Herring Stock Estimates from Diving Surveys of Spawn for the Lower East Coast of the Queen Charlotte Islands in 1987

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ABSTRACT

Haegele, C. W. and J. F. Schweigert. 1987. Herring stock estimates from diving surveys of spawn for the lower east coast of the Queen Charlotte Islands in 1987. Can. MS Rep. Fish. Aquat. Sci. 1956: 41 p.

Using the results of diving surveys of spawn, we estimated the 1987 adult spawner biomass in the lower east coast of the Queen Charlotte Islands at 17,171 tonnes. Divers surveyed spawns in Poole Inlet (1906 tonnes), Alder Island (42 tonnes), Section Cove (288 tonnes), Huxley Island (4090 tonnes), Saw Reef (2606 tonnes), Sedgwick Bay (307 tonnes), Selwyn Inlet (1719 tonnes), and Conglomerate Point (617 tonnes). Twenty-four percent of this spawn was deposited on *Macrocystis* sp. and the remainder on understory vegetation and bottom substrate. The earliest spawn in Huston Inlet and a later small spawn in Beattie Anchorage were not surveyed by divers and were estimated from surface survey data to have been deposited by 2748 and 358 tonnes, respectively. Approximately 770 tonnes of herring spawned at eleven spawn-on-kelp pond sites and the roe seine fishery harvested 1720 tonnes. Spawn was deposited to 15 m below chart datum and the average inner and outer edge of spawns was 0.2 m and 8.8 m below chart datum. Approximately 90% of the spawn area and 75% of the eggs were below mean low water.

RÉSUMÉ

Haegele, C. W. and J. F. Schweigert. 1987. Herring stock estimates from diving surveys of spawn for the lower east coast of the Queen Charlotte Islands in 1987. Can. MS Rep. Fish. Aquat. Sci. 1956: 41 p.

D'après les résultats de levés des oeufs effectués en plongée autonome, les auteurs ont déterminé que la biomasse de géniteurs adultes sur la basse côte est des îles Reine-Charlotte se situait à 17 171 tonnes en 1987. Des plongeurs ont relevé les concentration de frai dans l'inlet Poole (1 906 tonnes), les eaux de l'île Alder (42 tonnes), l'anse Section (288 tonnes), les eaux de l'île Huxley (4 090 tonnes), le récif Saw (2 606 tonnes), la baie Sedgwick (307 tonnes), l'inlet Selwyn (1 719 tonnes) et à la pointe Conglomerate (617 tonnes). Ils ont noté que 24 % du frai avait été déposé sur <u>Macrocystis</u> sp. et le reste sur l'étage inférieur de végétation et le substrat. La première fraie dans l'inlet Huston et une petite fraie tardive au mouillage Beattie n'ont pas été étudiées par les plongeurs; d'après une estimation effectuée à partir de données recueillies au cours de levés de surface, le nombre de géniteurs a été fixé à 2 748 et 358 tonnes respectivement. Environ 770 tonnes de harengs ont frayé dans 11 enclos d'exploitation de la rogue sur varech tandis que 1 720 tonnes ont été capturées au cours de la pêche du hareng rogué à la senne. Les oeufs ont été déposés jusqu'à 15 m au-dessous du zéro des cartes et la limite intérieure et extérieure du frai se situait à 0,2 m et 8,8 m respectivement au-dessous du zéro des cartes. Environ 90 % de la superficie de la frayère et 75 % des oeufs se situaient au-dessous du niveau de la basse mer moyenne.

INTRODUCTION

Herring stocks in the Queen Charlotte Islands have been declining slowly since 1981 apparently due to the ageing of the very strong 1977 year class (Haist et al. 1987). There has been considerable uncertainty in escapement estimates for this region because a significant portion of the spawn is deposited on the giant kelp, *Macrocystis* sp., which is difficult to survey and assess. It was recommended at the 1986 Herring Stock Assessment Review Committee Meeting that the 1987 spawn in the lower east coast of the Queen Charlotte Islands (Fig. 1) be surveyed by divers so that adult spawner biomass could be directly estimated, independently from stock assessment model estimates, which were thought to be low. A diving survey was conducted between April 2 and 22, 1987 and is the subject of this report.

METHODS

Estimates of egg deposition were obtained from diving surveys, except in Huston Inlet and in Beattie Anchorage, where estimates were derived from traditional surface surveys. In the surface survey, visual observations were made from a boat, frequently a viewing box was used to increase the visibility of the bottom. 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 observed length and an adjusted width was used to calculate area. Egg density was estimated from egg layer observations. The equations and parameter estimates for these adjustments are similar to those in Haist and Schweigert (1987):

(1) $Width_{adj} = 74.7273 + 0.8164 * Width_{obs}$

(2) $Eggs * m^{-2} = 183251.6 + 76738.5 * Lay_{av}$

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 on vegetation were also estimated by divers for each quadrat. Samples were weighed and weighed subsamples preserved in Gilson's fluid for egg counts. Eggs on the bottom substrate were estimated from diver estimates of layers of eggs and percent of bottom covered by vegetation (Haegele et al. 1979) and added to eggs on vegetation.

Transects were established at nearly equal intervals along the length of the spawn 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 interval were calculated for each spawn and transect means were weighted by transect lengths (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 was determined by exploratory dives. This information was plotted on maps of marine vegetation at a scale of 1:6000 (e.g. Haegele and Hamey 1981), except for Huxley Island, Sedgwick Bay and Selwyn Inlet where marine charts enlarged to a scale of 1:10,000 were used, the boundaries of the spawn contoured, and the area of the spawn measured.

The egg deposition on Macrocystis sp. was estimated using a procedure developed by Haegele and Schweigert (1985). 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 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 counted. The occurrence of Macrocystis sp. was plotted on the maps and the area of Macrocystis sp. beds was 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 (1985) determined that this was the best estimator. However, estimates using plants and both mature and immature fronds were also calculated.

Adult spawner biomass (tonnes) was estimated as the product of egg estimates and 0.00000001, which reflects an assumed 200 eggs per gm female weight (Hay 1985) and a 1:1 sex ratio.

RESULTS

Herring spawned between March 7 and April 22 in the lower east coast of the Queen Charlotte Islands in 1987. The earliest spawn in Huston Inlet (March 7 to 17) had hatched by the beginning of the diving survey and was only surveyed from the surface. A small spawn in Beattie Anchorage (April 16 to 18) was also not surveyed by divers. The remaining nine spawns were surveyed by divers on 103 transects (Table 1; Appendix table 1). Spawn on understory vegetation occurred on 94 transects and spawn on Macrocystis sp. was observed on 67 transects. There was some concern during the survey that harvested Macrocystis sp. plants were not representative of plants along transects because larger plants were difficult to untangle. However, a comparison of fronds per plant for plants observed by divers and harvested plants shows the opposite to be true (Table 2). Harvested plants always had more fronds, although the difference was not significant for individual spawns (Student t-test). A number of immature plants, i.e. plants with no mature fronds, were observed along transects, but, since no immature plants were harvested, these plants were not included in the egg estimates (Appendix table 1). The immature plants generally had only a few scattered eggs and their exclusion will only slightly bias the egg estimates. Macrocystis sp. plants were up to 15 m tall, had up to 74 mature fronds per plant, as many as 18 layers of eggs, and the heaviest plant (including the weight of 76 million eggs) weighed 269.5 kg, (Appendix table 2). Average plant height was 6.8 m and Macrocystis sp. generally had more layers of eggs than the understory vegetation (Table 1).

Spawn was deposited to 15 m below chart datum and the average inner and outer edge of spawns was 0.2 m and 8.8 m below chart datum. Percent cover of understory vegetation, egg layers, and hence egg density declined with depth (Fig. 2). Therefore, while approximately 90% of the understory spawn area was below mean low water, only 75% of the eggs on understory vegetation and bottom substrate were below mean low water (Fig. 3). Sea grasses (Zostera marina) was the dominant understory vegetation in shallow water and, in deeper water, flat and stalked kelps (mostly Agarum sp., Laminaria sp., and Pterygophora sp.) were the dominant understory vegetation (Fig. 4). Filamentous and foliose red algae occurred throughout the depth range while rockweed occurred mostly in the intertidal zone.

It was estimated that 2727 tonnes spawned on Macrocystis sp. and 8848 tonnes on understory vegetation and bottom substrate in the spawns surveyed by divers (Tables 3 and 4). A further 3106 tonnes were estimated for spawns surveyed only from the surface (Table 5). The roe seine fishery harvested 1720 tonnes and 11 spawn-on-kelp licences utilized approximately 770 tonnes, for a total adult spawner biomass of 17,171 tonnes. It has been estimated that open spawn-on-kelp ponds require between 29 and 35 tonnes of herring to produce the 7.3 tonnes of product permitted by the license (Shields et al. 1985). Furthermore, between 39 and 42 tonnes of herring have been estimated to spawn on unharvested kelp and webbing per pond (Haegele and Schweigert 1987). Closed ponds require between 46 and 64 tonnes of herring (Shields et al. 1985). Since both open and closed ponds were used to obtain spawn-on-kelp product in the Queen Charlotte Islands in 1987, we used 70 tonnes of herring per license to estimate spawners that deposited eggs at spawn-on-kelp pond sites. Individual spawns are described, south to north, below.

HUSTON INLET

A surface survey reported 16 adjacent patches of spawn in Huston Inlet. This 8.425 km long spawn was estimated to have been deposited by 2748 tonnes and the area of spawn was estimated at 80.79 ha.

POOLE INLET

Spawn in Poole Inlet (Fig. 5) was 10.129 km long. *Macrocystis* sp. was the only spawn substrate along 1.257 km, there was no spawn on *Macrocystis* sp. along 3.030 km, and for the remaining 5.842 km there was spawn on both *Macrocystis* sp. and understory vegetation and bottom substrate. Average transect length for spawn on understory vegetation was 88 m and average transect slope was 0.133 (a rise of 13.3 m every 100 m). The average inner and outer edge of spawn was 0.4 m and 9.1 m below chart datum. Average egg layers were 2.04 on *Macrocystis* sp. and 0.67 on understory vegetation. Egg density on understory vegetation and bottom substrate was 201,038 eggs per sq. m and it was estimated that 1452 tonnes spawned on understory vegetation and bottom substrate. *Macrocystis* sp. density was 6708 mature fronds per ha and 454 tonnes were estimated to have spawned on *Macrocystis* sp. Total spawn area was 76.854 ha and total spawner biomass was 1906 tonnes.

