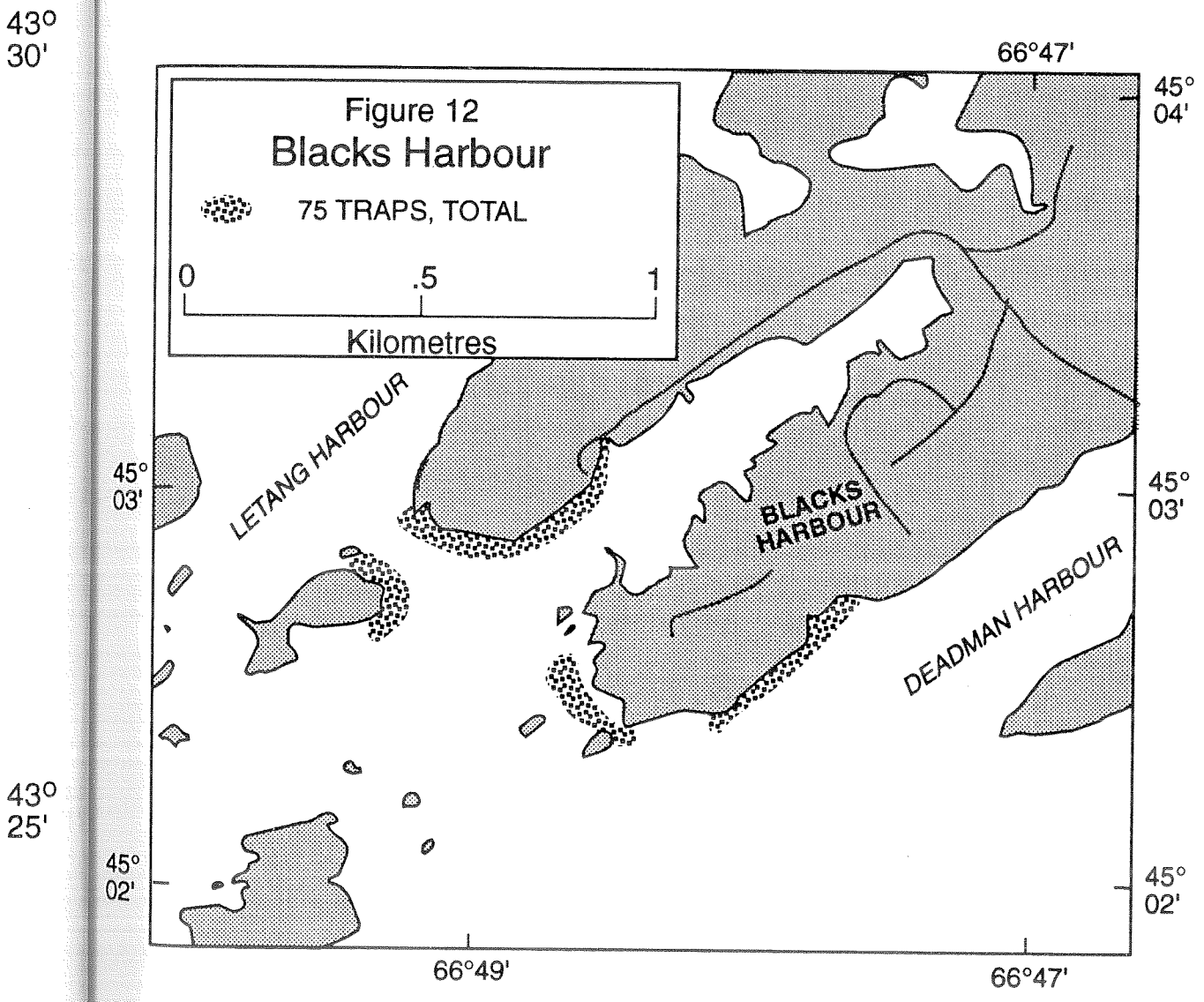
