# A Survey of the benthic macroinvertebrate fauna and solid pollutants in Howe Sound.

by
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# A Survey of the Benthic Macroinvertebrate Fauna and Solid Pollutants in Howe Sound

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# PREFACE

In 1970, great interest was stimulated in the Department of Indian Affairs and Northern Development and in the Department of Fisheries and Forestry concerning establishment of underwater parks in the Strait of Georgia. An Interdepartmental Task Force on National Marine Parks was appointed to investigate the federal responsibility and jurisdiction relative to such a concept. The identification of selected areas of the Strait of Georgia and Juan de Fuca Strait for public recreation and for the preservation of natural features, along with constraints, was one of the objectives of the Technical Working Group of that Task Force. It was clear early in the exercise that this seaway was already heavily used in parts by shipping, manufacturing industries, human population centres and recreational activities. These uses already had affected the quality of the water, the character of the bottom and the flora and fauna in portions of this area.

The present study was undertaken following approval of a proposal for research on environmental quality in relation to possible establishment of Marine Parks in the Strait of Georgia. It was planned to place emphasis on a study of pollution and other man-made effects in an area which might have direct or indirect influence on a region designated as a potential marine park.

The approval for the project provided one man-year and supporting funds for the Pacific Environment Institute to carry out one phase in Howe Sound, while the Pacific Biological Station in Nanaimo conducted another phase in the Gulf Islands. Because of limited staff and support, it was decided to carry out studies using SCUBA on the effects of industrial effluents, log storage, marinas and ferry terminal facilities on bottom flora and fauna in Howe Sound.

Mr. McDaniel was chosen for the work because of his experience as a SCUBA diver, his academic biological background, and his keen interest in underwater observation and photography. These talents and interests have been combined to provide a descriptive document on the biological characteristics of the benthos in selected disturbed and undisturbed parts of Howe Sound. We hope that this report will be a useful reference not only for the scientific community, but also for the amateur naturalists and recreational divers who frequent these waters. Not surprisingly, Howe Sound offers many excellent opportunities for recreational diving, in spite of the disturbing effects of many activities. We hope too that the report at least partly fulfils its mission concerning underwater marine parks.

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## ABSTRACT

Solid pollutants resulting from industrial activities, such as log booming and mining, cause a marked reduction in the ability of the substrate to support colonization by benthic organisms. Where input of solid wastes is intense, or of long duration, establishment of benthic fauna is sometimes entirely precluded. Long-term log storage and dumping activities in Howe Sound have resulted in massive, although localized, accumulations of sunken logs and wood debris which blanket the natural substrate and support only a few species of invertebrates. Long-term mining operations at Britannia have resulted in the buildup of a thick layer of tailings on the bottom adjacent to the mine which have not been colonized by benthic organisms. Commercial marina operations have resulted in the accumulation of inorganic refuse on the bottom, which in some instances provides artificial hard substrate for the attachment of epifauna or crevice space for motile forms, but which is more often aesthetically unpleasant.

Meaningful water quality regulations must include provisions to prevent these kinds of activities from operating in or adjacent to National Marine Parks.

## INTRODUCTION

The Technical Working Group of the Interdepartmental Task Force on National Marine Parks defined a National Marine Park as:

> "a specified marine environment which is part of a water quality management area and which includes the waterbed, water mass, water surface, inter-tidal zones, shorelines and backshore areas or any combination of these dedicated by the Parliament of Canada under the provisions of the National Parks Act for the conservation, protection and recreational use of its marine features".

In order that realistic restrictions could be implemented to protect those areas under consideration as "underwater parks", it was desirable to determine what types of industrial activities are potential sources of damaging waste products and the effects of these wastes on water quality, character of the bottom and marine organisms. Because much of the use of any park is for visual enjoyment by man, it is important to preserve the natural features.

The relative attractiveness of an underwater area to recreational SCUBA divers depends largely on the abundance and variety of marine life, especially the benthic invertebrates. Thus, the ecology and environmental quality of shallow coastal waters (0-50 m) are of legitimate concern to sport divers, as well as to fisheries biologists, marine ecologists, and conservationists. Howe Sound was not considered as a potential Marine Park, but being tributary to the Strait of Georgia, it is of interest because of influence it might have on any such an undertaking in nearby waters. Any adverse effect on water quality in Howe Sound would surely have some influence on the waters in those parts of the Strait of Georgia designated as potential marine parks, since the waters are contiguous and there is generally a free exchange by currents and mixing processes. The presence of heavy industrialization and substantial marine traffic in the Sound offered the opportunity to investigate the effects of various solid wastes on the character and distribution of the benthic invertebrate fauna.

This report presents the findings of SCUBA investigations carried out from September 1972 through February 1973 at 28 stations throughout Howe Sound. Studies were made to determine the number and variety of the macro-invertebrate fauna and to examine and photograph the physical effects of solid wastes on the substrate and on the composition of the associated invertebrate assemblages.

## NATURAL FACTORS AFFECTING THE DISTRIBUTION OF BENTHIC INVERTEBRATES

A multitude of environmental factors determine the vertical and horizontal distribution of marine organisms. These factors include: temperature, salinity, dissolved oxygen, currents, mixing, tidal range, type of substrate, the amount of siltation, light intensity, and the degree of exposure to air and to wave action. Certain generalizations can be made about the nature of these variables in Howe Sound.

### Temperature, salinity, and dissolved oxygen levels

Tables 1 and 2 (Waldichuk *et al.*, MS, 1968) present salinity, temperature, dissolved oxygen, and secchi disc (measure of water transparency) data for the months of February (1962) and July (1966), at the locations shown in Figure 1 (Stations H-1 to H-12). Because of increased snow melt, runoff from the Squamish and Cheakamus Rivers increases markedly in the early summer, causing an overall reduction in the surface salinities within the Sound. Waldichuk *et al.*, (MS, 1968) found surface salinities to be less than 11°/oo in all parts of the Sound during the month of July (Table 2).

There is a gradient of salinity along the north-south axis, with low salinities near the head and increasingly higher surface salinities further from the main freshwater source at Squamish. During the summer, the entire water mass is stratified, with the low-salinity water lying on top of the denser, high salinity water below. Salinities at depths below 10 m generally remain between 27 and 30°/oo the year around. The early summer discharge from the Fraser also influences the salinity profile of Howe Sound. But it does so in an indirect manner, by reducing salinities of the inflowing sea water coming from the Strait of Georgia.

Surface temperature in Howe Sound can vary by as much as 11°C, from a low of 7°C in February to 18°C in July, but seasonal variations at depths below 10 m are only 2-3°C at most. Organisms that live in the upper ten metres must be able to tolerate wide fluctuations in both temperature and salinity. Those with a narrow range of tolerances, with respect to these variables, will be restricted to depths below 10 metres, where these variables remain relatively uniform in space and time.

Dissolved oxygen concentrations in the upper 30 metres of the Sound appear to stay above 5 milligrams per litre all year round, so that lack of oxygen is not likely to be a limiting factor in the distribution of organisms in this shallow zone.

Secchi disc values show that vertical visibility is greatest during the winter months when there is least influx of fresh water and suspended sediment from the Squamish and Fraser River 'plumes'. The maximum recorded value was at Station H-8 in February (38 feet), while the minimum recorded value (2 feet) was in July near Squamish (Waldichuk *et al.*, MS, 1968). Water transparency is a factor in determining the vertical range of photosynthesizers, the marine plants, which in turn regulates the range of grazers such as limpets, chitons, echinoids, and other herbivores.

## Current and Wave Action

Since Howe Sound is part of the protected waters associated with the Strait of Georgia, continuous wave action is negligible compared to the exposed west coast of Vancouver Island. With the absence of narrow passages in the Sound, tidal currents do not approach the velocities encountered in such channels as the First and Second Narrows in Burrard Inlet (4-6 knots). However, current measurements during the summer of 1968 (Tabata and Giovando, unpublished information) indicate that peak velocities can exceed 1.5 knots in Queen Charlotte Channel (Figure 2). In areas of strong currents, sediment deposition is minimal and suspended food is continuously transported. Thus filter-feeding animals abound in current-swept passages such as Gabriola and Porlier Passes, where virtually every square inch of rocky substrate is colonized. Although current velocities in Howe Sound are only moderate, the presence of current-loving species such as the giant barnacle, *Balanus nubilus*, and the rock scallop, *Hinnites multirugosus*, at Station 15, indicates that tidal currents are a significant factor influencing the composition of the benthic fauna at this particular location.

## Substrate and Sediment deposition

Most of the bottom that is safely accessible with SCUBA (0-30 m) is part of the steep, rocky shore zone characteristic of the mainland and island shores. There are, however, a few deltas adjacent to the mouths of the Squamish River, Britannia Creek, and many other streams along the mainland shores where sand and silt have been deposited. Rocky substrates, owing to their stability and numerous micro-habitats, support more varied assemblages of plants and animals than do sandy substrates.

Although much of the silt content of the Squamish River is deposited in the delta part of the estuary, some of the finer material is swept down inlet for some distance before finally settling out. A surface plume has been observed as far down-inlet as Anvil Island (Figure 2). Diving stations situated toward the head of the inlet were characterized by heavy siltation; the upper surfaces of rocks were covered with a layer of sediment which precluded the growth of encrusting filter feeders. During the freshet, the Fraser River also contributes sediment to Howe Sound, carried in the large 'plume' that spreads over a large portion of the southern Strait of Georgia and its tributary inlets and connecting channels. Where sedimentation is exceptionally heavy, such as at the heads of inlets having glacially-fed drainage systems (Howe Sound, Bute and Knight Inlets), most macro-invertebrate organisms are restricted to crevices or to vertical rock walls where the smothering effect of the silt deposition is avoided.