ALDER ISLAND

The small early spawn on the west shore of Alder Island (Fig. 6) was 163 m long and spawn was on both *Macrocystis* sp. and understory vegetation and bottom substrate. Average transect length for spawn on understory vegetation was 48 m and average transect slope was 0.030. The average inner and outer edge of spawn was 3.6 m and 5.8 m below chart datum. Average egg layers were 1.13 on *Macrocystis* sp. and 1.34 on understory vegetation. Egg density on understory vegetation and bottom substrate was 240,004 eggs per sq. m and it was estimated that 20 tonnes spawned on understory vegetation and bottom substrate. *Macrocystis* sp. density was 22,667 mature fronds per ha and 22 tonnes were estimated to have spawned on *Macrocystis* sp. Total spawn area was 0.816 ha and total spawner biomass was 42 tonnes.

SECTION COVE

The earlier spawn on the west side of Section Cove (Fig. 6) was 923 m long. There was spawn only on understory vegetation and bottom substrate along 429 m, and for the remaining 494 m there was spawn on both *Macrocystis* sp. and understory vegetation and bottom substrate. Average transect length for spawn on understory vegetation was 48 m and average transect slope was 0.125. The average inner and outer edge of spawn was 1.6 m above and 5.4 m below chart datum. Average egg layers were 1.16 on *Macrocystis* sp. and 1.45 on understory vegetation. Egg density on understory vegetation and bottom substrate was 652,816 eggs per sq. m and it was estimated that 254 tonnes spawned on understory vegetation and bottom substrate. *Macrocystis* sp. density was 18,542 mature fronds per ha and 34 tonnes were estimated to have spawned on *Macrocystis* sp. Total spawn area was 4.092 ha and total spawner biomass was 288 tonnes.

WEST HUXLEY ISLAND

Spawn on the west shore of Huxley Island (Fig. 7) was 1.224 km long. There was spawn only on bottom understory vegetation and bottom substrate along 446 m, and for the remaining 778 m there was spawn on both Macrocystis sp. and understory vegetation and bottom substrate. Average transect length for spawn on understory vegetation was 34 m and average transect slope was 0.185. The average inner and outer edge of spawn was 1.0 m and 11.2 m below chart datum. Average egg layers were 4.50 on Macrocystis sp. and 1.27 on understory vegetation. Egg density on understory vegetation and bottom substrate was 388,090 eggs per sq. m and it was estimated that 101 tonnes spawned on understory vegetation and bottom substrate. Macrocystis sp. density was 4778 mature fronds per ha and 65 tonnes were estimated to have spawned on Macrocystis sp. Total spawn area was 5.332 ha and total spawner biomass was 166 tonnes.

EAST HUXLEY ISLAND

Spawn on the east shore of Huxley Island (Fig. 7) was 6.042 km long. There was spawn only on understory vegetation and bottom substrate along 1.773 km, and for the remaining 4.265 km there was spawn on both Macrocystis sp. and understory vegetation and bottom substrate. Average transect length for spawn on understory vegetation was 100 m and average transect slope was 0.077. The average inner and outer edge of spawn was 1.6 m and 9.4 m below chart datum. Average egg layers were 6.70 on Macrocystis sp. and 1.36 on understory vegetation. Egg density on understory vegetation and bottom substrate was 565,553 eggs per sq. m and it was estimated that 2934 tonnes spawned on understory vegetation and bottom substrate. Macrocystis sp. density was 4467 mature fronds per ha and 990 tonnes were estimated to have spawned on Macrocystis sp. Total spawn area was 54.246 ha and total spawner biomass was 3924 tonnes.

SAW REEF

Spawn extended from Saw Reef to Section Cove and included some spawn on the south shore of Alder Island (Fig. 8) for a distance of 5.995 km. Macrocystis sp. was the only spawn substrate along 1.525 km, there was no spawn on Macrocystis sp. along 3.017 km, and for the remaining 2.997 km there was spawn on both Macrocystis sp. and understory vegetation and bottom substrate. Average transect length for spawn on understory vegetation was 90 m and average transect slope was 0.100. The average inner and outer edge of spawn was 0.6 m and 7.2 m below chart datum. Average egg layers were 2.43 on Macrocystis sp. and 0.71 on understory vegetation. Egg density on understory vegetation and bottom substrate was 426,804 eggs per sq. m and it was estimated that 1856 tonnes spawned on understory vegetation and bottom substrate. *Macrocystis* sp. density was 7246 mature fronds per ha and 750 tonnes were estimated to have spawned on *Macrocystis* sp. Total spawn area was 46.201 ha and total spawner biomass was 2606 tonnes.

SEDGWICK BAY

Spawn in Sedgwick Bay (Fig. 9) was 3.219 km long. There was spawn only on understory vegetation and bottom substrate along 1.419 km, and for the remaining 1.800 km there was spawn on both *Macrocystis* sp. and understory vegetation and bottom substrate. Average transect length for spawn on understory vegetation was 32 m and average transect slope was 0.332. The average inner and outer edge of spawn was 0.2 m and 10.1 m below chart datum. Average egg layers were 0.94 on *Macrocystis* sp. and 0.64 on understory vegetation. Egg density on understory vegetation and bottom substrate was 214,384 eggs per sq. m and it was estimated that 225 tonnes spawned on understory vegetation and bottom substrate. *Macrocystis* sp. density was 16,500 mature fronds per ha and 82 tonnes were estimated to have spawned on *Macrocystis* sp. Total spawn area was 10.509 ha and total spawner biomass was 307 tonnes.

SELWYN INLET

Spawn in Selwyn Inlet (Fig. 10) was 8.651 km long. There was spawn only on understory vegetation and bottom substrate along 5.995 km, and for the remaining 2.656 km there was spawn on both *Macrocystis* sp. and understory vegetation and bottom substrate. Average transect length for spawn on understory vegetation was 50 m and average transect slope was 0.340. The average inner and outer edge of spawn was 1.2 m above and 14.1 m below chart datum. Average egg layers were 1.82 on *Macrocystis* sp. and 1.05 on understory vegetation. Egg density on understory vegetation and bottom substrate was 364,694 eggs per sq. m and it was estimated that 1622 tonnes spawned on understory vegetation and bottom substrate. *Macrocystis* sp. density was 5105 mature fronds per ha and 97 tonnes were estimated to have spawned on *Macrocystis* sp. Total spawn area was 44.486 ha and total spawner biomass was 1719 tonnes.

CONGLOMERATE POINT

Spawn at Conglomerate Point (Fig. 11) was 5.046 km long. *Macrocystis* sp. was the only spawn substrate along 716 m, there was no spawn on *Macrocystis* sp. along 1.948 km, and for the remaining 2.382 km there was spawn on both *Macrocystis* sp. and understory vegetation and bottom substrate.

Average transect length for spawn on understory vegetation was 57 m and average transect slope was 0.093. The average inner and outer edge of spawn was 0.8 m above and 3.3 m below chart datum. Average egg layers were 1.26 on Macrocystis sp. and 0.88 on understory vegetation. Egg density on understory vegetation and bottom substrate was 163,655 eggs per sq. m and it was estimated that 384 tonnes spawned on understory vegetation and bottom substrate. Macrocystis sp. density was 8085 mature fronds per ha and 233 tonnes were estimated to have spawned on Macrocystis sp. Total spawn area was 28.608 ha and total spawner biomass was 617 tonnes.

BEATTIE ANCHORAGE

The surface survey reported on 1.220 km of spawn in 3 patches in Beattie Anchorage. This spawn was estimated to have been deposited by 358 tonnes at an average egg density of 358,000 eggs per sq. m.

DISCUSSION

Diving surveys of spawn have been found to provide more accurate estimates of egg deposition than the traditional surface surveys. This is particularely true in locations with gradually sloping beaches and wide spawns, where the spawn is deposited mostly below the intertidal zone and for all deep spawns, regardless of beach slope. Both of these situations appear to prevail in the Queen Charlotte Islands. Furthermore, in the Queen Charlotte Islands, a significant portion of the spawn is deposited on Macrocystis sp., which is virtually impossible to assess from the surface. In 1987, approximately 24% of the spawn in the study area was deposited on Macrocystis sp., with the remainder deposited on understory vegetation and bottom substrate. Estimates of spawn on Macrocystis sp. were approximately 1.6 higher when plants rather than mature fronds were used as the estimator of kelp density. However, the 95% confidence interval for spawner biomass estimates were generally lower at 26% of the mean, using mature fronds, compared to 38% of the mean for plants. The 95% confidence interval for estimates of eggs on understory vegetation and bottom substrate was within 30% of the mean for all data, with a range of 48% to 73% for the major individual spawns. The high variance in mean egg density estimates can be mostly attributed to insufficient transects since optimal transects per km (after Schweigert et al. 1985) was never achieved (Table 6). Optimal samples per transects were achieved for 4 of the 9 spawns. It would require the sampling of more transects to reduce the variance on the spawn deposition estimates for individual spawns. This appears not to be possible given the time and logistic constraints of the survey. Overall, the survey results are sufficiently precise to provide acceptable estimates of spawner biomass for management purposes.

The cut-off level below which no biological catch is recommended is 13,100 tonnes for the lower east coast of the Queen Charlotte Islands, excluding Cumshewa Inlet (Haist and Schweigert 1987). Our spawn survey estimates, including roe fishery catch and spawn-on-kelp pond utilization, was 16,957 tonnes for this smaller area. An adult spawner biomass of 15,210 tonnes was forecast, hence a biological catch of 2210 was recommended and 2490 tonnes utilized, composed of the roe fishery catch of 1720 tonnes and the spawn-on-kelp utilization of 770 tonnes. In retrospect, based on the 20% harvest rate used for British Columbia herring, 3919 tonnes could have been utilized in the lower east coast of the Queen Charlotte Islands in 1987. However, herring stocks appear to be low enough in the Queen Charlotte Islands that caution in setting catch levels is advisable. Furthermore, the 95% confidence limits of our estimates are approximately 30% of the mean, hence the forecast biomass falls well within our confidence limits and the catch should be considered appropriate. The utility of the spawn diving surveys is that biomass can be directly estimated and used to corroberate, or refute, stock assessment model estimates. This survey agreed very well with the stock forecasts in Haist and Schweigert (1987).

As indicated above, there are constraints on the level of sampling that can be undertaken in any given year to achieve the desired precision in biomass estimates. The collection and processing of samples including egg counts is an expensive and time consuming procedure to undertake annually. For spawn on understory vegetation we have developed models to predict egg density from simple visual estimates by divers of egg layers and vegetation density (Schweigert et al. MS). Unfortunately, spawn on Macrocystis sp. does not lend itself to any simple visual assessment procedure. The development of a robust, inexpensive survey and sampling regimen for this important spawning substrate for B.C.'s northern herring remains an important challenge which will require further analysis of existing data and perhaps further sampling.

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Table 1. Summary of survey information for spawns sampled by divers in the Queen Charlotte Islands in 1987.

