Fisheries and Environment Canada

Environmental Protection

Pêches et environnement Canada

Protection de l'environnement

Environmental Assessment of an Ocean Dumpsite in the Strait of Georgia, B.C., Canada

Environmental Impact and Assessment
Report EPS 5-PR-77-2

Pacific Region
February 1977

ENVIRONMENTAL PROTECTION SERVICE REPORT SERIES

Surveillance reports present the results of monitoring programs carried out by the Environmental Protection Service. These reports will usually be published on a regular basis.

Other categories in the E.P.S. series include such groups as Regulations, Codes and Protocols, Policy and Planning, Technical Appraisal, Technology Developments Surveillance and Reprints of Published Papers.

Inquiries pertaining to Environmental Protection Service Reports should be directed to the Environmental Protection Service, Department of Fisheries and the Environment, Kapilano 100, Park Royal, West Vancouver, B.C. V7T 1A2.

ENVIRONMENTAL ASSESSMENT OF AN OCEAN DUMPSITE

IN THE

STRAIT OF GEORGIA, BRITISH COLUMBIA

by

Richard A.W. Hoos

Environmental Protection Branch
Environmental Protection Service
Pacific Region

Report Number EPS 5-PR-77-2
February, 1977

ABSTRACT*

During the period 1975-76, Environment Canada undertook an investigative program to assess the effects of the ocean disposal of a variety of wastes upon the receiving environment at a designated ocean dumpsite located in 250 metres of water, 4 miles west of the City of Vancouver, British Columbia. The wastes disposed were dominated by native uncontaminated and polluted dredged spoils, but also included construction rubble, excavation material, and forest industry residue. Now under government control, the site continues to be used for the disposal of these materials from trailing suction hoppers, bottom unloading barges, and scows equipped with clamshells, bulldozers, and/or front-end loaders.

The program investigated many components of the receiving environment, including the water column, the water-sediment interface, and the sediments, as well as examining organisms inhabiting these zones. Water-bottle casts, benthic grab and core sampling beam trawls, and manned submersible visual and photographic procedures were among the assessment techniques employed.

General preliminary conclusions are that the site appears to be suitable for the ocean disposal of the wastes in question, and that the deleterious impacts upon the resident biological communities are minimal. However, careful continued surveillance and monitoring of this area are required in order to ensure that dumping is carried out where designated, since a valuable trawl fishery exists in the waters between the dumpsite and the City of Vancouver. It is also necessary to ensure that levels of chemical contamination of the sediments and resident organisms remain at or below current levels.

Information gaps identified by this preliminary study were examined with a view toward extending the program to include analysis of concerns such as possible long-term (chronic) effects upon the receiving environment. Studies of this nature are presently being undertaken.

* Presented at the 7th World Dredging Conference,
San Francisco, California, July, 1976.

RÉSUMÉ

Au cours de 1975-1976, Environnement Canada a entrepris des recherches pour déterminer les effets, sur le milieu d'accueil, de l'immersion océanique de déchets dans un lieu de décharge à 250 m de profondeur et à 4 milles à l'ouest de la ville de Vancouver (Colombie-Britannique). Les déchets déversés étaient surtout d'origine végétale, non altérés, soit pollués, soit non contaminés; toutefois, ils contenaient aussi des débris de construction, des déblais et des résidus de l'industrie forestière. A l'heure actuelle, sous contrôle gouvernemental, on continue à utiliser cette décharge pour immerger les détritus entassés dans des trémies aspirantes remorquées ou encore sur des chalands à fond mobile ou transportant des bennes preneuses, des bullodozers ou des tracteurs à bennes frontales.

Ce programme a permis d'examiner de nombreux éléments du milieu d'accueil: entre autres, la masse d'eau verticale, la surface de contact entre l'eau et les sédiments, les sédiments eux-mêmes ainsi que les organismes vivant dans ces habitats. Parmi les méthodes d'évaluation utilisées, il convient de mentionner les prélèvements d'eau, les échantillonnages d'éléments benthiques et le carottage, les chaluts latéraux et les méthodes d'observation et de photographie sous-marines directes.

Les conclusions provisoires indiquent que la zone semble convenir à la décharge océanique des déchets considérés et que les communautés biologiques n'en subissent que des inconvénients minimes. Cependant, il faut continuer d'exercer, dans la région, une surveillance et un contrôle attentifs pour s'assurer que le déversement se fait exactement à l'endroit prévu. Il se pratique, en effet, un

chalutage de grande valeur dans les eaux s'étendant entre la décharge et la ville de Vancouver. Il faut aussi s'assurer que le taux de contamination chimique des sédiments et des organismes qui vivent dans ce milieu ne s'élève pas au-dessus du niveau actuel.

Des lacunes dans les données, révélées par cette étude préliminaire, ont fait l'objet d'un examen dans le but d'étendre le programme à des considérations telles que les incidences durables (ou chroniques) possibles de la décharge sur le milieu d'accueil. On est en train d'amorcer des études de cet ordre.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

On December 13, 1975, Canada promulgated the Ocean Dumping Control Act, thereby committing itself further to the International London Convention signed by 80 countries in 1972. Environment Canada was assigned the mandate to administer the provisions of the Act, including the establishment of a permit system to regulate the loading (for the purposes of dumping) and the disposal of wastes at sea. The legislation applies to the ocean disposal of most types of materials from ships, aircraft, and platforms operating in Canadian territorial or internal waters, and all Canadian vessels anywhere in the world. The only exceptions are disposal that is incidental to or derived from the normal operations of a ship or an aircraft, and, any discharges that are incidental to or derived from the exploitation of, and associated off-shore processing of sea bed mineral resources.

In anticipation of the forthcoming Act, the need to assess the effects of dumping, and the necessity to designate dump sites, the Environmental Protection Service of Environment Canada undertook a field program at one of the largest active sites currently in use in British Columbia. This particular location, Point Grey (Figure 1), had been identified as a dump site by the Ministry of Transport, in consultation with resource agencies, in 1970. It was selected on the basis of marine navigation requirements, deep water, and proximity to the lower mainland. Prior to the present study, no field investigation of this location had been undertaken.

In the past, the Point Grey area had been used mainly for the disposal of dredged material from the lower Fraser River and Vancouver harbour. The incomplete records show that, since the 1930's, in excess of three million cubic yards (2.3 million cubic metres) of silt, sand, gravel, construction rubble, and wood debris have been deposited at or close to the site. The current annual rate of deposition is estimated at 500,000 cubic yards (383 thousand cubic metres).

The objectives of the preliminary study program were to assess the physical, chemical, and biological characteristics of the receiving environment as a consequence of past and continuing disposal of solid wastes.

2 METHODS AND MATERIALS

2.1 Description of the Study Area

The designated dump site is delineated by a circular boundary with a 1-mile (1.6 km) radius, centred at 49°15.45'N, 123°22.10'W in the Strait of Georgia, roughly 4 miles (6.4 km) west of Point Grey, British Columbia (Figure 1). Water depths at this site vary from 210 to 275 metres, with an average of approximately 250 m. The study area extended 2 miles (3.2 km) beyond the dump site boundary, having a radius of 3 miles (4.8 km) and encompassing approximately 28 square miles (73 km squared).

The physical oceanography of this region of the Strait of Georgia is greatly influenced by the freshwater input from the Fraser River. Winds, tidal action, and currents impose secondary effects.

The deep-water sediments of the lower strait, including the study area, are typically silts and clays (Pharo, 1972), becoming more coarse with increasing proximity to the foreslope of the Fraser delta and the mainland. Although the delta front at the main arm of the Fraser River is advancing at a rate of approximately 3.5 m/yr laterally, and 30.5 cm/yr vertically, there has been no evidence of delta advancement in the study area since 1968 (Luternaur, personal communication). It is, therefore, assumed that the rate of natural sediment accretion at the dump site is very low.

The principal fish resources of the area are the 5 species of salmon, steelhead trout, eulachon and smelt, which migrate through the strait into the Fraser River system, and herring. The 30 to 100 m contours along the western front of Point Grey and Sturgeon Banks provide a habitat for substantial populations of 6 species of shrimp, which are commercially harvested with small-meshed trawls.

2.2 Research Vessels

The 1975-76 field program was carried out in three distinct phases as a result of available ship-time and study requirements. The vessels used and the tasks completed during each phase were as follows:

Phase 1:	"B.C. Trapper"	
	May 1-7, 1975	- physical oceanographic sampling
	May 22 - June 9, 1975	- quantitative benthic biota and sediment chemistry grab sampling
Phase 2:	"C.F.A.V. Laymore"	
	June 14-15, 1975	- Qualitative macrobenthic and sediment chemistry core sampling
Phase 3:	"Pandora II and Pisces IV"	
	January 22-24, 1976	- submersible observations and photography

2.3 Physical Oceanography

Water column sampling was carried out during slack tide over two days at nine stations as identified in Figure 2. Samples were collected at standard oceanographic depths (surface, 2, 5, 10, 25, 50, 100, 200, 250 m, or bottom) with a series of nine Nansen bottles, equipped with protected reversing and standard centigrade thermometers.

Immediately upon completion of each cast, temperatures were read and recorded, being corrected for thermal expansion of mercury later. Sub-samples for dissolved oxygen analyses were field-fixed and titrated in the laboratory using the azide modification of the Winkler method (Davidson et al, 1974). Dissolved oxygen values in mg/l were converted to percent saturation using the equation of Gameson and

Robertson (1955). Salinity and suspended solids (or non-filterable residue, i.e., NFR) sub-samples were also obtained. Salinities were measured with a refractometer, while NFR values were determined by weighing the dried residue (dried at 103°C for one hour) remaining on 0.45 micron filters.

