# Herring Stock Estimates from Diving Surveys of Spawn on the West Coast of Vancouver Island in 1986

C. W. Haegele and J. F. Schweigert

Department of Fisheries Oceans
Fisheries Research Branch
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6



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C. W. Haegele and J. F. Schweigert

Department of Fisheries and Oceans
Fisheries Research Branch
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

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## ABSTRACT

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Spawn surveys estimated herring stocks on the west coast of Vancouver Island in 1986 at 42,447 tonnes. In Area 23 (Barkley Sound), 26,600 tonnes were estimated to have spawned in a single wave, principally in Loudon Channel. In Area 24, 654 tonnes spawned in Clayoquot Sound and 1761 tonnes spawned in Hesquiat Harbour for an estimated total of 2415 tonnes. There were 8405 tonnes of spawners estimated in Area 25, all of which spawned in Esperanza Inlet and the bulk (93%) spawned in the second of three waves. There was no spawn observed in the Nootka Sound portion of Area 25 and no spawn was recorded in Area 26. In Klaskish Inlet a stock of 815 tonnes was estimated and in Forward Inlet a stock of 4009 tonnes was estimated, for an Area 27 total of 4824 tonnes. Stocks on the west coast of Vancouver Island showed a 50% increase over stocks estimated in a similar survey in 1985. Egg densities were lower in Area 24, at 74,825 eggs per sq. m, than in any of the other areas, where it ranged from 458,464 to 521,761 eggs per sq. m. Spawn was deposited deeper in Barkley Sound, where over 50% of the spawn was deposited lower than 6 m below chart datum, than in the other areas, where no eggs were deposited deeper than 6 m below chart datum. Sea grasses were the most common vegetation utilized for egg deposition in shallow water while filamentous red algae were the most common vegetation in deeper water. Approximately 3% of the eggs were deposited on the giant kelp, Macrocystis sp.

## RÉSUMÉ

Haegele, C. W. and J. F. Schweigert. 1987. Herring stock estimates from diving surveys of spawn on the west coast of Vancouver Island in 1986. Can. MS Rep. Fish. Aquat. Sci. 1959: 63 p.

Selon des levés de la fraie, l'abondance des stocks de hareng de la côte ouest de l'Île de Vancouver se situait à 42 447 tonnes en 1986. Dans le district 23 (baie Barkley), on a déterminé que 26 600 tonnes de hareng ont frayé en une seule vague en particulier dans le chenal Loudoun. Dans le district 24, 654 tonnes ont frayé dans la baie Clayoquot tandis que 1 761 tonnes ont frayé dans le port d'Hesquiat, soit un total estimatif de 2 415 tonnes. Pour ce qui est du district 25, les géniteurs totalisaient 8 405 tonnes; tous ont frayé dans l'inlet Esperanza, en majorité (93 %) au cours de la deuxième et de la troisième vague. Aucune fraie n'a été observée dans la baie Nootka du district 25 ainsi que dans le district 26. Dans les inlets Klaskish et Forward, on a fixé l'abondance respective à 815 et 4 009 tonnes, soit un total de 4 824 tonnes dans le district 27. Les stocks de la côte ouest de l'Île de Vancouver ont montré une augmentation de 50 % par rapport aux stocks évalués de la même manière en 1985. La densité des oeufs était moins élevée dans le district 24 (74 825 oeufs/mi$^2$) que dans les autres districts où elle variait de 458 464 à 521 761 oeufs/mi$^2$. Dans la baie Barkley, la fraie a eu lieu à de plus grandes profondeurs; ainsi, plus de 50 % des oeufs ont été pondus à plus de 6 m au-dessous du zéro des cartes; dans les autres districts, il n'y a pas eu de ponte au-dessous de ce niveau. Dans les eaux peu profondes, les herbiers ont servi de site de ponte tandis que dans les eaux plus profondes, les algues rouges filamenteuses ont servi de substrat à la rogue. Environ 3 % des oeufs ont été déposés sur des algues brunes du genre Macrocystis.

## INTRODUCTION

Herring spawns on the west coast of Vancouver Island have been surveyed by divers since 1982 to directly estimate adult spawner biomass, independently from stock assessment models (Haist et al. 1986). Area 23 herring spawn was surveyed by divers in 1982 (Haegele and Schweigert 1984), and in 1984 and 1985 most of the herring spawn on the west coast of Vancouver Island was surveyed by divers (Haegele and Schweigert 1985a and 1987). Diving surveys of herring spawn were again conducted on the west coast of Vancouver Island in 1986 and are the subject of this report.

## METHODS

Herring spawns were surveyed either by SCUBA divers or by traditional surface survey techniques. In the surface survey, visual observations were made from a boat, frequently a viewing box was used to increase the visibility of the bottom, and, in some instances, this was supplemented by snorkelling. Grapples were used to determine the presence of and obtain samples of spawn. From these observations the length and width of spawn and the layers of eggs were estimated. The proportion of the area of the spawn devoid of eggs or vegetation (bare area) was also estimated. The observed length and an adjusted width was used to calculate the area of the spawn. Egg density was estimated from egg layer observations. The equations and parameter estimates for these adjustments are given by Haist et al. (1986):

$$(1)\quad Width_{adj} = \exp\left[0.375 \log_e (Width_{obs}) + 3.401\right]$$

$$(2)\quad Eggs * m^{-2} = 75861 + 105321 * Lay_{av}$$

The analysis of the data from the 1982, 1984, and 1985 spawn surveys was re-done by treating the data for spawns surveyed only from the surface in the manner described above.

The diving survey estimated egg deposition on the giant kelp, Macrocystis sp., separately from egg deposition on the understory vegetation and bottom substrate. The understory and bottom substrate survey followed a two-stage sampling design (Schweigert et al. 1985). Transects perpendicular to the shore were the primary sampling unit and 0.5 sq. m quadrats sampled along the transect were the secondary sampling unit. Samples consisted of all the rooted or attached vegetation, and the eggs adhering to it, within the quadrat. Layers of eggs, percent cover of the vegetation, the dominant vegetation type, and depth were estimated by divers for each quadrat. Samples were weighed and weighed subsamples were preserved in Gilson's fluid and egg

counts obtained. Spawns on the islands in Barkley Sound were near hatching at the time of the survey and egg counts could not be obtained because the egg membranes ruptured on preservation. For these samples egg density for each quadrat was predicted with a model, modified from Schweigert and Fournier (1982), that uses the quadrat observations and sample weight. Eggs on the bottom substrate were estimated from diver estimates of layers of eggs and percent of bottom covered by eggs (Haegele et al. 1979) and added to eggs on vegetation.

Transects were established at nearly equal intervals and samples were collected at equal intervals along each transect with the spacing determined by the width of the spawn. The mean egg density and 95% confidence intervals were calculated for each spawn and transect means were weighted by transect length (Schweigert et al. 1985). The inner and outer edge of spawns were determined from measurements along the transects. The limits of a spawn beyond the outer transects was determined by exploratory dives. This information was plotted on maps of marine vegetation, where available, at scales of 1:4800 or 1:6000 (e.g. Haegele and Hamey 1987), the boundaries of the spawn contoured, and the area of the spawn measured. Where vegetation maps were not available, marine charts were used.

The egg deposition on Macrocystis sp. was estimated using a procedure developed by Haegele and Schweigert (1985b). Briefly, the number of plants and fronds (mature and immature) within 1 m on either side of the transect were counted, 1 or 2 plants were harvested at each transect, and the mean number of eggs per plant or frond were estimated. This was done by counting the number of fronds per plant, cutting the plant in 1 m sections, which were weighed, and preserving 1 blade and associated stipe, which was also weighed, per section. The number of eggs in the preserved material were determined. The occurence of Macrocystis sp. was plotted on the maps and the area of Macrocystis sp. beds measured. The number of eggs deposited was the product of area, frond density, and mean number of eggs per mature frond. The procedure developed by Haegele and Schweigert (1985b) determined that this was the best estimator. However, estimates using plants and all fronds were also calculated.

Spawner biomass (tonnes) was estimated as the product of spawn area, egg density and 0.00000001, which assumes 200 eggs per gm female weight (Hay 1985) and a 1:1 sex ratio.

## RESULTS

Herring spawns on the west coast of Vancouver Island (Fig. 1) were surveyed by divers in Barkley Sound (Area 23), lower Clayoquot Sound and Hesquiat Harbour (Area 24), Esperanza Inlet (Area 25), and Forward Inlet (Area 27). Divers surveyed approximately 90% of 1986 herring spawns, the remainder were surveyed from the surface (Table 1). In Barkley Sound spawn was deposited to 18 m below chart datum. Spawn was much shallower in the other

areas, with the outer edge of spawn not exceeding 6 m below chart datum. Generally, the percent cover of the vegetation declined with depth, while egg layers increased with depth (Fig. 2 and 3). At two locations, Port Langford and Forward Inlet, egg layers decreased with depth. Egg layers in lower Clayoquot Sound and Hesquiat Harbour were much lower than at the other locations. Egg density increased with depth only in Barkley Sound. The increase in egg layers apparently more than compensated for the decrease in the vegetative substrate. Hence, while egg density increased with depth, sample weight showed a slight decrease. Egg density decreased with depth at the other locations. Therefore, in Barkley Sound, over 50% of the eggs were deposited lower than 6 m below chart datum, while spawn in the other areas was deposited entirely above this depth (Fig. 4). Approximately 3% of the eggs were deposited on Macrocystis sp. (Table 2 and 3) with the remainder deposited on understory vegetation and bottom substrate (Table 4). Spawn on understory vegetation was deposited exclusively on sea grasses in lower Clayoquot Sound. In the other areas, sea grasses and filamentous red algae were the dominant vegetation (Fig. 5 and 6). The frequency of sea grasses decreased with depth while the frequency of filamentous red algae increased with depth. Flat and stalked kelps (mostly Agarum sp., Laminaria sp. and Pterygophora sp.), rockweed, and foliose red algae occurred infrequently.

The estimated 1986 adult herring biomass on the west coast of Vancouver Island was 42,447 tonnes, of which 42,034 tonnes was estimated from spawn surveys (Table 5). The remainder were estimated from catch (203 tonnes) in Barkley Sound and spawn-on-kelp pond utilization (210 tonnes) in Area 27. Individual spawns are described below.

## AREA 23 - BARKLEY SOUND

Herring were observed to spawn in Barkley Sound in 1986 in a single wave from March 17 to 22. The spawn was continuous along the Vancouver Island shoreline from above Maggie River to below Camp Bay (Maggie River, Macoah Passage, Twin Rivers, and Camp Bay in Fig. 7 to 10). Further south along the Vancouver Island shoreline, there was spawn at Itatsoo Creek and on both shores at the entrance of Ucluelet Inlet; Stuart Bay and Spring Cove (Fig. 11) and Francis Island. There was also spawn on the islands in and adjacent to Macoah Passage: Larkin and St. Ines islands (Fig. 12); Bryant Islands (Fig. 13); Spilling, Rowlands, and Ottaway islets, for convenience collectively called Spilling Islets, (Fig. 12); and David and Forbes islands (Fig. 14). All but two of the minor spawns (Itatsoo Creek and Francis Island) were surveyed by divers, while none of the spawns along the Vancouver Island shoreline in Macoah Passage nor the spawn on Spilling Islets was surveyed from the surface. At all of the spawn sites, eggs were deposited on the understory vegetation, while at four of the spawn sites (Itatsoo Creek, Stuart Bay, Spring Cove and Larkin Island), eggs were also deposited on Macrocystis sp. Herring spawned along 27.0 km of shoreline and over a 552.1 ha area.

It was estimated that 26,600 tonnes of herring spawned in Barkley Sound, of which 559 tonnes spawned on Macrocystis sp. In addition, an estimated 203 tonnes were fished for charter vessel payment, bringing the total estimated adult spawner biomass to 26,803 tonnes. Over 75% (20,192 tonnes) deposited their eggs along the Vancouver Island shoreline. The beach slope here is gradual and the average transect slope was 0.024 (a rise of 2.4 m in 100 m). Since the average outer edge of spawn was 6.8 m below chart datum and the maximum depth of spawn was 18.4 m below chart datum, average transect length (i.e. spawn width) was long at 368 m. Egg density was high and ranged from 208,399 to 567,113 eggs per sq. m. At the mouth of and in Ucluelet Inlet 1343 tonnes spawned, with approximately 40% of this spawn deposited on Macrocystis sp. Beach slope in Ucluelet Inlet is moderate at 0.073, but the average outer edge of spawn was 9.2 m below chart datum, hence average transect length was 159 m. Egg density in Ucluelet Inlet was low at 90,377 (Stuart Bay) and 121,245 (Spring Cove) eggs per sq. m. The spawn on the islands was deposited by 5065 tonnes and 31 of these spawned on Macrocystis sp. The beach slope on the islands, at 0.111, was the steepest encountered on this survey and the average outer edge of spawn was 5.9 m below chart datum. Average transect length was 112 m. Egg density was similar to that along the Vancouver Island shore and ranged from 339,278 to 637,750 eggs per sq. m, excluding the islands (Larkin and Bryant) surveyed with only one transect.

## AREA 24 - CLAYOQUOT SOUND AND HESQUIAT HARBOUR

Herring spawned in Area 24 in 1986 in Hesquiat Harbour on March 16 and in lower Clayoquot Sound on March 21. In lower Clayoquot Sound divers surveyed spawns at Yarksis (2) (Fig. 15), Elbow Bank and McIntosh Bay (Fig. 16). Spawns at Yarksis (1) and Opitsat were surveyed only from the surface. In Hesquiat Harbour, divers surveyed spawn outside of and inside of Antons Spit, Antons Spit (1) and Antons Spit (2) in Figure 17, while spawns at Leclaire Point, Rondeault Point, and Hesquiat Point were surveyed from the surface. Herring spawned along 13.8 km of shoreline and over a 195.7 ha area.

Of the 2415 tonnes estimated for Area 24, 654 tonnes spawned in lower Clayoquot Sound. Egg density was very light at Yarksis (36,006 eggs per sq. m) and also light on Elbow Bank (119,707 eggs per sq. m). The spawn at Elbow Bank and Yarksis did not extend over the available vegetation and, although beach slope is very gradual here at 0.007, average transect length was only 168 m. The average outer edge of spawn was 1.3 m below chart datum.

An estimated 1761 tonnes spawned in Hesquiat Harbour, but only the spawn from 362 tonnes was surveyed by divers. The egg density of these spawns was also very light, 22,303 and 76,384 eggs per sq. m, and beach slope was gradual at 0.026. The average outer edge of spawn was 2.6 m below chart datum and average transect length was 197 m.

AREA 25 - ESPERANZA INLET

Herring spawned in three waves in Esperanza Inlet in 1986. Herring spawned in Louis Bay on March 8 (Fig. 18), in Port Langford (Fig. 19) and Outer Nuchatlitz (Fig. 20) on March 11 to 17, and in Inner Nuchatlitz on March 22 to 23. All spawns were surveyed from the surface while only the two earlier waves were surveyed by divers. Total spawner biomass was estimated at 8405 tonnes, with 146 and 438 tonnes spawning in the early and late wave, respectively. In Outer Nuchatlitz some of the spawn (247 tonnes) occurred on Macrocystis sp. and most of the available vegetation inside of the reefs was utilized for spawning. The egg density of the early spawn in Louis Bay was light at 185,352 eggs per square m. The egg density in the second wave spawn was high, 545,791 and 555,795 eggs per sq. m. Average transect slope in Esperanza Inlet was gradual at 0.049, but since the average outer edge of spawn was only 2.8 m below chart datum, the average transect length was a moderate 147 m.

AREA 26 - KYUQUOT SOUND

There was no spawn reported from Area 26 although the charter vessel C. VENTURE #1 reported approximately 900 t of mature fish in Kyuquot Sound on March 13, 1986.

AREA 27 - FORWARD AND KLASKISH INLETS

Herring spawned in 1986 in Klaskish Inlet from March 14 to 17 and in Forward Inlet from March 17 to 22. The spawns in Klaskish Inlet were not surveyed by either divers or from the surface. However, the spawn-on-kelp operator made observations on the length and location of spawns. In Forward Inlet, herring spawned in North Harbour; along the west shore south of Greenwood Point [Hazard Point (1), Fig. 21] and north of the wharves in Winter Harbour [Winter Harbour (1), Fig. 22]; along the east shore from Hazard Point to the log booming grounds [Hazard Point (2), Fig. 21] and north of the booming grounds [Winter Harbour (2); Fig. 22], and at the head of the inlet above Wedel Island (Forward Inlet, Fig. 23) and between Wedel Island and the Vancouver Island shoreline (Wedel Island). All but the North Harbour and Wedel Island spawns were surveyed by divers while all the spawns were surveyed from the surface.

