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Ecological Research Series

EFFECTS OF POLLUTANTS ON SUBMARINE PLANT SYNECOLOGY

Environmental Research Laboratory
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EFFECTS OF POLLUTANTS ON SUBMARINE PLANT SYNECOLOGY

by

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ABSTRACT

Synecology of marine plant communities has been studied in areas differing in water quality. Major sources of deterioration of water quality include the Nooksack River, an oil refinery and an alumina reduction plant. A method of analysis involving comparisons of standing crops of species within the communities, standing crop of groups of morphologically similar species, and standing crop of entire communities is described. Stable species of the community are distinguished as well as those which appear to be indicators of environmental change. The floating bull kelp *Nereocystis leutkeana* is shown to have a depressing effect on standing crop and on the presence of other elements of the community. An increased respiration rate in kelps exposed to aluminum plant effluent was measured. Physical factors of the environment were measured. Poorer conditions for growth of algae in the environs of the aluminum company following its expansion are indicated by the accumulation of silt, the decrease in standing crop, and a loss of certain species.

This report was submitted in fulfillment of Grant Number 18050 DXI by Western Washington State College, Bellingham, under the sponsorship of the Environmental Protection Agency. Work was completed as of August, 1970.

CONTENTS

FIGURES

TABLES

SECTION I

CONCLUSIONS

1. Conditions favoring highest growth rates and standing crop occur at the northern end of the study area. These conditions include higher current velocities, greater mixing with offshore water, lower silt content, higher transparency, and lower temperature. Differences in silt demonstrate the diffusion gradients from the Nooksack River, shoreline erosion, and the effluent of the aluminum plant.

2. Filamentous algae appear to be most tolerant of high silt conditions.

3. Certain kelps respond with increased respiration rate when exposed to the waste containing fluoride from the Intalco Aluminum Plant. This appears to be a reaction similar to the toxic response of seed plants to fluoride.

4. Distribution of the bull kelp Nerocystis leutkeana is variable year to year. The presence of this kelp has considerable effect on the composition of other elements of the community particularly the smaller, filamentous species. The variation appears to be a natural fluctuation.

5. The presence of the floating bull kelp Nereocystis leutkeana has a depressing effect on the other members of the community.

6. There is value in classifying species of the community according to four growth types as an approach to understanding interactions within the community and the possible separate effects of environmental stresses.

7. Certain members of the community such as Iridaea chordata are stable and occur in every community at the -10' depth. Others do not appear as consistently. One group of five plants including Rhodomela laryx have shown a marked decrease since 1968. These five species were found in 1968 in only the four stations most close to industries. These species were not replaced by other species at station T and E but they were replaced by other species at state G.

8. Evidence seems to indicate poorer conditions for algal growth in the environs of Intalco Aluminum plant. The apparent silting over of the rock substrate at the -20 ft. depth at station C, the decrease in standing crop at station G, and the loss of more species from southern stations than from station W suggest a deterioration of quality in this area. This silt was derived from effluent waste, the Nooksack River, and drainage from the shore.

SECTION II

RECOMMENDATIONS

1. It is recommended that an analysis of this coastline be conducted periodically. It is suggested that these studies be conducted for two consecutive years after an interval of five years.

2. It is felt that in further studies of this type that an adequate amount of information may be gained from obtaining: 1) the total biomass within each of the four levels or growth types and 2) presence-absence records of all species within the community. It does not seem necessary to obtain the biomass of each separate species.

3. Further experiments into the response of algae to fluoride are recommended.

4. It is recommended that in further studies the species *Porphyra sp.*, *Pterochondria sp.*, *Rhodomela laryx*, *Rhodomenia palmata*, and *Rhodomenia pertusa* be regarded as possible indicators of environmental stress of the type found in the environs of the aluminum plant.

5. It is recommended that to preserve the quality of marine plant community along the Cherry Point shoreline, the dumping of industrial wastes in this area in the amounts experienced in the fall of 1968 not be permitted. A program to recycle wastes has been begun by this aluminum plant.

SECTION III

INTRODUCTION

The primary purpose of the study was to develop a method of examining quantitatively the structure of subtidal marine plant communities and to compare these plant communities and certain important ecological factors within both the study area and locations less affected by industrial waste. This comparison included plant community structure, and the productivity and physiology of certain plant species. In so doing a quantitative record of the biological condition of the area would be provided that may be used in assessing the effects of alteration of the environment after the establishment of additional industries.

The Shoreline under study is in an area in which industrial developments are taking place. The shoreline is approximately four miles long from Point Whitehorn south along Georgia Strait. The intertidal and subtidal substrate along this coast is composed principally of 6-12 in. boulders set in muddy sand. Underwater plant and animal life is quite abundant. Commercial crabbing is carried on along the southern, more sandy end. The northern end attracts many sports and commercial salmon fishermen. Since few marine herbivorous animals such as sea urchins and marine snails are present, the algae attached to rocks form luxurient stands.

Present sources of deterioration of water quality along the shoreline under study (Figures 1, 2) include the Mobil Oil Company refinery and the Intalco Aluminum Company ore processing plant. The outfall of the oil refinery consists of biologically treated wastes. The main constituents of the waste of the aluminum company are carbon and tars from anodes as well as soluble and insoluble fluorides, alumina and sulfur. The wastes have increased from a level (Table 1) when one pot line was in operation to a maximum with three lines beginning in the fall of 1968. When three lines were in operation the effluent consisted of 13 million gallons of water per day carrying 272-425 mg/l solids and 118-143 mg/l fluorine (as reported to the State Department of Ecology by Intalco Aluminum Corporation). The solids from the alumina reduction process contribute to the turbidity and silt load of the water along Sandy Point-Point Whitehorn shoreline. The nonindustrial sources of suspended solids include the Nooksack River, the Frasier River, small streams and other drainages which gradually erode the shoreline. In most inshore areas less than 20 feet deep, silt materials are carried off exposing a stable cobble bottom.

A subtidal rather than an intertidal approach was used in this study for a number of reasons: (1) The effects of pollution may be masked by the effects of intertidal environmental stresses such as freezing, drying, and heating. (2) Intertidal collecting is complicated by the limitations of tide and wave action. (3) It is

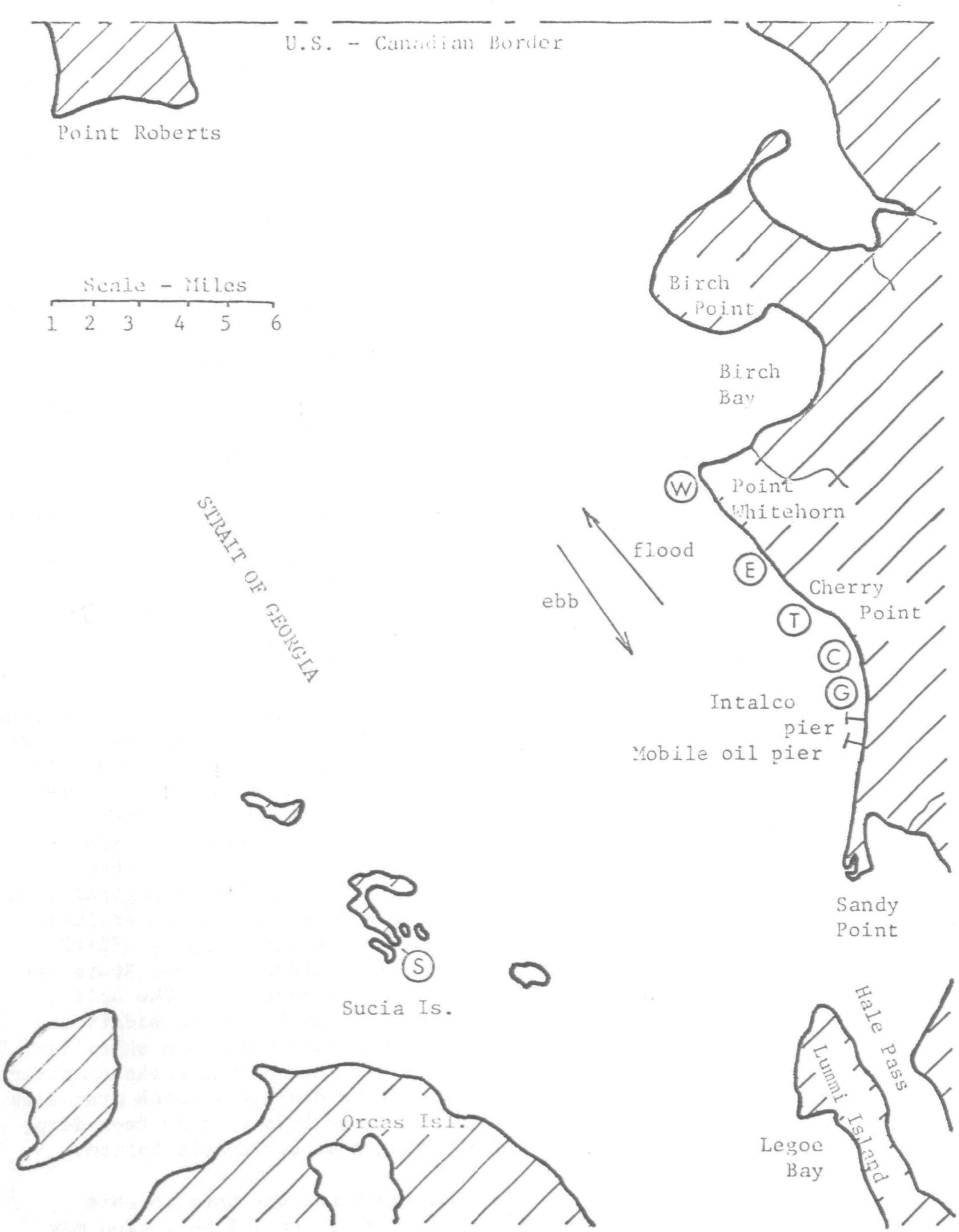

Figure 1. Map of southern end of the Strait of Georgia.