## UNNATURAL FACTORS AFFECTING THE DISTRIBUTION OF BENTHIC INVERTEBRATES

The environmental quality of Howe Sound is depreciated by gaseous, liquid and solid pollutants. Both liquid and solid wastes affect water quality. However, the effects of solid wastes are more obvious and more easily demonstrated in a short study. These were the focus of attention in this report.

One type of solid waste, released into the Sound by pulp mills (e.g. Port Mellon and Woodfibre, Figure 2), consists of water-borne wood fibres, chips and general plant wastes. Although SCUBA observations were not carried out directly in front of either of the two mills in Howe Sound, observations made in front of the Ocean Falls pulp mill during July, 1972, indicated that the water was carrying a dense suspension of fibrous wood and that there was a considerable accumulation of this debris on the bottom near the main docks. Bottom grabs taken in front of this mill and in different parts of Cousins Inlet (July and December, 1972 and April, 1973) showed that the basin of the uppermost section of the Inlet is completely covered with wood debris. An analysis of this material has revealed the absence of invertebrate organisms. Similarly, bottom grabs taken close to the Woodfibre pulp mill recovered decaying wood debris and reduced sediments which supported invertebrate assemblages of low diversity (Levings, McDaniel and Derksen, unpublished data).

Long-term log storage and log dumping also result in the buildup of wood debris. In this case, sunken logs, bark, splinters, and fibres, sink to the bottom and can adversely affect the growth and the establishment of benthic organisms. This source of pollution is of more serious consequence than pulp mills in terms of recreational SCUBA diving. The booms are held close to the shore, and affect the inter-tidal as well as the shallow zone utilized by sport divers. Wood debris from the pulp mills at Port Mellon and Woodfibre tends to settle out in the deep water in front of these two mills. A considerable part of the shoreline of the western side of Howe Sound is devoted to foreshore leases for log storage purposes. West, Centre, Long Bay (Port Graves), and Halkett Bay on Gambier are also used extensively for log-booming activities. Large areas on and adjacent to the Squamish River Delta are utilized for this purpose as well.

Another source of solid wastes is the copper mine at Britannia, where mine tailings are dumped into the Sound. In operation since the turn of the century, a considerable accumulation of so-called 'Britannia sand' exists on the slope adjacent to the mine on the east side of the Sound. This arises from the mine tailings discharged from the concentrator which releases as waste most of the pulverized rock from ore crushing and mineral separation.

Commercial marina operations (see Figure 2) result in the buildup of inorganic refuse on the bottom below them, most of the material being dropped from the floats. Activities at the ferry terminals at Horseshoe Bay and Langdale on the mainland and at Snug Cove on Bowen Island, have contributed solid wastes from litter and other debris during the many years of operation.

## METHODS

### Field procedures

Twenty-eight stations were examined (see Figure 2 for map of locations and Table 4 for coordinates of stations) for the number and variety of species present and the nature of the substrate. Each station was qualitatively surveyed from 0 to 30 metres, generally with a vertical transect from the shore along the bottom to deep water. A record was made of all visible macro-invertebrates (larger than 1 cm.)

using plexiglas writing slates, or by the use of an underwater tape-recording unit. The latter consisted of a full-face mask (U.S. Divers) with an underwater microphone (SubCom Systems), connected to a cassette tape recorder (Panasonic RQ 212S), in a plexiglas housing (Can-Aqua Ltd.).

Those invertebrates not readily identifiable in the field were collected and returned alive for examination in the laboratory. To document the consequences of certain industrial activities, underwater photographs were taken wherever water clarity permitted. Photographic apparatus consisted of a Nikonos II and Nikon F camera in a lexan housing (Ikelite U/W Systems) with an electronic flash (Honeywell Autostrobonar 332) in a plexiglas housing (Can-Aqua Ltd). Comparative observations were also made in several other mainland inlets in the course of general ecological studies. These included Cousins Inlet, Toba Inlet, Bute Inlet and Knight Inlet, Elcho Harbour and Swanson Bay.

## Laboratory procedures

Specimens were examined alive whenever possible with a dissecting microscope. Spicule preparations were made for all sponges collected. General texts on Pacific Coast marine life, such as those of Johnson and Snook (1927), Flora and Fairbanks (1966), Light *et al.* (1954), and Ricketts and Calvin (1962) were of limited use, but did provide valuable references to more detailed descriptions and keys in the literature (see Aids to Fauna Identification). The Friday Harbor Keys of the Friday Harbor Laboratory (University of Washington) proved to be a valuable source of information.

Intertidal surveys by Quayle (1970) and Lewis and Quayle (1972) provided useful ecological information regarding the distribution and habits of some benthos. Austin *et al.* (1971) have qualitatively described the subtidal benthos of the Barkley Sound Region from observations using SCUBA. Dredging activities by Bernard and Quayle (MS 1973) have documented the dominant benthos over much of the B.C. coastline.

## OBSERVATIONS

### The Number and Variety of Macro-invertebrates in Howe Sound

Table 3 presents a partial list of the shallow water (0 to 30 m) invertebrates of Howe Sound. A total of 172 forms were identified to the generic, and in most cases, to the specific level. However, many inconspicuous organisms were undoubtedly neglected in the survey. Of the 172 species identified, some 60 species (roughly 35%) were strictly epifaunal (attached organisms) and 25 species (15%) were found either on or in soft substrates such as sand or mud, while the remaining 87 species (50%) were motile forms capable of movement from one habitat to another, although the majority of these were more commonly associated with rocky substrates.

### Examination of Undisturbed Habitats

Three stations were surveyed as representative of undisturbed habitats, i.e. those areas comparatively remote from direct inputs of solid pollutants. Station 15, at Lookout Pt., was in Queen Charlotte Channel (Figure 2), the eastern passage into Howe Sound, while Station 16 at

Worlcombe Island was situated among the group of small islands in the western entrance into Howe Sound. Station 7, near Porteau, was located near the upper sill of the Sound, which separates the upper basin from the southern basin in the main part of Howe Sound.

Lookout Point (Station 15)

See Figure 2 for the location of Station 15, and Figure 3 for a pictorial impression of the distribution of the invertebrate fauna. The diagrammatic profile shows only the more conspicuous forms. The position of an organism on the slope indicates only the type of substrate and depth which that particular species typically occupies, and not the specific vertical range of the species.

At the upper extremes the barnacle, *Balanus glandula*, the bay mussel, *Mytilus edulis*, and the snail, *Littorina planaxis*, were abundant amongst clumps of the rockweed, *Fucus*. The seastars, *Pisaster ochraceus* and *Evasterias troschelli* were also numerous in the intertidal zone, feeding on mussels and barnacles. On broken rock substrate at the upper edge of the subtidal zone, the chitons, *Tonicella lineata* (see Figure 6B) and *Mopalia lignosa*, were abundant, while *Tonicella insignis* and *Mopalia ciliata* were present in small numbers. Shore crabs, such as *Hemigrapsus nudus* and *H. oregonensis*, although primarily found in the mid to high intertidal areas, occasionally ranged down to the low-water mark.

Subtidally, the tubeworm, *Serpula vermicularis*, (Figure 6L), the seastars, *Pycnopodia helianthoides* (Figure 6D) and *Dermasterias imbricata*, the green sea urchin, *Strongylocentrotus droebachiensis*, the ring-top snail, *Margarites lirulatus*, and the hermit crab, *Pagurus hirsutiusculus*, were abundant amongst the broad-leaf kelp, *Laminaria.* The bryozoan *Membranipora sp.* and the spiral tubeworm *Spirorbis spp.* were found growing attached to the fronds of the kelp. Several herbivores fed directly on this kelp, including the ring-top snail and the green sea urchin. The large gumboot chiton, *Cryptochiton stelleri,* was occasionally found in crevices at depths between 5-25 feet, and the sponge, *Esperiopsis rigida,* and the rock oyster, *Pododesmus macroschisma* were abundant at these depths. A few sea cucumbers, *Parastichopus californicus* (Figure 6C) and sea slugs, *Anisodoris nobilis,* were also present within the broad zone of kelp, which extended from just below the lowest low water mark to depths approaching 30-40 feet. A sparse growth of the bull kelp, *Nereocystis luetkeana,* existed at the lower edge of the *Laminaria* zone.

Directly below the lower extreme of the *Laminaria* there is a vertical rock face between 25 and 40 feet deep that is entirely encrusted with attached organisms. The most abundant forms were the tunicates, *Chelyosoma productum* (Figure 6F), *Corella willmeriana, Boltenia villosa,* and *Ascidia callosa,* the giant barnacle,*Balanus nubilus* and the zoanthid,*Epizoanthus scotinus* (Figure 6E), small decorator crab, *Oregonia gracilis,* the bryozoans, *Phidolopora pacifica* and *Bugula californica,* and several unidentified encrusting sponges. The presence of *Balanus nubilus* was indicative of significant tidal currents in this area, since this barnacle is abundant in current-swept channels such as Dodd Narrows, Discovery Passage, First Narrows, Gabriola and Porlier Pass, and is not common in quiet waters. Station 15 was the only location in Howe Sound where *B. nubilus* was observed.

