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# **FISHERIES RESEARCH BOARD OF CANADA**

## **MANUSCRIPT REPORT SERIES**

No. 1411

### **The Distribution and Abundance of Hake Pollock and Dogfish in the Strait of Georgia in 1975 Determined by Digital Echo-integration**

by

**F. H. C. Taylor and L. W. Barner**

**Pacific Biological Station, Nanaimo, B.C.**

September 1976

## ERRATA SHEET

### Erratum for MS Rep. 1411

While the manuscript was being printed, a previously unsuspected error in calibration was detected which will affect the calculated relative and actual densities and numbers.

The frequency response of the receiver was found not to be flat over the range covered by the receiver bandwidth, but to increase quite sharply at the higher frequency end. Since the frequency of the oscillator used in calibration was adjusted to give maximum amplitude from the calibrated output terminal on the receiver, calibration was effectively carried out at the high end of the bandwidth range and not near the midpoint at the transmitter frequency.

The integrator is fed from a heterodyne unit following the calibrated output stage. At the start of the receiver bandwidth the input/output ratio of the unit approached the 1:1 level specified by the manufacturer but decreased as frequency increased.

Since calibration was carried out at the high end of the frequency range and the heterodyne unit operated near the midpoint of the range, the ratio of calibrated output to heterodyne output voltage squared will differ from the specified 1:1 ratio. Measurement showed this ratio was 4.1 dB. Thus the relative and actual densities and corresponding numbers of fish will be too small by a factor of 2.6.

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ABSTRACT

Three acoustic surveys were carried out in January, February and June, 1975, using digital echo-integration to determine the distribution and abundance of fish stocks in the Strait of Georgia. Midwater trawl tows identified the major species present as hake, pollock, dogfish, and catshark. In January and February these species were found in deep water in the five major basins in the Strait. Relatively few fish were found above 100 m. In June, hake and pollock were found between 50-150 m in large concentrations along the shore from the north end of Gabriola Island to just above Cape Lazo. Dogfish appeared to be less numerous than in winter, but may have been in the surface layer excluded for technical reasons from the integrator analysis.

Relatively few fish were found in winter or summer in the southern part of the Strait where the bottom is subject to deposition from the Fraser River.

Estimates of the hake stock varied from 88,020 metric tons in February to 183,998 metric tons in June, and of the pollock from 11,431 metric tons in January to 24,501 metric tons in June. No estimates could be made of the number of dogfish. The tonnage estimates at present should be regarded only as indicators of stock size pending quantitative assessments of the various sources of error.

## INTRODUCTION

Westrheim (1974) initiated an exploratory program in 1971 to assess latent groundfish resources in British Columbia, particularly those in deep water not customarily fished by Canadian trawlers. In 1974, explorations were begun in the Strait of Georgia (Fig. 1) which showed the presence in winter in deep water of spawning stocks of hake (Merluccius productus) and pollock (Theragra chalcogramma).

In January, February and June, 1975, three acoustic surveys were carried out in this region to determine the distribution of hake and pollock and to estimate their abundance. These surveys were carried out in cooperation with the hake and pollock investigation of the Strait of Georgia program responsible for the investigation of the biology, life history and ecological relationships of these species.

## MATERIALS

### A. Fishing equipment

An Engel midwater trawl was used with 40 fm 5/8 in bridles, and 3 m<sup>2</sup> Süberkrüb otter boards. The forepart of the net was 434 16 in meshes in circumference. The net tapered to a codend of double 1 1/2 in web, with a 1 in liner.

The depth of the net was determined by a headline transducer connected by cable to an Elac echosounder operating at 30 kHz.

### B. Electronic equipment

The data acquisition and digital echo-integration system used is shown in block form (Fig. 2) and consists of:

1. A Simrad EK38A scientific sounder. The output from the sounder receiver was converted from 38 kHz to 12 kHz before being fed to other parts of the system. The sounder was operated with a nominal power output of 1000 watts, on narrow beam (7° × 13°) at a repetition rate of 48 pulses per minute and a pulse length of 0.6 milliseconds. The TVG and gain switch was set to 20 log R + 2<sub>0</sub>R, OdB. The settings of the other sounder controls have no effect on the echo-integrator system but determine the quality of the paper record.
2. An Ecosonics echo-integrator associated with a Digital PDP 11/10 computer and an ATT model ASR 33 teletype with paper tape reader and punch. The echo-integrator is derived from the system developed at the University of Washington (Thorne 1973; Nunnallee 1973) but, at present, utilizes only one echo sounder. The system processes signals from up to 40 specifiable depth strata over any selected time period (or distance travelled). The computer output appears in printed form on the teletype and is punched onto paper tape.

3. A Hewlett-Packard model 3960 four-track magnetic tape recorder. The output of the sounder besides going to the echo-integrator is recorded on magnetic tape (3M type 951 or 890) for later reprocessing in the laboratory if desired. Errors that occurred in the original processing in the field can be corrected and other depth zones and time periods examined.
4. A Tectronix model 495 dual trace oscilloscope was used to ensure the integrator was in operation and remained correctly locked to the bottom. A Telequipment S54A single beam oscilloscope monitored the output of the signal channel of the tape recorder.
5. A signal generator provided a 12 kHz calibration signal of a known fixed voltage at the start of each side of each reel of magnetic tape to ensure that tape recorder gain remained constant.
6. A 38 kHz oscillator was used to provide a signal to the echo sounder at the start of each tape to permit calibration of the time-varied gain and to ensure that no undetected changes in gain or other faults occurred in the echo sounder during the cruises.

## METHODS

### A. Period

Three acoustic surveys of the Strait of Georgia were carried out from the C.G.S. G.B. REED from January 6-17, February 10-21, and June 2-13, 1975.

### B. Coverage

Transect lines were laid out across the Strait at approximately 3-mile intervals (Fig. 3). The most southerly line was 1.75 miles north of East Point on the south end of Saturna Island, the most northerly, 2.4 miles south of Cape Mudge on Quadra Island. Off Gabriola Passage and off the Sand Heads where the axis of the Strait changes 30-45°, several lines fanned out from a single point. In June, because transects north of Point Young on the south end of Lasqueti Island were spaced more exactly at 3-mile intervals, there was one less transect in the northern part of the Strait than in January or February. This change does not affect the estimation of the distribution or abundance of fish species. Zig-zag transects were run in narrow channels such as Malaspina Strait and to provide extra coverage in some areas where large concentrations of fish were encountered. The transects extended as close to shore as outlying rocks and shallows permitted safe navigation. In areas with a gently sloping bottom, the lines extended into depths of 30-50 m, while off steep shores, where deep water lay close to shore, the lines terminated in depths of 100 m or more.

Echo sounding was carried out at 8 knots in January and February from 0800 hr to midnight, and in June from 0600 hr to 2200 to 2300 hr. Navigation was by radar fixes on shore points.

### C. Catches

Midwater trawl tows were made at intervals throughout all three cruises, in the period between the first and second cruise, and in the 2-week period immediately after the June cruise, to determine the species composition of the sound-scattering layers and how composition varied with region and depth.

On the first cruise, 18 tows were made (Fig. 4), on the second, 13 (Fig. 5), and on the third, 15 (Fig. 6). On the first cruise, a series of mid-water tows was made above, in, and below the main layer in three localities in Malaspina and Ballenas basins. In other localities in Ballenas, Quadra, and Hornby basins, tows were made in and above the main layer. On the second cruise, a group of tows was made in only one locality, in the northern part of Quadra Basin. Here tows were made in and above the main layer, above all layers, and immediately off the bottom.

On the June cruise, 4 tows were made in large concentrations of fish between 50 and 150 m, the remainder below 150 m through various concentrations of scattering organisms. Additional information on the species composition of the various sound-scattering layers was provided by 2 series of tows made by Beamish (1975) with the same vessel and equipment. The 1st series consisted of 32 tows made in the period between the first and second cruises, the 2nd of 54 tows made in the 2-week period immediately following the third (June) cruise. In the latter series, 2 or 3 tows were usually made in the same locality above, in, or below the major sound-scattering layers.

All catches were sorted and weighed by species. Samples were taken for later analysis by the Strait of Georgia Hake and Pollock Investigation (Beamish et al.). The data on location of each tow and on catch by species are deposited in the Data Record Series<sup>1</sup> (Barner and Taylor 1976).

### D. Echo sounder signals

In January and February, the echo-integrator was programmed to integrate over a series of depth zones determined during a trial run over part of the survey area. The depth zones selected were (i) 0-10 m so that surface reverberation could be excluded from further analyses; (ii) 10-50 m and 50-100 m to allow both for the chance encounter of shallow schools of fish such as herring, and for the possible diel migration of the main fish stocks; (iii) 100-300 m to encompass the major echo layer, and (iv) 300-500 m to include the relatively small areas in the major basins where depths exceed 300 m. In June, the distribution of fish and other sound-scatterers was considerably different, requiring changes in the depth zones integrated. The June zones were (i) 0-10 m, and 10-50 m; only on rare occasions were fish schools found above 50 m; (ii) 50-150 m; this zone encompassed the major fish schools encountered; (iii) 150 m to the bottom; below 150 m, the echoes appeared to be mainly from plankton.

Printouts were obtained every 360 pulses, the equivalent of a nautical mile at 8 kt, with the sounder transmitting 48 times a minute.

The computer output for each depth interval in a number,  $\bar{I}_t$ , related to fish density and averaged over the number of pulses such that:

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<sup>1</sup>A copy of the Data Record may be obtained from the issuing establishment upon written request.

$$\bar{I}_t = K \bar{N} \text{ volts rms}$$

where  $\bar{N}$  is the average fish density (fish per  $m^3$ )

$$\text{and } K = P_0^2 V_R^2 T_I \frac{c\tau}{2} \omega_0 (k_3 k_4 k_5 k_6 \frac{k_7 k_8}{\pi})^2 k_9 k_{10}$$

The symbols and nomenclature of the echo-integration constant follow Ford (1974), who also discusses its derivation in detail. All are measurable or can be determined by calibration, from manufacturer's specifications, or from the literature.

A normalizing constant can be inserted into the computer program to adjust for any or all of the terms in K. Values for all the terms are not usually available at the start of a survey. It has been the practice, therefore, to include in the normalizing constant (F) only those terms in K (excluding echo sounder controls) which can be varied at will during the survey. These are the gain terms of the various sections of the integrator-computer system ( $k_7$  to  $k_{10}$ ), and are determined as a unit by calibration. They depend on the value of the stepped integrator gain  $\frac{k_7}{\pi}$  selected (Table 1).

$$F = \frac{1}{k_f}$$

$$\text{where } k_f = \left(\frac{k_7}{\pi}\right)^2 \cdot k_8^2 \cdot k_9 \cdot k_{10}$$

The remaining terms of K are inserted at a later stage in the analyses in the conversion of relative numbers of hake and pollock to actual numbers and tonnages.

Thus the printed computer output for each depth zone is a measure of relative fish density and will be termed relative field density ( $\bar{N}_r$ )

$$\text{for } \bar{N}_r = K_1 \bar{N}$$

$$\text{where } \bar{N}_r = F \bar{I}_t$$

$$\text{and } K_1 = P_0^2 V_R^2 T_I \frac{c\tau}{2} \omega_0 (k_3 k_4 k_5 k_6)^2$$

For each depth zone the relative field density consists of an eight-figure decimal number with no zeros after the decimal point times an exponent of 10, ranging on these surveys from -2 to -5.

Each computer output also shows the proportion of each depth zone not occupied by the bottom. This figure will be 1.0 if the entire depth zone is above the bottom, and a decimal if the bottom intrudes into the interval for some part of the depth range and printout interval. It is therefore possible to calculate the average thickness of each depth zone for each printout interval.

For each depth zone that showed evidence of fish, the first figure of the decimal and the exponent of the relative field density estimates were plotted at the centre of the transect segment (usually 1 nautical mile) to which it applied. Contour lines were drawn at intervals<sup>2</sup> represented by the exponent and by 0.5 times the exponent. The result is a chart of the distribution of fish showing areas of greater or less relative abundance. Contour maps of relative field density were prepared in January and February for the 100-300 m (Fig. 7 and 9), and 300-500 m (Fig. 8 and 10) depth zones, and in June for the 50-150 m and 150-450 m (or bottom) depth zones (Fig. 11 and 12). Observation of the echo-sounder records, and catches, showed that in January and February there were virtually no fish above 100 m.

The area within contours can be measured by planimeter. The mean of all estimates of relative field density within a given contour interval was obtained, as also was the mean of all estimates of depth zone thickness. For each depth zone the relative number of fish within a contour interval is the product of the area, the average thickness of the depth zone, and the average relative field density. Summation over contour intervals and depth zones gives the total relative number of fish in a particular region or over the entire area surveyed.

The average field density within a contour interval divided by  $K_1$  gives the average actual density within that interval, which, when multiplied by area within the interval and the average thickness of the depth zone, results in an estimate of the number of fish.

