ECOLOGICAL STUDIES OF INTERTIDAL AND SHALLOW SUBTIDAL HABITATS IN LOWER COOK INLET

Prepared for

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SUMMARY

Field studies were initiated in intertidal and shallow subtidal habitats in Lower Cook Inlet to examine species composition, zonation and seasonal patterns, trophic structure, rates of production and energy pathways. Habitats examined included rocky intertidal and subtidal areas, sand beaches and mud flats.

Plant and animal assemblages on rocky habitats exhibited strong patterns in zonation and seasonal development. In Kachemak Bay, algal assemblages were well developed and highly productive out to a depth of at least 20 meters. Fucoid and laminarian algae were the dominant species. One dominant kelp, the canopy forming *Alaria fistulosa*, was estimated to produce annually between 7,140 and 18,580 g fresh tissue per m^2 where it forms beds (428 to 1,115 gC/m^2). Invertebrate assemblages are rich, especially in areas of high current flow. Functionally important forms include herbivores (e.g., sea urchins, chitons and limpets), suspension feeders (e.g., mussels, clams and polychaete worms) and predator/scavengers (e.g., starfish, crabs, and fish). It appears that sizeable quantities of plant tissue are exported to other habitats from rocky habitats in Kennedy Entrance and Kachemak Bay.

The animal assemblages studied in sand and mud habitats in Lower Cook Inlet differed distinctly among themselves and with those in rock habitats. Macrophytes were uncommon or absent on the soft bottoms. Sand beach faunas were dominated by short-lived gammarid amphipods (e.g., *Eohaustorius eous*) and polychaete worms (e.g., *Scolelepis* sp). The dominant feeding types were deposit and suspension feeders largely dependent on imported organic debris. Biomass was quite low (less than 5 g dry weight/m^2), and secondary production appeared low. Few resident predators were identified and it seems that transient predators, (birds, fish and crabs) were of greater consequence.

Mud flat faunas were dominated by long-lived clams (e.g., *Mya* spp. and *Macoma balthica*). The infaunal dominants were suspension and deposit

feeders largely dependent on imported organic debris. Resident predators were apparently of minor importance. Biomass was moderately high (up to 267 g dry tissue/m^2. Secondary production appeared moderately high. Predation by transient predators such as shorebirds, diving ducks and demersal fish appeared substantial and thus we concluded that this system probably contributes significantly to several other faunal assemblages and systems.

Zonation of the biological assemblages on soft substrates was readily apparent in the distribution of species abundance but generally not apparent in species composition. Many of the species were more abundant at the lower tidal levels.

Most of the species exhibited considerable seasonal changes in abundance. Generally, polychaete worms and amphipods were more abundant in summer, but clams were most abundant in spring. Juveniles of several species appeared in the samples only in the summer, a relatively mild period.

Evaluation of the trophic structures of these assemblages indicates that all are based on detritus. The great majority of the organisms are deposit feeders or suspension feeders. Resident predators are uncommon. Feeding observations suggest that a large proportion of the animals living in these habitats are eaten by transient predators from other assemblages and geographic areas. Some of the important groups that forage heavily in these habitats include crabs, fish (e.g., flatfish, cottids and juvenile salmon), shorebirds, and diving and dabbling ducks. Qualitative impressions of exploitation levels suggest that the mud flat assemblage is utilized much more heavily than the sand beaches. A comparison of abundance, biomass and growth data seems to support this hypothesis. Several bird species (e.g., Western Sandpipers and Dunlins) seem particularly dependent on mud flat assemblages during spring migration. Greater Scaup, Oldsquaw, Surf Scoters and Black Scoters feed extensively on mud flats in the winter.

These biological descriptions are crucial in arriving at several useful preliminary conclusions. First, by combining the biological attributes and contributions of the various assemblages with predicted ranking of various substrates to hydrocarbon uptake, storage and retention characteristics (based on geomorphological considerations and field observations at major oil spill sites, as described by Hayes et al., 1977), it appears that mud flats are the most sensitive of the substrates examined in this study to contamination by crude oil. Furthermore, based on the high probability that: (1) much of the seemingly high productivity of mud flats is used by animals from other systems, and (2) that mud flats are very important to a number of marine and terrestrial animals (some commercially important and others migrating across broad geographic ranges), the importance of protecting this habitat from pollution is quite obvious. Next, areas supporting large kelp stands probably contribute a substantial quantity of plant material to other systems in Lower Cook Inlet and may be of considerable importance in the economy of the Inlet. These habitats are concentrated in the southeast quadrant of the Inlet and thus planning can provide them considerable protection. Finally, because of the concentration of sand beaches in the northeastern quadrant of Lower Cook Inlet, and of mud flats in Kachemak Bay and on the west side of the Inlet, and most acceptable location for development of onshore facilities, in biological terms, is between Anchor Point and Nikiski.

1.0 INTRODUCTION

Potential development of oil and gas reserves in Lower Cook Inlet is accompanied by the prospect that the intertidal and shallow subtidal habitats of that estuary may be subjected to large scale chronic or acute contamination. The magnitude of this potential problem is based primarily on the overall importance of this littoral zone and its component habitats to the Inlet and associated systems, and secondarily, on the sensitivity of these habitats to the potential perturbations. Man tends to rank the importance of a resource according to his own observable utilization of the resource. Clamming is the most important human use of intertidal resources in Lower Cook Inlet directly perceived by most individuals, and, since only small segments of the coastline are used, the importance of intertidal habitats is often considered to be low. However, the importance and sensitivity of the zone cannot be evaluated until it has been adequately described and its relationships to other systems are at least generally defined. It is clear from experience in other parts of the world that the greatest observable impacts of oil-related problems occur in the intertidal and nearshore zones.

Intertidal and shallow subtidal habitats and assemblages in Lower Cook Inlet were generally undescribed until Dames & Moore biologists commenced rocky intertidal studies in Kachemak Bay in 1974 (Dames & Moore, 1976). Soft intertidal habitats (sand and mud) were not studied until spring and summer of 1976, when the Bureau of Land Management (BLM) initiated a reconnaissance of the physical, chemical and biological systems in Lower Cook Inlet through its Outer Continental Shelf Environmental Assessment Program (OCSEAP). These studies were initially designed to collect the information necessary to permit BLM to write the Environmental Impact Statement for the OCS oil and gas lease sale. As part of the reconnaissance, the first phase of this study (R.U. #417) was designed to examine beaches representative of the major intertidal and shallow subtidal habitats in Lower Cook Inlet (Dames & Moore, 1977).

The intertidal reconnaissance indicated that most of the rocky intertidal habitats in Lower Cook Inlet are located in Kachemak Bay and Kennedy Entrance, on the east, and in Kamishak Bay, on the west. In contrast, the intertidal areas north of Kachemak and Kamishak Bays are mainly soft, with the lower beaches in exposed areas being sand and in protected areas, mud. At lower tidal levels, approximately 50 percent of the shoreline on the west side is mud flats, largely as a consequence of the number of bays that deeply indent into the coastline. North of Kachemak Bay on the east side of the Inlet, the smooth shoreline is interrupted by just a few rivers and streams, and the lower tidal levels are almost exclusively sandy. The upper beaches (above MLLW) for a large proportion of the shoreline in the Lower Inlet are characterized by a steeper slope of coarse gravel and cobbles. Based on the slope, grain size, and impoverished fauna, this habitat appears to be the least stable of the soft, or unconsolidated, intertidal substrates in Lower Cook Inlet.

The reconnaissance study further indicated sharp differences, between the biotic assemblages of the sand and mud habitats. Although both habitats are characterized by detritus-based assemblages, and depend to varying degrees upon organic debris produced in other areas, the sand beaches support a rather impoverished assemblage with low biomass whereas the mud beaches support a more diverse assemblage with moderate biomass. The sand beach faunas are dominated by polychaete worms and gammarid amphipods whereas the mud flat faunas are heavily dominated by clams. The lower level of the gravel upper beach appears to be dominated by a gammarid amphipod and an isopod, both of which form dense aggregations under large cobbles (Dames & Moore, 1977).

It became suspected through the reconnaissance study that intertidal resources are important to several other organisms and systems. For instance, shorebirds, gulls and sea ducks feed heavily on soft intertidal substrates. At least one group is feeding there during each stage of the tide. Fish and crustaceans move into the intertidal zone during high tides to feed and some species remain there during low tide (Green 1968). Several investigators have reported that mud flats are important feeding areas for juvenile salmon (Sibert et al. 1977; Kaczynski et al. 1973).

However, only preliminary descriptions of the various systems examined were provided. The major objective of the research described in this report was to more fully describe the systems at specific sites, and identify the more important relationships and processes operating in these assemblages. This necessitated a fairly detailed examination of seasonal changes in species composition and structure. Trophic relationships were not emphasized because the most important predators (birds and fish) are the object of other research units.

The specific objectives of this study have been to:

1. Assess seasonal changes in composition and define trophic relationships among dominant intertidal and subtidal organisms in representative rock, sand and mud habitats in Lower Cook Inlet.

2. Determine the seasonal patterns of primary production, growth, and standing crop for the major macrophyte species.

3. Describe and evaluate the potential for impact by OCS oil and gas exploration, development and production on those intertidal and shallow subtidal habitats studied from FY 76 through FY 78.

Objectives 1 and 2 relate directly to objective 3 in that they provide the biological background necessary to accomplish objective 3. The research dictated by the first two objectives should provide reasonable descriptions of major intertidal biological assemblages and permit comparisons and discussions of relationships. These descriptions should permit identification of particularly important organisms, areas or relationships with potentially high susceptibility.