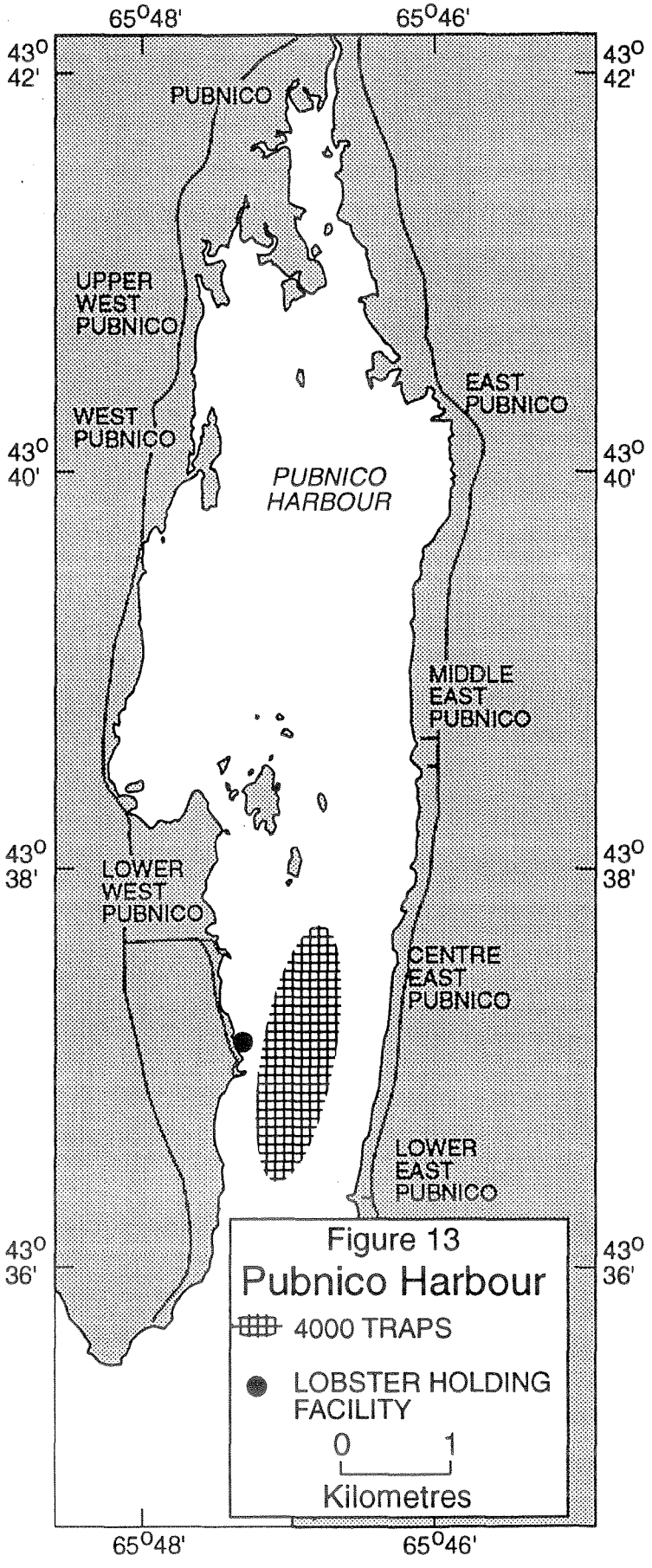
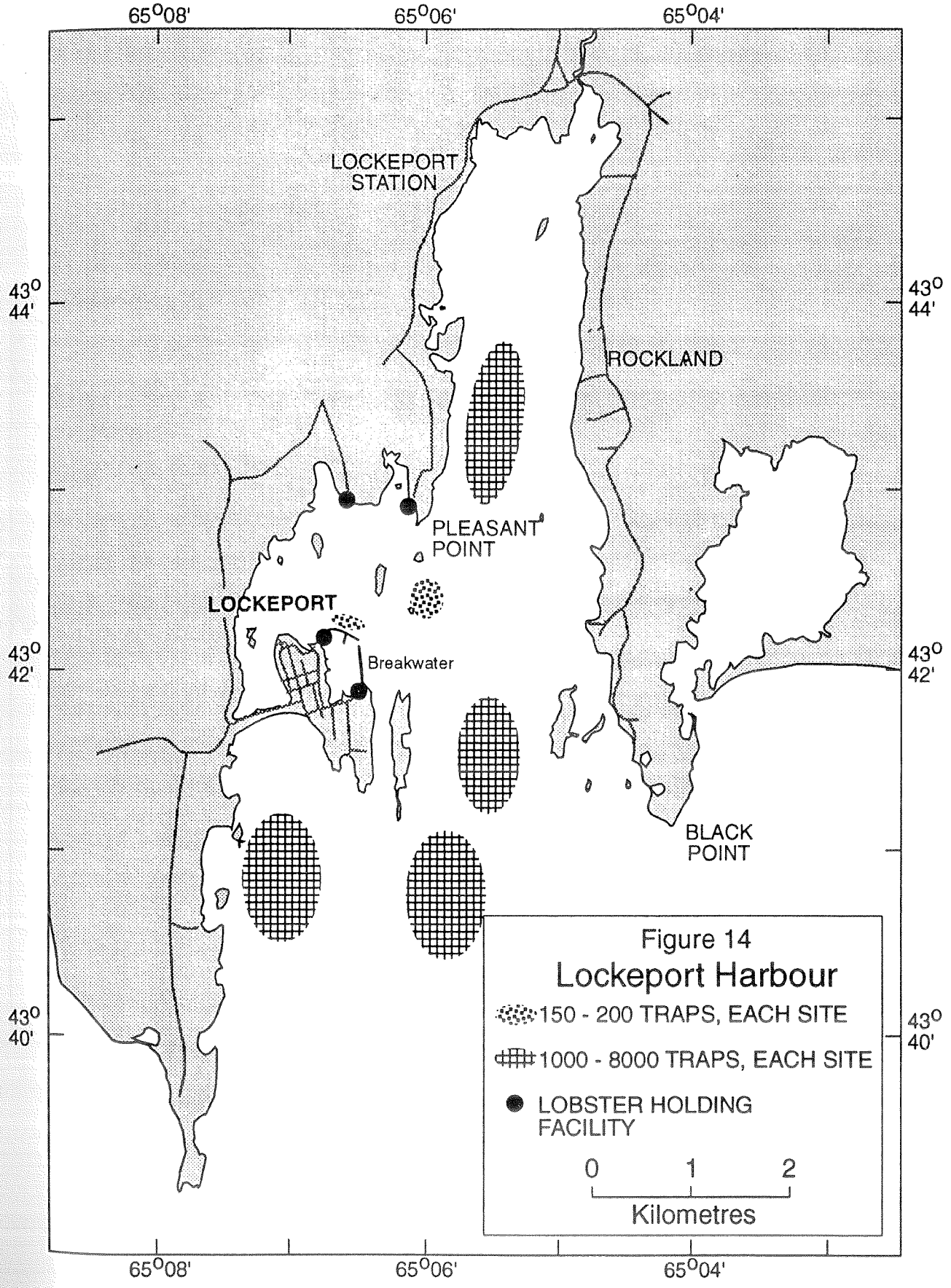