2.4 Sediment Grab Sampling

A 0.17 metre squared Petersen grab sample of bottom sediment was obtained at each of the fifty stations illustrated in Figure 3. Each sample was immediately placed in a polyproplylene tub, hand mixed, the total volume determined, and sub-samples removed for biological and chemical examination.

One six-litre aliquot of mud from every station was sieved by washing with seawater through a 0.5 mm screen, the retained material being preserved in 70% isopropyl alcohol.

In the laboratory, sieving was repeated. The remaining residue was sorted, identified, and quantitatively enumerated with a dissecting microscope and biological keys.

Sub-samples for chemical analyses were frozen as soon as possible prior to laboratory work-up. All sediment samples to be analyzed for trace elements were thawed, air-dried under cover at room temperature, disaggregated with a ceramic mortar and pestle, and sieved through an 80-mesh nylon sieve (2.5 phi). Portions of the less than 80-mesh fractions were then forwarded to the laboratory of Dr. W.K. Fletcher (Department of Geology, University of British Columbia), where they were digested in a 4:1 nitric-perchloric acid mixture, evaporated to dryness over an air-bath, taken up in 1.5 m HCL, and analyzed for cadmium (Cd), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), nickel (Ni), silver (Ag), and zinc (Zn) with a Perkin-Elmer 303 atomic absorption spectrophotometer. Background corrections were used in the

determination of Co, Ni, and Pb. Sub-samples for mercury analyses were retained pending the acceptance of an improved analytical method presently being evaluated by the Environment Canada laboratory.

Organic carbon content was determined by thawing samples at room temperature, drying at 103°C, grinding with mortar and pestle to pass through a 0.5 mm screen, digesting with a chromic acid-sulphuric acid mixture, and titrating with ferrous sulphate (Holme and McIntyre, 1971). Sediment size was determined by wet sieving through a screen series to a minimum mesh of 230 (63 microns). The fraction passing through the final screen was obtained by back-calculation.

2.5 Core Sampling

Bottom cores were obtained with a Benthos gravity corer at the 35 stations shown in Figure 3. Upon retrieval, the intact cores were extruded onto polyethylene liners, the lengths measured, and 5-centimeter core sections cut out at desired depth intervals (0-5 cm, 50-55 cm, and bottom 5 cm). These samples were then pre-treated and chemically analyzed as described previously under the sediment grab sampling section.

2.6 Macrobenthic Survey

Qualitative samples of the macrobenthos inhabiting the study area were obtained with a 3-metre beam trawl having mesh sizes ranging from approximately 2 cm at the mouth to 0.5 cm at the cod-end. Numerous trawls were attempted, but only the six runs shown in Figure 4 could be considered successful. All trawls fished approximately one-half a nautical mile of bottom, based on estimates of downtime and a vessel speed of 2 knots. Upon retrieval, the samples were photographed, qualitative observations recorded, and representative specimens preserved in 70% isopropyl alcohol or by freezing, for subsequent identification.

2.7 Submersible Observations and Photography

The "Pisces IV" submersible was obtained to provide visual and photographic observations of the study area. A total of six transects of varying lengths were completed (Figure 4). The dives were carried out during that time of year which best afforded clear visibility. Transects were selected primarily on the basis of data obtained previously from the grab-sampling and beam-trawling phases of the program.

The "Pisces IV" was equipped with externally mounted, remote-controlled video and 70 mm still (Hydro Products) cameras, while internally a scientific observer interpreted and recorded visual observations directly onto the video tape system and took 16 mm cine film with a Bolex camera. Each track was recorded on video tape, while 70 mm colour photographs and 16 mm tungsten colour film were taken of characteristic and/or unique features, including the range of demersal and benthic organisms encountered.

3 RESULTS AND DISCUSSION

Due to the extensive nature of the program and the data base generated, no attempt will be made to present all the information obtained at this time. The complete results will be published in a subsequent departmental report, which should be available by the end of 1976. For the purposes of this paper, the key features are reviewed.

3.1 Physical Oceanography

Figure 5 summarizes the water column temperature, salinity, and oxygen regimes obtained at the nine stations sampled during the May oceanographic survey.

Surface water temperatures at this time ranged from 10.36 to 12.53°C, the lower temperatures having been registered at stations sampled as the tide was turning to flood (see Figure 2, Stations 13, 25, 29, and 41). Generally, the thermocline occurred between 5 and 10 metres. However, at Stations 25, 29, and 41 a thin layer of cool water was "sandwiched" between two warm layers. This phenomenon was attributed to the combined effect of the Fraser River outflow and tidal action. Below the thermocline, temperatures gradually decreased. Between 25 metres and the bottom of the water column (200-250 m), temperatures ranged between 7.00 and 8.00 at all stations, with a mean of 7.57°C.

Water column salinities recorded at Stations 9, 11, 15, 27, and 31 revealed the presence of a thin surface lens of low-salinity water (17.5 - 19.5 ‰) extending no deeper than 2 metres. This observation is characteristic of the study area and, indeed, much of the lower Strait of Georgia, and results primarily from the discharge of less dense fresh water from the Fraser River to the strait. The seaward-moving surface layer gradually becomes more saline as a consequence of mixing at the sheer interphase between fresh and sea water (Waldichuk, 1957, (a) and (b); Hoos and Packman, 1974).

Below the top two metres, salinities rapidly increased to a depth of 10 metres, where the mean salinity for all stations was 29.0‰. Below this halocline, salinities gradually increased with depth to near 31.0 ‰ at 250 metres.

Dissolved oxygen concentrations at the surface ranged from 9.5 to 10.5 mg/l. The lower surface values were found at stations sampled on the rising tide, that is, those with more saline water. The oxycline generally occurred between the surface and 25 metres. Below this depth, oxygen concentrations diminished more slowly, with bottom values (200-250 m) ranging between 6 and 7 mg/l. Dissolved oxygen, expressed as percent saturation, ranged from a surface high of 114% at Station 27, to a bottom (250 m) low of 62% at Station 31.

Non-filterable residue concentrations at all stations and depths were generally low (mean of < 6 mg/l), with elevated values restricted to the surface (maximum of 36 mg/l at Station 9). These higher surface levels could be attributed to the input of sediment-laden fresh water from the Fraser River. However, as Waldichuk (1967) indicated, the transition zone between the fresh, turbid water of the Fraser River and the saline, clearer water of the Strait of Georgia generally occurs at a salinity of 15 ‰ . Therefore, one could assume that most of the sediment fractions contributed by the river had already been precipitated, with only the finest clay particles remaining in suspension.

In summary, the water quality sampling confirmed that the oceanography of the study area is dominated by the Fraser River estuary and the input of fresh water generally containing silt and clay particles. Secondary physical factors, such as local winds, barometric pressure, tides and currents, affect the subsequent distribution and dispersion of the inflowing fresh water.

With this information forming part of the preliminary data base, Environment Canada carried out dispersion studies at the Point Grey site, involving the disposal of dredged material from a suction hopper and clamshell material discharged from moving barges. This information is presently being collected and will be reported at a future date.

3.2 Sediment Characteristics and Chemistry

3.2.1 Grab Samples. The sediment-size analyses of the 50 grab samples obtained from the study area indicated that at all stations the prime components of the sediment were the silts and clays (< 63 microns). In fact, over the 50 stations, this component accounted for an average of 93.7% of the total sediment. However, since most of the material dumped at, and in the vicinity of, the dump site was of a coarser nature, an examination of the distribution of the larger size fractions proved more revealing (Figure 6). The coarser surface sediments were concentrated primarily in the north east section of the study area. Undoubtedly, the proximity of the north-arm outflow of the Fraser River to this area and the shoaling trend encountered as one proceeded to the east and northeast would have some impact on the size of the bottom sediments in this region. However, the physical description of many of the larger components (including lumps of hardpan clay, chunks of granite, brick, concrete and pavement, glass, rusting metal, wood debris, etc.) confirmed that the material picked up from these stations probably originated from the disposal of material by clamshell dredging operations.

The fact that much of the debris was found outside the designated dump site suggested that the materials may have drifted off-site when dumped, that the materials were disposed at this site prior to the establishment of the dump site, and/or that materials had been dumped there since the designation of the site.

Our investigation revealed that it was probably a combination of all three factors.

The organic content of the sediments from all 50 stations was low but typical (Clague, 1975), with an average value of only 1.37% and a maximum of 1.61% at Station 20. This suggested that the continuous deposition of wood debris and fibrous material in the vicinity of the dump site was not having a great impact upon the organic content of the bottom sediments.

The trace element analyses of the grab samples (representing the top 20 cm of the sediment) showed surprisingly few definite trends or areas of concentration. This was not expected, as the levels found in some of the dredged material on barges, prior to dumping, were often quite high (Environment Canada, unpublished data).

Of the nine elements examined, only copper and zinc concentrations appeared to be related to the main dumping area as identified by debris deposits. Figure 7 illustrates the distribution of copper in the surface sediments. Concentations ranged from a low of 37.1 micrograms per gram of sample at Station 3 (west of the north-arm jetty) to a maximum of 69.3 micrograms per gram of sample at Station 27 (on the eastern perimeter of the dump site), with a mean of 45.1 micrograms per gram of sample. Most of the elevated levels were found in the northeast quadrat. A similar distribution was recorded for zinc, with values ranging from a low of 87.5 micrograms per gram of sample at Station 42 (nearest the Iona jetty) to a high of 126.1 micrograms per gram of sample at Station 45 (northeast, outside dump site), with a mean value of 106.5 micrograms per gram of sample.

