Herring Stock Estimates from Diving Surveys of Spawn for the West Coast of Vancouver Island in 1985

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PREFACE

An early draft of this manuscript was presented at the September 1985 Herring Stock Assessment Committee meeting. At that time, spawner biomass estimates were made using a model which predicts egg density from visual observations and spawn sample weight. Since then, eggs in preserved samples have been counted and the results were used in this analysis. Spawner biomass estimates are approximately 25% greater than those presented in September 1985.

ABSTRACT

Haegele, C. W. and J. F. Schweigert. 1987. Herring stock estimates from diving surveys of spawn for the west coast of Vancouver Island in 1985. Can. MS Rep. Fish. Aquat. Sci. 1922: 73 p.

Using the results of diving surveys of spawn we estimated that 28,311 tonnes of herring spawned on the west coast of Vancouver Island in 1985. In Area 23 (Barkley Sound) 15,288 tonnes spawned, of which 12,647 tonnes spawned in a first wave and 2641 tonnes spawned in a second wave. Most of the herring in Barkley Sound (13,463 tonnes) spawned in Loudon Channel, the remainder spawned in Trevor Channel. In Area 24, 6253 tonnes spawned in Clayoquot Sound and 3870 tonnes spawned in Hesquiat Harbour for a total of 10,123 tonnes. There were 1121 tonnes of spawners in Area 25: 6 tonnes spawned in Nootka Sound, and 811 tonnes spawned in a first wave and 304 tonnes in a second wave in Esperanza Inlet. No spawn was observed in Area 26. In Klaskish Inlet in Area 27, 1320 tonnes spawned in three waves; 29 tonnes in the early spawn, 860 tonnes in the middle spawn which was not surveyed, and 431 tonnes in the last spawn. In Forward Inlet in Area 27 a spawning stock of 459 tonnes was estimated. Of this, 226 tonnes were used by the spawn-on-kelp operation, which harvested 14.5 tonnes of product and had the eggs from 81 tonnes remaining at the pond sites after harvest. Spawning stocks were 35% higher in Area 23 and 24 and 34% lower in Area 25 in 1985 than in 1984. The distribution of spawn by depth was documented, and, except for first wave spawns in Barkley Sound, most spawn was deposited shallower than 3 m below chart datum.

RÉSUMÉ

Haegele, C. W. and J. F. Schweigert. 1987. Herring stock estimates from diving surveys of spawn for the west coast of Vancouver Island in 1985. Can. MS Rep. Fish. Aquat. Sci. 1922: 73 p.

Les auteurs ont estimé, à partir des résultats d'inventaires par plongeurs des oeufs déposés, que 28 311 t de harengs avaient frayé sur la côte Ouest de l'île Vancouver en 1985. Ce total se répartit de la façon suivante. Dans la zone 23 (détroit Barkley) 15 228 t de harengs ont frayé, dont 12 647 t au cours d'une première vague de frai et 2 641 t au cours d'une seconde. La plupart des harengs du détroit Barkley (13 463 t) ont frayé dans le chenal Loudon, le reste dans le chenal Trevor. Dans la zone 24, 6 253 t de harengs ont frayé dans le détroit Clayoquot et 3 870 t dans le havre Hesquiat, pour un total de 10 123 t. Il y a eu en tout 1 121 t de harengs qui ont frayé dans la zone 25: 6 t dans le détroit Nootka et 811 t (première vague) et 304 t (deuxième vague) dans l'inlet Esperanza. On a pas observé de frai dans la zone 26. Dans l'inlet Klaskish, de la zone 27, 1 320 t de harengs ont frayé en trois vagues successives de 29 t, 860 t (absence d'inventaire) et de 431 t. Dans l'inlet Forward, aussi dans la zone 27, on a estimé le stock de frai à 459 t. De cette valeur, 226 t ont été utilisées pour la production d'oeufs sur varech qui a permis d'obtenir 14,5 t de produits. Les oeufs de 81 t de poisson ont été laissés dans les étangs après la récolte. Par rapport à 1984, les stocks de géniteurs s'étaient accrus de 35 % dans les zones 23 et 24 et avaient décliné de 34 % dans la zone 25. On a noté la répartition des oeufs selon les profondeurs et, à l'exception de la première vague de géniteurs du détroit Barkley, la plupart des poissons ont déposé leurs oeufs à une profondeur inférieur à 3 m en deçà du zéro des cartes.

INTRODUCTION

The abundance of herring spawning on the west coast of Vancouver Island declined over several years to a recent low in 1984 (Haist et al. 1986). Results of a diving survey of spawns indicated that 20,295 tonnes of herring spawned between Barkley Sound and Esperanza Inlet in 1984 (Haegele and Schweigert 1985a). The 1985 diving survey of herring spawns on the west coast of Vancouver Island is the subject of this report.

METHODS

Herring spawns were surveyed independently by Fishery Officers using traditional techniques and by SCUBA divers, some of whom were also Fishery Officers. Data from the traditional surface surveys were collected using various techniques. Visual observations were made from the surface 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. Information on the type of vegetation on which the eggs were deposited was also obtained but is not used in this report.

The diving survey followed a two-stage sampling design (Schweigert et al. 1985). Transects perpendicular to the shore were the primary sampling unit and 0.5 m^2 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 and percent cover of the vegetation were estimated by divers. The samples were weighed and weighed sub-samples were preserved in Gilson's fluid and egg counts obtained. Eggs on the bottom substrate were determined from diver estimates of layers of eggs and percent of bottom substrate covered by eggs (Haegele et al. 1979) and added to eggs on vegetation. Depths at sample sites were measured by divers and were corrected to chart datum using water levels observed at Tofino (Tides and Currents, Institute of Ocean Sciences, Sidney, B.C.).

Transects were established at nearly equal intervals and samples were collected at equal intervals along a transect. The mean egg density and 95% confidence interval were calculated for each spawn and transects means

were weighted by transect length (Schweigert et al. 1985). The inner and outer edge of spawns were determined from measurements along transects. The limits of a spawn beyond the outer transects were determined by exploratory dives. The information on spawn deposition was plotted on maps of marine vegetation at scales of 1:4800 to 1:6000 (Haegele and Hamey 1977, 1979, 1980, and in preparation for Area 27), the boundaries of the spawn contoured, and the area of the spawn measured. Spawner biomass (tonnes) was estimated as the product of spawn area, egg density, and 10^{-8}, which reflects an assumed 200 eggs • gm^{-1} female weight (Hay 1985) and a 1:1 sex ratio.

The number of eggs spawned on Macrocystis sp. was estimated separately using a procedure developed by Haegele and Schweigert (1985b). Briefly, the number of plants and fronds (mature and immature) within 1 m of the transect line 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 into 1 m sections, which were weighed, and preserving one blade and associated stipe, which were also weighed, per section. The number of eggs in the preserved material were then determined. The area of the Macrocystis sp. beds was calculated from measurements along transects, and the number of eggs spawned on Macrocystis sp. 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.

In Area 27, spawn was also deposited in spawn on kelp ponds. Eggs on pond webbing were calculated from the area of the webbing (estimated by measuring the circumference and depth of the ponds and adjusting for irregular shapes) and the estimated layers of eggs on the webbing. It was assumed that the deposition on web was similar to that on bottom substrate which assumes that 1 layer of eggs equals 340,000 eggs • m^{-2} (Haegele et al. 1979). Eggs on Macrocystis sp. fronds remaining after harvest were calculated from the number of fronds and estimates of the number of eggs per frond obtained using the procedure described above. Spawn was deposited on the bottom underneath pond site B. The area of this patch was determined and quadrat samples taken on two transects across the patch. Eggs in quadrats were estimated using the procedure described above. The mean eggs • m^{-2} for these samples was multiplied by the area of the patch to give an estimate of the number of eggs.

For spawns surveyed only by Fishery Officers, the observed length and an adjusted width was used to calculate area. Egg density was estimated from egg layer observations made by Fishery Officers. The equations for these adjustments are (Haist et al. 1986):

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

(2) $Eggs \cdot m^{-2} = 75.861 + 105.321 \cdot Lay_{av}$

The Fishery Officer data utilized in the 1984 spawn survey (Haegele and Schweigert 1985a) was also re-analyzed using this manipulation.

RESULTS

BIOMASS ESTIMATES

Spawn survey data indicates that 28,311 tonnes of herring spawned on the west coast of Vancouver Island in 1985. Spawn survey information on which estimates are based are presented in Table 1. Table 2 contains estimates of spawner biomass for individual spawns. Confidence intervals (C.I.) for mean egg density for individual spawns were in some cases quite broad, from 20% to 229% of the mean (Av = 88%). However, the 95% C.I. by statistical area were acceptably narrow, within 21% of the mean for Area 23, 42% of the mean for Area 24, 49% of the mean for Area 25, and 58% of the mean for Area 27. The biomass estimate based on statistical area means and individual spawn means were similar, 28,731 tonnes vs. 28,311 tonnes, respectively (Table 3).

Area 23 - Barkley Sound

Herring spawned in two waves in Barkley Sound in 1985. All but one of the spawns was surveyed by divers and all the known spawns were surveyed by Fishery Officers. The first wave spawns occurred from February 27 to March 1. In Loudon Channel herring spawned on Forbes Island (Fig. 1) and along the Vancouver Island shoreline from above Maggie River into Ucluelet Harbour (Figs. 2 to 6). These spawns were all surveyed by divers and average egg density, excluding spawn on Macrocystis sp., ranged from 84,405 eggs • m^{-2} [Maggie River (1)] to 512,071 eggs • m^{-2} [(Macoah Passage (1)]. A total of 12,647 tonnes were estimated to have spawned in the first wave spawns surveyed by divers in Loudon Channel, which included 183 tonnes estimated to have spawned on Macrocystis sp. in Ucluelet Harbour (Table 4). The second wave spawning occurred from March 29 to 31. In Loudon Channel this spawn was deposited at Maggie River (Fig. 7), in Macoah Passage (Fig. 8), and on Spilling Islets (Fig. 9). These spawns were all surveyed by divers and average egg density ranged from 222,271 eggs • m^{-2} [Macoah Passage (2)] to 547,843 eggs • m^{-2} (Spilling Islets). It was estimated that 816 tonnes spawned in the second wave spawns surveyed by divers in Loudon Channel. The second wave spawn in Trevor Channel on Congreve Island was surveyed by Fishery Officers only and was estimated to have been deposited by 1825 tonnes. Total second wave spawner biomass was estimated at 2641 tonnes. Total biomass of spawners for Barkley Sound was estimated at 15,288 tonnes.

Area 24 - Clayoquot Sound and Hesquiat Harbour

Most spawing in Area 24 occurred between March 7 and 9. A spawn at Ritchie Bay took place on March 23. All of the major spawns were surveyed by divers and all of the spawns, except the spawn in Bawden Bay, were surveyed by Fishery Officers. Five spawns were not surveyed by divers.

In lower Clayoquot Sound, spawns on Stubbs Island (Fig. 10) and on Vargas Island from Yarksis to McIntosh Bay (Figs. 11, 12) were surveyed by divers and Fishery Officers. Spawns on Vargas Island at Kakawis and in Ritchie Bay and on the Vancouver Island shoreline below Kraan Island were surveyed only by Fishery Officers. All of these spawns were estimated to have been deposited by 5968 tonnes. Egg density for spawns surveyed by divers was between 188,195 eggs • m^{-2} [Elbow Bank (1)] and 821,063 eggs • m^{-2} [Elbow Bank (2)]. As well, a spawn so small and patchy that it could not be adequately surveyed was observed by divers in Mosquito Harbour on Meares Island. In middle Clayoquot Sound, one spawn was found in Bawden Bay (Fig. 13). This spawn was surveyed by divers only and was estimated to have been deposited by 48 tonnes at an average egg density of 93,680 eggs • m^{-2}. In upper Clayoquot Sound one spawn outside of Hot Springs Cove, at Sharp Point, was surveyed by Fishery Officers and was estimated to have been deposited by 60 tonnes.

There were two spawns in Hesquiat Harbour. The spawn at Antons Spit (Fig. 14) was surveyed by both divers and Fishery Officers. The spawn at Hesquiat Point was surveyed only by Fishery Officers. The two spawns were estimated to have been deposited by 3870 tonnes and average egg density for Antons Spit was 278,851 eggs • m^{-2}.

In all of Area 24, 9946 tonnes were estimated to have spawned with all but 42 tonnes having spawned in the first wave. There was a 177 tonnes charter payment catch taken in Sidney Inlet, bringing the total estimated biomass to 10,123 tonnes.

Area 25 - Nootka Sound and Esperanza Inlet

Only one spawn was observed in Nootka Sound. This spawn, at Friendly Cove (Fig. 15), was estimated to have been deposited by 6 tonnes and average egg density was 35,231 eggs • m^{-2}.

Herring spawned in two waves in Esperanza Inlet. The first wave spawn occurred from March 20 to 22 in Nuchatlitz (Fig. 16) and was surveyed by divers and Fishery Officers. The second wave spawns occurred from March 26 to 29 in Rosa Harbour and in Inner and Outer Nuchatlitz and were surveyed by Fishery Officers only . It was estimated that 1115 tonnes spawned in Esperanza Inlet, 811 tonnes in the first wave and 304 tonnes in the second wave. Egg density for the two spawns surveyed by divers was 122,816 and 314,482 eggs • m^{-2}. Fishery Officers reported that some additional spawning occurred on March 27 in the area surveyed by divers on March 24 and 25 but this spawn was not surveyed.

Area 27 - Klaskish and Forward Inlets

There were three spawns in Klaskish Inlet. The spawn in Klaskish Anchorage [Klaskish (1)] (Fig. 17) was deposited on March 3 and was surveyed by both divers and Fishery Officers. The spawn at the head of the inlet [Klaskish (2)] (Fig. 17) occurred on March 3 and was surveyed by divers. There was also a spawn at the northern entrance to the inlet which was observed from the air on March 9 but was not surveyed. The spawn in Klaskish

Anchorage was estimated to have been deposited by 29 tonnes at an average egg density of 34,139 eggs • m^{-2}. The spawn at the head of the inlet was estimated to have been deposited by 431 tonnes, which included 13 tonnes that spawned on Macrocystis sp. (Table 4). The egg density on the understory was 1,009,484 eggs • m^{-2}. The spawn at the entrance of the inlet was estimated to have been deposited by 860 tonnes. The total spawner biomass for Klaskish Inlet was estimated to be 1320 tonnes.

In Forward Inlet, herring spawned from March 10 to 12 and all spawns were surveyed by divers. There was spawn along the shoreline in Winter Harbour [Winter Harbour (1 and 2)](Fig. 18), at Hazard and Greenwood points [Hazard Point (1 and 2)] (Fig. 19), and at the confluence of Forward and Browning inlets in North Harbour (Fig. 20). Spawn-on-kelp operators harvested 14.5 tonnes of product in Winter Harbour. In addition, there was unharvested spawn on kelp remaining at the two pond sites (Figs. 21, 22). Eggs were deposited on the web of four ponds at site A and two ponds at site B. At site B there was spawn underneath the pond site.

It was estimated that 238 tonnes spawned at the five shoreline sites, including 2 tonnes that spawned on Macrocystis sp. in North Harbour (Table 4). Average egg density ranged from 80,984 [Winter Harbour (1)] to 283,701 [Winter Harbour (2)] eggs • m^{-2} on the understory vegetation. At pond site A it was estimated that 18 tonnes spawned on webbing (Table 5) and 24 tonnes spawned on Macrocystis sp. that remained after harvesting (Table 6). At pond site B it was estimated that 24 tonnes spawned on webbing (Table 5) and 6 tonnes spawned on Macrocystis sp. that remained after harvesting (Table 6). The spawn underneath pond site B was estimated to have been deposited by 9 tonnes. The area of this spawn was 4380 m^2 and average egg density (n = 5) was 207,000 eggs • m^{-2}. The spawn on kelp operation was estimated to have accounted for 226 tonnes of spawners as follows: 145 tonnes harvested (assuming 1 tonne of spawners = 100 kg of product), 42 tonnes at pond site A, and 39 tonnes at pond site B. Hence, total spawning stock for Forward Inlet was estimated at 459 tonnes.

SPAWN DISTRIBUTION AND TIMING

Mean percent cover of vegetation, mean layers of eggs, and mean egg density were calculated by depth interval for the major spawns surveyed by divers (Figs. 23, 24). Depth intervals chosen were intertidal (above 0 m chart datum), upper subtidal (between 0 m and 3 m below chart datum), middle subtidal (between 3 m and 6 m below chart datum), and lower subtidal (deeper than 6 m below chart datum). The area of spawn at each depth interval was determined and, when multiplied by mean egg density, gave an estimate of egg distribution by depth interval (Figs. 25, 26). Except for first wave spawns in Barkley Sound, most spawn occurred in the intertidal and upper subtidal zone. Approximately half of the first wave spawn in Barkley Sound was deposited in the middle and lower subtidal zone. The percent cover was always highest in the intertidal zone and decreased with depth. Layers of eggs were generally lowest in the intertidal zone and increased with depth. However, when spawn was deposited deeper than the middle intertidal zone, egg layers

were lower in the lower intertidal zone than in the middle intertidal zone. Egg density generally peaked in the upper subtidal zone.

There was no consistent pattern in spawn timing in relation to tidal cycles. Both first and second wave spawns in Barkley Sound were during neap tides, whereas major spawns in Area 24, 25 and 27 occurred during spring tides (Fig. 27). First wave spawning progressed from south to north, except that in Area 25 spawning was later than the first wave spawns elsewhere.