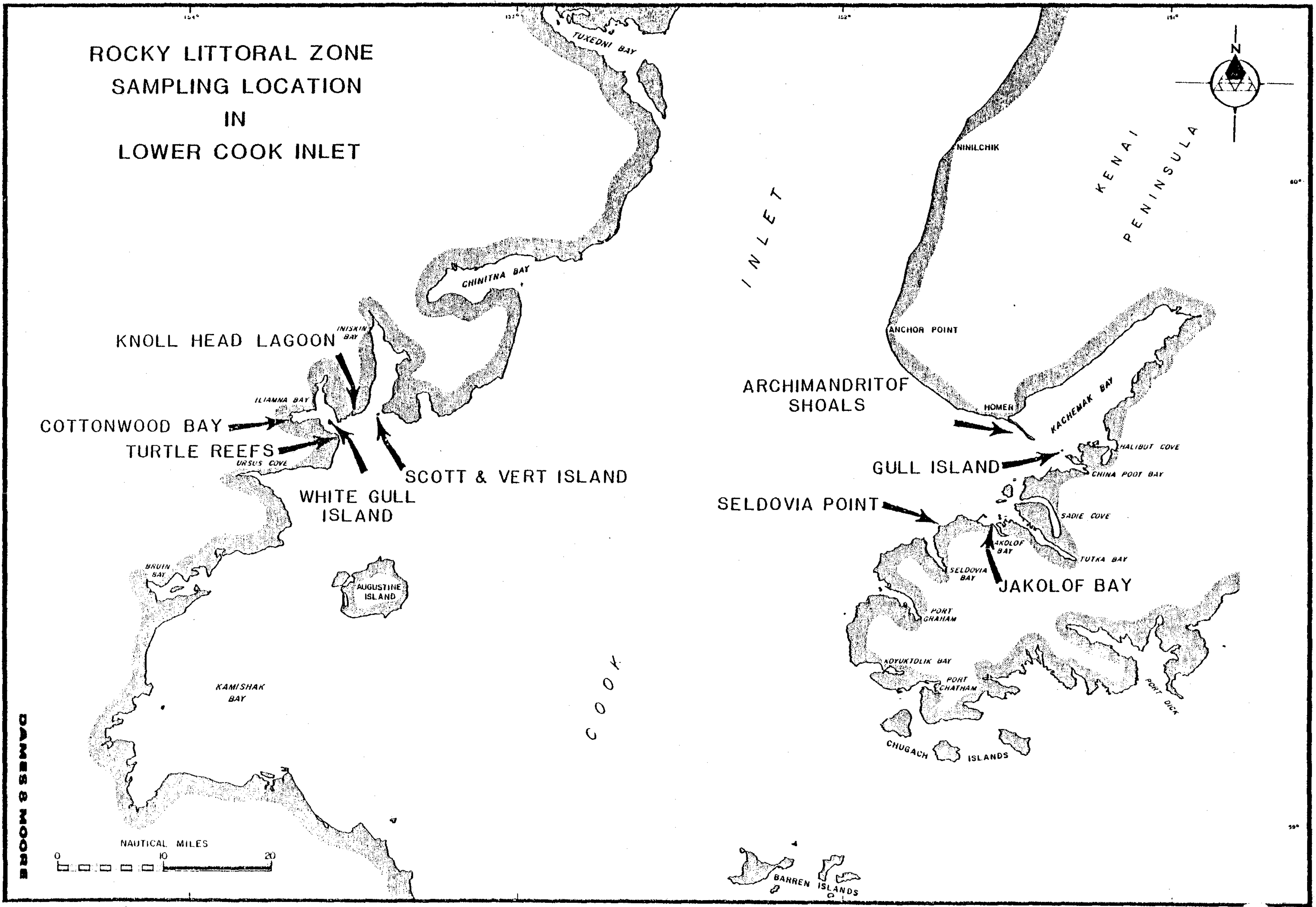
2.0 PHYSICAL SETTING

Cook Inlet is a large tidal estuary located on the northwest edge of the Gulf of Alaska in south-central Alaska. The axis of the inlet trends north-northeast to south-southwest and is approximately 330 km long, increasing in width from 36 km in the north to 83 km in the south. The inlet is geographically divided into the upper and lower portions by the East and West Forelands. The inlet is bordered by extensive tidal marshes, lowlands with numerous lakes, and glaciated mountains. Large tidal marshes and mud flats are common along much of the western and northern margins of the upper inlet. Tributary streams are heavily laden with silt and seasonally contribute heavy sediment loads, especially in the upper inlet. The range of the semi-diurnal tides is extreme with a normal amplitude of 9 m (30 ft) at the head of the inlet. Tidally generated currents are strong. The general net current pattern brings oceanic water through Kennedy Entrance and northward along the east side of the inlet. Turbid and usually colder waters from the upper inlet move generally southward along the west side of the inlet and through Kamishak Bay, leaving the inlet through Shelikov Strait (BLM 1976). It has been suggested, however, that a considerable proportion of the oceanic water entering Cook Inlet on an incoming tide is pumped back out on the subsequent outgoing tide (BLM 1976). During the winter and spring, ice conditions are much more harsh on the west side of the inlet. Thus, the oceanographic conditions on each side of the inlet are significantly different, resulting in notable differences in the nature of shallow water biological communities.

2.1 EAST SIDE OF INLET - ROCK

2.1.1 Gull Island

Gull Island is a series of rocky inlets located less than 4.8 km southeast of Homer Spit (Figure 2-1). The highest recorded land elevation on the island is 26 meters above sea level.



ROCKY LITTORAL ZONE
SAMPLING LOCATION
IN
LOWER COOK INLET

DAMES & MOORE

FIGURE 2-1

Gull Island is a well known landmark to local residents because it is a nesting colony for sea birds. Peak usage by common murres, black-legged kittiwakes, and three species of cormorants is during the late spring and summer. The estimated population of birds on the island was 3,724 nesting pairs of birds in a 1976 census (Erikson 1977). Heavy sea bird utilization is obvious from the vast amount of bird excrement that forms a chalky-white discoloration below the roosting and nesting sites.

The study site on Gull Island was on a steeply sloping rock islet at the extreme southwest end of the island. This rock, named "Gorilla Rock" because of its silhouette when viewed from the west (Dames & Moore 1976), rises approximately 14 meters above mean lower low water (MLLW). At extreme low tides, approximately 4.85 meters (16.0 feet) of the macrophyte zone are exposed to the atmosphere. Below the littoral zone, the sea floor is composed of exposed bedrock that abuts the vertical rock face; farther offshore are found outcroppings and channels. At depths of 12-50 meters below MLLW is an expanse of silty clay.

Sampling at Gull Island was conducted on a transect established in 1974 (Dames & Moore 1976) down the southwest rib of this rock pinnacle by permanently placed pins at 0, 5, 10, 15, and 20 m from the upper edge of the littoral zone. The upper portion of the transect (0 to about 8 m) sloped steeply to a relatively low level, but narrow bench extending to the 20-m pin (Figure 2-2). Beyond this pin the bench dropped sharply about 1 m to a second algal cover bench. The approximate elevations of the fixed pins were 0 m: +3.8 m MLLW; 5 m: +1.5 m MLLW; 10 m: +0.5 m MLLW; 15m: +0.2 m MLLW; 20 m: +0.0 m MLLW (Dames & Moore 1976).

This study area can be classified as semi-protected in terms of exposure to oceanic conditions because the transect is exposed to some ocean swells coming into Kachemak Bay as well as wave action generated by local winds. As a result of tidal emersion, the littoral zone is frequently exposed to summer desiccation and winter freezing. Abrasion by floating ice is minimal, however. Strong currents move by the island four times a day and surface waters are typically somewhat turbid, especially during the warmer months when several nearby glacial streams are flowing.

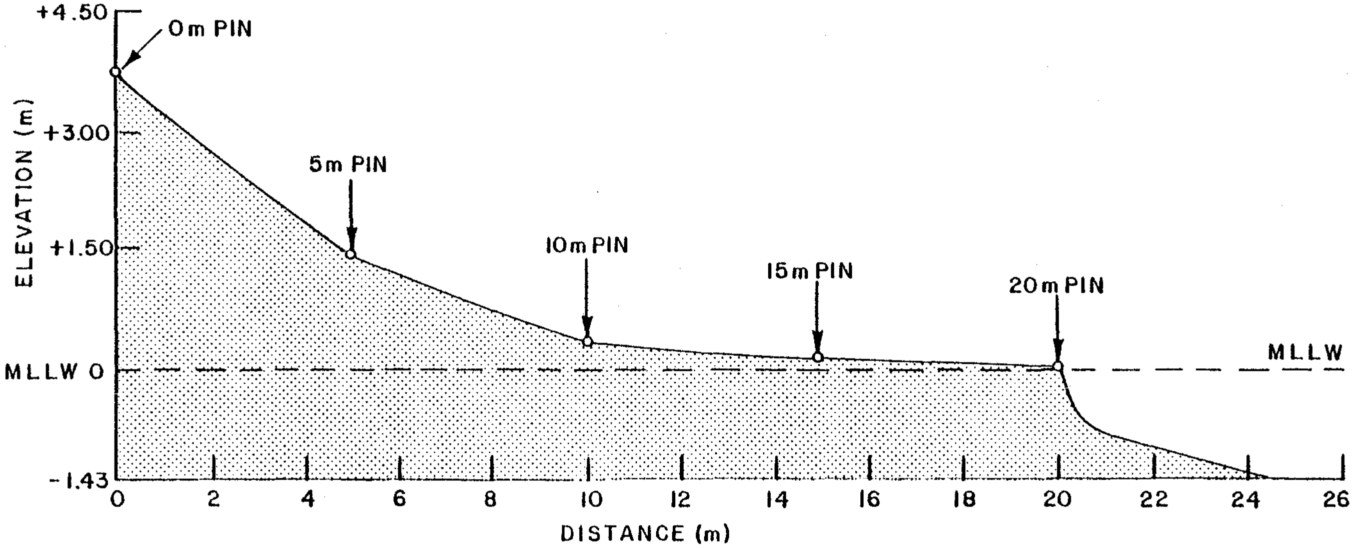


FIGURE 2-2

PROFILE OF PERMANENT TRANSECT ON GORILLA ROCK, GULL ISLAND

2.1.2 Archimandritof Shoals

The north side of Kachemak Bay west of Homer Spit is occupied by a broad, rocky shelf extending from Archimandritof Shoals, off the west side of Homer Spit, northwestward a distance of approximately 37 km (Figure 2-1). The shelf measured to the dramatic escarpment near the 18 km (10-fathom) isobath ranges from a minimum of about 2 km at Bluff Point to about 6.5 km at Anchor Point.

Surficially, the substrate of the shelf is a relatively flat bed of rock, cobble, boulders, and shell debris. The rock matrix was well consolidated by fine, silty sand and shell debris; small to medium boulders were scattered throughout the area. In several areas, the reefs or boulders are composed of coal (Dames & Moore 1976). Evidence of silt deposition varies locally on the shelf, being greatest from Archimandritof Shoals west to Bluff Point, perhaps in response to weaker currents and higher turbidities observed in this area (Dames & Moore 1976). Several sampling sites were examined in the Archimandritof Shoals study area (Figure 2-1). These ranged from about 1 km to about 5 km from the end of Homer Spit.