The only other element to show a distribution trend was manganese. Concentrations tended to increase with increasing distance from the mainland. This might be the result of manganese precipitation from the fresh water of the Fraser River.

Cobalt, iron, lead, and nickel data showed these elements to be randomly distributed in the surface sediments (see Figure 8 as an example). Silver and cadmium were below the detection level of 1.0 micrograms per gram of sample at all stations.

3.2.2 Core Samples. Table 1 summarizes the trace element results generated from the 35 gravity-core samples collected. Despite the long period of sediment build-up, cobalt, iron, and nickel concentrations appear to have remained fairly constant. The results for copper, lead, and zinc, however, show a definite trend, with the highest concentrations being found at the surface, and then gradually decreasing with increasing depth.

Elderfield and Hepworth (1975) report that observations of approximately 10% metal enrichment at the sediment surface compared with deeper sections cannot necessarily be interpreted as evidence for recent anthropogenic (pollutant) input and may be a consequence of sediment diagenesis. Our preliminary statistical analyses of the copper and zinc core data substantiate their findings.

Summarizing the trace-element data (both grab and core), it would appear that copper and zinc may be building up in the surface sediments (top 20 cm) of the northeast quadrat of the study area. This could be at least partially attributable to the deposition of contaminated dredged material. Lead levels in the top 5 cm throughout the study area seemed to be elevated in excess of concentrations normally attributable to natural source inputs and sediment biogenesis.

A comparison of the analytical results from the present study with those reported by Grieve and Fletcher (1975) for the Fraser River foreslope reveals that trace elements at the dump site were generally higher than those on the foreslope. This would corroborate their findings that these metals (with the exception of nickel) generally increase westward and northward on the foreslope, and appear to follow

TABLE 1 TRACE METAL CONCENTRATION RANGES IN CORE SAMPLES

	Surface Section (0-5 cm)					Mid-section (50-55 cm)					Bottom (last 5 cm) (mean length 73 cm)				
	Lowest Concentration	Station Number	Highest Concentration	Station Number	Mean	Lowest Concentration	Station Number	Highest Concentration	Station Number	Mean	Lowest Concentration	Station Number	Highest Concentration	Station Number	Mean
Cobalt µg/g	10.4	46	16.1	35	13.5	10.2	45	15.8	50	13.6	10.6	43	16.4	36, 33	13.80
Copper µg/g	38.3	6	59.5	10	45.9	37.8	30	49.9	43	43.2	37.6	50	50.3	39	41.88
Iron %	2.8	8	3.8	32, 33	3.4	2.8	10	4.0	31	3.5	2.7	8	3.8	32,39, 43,44 47	3.50
Manganese µg/g	291.2	44	373.8	1	330.3	283.7	30	366.7	31	319.0	286.1	37	369.4	39	326.40
Nickel µg/g	41.3	33	53.9	39	48.6	39.1	29	54.7	8	48.2	40.1	5	61.9	46	49.20
Lead µg/g	11.2	4	27.7	10	18.2	7.4	45	17.9	31	12.9	4.3	44	15.0	4	10.42
Zinc µg/g	87.5	3	113.1	40, 47	102.3	87.3	32	105.0	45	95.6	84.5	30, 32	104.1	39	90.60

the trend for sediment-grain size (that is, to diminish with increasing distance from the slope). Extending this further, it should be noted that the maximum concentrations of all trace elements found in the study area were still considerably lower than those reported for typical deep--sea clays of the Atlantic and Pacific oceans (Turekian & Wedepohl, 1961).

Because there are still many questions regarding the ultimate fate of the trace elements bound to materials disposed at this and other sites, Environment Canada has now extended the program to include investigations of contaminant build-up in the food chains, and an examination of the chemical interactions between elements and particles at the sediment-water interface and within the sediments.

3.3 Quantitative Benthic Fauna

Representatives from a total of 44 taxonomic groups (identified to genus for Echinodermata and Mollusca, and family for other Phyla) were identified from the 50 quantitative Petersen grab samples collected. In general, the infauna was dominated by polychaetes (worms), notably the sedentary maldanids (bamboo worms). The bivalves (clams: *Nucula* sp. and *Macoma* sp.) were also usually present in substantial numbers, as were holothurians (sea cucumbers: *Chiridota* sp. and *Molpadia intermedia*), the ophiuroid (brittle star, *Ophiura* sp., and the echinoid (heart urchin, *Brisaster latifrons.*

Figures 9, 10, and 11 illustrate the abundance distributions per square metre for the bamboo worms (Maldanidae), the brittle star (*Ophiura* sp.), and the sea cucumber (*Chiridota* sp.). Maldanids were found at 38 stations, but tended to concentrate in the eastern half of the study area, the greatest number (44 per square metre) being recorded at Station 1 in the northeast sector (Figure 9). *Ophiura* sp. were present at 35 stations, being most numerous in grabs from the northern half, with a maximum of 227 per square metre at Station 44 (Figure 10).

Chiridota sp. were recorded at 29 stations, with concentrations in the eastern portion of the dump site at Station 35 (110 per square metre) and in the northeast at Station 10 (94 per square metre).

The free-moving errant polychaetes were more numerous in grabs from the southern and southeastern portions of the survey area, although they were found throughout. They were most numerous at Station 3, which had the highest percentages of medium and fine-grained sand particles of the stations studied. The coarseness of the sediment at this site was attributed to its proximity to the Fraser River foreslope. However, errant forms were not particularly abundant in grabs from the northeast section, even though this area was also characterized by relatively high percentages of coarse sediments.

Sedentary polychaetes were most prevalent in samples from the eastern half of the survey area, with relatively few occurring in the sandy sediment of Station 3. They were relatively numerous in the area having most of the debris deposited by dumping activities.

3.4 Qualitative Macrobenthic Survey

The beam trawls, although qualitative, provided valuable information regarding the nature of the bottom, and on the demersal fish and macrobenthos inhabiting the area. Seven genera of bottom fish were collected, the most common being sole (probably Parophrys vetulus), short-spine thornyhead (Sebastolobes alascanus), and ratfish (Hydrolagus colliei). Of the macrobenthos encountered, the most abundant organism was the sea cucumber (Chiridota sp.). In fact, they were so plentiful that the net literally became clogged with them during each trawl. This was particularly interesting, since the large numbers were not forecast by the results of the benthic grab sampling, thus demonstrating the value of applying several sampling techniques when assessing an area. The starfish (Mediaster aequalis) was common in the three southern trawls while the brittle star (Ophiura sp.) appeared to be more abundant

from the center of the dumpsite to the north. Some shrimp (Crangon sp. and Pandalus sp.) and a few prawns (Pandalus platyceros) were also collected, but not in substantial numbers. Thirty-three other genera of invertebrates were also represented in the beam trawl catches, but none could be considered common.

Considerable wood debris was found in the trawls from Stations 1, 29, and 41, and some was present at Station 13. Trawling at Stations 9 and 25 was abandoned because the net was torn by objects littering the bottom. In fact, because of the likelihood of the sampling gear being damaged or perhaps lost, no trawls were attempted over the concentrated dumping area in the northeast section. The general picture of the bottom that began to emerge was one of a mud substrate with animal populations typical for this depth and area, but which was littered with large objects such as boulders, chunks of concrete and pavement, some scrap metal, and considerable wood debris.

3.5 Submersible Observations and Photography

During the course of the "Pisces" dives, approximately eight hours of videotape, two hours of 16 mm film, and 350 still photographs were generated, as well as many visual impressions not recorded by any of the aforementioned media. This information is presently being examined and edited, to be retained as a permanent photographic record of conditions as they existed in 1976.

In many ways the "Pisces" dives confirmed the insights gained from examination of the material collected by the beam trawl and benthic grab surveys. Relatively little dumped material was found within the dump site boundary, and virtually none occurred in the southern and western hemispheres. Epibenthic life and demersal fish were scarce in these areas. The benthos of all transects was deduced to be primarily infaunal owing to the abundant burrows and castings occurring on the mud surface.

Most of the debris noted had been deposited in the northern and eastern sections of the study area, with considerably more occurring outside, than inside, the limits of the designated dump site. Within the boundary, the most common materials found were lumps of hardpan clay and some wood debris, including a few deadheads. Outside the dump site, particularly along tracts 3, 3a, and 4, there were large quantities of construction rubble (including concrete pillars, reinforcing rods and cables), dredged material, and wood wastes. In some areas, regular mounds up to 2 metres high were found. These larger deposits were presumably the result of dumping by bottom-dump barges, the only likely mechanism whereby mounds of this scale could be generated. As would be expected, the deposits were randomly distributed, although more were present along transects 3, 3a, and 4.

With regard to the biological communities inhabiting the areas of concentrated debris, exposed objects such as deadheads, concrete blocks, scrap iron, etc., were attractive to many of the epibenthic macrofauna, including anemones, shrimp, and prawns, as well as to various species of fish. Apparently, the nooks and crannies provided niches with a measure of protection from predators, as well as firm substrates for the attachment of certain sessile organisms. This is a typical phenomenon experienced in the construction of artificial reefs in shallow waters and around shipwrecks. Many of the deadheads encountered were in an advanced state of decay, primarily due to heavy shipworm (Bankia sp.) infestations. Several were also covered in unidentified fungal and/or bacterial growths. In two instances, hundreds of large snails (Neptunea sp.) were found on logs covered with this growth. It is not yet clear whether the snails were feeding on the fungal and/or bacterial matter, or whether they were simply exhibiting a swarming behavior for mating purposes.