DISCUSSION

Herring spawning stocks in 1985 on the west coast of Vancouver Island were approximately 30% higher than in 1984 as determined from spawn surveys (Table 7). In Area 23 (Barkley Sound) there were 15,288 tonnes estimated to have spawned in 1985, compared to 11,279 tonnes estimated for Barkley Sound in 1984, of which 5879 tonnes spawned and 5400 tonnes were caught in the roe fishery. In Area 24 there were 7323 tonnes estimated in 1984 and 10,123 tonnes estimated in 1985. A larger proportion of fish spawned in the Hesquiat Harbour portion of Area 24 in 1985 (35%) than in 1984 (2%). The spawning biomass in the Nootka Sound portion of Area 25 remained small at 6 tonnes in 1985, compared to 109 tonnes, estimated entirely from Fishery Officer spawn reports, in 1984. The spawning stock in the Esperanza Inlet portion of Area 25 declined from 1584 tonnes in 1984 to 1115 tonnes in 1985. However, 930 tonnes were harvested in the roe fishery in Esperanza Inlet in 1984 and the stock that actually spawned in 1984 was 763 tonnes. There may not have been a first wave spawn in Esperanza Inlet in 1985 and these fish may have spawned elsewhere, possibly in Hesquiat Harbour. There was no diving survey of spawn conducted in Area 27 in 1984 and the 1985 estimate was 1779 tonnes of spawners, of which 226 tonnes spawned at spawn on kelp sites in Winter Harbour.

Confidence intervals for egg densities were quite broad for most spawns surveyed and this may have been the result of insufficient sampling. The sampling design was for a minimum of 5 samples per transect at 4 transects per km. Both were approximately achieved, there was an average of 5.2 (S.D. = 1.3) samples per transect for the average 3.5 (S.D. = 1.8) transects per km for 24 of the 25 spawns surveyed (Table 8). The 25th spawn [Elbow Bank (2)] had only 1 transect with 7 samples. However optimal transect density (after Schweigert et al. 1985) was achieved for only 3 spawns and optimal samples per transect for only 12 spawns (Table 8; Fig. 28).

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Table 1. Spawn survey results for the west coast of Vancouver Island in 1985.

Location	Diver					Fishery Officer					
	No. of transects	Length (m)	Av. transect length (m)	Area (ha)	Av. layers	No. of patches	Length (m)	Av. width (m)	Raw area (ha)	Adjusted area* (ha)	Av. layers
Area 23											
Forbes Island	4	1000	48	4.852	0.94	2	570	20	1.140	0.694	2.78
Maggie River (1)	3	1300	81	8.174	0.41	4	1385	43	5.895	2.951	0.60
Macoah Passage (1)	12	3100	114	36.783	1.82	14	2925	128	37.300	23.978	1.55
Twin Rivers	8	3600	357	124.877	1.21	11	3075	363	111.500	61.025	1.42
Camp Bay	6	3600	473	123.727	1.67	5	2550	534	136.125	68.513	2.89
Itatsoo Creek	3	1500	236	22.800	2.10	6	1050	16	1.670	1.388	3.22
Stuart Bay	4	1500	53	7.934	1.00	10	1830	24	4.318	2.398	1.06
Maggie River (2)	8	3600	53	19.594	1.14	2	2630	20	5.260	5.260	1.59
Macoah Passage (2)	4	1450	69	9.483	0.58	1	150	50	0.750	0.750	0.20
Spilling Islets	4	600	34	2.787	1.22	1	275	10	0.275	0.275	0.25
Congreve Island	No survey					5	3525	25	8.813	8.813	4.18
Area 23	56	21250	165	361.011	1.33	61	19965	157	313.046	176.045	2.15
Area 24											
Stubbs Island	2	600	155	7.776	0.62	3	819	175	14.337	14.032	0.38
Yarksis	5	3600	239	81.864	1.62	5	2226	189	42.132	30.872	2.83
Elbow Bank (1)	4	2400	535	120.844	0.60	6	2400	316	75.880	35.074	1.31
Elbow Bank (2)	1	140	344	4.693	1.90	1	180	90	1.620	1.620	4.00
Kakawis	No survey					2	160	40	0.637	0.550	0.37
Ritchie Bay	No survey					4	430	8	0.340	0.273	0.70
Kraan Island	No survey					6	441	38	1.695	1.347	0.86
Bawden Bay	3	1500	24	5.161	0.47	No report					
Sharp Point	No survey					2	159	41	0.654	0.409	2.23
Hesquiat Point	No survey					4	600	119	7.150	7.150	1.95
Antons Spit	10	7000	275	127.865	1.02	7	1346	72	9.757	5.675	1.51
Area 24	25	15240	272	348.203	1.04	40	8761	176	154.202	97.002	1.70

Table 1 (cont'd)

Location	Diver					Fishery Officer					
	No. of transects	Length (m)	Av. transect length (m)	Area (ha)	Av. layers	No. of patches	Length (m)	Av. width (m)	Raw area (ha)	Adjusted area* (ha)	Av. layers
Area 25											
Friendly Cove	3	380	42	1.668	0.24	1	366	46	1.684	1.263	0.10
Nuchatlitz (1)	6	1600	50	5.997	1.03	5	768	41	3.145	3.145	1.72
Nuchatlitz (2)	8	1150	480	50.632	0.71	4	1573	275	43.323	32.730	1.00
Rosa Harbour	No survey					1	110	55	0.605	0.303	1.40
Inner Nuchatlitz	No survey					3	502	17	0.873	0.517	0.55
Outer Nuchatlitz	No survey					3	895	40	3.624	3.025	1.17
Area 25	17	3130	150	58.297	0.75	17	4214	126	53.253	40.983	1.02
Area 27											
Klaskish (1)	4	1200	79	8.558	0.59	3	750	203	15.250	15.250	2.91
Klaskish (2)	4	1350	25	4.144	3.46	No report					
Klaskish (3)	No survey					1	3000	100	30.000	30.000	(2.00)
Winter Harbour (1)	5	1000	54	6.360	0.70	2	100	10	0.100	0.100	1.50
Winter Harbour (2)	3	670	27	2.284	0.82	2	100	10	0.100	0.100	1.50
Hazard Point (1)	3	800	26	2.835	1.22	1	50	10	0.050	0.050	1.50
Hazard Point (2)	6	1550	24	4.233	0.42	2	100	10	0.100	0.100	1.50
North Harbour	3	650	18	1.355	1.19	No report					
Area 27	28	7220	37	29.769	1.12	11	4100	111	45.600	45.600	2.30
W.C.V.I. total	126	46840	156	797.280	1.16	129	37040	153	566.101	359.630	1.93

*Adjusted area = length • width • (100 - % bare)

Table 2. Estimates of spawner biomass for the west coast of Vancouver Island in 1985.

Location	Source	Area (ha)	Eggs • m^{-2} • 10^{-3} (95% C.I.)	Tonnes of spawners (95% C.I.)
Area 23				
Forbes Island	Transects 1 to 4	4.852	249 (-200 to 698)	121 (0 to 339)
Maggie River (1)	Transects 1,2,4	8.174	84 (-65 to 234)	69 (0 to 191)
Macoah Passage (1)	Transects 5 to 16	36.783	512 (324 to 701)	1884 (1190 to 2577)
Twin Rivers	Transects 17 to 24	124.877	342 (275 to 409)	4275 (3439 to 5111)
Camp Bay	Transects 25 to 29,31	123.727	370 (62 to 678)	4580 (766 to 8394)
Ucluelet Inlet	Transects 33 to 39	30.734	500 (149 to 850)	1535 (459 to 2612)
- giant kelp	Transects 34 to 38	4.693[a]	-	183 (50 to 137)
Maggie River (2)	Transects 3 to 10	19.594	231 (48 to 413)	452 (94 to 810)
Macoah Passage (2)	Transects 1,2,11,12	9.483	222 (58 to 387)	211 (55 to 367)
Spilling Islets	Transects 13 to 16	2.787	548 (140 to 956)	153 (39 to 266)
Congreve Island	F.O. report	35.353	516 (-)	1825 (-)
Area 23 total		396.364		15288
Area 24				
Stubbs Island	Transects 1,2	7.776	290 (-274 to 955)	226 (0 to 665)
Yarksis	Transects 1 to 5	81.864	357 (70 to 645)	2924 (571 to 5276)
Elbow Bank (1)	Transects 1 to 4	120.844	189 (37 to 341)	2283 (446 to 4120)
Elbow Bank (2)	Transect 5	4.693	821 (119 to 1523)	385 (56 to 715)
Kakawis	F.O. report	1.914	115 (-)	22 (-)
Ritchie Bay	F.O. report	2.813	150 (-)	42 (-)
Kraan Island	F.O. report	5.175	166 (-)	86 (-)
Bawden Bay	Transects 1 to 3	5.161	94 (49 to 139)	48 (25 to 72)
Sharp Point	F.O. report	1.920	311 (-)	60 (-)
Hesquiat Point	F.O. report	10.802	281 (-)	304 (-)
Antons Spit	Transects 1 to 10	127.865	279 (63 to 495)	3566 (807 to 6324)
Charter catch	-	-	-	177 (-)
Area 24 total		370.827		10123

Table 2 (cont'd)

Location	Source	Area (ha)	Eggs • m^{-2} • 10^{-3} (95% C.I.)	Tonnes of spawners (95% C.I.)
Area 25				
Friendly Cove	Transects 1 to 3	1.668	35 (-27 to 98)	6 (0 to 16)
Nuchatlitz (1)	Transects 1 to 5,7	5.997	314 (-22 to 651)	189 (0 to 390)
Nuchatlitz (2)	Transects 8 to 15	50.632	123 (63 to 183)	622 (319 to 924)
Rosa Harbour	F.O. report	1.483	223 (-)	33 (-)
Inner Nuchatlitz	F.O. report	4.357	134 (-)	58 (-)
Outer Nuchatlitz	F.O. report	10.706	199 (-)	213 (-)
Area 25 total		74.843		1121
Area 27				
Klaskish (1)	Transects 1 to 4	8.558	34 (8 to 60)	29 (7 to 52)
Klaskish (2)	Transects 5 to 8	4.144	1009 (652 to 1367)	418 (270 to 567)
- giant kelp	Transect 8	0.130[a]	-	13 (-)
Klaskish (3)	F.O. report	30.000[b]	287 (-)	860 (-)
Winter Harbour (1)	Transects 4 to 8	6.360	81 (37 to 125)	52 (24 to 79)
Winter Harbour (2)	Transects 9 to 11	2.284	284 (50 to 517)	65 (12 to 118)
Winter Harbour	Pond site A	-	-	42 (-)
Winter Harbour	Pond site B	-	-	39 (-)
Hazard Point (1)	Transects 1 to 3	2.835	184 (87 to 282)	52 (25 to 80)
Hazard Point (2)	Transects 12 to 17	4.233	94 (7 to 181)	40 (3 to 77)
North Harbour	Transects 18 to 20	1.355	163 (53 to 274)	22 (7 to 37)
- giant kelp	Transect 18	0.050[a]	-	2 (-)
Spawn on kelp	Product	-	-	145 (-)
Area 26 total		59.769		1779

[a]Area of spawn on giant kelp is part of area for location and hence is not included in statistical area totals.

[b]F.O. observed length and unadjusted width used for area calculation.

Table 3. Estimates of spawner biomass using statistical area mean egg densities. These estimates are compared to estimates derived by summing results for individual spawns from Table 2.

Location and source	Area (ha)	Eggs • m^{-2} • 10^{-3} (95% C.I.)	Tonnes (95% C.I.)	Tonnes (sum)
Area 23-understory	396.364	378 (300 to 457)	14999 (11878 to 18121)	15105
Area 23-giant kelp	4.69[a]	-	183 (50 to 137)	183
Area 24-understory	370.827	290 (168 to 412)	10979 (6362 to 15595)	9946
Area 24-charter catch	-	-	177 (-)	177
Area 25-understory	74.843	141 (71 to 211)	1055 (534 to 1576)	1121
Area 27-understory	59.769	185 (78 to 292)	1105 (465 to 1743)	1538
Area 27-giant kelp	0.180[a]	-	7 (0 to 16)	15
Area 27-ponds	-	-	81 (-)	81
Area 27-product	-	-	145 (-)	145
Total	901.803		28731	28311

[a]Area of Spawn on giant kelp is part of area for location and hence is not included in total.

Table 4. Estimates of herring spawn on Macrocystis sp., using three density sources, for herring spawns surveyed on the west coast of Vancouver Island in 1985. Confidence intervals (95%) are given for means.

	Ucluelet Inlet	Klaskish	North Harbour	Area 27	WCVI
Area surveyed (m^2)	249	20	22	42	291
No. plants sampled	7	2	3	5	12
Plant height	2.9(1.5 to 4.2)	2.5(-)	4.0(-)	3.4(2.0 to 4.8)	3.1(2.3 to 3.9)
Egg layers	1.4(0.4 to 2.3)	2.6(-)	0.2(-)	1.1(-0.8 to 3.1)	1.3(0.5 to 2.0)
Eggs per plant • 10^{-3}	811(372 to 1249)	726(-)	589(-)	644(-137 to 1425)	741(409 to 1074)
Eggs per frond • 10^{-3}	83(49 to 117)	133(-)	66(-)	93(-5 to 191)	87(52 to 122)
E. per mat. frond • 10^{-3}	168(46 to 290)	275(-)	148(-)	199(-30 to 428)	184(83 to 284)
Area of spawn (ha)	4.693	0.130	0.050	0.180	4.873
Plants • m^{-2}	0.82	0.75	0.68	0.71	0.80
Fronds • m^{-2}	4.52	3.60	3.23	3.41	4.36
Mature fronds • m^{-2}	2.33	2.05	2.09	2.07	2.29
Total eggs • 10^{-8} from					
- plant estimate	312(143 to 481)	7(-)	2(-)	8(0 to 18)	289(159 to 419)
- frond estimate	176(104 to 248)	6(-)	1(-)	6(0 to 12)	185(110 to 259)
- mat. frond est.	183(50 to 317)	13(-)	2(-)	7(0 to 16)	205(93 to 317)

Table 5. Estimates of herring eggs on mesh in spawn on kelp ponds in Winter Harbour in 1985 (1 layer = 340,000 eggs • m^{-2}).

Site	Pond	Area (m^2)	Egg layers	No. of eggs • 10^{-8}
A	1	240	5	4.08
	2	240	4	3.26
	3	240	5	4.08
	4	290	7	6.90
	Total			18.32
B	1	500	8	13.60
	2	500	6	10.20
	Total			23.80

Table 6. Estimates of herring spawn on unharvested kelp fronds in spawn on kelp ponds in Winter Harbour in 1985.

Site	Location	No. of fronds	n	Av. layers (95% C.I.)	Eggs • frond^{-1} • 10^{-3} (95% C.I.)	Total eggs • 10^{-8} (95% C.I.)
A	Lines	1072	6	4.6 (2.1 to 7.2)	1057 (274 to 1841)	11.33 (2.94 to 19.74)
	Ponds	1438	8	4.7 (2.7 to 6.7)	844 (512 to 1177)	12.14 (7.36 to 16.93)
	Total	2510	14	4.7 (3.4 to 6.0)	936 (613 to 1258)	23.49 (15.39 to 31.58)
B	Lines	912	4	9.5 (6.7 to 12.3)	615 (318 to 912)	5.61 (2.90 to 8.32)
	Ponds	65	0	-	615 (318 to 912)*	0.40 (0.21 to 0.59)
	Total	977	4	9.5 (6.7 to 12.3)	615 (318 to 912)	6.01 (3.11 to 8.91)

*Fronds in pond not sampled and eggs per frond from lines samples used.

Table 7. Spawn and stock estimates for the west coast of Vancouver Island, based on results of spawn diving surveys conducted in 1982, 1984 and 1985.

Parameter	Year	Area 23	Area 24	Area 25	Area 27	WCVI
Length (km)	1982	31.2	n/a	n/a	n/a	n/a
	1984	11.5	19.2	7.7	n/a	n/a
	1985	24.8	17.0	4.6	10.2	56.6
Area (ha)	1982	414.24	n/a	n/a	n/a	n/a
	1984	172.44	406.85	69.02	n/a	n/a
	1985	396.36	370.83	74.84	59.77	901.80
Spawners(t)	1982	19022	n/a	n/a	n/a	n/a
	1984	5879	7323	763	n/a	n/a
	1985	15288	9946	1121	1553	27908
Stock (t)	1982	22622	n/a	n/a	n/a	n/a
	1984	11279	7323	1693	n/a	n/a
	1985	15288	10123	1121	1779	28311

Table 8. Estimated optimal sampling design to achieve a SE of 25% of the mean (after Schweigert et al. 1985) and achieved sampling density for 1985 diving surveys of herring spawn.