Also abundant at moderate depths (between 25 and 70 feet) were: the shrimps,*Pandalus goniurus;* the plumose anemone, *Metridium senile* (Figure 6I); tube worms *Serpula vermicularis;* the sea stars, *Pycnopodia helianthoides, Orthasterias koehleri, Henricia leviuscula, Mediaster aequalis* (Figure 7C), and *Pteraster tesselatus;* the chitons, *Mopalia lignosa* and *Tonicella lineata;* the hydroids, *Lafoea fruticosa* and *Obelia longissima;* the sea cucumbers, *Parastichopus californicus* and *Cucumaria miniata;* the gastropods, *Ceratostoma foliatum, Epitonium sp., Nassarius mendicus,* and *Fusitriton oregonensis;* and the calcareous sponge, *Scypha capillosa.*

Inside the empty shells of dead *B. nubilus,* the crab, *Cancer oregonensis,* was often observed, and the hermit crabs, *Pagurus hirsutiusculus, P. tenuimanus* and *P. beringanus* were abundant as well. In this same area were: other solitary tunicates, *Ascidia paratropa, Ciona intestinalis* (Figure 6J), and *Halocynthia aurantium* (Figure 6K); the sponge, *Esperiopsis quatsinoensis;* the sea stars, *Solaster dawsoni,* and more rarely, *Solaster stimpsoni;* the hydroid *Tubularia sp.,* and the nudibranchs, *Acanthodoris nanaimoensis, Dirona albolineata* (Figure 6H), *Dirona aurantia,* and *Hermissenda crassicornis.* The nudibranchs, *Tritonia festiva* and *Antiopella barbarensis,* have been observed on only a few occasions.

Amongst broken rock at about 50-60 feet, the octopus *Octopus dofleini* (Figure 7A), the anemones *Tealia crassicornis* (Figure 7B) and *Metridium senile,* and the zoanthid *Epizoanthus scotinus* were found. The brittle star *Ophiopholis aculeata* and the tunicate *Pyura mirabilis* have been observed under rocks. In pockets of soft sediments, the seapen, *Leioptilus guerneyi,* the burrowing anemone *Pachycerianthus fimbriatus* (Figure 7D), and the large nudibranch, *Dendronotus iris* (Figure 7I) were found; this predatory sea slug has been observed feeding on the former two Cnidarians. Rarely, the lithode crabs, *Phyllolithodes papillosus, Acantholithodes hispidus, Rhinolithodes wosnessenski,* and *Cryptolithodes* *typicus* have been observed, usually under rocks or in crevices. The red urchin, *Strongylocentrotus franciscanus* (Figure 7H) and the crinoid *Florometra serratissima* (Figure 7E) were found at depths below 40 feet.

In deeper water, below 70 feet, the rocky bottom slopes steeply to a vertical rock wall which shelves at about 110 feet. On the slope were many tubular hexactinellid sponges, *Rhabdocalyptus dawsoni* and 'cloud' sponges, *Aphrocallistes vastus* (Figure 7J), the brachiopod, *Terebratulina unguicula*, tubeworms, *Crucigera irregularis* and *C. zygophora*, the sea cucumber *Parastichopus californicus*, the sea anemone, *Actinostola sp.* (Figure 7F), and the cup-coral, *Carophyllia alaskensis*. On the rock face below, *Aphrocallistes* was abundant, often with the crabs, *Munida quadrispina, Oregonia gracilis, Acantholithodes hispidus*, or the shrimp, *Spirontocaris brevirostris*, inside of or clinging to the sponge. Also attached to the wall were the tubeworms *Crucigera spp.*, and *Protula pacifica* (Figure 7K), the tunicates *Halocynthia igaboja, Ascidia callosa*, and *Cnemidocarpa finmarkiensis*, the sea cucumber *Psolus chitonoides* (Figure 7L), and various unidentified sponges (*Demospongiae*). The seastars, *Crossaster papposus* and *Stylasterias forreri*, were present but not abundant, and rarely, *Hippasteria spinosa* was sighted. The shrimps *Pandalus platyceros* and *P. danae* were abundant in crevices. On the rocks at the base of the cliff, the large snail, *Fusitriton oregonensis*, was abundant as well as *Protula* and *Aphrocallistes*. The red urchin, *Strongylocentrotus franciscanus* was present in moderate numbers. Adult Puget Sound King Crabs, *Lopholithodes mandtii*, have been observed on rare occasions. Further to the south of the point at depths below 80 feet, the poecilosclerídan sponge, *Iophon pattersoni*, was abundant, often with the brittle star *Ophiopholis aculeata* crawling within its crevices (Figure 7G).

Worlcombe Island (Station 16)

Located on a reef at the extreme southwest corner of the island, this station is remote from populated or industrialized areas and on the fringe of Howe Sound. Harbour seals, *Phoca vitulina,* use this reef to 'haul out', and the northern sea lion *Eumetopias jubata* was observed here during the winter months.

The substrate consists of large rocks sitting on a rocky ledge which drops steeply at about 30 feet to a gently sloping bottom of sand and silt scattered with rocks, which marks the upper edge of the long incline into the basin of the Strait of Georgia.

The fauna here (Figure 4) was essentially similar to that found at Lookout Pt., but with some exceptions. For example, the seastar, *Luidia foliolata,* was present in sandy areas, and an unidentified sea pen *(Stylatula ?)* was noted at about 50 feet. The sea pen, *Leioptilus,* and the burrowing anemone, *Pachycerianthus,* were abundant on the soft sediments, as was their common predator, *Dendronotus iris.* The current-loving barnacle, *Balanus nubilus,* was not observed here.

Porteau Beach (Station 7)

Station 7 was located approximately ½ mile north of the wharf ruins at Porteau Cove. Here large rocks close to shore give way to a muddy slope at 30 to 40 feet which is studded with rocky outcrops. In shallow water, some of the more common organisms were the barnacle, *Balanus glandula,* the mussel, *Mytilus edulis,* the limpet, *Collisella pelta,* and the seastars, *Evasterias* and *Pycnopodia.* The nudibranch, *Anisodoris nobilis,* was numerous at about 25 feet, as was *Dendronotus rufus,* which was observed laying coiled egg masses in January.

The brachiopod, *Terebratalia transversa*, was abundant attached to the sides of rocks along with the tunicates, *Boltenia villosa*, *Halocynthia aurantium* and *Corella willmeriana*. The anemone, *Metridium senile*, also grew attached to many of the rocks. On the soft sediments, the crabs, *Cancer productus* and *C. magister*, as well as the asteroid, *Pisaster brevispinous*,were observed.

Deeper, the hexactinellid sponges, *Aphrocallistes* and *Rhabdocalyptus*, were present attached to rocks and the sponge, *Iophon*, was found in numerous clumps. The brachiopod, *Terebratulina unguicula*, and the anemone, *Actinostola*, were also present. Two sea pens were found here: *Leioptilus guerneyi*, the common orange form, and *Virgularia sp.*, a slender white sea pen that often exceeds 1.5 meters in height. The latter is uncommon in Howe Sound, having been observed only at this station and to the southeast of McNab Creek Landing, also at a depth of about 90 feet. Similar sea pens have been reported from the north tip of Croker Island near the head of Indian Arm.

Increased natural sedimentation appears to be responsible for many of the faunal differences between this station and those farther toward the mouth of the Sound.

Examination of Disturbed Habitats

Several stations were examined as representatives of habitats disturbed by solid pollutants. Stations 2 and 3 (Figure 2) were adjacent to the pulp mill at Woodfibre; Stations 18, 19, 20, 23, 24 and 25 were located in booming grounds; Stations 4, 5 and 6 were situated along the shore near the copper mine at Britannia; Station 14 was positioned below the floats at Sunset Marina on the east shore of Howe Sound; and Stations 26, 27 and 28 were situated on the Squamish River delta.

Stations 2 and 3 (Woodfibre)

Both Station 2 (approximately ½ mile north of the main dock at Woodfibre) and Station 3 (approximately 1 mile south of the main dock) were characterized by steep rocky dropoffs with sloping shelves, which were covered with fine silt deposited by the Squamish River. Fibrous wood material, such as was observed in front of the pulp mill at Ocean Falls, was not apparent at either of these stations although there is some buildup of larger wood debris from log storage and handling activities in this area. Undoubtedly, this difference in waste distribution is related to the difference in topographic and oceanographic characteristics between waters adjacent to Woodfibre and Ocean Falls, the latter being shallower and at the head of an inlet.

The rocky substrate fauna of these stations was similar to that of other stations further down the Sound, although the typical *Balanus glandula/Mytilus edulis/Fucus* assemblage appeared to be more scraggly and intermittent than was the case at stations further south. Several species observations were unique to this area: the brachiopod, *Laqueus californianus*, and the nudibranch, *Triopha carpenteri*, were observed at 50 feet at Station 2. The fauna here also included the tanner crab, *Chionoecetes bairdi*, which appears to be restricted to muddy substrates, such as those at the heads of some inlets; these crabs were observed in very large numbers near the head of Knight Inlet. The crab, *Munida quadrispina*, was present at both stations, but was very abundant at Station 2, in unusually shallow water. Although this species is common throughout Howe Sound, it had never before been observed in water depth less than 50 feet. Large numbers of *Munida* were observed in late January at depths as shallow as 10 feet.

Other species abundant in this area included: the tubeworms, *Crucigera spp.;* the brachiopods, *Terebratalia transversa* and *Terebratulina unguicula;* the anemone, *Actinostola sp.;* the crabs, *Hyas lyratus, Cancer magister, C. oregonensis;* the shrimp, *Pandalus goniurus;* and the sea cucumber, *Psolus chitonoides.* Compared to Station 15 or 16, Stations 2 and 3 have far fewer species of benthic invertebrates. This is probably due to several factors, including the low salinity surface water in the late spring and summer, when the freshwater discharge from the Squamish River increases markedly, the increased sedimentation, the light attenuation caused by the silt load entering the head of the Sound, and the buildup of wood debris.