	All spawn		Spawn on understory vegetation					Spawn on <u>Macrocystis</u> sp.					
Location	No. of tran.	Length (m)	No. of tran.	No. of quad.	Length (m)	Av. tran. len. (m)	Av. egg layers	No. of tran.	Plants samp.	Length (m)	Av. tran. len. (m)	Av. plt. ht. (m)	Av. egg layers
Poole Inlet	25	10129	20	94	8872	88	0.67	18	25	7099	35	7.0	2.04
Alder I.	2	163	2	6	163	48	1.34	2	2	163	8	10.5	1.13
Section Cove	4	923	4	13	923	48	1.45	2	4	494	24	9.0	1.16
Huxley I. - W	4	1224	4	14	1224	34	1.27	2	3	778	68	5.7	4.50
Huxley I. - E	16	6042	16	85	6042	100	1.36	11	14	4269	68	7.0	6.70
Saw Reef	19	7539	16	86	6014	90	0.71	11	9	4522	24	8.6	2.43
Sedgwick Bay	8	3219	8	31	3219	32	0.64	6	6	1800	18	4.3	0.94
Selwyn Inlet	13	8651	13	65	8651	50	1.05	8	6	2656	12	4.2	1.82
Conglomerate Pt.	12	5046	11	54	4330	56	0.88	7	10	3098	42	6.3	1.26
All locations	103	42936	94	448	39438	72	0.94	67	79	24879	35	6.8	2.74

Table 2. Comparison of fronds per *Macrocystis* sp. plant for diver counts along transect and harvested sample plants. Results of a student T-test (count = sample) are given (** = significantly different at the 1% level, * = significantly different at 5% level). (MF = mature fronds, IF = immature fronds, TF = total fronds.)

	Count av. (95% CI)				Sample av. (95% CI)				T-test Probability		
Location	n	MF	IF	TF	n	MF	IF	TF	MF	IF	TF
Poole Inlet	80	9.6 (7.3-11.8)	2.5 (1.8-3.1)	12.0 (9.5-14.5)	25	13.1 (9.0-17.2)	4.2 (3.0-5.3)	17.3 (12.8-21.8)	0.13	0.01**	0.04*
Alder I.	3	-	-	-	2	-	-	-	-	-	-
Section Cove	16	11.1 (6.4-15.9)	1.9 (1.1-2.7)	13.1 (7.9-18.3)	4	12.8 (7.7-17.8)	3.3 (-0.9-7.4)	16.0 (12.6-19.4)	0.56	0.41	0.29
Huxley I. - W	16	8.1 (3.0-13.2)	1.1 (0.6-1.7)	9.2 (4.3-14.1)	3	13.3 (-10.3-36.9)	8.3 (-1.7-18.4)	21.7 (-11.9-55.2)	0.47	0.09	0.26
Huxley I. - E	64	10.5 (8.3-12.7)	2.5 (2.0-3.0)	13.0 (10.5-15.4)	14	16.6 (10.1-23.2)	3.5 (2.2-4.8)	20.1 (12.7-27.6)	0.07	0.16	0.07
Saw Reef	41	9.0 (7.5-10.6)	2.9 (1.9-3.9)	11.9 (9.9-13.0)	9	15.8 (8.6-23.0)	3.1 (1.7-4.6)	18.9 (11.7-26.1)	0.07	0.29	0.06
Sedgwick Bay	35	10.4 (7.8-12.0)	1.9 (1.3-2.5)	12.3 (9.4-15.2)	6	13.0 (4.3-21.7)	4.2 (0.8-7.5)	17.2 (9.4-24.9)	0.49	0.15	0.18
Selwyn In.	15	6.5 (3.5-9.4)	0.7 (0.3-1.1)	7.1 (4.1-10.1)	6	10.0 (3.3-16.7)	3.5 (0.6-6.4)	13.5 (4.8-22.2)	0.27	0.06	0.13
Conglomerate	46	10.4 (8.0-12.7)	1.9 (1.3-2.5)	12.3 (9.7-14.9)	10	13.1 (8.2-18.0)	4.9 (2.8-7.0)	18.0 (12.6-23.5)	0.29	0.01**	0.06
All locations	316	9.9 (8.9-10.9)	2.2 (2.0-2.5)	12.1 (11.0-13.2)	79	14.6 (12.1-17.1)	4.1 (3.5-4.7)	18.7 (15.9-21.4)	0.00**	0.00**	0.00**

Table 3. Estimates of egg deposition on _Macrocystis_ sp. for spawns surveyed by divers in the Queen Charlote Islands in 1987. Confidence intervals (95%) are in brackets. (MP = mature plants, TF = total fronds, MF = mature fronds.)

Location	Area (ha)	Density (per ha)			Thousands of eggs per			Tonnes estimated from		
		MP	TF	MF	MP	TF	MF	MP	TF	MF
Poole Inlet	21.698	716	8435	6708	4387 (1642-7131)	256 (112-400)	312 (162-463)	681 (255-1108)	469 (205-732)	455 (236-673)
Alder I.	0.178	1000	26333	22667	9920 (-)	447 (-)	546 (-)	18 (-)	21 (-)	22 (-)
Section Cove	0.731	1667	21771	18542	3798 (-)	226 (-)	248 (-)	46 (-)	36 (-)	34 (-)
Huxley I. - W	2.993	593	5444	4778	8645 (-)	286 (-)	457 (-)	153 (-)	47 (-)	65 (-)
Huxley I. - E	25.201	427	5533	4467	18253 (4568-31937)	707 (389-1024)	879 (508-1249)	1964 (492-3437)	986 (542-1428)	990 (572-1406)
Saw Reef	10.571	801	9551	7246	11939 (2337-21540)	699 (243-1154)	979 (263-1696)	1011 (198-1824)	706 (245-1165)	750 (201-1299)
Sedgwick Bay	3.862	1591	19545	16500	1572 (0-3470)	81 (23-138)	128 (27-230)	97 (0-213)	61 (18-104)	82 (17-146)
Selwyn In.	3.900	789	5632	5105	3880 (1400-6361)	373 (88-658)	486 (76-895)	119 (43-196)	82 (19-145)	97 (15-178)
Conglomerate Pt.	11.498	780	9593	8085	3581 (763-6399)	177 (42-312)	250 (48-453)	321 (68-574)	196 (47-344)	233 (45-421)
All locations	80.632	698	8396	6856	7622 (4757-10487)	376 (278-474)	488 (362-615)	4290 (2677-5902)	2548 (1885-3212)	2699 (2000-3397)

Table 4. Estimates of spawner biomass for spawns surveyed by divers in the Queen Charlotte Islands in 1987. Confidence intervals (95%) are in brackets.

Location	Egg substrate	Area (ha)	Thousands of eggs per sq. m	Tonnes of spawners
Poole Inlet	Understory	72.719	201 (67-335)	1452 (483-2421)
	Macrocystis	21.698	-	454 (236-673)
	Both	76.854	-	1906
Alder I.	Understory	0.816	240 (0-535)	20 (0-44)
	Macrocystis	0.178	-	22 (-)
	Both	0.816	-	42
Section Cove	Understory	3.893	653 (0-1486)	254 (0-579)
	Macrocystis	0.731	-	34 (-)
	Both	4.092	-	288
Huxley I. - W	Understory	2.606	388 (139-637)	101 (36-166)
	Macrocystis	2.993	-	65 (-)
	Both	5.322	-	166
Huxley I. - E	Understory	51.892	566 (287-844)	2934 (1489-4381)
	Macrocystis	25.201	-	990 (572-1406)
	Both	54.246	-	3924
Saw Reef	Understory	43.489	427 (106-748)	1856 (460-3253)
	Macrocystis	10.571	-	750 (201-1299)
	Both	46.201	-	2606
Sedgwick Bay	Understory	10.509	214 (101-327)	225 (107-344)
	Macrocystis	3.862	-	82 (17-146)
	Both	10.509	-	307
Selwyn In.	Understory	44.486	365 (188-541)	1622 (836-2409)
	Macrocystis	3.900	-	97 (15-178)
	Both	44.486	-	1719
Conglomerate Pt.	Understory	23.491	164 (44-283)	384 (103-665)
	Macrocystis	11.498	-	233 (45-421)
	Both	28.608	-	617
All locations	Understory	253.901	365 (255-475)	9277 (6486-12068)
	Macrocystis	80.632	-	2699 (2000-3397)
	Both	271.134	-	11976
All locations (sum)	Understory	253.901	-	8848
	Macrocystis	80.632	-	2727
	Both	271.134	-	11575

Table 5. Estimates of spawner biomass for 1987 Queen Charlotte Island spawns not surveyed by divers in 1987. Estimates are based on surface survey data.

Locality	No. of patches	Length (m)	Av. width (m)		Area (ha)	Av. egg layers	Thousands of eggs per sq. m	Tonnes
			obs.	adj.				
Huston In.	16	8425	26	96	80.79	2.0	340	2748
Beattie An.	3	1220	9	82	10.00	2.3	358	358
Sum		9645			90.79			3106

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 1987 diving surveys of herring spawn in the Queen Charlotte Islands.

Location	Samples per transect	Av. transect length (m)	Achieved sampling fraction	Optimal sampling fraction	Achieved transects per km	Optimal transects per km
Poole Inlet	5.2	96.3	0.045	0.037	2.029	5.145
Alder I.	3.0	47.5	0.063	0.020	12.270	49.409
Section Cove	4.3	58.3	0.074	0.071	3.250	24.052
Huxley I. - W	3.5	33.5	0.104	0.376	3.268	6.329
Huxley I. - E	5.3	99.9	0.053	0.070	2.648	4.105
Saw Reef	5.4	89.5	0.060	0.102	2.660	7.521
Sedgwick Bay	3.9	32.1	0.121	0.214	2.485	4.020
Selwyn Inlet	5.0	50.2	0.100	0.117	1.503	2.148
Conglomerate Pt.	4.9	56.5	0.087	0.086	2.540	6.413