Location	Samples • transect^{-1}	Spawn width (area • length^{-1})	Achieved sampling fraction	Optimal sampling fraction	Achieved transects • km^{-1}	Optimal transects • km^{-1}
Forbes Island	4.0	48.5	0.08	0.08	4.0	64.6
Maggie River (1)	9.5	62.9	0.15	0.06	2.3	25.8
Macoah Passage (1)	6.4	118.7	0.05	0.04	3.9	3.3
Twin Rivers	6.9	346.9	0.02	0.04	2.2	0.8
Camp Bay	5.8	343.7	0.02	0.01	1.7	7.1
Ucluelet Inlet	5.3	102.5	0.05	0.06	2.3	6.9
Maggie River (2)	4.6	54.4	0.08	0.07	2.2	7.7
Macoah Passage (2)	5.0	65.4	0.08	0.09	2.8	8.7
Spilling Islets	5.0	46.5	0.11	0.07	6.7	18.8
Stubbs Island	5.5	129.6	0.04	0.02	3.3	56.2
Yarksis	5.2	227.4	0.02	0.02	1.4	5.6
Elbow Bank (1)	6.5	503.5	0.01	0.01	1.7	7.1
Bawden Bay	3.7	34.4	0.11	0.32	2.0	2.4
Antons Spit	6.1	182.7	0.03	0.02	1.4	5.2
Friendly Cover	4.0	43.9	0.09	0.16	7.9	120.5
Nuchatlitz (1)	4.7	37.5	0.13	0.08	3.8	21.8
Nuchatlitz (2)	4.8	440.3	0.01	0.01	7.0	10.3
Klaskish (1)	6.0	71.3	0.08	0.13	3.3	13.4
Klaskish (2)	4.0	30.7	0.13	0.33	3.0	2.0
Winter Harbour (1)	4.0	63.6	0.06	0.11	5.0	8.6
Winter Harbour (2)	3.8	34.1	0.11	0.21	4.5	15.4
Hazard Point (1)	5.0	35.4	0.14	0.17	3.8	5.4
Hazard Point (2)	3.7	27.3	0.14	0.18	3.9	13.8
North Harbour	4.5	20.9	0.22	0.48	4.6	5.7

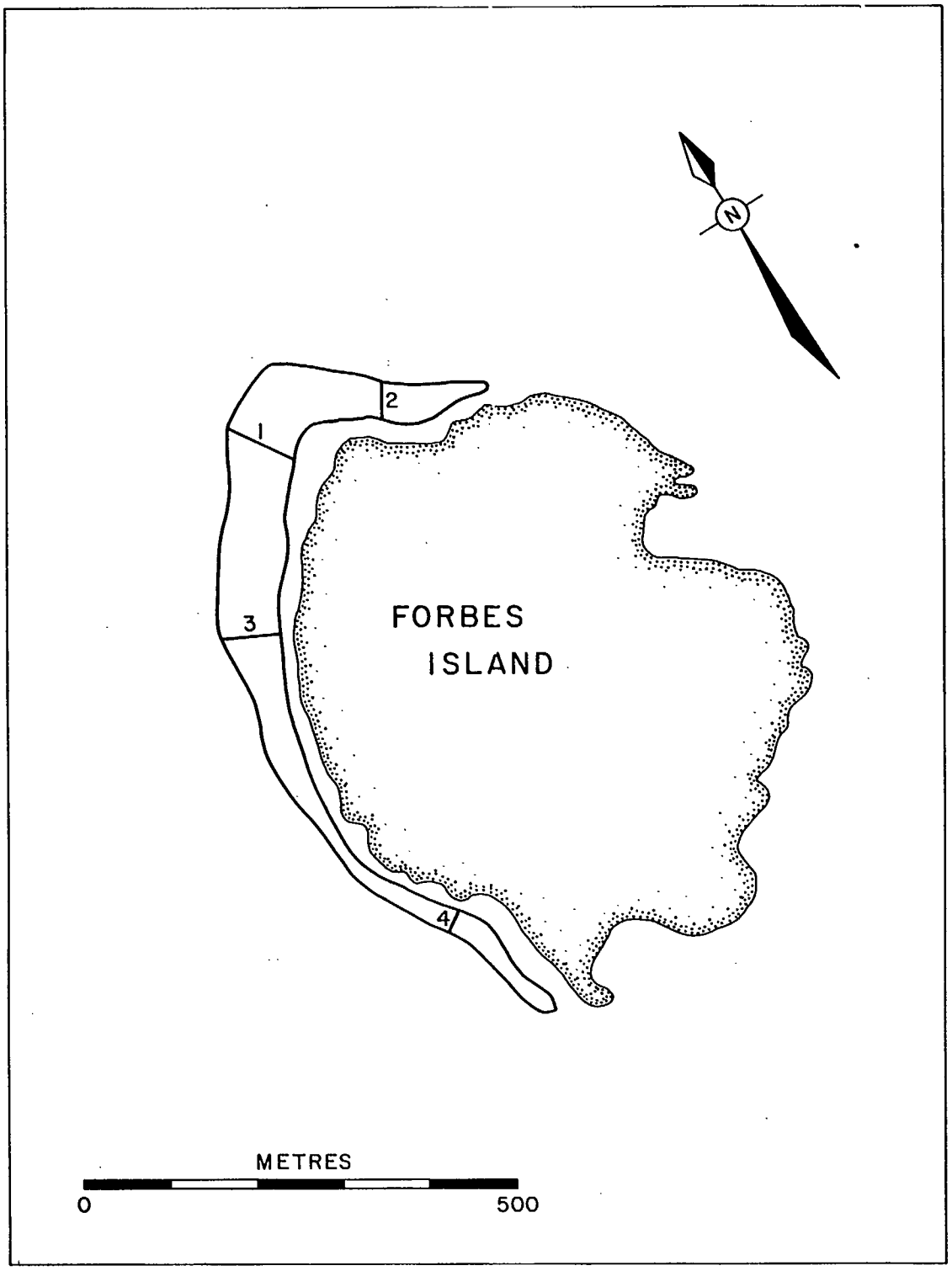


Fig. 1. Herring spawn on Forbes Island in Barkley Sound, surveyed by divers in 1985, with transect locations shown.

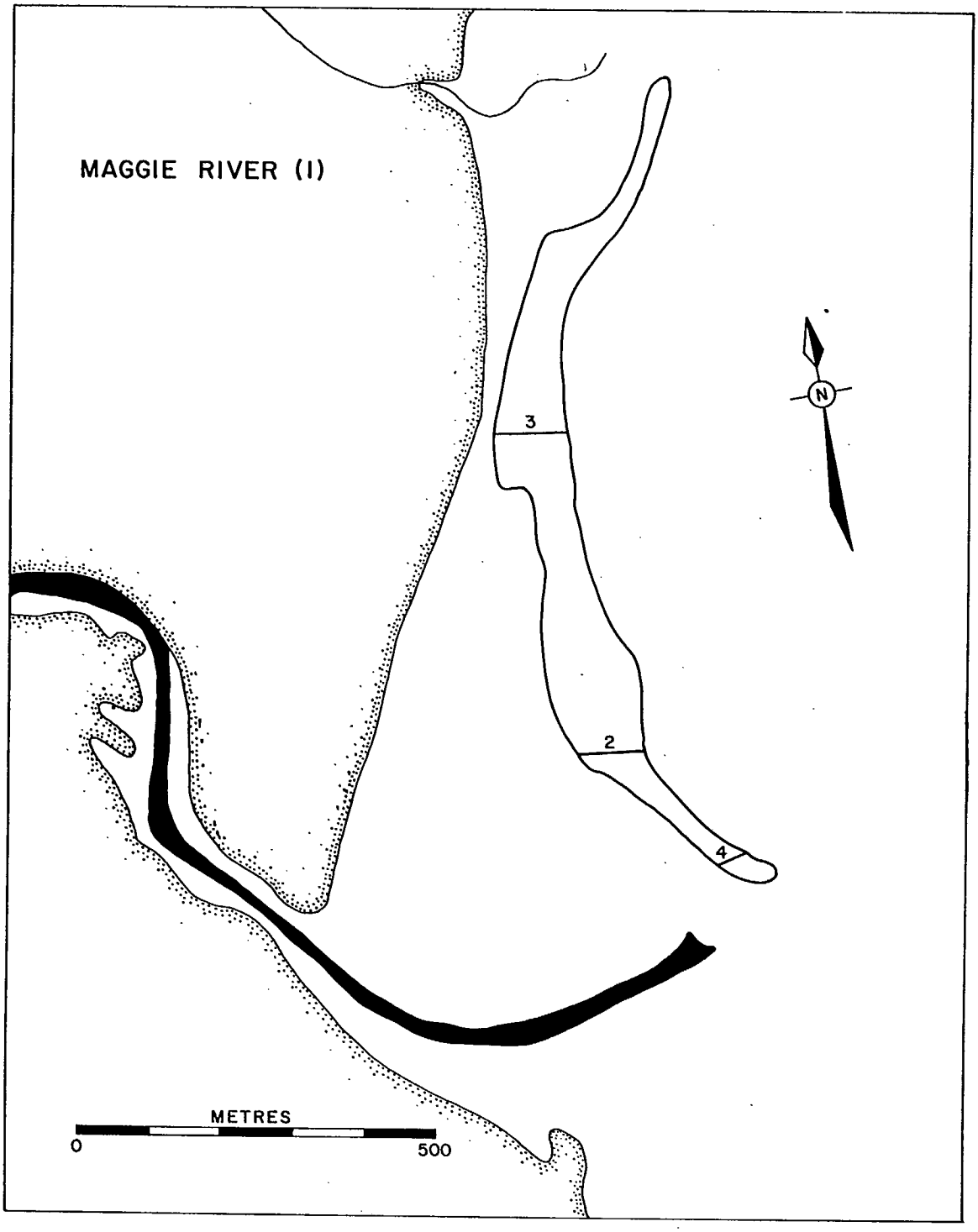


Fig. 2. Herring spawn at Maggie River (1) in Barkley Sound, surveyed by divers in 1985, with transect locations shown.

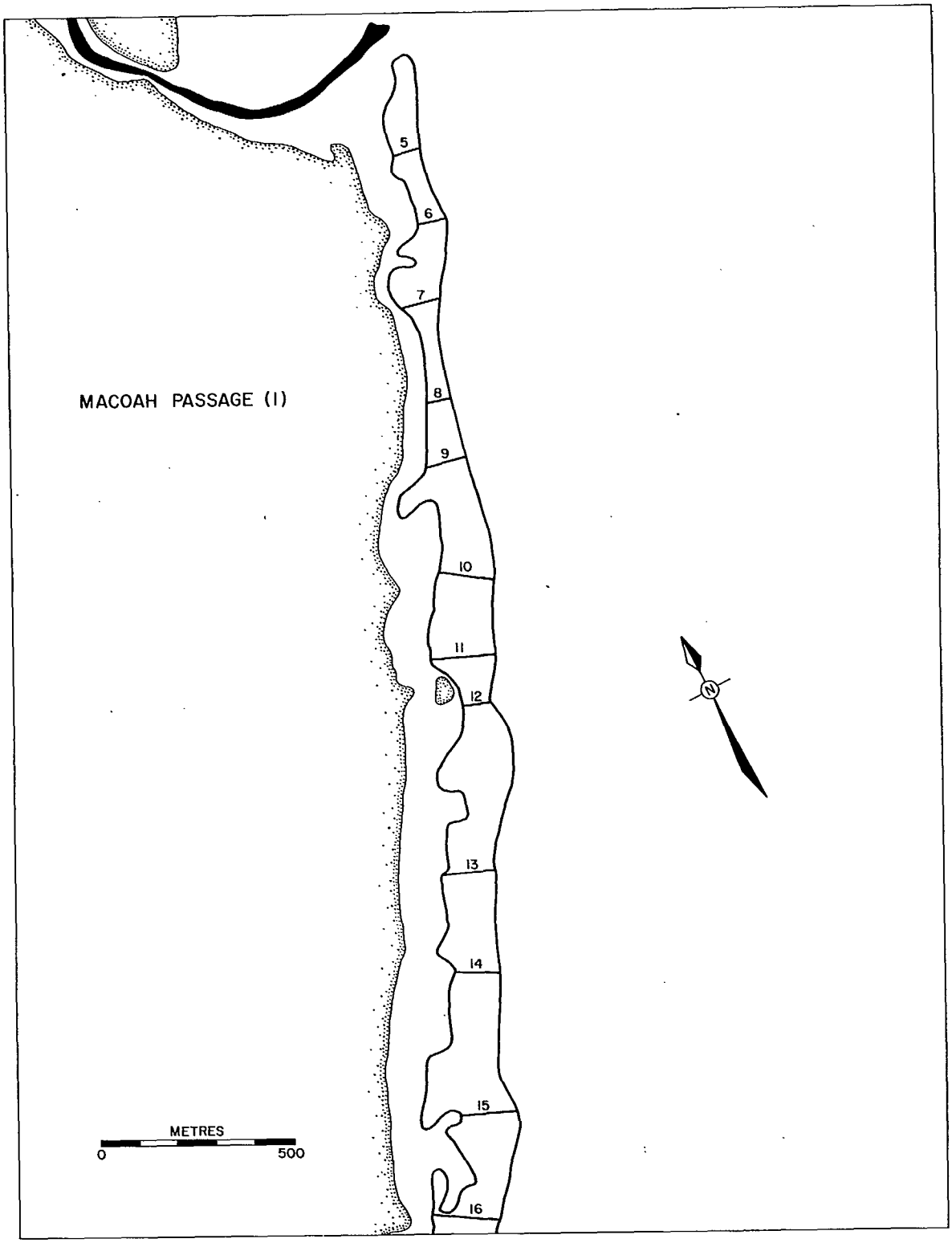


Fig. 3. Herring spawn in Macoah Passage (1) in Barkley Sound, surveyed by divers in 1985, with transect locations shown.

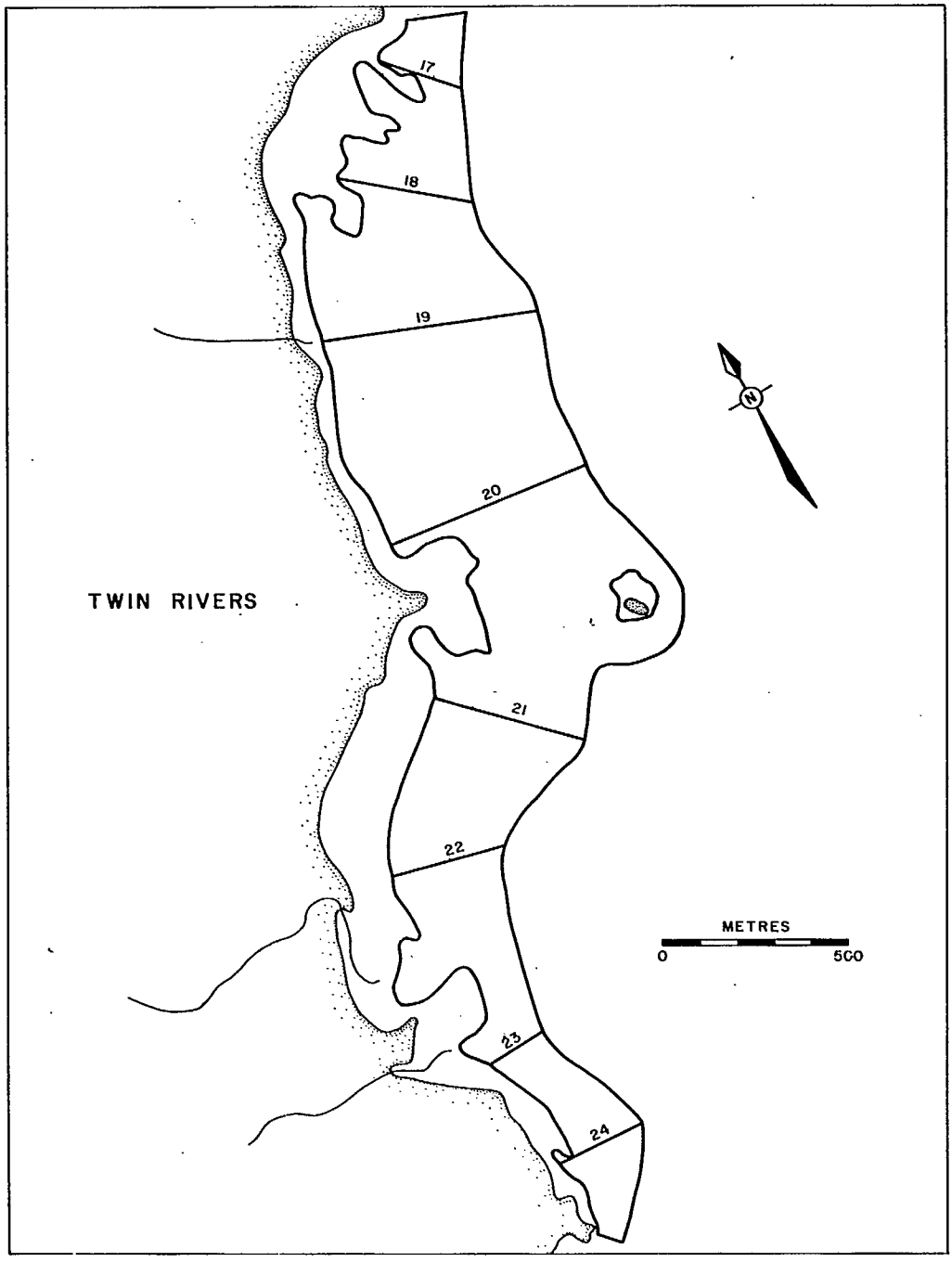


Fig. 4. Herring spawn at Twin Rivers in Barkley Sound, surveyed by divers in 1985, with transect locations shown.

