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EPA

United States Department of Commerce

National Oceanic and Atmospheric Administration
Seattle WA 98115

United States Environmental Protection Agency

Office of Environmental Engineering and Technology
Washington DC 20460

EPA-600/7-80-167
October 1980

Research and Development

Whidbey Island Intertidal and Shallow Subtidal Benthos

Interagency Energy/Environment R&D Program Report

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WHIDBEY ISLAND INTERTIDAL AND

SHALLOW SUBTIDAL BENTHOS

by

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Prepared for the MESA (Marine Ecosystems Analysis) Puget Sound Project, Seattle, Washington in partial fulfillment of

EPA Interagency Agreement No. D6-E693-EN
Program Element No. EHE625-A

This study was conducted
as part of the Federal
Interagency Energy/Environment
Research and Development Program

Prepared for

OFFICE OF ENVIRONMENTAL ENGINEERING AND TECHNOLOGY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D. C. 20460

November 1980

Completion Report Submitted to
PUGET SOUND ENERGY-RELATED RESEARCH PROJECT
OFFICE OF MARINE POLLUTION ASSESSMENT
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

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This work is the result of research sponsored by the Environmental Protection Agency and administered by the National Oceanic and Atmospheric Administration.

ABSTRACT

The intertidal and shallow subtidal (+6.0' to -10.0m) benthos of three representative habitats of the west coast of Whidbey Island were sampled by stratified random sampling for a two year period. All organisms >1 mm from a sand (West Beach), gravel (Ebey's Landing) and cobble (Partridge Point) habitat were identified, counted, weighed wet and preserved.

Species richness at the cobble site was greatest (700) followed by the gravel (612) and sand site (336). Although values of species richness at each site were similar for the two years sampling species composition was not. Similarity indices showed that at each site only around 60% of the species found in the first year were also found in the second.

At all sites the species richness in the intertidal area was lower than the subtidal. At the sand and gravel sites intertidal species richness was low (66-91) compared to the cobble site (around 309). At subtidal areas, species richness of the gravel site and sand site were similar (401-479) while that of the sand site was low (around 204).

Species composition in the intertidal areas of the three sites were not similar (lower than 37%). At subtidal areas species composition at the gravel and cobble sites were similar (around 65%) while similarity between cobble and sand and gravel and sand was low (around 40%).

At the sand and gravel sites only a few species (around 25) were found only in the intertidal area while at the cobble site around 110 species were found only in the intertidal area.

Highest values of numbers of individuals per $0.25m^2$ were noted at the gravel site and were due primarily to the amphipod Paramora mohri. At both the gravel and cobble sites the greatest number of individuals per $0.25m^2$ were observed in the intertidal area. Highest values of biomass were observed at the cobble and gravel sites and were a result of algae found at subtidal strata. There was considerable variation between the two years data.

Species specific data on number of individuals and biomass had high variability. Coefficients of variation showed the majority of species sampled had inadequate sample size and/or replicate number. Differences in number of individuals and/or biomass between seasons and years were not clear. At any given strata generally less than 5-10 percent of species showed significant differences with season or year sampled. Most species that showed a significant difference in biomass or numbers of individuals had higher values during summer sampling.

Results on species richness, numbers of individuals and biomass for these three sites on Whidbey Island agree in general with similar data from studies conducted in the Strait of Juan de Fuca, the San Juan Islands, and Georgia Strait.

FOREWORD

Increased petroleum transfer and refining activities are expected in northern Puget Sound and the Strait of Juan de Fuca in the future, which may increase the chances of oil spills into the marine environment. A five-year multidisciplinary research project, titled "An Environmental Assessment of Northern Puget Sound and the Strait of Juan de Fuca," was initiated in 1975 to provide information usable in solving environmental questions pertaining to increased petroleum-related activities. This report presents the results of the second year of a study of the benthos of the west coast of Whidbey Island and summarizes both years' data. It complements reports prepared previously which document the results of similar research conducted in northern Puget Sound and the Strait of Juan de Fuca.

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1. A list of species found, the mean weight and count per $0.25m^2$, the standard deviation of weights and counts for each site, season, stratum and year. Also included in each list are the dominant species for each year, the total number of individuals and weight and the species diversity index. Appendix One is available on microfiche.

ACKNOWLEDGMENTS

Acknowledgment is due: to Gary Smith for development of underwater sampling techniques and field collection; to Alice Benedict who was responsible for general taxonomy and who insured samples moved orderly through laboratory procedures; to Rick Henderson, Wendy Pounds and Sue Schonberg who assisted in the taxonomy of specific groups; and finally to the students of Huxley College and the Department of Biology whose careful attention to detail of procedure in field collection and laboratory analysis have contributed to insuring the accuracy of data.

SECTION 1

INTRODUCTION

Puget Sound is a descriptive term used to describe the inland sea of northwestern Washington State and southwestern British Columbia (Fig. 1). It consists of the Strait of Juan de Fuca, the southern portion of the Strait of Georgia, channels of the San Juan Islands, numerous estuaries, and the southern inlets that are Puget Sound proper. The increased use of northern Puget Sound waters and shorelines for the transportation and refining of oil has increased concern about potential damage to marine resources of the area. Since 1972 a number of studies have been initiated by industry and state and federal government to document the components of the ecological systems of northern Puget Sound. The biological communities of southern Georgia Strait have been studied by Battelle Northwest (1976) for the Atlantic Richfield Oil Company. The Washington State Department of Ecology in 1974 initiated a baseline study of biological resources of Northern Puget Sound (DOE, 1978). In 1975 the National Oceanic and Atmospheric Administration initiated a MESA Project (Marine Ecosystem Analysis) in Puget Sound that is designed to provide a data base on physical, chemical and biological components (MESA, 1978).

An important component of both the DOE baseline program and the NOAA MESA program is the characterization of the marine plants and animals of the intertidal and shallow subtidal areas of north Puget Sound. DOE studies have primarily focused on the geographical area from Anacortes to Blaine (Fig. 1) with major emphasis on the areas adjacent to oil shipping routes and refining activity, and similar "control" areas in the San Juan Islands. Results of these studies are available from the Washington State Department of Ecology (Nyblade, 1977; Webber, 1978).

NOAA's MESA project on the characterization of the intertidal and shallow subtidal benthos has focused on habitats of the Strait of Juan de Fuca (Nyblade, 1978). An important area of Puget Sound that is adjacent to oil shipping routes and has not had similar characterization studies of intertidal and shallow subtidal flora and fauna is the west coast of Whidbey Island from Admiralty Head to Deception Pass.

The west coast of Whidbey Island is predominantly unconsolidated material deposited by glaciation. Moderate wave action has acted on the material to form a shoreline composed of a series of beaches. At headland areas erosion has created beaches composed of material that is too heavy for wave action to transport. These are cobble beaches and are found primarily at the base of actively eroding bluffs. Material eroded from the bluffs is carried by longshore drift to areas where wave action is reduced or some barrier results in deposition. These areas are accretional and are characterized by sandy beaches with extensive backshore areas composed of sand dunes. A third type of beach

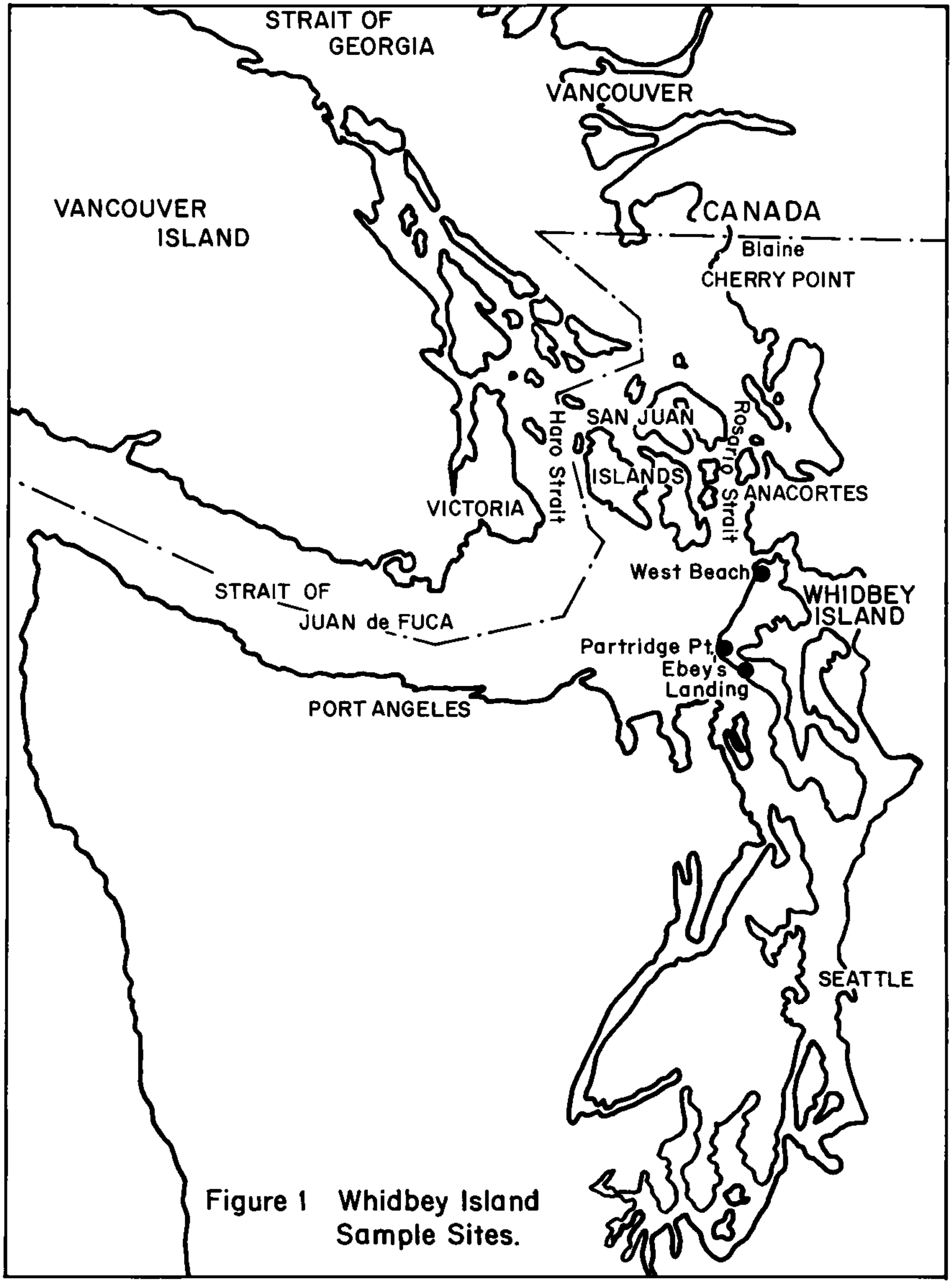

Figure 1 Whidbey Island Sample Sites.

is that where material is not actively eroding or accreting, but is carried along by longshore drift. These are transport beaches. Transport beaches are mostly gravel or coarse sand. The southerly portion of the study area is mostly a series of erosional and transport beaches, while the northerly portion is primarily an area of accretion.

Three sites were chosen in this study to reflect the predominant beach types: Partridge Point, an erosional area with a cobble beach; Ebey's Landing, a transport area with a gravel beach; and West Beach, an accretional area with a sandy beach.

This study is based on a habitat approach. That is, habitat types were chosen to reflect the dominant substrate type visible in the intertidal zone. By characterizing in detail the flora and fauna of a typical habitat type it is assumed that results can be extrapolated to other similar habitats.

Although the habitat type reflects the dominant substrate visible in the intertidal area, variability in substrate type exists. Substrate at most habitats at the +5 foot tide height and above often differs from the dominant substrate. Cobble beaches usually have a band of gravel at this height; mud beaches usually have a band of sand or cobbles. Also, the substrate below the tide line changes from the dominant type. With increasing depth below the 0.0 tide height wave action decreases and the proportion of silt in the substrate increases. Except in rocky areas and areas of large tidal current, substrate type becomes a relatively uniform mud at a depth of 10 m.

The objectives of this study were to quantitatively characterize the benthos of the intertidal and shallow subtidal areas of three habitats on the west coast of Whidbey Island. The study area was between +6.0' above mean low water to -10.0 m below mean low water. Stratified random sampling was used to select samples. Analysis was to 1 mm in size. This report discusses results for two years of sampling. Included is an analysis of species richness, species diversity, community structure, seasonal changes and dominant forms. Results of the first year sampling were reported in Webber, 1979.

SECTION 2

CONCLUSIONS

The intertidal areas of the sand (West Beach) and gravel (Ebey's Landing) habitats are essentially devoid of a distinct community. Only a few species are found that are not also found in the subtidal, and there is little similarity in species composition between the intertidal areas of the sand and gravel habitat. The cobble site (Partridge Point) on the other hand has a well defined intertidal flora and fauna that is not found in the subtidal.

Subtidal biota are not necessarily related to intertidal biota. The sand site has a relatively meager subtidal biota probably due to the instability of the substrate. The gravel site, although it had an impoverished intertidal biota, had a rich subtidal biota that was similar to that of the cobble site.

Species specific data on numbers of individuals and biomass had high variability. This variability restricts the usefulness of statistical tests to examine species specific data.

A definition of dominance based on species specific data had little success in identifying a group of species that characterized the structure and change with time of the communities of the three habitats.

Field observations indicated that algae that were "canopy" species (i.e., Laminaria, Nereocystis) were inadequately sampled.

The distribution of amphipods at the gravel site was restricted to a relatively narrow region in the intertidal area. Population peaks varied between the two years and sampling at each foot of tide elevation was required to describe population distribution.

SECTION 3

RECOMMENDATIONS

Abundance and biomass data were collected for almost 1,000 species during the study. The resulting large data set precluded detailed analysis and this report should be considered as a preliminary analysis. Three areas warrant continued analysis.

a) Species richness values between sites, seasons, and strata are relatively consistent. Analysis of species richness with similarity indices that are weighted by abundance or biomass values should be pursued.

b) The criterion of dominance used in data analysis was of limited use. Dominance was biased towards algae biomass and was not sensitive to species with small but stable values of abundance and/or biomass. Further investigation of the application of dominance to the data should be made.

Species specific data on numbers of individuals and biomass have high variability which restricts their use in statistical analysis. The usefulness of examining data from species complexes should be investigated.

This study has described the structural characteristics of benthic communities. In order to evaluate the sensitivity of these biological communities to environmental perturbations, study should be extended to functional characteristics. The contribution of littoral communities to primary productivity; the extent to which photosynthetic energy is utilized by herbivores and the extent to which it contributes to detritus; and the contribution of energy to higher trophic levels are such characteristics that warrant study.

SECTION 4

METHODS

STUDY AREAS

The sample sites were established on the west coast of Whidbey Island from Deception Pass to Admiralty Head (Fig. 1). They were, from north to south, West Beach (sand habitat), Partridge Point (cobble habitat) and Ebey's Landing (gravel habitat).

West Beach (lat. 48°, 22'1"; long. 123°, 41'3")

The West Beach sample site was approximately one mile west of State Highway 525 and was reached by travel west on Banta, Murray, and Powell Roads. The permanent reference marker consists of three spikes driven into the asphalt parking area. Each spike was located 15.8' above the 0.0' tide height. The specific location of the sample area is shown in Figure 2.

Partridge Point (lat. 48°, 13'8"; long. 123°, 46'2")

The cobble sample site was reached by traveling approximately three miles west on Libby Road from its intersection with State Highway 525. This intersection was approximately four miles southwest of Oak Harbor. On Libby Road approximately 200 feet before the public boat launch at Partridge Point, turn left into Padilla Estates. The sample location was at the foot of the private access beach road. The permanent reference marker at Partridge Point was the USGS marker located on the top of a large boulder (Fig. 3). The tide height of the marker was 12.4' above the 0.0' tide height. The location of the specific sampling area is shown in Figure 3.

Ebey's Landing (lat. 48°, 11'4"; long. 123°, 42'2")

The gravel site was located at Ebey's Landing. The site was reached by traveling west on Ebey road from its intersection with State Highway 525 approximately one mile north of Coupeville. The sample site was located adjacent to the road where it parallels the beach. The permanent reference marker was three spikes placed in the center of the road surface (Fig. 4). Each spike was 10.4' above the 0.0' tide height. The specific location of the sample site is indicated on Figure 4.

Sample Area

At each site the sample area was a 50 m wide strip from the +6' to -1' tide height. At given strata samples were located along the 50 m line by a table of random numbers. Adjacent 50 m wide areas were used in each of the

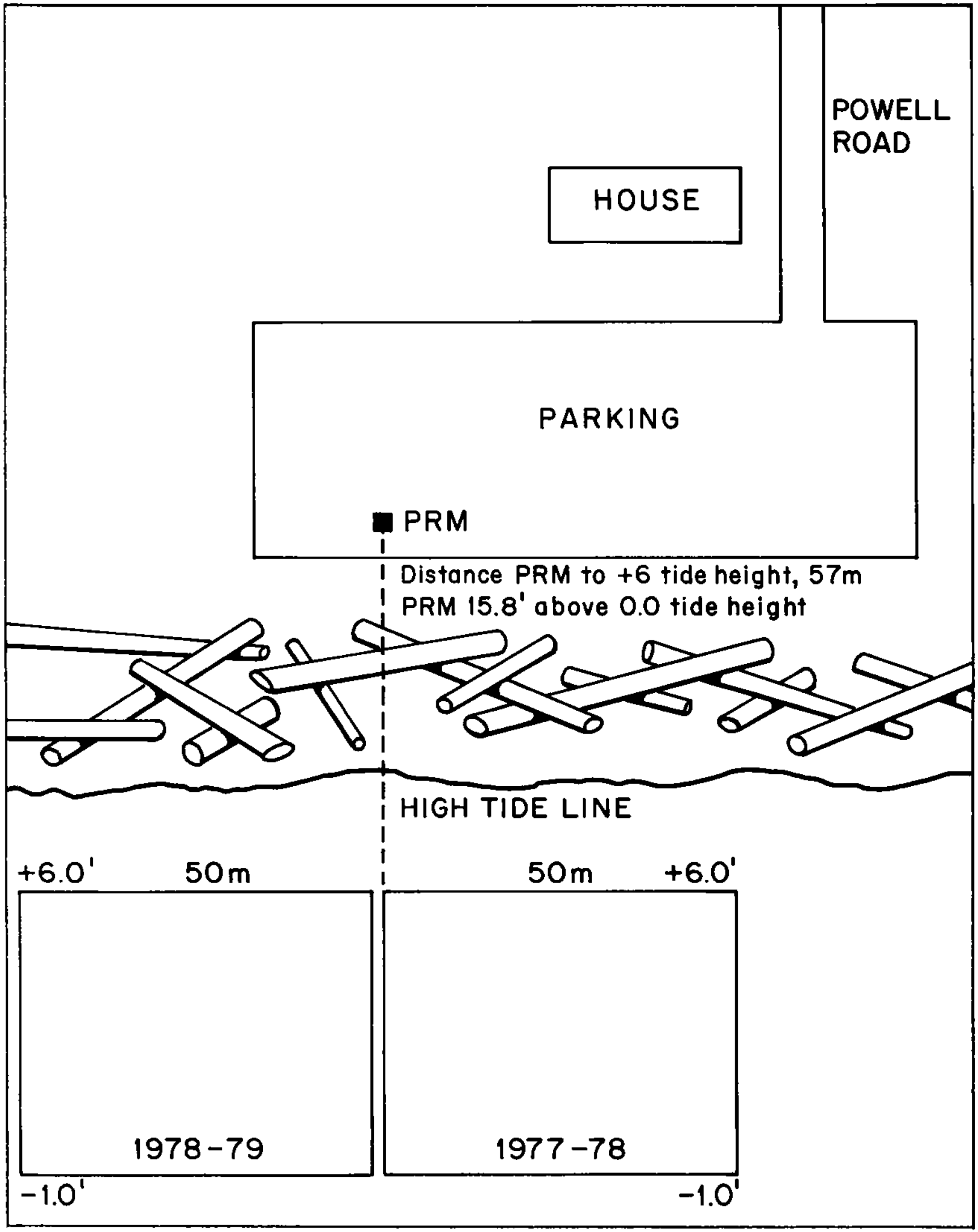

Figure 2 Site diagram, West Beach (sand)

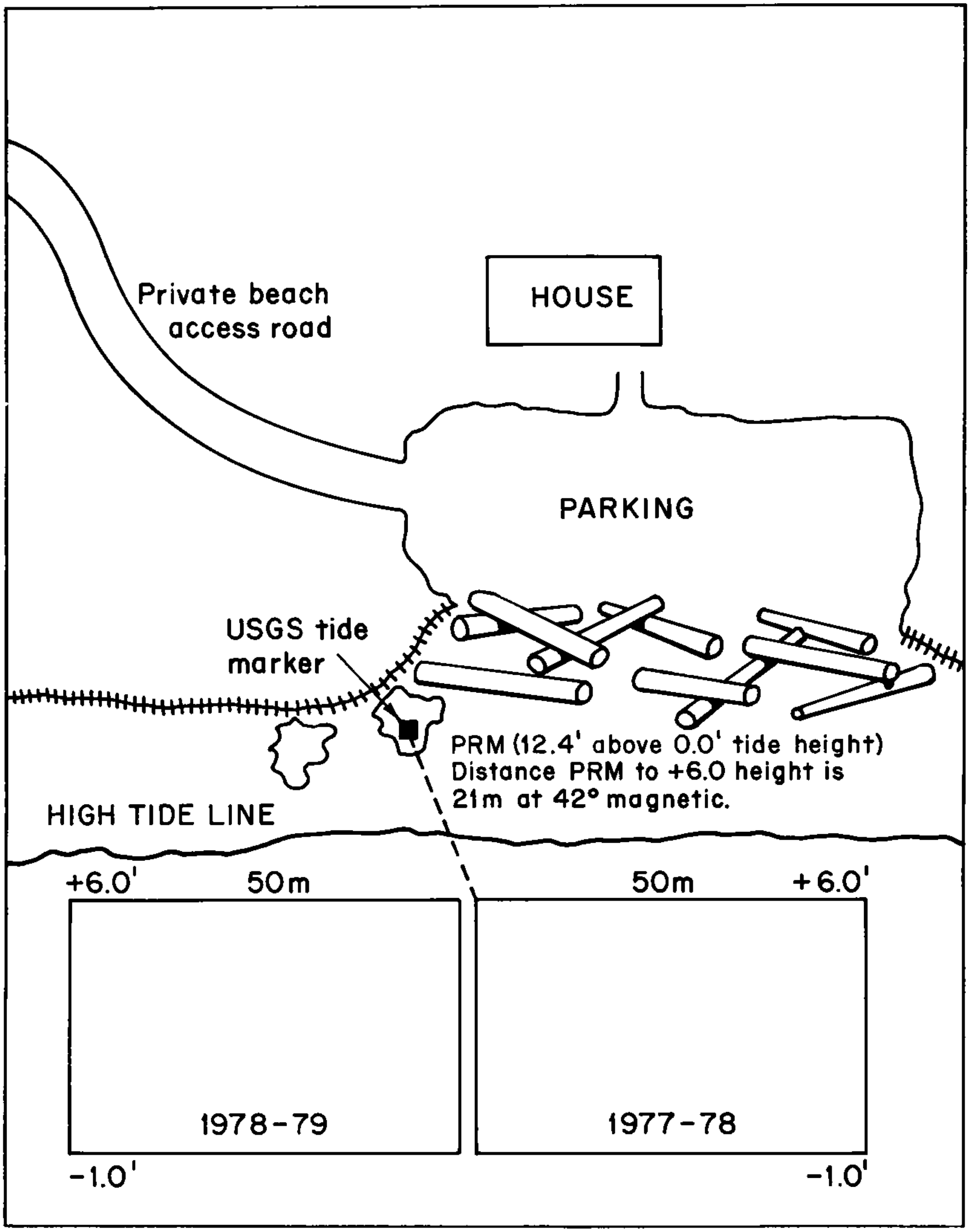

Figure 3 Site diagram, Partridge Point (cobble)