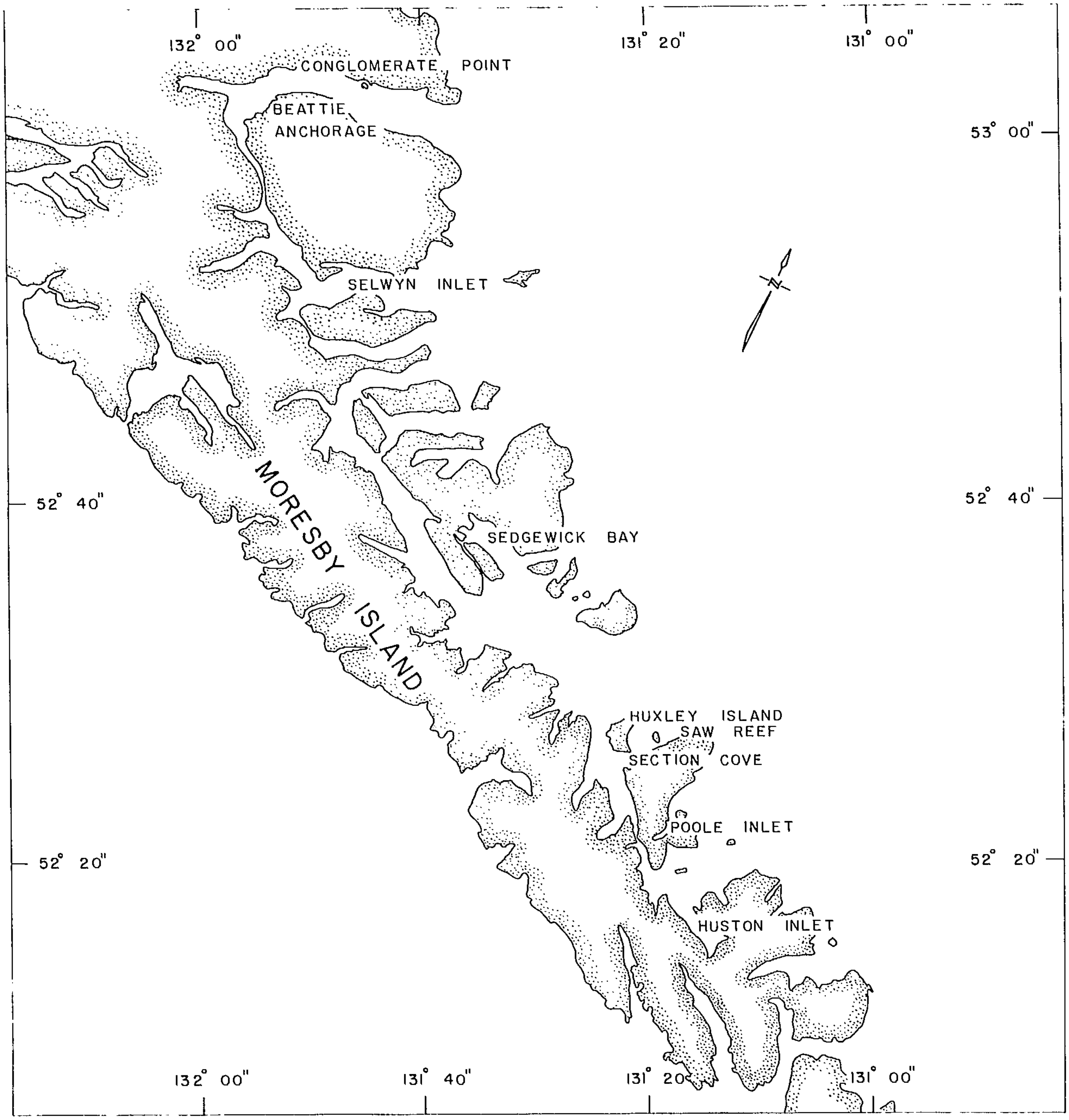

Fig. 1. Map of the lower east coast of the Queen Charlotte Islands study area with 1987 herring spawn sites identified.

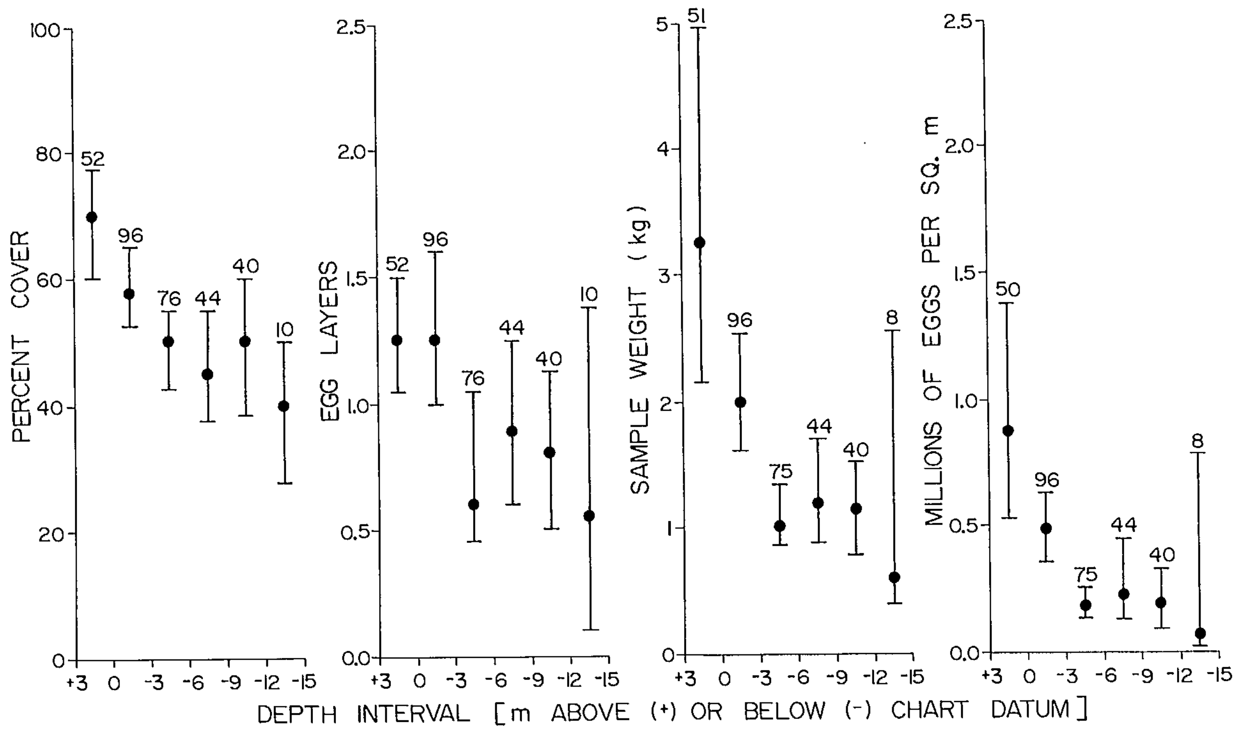

Fig. 2. Percent cover of understory vegetation, layers of eggs, sample weight and egg density (Wilcoxon median and 95% C.I.) by 3 m depth intervals for spawns surveyed by divers.

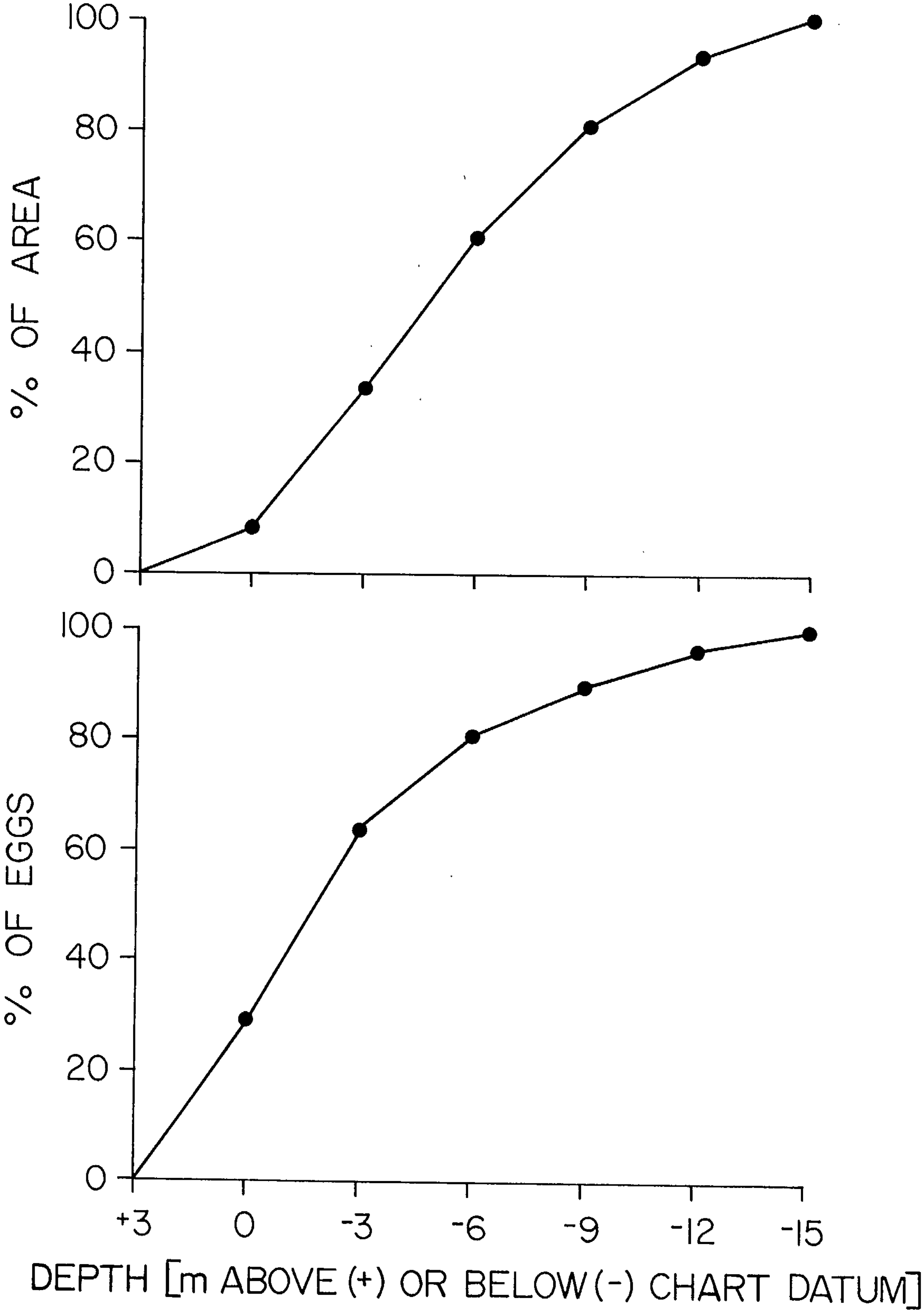

Fig. 3. Distribution of understory vegetation spawn area and eggs for spawns surveyed by divers.