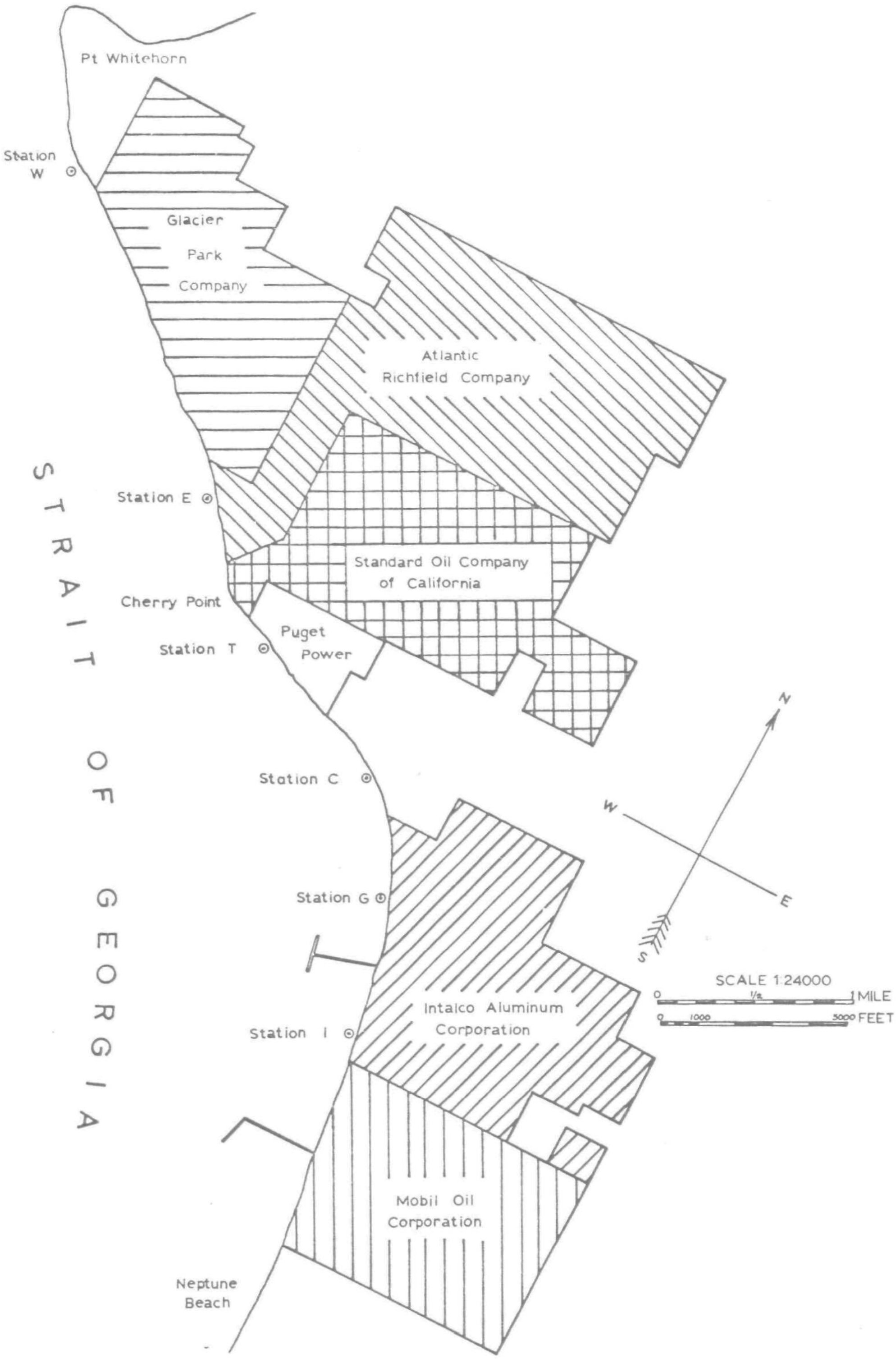

Figure 2. Shoreline of Strait of Georgia.

TABLE 1

ANALYSIS OF SAMPLES OF INTALCO WASTE*

Constituent	Dates of Collection 9-21-66 (mg/l)	11-14-66 (mg/l)
Calcium as Ca^{++}	14.5	16.0
Magnesium as Mg^{++}	11.1	5.0
Sodium as Na^{+}	26.0	22.0
Potassium as K^{+}	2.0	2.3
Hydrogen as H^{+}	0.76	0.60
Aluminum as Al^{+++}		
particulate	18.2	7.2
soluble	7.7	0.56
Chloride as Cl^{-}	2.5	0.5
Fluoride as F^{-}	132.6	107.0
Chloroform extractables	12.4	6.6
Ether extractables	16.0	10.8
SOLIDS AND RESIDUES--		
Total Residue	361	356
Fixed Total Residue	177	268
Volatile Total Residue	184	88
Filtrable Residue	236	193
Fixed Filtrable Residue	106	141
Volatile Filtrable Residue	130	52
Non-Filtrable Residue	125	163
Fixed Non-Filtrable Residue	71	127
Volatile Non-Filtrable Residue	54	36

*Sylvester, Robert O., Dale A. Carlson, Russell F. Christman, and Roy T. Oglesby, A Study of Wastewater Disposal for the Intalco Aluminum Corporation (University of Washington, College of Engineering, Dept. of Civil Engineering) Dec. 1966.

difficult at low tide to gain an accurate inventory of all of the primary consumers. (4) It would also appear that since plants of the intertidal have generally wider geographic range compared with those of the subtidal, they would therefore appear to be less sensitive to subtile differences in environmental factors. It appeared that a study of the subtidal community would provide the most appropriate bioassay of environmental quality.

In order to achieve this understanding of the response of the plant community a quantitative approach was used. Like most studies of underwater plant communities in various parts of the world, the previous studies on the Pacific Coast have been only relatively quantitative.

SECTION IV

MATERIALS AND METHODS

Study Sites were selected by use of photos from aerial surveys and from observations made by divers towed on a diving plane behind a boat. Seven Stations (Figures 1, 2) or study sites were selected. Stations were located in areas of most abundant algal growth. Stations I, G, C, T, E, and W were spaced at intervals down current on a flood tide from sources of industrial waste. Station I was discontinued after 1968. In 1970 station S was added on Sucia Island in an area having a substrate similar to the other sites. Stations G, C, T, E, and W were sampled each year at the -10 ft. depth (reference to mean low tide) as was station S in 1970. Stations sampled at the -20 ft. depth each year include stations W and T. The community at station C was sampled at the -20 ft. depth only in 1968.

The underwater sites were marked with two 4 ft. long 5/8" steel reinforcing rods driven into the substrate 100 ft. apart at the -10 ft. depth. The site was relocated by means of a 100' long 1/2" yellow plastic rope stretched between the rods. On returning to the site the general location was established from the surface by means of photographic records of shoreline features. Location by this method was accurate usually to within 50 ft. of the center of the rope. The divers entered the water slightly deeper than the study site and swam on a compass heading toward shore until the role was intercepted.

Water temperatures were read by a diver at the surface and bottom using a mercury thermometer.

Silt collectors were fashioned from 30" sections of 3" I.D. plastic pipe capped at the lower end. They were secured in an upright position on the bottom attached to 1/2" steel reinforcing rods driven into the bottom.

Light at stations was measured with light meters developed in this study. Light energy received by a silicone photocell was recorded by a Curtis 150 elapsed time meter. The plexiglass port through which light was transmitted was brushed clean of silt by means of magnets rotated by a clock motor within the enclosure.

Two inch square ceramic tiles attached to stainless bolt heads by marine epoxy cement were mounted on stainless steel racks supported 6" above concrete building blocks. The building blocks were prevented from rolling by means of a 1/2" steel reinforcing rod wired on the bottom of the concrete block in a direction perpendicular to the long axis of the block. Ceramic tiles were removed periodically for inspection.

Animals associated with the algae except for the most motile forms such as fish and some shrimp were drawn into the collecting bag with the algae. These were preserved and later identified. The animals counted are tabulated in Table II.

Plants of Laminaria saccharina and Costaria costata collected the aid of S.C.U.B.A. from the subtidal along the west side of Sucia Island and at Legoe Bay, Lummi Island (Figure 1). Plants awaiting analysis were stored in the dark in aerated 4°C sea water.

Readings of oxygen depletion were made with a Gilson Differential Respirometer at 20, 30, and 40 minute time intervals. These time periods permitted the depletion of approximately thirty microliters of oxygen. The water bath temperature was either 8 or 10 degrees centigrade, whichever most closely duplicated the ambient subtidal sea water temperature at the time of the collection. After respiration had been monitored for 60 to 90 minutes, the Intalco waste was added to the sea water and tissue to make a 1:50 dilution. The control vessels, selected at random, received distilled water in place of the effluent. At the end of the experiment the discs were removed, dried for forty-eight hours at 105 degrees centigrade, cooled in a desicator and then weighed.

The growth of the kelp Laminaria saccharina was obtained by measuring the displacement of a 3 mm hole punched in the blade 3.5 cm. distally from a point where the blade was 1 cm wide, or 1.0 cm from the 1 cm wide point in the case of some plants that were less than 10 cm. wide. Plants were attached by rubber bands to a 4-1/2' long, 1" diameter plastic pipe which was anchored on the bottom using concrete blocks.

Aerial photographs of the beds of Nereocystis leutkeana were made annually in September. At this time of the year, these plants reach their greatest development. Photographs were made from an altitude of 1,000 feet using 35 mm camera with a 50 mm lens. The flight path approximated a line which bordered the seaward side of the pictures. The photographs included enough of the shoreline to permit assembly of a composite photo of the shoreline of the entire study area. Maps were approximated from these composite photos.

A measurement of the density of the kelp Nereocystis leutkeana at locations along the study area was made while moving slowly through the bed with a boat. A record was made of the members of individual kelp floats occurring in intervals from the shore measured by a rangefinder. The strips sampled were 10 ft. wide.

Plant communities were sampled by removing at each station all plants within six square quadrats each half-meter on a side.

Quadrats were located along a line which was an extension of the marking line parallel to the shore. Six quadrats were positioned along this line by dropping the metal quadrat marker at points where at least 50 percent of the area of the quadrat was covered by rock substrate. In 1969 and 1970 the lines were located so sampling areas did not overlap those of the previous year.

Plants were scraped off the rocks within the 1/4 meter square marker using a putty knife. The detached plants were collected into a bag by means of a suction tube. The suction tube drew the detached plants into a plastic screen bag. The suction tube was a 3' long piece of 3-1/4" diameter plastic pipe. A water current was impelled through the suction tube by means of a water stream directed obliquely down the tube from a 1/4" nozzle. Water pressure was supplied by a 50 ft. 3/4" garden hose from a centrifugal pump on the surface. The pump was powered by a 1-1/2 h.p. four cycle gasoline engine. In addition to concentrating the detached plants the suction tube aided visibility by clearly silt disturbed in the collecting operation.

Plants were kept cool during transport to the laboratory. They were stored until sorting in aerated, 5^{o} C seawater. Plants of each quadrat were sorted to species, dried on aluminum foil, and weighed. The weights were entered on computer data processing cards.

Certain taxonomic generalizations were made because of the quantity of material processed. When more than one species was known to be present but they were not separated in processing, they were assigned to the genus as spp., as in Ulva spp. The species designation spp. was also used for Laminaria groenlandica and L. saccharina which are distinguished by the presence or absence of microscopic mucilage ducts. When the species was not determined and it was not observed if other species were present the designation sp. was used, for example, Ceramium sp. Plants belonging to Botryoglossom and Cryptopleura were assigned to Botryoglossom. Callophyllis flabellulata and Callophyllis edentata were assigned to Callophyllis flabellulata only during the 1968 study. The term species in this report is therefore generally applied to the lowest taxonomic hierarchy distinguished.

SECTION VI

RESULTS

Average summer surface and bottom temperatures at three stations are compared in Fig. 3. The generally elevated water temperature in 1969 compared with 1968 and 1970 may be explained by the restriction of water movement by the floating kelp Nereocystis leutkeana. The lowest average temperatures occurring at point Whitehorn (station W) indicate mixing with offshore water in this area.

Current velocity, silt, and light are highly interrelated factors in this environment. The amount of light reaching a plant depends upon amount of silt transported in the water. The amount of silt is a function of diffusion and mixing and therefore related to the velocity of the water. Estimated surface current velocities along this shore vary from up to 1.26 knots near station W (Schwartz, et. al. 1971) to approximately half this velocity at station G. The movement of inshore water is parallel to the shore on both the flood and ebb tides. The flood tide is in a northerly direction. Fig. 4 indicates the amount of silt deposited in collectors at each station. The grey silt collected by these tubes included black granular material presumed to be carbon particles resulting from decomposition of the Intalco Aluminum Corporation annodes.

The decreased amounts of silt deposited in collectors toward the north reflects the greater carrying capacity of this faster moving water, the diffusion of aluminum plant wastes, and the diffusion of wastes from the Nooksack River through Hales pass. These diffusion quadients are also reflected in the relative light measured at stations G, C, T, and W (Fig. 5), in which transparency of the water is seen to increase in the direction of station W.

The numbers of each type of organism found on vertically and horizontally oriented tiles October 5, 1968 after 71 days exposure are presented in Figure 6.

Surfaces exposed at the southern end of the study were found to be much more densely covered with barnacles while surfaces of substrate exposed at the more northern stations, though bearing some barnacles, were heavily covered with green algae. It is very likely that the type of organisms established on a fresh substrate is determined to a large extent by the order in which organisms arrive on the substrate.

To provide meaningful information it would appear to be necessary to place substrates out and observe them on a regular schedule (at one month intervals, for example) throughout the year.