2.1.3 Jakolof Bay

Jakolof Bay, less than 0.5 km wide and only about 3.25 km long, is located on the south side of Kachemak Bay, approximately 18.5 km due south of the City of Homer (Figure 2-1). The bay is generally shallow and has a narrow entrance less than 11 meters deep. The head of the bay is shallow and fed by a freshwater stream. The shoreline is rocky and wooded.

Most observations and underwater sampling were confined to the shallow reef that projects off the rocky headland on the northwest side of the bay. This area has been studied since 1974 (Dames & Moore 1976). This reef, marked by a small islet, nearly occludes the entrance to the bay. An overhead power transmission line crossing the reef is another useful landmark. A prominent kelp stand grows along the reef with its floating canopy usually visible on a slack tide. The substrate underlying the vegetative canopy is composed of bedrock, cobbles, and small to medium sized boulders (Dames & Moore 1976). Slope is moderate and surface relief is somewhat terraced. Fine sands and calcareous shell debris are conspicuous features at certain locations on the reef. Strong tidal currents are typical of this location. On either a flood or ebb tide the floating portion of the kelp bed is usually pulled below the sea surface. The currents generated during spring tide cycles are estimated to range between 2 and 3 knots. Subsurface water movement is greatest across the rock reef. This observation has been substantiated by the proliferation of suspension feeding forms (i.e., sea anemones, barnacles, sabellid polychaetes, and nestling clams), which were visual dominants at this location and depth (Dames & Moore 1976).

Steel bands and bark from floating rafts of logs being transported out of Jakolof Bay have accumulated on the sea floor. Since 1974 these objects have continued to collect on the reef; accumulation and decay rates of these materials are unknown (Dames & Moore 1976).

2.1.4 Seldovia Point

Seldovia Point is a prominent land projection on the southern side of Kachemak Bay northeast of the entrance to Seldovia Bay (Figure 2-1). The intertidal zone is composed of cobbles, boulders, and rock pavement. Shallow surge channels are prominent features of the lower rock bench. A cliff approximately 60 meters in elevation rises sharply from the rocky shoreline (Dames & Moore 1976). The boulder field at the base of the cliff is apparently replenished by erosion and subsequent landslides from the cliff. Boulders produced by the sloughing eventually weather and break down. The finer materials are washed away, leaving the bedrock and coarser materials in the littoral zone. The rock bench and boulder field continues into the sublittoral zone adjacent to Seldovia Point. Exposed bedrock, cobbles, and expanses of sand are characteristic features of the sea floor. Shell debris is moderate in this location.

The largest and most conspicuous kelp bed in Kachemak Bay is found in the vicinity of Seldovia Point. From 1974 through 1978 a major part of the kelp bed has been located off the northeast side of the point (see Dames & Moore 1976) with a narrower arm extending southward into Seldovia Bay. There is historical evidence for the occurrence of the Seldovia kelp bed since the early 20th century (Rigg 1915).

Sampling was conducted along a permanently marked transect (Dames & Moore 1976) extending NNW along the major axis of the point. The levels sampled in 1977 and the three levels sampled in 1978 ranged from near MLLW to about +3 m MLLW (Figure 2-3). The near-shore subtidal zone was sampled from the intertidal-subtidal fringe out to the 18 fathom contour, approximately 2.7 km offshore. Seldovia Point is strategically located in terms of exposure to the surface waters of Lower Cook Inlet, receiving the full impact of northerly or northwesterly swells from the upper inlet, or swells have curved around from waves coming through the ocean entrances. Wave activity frequently amounts to only a moderate onshore break. During late spring and summer the fringing kelp bed probably dampens some of the sea surface water movement in the vicinity of the point (Dames & Moore 1976). However, conditions in fall and winter are somewhat more rigorous. Inshore currents are typically strong, especially during periods of spring tides. Silt is prominent on most of the solid substrate and associated vegetation in the sublittoral zone.

2.2 WEST SIDE OF INLET - ROCK

2.2.1 Scott Island

Scott Island is a low, relatively flat island of moderate size (30 hectare) on the east side of the entrance to Iniskin Bay (Figure 2-1). Large reefs marked by a number of small islets and emergent rocks provide the shorelines of the island considerable protection from the oceanic swells crossing Lower Cook Inlet from the ocean entrances, especially during low tides. The island is heavily wooded and is protected around much of its perimeter by steep cliffs, some 30 m in

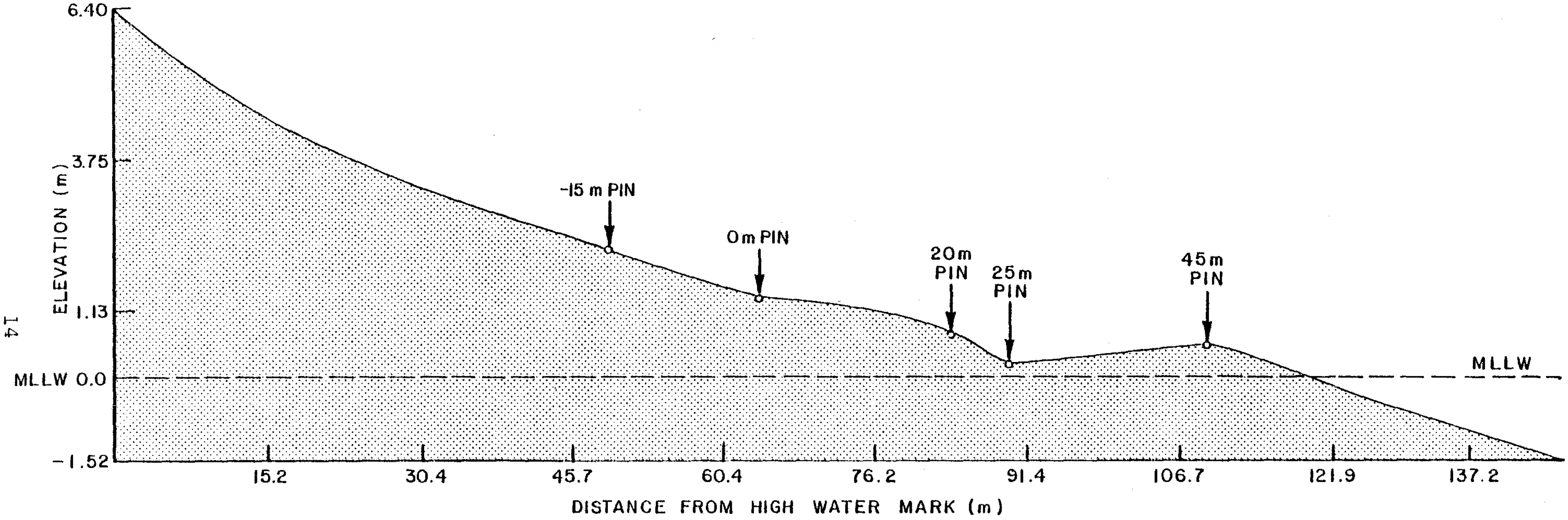


FIGURE 2-3

PROFILE OF PERMANENT TRANSECT AT SELDOVIA POINT height, that extend well down into the intertidal zone. Small gravelly beaches on the landward (NE, N, and W) sides of the island provide a boat landing and access to the wooded top of the island.

A transect was laid out in April 1978 across the intertidal zone of the southernmost corner of the island. From the base of the cliff the transect crosses a rock bench sloping generally seaward. The transect is cut by several shallow surge channels and two major lateral ridges. The upper level sampled is located shoreward of the uppermost ridge in the approximate center of the Fucus zone. The middle level sampled was on the seaward face of the second ridge in the center of the Rhodymenia zone. The lowest level sampled was on a lower bench at about -0.5 m MLLW. Several large shallow tide pools were scattered about this bench. Below this level, scattered channels of shelly gravel and sand interspersed with bedrock extended subtidally. Bedrock of Scott Island consists of a conglomerate of fist-sized or larger cobbles firmly cemented in a hardened sandy matrix. Very little loose material or even boulder-sized rocks are present except in the channels. Subtidally, scoured sand predominated and rock was limited to scattered medium to large boulders extending up to 2 m above the sand.

2.2.2 Vert Island

Vert Island is a small low island of bedrock situated 0.3 km south-southwest of Scott Island on the east side of the entrance to Iniskin Bay. The channel separating these islands is about 6 m deep. Maximum elevation is about 10 m. The flattened top of the island is grass covered and used extensively for nesting by glaucous-winged gulls, tufted puffins, and common eiders.

2.2.3 Knoll Head Lagoon

Knoll Head is a rocky headland rising steeply to 890 m in elevation on the west side of the entrance to Iniskin Bay. The complex shoreline west from the mouth of Iniskin comprises vertical rock cliffs, angular sea stacks, rocky islets and reefs; just east of the major unnamed stream between Knoll Head and Iliamna Bay are two moderate-sized embayments with gravel and even muddy sand beaches alternating with vertical rock faces. East of these bays is a less protected cove opening to the south that we have named Knoll Head Lagoon (Figure 2-1).

The study transect began at the base of a 5- to 6-m cliff rising to tundra and alder thickets above. The transect crossed an undulating bedrock beach comprising a descending series of rock benches separated by lower lying channels. The upper level sampled was on a rock "hogback" in the area of maximum *Fucus* cover. The middle level was on a lower, more gently rounded ridge. This level was largely in the *Rhodymenia* zone. However, drier outcrops supported considerable *Fucus*, while wetter pockets and channels were dominated by *Laminaria*. The lowest level sampled was also in the *Rhodymenia* zone on a similar but smaller rounded rock ridge at about MLLW. Below MLLW a series of low bouldery tide pools broke up the beach pattern.

Offshore, a series of low reefs oriented nearly parallel to shore protects these beaches from the southerly swells originating at the ocean entrances, except when the tide is fairly high.

Subtidal surveys were conducted between the intertidal zone and the offshore reefs. Bedrock extends down to a depth of about 6 m, where silty gravel becomes the dominant substrate.

2.2.4 White Gull Island

White Gull Island is a small low-lying island situated in mid-channel just inside the entrance to the Iliamna-Cottonwood Bay complex (Figure 2-1). The protected western and northern sides of the island have moderately sloped beaches of cobble, gravel and coarse sand interspersed with bedrock ribs and outcrops. The eastern shore, facing Lower Cook Inlet, has little protection from swells coming through the ocean entrances. This beach consists of a coarse cobble upper beach and an irregular lower bedrock bench punctuated with pinnacles and outcrops and interspersed with channels and tide pools. The pinnacles and outcroppings provide some protection for the cobble upper beach.