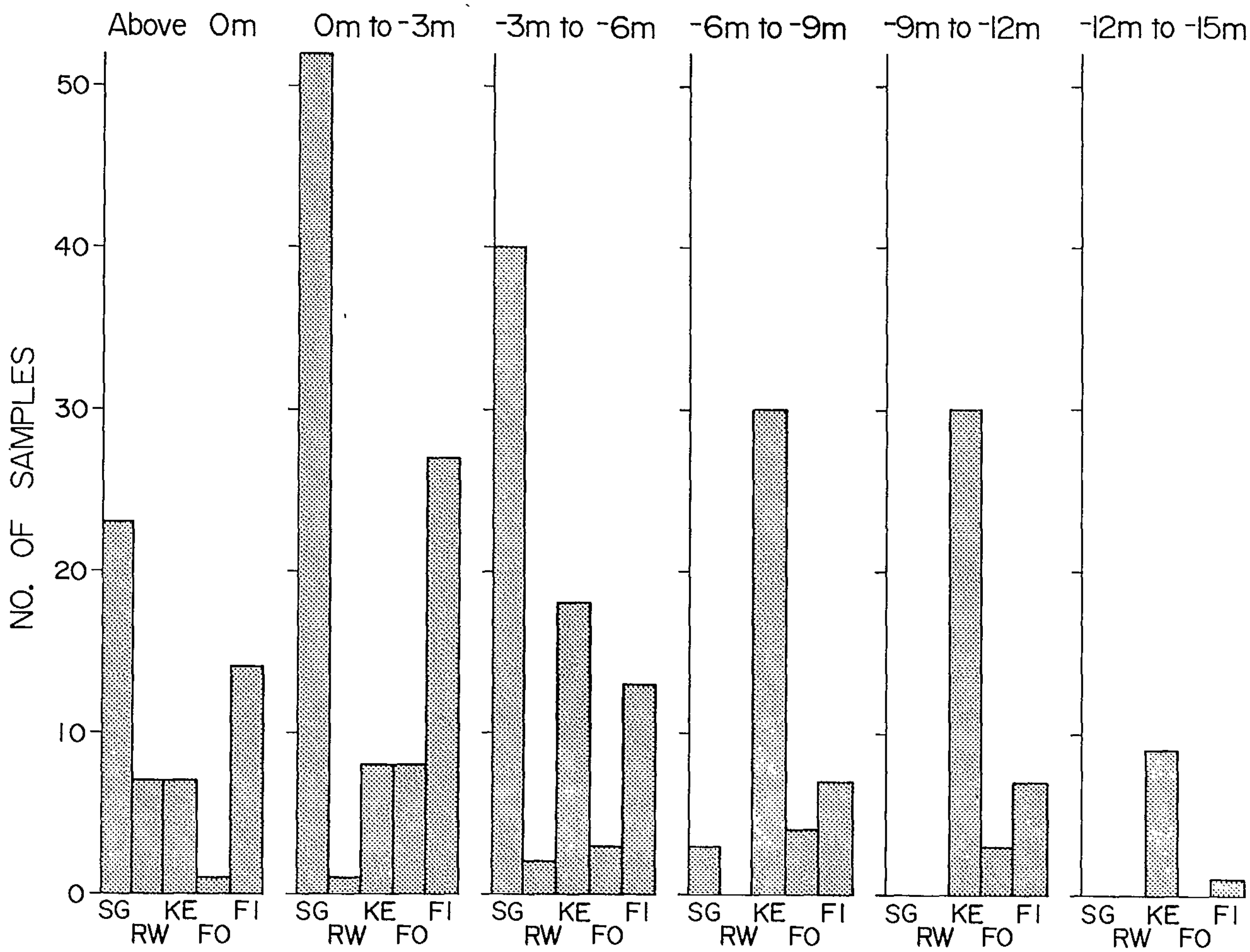

Fig. 4. Dominant vegetation types for quadrat spawn samples by 3 m depth intervals. (SG = sea grasses, RW = rockweed, KE = kelp, FI = filamentous red algae, FO = foliose red algae.)

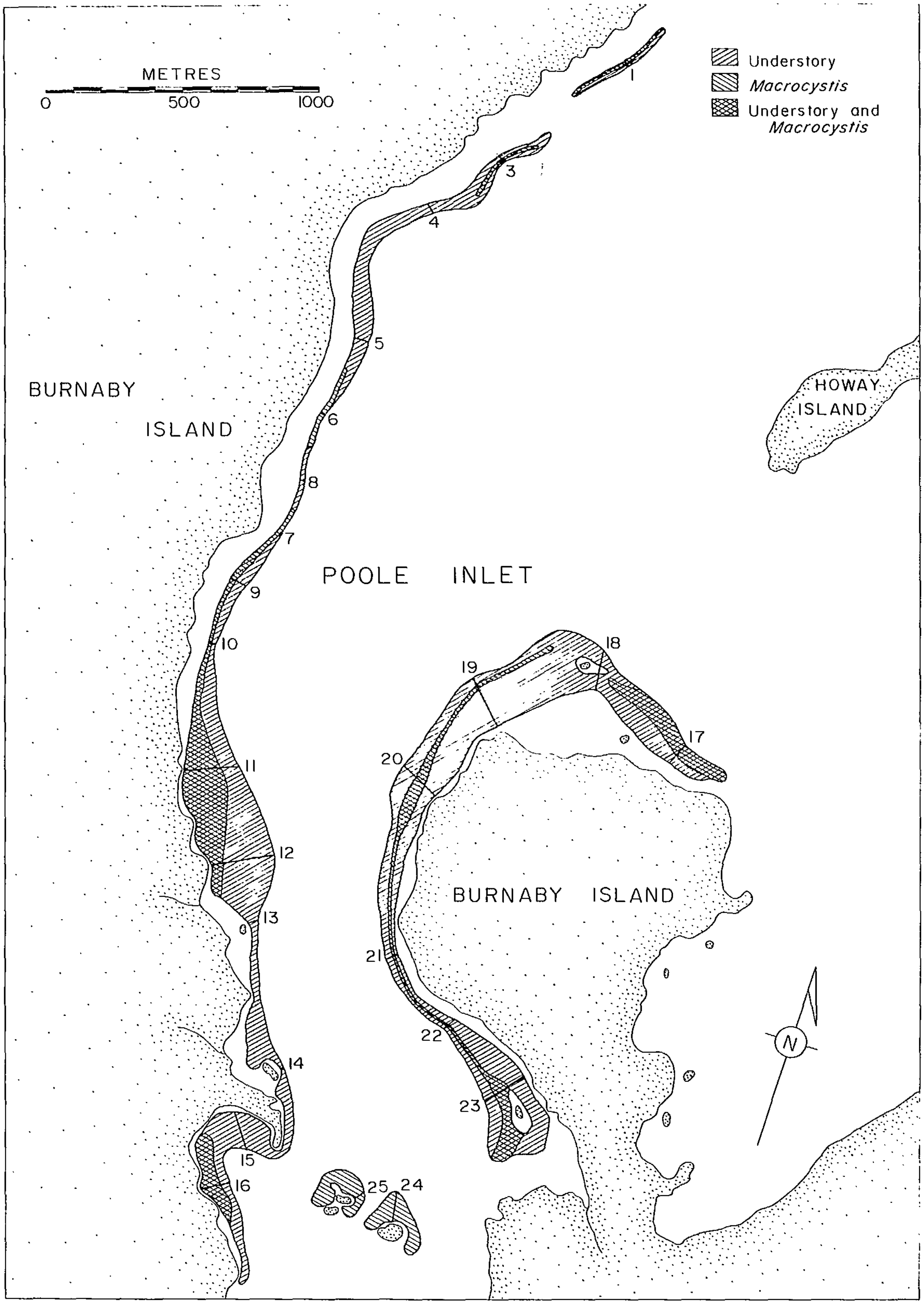

Fig. 5. Herring spawn in Poole Inlet, surveyed by divers in 1987, with transect locations shown. Hatching indicates where spawn was observed on understory vegetation and on Macrocystis sp.

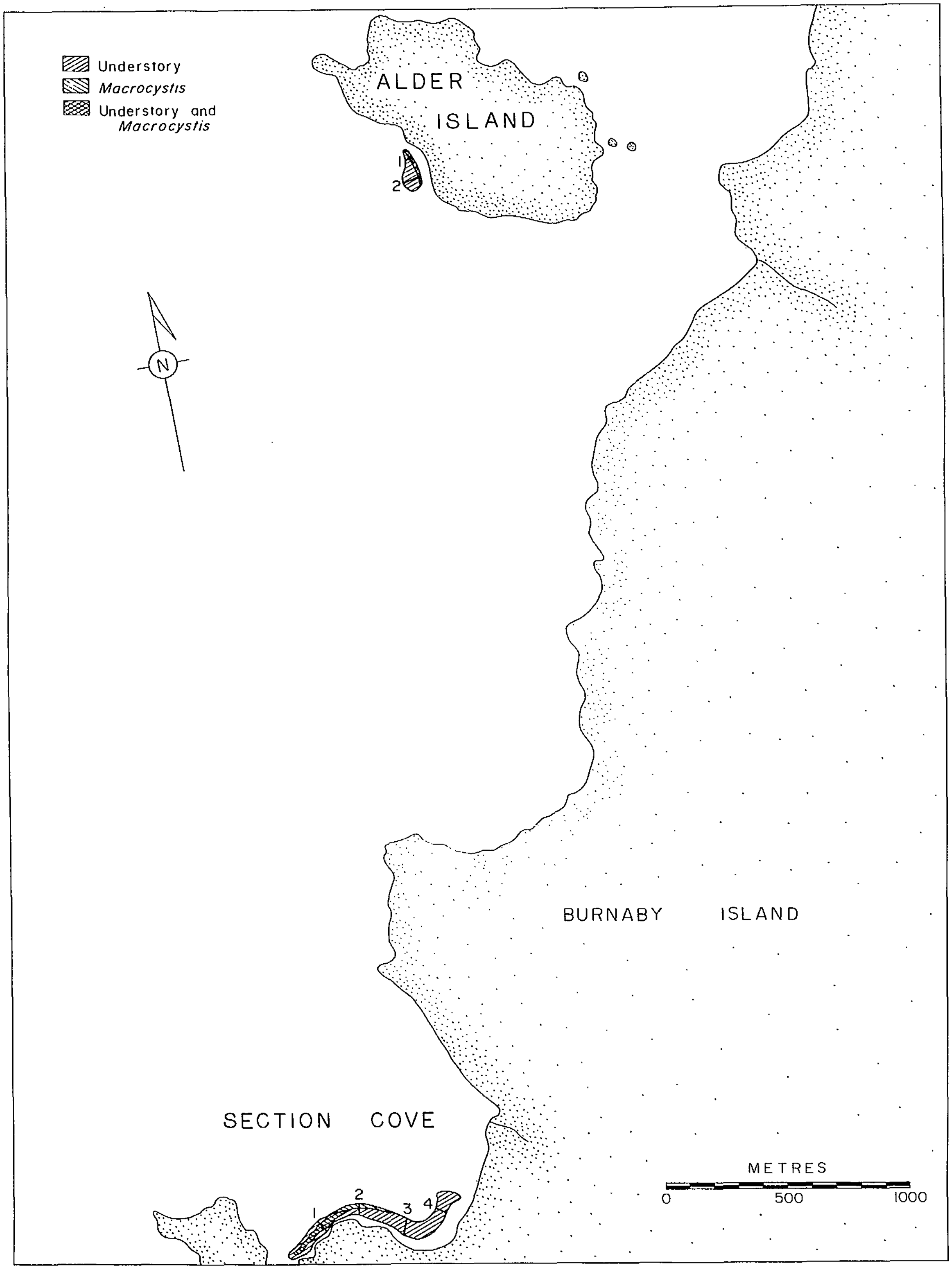

Fig. 6. Herring spawn at Alder Island and in Section Cove, surveyed by divers in 1987, with transect locations shown. Hatching indicates where spawn was observed on understory vegetation and on Macrocystis sp.