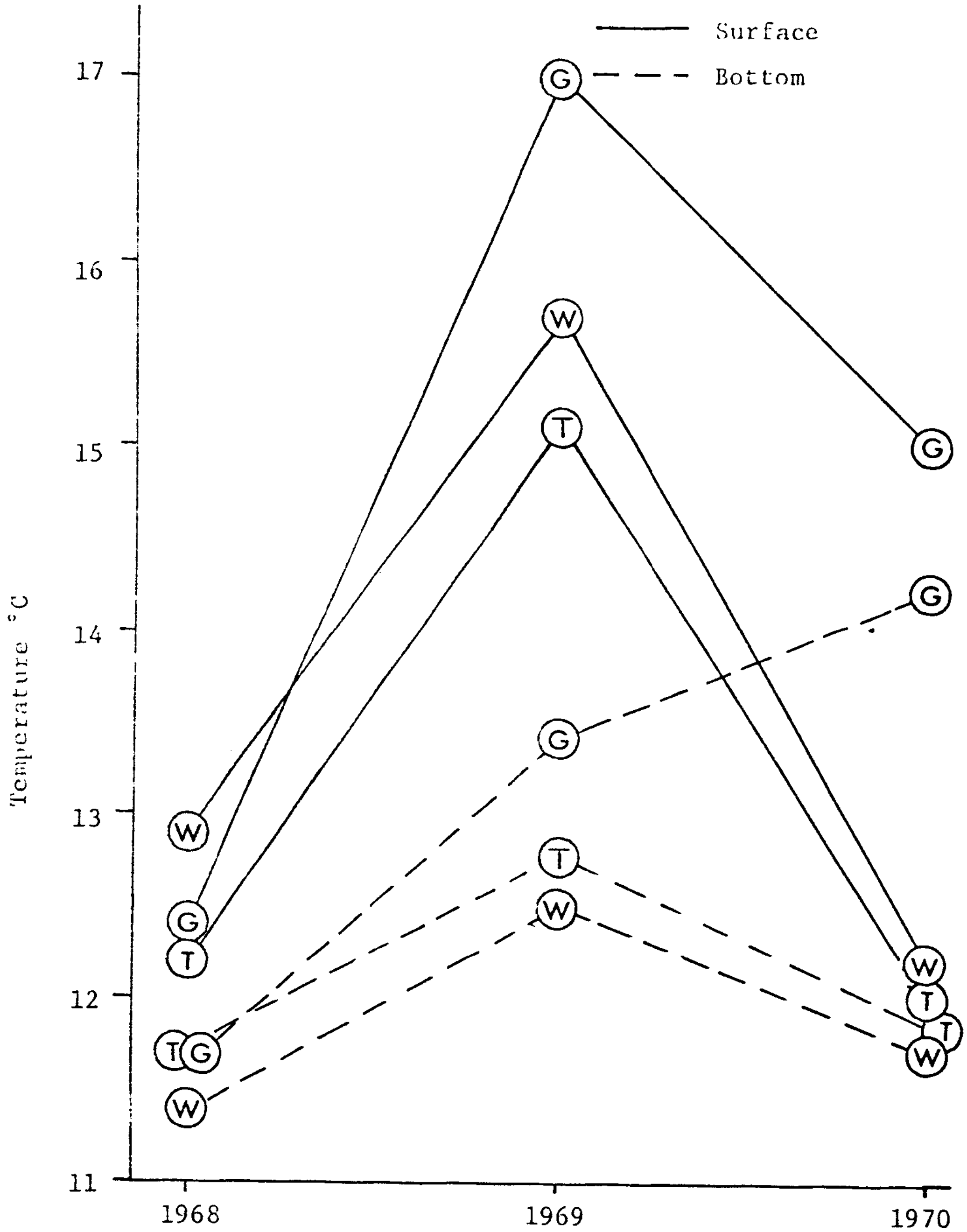

Figure 3. Average surface and bottom temperature at Stations G, T, & W for summers 1968, 1969, and 1970.

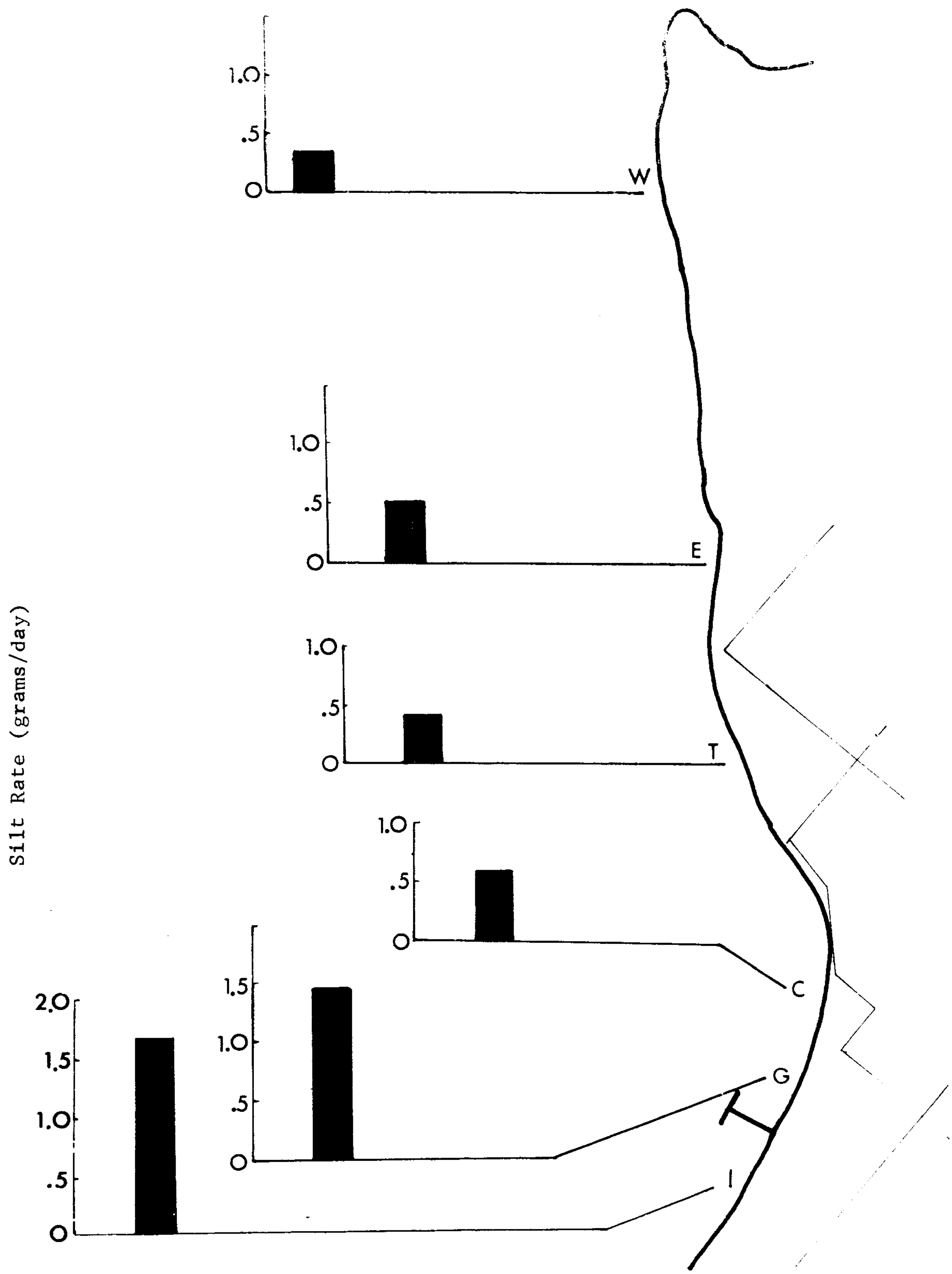

Figure 4. Silt collected in 30" high, 3" diameter vertically oriented tubes at stations I, G, C, T, E, and W. Averaged for period 7-26-68 to 8-27-68.

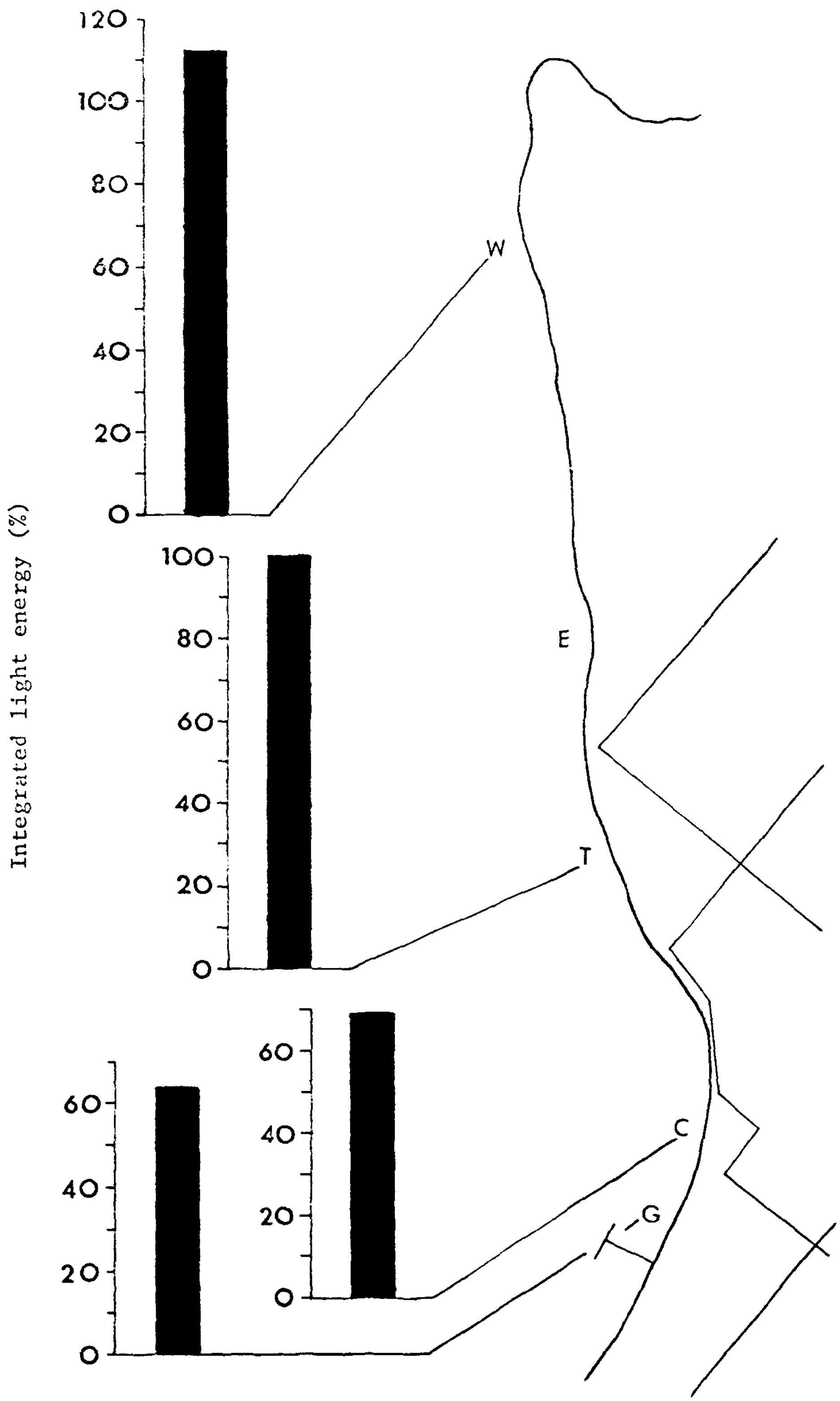

Figure 5. Light integrated for periods of 1-2 weeks at the -10 ft. depth at Stations W, C, and G relative to recordings at Station T. (July 1969)