The sounder is calibrated for  $P_0$  and  $V_R$  at intervals during the year; any change in these terms indicates a major failure in the sounder system. In determining  $K_1$  the most recent values of  $P_0$  and  $V_R$  were used. The equivalent beam angle,  $\omega_0$ , is determined by the transducer design, and is obtained from manufacturer's specifications. The value used corresponded to -18.0 dB. The gain term  $k_B$ , the gain of the 38 to 12 kHz frequency-converter is assumed to be 1.0. The tape recorder gain,  $k_E$ , is set at 1.0 for each reel. The value of  $k_3$  is 1.0, unless the TVG switch is in the not-usually-used -20 dB position. The

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<sup>2</sup>In Figures 7 to 12 in expressing the contour interval the exponent is incorporated into the number which is expressed as a decimal with zeros after the decimal point. Thus a density of  $0.12345678 \times 10^{-2}$  (0-0012345678) lies in the contour interval .00096-.0055.

constant  $k_4$  represents the slope of the change in receiver gain with depth (TVG). The slope ideally should be examined at a series of depth intervals to determine how well the actual curve approximates the theoretical. The necessary correction can be made through the computer program. However, until the present program is modified, this approach is not possible. Therefore, to date, the theoretical value at maximum TVG operating range has been used and corresponds to -63.6 dB. The term  $\frac{c\tau}{2}$  depends on the velocity of sound ( $c$  is 1460 m/s) and pulse length ( $\tau$ ) selected (0.6 m/s). The value used is -3.6 dB. It is at present beyond the capability of our equipment to determine the target strength,  $T_1$ , which depends on species, size, and aspect angle of the fish. An approximate value, taken from the literature, is therefore used. According to Love (1971) the dorsal aspect target strength ( $TS_0$ ) is given by:

$$TS_0 = 10 \log \frac{S}{4 \pi}$$
$$\text{and } S = 0.041 \frac{L^{1.94}}{\lambda} \cdot \lambda^2$$

where  $\lambda$ , the wave length, and  $L$ , the fish length, are in meters.

Using a value of .44 m, the modal length for hake, throughout the Strait,  $TS_0$  for the species becomes -32.6 dB. For pollock, the modal length was .42 m and  $TS_0$  -33.0 dB. For reasons discussed later, no value was assigned for the target strength for dogfish.

## RESULTS

The total area surveyed was about 1,200 sq mi; 460 mi of transect lines were traversed in January, 480 mi in February, and 560 mi in June. In February, the two most southerly lines were not completed but additional zig-zag transects were run in Hernando Basin and in Malaspina Strait. The net result was an increase of 20 mi of track lane. In June, the pattern was the same as in February, except for one less transect in the northern part of the Strait, and the addition of a series of criss-cross transects on the west side between the north end of Gabriola Island and the south end of Lasqueti Island, and south of Hornby Island to Qualicum Bay.

### A. Bathymetry

The Strait of Georgia contains a number of prominent bathymetric features likely to influence the distribution of fish. There are two distinctive regions divided roughly by a line from Bowen Island to Porlier Pass (Pharo 1972). Southeast of the line, the Strait has a smooth topography associated with rapid deposition of sand and mud from the present mouth of the Fraser River and from a former, more southerly, mouth. The main features of this area are the Sand Heads and Roberts Swell, extending almost across the Strait to Active Pass (Fig. 1). To the northeast of the line, the Strait is characterized by a rugged basin and ridge topography. It is an area of extreme relief with depths ranging from less than 50 m on offshore banks to about 420 m in the deepest basin.

There are four major basins with depths in excess of 300 m (Cockbain 1963a and b). Ballenas Basin is the deepest and lies on the westerly side of the Strait from the Ballenas Island to Valdes Island. Approximately opposite Nanaimo, this basin is joined by the Malaspina Basin, which extends up the east side of the Strait of Georgia through Malaspina Strait between Texada Island and the mainland to Powell River. In its southeastern part, this basin approximates Ballenas Basin in depth (about 400 m) but shallows in its northern part to 320 m. Quadra Basin runs from between the south end of Texada and Lasqueti islands north to Sutil Channel off Quadra Island. The depth ranges from 350-370 m in the south to about 270 m in the north. A fourth, and somewhat smaller basin, the Hornby Basin, runs along the Vancouver Island shore from Cape Lazo to the Ballenas Islands. This basin is about 350-370 m deep. It is separated from Ballenas Basin by a low col joining Sangster Ridge to the Ballenas Islands. The Ridge also separates Ballenas and Malaspina basins (Cockbain 1963a). Hornby Basin is bounded on the north by the Lasqueti Ridge which also forms part of the western boundary of Quadra Basin. In the northeast corner of the Strait, a small basin with depths to 350 m extends out of Desolation Sound and is bounded by Hernondo and Savary islands. In this report, this basin is referred to as Hernando Basin. Between the eastern edges of Malaspina and Ballenas basins and the mainland lies a series of almost parallel ridges. Round and South ridges lie on the edge of the basins, to the east of these is Halibut Ridge and Bank and finally, further east, the more extensive McColl Ridge and Bank. Between McColl Ridge and the mainland, is a small shallow basin (160-180 fm deep), Sechelt Basin (Pharo 1972).

#### B. Appearance of echograms

In January and February, a diffuse layer was generally present throughout the Strait from about 100 m to the bottom (Fig. 13A). This layer tended to become denser from about 150 m to 300 m and again sometimes about 50 m from the bottom. In places, a very light blurred layer appeared above the main layer at 100 m. Only in one locality in the northern part of Sabine Channel was the layer sufficiently concentrated to appear as a series of discrete schools. The main layer appeared to be an aggregation of single fish or perhaps small groups of fish. Density varied horizontally and vertically, giving the layer a blotchy appearance. Close to the bottom the layer appeared more blurred. The layer maintained its depth as the water shallowed. It thus became much reduced in size at bottom depths of 150 m and virtually disappeared at bottom depths of 100 m.

In June there were striking changes in the appearance of the echograms. Fish seemed to lie mainly above 150 m. On the west side of the Strait from about the north end of Gabriola Island to just north of Cape Lazo, a series of dense concentrations of fish were encountered in this zone. These had the typical curtain-like appearance of hake schools (Fig. 13B). To seaward, the schools became less intense and appeared as a layer of single fish aggregations decreasing in both intensity and density. There was also a noticeable difference in the appearance of the echograms below 150 m. In winter, in deep water, echoes appeared to be aggregations of single fish traces. In June, however, the layer was not only more intense, but also lacked definable structure, appearing as a dark homogenous wash.

In January and February more fish were caught in the main layer between 100 and 300 m than in the less dense zone above it, and more fish from the denser near-bottom part than from the main layer itself (Table 2). In one tow made above any indication of fish, the catch was 12 kg, compared to catches in the same locality of 769 kg from the main layer and 1,224 kg from near bottom. The catches in the main layer were much greater at densities of  $.1$  to  $.5 \times 10^{-3}$  than at densities of  $.6$  to  $.9 \times 10^{-4}$  (Table 3). The decrease in catch was greater than the indicated decrease in density. Below the main layer the relation may be similar, although the numbers of hauls (4 and 1) are too small for reliable comparisons. Above the main layer, catch was a little greater at low densities than at high. It therefore seems reasonable to conclude that the main layer is made up mainly of fish, and that a considerable amount of fish also occurs below the main layer.

In June the average catch per tow at depths of 50-150 m was very much greater (974 kg) than below 150 m (66 kg). Schools were sometimes found and fished above 50 m. For this reason, the average catch from 0-50 m (894 kg) is only a little less than that from 50-150 m. In the 50-150 m zone, the size of the catch varied directly with relative density (Table 3). The decrease in catch was again greater than the indicated decrease in density. The reason is that tows were made in a restricted depth range where the fish density was highest while the measured density was the average for the full depth range of 50 to 150 m. Below 150 m, catches were small and tended to increase with decreasing density. Thus it appears that fish occur mainly between 50 and 150 m and are scarce below this depth zone, where small reflecting organisms not retained by the net become the principal sound scatterers.

### C. Distribution of fish

The relative field density varied a thousandfold, from  $10^{-2}$  to  $10^{-5}$ . At densities of  $10^{-2}$ , fish were in dense discrete schools rather than in a diffuse layer as at all lower densities. At densities of  $10^{-3}$ , a well developed layer of single fish traces was present representing a concentration of fish, although not one dense enough to form discrete schools of the type usually attractive to commercial fishermen. At densities down to  $0.5 \times 10^{-4}$ , the layer remained fairly prominent; but at densities below this level, it became increasingly less obvious. At densities of  $10^{-5}$  virtually no fish were present, with only a very sparse scattering of single fish echoes appearing on the echogram. In June, the homogenous deep-water layer (below 150 m) was intense, and produced relative field densities of  $10^{-2}$  in two areas, one in the northern, the other in the southern part of the Strait, and densities of  $10^{-3}$  over the greater part of the Strait. This layer is probably composed of zooplankton and small schooling fish too small to be retained in quantity by the net.

In all three months, relatively few fish were found southeast of the Bowen Island-Porlier Pass line (Fig. 1). The major fish concentrations occurred in that part of the Strait characterized by a rugged basin and ridge topography. In January and February fish were found mainly from 100-300 m associated with the major basins (Fig. 7 and 9) although not necessarily delineated by them. Overlapping onto intervening areas and banks occurred. In June, the fish were concentrated between 50 and 150 m. Dense schools occurred relatively close to shore along the western side of the Strait from Gabriola

Island to Cape Lazo (Fig- 11).

### 1. Winter distribution

In January the total relative number of fish in the area surveyed was  $60.611 \times 10^6$  and in February  $57.369 \times 10^6$  (Table 4). In both surveys about 92% occurred in the five basins and about the same proportion between 100 and 300 m. In January, Malaspina Basin<sup>3</sup> contained the most fish ( $23.132 \times 10^6$ ) with half of it occurring between Jervis Inlet and the south end of Texada Island. Ballenas Basin was next ( $13.738 \times 10^6$ ), followed by Quadra Basin ( $12.835 \times 10^6$ ). Hornby and Hernando basins contained relatively small amounts ( $3.771 \times 10^6$  and  $2.029 \times 10^6$  respectively).

In February, Malaspina Basin again contained the greatest amount of fish ( $22.797 \times 10^6$ ), however half of it occurred south of Texada Island instead of in Malaspina Strait. In Ballenas Basin, the quantity of fish increased somewhat (to  $14.201 \times 10^6$ ). The net effect was a considerable increase in the quantity in the Strait south of Texada Island. In Malaspina Strait there was a marked reduction in the quantity north of Jervis Inlet and a somewhat smaller reduction between Jervis Inlet and the south end of Texada Island. The quantity of fish in Quadra Basin was reduced one-third (to  $8.947 \times 10^6$ ). The fish were in two areas (Fig. 9), one in the north from Cape Lazo to Cape Mudge, the other in the south in Sabine Channel, although the dense concentration found there in January had disappeared. The small increase in Hernando Basin was probably a result of the extension of the survey to the more northern part where the concentrations were denser than in the southern part. A small increase occurred in Hornby Basin.

The estimates of the relative number of fish (Table 4) and the distribution charts (Fig. 7 and 9) show that a definite southward movement of fish occurred between the beginning of January and mid-February, leading to a concentration south of Texada Island. There was some indication of a movement eastward into the area of the Halibut and McColl ridges and also of a concentration along the shore of Vancouver Island. The fish that were found in January in small amounts in Shearwater and Algerine passages off the north end of Texada Island and over the Lasqueti Ridge off Hornby Island had disappeared in February.

### 2. Summer distribution

In June, major concentrations of fish were present between 50 and 150 m. Below 150 m, the echograms differed in appearance both from those from above 150 m and from those from January and February below 100 m. The appearance of the echograms suggests that the reflecting organisms below 150 m were small, perhaps zooplankton or small schooling fish. Catches (discussed later) confirm that there were relatively few large fish (hake, pollock or dogfish)

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<sup>3</sup>Malaspina Basin comprises the localities referred to in Table 3 as Malaspina Strait in the north central section of the Strait of Georgia and south Malaspina Basin in the south central section.

below 150 m. In June, the total relative biomass in the 50-150 m depth stratum was  $80.959 \times 10^6$  (Table 4). There were four major concentrations of fish characterized by dense schools and delineated by relative field densities greater than  $0.5 \times 10^{-3}$ . These concentrations accounted for 38% of the biomass but occupied only 6% of the volume of the 50-150 m layer. The largest concentration (18% of the biomass between 50 and 150 m) extended from just north of Cape Lazo to the northern end of Hornby Island, the concentration between the north end of Gabriola Island and Nanoose Harbour contained 10%, that off the southern ends of Denman and Hornby islands 7%, and the concentration to the north of Nanoose Harbour 2%. Areas with lower concentrations characterized by relative field densities of  $.1$  to  $.5 \times 10^{-3}$  showed on the echograms as aggregations of varying intensities of single fish traces and occurred over extensive areas of the Strait of Georgia, in Hernando Basin, and in Malaspina Strait. In the Strait of Georgia the zone extended in a broad band from Sutil Channel in the north along the Vancouver Island shore south to Gabriola Island and then across the Strait to Bowen Island (Fig. 11). Farther south, a second band extended across the Strait from Porlier Pass to Sand Heads. The areas with relative field densities between  $.1$  and  $.5 \times 10^{-3}$  contained 51% of the total relative biomass and made up 45% of the volume of the 50-150 m layer.

Below 150 m virtually the entire Strait was characterized by relative field densities of  $.1$  to  $.5 \times 10^{-3}$ , except for an area north of Cape Lazo and a small area in Hernando Basin and off Texada Island where the intensity increased to  $.1$  to  $.2 \times 10^{-2}$ , and in area over Ballenas Basin and the southern end of Malaspina Basin where the density decreased to  $0.5$  to  $0.9 \times 10^{-4}$ . The total relative biomass below 150 m was estimated to be  $99.581 \times 10^6$ ; and probably consists mainly of zooplankton and small schooling fish.