Stations 18, 19, 20, 23, 24 and 25. (Booming Grounds)

Station 20 at Mannion Bay on the west side of Gambier Island represented the most thoroughly examined booming area which was considered to be a typical example of the effects of log storage and booming activities. Figure 5 shows a diagrammatic profile of the bottom. This station consisted of a bench of broken rock which fell steeply at its outer edge to a soft, sloping bottom with many submerged logs and a substantial build-up of wood debris, including bark, twigs, splinters, and other bits and pieces of wood. Figure 8C shows an area of the bottom 3 foot by 4 foot in size at a depth of 60 feet directly below the booming area. This foreshore lot has been leased since 1953 (L6246).

Since the booms were held off the shore by large cement 'bumpers', the intertidal zone did not appear to be affected by the booms, except for the distinct decrease in the abundance of the kelp, *Laminaria,* presumably due to the light reduction caused by the shadowing effect of the booms. Abundant in the shallows were the barnacle, *Balanus glandula,* the blue mussel, *Mytilus edulis,* the snails, *Thais lamellosa* (Figure 6A) and *Margarites lirulatus,* the sea stars, *Evasterias troschelli* and *Dermasterias imbricata,* and the rockweed, *Fucus.* In the large area of sunken logs and wood debris below the booms, the deposit-feeding sea cucumber, *Parastichopus californicus,* was abundant. The tunicate *Ascidia paratropa,* the anemones, *Actinostola sp.,* and *Metridium senile,* were occasionally observed attached to the surface of the sunken logs. In deeper water at about 70 to 100 feet, the sea star, *Stylasterias forreri,* was observed in small numbers, and the two-spotted prawn, *Pandalus platyceros,* and the "squat lobster", *Munida quadrispina,* were very abundant, using the sunken logs for crevice space (Figure 8A).

The shipworm, *Bankia setacea,* was abundant at all depths below 30 feet. It is responsible through its wood-boring activity for the breakdown of many of the sunken logs in this area. Their respiratory siphons were often seen projecting from their burrows in the wood (Figure 8I). The bark of these sunken logs seemed particularly impervious to attack by *Bankia,* often resulting in large hollow tubes of bark where the shipworms had eaten away the core of the log. *Pachycerianthus fimbriatus,* a tube-dwelling anemone that is very common throughout Howe Sound on sandy or muddy bottoms from 30 feet to depths in excess of 100 feet, was absent below the booms where there was a large accumulation of wood debris. In areas immediately adjacent to the booming grounds, but not subject to as great a build-up of debris, *Pachycerianthus* (Figure 8F) was found burrowing the soft bottom. This inverse relationship between the relative abundance of certain benthic forms and the amount of wood debris is also true for the various members of the infauna such as the bivalves, *Saxidomus giganteus, Clinocardium nutalli, Protothaca staminea,* and their asteroid predators, *Pisaster brevispinus* and *Pycnopodia helianthoides.* The sea pen, *Leioptilus guerneyi,* is another soft bottom form that was affected in this manner.

Ellis (MS, 1971), who examined log dumping and rafting areas in Alaska with SCUBA, found large but localized accumulations of wood debris at log dumps which eliminated plants and most of the animals. His observations below a log storage area revealed little or no abnormal appearance in the littoral plants and animals, although there was a marked decrease in the abundance of algae directly below the booms. The log storage area that he examined, however, had been used for only 7 years, whereas some of the booming areas in Howe Sound have been utilized for over 20 years.

Observations made by this writer in areas other than Howe Sound indicate that log dumping and storage have disrupted the substrate so that establishment of bottom invertebrates is inhibited. Personal observations made in Halfmoon Bay on the Sechelt Peninsula show that massive accumulations of wood debris have precluded the survival of the common soft bottom forms such as *Pachycerianthus, Leioptilus, Saxidomus* and other bivalves. Similar observations have been made in Agamemnon Channel, which separates the Sechelt Peninsula from Nelson Island and where there are extensive log dumping and booming activities.

In Howe Sound, Station 18 at Halkett Bay (original foreshore lease granted in 1950), Station 19 at Centre Bay (1949), Station 23 near Hillside Gravel Pit, Station 24 at Plowden Bay, and Station 25 at the north-west tip of Gambier Island were severely disturbed by the presence of large amounts of wood debris which prevented the growth of most bottom organisms.

Station 14 (Sunset Marina)

The substrate here consists of a sandy sloping bottom directly below the main floats at the marina. Only a few scattered clumps of rock are present, but the bottom is strewn with a wide variety of refuse including containers made of glass, metal, paper or plastic, rope and cable, scrap metal, and rubber tires (Figures 8H, 8J and 8K).

*Balanus glandula* and *Mytilus edulis* were abundant in the shallows and were preyed upon by the seastar *Pisaster ochraceus*. On isolated rocks and cement blocks at 30 feet, the tunicates *Halocynthia aurantium*, *Ascidia paratropa*, *A. callosa*, and *Corella willmeriana*, the crab *Oregonia gracilis*, and the seastar *Pycnopodia* were numerous. On the sandy bottom, the brittle star *Ophiura lutkeni*, and the seastars, *Stylasterias forreri* and *Evasterias troschelli*, were found at depths between 30 and 100 feet. *Metridium senile*, the plumose anemone, was observed attached to rocks. At this particular station, there was a decided lack of hard substrate for the attachment of epifauna, so that submerged 'junk' has resulted in more hard substrate than was present naturally. Glass bottles form substrates for many organisms such as bryozoans, encrusting red algae, and the rock oyster, *Pododesmus*, but metal cans generally deteriorate too quickly to provide much permanent substrate. Submerged tires appeared to support little growth directly attached to them, although many animals utilized the crevice spaces created (Figure 8G).

Stations 4, 5 and 6 (Britannia Beach)

Station 5 was a vertical transect perpendicular to the shore from the surface to a depth of 110 feet directly between the two main docks at the townsite. The bottom is thickly covered with tailing deposits from the mine operation which are green-brown in colour and are very easily disturbed.

Water transparency was very low owing to the fine suspension of sediment in the water column. Over the length of the transect, no flora or epifauna were observed, nor were there any holes in the sediment that might have indicated infaunal populations. Harger (MS, 1971), studying the environmental impact of the Anaconda Mine at Britannia on the marine environment, found that typical intertidal macro-invertebrates were absent from stations adjacent to the mouth of Britannia Creek, near which much of the tailings are dumped from several effluent pipes.

At Station 4, which was located near a small islet about one mile north of Station 5, the rocky shore drops steeply to about 30 feet to a heavily sedimented substrate. The usual *Balanus glandula/Mytilus edulis* band of the intertidal zone which is common elsewhere in the Sound, was absent here, replaced instead by only a few scattered patches of these mussel and barnacle colonies. In these patches, the sea slug, *Onchidoris bilamellata*, was observed laying eggs in late January. Slightly deeper, the nudibranchs, *Hermissenda crassicornis* and *Aeolidia papillosa*, were found feeding on the hydroid *Obelia*. At about 30 feet, on a vertical rock face, there were rock oysters, *Pododesmus macroschisma*, and tubeworms, *Crucigera spp.* Also found were the nudibranch, *Acanthodoris nanaimoensis*, the edible crab, *Cancer magister*, and a few plumose anemones, *Metridium senile*. On the heavily sedimented slope, some juvenile tanner crabs, *Chionoecetes bairdi*, were observed as well as groups of unidentified mysids swimming close to the bottom. Holes in the sediment (Figure 8L) suggested the presence of some infaunal assemblage; however, its composition was not determined. Members of some of the most commonly observed groups of invertebrates in Howe Sound, such as seastars, sea cucumbers, sea urchins, and tunicates, were not present.

Station 6 was located about 1½ miles south of Station 5 at the point south of Daisy Creek. The substrate consisted of broken rock in the shallows with a short rocky slope dropping to a soft, muddy bottom. In the shallows, *Balanus glandula* and *Mytilus edulis* were abundant, as was the oyster *Crassostrea gigas*. The sea slug, *Onchidoris bilamellata*, was found laying eggs amongst the barnacles. The crabs, *Cancer magister* and *C. oregonensis*, were present, and the shrimp *Pandalus goniurus* were found in crevices. The nudibranch, *Hermissenda crassicornis*, was observed feeding on hydroids and the large sea slug, *Dendronotus rufus*, was found laying eggs at about 30 feet. Although the common purple seastar, *Pisaster ochraceus*, was absent, the other common intertidal seastar, *Evasterias troschelli*, was abundant. In deeper water, the urchin *Strongylocentrotus droebachiensis*, the plumose anemone *Metridium senile*, the tunicate *Halocynthia aurantium*, the rock oyster *Pododesmus macroschisma*, the anemone *Actinostola sp.* and the brachiopod *Terebratulina unguicula* were found. The seastar, *Dermasterias imbricata*, was present, but not abundant. On the muddy bottom, some tanner crabs, *Chionoecetes bairdi*, were observed. On a deep vertical rock face slightly to the south of the point, the 'cloud' sponge *Aphrocallistes vastus* was abundant.

The substrate in the area immediately adjacent to Britannia Creek has been significantly disturbed by the input of suspended sediment in the form of tailings from the copper mine operations. This material appears to have completely blanketed the original substrate, most probably a sandy or silty type of bottom, and has precluded the growth of benthic invertebrates here. The stations north and south (Stations 4 and 6) revealed rather impoverished faunas compared to stations located across the inlet near Woodfibre (Stations 2 and 3).