The study transect was on the exposed east side of the island. It ran due east across the bench between two elevated rock outcrops that extend to near or above the high tide line. Permanent markers (20-cm steel spikes) were placed at two levels. The upper level was in the *Fucus* zone on an irregular rock bench with ridges and gullies varying in elevation by up to 1 m. The lower level was on a relatively flat rock bench outside of the protecting rock pinnacles. This bench was near or slightly above MLLW but contained numerous tide pools and channels. The outer lip of this bench is a vertical to overhanging precipice dropping to a depth of about 10 m. From the base of this wall, a talus bottom with small to large boulders sloped down to about 13 m. Diving surveys were conducted mainly along the base of the wall on the talus slope. Because of the steepness and irregularity of the habitat, the complexity of the fauna, and the degree of siltation, quantitative work was not attempted.

2.2.5 Turtle Reef

Turtle Reef is a series of rock reefs and outcroppings fringing the shore of South Head, the southern headland guarding the entrance to Iliamna Bay (Figure 2-1). The reef extends to about 1 km offshore and most of the rocks are emersed at low tide.

2.3 SOFT SUBSTRATES IN LOWER COOK INLET

Hayes et al. (1977) provides useful characterizations of numerous beaches on both sides of Lower Cook Inlet. Most of the beaches from Kachemak Bay north, on the east side of the Inlet, are characterized by a narrow, fairly steep, unstable, gravel beach face extending down to an elevation of from about two feet to MLLW and a broad, flat, more consolidated fine sand low-tide terrace extending out into the subtidal zone (Figure 2-4). The boundary between the gravel and sand facies is generally sharply demarcated by changes both in slope and substrate. However, in some locations, it is interrupted by a narrow band of small boulders. In many instances, a small water-filled trough also occurs at the boundary, apparently as a consequence of the water draining out of the gravel slope above. This trough produces small drainage channels running perpendicularly to the shoreline at intervals along the beach (Figure 2-4).

The beaches initially selected for study in Lower Cook Inlet and discussed herein include two of sand and one of mud. The sandy beaches

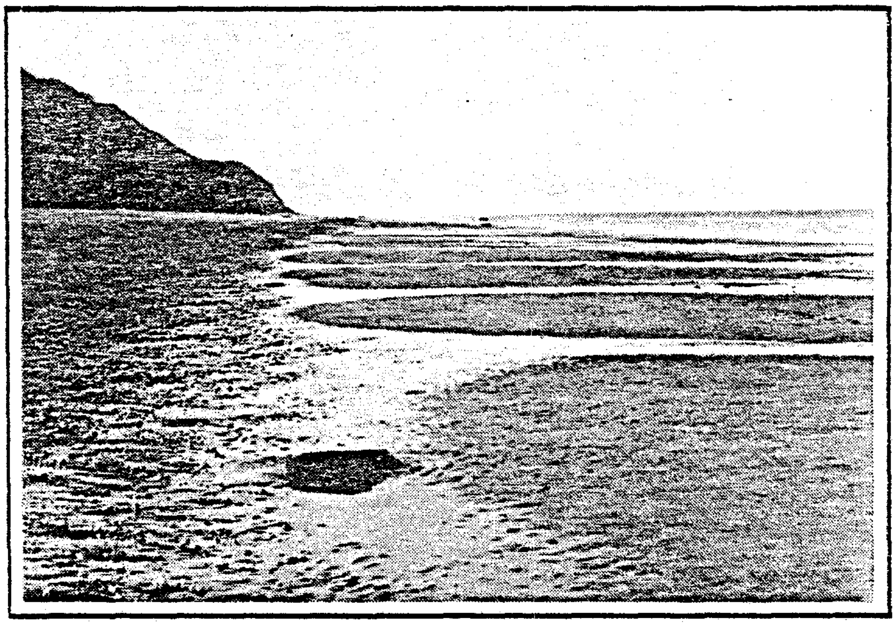


FIGURE 2-4 - VIEW OF BEACH AT DEEP CREEK, SHOWING STRUCTURE OF THE FORESHORE IN 1977 are located on the east side of Lower Cook Inlet (Figure 2-5). Both were accessible by vehicle. The Deep Creek site is fairly representative of beach conditions between Anchor Point and Clam Gulch. We selected the Homer Spit site because it appeared to support a richer fauna and higher standing stock than Deep Creek. The mud flat site is at Glacier Spit, Chinitna Bay, on the west side of the Inlet (Figure 2-5). It was chosen because it is typical of mud flats on the west side, has a year-round resident and shelter (Dames & Moore, 1977).

2.3.1 Sand Beaches - Homer Spit and Deep Creek

The sandy beaches are located on the east side of Lower Cook Inlet (Figure 2-5). Both were selected for accessibility. Based on his razor clam surveys, Mr. David Nelson, ADF&G (personal communication), indicated

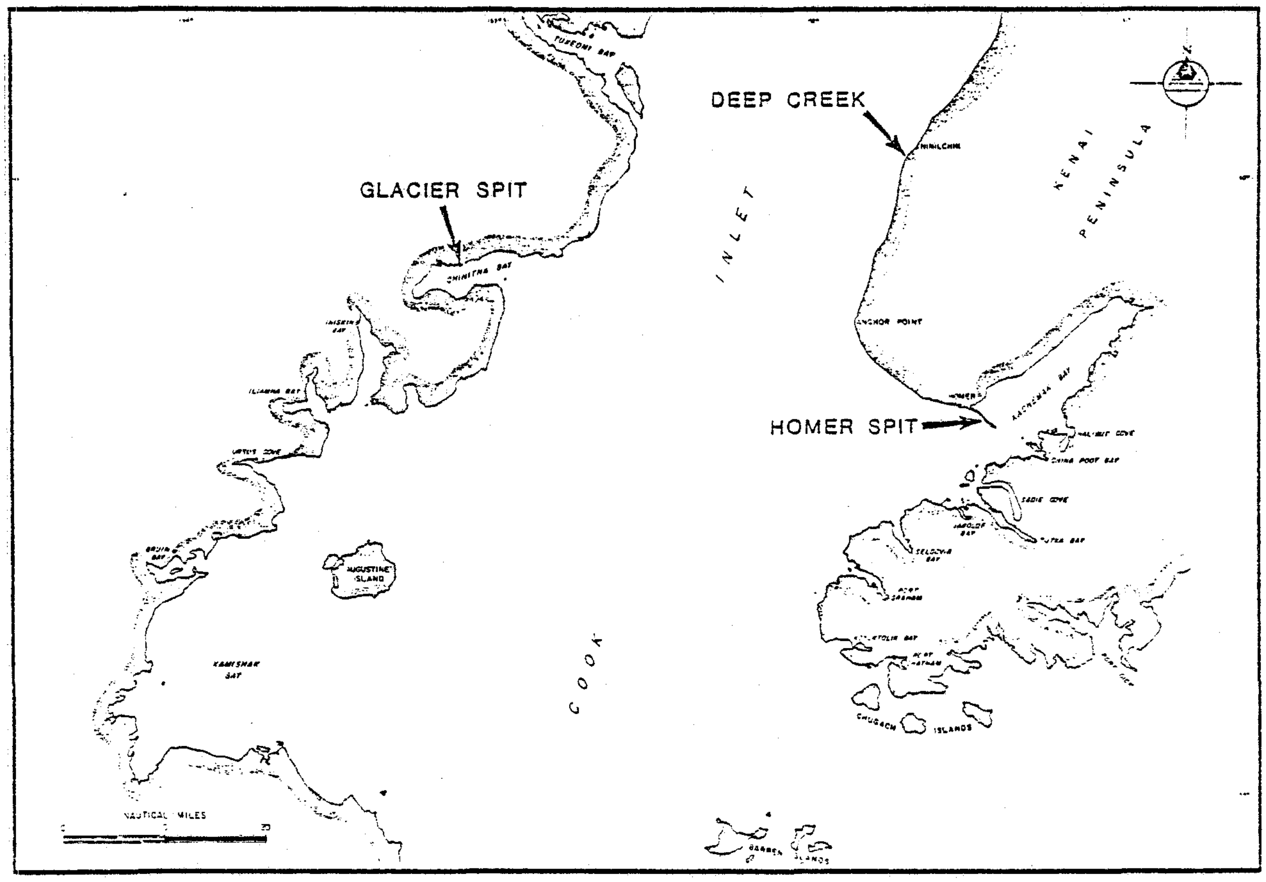


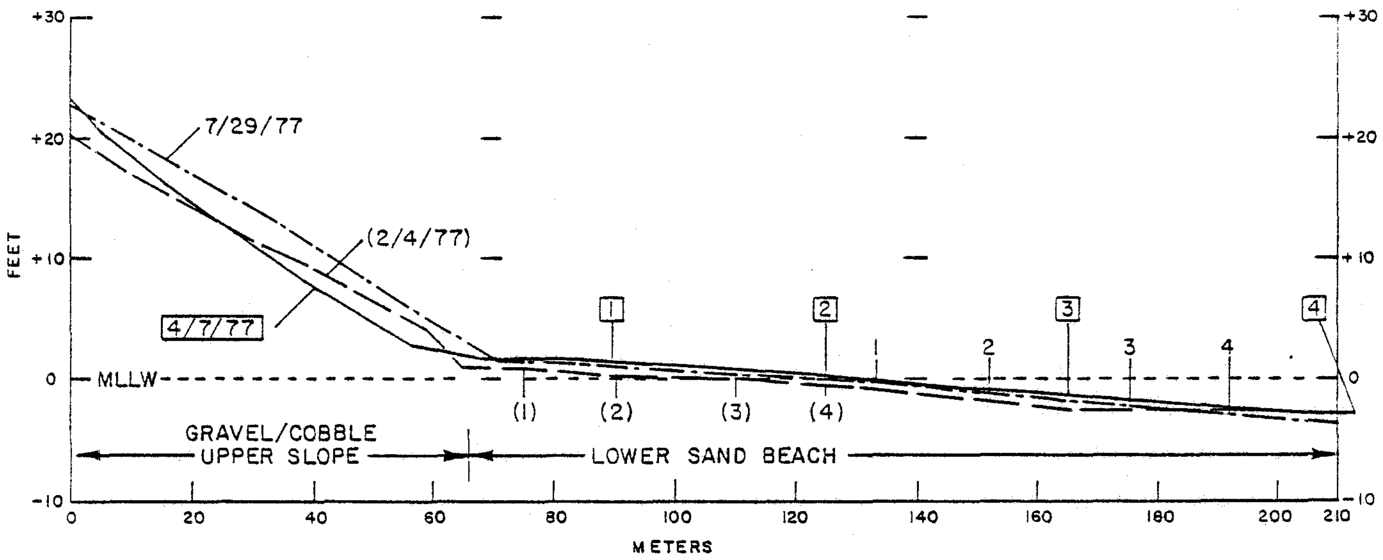
FIGURE 2-5 - SOFT SUBSTRATE LOCATIONS IN LOWER COOK INLET that the Deep Creek site, 1.5 miles south of the beach park, is fairly representative of beach conditions between Anchor Point and Clam Gulch. The base point for the transect is a room-sized triangular boulder at the base of the bluff (an erosional scarp). We selected the Homer Spit site, 2.5 miles south of the Kachemak Drive, because it appeared to support a richer fauna and higher standing stock than the Deep Creek site.

