Observations of Abalone and Subtidal Communities Made During a Survey of the Queen Charlotte Strait and Upper Johnstone Strait Areas July 13-20, 1977.

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OBSERVATIONS OF ABALONE AND SUBTIDAL COMMUNITIES MADE DURING A SURVEY OF THE QUEEN CHARLOTTE STRAIT AND UPPER JOHNSTONE STRAIT AREAS, JULY 13-20, 1977.

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ABSTRACT

Breen, P. A., B. E. Adkins, and G. D. Heritage. 1978. Observations of abalone and subtidal communities made during a survey of the Queen Charlotte Strait and upper Johnstone Strait areas, July 13-20, 1977. Fish. Mar. Serv. Tech. Rep. 789: 91 p.

The research vessel CALIGUS was used from July 13 through 20, 1977; and examinations were made for abalone at 34 sites. Abalone were abundant in good commercial quantities at only two sites, but were marginally commercial at several others. The effect of harvesting was seen in the Port Hardy area, where densities are generally low; in addition, low juvenile numbers indicate slow recovery from fishing. Abalone were not found south of Malcolm Island in the areas surveyed, except for an isolated and self-sustaining population in Port Neville. Observations were made on the kelp communities present at each site, and are presented here.

RÉSUMÉ

Breen, P. A., B. E. Adkins, and G. D. Heritage. 1978. Observations of abalone and subtidal communities made during a survey of the Queen Charlotte Strait and upper Johnstone Strait areas, July 13-20, 1977. Fish. Mar. Serv. Tech. Rep. 789: 91 p.

Le bateau de recherches Caligus a servi du 13 au 20 juillet 1977; on a cherché des ormeaux dans 34 endroits. Ils étaient assez abondants pour l'exploitation à l'échelle commerciale en deux endroits seulement, mais on a trouvé des quantités presque exploitables commercialement en plusieurs autres endroits. On a observé l'effet de la pêche dans la région de Port Hardy, où les densités sont habituellement faibles; en outre, le faible nombre de jeunes montre un lent rétablissement. On n'a pas trouvé d'ormeaux dans les régions étudiées au sud de l'île Malcolm, à l'exception d'une population isolée et autonome à Port Neville. On a étudié le varech à chacun de ces endroits et les observations sont présentées ci-après.

INTRODUCTION

The B.C. fishery for abalone (Haliotis kamtschatkana Jonas 1845) suddenly expanded in 1976. Annual landings jumped to more than 600,000 lb (275 m.t.) from the previous average (1970-1975) of about 100,000 lb (45 m.t.).

This expansion was caused by the entry of a few large vessels into a fishery previously composed of small boats. The larger boats, with freezing equipment, were able to harvest abalone from the Queen Charlotte Islands and take it to Prince Rupert for shipment to Japan. Thus a shift in landings from the south coast to the north coast also took place.

In 1977 approximately 1 million lb (450 m.t.) were taken. The 1978 landings are expected to exceed 600,000 lb (275 m.t.). Because of the size structure of abalone populations (Quayle 1971; Miller, unpublished data; Adkins and Stefanson 1977; Adkins 1978), and because the fishery is operating in places not previously harvested, most of these landings represent accumulated stock. Abalone have relatively slow growth and recruitment (Quayle 1971; our unpublished data), so when the fishery reaches equilibrium, the annual sustainable yield per unit area will be considerably less than the initial yield.

Valuable information can be obtained from areas already harvested. In particular, the abundance of individuals less than legal size provides an indication of future prospects for harvesting. The purpose of this trip was to examine populations in the Queen Charlotte Strait and Johnstone Strait area. This report presents our observations of abalone populations, and also our notes on other species, especially large algae and sea urchins.

METHODS

Each day from July 13 through 20, we made from two to eight dives in the area from Shushartie Bay in Goletas Channel to Port Neville in Johnstone Strait. The three authors dove in rotation, with one always acting as diving tender. We chose dive sites within this area after talking with Fisheries people, fishermen, and biologists familiar with the area. At each site we swam to 10 m below chart datum, if possible, noting: substrate type and slope; the distribution and abundance of abalone and sea urchins; the dominant flora and fauna and their depth ranges; and other species. Depths were read to 1 ft (0.31 m) from a diver's depth guage that had been previously calibrated, then corrected to chart datum using the tide height at the mid point of the dive calculated from tide tables. ALL DEPTHS REPORTED ARE FEET BELOW CHART DATUM. Notes were made on plastic paper and transcribed on the same day at the surface. Organisms were either identified visually or were collected and brought to Nanaimo for identification. In the case of species such as Alaria, Laminaria, and Agarum, the genus could be positively noted but the species could not always be. It was frequently not clear whether there was one species or more than one; in the descriptions below only "sp." is used to indicate unknown species. Where "spp." is used, we are certain of more than one species. The specific name of species in monospecific genera (e.g. Nereocystis leutkeana) is given only on initial mention. Encrusting red algae resembling Lithothamnion spp. are referred to as "lithothamnion", and this term includes other species.

Where abalone were sufficiently abundant, we collected a sample for length measurements. However, we considered that where abalone were not abundant it was more useful to cover a larger area than to try to collect a sample from a smaller area. Abalone density was estimated visually, a practice justified by the low densities that we encountered in all but three places. At one such place, we measured density by counting the abalone found within a 1 m^2 quadrat in sequential transects.

RESULTS

The dive sites are shown in Fig. 1-6. We present below a summary of the observations on abalone; then descriptions of the sites we examined. Dive sites 16 through 28, at which only four abalone were seen during the course of 2 1/2 days' work, were chosen by an error: log sheets returned by a fisherman contained an ambiguity (later corrected) that led us to believe there were commercial quantities of abalone in the area, when in fact there were not.

ABALONE

The estimated density and size range of abalone seen at each site are shown in Table 1.

One of our two dives in Goletas Channel revealed a population with commercial size and abundance, and several of the sites in the Deserters, Walker, Gordon, and Masterman Groups had enough abalone to support harvesting (and in fact harvesting later took place in this general area). In the huge kelpbeds south of Port Hardy and on the west end of Malcolm Island, however, we failed to find anything like the abundance of abalone that had been reported to exist in the past.

It was difficult to find juveniles, although we spent considerable time on each dive looking in crevices and under rocks. Juveniles were abundant at Shushartie Bay, where we found a population entirely composed of sub-legals (Fig. 8). Most of these individuals were on the surface of a vertical wall of rock. They were most abundant near datum but extended to 5 m. D. B. Quayle has told us that he found a very similar population here 15 yr ago. Although the absence of legal-sized abalone might have been caused by harvesting, or by the predatory activities of the numerous Octopus dofleini we found here, it is more likely that the exposure of this site prevents abalone from ever reaching legal size.

Juveniles were also abundant on the Nigei Island side of Goletas Channel (Fig. 9), and here they formed part of an abundant commercial population. In the rest of this area, however, juveniles were extremely

Table 1. Estimated density and size range of abalone seen at dive site. Density was estimated visually except at site 29; sizes were also estimated except where noted.

Site No.	Figure No.	General Location	Abalone density	Abalone size
			Walker and Deserters Groups	
1	1	islet in Walker Group	0-5/m^2 highly variable	almost all around legal size
2	1	Shelter Passage	0-5/m^2 highly variable	all around legal size
3	1	Kent Is.	< 10 seen in 45 min	all legal
4	1	Deserters Is.	1/m^2 average within Pterygophera bed	mostly legal, to approximately 130 mm
5	1	Walker Group	none	--------
6	1	McLeod Is.	1/m^2 in scattered patches, especially at 4 m depth	all just below legal size. See Fig. 7.
			Below Port Hardy	
7	2	Keough Shoals	none	--------
8	2	False Head	< 10 seen during dive	all legal, largest 139 mm
9	2	Eagle Is.	1/m^2, variable	all near legal size
10	2	Deer Is.	1/m^2	all legal

Table 1 (cont'd)

Site No.	Figure No.	General Location	Abalone density	Abalone size
			Goletas Channel	
11	3	Shushartie Bay	1-5/m^2	all sublegal. See Fig. 8
12	3	Nigei Is.	0-5/m^2, average about 1/m^2	mixed, see Fig. 9
13	1	off Harlequin Bay	1-2/m^2, variable	all near legal size
14	1	off Bell Is.	consistent 0.5/m^2	30 mm to legal size, most near legal size
15	2	Malcolm Is. w. side	2 seen in 10 min	approximately 120 mm
16-22	4	(mouth of Knight Inlet)	4 seen in 7 dives	all near legal size
23-28	5	(above Harbledown Is.)	none	--------
			Port Neville	
29	6	Cuthbert Rock	to 10/m^2	all sizes, see Fig. 10, 11
30	6	Channel Rock	none	--------
31	6	Port Neville	none	--------
32	6	Port Neville	approximately 10 seen in 20 min	all near legal size
33	6	Port Neville	none	--------
34	6	Milly Is.	2 seen in 60 min	both legal

scarce. The patchy populations in the Deserters and Walker Groups had almost none, and we found none in the large kelpbeds off the airport at Port Hardy and off Malcolm Island. We presume that there were once much more abundant populations of adults in these areas, and the present lack of recruitment indicates a disappointing failure of the abalone beds to recover from harvesting.

The absence of abalone in the area of dives 16-28 (Fig. 4, 5) is puzzling. There was kelp throughout the area, Laminaria spp. growing abundantly where floating kelps were absent (Fig. 26-33). We found red sea urchins wherever there was strong tidal current or exposure to the Sound, but there were no abalone except four seen at Kate Islet.

At Port Neville (Fig. 6) we found an abundant and apparently vigorous population in the narrows around Cuthbert Rock. This rock, the boulders near it and the opposite shore were populated by clusters of large abalone, whose shells were very heavily encrusted with lithothamnion. It was obvious from their distribution that some harvesting had taken place. We found juveniles both on Cuthbert Rock (Fig. 10) and on the shallow floor of the narrows (Fig. 11), where they were present on cobbles and in empty butter clam shells. The average density on Cuthbert Rock was $1.7/m^2$.

We examined several locations between the narrows and the mouth of Port Neville (Fig. 6). There were a handful of abalone on one point about halfway to the mouth. There were none on Channel Rock, which is similar to Cuthbert Rock except that it lies on coarse sand instead of gravel and cobbles. F. R. Bernard (personal communication) and fishermen have told us that once abalone were very abundant on Channel Rock. We saw only two on Milly Island, outside Port Neville.

These observations imply that the recruits for the large population in the narrows at Port Neville must be supplied by the population itself. This is unlike other populations, where tidal movements must carry away most of the veligers produced by abalone at any one spot, and where most of the recruits to any spot must therefore be the product of abalone on a different part of the shore.

GENERAL OBSERVATIONS

We determined the vertical distribution of each species that was dominant in abundance. Where the kelp formed several layers, we tried to record the dominant in each layer. This information is summarized for most sites in profiles of the type shown in Fig. 12. This figure is a key showing symbols used for various dominant species. These profiles are a more compact way of describing the communities than the narrative reports, in which the list of species present tends to obscure the physical importance of the few dominants.

WALKER AND DESERTERS GROUPS. DIVES 1-6

These groups lie in a moderately exposed location, feeling the effects of swells from Queen Charlotte Sound and southeast winds coming up Queen Charlotte Strait. However, within the groups there are sheltered locations, such as Site 5 (Fig. 1). There is noticeable tidal action around and within the groups.

Except for Site 5, we found communities that seemed typical of moderate exposure. The lower intertidal zone supported Mytilus californianus and Balanus cariosus; Hedophyllum sessile, Egregia menziesii, Alaria sp. and Phyllospadix scouleri. In the upper subtidal zone, Nereocystis luetkeana formed a canopy above a mixture of Alaria sp., Costaria costata, Laminaria sp., Cymathere triplicata, Desmarestia ligulata var. ligulata and D. viridis and at Site 4 Pterygophora californica. The lower limit of kelps was set by Strongylocentrotus franciscanus, although patches of kelp could be found among the sea urchins; and Agarum fimbriatum and A. cribrosum were present deeper. The rock surface itself was covered with lithothamnion and colonies of the colonial polychaete Dodecaceria fewkesi, the former up to 80% cover and the latter more abundant in deeper water, up to 50% cover. The grazers Acmaea mitra, Collisella ochracea, Amphissa columbiana, Tonicella lineata, Tegula pulligo , and Calliostoma ligatum were all numerous (at least $1/m^2$), and pagurid crabs living in sponges were common. Groups of unidentified sponges and the anenome Metridium senile were seen in deeper water, the cup coral Balanophyllia elegans was present at each site except 5, beginning about 10 ft below datum. Unidentified porpoises were common between the Deserters and Gordon Groups, and on two trips we saw a minke whale (identified by Mike Bigg, from a photograph) in the Gordon Group.

Site 1. Islet off Kent Island, Walker Group

The substrate at this site was gently sloping (approximately 15°) bedrock, with undulations, boulders, and patches of shell/sand (Fig. 13). The upper intertidal zone was dominated by Mytilus californianus and Balanus cariosus; the lower part by the algae Hedophyllum, Alaria sp., Laminaria sp., Costaria, and Cymathere. There was a narrow band of Phyllospadix at datum.

In the upper subtidal zone there was a canopy of Nereocystis and Egregia, beneath which we found an understory of Agarum sp. (mostly A. fimbriatum) and Desmarestia viridis; and under these a turf of erect corallines and polysiphonous reds. At 6 ft below datum, this group of algae gave way to S. franciscanus, which continued to 40 ft. The red sea urchin distribution was very patchy, and there were large areas with none. Density was greatest ($5/m^2$) near the kelp, and decreased in deeper water. S. droebachiensis also occurred in this area at about $3/m^2$.

At depths between 11 and 25 ft there were patches of Alaria spp., Laminaria spp., Nereocystis, Agarum spp., and Desmarestia viridis. The Nereocystis in these situations was more abundant than that in the shallow zone. There was a gradual increase in algal cover with depth, and an increase in the proportion of Agarum spp., until at 40 ft Agarum formed about 50% of the cover.

The abundant fauna were those grazers already mentioned plus Diadora aspera, Balanophyllia at about $5/m^2$ in the sea urchin zone and deeper, and the asteroids Solaster sp., Pycnopodia helianthoides, Evasterias troschellii, Orthasterias koehleri. The abalone that we saw were all in the shallow kelp zone or in the upper sea urchin zone.

Site 2. Shelter Passage

We dove around a drying rock lying off Staples Island. The substrate was steep bedrock (from 20° to sheer), either smooth or broken into large rectangular blocks; changing to shell/sand at depths ranging between 20 and 30 ft below datum (Fig. 14).

The intertidal zone was the same as Site 1. The subtidal kelp zone was narrow, ending at 4-6 ft below datum. It was composed again of the species listed for Site 1, in variable proportions. The red turf underneath contained abundant *Polyneura latissima* Below the kelp, *S. franciscanus* began at 10-25/m^2, and were still at 2-5/m^2 at the bottom of the bedrock. There were several early year-classes present, and approximately half the sea urchins were less than legal size (100 mm). Again there were substantial patches of kelp within the sea urchin zone, containing *Nereocystis* that reached the surface, *Costaria*, *Desmarestia ligulata* var. *ligulata* and *D. viridis*. Below 15 ft, the patches contained *Agarum* sp.

The surface of the bedrock itself was covered with lithothamnion at about 80% cover, with *Dodecaceria* increasing with depth, especially on the sheer wall. From the shells of two abalone that were collected, we identified *Lithothamnion pacificum* and *Lithophyllum* sp. The fauna were similar to Site 1, except that here *Parastichopus californicus* occurred at 1/m^2 (it was not present at Site 1), and we noted many *Cryptochiton stelleri* during the dive.

Site 3. Kent Island

At this site the solid bedrock descended very steeply in stepwise manner to a sand/shell floor at 34 ft below datum (Fig. 15). The subtidal kelp fringe was again narrow, ending at 4-7 ft below datum. It consisted of abundant *Nereocystis*, under which grew *Pleurophycus gardneri*, large *Cymathere* and *Desmarestia ligulata* var. *ligulata*. *S. franciscanus* began at densities of 10-25/m^2, which decreased to about 2/m^2 at the bottom of the bedrock. Patches of kelp within the sea urchin zone included *Costaria*, *Nereocystis*, *Laminaria* spp. and *Desmarestia* spp. There was no turf: erect corallines were present but not an appreciable part of the cover; the same was true of isolated patches of polysiphonous reds. The rock itself was heavily covered with lithothamnion and *Dodecaceria*; also with encrusting red algae resembling *Hildenbrandia*. The sand/shell floor supported *Nereocystis* growing from shells to the surface, and very large *D. ligulata* var. *ligulata*, also *Costaria* and *Laminaria* spp.

The abalone we saw were on the upper part of the wall, just below the kelp zone. The fauna was as described above, but with *Balanus nubilus* at densities of 0.5/m^2, a few scattered *Hinnites giganteus*, and aggregations of *Metridium* reaching 1 m in length.

Site 4. Deserters Island.

The substrate here was solid bedrock descending steeply in steps (Fig. 16) to unknown depths. In the parts with shallow slope were boulders. The lower intertidal zone supported *Hedophyllum* and *Phyllospadix*, then began a three-layered community with dense *Nereocystis* and *Pterygophora*, and a light understory of *D. ligulata* var. *ligulata* and polysiphonous reds. *Nereocystis*, *Desmarestia*,and polysiphonous reds also occurred in patches to 22 ft.

S. franciscanus began at 7 ft and continued to 27 ft with a density about 5/m^2 at the top of their zone. The rock surface in the sea urchin zone was 90% covered with lithothamnion, giving way to some *Dodecaceria* below 12 ft.

Erect corallines were present but not abundant. All the abalone that we saw were in the Pterygophora forest. The rest of the fauna was as described above, except that from about 20 ft into deeper water, large yellow unidentified sponges became abundant, perhaps covering 10% of the rock surface.

Site 5. Between Kent and Staples Islands

We entered the water in a small bay on the side of the channel between the large islands. There was a strong current running in the centre of the channel even though the tide was almost full. The shallow floor of the bay was covered with sand/shell and boulders, the latter covered with large and dusty Alaria sp., Costaria, Cymathere, and Laminaria sp.

Towards the channel, erratic groups of S. franciscanus appeared on bare rock; between such groups the kelps just named descended from the intertidal zone to the sand/shell. Further still towards the channel, Nereocystis appeared. The rock surface itself was covered with lithothamnion at about 50% cover, Dodecaceria were present but not important, and Spirorbis sp. were very numerous. Large Metridium and Fusitrition oregonensis were common, Pycnopodia were present at up to $0.1/m^2$, and Parastichopus at $0.2/m^2$. From the kelp we collected the scyphomedusa Haliclystis salpinx.

Site 6. McLeod Island

We dove in the channel between McLeod and Deserters Islands. The substrate varied greatly in shallow water, from solid bedrock plunging straight down, to gently sloping sand/shell with boulders. On the sheer wall we found Costaria and D. ligulata var. ligulata to about 7 ft below datum, where patches of S. franciscanus began. At 16 ft on the wall were small acorn barnacles (unidentified, but not B. glandula), small Agarum sp. and patches of ulvoids. Where the slope was slightly undercut, the cover was 100% Metridium. Where the substrate was flat bedrock, we found three different types of algal groups in the upper subtidal area. The first was Nereocystis growing to 8 ft, with a dense understory of Costaria. The second was 100% cover of Botryoglossum farlowianum, and the third was 100% cover of Ulva sp.

Below 15 ft, both the substrate and algae became more uniform: the bedrock descended steeply in large blocks to at least 60 ft and was dominated by Agarum spp. It seemed that A. cribrosum became relatively more abundant with depth, but this was not measured. The rock itself was covered with both lithothamnion and Dodecaceria, and S. franciscanus remained patchy at densities around $2-5/m^2$. We found abalone from near the intertidal zone down to 50 ft, but they were most abundant near the top of the sea urchin zone. Tonicella lineata were extremely abundant at $10-30/m^2$.

Site 7. Keough Shoals

The level bottom here consisted of cobbles and boulders on sand 16 ft below datum. A thick canopy of Macrocystis integrifolia covered most of the area. An understory of Pleurophycus, Costaria, Desmarestia viridis, and Agarum sp. formed 75% cover. These species extended out from under the canopy, and Laminaria spp. occurred there as well (Fig. 17). All the individual kelp plants were large compared with those seen elsewhere. Beneath the kelps was a turf formed by Plocamium pacificum var. pacificum, Polysiphonia sp., Botryoglossum farlowianum, and Bossiella californica spp. schmittii.