The adult spawner biomass in Area 27 was estimated to be 4824 tonnes. The Klaskish Inlet biomass was estimated from the observed lengths, from widths reported for these locations in a 1985 diving survey (Haegele and Schweigert 1987), and an estimated egg density of 2 layers. It was estimated that 745 tonnes spawned in Klaskish Inlet and it was estimated that 70 tonnes spawned in the spawn-on-kelp pond in Klaskish Inlet.

This estimate assumes that the eggs from 35 tonnes were harvested (Shields et al. 1985) and that 35 tonnes spawned on unharvested kelp and pond webbing (Haegele and Schweigert 1987). Total estimated spawner biomass in Klaskish Inlet was therefore 815 tonnes.

In Forward Inlet, an estimated 3869 tonnes of herring spawned along 10.2 km of shoreline and spawn area was estimated at 66.07 ha. In addition, an estimated 140 tonnes spawned in two spawn-on-kelp ponds, for a total adult biomass of 4009 tonnes. In the Hazard Point spawns, an estimated 456 tonnes deposited eggs on Macrocystis sp. Egg density on the understory vegetation was generally heavy and egg density ranged from 194,366 to 889,295 eggs per sq. m. for spawns surveyed by divers. Beach slope was moderate at 0.475 and the average outer edge of spawn was only 2.1 m below chart datum. Therefore, the average transect length was only 74 m, the lowest area average in this survey.

## DISCUSSION

The 95% confidence limits for egg density estimates were quite broad for individual spawns, averaging 90% of the mean and ranging from 11% (McIntosh Bay) to 485% (Spring Cove) of the mean. However, 95% confidence intervals for area mean egg densities were lower at 22%, 56%, 35%, and 52% of the mean for Area 23, 24, 25 and 27, respectively. The estimates of spawner biomass derived by applying area means are the same as estimates derived by summing results for individual spawns at 40,764 tonnes versus 40,722 tonnes for eggs on understory vegetation (Table 5). Hence, estimates for individual spawns appear to be reasonably precise, despite the observed high variance. The high variance appears to be the result of insufficient transects. The optimal sampling fraction (quadrats per transect), after Schweigert et al. (1985), was achieved or nearly achieved for 16 of the 23 spawns, while the optimal transect per km were achieved or nearly achieved for only 3 spawns (Table 7). The variance for area means was lower because the optimal sampling fraction and the optimal transects per km were achieved or nearly achieved in all Areas (Table 7).

It was estimated that the 1986 west coast of Vancouver Island mature herring stock, exclusive of Area 26, was 42,447 tonnes (Table 7). Area 23 (Barkley Sound) had the highest spawning escapement since diving surveys were conducted there (1982) and 1986 stocks were estimated to exceed the 1982 level, when there was a 3600 t fishery, by 4168 tonnes. Area 24 experienced a significant decline in stocks from levels previously observed. The 2415 tonnes estimated to have spawned there in 1986 were approximately 24% of the biomass estimated in 1985 and 31% of the biomass estimated in 1984. Area 25 showed a significant increase in spawners from 822 tonnes in 1984, when there was a 930 tonnes fishery, to 8405 tonnes in 1986. Total stock was lowest in Area 25 in 1985, when 1121 tonnes were estimated. The substantial decrease in biomass in Area 24 and the concomitant increase in biomass in Area 25 suggests

that spawners may move between these areas between years. Based on geographical proximity and biomass estimates and movements documented during the pre-fishery echosounding program, this affinity is partially substantiated. There have been only two years in which divers surveyed spawns in Area 27 and in both years major spawns in one of the two major inlets (Klaskish Inlet) were not surveyed. However, indications are that stocks in 1986 are substantially above 1985 levels. In Forward Inlet, where spawns were surveyed by divers in both years, the 1986 estimated biomass of 4009 tonnes was 7.1 times the 1985 estimated biomass of 459 tonnes.

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Table 1. Spawn survey results for the west coast of Vancouver Island in 1986.

| Location | Diving survey | | | | | Surface survey | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of transects | Length (m) | Av. transect length (m) | Area (ha) | Av. egg layers | No. of patches | Length (m) | Av. width (m) | Raw area (ha) | Adjusted area[a] (ha) | Av. egg layers |
| Area 23 | | | | | | | | | | | |
| Maggie River | 4 | 4230 | 121 | 30.06 | 1.6 | No survey | - | - | - | - | - |
| Macoah Passage | 4 | 3270 | 197 | 49.56 | 2.6 | No survey | - | - | - | - | - |
| Twin Rivers | 3 | 3700 | 727 | 208.44 | 2.2 | No survey | - | - | - | - | - |
| Camp Bay | 4 | 2900 | 519 | 118.53 | 2.4 | No survey | - | - | - | - | - |
| Itatsoo Creek | No survey | - | - | - | - | 2 | 575 | 50 | 2.88 | 2.66 | 4.0 |
| Stuart Bay | 3 | 1720 | 53 | 9.45 | 1.1 | 6 | 1200 | 22 | 2.61 | 1.74 | 3.6 |
| Spring Cove | 4 | 3000 | 177 | 21.51 | 1.4 | 5 | 1580 | 74 | 11.70 | 5.85 | 5.2 |
| Francis Island | No survey | - | - | - | - | 1 | 225 | 20 | 0.45 | 0.34 | 3.7 |
| Larkin Island | 1 | 730 | 120 | 5.23 | 1.9 | 3 | 520 | 70 | 3.62 | 3.62 | 1.8 |
| St. Ines Island | 3 | 2015 | 186 | 30.48 | 2.8 | 7 | 1725 | 96 | 16.49 | 16.49 | 6.3 |
| Bryant Islands | 1 | 500 | 71 | 2.87 | 7.6 | 3 | 410 | 46 | 1.90 | 1.42 | 2.5 |
| Spilling Islets | 6 | 1500 | 154 | 22.47 | 2.7 | No survey | - | - | - | - | - |
| David Island | 3 | 1045 | 211 | 25.84 | 2.4 | 4 | 1110 | 25 | 2.78 | 1.57 | 3.4 |
| Forbes Island | 4 | 1625 | 140 | 18.10 | 2.0 | 7 | 1785 | 40 | 7.16 | 4.03 | 3.6 |
| Area 23 total | 40 | 26235 | 231 | 542.54 | 2.3 | 38 | 9130 | 54 | 45.59 | 37.72 | 5.1 |
| Area 24 | | | | | | | | | | | |
| Yarksis (1) | No survey | - | - | - | - | 1 | 150 | 100 | 1.50 | 1.13 | 0.3 |
| Yarksis (2) | 4 | 1740 | 190 | 20.72 | 0.1 | 3 | 1175 | 130 | 15.25 | 12.22 | 0.3 |
| Elbow Bank | 5 | 2615 | 207 | 40.81 | 0.5 | 4 | 2400 | 104 | 24.99 | 21.30 | 0.3 |
| McIntosh Bay | 2 | 222 | 159 | 2.32 | 0.9 | 1 | 120 | 60 | 0.72 | 0.72 | 1.5 |
| Opitsat | No survey | - | - | - | - | 1 | 70 | 20 | 0.14 | 0.11 | 0.3 |
| Antons Spit (1) | 4 | 1360 | 299 | 36.53 | 0.4 | 1 | 457 | 274 | 12.52 | 10.02 | 0.8 |
| Antons Spit (2) | 9 | 3000 | 152 | 37.21 | 0.2 | 5 | 1827 | 58 | 10.53 | 8.47 | 0.4 |
| Leclaire Point | No survey | - | - | - | - | 11 | 2265 | 21 | 4.78 | 4.57 | 2.8 |
| Rondeault Point | No survey | - | - | - | - | 1 | 1280 | 75 | 9.60 | 9.60 | 1.0 |
| Hesquiat Point | No survey | - | - | - | - | 1 | 1100 | 50 | 5.50 | 5.50 | 1.0 |
| Area 24 total | 24 | 8937 | 195 | 137.59 | 0.3 | 29 | 10844 | 79 | 85.53 | 73.64 | 0.7 |

Table 1 (cont'd)

| Location | Diving survey | | | | | Surface survey | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of transects | Length (m) | Av. transect length (m) | Area (ha) | Av. egg layers | No. of patches | Length (m) | Av. width (m) | Raw area (ha) | Adjusted area[a] (ha) | Av. egg layers |
| Area 25 | | | | | | | | | | | |
| Louis Bay | 5 | 720 | 82 | 7.90 | 1.0 | 3 | 410 | 81 | 2.51 | 2.13 | 4.3 |
| Port Langford | 14 | 3800 | 57 | 17.68 | 2.5 | 3 | 2920 | 25 | 7.28 | 5.69 | 2.0 |
| Outer Nuchatlitz | 12 | 4100 | 308 | 118.91 | 2.3 | 24 | 3720 | 236 | 85.59 | 59.46 | 1.4 |
| Inner Nuchatlitz | No survey | - | - | - | - | 6 | 1500 | 221 | 33.19 | 25.51 | 0.5 |
| Area 25 total | 31 | 8620 | 158 | 144.49 | 2.2 | 36 | 8550 | 154 | 128.57 | 92.79 | 1.3 |
| Area 27 | | | | | | | | | | | |
| Klaskish Anch | No survey | - | - | - | - | (est.) | 2000 | 80[b] | 16.00 | 16.00 | 2.0[b] |
| Klaskish In | No survey | - | - | - | - | (est.) | 4000 | 25[b] | 10.00 | 10.00 | 2.0[b] |
| North Harbour | No survey | - | - | - | - | 2 | 200 | 20 | 0.40 | 0.30 | 1.6 |
| Hazard Pt (1) | 3 | 2080 | 81 | 16.79 | 1.9 | 1 | 2000 | 80 | 16.00 | 8.00 | 1.9 |
| Hazard Pt (2) | 6 | 2158 | 28 | 6.26 | 1.1 | 5 | 1780 | 18 | 3.14 | 2.04 | 1.4 |
| Winter Hr (1) | 2 | 1130 | 30 | 3.66 | 0.8 | 1 | 1200 | 20 | 2.40 | 1.68 | 1.8 |
| Winter Hr (2) | 2 | 1190 | 36 | 3.96 | 1.1 | 1 | 900 | 20 | 1.80 | 1.44 | 2.4 |
| Forward Inlet | 5 | 2600 | 162 | 29.17 | 1.4 | 3 | 2000 | 22 | 4.30 | 2.87 | 1.3 |
| Wedel Island | No survey | - | - | - | - | 1 | 800 | 5 | 0.40 | 0.20 | 0.5 |
| Area 27 total | 18 | 9158 | 75 | 59.84 | 1.3 | 14 | 14880 | 37 | 54.44 | 42.53 | 1.9 |

[a]Area adjusted for percent bare observation.
[b]Lengths, from aerial survey, only; hence widths from 1985 diving survey in these locations and 2 layers assumed.

Table 2. Summary of survey information for spawn on Macrocystis sp. for the west coast of Vancouver Island in 1986. Confidence intervals (95%) are given for means.

| Location | Area surveyed (sq. m) | Plants sampled | Av. plant height (m) | Av. egg layers |
|---|---|---|---|---|
| Area 23 | | | | |
| Larkin Island | 160 | 2 | 6.0 (-) | 4.0 (-) |
| Stuart Bay | 72 | 6 | 2.7 (2.1-3.2) | 1.5 (0.4-2.5) |
| Spring Cove | 290 | 4 | 3.8 (2.2-5.3) | 1.4 (0.0-3.0) |
| Area 23 | 522 | 12 | 3.6 (2.7-4.5) | 1.8 (0.9-2.7) |
| Area 25 | | | | |
| Outer Nuchatlitz | 514 | 11 | 3.3 (2.0-4.6) | 1.3 (0.2-2.4) |
| Area 27 | | | | |
| Hazard Point (1) | 146 | 6 | 3.5 (2.6-4.4) | 1.7 (0.5-2.9) |
| Hazard Point (2) | 20 | 2 | 2.0 (-) | 2.4 (-) |
| Area 27 | 166 | 8 | 3.1 (2.2-4.1) | 1.9 (1.0-2.8) |

Table 3. Estimates of egg deposition on Macrocystis sp., by individual spawns, for the west coast of Vancouver Island in 1986. Confidence intervals (95%) are in brackets. (MP = mature plants, AF = all fronds, MF = mature fronds.)

| Location | Area (ha) | Density (per ha) | | | Thousands of eggs per | | | Tonnes estimated from | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MP | AF | MF | MP | AF | MF | MP | AF | MF |
| Area 23 | | | | | | | | | | |
| Larkin Island | 1.85 | 1900 | 8600 | 6400 | 1551 (-) | 215 (-) | 265 (-) | 55 (-) | 34 (-) | 31 (-) |
| Itatsoo Creek[a] | 3.74 | 5900 | 27100 | 11400 | 630 (275-980) | 117 (41-192) | 245 (38-452) | 139 (61-216) | 119 (42-195) | 104 (16-193) |
| Stuart Bay | 3.09 | 16400 | 68900 | 39600 | 432 (0-901) | 119 (0-280) | 312 (0-799) | 219 (0-457) | 253 (0-596) | 319 (0-978) |
| Spring Cove | 4.33 | 5400 | 27000 | 7200 | 467 (0-1051) | 64 (12-116) | 134 (45-223) | 109 (0-246) | 75 (14-136) | 42 (14-70) |
| Area 25 | | | | | | | | | | |
| Outer Nuchatlitz | 13.45 | 3500 | 26100 | 13900 | 594 (0-1310) | 71 (0-147) | 132 (0-280) | 280 (0-617) | 249 (0-516) | 247 (0-524) |
| Area 27 | | | | | | | | | | |
| Hazard Point (1) | 8.36 | 7100 | 52600 | 31200 | 741 (0-1631) | 116 (20-211) | 174 (27-321) | 440 (0-968) | 510 (88-928) | 454 (70-837) |
| Hazard Point (2) | 0.39 | 4000 | 15500 | 6500 | 335 (-) | 84 (-) | 91 (-) | 5 (-) | 5 (-) | 2 (-) |

[a]Not sampled by divers and Barkley Sound means were used.

Table 4. Estimates of egg deposition on understory vegetation, by individual spawns, for the west coast of Vancouver Island in 1986. Where the data source was exclusively from surface survey reports, widths were adjusted and egg densities estimated as outlined in the Methods section.

| Location | Source | Area (ha) | Thousands of eggs per sq. m (95% C.I.) | Tonnes of spawners (95% C.I.) |
|---|---|---|---|---|
| Area 23 | | | | |
| Maggie River | Transects 1-4 | 30.06 | 208 (0-627) | 626 (0-1885) |
| Macoah Passage | Transects 5-8 | 49.56 | 484 (209-760) | 2401 (1036-3766) |
| Twin Rivers | Transects 9-11 | 208.44 | 501 (426-576) | 10443 (8877-12008) |
| Camp Bay | Transects 12-15 | 118.53 | 567 (272-863) | 6722 (3221-10223) |
| Itatsoo Creek | Surface survey | 7.48 | 497 (-) | 372 (-) |
| Stuart Bay | Transects 37,40,42 | 9.45 | 90 (28-152) | 85 (27-144) |
| Spring Cove | Transects 33,35-36,39 | 21.51 | 121 (0-706) | 261 (0-1519) |
| Francis Island | Surface survey | 2.08 | 466 (-) | 97 (-) |
| Larkin Island | Transect 31 | 5.23 | 319 (-) | 167 (-) |
| St. Ines Island | Transects 29-30,32 | 30.48 | 452 (0-1090) | 1378 (0-3322) |
| Bryant Islands | Transect 34 | 2.87 | 1170 (-) | 336 (-) |
| Spilling Islets | Transects 23-28 | 22.47 | 397 (196-598) | 891 (439-1343) |
| David Island | Transects 20-22 | 25.84 | 638 (378-897) | 1648 (978-2318) |
| Forbes Island | Transects 16-19 | 18.10 | 339 (150-529) | 614 (271-957) |
| Area 24 | | | | |
| Yarksis (1) | Surface survey | 2.53 | 107 (-) | 27 (-) |
| Yarksis (2) | Transects 1-3,13 | 20.72 | 36 (0-74) | 75 (0-153) |
| Elbow Bank | Transects 4-6,8,11 | 40.81 | 120 (8-231) | 489 (34-943) |
| McIntosh Bay | Transects 7,9 | 2.32 | 241 (214-268) | 56 (50-62) |
| Opitsat | Surface survey | 0.65 | 107 (-) | 7 (-) |
| Anton Spit (1) | Transects 7-10 | 36.53 | 76 (35-117) | 279 (130-429) |
| Anton Spit (2) | Transects 1-6,11-13 | 37.21 | 22 (0-46) | 83 (0-171) |
| Leclaire Point | Surface survey | 21.28 | 371 (-) | 789 (-) |
| Rondeault Point | Surface survey | 19.38 | 181 (-) | 351 (-) |
| Hesquiat Point | Surface survey | 14.31 | 181 (-) | 259 (-) |