The numerous holes and castings indicative of infaunal populations of polychaetes, holothurians, echinoids, and crustacea prevailed throughout the study area, including those sites where concentrated

dumping had occurred. In fact, they were even found over all the large mounds described earlier, suggesting that infaunal recolonization of smothered areas was taking place.

The relatively shallower depths and the presence of noticeable bottom currents (as opposed to the negligible water movements typical of the dump site) along tracks 3, 3a, and 4, have apparently provided optimum conditions for ophiuroids. A dense population was found covering the bottom, including the areas of deposition, along the entire length of these transects.

In summary, "the Pisces dives" confirmed that the majority of the material dumped off Point Grey was, in fact, not found at the designated site, but rather to the northeast, toward the City of Vancouver. Many of the areas surveyed with "Pisces" were impossible to sample with trawling gear due to the variety of debris on the bottom. However, this debris did not appear to be adversely affecting the epibenthic macrofauna and served to attract to these areas many of the major life forms found. Nevertheless, these conclusions should not be considered a sanction for ocean disposal in sites other than those officially designated. In many locations, including the Point Grey area, a valuable trawl fishery exists in the more productive near-shore regions. Should such areas be littered with debris, fishermen would find it impossible to trawl their nets over the bottom.

REFERENCES

Clague, J.J. (1975). Quaternary Geology, Northern Strait of Georgia, British Columbia, in Report of Activities, Part B, Geological Survey of Canada, Paper 75-1.

Davidson et al, (1974). Environment Canada Laboratory Manual.

Elderfield, H. and A. Hepworth (1975). Diagenesis, metals and pollution in estuaries. Marine Pollution Bulletin 6 (6).

Gameson, A.L.H. and K.J. Robertson (1955). The solubility of oxygen in pure water and sea-water. Journal of Applied Chemistry (5): 502.

Grieve, D. and K. Fletcher (1975). Trace metals in sediments of the Fraser River delta front, British Columbia. Department of Supply and Services Contract #01SU-23233-4-0210 for Geological Survey of Canada.

Holme, N.A. and A.D. McIntyre (1971). Methods for the study of marine benthos. International Biological Program. Handbook No. 16. 334.

Hoos. L.M. and G.A. Packman (1974). The Fraser River Estuary: Status of environmental knowledge to 1974. Special Estuary Series No. 1. Environment Canada.

Pharo, C.H. (1972). Sediments of the central and southern Strait of Georgia. Ph.D. Thesis, University of British Columbia.

Turekian and Wedepohl (1961). Distribution of the elements in some major units of the earth's crust. Geological Society of America Bulletin 72 (3).

Waldichuk, M. (1957)(a). Oceanography of the Strait of Georgia. VII. Water Masses. Pac. Coast. Stn., Fish. Res. Bd. Can. Prog. Rept. (108): 3-6.

Waldichuk, M. (1957)(b). Physical oceanography of the Strait of Georgia, J. Fish. Res. Bd. Can. 14 (3): 321-486.

Waldichuk, M. (1967). Currents from aerial photography in coastal pollution studies. Advances in pollution research. Proc. 3rd.

Intern. Conf. on Water Pollution Res., Munich, Germany. September 5-9, 1966. 3: 263-284 discussions pp. 284-294. Water Pollution Control Federation, Washington, D.C.

ACKNOWLEDGEMENTS

The author would like to thank all individuals who participated in this work, particularly V. Bradshaw, N. Holman, and G. Packman, as well as the masters and crews of "C.F.A.V. Laymore", "B.C. Trapper", "Pandora II", and "Pisces IV".