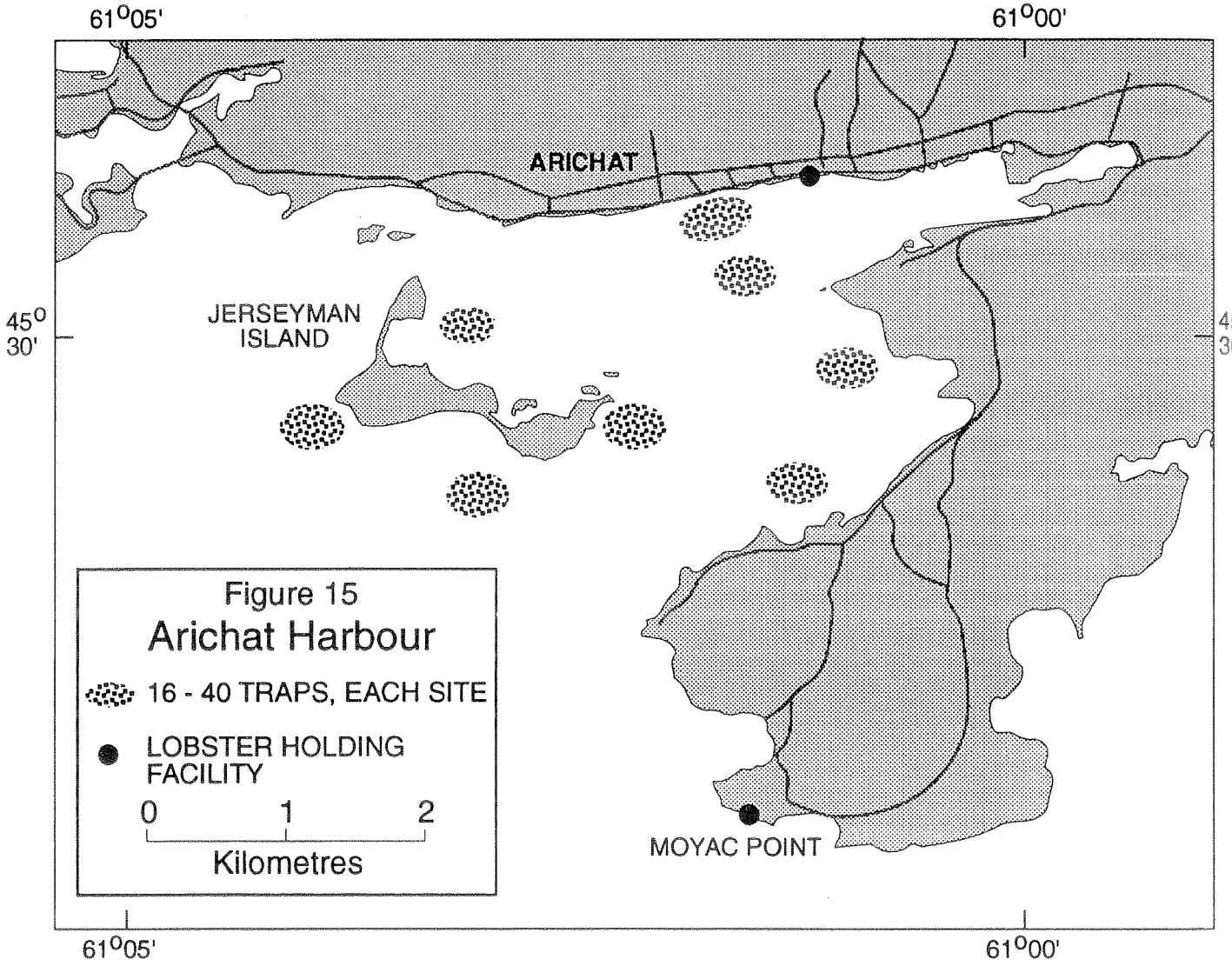