Stations 26, 27, and 28 (Squamish Estuary)

Station 26 (adjacent to the bluff south of the river mouth)

The substrate consists of a very muddy bottom sloping steeply away from the rocky cliff, which extends only about ten feet below the surface of the water. The edible crab, *Cancer magister*, was abundant at all depths surveyed to 100 feet, most often buried in the soft mud, with only the eyes and the antennae protruding. The nudibranch, *Hermissenda crassicornis*, and the tanner crab *Chionoecetes bairdi*, were also observed on the muddy substrate. On the rare rocky outcrops which projected above the level of the mud, the tubeworm, *Serpula vermicularis*, encrusting sponges, the seastar, *Evasterias troschelli*, the anemone, *Actinostola sp.*, and the tunicate, *Halocynthia aurantium*, were present. The shipworm *Bankia setacea*, was found boring in most of the sunken logs, except those near the surface where salinities were probably too low for the shipworm to survive. The shrimps, *Pandalus goniurus* and *P. danae* were observed under some of the sunken logs at depths between 30 feet and 70 feet.

Station 27 (at the mouth of the central basin east of the Squamish River)

The plateau within the basin is mostly sandy, but drops sharply at its outer edge: a very muddy substrate slopes into deeper water. Very abundant on the muddy slope was *Cancer magister;* however, there was also a large population of *Hermissenda*, which ranged from about ¼ inch to 1½ inches in length. *Chionoecetes* were also abundant. A few small anemones, *Metridium senile*, were observed attached to a sunken log at about 40 feet and some small *Pandalus goniurus* were hiding in crevices beneath the logs.

Station 28 (adjacent to the beacon at the mouth of the Mamquam Channel)

The area surveyed was on the west side of the beacon. The mudflats just east of the beacon are used extensively for log booming purposes, and the Mamquam Channel itself is heavily industrialized, the majority of the solid wastes resulting from the numerous log dumps situated along its length. The muddy bottom at Station 28 was strewn with a large amount of wood debris. A few *Cancer magister* and *Chionoecetes bairdi* were observed, but were not nearly as abundant as at Stations 26 and 27. A few *Hermissenda,* and some crabs *Cancer productus* and *C. oregonensis,* were also found.

## DISCUSSION

The degradation of bottom sediments by the deposition of wood solids is a serious pollution problem in Howe Sound. Wood wastes result from the pulp mills at Woodfibre and Port Mellon (Werner and Hyslop, MS, 1968b), and from log dumping and booming activities. These wood wastes depreciate the quality of the bottom sediments and the adjoining water column in a number of ways. Certain 'leachates' may have direct toxic effects on marine organisms. Natural decay of organic material removes oxygen from the water. Microorganisms may produce toxic gases, such as hydrogen sulphide and methane, in the process of decomposing accumulations of wood wastes (Werner and Hyslop, MS, 1968a). Gases formed occasionally lift mats of accumulated wood fibres to the surface.

On level substrates, especially in areas used extensively for log dumping or booming, or subject to intensive input of waste from pulp mills, physical 'smothering' has been observed as a result of the gross accumulations of debris which eventually form large sludge beds of slowly decomposing wood wastes. Recent hydrographic observations near the head of Cousins Inlet, where the Ocean Falls pulp mill is situated, indicated that the dissolved oxygen levels at the water/substrate interface were very low and generally coincided with the presence of wood debris (Levings and McDaniel, unpublished information). Rapid breakdown of large wood debris such as sunken logs is carried out by the boring mollusc, *Bankia setacea*. These borers are effective in reducing some of the wood, but it has been observed that the bark of most softwoods is relatively impervious to attack by *Bankia*. Sessile organisms were sometimes found attached to sunken logs, the most commonly observed forms being sea anemones, tunicates and hydroids. Normal soft bottom assemblages of burrowing sea anemones, sea pens, and burrowing bivalves were absent below booming grounds, because of the blanket of wood debris which precluded their establishment. Extensive portions of the foreshore of Howe Sound are used as log storage areas, and for sorting logs for pulp mills and sawmills. Thus, large areas are despoiled as far as recreational diving is concerned.

Particulate wastes, for example, the massive volumes of mine tailings released at Britannia, although considered comparatively inert, create unsatisfactory settling conditions for larval invertebrates. The original substrate is blanketed with sediment from the mine, leaving an unstable layer of tailings. Even if organisms were able to settle, the subsequent sediment deposition would quickly bury these newly settled organisms. Crushed rock wastes can also leach metallic substances such as copper, zinc, mercury and lead, which can become toxic at certain concentrations. The major portion of the tailings from Britannia appears to have settled on the slope and in the basin in front of the mine. Stations 4 and 6 (see Figure 2) approximately one mile north and 1½ miles south of Britannia, respectively, supported impoverished faunas compared to sites on the opposite shore of the Sound, yet they were sufficiently distant from the main discharge of solids to sustain some benthos.

Inert solid wastes from marina operations and commercial harbour facilities often form a suitable artificial substratum for the growth of invertebrate organisms. Provided it is firm, inert, with a suitable attachment surface, and does not disintegrate with time, artificial substrate can enhance colonization and increase invertebrate populations. Plastic bags, sheets and rope neither decompose nor serve as a suitable substrate. This material does little to enhance the value of the area for underwater recreation and the subsurface viewing of marine life. The concept of 'artificial reefs' composed of automobile bodies, rubber tires, and sunken barges has evolved as a means of increasing the productivity of an area lacking in stable substrate. Man-made rock breakwaters have often become very rich in terms of the variety and numbers of species present. Stable materials, such as large blocks of granite or concrete, seem to provide very stable settling surfaces; however, less stable materials, such as steel and rubber tires, do not appear to be as effective in promoting the growth of epifauna. The substrate within boat harbours and marinas does not seem to be seriously degraded in terms of any tangible loss or reduction in the abundance of macro-benthos. However, the underwater appearance of these areas is comparable to that of junkyards on land, and as such, is not conducive to recreational pursuits.

## CONCLUSIONS

1. In Howe Sound, the most common solid pollutants are wood wastes which result from log storage, log dumping, and pulp mill operations.

2. Mine tailings, confined to the area adjacent to Britannia, 'blanket' the original substrate with soft mineral deposits which are unsuitable for the establishment of benthic invertebrate organisms.

3. Hard, inert materials introduced into the marine environment may provide an artificial substrate for benthic organisms, as well as food and shelter for fishes.

4. The effects of man on the bottom fauna of Howe Sound appear to be confined to the centres of industrial and commercial activity, i.e. (a) log booming and dumping areas; (b) pulp mills; (c) mining and mineral concentrating; (d) ferry terminals and marinas; and (e) port development activities involving dredging and filling.

5. Although much of Howe Sound is despoiled by solid pollutants, there are still many undisturbed areas supporting a rich flora and fauna in a variety of habitats, which offer diverse opportunities for studies by the scientist, student, and naturalist, and for observation and photography by the recreational diver.

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TABLES 1-4

Table 1: Temperature, salinity, dissolved oxygen and secchi disc data for Stations H-1 to H-12, February 19-20, 1962. (Data from Waldichuk, M., J.R. Markert and J.H. Meikle, MS. 1968).

Temperature (T) in $^{o}$ Centigrade
Salinity (S) in parts per thousand ($^{o}/oo$)
Dissolved oxygen ($O_2$) in milligrams per litre (mg./l.)

Secchi disc readings in feet.

| Station | Surface | | | 10m. (33ft.) | | | 30m. (99ft.) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T | S | $O_2$ | T | S | $O_2$ | T | S | $O_2$ | Secchi (ft) |
| H-1 | 7.0 | 25.6 | 9.9 | 7.6 | 28.6 | 7.6 | 7.7 | 30.1 | 7.0 | 25 |
| H-2 | 7.0 | 26.4 | 9.7 | 7.5 | 28.9 | 7.6 | 7.9 | 30.1 | 7.0 | 34 |
| H-3 | 7.3 | 26.3 | 9.4 | 7.0 | 26.7 | 9.0 | 8.2 | 30.2 | 6.0 | 23 |
| H-4 | 7.2 | 22.8 | 10.0 | 7.6 | 29.1 | 7.4 | 8.3 | 30.3 | 5.6 | 20 |
| H-5 | 7.3 | 25.4 | 9.8 | 7.5 | 28.9 | 7.6 | 8.4 | 30.2 | 5.3 | 21 |
| H-6 | 6.2 | 17.6 | 10.5 | 7.5 | 28.8 | 7.1 | 8.3 | 30.2 | 5.6 | 21 |
| H-7 | 6.6 | 25.2 | 9.8 | 7.2 | 28.1 | 8.2 | 8.3 | 30.2 | 5.8 | 31 |
| H-8 | 6.4 | 24.9 | 10.1 | 7.2 | 27.9 | 8.3 | 8.3 | 30.1 | 5.7 | 38 |
| H-9 | 6.5 | 24.0 | 10.3 | 7.3 | 28.2 | 7.9 | 8.4 | 30.2 | 5.4 | 26 |
| H-10 | 7.1 | 24.1 | 10.4 | 7.4 | 28.3 | 7.9 | 8.4 | 30.2 | 5.4 | 26 |
| H-11 | 7.0 | 24.1 | 10.4 | 7.1 | 27.0 | 8.9 | 8.4 | 30.3 | 5.6 | 25 |
| H-12 | 6.9 | 24.5 | 10.5 | 7.2 | 28.0 | 8.2 | 8.1 | 30.1 | 6.3 | 31 |

Table 2: Temperature, salinity, dissolved oxygen and secchi disc data for Stations H-1 to H-12, July 10-11, 1966. (Data from Waldichuk, M., J.R. Markert, and J.H. Meikle, MS. 1968).

