Shoreline Vegetation on Herring Spawning Grounds Between Deep Bay and Dorcas Point, Strait of Georgia, B.C.

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SHORELINE VEGETATION ON HERRING SPAWNING GROUNDS BETWEEN DEEP BAY AND DORCAS POINT, STRAIT OF GEORGIA, B.C.

by

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ABSTRACT

Haegele, C. W. 1978. Shoreline vegetation on herring spawning grounds between Deep Bay and Dorcas Point, Strait of Georgia, B.C. Fish. Mar. Serv. MS Rep. 1485: 49p.

The ability to accurately record and assess herring spawnings depends to a considerable degree on a knowledge of the vegetative substrate upon which the adhesive eggs are deposited. Large format colour and colour-infrared photographs were obtained for the shoreline between Deep Bay and Dorcas Point on April 7, 1977. Vegetation maps were prepared from these using colour and texture keys previously developed. Subsequently, between March 5 and April 11, 1978, a diver survey of herring spawnings in the study area was used to evaluate the accuracy of the photo-mapped vegetation. Divers collected 418 samples on 62 diving transects. Vegetation was identified on aerial photographs for 72% of these samples. For samples taken on herring spawn transects, vegetation was identified for 80% of samples. Vegetation not identified on photographs was always in deeper water and of low percent cover. There were 103 species of algae and sea grasses collected. The vegetation is commonly up to 600 m wide and the total area of vegetation identified from photographs is 6.2×10^6 m^2 along 60 km of coastline.

RÉSUMÉ

Haegele, C. W. 1978. Shoreline vegetation on herring spawning grounds between Deep Bay and Dorcas Point, Strait of Georgia, B.C. Fish. Mar. Serv. MS Rep. 1485: 49p.

L'exactitude des observations et des evalu du frai du Hareng dépend en grande partie de la connaissance du substrat végétal sur lequel les oeufs sont agglutinés. Nous avons tiré des épreuves grand format de photographies couleur et infra-rouge du rivage, prises le 7 avril 1977, entre la baie Deep et la pointe Dorcas. Des cartes de la végétation ont ensuite été préparées à partir de ces photographies, à l'aide de clés couleurs et des textures, mises au point auparavant. Puis, du 5 mars au 11 avril 1978, des plongeurs ont dressé l'inventaire des frayères du Hareng de la région étudiée afin d'évaluer l'exactitude de ces cartes. Le plongeurs ont recueilli 418 échantillons sur 62 transects sous-marins: 72% de ces échantillons ont été indentifiés sur les photographies aériennes, et ce chiffre s'élevait à 80% pour les échantillons prélevés directement sur les frayères. Les types de végétation non identifiés sur les photographies étaient toujours situés en eau plus profonde, dands des endroits à faible densité de végetation.

Nous avons recueilli 103 espèces d'algues et de plantes aquatiques. La végétation occupe généralement une bande dont la largeur maximale est de 600 m. L'identification des plantes à partir des photographies a porté sur une superficie de $6,2 \times 10^6$ m^2, s'étendant sur 60 km de côte.

INTRODUCTION

Aerial photographs are used to map vegetation on herring spawning grounds in British Columbia (Haegele and Hamey 1976, 1977). These maps are used to record and assess herring spawnings which take place mainly on rooted algae and sea grasses in the littoral and upper sublittoral zone.

Some field ckecking to verify aerial photograph data and interpretation (ground-truth determinations) have been carried out for a few of the areas mapped (Haegele and Humphreys 1976; Haegele 1977), but constraints of time and cost prohibit ground-truthing all the maps from one flight, usually a distance of 60 km. In late winter and early spring of 1978, a diver survey of herring spawnings between Deep Bay and Dorcas Point on the central Vancouver Island shoreline of Georgia Strait afforded the opportunity to do this for vegetation maps prepared from photographs obtained on April 7, 1977.

In addition to establishing whether this mapping project is worthwhile in terms of the use to which these maps are put, the diver survey provided information on species composition and percent cover of the bottom vegetation. This information is not obtained from the photographs but is an important factor when determining the number of herring eggs deposited (Haegele 1978).

METHODS

AERIAL PHOTOGRAPHY AND MAPPING

Vertical aerial photographs of 24cm × 24 cm format at a photo scale of 1:6000 were obtained for the shoreline between Deep Bay and Dorcas Point on April 7, 1977 (Fig. 1). The predicted low tide for that day was +0.9 m at 1405 PST. There were nine flight lines with two pairs being parallel at 20% sidelap. Forward overlap was 60%. Two types of film were used: Kodak Aerochrome Infared No. 2443 with a medium yellow (Wratten No. 12) filter and Kodak Aero Color Negative No. 2445. Although not the preferred colour film, No. 2445 was used instead of the usual Kodak Ektachrome MS Aerographic No. 2448 because of deteriorating light conditions. No. 2445 film has an aerial exposure index of 32 while for No. 2448 it is 6. The No. 2445 film was processed to diapositives, the No. 2443 already being a colour reversal film. The infrared (No. 2443) photography was flown before low tide (1305 to 1400 PST) and the colour (No. 2445) after low tide (1400 to 1505 PST).

Vegetation maps were prepared at the scale of photography, using enlarged marine charts as a base map, with standard photogrammetric techniques. Exposed vegetation was identified from infrared photographs

using a colour key previously developed (Haegele 1975). For vegetation submerged at the time of photography, identification was by colour and texture from the colour photographs. The vegetation was charted by five major types, recognizable on the photographs: sea grasses, rockweeds, red algae, brown algae, and green algae.

SURVEYING AND SAMPLING

Transects roughly perpendicular to the shoreline were established at varying intervals, usually no closer than 400 m apart and sometimes several kilometers apart. There were two types of transects, spawn transects and vegetation transects. Spawn transects ended at the outer edge of herring spawn, which did not necessarily coincide with the outer edge of vegetation. Vegetation transects always ended at the outer edge of the vegetation. A team of divers sampled along each transect at intervals dictated by changes in vegetation type, percent cover, or herring spawn density. Usual intervals between samples ranged from 20 m to 50 m and consisted of all but crustose vegetation rooted within a 1/4 m^2 or 1 m^2 quadrat. A detailed description of the sampling and surveying procedure has been published by Humphreys and Haegele (1976).

In addition to the sample and its position, the following information was obtained:

1. Bottom type - one or more of the following; classified according to these criteria.

Bottom-type class	Particle size	Code
Shells	Usually bivalve	s
Mud	< 0.02 cm	M
Sand	0.02-0.15 cm	S
Pebbles	0.16-6.0 cm	P
Cobbles	6.1-25.0 cm	C
Boulders	> 25.0 cm	B
Rock	Rockshelf	R

2. Percent cover; the percentage of the bottom, within the sample quadrat, that was occupied by vegetation.

3. Depth; the depth of water at which the sample was taken. This was corrected to chart datum from Ocean and Aquatic Sciences tidal height printouts.

SAMPLE PROCESSING

All samples of vegetation were sorted by species, according to Widdowson (1973, 1975) and Scagel (1967), and weighed fresh to the nearest gram.

RESULTS

The shoreline vegetation from Deep Bay to Dorcas Point, a distance of 60 km, was mapped from aerial photographs and is presented on 12 maps, reduced photographically from photo scale (Fig. 2-13). Diving transects and sampling stations are also shown on these maps. Spawn transect numbers are prefixed by an S, vegetation transect numbers by a V. For the Deep Bay map (Fig. 2) and Englishman River map (Fig. 11) there were no diving transects. There were 256 samples obtained on 31 vegetation transects and 162 samples on 31 spawn transects.

There were 103 species of "seaweeds" identified (Table 1). Of these, 20 were identified only to the genus level. These species were grouped into seven vegetation types according to their taxonomy and physical appearance to herring spawn assessment requirements. Each sample was classified into one of these vegetation types by the percent contribution by weight of the species within that type to the total weight of the sample. For each sample, each species was also rated whether it was:

1. dominant - heaviest
2. major - $\geqslant$ 5% of sample weight
3. minor - $<$ 5% of sample weight

Red algae were represented by the largest number of species (80) and were also most often the dominant vegetation type (48%). The vegetation types and the major contributing species are listed in Table 2.

Samples were collected between +2.9 m and -14.0 m (Table 3), the middle 80% (between 10% and 90%) were collected between +1.4 m and -6.0 m. The depth ranges differ for the vegetation types, rockweed samples were collected highest on the beach, kelp samples the deepest. Percent cover also varies with depth for the vegetation types (Table 4), usually being highest at the upper end of the depth range of the vegetation type. Bottom types also are different for the various vegetation types (Table 5). A summary of these physical properties pertaining to vegetation type appears in Table 6.

The identification of vegetation from aerial photographs was better in shallow water than in deep water and better at higher percent covers than lower percent covers (Table 7). Overall, 60% of the transect samples were correctly mapped from aerial photographs while the presence of

vegetation was identified for 72% of the transect samples. The correct identification of vegetation was higher for spawn transect samples (71%) than vegetation transect samples (54%), also the presence of vegetation was noted more frequently for spawn samples (80%) than vegetation samples (64%). Shoreline vegetation incorrectly mapped as bare from aerial photographs was almost exclusively (90%) beyond the outer edge of vegetation identified in photographs and in deep water. The average percent cover of these "incorrectly identified as bare" samples was much lower than for correctly identified samples (65 vs. 40).

Not all sections of the shoreline between Deep Bay and Dorcas Point were sampled equally (Table 8). Of the 10 maps with transects, between 9 samples on 2 transects (Qualicum River) and 90 samples on 8 transects (Parksville Bay) were obtained. The average percent cover varies between maps as well as between vegetation types (Table 9). The distribution of samples by depth is different for individual maps (Table 10). Bottom types also differ between maps with rock and boulders occurring more frequently in the southern part of the study area (Table 11).

DEEP BAY

No transects were obtained for the Deep Bay map. Within the bay, vegetation appears patchy and sparse on aerial photographs. East of the spit there is a nearly continuous band of rockweeds, succeeded seaward by red and brown algae interspersed with patches of sea grasses. Beyond this, there are fairly extensive beds of sea grasses.

THAMES CREEK

Eleven vegetation transects roughly 500 m apart and yielding 74 samples were obtained for the Thames Creek map. The vegetation is very diverse here with 76 species of "seaweeds" encountered. Close to shore there is a band of rockweeds, succeeded seaward by a mixture of red and brown algae interspersed with patches of eelgrass. Beyond this there is a band of kelp mostly not identified on aerial photographs. The percent cover of the deeper kelp is substantially lower than for the mixed red and brown algae. The vegetation is 400 m wide on the average. The major species are Fucus distichus, Neoagardhiella baileyi, Agarum fimbriatum, Laminaria saccharina, Sargassum muticum, and Gigartina exasperata.

QUALICUM BAY

Nine vegetation transects with 48 samples were obtained for the shoreline in the Qualicum Bay map. West of Nile Creek the vegetation is similar to and continuous with the vegetation in the Thames Creek map,

averaging 300 m in width and consisting mostly of an inner red algae band identified on photographs and an outer, deeper kelp band of lower percent cover not identified in the aerial photographs. East of Nile Creek the vegetation is sparse and patchy until the inside of Qualicum Bay is reached from where an extensive bed an average of 550 m wide continues to Qualicum River. The inner band of high percent cover red algae was identified from aerial photographs while the outer bed of lower percent cover kelp was not. Sea grasses and rockweeds occur infrequently and in small patches in this section of the coast. The major species, of the 57 species encountered, are Laminaria saccharina, Neoagardhiella baileyi, Gigartina exasperata, Prionitis sp., and Gracilariopsis sjoestedtii.