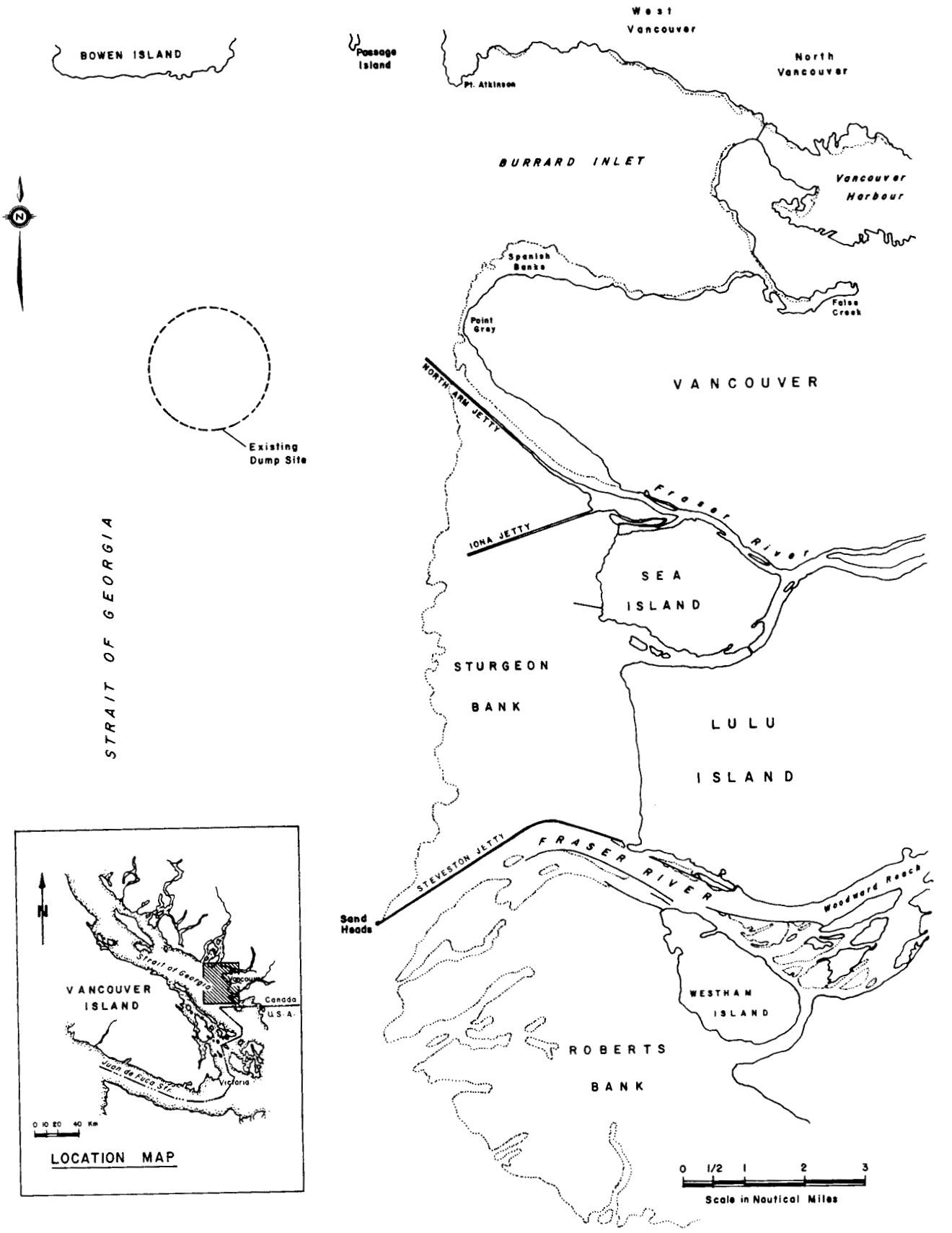

FIGURE I POINT GREY DUMP SITE

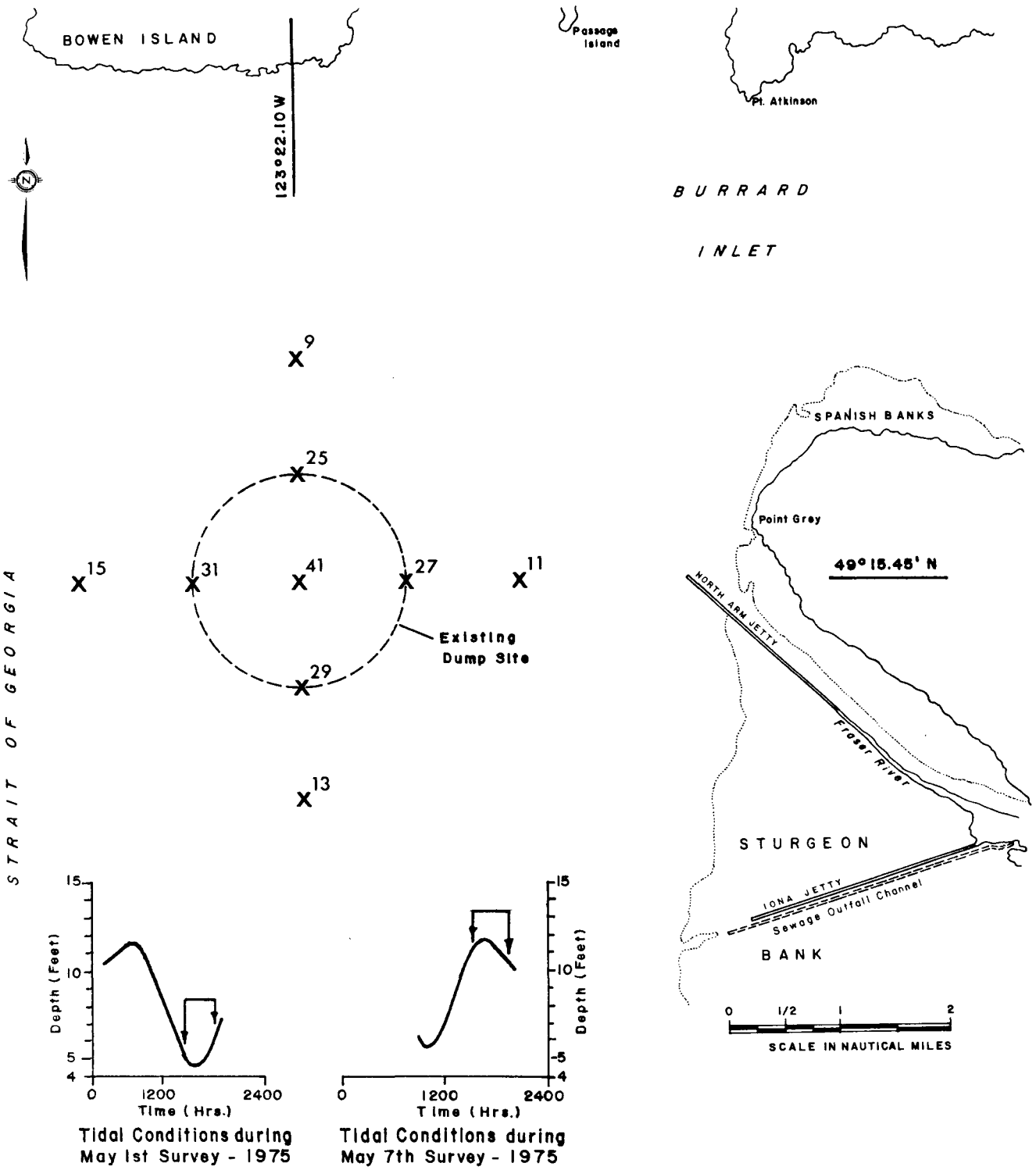

FIGURE 2 WATER COLUMN SAMPLING STATIONS - PREVAILING TIDAL CONDITIONS

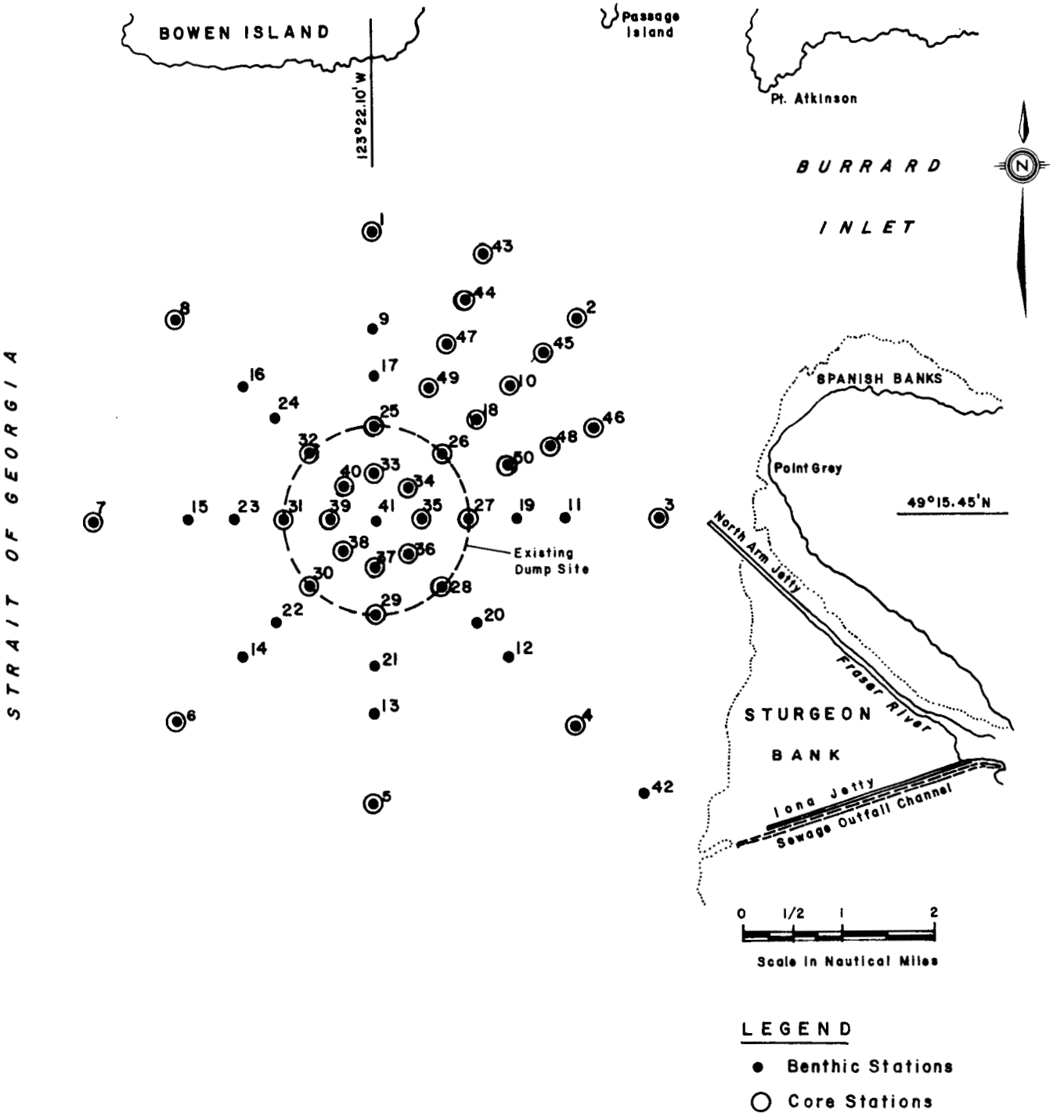

FIGURE 3 BENTHIC GRAB AND SEDIMENT CORE STATIONS