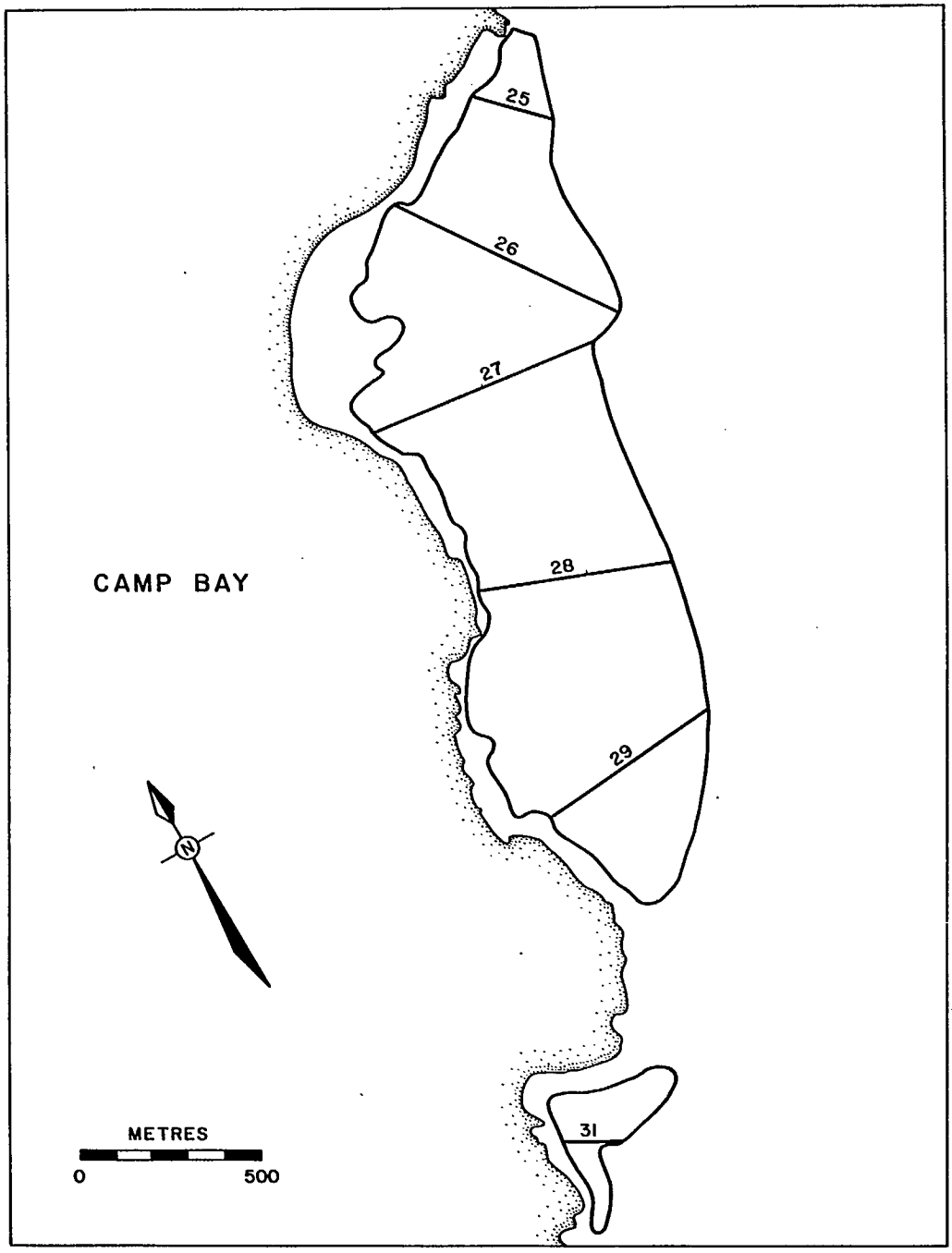


Fig. 5. Herring spawn in Camp Bay in Barkley Sound, surveyed by divers in 1985, with transect locations shown.

Fig. 6. Herring spawn in Ucluelet Inlet in Barkley Sound, surveyed by divers in 1985, with transect locations shown. Shaded area shows where spawn was deposited on Macrocystis sp.

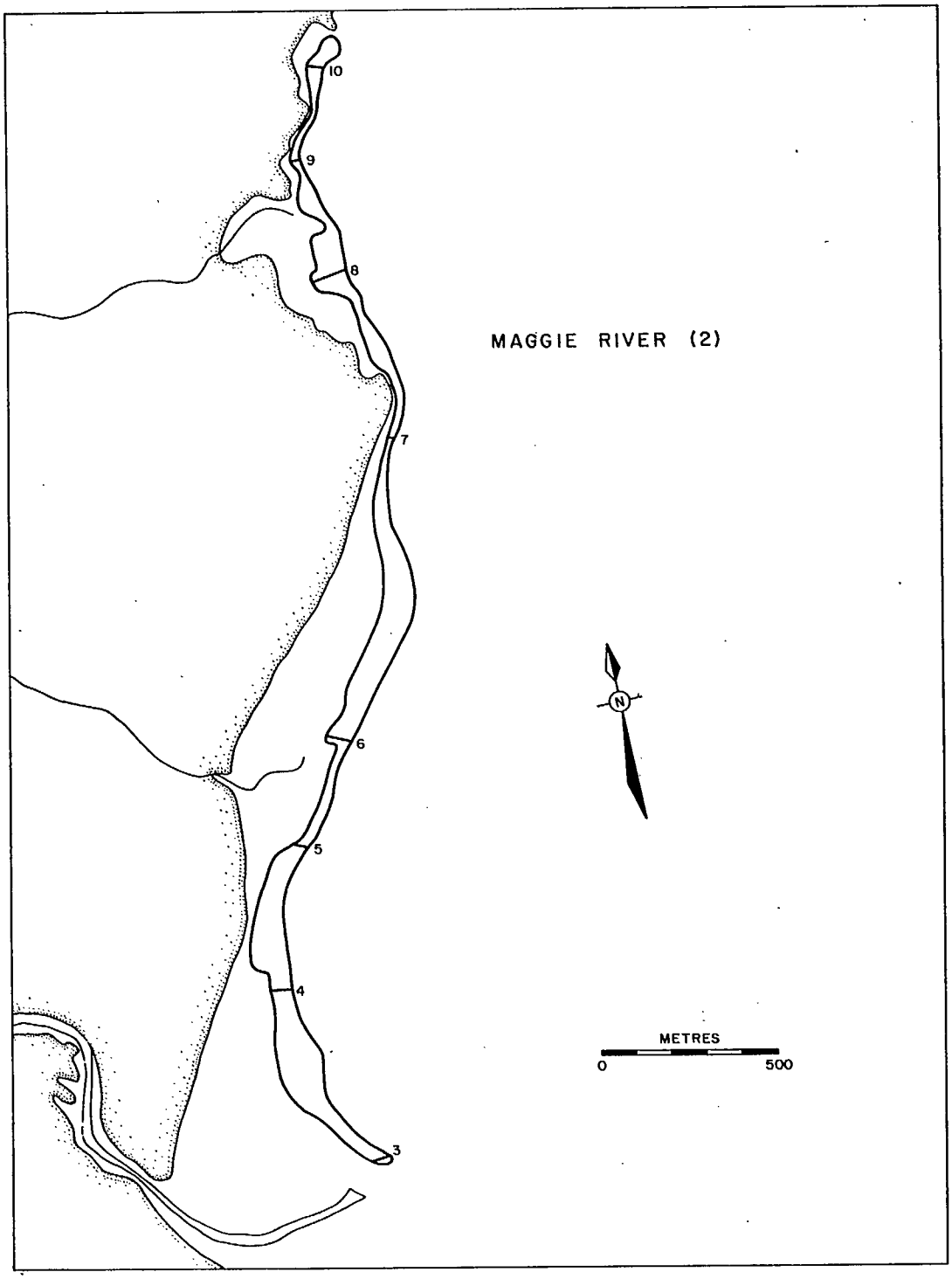


Fig. 7. Herring spawn at Maggie River (2) in Barkley Sound, surveyed by divers in 1985, with transect locations shown.

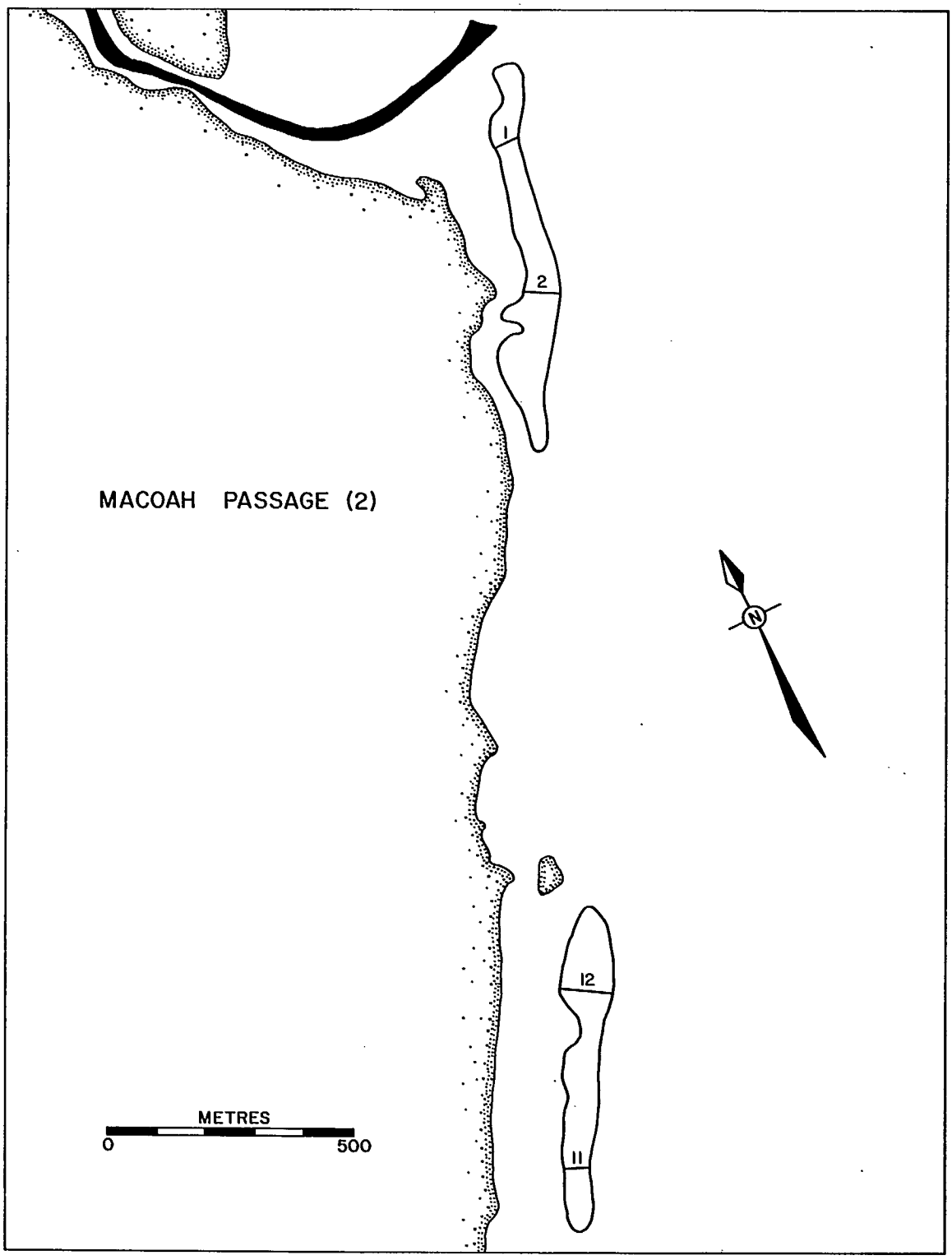


Fig. 8. Herring spawn in Macoah Passage (2) in Barkley Sound, surveyed by divers in 1985, with transect locations shown.

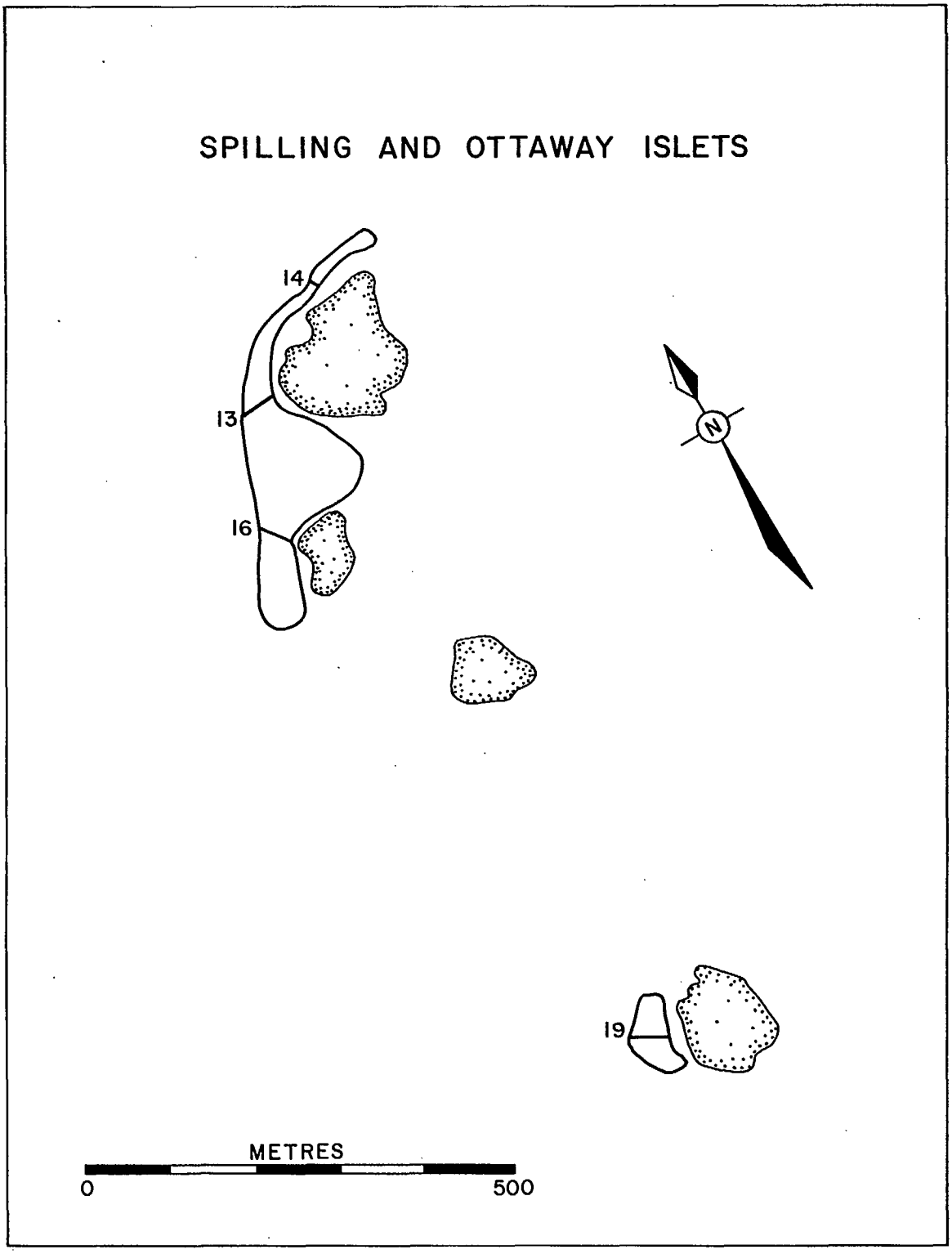


Fig. 9. Herring spawn on Spilling Islets in Barkley Sound, surveyed by divers in 1985, with transect locations shown.

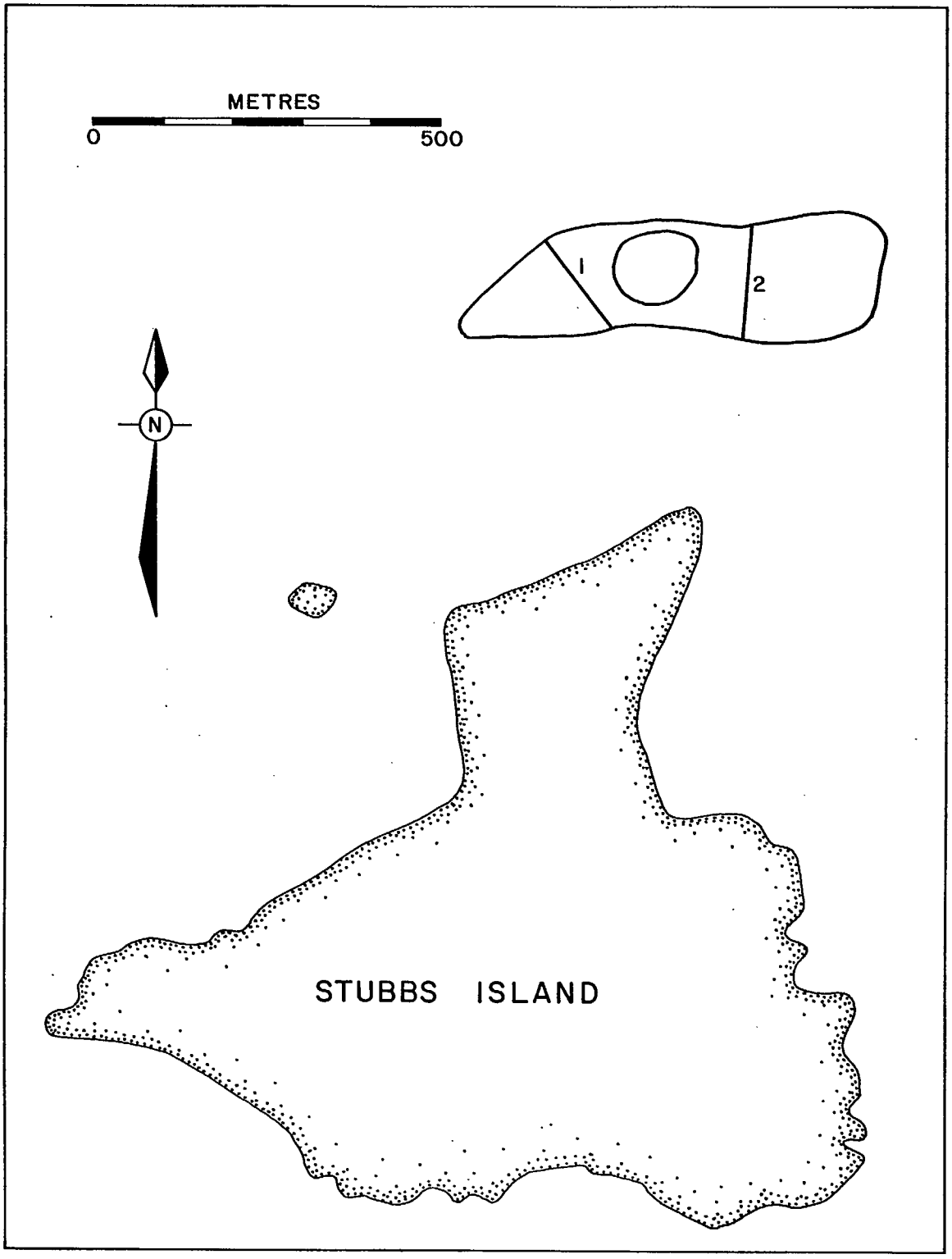


Fig. 10. Herring spawn on Stubbs Island in Clayoquot Sound, surveyed by divers in 1985, with transect locations shown.