Corrected beach profiles for the Deep Creek and Homer Spit sites (Figure 2-6) provide two important pieces of information. First, it appears that the shape of the beaches change very little seasonally compared to beaches exposed to the open ocean (Bascom, 1964).

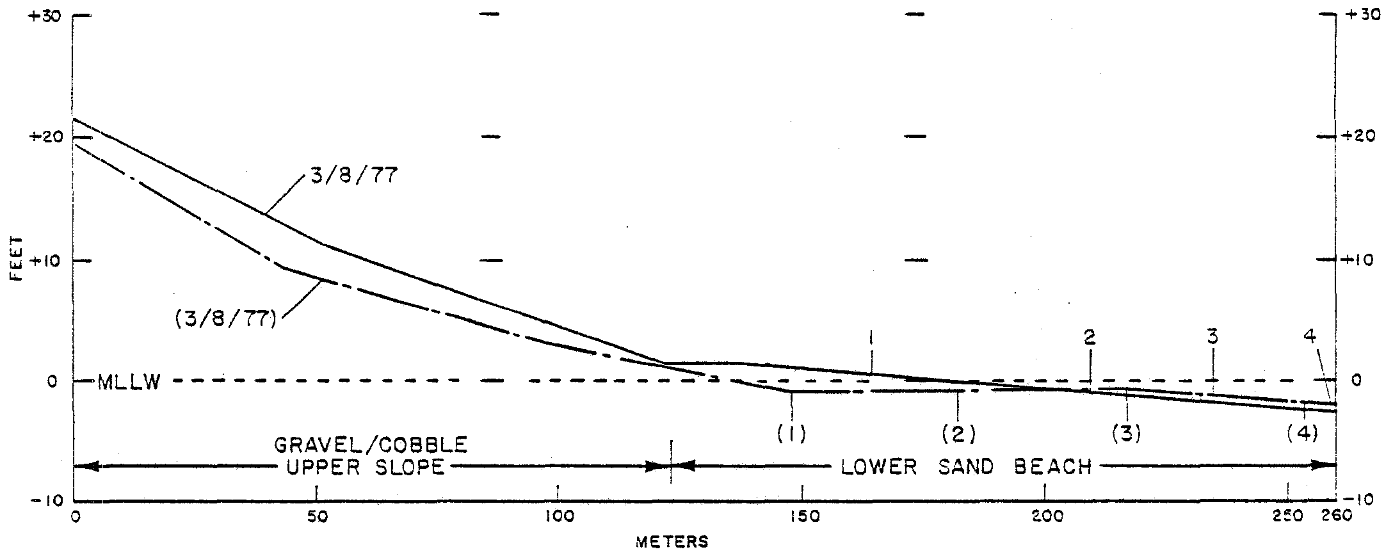
However, because of large inaccuracies in the original profile data, the accuracy of the corrected profiles is undetermined. Our notes and recollections of fixed features on the beach lead us to accept the general shape of the profiles, but to question the changes recorded for the gravel upper slopes at both sites.

Second, the gravel upper beach is considerably steeper at Deep Creek than at Homer Spit. According to Bascom (1964) this indicates that the beach at Homer is somewhat less exposed than at Deep Creek. Shepard (1963) also points out that the beach at Homer should be coarser and more porous.

Based on sediment samples collected at two levels from both lower beaches, sediment conditions are quite similar (Table 2-1). The sand may be slightly coarser at Homer Spit than at Deep Creek. The sediment in both areas is a moderate to well-sorted fine to medium sand with a significant quantity of small gravel; fine sand was mainly found at the lower levels. Also, thin strata of pulverized coal were common at both beaches. Evidence of anoxic conditions (blackened sand or sulfide odor) was lacking at both sites.



DEEP CREEK



HOMER SPIT

FIGURE 2-6
BEACH PROFILES FOR DEEP CREEK AND HOMER SPIT

TABLE 2-1. SEDIMENT PARAMETERS FOR SAND BEACH SAMPLING SITES IN LOWER COOK INLET, MAY 1978.

Location	Grain Size M_d (mm)	 M (mm)	Dispersion $\sigma\phi$	 $\alpha\phi$
Homer Spit - 30m level				
Replicate 1	0.24	0.24	0.39	0.06
2	0.28	0.28	0.54	0.04
3	0.35	0.41	0.70	-0.31
$\bar{x}$	0.29	0.31	0.54	-0.07
s	0.06	0.09	0.16	0.20
Homer Spit - 135m level				
Replicate 1	0.21	0.22	0.45	-0.14
2	0.25	0.25	0.56	-0.01
3	0.22	0.24	0.57	-0.19
$\bar{x}$	0.23	0.24	0.53	-0.11
s	0.02	0.02	0.07	0.09
Deep Creek - Level 1				
Replicate 1	0.26	0.27	0.50	-0.10
2	0.28	0.28	0.45	0.01
3	0.24	0.25	0.56	-0.17
$\bar{x}$	0.26	0.27	0.50	-0.09
s	0.02	0.01	0.06	0.09
Deep Creek - Level 3				
Replicate 1	0.22	0.21	0.40	0.06
2	0.21	0.20	0.48	0.05
3	0.21	0.20	0.42	0.06
$\bar{x}$	0.21	0.20	0.43	0.06
s	0.01	0.01	0.04	0.01

2.3.2 Mud Flat at Glacier Spit, Chinitna Bay

The mud beach study site is adjacent to the Byer homestead, on Glacier Spit, Chinitna Bay, on the west side of the Inlet. It was chosen because it is a typical mud flat, and has a year-round resident and shelter. The base point for the transect is a solitary group of large boulders at the border between the gravel upper slope and the mud low-tide terrace.

The basic structure of the beach at the Chinitna site is similar to that described for the two sand beaches (Figure 2-7). An important difference is the flatter slope of the mud flat. However, the slope of the gravel upper beach at Glacier Spit is steeper than at either sand beach site.

Sediment samples from Glacier Spit have not yet been processed. However, the sediment is basically a sandy silt with appreciable clay. It appears to be moderately well consolidated. Evidence of anoxic conditions (blackened sediment and shells, odor of sulfides) occur within 10 cm of the surface.

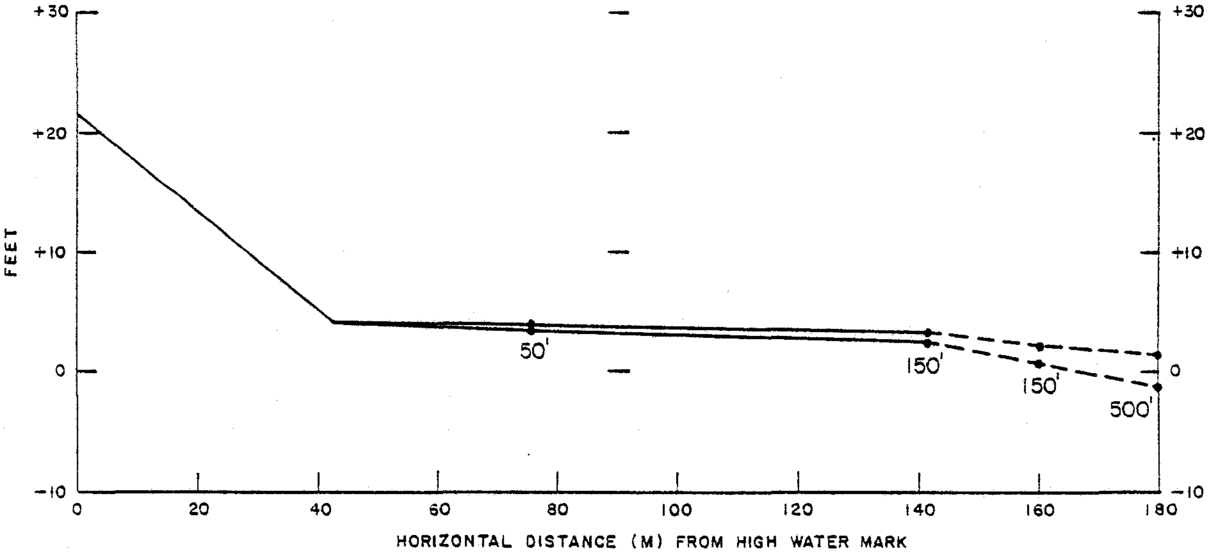


FIGURE 2-7 - ESTIMATED BEACH PROFILE FOR GLACIER SPIT, CHINITNA BAY

2.3.3 Sampling Levels

At the Homer Spit and Chinitna Bay sites, the sampling levels were established at predetermined distances from the gravel-sand interface. The location of these levels and their approximate elevations are indicated in Table 2-2.

At the Deep Creek site, we attempted to locate the levels according to predetermined elevations, specifically, MLLW, -1, -2 and -3 feet below MLLW. This was not successful because of the various sources of error inherent to the surveying method used and the unreliable or incomplete nature of the tidal information upon which we operated. The approximate elevations sampled at Deep Creek are indicated in Table 2-3.

On the sand beaches, neither of these methods of relocating sampling levels was completely satisfactory but the method used on the mud flat was satisfactory. A major technical problem on sand beaches is that the movement of the sand associated with changes in profile or elevation will cause some animals (e.g., amphipods) to relocate quickly to a suitable elevation but others such as deep-burrowing polychaetes cannot respond rapidly. Therefore, sampling at a set distance from a known point permits reasonable samples of polychaete populations, but any seasonal changes in elevation may cause problems for sampling amphipods. On the other hand, sampling at pre-determined elevations appears difficult to accomplish and also can result in large differences in the horizontal position of sequential sample sets at the same level. This would preclude sampling the same polychaete populations.