Thus in June there appears to have been a large increase in the total relative biomass in the Strait of Georgia (to  $180.540 \times 10^6$ ). While most of this increase was in deep water (below 150 m) and was probably due to small reflecting organisms, an increase in the quantity of larger fish (to  $80.959 \times 10^6$ ) occurred, accompanied by a change in distribution. In January and February, most of the large fish occurred between 100 and 300 m over the major deep basins of the Strait. In June, most occurred between 50 and 150 m along the Vancouver Island shore.

#### D. Composition of the catches

Catches were mainly of four species, hake, dogfish (Squalus acanthias), pollock, and brown catshark (Apristurus brunneus). In some tows glass shrimp and the small deepsea smelt (Leuroglossus stilbius) appeared relatively numerous but because of their size were not retained by the net in proportion to their abundance. They did not, however, appear to be in dense schools. In January and February, hake and dogfish occurred throughout the layer. Hake was the dominant contributor to the denser main midwater and near-bottom parts of the layer, while dogfish were proportionately more numerous above the main layer than in it (Table 2). Pollock were scarce in January and in February. More were found above the midwater layer than in or below it. Pollock was the dominant species in 2 tows only, one in the main layer, the other a tow aimed at a collection of very small but intense targets above the main layer at a depth of less than 100 m.

The species composition of the catches varied with region. In January in the northern part of Quadra Basin, in the southern part of Malaspina Basin and in Hornby Basin, hake formed 65-70% of the catch<sup>4</sup>, dogfish 27-32%, and pollock and catshark less than 5% each (Table 5). In Ballenas Basin, hake formed 55% of the catch, dogfish 33%, and pollock 9%. In Sabine Channel and the central part of Quadra Basin, hake formed 79% of the catch, dogfish 5-10%, and pollock up to 16%. In Malaspina Strait, the catch was 94% hake, 4% dogfish and 2% pollock, with traces of catshark and other species. In February in the northern part of Quadra Basin, the proportions of hake and dogfish remained unchanged at about 65% and 30% respectively. In Ballenas and Hornby basins, the proportion of hake decreased (to 42% and 49% respectively), and of dogfish increased (to about 49% in both). In Malaspina Basin, the presence of one tow with a high proportion of pollock complicated the interpretation of the catches. If this catch is excluded on the basis that it is exceptional, then the proportion of hake in Malaspina Strait remains about 62%, while the proportion of pollock (11%) increases and of dogfish (26%) decreases somewhat. If the catch is included, the proportion of hake decreases to 50% and of dogfish to 21%, while the proportion of pollock increases to about 27%. No catches were made in February in Malaspina Strait. In Jervis Inlet, hake formed 10% of the catch, dogfish 32%, pollock 4%, and catshark 7%.

A number of midwater trawl hauls were made in the period between the January and February cruises (Beamish et al. in prep.) The composition of the catches generally supports the trend established from the January and February cruises. Tows were made at this time in several regions, particularly in the southern part of the Strait of Georgia not fished in January and February. The catches in the southern part of the Strait were small, as could be expected from the low densities of fish shown on the acoustic surveys. Hake formed 50-55%, pollock 20-25% and dogfish 8-14%. Tows made in Jervis Inlet indicated a lower proportion of hake (48%) and of dogfish (16%), but a higher proportion of pollock (35%) than in Malaspina Strait.

In June, catches in the 50 to 150 m depth stratum over most of the Strait where concentrations of fish were encountered, consisted mainly of hake (88%). Pollock and dogfish formed about 6% each, the percentage composition varied relatively little over the major portion of the Strait from Mitlenatch Island in the north to Gabriola Pass in the south. In Quadra Basin, along the Lasqueti Ridge, and in Ballenas Basin, hake, pollock and dogfish formed 88%, 6% and 6% respectively. In Hornby Basin, the proportions were 88%, 9% and 3% respectively. In the southern part of Malaspina Basin where relative density was low ( $.1$  to  $.5 \times 10^{-4}$ ), pollock was the predominant species forming 61% of the catch, while hake formed 29% and dogfish 12%. In the southern part of the Strait between Porlier and Active passes, hake formed 66% of the catch, pollock 16% and dogfish 18%. In the central part of Malaspina Strait, hake formed 91% of the catch, pollock 8% and dogfish 1%, while in the southern part the

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<sup>4</sup>Catches made in less than 100 m were excluded since they were not relevant to the main zone integrated, and catches of less than 50 kg were also excluded as too small to give a reliable indication of species composition.

proportions were 58%, 38% and 4% respectively. Below 150 m where catches were small, hake remained predominant in most areas, comprising over 80% and often over 90% of the catch. Dogfish were usually somewhat more numerous than pollock.

In the small catches of less than 50 kg, pollock and dogfish tended to form a large proportion of the catch, sometimes equalling or exceeding the proportion of hake. However, proportions derived from catches less than 50 kg are not considered reliable.

Species composition clearly varied with region, from one cruise to another, and to a lesser extent with depth.

The catch composition (Table 5) used on these cruises in the estimation of the relative numbers of fish of each major species in each region was based on data from the appropriate cruise and region where possible. If no hauls were made in a region, the catch composition for an adjacent region was used, and if this was not possible, then the catch composition for the period between cruises for the same or for an adjacent region was used.

#### E. Estimation of abundance by species

As already mentioned, the total biomass in winter from 100 m to the bottom, and in summer from 50-150 m, was considered to be fish. Other depth zones were assumed to contain relatively few fish, and the sound-reflecting organisms present to be either zooplankton or small schooling fish not retained by the net in proportion to their number. It is not possible for the integrator to discriminate between different species of fish. The average relative field density thus represents the combined response from all species. One approach to estimating the relative quantity of each species present would be to subdivide the average relative field density estimates for a contour interval in a region according to the percent species composition based on weight of catch. This approach assumes that the reflecting properties of the major species (hake, dogfish, pollock and catshark) are related in a similar manner to the weight of the fish. This is probably a reasonable assumption for hake and pollock on the one hand, and for dogfish and catshark on the other. Information on the target strength of Elasmobranchs in general and dogfish in particular is scarce. Nakken and Olsen (1973, Fig. 5F) show that at 38 kHz the target strength of dogfish (based on three specimens) at a mean length of about 100 cm is about 6.5 dB below that of cod of comparable size. Put another way, the target strength of a 100-cm dogfish is about equivalent to that of a 60-cm cod. On the basis of this small amount of information, it appears that dogfish are definitely poorer targets than cod-like fishes. Dogfish covered a large size range from about 20 to 120 cm. Catshark were similar in size to small dogfish. Small dogfish and catshark will be poor sound reflectors and will be underestimated in number. However the generally larger size of adult dogfish may compensate to some extent for their poorer reflective properties. The net effect may be to overestimate the relative number of hake and pollock and to underestimate the number of dogfish. Catshark, although the fourth most prominent species, were not sufficiently numerous to warrant estimation of relative numbers.

The total relative number of fish in the various regions was proportioned into the relative number of hake, pollock and dogfish (Table 3) on the basis of the percent composition of the catch. By assigning values to the parameters in K, the actual numbers (Table 6) can be calculated from the relative numbers using an estimated value for target strength (Love 1971). Target strength is a complex function depending on density differences of different parts of the body, on size, on aspect angle, and on sounder frequency. Thus, while it can reasonably be assumed that hake and pollock of a similar size will have a similar target strength representative of bony fish with air bladders, the target strength of dogfish may be very different (see above). Because of the small amount of information available, it would not seem worthwhile at present to try to assign a value for target strength to dogfish, so no calculations of actual numbers or weight were made for this species. Its distribution and abundance will be discussed in terms of relative numbers only.

#### F. Distribution and abundance of hake

In January there were estimated to be 117,268 metric tons of hake in the Strait of Georgia, 86% in Quadra, Malaspina and Ballenas basins, and another 9% in Hornby and Hernando basins. Malaspina Basin contained as much as the other two basins combined, half of it in Malaspina Strait south of Jervis Inlet. Only small amounts of hake were found in areas outside the major basins, and in the area south of Gabriola Pass. In February, the estimated quantity of hake was 88,020 metric tons, a decline of 25% from January. Of this amount, 93% occurred in the five major basins, 73% in the three largest - Quadra, Malaspina and Ballenas basins. The decrease amounted to 37% in Quadra Basin, 27% in Malaspina Basin and 21% in Ballenas Basin. Within Malaspina Basin, the quantity in Malaspina Strait declined sharply while the quantity south of Texada Island increased. In the northern part of Ballenas Basin, the quantity present decreased 28%, while in the southern part there was a slight increase. Because of the difficulty in assigning some areas to a particular basin, it would seem preferable to consider that there was a net increase in the Strait of Georgia south of Texada Island, rather than an increase in one part (the eastern side) and a decrease in another (the western side). There was a small increase in the southern part of the Strait off Sand Heads and in the southern ridge area (McColl and Halibut banks). The quantity in Hernando and Hornby basins was about the same in both months.

The decrease in the quantity of hake in February is unexpected in a species presumed to be concentrating to spawn. It could be due in part to errors in catch composition arising from an inadequate number of tows.

In June there were estimated to be 183,998 metric tons of hake in the Strait of Georgia, an increase of 57% over the January estimate. Most of the hake (80%) occurred in a band running from Sutil Channel in the north along the Vancouver Island shore to the north end of Gabriola Island and then across the Strait to Bowen Island. Within this band, large concentrations with dense schools occurred between Cape Lazo and Hornby Island (20%), off the south end of Denman Island (9%), just north of Nanoose Harbour (3%), and off the north end of Gabriola Island (12%). In the first two areas the hake occurred over a gently sloping soft bottom; in the latter two, over a rugged rocky bottom. The remaining hake within the band were less densely concentrated and spread over

a large area surrounding the centres of concentration. Relatively small quantities of hake occurred in Hernando Basin (7,661 metric tons), in Malaspina Strait (13,945 metric tons) and in the southern Strait of Georgia from Porlier Pass to Sand Heads.

Between January and February there was a southward movement of hake in the Strait of Georgia and concentration south of Texada Island. There was also some evidence of a small increase in the southern part of the Strait off the Sand Heads and in the vicinity of McColl and Halibut banks. In June there was a marked increase in the estimated quantity of hake in the Strait and a noticeable change in the distribution pattern. The hake occurred almost entirely between 50 and 150 m along the Vancouver Island shore instead of in deep water in the major basins.

#### G. Distribution and abundance of pollock

The quantity of pollock was very much smaller than hake. There was estimated to be 11,431 metric tons in January, 17,871 metric tons in February and 24,501 metric tons in June (Table 6). Centres of abundance in January were the southern part of Quadra Basin and the northern part of Ballenas Basin. In February there was a pronounced increase in the Strait south of Texada Island, and small increases in areas south of Gabriola Pass. There was relatively little pollock in Malaspina Strait, in the northern part of Quadra Basin or in Hernando and Hornby basins in January or February.

In June, pollock were relatively evenly distributed over the central and southern parts of the Strait. About 26% occurred between Cape Lazo and the Ballenas Islands, 22% from the Ballenas Islands to Gabriola Island, 22% in Malaspina Strait and 16% in the southern Strait of Georgia from Porlier Pass to the Sand Heads. The June distribution resembles that in January except that the pollock were in shallow water close to shore rather than in deep water in the basins.

The quantity of pollock estimated to be in the Strait increased 60% in February and another 39% in June. It is difficult to determine from the available information whether the increase is real or the result of estimation errors. One major source of error may again be the estimates of species composition. Species compositions in January and February were derived from relatively small numbers of tows not covering all areas of the Strait.

#### H. Distribution of dogfish

Since the information on target strength for dogfish is very limited, it is not worthwhile to estimate actual numbers of the species. The following discussion is therefore based on relative numbers (Table 4).

In January, dogfish were most numerous in the Strait of Georgia south of Texada Island, and were also numerous in the northern part of Quadra Basin. In February, the quantity of dogfish increased about 46%. The main increase occurred south of Texada Island and in the southern part of Malaspina Strait. The quantity in the northern part of Quadra Basin declined. The southward movement and concentration south of Texada Island noted in hake and pollock is

apparent in dogfish. The same caution applies in interpreting the changes in relative numbers of dogfish as in actual numbers of hake and pollock.

In June, the quantity of dogfish was only about 29% of that in February, and 42% of that in January. A decrease of this magnitude was unexpected. It may be the result of a change in depth distribution. Dogfish in summer may be in the surface layer not fished or included in the integration analysis. Observations on several occasions of dogfish schools finning on the surface support this possibility. In June, dogfish were most numerous in the south central Strait (from the south end of Lasqueti Island to the north end of Gabriola Island) and in the southern part of the Strait (off Valdes and Galiano islands).

#### I. Reliability of estimates

Echo-integration has provided useful information on the distribution and abundance of fish stocks in the Strait of Georgia. Because of the volume of data, estimates of associated sampling errors and the setting of confidence limits have been postponed pending the acquisition of the necessary computer techniques.

Information on distribution will be more accurate than information on abundance since there are fewer assumptions involved, and information on both distribution and abundance relating to fish biomass more accurate than similar information relating to stocks of particular species. If only one species occurs within an area, or if several species occur in a well segregated manner, then the estimates of abundance by species may approach those for biomass in accuracy.