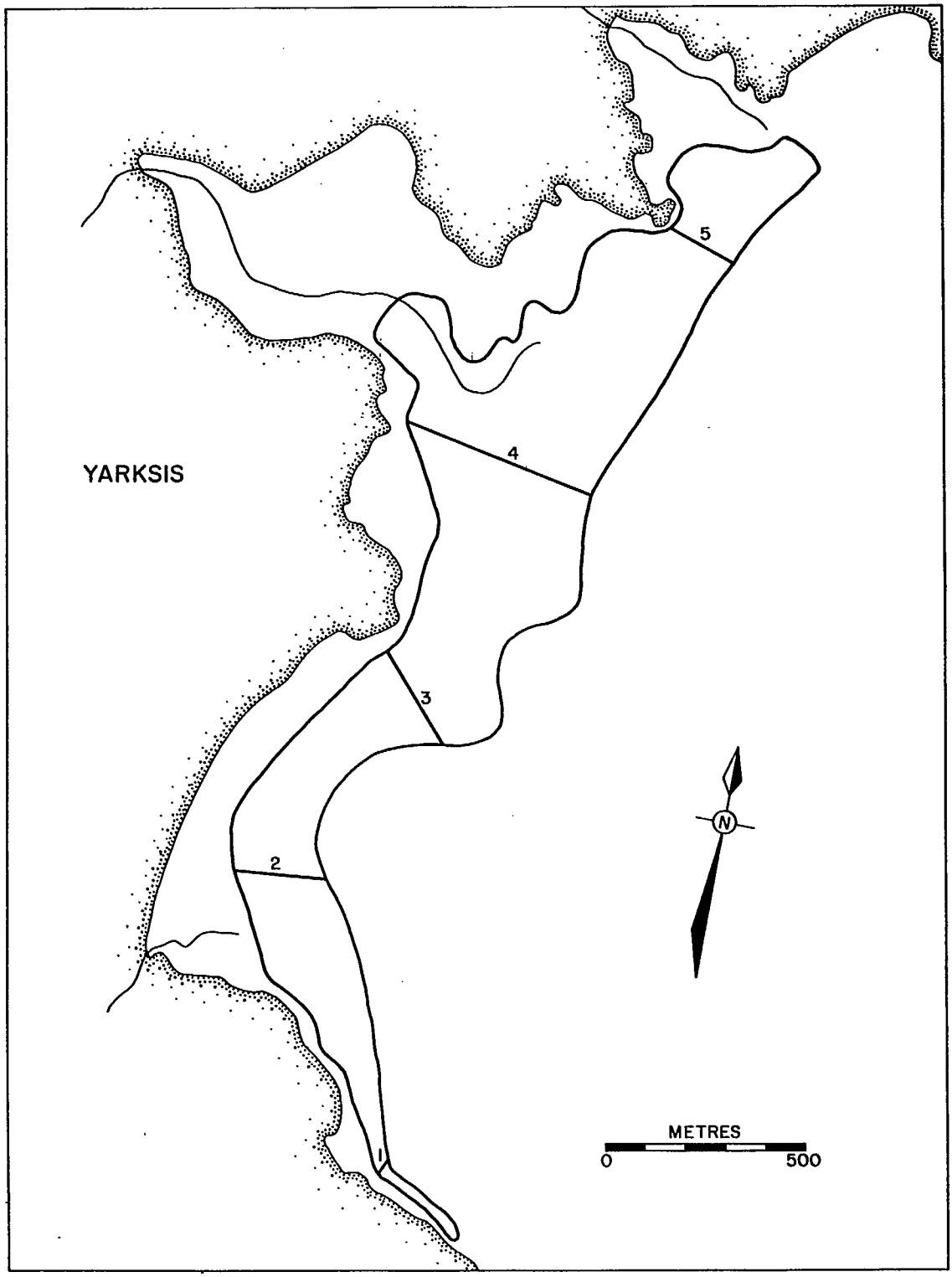


Fig. 11. Herring spawn at Yarksis in Clayoquot Sound, surveyed by divers in 1985, with transect locations shown.

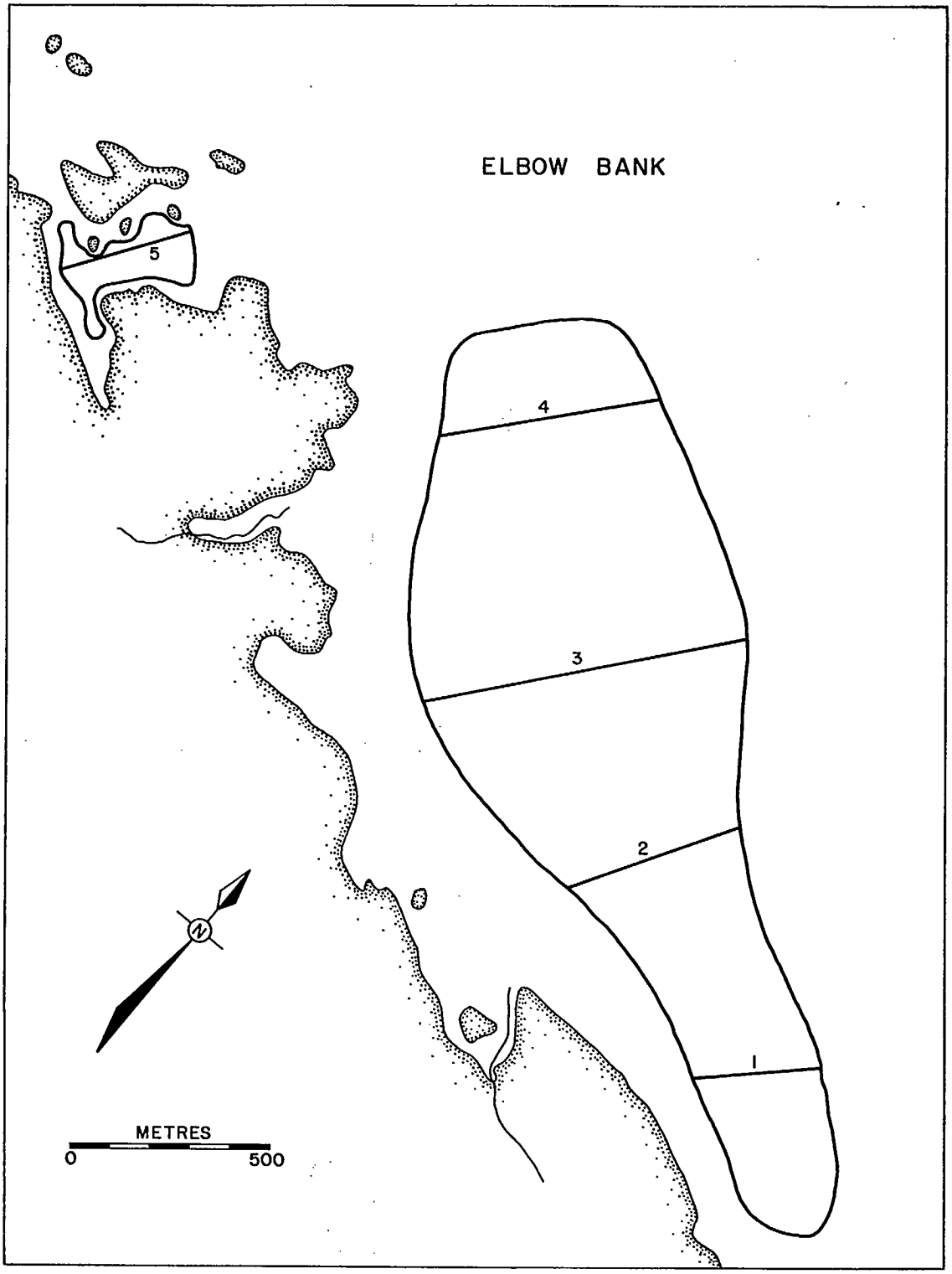


Fig. 12. Herring spawn on Elbow Bank (1 and 2) in Clayoquot Sound, surveyed by divers in 1985, with transect locations shown.

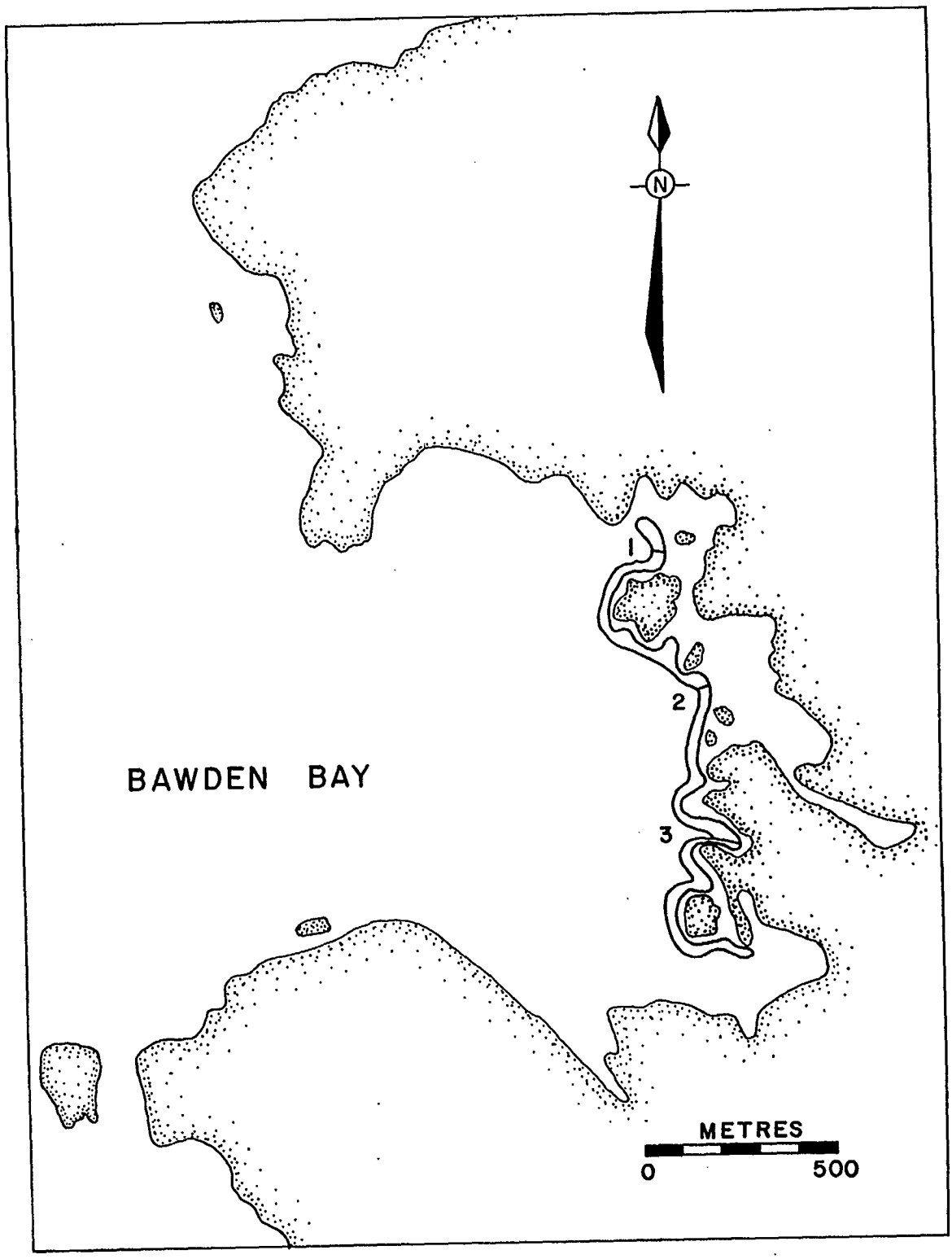


Fig. 13. Herring spawn in Bawden Bay in Clayoquot Sound, surveyed by divers in 1985, with transect locations shown.

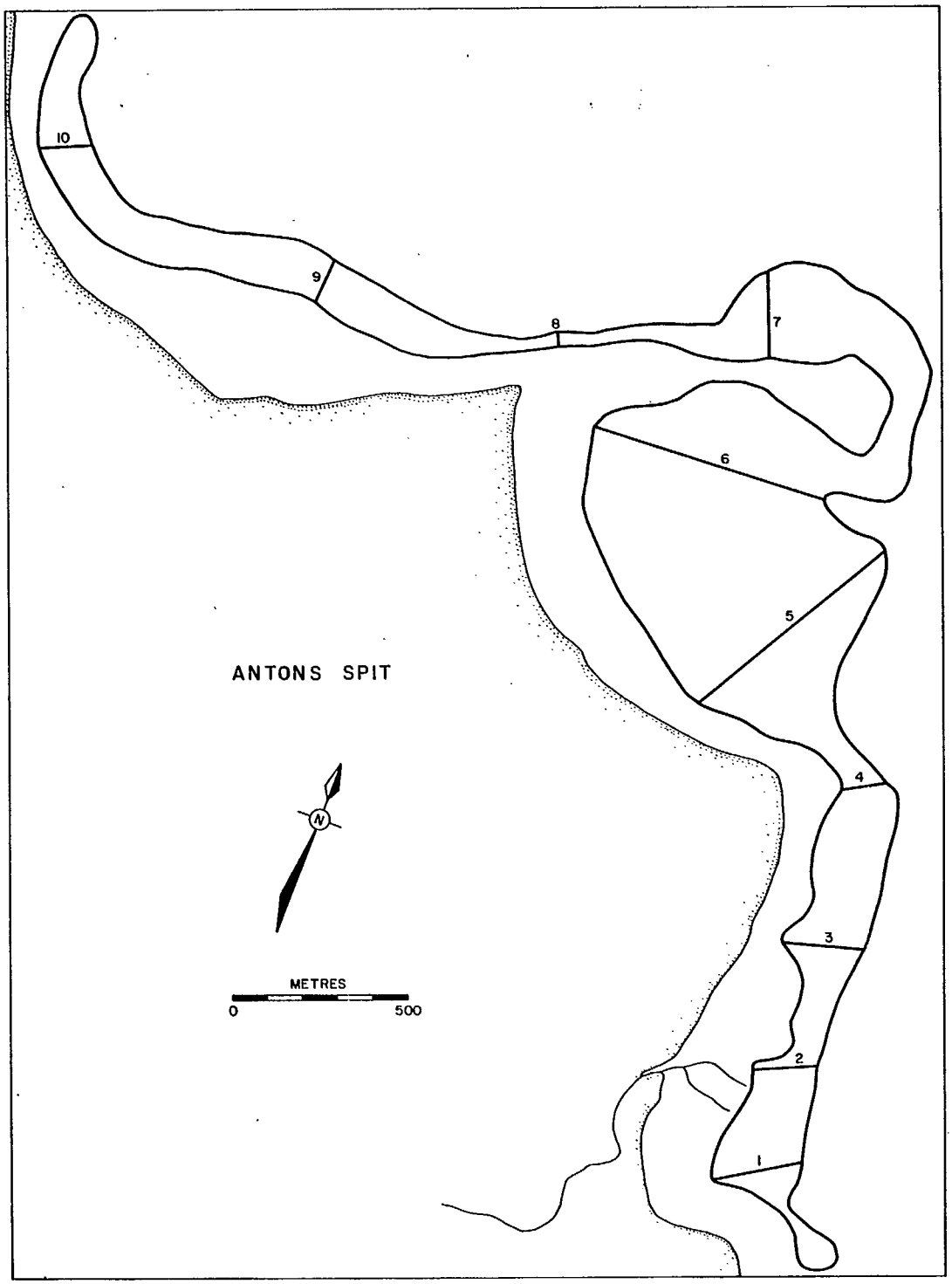


Fig. 14. Herring spawn on Antons Spit in Hesquiat Harbour, surveyed by divers in 1985, with transect locations shown.

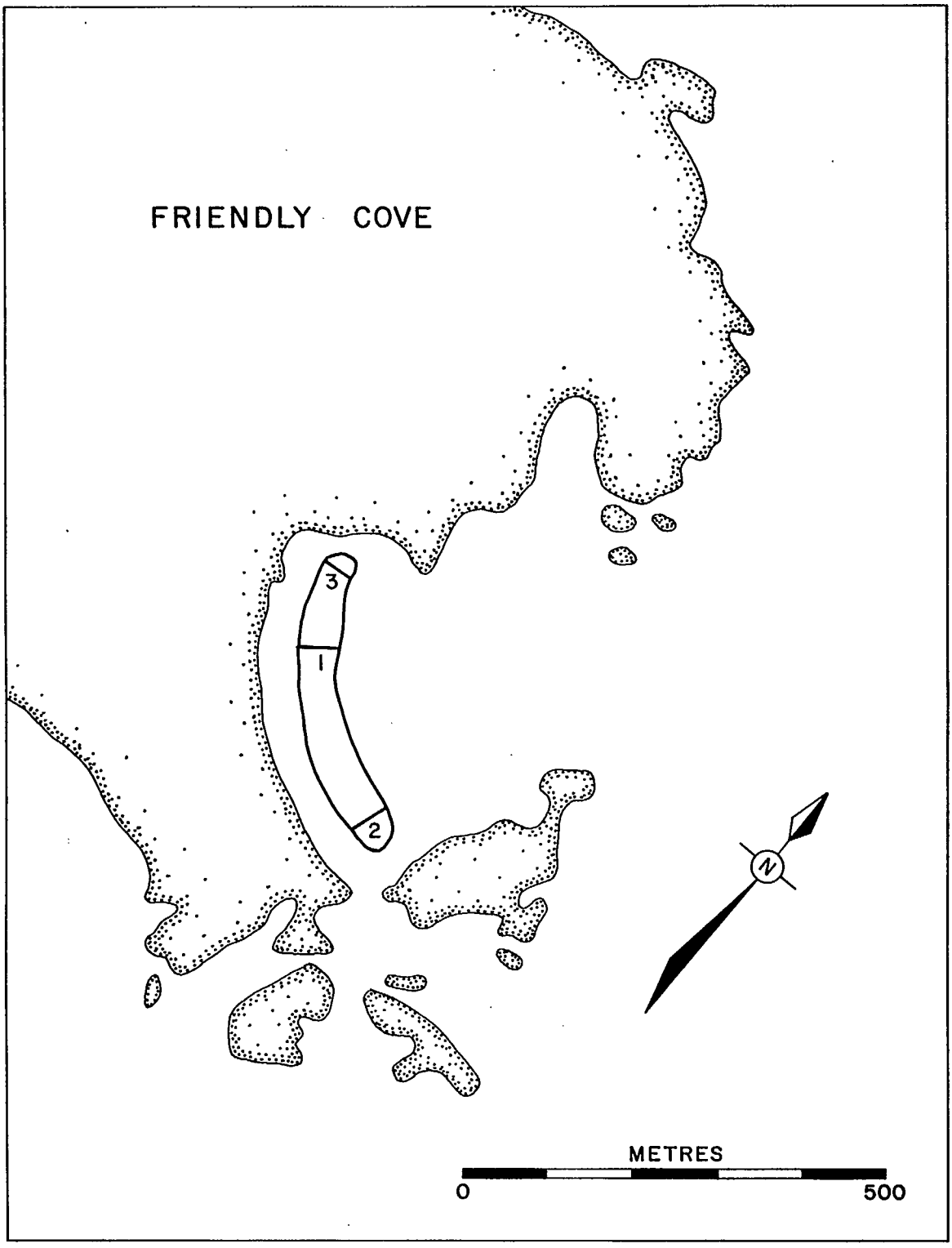


Fig. 15. Herring spawn in Friendly Cove in Nootka Sound, surveyed by divers in 1985, with transect locations shown.