Table 4 (cont'd)

| Location | Source | Area (ha) | Thousands of eggs per sq. m (95% C.I.) | Tonnes of spawners (95% C.I.) |
|---|---|---|---|---|
| Area 25 | | | | |
| Louis Bay | Transects 1-3,7-8 | 7.90 | 185 (111-259) | 146 (88-205) |
| Port Langford | Transects 1-5,7-15 | 17.68 | 546 (228-863) | 965 (404-1526) |
| Outer Nuchatlitz | Transects 1-11,15 | 118.91 | 556 (266-846) | 6609 (3162-10056) |
| Inner Nuchatlitz | Surface survey | 34.06 | 129 (-) | 438 (-) |
| Area 27 | | | | |
| Klaskish Anch | Surface survey | 16.00 | 287 (-) | 458 (-) |
| Klaskish In | Surface survey | 10.00 | 287 (-) | 287 (-) |
| North Harbour | Surface survey | 1.84 | 244 (-) | 45 (-) |
| Hazard Pt (1) | Transects 1,2,20 | 16.79 | 889 (434-1345) | 1493 (729-2258) |
| Hazard Pt (2) | Transects 3,4,6-9 | 6.26 | 454 (116-792) | 284 (73-496) |
| Winter Hr (1) | Transects 11,12 | 3.66 | 194 (95-294) | 71 (35-107) |
| Winter Hr (2) | Transects 10,13 | 3.96 | 638 (0-1408) | 253 (0-558) |
| Forward Inlet | Transects 14-18 | 29.17 | 415 (30-800) | 1211 (88-2334) |
| Wedel Island | Surface survey | 4.39 | 129 (-) | 56 (-) |

Table 5. Estimates of spawner biomass using Statistical Area mean egg densities for the west coast of Vancouver Island in 1986. These estimates are compared to estimates derived by summing results for individual spawns from Table 3 and 4. Catch and spawn-on-kelp pond utilization are also included.

| Location and source | Area (ha) | Thousands of eggs per sq. m (95% C.I.) | Tonnes (95% C.I.) | Tonnes (sum) |
|---|---|---|---|---|
| Area 23 - understory | 552.10 | 458 (357-560) | 25312 (19724-30900) | 26041 |
| Area 23 - Macrocystis sp. | 13.01 | - | 363 (56 - 670) | 559 |
| Area 23 - charter catch | - | - | 203 (-) | 203 |
| Area 24 - understory | 195.74 | 75 (32-117) | 1465 (629-2300) | 2415 |
| Area 25 - understory | 178.55 | 522 (337-706) | 9316 (6026-12606) | 8158 |
| Area 25 - Macrocystis sp. | 13.45 | - | 247 (0 - 524) | 247 |
| Area 27 - understory | 92.07 | 507 (245-770) | 4671 (2251-7090) | 4158 |
| Area 27 - Macrocystis sp. | 8.75 | - | 379 (114 - 646) | 456 |
| Area 27 - SonK ponds | - | - | 210 (-) | 210 |
| Total | 1018.46 | | 42166 | 42447 |

Table 6. Estimated optimal sampling design to achieve a SE of 25% of the mean (after Schweigert et al 1985) and achieved sampling density for 1986 diving surveys of herring spawn on the west coast of Vancouver Island in 1986.

| Location | Samples per transect | Av. transect length (m) | Achieved sampling fraction | Optimal sampling fraction | Achieved transects per km | Optimal transects per km |
|---|---|---|---|---|---|---|
| Maggie River | 4.8 | 120.8 | 0.039 | 0.028 | 0.946 | 19.457 |
| Macoah Pass | 6.0 | 197.0 | 0.030 | 0.040 | 1.223 | 2.572 |
| Twin Rivers | 18.0 | 727.0 | 0.025 | 0.053 | 0.811 | 0.251 |
| Camp Bay | 13.0 | 519.0 | 0.025 | 0.012 | 1.379 | 2.426 |
| Stuart Bay | 7.0 | 53.3 | 0.131 | 0.127 | 1.744 | 5.111 |
| Spring Cove | 6.5 | 177.0 | 0.037 | 0.042 | 1.333 | 139.236 |
| St. Ines I. | 7.3 | 186.3 | 0.039 | 0.033 | 1.489 | 16.372 |
| Spilling I. | 7.5 | 153.5 | 0.049 | 0.047 | 4.000 | 6.642 |
| David I. | 5.7 | 210.7 | 0.027 | 0.053 | 2.871 | 3.871 |
| Forbes I. | 6.0 | 139.8 | 0.043 | 0.063 | 2.462 | 5.096 |
| Yarksis | 6.5 | 190.0 | 0.034 | 0.034 | 2.299 | 13.369 |
| Elbow Bank | 6.4 | 207.2 | 0.031 | 0.019 | 1.912 | 8.570 |
| McIntosh Bay | 6.0 | 159.5 | 0.038 | 0.545 | 9.009 | 0.702 |
| Anton Spit (1) | 8.0 | 299.0 | 0.027 | 0.030 | 2.941 | 5.843 |
| Anton Spit (2) | 6.2 | 152.3 | 0.041 | 0.048 | 3.000 | 23.006 |
| Louis Bay | 5.2 | 82.2 | 0.063 | 0.100 | 6.944 | 7.936 |
| Port Langford | 5.3 | 56.5 | 0.094 | 0.086 | 3.684 | 6.840 |
| Outer Nuchatlitz | 8.1 | 307.6 | 0.026 | 0.010 | 2.972 | 4.768 |
| Hazard Point (1) | 5.3 | 81.0 | 0.066 | 0.136 | 1.442 | 2.502 |
| Hazard Point (2) | 5.7 | 27.5 | 0.206 | 0.172 | 2.780 | 8.481 |
| Winter Hr. (1) | 5.5 | 30.0 | 0.183 | 1.883 | 1.770 | 0.801 |
| Winter Hr. (2) | 5.0 | 36.0 | 0.139 | 0.090 | 1.681 | 9.871 |
| Forward Inlet | 5.8 | 162.0 | 0.036 | 0.036 | 1.923 | 8.655 |
| Area 23 | 8.0 | 231.4 | 0.034 | 0.024 | 1.525 | 0.485 |
| Area 24 | 6.6 | 195.1 | 0.034 | 0.021 | 2.685 | 3.155 |
| Area 25 | 6.4 | 157.8 | 0.040 | 0.017 | 3.596 | 2.164 |
| Area 27 | 5.6 | 75.0 | 0.074 | 0.070 | 1.965 | 1.761 |

Table 7. Estimates of herring spawn and adult herring biomass for the west coast of Vancouver Island from 1984 to 1986 for all Areas and for 1982 for Area 23.

| Year | Diving survey | | | Surface survey | | | Both surveys | | Adult biomass (tonnes) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Length (m) | Area (ha) | Spawners (tonnes) | Length (m) | Area (ha) | Spawners (tonnes) | Length (m) | Area (ha) | Spawners | Catch | Total |
| Area 23 | | | | | | | | | | | |
| 1982 | 26400 | 371.58 | 17123 | 4800 | 42.66 | 1899 | 31200 | 414.24 | 19022 | 3613 | 22635 |
| 1984 | 10850 | 162.02 | 4195 | 640 | 10.42 | 189 | 11490 | 172.44 | 4384 | 5581 | 9965 |
| 1985 | 21250 | 361.01 | 13463 | 3525 | 35.35 | 1825 | 24775 | 396.36 | 15288 | 0 | 15288 |
| 1986 | 26235 | 542.54 | 26027 | 800 | 9.56 | 573 | 27035 | 552.10 | 26600 | 203 | 26803 |
| Area 24 | | | | | | | | | | | |
| 1984 | 16598 | 388.87 | 6765 | 2625 | 17.98 | 974 | 19223 | 406.85 | 7739 | 0 | 7739 |
| 1985 | 15240 | 348.20 | 9432 | 1790 | 22.62 | 514 | 17030 | 370.82 | 9946 | 177 | 10123 |
| 1986 | 8937 | 137.58 | 982 | 4865 | 58.16 | 1433 | 13802 | 195.74 | 2415 | 0 | 2415 |
| Area 25 | | | | | | | | | | | |
| 1984 | 6510 | 53.88 | 581 | 1180 | 15.14 | 241 | 7690 | 69.02 | 822 | 771 | 1593 |
| 1985 | 3130 | 58.30 | 817 | 1507 | 16.55 | 304 | 4637 | 74.84 | 1121 | 0 | 1121 |
| 1986 | 8620 | 144.49 | 7967 | 1500 | 34.06 | 438 | 10120 | 178.55 | 8405 | 0 | 8405 |
| Area 27 | | | | | | | | | | | |
| 1984 | 0 | 0.00 | 0 | 6700 | 64.07 | 4342 | 6700 | 64.07 | 4342 | 321 | 4663 |
| 1985 | 7220 | 29.77 | 693 | 3000 | 30.00 | 860 | 10220 | 59.77 | 1553 | 221 | 1774 |
| 1986 | 9158 | 59.84 | 3768 | 7000 | 32.23 | 846 | 16158 | 92.07 | 4614 | 210 | 4824 |
| W.C.V.I. | | | | | | | | | | | |
| 1984 | 33958 | 604.77 | 11541 | 11145 | 107.61 | 5746 | 45103 | 712.38 | 17287 | 6673 | 23960 |
| 1985 | 46840 | 797.28 | 24405 | 9822 | 104.52 | 3503 | 56662 | 901.79 | 27908 | 398 | 28306 |
| 1986 | 52950 | 884.45 | 38744 | 14165 | 134.01 | 3290 | 67115 | 1018.46 | 42034 | 413 | 42447 |

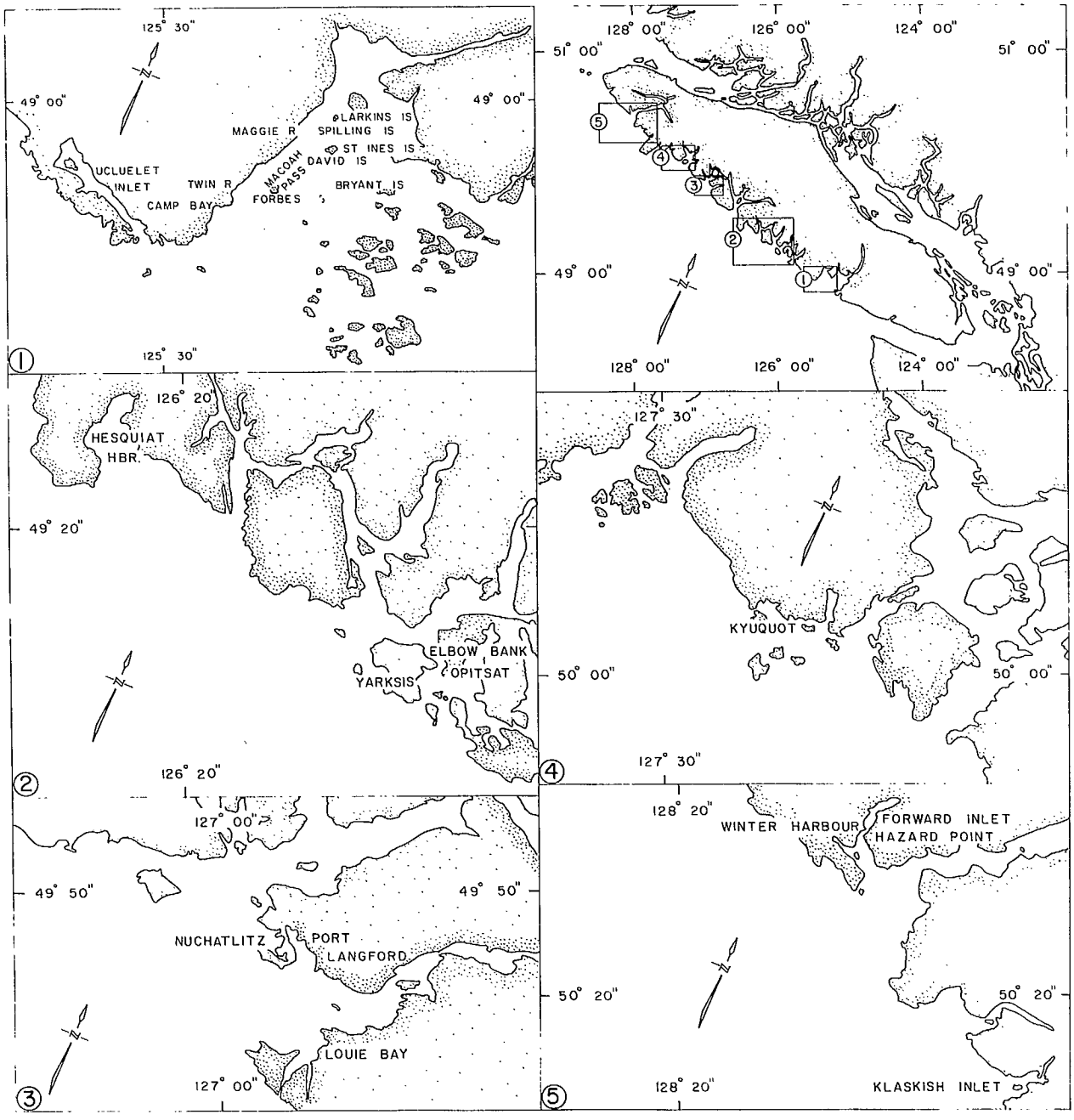


Fig. 1. Location of 1986 west coast of Vancouver Island herring spawn survey study sites.

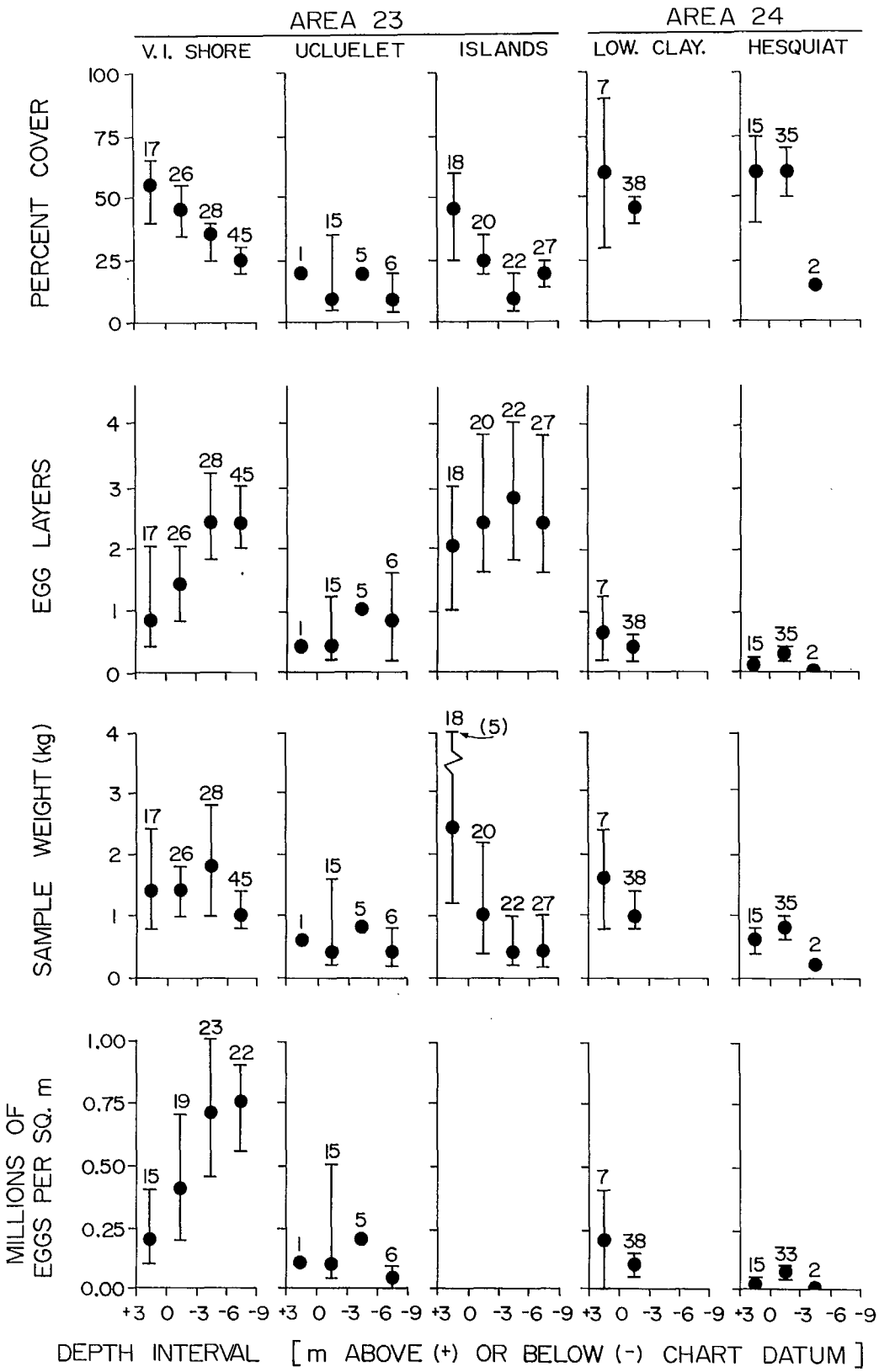


Fig. 2. Wilcoxon mean and estimated 95% confidence interval for percent cover of vegetation, layers of eggs, sample weight and egg density by 3 m depth intervals for the lower west coast of Vancouver Island herring spawns surveyed by divers in 1986.