The reliability of information on distribution depends on the error associated with the individual estimates of relative field density and on the accuracy of navigation and plotting. The estimate of relative field intensity per nautical mile is based on a large number of samples and each provides an estimate or sample of relative field density. The associated error could thus be small, but will be determined by how the data fit the type of frequency distribution assumed for fish density. The distribution may be contagious rather than normal. Navigation in the Strait of Georgia was by radar fixes on shore points. Speed, while monitored by a SAL log, did not take into account wind and tide. Error from both sources could lead to discrepancies of up to perhaps 0.5 nautical miles on position.

Estimates of the relative abundance of fish involve the determination of volume surveyed. The associated errors will be in addition to those affecting distribution and are likely to be larger. The major source is probably contouring, a highly subjective process. Computer contouring may become available and could remove the element of subjectivity.

The conversion of relative abundance of fish to relative abundance of individual species brings in another possible major source of error, that associated with catch composition. In January and February, catch composition estimates were based on a total of 18 and 13 tows respectively, with only 1 to 4 tows in any one region, a small number of tows from which to derive reliable

estimates of species composition. The inclusion of Beamish's tows with the same gear made between the January and February cruises and in the 2-week period immediately following the June cruise, increases substantially the number of tows but introduces another source of error, that associated with possible changes of distribution in the intervening time.

Conversion of relative numbers of a species to actual numbers involves the introduction of target strength estimates and of a number of equipment calibration factors. With care, the electronic equipment can be accurately calibrated, and is unlikely to be a major source of error. Target strength should properly be determined in situ for each species. The use of a calculated general value may be a source of error. The effect cannot be evaluated until some data on actual in situ target strengths for the species involved become available. Target strength varies with fish size. For hake and pollock the modal length was used since the length frequency distribution was polymodal, the selection of the main target mode may bias results and lead to an underestimate of numbers.

To obtain the size of the stock in terms of weight, the average weight of each species was used. For hake and for pollock the average weight would be less than the weight at the main mode, so total weight would be underestimated again.

These three echo-integration surveys have provided considerably more detailed information on the distribution of fish (hake, pollock, and dogfish) in the Strait of Georgia much more rapidly than previously available methods. The estimates of abundance relative or absolute, also quickly and simply derived are probably as accurate as any provided by older methods. The abundance estimates are, however, subject to a number of sources of error of largely unknown magnitude. The relative estimates will be more reliable than the absolute estimates and those for total fish biomass more reliable than for biomass of individual species.

SUMMARY

1. Three acoustic surveys of the Strait of Georgia were carried out from January 6-17, February 10-21, and June 2-13, 1975, to estimate the distribution and abundance of pelagic fish.
2. The area surveyed covered approximately 1,200 square miles and extended from Sutil Channel in the north to Active Pass and Point Roberts in the south.
3. Midwater trawl tows were made on all three cruises to identify the species of fish associated with the sound-scattering layers. The major species encountered were hake, pollock, and dogfish. Brown catshark occurred in small numbers on the first two cruises.
4. In January and February the midwater trawl catches confirmed the basic assumption that large fish (hake, pollock, dogfish) were the dominant contributors to echoes below 100 m but not to those where zooplankton or small schooling fish were probably predominant. In June, the catches substantiated the assumption that all echoes from 50-150 m were fish - hake, pollock, or dogfish - and that the diffuse layer below 150 m contained few large fish.
5. In January and February, hake, pollock and dogfish were found in a layer over the major basins making up the northern and central parts of the Strait of Georgia region. The layer was generally most intense from 150-300 m and sometimes also in the bottom 50 m. There was evidence of a southward movement of hake and pollock in February, leading to an increased concentration south of Texada Island.
6. In June, hake and pollock were found in relatively shallow water from 50-150 m near the Vancouver Island shore from the north end of Gabriola Island to just north of Cape Lazo. Dogfish were comparatively scarce. Visual observations suggest they may have been in the surface layer excluded from analysis. A diffuse, often dense layer, was widespread from 150 m to the bottom. This layer contained few large fish and was most probably zooplankton or small schooling fish too small to be returned by the net.
7. Estimates of the numbers and tons of hake and pollock were made. In January there were 116,760 m.tons of hake and 11,135 m.tons of pollock in the Strait. In February there were 87,979 m.tons of hake and 17,871 m.tons of pollock, and in June, 183,998 m.tons of hake and 24,501 m.tons of pollock.
8. Estimates of the quantity of dogfish could not be made because no reliable estimate for target strength for the species was available.
9. The errors associated with the estimated quantities of hake and pollock were not calculated. The major sources most probably derive from the estimates of volume between contours and of the species composition of the catches. In relation to them, errors associated with fish density and parameters of the electronic system would probably be small. The estimates of quantity in metric tons should therefore be regarded with caution and for the present taken only as indicative of a general level of abundance.

REFERENCES

- Barner, L. W., and F. H. C. Taylor. 1976. Midwater trawl tows and catches made on G.B. REED cruises GBR 75-1, -2, and -3, and GBR 76-1 and -2 in the Strait of Georgia. Fish. Mar. Serv. Data Rec. 19.
- Beamish, R. J., M. Smith, and R. Scarsbrook. Hake and pollock study, Strait of Georgia cruises G.B. REED, January 6 to February 21, 1975. Fish. Mar. Serv. Data Rec. (In prep.)
- Cockbain, A. E. 1963a. Submarine topography and sediment thickness in the southern Strait of Georgia. Inst. Oceanogr. Univ. B.C. MS Rep. 14: 8 p.
- 1963b. Distribution of sediments on the continental shelf off the southern British Columbia coast. Inst. Oceanogr. Univ. B.C. MS Rep. 15: 7 p.
- Ford, J. S. 1974. Echo integrator absolute constants put into real numbers. Fish. Mar. Serv. Res. Dev. Tech. Rep. 467: 33 p.
- Love, R. H. 1971. Measurements of fish target strength. A review. U.S. Dep. Commer. Natl. Mar. Fish. Serv. Fish. Bull. 69(4): 705-715.
- Nakken, O., and K. Olsen. 1973. Target strength measurements of fish. ICES, FAO and ICNAF Joint Symposium on Acoustic Methods in Fisheries Research. June 1973. Paper No. 24: 33 p.
- Nunnallee, E. P., Jr. 1973. A hydroacoustic data acquisition and digital data analysis system for the assessment of fish stock abundance. Fish. Res. Inst. Univ. Wash. Circ. 73-3: 48 p.
- Pharo, C. H. 1972. Sediments of the central and southern Strait of Georgia, British Columbia. Ph.D. Thesis, Dep. Geology, Univ. B.C. 290 p.
- Thorne, R. H. 1973. Digital hydroacoustic data-processing system and its application to Pacific hake stock assessment in Port Susan, Washington. U.S. Dep. Commer. Natl. Mar. Fish. Serv. Fish. Bull. 71(3): 837-843.
- Westrheim, S. J. 1974. Exploration of deep-water trawling grounds in the Strait of Georgia in 1974. Fish. Res. Board Can. MS Rep. 1320: 25 p.

Table 1. Integration normalizing constants by integrator gain setting.

<u>Integrator gain (dB)</u>	<u>Normalizing constant</u>
3	2.14358
6	1.00068
9	0.51028
12	0.25154
15	0.12926
18	0.06390

Table 2. Total catch and percentage composition of midwater trawl tows in the same locality above, in, and below the main layer.

	No. of tows	Total catch	Percent				
			Hake	Dogfish	Pollock	Catshark	Other
Above main layer	6	1,418	42.0	47.6	8.6	0.6	1.1
In main layer	6	4,884	83.1	12.9	0.7	1.6	1.7
Near bottom	4	4,545	82.2	14.8	0.1	1.2	1.6
In main layer	4	2,654	77.4	17.5	0.3	2.1	2.8

Table 3. The relation between average catch (kg) and average density of fish.

Period	Depth zone (m)	Density level	Position	No. of tows	Average density	Average catch (kg)	Range in catch (kg)
Jan-Feb	100-450	$.1-.5 \times 10^{-3}$	In main layer	10	$.2 \times 10^{-3}$	1,460	183- 4,987
			Below main layer	4	$.2 \times 10^{-3}$	1,150	517- 2,692
			Above main layer	4	$.2 \times 10^{-3}$	242	27- 426
		$.6-.9 \times 10^{-4}$	In main layer	4	$.6 \times 10^{-4}$	260	150- 380
			Below main layer	1	$.6 \times 10^{-4}$	780	-
			Above main layer	4	$.7 \times 10^{-4}$	392	150- 308
June	50-150	$.1-.5 \times 10^{-3}$	In layer	5	$.2 \times 10^{-3}$	6,702	3,350-11,463
			" "	4	$.7 \times 10^{-3}$	1,430	1,205- 1,627
			" "	17	$.1 \times 10^{-4}$	258	8- 1,035
			" "	2	$.6 \times 10^{-4}$	207	205- 210
			" "	4	$.2 \times 10^{-4}$	59	20- 109
	150-450	$.1-.5 \times 10^{-2}$	In layer	3	$.1 \times 10^{-2}$	22	7- 31
			" "	5	$.7 \times 10^{-3}$	34	5- 80
			" "	19	$.3 \times 10^{-3}$	52	0- 180
			" "	5	$.7 \times 10^{-4}$	128	16- 358

Table 4. Total relative biomass ( $\times 10^6$ ) and total relative numbers ( $\times 10^6$ ) of hake, pollock and dogfish in the Strait of Georgia in January, February and June, 1975.

	Total biomass			Hake			Pollock			Dogfish		
	Jan.	Feb.	June	Jan.	Feb.	June	Jan.	Feb.	June	Jan.	Feb.	June
<u>Northern Strait</u>												
Quadra Basin	12.835	8.937	15.124	9.292	5.719	13.310	0.896	0.727	0.907	2.570	2.251	0.907
Hernando Basin	2.029	2.141	3.206	1.380	1.370	2.822	0.020	0.064	0.192	0.609	0.642	0.192
Shearwater Pass, etc.	0.595	0.057		0.524	0.052		+	+		0.060	0.003	
Total	15.459	11.135	18.330	11.196	7.141	16.132	0.916	0.791	1.099	3.239	2.896	1.099
<u>North Central Strait</u>												
Hornby Basin	3.771	4.667	24.003	2.451	2.287	21.123	0.038	-	2.160	1.207	2.287	0.750
Lasqueti Ridge	1.047	0.229		0.168	0.037		0.419	0.092		0.168	0.037	
Malaspina Strait	17.374	11.436	7.120	16.332	9.035	5.137	0.348	0.114	1.789	0.695	2.058	0.193
Total	22.192	16.332	31.123	18.951	11.359	26.260	0.805	0.206	3.949	2.070	4.382	0.943
<u>South Central Strait</u>												
S. Malaspina Basin	5.758	11.361		3.915	5.681		0.230	3.067		1.555	2.386	
Ballenas Basin	13.738	14.201		7.556	5.965		1.236	1.136		4.396	6.816	
South Ridges	1.590	2.198		0.827	1.143		0.239	0.330		0.477	0.659	
Total	21.086	27.760	23.069	12.298	12.789	19.821	1.705	4.533	1.834	6.428	9.861	1.418
<u>Southern Strait</u>												
Sand Heads	1.643	2.046		0.871	1.084		0.361	0.450		0.131	0.164	
Roberts Swell	0.231	0.096		0.125	0.052		0.058	0.024		0.032	0.013	
Total	1.874	2.142	8.437	0.996	1.136	5.568	0.419	0.474	1.350	0.163	0.177	1.518
Grand total	60.611	57.369	80.959	43.441	32.425	67.781	3.845	6.004	8.232	11.900	17.316	4.978

Table 5. The relative proportions of the major species used in the calculation of relative numbers by species and region for January, February and June, 1975.

Region	January			February			June <sup>c</sup>					
	No. of samples	Hake	Pollock	Dogfish	No. of samples	Hake	Pollock	Dogfish	No. of samples	Hake	Pollock	Dogfish
Hernando Basin	[2] <sup>a</sup>	[68]	[1]	[30]	[3]	[64]	[3]	[30]	[8]	[88]	[6]	[6]
Quadra Basin												
N of Exeter Shoal	2 <sup>d</sup>	68	1	30	3	64	3	30	8	88	6	6
S of Exeter Shoal	1	79	16	5	(2) <sup>b</sup>	(64)	(19)	(15)	[8]	[88]	[6]	[6]
Malaspina Basin												
N of Jervis Inlet	[3]	[94]	[2]	[4]	[4]	[(79)]	[(1)]	[(18)]	2	91	8	1
S of Jervis Inlet	3	94	2	4	(4)	(79)	(1)	(18)	1	58	38	4
S of Texada Isl.	3	68	4	27	4	50	27	21	3	29	61	10
Hornby Basin	2	65	1	32	1	49	-	49	5	88	9	3
Ballenas Basin												
N of Gabriola Pass	5	55	9	33	1	42	8	48	8	88	6	6
S of Gabriola Pass	[5]	[55]	[9]	[33]	[1]	[42]	[8]	[48]	[8]	[88]	[6]	[6]
Shearwater-Algerine Pass	2	88	+	10	(2)	(91)	(+)	(6)	[8]	[88]	[6]	[6]
Lasqueti Ridge	(1)	(16)	(40)	(16)	(1)	(16)	(40)	(16)	[5]	[88]	[9]	[3]
South Ridges Area	(3)	(52)	(15)	(30)	(3)	(52)	(15)	(30)	[8]	[88]	[6]	[6]
Sand Heads	(1)	(53)	(22)	(8)	(1)	(53)	(22)	(8)	} 1	66	16	18
Roberts Swell	(1)	(54)	(6)	(14)	(1)	(54)	(6)	(14)				

<sup>a</sup> [% from an adjacent region for the same period.