A completely satisfactory solution to this problem seems unlikely. However, based on the preliminary information that seasonal changes in the beach profiles are small, it seems most acceptable to sample at given distances from a fixed feature on the beach.

2.3.4 General Environmental Conditions

A comparison of environmental conditions at the three sites reveals some distinct differences. The factors considered are sediment tempera-

TABLE 2-2. LOCATION AND APPROXIMATE ELEVATION OF SAMPLING LEVELS AT HOMER SPIT AND GLACIER SPIT, CHINITNA BAY, 1977.

	Homer Spit			Glacier Spit, Chinitna Bay	
Sampling Level	Distance from Interface (meters)	Approximate Elevation (feet) 3/8/77	7/28/77	Distance from Interface (meters)	Approximate Elevation (feet)
1 (Upper)	30	+0.75	-1.0	50	3.8 to 3.6
2	75	-0.75	-0.75	150	3.25 to 2.5
3	100	-1.75	-0.5	350	2.1 to 0.9
4 (Lower)	135	-2.5	-1.5	500	1.3 to -1.2

TABLE 2-3. VARIATION IN APPROXIMATE ELEVATION (FEET) OF SAMPLING LEVELS AT DEEP CREEK IN 1977.

Sampling Level	2/4/77	4/7/77	7/29/77
1 (Upper)	+1.0	+1.5	0.0
2	+0.5	+0.5	-1.0
3	0.0	-1.25	-2.0
4 (Lower)	-0.5	-2.75	-2.75

ture, ice cover and scour, salinity, turbidity, wave action and tidal currents. The comparisons are qualitative and frequently based on inference.

Severe winter air temperatures are somewhat lower at Chinitna Bay and Deep Creek than at Homer Spit. Surface sediment temperatures at the Spit are probably less severe during night low tides than at the other two sites. Chinitna Bay may also experience stronger winds than the other sites, causing greater wind chill effects. The surface layer of sediment freezes at all three sites during low tides in late fall and winter, but our impression is that it freezes deeper at Chinitna.

The scouring effects of sea ice range from substantial at Chinitna to low at both Deep Creek and Homer Spit. Wayne Byer, a resident on Glacier Spit, reports that during winter low tides, thickness of stranded ice approaches 2 m opposite his homestead (personal communication). In contrast, stranded ice blocks are not common at either of the sand beaches, but can occur during harsh winters. Floe ice at Glacier Spit may protect the sediment from extremely low temperatures in many cases, but can scour extensively.

Based on location, it would appear that salinity would be highest, and least variable, at Homer Spit, and lowest and most variable at Glacier Spit, which is essentially estuarine and situated in a bay near a number of streams. This inference is supported by the salinity patterns described by Kinney et al. (1970).

Our observations indicate that turbidity (suspended solids) is lowest, but highly variable, at Homer Spit, and highest and least variable at Glacier Spit. This agrees with the basic pattern reported by Sharma et al. (1974).

Wave action is a powerful influence at both Homer Spit and Deep Creek. Homer Spit has a maximum fetch for direct wind waves of 100 miles, and is only slightly protected from waves generated in Skelikof Straits. Breakers up to 2.5 m high have been observed there, and Hayes et al. (1977) predicts 3 m. However, Homer Spit is generally protected from northerly storms. Although Deep Creek is exposed to waves from south, west and north, and so is probably disturbed by wave action more regularly, the maximum fetch for direct waves is only about 30 miles. Because the stronger north and south waves will approach at an oblique angle, their force will be greatly reduced. Glacier Spit is generally protected from all but waves from the southeast, and surf over 1 m high is probably rare.

The influence of tidal currents varies greatly among the three sites. Exposure is greatest at Deep Creek, as it is located directly on the shoreline of the Inlet. The Homer Spit site is only slightly affected by tidal currents because of the protection provided by the Spit, particularly during outgoing tides. Glacier Spit, located near the head of Chinitna Bay, is subjected to only minimal tidal currents.

The differences in exposure to wave action and tidal currents are clearly reflected in the contrasting sediment regimes at Homer Spit and Deep Creek, on one hand, and Glacier Spit, on the other. Furthermore, slope of the upper beach indicates that Homer Spit is exposed to heavier surf; fall storms are particularly strong. However, tidal currents are stronger at Deep Creek and occur four times daily, so their overall effect may be greater.

3.0 METHODS AND MATERIALS

Methods used to sample rocky littoral substrates in Lower Cook Inlet during 1977 and 1978 largely evolved from techniques used by Dames & Moore (1976, 1977) in previous surveys in the area. Based on results from these early works, methods were trimmed to distribute field and laboratory effort more efficiently and tailored to focus on the major objectives of the continuation studies.

3.1 DISTRIBUTION AND ABUNDANCE - ROCKY SUBSTRATES

A variety of techniques was used to document the distribution and abundance of littoral organisms. At all of the intertidal and some of the subtidal sites described in Section 2.0, sampling was focused on permanently marked transects at discrete intertidal levels or subtidal depths.

3.1.1 Quadrat count and removals

A stratified random sampling design was used to gather the majority of distribution and abundance information obtained in this study. At each level to be sampled a 30- or 50-m tape was laid out along the beach or depth contour perpendicular to the transect. Intertidally, square, quarter-square meter quadrats were positioned along the tape (the sampling transverse) at locations dictated by random numbers. From each quadrat the following information was recorded:

a) density and/or percent cover of individual algal species
b) percent cover of sessile or colonial animals (barnacles, mussels, bryozoans, sponges, etc.)
c) numbers of other macrofauna

Moreover, these quadrats were used to obtain samples to estimate plant biomass. During 1977 all nonencrusting algae were removed from the quadrats sampled at Gull Island and Seldovia Point. These samples were placed in distinctly labelled bags and returned to the laboratory for length and/or weight measurements. During 1978, algal removal was terminated at Gull Island because of our concern over sampling effects due to the limited size of the study site. Also during 1978, other changes in the seaweed removal program were instituted to increase efficiency at Seldovia Point. Only Fucus was removed from the upper level (+2.1 m), all algae were removed from the +1.4 m level, and only brown algae were removed from the lowest level (0.0 m). Data from 1977 had previously indicated that these groups included the vast majority of algal biomass at these levels. At the intertidal sites on the west side, only Fucus was removed from upper level quadrats and all algae were removed from middle and lower level quadrats.

Subtidally, the quadrat size used for estimating densities of plants, invertebrates, and fish ranged up to 50 m^2 depending on the size and density of the various target species because it was not practical to gather all of the above data from a single-sized quadrat. For the larger quadrat sizes (usually 2.5, 5, or 25 m^2), organisms along the transect line were enumerated by delimiting the prescribed area along the transect line with a hand-held staff 0.5 m long. The diver would move the staff perpendicularly along the transect line for a set distance (e.g. 5 m), counting all individuals of a given species in the path of the staff.

Fish densities were assessed by this same method using 25 or 50 m^2 quadrats. Generally, the diver would count the more motile species (e.g. greenling) on a quick pass along the transect line, and then count the more sedentary or cryptic species during a return pass along the line.

We attempted to obtain 10 replicates of the 0.25 m^2 quadrats at each zone or level sampled in order to obtain reliable estimates of density, relative cover, and biomass of the major species present. The desire was to reduce variance to the lowest practical level. However, the number of replicates was often reduced because of the constraints imposed by water and tide conditions, available working time, weather, boat safety, etc. Working time at intertidal sites was controlled by emersion periods and, at subtidal sites, by the duration of slack tidal currents.

Generally, sampling adequacy was examined by a comparison of the mean and variance of a parameter. Collection of replicate samples provides an estimate of the sampling distribution. Subsequent comparison of sampling distributions from two or more sampling periods by one of a number of statisical tests permitted evaluation of the observed differences. We routinely used a significance level of $\alpha = 0.05$ to decide if a difference was real and due to natural changes or sampling variability. This is a relatively simple procedure in population studies. However, it is not really practical for broad, descriptive ecological assessments where densities of important species may range from less than $1/m^2$ for large plants and predators more than $1,500/m^2$ for mussels, etc., and biomass of functionally important species may range from $20\ gm/m^2$ to over $50\ kg/m^2$. Because temporal and financial constraints limited sampling severely, our ability to detect differences between natural and sampling variability was limited. However, despite this limitation, changes were so dramatic that identification of seasonal and bathymetric patterns for dominant species was often possible. Selected specimens of flora and fauna were preserved for taxonomic verification and added to the reference collection from previous studies in Kachemak Bay and Lower Cook Inlet.

3.1.2 Color photography

The appearance of the intertidal zone was recorded photographically during each sampling period on 35-mm color slides. At each fixed pin on the intertidal transects, photographs were taken of a $0.25\ m^2$ quadrat in a fixed position relative to the pin; the same beach surface area was photographed each time. An electronic flash was used during periods of poor ambient lighting.

3.1.3 Laboratory techniques

The algal samples removed from the quadrats were returned to the laboratory where they were sorted to species or major taxon. In 1977 red and green algae were then weighed wet and recorded by the lowest practical taxon. Because separation of the red and green algae was quite time-consuming and appeared to contribute only minimally to our objectives in 1978, we separated those groups only to major taxon (Rhodophyta and Chlorophyta) and measured aggregate wet weights. Brown algae were separated by species both years. For the laminarians, stipe and total length and whole wet weight were measured for individual plants to provide data on age-stucture and length-weight relationships. In 1977 aggregate weights were obtained for Fucus, but in 1978 we obtained individual plant weights as well.

3.2 GROWTH

Information on growth and growth rates of major laminarian algae was obtained by (1) direct tagging experiments, and (2) by analysis of length-frequency and biomass data. Limited growth data for certain key animals were also obtained using the latter method.

3.2.1 Plant growth experiments

Basically, the procedure employed in the kelp growth rate studies was to tag individual plants with unique identification labels and then place a mark on each blade to permit measurement of growth. The greatest component of blade growth in kelp takes place in the meristematic area at junction of the stipe and the base of the blade (intercalary meristem) (Dawson 1966). The migration of a mark from the base to the tip of a blade is evidence of growth. Measuring the position of such marks at various points in time, then, permits determination of growth rates.