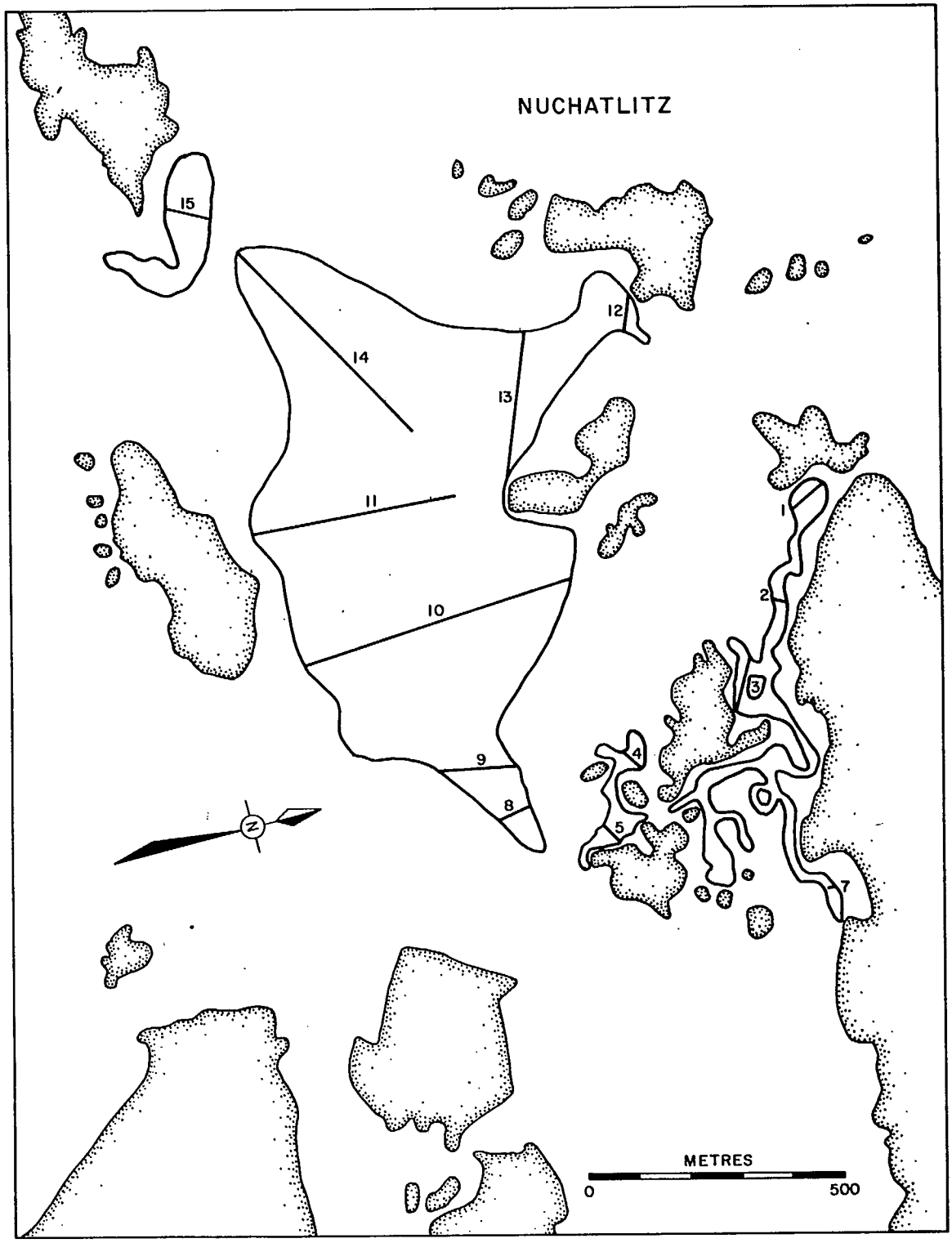


Fig. 16. Herring spawn in Nuchatlitz (1 and 2) in Esperanza Inlet, surveyed by divers in 1985, with transect locations shown.

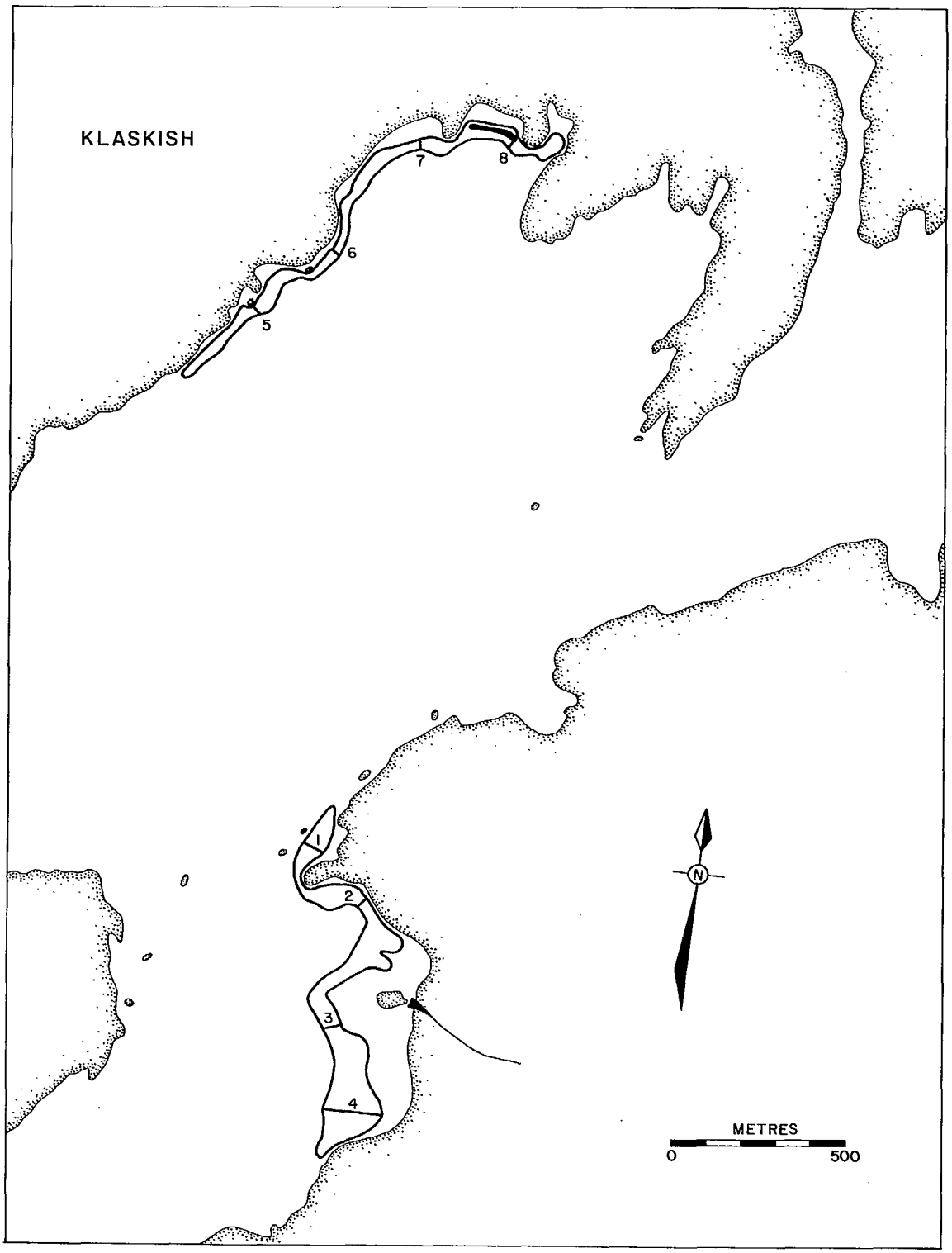


Fig. 17. Herring spawn in Klaskish (1 and 2) in Klaskish Inlet, surveyed by divers in 1985, with transect locations shown. Shaded area shows where spawn was deposited on Macrocystis sp.

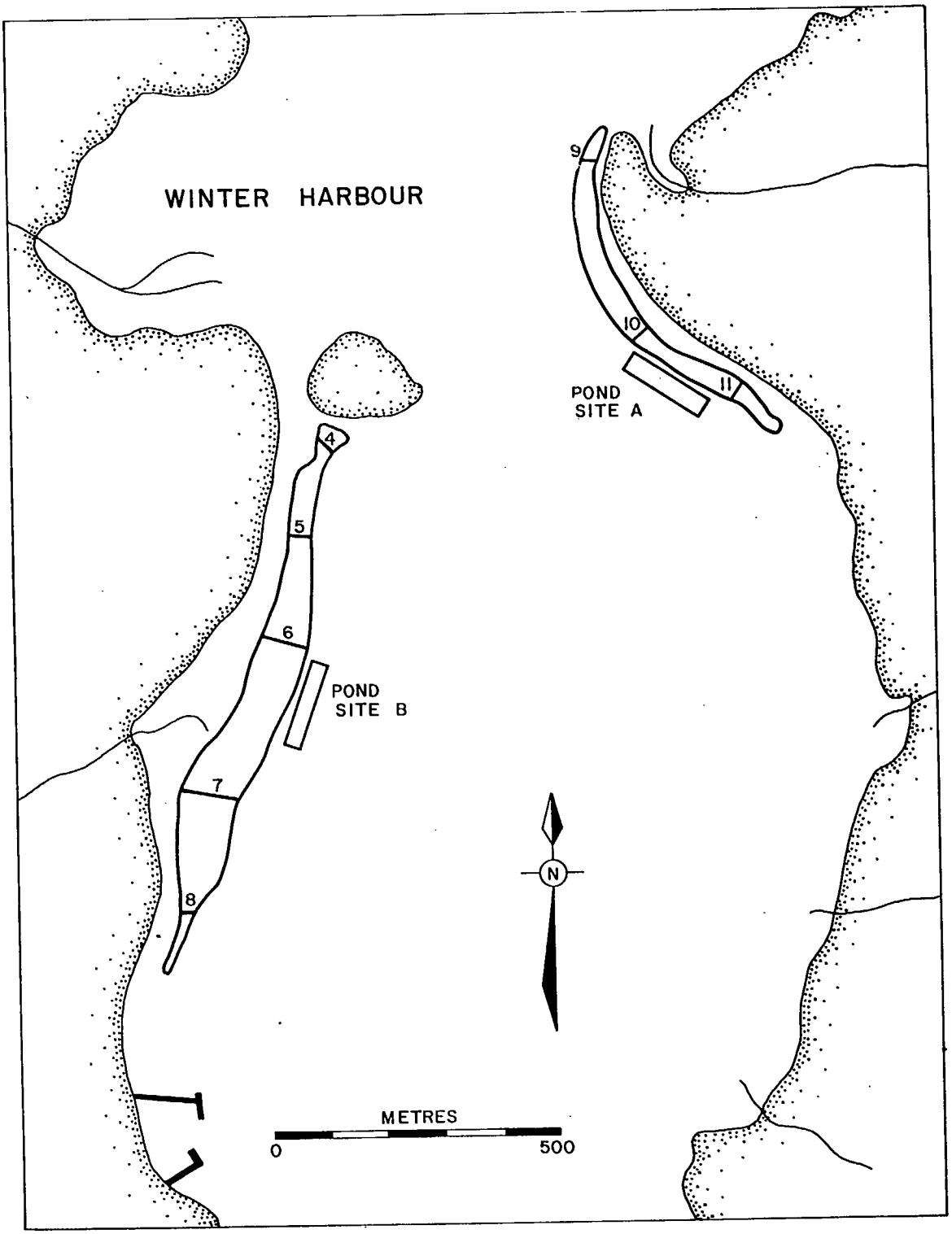


Fig. 18. Herring spawn in Winter Harbour (1 and 2) in Forward Inlet, surveyed by divers in 1985, with transect locations shown. Location of spawn on kelp pond sites A and B are identified.

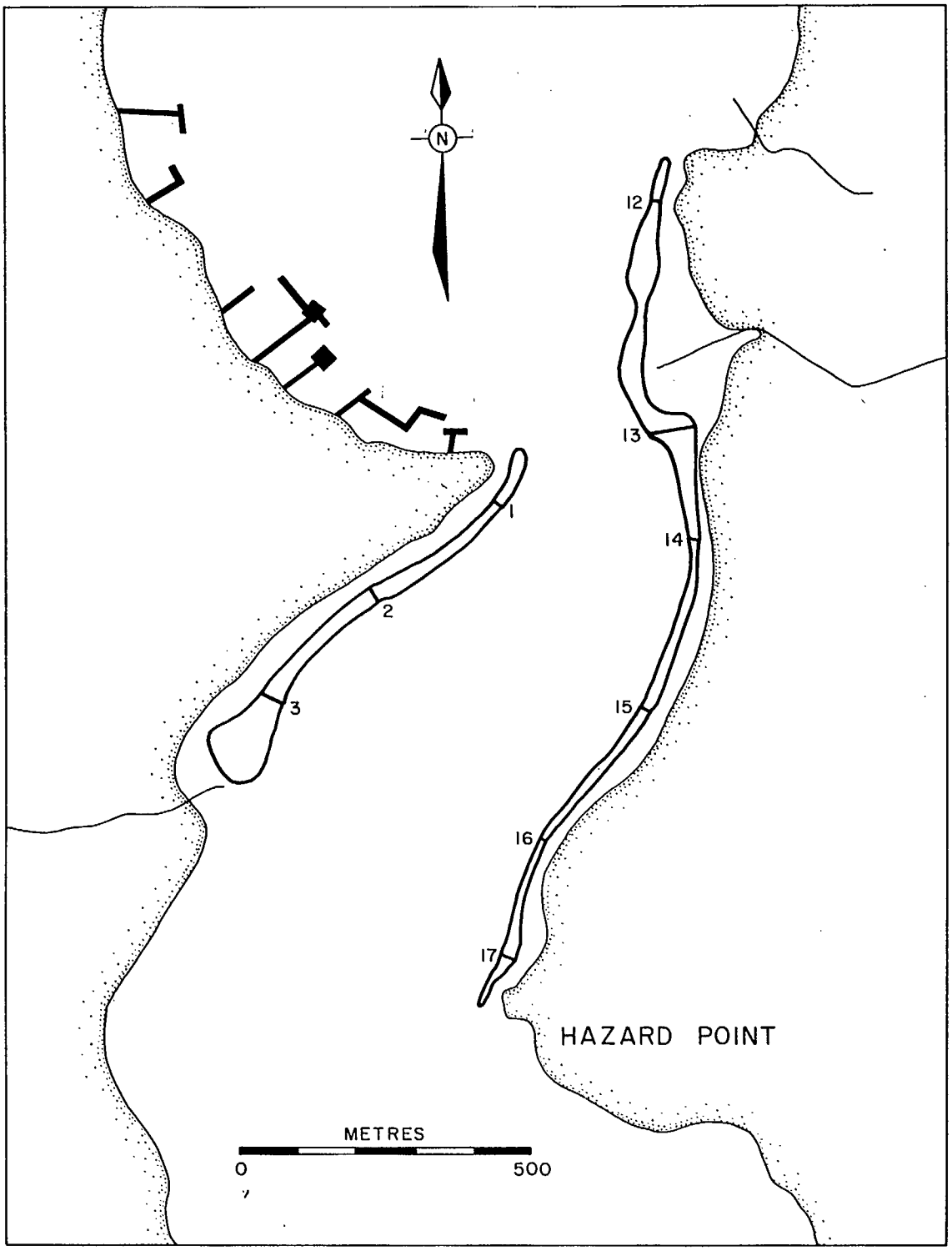


Fig. 19. Herring spawn at Hazard Point (1 and 2) in Forward Inlet, surveyed by divers in 1985, with transect locations shown.