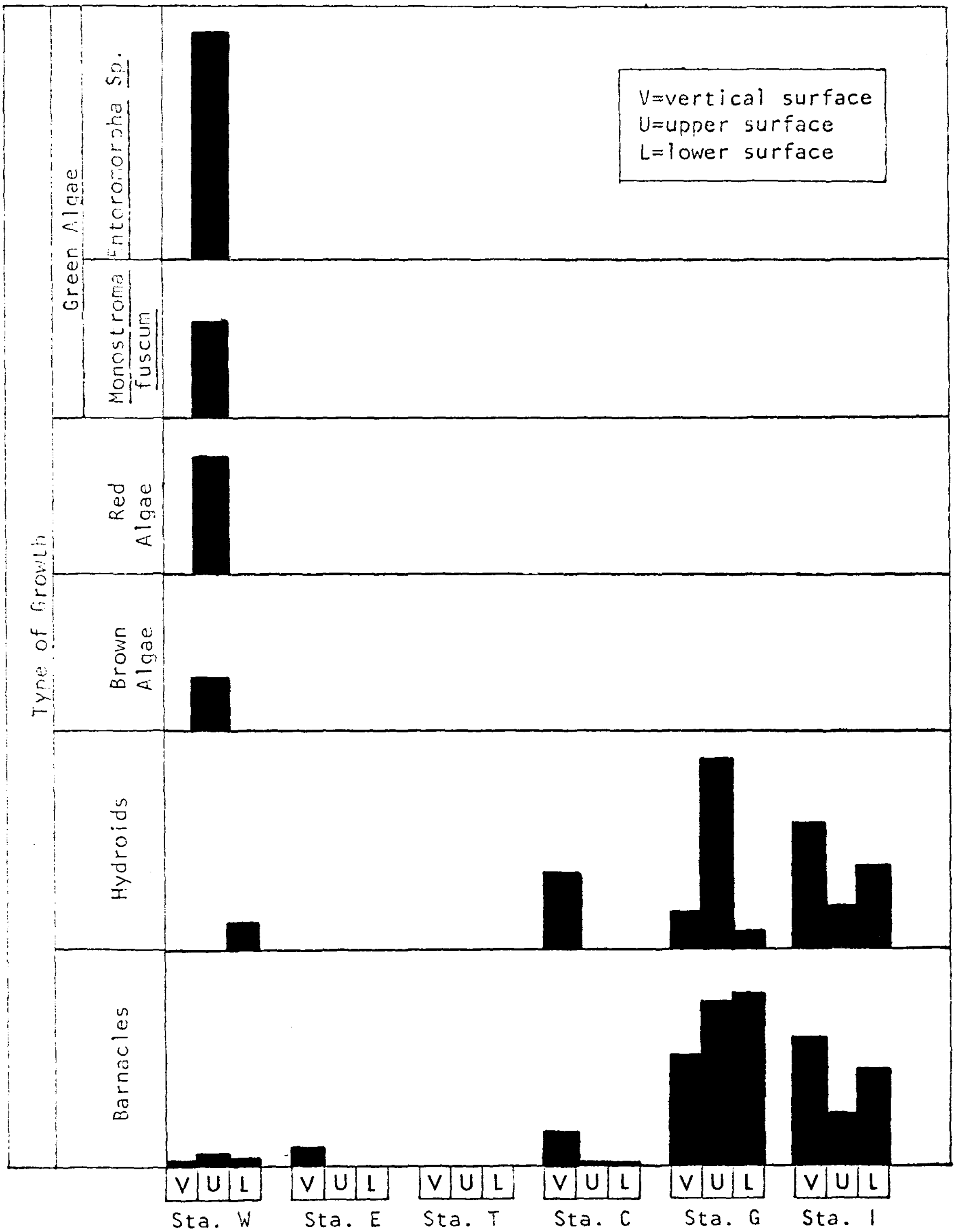

Figure 6. Growth on artificial substrates 7-26-68 to 10-5-68.

The study of the effect of the effluent of the aluminum plant on the rate of respiration in Laminaria saccharina (Table 2) and Costaria costata (Table 3) constitutes part of a masters degree thesis of a student working on the project. In these experiments the effluent was diluted 1:50, a concentration estimated by Sylvester (1966) to occur in the vicinity of the outfall of the aluminum plant. The respiration rate in both species was found during some seasons to increase and at other times to decrease with the addition of the effluent. The change in respiration rate was generally greater with Costaria costata than with Laminaria saccharina. The greater response of tissue of Costaria costata to Intalco effluent was observed in September, 1968, when a 155% increase over the respiration rate of Costaria costata tissue in sea water was recorded. Costaria costata is known to undergo comparatively more physiological change seasonally. A difference in response and sensitivity to some constituent of the effluent such as fluoride would not, therefore, be unexpected. An experiment in September, 1969, was run with Costaria costata designed to replicate the experiments of September 1968, in which greatly increased respiration rate was observed. In this experiment an increase of only 13.6% in respiratory rate was obtained using effluent from the same sample used in the test of the previous year. The lack of agreement in the response the two succeeding Septembers may possibly result from changes in fluoride activity. It is now known if the fluoride activity of the sample was higher in September 1968, since activity measurements were not being made at that time.

An indication of growth in Laminaria sp. growing at stations C and W was obtained in 1968 (Fig. 7). The rate of growth of plants transplanted from Sucia Island was 53.8% greater at Station W compared with C. In a similar experiment in 1968 the growth of Laminaria sp. at station T was found to be quite similar to growth at station W.

The development of the floating kelp Nereocystis leutkeana was observed to be more extensive during the summer of 1969 compared with its stand the other two years of the study. The map, Figure 8, based on aerial photographs shows these differences in distribution but it is not effective in showing density of the kelp beds. Results of one method of recording density of kelps are shown in Figure 9. The failure of Nereocystis leutkeana to return to the same locations in the same abundance each year may be explained by the fact that this species is obligated to regenerate from a spore generated microscopic phase. It does not regenerate from the holdfast of the plant of the previous year.

TABLE 2

RESPIRATION RATE OF *LAMINARIA SACCHARINA* BEFORE AND AFTER ADDITION OF 1:50 DILUTION OF INTALCO ALUMINUM CO. EFFLUENT

Date of Experiment	9-3-68	12-20-68	3-12-69	5-17-69
No. of samples	13	12	13	7
Bath Temperature (°C)	10	8	8	10
Mean respiration before treatment (μL/100 mg/Hr)	39.30	24.80	58.28	104.2
Standard deviation	13.16	6.78	10.44	21.40
Mean respiration after treatment (μL/100 mg/Hr)	42.00	20.26	61.08	123.08
Standard deviation	13.52	7.34	10.82	16.98

TABLE 3

RESPIRATION RATE OF *COSTARIA COSTATA* BEFORE AND AFTER ADDITION OF 1:50 DILUTION OF INTALCO ALUMINUM CO. EFFLUENT

Date of Experiment	9-2-68	10-12-68	12-22-68	3-11-69	3-27-69
No. of samples	12	14	13	13	12
Bath temperature (°C)	10	10	8	8	8
Mean respiration before treatment (μL/100 mg/Hr)	64.38	79.22	28.3	87.5	87.8
Standard deviation	17.06	15.64	6.0	11.9	18.0
Mean respiration after treatment (μL/100 mg/Hr)	163.16	85.95	23.0	109.6	98.7
Standard deviation	36.14	16.8	6.9	12.4	18.4

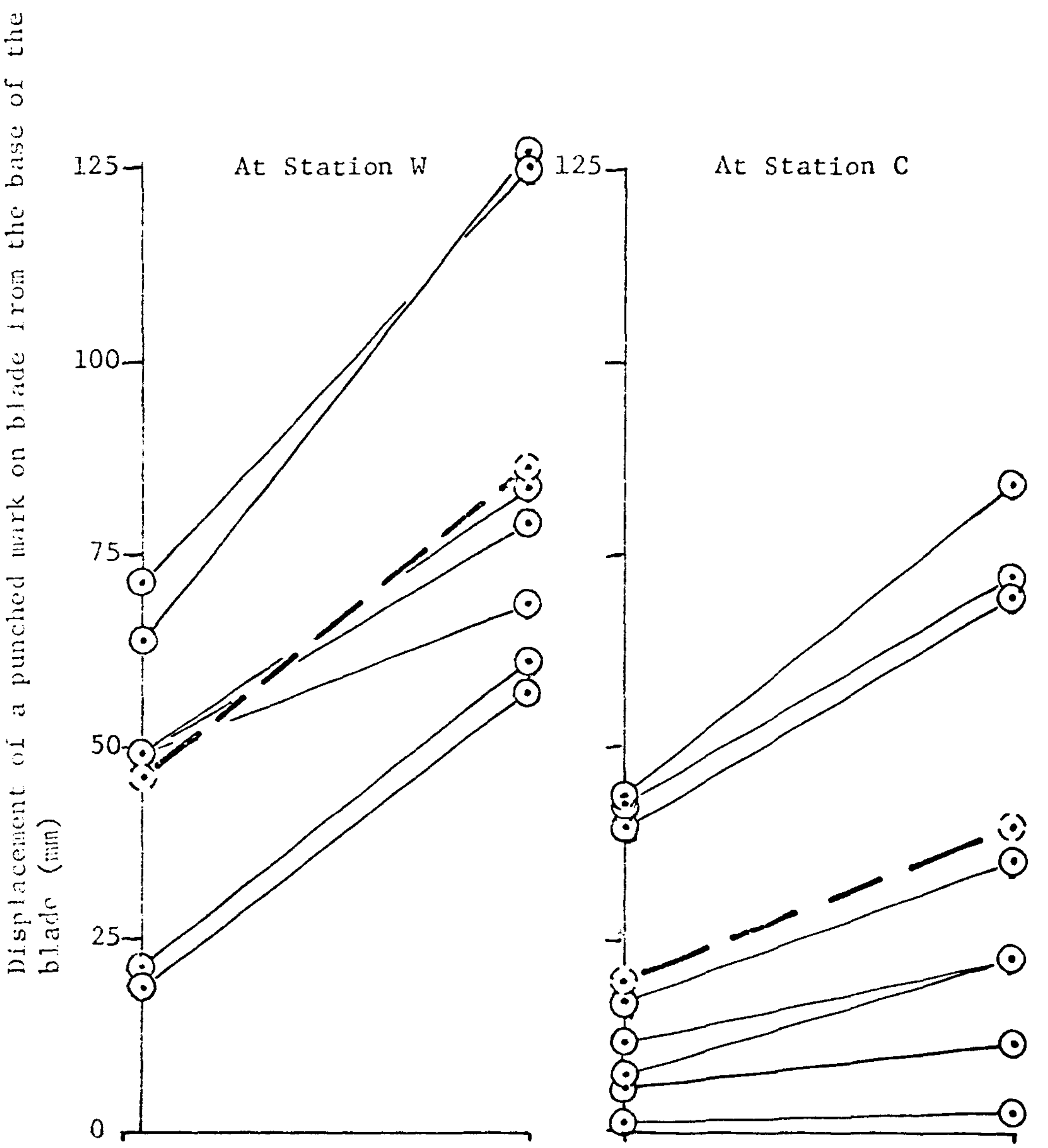

Figure 7. Growth of the blade of Laminaria sp. grown at Stations W and C transplanted from Legoe Bay, Lummi Island, July 13, 1968.

Figure 8. Distribution of Bull Kelp. A comparison of the distribution of the bull kelp Nereocystis leutkeana (level 4) from aerial photographs made in late summers of 1968, 1969, and 1970. Areas south of the dashed lines in maps of 1968 and 1970 were not photographed.