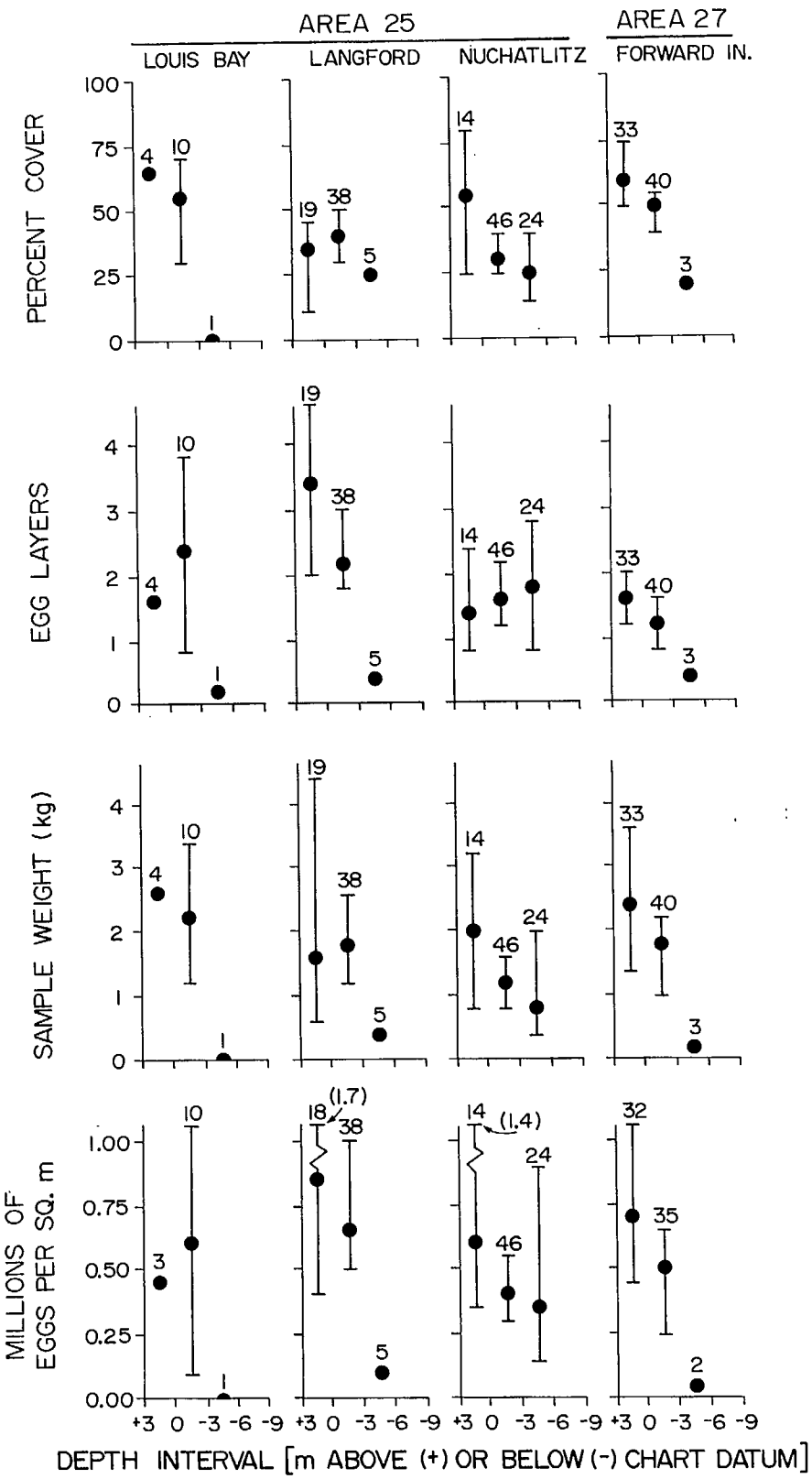


Fig. 3. Wilcoxon mean and estimated 95% confidence interval for percent cover of vegetation, layers of eggs, sample weight and egg density by 3 m depth intervals for the upper west coast of Vancouver Island herring spawns surveyed by divers in 1986.

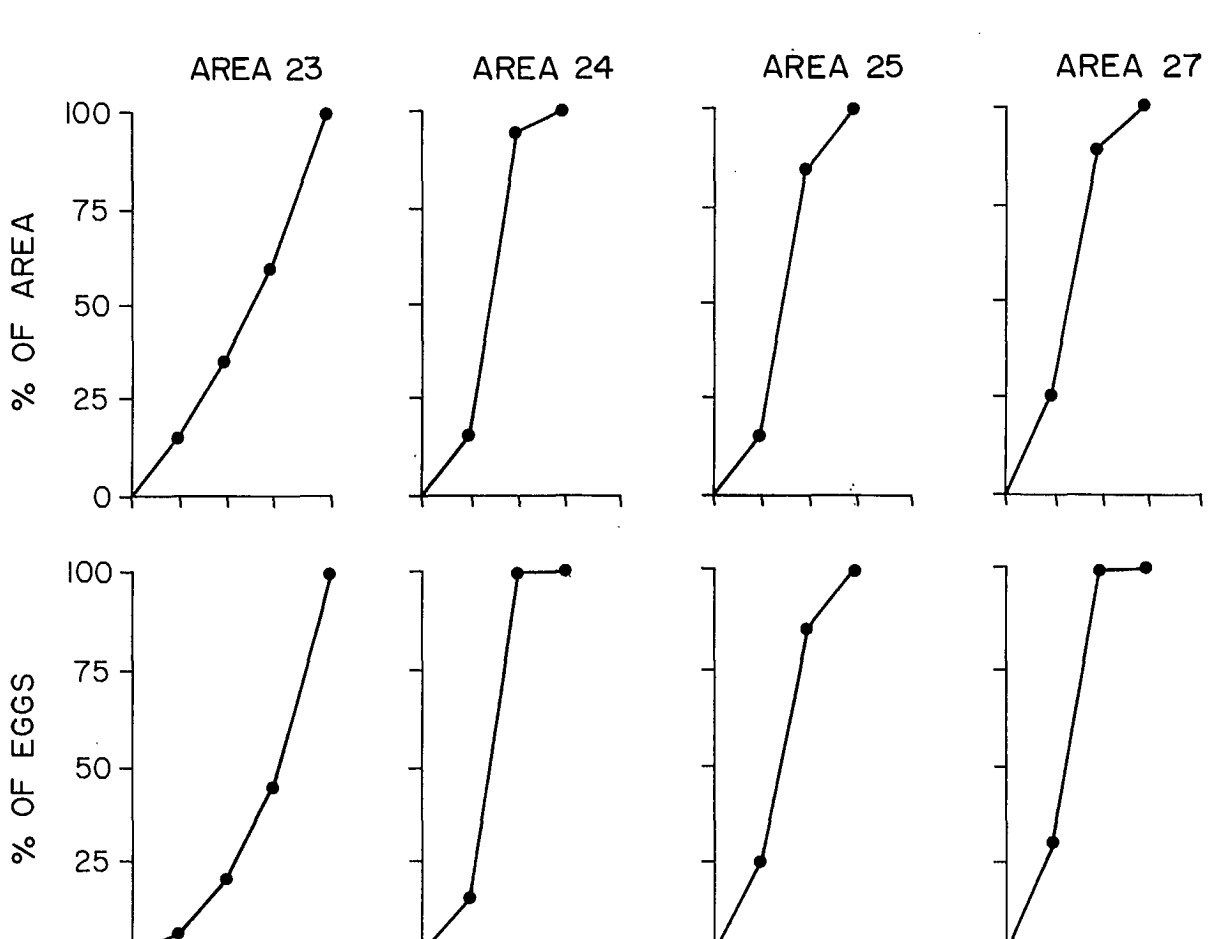


Fig. 4. Distribution of spawn area and eggs by depth for the west coast of Vancouver Island in 1986.

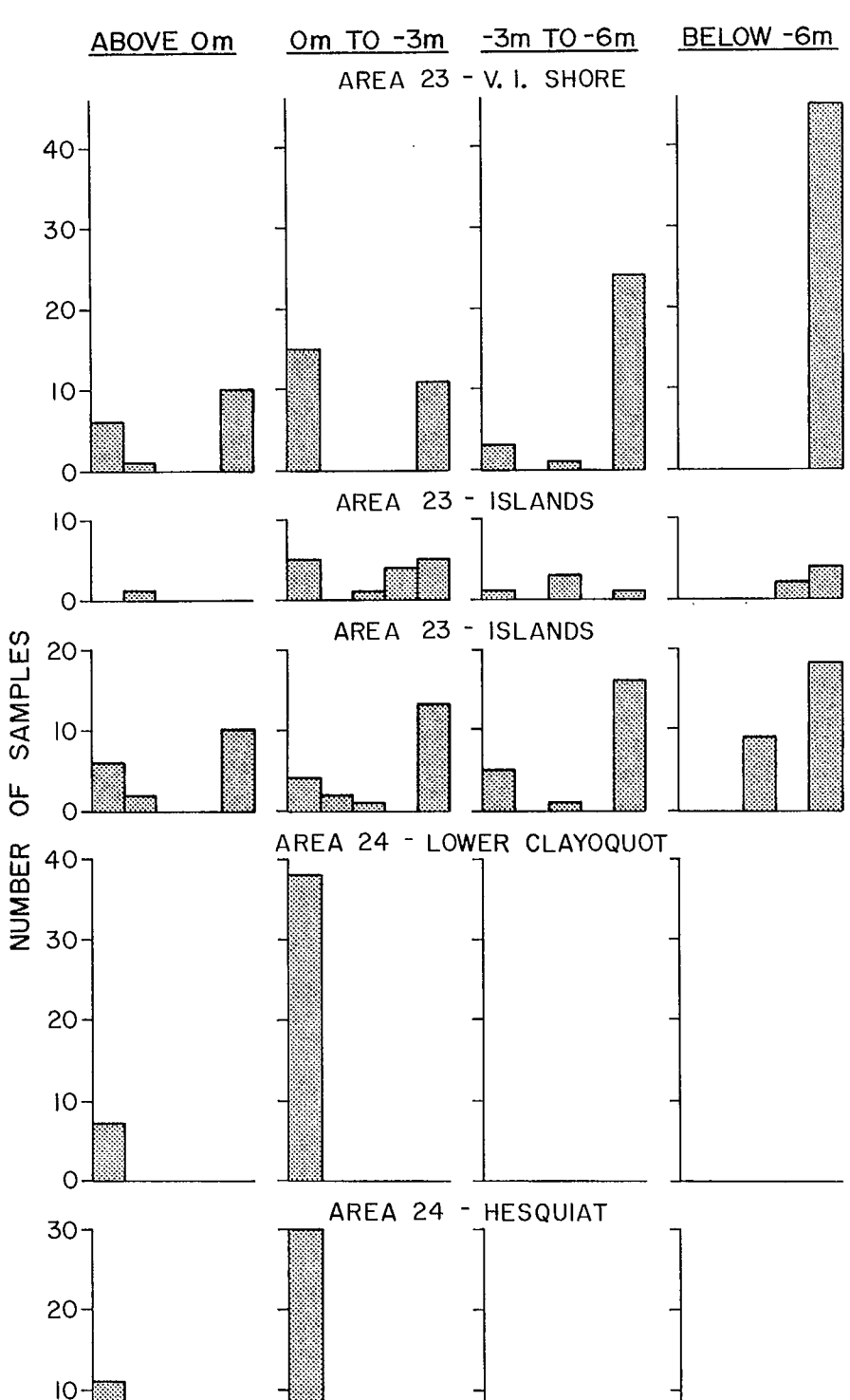


Fig. 5. Dominant vegetation on which herring spawn was deposited, by 3 m depth interval, for the lower west coast of Vancouver Island in 1986. (SG = sea grasses, RW = rockweed, KE = kelps, FO = foliose red algae, FI = filamentous red algae.)

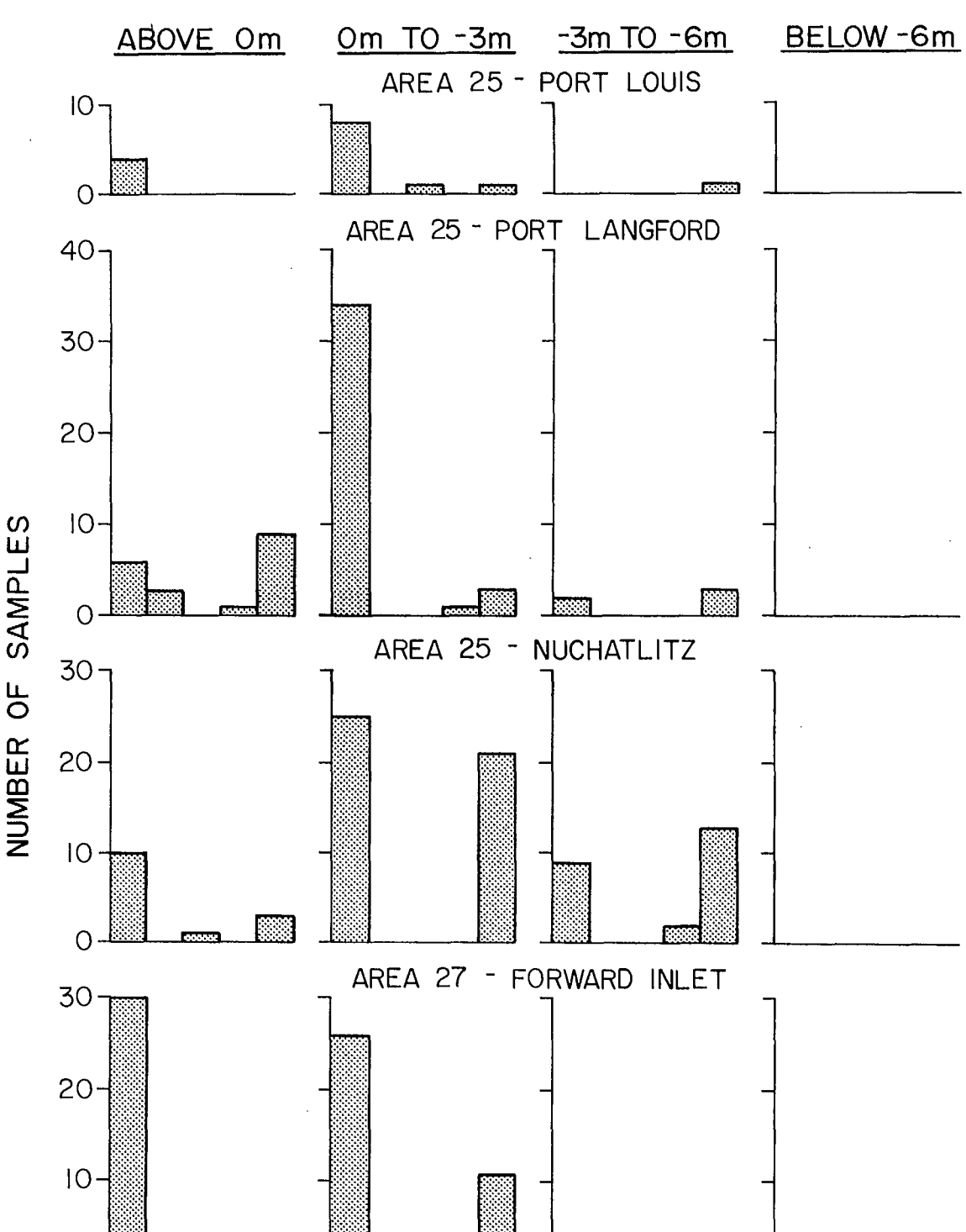


Fig. 6. Dominant vegetation on which herring spawn was deposited, by 3 m depth interval, for the upper west coast of Vancouver Island in 1986. (SG = sea grasses, RW = rockweed, KE = kelps, FO = foliose red algae, FI = filamentous red algae.)