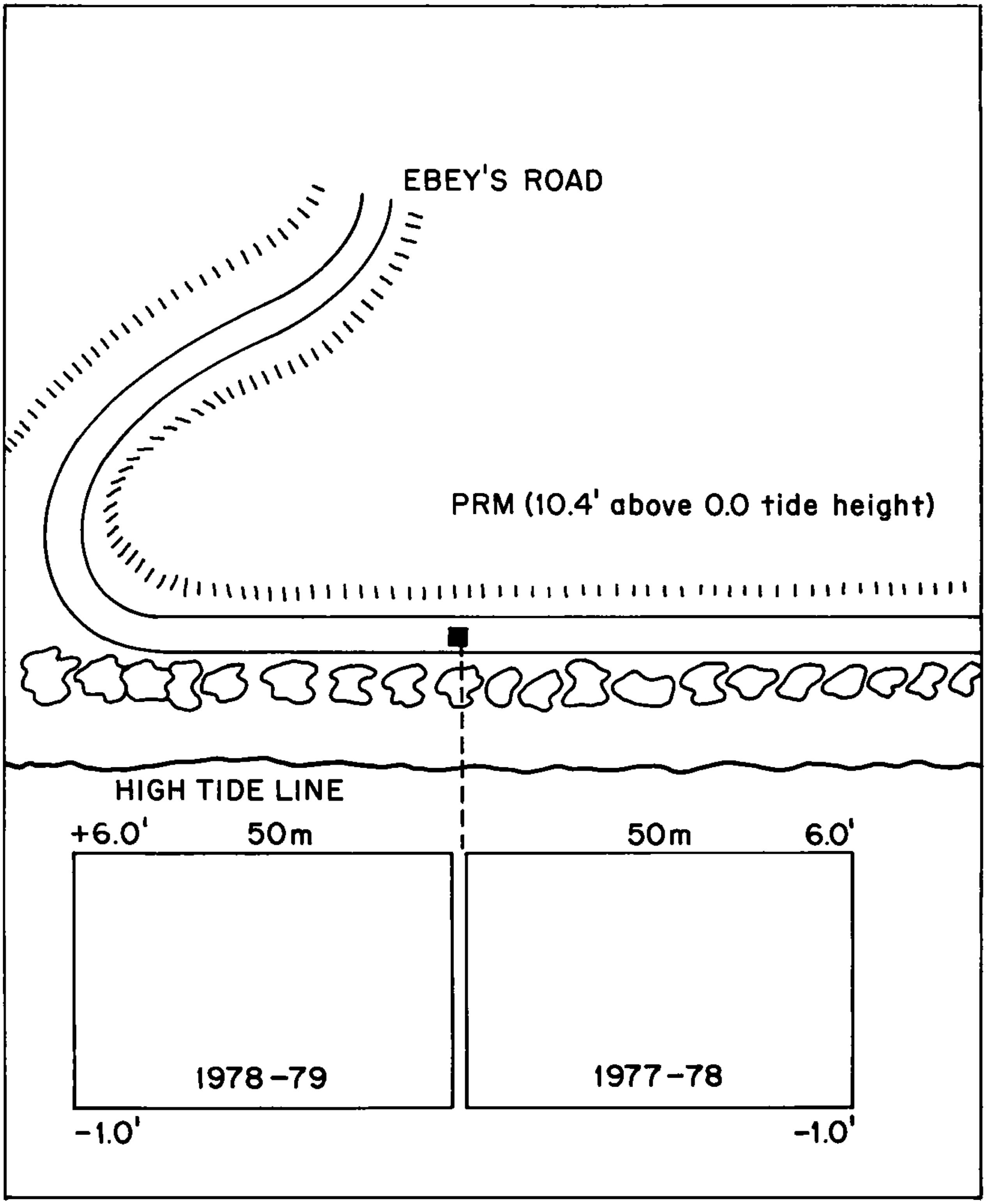

Figure 4 Site diagram, Ebey's Landing (gravel)

two years (Figs. 2-4).

Subtidal sample areas were located immediately offshore of the intertidal sites. Subtidal samples were located on depth contours in haphazard fashion along a line of approximately 30 m width. Subtidally sample heights were expressed as depth in meters. Intertidally, because of contract requirements, sample heights were expressed as feet above the 0.0 tide height.

SAMPLE SCHEDULE

Sample effort varied at site and season. Intertidally one tide height in each of the upper, mid and lower tide areas was sampled in each of the four seasons (see Table 1). For Ebey's Landing and West Beach five replicates were located at each of the three tide heights. During summer and winter sampling periods each additional tide height between +6 and -1 feet was sampled with triplicates. For subtidal sampling triplicates were used at all strata and all seasons. A summary of sampling times and replicate numbers is given in Table 1.

INTERTIDAL FIELD METHODS

Ebey's Landing (gravel) and West Beach (sand)

a. Live Sieves. An area of $0.25m^2$ was removed to a depth of 30 cm. Material was passed through a 0.5 $inch^2$ (1.3 cm) wire mesh and bivalves and mobile crustacea retained and preserved in 12% buffered formalin. Live sieves were taken only at the +6, +3, and 0.0' strata, at each of the replicates.

b. Cores. At each replicate a core $0.05m^2$ by 15 cm deep was removed with minimum disruption and placed in a bucket. Twelve percent buffered formalin was gently worked through the sediment for preservation.

c. Grain Size Sample. Approximately 1 liter of sediment was taken at +6, +3 and 0.0' strata for grain size analysis.

Partridge Point

a. +6' Stratum. The +6' stratum was sampled as described for West Beach and Ebey's Landing.

b. Live Sieves. At the +2' and 0.0' strata cobbles were removed from a $0.25m^2$ area and mobile invertebrates greater than 1 cm were retained. Sediment was removed to a depth of 30 cm and passed through a 0.5 $inch^2$ (1.3 cm) wire mesh. Any organism was retained and preserved in 12% buffered formalin. Live sieves were taken at each replicate.

c. Scrapes. At each replicate a $0.25m^2$ grid subsectioned into 25 $.01m^2$ areas was placed on the cobbles. From five subsections (randomly chosen), all algae and invertebrates greater than 1 mm in size were removed from the tops, sides and bottoms of the cobbles. Each $.01m^2$ subsample was separately preserved in 12% buffered formalin.

TABLE 1

A. NUMBER OF REPLICATES AND STRATA SAMPLED IN EACH OF THE TWO YEARS SAMPLING +6' to -1' are tide heights in feet (Port Townsend tide tables). -1.5 m to -10 m are depths in meters below the 0.0' tide height. PP = Partridge Point, EL = Ebey's Landing, WB = West Beach.

Height	Spring, Fall	Summer, Winter
+6'	PP4, WB5, EL5	PP4, WB5, EL5
+5'	not sampled	PP3, WB3, EL3
+4'	not sampled	PP3, WB3, EL3
+3'	WB5, EL5	PP3, WB5, EL5
+2'	PP4	PP4, WB3, EL3
+1'	not sampled	PP3, WB3, EL3
0'	PP4, WB5, EL5	PP4, WB5, EL5
-1'	not sampled	PP3, WB3, EL3
-1.5 m	PP3, WB3, EL3	PP3, WB3, EL3
-2.5 m	not sampled	PP3, WB3, EL3
-5.0 m	PP3, WB3, EL3	PP3, WB3, EL3
-7.5 m	not sampled	PP3, WB3, EL3
-10.0 m	PP3, WB3, EL3	PP3, WB3, EL3

B. SAMPLING DATES

	Spring		Summer		Fall		Winter	
	Int.	Sub.	Int.	Sub.	Int.	Sub.	Int.	Sub.
West Beach	4/6/77 4/25/78	4/19/77 4/18/78	7/2/77 6/20/78	8/10/77 6/29/78	10/15/77 10/17/78	11/18/77 10/14/78	1/6/78 1/25/79	1/24/78 1/21/79
Ebey's Landing	4/7/77 4/26/78	4/28/77 5/8/78	7/1/77 6/21/78	8/22/77 6/30/78	10/17/77 10/18/78	11/3/77 10/12/78	1/7/78 1/26/79	2/13/78 1/18/79
Partridge Point	4/8/77 4/27/78	4/30/77 5/16/78	6/30/77 6/22/78	8/26/77 7/1/78	10/18/77 10/19/78	11/8/77 10/13/78	1/8/78 1/27/79	2/6/78 1/22/79

d. Algae. From the remaining $0.20m^2$ area all surface algae and all macroinvertebrates larger than 1 cm were removed and preserved in 12% buffered formalin. In the second year, all biota smaller than 1 mm were removed for comparison of methods. This was possible because the area was not heavily colonized by barnacles.

e. Core. Cobbles were removed from the $0.25m^2$ area and a $0.05m^2$ by 15 cm core was removed with minimum disruption. Sediment was preserved in 12% buffered formalin.

SUBTIDAL FIELD METHODS

Subtidal samples were taken with the aid of scuba equipment and a working platform that was placed over the sample site. A $0.25m^2$ quadrat was placed on the bottom and all algae and animals were removed and sucked by air lift into a cloth bag of 0.7 mm mesh size. Tests indicated that a 0.7 mm mesh size retained organisms of a similar size to a 1.0 mm mesh size used to sieve dead organisms. Once algae were removed, a $0.05m^2$ by 15 cm core was removed and sucked by air lift into a bag of 0.7 mm mesh size. Organisms were preserved in 12% buffered formalin. One liter of sediment was taken from each subtidal stratum for grain size analysis.

LABORATORY PROCEDURES

a. Live Sieves. Organisms were sorted to species, identified, enumerated, and weighed. Trace weights (<.01 g) were recorded as .001 g for ease of computer handling. Molluscs were weighed with shells. Each sample was labeled and placed in 30% isopropyl alcohol and 5% glycerine for permanent storage.

b. Intertidal Scrapes. Organisms from the five $0.01m^2$ scrapes were sorted to species. Wet weight biomass was recorded for algae. For animals, numbers of individuals and wet weight were recorded. Each sample was preserved and labeled for semi-permanent storage. Algae were preserved in 6% buffered formalin. Animals were preserved as described above in a.

c. $0.25m^2$ Algae. Algae were sorted to species, identified, enumerated, weighed, labeled and preserved as described above. In the first year all molluscs and crustaceans > 1 cm found on the algae were sorted, identified, weighed and stored. In the second year all animals > 1 mm found on the algae were sorted, identified, weighed and stored.

d. Cores. Sediment was washed through a 1.0 mm screen. The retained sediment and organisms were flooded with .02% rose bengal dye in 35% isopropyl alcohol. Material was left for at least 48 hours before sorting. (All algae fragments and animals were removed and sorted to species. Each species was identified, enumerated, weighed, and preserved for permanent storage as described above.)

e. Subtidal Algae. Algae and animals were sorted to species and treated as described in c. above.

f. Subtidal Cores. Organisms were dyed in 0.02% rose bengal in 35% isopropyl alcohol, sorted to species and treated as described above.

g. Sediment Samples. Samples for grain size analysis were dried at 80°C for 24 hours then passed through a series of sieves into the following fractions: > 0.065 mm; 0.065 to 0.125 mm; 0.125 to 0.5 mm; 0.5 to 1.0 mm; 1.0 to 2.0 mm; 2.0 to 4.0 mm; 4.0 to 64.0 mm and 64 to 256 mm.

TAXONOMY

Where possible organisms were identified to the species level. Some groups (i.e., Oligochaetes, Nemerteans) are not well known and were identified to higher taxonomic levels. Juvenile or fragmentary individuals were often not identifiable to species. The taxonomic references used are listed in the bibliography.

DATA PROCESSING

Data for each species taken by each collection method were coded using the NOAA National Oceanographic Documentation Center (NODC) format. Data were stored on computer tape and are available from the NOAA Environmental Data and Information Service data library. The following categories of data are on file:

	Code Number
I Intertidal	
a. 0.20 m quadrat surface only	
- algae > 1 mm	29
- epifauna > 1 mm	29
- selected invertebrates > 1 cm	42
b. $0.05m^2$ x 15 cm core	
- cores	17
c. $0.01m^2$ selected quadrats (5 per $0.25m^2$)	
- scrapes	28
d. $0.25m^2$ x 30 cm deep core (1/2 inch mesh)	
- live sieve	16
II Subtidal	
a. $0.25m^2$ quadrat, surface airlift 0.7 m mesh	
- algae > 1 mm	43
- epifauna > 1 mm	43
- selected invertebrates > 1 cm	44
b. $0.05m^2$ x 15 cm core, airlift 0.7 m mesh	
- core	41

DATA MANIPULATION

To compare data from various collection methods data were normalized to a $0.25m^2$ quadrat , 15 cm in depth. Data from various collection methods were recombined to create the $0.25m^2$ quadrat in the following manner:

I First Year Data:

a. Intertidal.

Normalized surface algae were produced by adding the $0.20m^2$ and 5, $0.01m^2$ data together. Surface invertebrate data were created by multiplying the 5, $0.01m^2$ data to $0.25m^2$. Infauna data were created by multiplying the $0.05m^2$ x 15 cm data to $0.25m^2$ x 15 cm.

b. Subtidal.

For the first year there were no data for epifauna > 1 mm. Data from selected animals > 1 cm were used instead. The $0.25m^2$ x 15 cm quadrat was created by: algae - $0.25m^2$ quadrat; surface invertebrates - selected invertebrates > 1 cm; infauna - multiplying the $0.05m^2$ by 15 cm deep core to $0.25m^2$.

II Second Year Data:

a. Intertidal.

The same procedure as for the first year intertidal data was followed. In the second year all epifauna > 1 mm were identified. If desired, these data could be used instead of multiplying the 5, $0.01m^2$ areas.

b. Subtidal.

In the second year epifauna > 1 mm were identified for the $0.25m^2$ surface scrape. The $0.25m^2$ quadrat was created by: algae - $0.25m^2$ quadrat; surface invertebrates - epifauna > 1 mm; infauna - multiplying the $0.05m^2$ by 15 cm deep core data to $0.25m^2$.

DOMINANCE

Dominant species were identified for each stratum. Dominant species were those species comprising at least 5% of the total number of individuals, or at least 5% of the total biomass at a given stratum. Invertebrates having 10.0 g total weight or more were automatically classified as dominant and the weight of that species was subtracted from the total weight for that stratum before determining remaining dominant species.

STATISTICAL METHODS

Similarity Index

The similarity index used was:

$$S = \frac{2C}{A+B}$$

where: S = index of similarity, usually expressed as a percent
C = number of species in common
A = total number of species in Sample A
B = total number of species in Sample B

Species Diversity

Species diversity was calculated using the Shannon index of general diversity:

$$H = \Sigma \frac{n_i}{N} \log \frac{n_i}{N}$$

where: n_i = number of individuals for each species
N = number of species

Coefficient of Variability

The coefficient of variability as described by Ebelhart (1978) in which the standard deviation is divided by the mean was used to evaluate variability in data.

"t" Tests

Student's t tests were used to compare means (two-tailed) or to compare a mean against 0 (one-tailed). The probability level of $p = 0.05$ was chosen to define significant differences. When comparing sites and years, summer data were used because species richness was greater than winter, and all strata were sampled.

SECTION 5

RESULTS

HABITAT DESCRIPTIONS

West Beach, Sand Habitat

The location of the sand habitat is shown in Fig. 1. A detailed diagram of the site is given in Fig. 2. West Beach is an accretion beach. Littoral drift sediment accumulates in this area resulting in a well established backshore berm. Wave action is moderate. The dominant visual feature of the intertidal area is sand with occasional patches of gravel. No attached algae were apparent offshore and when wave action was moderate surf was observed, indicating an offshore bar. Beach slope was relatively gradual and the most variable of the three habitats (Fig. 5). At the beginning of sampling (June 1977) beach width was 23 m. In January 1978 beach width was 54 m, indicating the deposition of sand. By April 1978 beach width was reduced, and by June 1978 it was almost the same as June 1977. In January 1979 beach width remained at around 27 m. The deposition of sand noted in the winter of the first year sampling was not observed in the second winter sampling.

Subtidally the sediment of the sandy habitat was similar to the intertidal area. Basically, the substrate was sand with some cobbles at shallow depths and some silt at deeper depths. There was a difference related to intertidal beach slope. During those sample times when beach slope was relatively steep (Fig. 5) the -1.5 m and -2.1 m strata had patches of cobbles covering about 20% of the bottom. These cobbles had no attached flora or fauna. During the sample time when beach slope was most gradual (January 1979) the cobble patches were not observed.

An offshore sand bar was a persistent feature of this site subtidally. The bar was present at all sample times between the -5.0 m and -7.0 m strata. In all cases the -5.0 m sample was taken on the seaward side of the bar. The -1.5 m and -2.5 m samples were taken on the landward side of the bar.

Sediment composition of intertidal and subtidal areas are given in Table 2. Surface water temperature and salinity values for West Beach are given in Table 3. Temperature ranged from 5° C to 13.5° C over the two years. Salinity ranged from 29.8 ^{o}/oo to 34.0 ^{o}/oo.

Partridge Point, Cobble Habitat

The location of the cobble habitat is shown in Fig. 1. A detailed diagram of the site is given in Figure 3. Partridge Point is one of a series of erosional headlands along the west coast of Whidbey Island. Cobbles deposited by erosional activity form the dominant feature of the beach, although a gravel

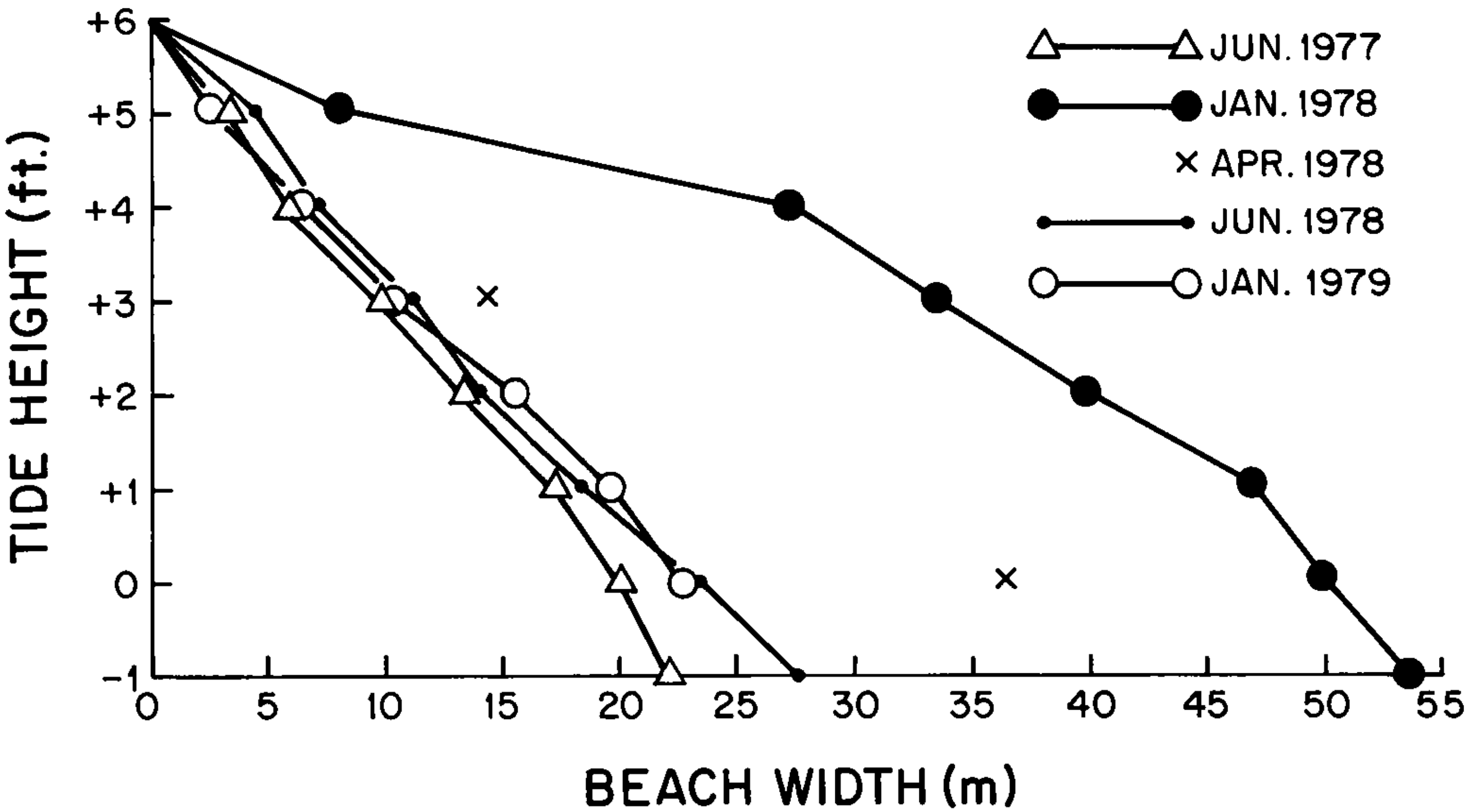

FIGURE 5 BEACH SLOPE, WEST BEACH (SAND)

TABLE 2

SEDIMENT COMPOSITION AT SAMPLING SITES. Values are percent of the sample in each size class of the Wentworth Scale: cobbles, 64-256 mm; pebbles, 4-64 mm; granules, 2-4 mm; sand 0.062-4 mm; silt, 0.004-0.062 mm. "First" is first year sample period, "second" is the second year.