QUALICUM RIVER

Sampling data for this map was obtained on four spawn transects with 14 stations. All but one station was correctly identified on aerial photographs. However, since transects were started and ended with the presence of herring spawn, there may be deeper vegetation, probably kelp at low percent cover, beyond the red algae band identified from aerial photographs. The higher percent cover vegetation is, on the average, 200 m wide and the filamentous red algae Neoagardhiella baileyi, Odonthalia flocossa, Plocamium coccinium, and Rhodomela larix predominate. Of the 33 species encountered, 28 were red algae. Rockweeds and sea grasses occur infrequently in narrow bands and in small patches.

LITTLE QUALICUM RIVER - WEST

Sampling for this section was confined to five spawn transects, yielding 27 samples. The vegetation here is continuous with that in the Qualicum River map with the addition of seagrasses beyond the red algae zone. Again, there is probably low percent cover kelp beyond the photo-identified vegetation. The mapped vegetation averages 200 m wide. There were 37 species encountered with the following predominating. Gigartina exasperata, Neoagardhiella baileyi, Plocamium coccineum, Gracilariopsis sjoestedtii, and Zostera marina.

LITTLE QUALICUM RIVER

The predominantly red algae vegetation ends at the mouth of the Little Qualicum River. East of the river, two spawn transects with 9 samples were obtained. The vegetation here is quite sparse with an average percent cover of 32(+18)% and Sargassum muticum the most frequently encountered species. On the flats off the spit, the vegetation is quite narrow, about 100 m, widening to 250 m towards Qualicum Beach. The other species present in significant amounts are Neoagardhiella baileyi and Gracilariopsis sjoestedtii.

QUALICUM BEACH

The western portion of this map is predominantly a narrow (< 50 m) band of vegetation on the sandy bottom of Qualicum Beach. Only one sample was obtained for this section and it was exclusively Zostera marina. On the aerial photographs this vegetation was identified as a mixture of red and brown algae. The bottom changes to a mixture of pebbles and cobbles in sand on the eastern section of the map and is accompanied with a change in vegetation. The photo-identified vegetation is up to 300 m wide and consists of Zostera marina alternating with a mixture of Sargassum muticum and filamentous red algae. At the vegetation transect V14T1 the vegetation continues to 600 m but beyond the photo-identified outer edge, the vegetation averages only 14(+11)% cover with Neoagardhiella baileyi the dominant species.

FRENCH CREEK

The western half of this map was not sampled and according to the aerial photographs the vegetation is sparsely distributed on sandy bottom as patches of sea grasses below 0.0 m and rockweeds, green and red algae above 0.0 m. On either side of French Creek, the vegetation was extensively sampled on four spawn and four vegetation transects, with 64 samples taken. West of French Creek, Zostera marina occurs beyond the red and brown algae identified from photographs at high [60(±18)] percent cover in deep water. Vegetation for the section around French Creek averages 300 m wide and a large number of species (60) were identified. Common species encountered are Gigartina exasperata, Sargassum muticum, Neoagardhiella baileyi, Gracilariopsis sjoestedtii, Plocamium coccineum, and Zostera marina.

PARKSVILLE BAY

Only the eastern half of this map was surveyed and five spawn and three vegetation transects produced 90 samples. The vegetation mapped from aerial photographs was correctly identified but there is considerable vegetation beyond this 300 m wide zone at V9T2 to V11T2. There the vegetation continues to 600 m. The additional vegetation consists mostly of Agarum fimbriatum and Gigartina exasperata at 56(±20)% cover and at depth from -3.5 to -10.2 m, averaging -6.1(±2.0) m. The head of the bay was not surveyed and, from the photographs, the vegetation appears to consist mostly of sea grasses, which give way to red and brown algae towards Englishman River. Of the 67 species encountered, the most common are Gigartina exasperata, Sargassum muticum, Gracilariopsis sjoestedtii, Neoagardhiella baileyi, Agarum fimbriatum, and Fucus distichus.

ENGLISHMAN RIVER

This map does not contain much information that is not duplicated because of overlap on the two maps, Parksville Bay and Madrona Point, which it ties together. One vegetation transect was obtained for the vegetation shown on this map but it appears on the Madrona Point map.

MADRONA POINT

This map has three distinct vegetation regions. The western portion is a wide, up to 550 m, section between Parksville Bay and Craig Bay. The outer 150 m is mostly kelp (Laminaria saccharina) and foliose red algae (Rhodymenia pertusa) in deep water and not identified on aerial photographs. Shoreward of this is a 400 m wide band of alternating grasses (Zostera marina), other brown algae (Sargassum muticum), and filamentous red algae (Neoagardhiella baileyi). The second section is the extensive sea grasses bed in the shallow parts of Craig Bay. There were no transects for this section, the widest portion of the bed being 1,000 m wide. The third section is a rocky, steep shoreline from Madrona Point eastward. The vegetation here is only 75m wide and consists mostly of kelp (Agarum fimbriatum) and red algae, of which there were 27 species in five samples with none predominant.

NORTHWEST BAY

No transects were run in Northwest Bay itself but there were eight spawn transects in adjacent Nuttal Bay with 41 samples. The vegetation along this relatively steep, mostly rocky shoreline is fairly uniform. There is generally a narrow (about 20 m wide) inner band of rockweeds succeeded seaward by a 50 m wide band of mostly red algae and an outer deep band of mostly kelp. All but the deeper portions (below -6.0 m) of the kelp band were identified on aerial photographs. The most frequently encountered species are Agarum fimbriatum, Laminaria saccharina, Prionitis sp., Plocamium coccineum, and Laurencia spectabilis.

DISCUSSION

The presence of vegetation was determined on aerial photographs for 72% of the samples obtained on all transects and the vegetation was correctly identified for 60% of the samples. However, for samples obtained on spawn transects, the presence of vegetation was determined for 80% of the samples and correctly identified for 71% of samples. Better results

were obtained on spawn transects because they sometimes ended before the outer edge of the vegetation was reached and vegetation not determined from photographs was always in deeper water and of low percent cover. This is a direct result of the limited water penetration capabilities of aerial films, especially colour-infrared film. Since only deep, sparse vegetation escapes detection on aerial photographs and vegetation on which herring spawn occurs is mostly correctly identified, it would appear unnecessary to do much further ground-truth determination for the herring spawning ground vegetation mapping program. Only if detailed information on percent cover and species composition is required for mapped areas, should diver surveys be necessary.

The vegetation along this shoreline is quite complex with very few single vegetation-type associations (Table 2). Sea grasses come closest to being a pure vegetation type. An average of 98% of the weight is accounted for by sea grasses in sea grasses typed samples. On the other end of the scale, filamentous red algae contribute an average of 68% of the biomass to samples typed as filamentous red algae. Concommitantly, filamentous red algae occur in 91% of all vegetation transect samples while only 28% of these samples are typed in this category.

The amount of vegetation along this shoreline is considerable. From Deep Bay to Madrona Point, the vegetation on a shelving shoreline is frequently up to 500 m wide. Vegetation transects for this section average 400($\pm$175) m and spawn transects average 266($\pm$115) m. From Madrona Point to Dorcas Point, the beach slope is steeper and transects average 133($\pm$28) m long. Typically, vegetation consists of an inner, patchy band of rockweeds and green algae mixed. Seaward of this, vegetation becomes a mixture of filamentous red algae and other brown algae interspersed with rockweeds. Subtidally, this is succeeded by a mixture of foliose and filamentous red algae that is replaced by a mixture of kelp and foliose red algae below -3 m. Interspersed with this and in bays such as Parksville and Craig Bay, where pure sand bottoms predominate, are beds of sea grasses.

It is perhaps interesting to speculate what a desired escapement of spawners would be for this section of coastline. The total area of photo-identified vegetation from Deep Bay to Dorcas Point is 6.216×10^6 m^2 (Table 11). At a spawn density of one layer of eggs, the potential for seeding of herring eggs is 2.837×10^{12} eggs. This would require 27,786 tons of herring, based on average (1971-1977) weights and percent age composition of seine catches in southern B.C. and preliminary fecundity data.

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Table 1. Number of occurrences of vegetation species by vegetation type and importance of occurrence.

	Dominant	Major	Minor	All
SEA GRASSES				
Phyllospadix scouleri	1			1
Zostera marina	36	7	14	57
ROCKWEEDS				
Fucus distichus	40	17	10	67
Pelvetiopsis limitata	1			1
KELPS				
Agarum fimbriatum	41	9	4	54
Costaria costata	1	10	22	33
Laminaria saccharina	39	38	22	99
Laminaria sp.			1	1
OTHER BROWN ALGAE				
Colpomenia sinuosa			1	1
Desmarestia aculeata		1		1
Desmarestia ligulata	1	8	6	15
Desmarestia viridis	1	9	14	24
Petalonia fascia		4	13	17
Punctaria hesperia			1	1
Sargassum muticum	49	48	32	129
Scytosiphon lomentaria		2	4	6
FOLIOSE RED ALGAE				
Botryglossum farlowianum			1	1
Callophyllis firma	1	1	11	13
Callophyllis flabellulata			18	18
Callophyllis haenophylla			7	7
Callophyllis violacea			1	1
Callophyllis sp.	1	5	50	56
Constantinea simplex	2	18	26	46
Constantinea subulifera	1	8	5	14
Constantinea sp.		1	2	3
Cryptomenia ovalifolia			1	1
Crypopleura sp.		5	47	52
Fryella gardneri		2	9	11
Gigartina exasperata	48	71	32	151
Gigartina papillata	1	3	13	17
Gigartina sp.		3	7	10
Grateloupia dorphyra		1	2	3
Gymnogongrus leptophyllus		2	20	22
Gymnogongrus linearis		1	4	5
Gymnogongrus sp.			5	5
Hymenema sp.		5	47	52
Iridea cordata		16	32	48
Iridea sp.		3	17	20
Membranoptera platyphylla		1		1
Neodilsea americana		3	6	9
Opuntiella californica		2	1	3
Polyneura latissima		4	33	37
Porphyra perforata		1	1	2
Porphyra sp.	1	1	8	10
Prionitis lanceolata		5	12	17
Prionitis lyalli		1	3	4
Prionitis sp.	17	40	59	116
Rhodoglossum affine			1	1
Rhodoglossum sp.		3	5	8
Rhodymenia pacifica		1		1
Rhodymenia palmata	1	2	2	5
Rhodymenia pertusa	8	24	28	60
Rhodymenia stipitata		1		1
Sarcodiotheca furcata		10	23	33
Schizemenia pacifica		3	18	21
Weeksia fryeana	1	1	4	6

Table 1 (cont'd)

	Dominant	Major	Minor	All
FILAMENTOUS RED ALGAE				
Ahnfeltia plicata		5	18	23
Antithamnionella glandulifera			6	6
Bossiella plumosa			1	1
Bossiella sp.			2	2
Calliarthron regenerens		1	2	3
Ceramium californicum		4	20	24
Ceramium pacificum		3	51	54
Ceramium sp.			22	22
Corallina pilulifera			1	1
Corallina vancouveriensis	1	1	17	19
Cryptosiphonia woodii	3	22	31	56
Delesseria decipiens		1	5	6
Farlowia compressa		1	1	2
Farlowia mollis			12	12
Gastroclonium coulteri			4	4
Gelidium crinale	1	8	13	22
Gelidium robustum			1	1
Gracilariopsis sjoestedtii	15	61	68	144
Griffithsia pacifica			3	3
Herposiphonia sp.			16	16
Laurencia spectabilis	4	47	54	105
Lomentaria hakodatensis		8	42	50
Microcladia borealis			1	1
Microcladia coulteri		1	9	10
Neoagardhiella baileyi	49	69	50	168
Odonthalia flocossa	5	20	43	68
Platythamnion reversum		2	1	3
Platythamnion sp.		1	3	4
Plocamium coccineum	10	59	71	140
Plocamium tenue			5	5
Plocamium sp.			1	1
Polysiphonia hendryi	4	5	9	18
Polysiphonia urceolata	5	8	15	28
Polysiphonia sp.			18	18
Pterosiphonia bipinnata		1	3	4
Pterosiphonia gracilis			15	15
Pterosiphonia sp.			7	7
Rhodomela larix	16	31	23	70
Rhodoptilum plumosum		4	14	18
Stenogramme interrupta			5	5
GREEN ALGAE				
Bryopsis corticulans			1	1
Cladophora microcladioides	1		3	4
Cladophora sp.	1	2	13	16
Enteromorpha intestinales			1	1
Enteromorpha linza	1	2	2	5
Spongomorpha sp.			2	2
Ulva lactuca	10	24	66	100

Table 2. List of vegetation types, their frequency of occurrence and the major contributing species.