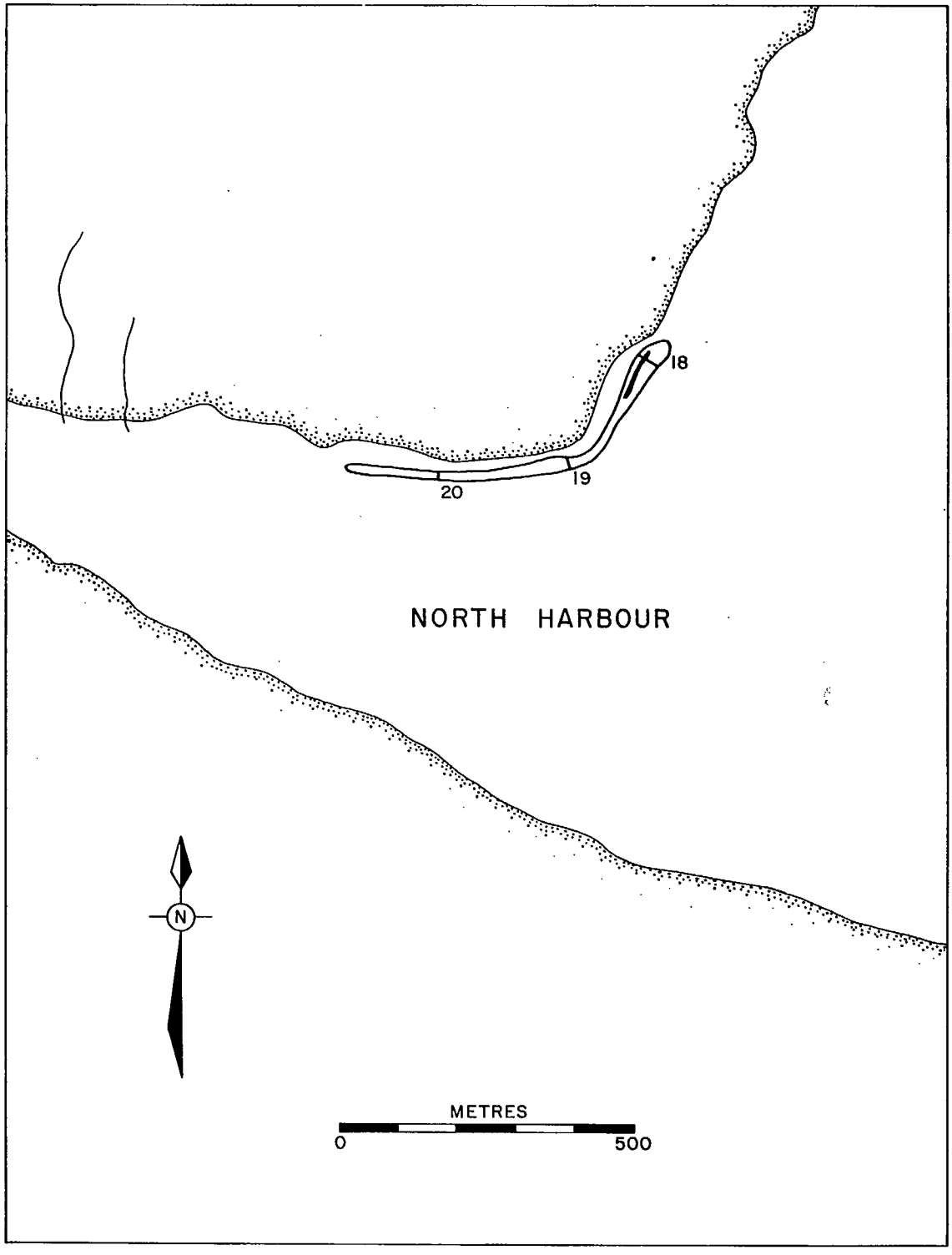


Fig. 20. Herring spawn in North Cove in Forward Inlet, surveyed by divers in 1985, with transect locations shown. Shaded area shows where spawn was deposited on Macrocystis sp.

Fig. 21. Spawn on kelp pond site A in Winter Harbour in Forward Inlet showing location of ponds and lines supporting Macrocystis sp. fronds.

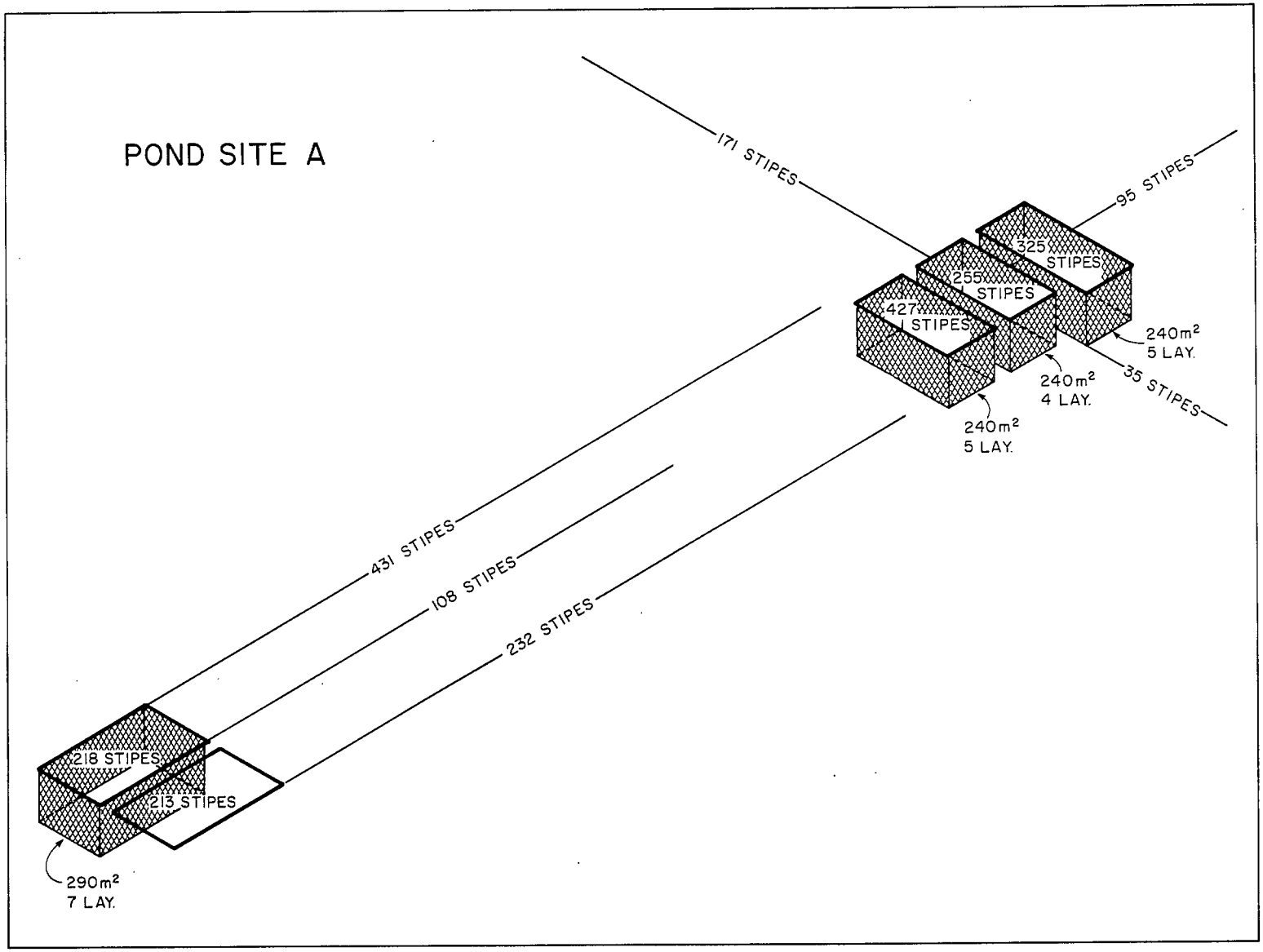

POND SITE A
171 STIPES
95 STIPES
325 STIPES
255 STIPES
427 STIPES
240m²
5 LAY.
240m²
4 LAY.
35 STIPES
240m²
5 LAY.
431 STIPES
108 STIPES
232 STIPES
218 STIPES
213 STIPES
290m²
7 LAY.

Fig. 22. Spawn on kelp pond site B in Winter Harbour in Forward Inlet showing location of ponds and lines supporting Macrocystis sp. fronds and outline of area underneath pond site where spawn was also deposited.

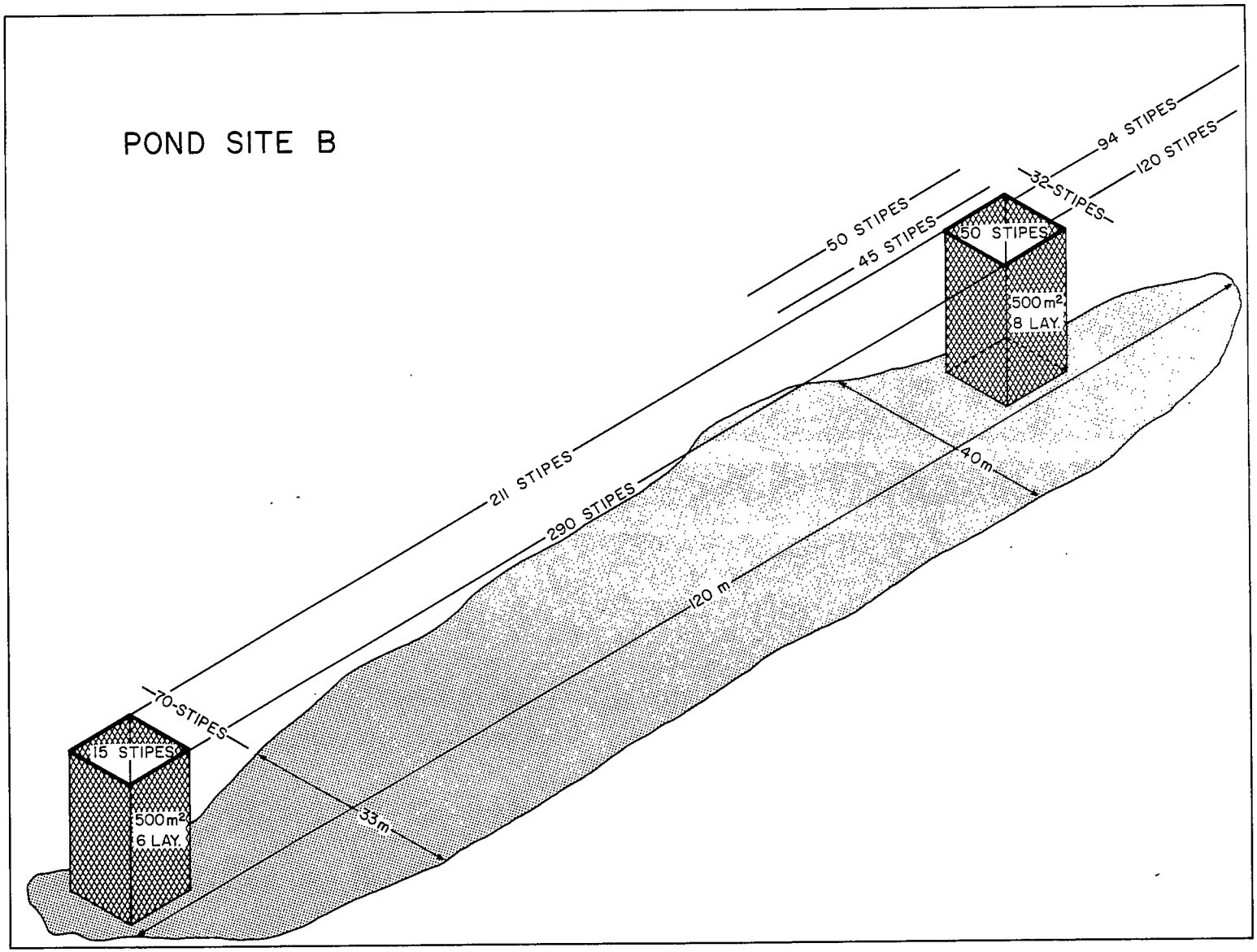

POND SITE B
50 STIPES
45 STIPES
94 STIPES
32 STIPES
120 STIPES
50 STIPES
500 m²
8 LAY.
211 STIPES
290 STIPES
40m
120 m
70 STIPES
15 STIPES
500 m²
6 LAY.
33m

Fig. 23. Comparison of average percent cover, layers of eggs, and egg density (± 2 SE) by depth interval for herring spawns in Barkley Sound in 1985.

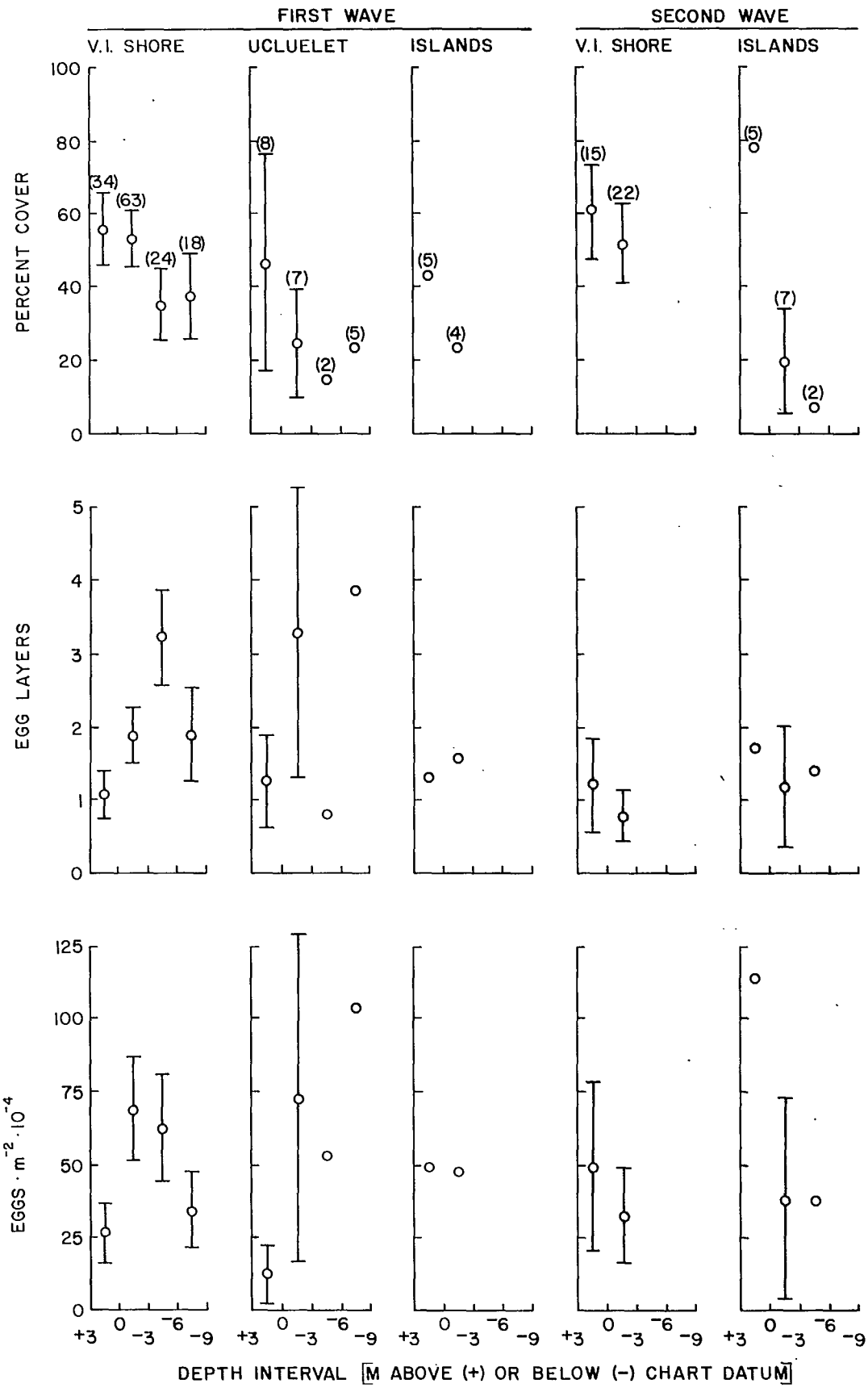

FIRST WAVE
SECOND WAVE
V.I. SHORE
UCLUELET
ISLANDS
V.I. SHORE
ISLANDS
PERCENT COVER
EGG LAYERS
EGGS · m⁻² · 10⁻⁴
(34)
(63)
(24)
(18)
(8)
(7)
(2)
(5)
(5)
(4)
(15)
(22)
(5)
(7)
(2)
+3
0
-3
-6
-9
DEPTH INTERVAL [M ABOVE (+) OR BELOW (-) CHART DATUM]

Fig. 24. Comparison of average percent cover, layers of eggs, and egg density (± 2 SE) by depth interval for herring spawns in Area 24, 25 and 27 in 1985.