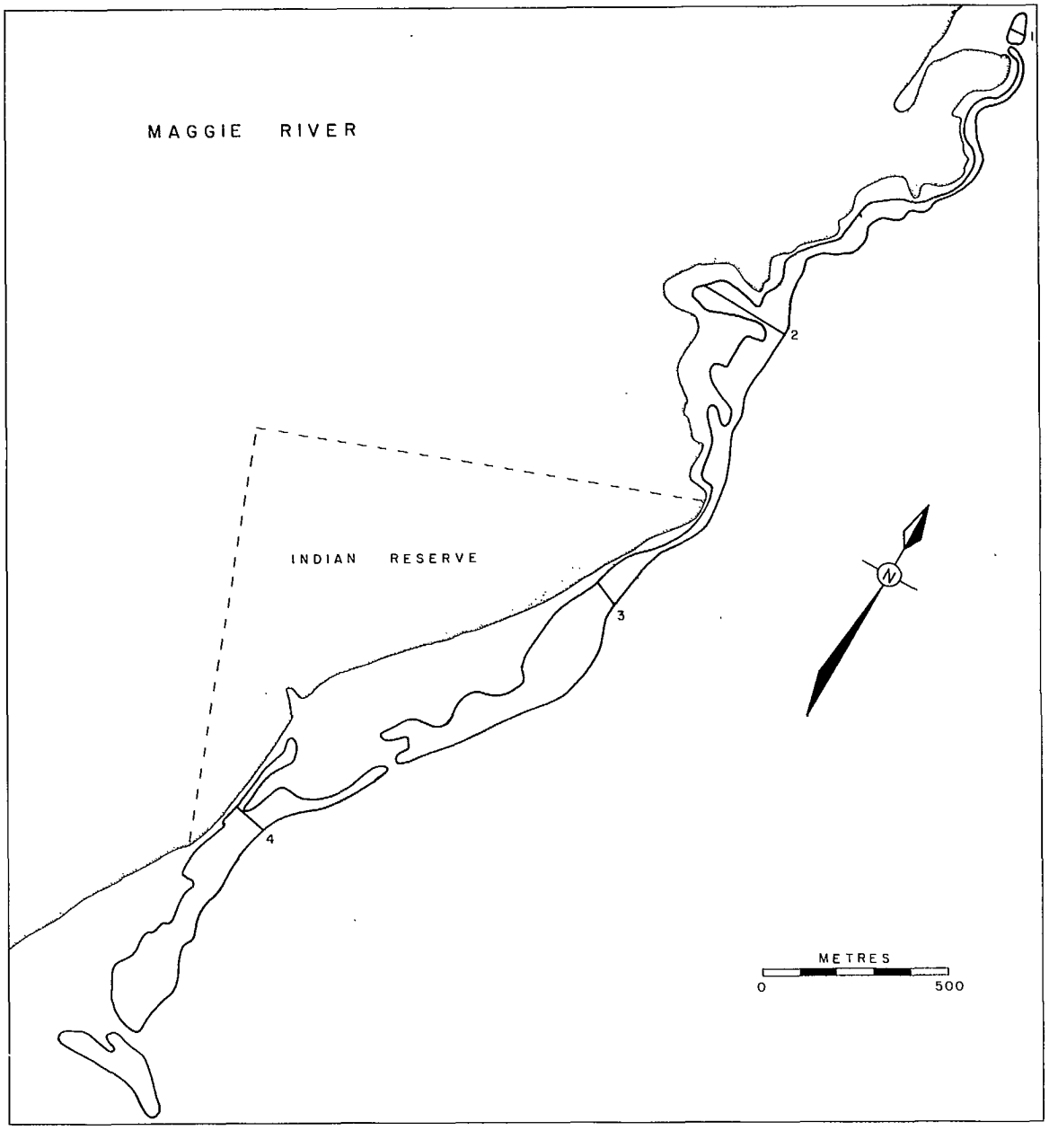


Fig. 7. Herring spawn at Maggie River in Barkley Sound, surveyed by divers in 1986, with transect locations shown.

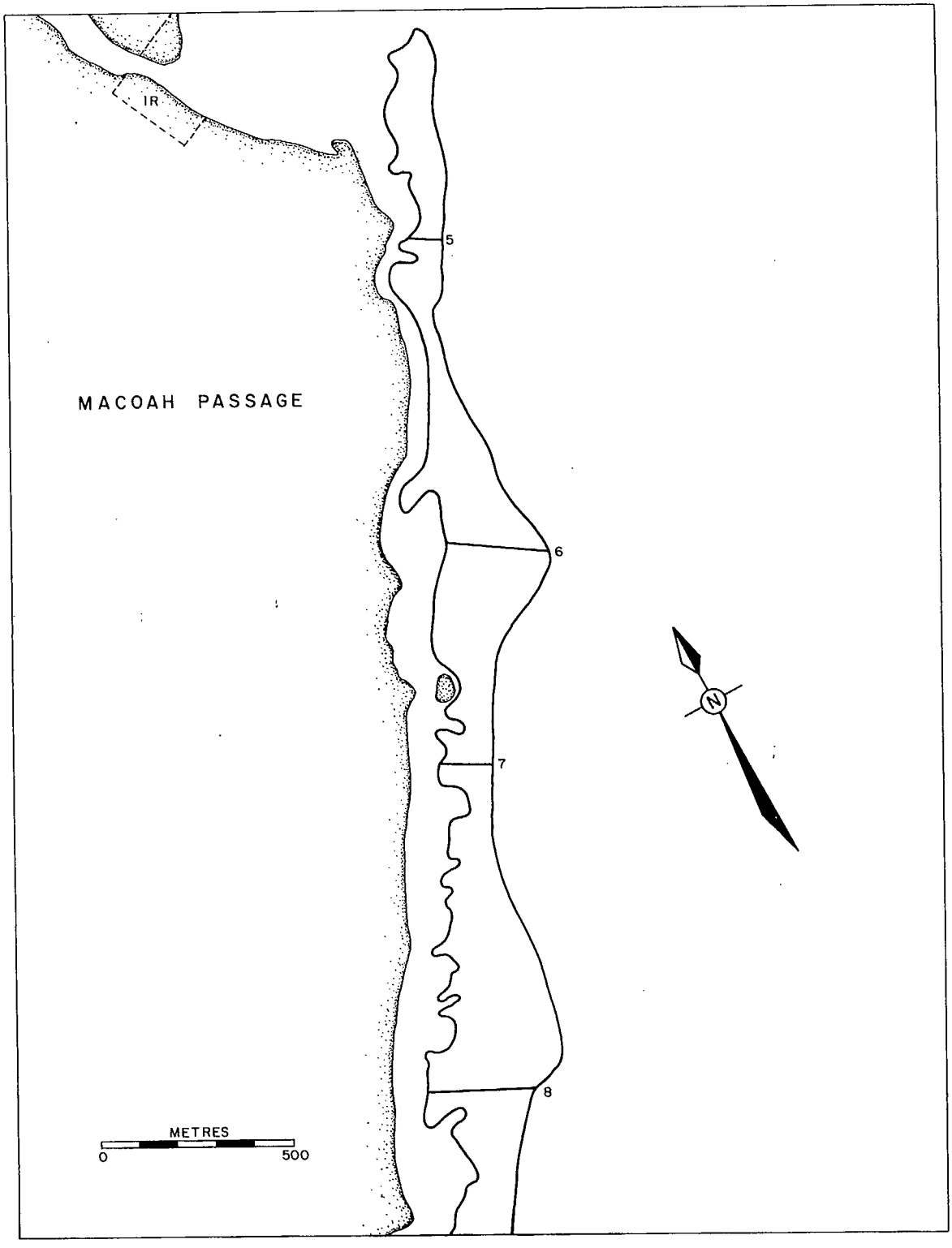


Fig. 8. Herring spawn in Macoah Passage in Barkley Sound, surveyed by divers in 1986, with transect locations shown.

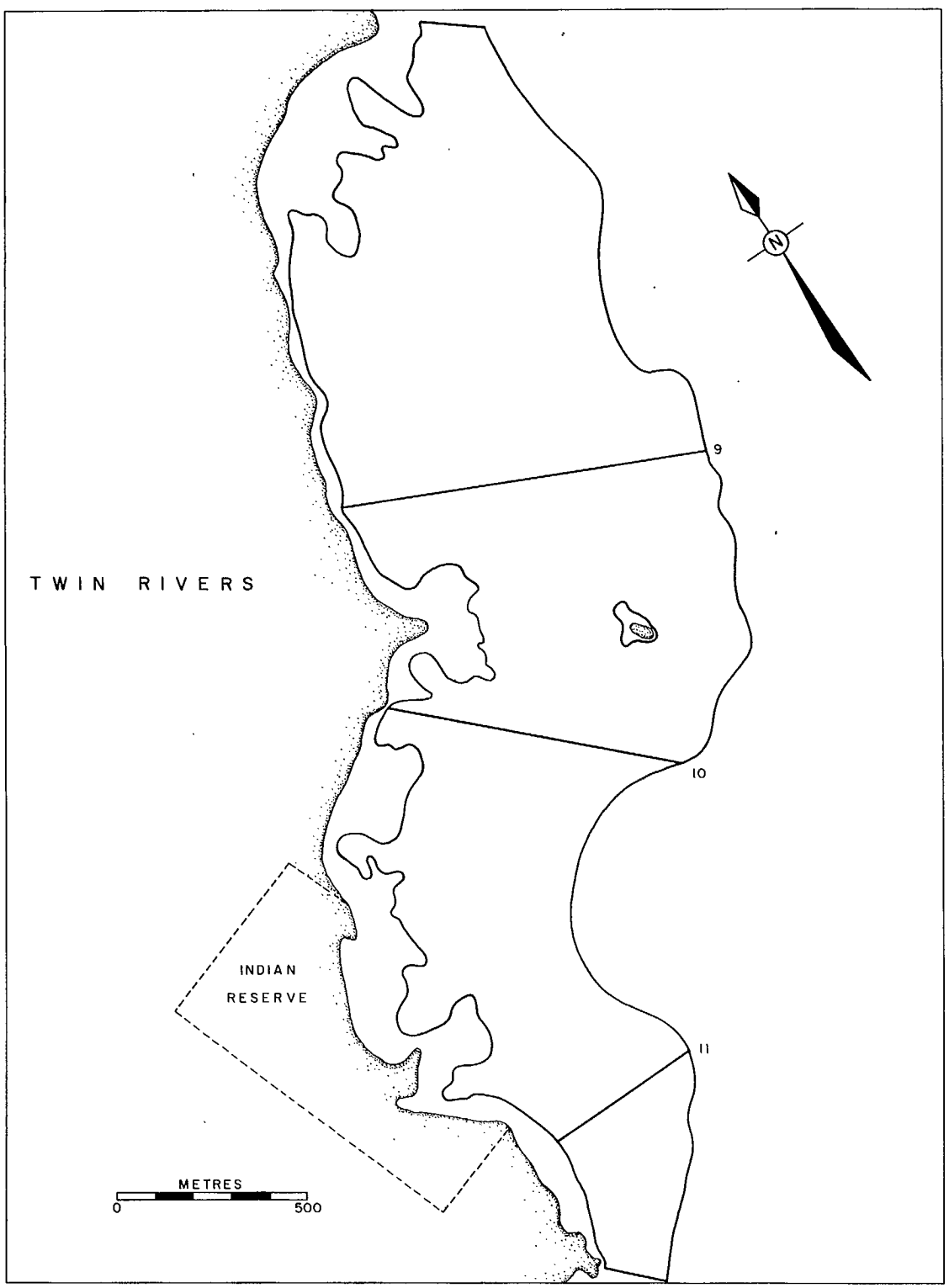


Fig. 9. Herring spawn at Twin Rivers in Barkley Sound, surveyed by divers in 1986, with transect locations shown.

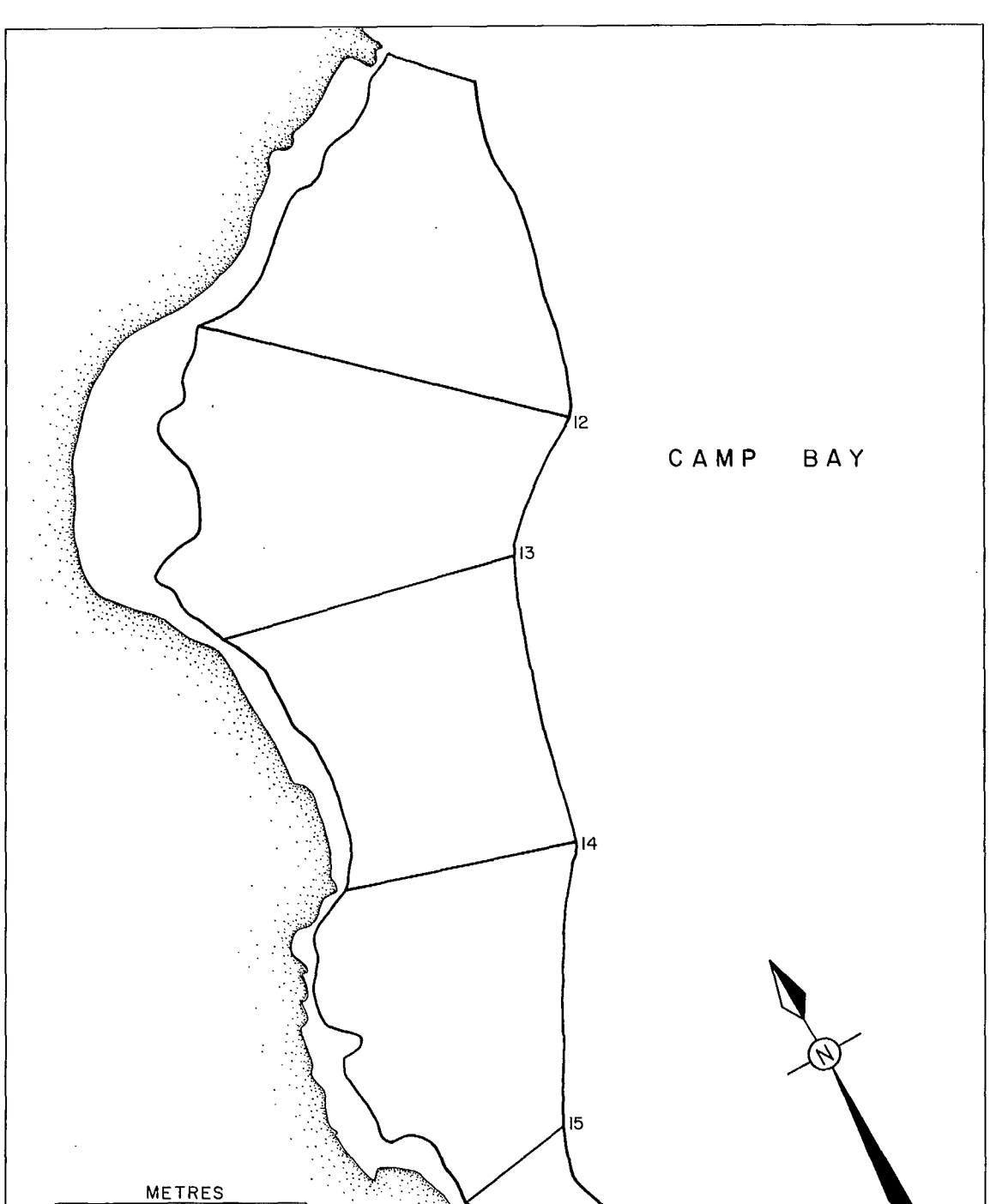


Fig. 10. Herring spawn in Camp Bay in Barkley Sound, surveyed by divers in 1986, with transect locations shown.