Vegetation type	No. of times dominant	No. of species	Most frequently occurring species
Sea grasses	36	2	*Zostera marina*
Rockweeds	40	2	*Fucus distichus*
Kelps	80	4	*Agarum fimbriatum* *Laminaria saccharina*
Other brown algae	49	8	*Sargassum muticum*
Foliose red algae	83	40	*Gigartina exasperata* *Prionitis* sp. *Rhodymenia pertusa*
Filamentous red algae	118	40	*Neoagardhiella baileyi* *Plocamium coccineum* *Rhodomela larix* *Gracilariopsis sjoestedtii* *Laurencia spectabilis*
Green algae	12	7	*Ulva lactuca*

Table 3. Number of samples at depth for vegetation types.

Depth in m (Datum)	Vegetation type							
	Sea Grasses	Rock-weeds	Kelps	Other brown algae	Fol. red algae	Fil. red algae	Green algae	All
+ 2.9 to + 2.5		3				1		4
+ 2.4 to + 2.0		7		2		2		11
+ 1.9 to + 1.5		7		4	1	9		21
+ 1.4 to + 1.0	1	14		6	2	9	3	35
+ 0.9 to + 0.5	5	7		11	5	14	6	48
+ 0.4 to 0.0	2			10	10	15	2	39
- 0.1 to - 0.5	4	1	2	3	8	15		33
- 0.6 to - 1.0	2	1	1	2	5	11		22
- 1.1 to - 1.5	4		2	5	14	6	1	32
- 1.6 to - 2.0	6		3	2	4	12		27
- 2.1 to - 2.5	2		4	2	3	4		15
- 2.6 to - 3.0	2		5	1	5	6		19
- 3.1 to - 3.5	1		3		5	3		12
- 3.6 to - 4.0	3		4	1	6	3		17
- 4.1 to - 4.5	1		5		4	3		13
- 4.6 to - 5.0	2		5		6	2		15
- 5.1 to - 5.5	1		3			2		6
- 5.6 to - 6.0			5		1	1		7
- 6.1 to - 6.5			6					6
- 6.6 to - 7.0			3					3
- 7.1 to - 7.5			5					5
- 7.6 to - 8.0			6					6
- 8.1 to - 8.5			4					4
- 8.6 to - 9.0			3					3
- 9.1 to - 9.5			2		1			3
- 9.6 to -10.0			3		1			4
-10.1 to -10.5			2		1			3
-10.6 to -11.0			1		1			2
-11.1 to -11.5			1					1
-12.1 to -12.5			1					1
-13.6 to -14.0			1					1
ALL	36	40	80	49	83	118	12	418

Table 4. Average percent cover at depth for vegetation types.

Depth in m (Datum)	Sea grasses	Rock-weeds	Kelps	Other brown algae	Fol. red algae	Fil. red algae	Green algae	All
+ 2.9 to + 2.5		52				50		51
+ 2.4 to + 2.0		46		42		50		46
+ 1.9 to + 1.5		85		62	70	51		65
+ 1.4 to + 1.0	30	59		54	70	51	63	56
+ 0.9 to + 0.5	64	79		57	80	66	72	68
+ 0.4 to 0.0	70			57	74	80	90	72
- 0.1 to - 0.5	54	40	70	57	71	61		62
- 0.6 to - 1.0	80	80	70	22	66	61		62
- 1.1 to - 1.5	49		70	20	75	87	20	64
- 1.6 to - 2.0	52		75	12	92	32		49
- 2.1 to - 2.5	48		78	25	67	42		55
- 2.6 to - 3.0	12		58	10	51	40		43
- 3.1 to - 3.5	40		43		56	42		48
- 3.6 to - 4.0	22		41	40	63	18		41
- 4.1 to - 4.5	80		48		66	9		47
- 4.6 to - 5.0	8		63		68	22		52
- 5.1 to - 5.5	70		41			6		34
- 5.6 to - 6.0			40		40	80		46
- 6.1 to - 6.5			55					55
- 6.6 to - 7.0			60					60
- 7.1 to - 7.5			46					46
- 7.6 to - 8.0			44					44
- 8.1 to - 8.5			39					39
- 8.6 to - 9.0			50					50
- 9.1 to - 9.5			15		50			27
- 9.6 to -10.0			27		50			32
-10.1 to -10.5			45		2			31
-10.6 to -11.0			10		2			6
-11.1 to -11.5			20					20
-12.1 to -12.5			30					30
-13.6 to -14.0			40					40
ALL	49	64	49	47	67	55	69	56

Table 5. Number of occurrences of bottom types for substrate types.

	Sea grasses	Rock-weeds	Kelps	Other brown algae	Fol. red algae	Fil. red algae	Green algae	All
s, S	2		1			2		5
s, S, P	1		1	3		5		10
s, S, P, C		1	8		3	4		16
s, S, P, C, B			5		1		1	7
s, S, C		1	4	3	2	2	1	13
s, S, C, B					1	3		4
s, P			1					1
s, P, C					1	1		2
s, P, C, B					1			1
s, C	1							1
M			1			1		2
S	22		3	4	3	8		40
S, P	6	1	4	12	1	12		36
S, P, C	4	7	17	14	17	34	2	95
S, P, C, B		2	5	2	9	1		19
S, P, C, R					1			1
S, P, B					3			3
S, C			7	2	11	12	2	34
S, C, B		4	4	1	6	11		26
S, C, R			1		1		1	3
S, B			1	1	3	2		7
S, B, R			2					2
P		1						1
P, C		2	2		4	4	2	14
P, C, B		6	3	2	3		1	15
P, C, R			1					1
C		2	1	1	3	2	1	10
C, B		7		2	5	9	1	24
C, B, R			1		1			2
C, R			1		1	1		3
B				1				1
B, R			5		1	1		7
R	1	5	1	1	1	3		12
ALL	36	40	80	49	83	118	12	418

Table 6. Summary of physical properties pertaining to vegetation type.

Vegetation type	Depth range in meters (Datum)			Most common bottom types
	All samples	Middle 80% of samples	Above average % cover	
Sea grasses	+1.4 to -5.5	+0.9 to -4.0	+1.4 to -2.0	Sand
Rockweeds	+2.9 to -1.0	+2.4 to +0.5	+1.9 to +0.5	Pebbles, cobbles
Kelps	-0.1 to -14.0	-1.1 to -9.5	-0.1 to -3.0	Sand, cobbles
Other browns	+2.4 to -4.0	+1.4 to -1.5	+2.4 to -0.5	Sand, pebbles
Fol. reds	+1.9 to -11.0	+1.4 to -4.5	+1.9 to -2.5	Sand, cobbles
Fil. reds	+2.9 to -6.0	+1.9 to -3.0	+0.9 to -1.5	Sand, cobbles
Greens	+1.4 to -1.5	+1.4 to 0.0	+1.4 to 0.0	Cobbles
All	+2.9 to -14.0	+1.4 to -6.0	+2.4 to -1.5	Sand, cobbles

Table 7. Comparison of vegetation and spawn transect results with photo-mapped shoreline vegetation.

	Thames Creek	Qualicum Bay	Qualicum River	Little Qualicum River-west	Little Qualicum River	Qualicum Beach	French Creek	Parksville Bay	Madrona Point	Northwest Bay	All
A. Vegetation transects											
1. No. of samples	74	48				15	41	53	25		256
2. Correctly identified											
a. % of total samples	58	40				20	85	51	44		54
b. Av. % cover	75 (±20)	56 (±24)				35 (±33)	50 (±28)	57 (±26)	50 (±15)		60 (±26)
c. Av. depth (m)	+0.1 (±1.2)	-0.7 (±1.4)				+1.2 (±0.5)	-1.2 (±2.0)	-0.1 (±1.7)	-1.2 (±1.9)		-0.4 (±1.7)
3. Veg. incorrectly identified											
a. % of total samples	14	6				7	5	8	20		10
b. Av. % cover	68 (±19)	57 (±12)				100 (-)	90 (±14)	55 (±33)	26 (±15)		57 (±26)
c. Av. depth (m)	+0.8 (±0.9)	-3.3 (±3.2)				+1.3 (-)	+0.9 (±0.3)	+1.6 (±1.0)	+0.3 (±1.2)		+0.4 (±1.9)
4. Incorrectly identified as bare											
a. % of total samples	28	54				73	10	41	36		3[illegible]
b. Av. % cover	42 (±26)	37 (±24)				14 (±11)	58 (±40)	54 (±26)	17 (±13)		39 (±27)
c. Av. depth (m)[a]	-4.1 (±2.9)	-4.7 (±2.8)				-3.1 (±1.5)	-4.8 (-)	-5.4 (±3.6)	-5.8 (±2.6)		-4.9 (±2.5)
B. Spawn transects											
1. No. of samples			14	27	9	11	23	37		41	162
2. Correctly identified											
a. % of total samples			93	81	33	91	74	65		64	71
b. Av. % cover			78 (±21)	73 (±23)	30 (±17)	54 (±27)	68 (±20)	63 (±29)		80 (±23)	70 (±26)
c. Av. depth (m)			+0.4 (±1.0)	0.0 (±1.2)	+0.4 (±0.6)	+0.4 (±1.0)	-0.1 (±1.1)	-0.6 (±1.5)		-2.0 (±2.4)	-0.4 (±1.6)
3. Veg. incorrectly identified											
a. % of total samples				15	22	9	9	11		2	9
b. Av. % cover				49 (±32)	45 (±7)	100 (-)	65 (±35)	45 (±40)		60 (-)	54 (±30)
c. Av. depth (m)				-1.4 (±1.7)	-0.8 (±0.6)	-0.6 (-)	-0.8 (±1.8)	+1.9 (±0.6)		0.2 (-)	-0.1 (±1.7)
4. Incorrectly identified as bare											
a. % of total samples			7	4	45		17	24		34	20
b. Av. % cover			70 (-)	100 (-)	28 (±22)		60 (±18)	19 (±34)		45 (±23)	41 (±30)
c. Av depth (m)[a]			-2.5 (-)	-	-1.8 (±0.1)		-3.8 (±1.4)	-6.0 (±2.4)		-9.3 (±2.3)	-6.8 (±3.3)

[a]of samples taken beyond outer photo-identified edge.

Table 8. Number of samples by vegetation type for ten maps.

	Thames Creek	Qualicum Bay	Qualicum River	Little Qualicum River-west	Little Qualicum River	Qualicum Beach	French Creek	Parksville Bay	Madrona Point	Northwest Bay	All
Sea grasses	2	1		4		8	8	6	3	4	36
Rockweeds	12	1	1	4	1	2	7	8	1	3	40
Kelps	15	19		1		1	3	12	6	23	80
Other brown algae	8	2		2	6	1	8	15	5	2	49
Fol. red algae	14	9	2	6			18	27	3	4	83
Fil. red algae	18	12	11	10	2	13	19	21	7	5	118
Green algae	5	4			1	1	1				12
All	74	48	14	27	9	26	64	90	25	41	418

Table 9. Average percent cover by vegetation type for ten maps.