<sup>b</sup> (%) % for the same region but for another period, usually between the January and February cruises.

<sup>c</sup> June %'s are based on catches > 50 kg taken in the 50-150 m depth zone.

<sup>d</sup> The %'s do not always add up to 100%, as the % of other unidentified species is excluded.

Table 6. The estimated quantity in numbers ( $\times 10^6$ ) and in metric tons of hake and pollock by region in the Strait of Georgia in January, February and June, 1975.

	Hake						Pollock					
	Actual no. ( $\times 10^6$ )			Metric tons			Actual no. ( $\times 10^6$ )			Metric tons		
	Jan.	Feb.	June	Jan.	Feb.	June	Jan.	Feb.	June	Jan.	Feb.	June
<u>Northern Strait</u>												
Quadra Basin	39.637	24.396	56.778	25,224	15,524	36,131	4.191	3.400	4.242	2,667	2,164	2,699
Hernando Basin	5.887	5.844)	12.038	3,746	3,719)	7,661	0.094	0.299)	0.898	60	190)	571
Shearwater Pass	2.235	0.222)		1,422	141)		+	+		+	+	
Total	47.761	30.462	68.816	30,392	19,384	43,792	4.285	3.699	5.140	2,727	2,354	3,270
<u>North Central Strait</u>												
Hornby Basin	10.455	9.756)	90.106	6,653	6,208)	57,340	0.178	- )	10.103	113	- )	6,429
Lasqueti Ridge	0.717	0.158)		456	101)		1.960	0.430)		1,247	274)	
Malaspina Strait	69.670	38.541	21.913	44,336	24,526	13,945	1.628	0.533	8.368	1,036	339	5,325
Total	80.842	48.455	112.019	51,445	30,835	71,285	3.766	0.963	18.471	2,396	613	11,754
<u>South Central Strait</u>												
S. Malaspina Basin	16.701	24.234		10,628	15,422		1.076	14.346		685	9,129	
Ballenas Basin	32.233	25.445		20,512	16,192		5.781	5.313		3,679	3,381	
South Ridge	3.536	4.876		2,250	3,103		1.118	1.544		711	983	
Total	52.470	54.555	84.552	33,390	34,717	53,806	7.975	21.203	8.578	5,075	13,493	5,459
<u>Southern Strait</u>												
Sand Heads	2.675	4.624		1,702	2,943		1.668	2.105		1,061	1,340	
Roberts Swell	0.533	0.222		339	141		0.271	0.112		172	71	
Total	3.208	4.846	23.752	2,041	3,084	15,115	1.939	2.217	6.314	1,233	1,411	4,018
Grand total	184.281	138.318	289.139	117,268	88,020	183,998	17.965	28.082	38.503	11,431	17,871	24,501

FIGURES



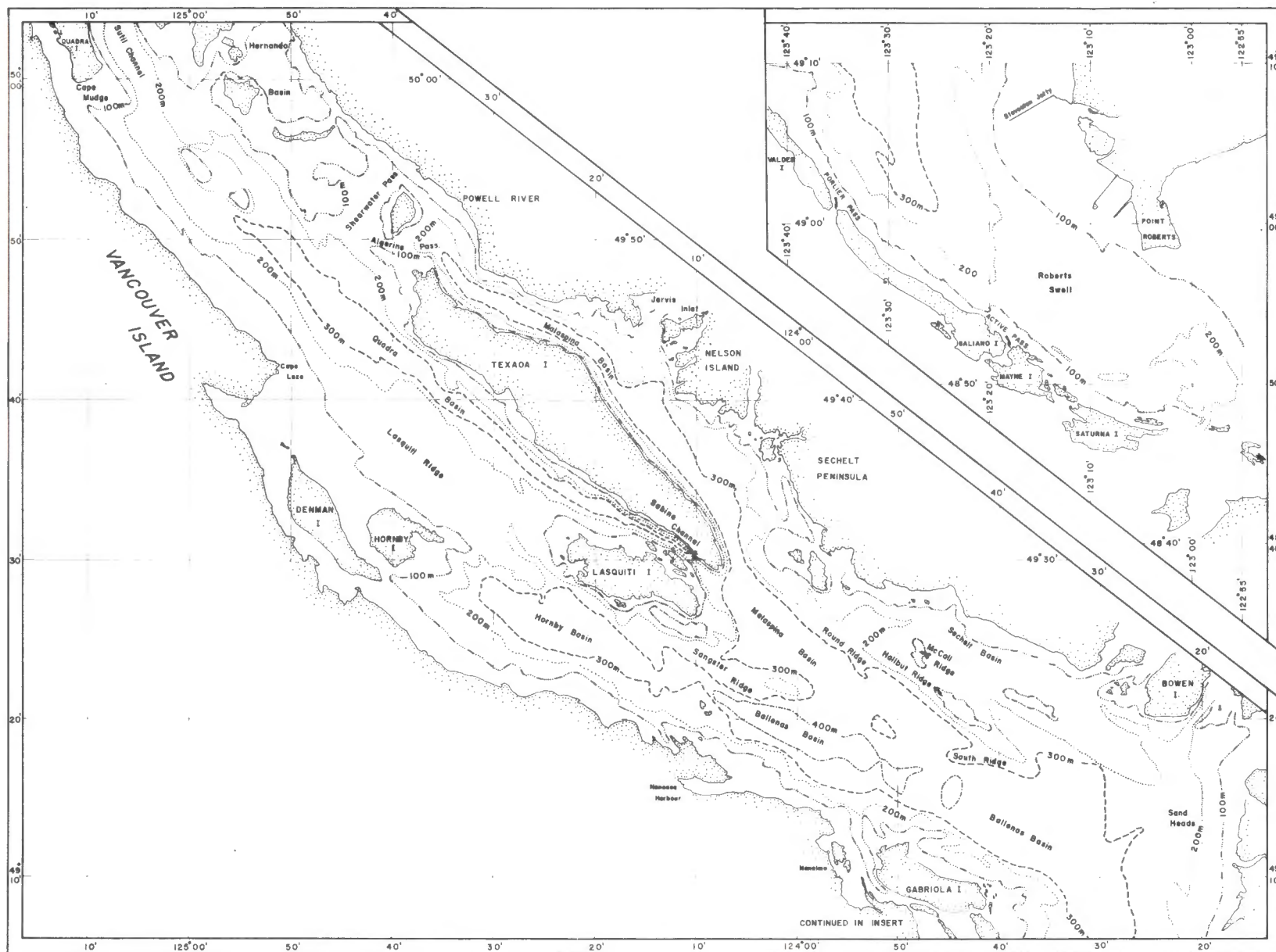


Fig. 1. Map of the Strait of Georgia, showing place names referred to in the text.



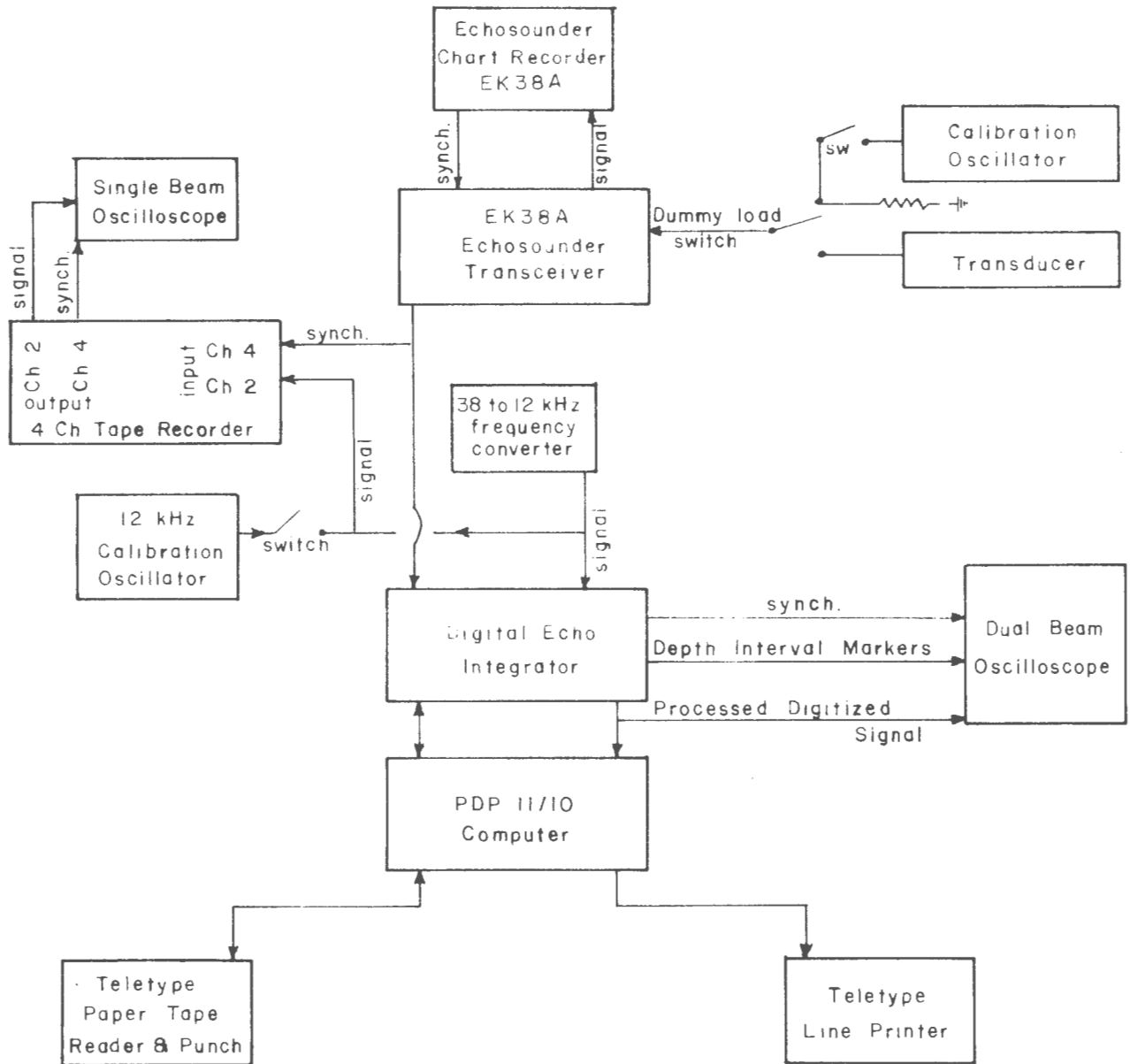


Fig. 2 Shipboard data acquisition and integration system.



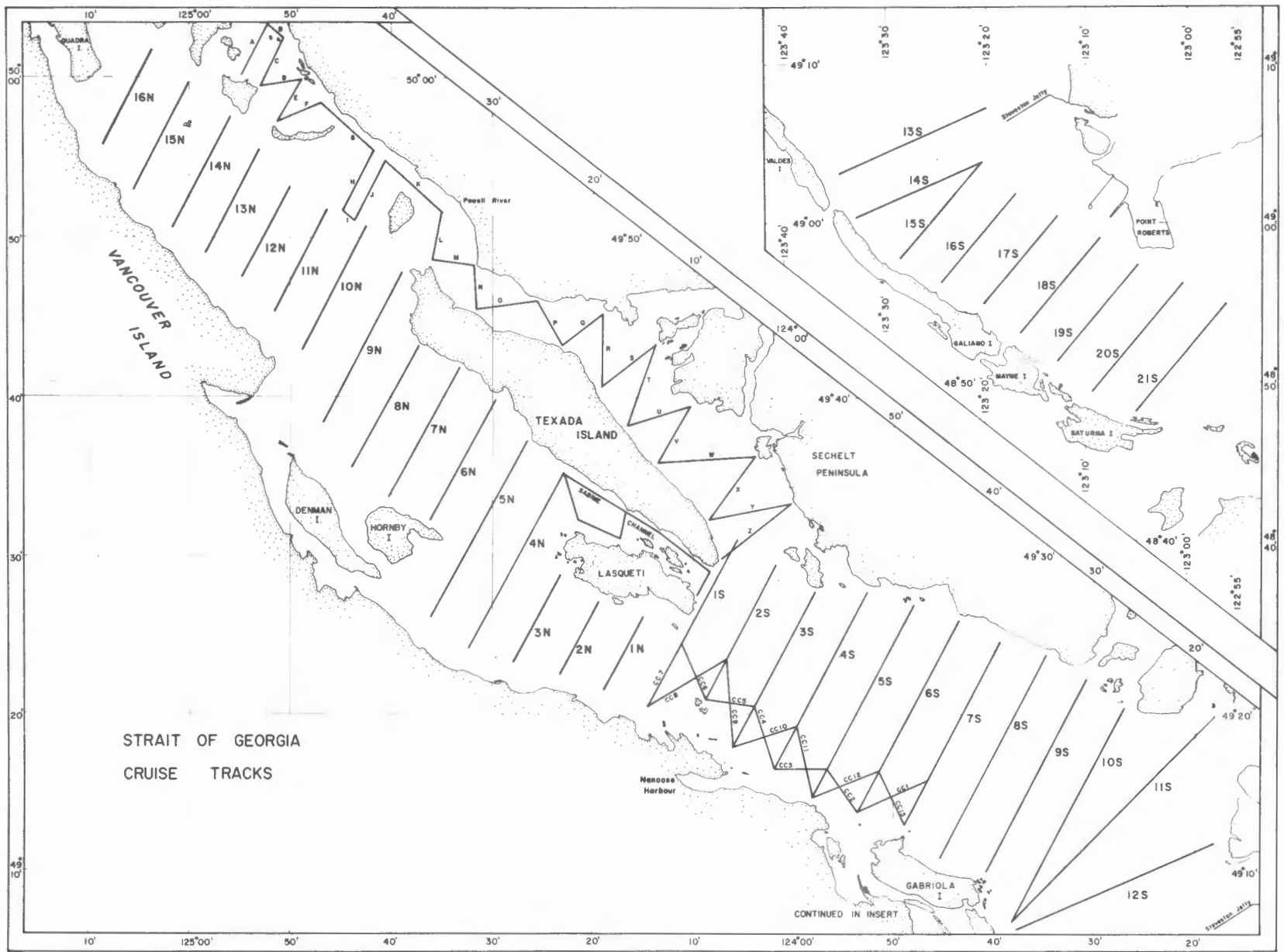


Fig. 3. Plan of the transect lines in the Strait of Georgia followed on G.B. REED Cruises 75-1, 75-2 and 75-3.