On the sand surface we noted the starfishes Pycnopodia and Solaster sp., and shells of Tresus spp. and Saxidomus giganteus. On the rocks were Fusitriton, Acmaea mitra and Tegula pulligo. The grazers Calliostoma ligatum and Amphissa columbiana were abundant on the kelp surfaces. We saw no abalone or sea urchins in this area.

Site 8. False Head

This site was similar to Keough Shoals, but was more shallow (Fig. 18). There was a dense surface canopy of Macrocystis, under which Costaria, Alaria spp., Desmarestia ligulata var. ligulata, and Laminaria sp. formed 60% cover. The understory species formed 100% cover where there was no surface canopy. Beneath the understory kelps were Odonthalia kamtschatkana, Bossiella californica ssp. schmittii, and B. orbigniana ssp. orbigniana.

The abundant fauna were Cucumaria miniata, Parastichopus, and Tresus sp. Only one group of S. franciscanus was seen, all on the same rock.

Site 9. Eagle Islet south of Deer Island

The substrate was craggy, undulating bedrock strewn with boulders, descending at variable angles to sand/shell at 26 ft below datum (Fig. 19). From the intertidal zone to 4-8 ft there were two types of cover: a turf of Odonthalia kamtschatica, Desmarestia viridis, and ulvoids not identified; alternating with dense Laminaria saccharina and a turf of Bossiella californica ssp. schmittii and Calliarthron regenerans. From 4-8 ft down to 18 ft, Nereocystis formed a dense surface canopy, under which grew Alaria spp., Laminaria saccharina, Costaria, and Cymathere at about 50% cover. Agarum spp. appeared at 12 ft and continued out from under the canopy to the bottom of the rock slope. Again it appeared that A. cribrosum was dominant in the deeper water, but we didn't measure this. The rock surface itself was covered mostly with thick hummocked colonies of Dodecaceria, which formed 80-100% cover in the upper subtidal zone and decreased with depth. Hildenbrandia-like encrusting red algae were abundant; lithothamnion was present but not important.

S. franciscanus began at 14 ft and continued to the bottom of the rock slope, but were widely scattered and much less than $1/m^2$. The most abundant animal among the kelps was Cucumaria lubrica, which formed 100% cover in patches. The abalone were variable, but probably averaged nearly $1/m^2$ among the Nereocystis.

Site 10. Deer Island

This site had smooth bedrock descending gently at first, then more steeply, and was broken into boulders at the foot (Fig. 20). The lower intertidal zone supported Egregia, Alaria sp., and Phyllospadix. From 1 ft above datum to about 7 ft was a surface canopy of Nereocystis; beneath this an understory of Cymathere from 50-100% cover. Macrocystis, Laminaria sp., and Desmarestia ligulata var. ligulata were all present but were not abundant enough to be important in the understory. At depths beneath the Nereocystis were three types of community: barren rock with S. franciscanus; patches of D. ligulata var. ligulata at 100% cover; and a mixture of Agarum sp. and Laminaria sp. Toward the bottom of the rock slope, Agarum sp. dominated everywhere. The rock surface was dominated covered with a mixture of lithothamnion and Dodecaceria. As at Eagle Islet, abalone were variable in density and most were under the Nereocystis canopy, at about $1/m^2$.

Site 11. Shushartie Bay

The substrate was vertical bedrock to about 25 ft, then a gradually sloping shell/sand bottom overlain with boulders and smaller stones (Fig. 21). Both the location of the site, exposing it to ocean swells from the southeast and northwest, and the organisms observed here, suggested that the site was moderately exposed.

The lower intertidal zone was dominated by Alaria sp. and Egregia, under which B. cariosus dominated the rock surface. In the narrow vertical zone from datum to 8 ft were Nereocystis, Costaria, Desmarestia ligulata var. ligulata, and Laminaria sp., all forming a dense cover. Under these were erect coralline red algae, and the remaining rock surface was covered with Dodecaceria. S. franciscanus began at the bottom of the kelp zone, in densities varying from 2 to $25/m^2$, and continued at reduced densities as far down as we swam. A high proportion of the S. franciscanus population was in the first three year classes. Large S. droebachiensis were also abundant at the bottom edge of the kelp zone.

Where the rock wall was incurved, Metridium senile dominated the surface. Elsewhere, lithothamnion and Dodecaceria formed the primary cover, with Balanophyllia also a forming a significant cover. Abalone density was $1-5/m^2$. They appeared to be most numerous just below the kelp zone, but they may have been equally abundant among the plants, where it was difficult to search. They were all less than legal size (Fig. 8).

Site 12. Nigei Island shore, Goletas Channel

The substrate at this site was bedrock sloping easily to datum, then cobble and boulders on a sand/shell floor sloping gently (Fig. 22). Fucus distichus and Iridaea sp. dominated the mid-intertidal zone, with Egregia forming a narrow band in the lower intertidal zone. Ulvoids and bladed reds dominated the area from datum to 3 ft, where a luxuriant kelp bed began and continued to 8 ft. This was dominated by a thick canopy of Nereocystis above, and dense Cymathere below, with some Costaria and D. ligulata var. ligulata also present. The rock surface was covered by thick lithothamnion.

S. franciscanus began at 8 ft in densities of about $2-5/m^2$, but their abundance tapered off quickly after several feet of depth and Agarum sp. dominated the bottom below 15 ft. Cucumaria miniata were very abundant in the sea urchin zone, and their tentacles formed about 50% cover.

Abalone were large (Fig. 9), gregarious, and irregularly distributed, mostly under the kelp canopy. Their density averaged nearly $1/m^2$.

Site 13. Harlequin Bay

This site was an exposed rock at the mouth of Harlequin Bay. The substrate was bedrock sloping steeply to 10 ft where it changed to sand/shell sloping gradually into deep water. Vertical rock faces occurred on large rocks to a depth of 30 ft (Fig. 23).

Mytilus californianus, Balanus cariosus, and a small unidentified orange anemone were dominant in the upper intertidal zone. Pleurophycus, Laminaria spp., and Ulva sp. were dominant in the lower intertidal zone to 3 ft below datum.

Nereocystis and Egregia formed a canopy between 3 and 5 ft. A narrow band of S. droebachiensis occurred at 5 ft and a wide band of S. franciscanus began below. Neither sea urchin was abundant. Metridium was abundant between 14 and 23 ft, covering up to 90% of the vertical rock surfaces. Abalone were present between 5 and 23 ft. Distribution was patchy with densities ranging from $2/m^2$ at the kelp-sea urchin interface to $1/m^2$ at 23 ft. Most of the abalone were of sub-legal size.

Site 14. Bell Island

The substrate at this site was steeply sloping bedrock with scattered boulders (Fig. 24).

Pterygophora, Alaria sp., B. cariosus and Katharina tunicata were abundant to a depth of 2 ft below datum. Nereocystis formed a canopy between 2 and 6 ft under which grew Codium setchellii and small patches of Laminaria sp., and Pleucophycus. At 6 ft these species stopped and Agarum sp. became the dominant cover. Beneath the kelps, Spongomorpha coalita, Callophyllis heanophylla, and Bossiella californica ssp. schmittii formed the understory.

S. franciscanus began at a depth of 6 ft, but maximum density was estimated to be only $0.4/m^2$. Parastichopus, S. droebachiensis, and large beds of Metridium occurred at depths below 23 ft.

Abalone density was $0.4/m^2$ between 2 and 20 ft. Only a narrow size range of abalone was apparent at this site; most being slightly less than legal size.

Site 15. Malcolm Island

Only a short dive was made here. At this site the substrate ranged from boulders to sand (Fig. 25). The bottom was level and between 15 and 17 ft below datum.

A dense canopy of Nereocystis, at least 400 m wide, covered the area. The Nereocystis plants varied from $0.25/m^2$ to $1/m^2$. Attached to small rocks and shells below the canopy, Cymathere was most abundant, with Costaria and Laminaria sp. occurring as well. Beneath the kelps on larger boulders were Calliarthron regenerans, Polysiphonia sp., and Plocamium coccimium var. pacificum.

Abalone were widely scattered individuals of large size. The grazers Acmaea mitra and Tonicella lineata were abundant.

Sites 16, 18, and 19. Evening Rocks, Kate Islet, and Coach Islet

These sites were similar, all being exposed to swells from Queen Charlotte Strait. They were solid bedrock sloping at about 45° to a shell/sand bottom at 20-25 ft (Fig. 26 and 27). The intertidal zones were dominated by barnacles (B. cariosus), chitons (T. lineata, Mopalia lignosa, and Katherina tunicata), limpets (Notoacmaea scutum, Collisella ochracea, and A. mitra), and whelks (Thais emarginata and T. lamellosa).

At both sites, Alaria sp. dominated the lower intertidal zone. Sparse Nereocystis began at about 2 ft, with a sparse cover of D. ligulata var. ligulata beneath. At about 5-7 ft, macrophytes ended, and S. franciscanus began at densities of about $5\text{-}10/m^2$. In deeper water where sea urchins were not numerous grew Agarum sp. and stunted Nereocystis. The rock surface itself was covered with lithothamnion and dense thick colonies of Dodecaceria. At sites 18 and 19, S. droebachiensis were at $2/m^2$ among the upper S. franciscanus.

Only four abalone were seen, all at site 16.

Site 17. Fog Islets

The substrate was bedrock curving off at various angles to a sand/shell floor at a depth of 25-30 ft. Intertidally Alaria sp. and Hedophyllum formed a dense cover.

At 3 ft below datum Laminaria sp. and Costaria began, and extended down to the sand/shell floor. A canopy of Nereocystis began halfway down the slope, ending at a depth of 20 ft. These plants were of varying heights, and few reached the surface. Laminaria sp., Costaria sp., Alaria sp., and Ulva sp. were abundant in the understory beneath the canopy. On the more exposed side of the islet, Pleurophycus was most abundant species below the Nereocystis canopy.

There were no sea urchins and no abalone.

Sites 20 and 21. Sunday Harbour and Spiller Passage

These sites were both protected, and solid rock met shell/sand or mud at 5-10 ft (Fig. 28 and 29). The intertidal zone supported dense Fucus and ulvoids. Laminaria sp. was dominant in the subtidal zone of both places, mixed with Cymathere at Site 20. Nereocystis grew from boulders in deeper water at Site 20 also.

No abalone or red sea urchins were found at either site. At Site 21, we noted that Calliostoma ligatum obtained densities of more than $100/m^2$ on the kelps, and that the gastropods Thais lamellosa, Bittium eschrichtii, Collisella ochracea and Ceratostoma foliata were abundant at both sites. The asteroids Pycnopodia and Evasterias were also numerous.

Site 22. Eden Island

This site was a submerged rock on the south side of Eden Island. The substrate was solid, sloping at 30° to 23 ft where it levelled off at a sand/shell floor (Fig. 30). From datum to 6 ft, Ulva spp. were the dominant cover. Costaria sp., Desmarestia spp., Agarum sp., and Porphyra sp. formed a light cover between 3 and 6 ft. At 6 ft, a few S. franciscanus were found.

A canopy of Nereocytis grew from 8 to 13 ft. Beneath this, Agarum sp. formed a dense understory. From 13 ft to 23 ft, an Agarum sp. monoculture covered up to 80% of the bottom, becoming less dense in deeper water. Small patches of Costaria sp. and Desmarestia spp. occurred on the sand/shell floor. There were no abalone here. Tonicella was the dominant grazer, at 10/m^2. Also found were A. mitra and Balanus nubilus at 1/m^2.

Sites 23-26. Village Channel and Indian Channel

We dove at four sites among the islands, which provided shelter to this area.

At all four sites, solid bedrock sloped steeply from the intertidal area to depths varying between 5 and 30 ft. A sand/shell floor began at the bottom of the rock slope and gradually sloped into deeper water. Boulders were sometimes found at the rock-sand/shell interface (Fig. 31). Intertidally, the dominant organisms were Fucus, Balanus glandula, B. cariosus, Ceratostoma, and Thais lamellosa.

Laminaria spp. were the dominant cover to 5 ft. Agarum sp. began at 5 ft and continued to the bottom of the rock slope. The percent cover varied from site to site, from almost bare to 100%. Except for sparse Iridaea sp., there was no understory. Where the sand/shell substrate began in shallow water, Zostera sp. was present.

Evasterias occurred on the rock and Pycnopodia on the sand/shell. Neither species was very abundant at any of the sites. Among the boulders at the bottom of the rock slopes were Cucumaria miniata. Tresus siphons were often seen on the sand shell floor. Lithothamnion was noticeably scarce at these sites, occurring only below 10-15 ft. Hildenbrandia-like red algae and Petrocelis sp. were the dominant encrusting algae at all four sites.

There were no abalone and no sea urchins.

Site 27. Whitebeach Passage

This site was located between two islands in a narrow passage, where a considerable current flows. The substrate was bedrock and boulders, sloping at about 20° into deeper water (Fig. 32). Intertidally, Balanus cariosus was dominant. Subtidally, Nereocystis occurred between 0 and 5 ft, forming a thick canopy on the surface. Cymathere and Costaria covered up to 50% of the bottom beneath the canopy, and beneath these were dense red corallines and lithothamnion.

At the bottom edge of the kelp zone, S. franciscanus began at densities ranging from 20 to $30/m^2$. This species extended as far down the slope as we went. On our 10 min dive, moving quickly with the fast current, we saw no abalone.

Site 28. Beware Rock

This dive was on Beware Rock itself, a submerged rock in the center of Beware Passage. The top of the rock is at 12 ft and is marked at the surface by a canopy of Nereocystis. A considerable current flows past this site. The substrate was bedrock protruding through sand/shell (Fig. 33).

There was a Nereocystis canopy with a sparse understory of Costaria and Pleurophycus covering most of this area. The byrozoan Membranipora membranacea was abundant on the blades of Pleurophycus. Scattered dense patches of S. droebachiensis occurred throughout the area. They had removed all the understory from beneath the Nereocystis where they occurred.

Parastichopus were abundant on the rock surfaces and Tresus sp. occurred in the patches of sand/shell. There were no red sea urchins and no abalone.

Site 29. Cuthbert Rock, Port Neville

We examined the rock itself, and the shore on either side of the channel. The rock dries to plus 8 ft, and extends down to 15 ft, where the bottom is cobble and larger rocks on sand. On the rock itself, Nereocystis extended from near datum to about 10 ft, forming only a light canopy at the surface. Underneath were Alaria spp. and erect corallines (Fig. 34). Abalone reached densities in excess of $10/m^2$ on the rock, and the size range was wide (Fig. 10). It was obvious from their distribution that fishing had taken place, as the area was then still open to commercial harvesting. Only a few S. franciscanus were found, but S. droebachiensis reached $1/m^2$, and were large individuals.

On the north shore, the substrate was cobble and rocks lying on shell/sand, sloping very gently out into the channel. Butter clam shells formed an important part of the substrate despite the strong currents. Alaria sp. dominated the intertidal zone and down to about 5 ft, then there was a band of Nereocystis with Laminaria sp. growing beneath. All these algae grew attached to shells and larger rocks on the bottom, and hence were relatively sparse. Nereocystis ended at 10 ft.

Abalone were abundant on the rocks, cobbles, and shells below the kelp zone. One boulder was nearly 100% covered with abalone, at an instantaneous density of more than $50/m^2$. The average density was more than $5/m^2$ in this area, and a wide range of sizes was represented (Fig. 11). There were no attached algae, and the abalone appeared to be capturing bits of drift kelp. The rock surface, as well as the abalone shells, were covered with thick lithothamnion, but there was no Dodecaceria. A. mitra were abundant, but not as numerous as abalone. Toward the centre of the channel, the bottom became softer and was completely covered with the tentacles of sabellid worms.

The south channel shore was steep bedrock to about 15 ft, and resembled Cuthbert Rock. Several species of sponges (see Appendix 1) were present at up to 20% cover of the rock surface.

Site 30. Channel Rock

At this site was a large boulder, 10 ft across and 6-8 ft high, set in a bed of coarse sand. Smaller boulders and cobbles lay near the larger rock. A strong tidal current flows past this site. Nereocystis growing on the smaller rocks produced a light canopy on the surface. No understory was present beneath this canopy. The rock was heavily covered with lithothamnion, sponges, and serpulid worms.

The sea urchins S. fransciscanus and S. droebachiensis occurred on the rocks at densities of $5/m^2$ and $3/m^2$, respectively. All the sea urchins were large. Balanus nubilus were also abundant on the rocks at this site. There were no abalone.

Site 31. North Shore, Port Neville

The substrate at this site was sand and cobbles at the bottom of a steep bedrock intertidal area. A very quick dive showed that Ulva spp. and Cancer productus were the dominant species at this site. There was no suitable abalone habitat.

Site 32. Islet on the south shore of Port Neville

The substrate at this site was solid bedrock sloping steeply to a depth of 20 ft where it changed to large boulders on a mud floor. From datum to 10 ft Laminaria spp. produced up to 50% bottom cover. Below, Agarum cribrosum became the dominant cover.

Cucumaria miniata and serpulids were abundant on the rock surfaces; Cancer productus occurred on the mud, and small shrimp were abundant everywhere. Lithothamnion was absent at this site; and Hildenbrandia-like algae were the dominant encrusting cover. Abalone were scarce, occurring together in small groups usually in crevices. Their shells were clean, indicating rapid growth.

Site 33. July Point Bank

We dove here after finding a Nereocystis canopy at the surface. The substrate was cobbles and boulders scattered over a flat/sand mud bottom 14 ft below datum. Nereocystis attached to the cobbles and boulders formed a light canopy on the surface with Desmarestia ligulata var. ligulata and Costaria in the sparse understory beneath. There were no abalone. The only other species of note at this site were S. droebachiensis and Fusitriton, which occurred in moderate numbers on the rock surfaces. Ratfish were numerous here.

Site 34. Milly Island

We dove at each end of Milly Island. The substrate was solid bedrock sloping at about 20°, changing to rocks and boulders after a few feet below datum (Fig. 35). Alaria sp. dominated the intertidal zone to datum. From datum to about 5 ft, Nereocystis and Desmaresia viridis formed the canopy and understory, respectively. Patches of S. franciscanus began just below 0 ft, within the kelp zone. There was no distinct line between the sea urchin and kelp zones; instead the kelp tapered off gradually among the sea urchins. A cover of Agarum cribrosum began below the sea urchin zone and continued into deeper water. Cucumaria miniata and S. droebachiensis both were abundant at these sites. Abalone were present but were widely scattered, occurring mainly in shallow water near the lower limits of the kelp zone.

DISCUSSION

The areas that we examined fall into four broad types:

(1) Sites 1 through 6 and 9 through 14 are all influenced considerably by exposure and are probably representative of Queen Charlotte Strait. They were all dominated by Nereocystis in the upper subtidal and by red sea urchins and Agarum spp. in the lower subtidal. All except Site 5 were apparently good abalone habitat, but had generally low densities of abalone ($1/m^2$ or less), and a scarcity of juveniles. The exceptions to this were Sites 11 and 12: Site 11 had a high abalone density, but no legal-sized; and Site 12 had a high density of all sizes. The most probable explanation for these observations is that heavy abalone fishing has occurred in the area around Port Hardy, reducing adult density to such a low level that juvenile production is now seriously low. Site 12 has probably been overlooked except by recreational harvesters (who informed us of the site) and Site 11 may be too exposed to produce legal-sized adults. If this explanation is correct, it means that the rate of exploitation has been too high, and the area should be closed to further harvesting until some recovery, in the form of juvenile recruitment, has taken place.

(2) The large kelpbeds on level bottom off the Port Hardy airport and off the end of Malcolm Island are areas that produced large catches of abalone. These areas are not influenced by sea urchins, and the production of plant material available to grazers on drift must be extremely high. We could not find commercial densities of abalone, nor could we find juveniles. Again, these areas may have been heavily harvested; and since the populations originally contained a very high proportion of large, old adults, harvesting has greatly reduced the supply of juveniles.