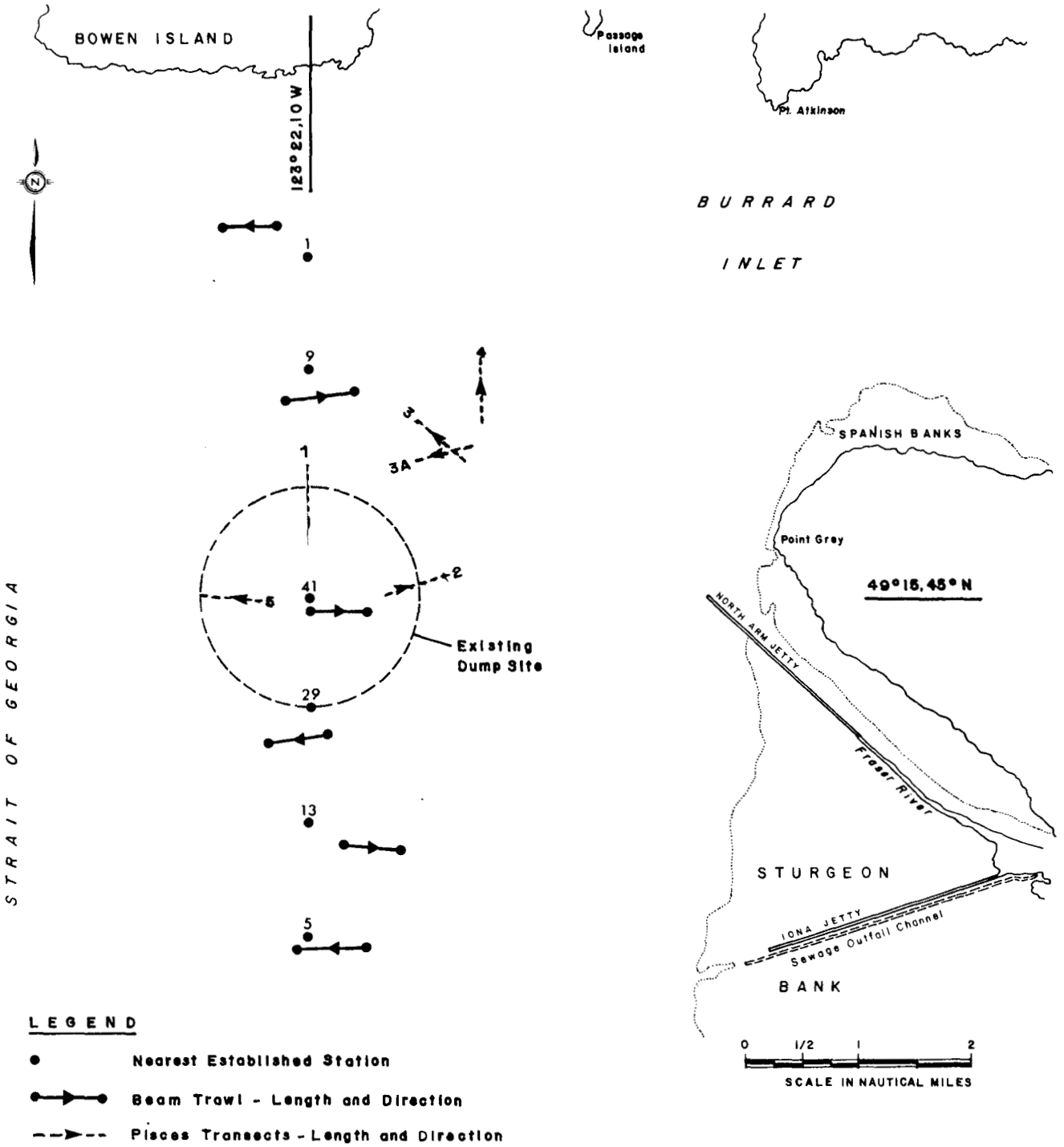

FIGURE 4 BEAM TRAWL AND PISCES IV TRANSECTS

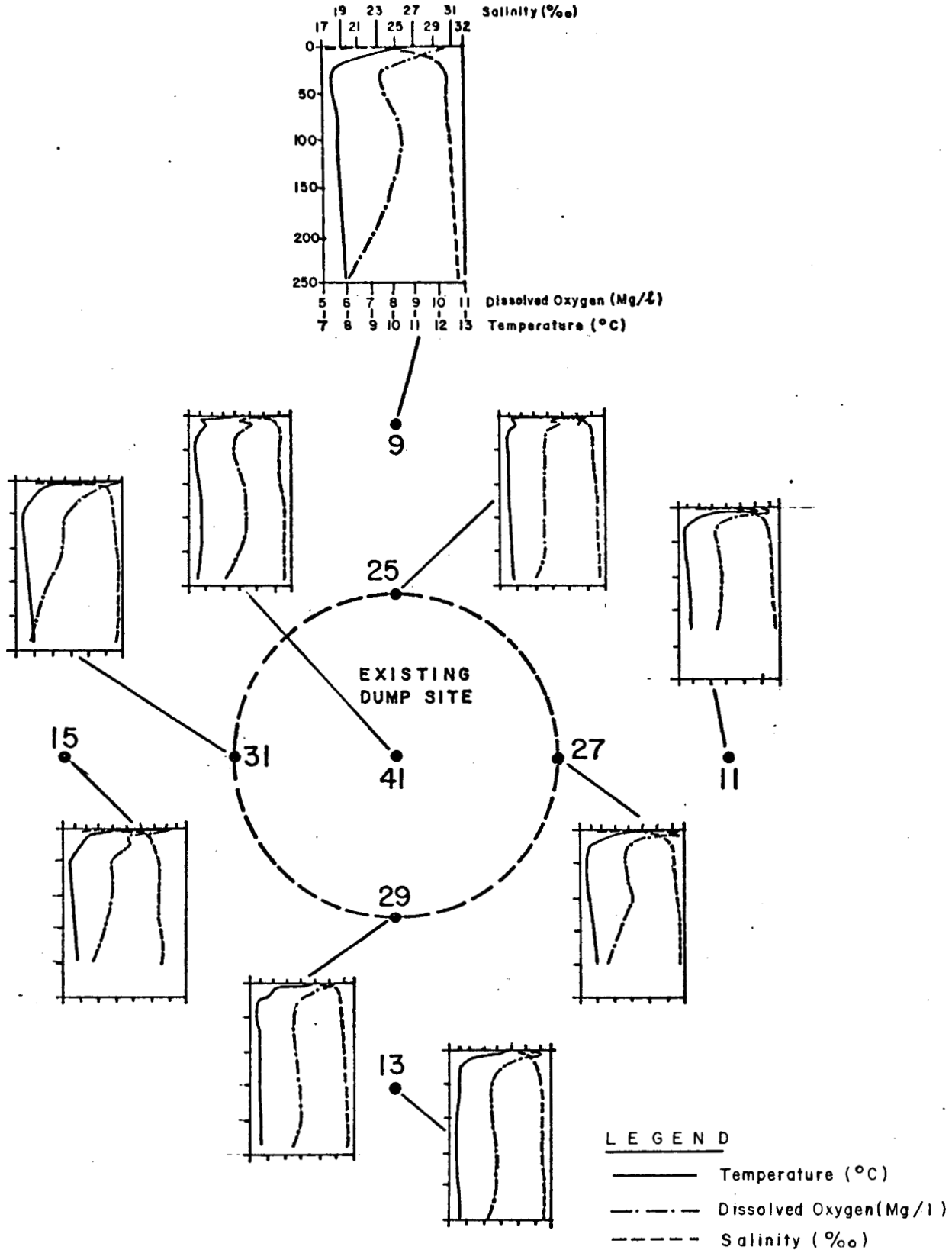

FIGURE 5 WATER COLUMN TEMPERATURE, SALINITY, AND DISSOLVED OXYGEN PROFILES

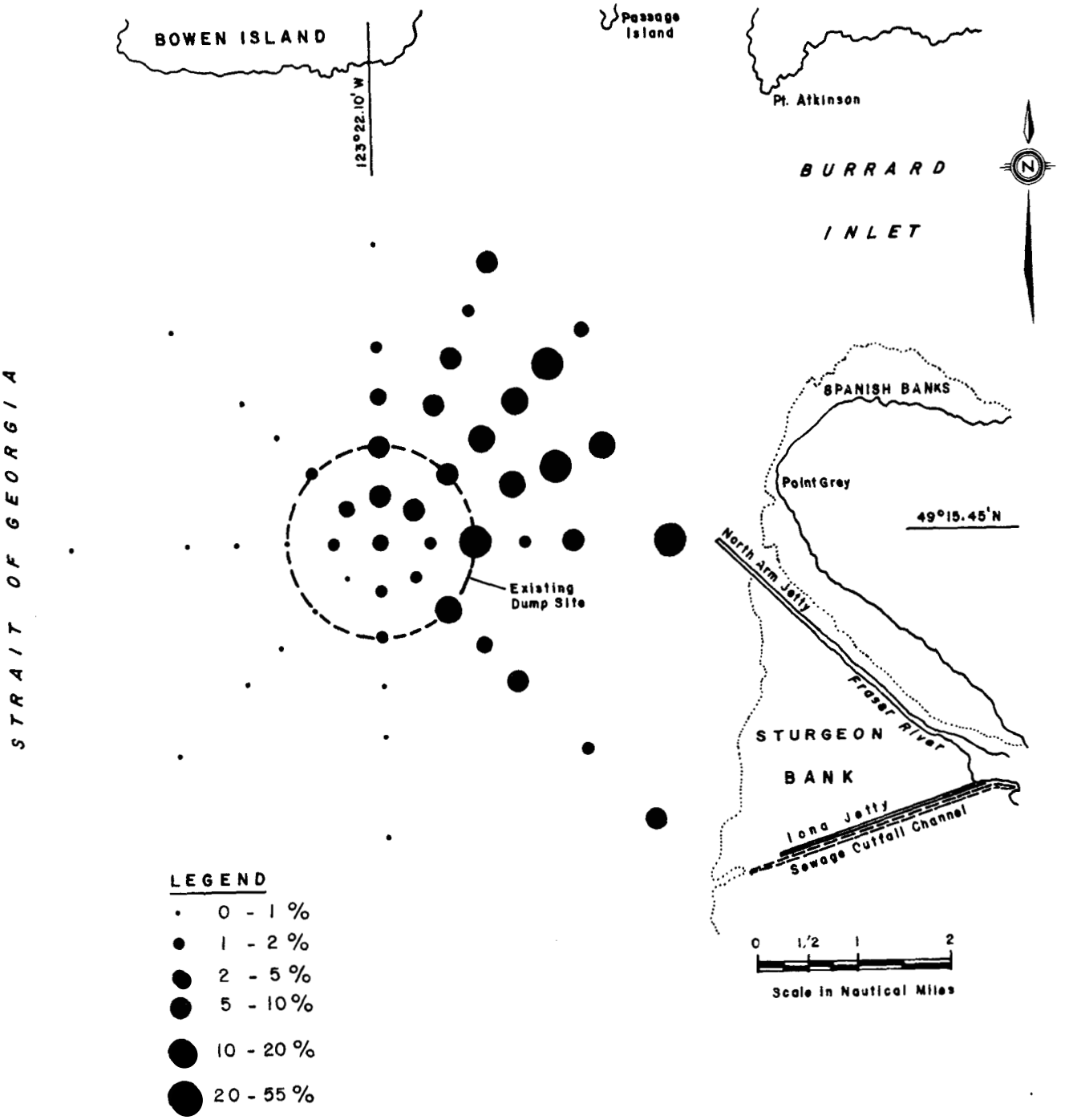

FIGURE 6 PERCENT OF SEDIMENT GREATER THAN 63 μ (SILTS AND CLAYS)