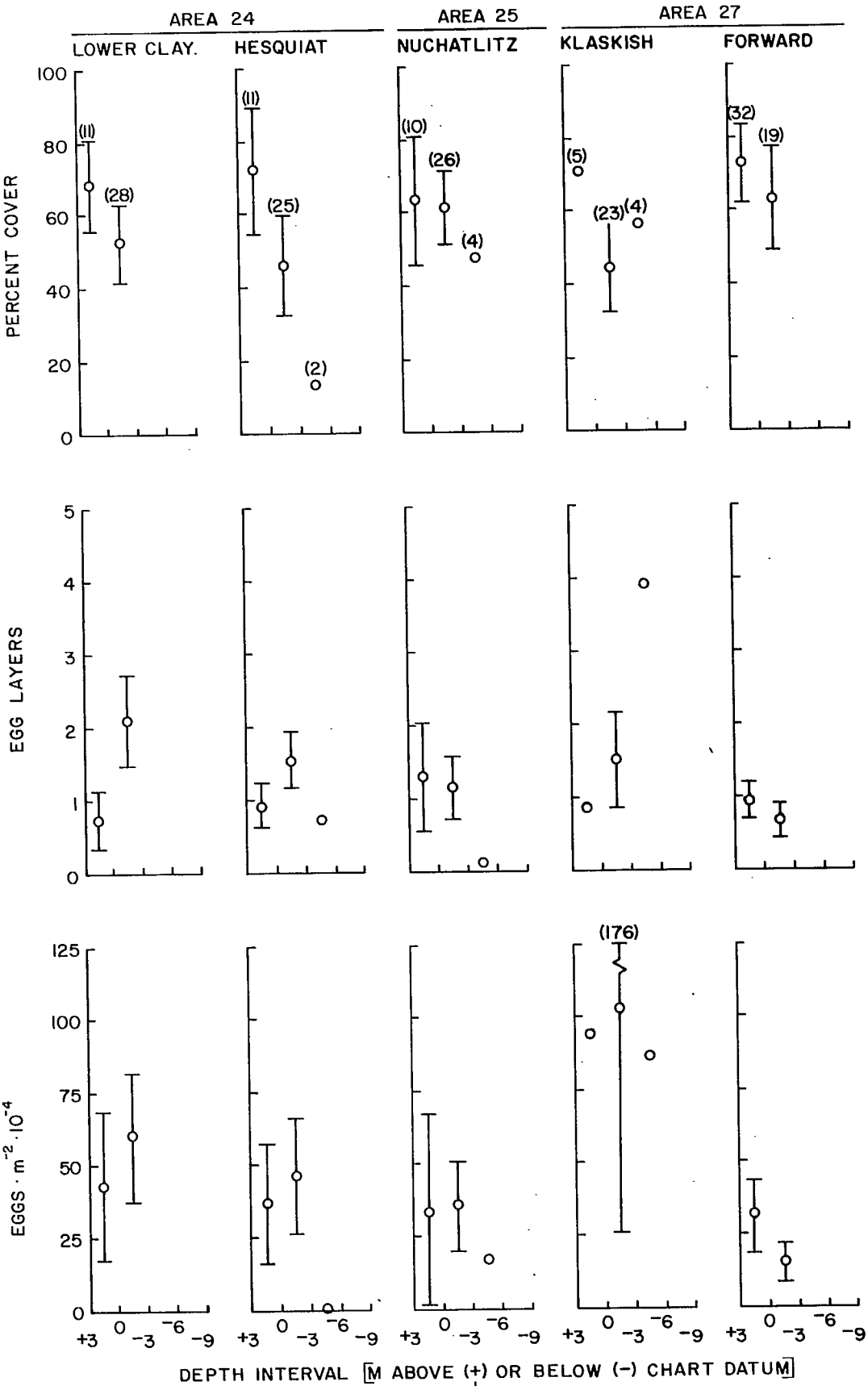

AREA 24
AREA 25
AREA 27
LOWER CLAY.
HESQUIAT
NUCHATLITZ
KLASKISH
FORWARD
PERCENT COVER
EGG LAYERS
EGGS · m⁻² · 10⁻⁴
(11)
(28)
(11)
(25)
(2)
(10)
(26)
(4)
(5)
(23)
(4)
(32)
(19)
(176)
DEPTH INTERVAL [M ABOVE (+) OR BELOW (-) CHART DATUM]

Fig. 25. Distribution of spawn area and eggs by depth for herring spawns in Barkley Sound in 1985.

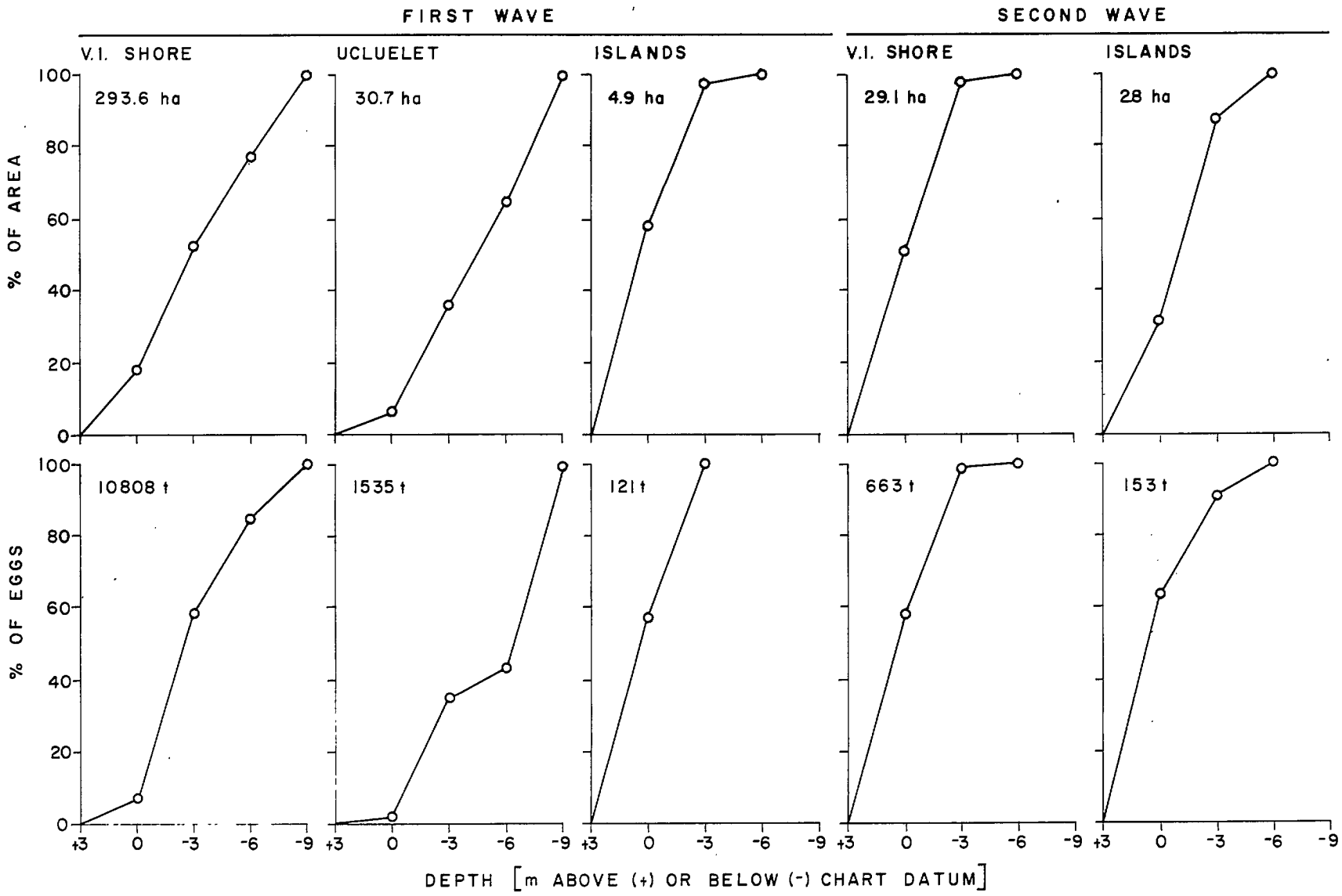

FIRST WAVE
SECOND WAVE
V.I. SHORE
UCLUELET
ISLANDS
V.I. SHORE
ISLANDS
293.6 ha
30.7 ha
4.9 ha
29.1 ha
28 ha
10808 t
1535 t
121 t
663 t
153 t
% OF AREA
% OF EGGS
100
80
60
40
20
0
+3
0
-3
-6
-9
DEPTH [m ABOVE (+) OR BELOW (-) CHART DATUM]

Fig. 26. Distribution of spawn area and eggs by depth for herring spawns in Area 24, 25 and 27 in 1985.

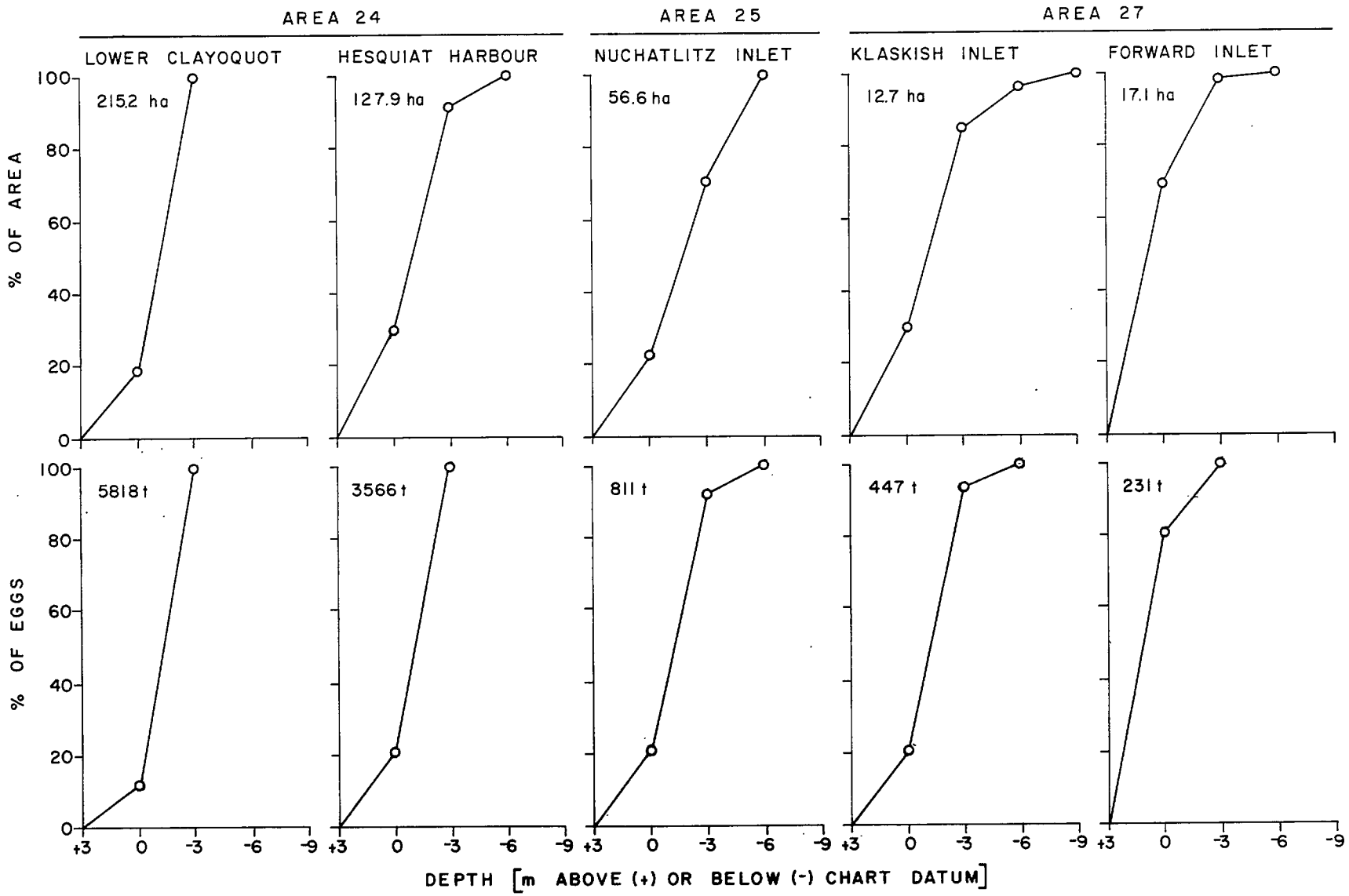
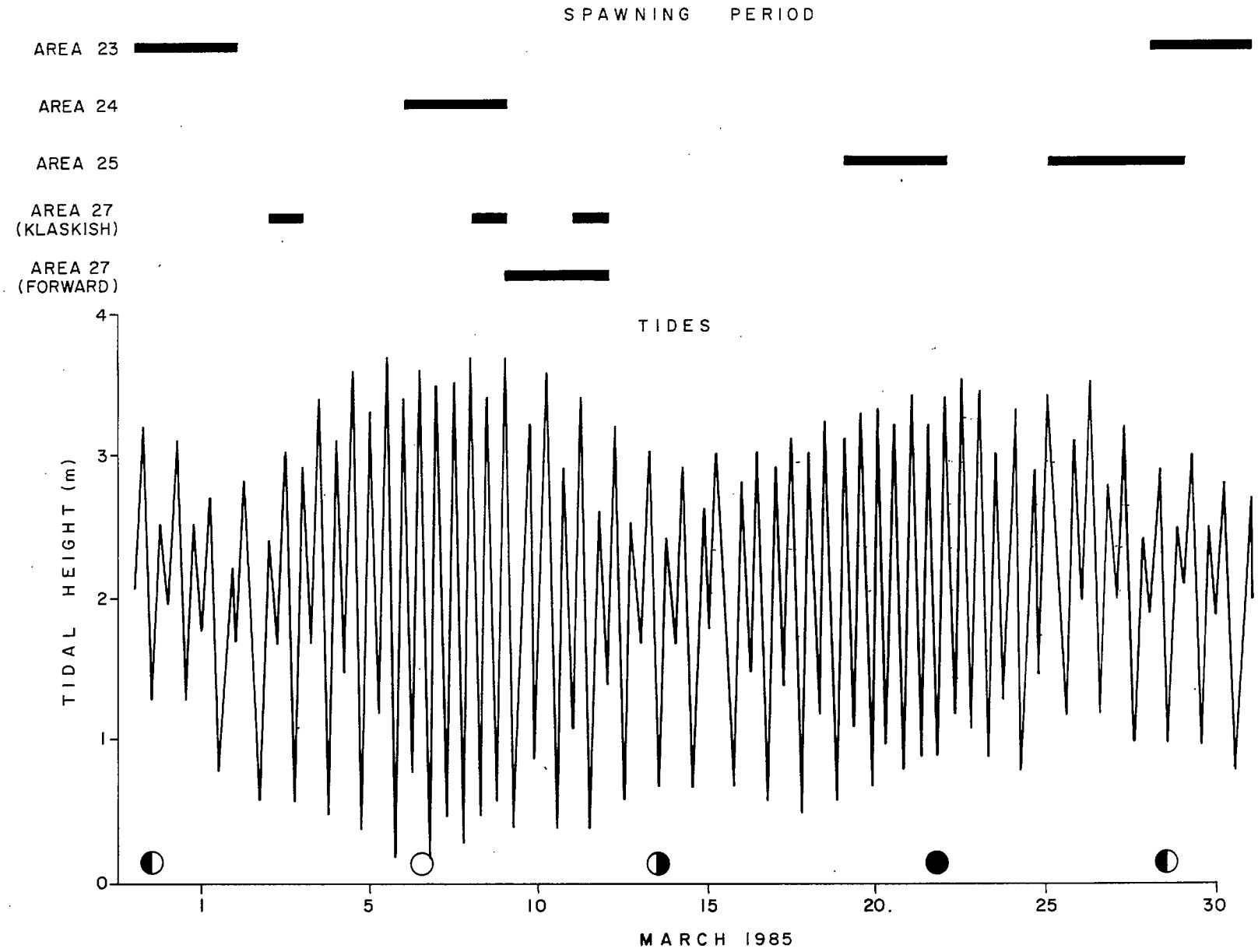

AREA 24
AREA 25
AREA 27
LOWER CLAYOQUOT
HESQUIAT HARBOUR
NUCHATLITZ INLET
KLASKISH INLET
FORWARD INLET
215.2 ha
127.9 ha
56.6 ha
12.7 ha
17.1 ha
5818 t
3566 t
811 t
447 t
231 t
% OF AREA
% OF EGGS
0
20
40
60
80
100
+3
0
-3
-6
-9
DEPTH [m ABOVE (+) OR BELOW (-) CHART DATUM]

Fig. 27. Tidal heights and spawning times for the west coast of Vancouver Island in 1985.


SPAWNING PERIOD
AREA 23
AREA 24
AREA 25
AREA 27 (KLASKISH)
AREA 27 (FORWARD)
TIDES
TIDAL HEIGHT (m)
0
1
2
3
4
1
5
10
15
20.
25
30
MARCH 1985

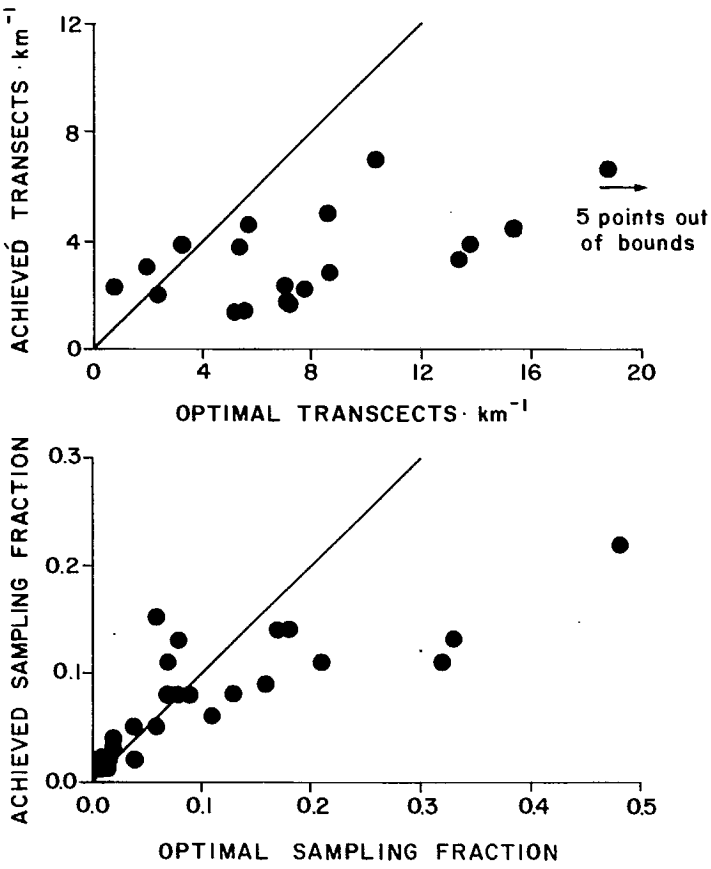


Fig. 28. Plot of optimal sampling design to achieve a SE of 25% of the mean versus achieved sampling density for 1985 diving surveys.