Figure 12
Blacks Harbour
75 TRAPS, TOTAL
0
.5
1
Kilometres
LETANG HARBOUR
BLACKS HARBOUR
DEADMAN HARBOUR
66°47'
45° 04'
45° 03'
43° 30'
43° 25'
45° 02'
66°49'
66°47'


65°48'
65°46'
43° 42'
43° 40'
43° 38'
43° 36'
PUBNICO
UPPER WEST PUBNICO
WEST PUBNICO
EAST PUBNICO
PUBNICO HARBOUR
MIDDLE EAST PUBNICO
LOWER WEST PUBNICO
CENTRE EAST PUBNICO
LOWER EAST PUBNICO
Figure 13
Pubnico Harbour
4000 TRAPS
LOBSTER HOLDING FACILITY
0 1
Kilometres


65°08'
65°06'
65°04'
LOCKEPORT STATION
43° 44'
ROCKLAND
PLEASANT POINT
LOCKEPORT
Breakwater
43° 42'
BLACK POINT
43° 40'
Figure 14
Lockeport Harbour
150 - 200 TRAPS, EACH SITE
1000 - 8000 TRAPS, EACH SITE
LOBSTER HOLDING FACILITY
0 1 2
Kilometres


61°05'
61°00'
ARICHAT
JERSEYMAN ISLAND
45° 30'
MOYAC POINT
Figure 15
Arichat Harbour
16 - 40 TRAPS, EACH SITE
LOBSTER HOLDING FACILITY
0 1 2
Kilometres

APPENDIX 2

TABLES

Table 1. Estimated lobster fishing and catch in major harbours in the Maritime Provinces. (Note: The commercial fishery deals in pounds [0.454 Kg].)