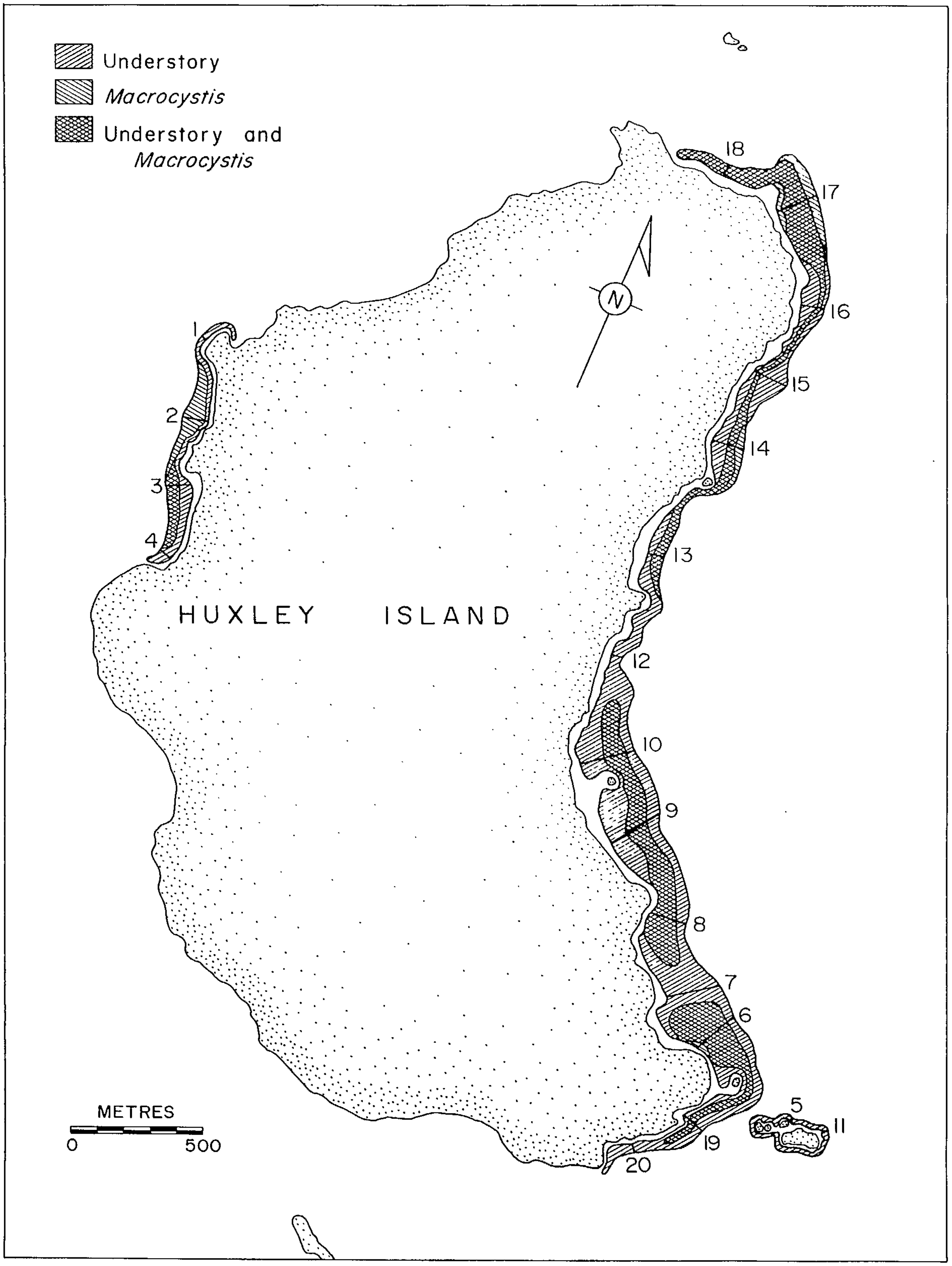

Fig. 7. Herring spawn at Huxley Island (west and east), surveyed by divers in 1987, with transect locations shown. Hatching indicates where spawn was observed on understory vegetation and on Macrocystis sp.

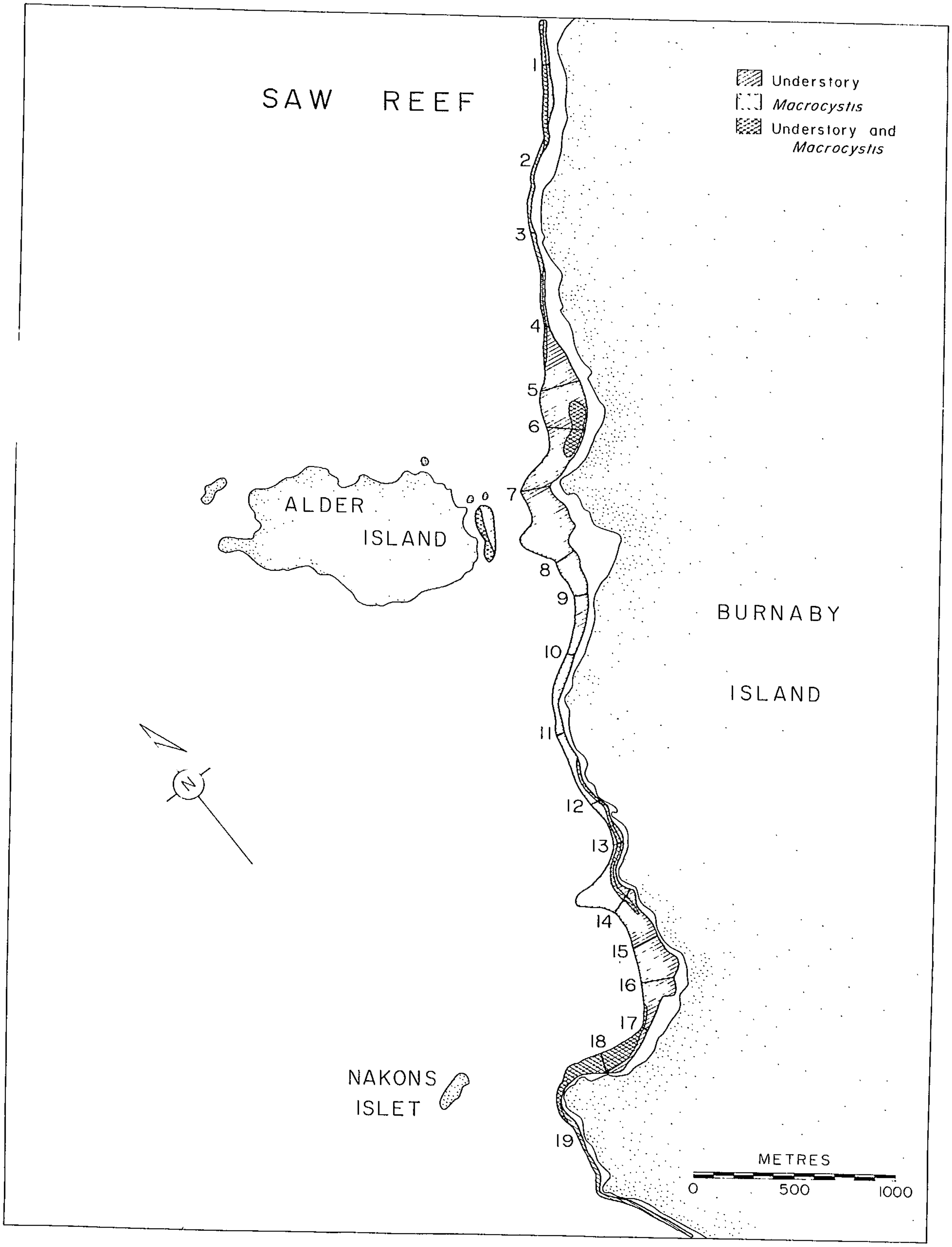

Fig. 8. Herring spawn on Saw Reef, surveyed by divers in 1987, with transect locations shown. Hatching indicates where spawn was observed on understory vegetation and on Macrocystis sp.

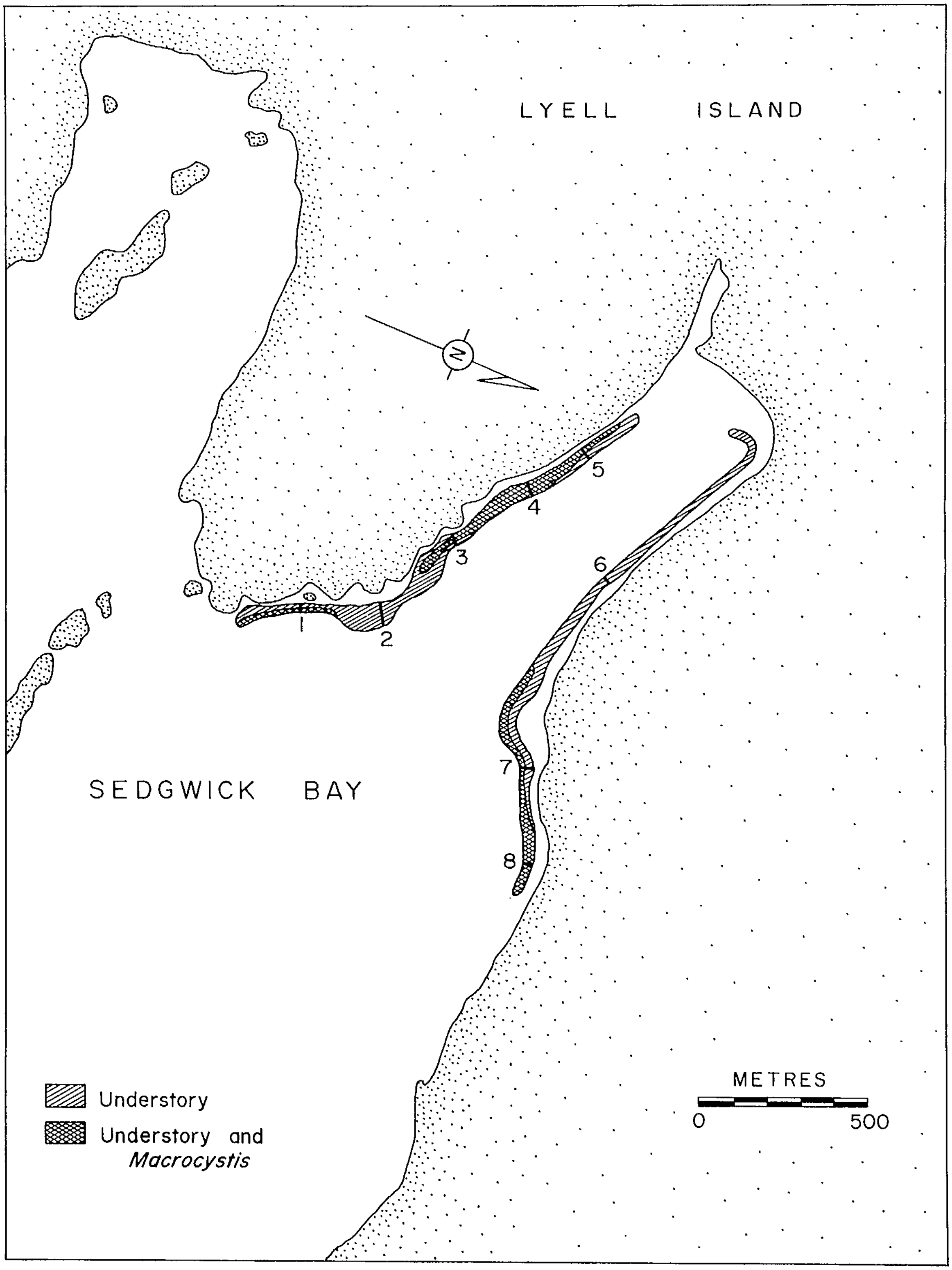

Fig. 9. Herring spawn in Sedgwick Bay, surveyed by divers in 1987, with transect locations shown. Hatching indicates where spawn was observed on understory vegetation and on Macrocystis sp.