	Thames Creek	Qualicum Bay	Qualicum River	Little Qualicum River-west	Little Qualicum River	Qualicum Beach	French Creek	Parksville Bay	Madrona Point	Northwest Bay	All
Sea grasses	75	10		67		56	51	20	50	55	49
Rockweeds	59	40	70	83	40	31	83	55	50	83	64
Kelps	61	39		80		10	25	56	26	58	49
Other brown algae	39	33		45	37	40	44	60	30	85	47
Fol. red algae	81	61	85	64			71	59	47	90	67
Fil. red algae	67	39	76	74	15	26	49	55	27	96	54
Green algae	74	80				5	80	50			69
All	65	46	77	70	32	35	58	55	34	68	56

Table 10. Number of samples at depth for 10 maps.

Depth in m (Datum)	Thames Creek	Qualicum Bay	Qualicum River	Little Qualicum River-west	Little Qualicum River	Qualicum Beach	French Creek	Parksville Bay	Madrona Point	Northwest Bay	All
+ 2.9 to + 2.5	1						1	2			4
+ 2.4 to + 2.0	3						2	5		1	11
+ 1.9 to + 1.5	2		2	2	1	4	1	7	1	1	21
+ 1.4 to + 1.0	8	1	1	7		1	10	3	4		35
+ 0.9 to + 0.5	13	5	3	2	1	6	5	11	1	1	48
+ 0.4 to 0.0	10	6	2		1		6	7	3	4	39
- 0.1 to - 0.5	4	2	3	4	3	3	6	5	1	2	33
- 0.6 to - 1.0	4	2		3		1	4	5	1	2	22
- 1.1 to - 1.5	8	2	2	5	1	1	4	5	2	2	32
- 1.6 to - 2.0	6	1		2	2	2	6	2	2	4	27
- 2.1 to - 2.5	1	3	1	1			4	2	1	2	15
- 2.6 to - 3.0	1	4		1		2	3	5	2	1	19
- 3.1 to - 3.5		3				1	4	3		1	12
- 3.6 to - 4.0	2	5				2	2	3	2	1	17
- 4.1 to - 4.5	2	2				2	3	2		2	13
- 4.6 to - 5.0	1	2					2	9	1		15
- 5.1 to - 5.5		2				1	1	2			6
- 5.6 to - 6.0	3	1						2		1	7
- 6.1 to - 6.5		1							1	4	6
- 6.6 to - 7.0		1						2			3
- 7.1 to - 7.5	3	1							1		5
- 7.6 to - 8.0	1	1						1	1	2	6
- 8.1 to - 8.5	1							2		1	4
- 8.6 to - 9.0		1								2	3
- 9.1 to - 9.5								1	1	1	3
- 9.6 to -10.0		1						2		1	4
-10.1 to -10.5								1		2	3
-10.6 to -11.0		1						1			2
-11.1 to -11.5										1	1
-12.1 to -12.5										1	1
-13.6 to -14.0										1	1
ALL	74	48	14	27	9	26	64	90	25	41	418

Table 11. Number of occurences of bottom types for 10 maps.

	Thames Creek	Qualicum Bay	Qualicum River	Little Qualicum River-west	Little Qualicum River	Qualicum Beach	French Creek	Parksville Bay	Madrona Point	Northwest Bay	All
s, S	1	1					1		2		5
s, S, P	1					1	1		7		10
s, S, P, C	4	10				1			1		16
s, S, P, C, B	3	2				1		1			7
s, S, C	13										13
s, S, C, B	2	1						1			4
s, P		1									1
s, P, C	1						1				2
s, P, C, B	1										1
s, C	1										1
M							2				2
S	1	4		7	1	3	9	11	2	2	40
S,P		2			8	9	9	3	3	2	36
S, P, C	11	17	6	6		8	18	18	1	10	95
S, P, C, B	8							10		1	19
S, P, C, R										1	1
S, P, B							3				3
S, C	9	5	5				2	10	1	2	34
S, C, B	7	1	1	8				8		1	26
S, C, R							2			1	3
S, B	1			2			2	2			7
S, B, R									1	1	2
P						1					1
P, C	2	1				1	3	6	1		14
P, C, B	3	3					3	6			15
P, C, R										1	1
C	2		2				2	4			10
C, B	3			4		1	5	10		1	24
C, B, R										2	2
C, R									2	1	3
B										1	1
B, R										7	7
R							1		4	7	12
ALL	74	48	14	27	9	26	64	90	25	41	418

Table 12. Distribution of percent contribution by substrate type for 7 categories of vegetation samples from vegetation transects.

Vegetation sample category (by substrate type)	% occurence (top line) and average % contribution of.						
	Sea grasses	Rock-weeds	Kelps	Other brown algae	Fol. red algae	Fil. red algae	Green algae
Sea grasses	100 98 (±3)	- -	8 + (-)	25 1 (-)	17 2 (-)	33 4 (±4)	- -
Rock-weeds	- -	100 77 (±23)	+ + (-)	36 2 (±1)	68 10 (±12)	68 14 (±14)	68 8 (±10)
Kelps	6 2 (±1)	- -	100 77 (±20)	26 11 (±11)	77 12 (±11)	90 12 (±14)	8 3 (±2)
Other brown algae	13 12 (±13)	13 22 (±12)	13 12 (±15)	100 70 (±22)	68 13 (±12)	100 12 (±12)	29 9 (±10)
Fol. red algae	2 1 (-)	2 3 (-)	38 19 (±14)	31 13 (±11)	100 73 (±17)	87 17 (±14)	14 3 (±5)
Fil. red algae	15 20 (±20)	12 15 (±14)	29 13 (±11)	52 12 (±12)	75 18 (±14)	100 68 (±17)	48 8 (±10)
Green algae	- -	18 16 (±15)	27 6 (±7)	54 18 (±15)	45 9 (±13)	91 16 (±10)	100 66 (±21)

Table 13. Area of photo-identified vegetation

Map	Area in $m^2 \times 10^3$ of: Sea grasses	Rock-weed	Brown algae	Red algae	Red and brown algae	Green algae	All
Deep Bay	202	94	-	10	204	99	609
Thames Creek	142	21	-	29	382	70	644
Qualicum Bay	29	15	17	5	376	33	475
Qualicum River	88	6	-	1	417	30	542
Little Qualicum River - west	122	12	-	33	383	72	622
Little Qualicum River	90	36	6	16	209	100	457
Qualicum Beach	42	54	-	13	182	34	325
French Creek	64	40	-	66	257	24	451
Parksville Bay	158	117	-	62	402	16	755
Englishman River[a]	16	14	2	-	45	5	82
Madrona Point[b]	483	64	19	26	182	55	849
Northwest Bay[b]	6	69	2	7	286	35	405
Total area ($\times 10^3$ m^2)	1,442	562	46	268	3,325	573	6,216
No. of eggs/m^2 ($\times 10^3$) at 1 layer and average % cover[c]	362	620	389	483	451	559	-
No. of eggs $\times 10^6$	522	348	18	129	1,500	320	2,837

[a] For section not covered on adjacent maps.

[b] Excluding Mistaken Island.

[c] From Haegele and Hourston 1978.

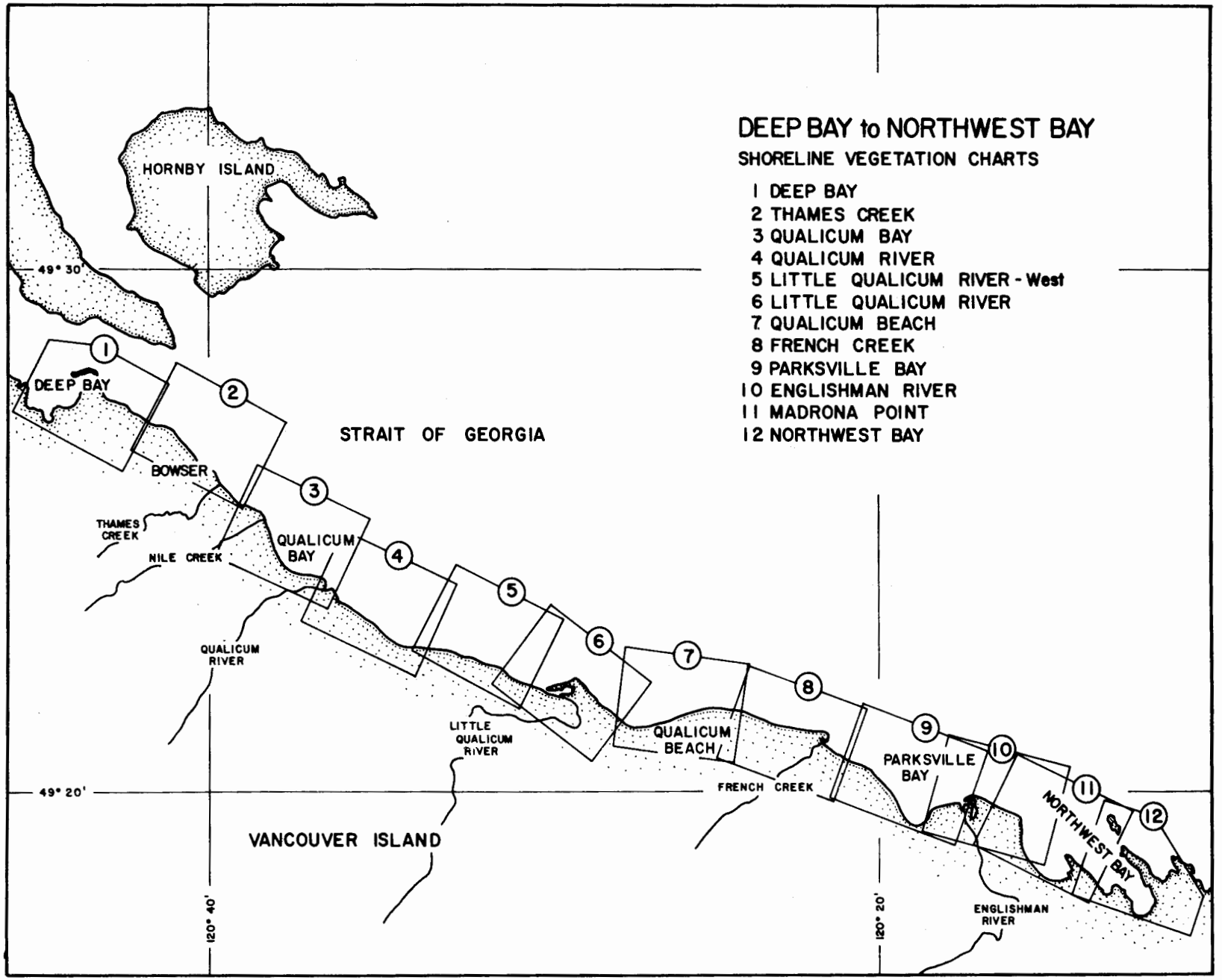

Fig. 1. Shoreline vegetation maps for study area.