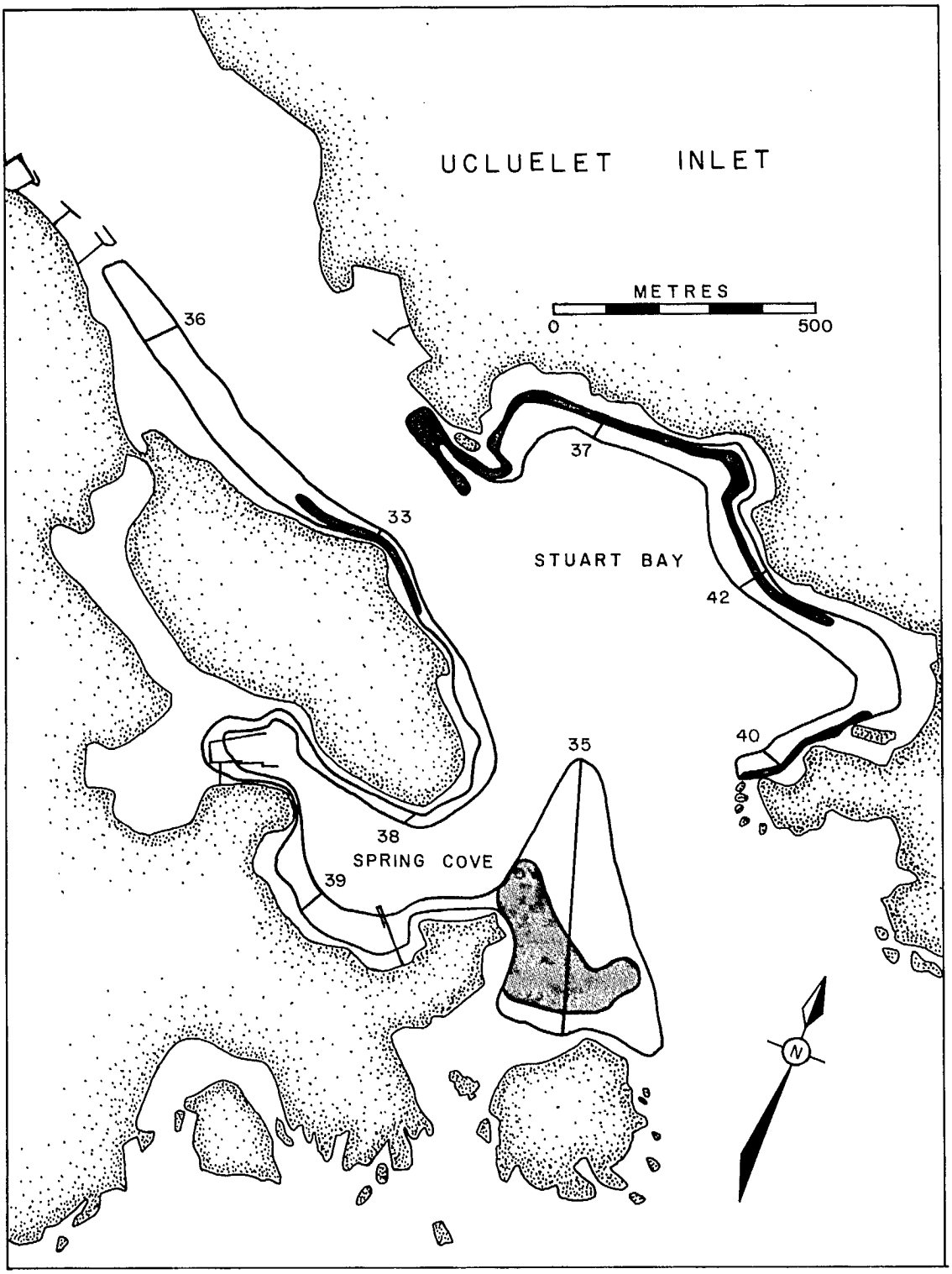


Fig. 11. Herring spawn in Stuart Bay and Spring Cove in Barkley Sound, surveyed by divers in 1986, with transect locations shown. Shaded area shows where spawn was deposited on Macrocystis sp.

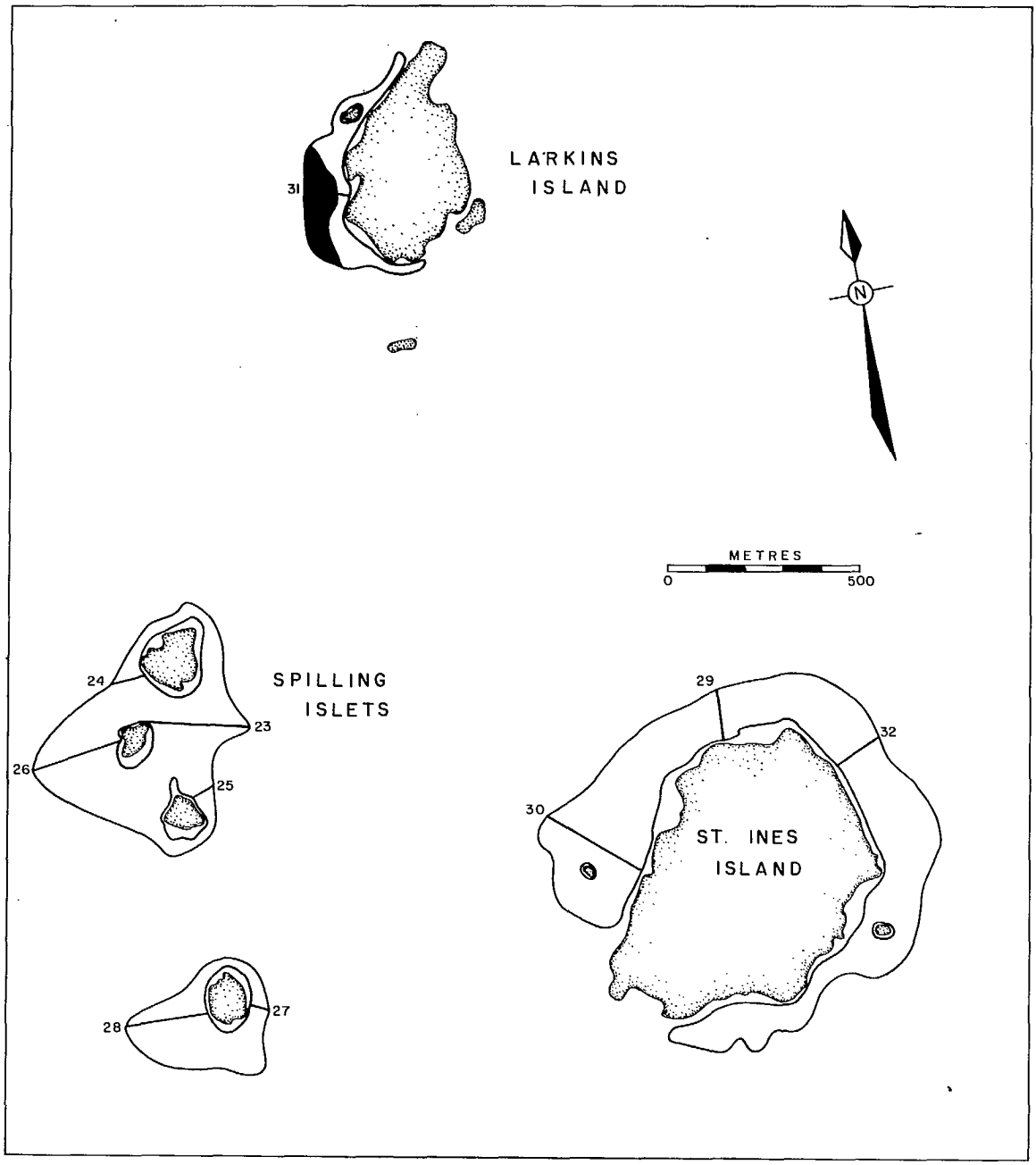


Fig. 12. Herring spawn on Larkin and St. Ines islands and on Spilling islets in Barkley Sound, surveyed by divers in 1986, with transect locations shown. Shaded area shows where spawn was deposited on Macrocystis sp.

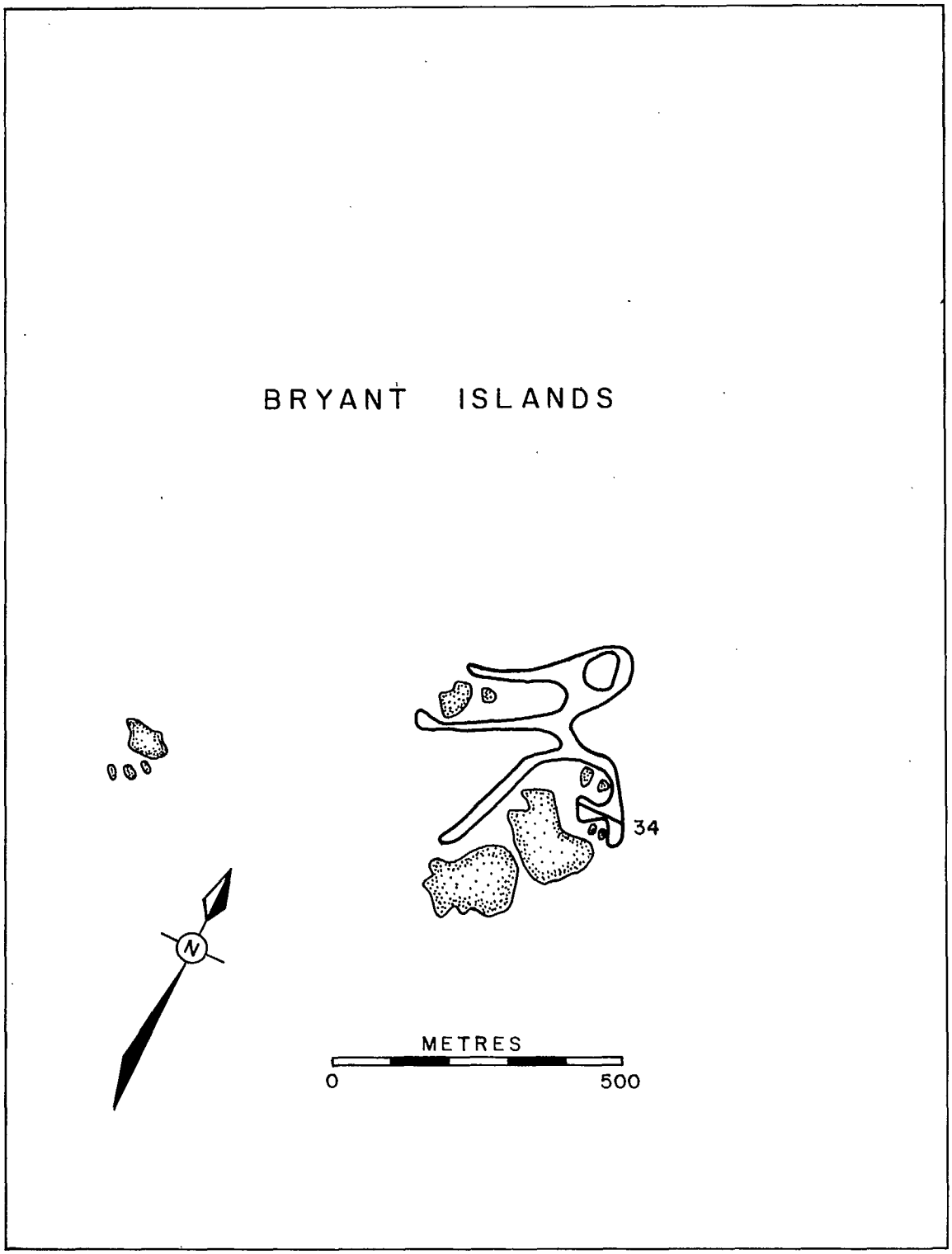


Fig. 13. Herring spawn on Bryant Islands in Barkley Sound, surveyed by divers in 1986, with transect locations shown.

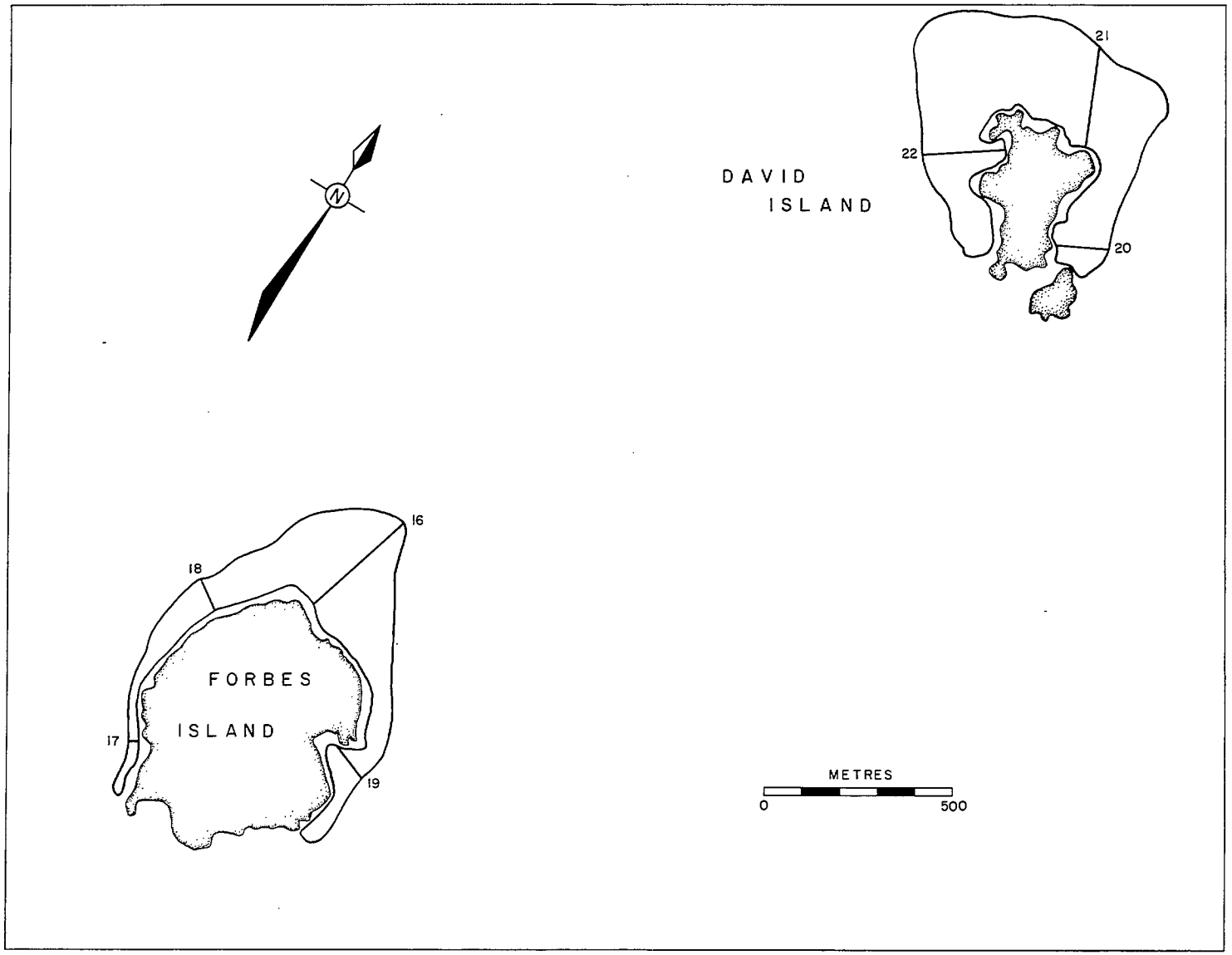


Fig. 14. Herring spawn on David and Forbes islands in Barkley Sound, surveyed by divers in 1986, with transect locations shown.

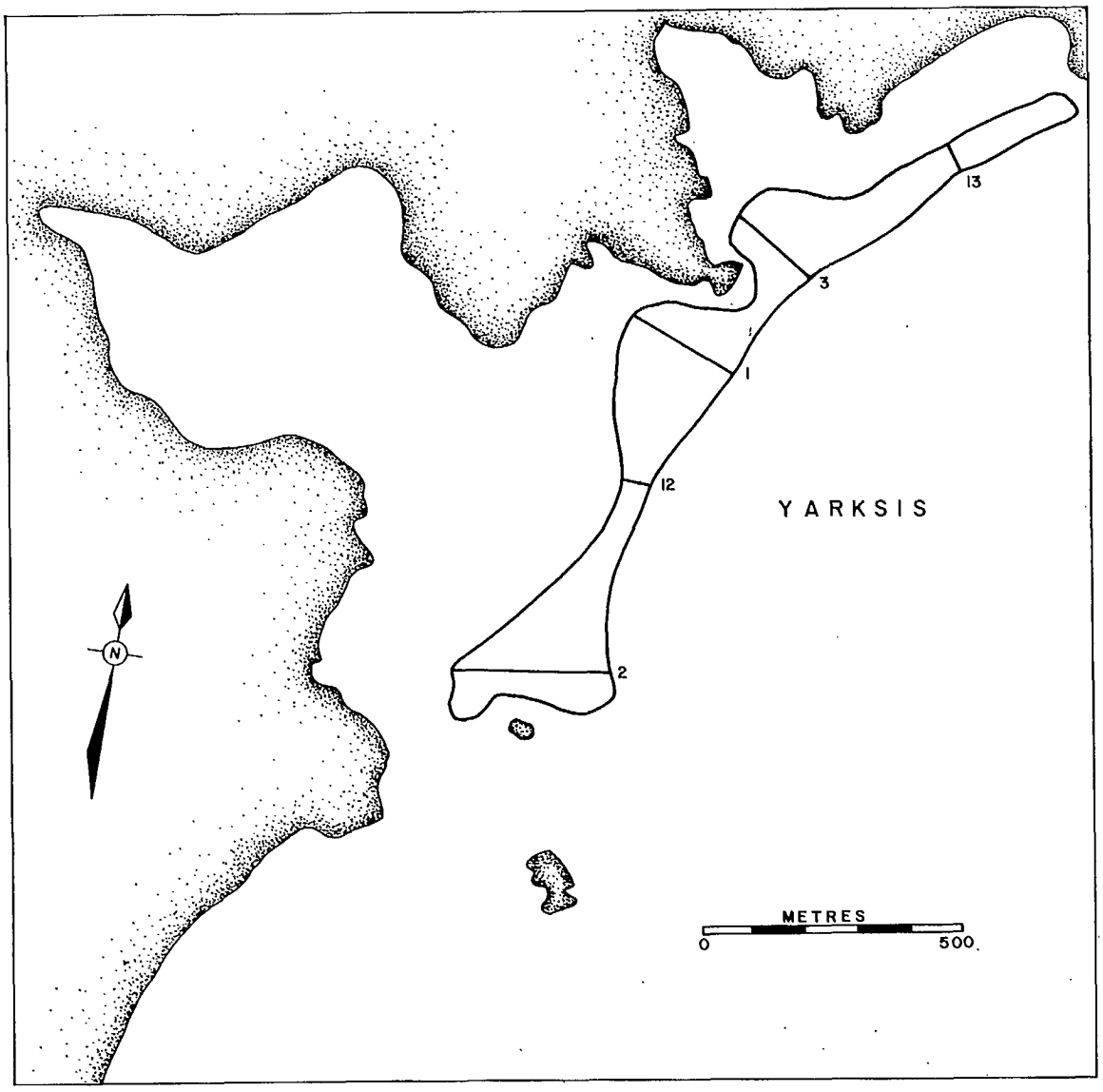


Fig. 15. Herring spawn at Yarksis (2) in Clayoquot Sound, surveyed by divers in 1986, with transect locations shown.