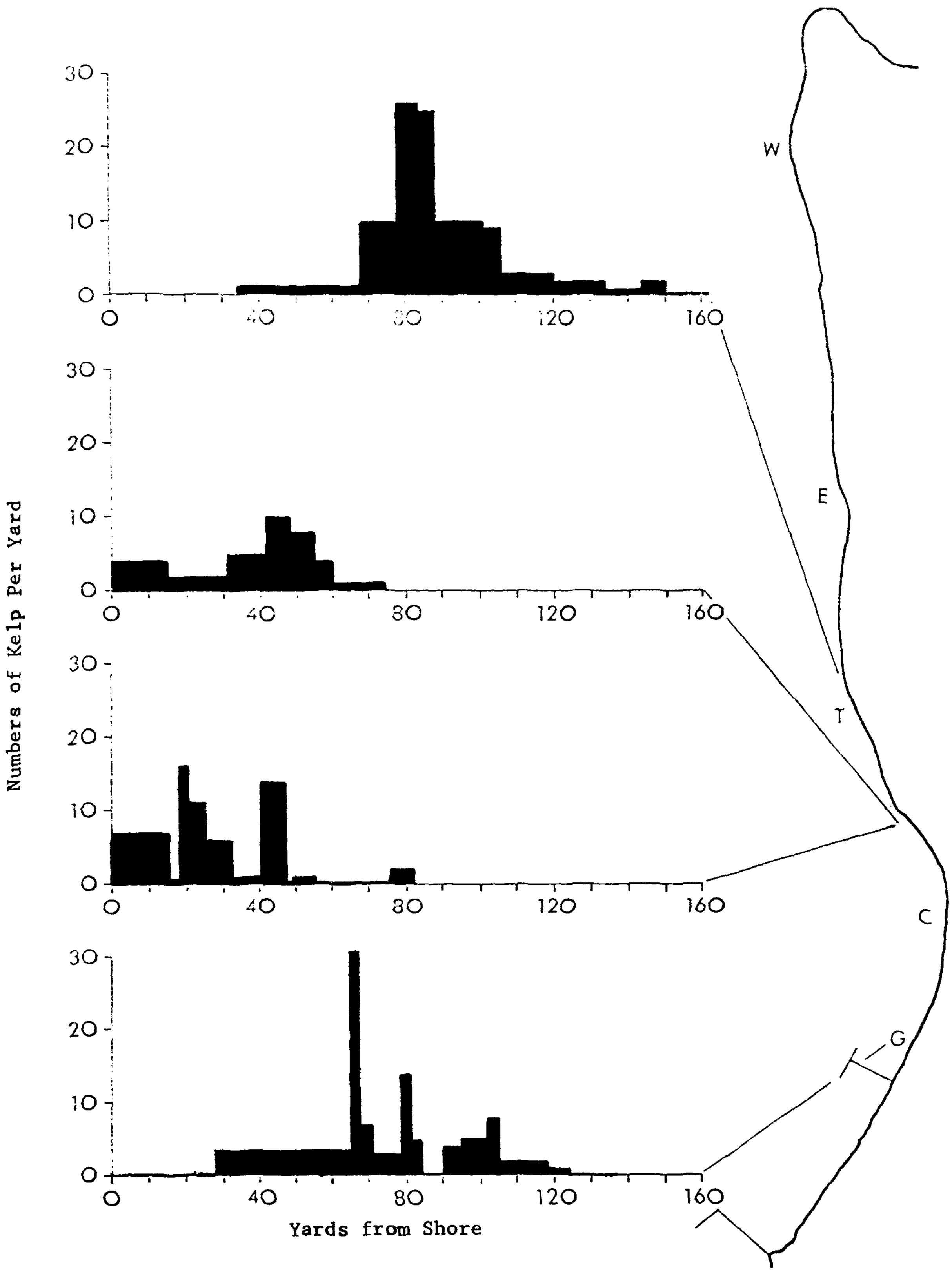

Figure 9. Numbers of kelp per yard counted on the surface in 10 foot wide strips at indicated locations along the shoreline.

Plant Community Analysis

Plant communities at the 10' depth were sampled in 1968 on the following dates:

Station	G	C	T	E	W
Date of Sampling	8-7-68	8-1-68	7-13-68	8-2-68	8-9-68

Communities at the -20' depth were sampled at the following dates:

Station	C	T	W
Date of sampling	8-23-68	8-21-68	8-22-68

These stations were sampled within a week of these dates during the two succeeding summers. Station S was sampled once on 8-28-70. Station C was sampled only in 1968 at the -20' depth. It was not possible to find rocky substrate at this depth at this station in subsequent years. The bottom appeared to have accumulated enough silt to cover the boulders.

There is a clearly consistent pattern of decreased total biomass (Table 4) of communities at all stations at the -10' depth. This is shown in this report to result from the large kelp cover occurring that year. The most significant decrease over the three years is seen at station G. Comparisons of total biomass year to year or station to station should be made cautiously because of variations in the area of rock substrate appearing within the same quadrats.

TABLE 4

MEAN BIOMASS OF ENTIRE PLANT COMMUNITIES (GRAMS/1-1/2 SQ. METER)

Stations	Depth (Ft.)	1968	1969	1970	3-yr Avg.
G	-10	574.9340	294.0132	238.7725	369.2399
C	-10	433.3719	415.4119	408.6606	419.1481
T	-10	416.8385	212.5275	1041.3173	556.8944
E	-10	779.7178	448.8629	698.6252	642.4020
W	-10	916.2987	196.2562	1443.9465	852.1671
T-deep	-20	68.9038	83.6334	115.3865	89.3079
W-deep	-20	73.0061	192.0323	202.8124	155.9503
C-deep	-20	118.1399			118.1399
S	-10			521.8860	521.8860

In this study plants are arranged according to four growth types or levels. This is done with a view at discovering possible relationships between elements of the plant community and possible effects of industrial effluent on distinct types of plants within the community. Level one includes the uni- and pluriseriate filamentous types; level two, the foliose types which includes most other algae; level three, the bottom kelps; and level four, the floating bull kelp. This classification recognizes the relationship between morphology of plants and environmental niches occupied by plants. At one extreme is the bull kelp (Level 4) with the floating portion of its stipe periodically exposed to the atmosphere, its association with other algae occurring only around its holdfast. At the other extreme are the filamentous algae (Level 1) tufted between leafy, more or less, upright algae (Level 2) and frequently covered by blades of bottom kelps (Level 3). Species are listed by levels in Table 5. In Figure 10, communities are compared according to the biomass of their constituent levels.

One fairly consistent pattern is seen in the relative decrease in abundance of filamentous, Level 1, algae from station C toward station W (Figure 10). It would appear that algae of level 1 are favored by conditions of higher silt found at C. This explanation is supported by the fact that level 1 plants are also the ones which dominate in the deeper, -20' depth community at station T where current at the bottom is less than at the bottom at the -10' depth and plants are therefore more heavily dusted with silt. It may be the case that up to a point silt favors the filamentous algae of the community indirectly by depressing the growth of bottom kelps (Level 3) with which the filamentous algae compete. Kelps are usually layered with fine silt at these southern stations. Filamentous algae (Level 1) having more surface area, may be more suited than the kelps to carry out the functions of photosynthesis and nutrient exchange under the silt conditions. This theory of level 1 filamentous algae being more successful competitors in a silty environment is not supported by the biomass values for level 1 at station G in 1969 and 1970. This station is, however, most directly exposed to the outfall of the aluminum plant. This company produced its peak outfall in the fall of 1968, prior to the measurements of low biomass in the summer of 1969. At this time chemical or silting conditions may have been excessive for these plants as well as the kelps. The source of the silt accumulated at the -20' depth at station G was not determined. A small amount was no doubt due to erosion in this area resulting from changing the landscape of the bank in front of the aluminum plant site. Beginning in the fall of 1968 the effluent of the aluminum plant was increased with the addition of a third pot line.

The most important modification of the community over the three years was the increase in abundance of bull kelp Nereocystis

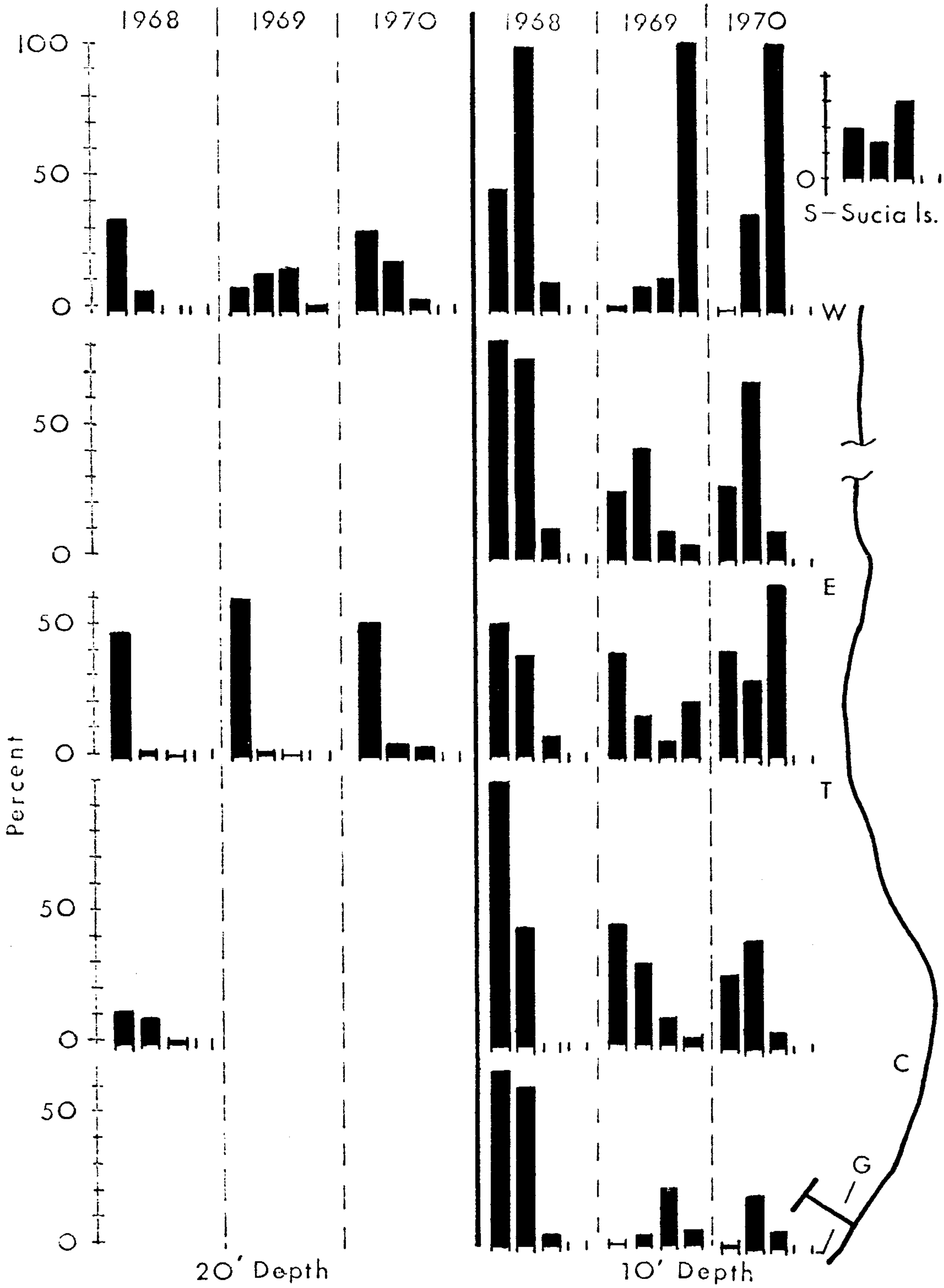

Figure 10. Biomass of plant communities by levels. Levels 1, 2, 3, and 4 are represented left to right by the four bars for each station, year, and depth. The values are relative to the highest biomass within that level at any station during the three years.

leutkeana (Level 4) in 1969 (Figure 10). With this more developed level 4 kelp canopy in 1969, there was a general decrease in abundance of plants of the lower three levels of the communities at the -10' depth. The depression was great enough to result in below average biomass for entire communities including Nereocystis at all stations at the -10' depth in the years 1968 and 1970. The plants with the greatest percentage decrease were those of levels 1 and 2. In 1970 when the kelp cover returned to a density similar to that of 1968, there was an increase in abundance of levels 1, 2, and 3. Evidence that the kelp cover was the cause of the modification in abundance of levels 1, 2, and 3 lies in the fact that in the deeper -20' community at station T, where kelps were absent all three years the biomass in community levels 1, 2, and 3 remains quite constant year to year (Figure 10). The cause of variations in kelp frequency and distribution are not known. There is no evidence that it was linked to industrial effects.