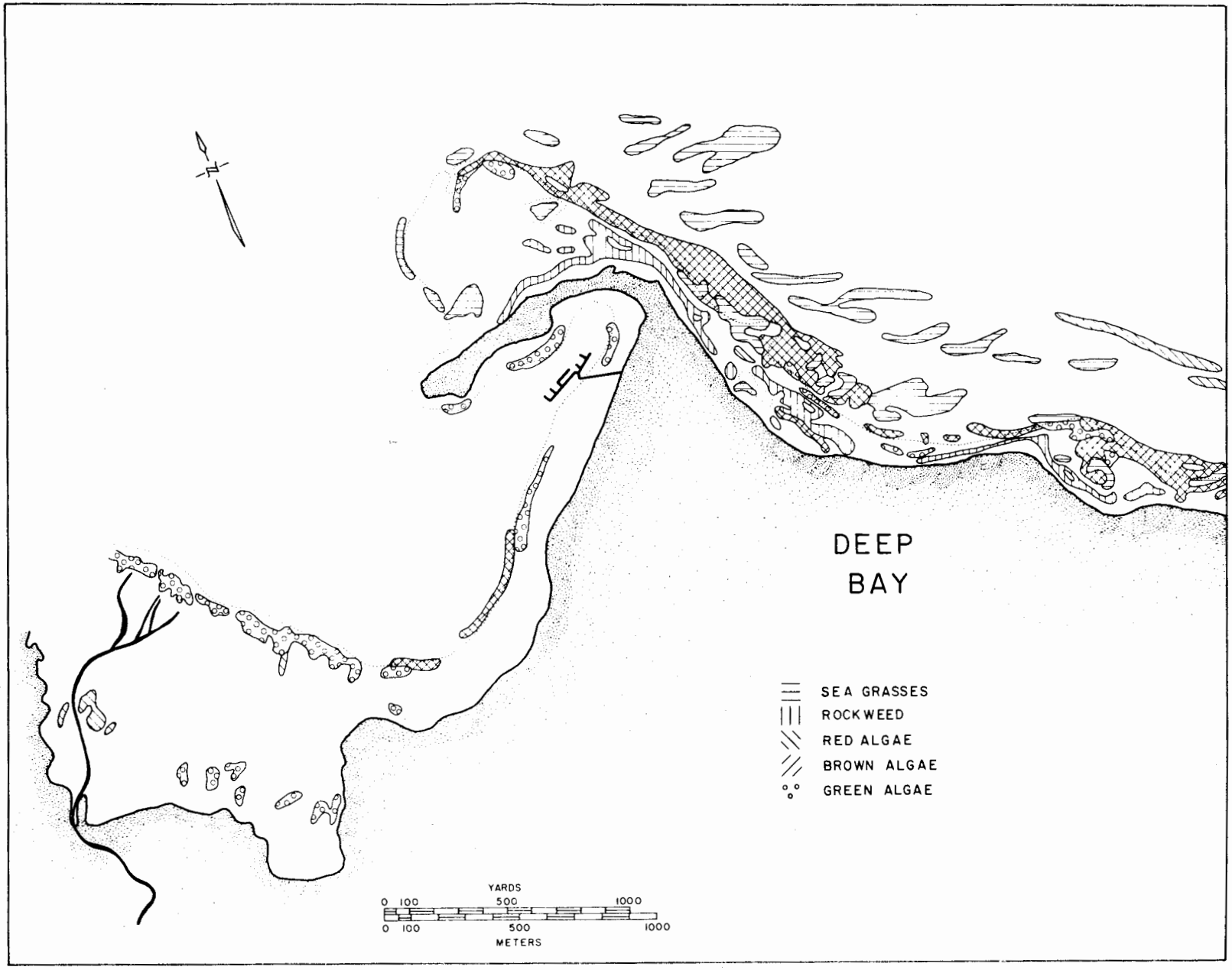

Fig. 2. Shoreline vegetation map from aerial photographs for Deep Bay.

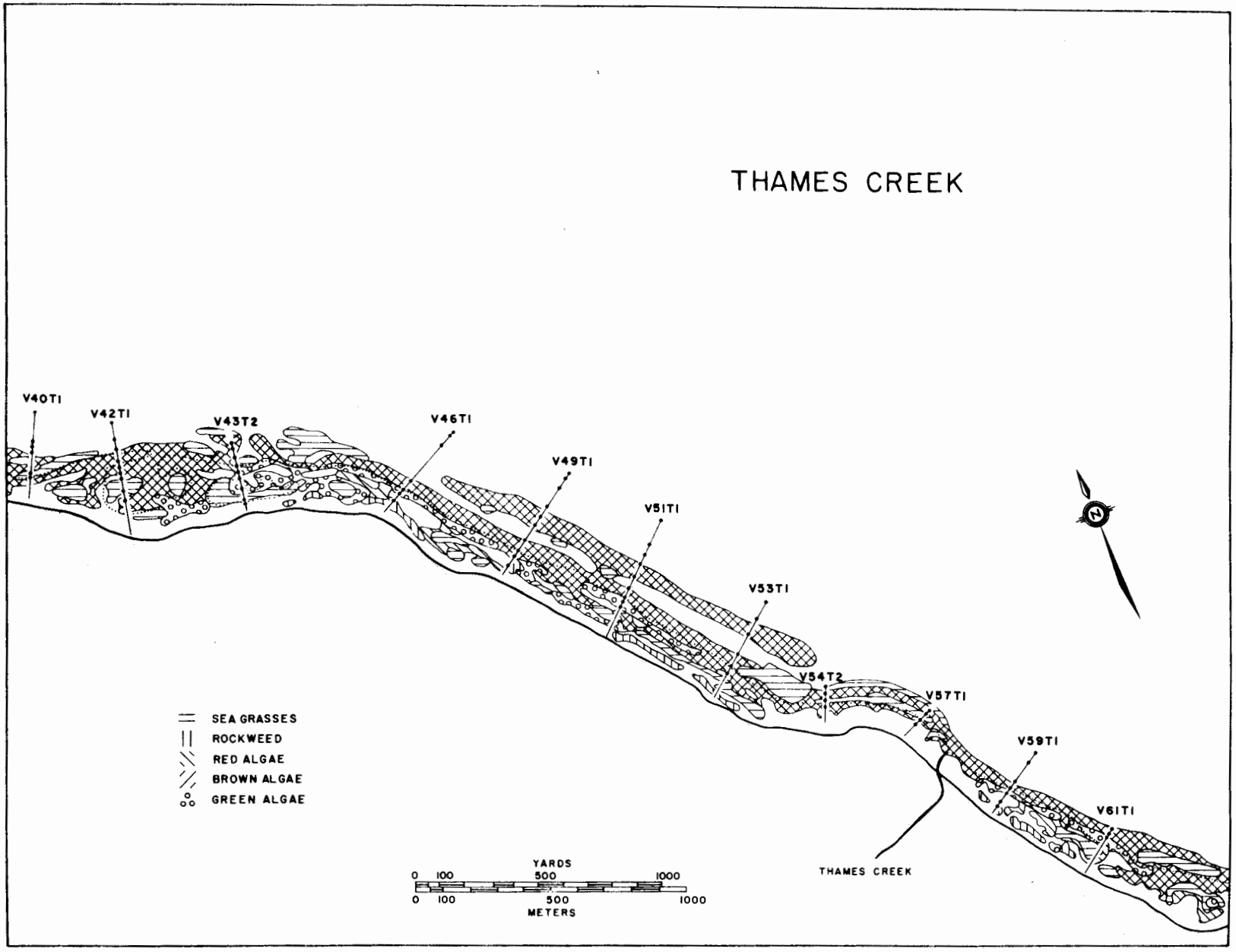

Fig. 3. Shoreline vegetation map from aerial photographs for Thames Creek. Diver survey transects and sampling stations are indicated.

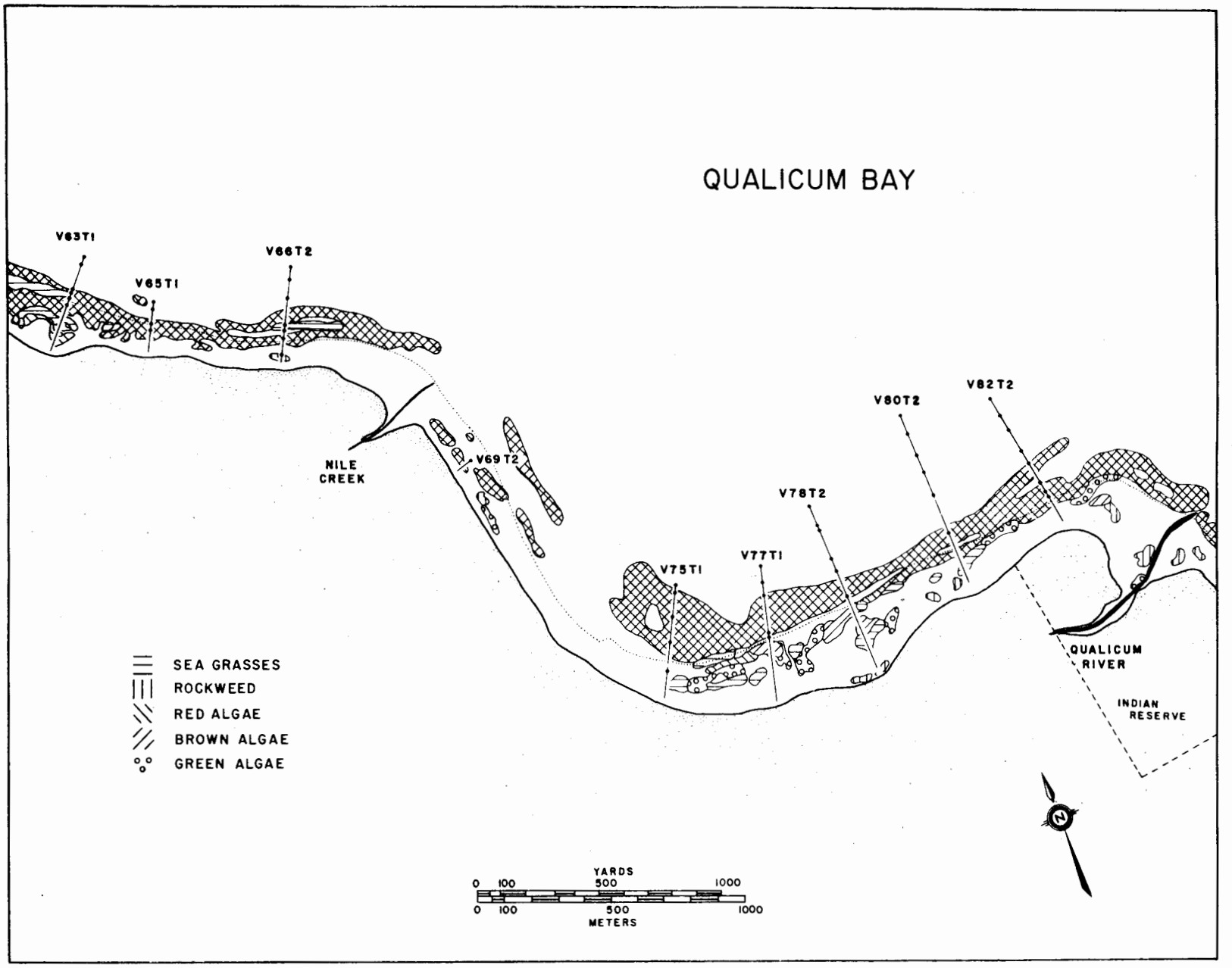

Fig. 4. Shoreline vegetation map from aerial photographs for Qualicum Bay. Diver survey transects and sampling stations are indicated.