Temperature (T) in $^{o}$ Centigrade
Salinity (S) in parts per thousand ($^{o}/oo$)
Dissolved oxygen ($0_2$) in milligrams per litre (mg./l.)

Secchi disc readings in feet

| Station | Surface | | | 10m. (33ft.) | | | 30m. (99ft.) | | | Secchi (ft) |
|---|---|---|---|---|---|---|---|---|---|---|
| | T | S | $0_2$ | T | S | $0_2$ | T | S | $0_2$ | |
| H-1 | 17.3 | 10.8 | 11.3 | 10.2 | 26.6 | 7.2 | 9.3 | 29.5 | 6.6 | 13 |
| H-2 | 17.2 | 7.5 | 10.5 | 9.9 | 26.8 | 7.2 | 9.0 | 29.5 | 6.7 | 10 |
| H-3 | 15.1 | 4.1 | 10.6 | 9.6 | 27.3 | 7.3 | 8.9 | 29.5 | 6.6 | 3 |
| H-4 | 9.8 | 0.0 | 11.7 | 9.6 | 27.0 | 7.3 | 8.2 | 29.4 | 7.1 | 2 |
| H-5 | 10.4 | 0.0 | 11.4 | 9.6 | 26.9 | 7.3 | 8.3 | 29.4 | 6.9 | 2 |
| H-6 | 10.6 | 0.0 | 11.1 | 9.7 | 26.5 | 7.3 | 8.3 | 29.3 | 7.1 | 2 |
| H-7 | 16.4 | 6.4 | 10.3 | 9.6 | 27.2 | 7.2 | 8.5 | 29.4 | 6.9 | 7 |
| H-8 | 17.5 | 6.5 | 9.9 | 9.8 | 27.0 | 7.2 | 8.4 | 29.2 | 7.1 | 12 |
| H-9 | 17.9 | 6.1 | 9.6 | 9.9 | 26.9 | 7.2 | 8.5 | 29.4 | 7.0 | 9 |
| H-10 | 18.0 | 7.3 | 9.8 | 9.9 | 26.6 | 7.1 | 8.4 | 29.3 | 7.0 | 8 |
| H-11 | 16.7 | 10.2 | 9.8 | 9.8 | 26.8 | 7.2 | 8.3 | 29.2 | 7.1 | 11 |
| H-12 | 16.6 | 10.5 | 10.0 | 10.2 | 26.6 | 7.1 | 8.2 | 29.4 | 6.9 | 13 |

Table 3: Partial list of the Macrobenthos of Howe Sound (major group headings according to Meglitsch, 1967)

PORIFERA

Cl. Calcarea
*Scypha capillosa*

Cl. Hexactinellida
*Aphrocallistes vastus*
*Rhabdocalyptus dawsoni*
*Chonelasma calyx*

Cl. Demospongia
*Esperiopsis quatsinoensis*
*E. rigida*
*Lissodendoryx firma*
*L.* aff. *kyma*
*Cliona celata*
*Mycale adhaerens*
*Iophon pattersoni*
*Esperella occidentalis*

CNIDARIA

Cl. Hydrozoa
*Obelia longissima*
*Grammaria abietina*
*Sertularella tricuspidata*
*Lafoea fruticosa*
*Selaginopsis sp.*
*Abietinaria sp.*
*Tubularia sp.*

Cl. Anthozoa
Subcl. Alcyonaria
O. Pennatulacea
*Leioptilus guerneyi*
*Virgularia sp.*
*Stylatula ?*

Subcl. Zoantharia
O. Actinaria
*Tealia coriacea*
*T. crassicornis*
*Metridium senile*
*Anthopleura artemisia*
*Actinostola sp.*
*Epiactis prolifera*

O. Ceriantharia
*Pachycerianthus fimbriatus*

O. Zoanthidea
*Epizoanthus scotinus*

O. Madreporaria
*Balanophyllia elegans*
*Carophyllia alaskensis*

ECTOPROCTA
Cl. Gymnolaemata
O. Cheilostomata
*Bugula californica*
*Membranipora sp.*
*Phidolopora pacifica*

BRACHIOPODA
Cl Articulata
*Terebratalia transversa*
*Terebratulina unguicula*
*Laqueus californianus*

MOLLUSCA
Cl. Amphineura
O. Polyplacophora
*Cryptochiton stelleri*
*Mopalia laevior*
*M. ciliata*
*M. lignosa*
*Ischnochiton trifidus*
*Tonicella lineata*
*T. insignis*

Cl. Gastropoda
Subcl. Prosobranchia
O. Mesogastropoda
*Epitonium sp.*
*Natica clausa*
*Crepidula fornicata*
*Trichotropis cancellata*
*Lacuna variegata*
*Littorina planaxis*
*Fusitriton oregonensis*
*Trophonopsis lasius*

O. Archeogastropoda
*Diodora aspera*
*Puncturella sp.*
*Collisella pelta*
*Margarites lirulatus*

O. Neogastropoda
*Ceratostoma foliatum*
*Thais lamellosa*
*Amphissa columbiana*
*Nassarius mendicus*

Subcl. Opisthobranchia
O. Nudibranchia
*Anisodoris nobilis*
*Cadlina marginata*
*C. flavomaculata*
*Onchidoris bilamellata*
*Acanthodoris nanaimoensis*
*Dialula sandiegensis*
*Pleurophyllidia californica*
*Dendronotus iris*
*D. rufus*
*Hermissenda crassicornis*
*Aeolidia papillosa*
*Antiopella barbarensis*
*Dirona albolineata*
*D. aurantia*
*Tritonia festiva*
*Triopha carpenteri*
*Melibe leonina*

Cl. Pelecypoda
O. Filibranchia
*Mytilus edulis*
*Pododesmus macroschisma*
*Pecten hericius*
*Hinnites multirugosus*

O. Eulamellibranchia
*Crassostrea gigas*
*Saxidomus giganteus*
*Solen sicarius*
*Protothaca staminea*
*Clinocardium nuttalli*
*Mya truncata*
*Gari californica*
*Macoma nasuta*
*Humilaria kennerleyi*
*Hiatella arctica*
*Bankia setacea*

Cl. Cephalopoda
O. Teuthoidea
*Rossia pacifica*

O. Octopoda
*Octopus dofleini*

ANNELIDA
Cl. Polychaeta
Subcl. Errantia
*Nereis sp.*
*Cheilonereis cyclurus*

Subcl. Sedentaria

*Demonax medius*
*Laonome sp.*
*Branchiomma burrardum*
*Crucigera irregularia*
*C. zygophora*
*Serpula vermicularis*
*Protula pacifica*
*Spirorbis spp.*
*Apomatus timmsii*
*Chitinopoma groenlandica*

ARTHROPODA

Cl. Crustacea

Subcl. Cirripedia

O. Thoracica

*Balanus cariosus*
*B. glandula*
*B. nubilus*
*B. crenatus*

O. Valvifera

*Idothea wosnesenskii*

Subcl. Malacostraca

O. Decapoda

SubO. Natantia

*Crago sp.*
*Pandalus danae*
*P. platyceros*
*P. goniurus*
*Spirontocaris brevirostris*

SubO. Anomura

*Cryptolithodes typicus*
*Lopholithodes mandtii*
*L. foraminatus*
*Rhinolithodes wosnessenskii*
*Phyllolithodes papillosus*
*Munida quadrispina*
*Acantholithodes hispidus*
*Pagurus beringanus*
*P. hirsutiusculus*
*P. tenuimanus*
*P. aleuticus*

SubO. Brachyura

*Cancer magister*
*C. productus*
*C. oregonensis*
*Hemigrapsus nudus*
*H. oregonensis*
*Oregonia gracilis*

*Pugettia gracilis*
*Hyas lyratus*
*Chionoecetes bairdi*

ECHINODERMATA
Cl. Crinoidea
*Florometra serratissima*

Cl. Holothuroidea
*Parastichopus californicus*
*Cucumaria miniata*
*Psolus chitonoides*

Cl. Echinoidea
*Strongylocentrotus droebachiensis*
*S. franciscanus*

Cl. Asteroidea
O. Phanerozonia
*Dermasterias imbricata*
*Hippasteria spinosa*
*Luidia foliolata*
*Mediaster aequalis*
*Ceramaster patagonicus*

O. Spinulosa
*Solaster endeca*
*S. stimpsoni*
*S. dawsoni*
*Crossaster papposus*
*Henricia leviuscula*
*Pteraster tesselatus*

O. Forcipulata
*Pisaster ochraceus*
*P. brevispinous*
*Orthasterias koehleri*
*Stylasterias forreri*
*Pycnopodia helianthoides*
*Evasterias troschelli*

Cl. Ophuroidea
*Ophiopholis aculeata*
*Ophiura lutkeni*

CHORDATA
Cl. Ascidiacea
O. Phlebobranchia
*Ascidia callosa*
*A. paratropa*
*Chelyosoma productum*
*Ciona intestinalis*
*Corella willmeriana*

O. Stolidobranchia

*Boltenia villosa*
*Cnemidocarpa finmarkiensis*
*Halocynthia aurantium*
*H. igaboja*
*Pyura mirabilis*