		Spring					Summer					Fall					Winter				
		Cobble	Pebble	Gravel	Sand	Silt	Cobble	Pebble	Gravel	Sand	Silt	Cobble	Pebble	Gravel	Sand	Silt	Cobble	Pebble	Gravel	Sand	Silt
WEST BEACH (sand)																					
+6.0'	first	0	49	11	34	0	0	4	1	95	0	0	5	1	94	0	0	19	4	17	0
	second	0	75	3	21	0	0	52	6	41	0	0	72	4	25	0	0	60	4	36	0
+3.0'	first	0	57	11	28	0	0	64	6	30	0	0	76	6	18	0	0	24	5	70	0
	second	0	54	3	42	0	0	41	6	53	0	0	55	15	31	0	0	40	5	54	0
+0.0'	first	0	57	3	37	0	0	44	5	51	0	0	67	10	23	0	0	25	12	63	0
	second	0	5	2	93	0	0	1	0	99	0	0	49	11	40	0	0	17	4	79	0
-1.5 m	first	0	0	0	100	0	36	48	4	14	0	0	0	0	99	0	0	0	0	98	0
	second	0	0	0	99	0	0	0	0	99	0	0	1	0	99	0	0	0	0	99	0
-5.0 m	first	0	0	0	100	0	0	0	0	99	0	0	0	0	99	0	0	0	0	99	0
	second	0	0	0	99	0	0	0	0	99	1	0	0	0	99	0	0	0	0	99	2
-10.0 m	first	0	0	0	98	2	0	0	0	97	3	0	0	0	96	4	0	0	0	98	2
	second	0	0	0	97	3	0	0	0	95	4	0	0	0	96	4	0	0	0	97	3
PARTRIDGE POINT (cobble)																					
+6.0'	first	20	48	11	16	0	0	44	25	30	0	10	59	7	23	0	0	33	28	39	0
	second	0	99	0	1	0	0	36	58	6	0	15	17	7	62	0	73	19	2	6	0
+2.0'	first	0	68	6	22	0	30	37	7	26	0	24	50	6	19	0	0	71	7	22	0
	second	0	66	9	25	0	0	55	9	36	0	28	46	7	20	0	34	43	7	17	0
+0.0'	first	7	53	9	25	0	0	49	11	39	0	8	49	8	35	0	34	47	3	16	0
	second	0	50	13	37	0	6	48	6	40	0	45	35	4	15	0	37	42	5	16	0
-1.5 m	first	40	31	3	21	0	46	20	3	30	0	0	43	10	46	0	38	46	5	11	0
	second	28	20	10	41	0	0	42	11	45	0	0	85	2	13	0	35	31	7	26	0

(continued)

TABLE 2 (continued)

	Spring					Summer					Fall					Winter				
	Cobble	Pebble	Gravel	Sand	Silt	Cobble	Pebble	Gravel	Sand	Silt	Cobble	Pebble	Gravel	Sand	Silt	Cobble	Pebble	Gravel	Sand	Silt
-5.0 m first	0	46	15	36	0	0	58	11	30	0	0	58	18	24	0	0	57	12	31	0
second	0	56	9	35	0	0	48	11	41	0	0	32	11	56	0	0	60	15	24	0
-10.0 m first	0	33	12	51	0	0	31	10	57	1	0	31	15	53	1	0	37	14	47	1
second	0	34	10	55	1	0	34	14	49	3	0	36	16	46	1	0	34	15	48	2
EBEY'S LANDING (gravel)																				
+6.0' first	0	59	9	28	0	0	38	10	52	0	0	33	2	65	0	0	67	12	20	0
second	0	59	8	33	0	0	21	23	56	0	0	8	2	90	0	0	49	11	40	0
+3.0' first	0	57	15	23	0	0	79	11	11	0	0	55	10	35	0	0	70	11	19	0
second	0	52	20	28	0	0	46	20	33	0	0	53	16	30	0	0	61	9	30	0
0.0' first	0	75	6	16	0	0	62	11	26	0	0	82	3	15	0	0	73	10	17	0
second	0	81	5	13	0	29	45	10	16	0	0	65	16	18	0	0	54	8.5	37	0
-1.5 m first	13	72	4	5	0	33	53	5	9	0	0	63	7	28	0	21	19	3	8	0
second	14	63	5	18	0	43	47	4	7	0	24	71	2	3	0	0	74	6	20	0
-5.0 m first	0	30	18	48	0	0	3	28	67	0	0	20	8	72	0	0	35	13	50	0
second	0	45	10	44	0	0	24	11	63	0	0	3	5	89	1	0	22	11	64	3
-10.0 m first	0	20	25	51	0	1	28	13	57	1	0	46	12	51	1	0	49	8	41	1
second	0	14	22	63	1	0	46	13	39	1	0	21	16	61	1	0	36	15	48	0

TABLE 3

SURFACE TEMPERATURE (°C) AND SALINITY ($^{o}/oo$)

FOR SITES AT TIMES OF SAMPLING

		Spring		Summer		Fall		Winter	
		Temp.	Sal.	Temp.	Sal.	Temp.	Sal.	Temp.	Sal.
WEST BEACH (sand)									
Intertidal	77/78	9.0	29.8	13.5	29.1	9.0	33.7	7.0	32.1
	78/79	10.0	29.0	12.0	32.0	10.0	31.0	5.0	
Subtidal	77/78	8.5	30.7	12.5		8.5	32.3	8.0	30.4
	78/79	9.0	30.0	11.0	30.0	10.0	31.0	6.0	
PARTRIDGE POINT (cobble)									
Intertidal	77/78	9.0	30.4	13.5	30.1	9.0	31.2	7.0	31.6
	78/79	11.0	34.0	8.5	30.0	10.0	32.0	6.0	
Subtidal	77/78	9.0	30.7	12.0		8.0	32.1	7.0	32.7
	78/79	10.0	29.0	12.0	31.0	9.0	30.0	6.0	
EBEY'S LANDING (gravel)									
Intertidal	77/78	9.0	30.4	13.0	31.1	9.0	33.1	7.0	32.1
	78/79	11.0	32.0	11.0	31.0	9.0	31.0	5.0	
Subtidal	77/78	8.5	31.0	12.0		9.0	31.4	8.0	30.4
	78/79	10.0	31.0	12.0	32.0	9.0	33.0	6.0	

band is presented at the high tide area. Beach slope (Fig. 6) is relatively gradual, intermediate to that of the sand and gravel habitats. The beach width between the +6' and -1' tide heights was 38 m. Slope through the two years was relatively constant indicating little or no accumulation of sediment. In the mid to upper tide zone the cobbles were bare. In the lower tidal area, however, cobbles were covered by algae. Data on algae cover through the two years at the cobble habitat are given in Table 4. Cover was most dense at the 0' and -1' strata. Little algae was found above the +3' stratum. Algae cover was greater in summer than in winter. Beneath the cobble layer the sediments were relatively fine. Data on sediment composition are given in Table 2.

Subtidally the habitat at Partridge Point resembled the intertidal habitat. The -1.5 m stratum was composed of cobbles (20-25 cm in diameter) with a pebble sand matrix between. Algae were common on the cobbles, indicating the cobbles were relatively stable. In most areas Laminaria formed an overstory with red algae as common understory species. Patches of the eel grass Phyllospadix were also common at that depth.

The -2.5 m stratum was similar to the -1.5 m stratum with the exception that soft tubed polychaetes in the fines between the cobble indicated little movement of the sediment by wave action. From -2.5 to -5.0 m pebble and sand began to predominate over cobbles. Nereocystis became more abundant in this area. From -5 m to -10 m depth a sand/pebble/silt substrate predominated (Table 2).

Surface temperature and salinity values for Partridge Point are given in Table 3. Temperature ranged from 7.0 to 13.0°C through the year. Salinity ranged from 30.1 to 32.7 $^{o}/oo$.

Gravel Habitat, Ebey's Landing

The location of the sample site at Ebey's Landing is shown in Fig. 1. A detailed diagram of the site is given in Fig. 4. This gravel habitat is located in a littoral drift transport area. The dominant visual feature of the intertidal zone is gravel and patches of coarse sand. In the shallow subtidal area occasional patches of Nereocystis can be seen in summer and fall. The site is located in an area that is rip-rapped above the +8.0' tide height to protect the roadway from wave action. North and south of the road area the bank is stable and covered with vegetation. Beach slope at the gravel site (Fig. 7) is steeper than at the sand or cobble habitats. This is characteristic of beaches where there is little erosion of backshore cliffs or accumulations of littoral drift material. Beach slope changed with season. The width of the beach from the +6' to -1' tidemarks ranged from 26 m in January 1978 to 16 m in June and July 1979. Apparently there was an accumulation of sediment in winter months. Sediment material in the intertidal area was mostly gravel (Table 2). There was little change in composition of sediment with tide height or season. During the summer sample period, a layer of cobbles was observed at the -1' stratum. These cobbles provided a substrata for the algae Enteromorpha linza.

TABLE 4

PARTRIDGE POINT ALGAE COVER (in percent). Strata are tide height in feet. Each value is the mean of eight observations of 0.25 m^2 areas. - indicates no observation was made.

	Spring		Summer		Fall		Winter	
	77/78	78/79	77/78	78/79	77/78	78/79	77/78	78/79
+6.0	0	1	0	0	0	0	0	0
+5.0	-	-	0	3	-	-	0	0
+4.0	-	-	0	3	-	-	3	0
+3.0	-	-	0	7	-	-	1	0
+2.0	4	8	1	20	4	5	1	2
+1.0	-	-	18	22	-	-	2	5
0.0	67	62	76	89	68	22	5	7
-1.0	-	-	87	99	-	-	32	37

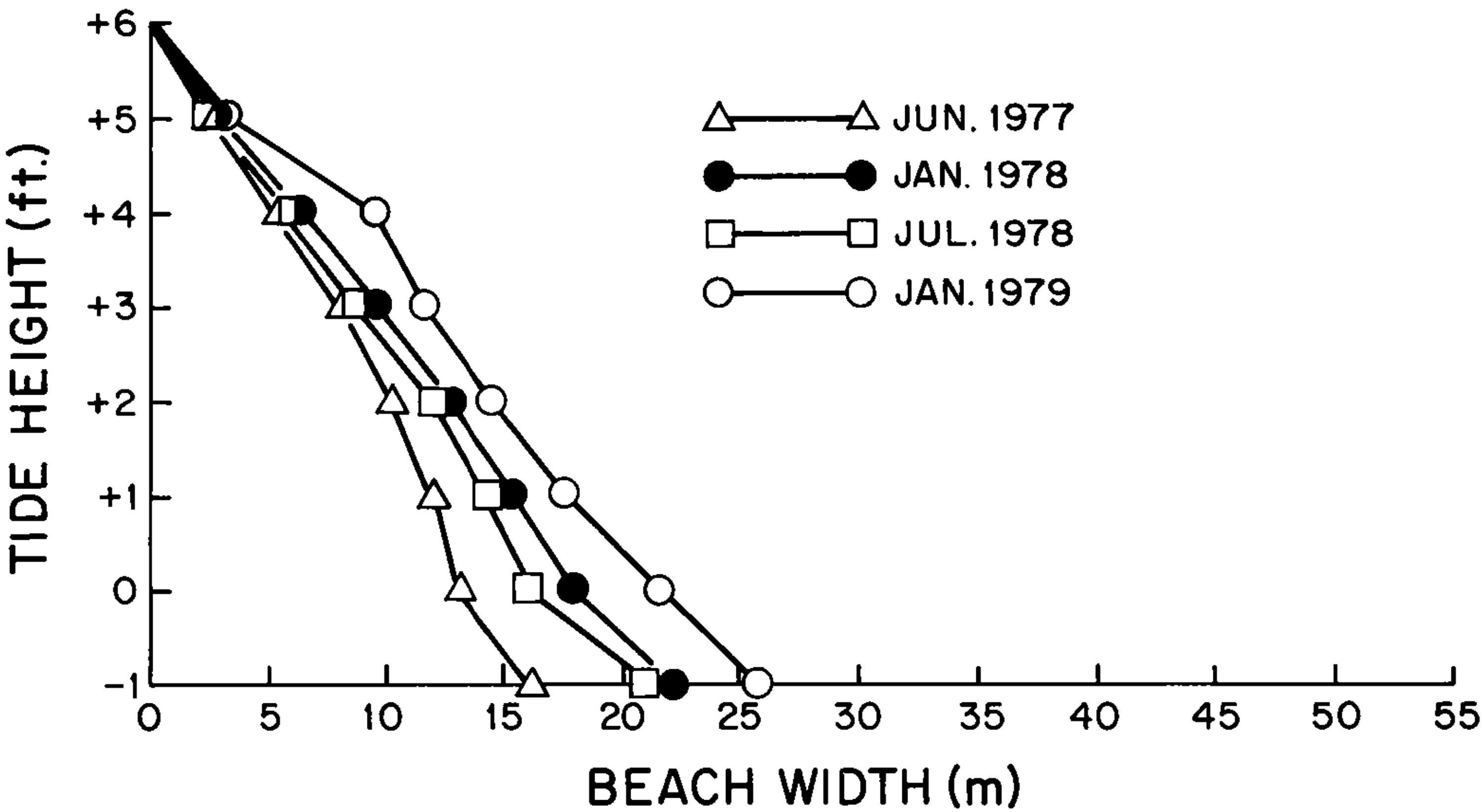

Figure 6 Beach slope, Partridge Point (cobble)

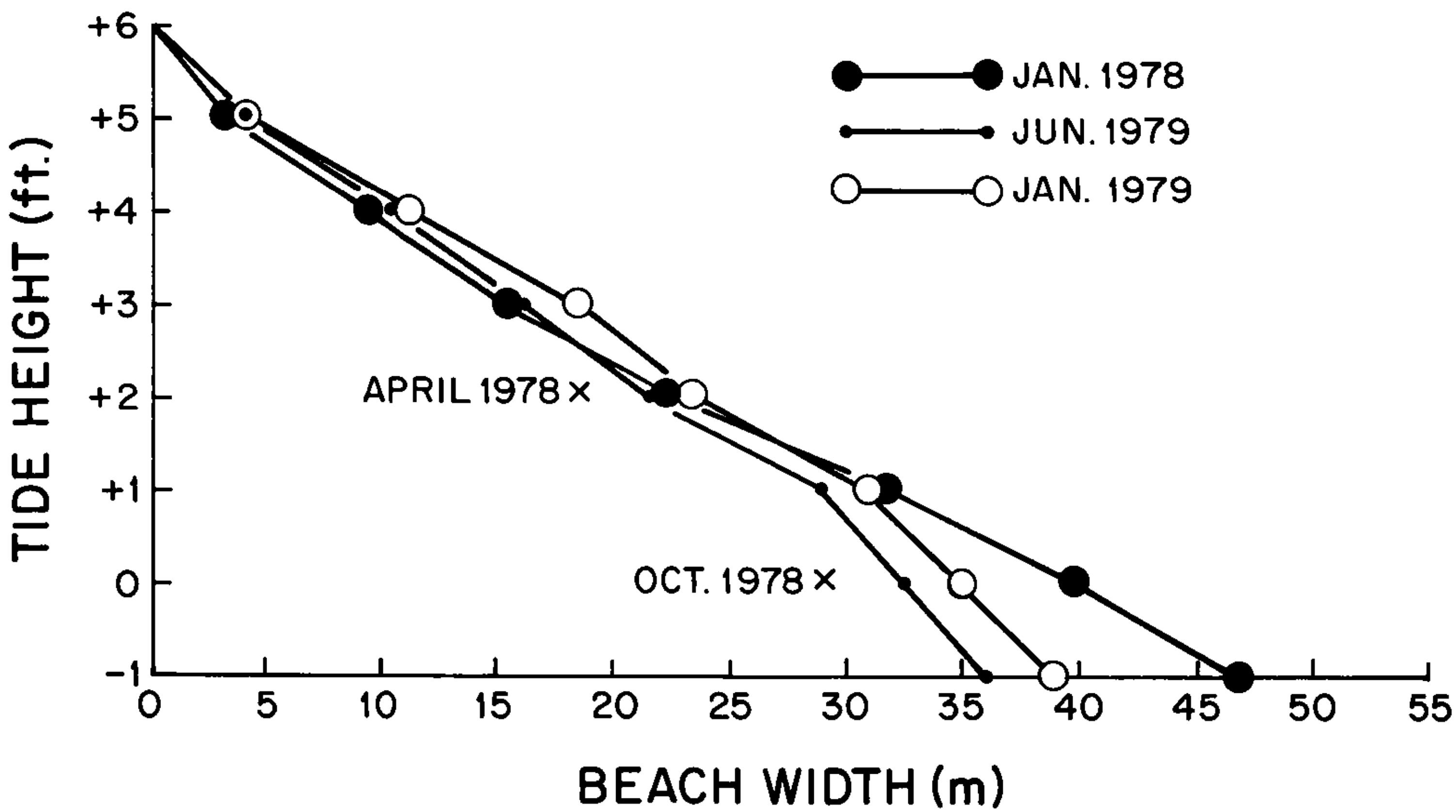

FIGURE 7 BEACH SLOPE, EBEY'S LANDING (GRAVEL)

Subtidally the habitat at Ebey's Landing changed considerably from the gravel of the intertidal area (Table 2). At -1.5 m stratum cobbles of approximately 20 cm in size covered approximately 90% of the surface. In the sample area observation indicated that wave action moved the cobbles. The only organisms observed were filamentous diatoms. Approximately 50 m to the north of the sample site, more stable cobbles with up to ten species of red and brown algae were observed, indicating more stable cobble conditions in that area. At the -2.5 m stratum conditions were similar to the -1.5 m stratum. At the -5.0 m stratum the cobble bottom began to give way to sandy and gravel patches that had dense patches of the eelgrass Zostera marina. Algae growth on cobbles indicated that wave action did not turn over cobbles at this depth. From the -5 to -10 m strata the bottom was almost totally sand and gravel (Table 2). Clam shells and worm castings indicated a stable infauna.

Surface temperature and salinity values for Ebey's Landing are given in Table 3. Temperature ranged from 7.0 to 9.0° through the year. Salinity ranged from 30.4 to 32.1 $^{o}/oo$.

SPECIES RICHNESS

The following discussion of species richness, abundance, and biomass evaluate data from a number of collection methods that have been combined to represent all organisms 1 mm in size and larger from a $0.25m^2$ by 15 cm deep volume. Appendix 1 gives the values of mean number and mean wet weight for each species found at each stratum, season, site, and year. Included in Appendix 1 are standard deviations, total number of individuals, total biomass, and species diversity indices.

Data from a collection method that was not included in the recombination (0.25 cm^2 by 30 cm deep, 0.5 inch mesh size live sieve) are treated separately.

Species Richness, Sites Combined

A total of 990 species were collected from the three sites during the study period--641 in the first year and 735 in the second. The similarity index for the two years was 66.1% (Table 5), indicating that approximately two-thirds of the species were found in both years.

Species Richness by Site

The cobble site (Partridge Point) had the highest species richness (Table 5) of the three sites (770 species) followed by the gravel site (Ebey's Landing, 612 species) and the sand site (West Beach, 336 species). The number of species in each of the two years collected at each site was less than the total and was relatively constant (Table 5). Similarity indices for each site for the two years were: West Beach, 58%; Partridge Point, 60%; and Ebey's Landing, 59%. That is, at each site approximately 60% of species were found in both years while 40% occurred in only one of the two years.

When intertidal and subtidal species richness between sites is examined (Table 5) the differences between sites are more pronounced. The cobble site

TABLE 5

SUMMARY OF SPECIES RICHNESS AND SIMILARITY INDEX VALUES

A. Sites combined. B. By sites. C. Intertidal only, subtidal only, and those species at both intertidal and subtidal areas of each site. D. Similarity between sites.

A. Total Species all Sites

first year	641
second year	735
both years	990
number of species common between years	455

Similarity between years = 66.1%

B. Total Species by Sites

	both	first	second	common
West Beach	336	249	223	136
Partridge Point	770	522	533	335
Ebey's Landing	612	425	444	257

Similarity between sites first and second year:

West Beach	57.6%
Partridge Point	60.1
Ebey's Landing	59.1

C. Intertidal and Subtidal Species by Site

	First year		both	Second year		both
	Int. only	Sub. only	I & S	Int. only	Sub. only	I & S
West Beach	31	183	35	29	155	39
Partridge Point	121	213	188	104	231	248
Ebey's Landing	23	362	40	22	352	71

Similarity between intertidal and subtidal regions:

	First year	Second year
West Beach	24.6	29.8
Partridge Point	52.9	59.7
Ebey's Landing	17.2	27.5

(continued)

TABLE 5 (continued)

D. Similarity Between Sites

1. West Beach - Partridge Point

	First	Second
Intertidal only	18.1	19.5
Subtidal only	38.4	36.8
Both	35.5	37.5

2. West Beach - Ebey's Landing

	First	Second
Intertidal only	37.2	32.3
Subtidal only	40.6	38.6
Both	40.6	42

3. Ebey's Landing - Partridge Point

	First	Second
Intertidal only	21.0	22.4
Subtidal only	61.0	70.9
Both	57.2	65.4

(Partridge Point) had a relatively higher similarity (approximately 53-59%) between intertidal and subtidal species richness than the sand and gravel sites (17-30%). Also, the intertidal species richness at the sand and gravel sites was lower than the cobble site. The intertidal flora and fauna at the cobble site was richer than the sand and gravel site and was more similar to the subtidal species richness.

The intertidal flora and fauna of the sand, cobble, and gravel sites were not very similar (Table 5). Values ranged from 18 to 37%, the lowest being the similarity between West Beach and Partridge Point and the highest between West Beach and Ebey's Landing.

At subtidal areas, the gravel and cobble sites (Table 5) had relatively high similarity (61-71%) while the similarity between gravel and sand (38-40%) and cobble and sand (37-38%) were relatively low.

The picture that emerges is that the gravel and sand sites have distinct intertidal and subtidal flora and fauna that were not very similar, that the cobble site had a more similar intertidal and subtidal flora and fauna, and that the subtidal regions of the cobble and gravel site were relatively similar.

Species Richness by Strata

The relatively low species richness of the intertidal areas of the sand and gravel sites is reflected in the graphs of number of species at each stratum (Figs. 8 to 10). At West Beach and Ebey's Landing the total number of species collected at each stratum was generally less than 20, with the value for each year lower than the total (Figs. 8 and 10).

At the cobble site, there was a relatively higher species richness at all strata except the +6.0' and +5.0' heights (Fig. 9). Species richness at the cobble site increased with decrease in tide height to a value of 200 species at the -1.0' height. In general, at all sites there were more species collected the second year than the first, although it is not clear if the differences were significant.