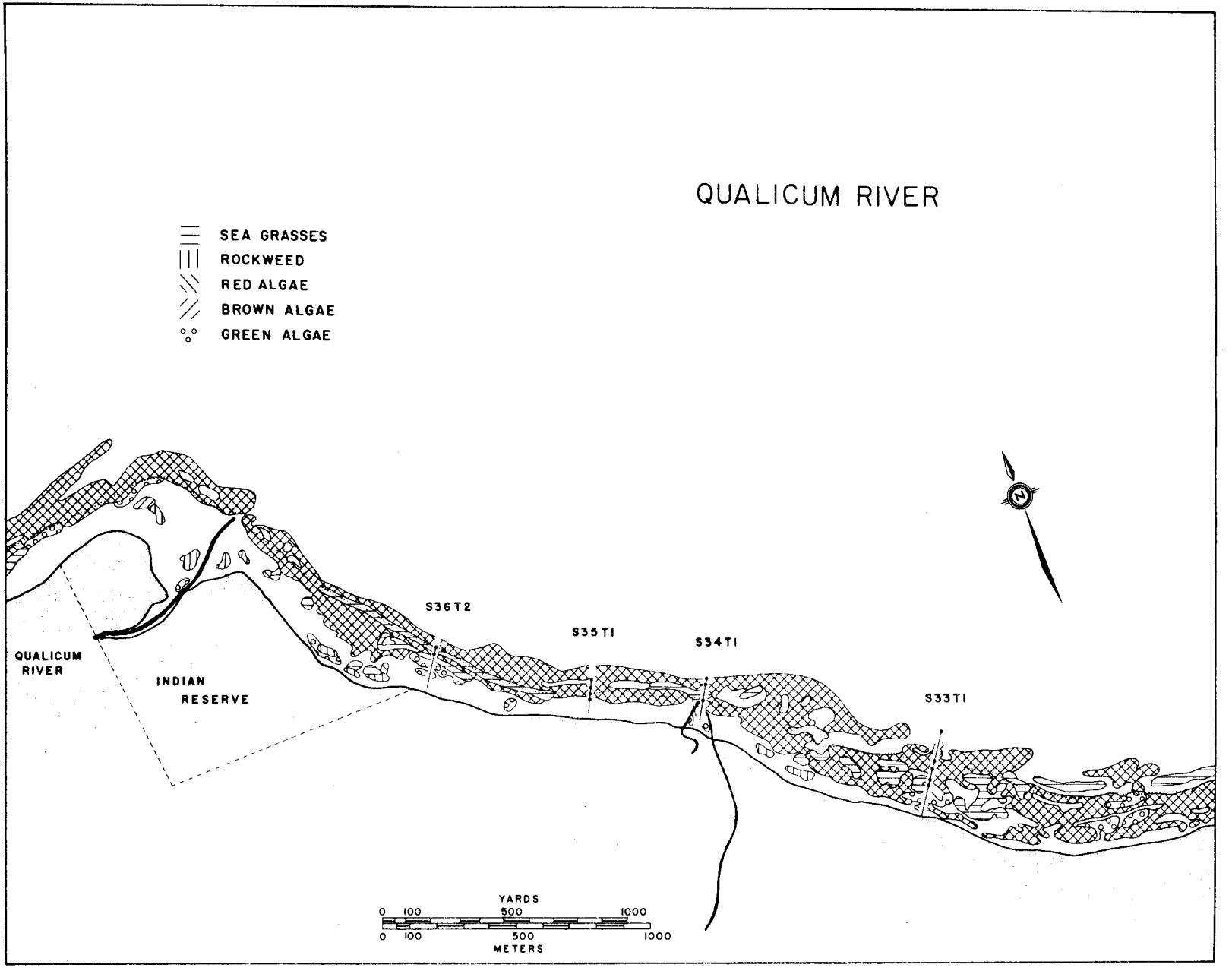

Fig. 5. Shoreline vegetation map from aerial photographs for Qualicum River. Diver survey transects and sampling stations are indicated.

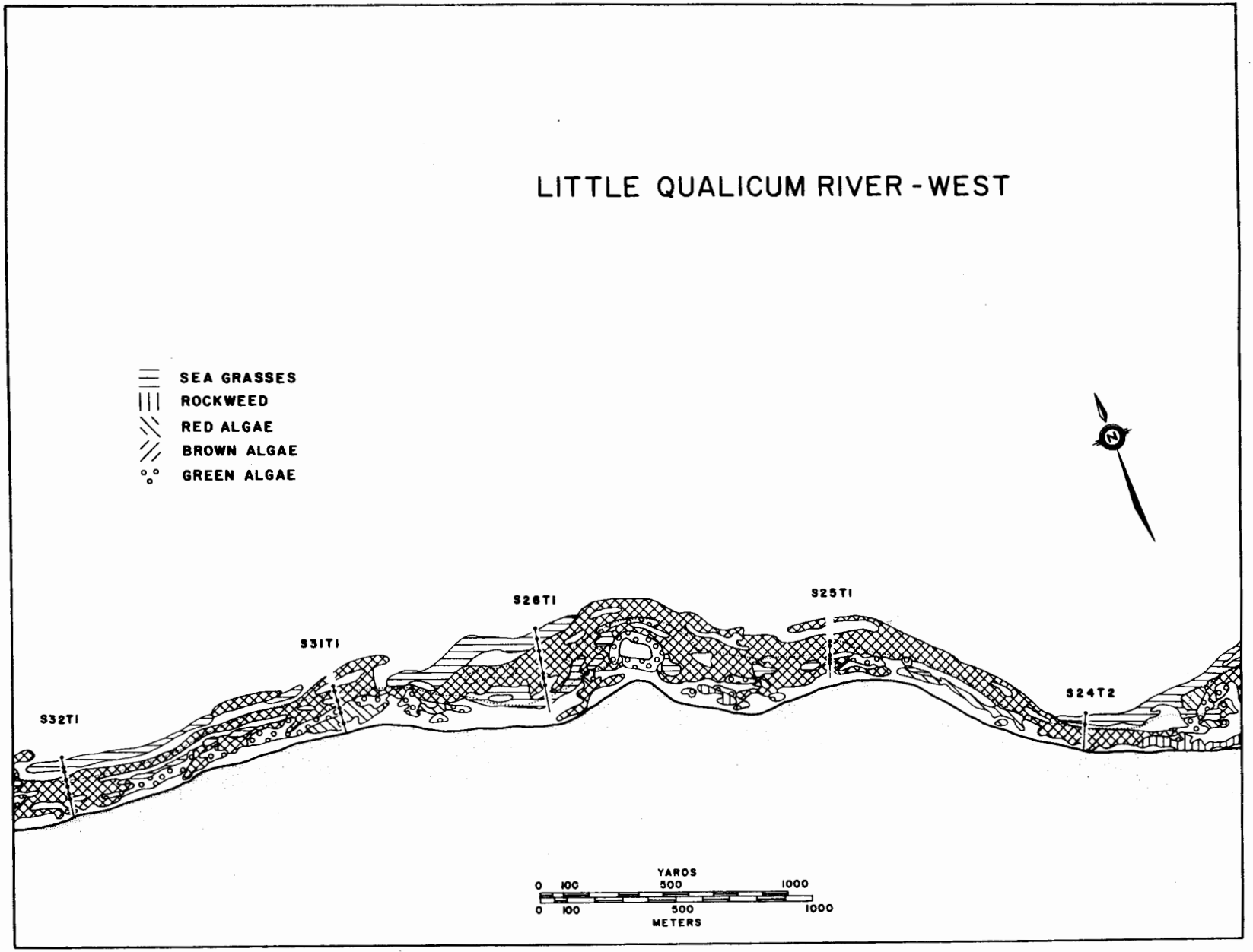

Fig. 6. Shoreline vegetation map from aerial photographs for Little Qualicum River - west. Diver survey transects and sampling stations are indicated.

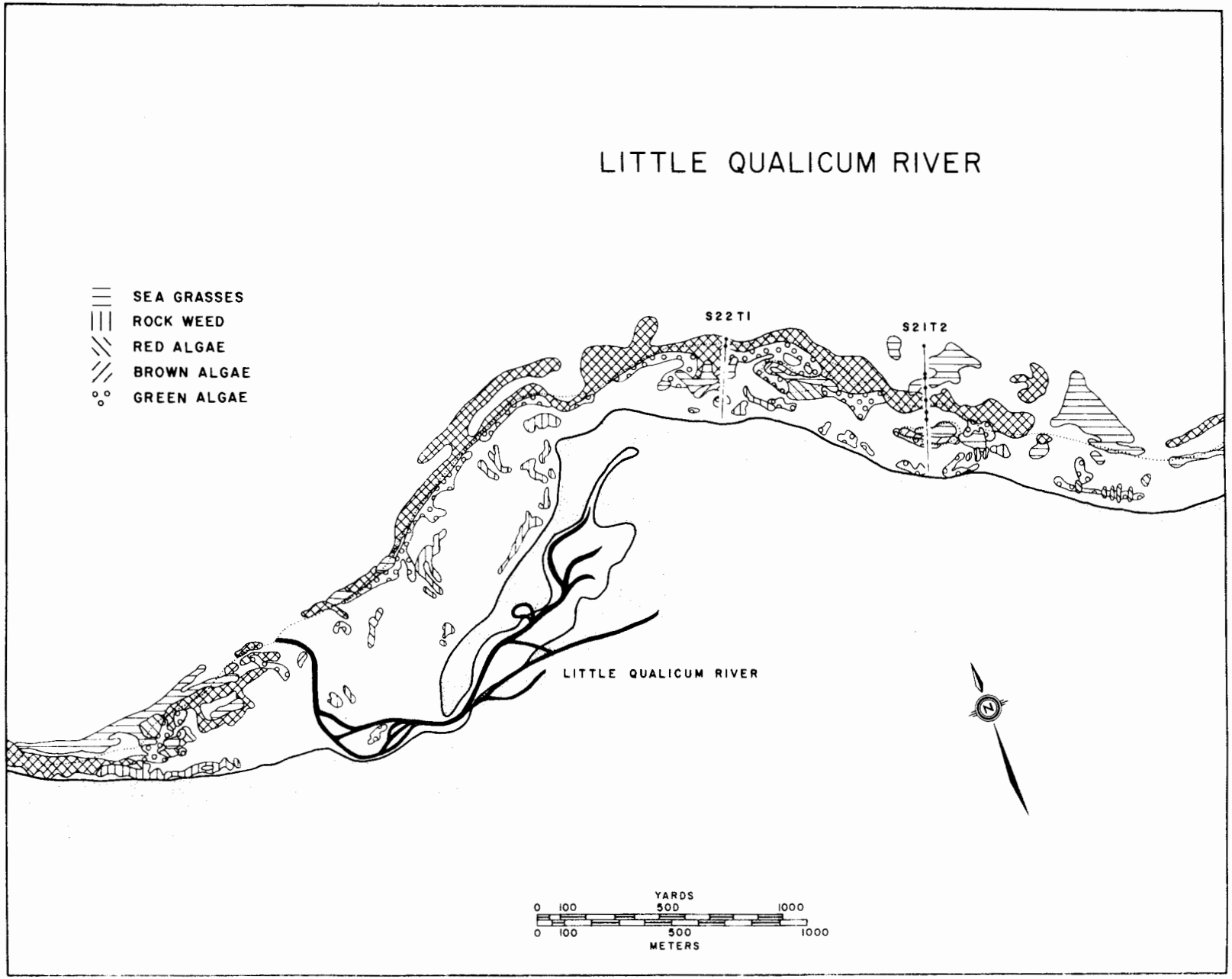

Fig. 7. Shoreline vegetation map from aerial photographs for Little Qualicum River. Diver survey transects and sampling stations are indicated.