Table 4

Diving Station Locations

(Refer to Canadian Hydrographic Service Chart #3586)

| Station | Latitude | Longitude | General description of site |
|---|---|---|---|
| 1. | 49°40.35'N | 123°13.67'W | West shore of Howe Sound 2 miles north of Woodfibre |
| 2 | 49°40.10'N | 123°14.75'W | Just north of log pond at Woodfibre |
| 3 | 49°39.45'N | 123°15.36'W | First point south of Woodfibre |
| 4 | 49°37.90'N | 123°12.64'W | Near small islet north of Britannia |
| 5 | 49°37.47'N | 123°12.45'W | Between the two main docks at Britannia |
| 6 | 49°36.65'N | 123°12.94'W | First point south of Britannia |
| 7 | 49°34.10'N | 123°13.82'W | ¼ mi. north of Porteau Beach |
| 8 | 49°33.36'N | 123°20.97'W | Point on west shore opposite Anvil Island. |
| 9 | 49°31.37'N | 123°16.95'W | Point on Anvil Island opposite Brunswick Pt. |
| 10 | 49°30.00'N | 123°18.08'W | West point of Cristie Islet. |
| 11 | 49°28.63'N | 123°14.55'W | Point just north of log dump at Brunswick Beach |
| 12 | 49°25.97'N | 123°16.50'W | Reef NW of Bowyer Island |
| 13 | 49°25.48'N | 123°15.60'W | Off east shore of Bowyer Island. |
| 14 | 49°24.27'N | 123°14.63'W | Below docks at Sunset Marina |
| 15 | 49°22.64'N | 123°17.30'W | Just north of light at lookout Pt. |
| 16 | 49°20.93'N | 123°27.97'W | Reef to SW of Worlcombe Island |

| | | | |
|---|---|---|---|
| 17 | 49°26.77'N | 123°19.10'W | Halkett Pt. |
| 18 | 49°27.13'N | 123°19.35'W | East shore of Halkett Bay |
| 19 | 49°27.87'N | 123°23.20'W | West shore of Centre Bay |
| 20 | 49°27.38'N | 123°26.85'W | Near point south of Mannion Creek |
| 21 | 49°29.14'N | 123°28.10'W | Witherby Pt. |
| 22 | 49°30.14'N | 123°27.52'W | Southern shore of Woolridge Island. |
| 23 | 49°30.29'N | 123°29.51'W | Just north of Hillside Gravel Pit |
| 24 | 49°31.92'N | 123°27.70'W | Point just east of Plowden Bay |
| 25 | 49°31.64'N | 123°25.46'W | North-west tip of Gambier Island. |
| 26 | 49°41.06'N | 123°11.01'W | Near bluff south of river mouth |
| 27 | 49°41.13'N | 123°10.50'W | At mouth of central basin |
| 28 | 49°40.80'N | 123° 9.84'W | Near flashing red beacon atop dolphin at mouth of Mamquam Channel. |

FIGURES 1-8

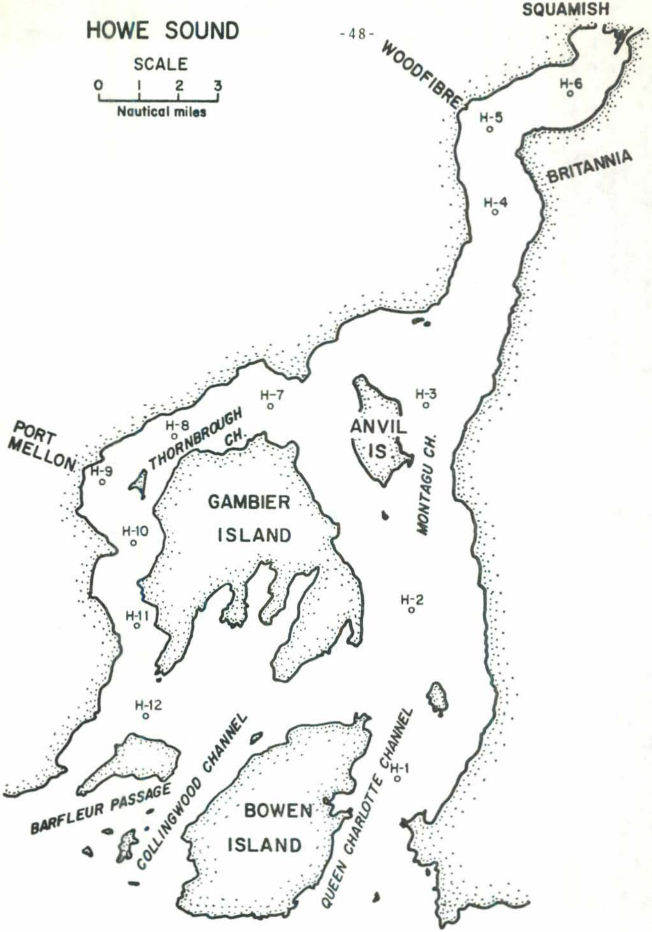



Figure 1: Location of oceanographic stations H-1 to H-12 (from Waldichuk *et al*, MS, 1968).

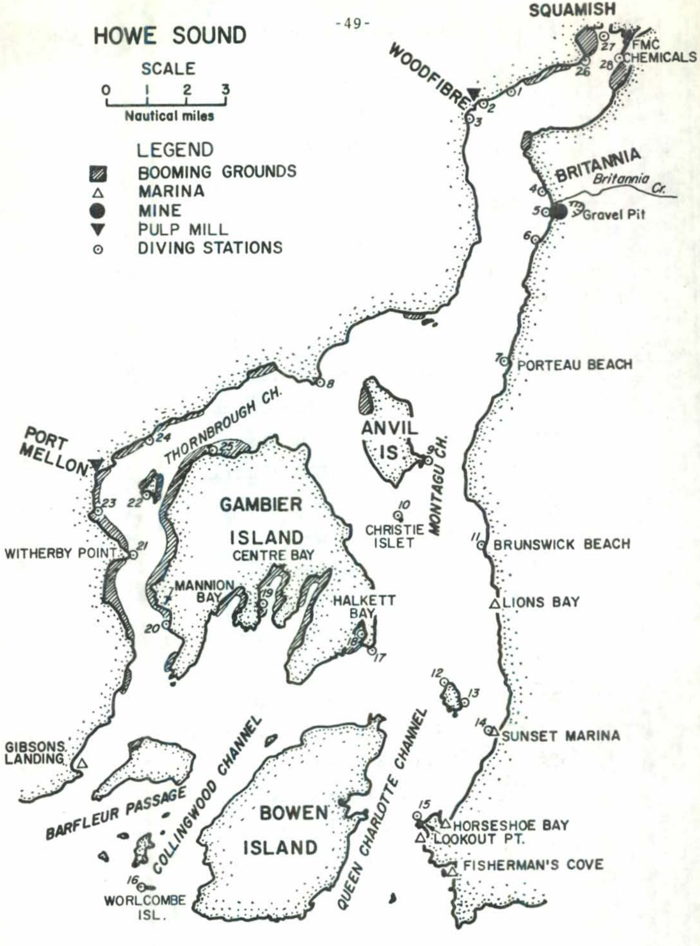



Figure 2: Diving station locations and sources of solid wastes in Howe Sound.

## LEGEND TO FIGURES 3, 4 and 5

Hexactinellida (siliceous sponges)
Demospongia (sponges)
Hydrozoa (hydroids)
Pennatulacea (sea-pens)
Actinaria (sea anemones)
Ceriantharia (burrowing anemones)
Zoanthidae (colonial polyps)
Madreporaria (stony corals)
Brachiopoda (lamp shells)
Polyplacophora (chitons)
Prosobranchia (limpets, snails)
Nudibranchia (sea slugs)
Pelecypoda (bivalve molluscs)
Cephalopoda (squid, octopus)
Polychaeta (worms)
Thoracica (barnacles)
Natantia (shrimps)
Anomura (hermit and lithode crabs)
Brachyura (true crabs)
Crinoidea (feather stars)
Holothuroidea (sea cucumbers)
Echinoidea (sea urchins)
Asteroidea (Seastars)
Ophuroidea (brittle stars)
Ascidiacea (sea squirts)

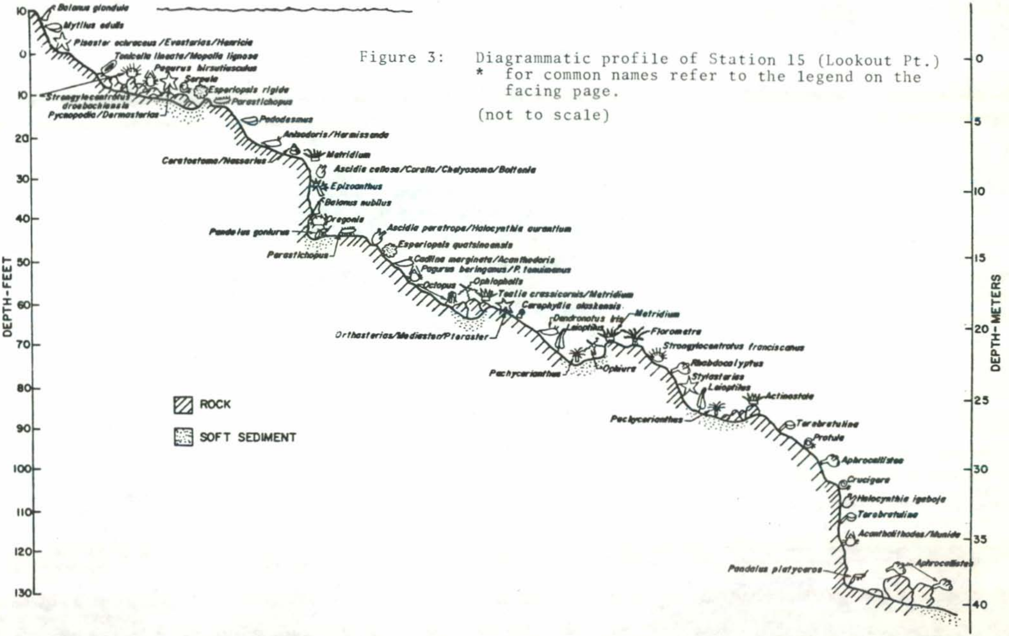



Figure 3: Diagrammatic profile of Station 15 (Lookout Pt.)
* for common names refer to the legend on the facing page.