(3) Sites 16 through 28 were, as previously pointed out, surveyed as the result of ambiguity in a fisherman's log sheets. There were abalone in only one of these sites. Sites 20, 21, and 23-26 are all sheltered, dominated by Laminaria spp. in the upper part and Agarum spp. in the lower part; Sites 16, 18, and 22 appeared to be similar to other Queen Charlotte Strait sites, and 27 and 28 were sheltered locations strongly influenced by tidal currents and sea urchins. There is no reason to suppose that abalone were ever present at any of these sites, but their absence is puzzling.

(4) The population at Port Neville is unique. Cuthbert Rock is apparently ideal for abalone growth and survival: the strong tidal current carries with it abundant drift kelp from the extensive beds in the vicinity of the narrows. The distribution of abalone in Port Neville indicates that the narrows population must supply its own recruits; hence that most free-swimming veligers must be

carried back and forth through the narrows for several days, finally settling near where they were released. The effects of commercial harvesting are evident in reduced numbers of abalone, but there will be rapid recovery in the Cuthbert Rock area. There are reports that a similar population once existed on Channel Rock. However, if this is true, the population has been removed and has not been replenished. Channel Rock is not surrounded by suitable habitat, and perhaps predators are now able to remove all the settling larvae as they arrive.

ACKNOWLEDGEMENTS

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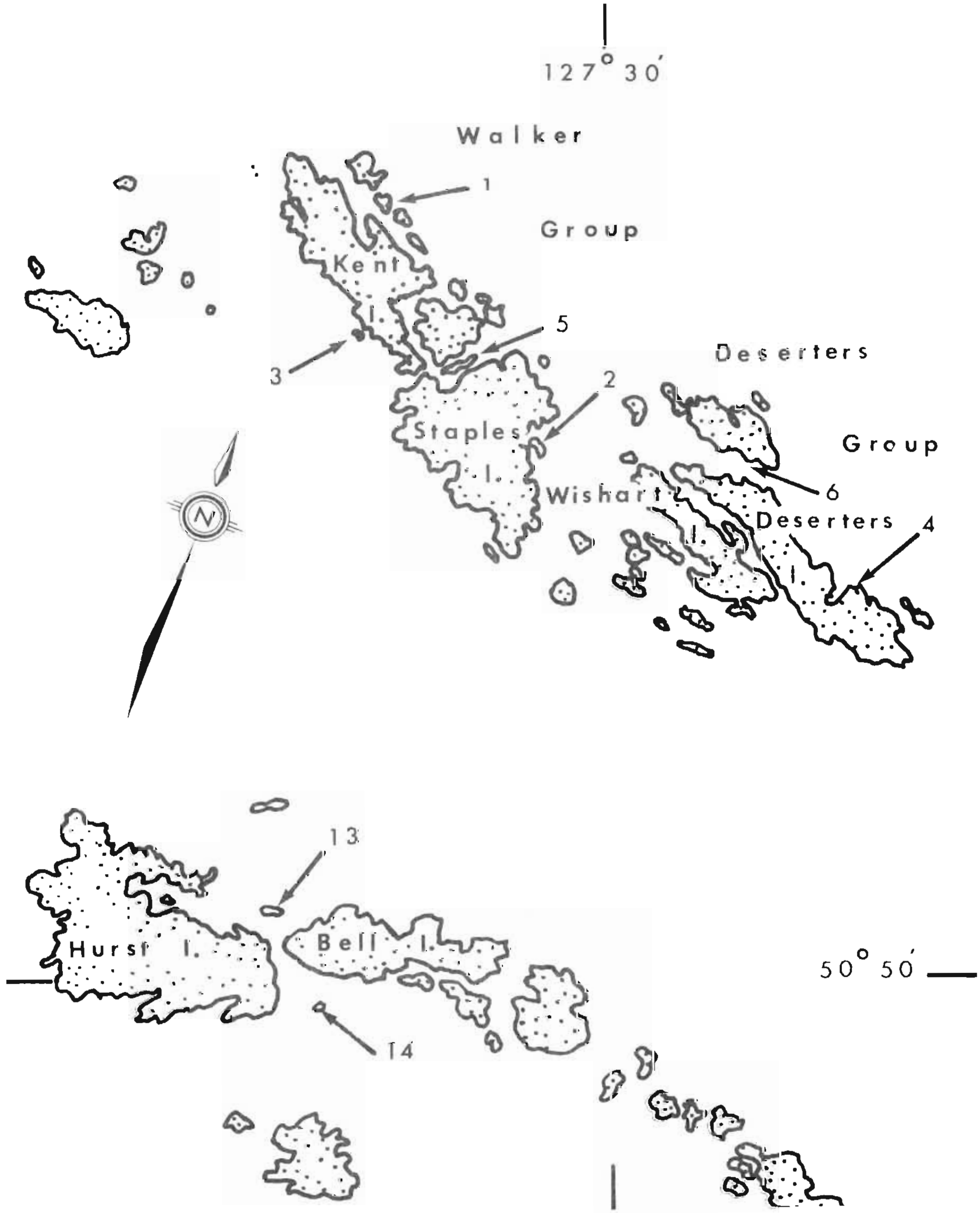


Fig. 1. Dive sites in the area near Port Hardy.

Fig. 2. Dive sites in the area below Port Hardy.

Fig. 3. Dive sites in Goletas Channel.

Fig. 4. Dive sites in the bottom of Queen Charlotte Strait.

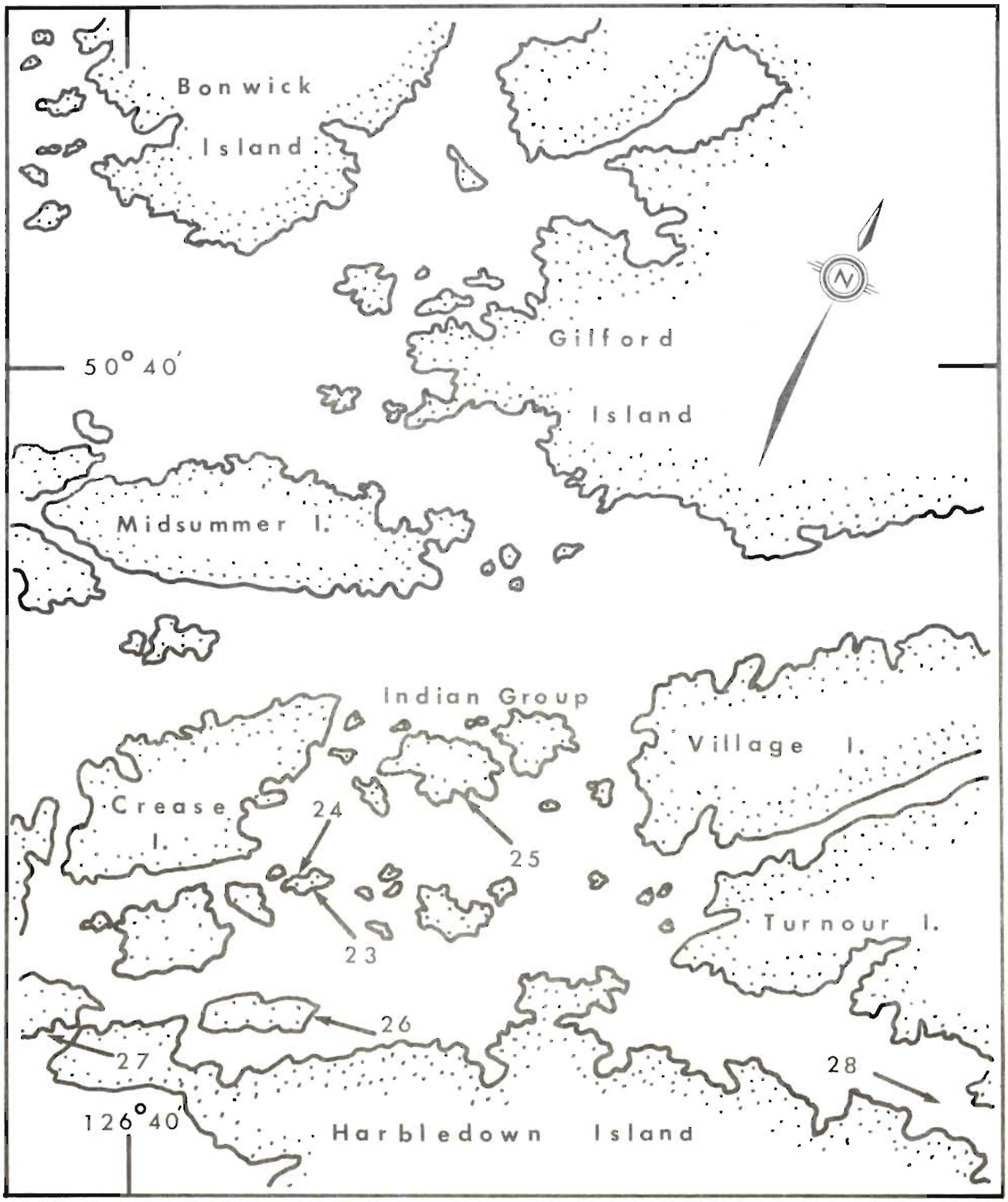


Fig. 5. Dive sites in the Indian Channel area.

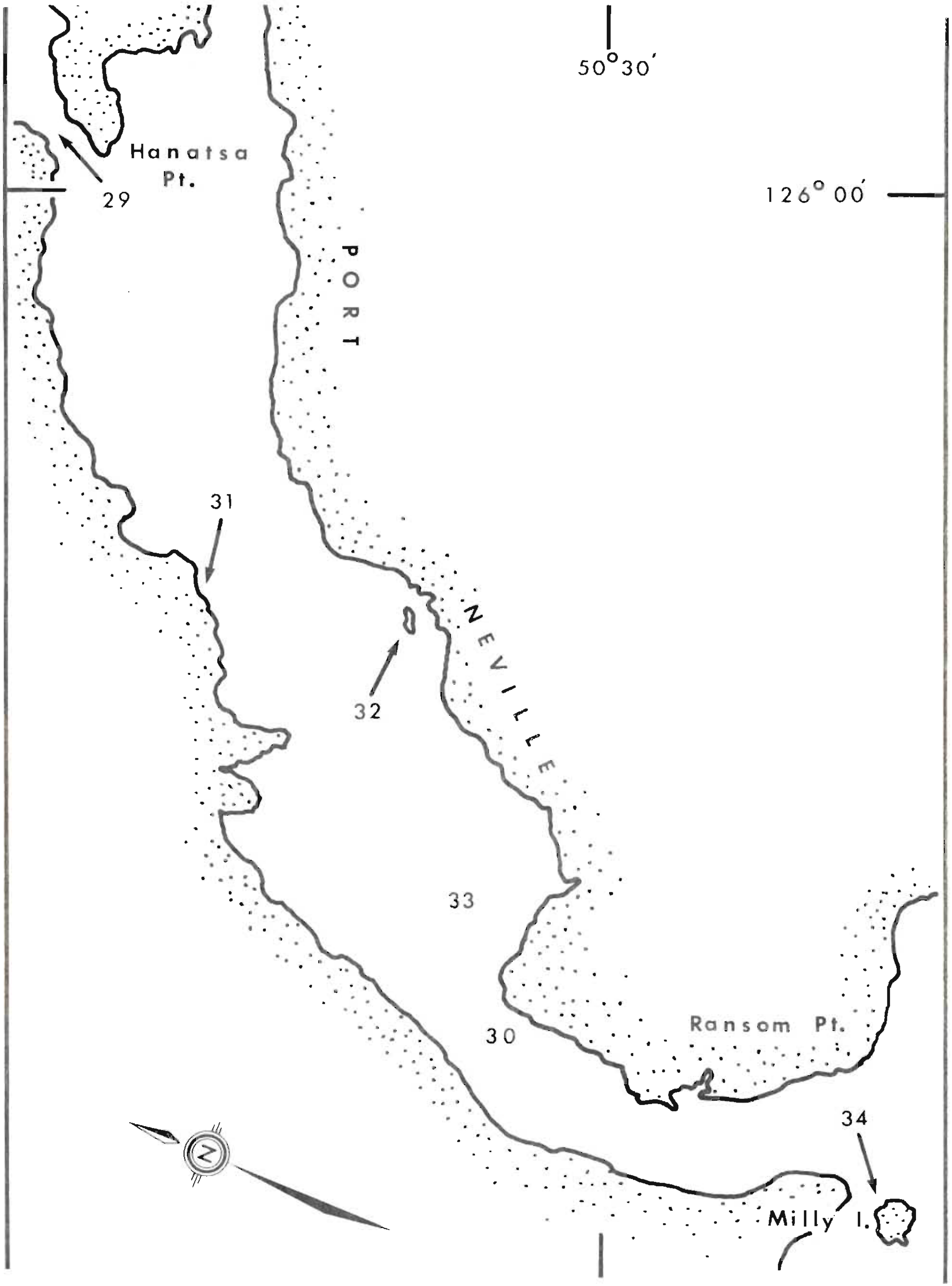


Fig. 6. Dive sites at Port Neville.

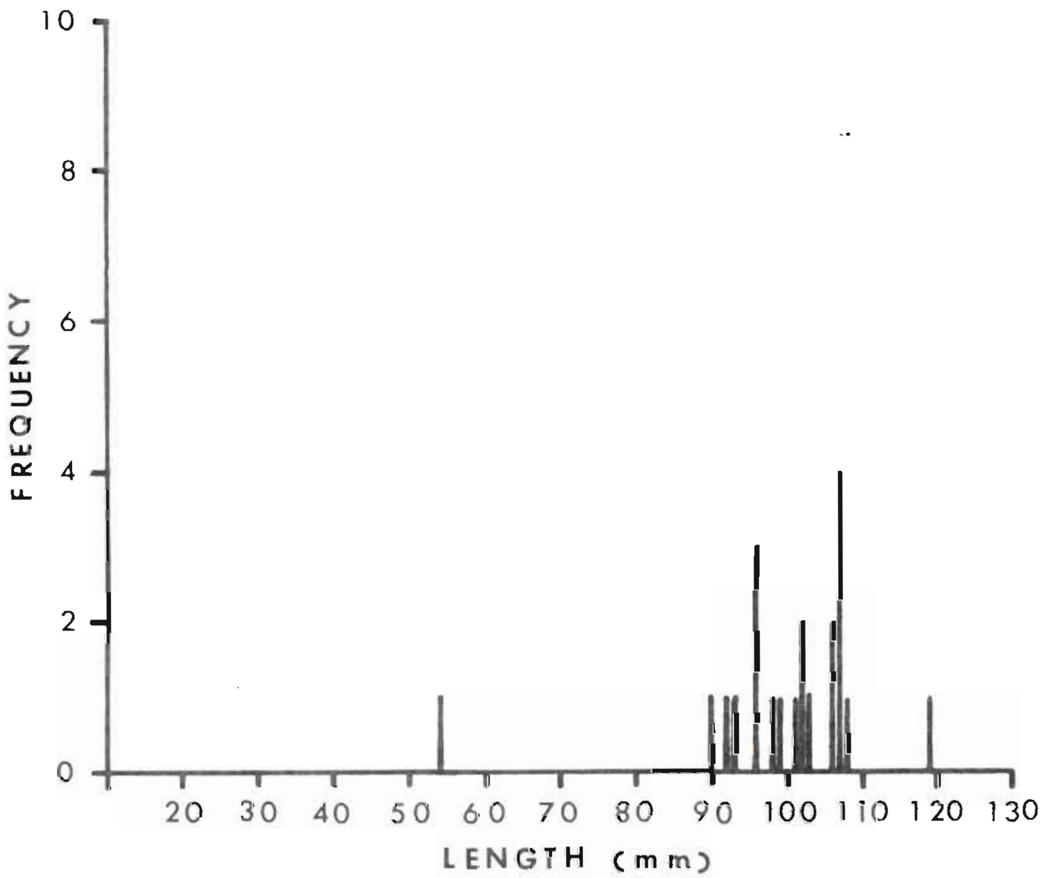


Fig. 7. Sizes of abalone collected at Site 6, McLeod Island.

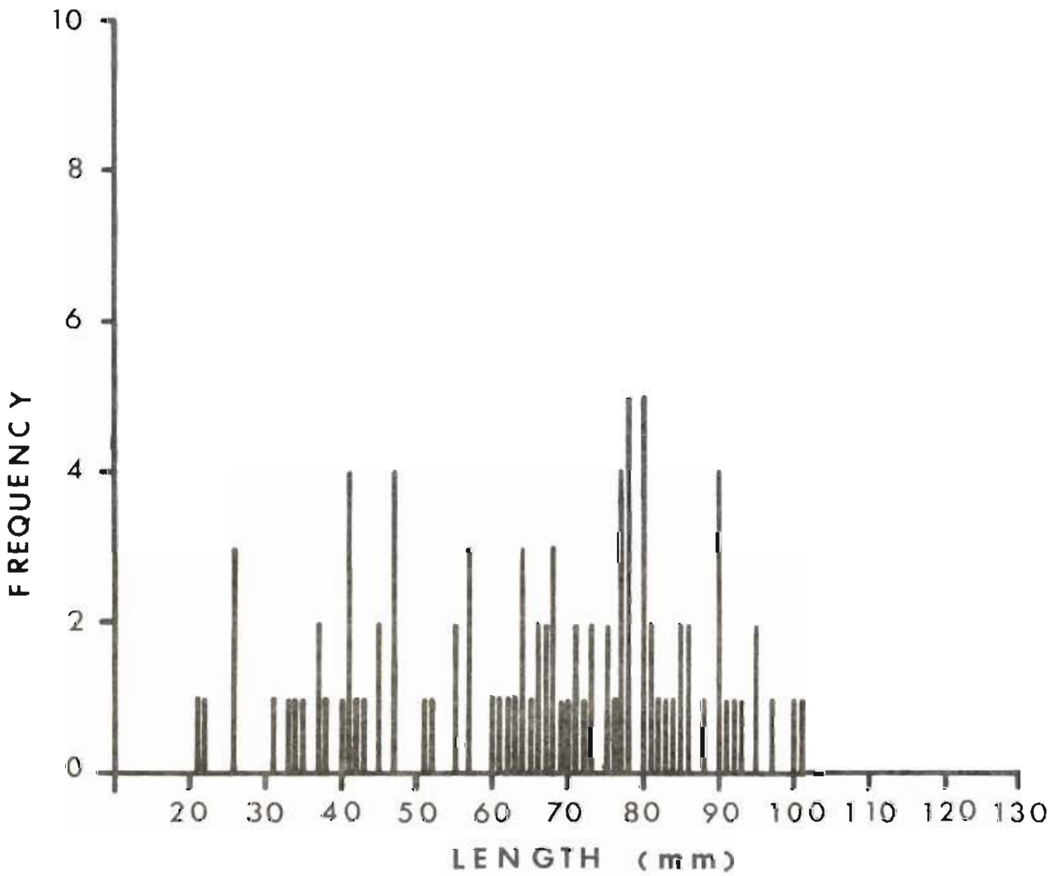


Fig. 8. Sizes of abalone collected at Site 11, Shushartie Bay.