At subtidal strata the species richness at these three sites each showed a different pattern. At the cobble site species richness decreased at the -1.5 m stratum and, although gradually increased with increasing depth, at -10.0 m it was still lower than species richness at the -1.0' stratum. At the gravel site species richness increased rapidly with depth from the -1.5 m to -10 m strata. Species richness at the cobble and gravel sites were relatively similar from the -1.5 m to -10 m strata. This similarity corresponds to the index of similarity for the two habitats at subtidal strata (65%, Table 5). The sand habitat showed yet another pattern at subtidal strata. At the -1.5 m and -2.5 strata species richness was relatively low at approximately 15 species per stratum. At the -5.0 m stratum species richness increased to 45 species and continued to increase through the -10 m stratum. However, species richness at these depths at the sand habitat was lower than the gravel and cobble habitats. The reason for the relatively low species richness at the -1.5 m and -2.5 m strata of the sand habitat was probably the unstable nature

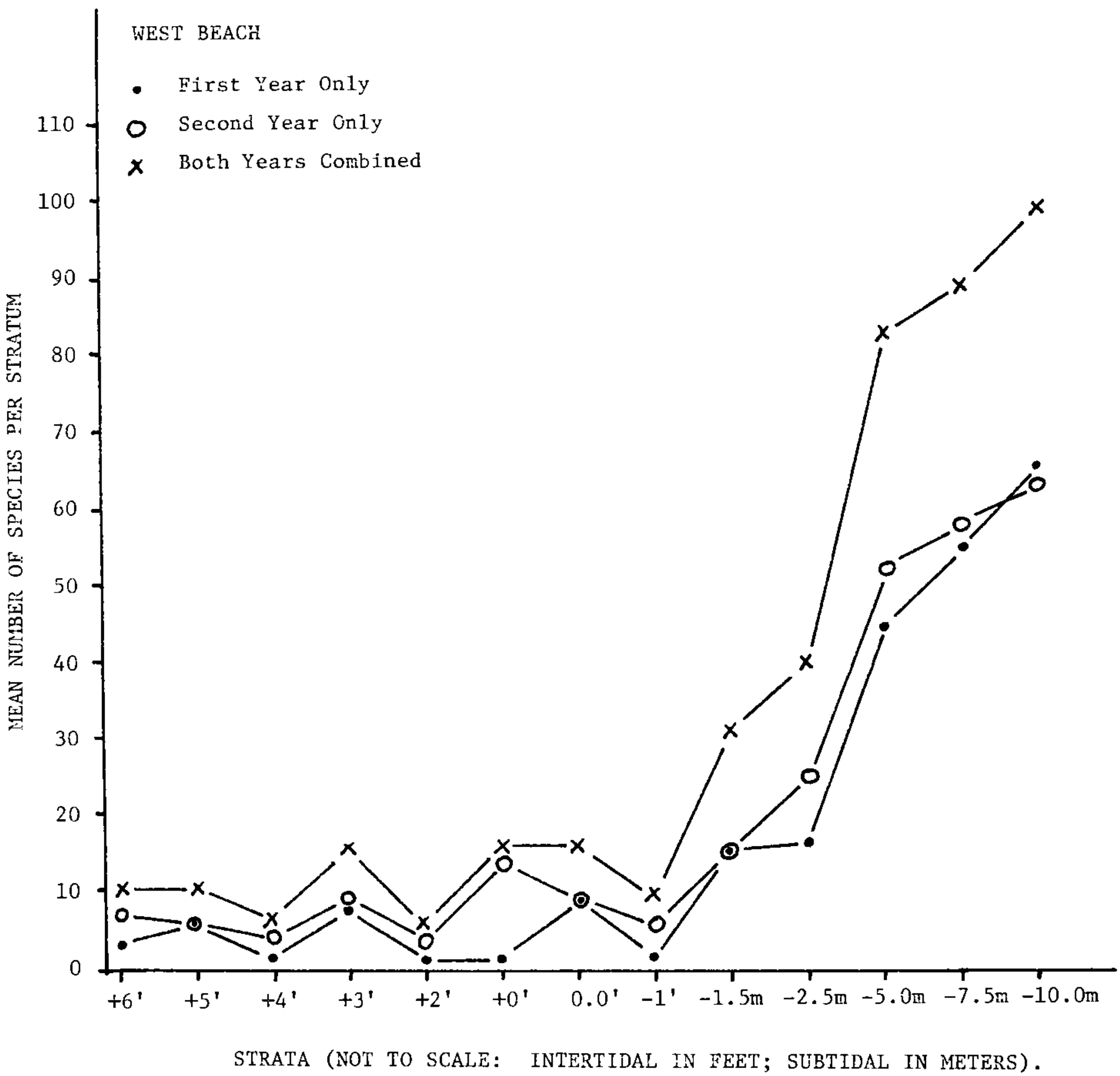

FIGURE 8 MEAN NUMBER OF SPECIES PER STRATUM, WEST BEACH

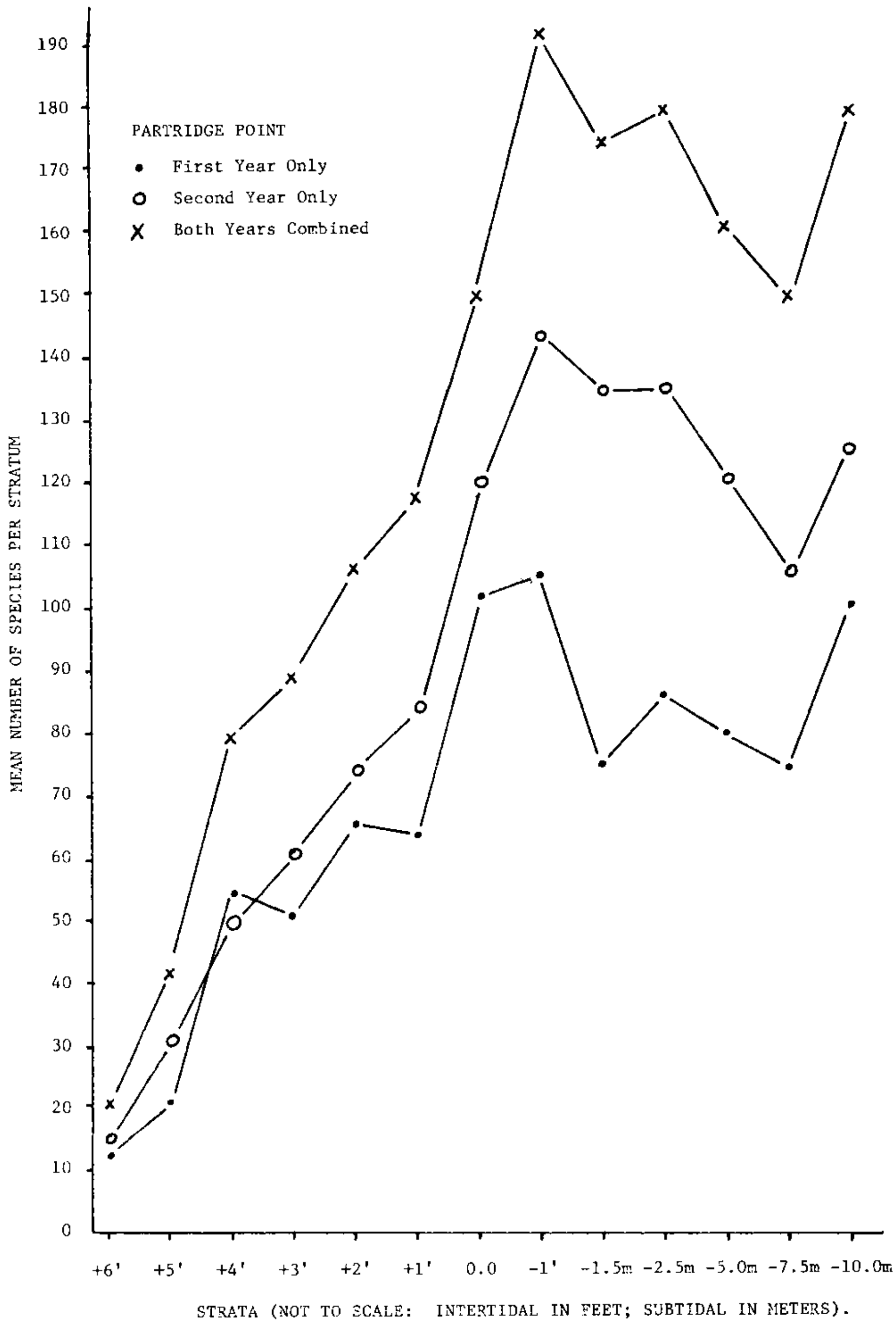

FIGURE 9 MEAN NUMBER OF SPECIES PER STRATUM, PARTRIDGE POINT

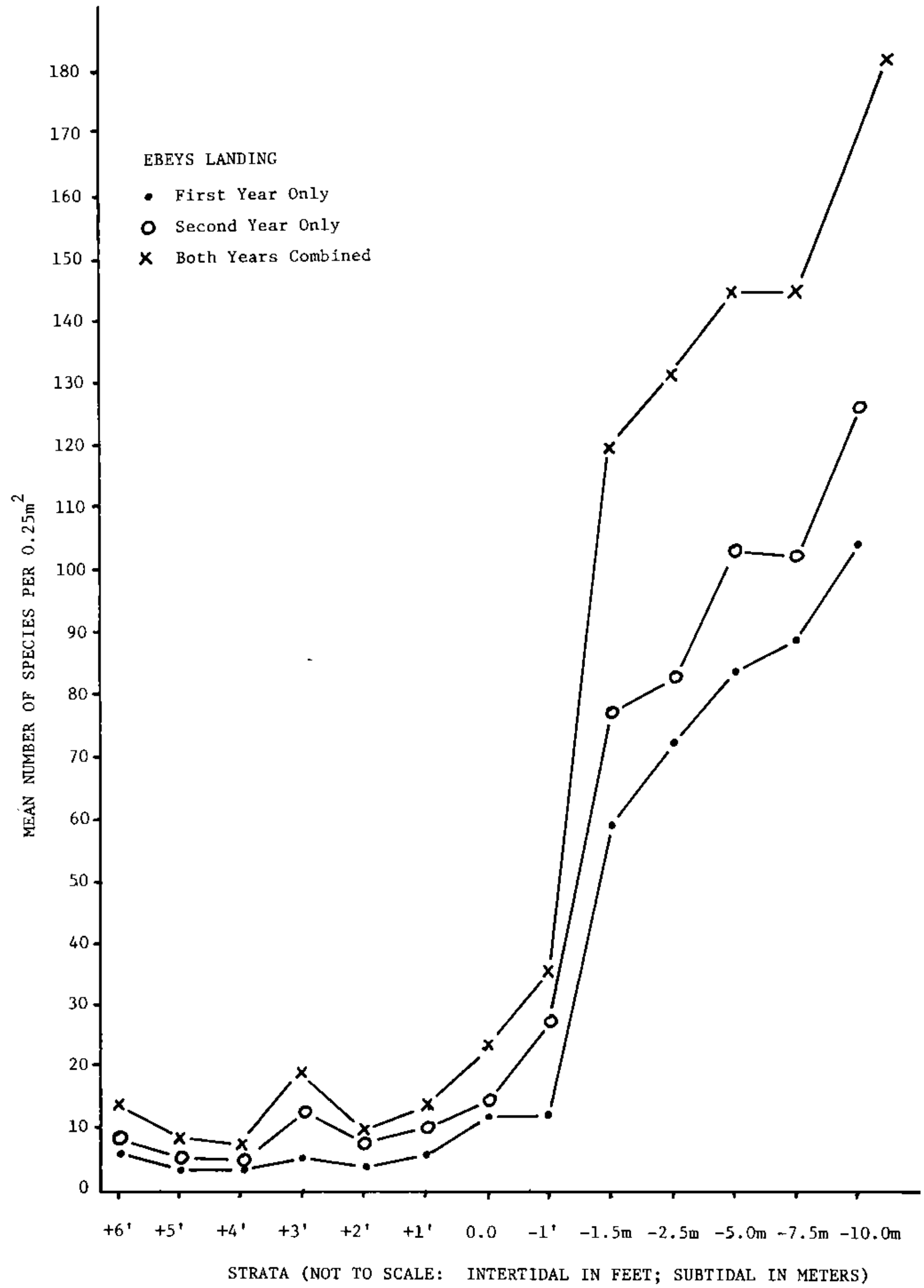

FIGURE 10 MEAN NUMBER OF SPECIES PER STRATUM, EBEY'S LANDING

of the substrate. These strata were inside the offshore bar and were probably subjected to relatively high movements of the substrate. Also, Fig. 5 indicates that the shallow subtidal strata also showed a seasonal shift in substrate.

In general, there were more species collected at both intertidal and subtidal areas in the second year than the first, although at each site the pattern of distribution of species richness with depth was similar in the two years of study.

Species Richness by Season

Table 6 gives the number of species collected at intertidal strata for each site for each of the four seasons. For the gravel and sand habitats species richness in summer and fall sample periods was higher than spring or winter. At the cobble habitat species richness was greatest in the summer.

Species richness at subtidal strata (Table 6) also showed variation with season through the two years of study. For the sand habitat species richness varied from 67 to 116 species; for the gravel habitat from 151 to 259 species, and for the cobble habitat from 161 to 264 species. However, there was no consistent pattern of variation with season at any of the habitats.

Species Richness by Taxonomic Groups

Approximately 90% of species collected in the study belong to one or another of twelve taxonomic groups (Table 7) including three groups of algae and nine groups of animals. The total number of species of each taxonomic group for the study is given in Table 7. The dominant taxonomic group was the polychaete worms with 250 species collected. In successive order of dominance followed the red algae, amphipods, gastropods, and bivalves. For the polychaetes the gravel habitat had the highest representation with approximately 73% of the total polychaete species collected. The cobble habitat had approximately 69% while the sand habitat had approximately 49%. For other taxonomic groups, however, the highest representation was generally at the cobble habitat, followed by the gravel, then sand habitat. In all taxonomic groups the sand habitat had the lowest representation.

The representation of taxonomic groups in the intertidal and subtidal portions of each habitat are also given in Table 7. At the gravel site all taxonomic groups had richer representation at subtidal than at intertidal strata.

At the cobble site some taxonomic groups had more intertidal species than subtidal. Green algae, barnacles, and echinoderms all had more species intertidally than subtidally. The remaining taxonomic groups at the cobble habitat had greater subtidal representation.

TABLE 6

SPECIES RICHNESS BY SEASON ALL SITES

For fall and spring all strata were combined and means taken. For summer and winter only those strata that corresponded to fall and spring were summed. Int - intertidal, Sub - subtidal, 1st - first year samples, 2nd - second year samples.

		Spring		Summer		Fall		Winter	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
WB	Int	21	19	21	27	24	25	17	33
	Sub	113	83	67	98	108	116	95	83
P.P.	Int	112	148	185	233	143	101	161	182
	Sub	161	211	212	264	162	253	179	255
EL	Int	19	23	24	63	34	25	19	22
	Sub	157	197	187	259	190	226	207	189

TABLE 7

SPECIES RICHNESS IN MAJOR TAXONOMIC GROUPS

(Seasons and Strata Combined)

	Total number of species - both years			Total number of species, first and second years						Total number of intertidal species - first and second years					
	Total number of species collected	Total first year	Total second year	West Beach first year	West Beach second year	Partridge Point first year	Partridge Point second year	Ebey's Landing first year	Ebey's Landing second year	West Beach first year	West Beach second year	Partridge Point first year	Partridge Point second year	Ebey's Landing first year	Ebey's Landing second year
Green algae	23	19	14	4	3	12	9	9	9	0	0	10	9	8	0
Brown algae	28	20	24	0	1	14	21	12	16	0	1	8	16	0	0
Red algae	186	140	131	17	3	122	120	77	74	1	0	63	71	1	1
Polychaetes	250	172	188	86	90	132	145	123	122	17	23	60	93	20	38
Gastropods	70	45	56	12	11	36	45	24	26	4	3	23	30	3	5
Chitons	18	17	10	0	0	15	9	11	8	0	0	7	7	0	0
Bivalves	62	45	44	20	21	28	31	26	26	1	3	10	12	0	2
Barnacles	8	7	6	0	1	5	6	4	3	0	1	5	4	0	1
Isopods	39	29	27	10	7	17	21	18	17	3	2	14	11	5	5
Amphipods	98	64	75	40	32	47	60	40	50	13	11	26	29	9	14
Decapods	51	38	37	14	14	27	29	25	25	4	3	11	18	6	5
Echinoderms	18	13	12	5	6	7	10	9	6	0	1	6	6	1	0

(continued)

TABLE 7 (continued)

	Total number of subtidal species - first and second year					
	West Beach first year	West Beach second year	Partridge Point first year	Partridge Point second year	Ebey's Landing first year	Ebey's Landing second year
Green algae	4	3	5	3	9	6
Brown algae	0	1	11	16	12	16
Red algae	16	3	100	106	76	74
Polychaetes	60	80	79	122	90	114
Gastropods	9	10	24	25	24	25
Chitons	0	0	12	8	11	8
Bivalves	20	20	26	30	26	25
Barnacles	0	0	3	3	4	3
Isopods	9	6	10	17	16	17
Amphipods	32	28	41	52	37	48
Decapods	13	13	22	22	21	25
Echinoderms	5	6	4	8	9	6

NUMBERS OF INDIVIDUALS AND BIOMASS

The patterns of distribution of numbers of species with site, strata, and season have been examined above. To determine if total numbers of individuals and biomass (wet weight) followed a similar pattern, the mean number of individuals and the mean biomass per $0.25m^2$ for each stratum and site were plotted (Figs. 11 to 14). In this analysis keep in mind that algae are represented only by biomass, animals by numbers of individuals and biomass.

Numbers of Individuals

Figs. 11 and 12 show that in the intertidal area there was a large variability in numbers of individuals per $0.25m^2$ at all sites and seasons. The cobble and gravel sites were more similar, particularly at lower tide heights. The sand habitat had relatively low numbers of individuals throughout the intertidal zone. These patterns corresponded reasonably well with those of the distribution of species with tide height (Figs. 7-10).

A number of features of the curves in Figs. 11 and 12 bear mention. The greatest number of individuals per $0.25m^2$ were observed at the gravel habitat (Ebey's Landing). At intertidal strata the large values (Fig. 12) were caused almost entirely by the amphipod *Paramoera mohri*. This species tended to be clumped in narrow bands through the lower intertidal area. In the first year the peak of abundance was at the 0.0' tide height; in the second year it was at the +1.0' tide height. It is interesting to note that if sampling were conducted only at the +3.0' and 0.0' tide heights, the small peaks at the +4.0' and +5.0' heights in both years and the larger peak noted in the second year would have been entirely missed.

The peak in abundance at the -2.5 m height (Fig. 12) was due almost entirely to the amphipod *Ischyroceros* sp. This species did not occur at all in the first year at this depth although it was found at relatively low densities at the -5.0 m and -1.5 m depths.

At the cobble site, the greater number of individuals per stratum (Fig. 11) generally reflected the greater species richness observed (Fig. 9). Two points from Fig. 11 bear mention. In the second year at the +2.0' and +1.0' tide heights there are peaks not observed in the first year. The bulk of the density at these two strata were due to the polychaete worm (*Protodorvillea gracilis*) and to Oligochaetes. At the -1.5 m and -2.5 m strata (Fig. 11) second year values were also considerably greater than first year values. These peaks were due to higher densities of Oligochaetes and the gastropod *Lacuna variegata*.

The curves of densities for West Beach (Fig. 11) show uniform low values through the intertidal areas, increasing with depth subtidally. The difference between first and second year values at the -10.0 m stratum was due primarily to reduced numbers of the bivalve *Psephidia lordi* and the phoxocephalid amphipods in the second year.