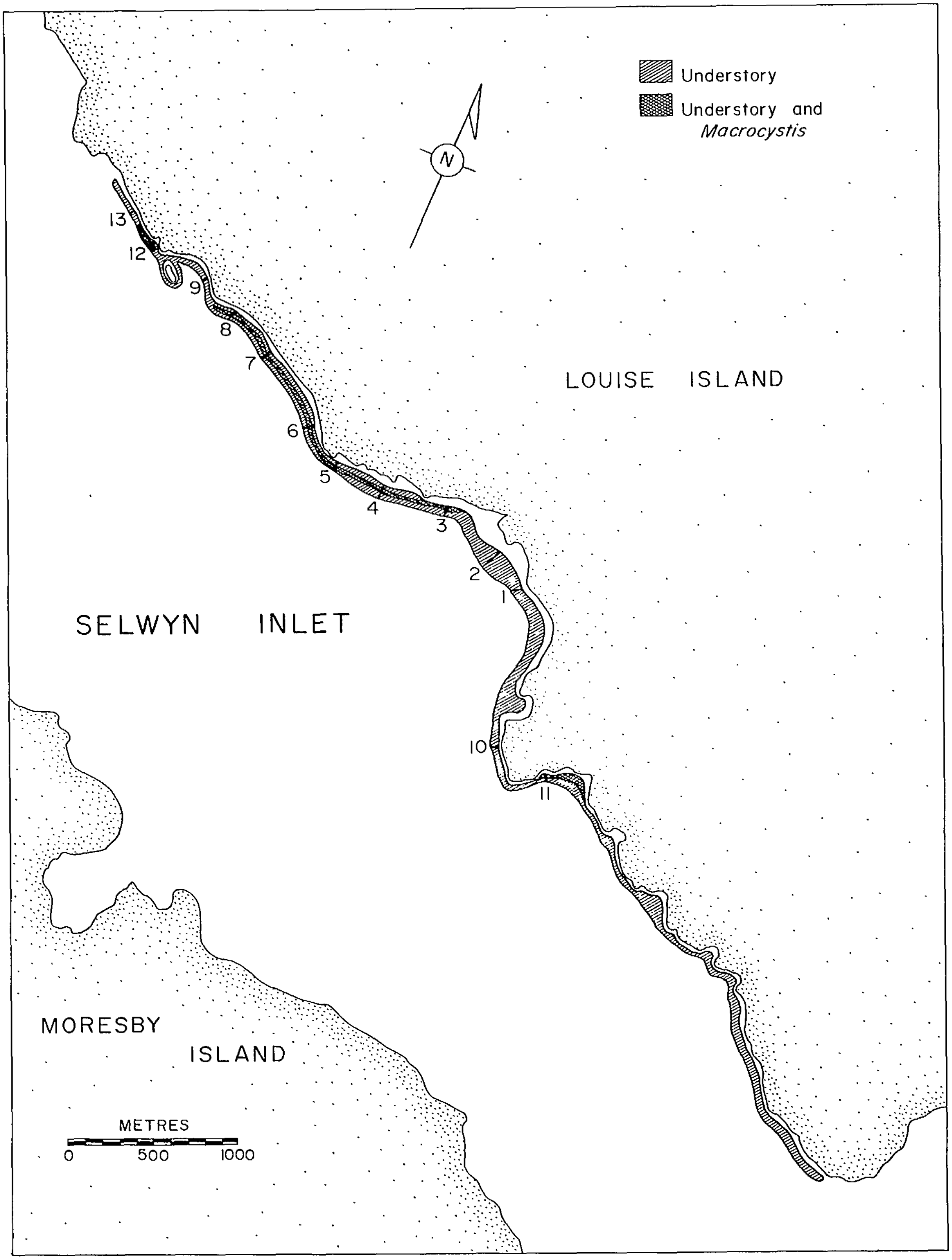

Fig. 10. Herring spawn in Selwyn Inlet, surveyed by divers in 1987, with transect locations shown. Hatching indicates where spawn was observed on understory vegetation and on Macrocystis sp.

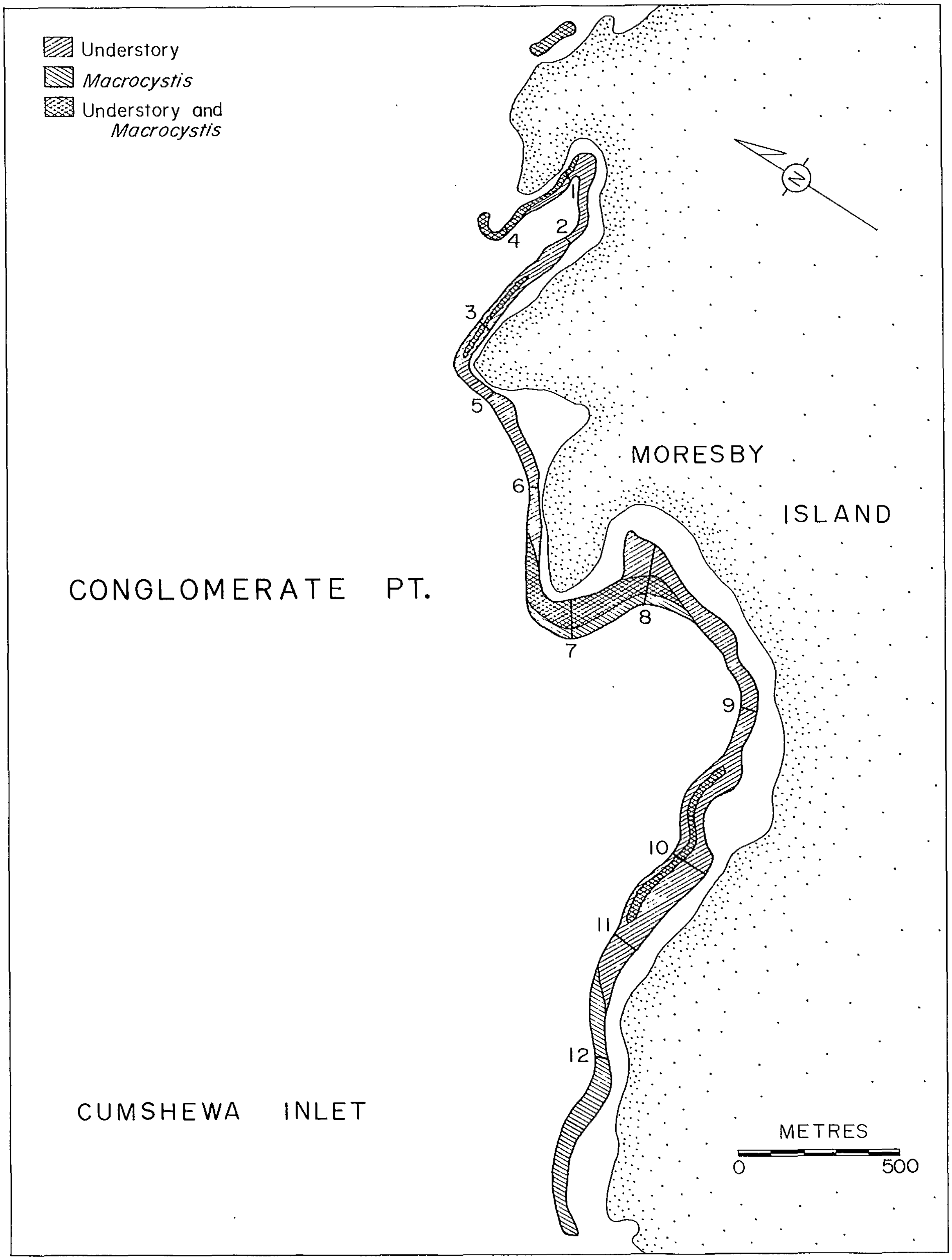

Fig. 11. Herring spawn at Conglomerate Point, surveyed by divers in 1987, with transect locations shown. Hatching indicates where spawn was observed on understory vegetation and on Macrocystis sp.

Appendix table 1. Transect information for spawns surveyed by divers in the Queen Charlotte Islands in 1987. (For *Macrocystis* sp. data: MP = mature plants, IP = immature plants, MF = mature fronds, IF = immature fronds, TF = total fronds. US = understory.)