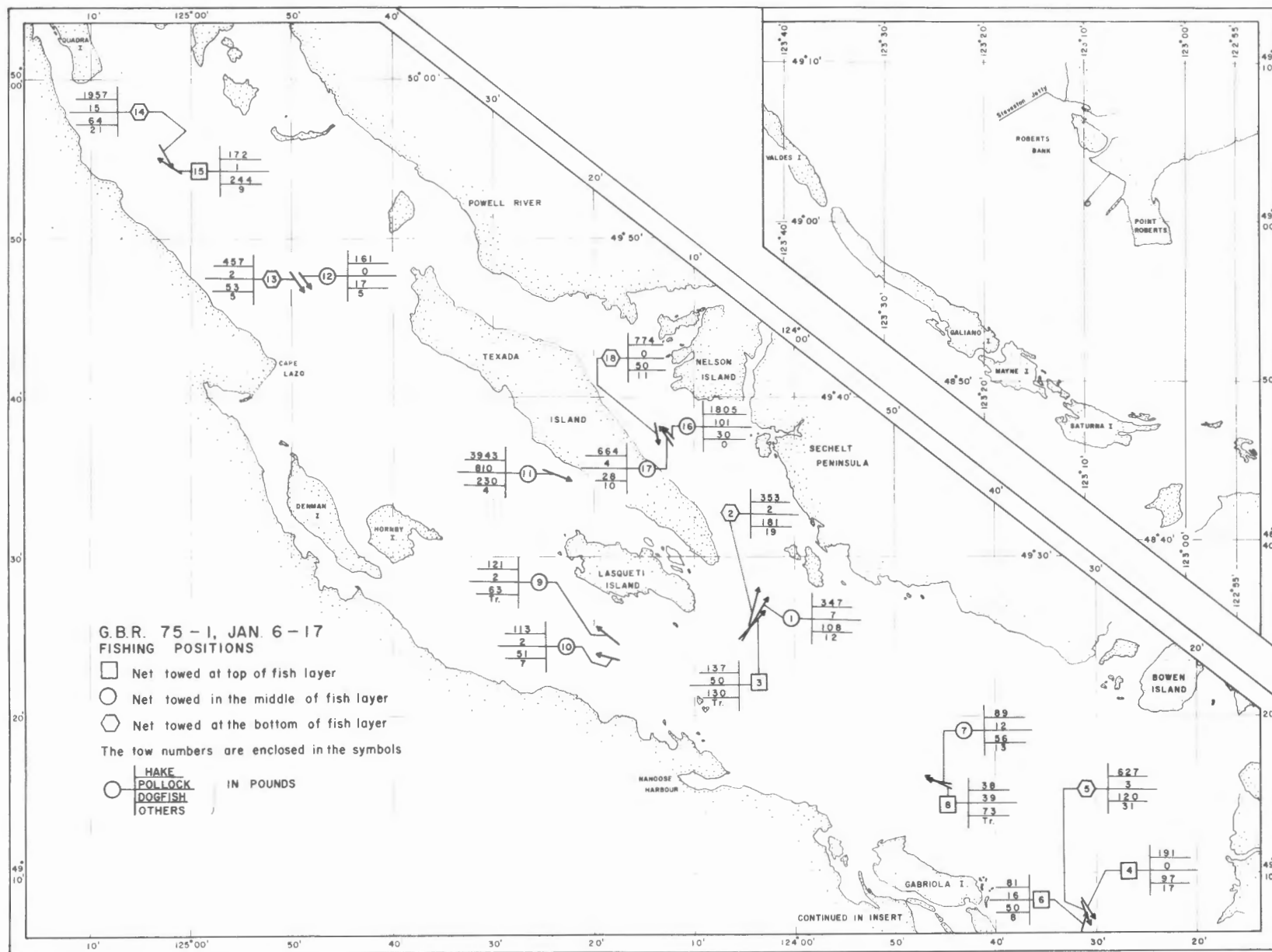


Fig. 4. The locations of midwater trawl tows made on G.B. REED Cruise 75-1, to the Strait of Georgia, Jan. 6-17, 1975.



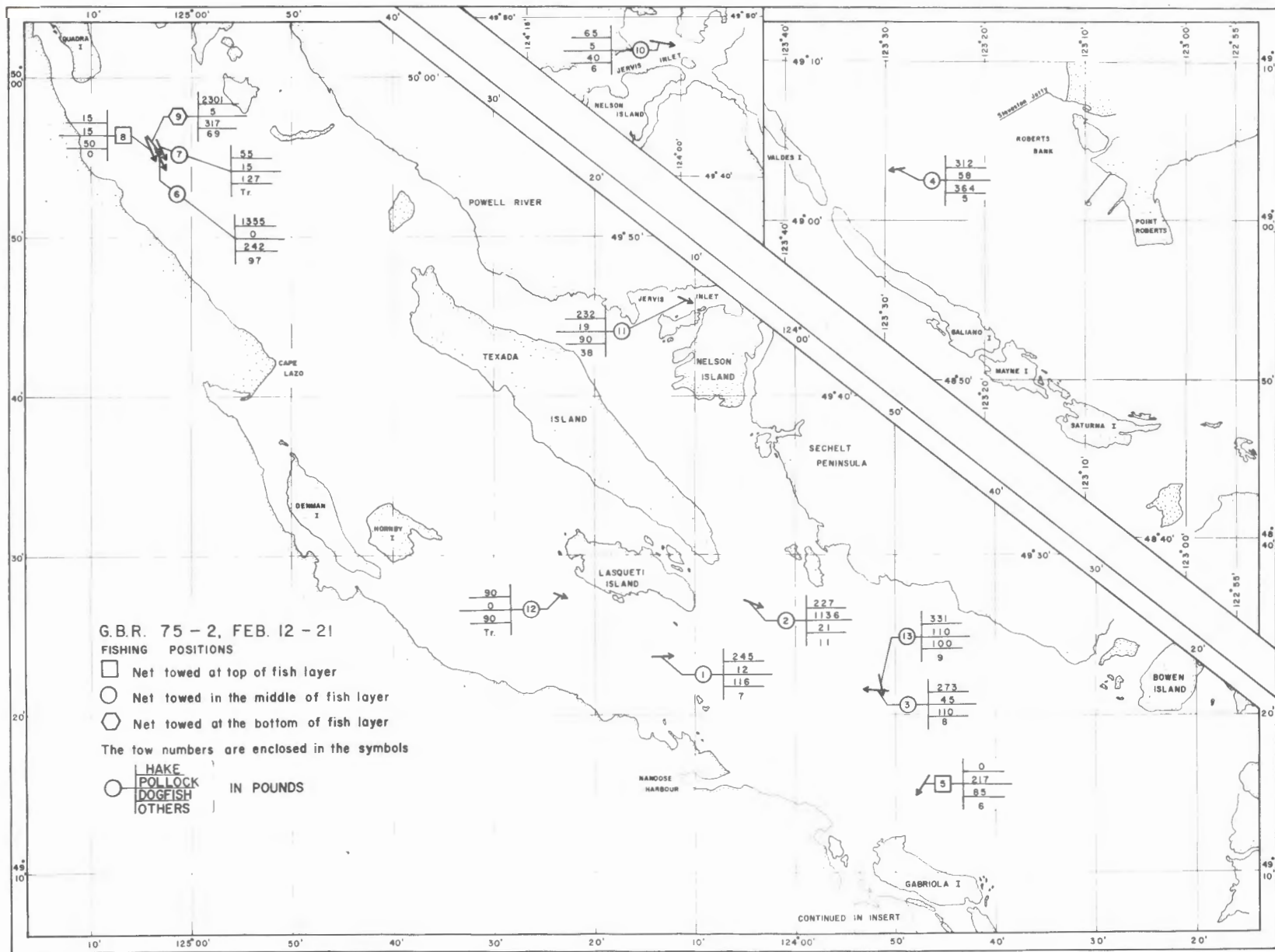


Fig. 5. The locations of midwater trawl tows made on G.B. REED Cruise 75-2, to the Strait of Georgia, Feb. 10-21, 1975.



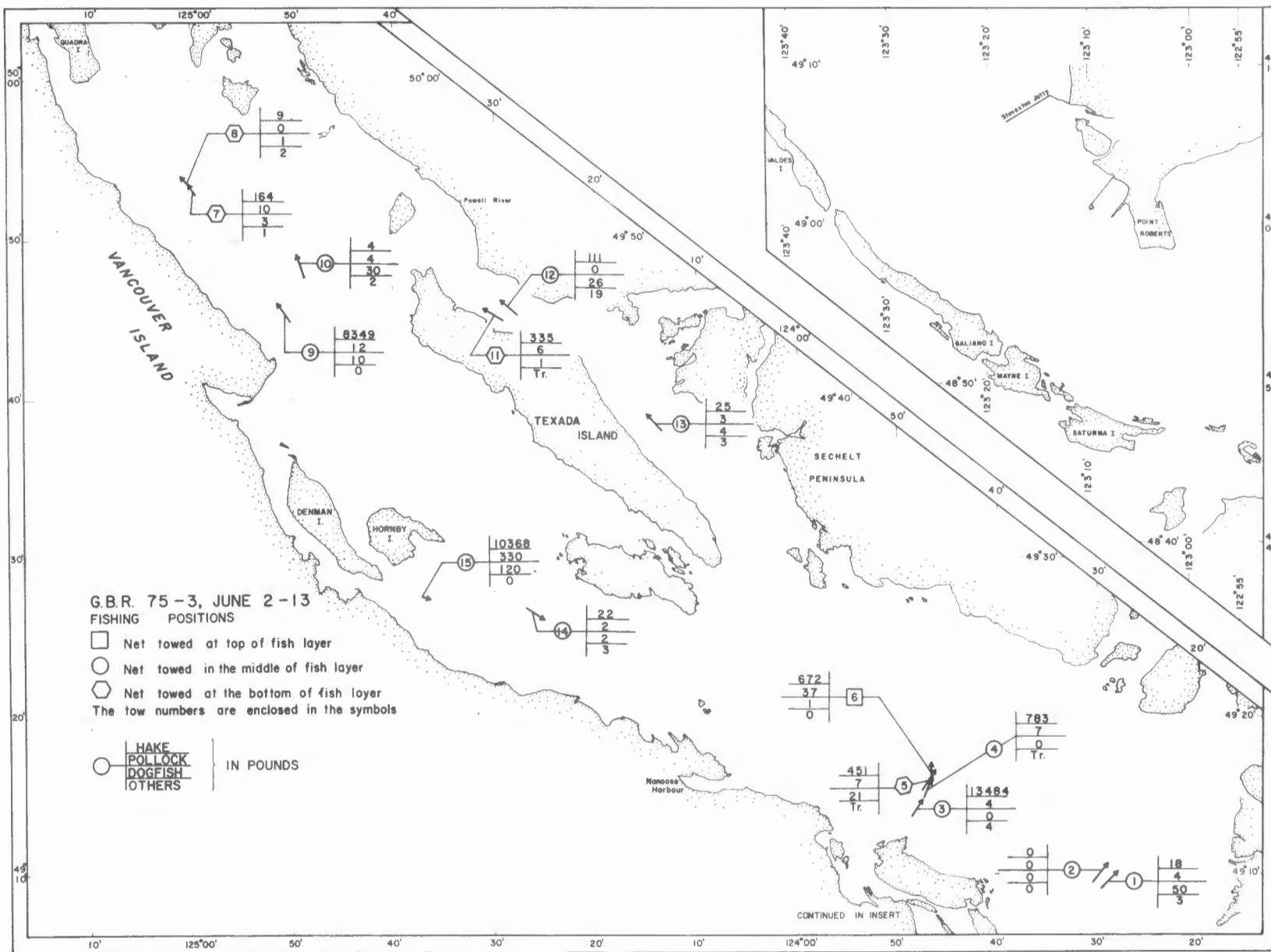


Fig. 6. The locations of midwater trawl tows made on G.B. REED Cruise 75-3, to the Strait of Georgia, June 2-13, 1975.