The following are among the conclusions that can be drawn from the data of Table 5 regarding individual species at the -10' level. Species present in at least 80% of the stations at this level throughout the three years include:

Pterosiphonia dendroidea
Pterosiphonia gracilis
Ahnfeltea plicata
Botryoglossum sp.
Callophyllis fabellulata
Constantinea simplex
Iridaea costata
Laurencia spectabilus
Odonthalia floccosa
Odonthalia washingtonensis
Plocamium pacificum
Prionitis lyallii
Laminaria sp.

These thirteen species would appear to be the stable elements of the community and are therefore most resistant to naturally and industrially imposed stresses that differ either in time or in location.

Species listed in Table 6 are those which occur inconsistently at the -10' level. They are absent during one or more years but are otherwise present at more than one station in one year.

These species are possible indicators of types of environmental change since they show significant change in frequency in time. The largest number are found in Group I (Table 6). There are more plant species which were present in 1968 and lost in succeeding years (Group I) compared with species gained in other years (Groups II, VI). It would appear that species of Group I may be affected by some environmental disturbance. It would appear that such a disturbance is restricted to the more southern end of the study area since the species lost were from stations south of Station W. Plants of Group I may have responded to the waste of the aluminum plant which began to be discharged just prior to the beginning of this study and reached a peak in the fall of 1968.

TABLE 5

BIOMASS (gm/1-1/2 sq. m.) TOTAL DRY WEIGHT (grams) OF SPECIES COLLECTED WITHIN 6, 1/2 METER SQUARE QUADRATS AT EACH STATION, YEAR AND DEPTH SAMPLED

Species	Depth / Year / Station	-10 feet 1968 G	C	T	E	W
LEVEL I						
Antithamnion sp.			0.0798	0.3954		
Ceramium sp.			0.0487	0.0061		
Herposiphonia rigida		6.7357	12.1500	8.2561	7.6818	4.6328
Platythamnion sp.				7.4513	0.0092	
Pleonosporium sp.				2.3336		
Polysiphonia sp.			1.1328	1.1869	0.0930	
Pterochondria sp.			0.2285		0.1139	
Pterosiphonia dendroidea		3.1519	18.2539		13.6299	7.0244
Pterosiphonia gracilis		100.4081	126.4098	29.9348	92.9438	66.7188
Spermothamnion sp.		0.2405	10.2260	7.6541	0.5689	0.0002
Sphacillaria sp.				0.7108		
Spongomorpha sp.						
LEVEL II						
Agardiella tenera						
Ahnfeltia plicata		15.2448	0.0592	2.4366	3.5915	0.8276
Bossiella corymbifera				0.0713	0.3829	
Botrioglossum sp.		59.5004	54.8718	32.9105	131.4996	207.7530
Callophyllis edentata						
Callophyllis flabellulata		35.8189	10.9854	5.5609	9.2126	4.8314
Corallina vancouveriensis						
Constantinea simplex		2.8642	4.2966	70.3916	91.2342	108.6226
Cystoseira geminata					0.0708	
Delesseria decipiens				0.4826		
Desmarestia intermedia					0.7059	
Dilsea californica		0.4850				
Farlowia mollis				4.5536		
Gelidium sp.						0.2632
Gigartina cristata						3.7685
Gigartina exasperata		0.8539	0.4483	0.0745		9.3367
Gracillariopsis sjoestedtii			0.1400	0.1302	0.6531	0.2116
Grateloupia sp.						
Gymnogongrus linearis					0.0358	
Gymnogongrus platyphyllus			0.0249			
Iridaea cordata		51.01[illegible]	[illegible].[illegible]943	40.7654	68.9063	56.2222
Laurencia spectabilis		7.4277	3.3843	2.6854	11.4962	24.2837
Microcladia coulteri						
Monostroma fuscum			0.2635		1.0315	10.3659

TABLE 5 (continued)

BIOMASS (gm/1-1/2 sq. m.) TOTAL DRY WEIGHT (grams) OF SPECIES COLLECTED WITHIN 6, 1/2 METER SQUARE QUADRATS AT EACH STATION, YEAR AND DEPTH SAMPLED

Species / Depth / Year / Station	-10 feet 1968 G	C	T	E	W
LEVEL II (Continued)					
Nienburgia borealis			0.6529		
Odonthalia floccosa	17.1986	12.8281	6.5689	90.5056	72.5964
Odonthalia washingtonensis	16.5958	2.1918	1.7588	2.7800	96.7946
Opuntiella californica					
Plocamium pacificum	154.2101	182.2144	57.3259	100.1546	52.0793
Polyneura latissiua	29.1345	13.8098	5.6156	24.7079	55.2462
Porphyra sp.			3.6843	0.6896	
Prionitis lyallii	7.1945	0.4852	39.8894	24.5236	33.0351
Rhodoglossum affine			0.4371		
Rhodomela larix	0.2536	0.0668	0.1341	0.6665	
Rhodoptilum plumosum			2.3124		
Rhodomenia palmata	0.2218		0.0549		
Rhodomenia pertusa	49.4299	12.1179	0.2871		
Sargassum muticum					
Ulva spp.	21.8029	0.2983		0.1988	0.3213
LEVEL III					
Alaria marginata					
Costaria costata					
Fucus gardneri					
Laminaria spp.	34.6864		85.4787	129.7329	129.5335
Pterygophora californica					
LEVEL IV					
Nereocystis leutkeana					

TABLE 5 (continued)

BIOMASS (gm/1-1/2 sq. m.) TOTAL DRY WEIGHT (grams) OF SPECIES COLLECTED WITHIN 6, 1/2 METER SQUARE QUADRATS AT EACH STATION, YEAR AND DEPTH SAMPLED

Species	Depth / Year / Station	-10 Feet 1969 G	C	T	E	W
LEVEL I						
Antithamnion sp.						
Ceramium sp.		0.0031	0.0023			
Herposiphonia rigida			0.9131	4.5939	1.3962	
Platythamnion sp.						0.0236
Pleonosporium sp.						
Polysiphonia sp.			19.9624	0.3442	0.3764	
Pterochondria sp.						
Pterosiphonia dendroidea			6.3811	5.2083	6.9757	0.0358
Pterosiphonia gracilis		0.2357	20.5699	30.0362	18.0765	0.3328
Spermothamnion sp.		0.5756				
Sphacillaria sp.						
Spongomorpha sp.				0.0350		
LEVEL II						
Agardiella tenera			0.1061	4.6496	0.3204	0.2009
Ahnfeltia plicata		3.0080	0.0358	12.0271	7.3844	16.5355
Bossiella corymbifera				9.5391	0.9463	
Botrioglossum sp.		4.0262	3.1890	7.2156	35.8890	2.3586
Callophyllis edentata		4.5158	0.2177		2.1372	0.0167
Callophyllis flabellulata		0.5271	1.2517	0.6468	0.6683	0.0816
Corallina vancouveriensis						
Constantinea simplex			46.7558	4.4595	99.2163	10.9468
Cystoseira geminata						
Delesseria decipiens						
Desmarestia intermedia						
Dilsea californica						
Farlowia mollis						
Gelidium sp.						
Gigartina cristata						
Gigartina exasperata				0.0824		
Gracillariopsis sjoestedtii						
Grateloupia sp.						
Gymnogongrus linearis						
Gymnogongrus platyphyllus						
Iridaea cordata		4.3223	6.3581	6.5003	50.5326	5.3668
Laurencia spectabilis		0.0295	1.0202	4.5262	15.9246	2.7646
Microcladia coulteri						
Monostroma fuscum		1.8493	2.0904	3.7642	6.2089	5.7657

TABLE 5 (continued)

BIOMASS (gm/1-1/2 sq. m.) TOTAL DRY WEIGHT (grams) OF SPECIES COLLECTED WITHIN 6, 1/2 METER SQUARE QUADRATS AT EACH STATION, YEAR AND DEPTH SAMPLED

Species	Depth / Year / Station	-10 feet 1969 G	C	T	E	W
LEVEL II (Continued)						
Nienburgia borealis						
Odonthalia floccosa		1.5834	37.7403	6.8989	48.1887	2.0362
Odonthalia washingtonensis		1.1056	0.9521	0.4708	12.7126	5.9624
Opuntiella californica						
Plocamium pacificum		11.3556	135.9815	46.6525	21.7184	2.4256
Polyneura latissiua			0.0887	0.3407	0.1367	
Porphyra sp.			0.4027			
Prionitis lyallii			1.6857	2.9049	20.7079	4.8316
Rhodoglossum affine						
Rhodomela larix						
Rhodoptilum plumosum						
Rhodomenia palmata						
Rhodomenia pertusa						
Sargassum muticum			12.2772	0.0928		0.0786
Ulva spp.						
LEVEL III						
Alaria marginata			5.5442	1.5131	1.6659	32.9164
Costaria costata		29.0697	61.7530	35.2480	71.0385	0.2964
Fucus gardneri						
Laminaria spp.		232.1183	71.0123	26.4796	38.8747	114.2757
Pterygophora californica						
LEVEL IV						
Nereocystis leutkeana		565.9626	342.0518	20043.9978	460.1938	10261.5508

TABLE 5 (continued)

BIOMASS (gm/1-1/2 sq. m.) TOTAL DRY WEIGHT (grams) OF SPECIES COLLECTED WITHIN 6, 1/2 METER SQUARE QUADRATS AT EACH STATION, YEAR AND DEPTH SAMPLED

Species	Depth			-10 feet		
	Year			1970		
	Station G	C	T	E	W	S
LEVEL I						
Antithamnion sp.	0.0450					0.8107
Ceramium sp.						0.7718
Herposiphonia rigida	0.1984	2.6951	0.3650	2.4582	0.1776	1.5135
Platythamnion sp.				0.0364		
Pleonosporium sp.			0.0182			
Polysiphonia sp.	0.0832					0.3339
Pterochondria sp.						
Pterosiphonia dendroidea	0.0402	2.2908	16.0874	2.8295	0.0326	1.3760
Pterosiphonia gracilis	2.8922	23.4596	26.2089	25.1181	0.1281	15.5417
Spermothamnion sp.		0.5370	0.0535			0.0442
Sphacillaria sp.						
Spongomorpha sp.						
LEVEL II						
Agardiella tenera		0.4597	0.3734	1.5999	0.5661	
Ahnfeltia plicata	0.5758	3.0475	0.0835	5.0202	4.5371	
Bossiella corymbifera					0.3319	
Botrioglossum sp.	8.3492	22.3577	26.3202	167.2632	64.5838	
Callophyllis edentata	2.1616	4.0785	0.4986	0.7299	0.3557	0.1824
Callophyllis flabellulata	2.9234	16.1693	0.0748	3.3393	0.4707	0.3127
Corallina vancouveriensis				0.2927		6.9210
Constantinea simplex	10.4699		0.8150	58.6708	54.8173	
Cystoseira geminata		0.2369	0.1565			
Delesseria decipiens						
Desmarestia intermedia	0.4625	0.0417	0.3475	0.5750		0.8922
Dilsea californica						
Farlowia mollis						
Gelidium sp.					0.2344	
Gigartina cristata						
Gigartina exasperata	1.1068	6.4969	2.2501			
Gracillariopsis sjoestedtii			0.1588		0.2202	
Grateloupia sp.				0.0989		
Gymnogongrus linearis						
Gymnogongrus platyphyllus						
Iridaea cordata	3.8420	0.1383	14.3725	36.9538	77.5323	
Laurencia spectabilis	4.9874	3.3145	7.8812	15.0724	17.9460	10.4769
Microcladia coulteri	0.0722					
Monostroma fuscum	0.4632	0.0461	0.6751	0.4384	1.8121	2.0250

TABLE 5 (continued)

BIOMASS (gm/1-1/2 sq. m.) TOTAL DRY WEIGHT (grams) OF SPECIES COLLECTED WITHIN 6, 1/2 METER SQUARE QUADRATS AT EACH STATION, YEAR AND DEPTH SAMPLED