Harbour	# Boats Fishing Lobster	Total # Traps set·day^{-1}	Seasonal Catch (lbs)	Comments
Nova Scotia				
Digby		- no fishing in harbour		
Yarmouth		- no fishing in harbour		
Pubnico	24	4000	50000	
Clark's Harbour	30	625	125000	
Shelburne	11	1300	14000	to Gunning Cove
Lockeport	3	150	3000	outside breakwater
Liverpool	8	600	36000	in outer harbour
Lunenburg	3	250	9300	outer harbour
Halifax	68	7500	500000	mainly outer harbour
Sheet Harbour		- no fishing in harbour		
Canso		- no fishing in harbour		
Arichat	4	36	1400	poor to fair fishing
Port Hawkesbury	5	30	750	few scattered pots
Sydney	52	4250	200000	
Pictou	26	250	15000	outer harbour
New Brunswick				
Saint John	3	900	20000	medium effort
Blacks Harbour	5	75	2000	outer harbour
North Head, Grand Manan Island		- no fishing in harbour		
Dalhousie	3	320	2250	outer harbour
Bathurst		- no fishing in harbour		
Prince Edward Island				
Charlottetown		- no fishing in harbour		
Summerside		- no fishing in harbour		

Table 2. Point sources of PAHs from industries and utilities in harbours with lobster fishing in the Maritime Provinces (NRCC 1983; P. Lane & Associates Ltd. 1988; Lavalin Environnement 1988; O'Neill and Kieley 1992; Environment Canada, unpublished information).

Harbour	Point Source	Products
Nova Scotia		
Pubnico	-	
Clark's Harbour	-	
Shelburne	-	
Lockeport	-	
Liverpool	petroleum and coal products industry	asphalt
Lunenburg	-	
Halifax	2 oil refineries	petroleum
	petroleum and coal products industry	asphalt
	other steel industries	steel products
	oil-fired generating station	electric power
	industrial inorganic chemical industry	acetylene
Arichat	-	
Port Hawkesbury	oil refinery (closed)	
	coal-fired generating station	electric power
Sydney	steel mill	steel
	coke ovens, now closed	coke
	coal mining	
	industrial inorganic chemical industry	acetylene
Pictou	tire plant	rubber products
	coal mining	
	industrial inorganic chemical industry	chlorine, lye
	coal-fired generating station	electric power
	petroleum and coal products industry	asphalt

Table 2 (Continued)

Harbour	Point Source	Products
New Brunswick		
Saint John	petroleum and coal products industry	asphalt
	oil refinery	petroleum
	industrial inorganic chemical industry	acetylene
Blacks Harbour	-	
Dalhousie	industrial inorganic chemical industry	chlorine, lye
	coal/oil-fired generating station	electric power

Table 3. Population and sewage treatment in major harbours with lobster fishing (Anon. 1987; Statistics Canada 1986a & b).

Harbour	Population (1986)	Sewage Treatment Type	Flow ($m^3 \cdot day^{-1}$)	Percent Population Served
Nova Scotia				
Pubnico	818	lagoons	250	100
Clark's Harbour	1082	secondary	400	92
Shelburne	2700	secondary	1500	100
Lockeport	1200	secondary	410	88
Liverpool	3650	secondary	300	27
Lunenburg	3150	none	—	0
Halifax	122000	none	—	0
Dartmouth	80000	none	—	0
Eastern Passage				
Cole Harbour	25000	primary	12000	80
Bedford, Sackville	35600	secondary	13200	84
ΣHalifax Harbour	262600	limited	25200	19
Arichat	900	secondary	600	100
Port Hawksbury	4500	secondary	1400	100
Sydney	35000	none	—	0
North Sydney	7800	none	—	0
Sydney Mines	9000	none	—	0
ΣSydney Harbour	51800	none	—	0
Pictou	4630	none	—	0
Abercrombie	590	none	—	0
Westville	4520	secondary	3500	77
Trenton + Stellarton + New Glasgow	19050	secondary	14700	100
ΣPictou Harbour	28790		18200	78
New Brunswick				
Saint John	80521	secondary	4550	49
Blacks Harbour	1356	none	—	0
Dalhousie	5707	lagoons	5460	96

Table 4. Industrial and commercial activity in major harbours in the Maritime Provinces (New Brunswick Department of Economic Development and Tourism 1992; Nova Scotia Department of Economic Development 1992).