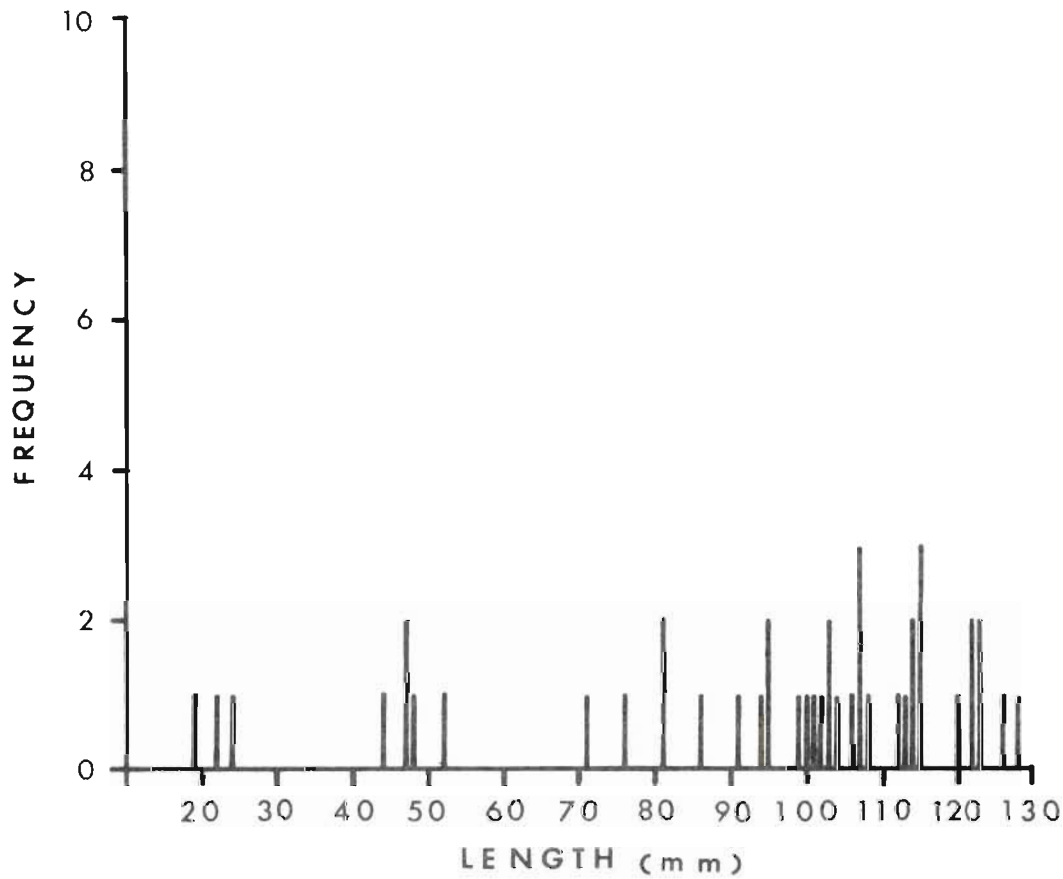


Fig. 9. Sizes of abalone collected at Site 12, Nigei Island.

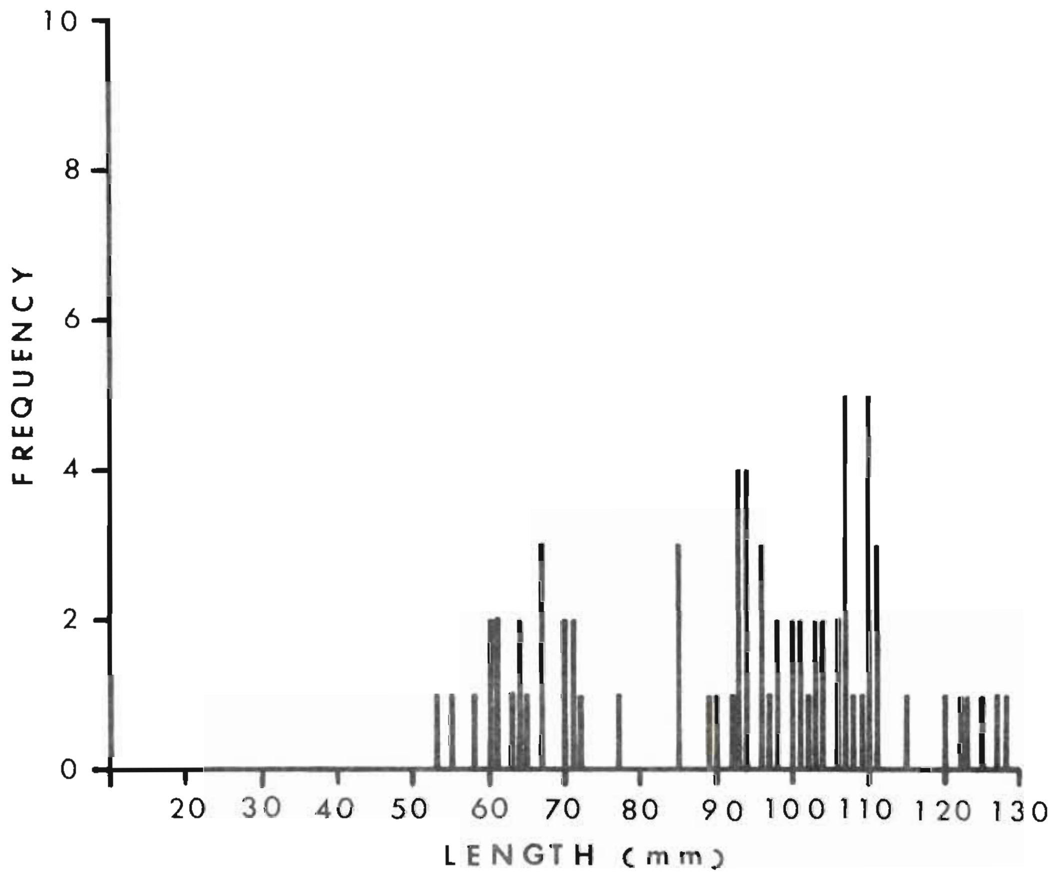


Fig. 10. Sizes of abalone collected at Site 29, Cuthbert Rock.

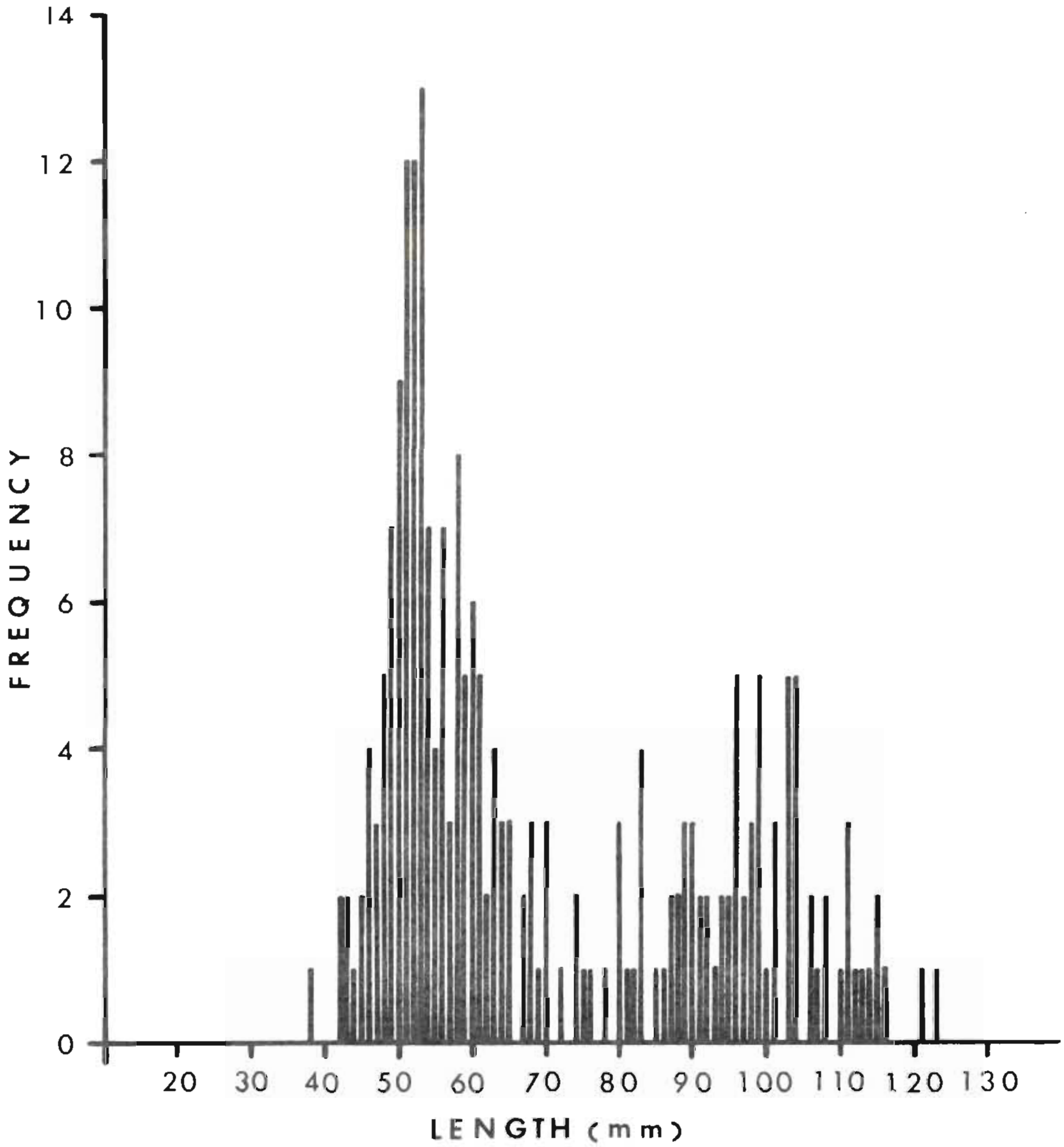


Fig. 11. Sizes of abalone collected at Site 29, on the shore near the Cuthbert Rock.

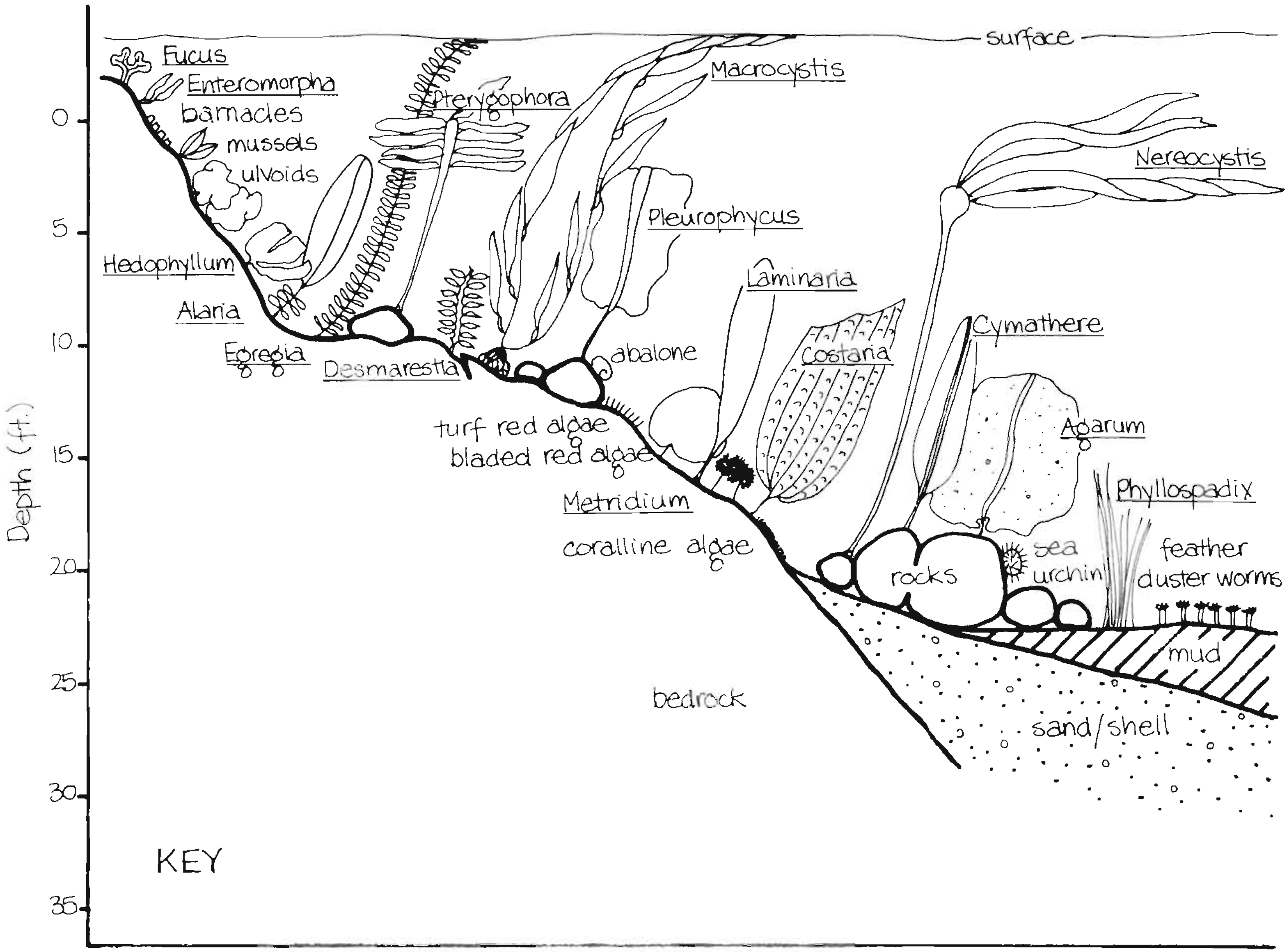


Fig. 12. Schematic key to algal profiles.

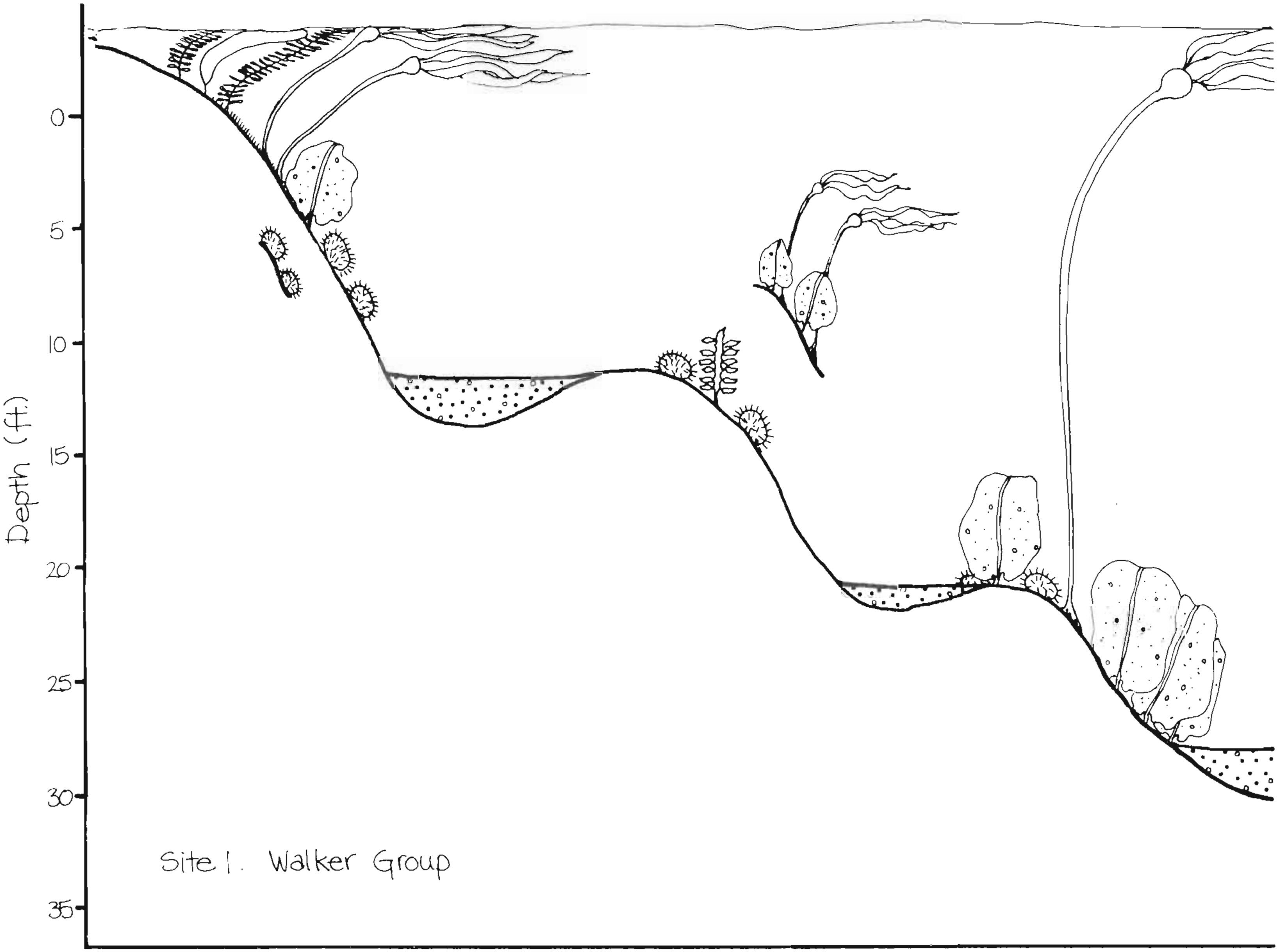


Fig. 13.

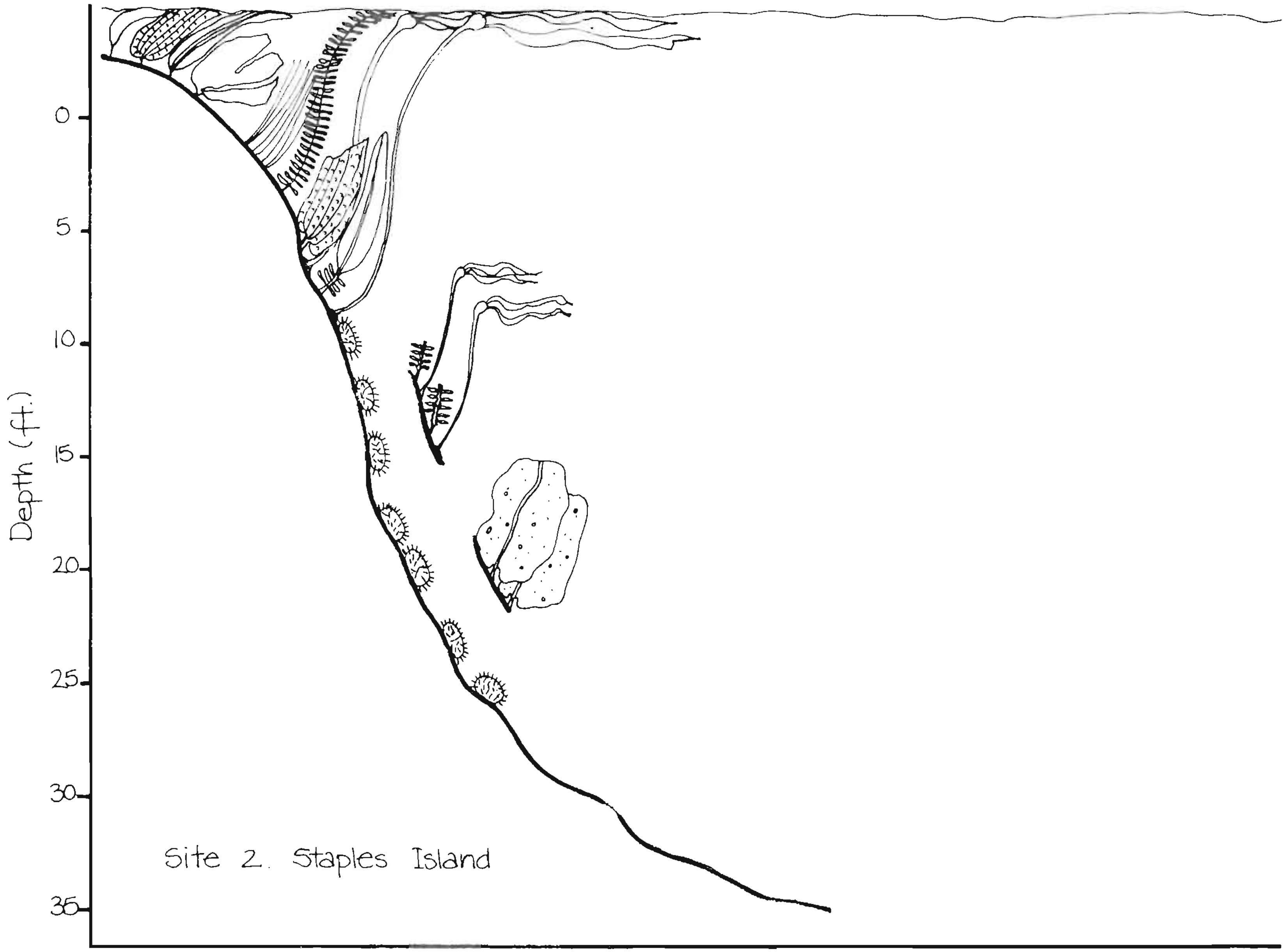


Fig. 14.