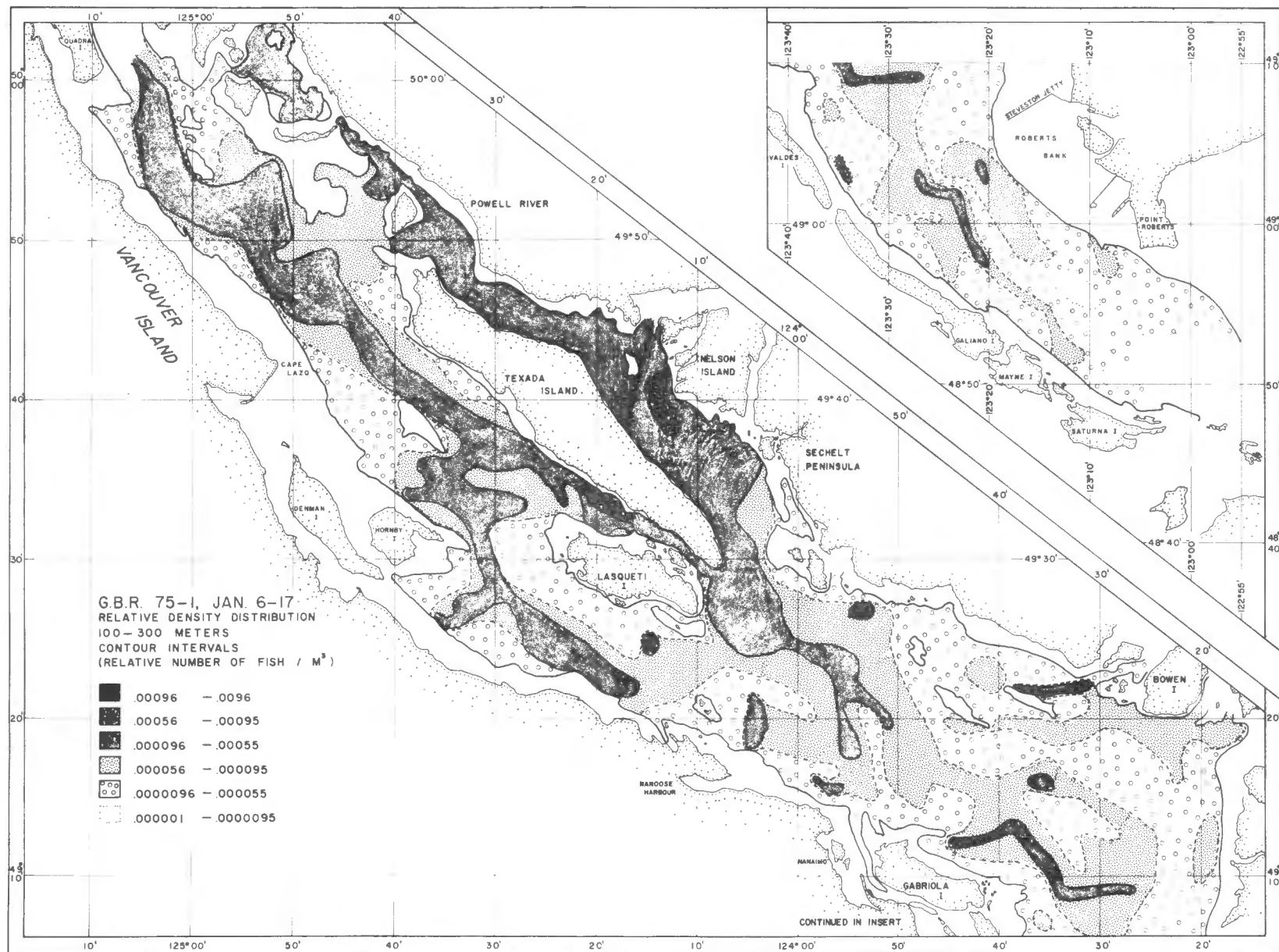


Fig. 7. Distribution of fish in the 100-300 m depth zone in the Strait of Georgia on G.B. REED Cruise 75-1.



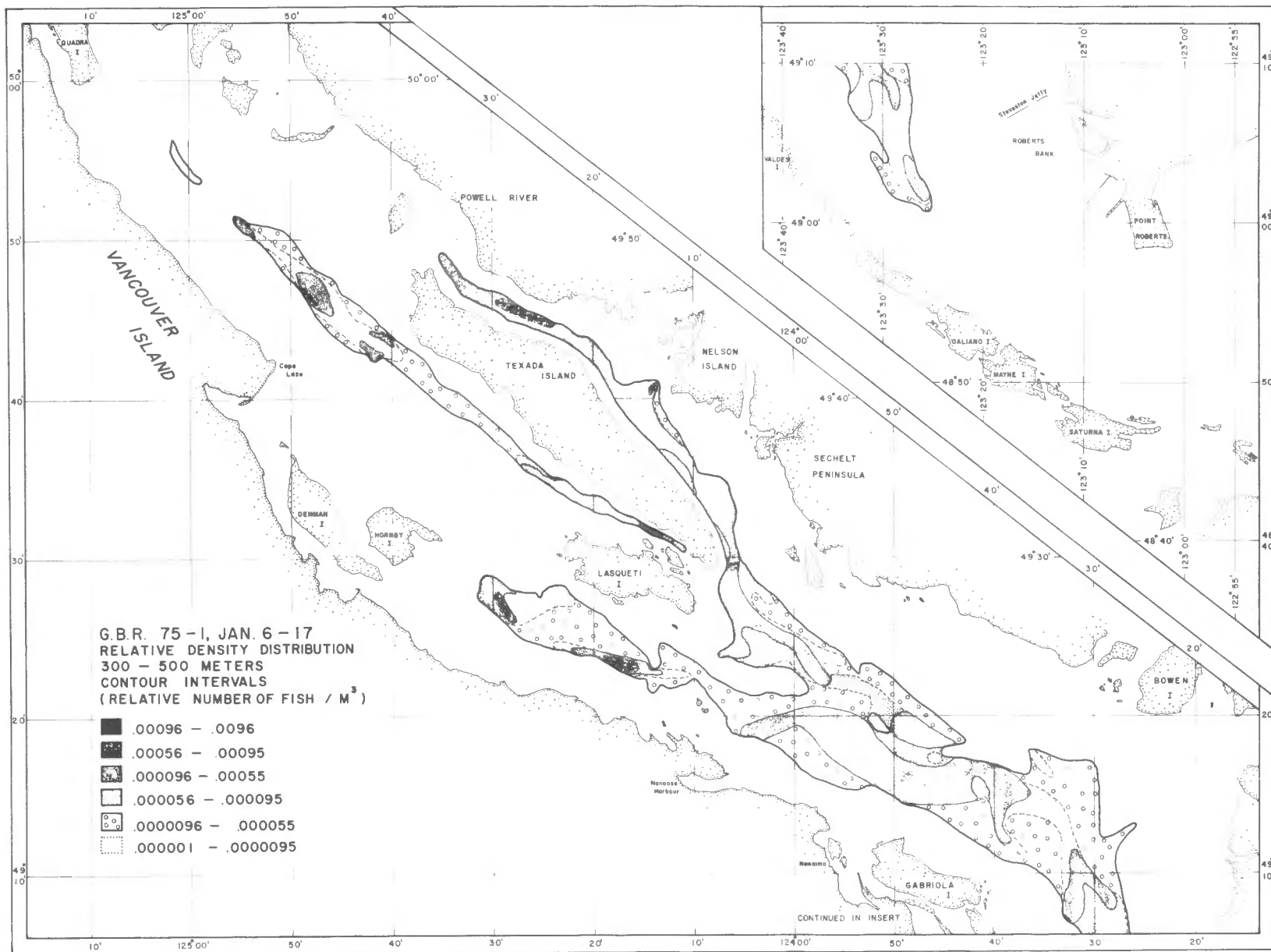


Fig. 8. Distribution of fish in the 300-500 m depth zone in the Strait of Georgia on G.B. REED Cruise 75-1.



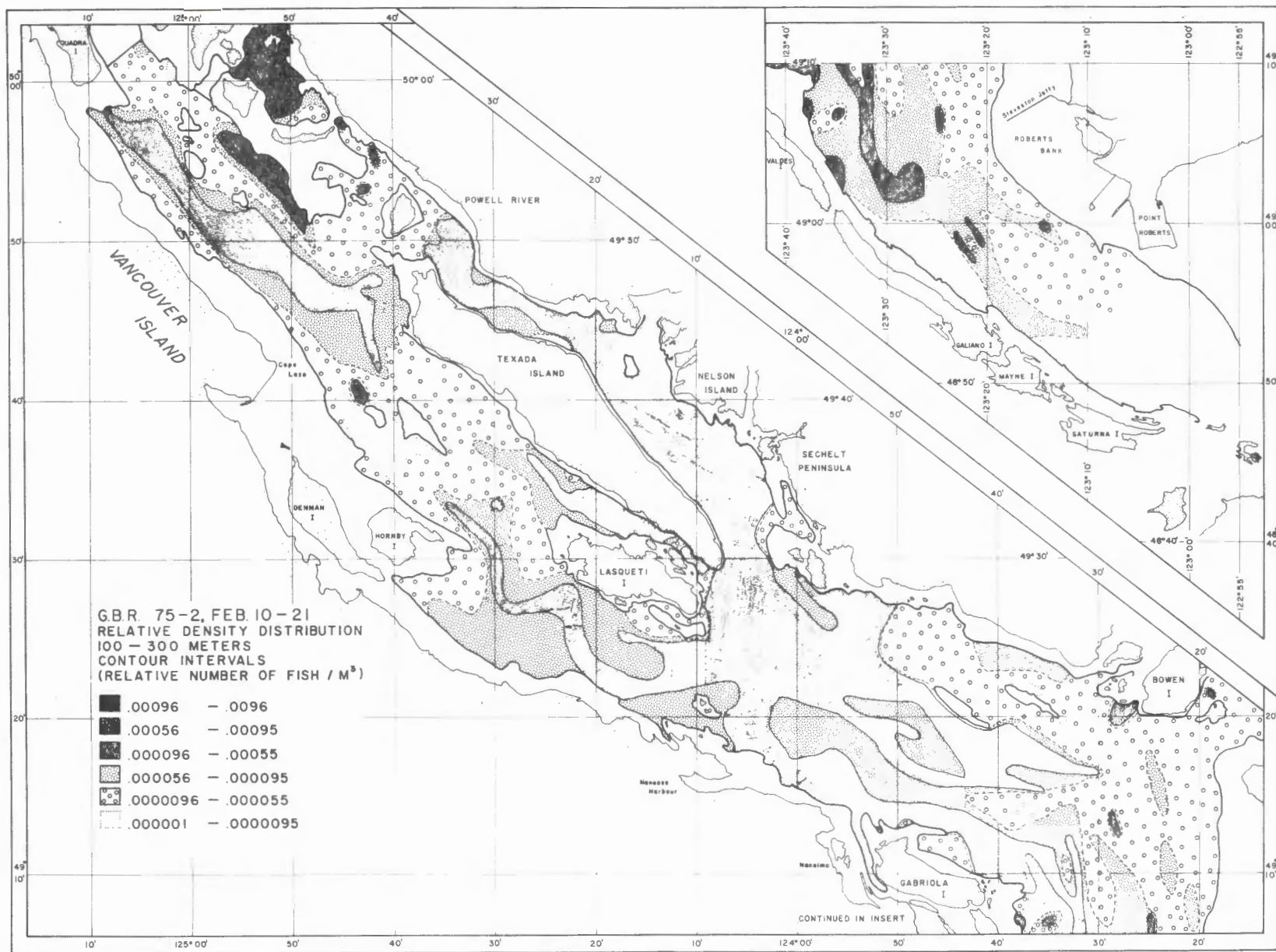


Fig. 9. Distribution of fish in the 100-300 m depth zone in the Strait of Georgia on G.B. REED Cruise 75-2.