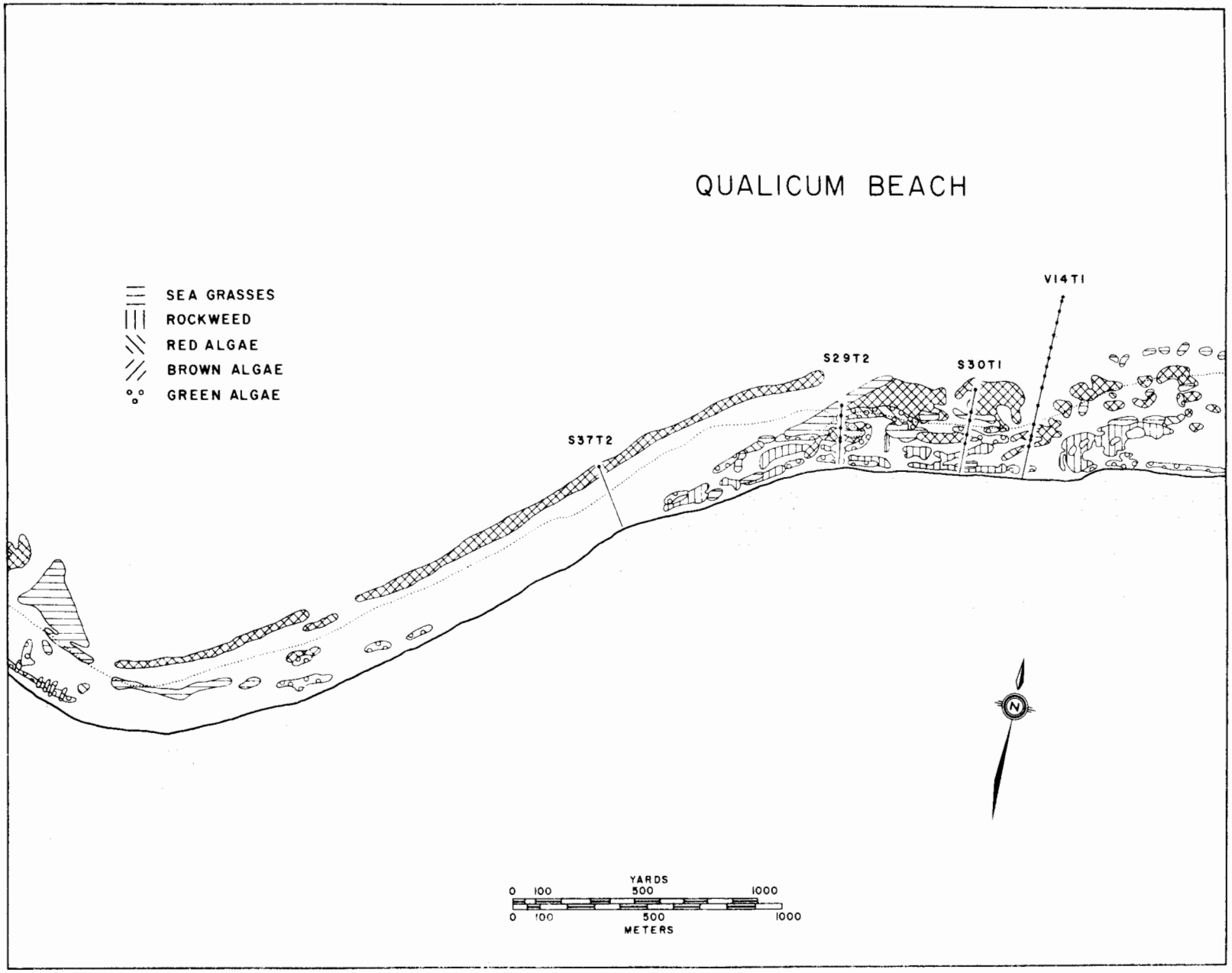

Fig. 8. Shoreline vegetation map from aerial photographs for Qualicum Beach. Diver survey transects and sampling stations are indicated.

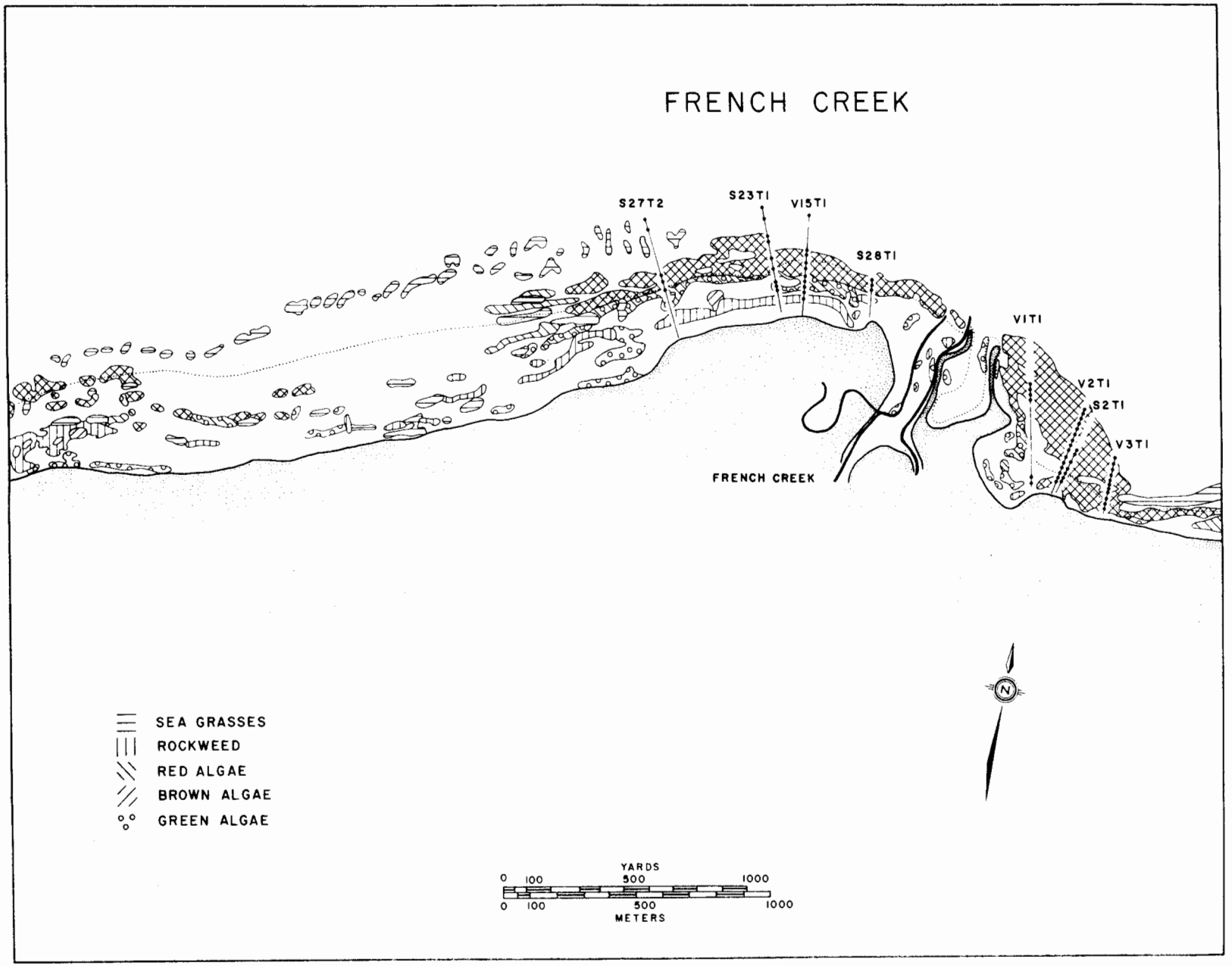

Fig. 9. Shoreline vegetation map from aerial photographs for French Creek. Diver survey transects and sampling stations are indicated.

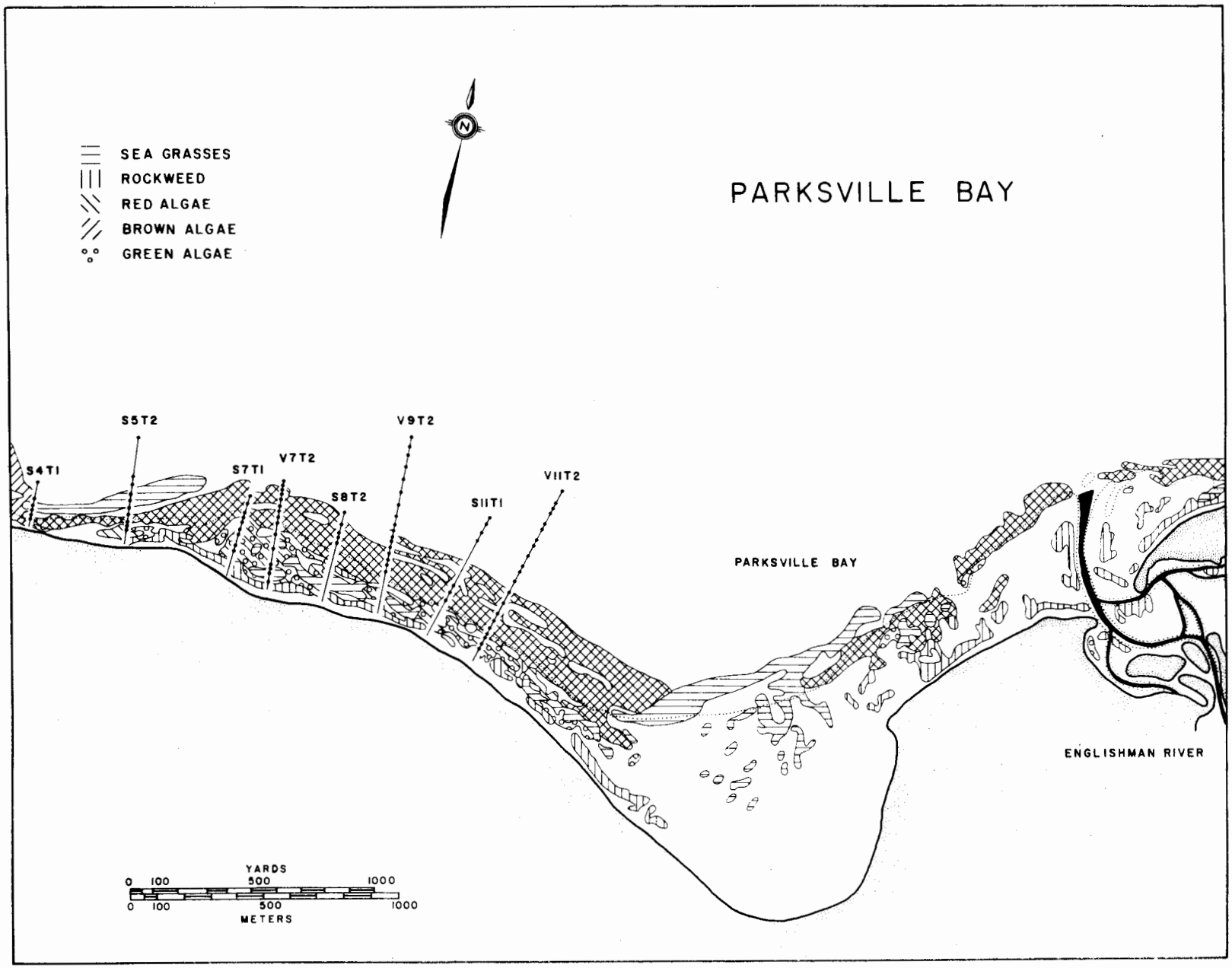

Fig. 10. Shoreline vegetation map from aerial photographs for Parksville Bay. Diver survey transects and sampling stations are indicated.