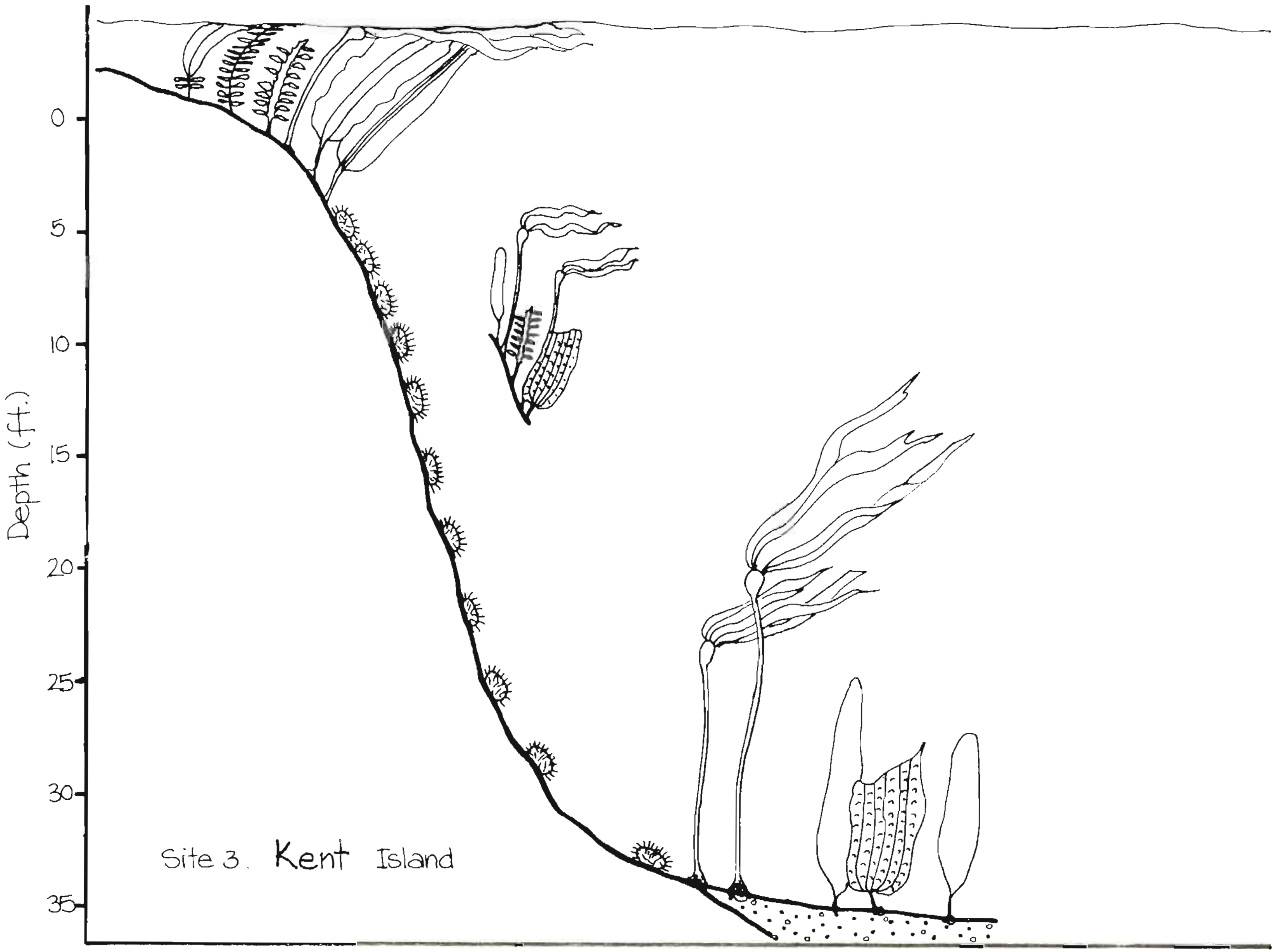


Fig. 15.

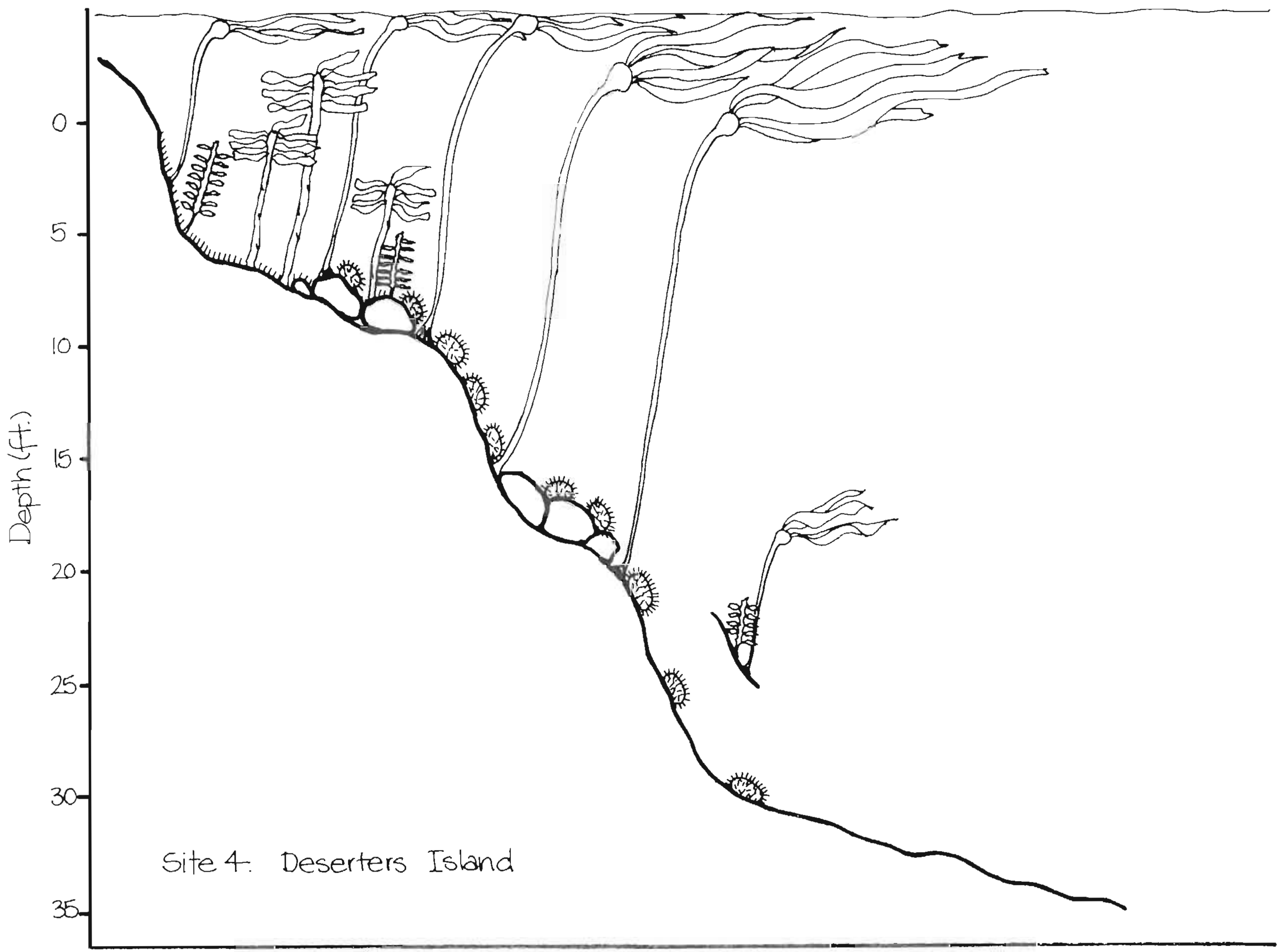


Fig. 16.

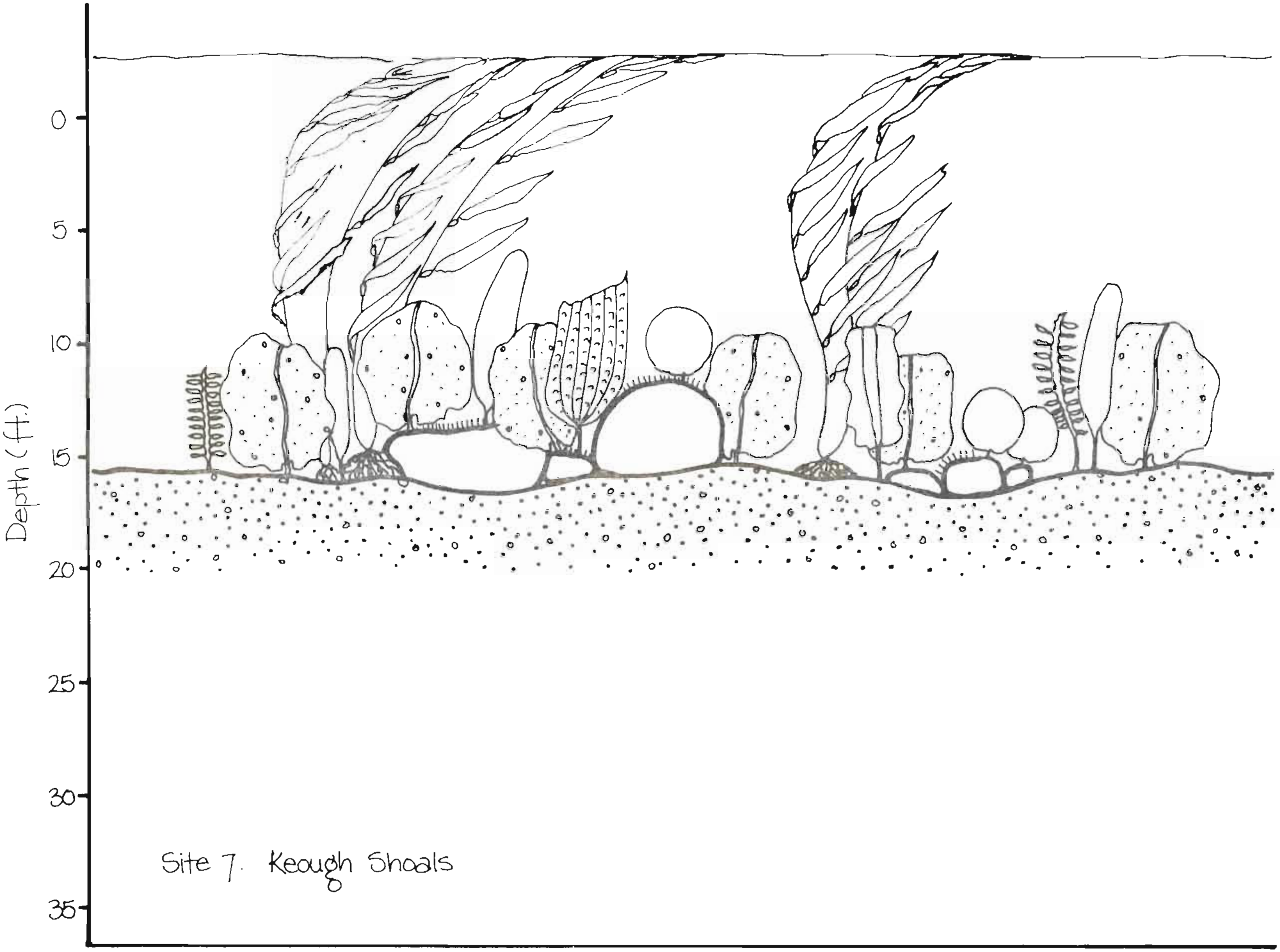


Fig. 17.

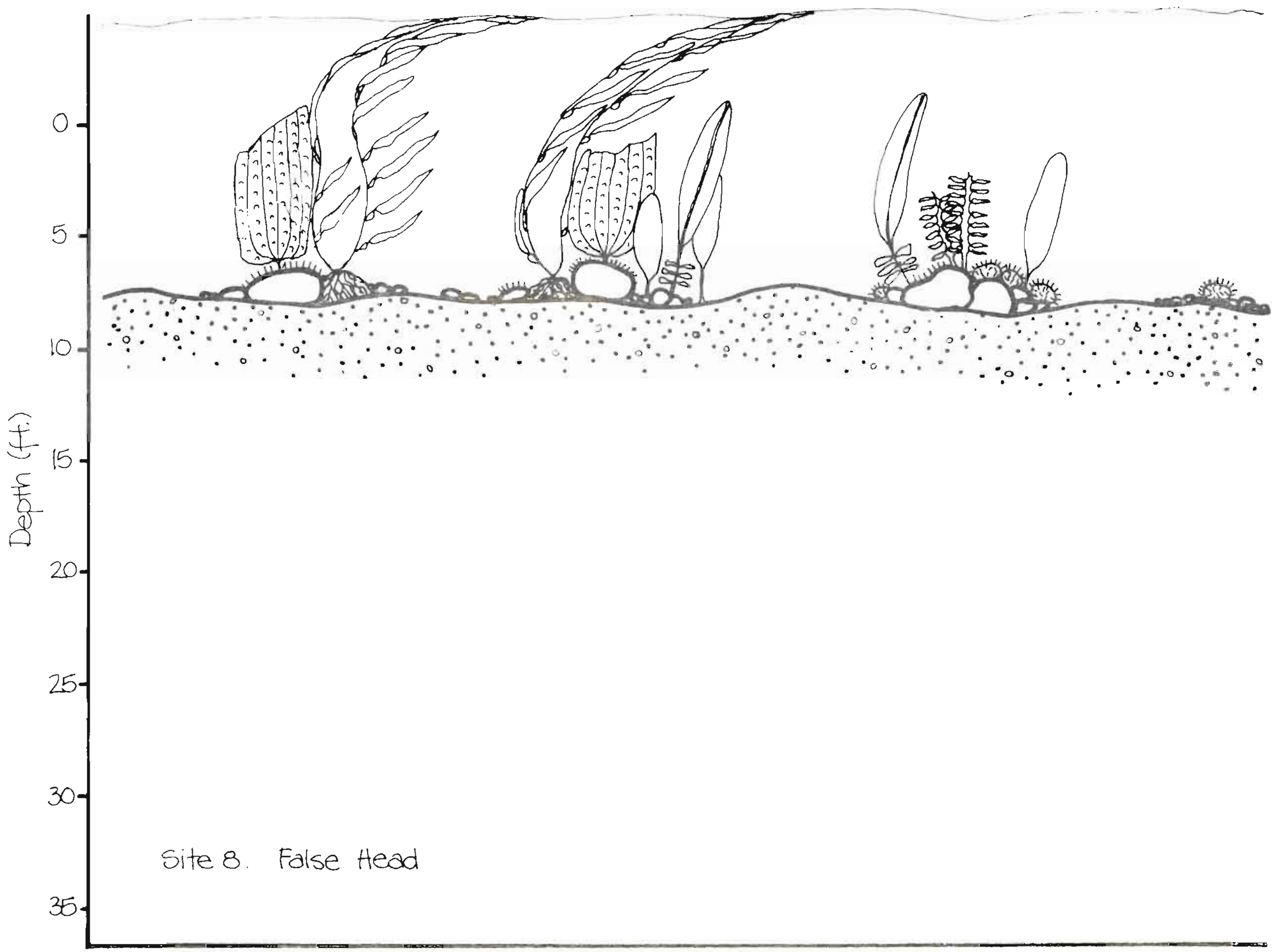
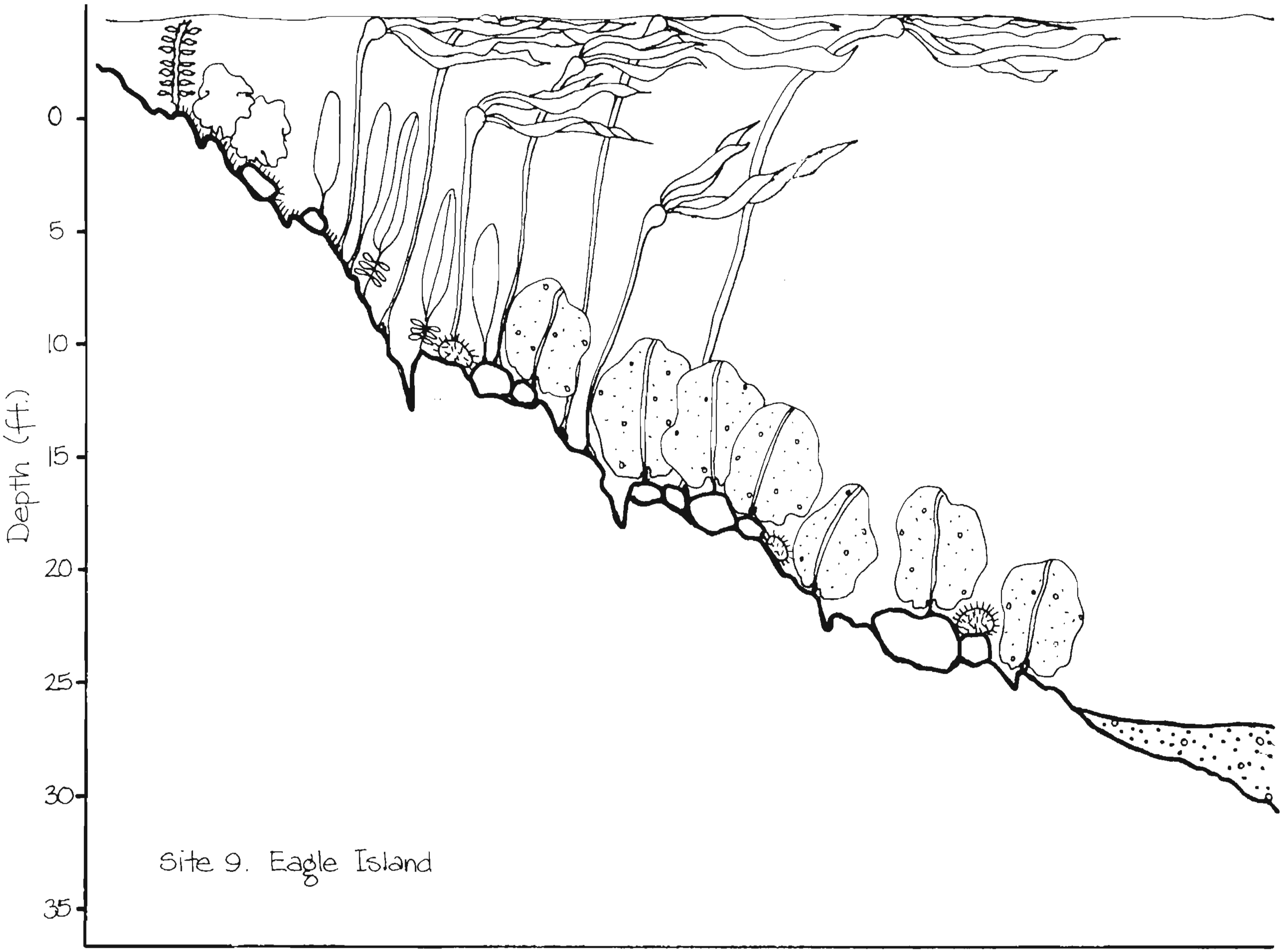


Fig. 18.