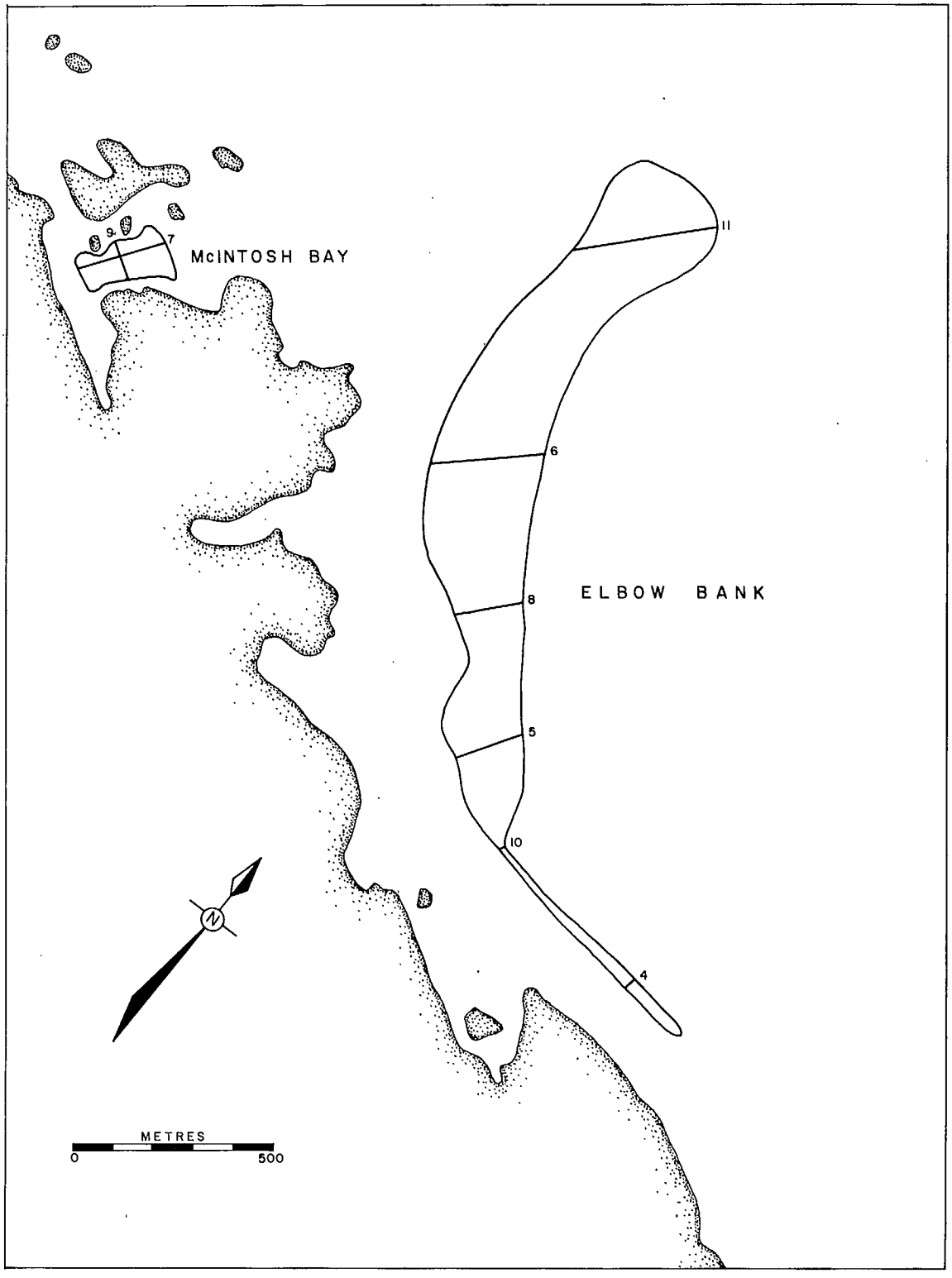


Fig. 16. Herring spawn on Elbow Bank and in McIntosh Bay in Clayoquot Sound, surveyed by divers in 1986, with transect locations shown.

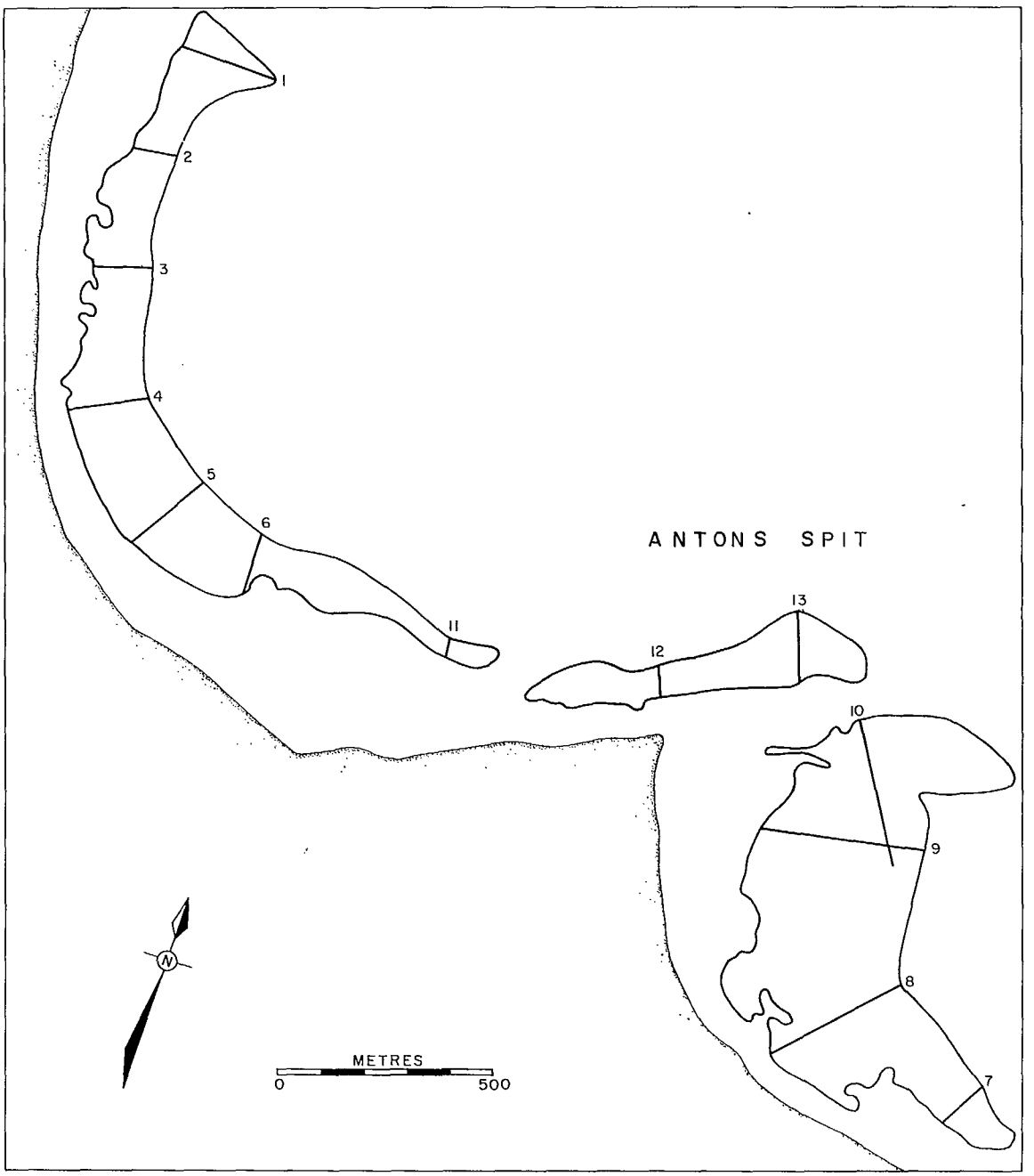


Fig. 17. Herring spawn at Antons Spit (1) and (2) in Hesquiat Harbour, surveyed by divers in 1986, with transect locations shown.

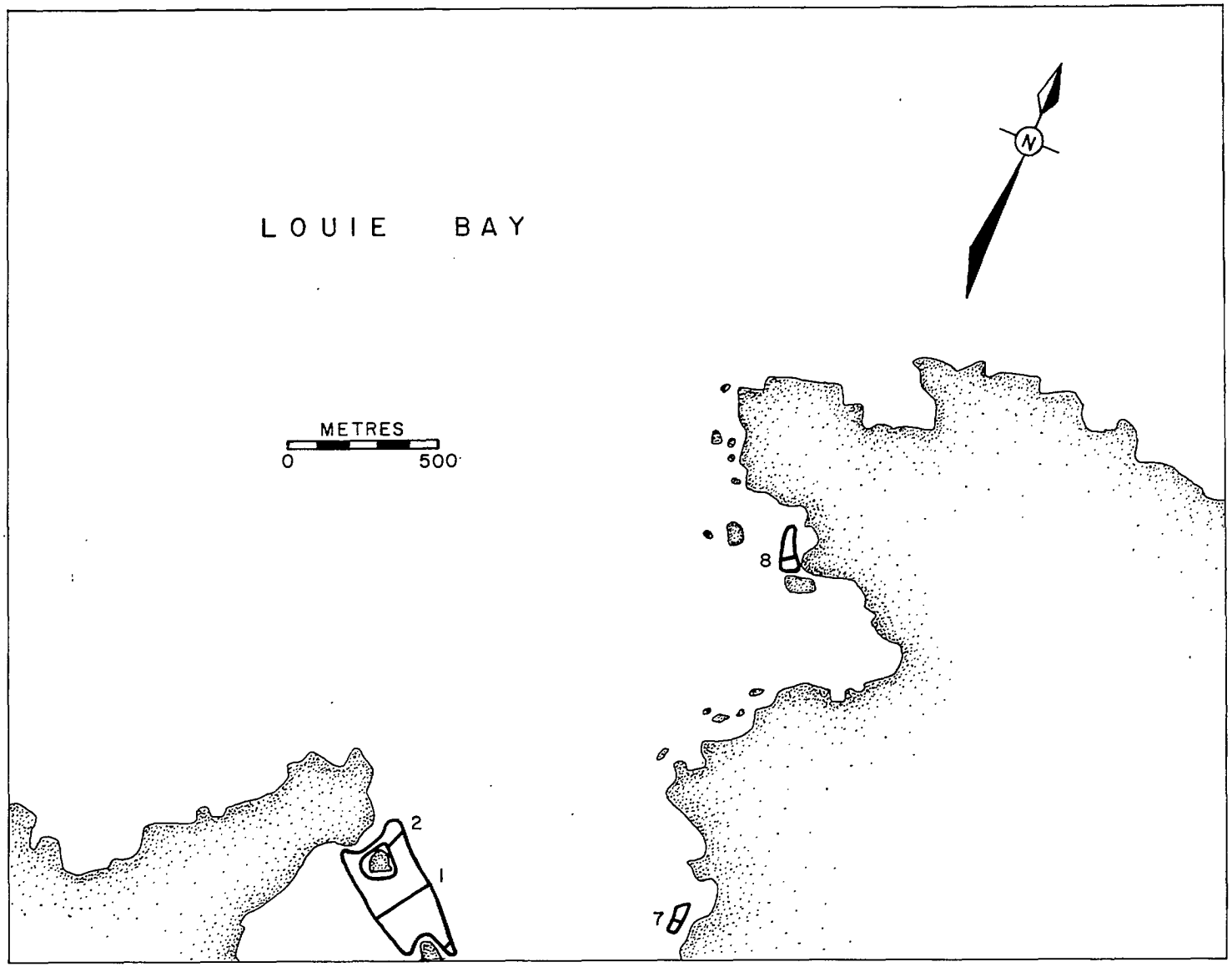


Fig. 18. Herring spawn in Louie Bay in Esperanza Inlet, surveyed by divers in 1986, with transect locations shown.

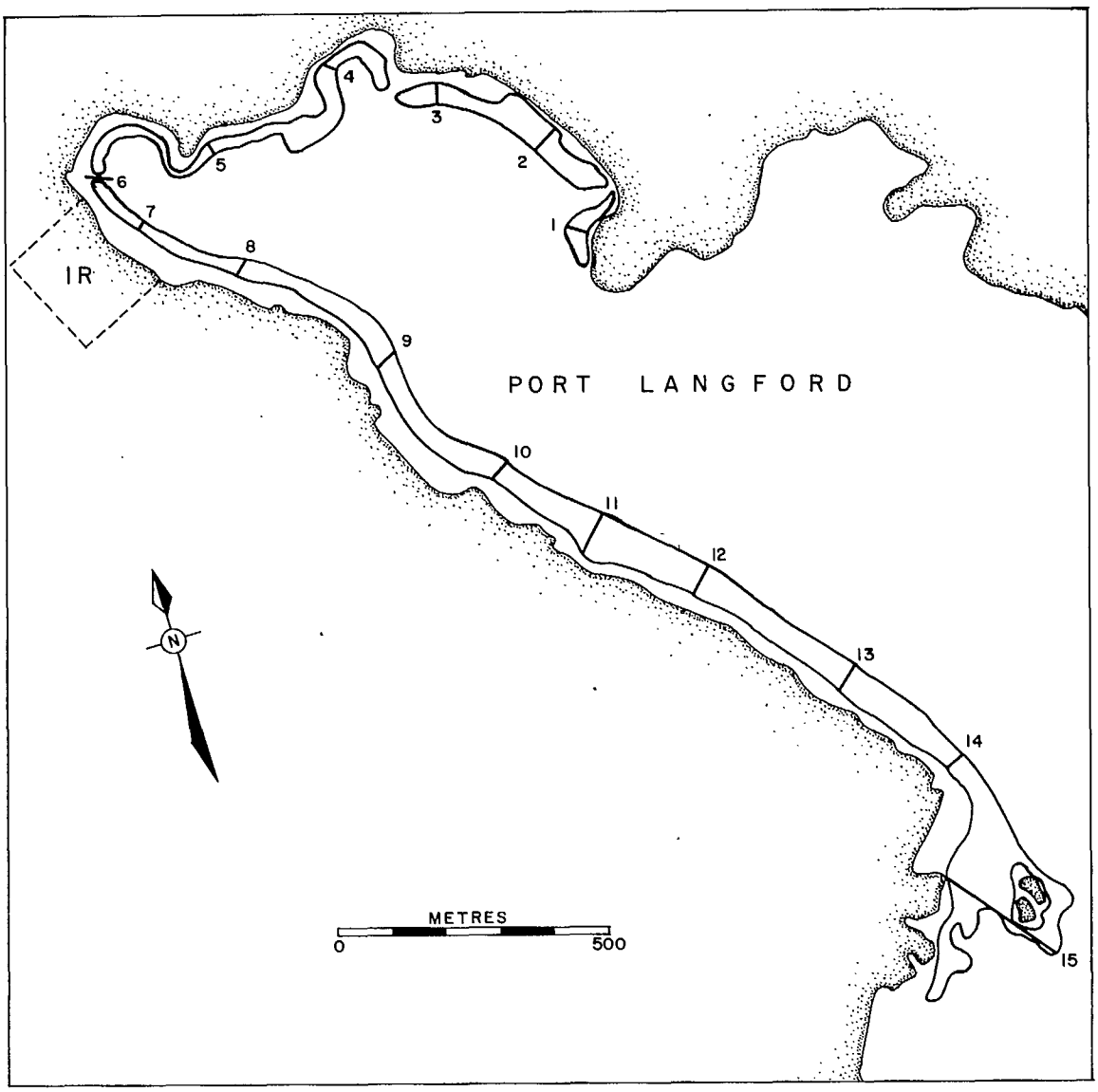


Fig. 19. Herring spawn in Port Langford in Esperanza Inlet, surveyed by divers in 1986, with transect locations shown.