These operations were performed by divers. Identification labels were fabricated by affixing an individually imprinted piece of DYMO labelling tape to an electrical wire "tie-wrap" (Figure 3-1). Divers placed these individual labels around the stipes of plants so as to fit fairly snugly, but loose enough to allow an increase in stipe diameter (growth).

Blades were marked in several ways to permit measurement of growth. The basic method used was dictated by blade structure. The simple structure and thickness of the blades of Laminaria groenlandica permitted marking by simply punching a small, neat hole in the blade with a sharpened piece of tubing or a large caliber rifle cartridge. Such holes were generally easy to follow and recognizable for several months (Figure 3-1). This method was unsatisfactory for Agarum cribrosum and Alaria fistulosa, however, because of more complex structure. Both species have a heavy midrib bisecting the blade. Furthermore, the laminae of Agarum are perforated by numerous holes and those of Alaria are thin and rather filmy (Figure 3-2). These conditions combined to preclude the use of a punched hole for following growth. Several other methods were used with varying degrees of success. With Agarum we first threaded a loop of bright colored yarn through natural perforations and around the midrib near the base of the blade. This method worked fairly well but was not considered satisfactory for several reasons. It was difficult to pass the thread through the natural perforations without tearing their edges. Furthermore, waves and tidal currents tended to unravel the yarn and foul it with filamentous algae or the arms of sea stars and spines of sea urchins. A more satisfactory method was to manually place a 0.5-inch long staple of stainless steel suture wire through the midrib with the axis oriented longitudinally so as to disturb the least amount of tissue (Figure 3-2). This method was quite satisfactory and was also employed on Alaria plants. However, we did have two problems with the staple method. First, the midrib tended to split above the distal limb of the staple and below its proximal limb, apparently as a result of secondary cell expansion. Second, the staples were frequently rather difficult to detect underwater because of poor light, turbidity, and water turbulence. We therefore tried Petersen disc tags with yellow or international red discs and stainless steel pins. This brightly colored tag, which only pierces the midrib at a single

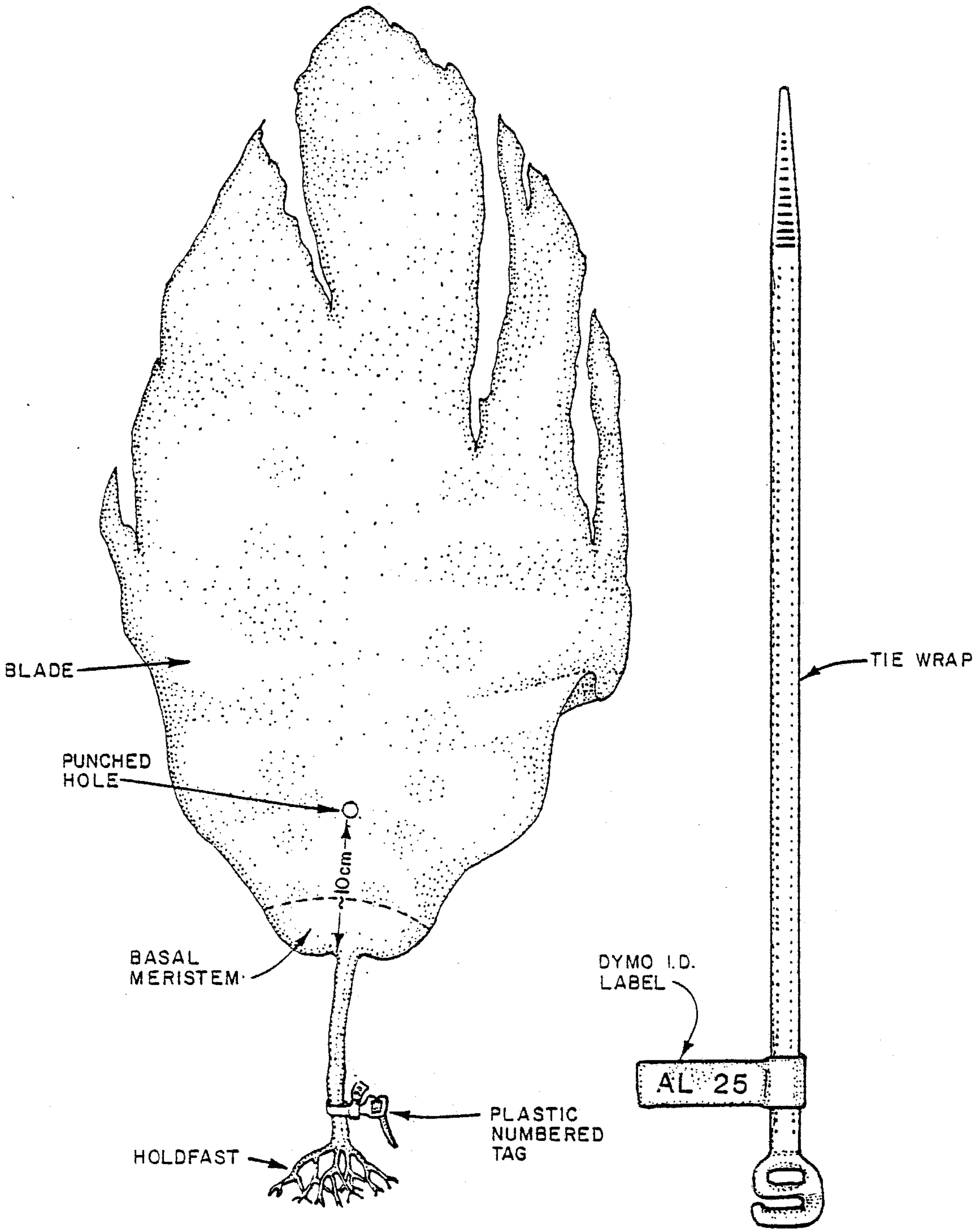


FIGURE 3-1

CONSTRUCTION OF PLANT IDENTIFICATION TAG
AND METHOD OF MARKING BLADE
FOR MEASURING GROWTH FOR LAMINARIA GROENLANDICA

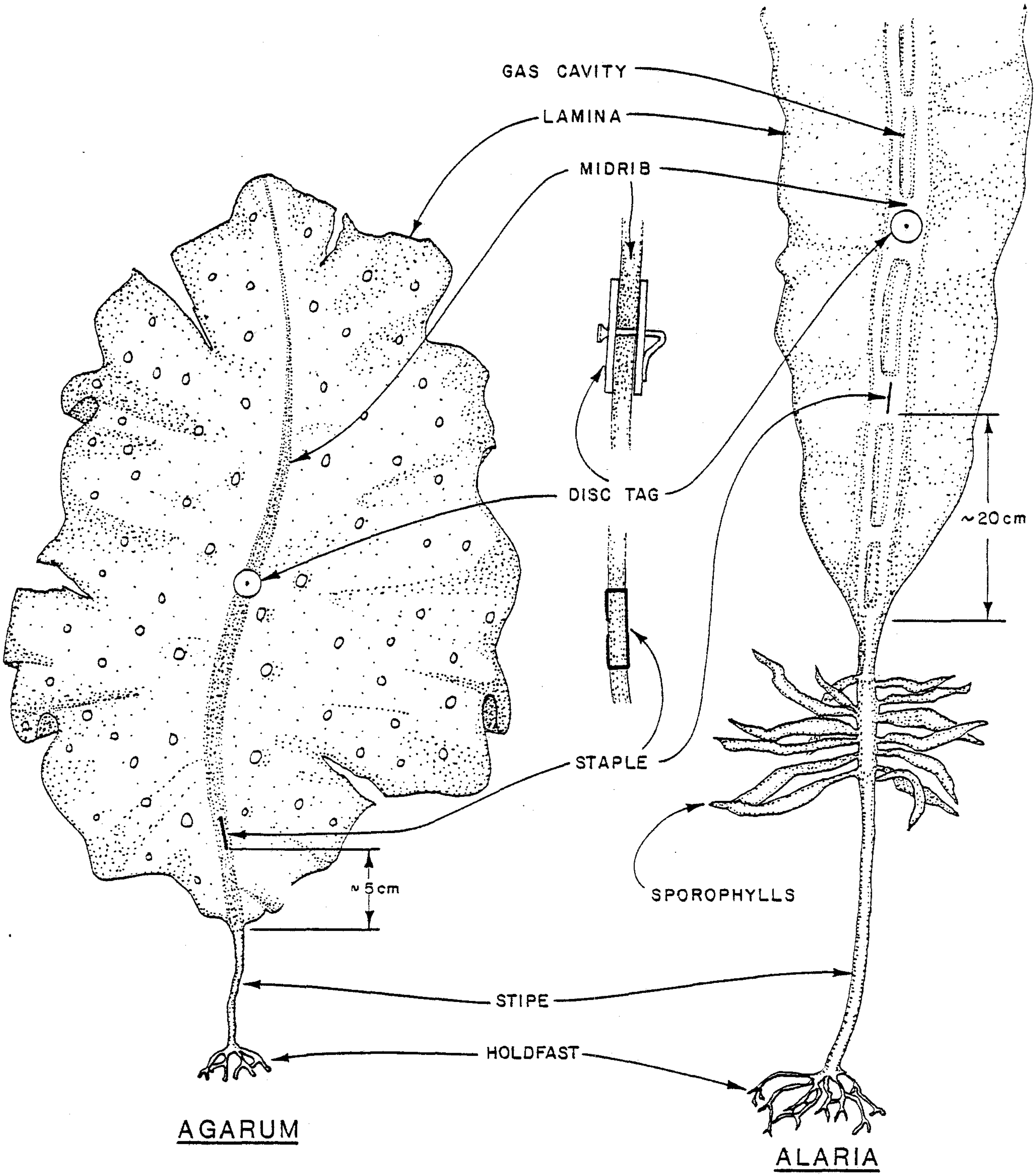


FIGURE 3-2

METHODS OF MARKING BLADE FOR MEASURING GROWTH FOR AGARUM CRIBROSUM AND ALARIA FISTULOSA location, resolved both drawbacks of the staple, and was also somewhat quicker and gentler to install on the plant (Figure 3-2).

After each plant was marked with an identification (ID) label and the blade marked, its ID and the position of the blade mark were recorded (centimeters from the stipe/blade junction). The position of the initial blade mark varied with the species. It was located about 5 cm, 10 cm, and 20 cm from the stipe/blade junction, respectively, for Agarum, Laminaria, and Alaria. If time permitted, stipe length, total plant height, and sporophyll length (for Alaria) were recorded. At subsequent observations, the same measurements were recorded and, when necessary, the blade was remarked near the basal meristem.