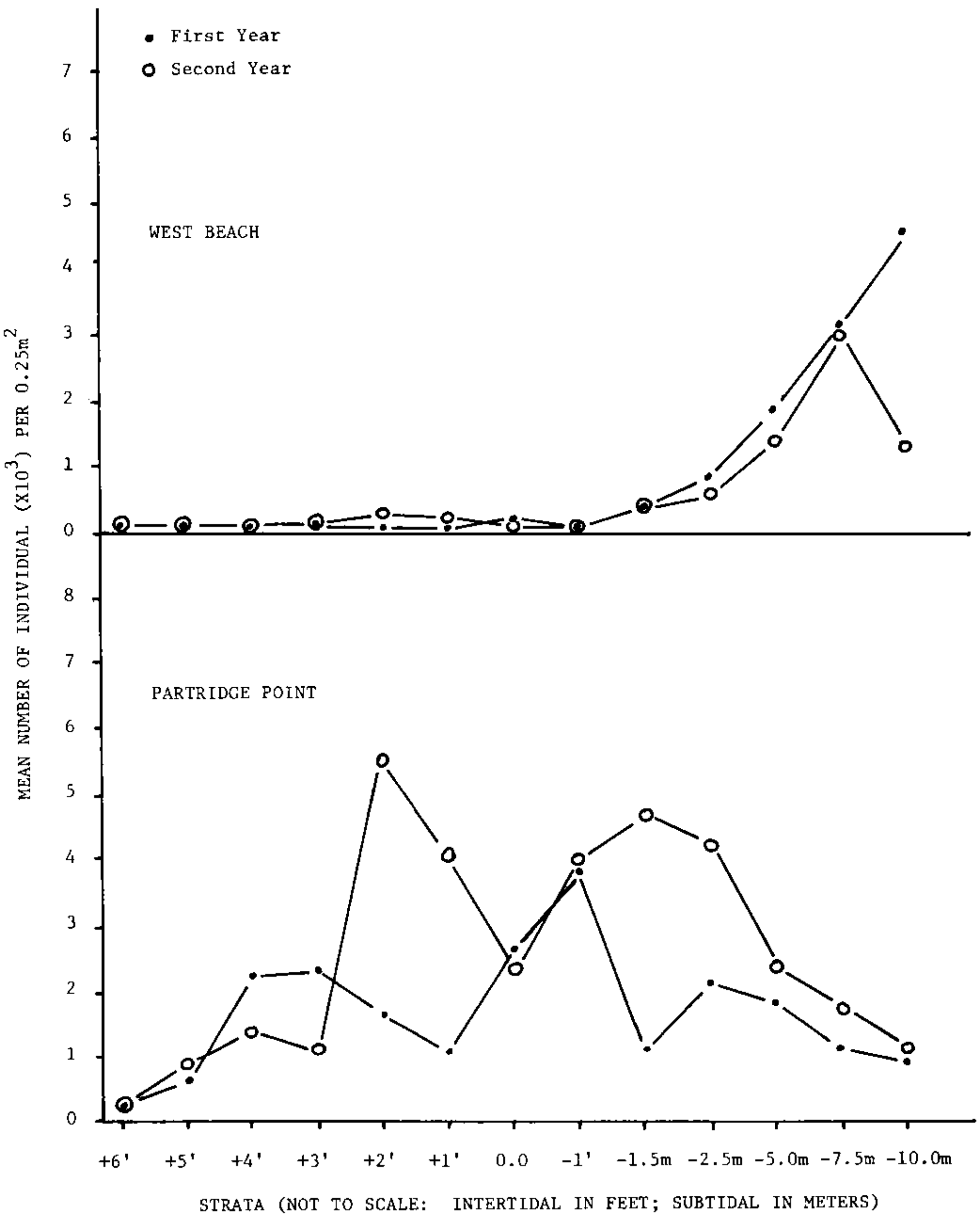

FIGURE 12 MEAN NUMBER OF INDIVIDUALS PER 0.25 M^2, EBEY'S LANDING

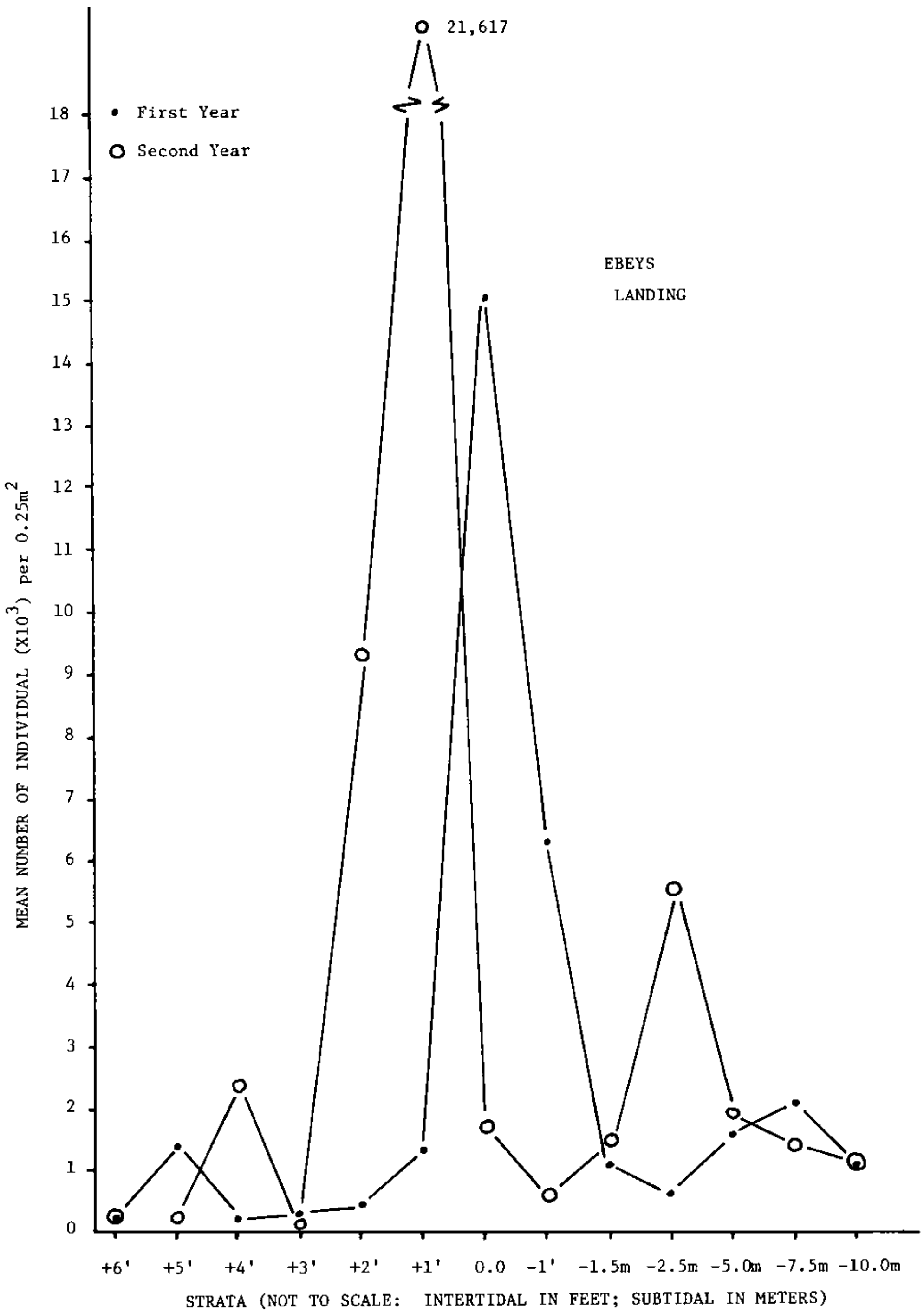

FIGURE 11 MEAN NUMBER OF INDIVIDUALS PER 0.25 M^2, WEST BEACH AND PARTRIDGE POINT

Biomass

Figures 13 and 14 show the distribution of biomass for each stratum at the three sites. West Beach (Fig. 13) showed a uniformly low biomass through the intertidal strata. At the subtidal strata values were greater than at the intertidal strata (although they were lower than values for subtidal strata at the other sites). The curve of biomass with strata for West Beach (Fig. 13) corresponds well with graphs of species richness (Fig. 8) and numbers of individuals (Fig. 11).

At Ebey's Landing there was relatively low biomass at intertidal strata except for the +2.0' and +1.0' strata in the second year. The values were due almost entirely to the amphipod *Paramora mohri*. Subtidally at Ebey's Landing there were peaks of biomass at the -1.5 m and -2.5 m strata that were due primarily to algae, and at the -10.0 m stratum that were due to bivalves.

At Partridge Point, the curves of biomass with strata (Fig. 14) showed close agreement between the two years. The peaks in biomass at the 0.0', -1.0', -1.5 m, and -2.5 m strata were due primarily to algae.

CHANGE IN NUMBERS OF INDIVIDUALS AND BIOMASS WITH SEASON

The patterns of change in numbers of individuals and biomass per $0.25m^2$ with season at each site are shown in Figures 15 to 18. For all sites the summer generally had the greatest number of individuals with no clear differences between years. At Ebey's Landing (Fig. 16) the first year values appear much greater than the second. However, the data used to prepare the curve for the second year did not show values for the +1.0' and +2.0' strata.

Values of biomass with season (Figs. 17 and 18) did not correspond well with density. Also, there was no clear pattern of change of biomass with season. At West Beach (Fig. 17) there was no clear pattern with biomass and season. At Partridge Point, although density was greatest during summer, biomass was similar in spring, summer and fall.

At Ebey's Landing maximum biomass was in summer corresponding to maximum density.

DOMINANT SPECIES

Those species that comprised either 5% of the total number of individuals or 5% of the total biomass of a given stratum were defined as dominant species (see Methods). Dominant species are listed for each stratum in Appendix 1. A summary of the distribution of dominant species at the three sites is given in Table 8. For the intertidal regions of West Beach and Ebey's Landing (where species richness was relatively low, approximately 5-15 species) often every species was dominant. For the intertidal region of Partridge Point, and for the subtidal regions of all sites, the number of dominant species was around 10% of the total number of species.

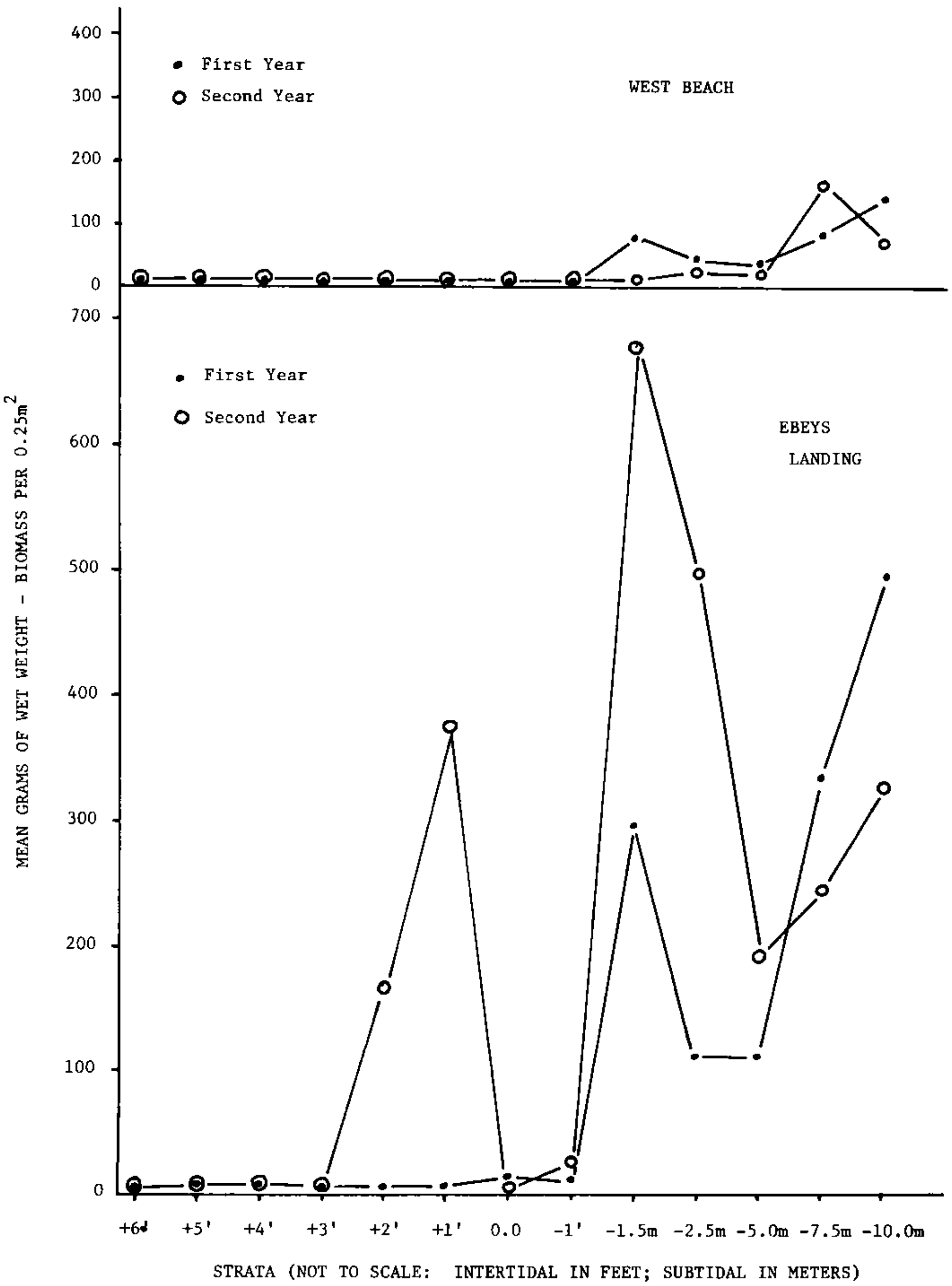

FIGURE 13 MEAN NET WEIGHT BIOMASS PER 0.25 M^2, WEST BEACH AND EBEY'S LANDING

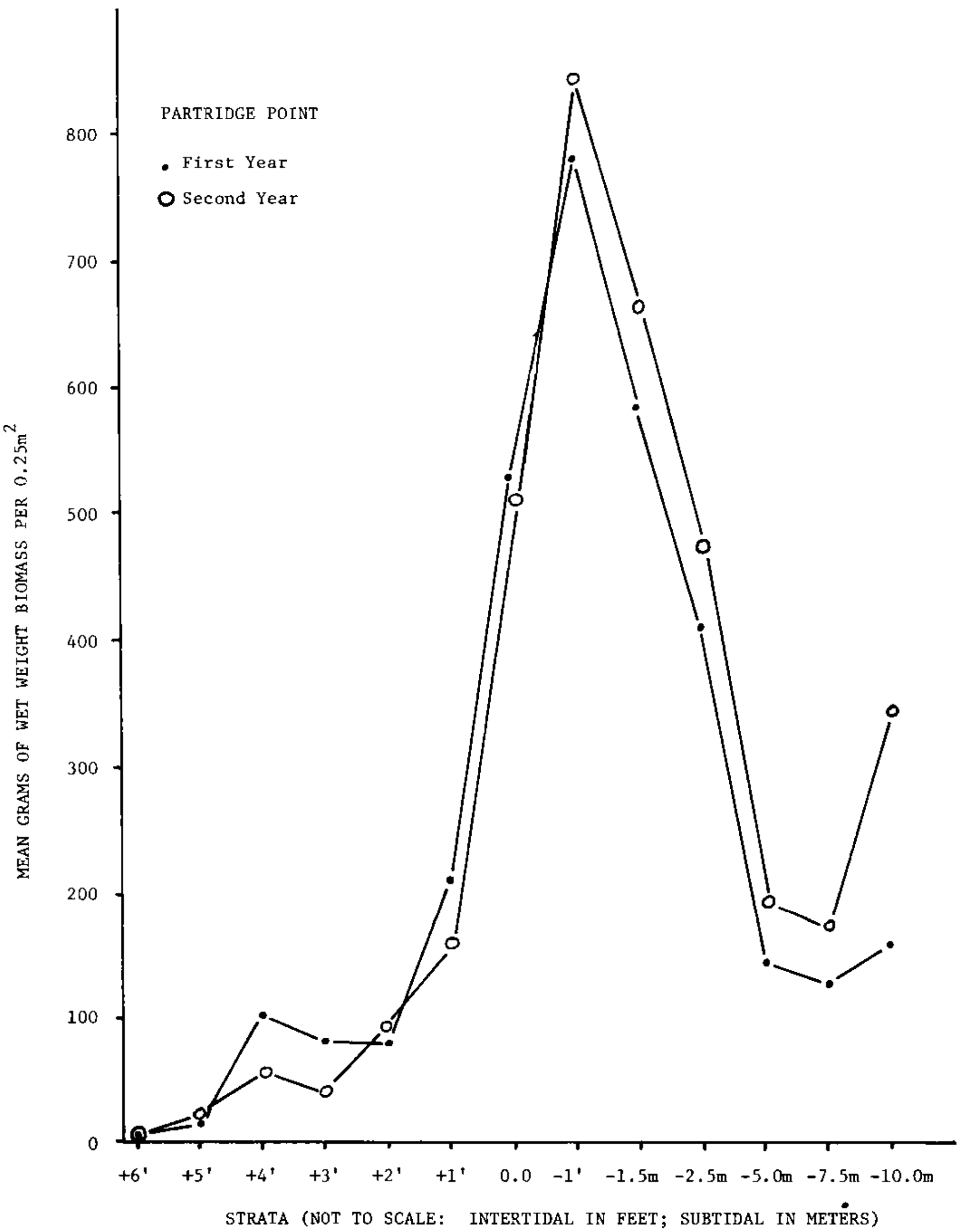

FIGURE 14 MEAN NET WEIGHT PER 0.25 M^2, PARTRIDGE POINT

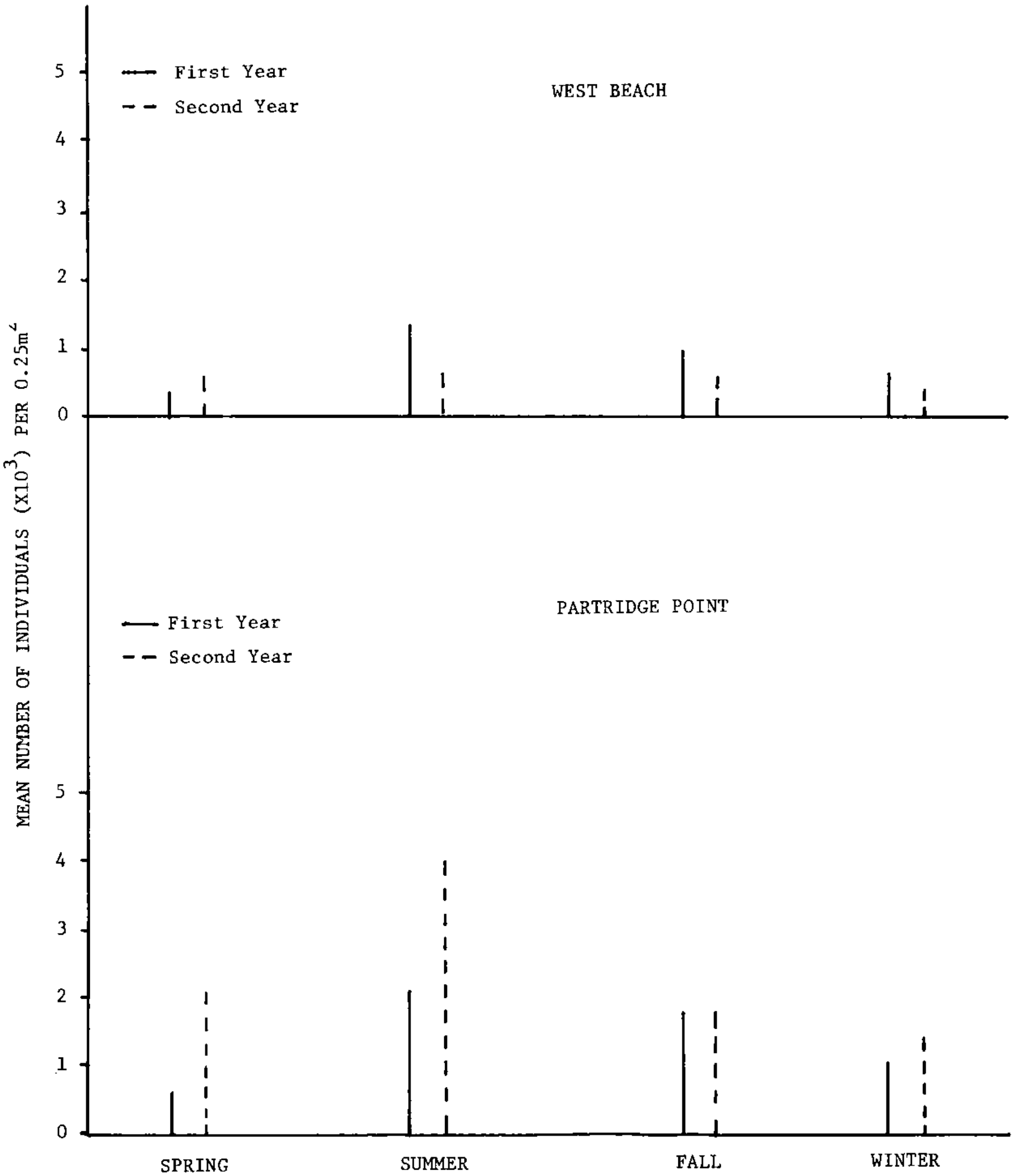

FIGURE 15 MEAN NUMBER OF INDIVIDUALS PER SEASON. WEST BEACH, PARTRIDGE POINT. FOR WEST BEACH, VALUES ARE MEANS OF +6.0', +3.0' AND +0.0' TIDE HEIGHTS. FOR PARTRIDGE POINT, VALUES ARE MEANS OF +6.0', +2.0', AND +0.0' TIDE HEIGHTS.

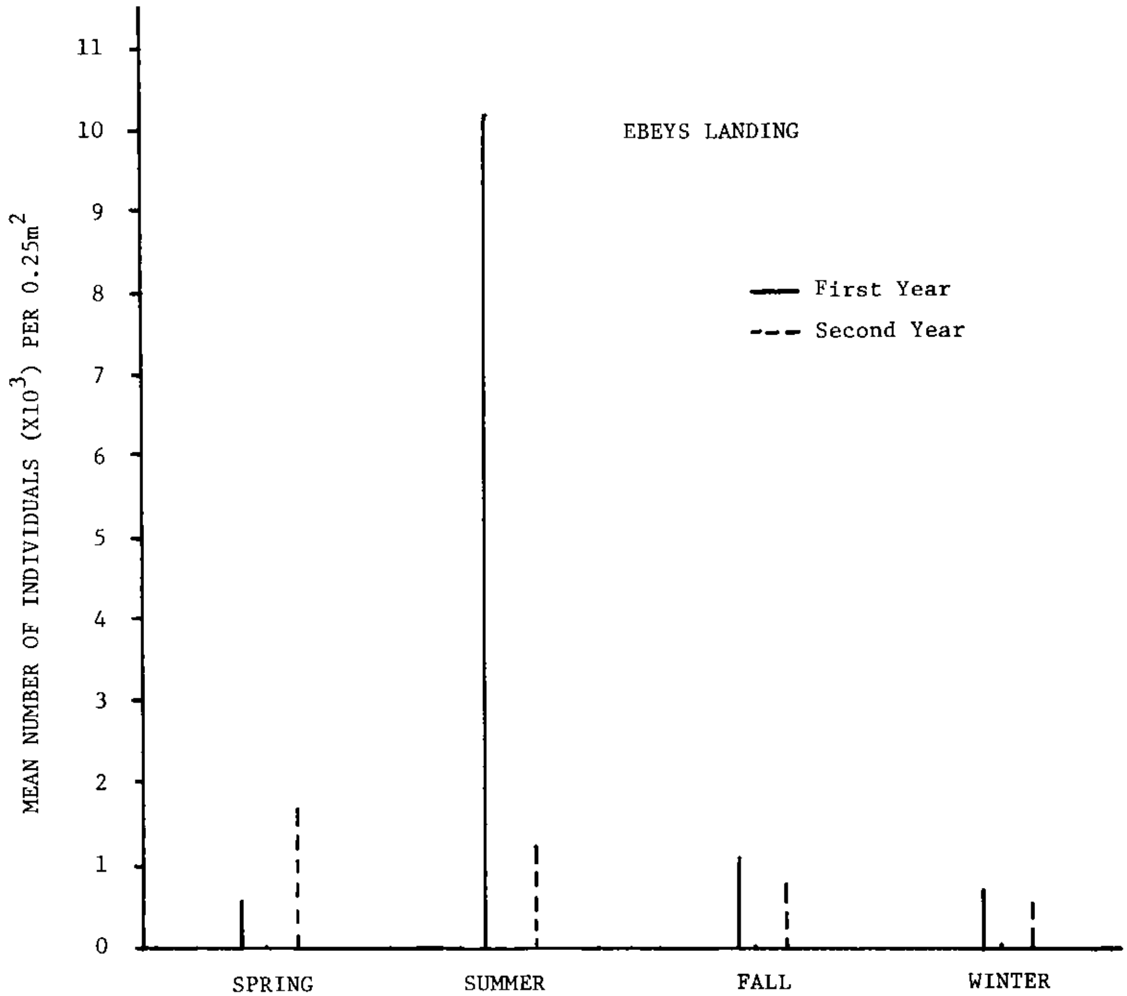

FIGURE 16 MEAN NUMBER OF INDIVIDUALS PER SEASON, EBEY'S LANDING. VALUES ARE MEANS OF +6.0', +3.0' AND +0.0' TIDE HEIGHTS.