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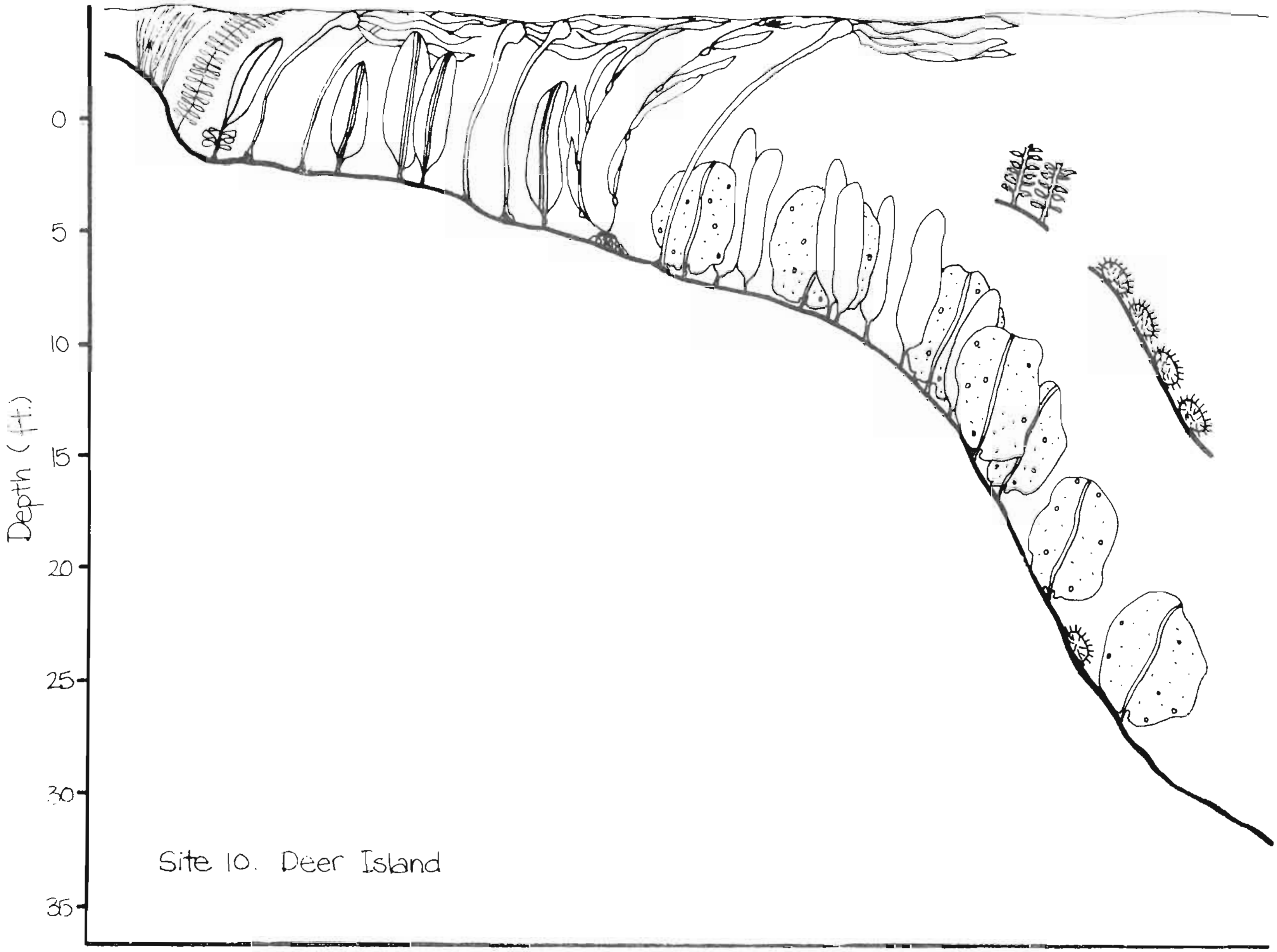
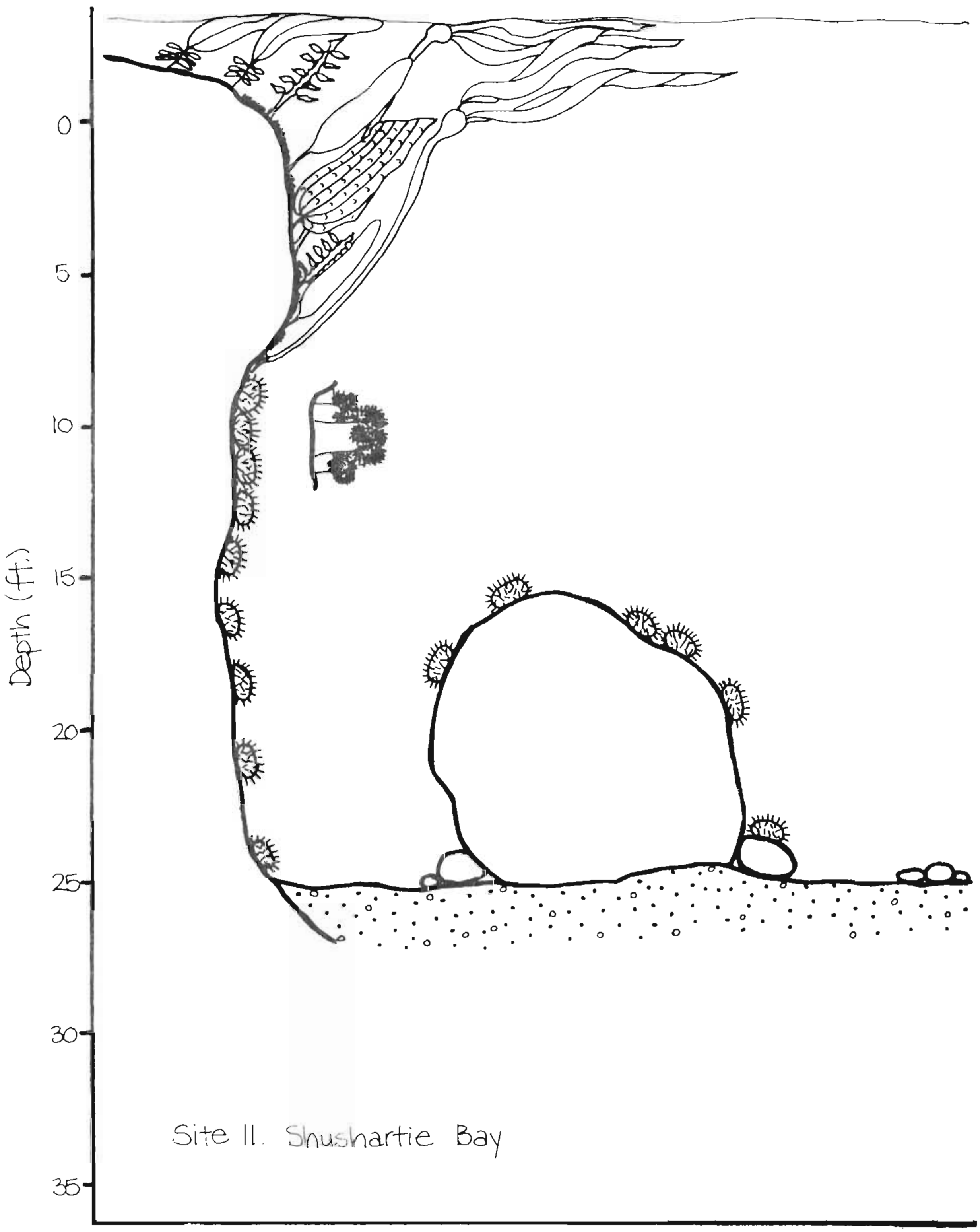


Fig. 20.



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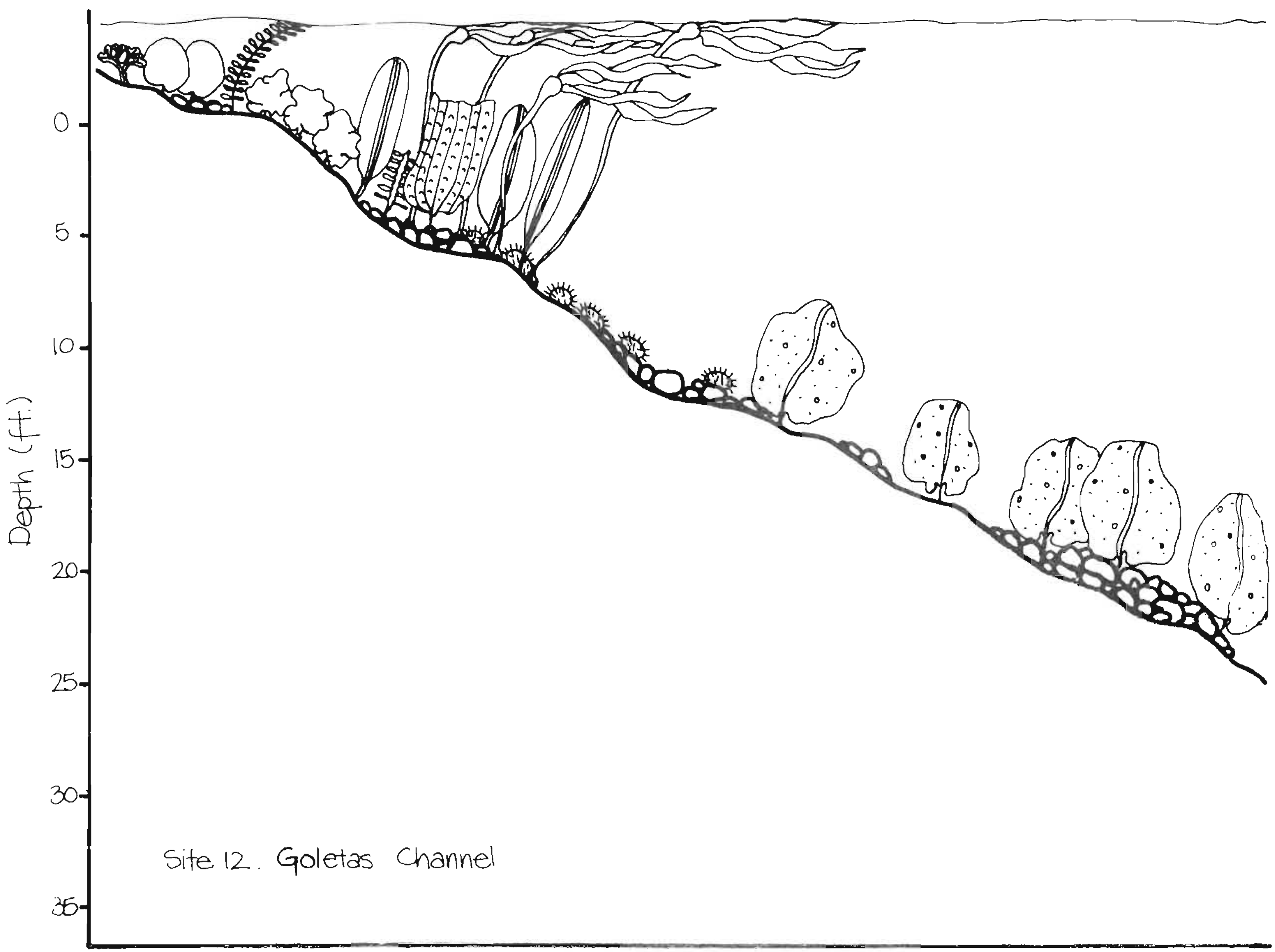


Fig. 22.

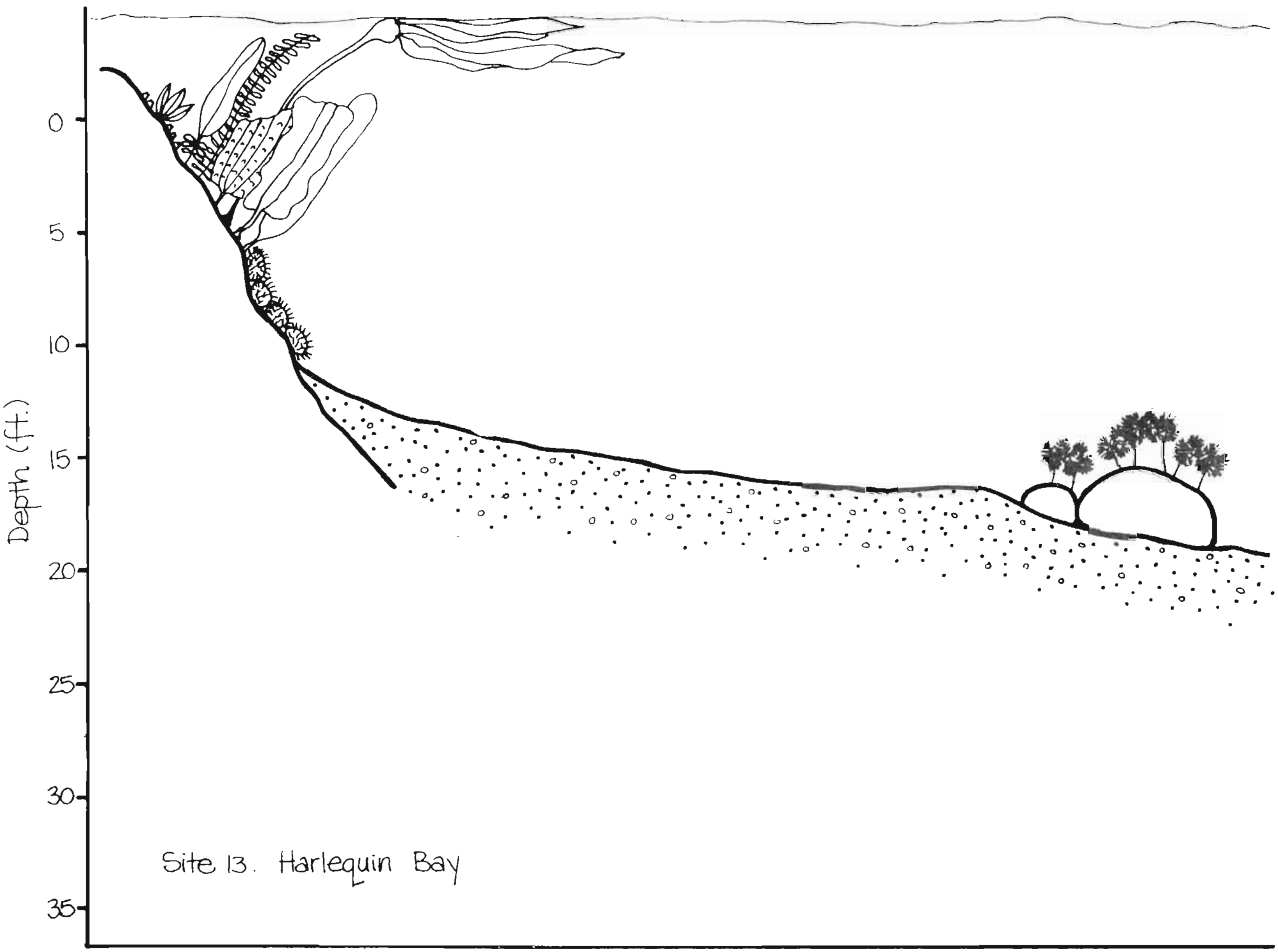
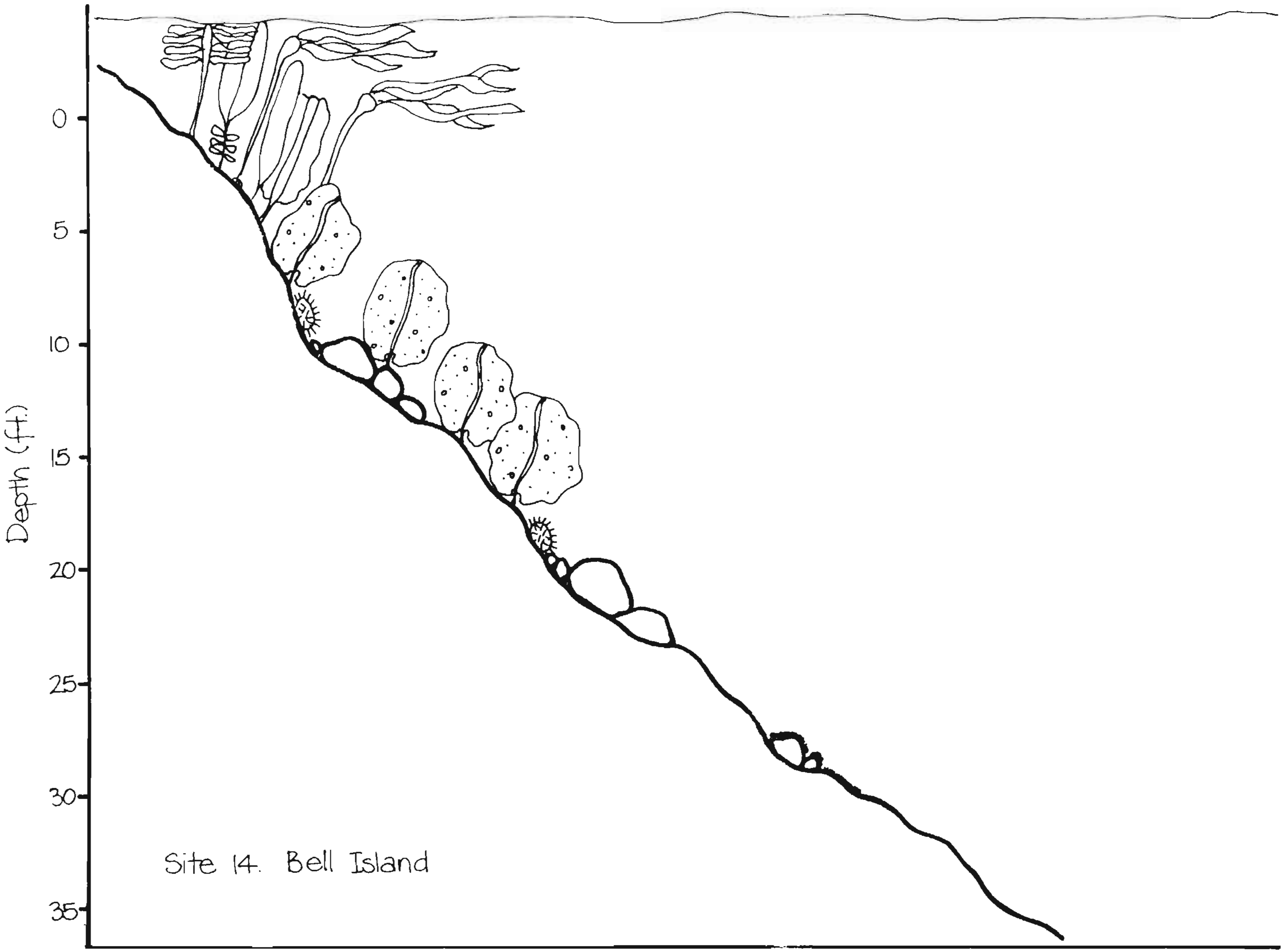


Fig. 23.