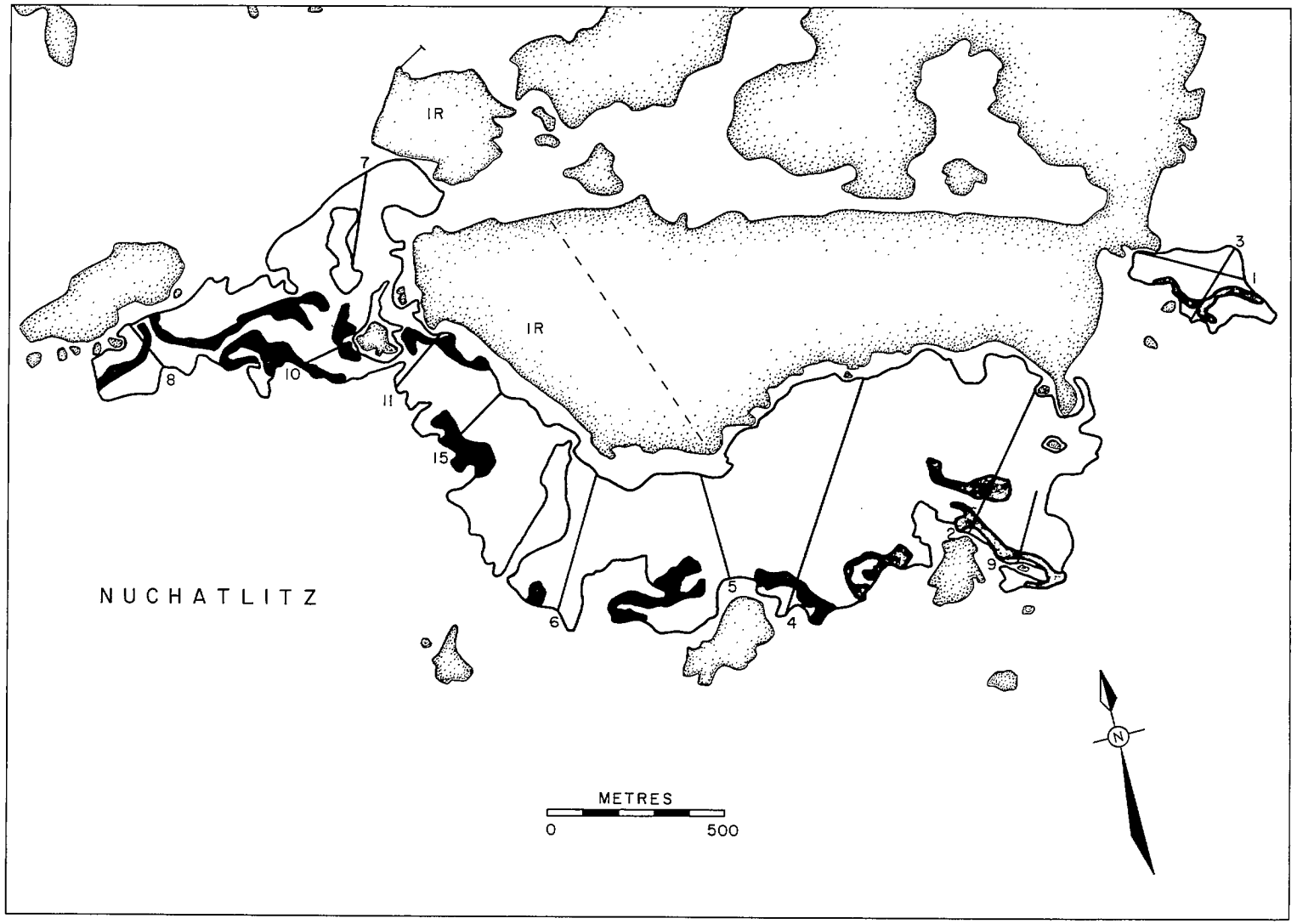


Fig. 20. Herring spawn in Outer Nuchatlitz in Esperanza Inlet, surveyed by divers in 1986, with transect locations shown. Shaded area shows where spawn was deposited on Macrocystis sp.

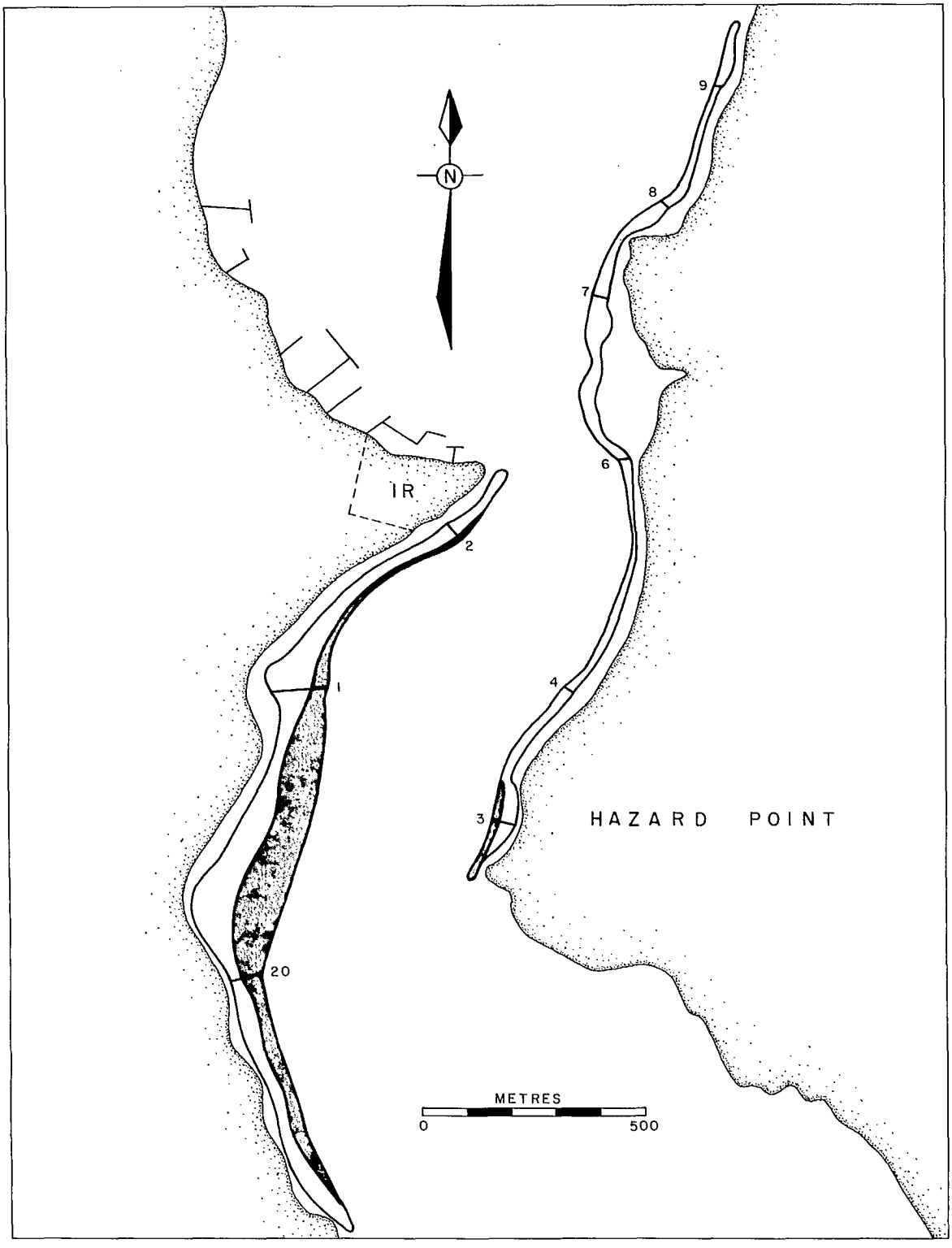


Fig. 21. Herring spawn at Hazard Point (1) and (2) in Forward Inlet, surveyed by divers in 1986, with transect locations shown. Shaded area shows where spawn was deposited on Macrocystis sp.

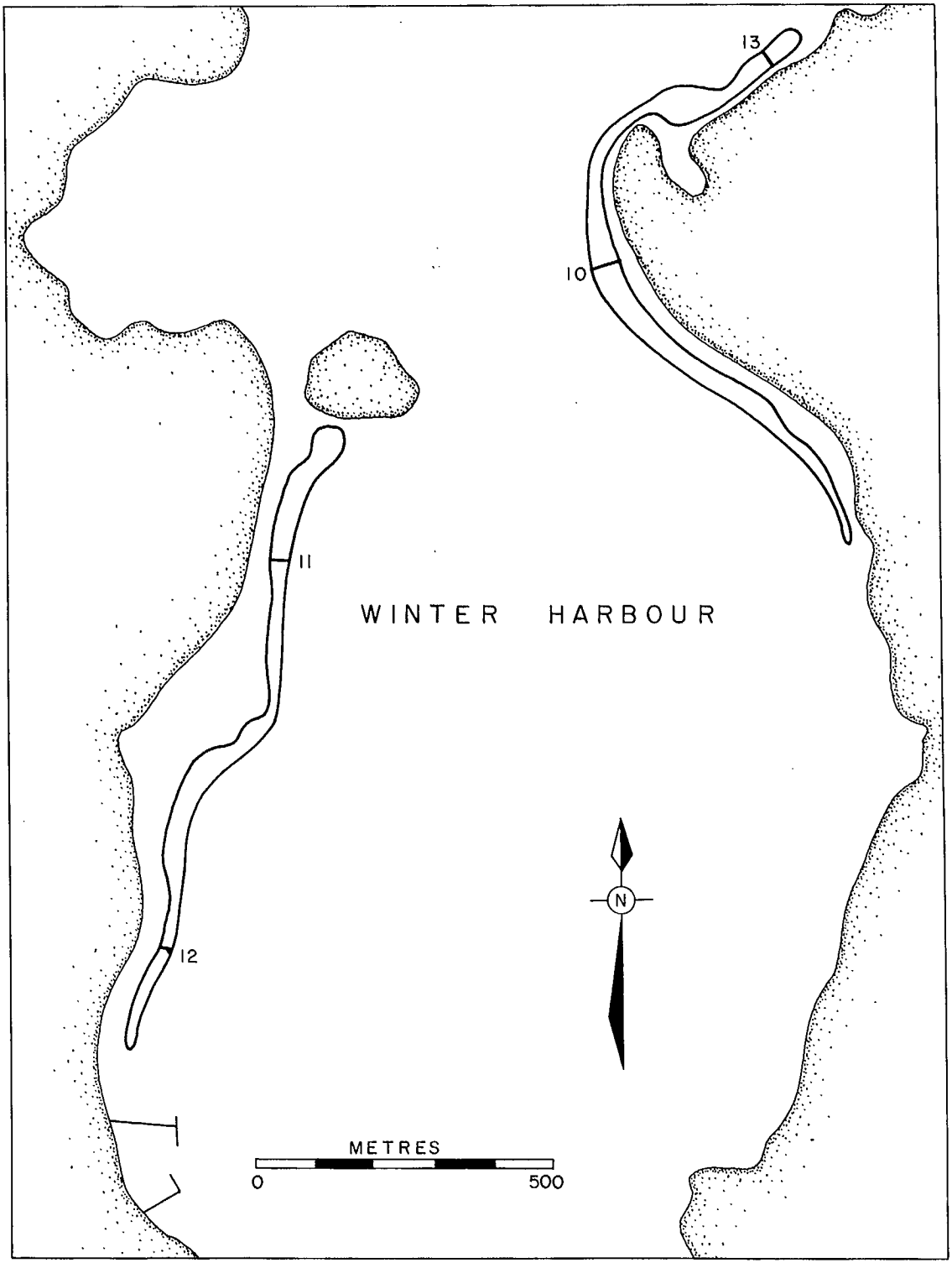


Fig. 22. Herring spawn in Winter Harbour (1) and (2) in Forward Inlet, surveyed by divers in 1986, with transect locations shown.

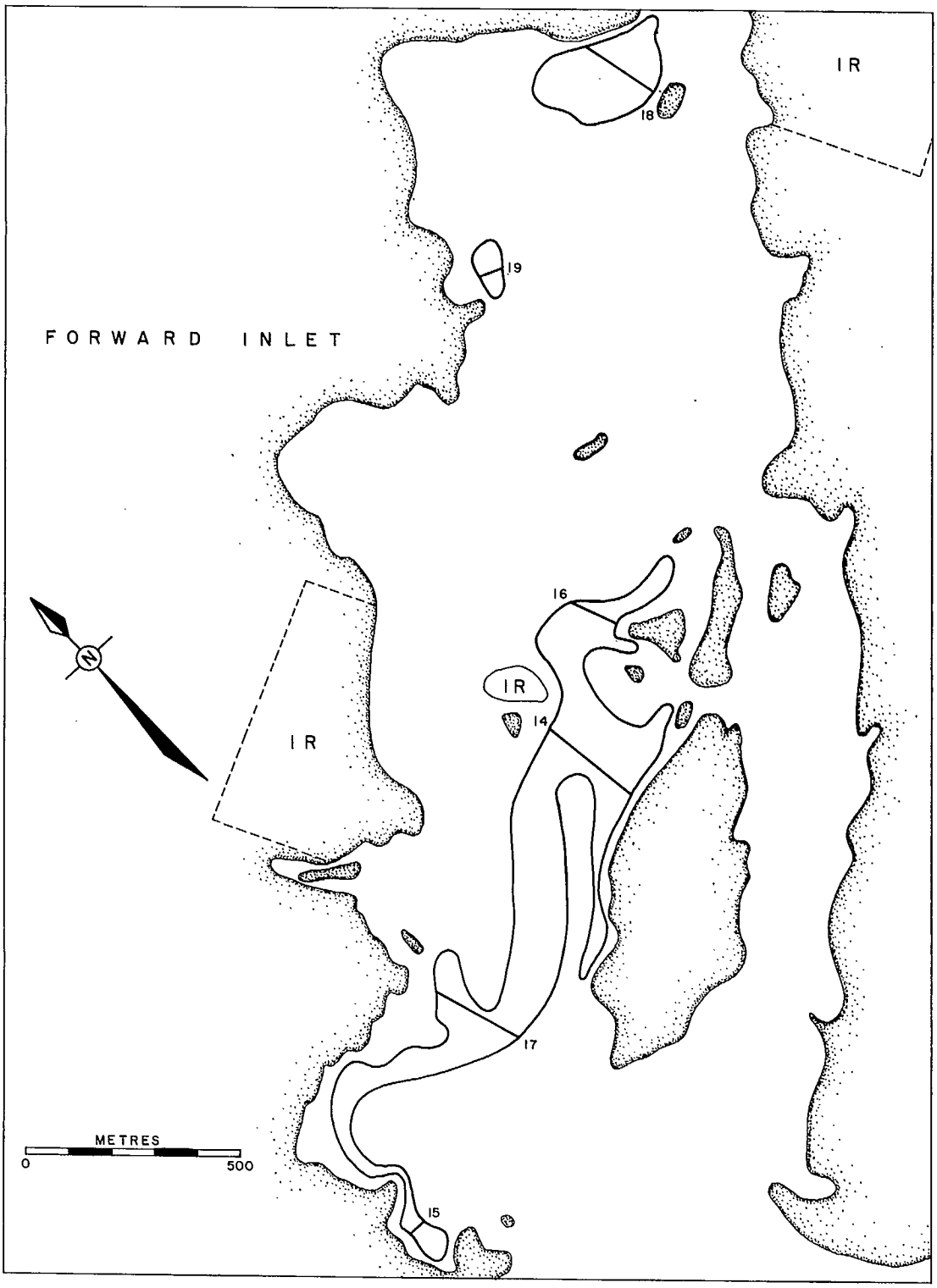


Fig. 23. Herring spawn at the head of Forward Inlet, surveyed by divers in 1986, with transect locations shown.