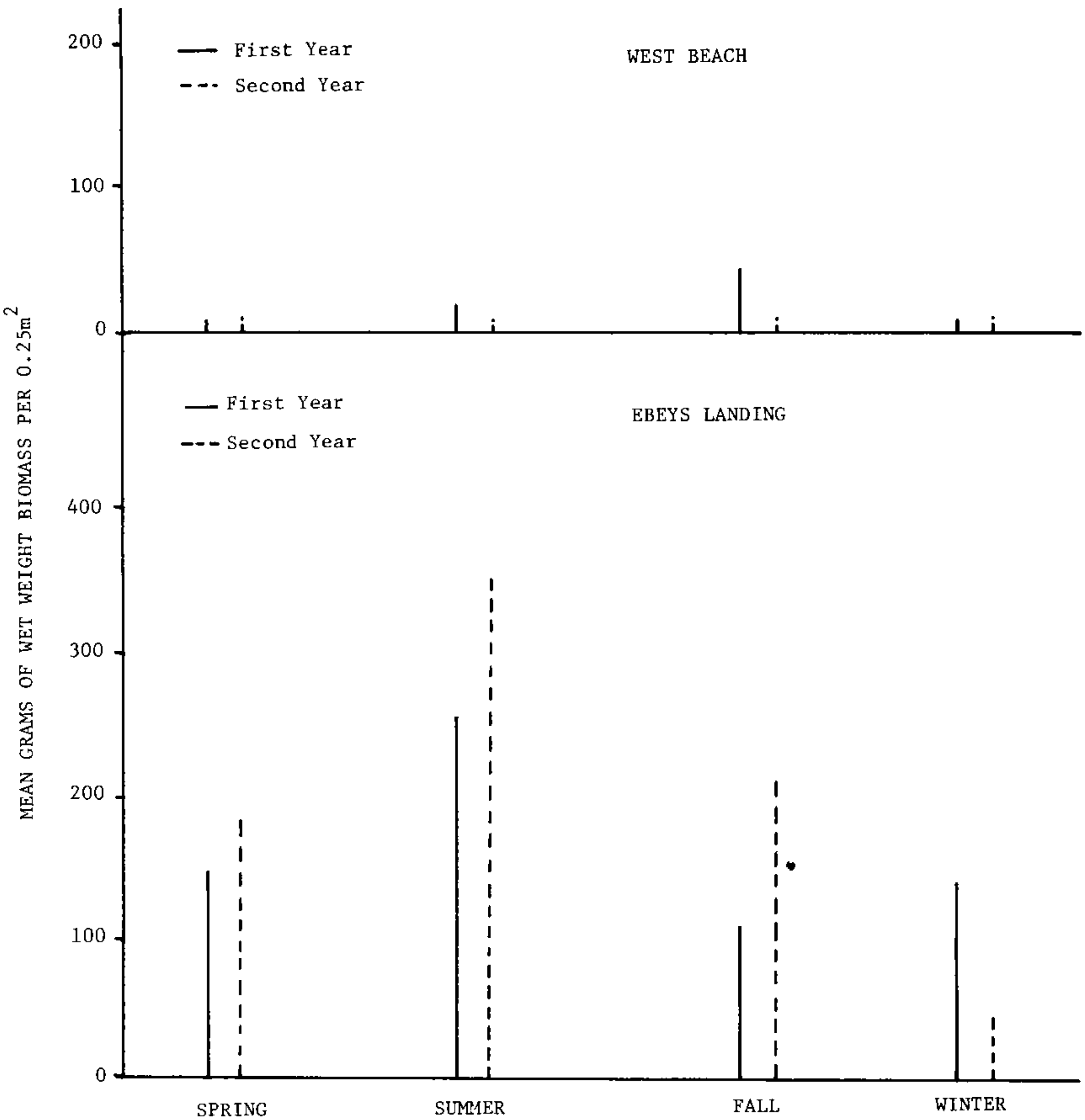

FIGURE 17 MEAN WET WEIGHT BIOMASS PER SEASON, WEST BEACH AND EBEY'S LANDING. VALUES ARE MEANS FROM +6.0', +3.0' AND +0.0' TIDE HEIGHTS

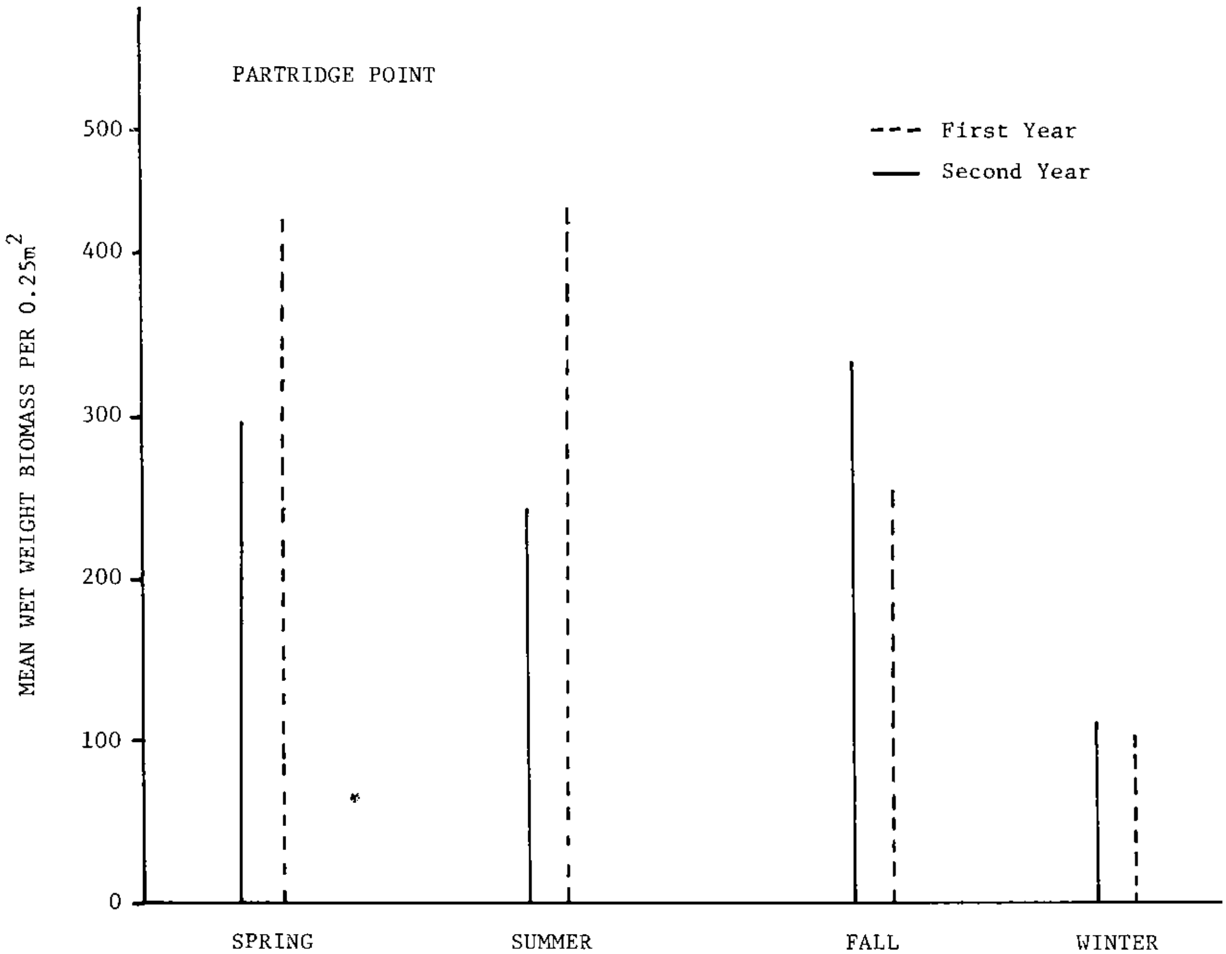

FIGURE 18 MEAN WET WEIGHT BIOMASS PER SEASON, PARTRIDGE POINT. VALUES ARE MEANS FROM +6.0', +2.0' AND +0.0' TIDE HEIGHTS

TABLE 8

SUMMARY OF DISTRIBUTION OF DOMINANT SPECIES IN SUMMER AND WINTER SAMPLE PERIODS

For each site and stratum, the total number of species collected in both years, the total number of dominant species in both years, the number of dominant species in each of the two years, and the number of species that were dominant in both years.

	WEST BEACH (Summer)					PARTRIDGE POINT (Summer)					EBEY'S LANDING (Summer)				
	total #sp	total #dom	#dom 1st year	#dom 2nd year	#dom both years	total #sp	total #dom	#dom 1st year	#dom 2nd year	#dom both years	total #sp	total #dom	#dom 1st year	#dom 2nd year	#dom both years
+6.0'	12	7	5	4	2	21	8	6	2	0	12	7	5	4	2
+5.0'	17	13	9	5	1	59	12	9	7	4	10	5	3	4	2
+4.0'	7	7	2	5	0	77	21	15	13	7	10	8	5	4	1
+3.0'	19	12	8	5	1	110	17	12	10	5	18	6	3	4	1
+2.0'	4	4	4	1	1	146	18	8	11	1	16	6	3	4	2
+1.0'	7	5	0	5	0	142	19	11	13	5	17	7	4	5	2
0.0	12	11	6	6	1	226	24	16	14	6	25	7	4	4	2
-1.0'	11	6	4	2	0	216	20	15	11	6	60	13	4	9	0
-1.5 m	36	11	6	5	0	202	27	12	18	3	120	20	12	10	2
-2.5 m	40	10	6	7	3	192	27	12	20	5	183	22	13	11	2
-5.0 m	88	9	7	5	3	189	20	12	10	2	181	19	10	12	3
-7.5 m	98	10	8	7	5	166	20	11	12	3	161	17	12	8	3
-10.0 m	95	12	9	7	4	202	16	10	9	3	189	20	13	10	3

(continued)

TABLE 8 (continued)

	WEST BEACH (Winter)					PARTRIDGE POINT (Winter)					EBEY'S LANDING (Winter)				
	total #sp	total #dom	#dom 1st year	#dom 2nd year	#dom both years	total #sp	total #dom	#dom 1st year	#dom 2nd year	#dom both years	total #sp	total #dom	#dom 1st year	#dom 2nd year	#dom both years
+6.0'	5	5	3	3	0	21	7	2	7	2	9	9	3	6	0
+5.0'	6	6	4	2	0	29	11	9	7	5	5	1	1	1	1
+4.0'	5	5	2	3	0	89	17	13	8	4	4	3	2	2	1
+3.0'	6	3	2	2	1	74	16	12	9	5	11	8	3	7	2
+2.0'	8	4	2	2	0	95	16	11	9	5	5	4	3	3	2
+1.0'	22	9	1	8	0	98	18	12	10	5	10	7	1	7	1
0.0	7	7	4	4	1	120	18	11	12	6	14	3	1	3	1
-1.0'	7	7	3	5	1	183	19	14	10	5	12	2	2	2	2
-1.5 m	21	6	3	4	1	129	12	8	9	5	106	18	10	11	3
-2.5 m	40	5	4	4	3	172	11	9	7	5	85	16	10	6	0
-5.0 m	76	8	5	6	3	139	21	14	11	4	121	13	9	6	2
-7.5 m	81	10	7	10	7	135	9	5	5	1	140	16	11	7	2
-10.0 m	99	12	10	7	5	166	20	16	5	1	169	17	12	8	3

In each of the two years the number of dominant species at each stratum was similar. However, when the lists of those species that were dominant at both years at a given stratum are examined (Table 8) it is clear there was little similarity in those species that were dominant the first year, and those that were dominant in the second. In general, only 10-20% of the dominant species were dominant at a given stratum in both years.

To characterize the dominant flora and fauna of the intertidal and subtidal areas of the three sites, those species that were dominant at each stratum in each of the two years were examined (Table 9). Distinct differences between the sites were evident. At West Beach the only group consistently dominant in the intertidal area was the Nemerteans. Subtidally at West Beach the clam Psephidia lordi and phoxocephalid amphipods were characteristic of all strata below -2.5 m in both summer and winter. The polychaete Onuphis sp was also common at subtidal strata. Seasonal variation was noted in the distribution of the polychaete Scoloplos pugetensis. This worm was dominant both years in the winter at depths greater than -2.5 m. It was not, however, dominant during the summer collection periods.

At the cobble site, Partridge Point, the distinct intertidal flora and fauna referred to in the discussion of species richness was evident in the distribution of dominant species (Table 8), although no single species characterized all intertidal strata. The more common dominant species included: the polychaete Onuphis sp and Protodorvillea gracilis, the snails Littorina sitkana and L. scutulata, Oligochaetes, and the crab Hemigrapsus nudus. Algae were dominant at the 0.0' tide height during summer collections but not during winter.

Subtidally at Partridge Point (Table 9) no species was dominant at most of the strata. A few species (Spiophanes bombyx) and Modiolus rectus) were dominant both summer and winter.

At the gravel site (Ebey's Landing) only Nemerteans and the amphipod Paramora mohri were common dominant species at intertidal strata (Table 9).

Subtidally at Ebey's Landing (Table 9) algae were important dominant species to the -7.5 m stratum. Algae were dominant in both summer and winter. Except for Oligochaetes, no species was dominant over a range of strata subtidally. Also, except for some algae, no species were dominant both summer and winter. It is not possible to determine if this represents seasonal variation or some other factor.

In the analysis of similarity between sites the subtidal regions of Partridge Point and Ebey's Landing were similar (61-70%). A comparison of the dominant species subtidally at Partridge Point and Ebey's Landing, however, showed little similarity (Table 9). Only four species occurred as dominants at the subtidal areas of these two sites (Protodorvillea gracilis, Desmarestia ligulata, Callophyllis flabellulata, and Glycymeris subobsoletus).

TABLE 9

LIST OF THOSE SPECIES THAT WERE DOMINANT IN BOTH OF THE YEARS' SAMPLING FOR SUMMER AND WINTER

	SUMMER	WINTER
West Beach		
+6.0'	Nemertea	Nemertea Oligochaetes
+5.0'	Nemertea	none
+4.0'	none	none
+3.0'	Nemertea	Nemertea
+2.0'	Nemertea	none
+1.0'	none	none
0.0'	Phoxocephalidae	Nemertea
-1.0'	none	Nemertea
-1.5 m	none	Phoxocephalidae
-2.5 m	*Psephidia lordi* Phoxocephalidae *Dendraster excentricus*	*Scoloplos pugettensis* *Psephidia lordi* Phoxocephalidae
-5.0 m	*Onuphis* sp *Psephidia lordi* Phoxocephalidae	*Scoloplos pugettensis* *Psephidia lordi* Phoxocephalidae
-7.5 m	*Onuphis* sp *Mysella tumida* *Psephidia lordi* Phoxocephalidae Ophiuroidea	*Onuphis* sp *Scoloplos pugettensis* *Mysella tumida* *Psephidia lordi* *Leptochelia savignyi* Phoxocephalidae Ophioroidea
-10.0 m	*Onuphis* sp *Psephidia lordi* Phoxocephalidae Ophiuroidea	*Onuphis* sp *Scoloplos pugettensis* *Psephidia lordi* Phoxocephalidae Ophiuroidea

TABLE 9 (continued)

	SUMMER	WINTER
Partridge Point		
+6.0'	none	*Littorina sitkana* *Paramoera mohri*
+5.0'	Nematoda *Onuphis* sp *Littorina sitkana*	*Pholoe minuta* *Hemipodus borealis* *Protodorvillea gracilis* Oligochaeta *Littorina sitkana*
+4.0'	*Onuphis* sp *Cirratulus cirratus* *Littorina sitkana* *Littorina scutulata* *Nucella lamellosa* *Hemigrapsus nudus*	*Onuphis* sp Oligochaeta *Littorina sitkana* *Paramoera mohri*
+3.0'	*Anthopleura elegantissma* *Onuphis* sp Oligochaeta *Littorina sitkana* *Hemigrapsus nudus*	*Onuphis* sp Oligochaeta *Littorina sitkana* *Littorina scutulata* *Hemigrapsus nudus*
+2.0'	Oligochaeta	*Onuphis* sp *Protodorvillea gracilis* Oligochaeta *Littorina sitkana* *Hemigrapsus nudus*
+1.0'	*Enteromorpha linza* *Protodorvillea gracilis* *Cirratulus cirratis* Oligochaeta *Lacuna variegata*	Nematoda *Protodorvillea gracilis* Oligochaeta *Notoacmea scutum* *Hemigrapsus nudus*
0.0'	*Iridaea* sp *Rhodoemela larix* *Odonthalia floccosa* Oligochaeta *Lacuna variegeta* *Hyale* sp	*Anthopleura elegantissma* *Typosyllis* sp *Protodorvillea gracilis* *Thelepus crispus* Oligochaeta *Hemigrapsus nudus*

(continued)

TABLE 9 (continued)

	SUMMER	WINTER
-1.5 m	Alaria marginata Phyllospadix scouleri Oligochaeta	Laminaria groenlandica Alaria mangmata Hesionura coineaui difficilis Protodorvillea gracilis Oligochaeta
-2.5 m	Laminaria setchelli Odonthalia floccosa Phyllospadix scouleri Onuphis sp Oligochaeta	Laminaria groenlandica Phyllospadix scouleri Onuphis sp Oligochaeta Typosyllis sp
-5.0 m	Micropodarke dubia Oligochaeta	Micropodarke dubia Glycymeris subobsoletus Oligochaeta Cancer oregonensis
-7.5 m	Laminaria setchelli Micropodarke dubia Oligochaeta	Glycymeris subobsoletus
-10.0 m	Desmarestia ligulata Callophyllis flabellulata Polyneura latissma	Astarte alaskensis
Ebey's Landing		
+6.0'	Nemertea Paramoera mohri	none
+5.0'	Nemertea Paramoera mohri	Paramoera mohri
+4.0'	Paramoera mohri	Paramoera mohri
+3.0'	Paramoera mohri	Nemertea Paramoera mohri
+2.0'	Nemertea Paramoera mohri	Nemertea Paramoera mohri

(continued)

TABLE 9 (continued)

	SUMMER	WINTER
+1.0	Nemertea Paramoera mohri	 Paramoera mohri
0.0'	Paramoera mohri	Paramoera mohri
-1.0'	none	Nemertea Paramoera mohri
-1.0'	Alaria marginata Egregia menziesii Iridaea cordata Oligochaeta Lacuna variegata	Rhodomela larix Protodorvillea gracilis Thelepus crispus Oligochaeta Hyale sp
-1.5 m	Lacuna sp Melita sp	Pterygophora californica Capitella capitata Pontogeneia sp
-2.5 m	Aoroides columbiae Pontogeneia sp.	none
-5.0 m	Enteromopha linza Zostera marina Portodorvillea gracilis	Zostera marina Leptochelia savignyi
-7.5 m	Costaria costata Spiophanes bombyx Psephidia lordi	Spiophanes bombyx Glycymeris subobsoleta
-10.0 m	Desmarestia ligulata Callophyllis flabellulata Modiolus rectus	Callophyllis flabellulata Botryoglossum farlowianum Modiolus rectus

LIVE SIEVES

Results of sampling by live sieves are given in Table 10. At the sand and gravel sites no fauna were found in the first year and these sites were not sampled the second year. At the cobble site, however, fauna were regularly found at the 0.0 and +2.0' strata and occasionally collected at the +6.0' stratum. Most species collected were epifaunal; bivalves were found occasionally. Apparently the substrate at the cobble site (mostly clay below 15-20 cm) is not suitable for large bivalves. The epifaunal species assemblage is apparently different at the +2.0' and 0.0' strata. For example, Hemigrapsus which is common at +2.0' gives way to Pugettia at the 0.0' level. There is no apparent pattern between the two years sampling.

SPECIES DIVERSITY INDICES

The species diversity index for each site, stratum, year, and season is given in Table 11. In general, the cobble site (Partridge Point) had higher diversity than the gravel (Ebey's Landing) or sand site (West Beach). Highest diversity was found at the deepest sampling stratum (-10 m).

There was no evident pattern of change in diversity with season although indices were generally greater in summer than winter.

At intertidal strata the species diversity indices of two of the three sites were similar. The sand site (West Beach) and the gravel site (Ebey's Landing) had relatively low species diversity in the intertidal.

At all sites in the intertidal there was no evident pattern of diversity indices with change in stratum. For example, the range of indices found at the +6' stratum was similar to the range found at the 0.0' stratum.

At subtidal strata there was less difference between the three sites than there was at intertidal strata. At any given stratum the sand site (West Beach) had the lowest species diversity. The other two sites (Partridge Point and Ebey's Landing) had similar diversity indices subtidally.

The highest diversity indices were observed at the deepest stratum (-10 m). Except for this, however, there was no evident pattern of change in diversity with change in depth at subtidal strata. There was no apparent difference in the pattern of distribution of species diversity indices between the two years' sampling.

ANALYSIS BY "t" TEST

Seasonal Variation, Summer vs. Winter

Differences in mean number of individuals and mean weights for summer and winter were examined statistically with the students' "t" test. Each stratum at each site was examined. Table 12 lists those species that had a significant difference in either mean weight or mean numbers ($p = 0.05$) for each of the three sites and two years.

TABLE 10

PARTRIDGE POINT LIVE SIEVE ($0.25 m^2$ by 30 cm deep; 0.5" mesh) SPECIES LISTS, MEAN COUNT AND MEAN WET WEIGHT. n = 4. (West Beach and Ebey's Landing had no fauna and were not sampled the second year.)*

0.0'		FIRST YEAR				SECOND YEAR			
		Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Anthopleura elegantissima	ct wt				0.3 0.2	1.5 3.2			
Epiactis prolifera	ct wt			0.8 0.8		0.3 2.1			
Katharina tunicata	ct wt				0.3 5.1				
Mopalia lignosa	ct wt				0.3 2.3				
Acmaea mitra	ct wt				0.3 0.7				
Collisella pelta	ct wt				0.3 1.3				1.5 9.4
Notoacmaea persona	ct wt	0.3 0.5							
Notoacmaea scutum	ct wt			1.5 4.4	1.0 3.3	3.3 8.6	0.3 0.6	0.8 2.5	1.8 3.9
Diodora aspera	ct wt						0.3 2.6		
Nucella lamellosa	ct wt	2.2 9.8	0.8 3.3	0.3 1.2	1.3 4.2	2.0 5.5	0.3 0.6	0.8 2.4	1.8 5.7

(continued)

TABLE 10 (continued)

		FIRST YEAR				SECOND YEAR			
		Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Searlesia dira	ct	0.3							
	wt	1.0							
Protothaca staminea	ct					0.3			
	wt					0.4			
Saxidomus giganteus	ct	0.3							
	wt	33.9							
Idotea wosnesenskii	ct		1.3	1.5	1.5	0.3	0.5		1.3
	wt		0.6	1.4	1.1	0.2	0.4		0.8
Pagurus hirsutiusculus	ct		0.3			0.3			
	wt		0.3			0.5			
Pugettia gracilis	ct	1.0	0.8	1.0	0.3		0.8		
	wt	2.1	1.1	1.7	0.3		0.4		
Oregonia gracilis	ct					0.3			
	wt					0.2			
Hemigrapsus nudus	ct	2.0	1.0	0.3	4.8			3.3	1.3
	wt	11.8	7.3	1.0	16.6			25.2	6.4
Cancer oregonensis	ct	0.8				0.3			
	wt	2.6				0.1			
Leptasterias hexactis	ct	0.5	0.3	1.3	0.5	1.5			
	wt	1.9	1.3	3.3	0.1	4.3			
Psychrohites paradoxus	ct	0.3							
	wt	1.0							

(continued)

TABLE 10 (continued)

+2.0'		FIRST YEAR				SECOND YEAR			
		Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Anthopleura elegantissima	ct	0.3		0.3	0.8	1.0	1.8		
	wt	0.2		0.2	1.5	2.6	1.8		
Collisella pelta	ct	0.3							0.3
	wt	0.1							0.6
Notoacmaea scutum	ct			3.5		2.5	4.0	0.3	0.5
	wt			3.3		5.8	4.9	2.1	1.3
Notoacmaea persona	ct	5.5	1.8	0.3					
	wt	5.3	2.1	0.7					
Littorina sitkana	ct							0.3	
	wt							0.2	
Nucella emarginata	ct				0.3				
	wt				0.4				
Nucella lamellosa	ct		0.8	0.3	0.8	0.5	1.8	2.5	
	wt		1.1	0.7	2.4	1.2	9.5	4.9	
Searlesia dira	ct	1.0						0.3	
	wt	2.0						1.3	
Saxidomus giganteus	ct	0.3	0.3						
	wt	15.4	2.1						
Idotea wosnesenskii	ct		3.0	0.3	1.5		11.8	1.0	
	wt		1.7	0.3	1.1		10.3	0.5	
Pagurus hirsutiusculus	ct	0.3		0.3			0.5		
	wt	0.1		0.1			0.2		

(continued)

TABLE 10 (continued)

		FIRST YEAR				SECOND YEAR			
		Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Hemigrapsus nudus	ct	3.0	2.2	0.5	1.3	3.5	2.8	5.0	1.8
	wt	15.2	3.0	3.8	2.9	28.1	18.6	44.7	5.7
Leptasterias hexactis	ct	1.5	0.8	0.5		0.3	1.5		
	wt	1.4	0.7	0.3		0.8	1.9		
Gobiesox meandricus	ct	0.3				0.3	0.3		
	wt	2.9				1.7	1.9		
Leptocottus armatus	ct								0.3
	wt								1.2
+6.0'									
Nucella lamellosa	ct	0.3	1.8						
	wt	1.9	8.7						
Hemigrapsus nudus	ct		1.8						
	wt		13.3						
Leptasterias hexactis	ct	2.0	0.5						
	wt	1.7	1.1						
Notoacmea persona	ct	4.0	1.0						
	wt	1.9	0.7						
Searlesia dira	ct	0.3							
	wt	0.2							
Notoacmea sp	ct		1.0						
	wt		0.9						

*In the first year report (Webber, 1979), a systematic error occurred in the live sieve data (Table 15) where both weights and counts were divided by an incorrect sample number of 3 instead of 4 for spring, summer and fall means. This error has been corrected in this report and Table 10 reflects the correct mean values.