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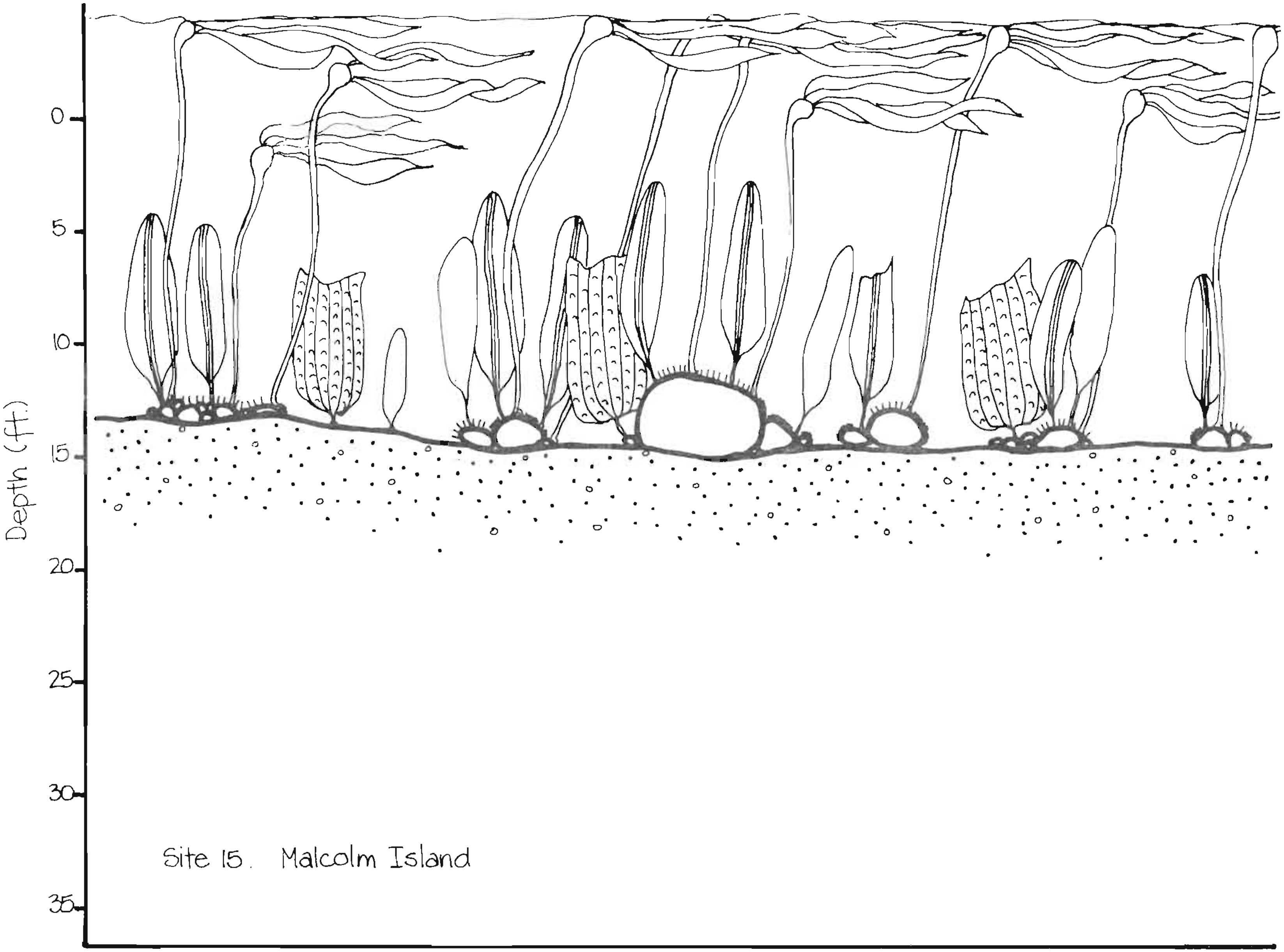

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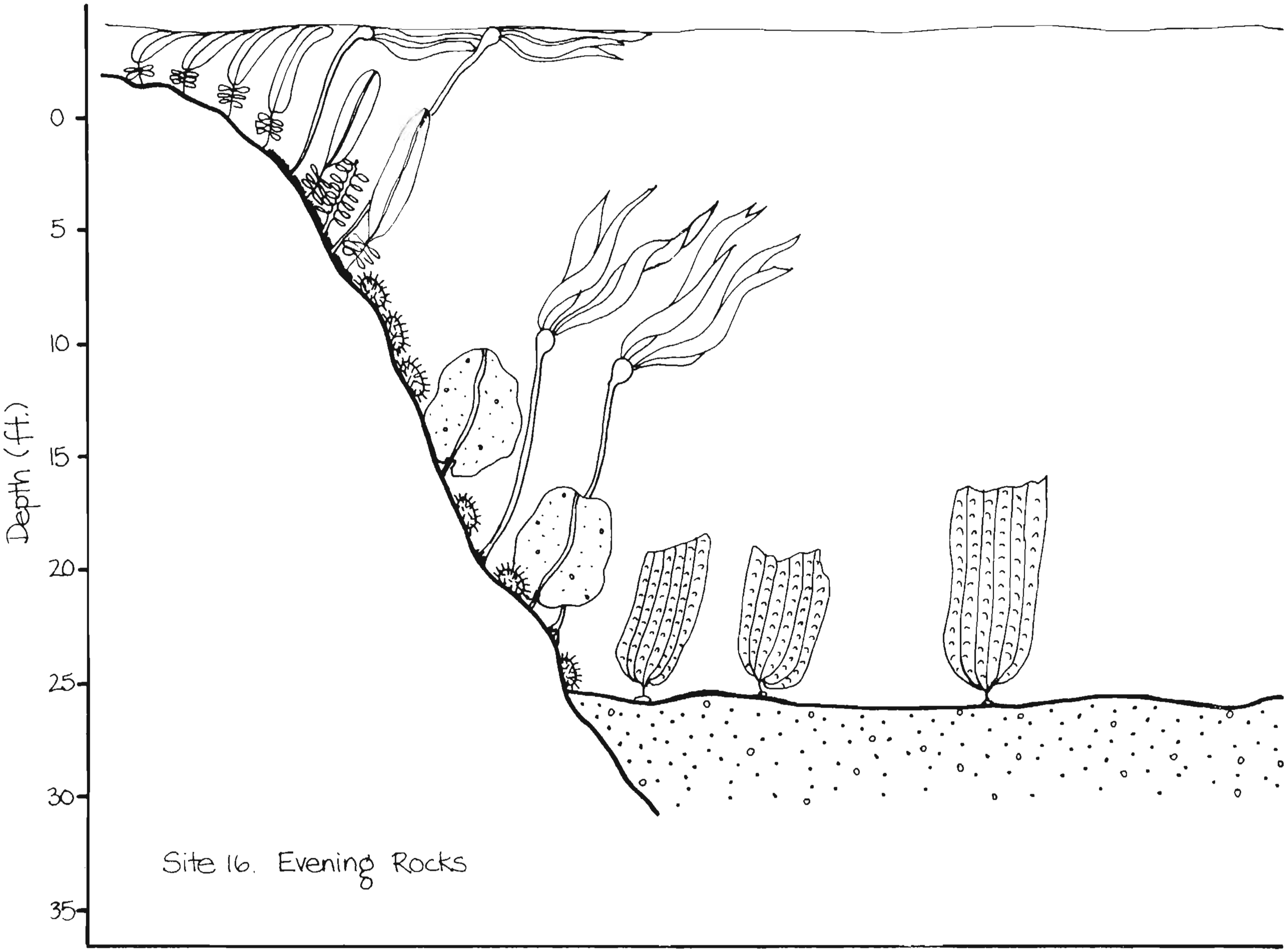

Fig. 26.

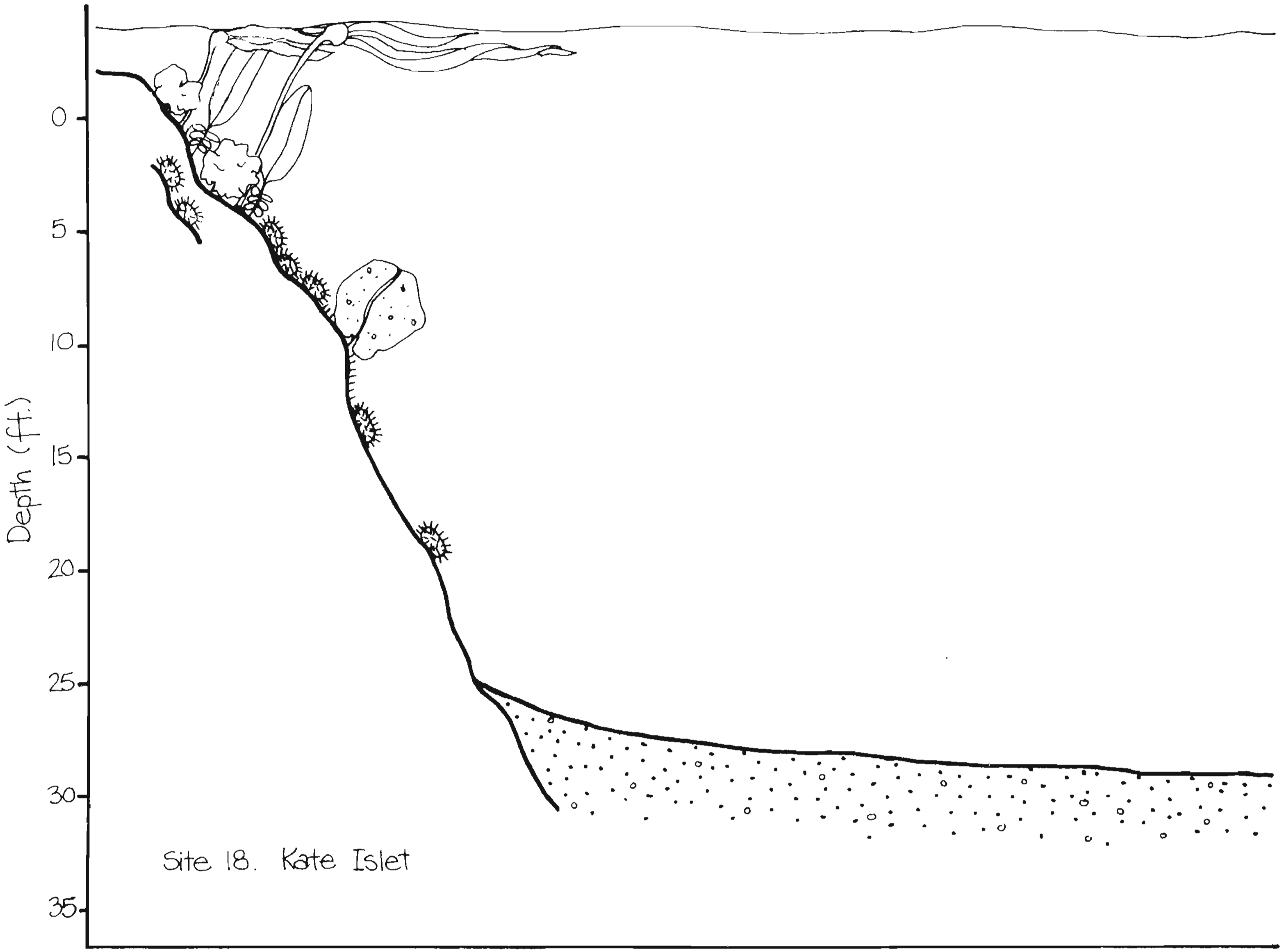

Fig. 27.

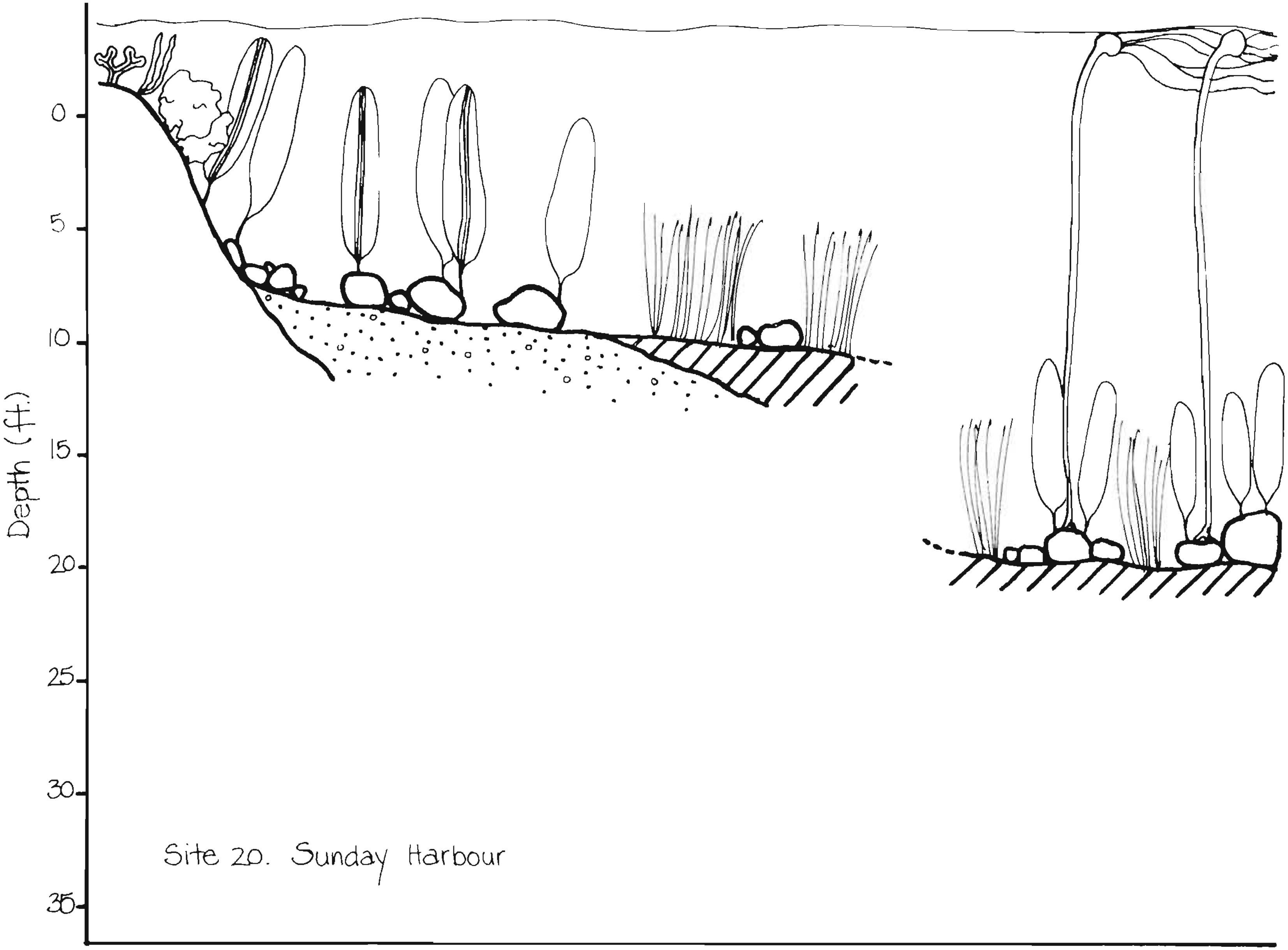

Fig. 28.

Fig. 29

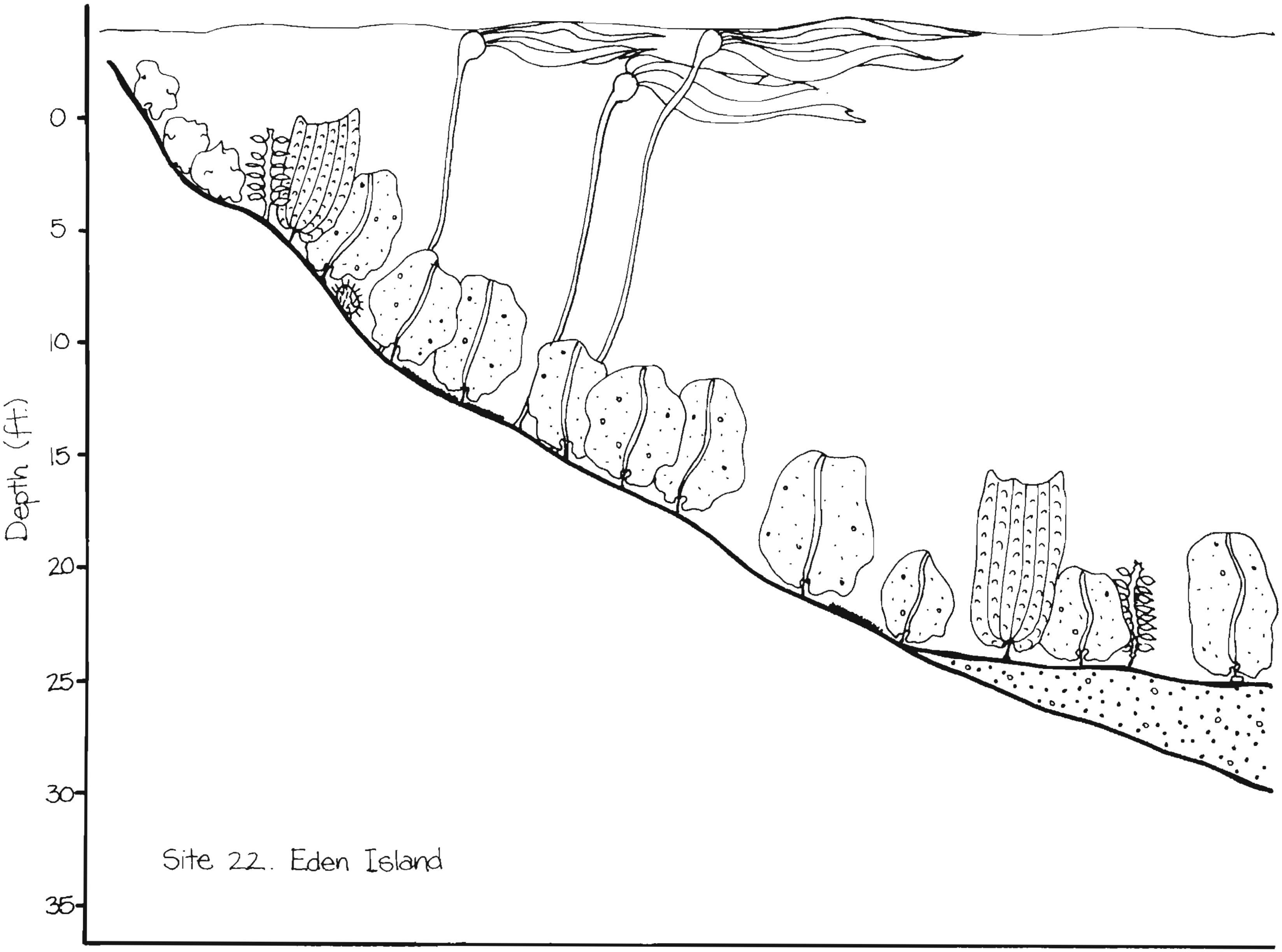

Fig. 30.

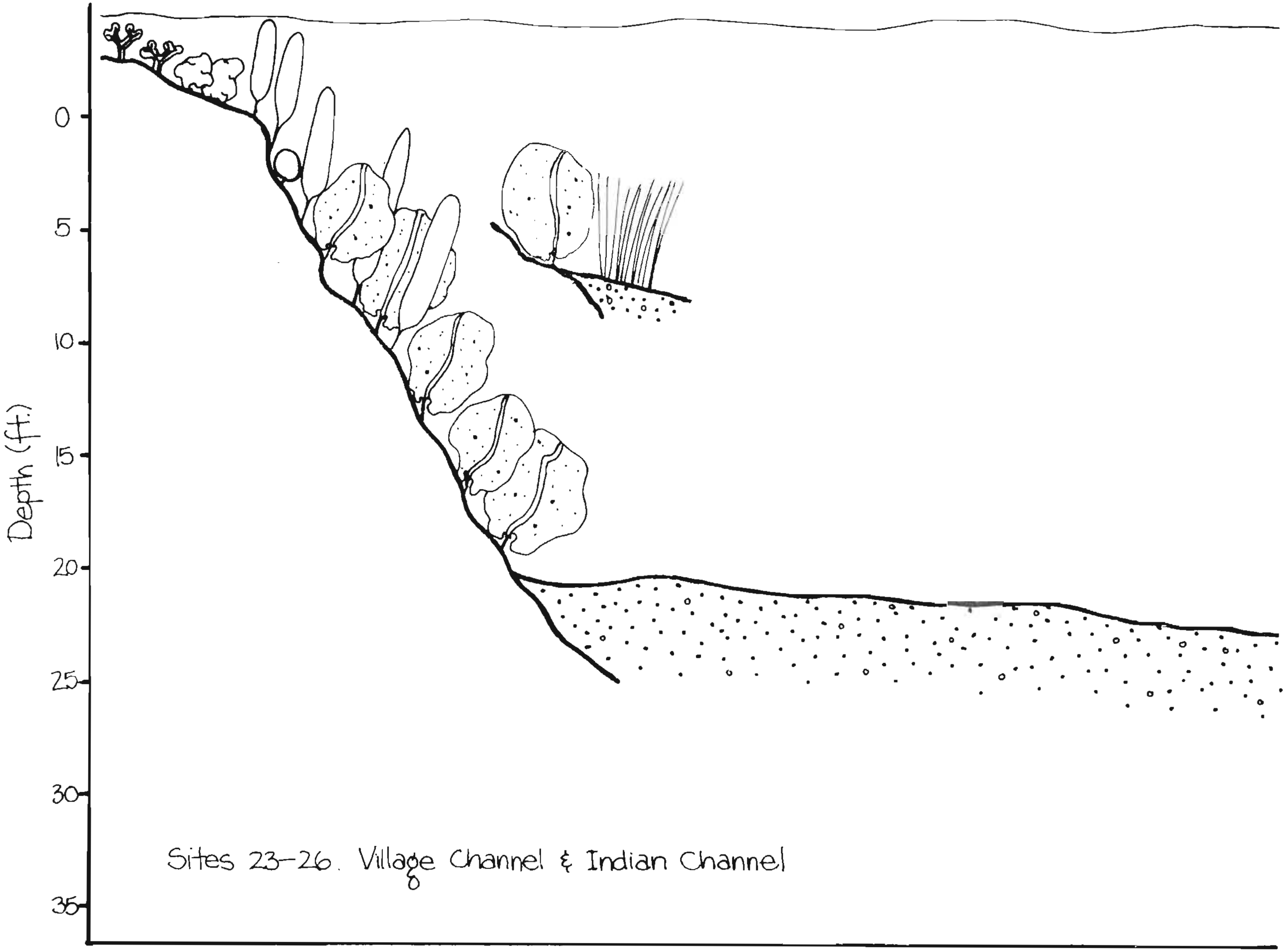
Depth (ft.)
0
5
10
15
20
25
30
35
Sites 23-26. Village Channel & Indian Channel

Fig. 31.