(not to scale)

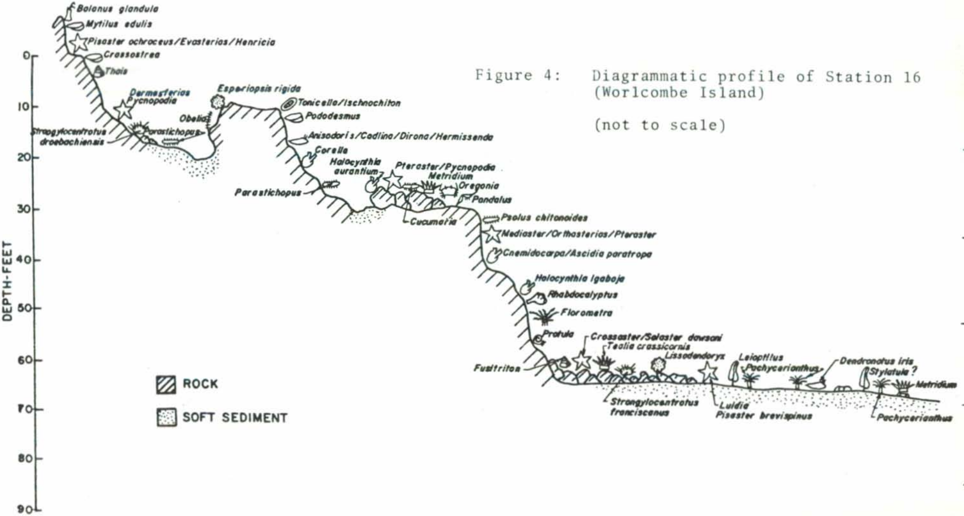



Figure 4: Diagrammatic profile of Station 16 (Worlcombe Island)

(not to scale)

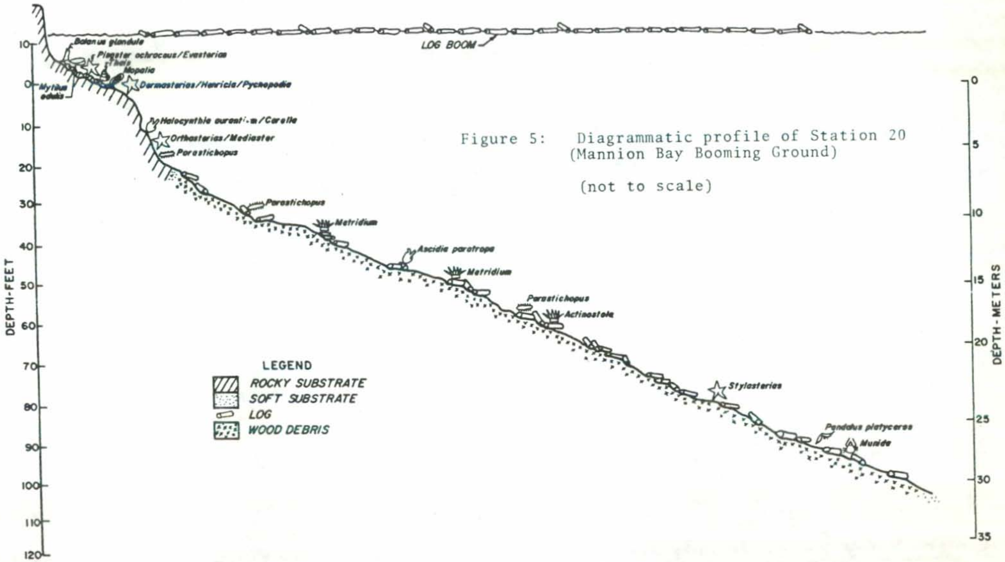



Figure 5: Diagrammatic profile of Station 20 (Mannion Bay Booming Ground)

(not to scale)

# SUBJECT INDEX

Figure 6

A. The snails, *Thais lamellosa,* laying eggs during December in shallow water at Station 15.

B. The lined chiton, *Tonicella lineata,* at 15 feet (Station 15).

C. The sea cucumber, *Parastichopus californicus,* at 20 feet (Station 15).

D. The sea star, *Pycnopodia helianthoides,* at 20 feet (Station 15)

E. The giant barnacle, *Balanus nubilus,* surrounded by the colonial polyp, *Epizoanthus scotinus,* at 30 feet (Station 15).

F. The horseshoe tunicate, *Chelyosoma productum,*, and the brachiopod, *Terebratalia transversa,* (bottom center) at 30 feet (Station 15).

G. The sea slug, *Hermissenda crassicornis,* at 30 feet (Station 15).

H. The sea slug, *Dirona albolineata,* at 40 feet (Station 15).

I. A group of plumose anemones, *Metridium senile,* attached to a rock wall at 40 feet (Station 15).

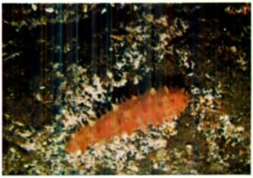
J. The solitary tunicate, *Ciona intestinalis,* at 40 feet (Station 15).

K. A rock wall covered with the tunicate, *Halocynthia aurantium,* at 40 feet (Station 11).

L. The calcareous tube-worm, *Serpula vermicularis,* at 20 feet (Station 13).

A

B



C

D

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Figure 7

A. The octopus, *Octopus dofleini*, guarding eggs in a cave at 50 feet (Station 15).

B. The sea anemone, *Tealia crassicornis*, at 45 feet (Station 15).

C. The sea star, *Mediaster aequalis*, at 45 feet (Station 15).

D. The sea pen, *Leioptilus guerneyi*, (left) and the tube dwelling sea anemone, *Pachycerianthus fimbriatus*, on sand/shell substrate at 70 feet (Station 15).

E. The crinoid (feather star), *Florometra serratissima*, at 60 feet (Station 15).

F. The 'swimming' sea anemone, *Actinostola sp.*, at 70 feet (Station 15).

G. The sponge, *Iophon pattersoni*, with the brittle star, *Ophiopholis aculeata*, at 90 feet (Station 15).

H. The long-spined sea urchin, *Strongylocentrotus franciscanus*, at 70 feet (Station 15).

I. The giant nudibranch (sea slug), *Dendronotus iris*, at 70 feet (Station 15).

J. The hexactinellid sponge, *Aphrocallistes vastus*, attached to a vertical rock wall at 100 feet (Station 15).

K. The calcareous tube-worm, *Protula pacifica*, at 90 feet (Station 15).

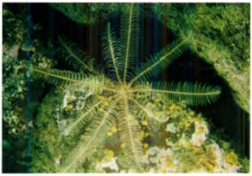
L. A vertical rock wall at 90 feet with the sea cucumber, *Psolus chitonoides*, (center), the brachiopods, *Terebratulina unguicula*, (lower left and right), and the cup-coral, *Carophyllia alaskensis*, (top) attached. (Station 15).

A

B

C

D



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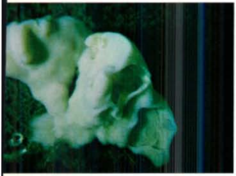


J

K

L

Figure 8

A. The "squat lobster", *Munida quadrispina*, (with long chelipeds) and the prawn, *Pandalus platyceros*, (with long banded antennae) under a sunken log at 90 feet (Station 20).

B. *Munida quadrispina* utilizing cover space provided by wood debris at 90 feet (Station 20).

C. The buildup of wood debris below a booming ground. Photograph shows an area 3 foot by 4 foot in size at 60 feet (Station 20).

D. Wood debris at 40 feet depth at Station 19 (Centre Bay, Gambier Island): representative area 3 ft. by 4 ft. in size.

E. Wood debris at 60 feet depth at Station 19: area represented 3 ft. by 4 ft. in size.

F. The burrowing sea anemones, *Pachycerianthus fimbriatus*, at 40 feet on sandy substrate (Station 19).

G. The sea stars, *Evasterias troschelli* and *Pycnopodia helianthoides*, on a sunken tire at Station 14.

H. Typical debris found under marinas. Depth 40 feet at Station 14 (Sunset Marina).

I. The respiratory siphons of the shipworm, *Bankia setacea*, extending from the holes in the sunken log in which they are boring, 40 feet at Station 24.

J. Debris under Sunset Marina (Station 14).

K. Debris under Marina at Station 14 (50 feet).

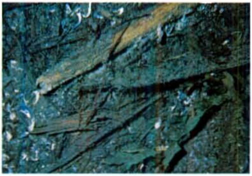
L. Photograph of soft bottom at 35 feet at Station 4 (one mile north of Britannia Beach). Holes in substrate suggest infaunal populations are present.

A

B

C

D

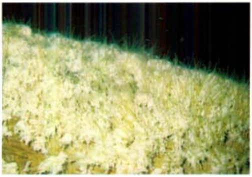


E

F

G

H



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J

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L

## SUBJECT INDEX