Species	Depth Year Station			-10 feet 1970			
		G	C	T	E	W	S
LEVEL II (Continued)							
Nienburgia borealis							
Odonthalia floccosa		12.9804	19.8585	37.4815	95.5840	21.9709	38.9201
Odonthalia washingtonensis		13.7874	8.7421	10.5273	9.9560	0.8137	7.7762
Opuntiella californica				0.8711			
Plocamium pacificum		88.0315	210.5590	118.0663	74.1905	6.4527	13.1404
Polyneura latissiua		0.1531	4.3675	1.7821	15.1813	1.1836	0.4775
Porphyra sp.							
Prionitis lyallii		0.6986	1.1736	0.2204	24.1879	19.6519	0.0730
Rhodoglossum affine							
Rhodomela larix							
Rhodoptilum plumosum							
Rhodomenia palmata							
Rhodomenia pertusa					1.8831		
Sargassum muticum							2.2908
Ulva spp.		3.3025	0.7106		0.1940		18.8090
LEVEL III							
Alaria marginata							
Costaria costata							
Fucus gardneri							2.2854
Laminaria spp.		81.1344	68.8803	775.7012	110.8430	1181.4341	259.9897
Pterygophora californica							97.0230
LEVEL IV							
Nereocystis leutkeana							

TABLE 5 (continued)

BIOMASS (gm/1-1/2 sq. m.) TOTAL DRY WEIGHT (grams) OF SPECIES COLLECTED WITHIN 6, 1/2 METER SQUARE QUADRATS AT EACH STATION, YEAR AND DEPTH SAMPLED

Species / Depth / Year / Station	-20 feet 1968 C	1968 T	1968 W	1969 T	1969 W
LEVEL I					
Antithamnion sp.	0.2101	1.4151	1.4401		
Ceramium sp.	0.0220		0.1654	0.1978	
Herposiphonia rigida	1.6863	3.0408	2.0787		1.4913
Platythamnion sp.	0.6292	2.3477	10.6736	3.7256	0.5746
Pleonosporium sp.	0.0608	2.4548	0.6075		
Polysiphonia sp.	0.4379	0.0562	0.1274		
Pterochondria sp.					
Pterosiphonia dendroidea	0.0946	0.1084		0.1152	0.2737
Pterosiphonia gracilis	17.3510	62.1426	34.4845	2.9516	6.6556
Spermothamnion sp.	0.6565	2.0230	0.9832	56.7785	1.2118
Sphacillaria sp.		0.0013			
Spongomorpha sp.					
LEVEL II					
Agardiella tenera				0.1180	4.3511
Ahnfeltia plicata	0.1897	0.0700	0.1457	0.0253	0.2518
Bossiella corymbifera					
Botrioglossum sp.	0.7437	0.2245	2.2492	0.5717	4.5726
Callophyllis edentata					1.7724
Callophyllis flabellulata	5.5553	3.1423	6.7330	0.0513	1.4045
Corallina vancouveriensis					
Constantinea simplex				0.0921	4.3148
Cystoseira geminata	14.5878	0.0814			
Delesseria decipiens					
Desmarestia intermedia			0.3585		
Dilsea californica					
Farlowia mollis					
Gelidium sp.					
Gigartina cristata					
Gigartina exasperata	3.1524			6.6418	9.6734
Gracillariopsis sjoestedtii	5.8333	0.4671	0.1318		
Grateloupia sp.					
Gymnogongrus linearis					
Gymnogongrus platyphyllus					
Iridaea cordata	0.0944		3.5949		0.6373
Laurencia spectabilis	1.0007	0.0192	0.2276	0.4821	16.8175
Microcladia coulteri					
Monostroma fuscum		0.0531	0.1817		

TABLE 5 (continued)

BIOMASS (gm/1-1/2 sq. m.) TOTAL DRY WEIGHT (grams) OF SPECIES COLLECTED WITHIN 6, 1/2 METER SQUARE QUADRATS AT EACH STATION, YEAR AND DEPTH SAMPLED

Species / Depth / Year / Station	-20 feet 1968 C	1968 T	1968 W	1969 T	1969 W
LEVEL II (Continued)					
Nienburgia borealis		0.0501	9.1062		
Odonthalia floccosa	5.2836	0.0068	0.1479	0.3943	16.2541
Odonthalia washingtonensis	0.4923				15.0866
Opuntiella californica					4.1635
Plocamium pacificum	5.4556	0.3631	0.1528	0.3950	19.3724
Polyneura latissima		1.7223	5.9866		
Porphyra sp.					
Prionitis lyallii					2.9018
Rhodoglossum affine					
Rhodomela larix					
Rhodoptilum plumosum	0.0889	0.6846	0.9091		
Rhodomenia pertusa	29.7087		5.4609		
Rhodomenia palmata	8.3577	1.5717			
Sargassum muticum				0.0658	
Ulva spp.	0.2607	0.0206			
LEVEL III					
Alaria marginata					
Costaria costata					161.2945
Fucus gardneri					
Laminaria spp.	18.8172	8.6046		9.8232	25.0176
Pterygophora californica					
LEVEL IV					
Nereocystis leutkeana					1.4866

TABLE 5 (continued)

BIOMASS (gm/1-1/2 sq. m.) TOTAL DRY WEIGHT (grams) OF SPECIES COLLECTED WITHIN 6, 1/2 METER SQUARE QUADRATS AT EACH STATION, YEAR AND DEPTH SAMPLED

Species / Depth / Year / Station	-20 Feet 1970 T	-20 Feet 1970 W
LEVEL I		
Antithamnion sp.	2.2325	0.0047
Ceramium sp.		
Herposiphonia rigida	0.0504	0.8292
Platythamnion sp.		1.2981
Pleonosporium sp.		
Polysiphonia sp.		0.2407
Pterochondria sp.		
Pterosiphonia dendroidea	0.1206	0.4372
Pterosiphonia gracilis	51.3831	28.1127
Spermothamnion sp.		0.1137
Sphacillaria sp.		
Spongomorpha sp.		
LEVEL II		
Agardiella tenera	0.5926	1.9301
Ahnfeltia plicata	0.0604	0.0195
Bossiella corymbifera		
Botrioglossum sp.	2.5678	0.8978
Callophyllis edentata	0.2686	2.1320
Callophyllis flabellulata	10.9115	41.9479
Corallina vancouveriensis		
Constantinea simplex		6.6492
Cystoseira geminata		
Delesseria decipiens		
Desmarestia intermedia		
Dilsea californica		
Farlowia mollis		
Gelidium sp.		
Gigartina cristata		
Gigartina exasperata	1.0028	25.2965
Gracilariopsis sjoestedtii	0.4612	1.6038
Grateloupia sp.		
Gymnogongrus linearis		
Gymnogongrus platyphyllus		
Iridaea cordata	0.4762	1.7632
Laurencia spectabilis	0.1864	0.6389
Microcladia coulteri		
Monostroma fuscum		0.0299

TABLE 5 (continued)

BIOMASS (gm/1-1/2 sq. m.) TOTAL DRY WEIGHT (grams) OF SPECIES COLLECTED WITHIN 6, 1/2 METER SQUARE QUADRATS AT EACH STATION, YEAR AND DEPTH SAMPLED

Species — Depth / Year / Station	-20 feet, 1970: T	-20 feet, 1970: W
LEVEL II (Continued)		
[illegible]burgia borealis		0.2886
Odonthalia floccosa	0.1647	1.0787
Odonthalia washingtonensis	0.2175	2.6745
Opuntiella californica		11.1475
Plocamium pacificum	2.3050	22.2677
Polyneura latissiua	6.2691	9.9464
Porphyra sp.		
Prionitis lyallii		
Rhodoglossum affine		
Rhodomela larix		
Rhodoptilum plumosum		0.3012
Rhodomenia palmata		0.2680
Rhodomenia pertusa	8.6438	4.1461
Sargassum muticum		
Ulva spp.		0.0330
LEVEL III		
Alaria marginata		
Costaria costata		
Fucus gardneri		
Laminaria spp.	27.4689	36.3600
Pterygophora californica		
LEVEL IV		
Nereocystis leutkeana		

TABLE 6

NUMBER OF STATIONS AT WHICH SPECIES OF INCONSISTENT OCCURRENCE ARE PRESENT DURING EACH YEAR

Species		1968	1969	1970
Group I	*Porphyra sp.*	2	1	0
	Pterochondria sp.	2	0	0
	Rhodomela laryx	4	0	0
	Rhodomenia palmata	2	0	0
	Rhodomenia pertusa	3	0	1
Group II	*Gratiloupia sp.*	0	0	2
	Corallina sp.	0	0	2
Group III	*Antithamnion sp.*	2	0	1
	Cystoseira geminata	1	0	2
	Desmarestia intermedia	1	0	4
	Gracilariopsis sjoestedtii	4	0	2
	Pleonospprium sp.	1	0	1
	Spermothamnion sp.	5	1	3
	Ulva sp.	4	0	3
Group IV	*Ceramium sp.*	1	2	0
	Sargassum muticum	0	3	0
Group V	*Polysiphonia sp.*	3	3	1
	Bossiella corymbifera	2	2	1
Group VI	Agardiella tenera	0	4	4

TABLE 7

NUMBERS OF ANIMALS COLLECTED WITH PLANT SAMPLES AT INDICATED STATIONS, YEARS AND DEPTHS

Species	Depth	10'									
	Year	1968					1969				
	Station	G	C	T	E	W	G	C	T	E	W
Porifera											
Cnidaria											
Aglaophenia sp.		3									
Anemone sp.											
Epiactis prolifera					1						
Obelia sp.								18	2	4	12
Unidentified					2						
Platyhelminthes											
Notoplana sp.			1			3		1			
Rhynchocoela											
Unknown		1						4	2		1
Annelida											
Armandia brevis										2	1
Axiothella rubrocincta					2			25	6	14	4
Eudistylia polymorpha						1					
Glycera sp.		1						4			
Halosydna brevisetosa		26	4		47	18	2	75	38	64	28
Hoploscoloplos sp.						2					
Nereidae											
Neries procera		17	9		59	25	15	73	64	142	116
Phyllodoce sp.											
Pleisidice aspera											
Polycheata						4					
Sabellaria cemetarium											
Sabellidae sp.											
Serpula vermicularis									33		
Spirorbis sp.			10			25	2	50		14	8
Thelepus sp.		4								3	
Mollusca											
Acanthodoris brunnea		10			2	9		5		6	1
Acmea mitra											
Acmea sp.			2					1		2	1
Amicula amiculata											
Amphissa versicolor											
Anisodoris nobilis											

TABLE 7 (continued)

NUMBERS OF ANIMALS COLLECTED WITH PLANTS SAMPLES AT INDICATED STATIONS, YEAR AND DEPTHS

Species	Depth				10'					
	Year		1968					1969		
	Station	G	C	T	E	W	G	C	T	E	W
Mollusca (continued)										
Basiliochiton flectens										
Balcis columbiana										
Bittium sp.					1		2	7	2	
Clinocardium nuttallii	6	3		12	3	5	12		4	2
Crepidula sp.							3			12
Cryptochiton stelleri										
Cryptomya californica							8	5		
Cypraeolina pyriformis										
Gastropods		2								
Haminoea sp.	1	1				2				
Hermissenda crassicornis					1					
Hiatella arctica		1			4		8		2	4
Ischnochiton mertensii				1						
Lacuna variegata	31	39		92	30	45	361	243	75	128
Lyonsia californica										
Macoma sp.										
Margarites lirulatus	1	25		79	14	1	97	101	149	75
Melibe leonina						2				1
Mitrella gausapata				9		3	47	26	39	19
Modiolus modiolus										
Mopalia sp.				4	1		4	1	3	3
Mytilus edulis	2	5		6	10	1		2	5	
Nassarius mendicus									4	2
Nudibranchs									3	
Pecten hericius		1								
Pendrochiton thamnoporous										
Placiphorella velata										
Pododesmus macroschisma				2	3		4		3	
Protothaca staminea		3		3			26		3	6
Schizothaerus nuttallii		1					1			
Searlesia dira							2	11		
Sulcoretusa sp.										
Tellina buttoni				3	1		14		2	2
Thais lamellosa										
Tonicella lineata										
Trichotropis cancellata										
Tritonia sp.										
Turbonilla aurantia										
Arthropoda										
Amphipoda--Caprellidae						6	37	10	53	21
Amphipoda--Gammaridae	51	40		91	59	6	74	8	153	75