TABLE 11

SPECIES DIVERSITY INDICES (SHANNON INDEX) FOR EACH SITE, SEASON, STRATUM AND YEAR
WB - West Beach, PP - Partridge Point, EL - Ebey's Landing. 1 - first year, 2 - second year. Blanks indicate no sample taken.

	SPRING						SUMMER					
	PP		EL		WB		PP		EL		WB	
Species Diversity Indices	1	2	1	2	1	2	1	2	1	2	1	2
+6.0'	2.2	1.2	2.2	1.2	1.5	2.2	2.6	1.2	2.1	2.6	1.7	2.0
+5.0'							2.5	2.8	1.2	1.5	2.0	1.7
+4.0'							2.6	3.4	2.0	1.7	0.7	1.4
+3.0'			1.8	2.5	2.1	1.1	3.5	3.0	1.0	2.2	2.4	2.6
+2.0'	3.4	4.0					2.5	3.5	1.6	0.9	1.2	0
+1.0'							2.1	3.1	1.5	1.1	0	1.5
0.0'	3.8	3.9	0.5	1.5	1.3	2.3	2.9	3.9	1.5	1.9	2.1	2.3
-1.0'							3.3	4.0	1.3	3.5	1.2	2.0
-1.5 m	3.5	3.2	2.0	3.5	2.6	2.3	3.3	4.1	3.0	3.6	3.0	2.3
-2.5 m							3.8	3.8	4.0	4.4	2.3	2.7
-5.0 m	3.3	3.8	3.7	4.1	2.5	3.4	3.8	4.1	4.0	4.3	2.9	2.5
-7.5 m							3.4	3.8	3.8	4.1	2.7	3.5
-10.0 m	4.3	4.1	4.3	4.6	3.6	3.8	4.6	4.1	4.5	4.7	3.1	3.2

(continued)

TABLE 11 (continued)

Species Diversity Indices	FALL						WINTER					
	PP		EL		WB		PP		EL		WB	
	1	2	1	2	1	2	1	2	1	2	1	2
+6.0'	2.7	2.3	2.3	2.4	2.4	0.9	0.9	1.9	1.7	1.7	1.0	0.9
+5.0'							3.1	2.1	0.3	0	1.9	0.7
+4.0'							2.5	3.0	0.4	0	0.7	1.0
+3.0'			0.6	2.1	3.2	2.8	3.0	3.2	2.2	1.9	0.7	1.8
+2.0'	3.6	3.8					3.8	3.8	1.3	1.3	0.6	0.7
+1.0'							3.6	2.2	0.4	1.7	0	2.9
0.0'	3.9	3.8	1.8	2.4	1.7	2.5	3.8	4.0	1.0	1.5	1.0	1.1
-1.0'							3.9	4.1	1.0	1.3	1.3	1.7
-1.5 m	3.8	4.5	4.2	3.9	2.2	2.7	2.9	3.2	3.8	3.2	2.3	2.1
-2.5 m							3.9	4.3	3.7	2.4	2.5	1.9
-5.0 m	3.6	4.3	4.3	4.0	3.1	3.1	3.7	4.2	4.2	4.2	3.0	3.2
-7.5 m							3.3	4.3	3.8	4.3	3.2	3.5
-10.0 m	4.5	4.8	4.7	4.8	3.7	3.6	4.3	4.6	4.7	4.8	3.9	3.5

TABLE 12

SPECIES WITH SIGNIFICANT DIFFERENCES ($p = 0.05$) IN MEAN NUMBER AND/OR WEIGHT BETWEEN SUMMER AND WINTER SAMPLE PERIODS. The year indicates whether the species showed significant differences in the first, second, or both years. Summer/winter refers to the season in which the value was greater. #/Wt refers to whether numbers of individuals, weight or both were significantly different.

	Year	Summer/Winter	#/Wt
WEST BEACH			
-10.0 m			
Pholoe minuta	1	S	#
Phyllodoce sp	1	W	#
Prionospio cirrifera	1	S	#
Spiophanes bombyx	1	S	#
Axinopsida serricata	1	S	wt
Tellina modesta	1	S	#
Psephidia lordi	1	S	wt
Phoxocephalidae	1	S	#
-7.5 m			
Scoloplos pugettensis	1	W	#
Armandia brevis	1	W	#
Owenia fusiformis	1	W	#
Phoxocephalidae	1	S	#
"	2	S	wt
Onuphis sp	2	W	wt
Spiophanes bombyx	2	W	#
Nucula tenuis	2	W	#/wt
Clinocardium ciliatum	2	W	#
Psephidia lordi	2	S	#/wt
Leptochelia savignyi	2	W	wt

(continued)

TABLE 12 (continued)

	Year	Summer/Winter	#/Wt
-5.0 m			
Psephidia lordi	1	S	#/wt
" "	2	S	#
Photis sp	1	S	#
Phoxocephalidae	1	S	#
Phoxocephalidae	2	W	#/wt
Glycinde picta	2	S	#
-2.5 m			
Psephidia lordi	1	W	#
Diastylis sp	1	S	#
Phoxocephalidae	1	S	#
"	2	W	#/wt
-1.5 m			
Phoxocephalidae	1	W	#
"	2	S	#/wt
Psephidia lordi	2	S	#/wt
-1.0' to +6.0'			
none			
PARTRIDGE POINT			
-10.0 m			
Callophyllis flabellulata	1	S	wt
Protodorvillea gracilis	1	S	#
-7.5 m			
Nicomache personata	2	W	#/wt
Chone sp	2	W	wt
Lacuna variegata	2	S	#

(continued)

TABLE 12 (continued)

	Year	Summer/Winter	#/Wt
Cyclocardia ventricosa	2	W	wt
Psephidia lordi	2	W	#/wt
Aoriodes columbiae	2	W	#
Leptosynapta clarki	2	W	#
-5.0 m			
Nematoda	1	S	#/wt
Hemipodus borealis	1	W	#
Spio filicornis	1	S	wt
Maldanidae	1	W	#
Pinnixa occidentalis	1	S	#
Polyneura latissima	2	S	wt
Micropodarke dubia	2	S	#/wt
Typosyllis sp	2	W	#
Onuphis sp	2	S	#
Spiophanes bombyx	2	W	#/wt
Myella tumida	2	S	#
Psephidia lordi	2	S	#
Leptochelia savignyii	2	W	#
Pontogeneia sp	2	S	#
Cancer oregonensis	2		#
-2.5 m			
Oligochaeta	1	S	#
"	2	S	#
Micropodarke dubia	2	S	#
Typosyllis sp	2	W	#/wt
Exogone lourei	2	W	#/wt
Polycirrus kerguelens	2	S	#

(continued)

TABLE 12 (continued)

	Year	Summer/Winter	#/Wt
Lacuna variegata	2	S	#
Glycymeris subobsoleta	2	S	#/wt
Amphilochus litoralis	2	S	#
Aoroides columbiae	2	W	#
Pontogeneia sp	2	W	#/wt
Ischyroceros sp	2	W	#/wt
Heptacarpus brevirostrus	2	S	#
Pugettia richii	2	W	#
-1.5 m			
Lacuna variegata	2	S	#
Barleeia sp	2	S	#/wt
Ampithoe sp	2	S	wt
Pontogeneia sp	2	S	#/wt
Ischyroceros sp	2	S	#/wt
-1.0'			
Nemertea	1	W	#
Chaetozone sp	1	W	#
Exosphaeroma amplicauda	1	S	#
Hyale sp	1	S	wt
Monostroma fuscum	2	W	wt
Gigartina papillata	2	W	wt
Exogone sp	2	W	#
Natica clausa	2	S	wt
Idotea aculeata	2	W	wt
Hyale sp	2	W	#/wt
Parallorchestes ochotensis	2	S	wt

(continued)

TABLE 12 (continued)

	Year	Summer/Winter	#/Wt
0.0'			
Rhodomela larix	1	S	wt
Idotea sp	1	S	#
Platynereis bicanaliculata	2	S	#
Lumbrineris sp	2	W	#
Boccardia columbiana	2	S	wt
Cirratulus cirratus	2	S	wt
Notoacmea scutum	2	W	#
Lacuna variegata	2	S	#/wt
Barleeia sp	2	S	#/wt
Natica clausa	2	S	#/wt
Ianiropsis kincaidii	2	S	#
Ampithoe sp	2	S	#
Hyale sp	2	S	#/wt
Pugetti richii	2	S	wt
Leptasterias hexactis	2	S	#
+1.0'			
Notoacmea scutum	1	W	#/wt
Exogone lourei	2	S	#
Thelepus crispus	2	S	#
Idotea wosnesenskii	2	S	wt
+2.0'			
Littorina sitkana	1	W	#/wt
" "	2	W	#/wt
Gigartina papillata	2	S	wt
Hemipodus borealis	2	S	#
Cirratulus cirratus	2	S	#/wt

(continued)

TABLE 12 (continued)

	Year	Summer/Winter	#/Wt
Chaetozone sp	2	S	#
Thelepus crispus	2		#
Oligochaeta	2	S	wt
Lacuna variegata	2	S	#/wt
Exosphaeroma amplicauda	2	S	wt
Idotea wosnesenskii	2	S	#
+3.0'			
Onuphis sp	1	S	wt
Protodorvillea gracilis	1	W	#
Exogone lourei	2	S	#
Gnorimosphaeroma oregonensis	2	S	#/wt
+4.0'			
Typosyllis sp	1	S	#
Hemipodus borealis	1	S	#
Oligochaeta	1	S	#/wt
Notoacmea persona	2	S	#
+5.0', +6.0'	none		
EBEY'S LANDING			
-10.0 m			
Desmarestia ligulata	1	S	wt
Callophyllis flabellulata	1	S	wt
Scalibregma inflatum	1	S	wt
Armandia brevis	1	S	#/wt
Nicomache personata	1	S	wt

(continued)

TABLE 12 (continued)

	Year	Summer/Winter	#/Wt
Owenia fusiformis	1	W	#
Saxidomus giganteus	1	W	#
Melita sp	1	W	#
Ophiuroidea	1	W	#
Pholoe minuta	2	S	#
Eteone longa	2	S	#
Typosyllis sp	2	S	#
Aonides sp	2	S	#
Mediomastus ambiseta	2	W	wt
Owenia fusiformis	2	S	wt
Oligochaeta	2	S	#
Calyptraea fastigiata	2	S	#
Mysella tumida	2	W	#
Mya arenaria	2	W	wt
-7.5 m			
Nematoda	1	W	#
Spiophanes bombyx	1	S	wt
" "	2		#/wt
Travisia brevis	1	S	#
Oligochaeta	1	S	#
Psephidia lordi	1	S	#/wt
" "	2		#
Corophium sp	1	S	#
Leptosynapta clarki	1	S	wt
Typosyllis sp	2	S	#
Owenia fusiformis	2	S	#
Margarites pupillus	2	S	#
Mysella tumida	2	S	#/wt

(continued)

TABLE 12 (continued)

	Year	Summer/Winter	#/Wt
-5.0 m			
Spio filicornis	1	S	#
" "	2	S	#
Anaitides maculata	2	W	#
Micropodarke dubia	2	S	#
Platynereis bicanaliculata	2	S	wt
Hemipodus borealis	2	W	#
Prionospio steenstrupi	2	W	wt
Spiophanes cirrata	2	S	#
Chaetozone sp	2	W	#
Mediomastus ambiseta	2	W	#
Nicomache personata	2	W	#
Owenia fusiformis	2	W	#/wt
Lacuna variegata	2	S	#
Psephidia lordi	2	S	#
Leptochelia savignyi	2	S	wt
Ampithoe sp	2	W	#
Aoroides columbiae	2	W	wt
Ischyroceros sp	2	S	#/wt
-2.5 m			
Prionospio steenstrupi	1	S	#
Atylus sp	1	W	#
Mediomastus ambiseta	2	S.	#
Pontogeniea sp	2	S	#
Phoxocephalidae	2	W	#/wt

(continued)

TABLE 12 (continued)

	Year	Summer/Winter	#/Wt
-1.5 m			
Lacuna variegata	2	S	#
Pontogeniea sp	2	S	#
Heptacarpus brevirostrus	2	S	#
-1.0'			
Armandia brevis	2	S	#
Lacuna variegata	2	S	#
Leptochelia savignyi	2	S	#
0.0'			
Paramoera mohri	1	S	#
+1.0' none			
+2.0' none			
+3.0' none			
+4.0'			
Oligochaeta	2	S	#
+5.0' none			
+6.0' none			

West Beach. At the sand site there were no significant seasonal differences in numbers or weight per species found at the intertidal strata (Table 12). At subtidal strata the percent of species with significant differences ranged from around 5% to 17% of the total number of species. The bulk of species showed significant differences in mean number. Only a few showed differences in mean weight. Except for the -10.0 m stratum, there were approximately the same number of significant differences in each of the two years. At -10.0 m there were 20 species with significant differences the first year and 13 the second.

At all strata only a few species were significant in both years. In most cases the species that showed significant differences the first year were different than the second year (Table 12).

Table 12 shows that more species had higher numbers or weights in summer compared to winter. Twenty species had higher values of mean number or weight in summer, and only 12 had greater values in winter.

Partridge Point. Unlike the sand or gravel site, Partridge Point had a number of species with significant differences in mean number or weights at intertidal strata (Table 12). From +4.0' to -1.0' tide heights approximately 5-10% of species showed significant differences. More species had significant differences in mean number than mean weight. Only a few species had significant differences in numbers and weight. More species in the second year (72) showed significant differences than the first year (22). Only one species was significantly different in both years.

At subtidal strata there were fewer significant differences in number and weight at the cobble site compared to the gravel and sand sites (Table 12). The percent of significant species at subtidal strata was approximately 5%. Most species had significant differences in mean numbers. Fewer had significant differences in mean weight. Only a few species showed significant differences in both numbers and weights. There were more significant differences in the second year than the first. There was only one species significant in both years.

Table 12 shows that at the cobble sites more species had greater mean numbers of individuals or weight in summer (59) than in winter (30). There was no evident pattern of summer or winter dominance with tide height or subtidal depth. At both intertidal and subtidal strata the fraction of species with summer or winter dominance was similar.

Ebey's Landing. At intertidal strata the gravel site was similar to West Beach in that almost no species showed significant differences between summer and winter (Table 12). At the 0.0' tide height *Paramoera mohri* showed significant higher numbers in summer.

At subtidal strata the percent of species with significant differences ranged from 0 to around 10% (Table 12). More species had significant differences in mean number than mean weight. Only a few species showed significant differences in numbers and weight. Twenty species had significant differences in the first year, 41 in the second. Only three species showed significant differences in both years.

Table 12 shows Ebey's Landing had higher numbers of weights in summer. Forty-one species had higher values in summer; 19 had higher weights in winter. The amphipod Paramoera mohri, although numerous at most intertidal strata, were only significantly greater in summer at the 0.0' tide height.

Differences Between Years

Students' "t" test was used to identify species with significant differences in abundance or biomass between the two years at each site for the summer sample period. Table 13 gives a list of species at each stratum showing whether the numbers and/or weights were significantly different, and whether the first year was greater than the second.

At the intertidal strata of West Beach there were no significant differences in abundance or density between the first and second years. At most subtidal strata about 5-10% of the species showed significant differences. In most cases they were species that were dominant in either or both of the two years. Most showed significant differences in both numbers and weights. Ten species had greater numbers or weights in the first year, and ten in the second year.

The intertidal strata of Partridge Point (Table 13) showed a number of significant differences in abundance or weights between the two years. Most were not dominant species. Twenty-one species had greater numbers and/or weights in the second year, nine in the first.

Approximately 5% of species at the subtidal strata of Partridge Point showed significant differences in number and/or weights between the two years (Table 13). Only in one case was the species dominant. Nine species had greater numbers and/or weight in the first year, 15 in the second.

Only three species at the intertidal strata of Ebey's Landing showed significant differences between the two years (Table 13). All were dominant in either the first or second year. In the subtidal area at Ebey's Landing about 5% of species showed significant differences between the first and second years. Eight were significantly greater in the first year, 10 in the second.

VARIABILITY

Since standard deviation increases with the mean it is not a convenient relative measure of variability of data. The coefficient of variability (Eberhart, 1978) allows rapid comparison of variability in data sets. The C.V. is the standard deviation divided by the mean.

Eberhart has compiled C.V. data for a range of sampling methods for flora and faunal groups. For benthos he reports C.V. of between 0.4 and 0.8. To appraise variability of data in this study it was assumed that those species with a C.V. < 1.0 had acceptable variability, that is, the sample area and replicate number were adequate to provide data that could be used for statistical comparison. Those species that had C.V. of 1.0 or greater are assumed to have unacceptable variability for statistical comparison.

TABLE 13

SPECIES WITH SIGNIFICANT DIFFERENCES (p = 0.05) IN MEAN NUMBER AND/OR WEIGHT BETWEEN THE FIRST AND SECOND YEAR SAMPLE PERIODS. The #/wt refers to whether mean number of individuals or biomass or both were greater. The year refers to when the higher value was observed. D indicates that the species was dominant at that stratum in one of the two years. Only summer data were examined.

	Wt/#	Year	Dominant
WEST BEACH			
-10.0 m			
Pholoe minuta	wt/#	1	D
Prionospio cirrifera	#	1	
Nucula tenuis	wt	1	D
Psephidia lordi	#/wt	1	D
Phoxocephalidae	#/wt	1	D
Ophiuroidea	#/wt	1	D
-7.5 m			
Scoloplos pugettensis	#	2	
Prionospio cirrifera	#	2	
Nucula tenuis	wt/#	2	D
Axinopsida serricata	#/wt	2	D
Mysella tumida	#	2	D
Psephidia lordi	wt	1	D
Ophiuroidea	#	2	D
-5.0 m			
Scoloplos pugettensis	#/wt	2	D
Spiophanes bombyx	wt	1	
Protomediea	#/wt	1	D
-2.5 m			
Phoxocephalidae	#	1	D

(continued)

TABLE 13 (continued)

	Wt/#	Year	Dominant
-1.5 m			
Psephidia lordi	#/wt	2	D
Diastylis sp	#	2	
Phoxocephalidae	#/wt	2	D
-1.0 m none			
0.0 none			
+1.0; - 6.0' none			
PARTRIDGE POINT			
-10.0 m			
Callophyllis flabellulata	wt	1	D
Pterosiphonia sp	wt	2	
Protodorvillea gracil	#	1	
Chaetozone sp	wt	1	
Scalibregma inflatum	#	1	
-7.5 m			
Exogone lourei	#	2	
-5.0 m			
Rhodymenia palmata	wt	1	
Pterosiphonia sp	wt	2	
Nemertea	wt	2	
Nematoda	wt	1	
Spio filicornis	wt	1	
Pinnixa occidentalis	#	1	
Leptosynapta	wt	1	
Polyneura latissima	wt	2	

(continued)

TABLE 13 (continued)

	Wt/#	Year	Dominant
-2.5 m			
Desmarestia ligulata	wt	2	
Exogone lourei	#	2	
Nereis sp	#	2	
Spio filicornis	#	2	
Polycirrus kereguelensis	#	2	
Glycmeris subobsoleta	#	2	
Aoroides columbiae	#	2	
Hyale sp	#	2	
-1.5 m			
Haliclystus auricula	#	2	
Hyale sp	wt	2	
-1.0 m			
Rhodomela larix	wt	1	D
Nematoda	#	2	
Chaetozone sp	#	2	
Natica clausa	wt	2	
Idotea aculeata	#	2	
Ampithoe	#	1	
Hyale sp	wt	1	D
0.0			
Gigartina papillata	wt	2	
Rhodomela larix	wt	2	D
Sphaerosyllis pirifera	#	1	
Nereis sp	#	1	
Hemipodus borealis	#	1	

(continued)

TABLE 13 (continued)

	Wt/#	Year	Dominant
Polydora columbiana	#	2	
Thelepus crispus	#	2	
Natica clausa	#	2	
Pugettia gracilis	#	1	
+1.0'			
Exogone lourei	#	2	
Thelepus crispus	#	2	
+2.0'			
Enteromorpha linza	wt	2	D
Gigartina papillata	wt	2	D
Exogone lourei	#	2	
Chaetozone sp	#	2	
Lacuna variegata	#	2	D
Exosphaeroma amplicauda	wt	2	
+3.0'			
Exogone lourei	#	2	
Littorina scutulata	wt	1	D
Gnorimosphaeroma oregonensis	wt	2	D
+4.0' None			
+5.0'			
Littorina scutulata	#	1	D
+6.0' None			

(continued)

TABLE 13 (continued)

	Wt/#	Year	Dominant
EBEY'S LANDING			
-10.0 m			
Desmarestia ligulata	wt	1	D
Chaetozone sp	#	1	
Armandia brevis	#	1	
Nicomache personata	#	1	
Owenia fusiformis	#/wt	2	
Mya arenaria	#	2	
-5.0 m			
Micropodarke dubia	#	2	
Psephidia lordi	#	2	D
Photis sp	#/wt	2	
Armandia brevis	wt	1	
Synchelidium shoemakeri	#	1	
-2.5 m			
Armandia brevis	wt	1	D
Synchelidium shoemakeri	#	1	
-1.5 m			
Alaria marginata	wt	2	D
Heptacarpus sp	#/wt	2	
-1.0 m			
Enteromorpha linza	wt	2	D
Exosphaeroma amplicauda	#/wt	2	D
Gnorimosphaeroma oregonensis	#/wt	2	D

(continued)

TABLE 13 (continued)

		Wt/#	Year	Dominant
0.0'				
	Hemipodus borealis	wt	1	D
	Gnorimosphaeroma oregonensis	#/wt	2	D
+1.0'	None			
+2.0'	None			
+3.0'	None			
+4.0'				
	Oligochaeta	#	2	D
+5.0'	None			
+6.0'	None			

A summary of C.V. data is given in Table 14. For the replicates at each site, season and strata, the percent of the number of species that had a C.V. of 1.0 or greater is shown.