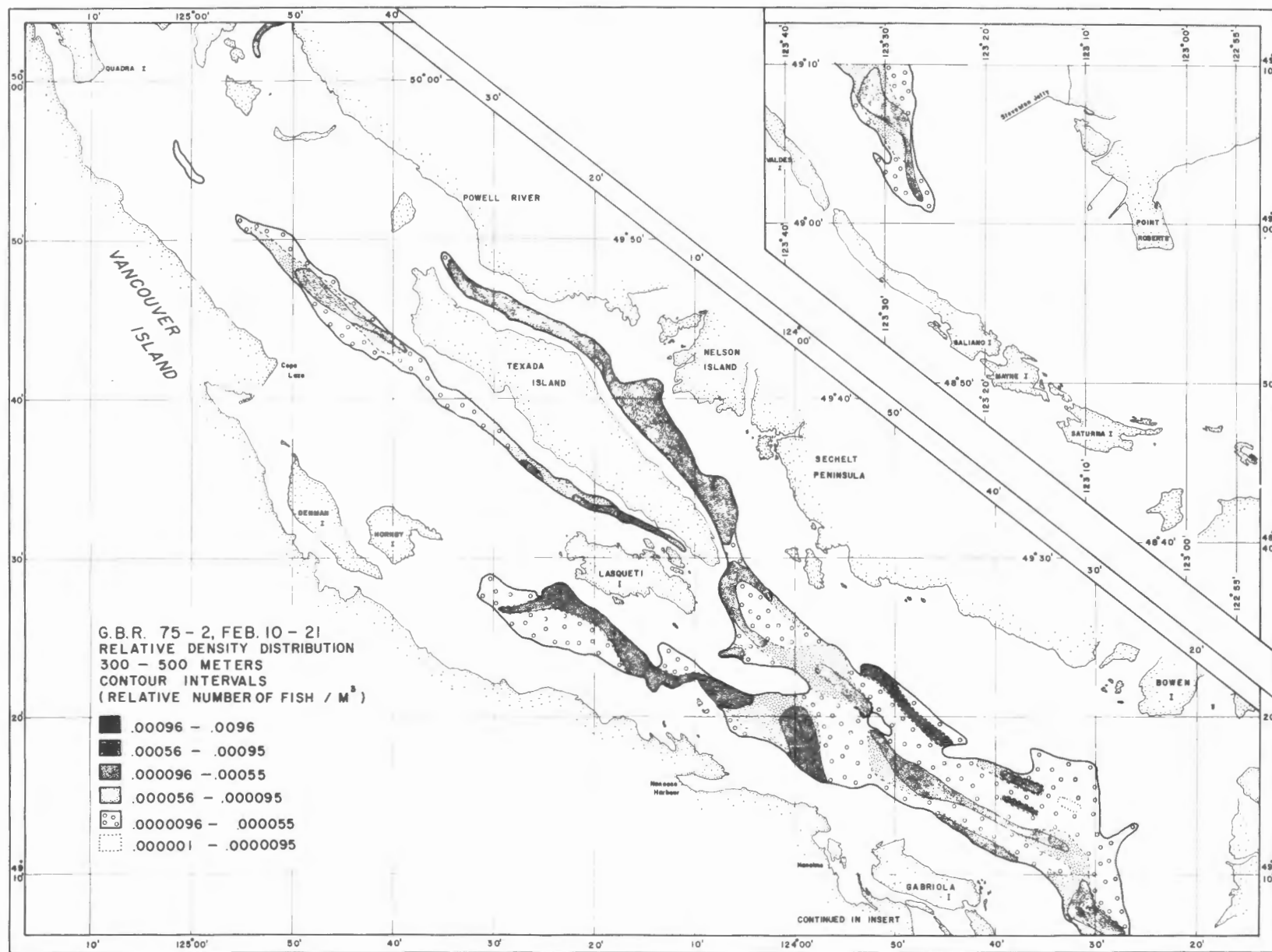


Fig. 10. Distribution of fish in the 300-500 m depth zone in the Strait of Georgia on G.B. REED Cruise 75-2.



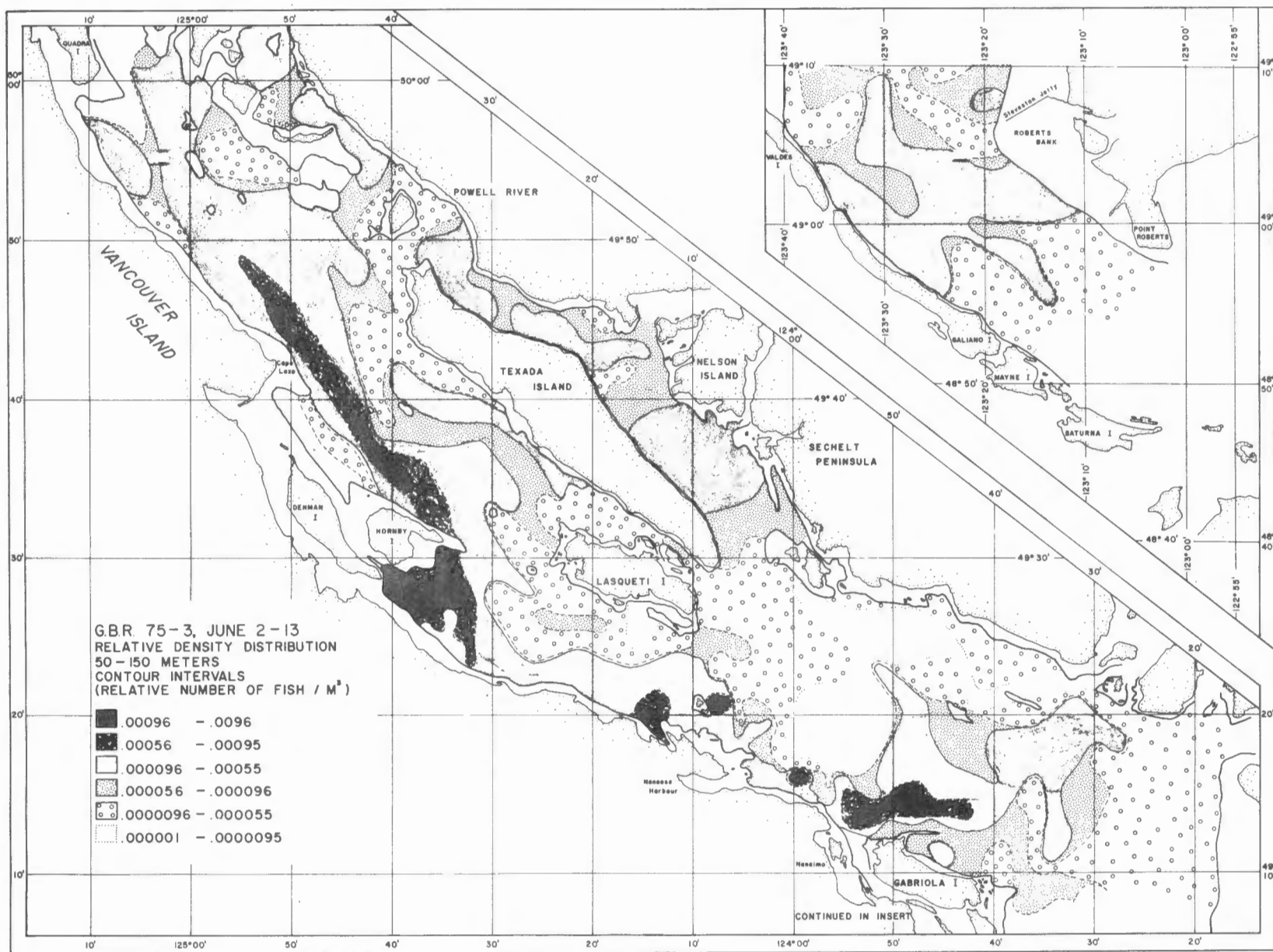


Fig. 11. Distribution of fish in the 50-150 m depth zone in the Strait of Georgia on G.B. REED Cruise 75-3.



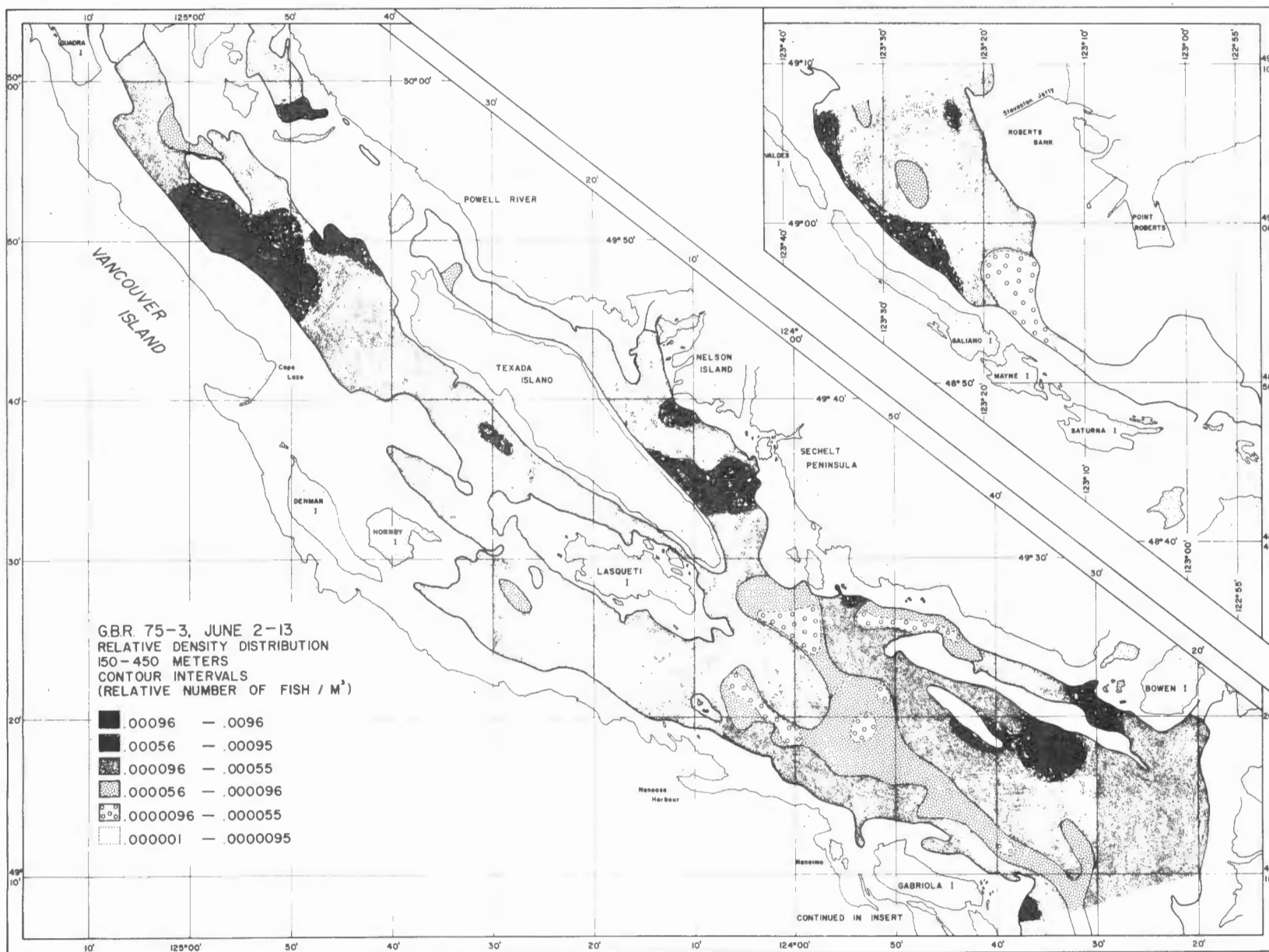


Fig. 12. Distribution of fish in the 150-450 m depth zone in the Strait of Georgia on G.B. REED Cruise 75-3.



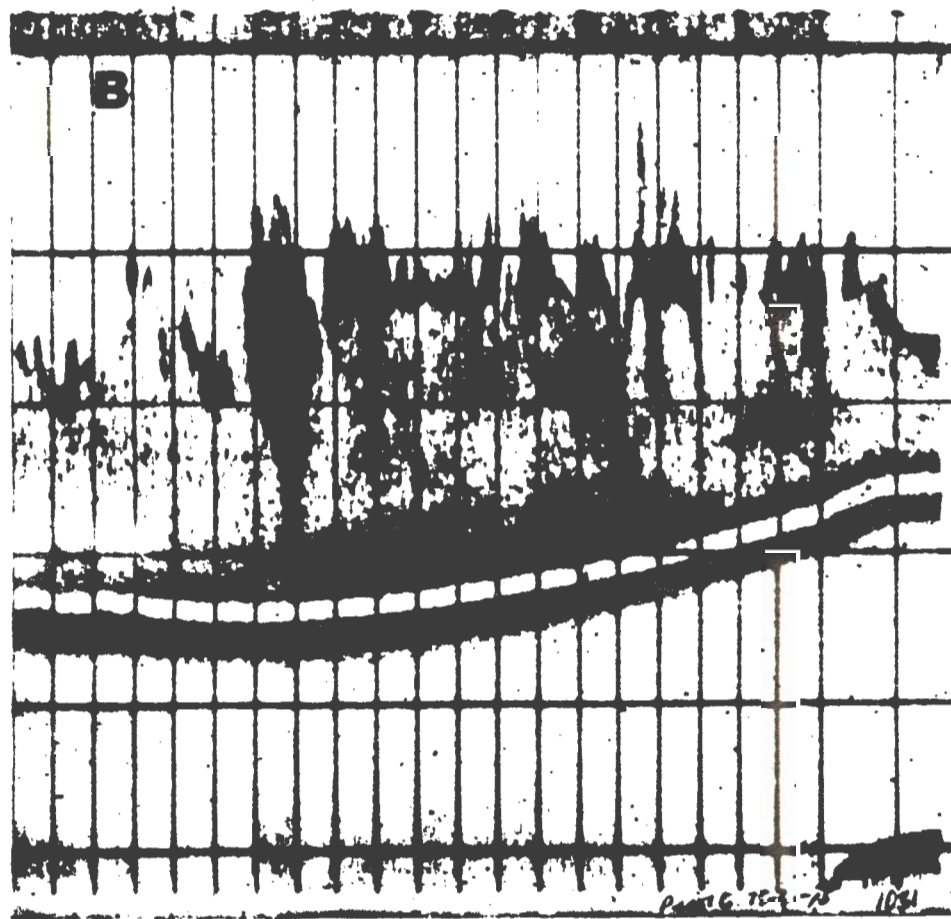


Fig. 13. Appearance of the sound-reflecting layers in the Strait of Georgia in January and February, 1975 (A) and in June, 1975 (B).