Harbour	# Manufacturing and Processing Firms	Total Employment	Major Commercial/Industrial Activity
Nova Scotia			
Pubnico	6	209	fishing, fish products
Clark's Harbour	14	331	fishing, fish products, boat building and repair
Shelburne	15	522	fishing, fish products, boat building and repair, machine shop industry
Lockeport	3	98	fishing, fish products
Liverpool	13	1015	fishing, fish products, newsprint, machinery and equipment industries
Lunenburg	16	1679	fishing, fish products, shipbuilding and repair, machinery and equipment industry
Halifax	394	9348	food and beverage industries, plastic products, transportation and equipment industries, refined petroleum, other petroleum industries, printing, publishing, and allied industries, ship building and repair, fabricated metal product industries
Arichat	5	240	fishing, fish products
Port Hawkesbury	7	1590	newsprint industry
Sydney	95	2656	steel plant, fishing, fish products, coal mining, non-metallic mineral products
Pictou	55	3979	rubber products, pulp industry, primary metal industries, industrial inorganic chemical industry, coal mining, other petroleum and coal products, fish products

Table 4. (continued)

Harbour	# Manufacturing and Processing Firms	Total Employment	Major Commercial/Industrial Activity
New Brunswick			
Saint John	142	9940	chemical and chemical products industry, food and beverage industries, refined petroleum products, pulp and newsprint industries, fabricated metal product industries, shipbuilding and repair
Blacks Harbour	1	50	fishing, fish products
Dalhousie	8	1099	industrial inorganic chemical industry,newsprint industry

Table 5. Ship traffic recorded as number of vessel movements, international and domestic shipping by port, 1991 (Statistics Canada 1992). Included are cargo movements (arriving and departing with cargo) and ballast movements (no cargo unloaded when arriving or loaded when leaving). Not recorded are cargo vessels under 15 gross registered tons, tugs, naval or fishing vessels, research vessels, and tow boats. (-) indicates no registered movements for the port.

Harbour	Shipping- Number of Vessel Movements International	Domestic	Total
Nova Scotia			
Pubnico	-	-	-
Clark's Harbour	-	-	-
Shelburne	68	42	110
Lockeport	-	-	-
Liverpool	101	5	106
Lunenburg	6	0	6
Halifax	3022	826	3848
Arichat	-	-	-
Port Hawkesbury	237	39	276
Sydney	408	152	560
Pictou	11	18	29
New Brunswick			
Saint John	1271	500	1771
Blacks Harbour	118	0	118
Dalhousie	130	13	143

Table 6. Number and tonnage of Canadian Fishing Vessels (CFV's) in harbours with lobster fishing in the Maritime Provinces (DFO Statistics 1992, unpublished data).

Harbour	Number of CFV's	Total Tonnage
Nova Scotia		
Pubnico	141	7269
Clark's Harbour	187	3263
Shelburne	197	21104
Lockeport	120	3553
Liverpool	52	3371
Lunenburg	88	27457
Halifax	86	3689
Arichat	79	1076
Port Hawkesbury	4	4
Sydney	132	10964
Pictou	9	-
New Brunswick		
Saint John	35	740
Blacks Harbour	19	1834
Dalhousie	7	-

Table 7. Scores for ranking the potential for PAH contamination of lobster in major harbours in the Maritime Provinces. (Total score = (a) + (b) + (c) + (d) + (e). Maximum score indicating the highest potential is 20.)

Harbour	(a) Point Sources	(b) Population	(c) Industrial Activity	(d) Shipping	(e) CFVs	Total Score
Nova Scotia						
Pubnico	1	1	1	1	3	7
Clark's Harbour	1	1	2	1	4	9
Shelburne	1	2	3	3	4	13
Lockeport	1	1	1	1	3	7
Liverpool	2	2	4	3	2	13
Lunenburg	1	2	4	2	2	11
Halifax	4	4	4	4	2	18
Arichat	1	1	1	1	2	6
Port Hawkesbury	3	2	4	4	1	14
Sydney	4	4	4	4	3	19
Pictou	4	4	4	2	1	15
New Brunswick						
Saint John	4	4	4	4	1	17
Blacks Harbour	1	1	1	3	1	7
Dalhousie	3	3	4	3	1	14