Location	Transect no.	Width (m)		Surveyed area (sq. m)	No. of plants		No. of MP fronds			No. of IP-IF
		US	Macro		MP	IP	MF	IF	TF	
Poole Inlet	1	15	2	0	-	-	-	-	-	-
	2	0	0	-	-	-	-	-	-	-
	3	23	7	0	-	-	-	-	-	-
	4	39	0	-	-	-	-	-	-	-
	5	53	0	-	-	-	-	-	-	-
	6	0	10	20	5	1	23	11	34	2
	7	0	10	20	3	0	21	4	25	0
	8	11	11	22	7	4	61	15	76	7
	9	56	20	40	3	6	45	14	59	24
	10	18	15	30	4	3	50	42	92	10
	11	205	135	270	7	2	148	10	158	7
	12	240	35	70	2	0	9	3	12	0
	13	54	0	-	-	-	-	-	-	-
	14	10	0	-	-	-	-	-	-	-
	15	150	0	-	-	-	-	-	-	-
	16	105	70	0	-	-	-	-	-	-
	17	74	44	88	18	1	169	53	222	2
	18	83	0	-	-	-	-	-	-	-
	19	200	12	24	2	2	29	4	33	4
	20	160	45	90	4	1	37	6	43	2
	21	46	5	10	1	0	18	0	18	0
	22	48	2	4	1	0	1	0	1	0
	23	170	55	110	2	0	36	5	41	0
	24	0	120	240	18	33	77	20	97	38
	25	0	40	80	3	0	26	6	32	0
	Total			1118	80	53	750	193	943	96
Alder I.	1	20	10	20	2	0	64	7	71	0
	2	75	5	10	1	0	4	4	8	0
	Total			30	3	0	68	11	79	0
Section Cove	1	50	28	56	10	0	122	23	145	0
	2	16	20	40	6	2	56	8	64	4
	3	70	0	-	-	-	-	-	-	-
	4	55	0	-	-	-	-	-	-	-
	Total			96	16	2	178	31	209	4

Appendix table 1 (cont'd)

Location	Transect no.	Width (m) US	Width (m) Macro	Surveyed area (sq. m)	No. of plants MP	No. of plants IP	No. of MP fronds MF	No. of MP fronds IF	No. of MP fronds TF	No. of IP-IF
Huxley I. - W	1	2	0	-	-	-	-	-	-	-
	2	10	90	180	12	1	115	11	126	1
	3	80	45	90	4	0	14	7	21	0
	4	42	0	-	-	-	-	-	-	-
	Total			270	16	1	129	18	147	1
Huxley I. - E	5	5	0	-	-	-	-	-	-	-
	6	160	150	300	7	0	108	15	123	0
	7	205	0	-	-	-	-	-	-	-
	8	140	105	210	17	2	183	49	232	9
	9	217	87	174	4	0	44	7	51	0
	10	205	81	162	8	0	33	2	35	0
	11	6	0	-	-	-	-	-	-	-
	12	40	0	-	-	-	-	-	-	-
	13	55	40	80	4	1	43	7	50	8
	14	85	60	120	4	6	19	11	30	16
	15	135	10	20	2	0	57	4	61	0
	16	80	7	14	1	3	2	2	4	5
	17	110	150	300	12	3	104	51	155	8
	18	41	40	80	3	0	56	10	66	0
	19	85	20	40	2	1	21	2	23	3
	20	30	0	-	-	-	-	-	-	-
	Total			1500	64	16	670	160	830	49
Saw Reef	1	16	28	56	4	0	59	9	68	0
	2	0	5	0	-	-	-	-	-	-
	3	0	15	30	9	0	103	15	118	0
	4	15	4	8	1	0	9	3	12	0
	5	190	0	-	-	-	-	-	-	-
	6	175	50	100	7	1	49	39	88	3
	7	142	0	-	-	-	-	-	-	-
	8	100	0	-	-	-	-	-	-	-
	9	65	0	-	-	-	-	-	-	-
	10	39	0	-	-	-	-	-	-	-
	11	35	0	-	-	-	-	-	-	-
	12	50	10	20	2	0	24	6	30	0
	13	42	15	30	8	1	47	23	70	2
	14	135	20	40	1	0	12	7	19	0
	15	140	0	-	-	-	-	-	-	-
	16	160	0	-	-	-	-	-	-	-
	17	25	5	10	1	0	3	4	7	0
	18	103	100	200	6	5	37	7	44	14
	19	0	9	18	2	0	28	5	33	0
	Total			512	41	7	371	118	489	19

Appendix table 1 (cont'd)

Location	Transect no.	Width (m) US	Width (m) Macro	Surveyed area (sq. m)	No. of plants MP	No. of plants IP	No. of MP fronds MF	No. of MP fronds IF	No. of MP fronds TF	No. of IP-IF
Sedgwick B.	1	20	4	8	2	0	26	4	30	0
	2	75	0	-	-	-	-	-	-	-
	3	27	20	40	3	3	17	6	23	10
	4	38	38	76	10	0	119	10	129	0
	5	33	8	16	4	0	53	5	58	0
	6	16	0	-	-	-	-	-	-	-
	7	28	20	40	9	0	57	15	72	0
	8	20	20	40	7	0	91	27	118	0
	Total			220	35	3	363	67	430	10
Selwyn In.	1	65	0	-	-	-	-	-	-	-
	2	135	0	-	-	-	-	-	-	-
	3	44	5	10	3	0	10	3	13	0
	4	76	10	20	2	0	6	2	8	0
	5	35	10	20	1	0	8	0	8	0
	6	65	10	20	2	0	18	0	18	0
	7	45	30	60	3	0	10	3	13	0
	8	43	10	20	1	0	12	0	12	0
	9	13	0	-	-	-	-	-	-	-
	10	40	0	-	-	-	-	-	-	-
	11	33	10	20	1	0	3	0	3	0
	12	43	10	20	2	0	30	2	32	0
	13	15	0	-	-	-	-	-	-	-
	Total			190	15	0	97	10	107	0
Conglomerate Pt.	1	21	5	10	3	0	45	6	51	0
	2	20	0	-	-	-	-	-	-	-
	3	40	5	10	1	1	1	0	1	3
	4	17	17	34	6	0	70	26	96	0
	5	27	0	-	-	-	-	-	-	-
	6	22	0	-	-	-	-	-	-	-
	7	90	120	240	18	6	210	33	243	20
	8	145	85	170	6	10	76	18	94	24
	9	44	0	-	-	-	-	-	-	-
	10	110	20	40	5	0	28	1	29	0
	11	85	0	-	-	-	-	-	-	-
	12	0	43	86	7	0	47	5	52	0
	Total			590	46	17	477	89	566	47

Appendix table 2. Results for harvested Macrocystis sp. plants collected in the Queen Charlotte Islands in 1987. (MP = mature plant, MF = mature fronds, TF = Total fronds.)

Location	Transect no.	Plant no.	Height (m)	Egg layers	No. fronds		Thousands of eggs per			Plant weight (g)
					MF	TF	MP	MF	TF	
Poole Inlet	3	1	6	0.54	30	33	645	22	20	11072
		2	5	0.53	12	21	332	28	16	6288
	6	1	3	2.38	2	4	210	105	53	1388
		2	4	0.85	11	14	613	56	44	6061
	7	1	14	4.55	48	52	29387	612	565	131323
	8	1	5	0.30	27	35	1290	48	37	12705
		2	4	1.54	12	20	1544	129	77	8178
	9	1	7	4.35	13	18	2913	224	162	20001
	10	1	2	0.75	6	10	366	61	37	2487
		2	13	2.59	16	18	13106	819	728	64405
	11	1	5	1.50	19	27	1697	89	63	10984
	12	1	6	4.65	6	8	2896	483	362	12421
		2	6	4.69	7	8	6547	935	818	27772
	16	1	2	0.74	6	10	280	47	28	2533
	17	1	3	0.27	7	9	320	46	36	2470
		2	3	0.51	4	6	399	100	66	2431
	19	1	15	6.09	17	26	8829	519	340	33592
	20	1	9	3.28	7	12	1395	199	116	9888
		2	10	5.11	10	10	15120	1512	1512	61648
	21	1	12	1.20	13	17	7122	548	419	43514
		2	10	2.19	6	7	516	86	74	2739
	23	1	7	0.33	18	22	2426	135	110	16688
	24	1	7	1.27	10	12	1960	196	163	9268
		2	10	0.30	14	18	8155	582	453	46054
	25	1	8	0.36	7	15	1599	228	107	8574
Alder I.	1	1	11	0.20	74	83	6854	93	82	96963
	2	1	10	2.06	13	16	12987	999	812	52897
Section Cove	1	1	7	0.02	10	13	35	3	3	3282
		2	8	0.01	10	17	119	12	7	11265
	2	1	14	2.10	15	16	8337	556	521	23891
		2	7	2.51	16	18	6703	419	372	21855
Huxley I. - W	2	1	6	2.42	13	22	1388	107	63	24409
		2	2	5.69	4	8	961	240	120	4670
	3	1	9	5.40	23	35	23587	1026	674	98575
Huxley I. - E	6	1	12	9.35	38	45	75752	1993	1683	269538
	8	1	3	3.38	9	12	4030	448	336	12524
		2	6	1.27	22	25	5829	265	233	27126

Appendix table 2 (cont'd)

Location	Transect no.	Plant no.	Height (m)	Egg layers	No. fronds MF	No. fronds TF	Thousands of eggs per MP	Thousands of eggs per MF	Thousands of eggs per TF	Plant weight (g)
Huxley I. - E	9	1	6	10.64	21	25	14808	705	592	59239
	10	1	4	11.19	6	7	2138	356	305	12286
		2	5	17.73	4	6	3440	860	573	9357
	13	1	3	10.00	4	5	2351	588	470	6490
	14	1	14	5.67	28	36	36278	1296	1008	99728
	15	1	9	7.47	32	34	56905	1778	1674	151539
	17	1	7	5.20	4	7	5983	1496	855	17690
		2	14	4.37	21	24	35492	1690	1479	144781
	18	1	9	3.10	21	25	8704	414	348	39081
	19	1	3	3.16	17	24	2086	123	87	7578
		2	3	1.34	6	7	1740	290	249	7340
Saw Reef	1	1	9	0.45	15	18	3919	261	218	25410
	3	1	10	1.38	24	26	6346	264	244	34332
	4	1	10	1.84	22	22	6452	293	293	28266
	6	1	6	2.70	14	17	11018	787	648	31645
	12	1	7	2.92	4	7	7459	1865	1066	25340
	13	1	4	3.39	10	14	3136	314	224	9718
	14	1	12	3.06	15	22	43124	2875	1960	142592
	18	1	8	4.89	5	7	8060	1612	1151	23000
	19	1	11	1.23	33	37	17933	543	485	74611
Sedgwick Bay	1	1	5	1.46	18	20	1020	57	51	6857
	3	1	3	1.26	8	9	902	113	100	4897
	4	1	2	0.88	6	11	386	64	35	1702
	5	1	3	1.35	4	14	1128	282	81	5125
	7	1	9	0.32	25	29	5225	209	180	29989
	8	1	4	0.35	17	20	769	45	38	5099
Selwyn In.	3	1	4	2.20	7	7	2867	410	410	8945
	4	1	4	2.39	22	29	2549	116	88	8797
	6	1	5	2.04	5	8	5494	1099	687	17907
		2	5	1.90	12	16	6431	536	402	22461
	7	1	4	0.79	6	12	292	49	24	1959
	12	1	3	1.57	8	9	5649	706	628	17064
Conglomerate Pt.	1	1	7	2.38	21	28	7950	379	284	27451
	4	1	2	0.01	9	19	8	1	0	1421
	7	1	3	3.22	10	15	778	78	52	3770
		2	7	1.30	20	20	2018	101	101	11844
	8	1	10	1.28	23	29	5587	243	193	24970
		2	8	2.73	16	21	11293	706	538	37024
	10	1	7	0.91	8	14	6200	775	443	28296
		2	6	0.08	13	19	323	25	17	6168
	12	1	8	0.08	1	3	33	33	11	2366
		2	5	0.57	10	12	1617	162	135	8028