TABLE 7 (continued) NUMBERS OF ANIMALS COLLECTED WITH PLANTS SAMPLES AT INDICATED STATIONS, YEAR AND DEPTHS

Species	Depth			10'						
	Year	1968				1969				
	Station G	C	T	E	W	G	C	T	E	W
Arthropoda (continued)										
Balanus cariosus							80	63	7	1
Balanus crenatus	25	81		27	694	6	112		11	18
Balanus glandula		1								
Cancer magister	4	1			8					
Cancer (megalops stage)	1				1					
Cancer oregonensis									1	1
Cancer productus	4			5		2			12	2
Cancer sp.	2									
Crangon alaskensis	2				3		6		3	2
Cumacea sp.					1					
Gnorimosphaeroma oregonensis										2
Hemigrapsis oregonensis										
Heptacarpus brevirostris	2	2		3	8	2	13	7	62	37
Heptacarpus stylus										1
Heptacarpus sitchensis										
Idothea aculeata	12	2			2				2	1
Idothea sp.						1				1
Idothea urotoma									2	
Lophopanopeus bellus							2	2	1	1
Oregonia gracilis							17			
Pagurus sp.	2	2		2	4	3	34	9	9	57
Pandalus danae	2						1		9	
Petrolisthes eriomerus										
Pinnotheridae (crab)	2									
Pugettia gracilis	3	5		12	14	2	40	5	16	32
Telmessus cheiragonus								1	1	
Ectoprocta										
Bugula sp.										
Crisia pugeti	6	15		10	46				12	
Membranipora membranacea					2		4	1	2	4
Unknown sp.										
Echinodermata										
Evasterias troschelli									2	
Eupentacta quinquesimita	5	1		5		15	20	15	149	30
Leptasterias hexactis				1	1		1		3	3
Ophiurodea				5		1	18	7	16	12
Parastichopus californicus				1			1	3	4	7
Strongylocentrotus drobachiensis		1		7			16	8	22	3
Strongylocentrotus purpurata									1	
Chordata										
Ascidia paratropa				1			1		3	1
Boltenia villosa										1
Pholis laeta		2		1	1					1
Styela gibbsi										1

TABLE 7 (continued) NUMBERS OF ANIMALS COLLECTED WITH PLANTS SAMPLES AT INDICATED STATIONS, YEAR AND DEPTHS

Species / Depth / Year / Station	10' 1970 G	C	T	E	W	S
Porifera						
Cnidaria						
Aglaophenia sp.						
Anemone sp.			1	1	2	
E. prolifera						
Obelia sp.						
Unidentified						
Platyhelminthes						
Notoplana sp.						
Rhynchocoela						
Unknown		1				2
Annelida						
A. brevis	1					
A. rubrocincta		1				
E. polymorpha						
Glycera sp.						
H. brevisetosa	16	15	21	33	9	21
Hoploscoloplos sp.	1	5	1	3		
Nereidae						
Neries procera	25	14	13	23	16	34
Phyllodoce sp.	1					
P. aspera						
Polycheata						
S. cemetarium					1	
Sabellidae sp.						
S. vermicularis						1
Spirorbis sp.	100	6	1	31	88	12
Thelepus sp.						1
Mollusca						
A. brunnea	1					
A. mitra						
Acmea sp.		1	1			
A. amiculata			1	5	2	
A. versicolor			8			
A. nobilis					1	

TABLE 7 (continued)

NUMBERS OF ANIMALS COLLECTED WITH PLANTS SAMPLES AT INDICATED STATIONS, YEAR AND DEPTHS

Species	Depth			10'			
	Year			1970			
	Station	G	C	T	E	W	S
Mollusca (continued)							
B. flectens			2	2	4	1	7
B. columbiana							
Bittium sp.				9	1		13
C. nuttalli		24	33	9	48	1	2
Crepidula sp.					1	1	
C. stelleri							
C. californica							
C. pyriformis		4					38
Gastropods							
Haminoea sp.							
H. crassicornis							
H. arctica		5	17	26	6	5	16
I. mertensii							
L. variegata		545	14,192	3,530	4,805	2,120	582
L. californica				1			
Macoma sp.		7	23		19	7	18
M. lirulatus		36	266	230	204	167	103
M. leonina							
M. gausapata			8	24	75	56	1
M. modiolus				1		2	
Mopalia sp.							
M. edulis		1		1	1	11	
N. mendicus		1,116	3,382	770	1,035	248	1,430
Nudibranchs							
P. hericius				2			4
P. thamnoporous			2	12	3	1	6
P. velata			1		2		1
P. macroshisma							1
P. staminea			27	29	9	2	9
S. nuttallii							
S. dira							
Sulcoretusa sp.							
Tellina buttoni							
T. lamellosa							
T. lineata							
T. cancellata				11			
Tritonia sp.							
T. aurantia		3	28		14	1	8
Arthropoda							
A.--Caprellidae		1				16	4
A.--Gammaridae		451	199	48	493	460	189

TABLE 7 (continued) NUMBERS OF ANIMALS COLLECTED WITH PLANTS SAMPLES AT INDICATED STATIONS, YEAR AND DEPTHS

Species Depth			10'			
Year			1970			
Station	G	C	T	E	W	S
Arthropoda (continued)						
B. cariosus						
B. crenatus	134	2				
B. glandula						
C. magister						
C. (megalops stage)						
C. oregonensis	1					
C. productus	6	18				
Cancer sp.			7	7	5	
C. alaskensis						
Cumacea sp.						
G. oregonensis			2			
H. oregonensis						
H. brevirostris	124	25	5	22	218	140
H. stylus						2
H. sitchensis						
I. aculeata						
Idothea sp.	9	2		1	6	1
I. urotoma						
L. bellus	1					6
O. gracilis	1					
Pagurus sp.	19	64	15	5	25	20
P. danae						
P. eriomerus						
Pinnotheridae (crab)						
P. gracilis	55	51	32	18	23	44
T. cheiragonus		2		1		
Ectoprocta						
Bugula sp.						
Crisia pugeti						
M. membranacea						
Unknown sp.						2
Echinodermata						
E. troschelli		1	4	4	1	1
E. quinquesimita	1		10	2	2	24
L. hexactis						
Ophiurodea	2		9	6	1	19
P. californicus						
S. drobachiensis			1	2	1	2
S. purpurata						1
Chordata						
A. paratropa						
B. villosa						
P. laeta		1			1	
S. gibbsi						

TABLE 7 (continued)

NUMBERS OF ANIMALS COLLECTED WITH PLANTS SAMPLES AT INDICATED STATIONS, YEAR AND DEPTHS

Species	Depth				20'			
	Year		1968		1969		1970	
	Station	C	T	W	T	W	T	W
Porifera								
Cnidaria								
Aglaophenia sp.				110	18			
Anemone sp.								
E. prolifera								
Obelia sp.				3	16	2		
Unidentified					1			
Platyhelminthes								
Notoplana sp.								
Rhynchocoela								
Unknown				1	1			
Annelida								
A. brevis		1			7			
A. rubrocincta					1			
E. polymorpha								
Glycera sp.								
H. brevisetosa		13		22	2	11	3	28
Hoploscoloplos					1			
Nereidae								
N. procera		4		35	3	38	2	39
Phyllodoce sp.								
P. aspera								7
Polycheata				2				
S. cemetarium								
Sabellidae sp.				1				
S. vermicularis				1				
Spirorbis sp.							2	
Thelepus sp.								
Mollusca								
A. brunnea		1						
A. mitra						1		
Acmea sp.							1	1
A. amiculata								1
A. versicolor								1
A. nobilis								

TABLE 7 (continued) NUMBERS OF ANIMALS COLLECTED WITH PLANTS SAMPLES AT INDICATED STATIONS, YEAR AND DEPTHS

Species	Depth / Year / Station						
	Depth				20		
	Year		1968		1969		1970
	Station C	T	W	T	W	T	W
Mollusca (continued)							
B. flectens							5
B. columbiana							1
Bittium sp.			1		2	1	1
C. nuttallii	43		4	11	2	122	7
Crepidula sp.							12
C. stelleri					1		
C. californica							
C. pyriformis							1
Gastropods							
Haminoea sp.	4		1				
H. crassicornis							
Hiatella arctica			3	1	2	16	2
I. mertensii							
L. variegata	21		2	47	35	198	257
L. californica						1	
Macoma sp.						66	8
M. lirulatus	5		3	3	7	23	60
M. leonina							
M. gausapata			2	1	3	3	
M. modiolus							
Mopalia sp.					10		
M. edulis						1	2
N. mendicus	1				1	3,425	835
Nudibranchs	2						
P. hericius			1				
P. thamnoporous						1	2
P. velata							
P. macroschisma			11		2		
P. staminea			1	1		32	10
S. nuttallii			8				
Searlesia dira							
Sulcoretusa sp.						3	
T. buttoni	2		1	1			
T. lamellosa							
T. lineata							
T. cancellata			1				2
Tritonia sp.							
T. aurantia						13	2
Arthropoda							
A.--Caprellidae	1			9	18	2	23
A.--Gammaridae	8		281	66	64	73	723

TABLE 7 (continued) NUMBERS OF ANIMALS COLLECTED WITH PLANTS SAMPLES AT INDICATED STATIONS, YEAR AND DEPTHS

Species	Depth				20			
	Year		1968		1969		1970	
	Station	C	T	W	T	W	T	W
Arthropoda (continued)								
B. cariosus								
B. crenatus								
B. glandula								
C. magister								
C. (megalops stage)								
C. oregonensis								
C. productus		9			5	11		
Cancer sp.					1		4	10
C. alaskensis		3		8		2		
Cumacea sp.		1			1			
G. oregonensis						16		
H. oregonensis		1						
H. brevirostris				17	33	9	33	481
H. stylus								
H. sitchensis					1			
I. aculeata		2						
Idothea sp.								
I. urotoma						8		
L. bellus								
Oregonia gracilis		1		2		2		
Pagurus sp.		6		6	6	19	6	17
P. danae				2		1		
P. eriomerus							1	
Pinnotheridae (crab)								
P. gracilis		10		9	5	37	8	30
T. cheiragonus								
Ectoprocta								
Bugula sp.								5
C. pugeti		1		9	4			
M. membranacea								
Unknown sp.								2
Echinodermata								
E. troschelli								1
E. quinquesimita		17			96	3	5	8
L. hexactis								
Ophiurodea		1		3	101		9	14
P. californicus					4			
S. drobachiensis		2			2	9		
S. purpurata								
Chordata								
A. paratropa		2			3			
B. villosa				4	1			
P. laeta				1				
S. gibbsi					1			

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(Please read Instructions on the reverse before completing)

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16. ABSTRACT

Synecology of marine plant communities has been studied in areas differing in water quality. Major sources of deterioration of water quality include the Nooksack River, an oil refinery and an alumina reduction plant. A method of analysis involving comparisons of standing crops of species within the communities, standing crop of groups of morphologically similar species, and standing crop of entire communities is described. Stable species of the community are distinguished as well as those which appear to be indicators of environmental change. The floating bull kelp, Nereocystis leutkeana, is shown to have a depressing effect on standing crop and on the presence of other elements of the community. An increased respiration rate in kelps exposed to aluminum plant effluent was measured. Physical factors of the environment were measured. Poorer conditions for growth of algae in the environs of the aluminum company following its expansion are indicated by the accumulation of silt, the decrease in standing crop, and a loss of certain species.

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