As Table 14 shows, the number of species with unacceptable variability is high, in almost all cases well above 50%. In the upper intertidal areas of the sand habitat, unacceptable variability was often 100% of the species. There were no apparent differences in C.V. data between the two years.

Two factors should be kept in mind when examining Table 14. The +6', +3' and 0 strata, at the sand and gravel habitats had a replicate number of 5. The +6, +2 and 0.0 strata at the cobble site had a replicate number of 4. All other strata of each of the sites had a replicate number of 3. The difference between 3 and 5 replicates did not appear to have any pronounced effect on variability. In fact, in general, variability was generally lower in subtidal samples when sample size was 3. Quantitative applications of these data are limited by the high variability.

TABLE 14

SUMMARY OF COEFFICIENT OF VARIATION (sd/mean). - indicates no sample. Percent values are the percent of species with a CV of 1.0 or greater.

	+6	+5	+4	+3	+2	+1	0	-1	-1.5	-2.5	-5.0	-7.5	-10.0
SAND (WEST BEACH)													
Spring													
First year total #sp	3	-	-	4	-	-	2	-	18	-	26	-	45
% C.V. ≥ 1.0	100	-	-	75	-	-	100	-	50	-	58	-	67
Second year total #sp	6	-	-	10	-	-	9	-	12	-	58	-	66
% C.V. ≥ 1.0	67	-	-	100	-	-	100	-	92	-	62	-	68
Summer													
First year total #sp	5	9	2	10	4	-	6	4	24	14	48	58	58
% C.V. ≥ 1.0	100	100	100	100	100	-	83	100	58	57	58	57	50
Second year total #sp	10	9	5	11	1	7	7	8	14	32	49	60	61
% C.V. ≥ 1.0	90	89	100	91	100	71	57	75	50	66	59	48	57
Fall													
First year total #sp	10	-	-	15	-	-	21	-	25	-	57	-	73
% C.V. ≥ 1.0	90	-	-	73	-	-	95	-	80	-	70	-	44
Second year total #sp	10	-	-	13	-	-	18	-	24	-	57	-	81
% C.V. ≥ 1.0	90	-	-	85	-	-	89	-	25	-	65	-	60
Winter													
First year total #sp	3	4	2	4	2	1	5	3	17	32	39	50	73
% C.V. ≥ 1.0	100	50	100	100	100	100	30	100	65	69	59	44	58
Second year total #sp	3	2	3	3	7	21	4	5	9	19	49	56	47
% C.V. ≥ 1.0	100	100	66	100	86	95	100	80	67	74	59	37	57

(continued)

TABLE 14 (continued)

	+6	+5	+4	+3	+2	+1	0	-1	-1.5	-2.5	-5.0	-7.5	-10.0
COBBLE (PARTRIDGE POINT)													
<u>Spring</u>													
First year total #sp	7	-	-	-	39	-	73	-	70	-	50	-	79
% C.V. ≥ 1.0	86	-	-	-	85	-	74	-	78	-	62	-	61
Second year total #sp	24	-	-	-	72	-	129	-	109	-	130	-	118
% C.V. ≥ 1.0	45	-	-	-	51	-	55	-	90	-	50	-	60
<u>Summer</u>													
First year total #sp	15	19	32	46	66	41	74	86	68	73	82	61	93
% C.V. ≥ 1.0	100	68	73	70	73	78	66	63	96	68	63	64	55
Second year total #sp	7	47	57	82	101	115	169	154	166	149	132	113	142
% C.V. ≥ 1.0	83	74	63	83	76	50	66	55	69	52	66	55	72
<u>Fall</u>													
First year total #sp	13	-	-	-	52	-	79	-	69	-	63	-	75
% C.V. ≥ 1.0	85	-	-	-	83	-	63	-	74	-	54	-	45
Second year total #sp	11	-	-	-	54	-	89	-	156	-	117	-	127
% C.V. ≥ 1.0	82	-	-	-	100	-	91	-	54	-	78	-	53
<u>Winter</u>													
First year total #sp	12	22	56	44	49	53	55	77	40	64	78	52	77
% C.V. ≥ 1.0	100	86	79	66	69	74	80	68	78	64	42	71	62
Second year total #sp	14	17	14	41	71	51	95	132	111	122	105	102	119
% C.V. ≥ 1.0	92	62	66	48	80	71	67	57	65	63	62	49	62

(continued)

TABLE 14 (continued)

	+6	+5	+4	+3	+2	+1	0	-1	-1.5	-2.5	-5.0	-7.5	-10.0
GRAVEL (EBEY'S LANDING)													
Spring													
First year total #sp	7	-	-	5	-	-	10	-	13	-	62	-	81
% C.V. ≥ 1.0	100	-	-	100	-	-	90	-	77	-	69	-	65
Second year total #sp	6	-	-	18	-	-	11	-	84	-	100	-	123
% C.V. ≥ 1.0	100	-	-	67	-	-	100	-	70	-	59	-	71
Summer													
First year total #sp	5	4	5	7	7	9	12	19	48	62	75	71	90
% C.V. ≥ 1.0	80	75	40	100	29	56	83	79	69	71	44	55	61
Second year total #sp	10	9	6	14	12	13	20	49	81	144	139	112	132
% C.V. ≥ 1.0	80	89	50	86	76	77	75	65	57	69	64	52	49
Fall													
First year total #sp	11	-	-	12	-	-	24	-	78	-	76	-	83
% C.V. ≥ 1.0	91	-	-	92	-	-	89	-	59	-	63	-	57
Second year total #sp	11	-	-	13	-	-	16	-	110	-	93	-	139
% C.V. ≥ 1.0	45	-	-	100	-	-	50	-	52	-	67	-	45
Winter													
First year total #sp	3	6	3	6	4	5	8	10	61	49	71	66	84
% C.V. ≥ 1.0	66	100	100	67	75	60	100	60	80	76	65	64	56
Second year total #sp	6	1	2	7	3	7	9	5	35	22	85	94	115
% C.V. ≥ 1.0	100	100	100	100	100	86	100	80	82	59	50	70	57

SECTION 6

DISCUSSION

WEST COAST OF WHIDBEY ISLAND BEACH SYSTEM

The west coast of Whidbey Island is a series of beaches that are erosional, transport, or accretional in nature. Unconsolidated glacial deposits on uplands serve as sediment sources. Exposure to southerly and westerly winds provides moderate wave action from the Strait of Juan de Fuca. Generally the erosional beaches are cobble, the transport beaches gravel, and the accretion beaches sand. The sampling sites were chosen to reflect the three primary habitats.

The substrate characteristics at subtidal strata are, in general, similar to the intertidal substrate, except that with increasing depth and decreased wave action the proportion of silt in the substrate increases.

On the west coast of Whidbey Island, wave energy, temperature, and salinity were all similar at the three sites. Differences observed in intertidal and shallow subtidal communities are believed to be the result of different substrate types.

Species richness at the three intertidal habitats is related to substrate stability. At the gravel and sand habitats wave action causes movement of beach material through the year. Species richness is reflected in this. At the sand and gravel habitats there is a relatively poor species representation. (More species were found intertidally at the gravel habitat than the sand habitat.) Only polychaetes and amphipods were dominant organisms intertidally at the sand site, and they were distributed at low intertidal strata. Species found at these strata were more widely distributed subtidally.

Amphipods, oligochaete worms, polychaete worms, and nemerteans were the only dominant intertidal organisms at the gravel site. The amphipods, oligochaetes and probably nemerteans were a distinct intertidal fauna. The amphipod Paramoera mohri which was very common at the intertidal area of the gravel site, had virtually no subtidal distribution.

The sand site then had virtually no distinct intertidal community and that of the gravel site was relatively meager compared to the cobble site.

However, both algae and invertebrates were well represented in the intertidal area at the cobble site. Many community groups had a distinct intertidal presence. In the algae groups, red algae found at the intertidal strata were generally not found in the subtidal. Polychaetes at the cobble site were common at the intertidal strata. Although all but one of the polychaete species also had a subtidal distribution, a number had their peak of abundance in the intertidal strata. Gastropods, barnacles, decapods and echinoderms all had a distinctive intertidal distribution.

Species richness at subtidal strata at the sand and gravel habitats was much greater than at intertidal strata. Species richness at the cobble habitat in the subtidal area was lower than in the intertidal. There were distinct differences between the subtidal communities at the three habitats. The gravel and sand habitats at subtidal strata had a similarity index of 39%. The similarity between the cobble and sand was also low (38%) but between cobble and gravel it was relatively high (63%). The similarity is apparently related to substrate type. At the sand habitat the substrate in the subtidal area continued as sand with increasing silt content. The gravel habitat, however, had patches of cobble habitat in the subtidal area. Algae that require a stable substrate for attachment were common at the cobble and gravel habitats. Algae were virtually absent at sand habitat.

Bivalve abundance increased with increasing depth at all habitats. At the gravel and sand habitats polychaetes increased in number of species with depth. However, that pattern was not noted at the sand habitat. Gastropods were common at subtidal strata at both the gravel and cobble sites but not the sand site. Amphipods were common in the subtidal at the gravel and sand habitats but not the cobble habitat. Cobble and sand habitats were most distinctly different with the gravel site being similar to the cobble with some community groups and similar to the sand with others.

There are, then, distinct communities at the three habitats in the Whidbey Island beach system. At the sand and gravel site the clearest defined communities are subtidal with only a meager intertidal representation. At the cobble site there is a well developed, distinct intertidal community as well as a distinct subtidal community.

Some species stand out as being associated with various habitats. The amphipod _Paramoera mohri_ was very common only in the intertidal at the gravel habitat. Amphipods of the group Phoxocephalidae were very common in the subtidal area at the sand site. The snail _Littorina sitkana_ was very common in the intertidal area at the cobble site.

CHANGES WITH TIME

Seasonal Changes

There was a maximum number of individuals in summer and in general maximum biomass at each site in fall and winter. Seasonal patterns in separate community groups, however, did not always agree with the general pattern. The amphipod _Paramoera mohri_ did show a clear summer peak in numbers. However, for some community groups response differed according to strata. At the cobble site oligochaetes were more numerous in winter at lower strata. In some groups different species varied in patterns of abundance. At the cobble habitat the polychaete _Onuphis_ sp had a peak in numbers in summer while _Thelepus crispus_ had greater numbers in winter.

Seasonal changes then appear to be more complex than the general pattern and must be examined on a species-by-species basis.

Yearly Change

In general the species richness, numbers of individuals, biomass, species diversity indices, coefficients of variation, and numbers of species with significant differences between summer and winter, had similar values at given strata of the three sites in each of the two years' sampling. However, the species composition between the years was variable with similarities ranging between 58 and 60% for the three sites. That is approximately 40% of the species observed in the second year at a given stratum were not present in the first year and vice versa. Also, this variability in species composition was reflected in the analysis of dominant species. There was relatively little similarity between the species dominant at a given stratum in the first year and those dominant in the second year. Finally, when the lists of species that showed significant differences in number or weights between summer and winter were compared stratum by stratum there was little similarity between the two years.

An explanation of the variability in community structure is not possible at this time. It may be related to sampling error. That is that sample size area or replicate number were inappropriate to the community. Or it may be that the community structure is variable over time with structural changes in species that do not greatly affect the overall structure of the community. An analysis of functional types in the community would address this possibility.

EVALUATION OF SAMPLE METHODS AND ERRORS

Sample Methods. Since sample methods were designed to sample the greatest number of organisms possible, it is unavoidable that some species were inadequately sampled. Large relatively rare organisms (sea stars, crabs) were not taken at the study site. Also, macroalgae at the subtidal strata were probably inadequately sampled because of the relatively small sample size. For one species at least, it is known that sample area was inadequate. At both the cobble and gravel sites the kelp *Nereocystis luetkeana* was common in the shallow subtidal areas. However, this species was not sampled at either site; sample area was too small.

Another probable sample error was the procedure used for sampling the cobble site intertidally. The procedure required the removal from top and sides of cobbles' organisms from 5, 0.01 m^2 areas. It was extremely difficult under field conditions to accurately fix boundaries of the five subsample areas. It is possible to examine the effect of using the 5, 0.01 m^2 areas using the second year NOAA data. Files contain data for epifauna > 1 mm in size collected from (a) the 5, 0.01 m^2 areas, and (b) from the remaining 0.02 m^2 area. The effect of using either of these data to reconstruct the 0.25 m^2 quadrat could be examined.

Errors in data may result from the methods used to combine data from various collection methods into a single 0.25 m^2 quadrat. In the first year epifauna from 1 mm to 1 cm from subtidal sites were not sampled and consequently are not part of the data used to reconstruct the 0.25 m^2. Also, readers who compare data from the first year in this report to the data used in the report for the first year (Webber, 1979) should note that in Webber, 1979 invertebrates > 1 cm in size were included in the 0.25 m^2 quadrats. Those data were not included in this report.

A number of errors of various forms exist in the data sets. Species richness data assume that all entries for a given site are unique species. Not all groups were identified to species levels. For example, nemerteans and oligochaetes were not identified. This tended to underestimate species richness. On the other hand, unique entries were made that tended to overestimate species richness. Unique entries were made for the following:

i. fragments of organisms were often identified to the genus level.

ii. juvenile forms could often not be identified to species and were entered as a genus sp

iii. detritus was often entered to indicate a contribution towards biomass.

iv. egg masses and larval forms were entered as encountered.

Other errors will be found in the data sets. Spelling errors result in redundant listings that tend to overestimate lists of taxa. As well, with some species, identification in the first year was tentative and the entry made as a genus. In the second year, these species were confirmed and the full listing was used.

As the data on coefficients of variability showed, the sampling procedures used in this study resulted in data with relatively high variability. Such is the difficulty of community analysis studies in intertidal and shallow subtidal areas. These communities have a high degree of variability due primarily to variable environmental conditions and patchiness in distribution. Limits of time and money restrict such community studies to basically a descriptive level. Any statistical comparison must take into account the high variability of the data so as to not lead to erroneous conclusions.

COMPARISON TO OTHER AREAS

Similar intertidal and shallow subtidal community analyses have been done in recent years in other areas of Puget Sound. Nyblade (1978) studied areas along the Strait of Juan de Fuca, and Webber and Smith (1978) studied areas in Rosario Channel and southern Georgia Strait. The first year data in this report were compared to data from these other areas. A summary of data on species richness, number of individuals and biomass for the first year only, for cobble, sand, and gravel habitats is given in Tables 15 through 17.

Sand Habitat

Sand sites compared include North Beach Sand and Kydaka on the Strait of Juan de Fuca (Nyblade, 1978), West Beach on Whidbey Island and Birch Bay on southern Georgia Strait (Webber and Smith, 1978) (Table 15).

Species richness intertidally at these sites is apparently affected by the degree of exposure. West Beach, North Beach sand and Kydaka are all exposed and have relatively low but similar species richness. Birch Bay, which is more protected, had relatively greater species richness. West Beach had the lowest species richness.

At subtidal strata species richness at West Beach and Kydaka were similar, but that of North Beach sand was relatively higher and was more similar to the species richness of gravel and cobble habitats (Tables 16, 17).

Mean numbers of individuals at subtidal strata, however, were similar between North Beach sand and West Beach sand. Kydaka had relatively lower mean numbers.

Kydaka also showed the lowest mean biomass of the three sites.

Cobble Habitat

Cobble habitats compared include Morse Creek and North Beach (Nyblade, 1978) from the Strait of Juan de Fuca, Shannon Point, near Anacortes (Webber and Smith, 1978) and Partridge Point on Whidbey Island (Table 16). All cobble habitats showed greater species richness intertidally than the sand or gravel habitats. At all cobble habitats there was an increase in species number with decrease in tide height. Sites generally had similar values of species richness at intertidal strata although Shannon Point tended to have the greatest number of species per stratum through the intertidal range. The highest number of species (149) was noted at Morse Creek at the 0.0' stratum. However, at the +1' stratum the highest number of species was found at Shannon Point (118). At +4.0' stratum, Shannon Point and Partridge Point had a greater number of species than did Morse Creek or North Beach.

When numbers of individuals were compared, however, Morse Creek and North Beach had greater numbers of individuals per 0.25 m^2 at most strata than Shannon Point or Partridge Point (except the 0.0' strata where Partridge Point had the greatest number of individuals per 0.25 m^2).

When biomass was examined, at the lower strata Partridge Point and Shannon Point had greater biomass per 0.25m^2 than Morse Creek and North Beach. Since both Morse Creek and North Beach had greater numbers of individuals at the strata the size of organisms must have been relatively small at those habitats.

At the higher strata intertidally (+5.0' to +7.0') Shannon Point had a greater biomass than the other cobble habitats. Since Morse Creek and North Beach had greater numbers of individuals at these strata, again the size of organisms must have been relatively small.

TABLE 15

COMPARISON OF SAND SITES. North Beach Sand, Kydaka Beach - Strait of Juan de Fuca. West Beach - Whidbey Island. Birch Bay - Southern Georgia Strait. For West Beach only first year data were used. Data for North Beach and Kydaka Beach from Nyblade (1978); for Birch Bay from Webber (1979). Numbers of individuals are mean values per 0.25 m^2. Biomass values are mean grams of wet weight tissue per 0.25 m^2.

Elevation	North Beach Sand (moderate exposure)			Kydaka Beach (exposed)			West Beach (moderate exposure)			Birch Bay (moderate protected)		
	# of species	# of individuals	biomass	# of species	# of individuals	biomass	# of species	# of individuals	biomass	# of species	# of individuals	biomass
+7.0'	4	67	2	3	7	1						
+6.0'	9	52	4	6	12	1.2	5	50	0.3			
+5.0'	4	130	2	3	10	1	5	94	0	28	71	28
+4.0'	7	37	3	3	10	1	1	30	0	32	78	31
+3.0'	10	132	5	14	140	3	7	200	0	38	58	35
+2.0'	11	1,678	9	3	72	1	2	334	0.5	39	60	36
+1.0'	9	887	6	7	25	2	0	355	0.2	40	112	39
0.0'	18	298	8	11	12	3	8	9,870	24	37	60	37
-1.0							2	6,339	11	38	125	37
-5.0	163	1,324	97	51	575	13	45	1,700	25			
-10.0	109	1,470	15	53	1,142	13	64	2,200	56			

TABLE 16

COMPARISON OF COBBLE SITES. North Beach, Morse Creek - Strait of Juan de Fuca. Partridge Point - Whidbey Island. Shannon Point - Anacortes. For Partridge Point only the first year data were used. Data for North Beach and Morse Creek from Nyblade (1978); for Shannon Point from Webber (1979). Numbers of individuals are mean values per 0.25 m^2. Biomass values are mean grams of wet weight per 0.25 m^2.

Elevation	North Beach (moderate exposure)			Morse Creek (moderate exposure)			Partridge Point (exposed)			Shannon Point (moderate exposure)		
	# of species	# of individ-uals	biomass	# of species	# of individ-uals	biomass	# of species	# of individ-uals	biomass	# of species	# of individ-uals	biomass
+7.0'	8	45	1	6	101	0.5				20	400	50
+6.0'	25	176	5	5	2,167	1.0	13	31	0.7	35	700	150
+5.0'	44	3,432	138	9	842	10	20	658	16	43	1,100	180
+4.0'	23	1,714	30	41	6,844	104	55	6,404	328	58	975	175
+3.0'	54	13,387	591	62	6,514	142	51	4,128	199	70	1,000	180
+2.0'	49	9,835	218	51	9,096	223	66	2,623	243	114	1,050	630
+1.0'	75	12,928	223	70	2,981	328	64	1,952	807	116	750	350
+0.0'	78	2,109	43	149	6,950	1,016	102	7,749	1,239	118	900	200
-1.0'							106	13,252	1,406	45	1,100	100
-5.0'				74	373	26	81	1,805	140			
-10.0'				149	2,215	9	101	962	128			

At subtidal strata the cobble habitats of Morse Creek and Partridge Point showed no clear pattern of dominance in species number, number of individuals or biomass. At -5.0 m Partridge Point had a greater number of species and individuals and greater biomass. At -10 m Morse Creek had a greater number of species and individuals but lower biomass than Partridge Point. The size of organisms at Morse Creek must have been relatively small at this stratum.

Gravel Habitat

Gravel sites compared included Dungeness Spit and Twin Rivers (Nyblade, 1978) on the Strait of Juan de Fuca. Ebey's Landing on Whidbey Island and Legoe Bay (Webber and Smith, 1978) on the Northwest side of Lummi Island (Table 17).

At intertidal strata, species richness was relatively low. Of the sites Legoe Bay showed the greater species richness with up to 23 species taken at the +5.0' stratum. Except for Ebey's Landing where the amphipod *Paramoera mohri* was so common, the numbers of individuals and biomass generally followed species richness. Legoe Bay generally had the greatest number of individuals and biomass per stratum.

There was no clear pattern of change in species numbers with change in tide height at any of the gravel habitats except Ebey's Landing where there was an increase in species richness at the 0.0' and -1.0' strata.

At subtidal strata, there were no clear patterns of change in species richness, numbers of individuals or biomass at -5.0 m and -10 m at the three gravel sites: at the -5.0 m stratum, Twin Rivers had the greatest number of species and individuals, but lowest biomass indicating relatively small organisms. At the -10.0 m Ebey's Landing had the highest species number, number of individuals and biomass.

Species richness, numbers of individuals and biomass subtidally at the gravel habitat were similar to that of the cobble habitats.

TABLE 17

COMPARISON OF GRAVEL SITES. Dungeness Spit, Twin Rivers - Strait of Juan de Fuca. Ebey's Landing - Whidbey Island. Legoe Bay - Lummi Island. For Ebey's Landing only first year data were used. Data for Dungeness Spit and Twin Rivers from Nyblade (1978); for Legoe Bay from Webber (1979). Numbers of individuals are mean values per 0.25 m^2. Biomass values are mean grams of wet weight per 0.25 m^2.

Elevation	Dungeness Spit (exposed)			Twin Rivers (exposed)			Ebey's Landing (exposed)			Legoe Bay (moderate exposure)		
	# of species	# of individuals	biomass	# of species	# of individuals	biomass	# of species	# of individuals	biomass	# of species	# of individuals	biomass
+7.0'	2	10	1	2	30	1						
+6.0'	6	15	3	4	76	2	6	50	0	13	175	4
+5.0'	2	57	1	2	100	1	4	94	0	23	200	5
+4.0'	3	10	1	3	227	1	3	30	0	13	200	13
+3.0'	4	91	2	4	267	2	7	199	0.1	18	700	10
+2.0'	2	520	1	2	27	1	5	334	0.4	18	900	13
+1.0'	2	10	1	4	12	2	6	355	0.2	18	1,800	28
+0.0'	2	3	1	7	109	3	14	9,970	24	14	600	16
-1.0'							13	6,339	11	23	450	17
-5.0'	30	71	7	139	1,320	5	83	1,585	141			
-10.0'	90	957	34	65	1,523	2	107	1,483	386			

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