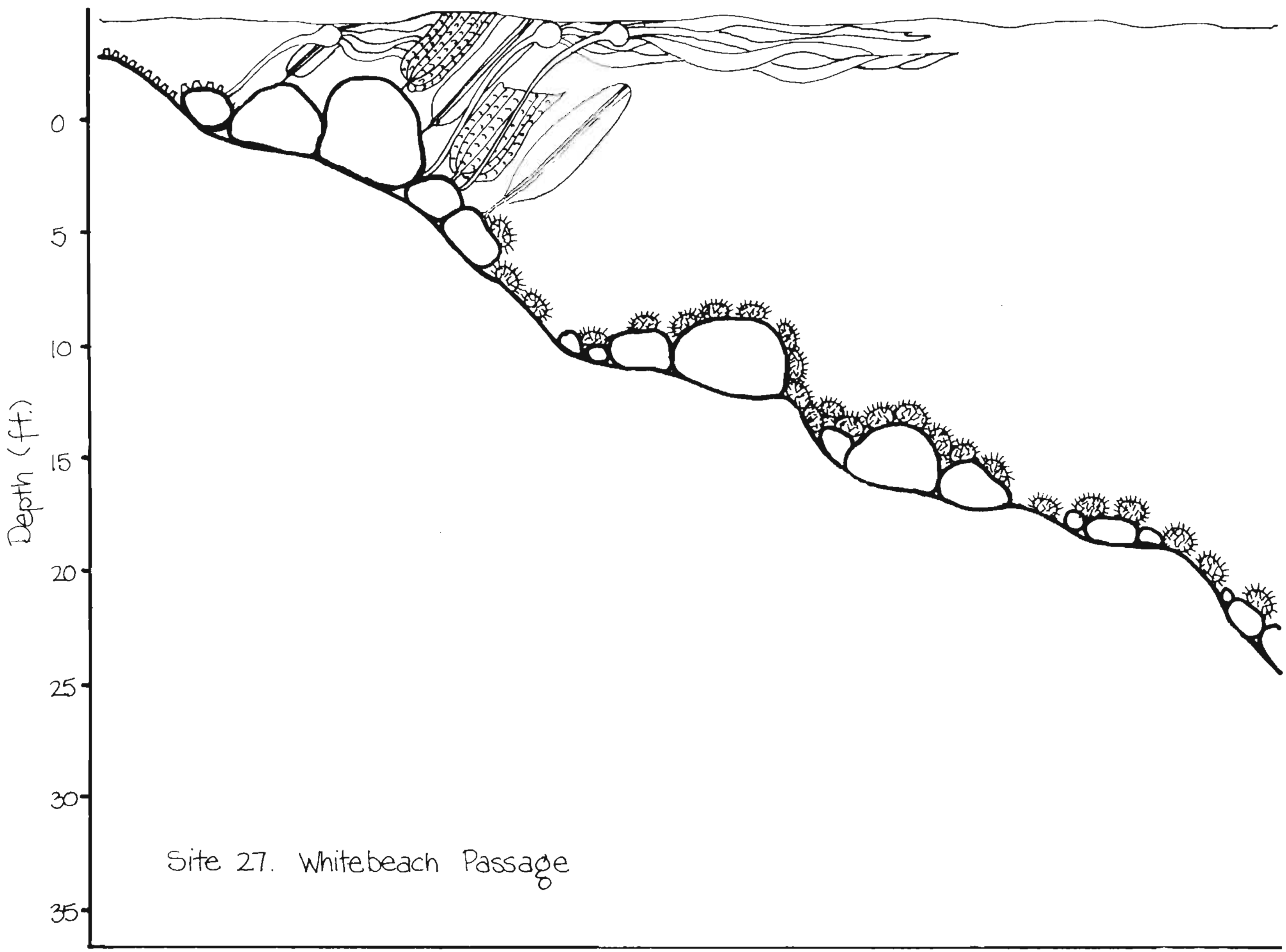

Fig. 32.

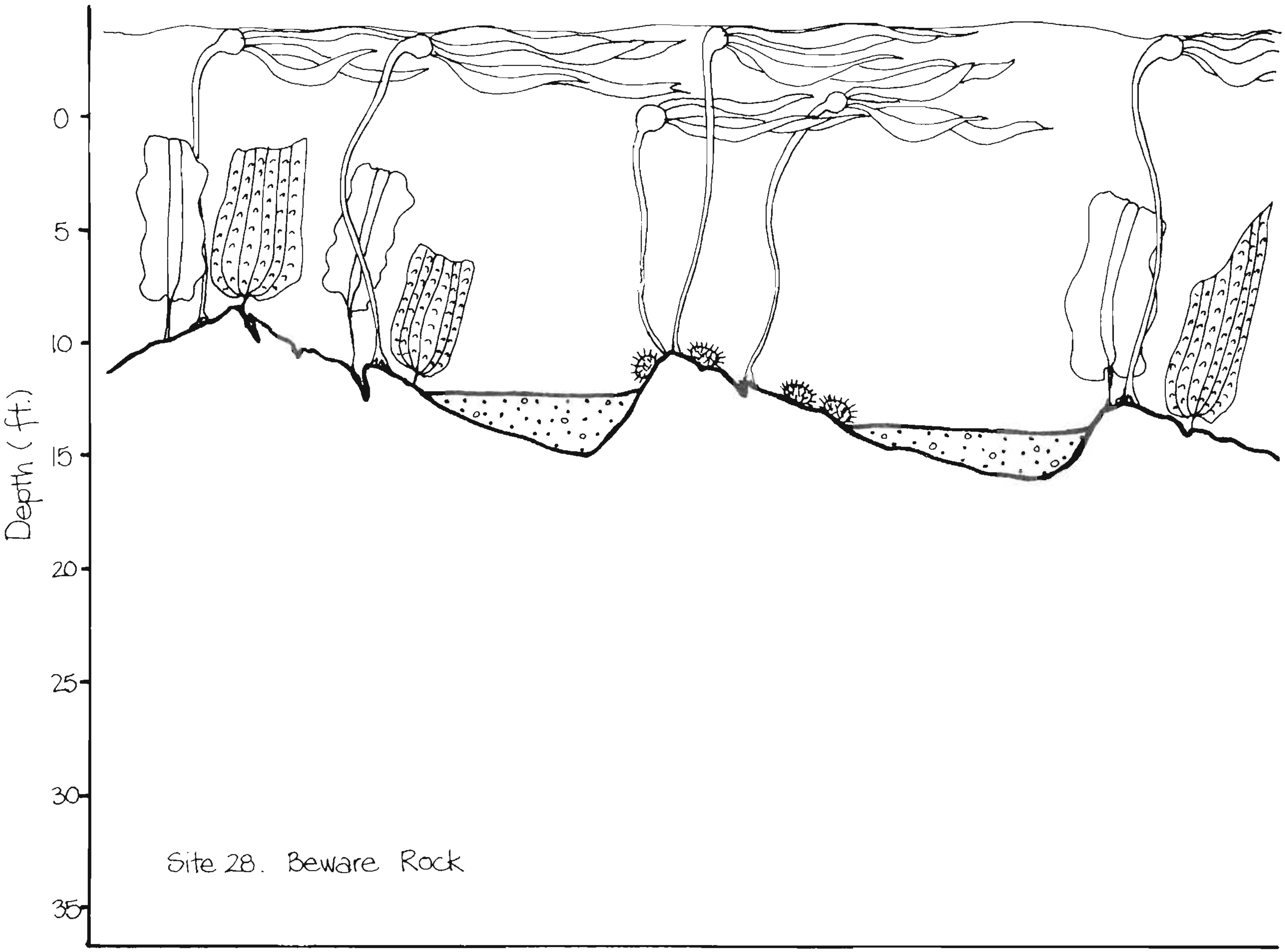

Fig. 33.

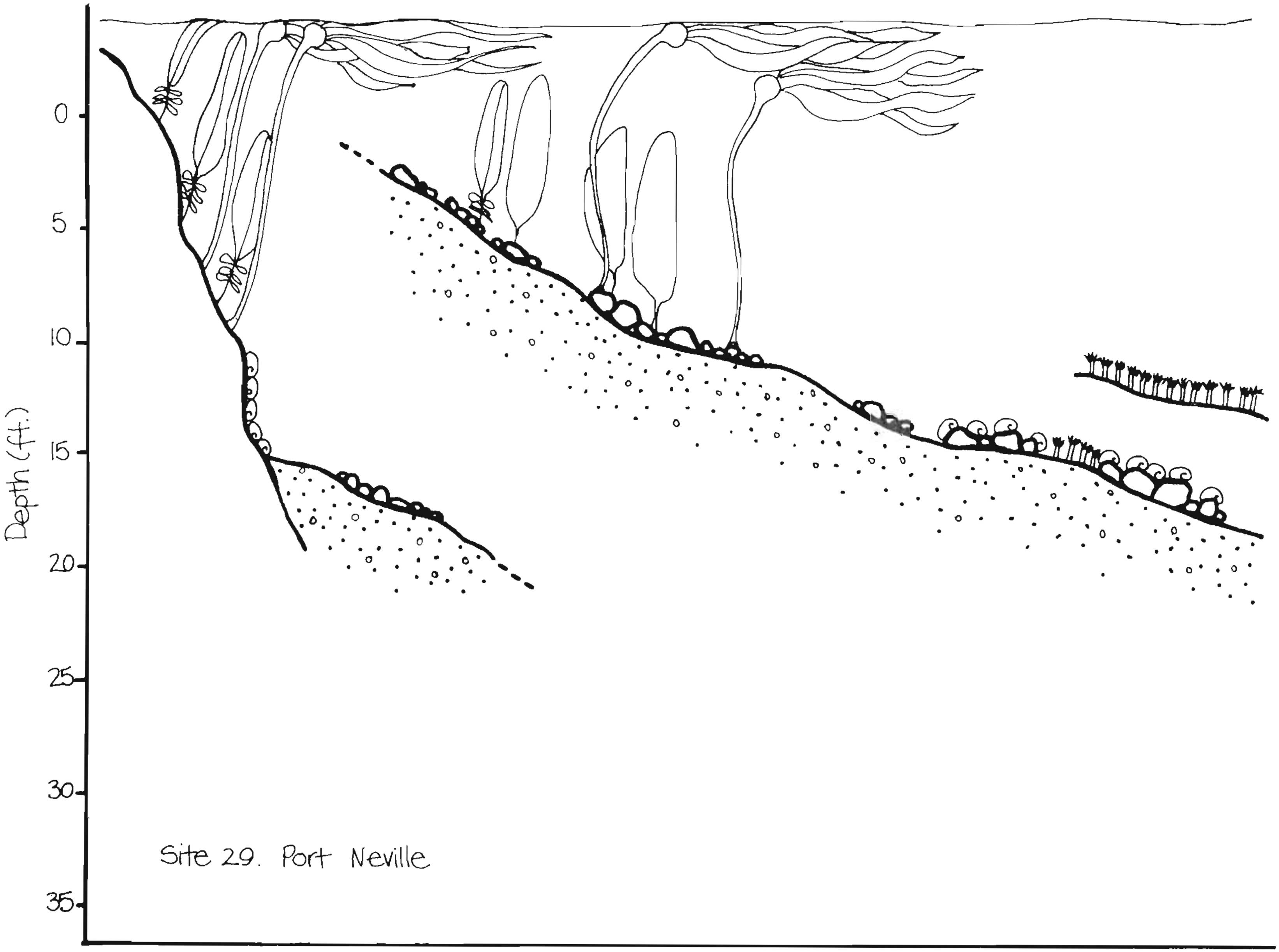

Fig. 34.

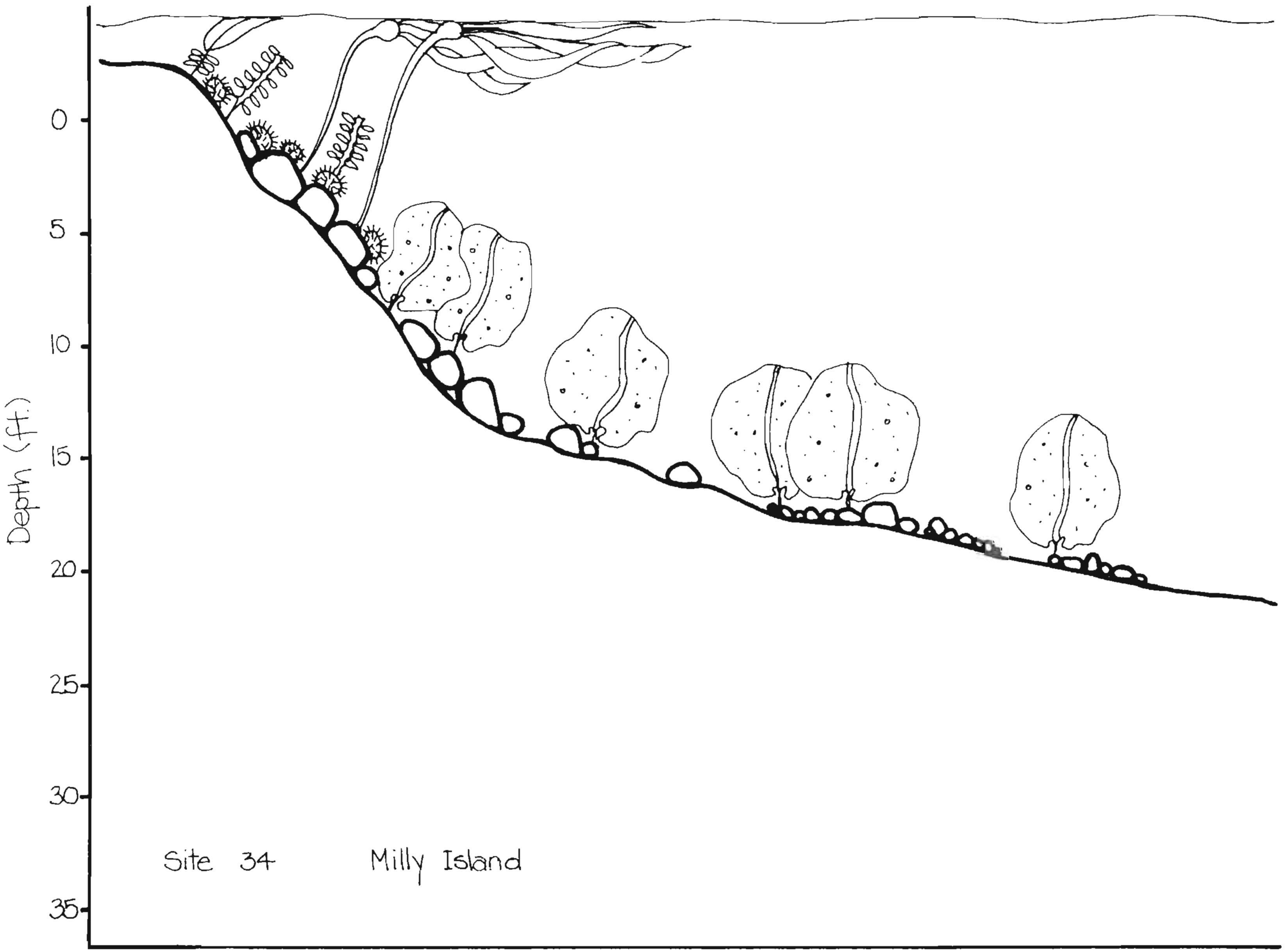

Fig. 35.

APPENDIX 1 (Species identified from collected material.)

Site	Algae
1. Walker Group off Kent Island	Polysiphonia sp. Agarum cribosum Laminaria saccharina
2. Staples Island in Shelter Pass	Laminaria saccharina Polyneura latissima Lithophyllum sp. Lithothamnion pacificum
3. W. side of Kent Island	Laminaria ephemera Laminaria sp. Callophyllis sp. Bossiella orbigniana
4. N. side Deserters Island	Botryoglossum farlowianum Polysiphonia sp. Laminaria complanata Bossiella californica ssp. schmittii
5. S. side McLeod Island	Botryoglossum farlowianum Desmarestia aculeata Bossiella orbigniana ssp. dichotoma Calliarthron regenerans Ulva sp.
7. Keough Shoals	Weeksia fryeana Plocamium coccineum var. pacificum Schizymenia pacifica Botryoglossum farlowianum Desmarestia aculeata Bossiella californica ssp. schmittii
8. False Head	Odonthalia kamtschatica Bossiella californica ssp. schmittii Bossiella orbigniana ssp. orbigniana
9. Eagle Islet below Deer Island	Odonthalia kamtschatica Desmarestia viridis Odonthalia floccosa Calliarthron regenerans Bossiella californica ssp. schmittii
13. Harlequin Bay	Calliarthron sp.
14. S. of Bell Island	Spongomorpha coalita Callophyllis heanophylla Bossiella californica ssp. schmittii

15. W. side Malcolm Island	*Plocamium coccineum* var. *pacificum* *Polysiphonia* sp. *Calliarthron regnerans*
16. Evening Rocks	*Laminaria saccharina* *Callophyllis heanophylla* *Polysiphonia hendryii* *Calliarthron regenerans*
17. Fog Islets	*Neoagardhiella baileyi* *Microcladia borealis* *Codium ritteri*
19. Coach Island Rocks	*Ulva* sp. *Codium ritteri*
21. Spiller Passage	*Schizymenia pacifica* *Agarum cribosum* *Callophyllis heanophylla* *Prionitis lanceolata* *Calliarthron regenerans*
25. S. side Maud Island	*Soranthera ulvoidea* f. *ulvoidea*, *epiphytic* on *Odonthalia floccosa*

INVERTEBRATES

Site	Genus/sp
1. Walker Group off Kent Island	*Calliostoma ligatum* *Amphissa columbiana* *Tegula pulligo*
2. Staples Island in Shelter Pass	*Cornye* sp.
3. W. side Staples Island	*Pagurus* sp. in *Fusitriton oregonensis*
4. N. side Deserters Island	*Calliostoma ligatum* *Amphissa columbiana* *Dodecaceria fewkesi*
5. Between Staples and Kent Island	*Haliclystis salpinx*
6. S. side McLeod Island	*Callistoma ligatum* *Amphissa columbiana*
8. False Head	*Lepidozona mertensii* *Acmaea mitra* *Amphissa columbiana* *Calliostoma ligatum*

9. Eagle Islet below Deer Island	*Cucumaria lubrica* *Cryptolithoides sitchensis* *Amphissa columbiana*
10. N. end Deer Island	*Calliostoma ligatum* *Calliostoma annulatum*
13. Harlequin Bay	*Calliostoma ligatum* *Acmaea mitra* *Tegula pulligo*
14. S. side Bell Island	*Trichotropis cancellata* *Acmaea mitra* *Diadora aspera*
16. Evening Rocks	*Mopalia lignosa* *Katharina tunicata* *Tonicella lineata* *Notoacmea scutum* *Collisella ochracea* *Acmaea mitra* *Calliostoma ligatum*
19. Coach Island Rocks	*Halocynthia igaboja*
21. Spiller Passage	*Bittium eschrichtii* *Collisella ochracea* *Thais lamellosa* *Ceratostoma foliata* *Calliostoma ligatum*
26. Mound Island	*Thais lamellosa*
28. Beware Rock	*Solaster dawsoni* *Boltenia villosa* *Membranipora membranacea*
29. Port Neville	*Abietinaria* sp. *Evasterias troschelii* *Calliostoma ligatum* *Tonicella lineata* *Acmaea mitra* *Collisella ochracea* *Terebratalia transversa* *Mycale adhaerens* *Mycale lingua* *Halichondria panicea* *Halidona* sp. *Lissodendoryx firma*