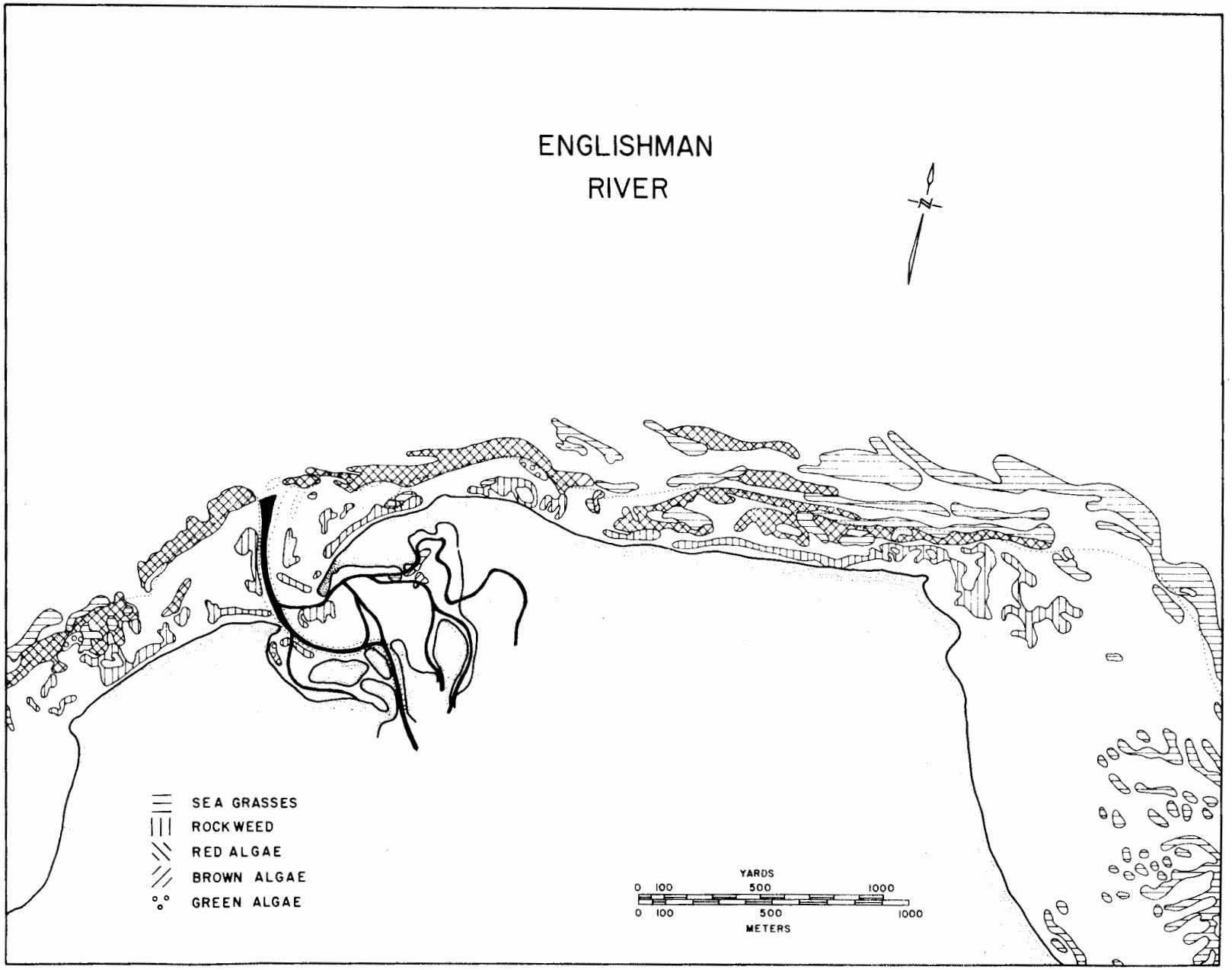

Fig. 11. Shoreline vegetation map from aerial photographs for Englishman River.

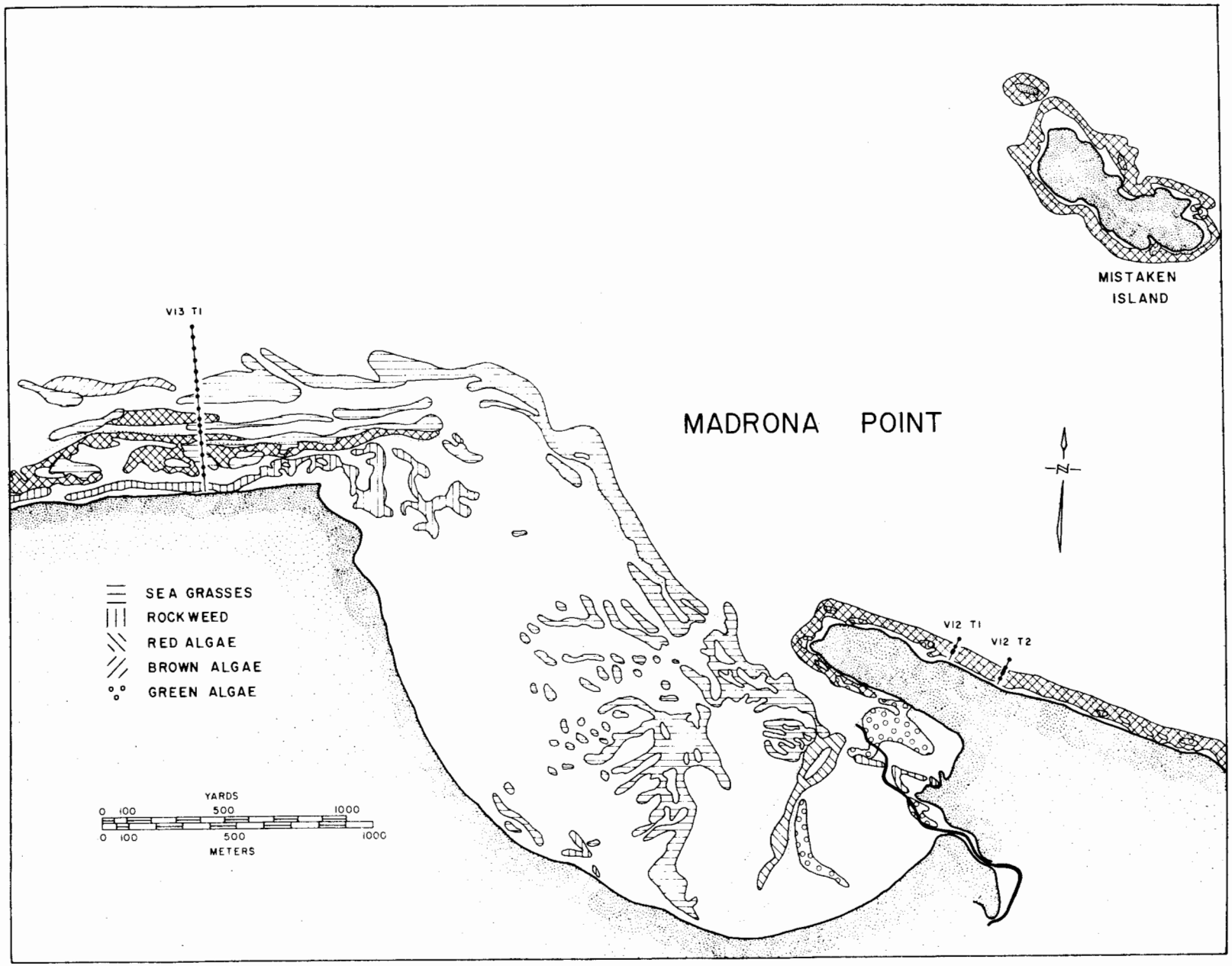

Fig. 12. Shoreline vegetation map from aerial photographs for Madrona Point. Diver survey transects and sampling stations are indicated.

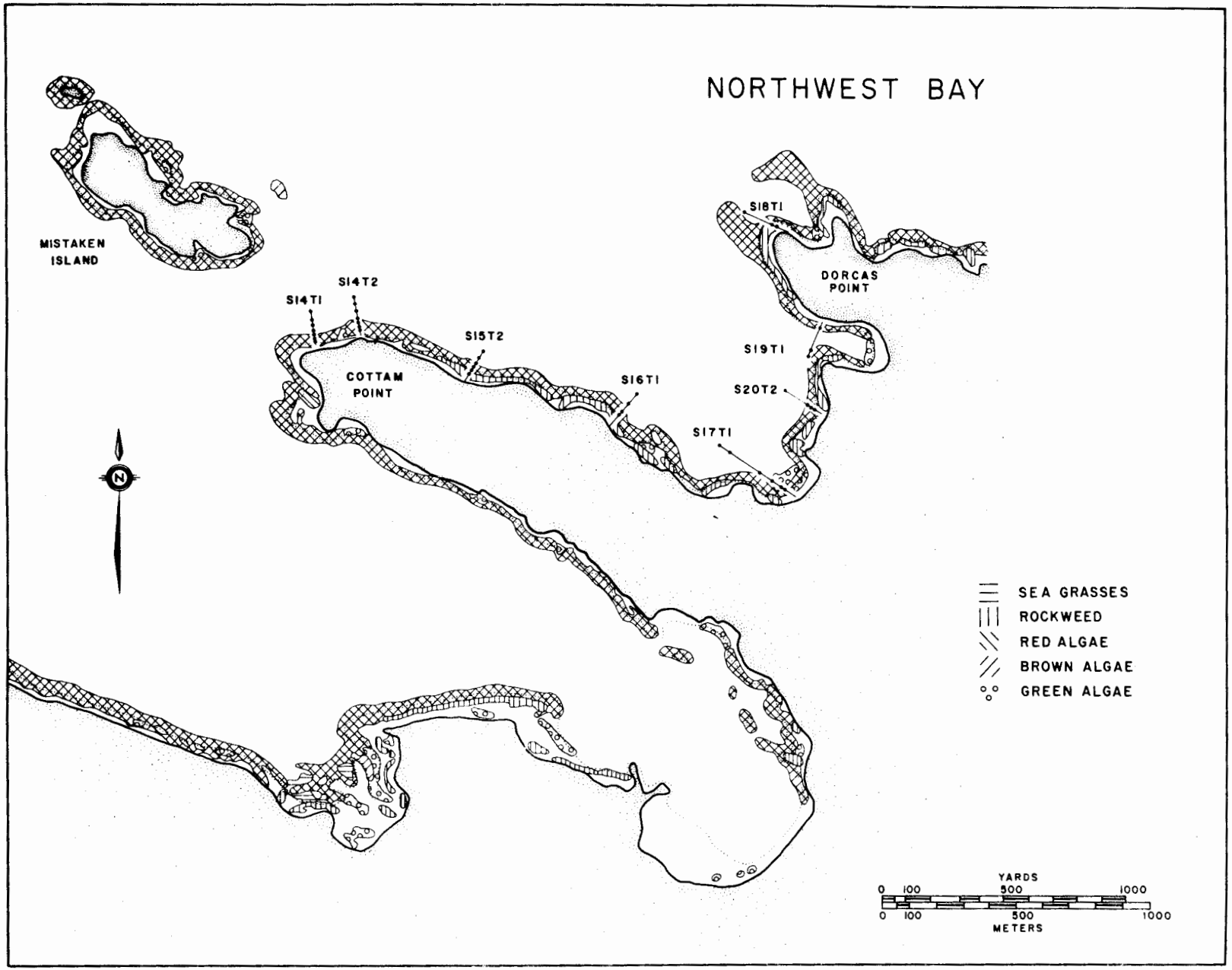

Fig. 13. Shoreline vegetation map from aerial photographs for Northwest Bay. Diver survey transects and sampling stations are indicated.