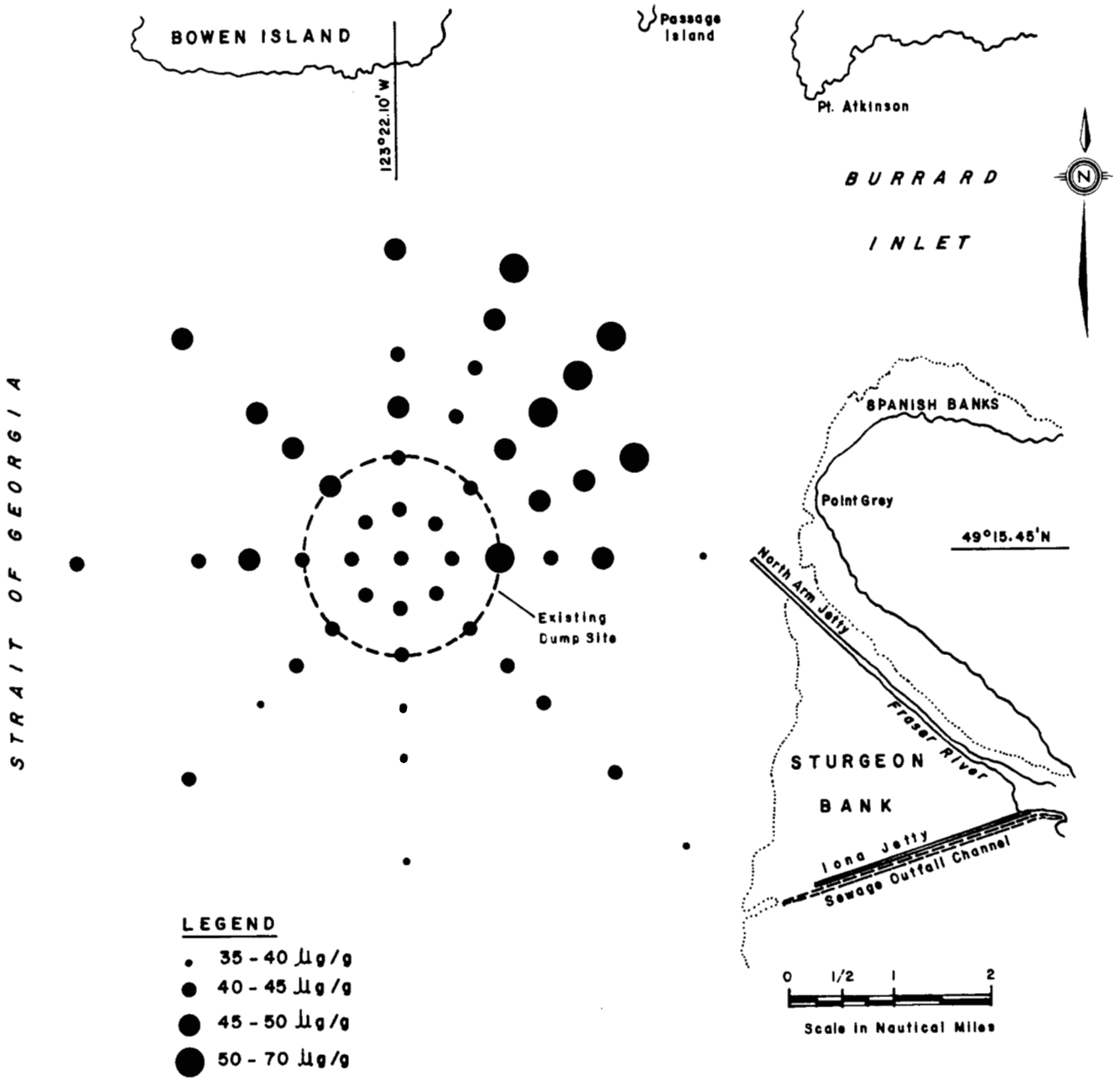

FIGURE 7 CONCENTRATION OF COPPER IN THE SURFACE (TOP 20 cm) SEDIMENTS

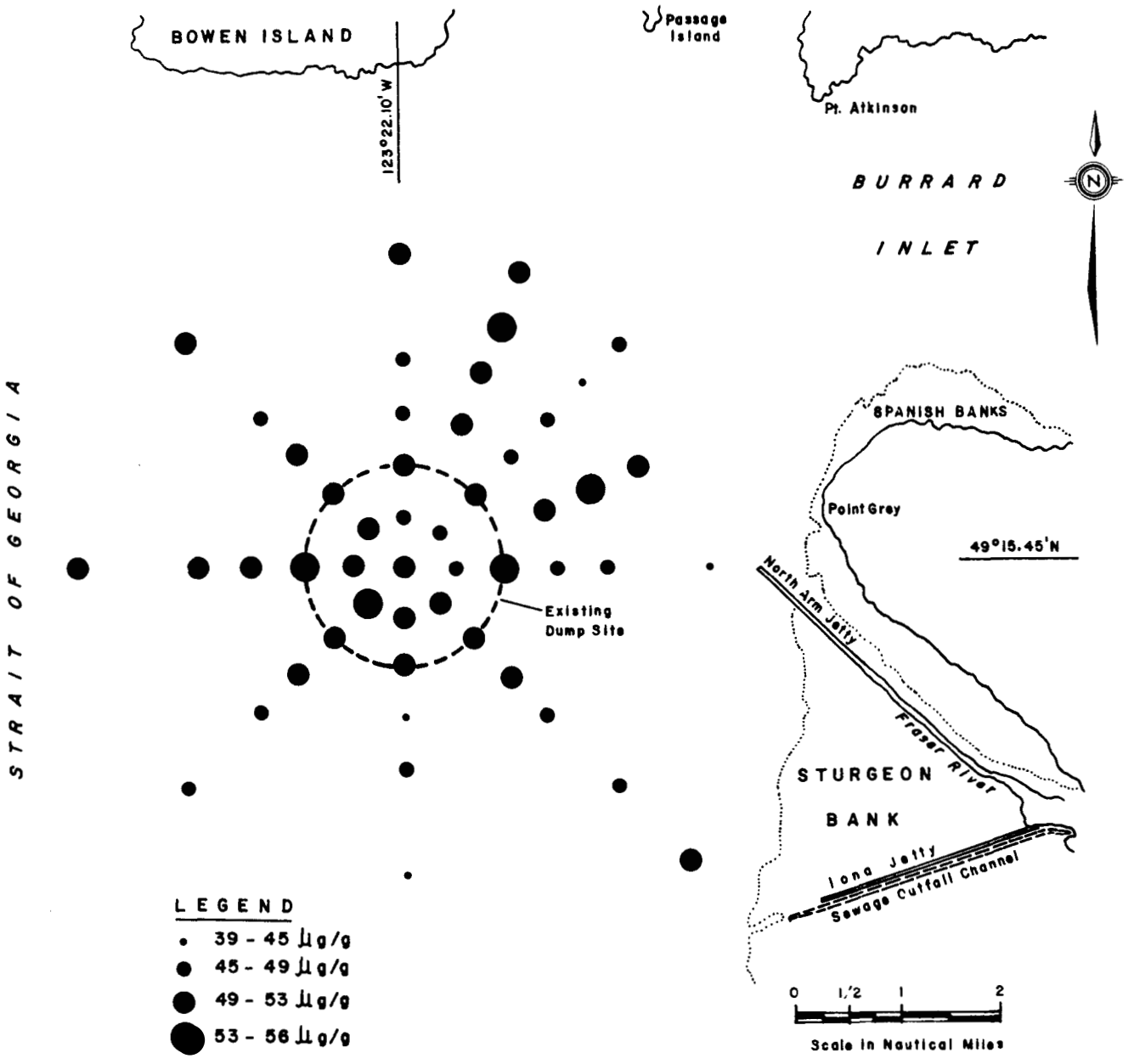

FIGURE 8 CONCENTRATION OF NICKEL IN THE SURFACE (TOP 20 cm) SEDIMENTS

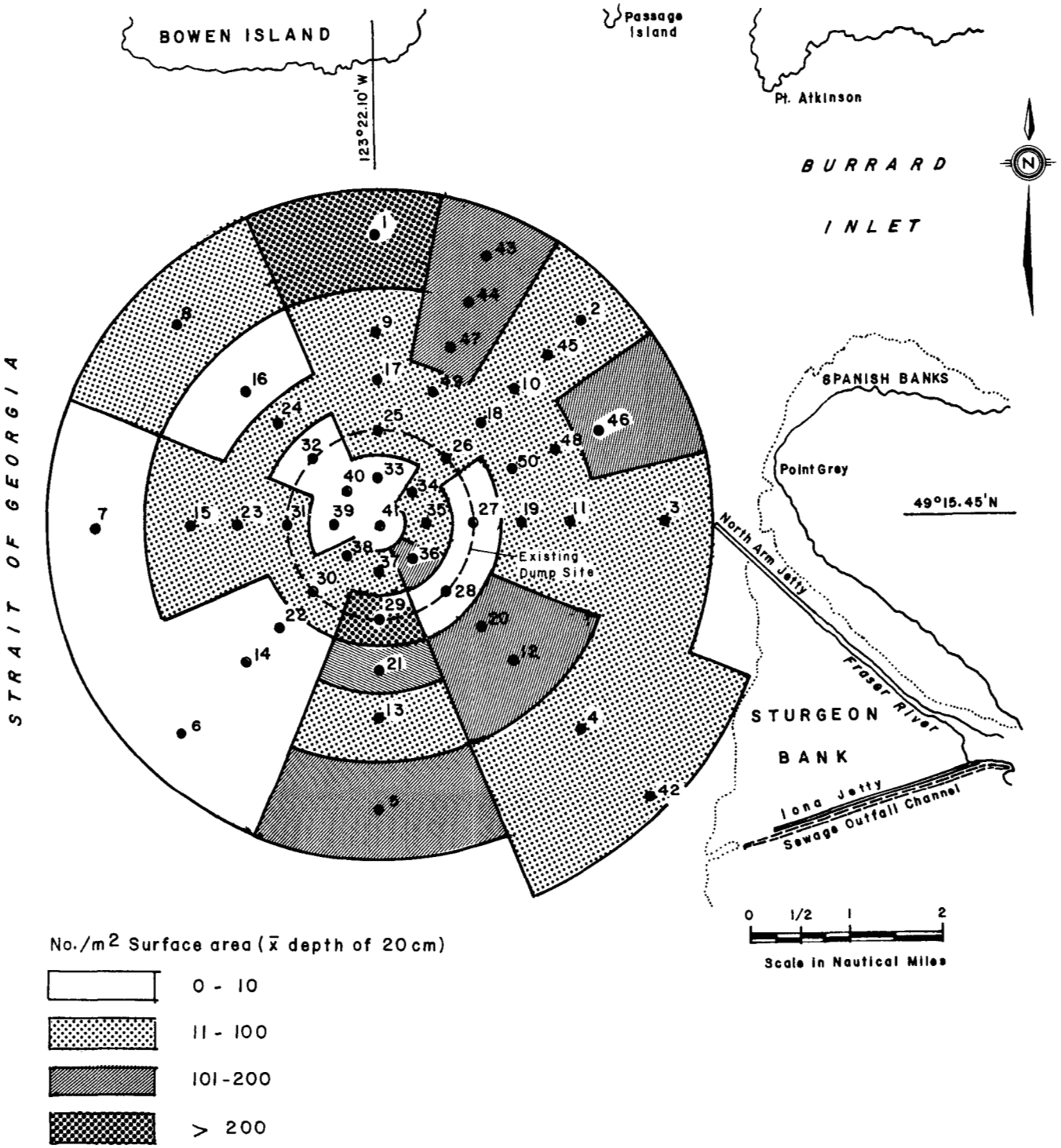

FIGURE 9 DENSITY OF Maldanidae AS DETERMINED FROM PETERSEN GRAB SAMPLES

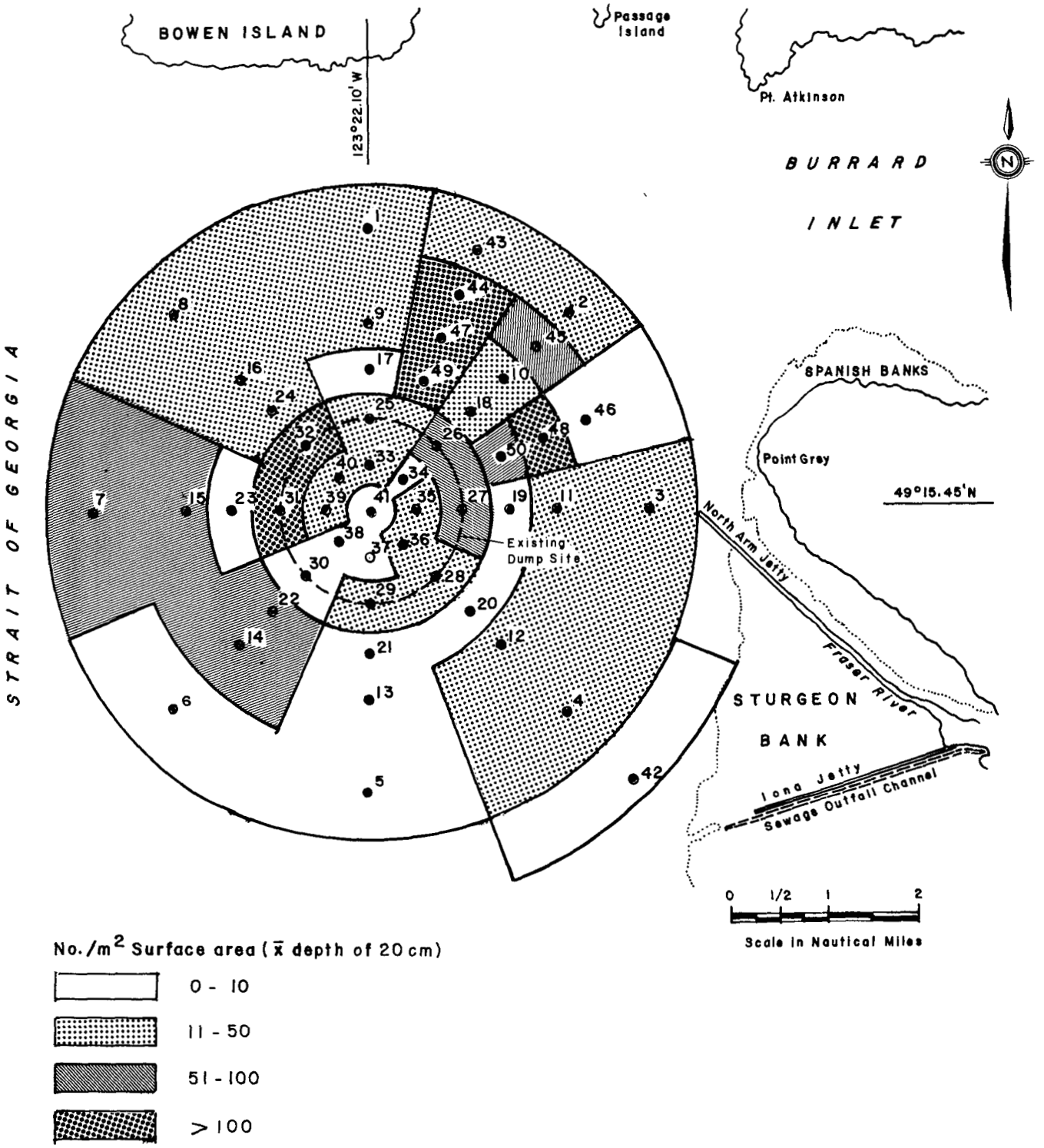

FIGURE 10 DENSITY OF *Ophiura sp* AS DETERMINED FROM PETERSEN GRAB SAMPLES

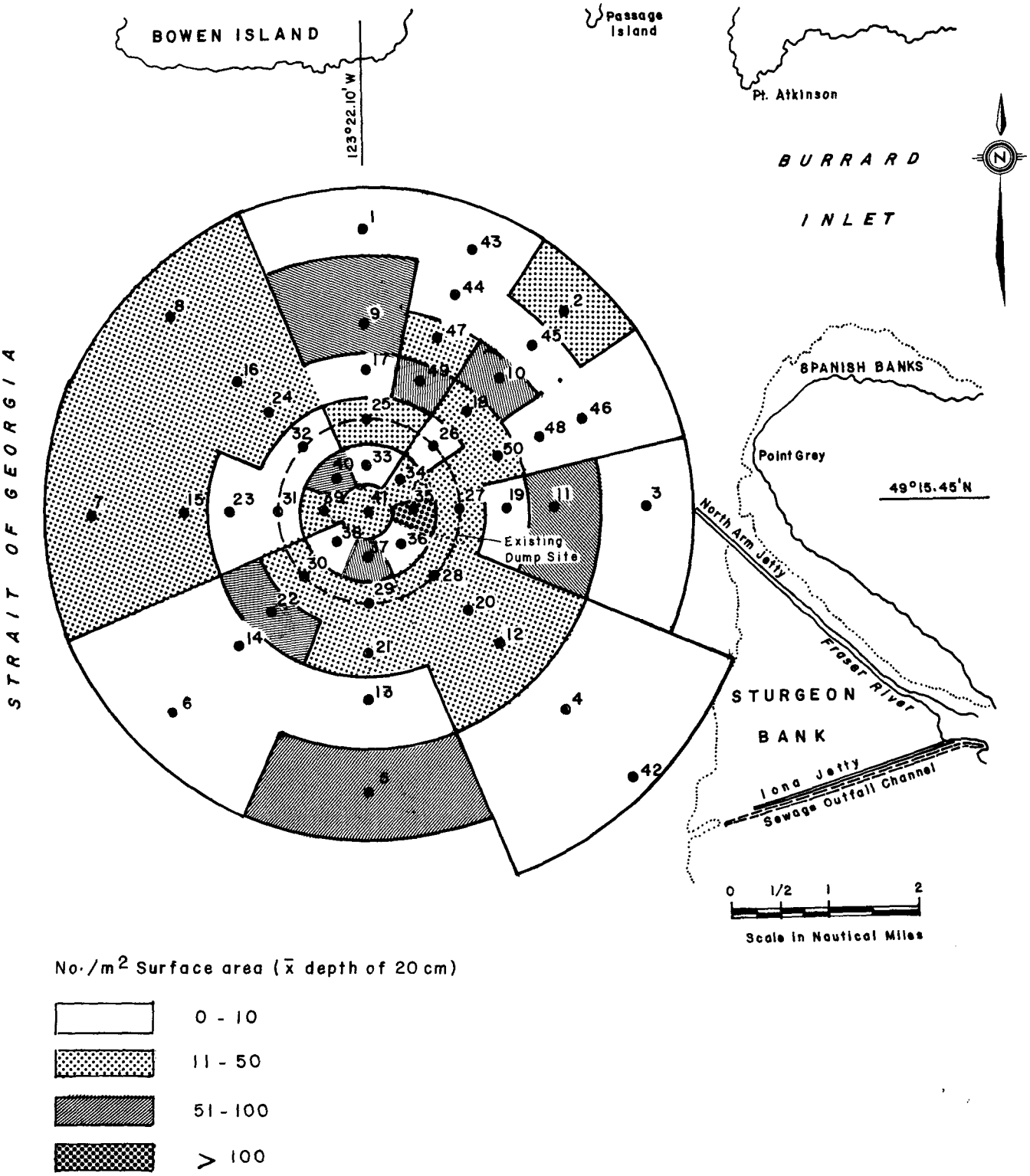

FIGURE 11 DENSITY OF *Chiridota sp* AS DETERMINED FROM PETERSEN GRAB SAMPLES