Plants were tagged in groups on or near prominent landscape features (e.g. conspicuous sponge-covered boulders, ledges, or near permanent transect lines). This procedure was adopted to facilitate relocation of tagged plants. The locations of these groupings were chosen to provide a general gradient of environmental parameters, in some cases permitting a rough assessment of environmental effects of growth rates.

An attempt was made to measure growth in Nereocystis luetkeana but was discontinued because of constraints in available time and funds. The methods used were the same as employed for Laminaria but several problems developed. Because of stipe structure, it would have been necessary to develop a new method for installing identification labels. Stipe growth is rapid in young plants, and it appears that growth rates may vary directly with size (because of shading, etc.). Also, it was necessary to measure stipe length concurrently with blade growth. However, measurement of stipe length is a rather difficult task, frequently requiring two divers, and commonly damaging the stipe or the pneumatocyst (gas bladder). Furthermore, it was frequently impossible to extricate the bladder and blades of an adult plant from the surface canopy without damaging them severely or inducing partial blade loss.

3.2.2 Indirect methods

Size data for selected invertebrates were used to develop life tables including estimates of growth and mortality rates. This was done using the method developed from the Brody-Bertalanffy growth equations by Ebert (1973).

3.3 NUMERICAL ANALYSIS

As indicated above (Section 3.1.1), standard statistical techniques were used to differentiate between sampling and natural differences in species composition, density, biomass, plant growth rates, etc., between sampling periods, tide levels, or sampling sites. Generally, confidence limits *per se* were not calculated. Instead, we routinely calculated standard deviation (not standard error) for all replicated data sets. Where confidence limits were deemed beneficial or could be applied to the analysis, we used the 95 percent confidence limits to describe the variability (or precision) of the sample means. These were calculated as follows:

$$\text{Lower Limit} = \bar{x} - t\sqrt{\bar{x}/n}$$

$$\text{Upper Limit} = \bar{x} + t\sqrt{\bar{x}/n}$$

where:

$\bar{x}$ = the arithmetic mean of a sample set
n = the number of observations
t = is the Student's "t" value for $\alpha = 0.05$ with degrees of freedom = $n-1$.

In most cases, sample size was too small to permit calculation of confidence limits using the sample variance (s^2), and frequently it was not advisable to assume a Poisson distribution. In these instances, these calculations were limited to standard deviation "s" or the standard error ($\sqrt{s^2/n}$, the standard deviation of the mean).

Depending on the type of data, we made statistical comparisons with either the Student's t-test, or one of a number of nonparametric tests. These included the Wilcoxin matched-pairs signed-ranks test, the Kolmogorov-Smirnov two sample test, the Mann-Whitney U test, χ^2 tests, the Kruskal-Wallis one-way, or Friedman two-way analysis of variance (Siegel 1956).

After tabulation of the field data, proper statistical tests were determined depending on the type of data under consideration, and parameters were compared between sampling levels within a survey, or between surveys at a specific level. The relationship between density, biomass, and size structure was examined to gain insight into the mechanics involved in observed changes. Frequently, where the data exhibited strong patterns, graphical presentations were more appropriate. This was often the case with the intertidal data, where strong seasonal and zonal (elevation) patterns were present. Also, the growth rate data and trophic structures were conducive to graphic presentation. However, in all cases, the complete data summaries (mean density or cover of all species at all sampling times) are presented in appendix form to permit other investigators access to them. Raw data have been submitted to NOAA in the NODC digital data format.

3.4 TAXONOMY

As expected, many problems were encountered in attempting to identify organisms found in this study with standard taxonomic references for the northeast Pacific Ocean. Intertidal and shallow subtidal organisms of Lower Cook Inlet have not been previously studied in a systematic way and few extensive collections from this area have been examined by taxonomists. Thus, many organisms were encountered with characters intermediate to or outside the ranges of variation considered definitive for separate species in standard keys. In some cases, it was possible to clear up these questions by reference to the original literature. In others, questions remain which must await a rigorous investigation by taxonomic specialists. Problematic individuals of some groups were submitted to such specialists for examination. Some groups of apparently minor ecological and economic importance that require extensive histological preparation and microscopic examination for positive identification (e.g. Nemertea) were not identified further. Thus, in the species lists in this report there are many organisms where identification was not pursued to the genus or species level and others where the identification as listed is considered questionable and is denoted with a question mark.

In several instances, we have submitted large collections of organisms to taxonomic specialists for verification or identification. This has been a definite benefit to our taxonomic capabilities and the validity of our data. The taxa and associated systematic specialists are listed below.

TAXON	SPECIALIST
Phaeophyta	Dr. Thomas Widdowson
Rhodophyta - Chlorophyta	Dr. Robert Scagel University of British Columbia
Rhodophyta	Dr. Isabel Abbott Stanford University
Rhodophyta - Delesseriaceae	Dr. Joan Stewart Scripps Institution of Oceanography
Polychaeta	Dr. Rita O'Clair University of Alaska - Juneau
Polychaeta	Mr. Rick Rowe University of Southern California
Paguridae	Ms. Janet Haig University of Southern California
Mollusca	Mr. Rae Baxter Alaska Department of Fish and Game
Tunicata	Mr. James Vallee Pacific Bio-Marine
Fish	Dr. Robert Lavenberg Los Angeles Couty Museum of Natural History

Two taxa, Hydroida and Bryozoa, have been examined extensively in-house, but the identifications have not been verified by outside authorities.

3.5 DISTRIBUTION AND ABUNDANCE - SOFT SUBSTRATES

3.5.1 Field Procedures

A stratified random sampling design was employed to examine the infauna of sand beaches at Homer Spit and Deep Creek, and the mud flat at Glacier Spit, Chinitna Bay. A transect extending across the beach from a specified point was established on each beach. Samples were collected at four specified levels or distances from the base of each transect. At each level, a measured line was laid out parallel to the shoreline and a set of vertical core samples was collected at random points along that line. All sample sets included ten replicate cores per level, except that only five per level were collected at Homer Spit in February 1977. The core sample collected was 10 cm in diameter (78.5 cm^2) by 30 cm in length (2356.2 cm^3). Each core sample was placed in a separate polyethylene bag and labelled. Subsequently, the core samples were sieved through a 1.0 mm screen to reduce the amount of inorganic material and the sample rebagged and preserved with a 10 percent formaldehyde-sea water solution.

Approximate beach profiles were determined using a measured PVC stadia rod, an expedient monopod and a telescopic level. Starting at the drift line of the previous high tide (estimated from the litter line and sediment dampness) a measured line was extended across the intertidal zone to the lower water line at low slack tide. Profile data were acquired by determining elevation changes over a measured horizontal ground distance with the level and stadia rod. Profile data were collected from high water to low water and back to high water; plotted profiles were averages of the two.

This method is subject to several inaccuracies. It is based on the accuracy of the published tide information on time and changes. Therefore, meteorological phenomena and correction factors are important sources of error.

3.5.2 Laboratory Analysis

In the laboratory each core was rough sorted under a dissecting microscope to separate the animals from the remaining sediment and to divide them by major taxa, mainly polychaete worms and crustaceans. At this time they were placed in a 30 percent isopropyl alcohol preservative. Subsequently, the samples were examined to identify the species and count the individuals. Initially, all specimens were also sent to taxonomic specialists to verify or obtain identifications. Subsequently, only difficult species have been sent out. The specialists consulted were: Bruce Benedict, formerly of Marine Biological Consultants, Inc., for gammarid amphipods, and Rick Rowe, Allan Hancock Foundation, University of Southern California, for polychaetes.

Following identification, the samples were reexamined to obtain length and weight data. Lengths of gammarid amphipods and small clams were measured on a dissecting microscope equipped with an ocular micrometer. Whole wet weights of animals were obtained by draining the specimens for about 15 seconds on damp paper towels and weighing them on a Torsion DWM2 balance accurate to ± 5 mg.

3.5.3 Numerical Analyses

Quantitative samples (cores) produced several numerical parameters useful in describing and comparing faunal assemblages. Used to describe abundance were 1) the total number of specimens per level (N), 2) the average number of specimens per core sample (± one standard deviation), and 3) the number of organisms per m^2. Species richness was described with 1) the total number of species per level (S), 2) the average (± s) number of species per core, and 3) the Brillouin diversity index ($H = 1/N \left(\log_2 \frac{N!}{n_1!n_2!\ldots n_j!}\right)$, where n_1, $n_2 \ldots n_j$ are the number of individuals in species 1 through j). The equitability, or evenness of the distribution of specimens among species was described by N/S and E, which was defined as $2^{H/S}$. Standard deviations are included to provide an indication of variability among the samples.

In addition, species-area curves were constructed to demonstrate the rate at which species were accrued within the assemblage observed at each level. This technique provided additional insight into the adequacy with which a level, or the area, was sampled.

To assist in describing zonation on the sand beaches, the abundance of each species was compared among levels to determine distribution patterns and composition at each elevation. Species that occurred at a given level in all three surveys and had a density exceeding $100/m^2$ at least once were categorized as "Dominants". "Subdominants" also occurred in each survey but their density never exceeded $100/m^2$. Species that occurred in only two surveys were categorized as "Frequent", regardless of density, and those that appeared only once, but at a density exceeding $100/m^2$, were considered "Seasonal". The categories for the mud beach, where data for only two surveys are included, are somewhat different. Species that occurred at a given level in both surveys and for which density exceeded $100/m^2$ at least once were categorized as "Dominant". "Subdominants" also occurred in both surveys but ranged between $100/m^2$ and $10/m^2$ in both surveys. Those which occurred in both surveys with densities ranging between $5/m^2$ and $10/m^2$ at least once were classified as "Frequent". Finally, species that occurred only once at densities of greater than $20/m^2$ were designated as "Seasonal".

4.0 RESULTS

4.1 ROCKY HABITATS - EAST SIDE

4.1.1 Gull Island

The general characteristics of rocky intertidal communities on the Gull Island ("Gorilla Rock") transect have been described by Dames & Moore (1976) based on the 1974-1976 studies. These characteristics are summarized here.

Uppermost intertidal rock surfaces wetted only by spray or the highest tide had a patchy band of the green alga *Prasiola meridionalis*. Rock crevices that retained spray and freshwater runoff had growths of the tubular green alga *Enteromorpha*. Slightly lower in the area wetted by most high tides (about +5.5 to 5 m) the acorn barnacle *Balanus glandula* formed dense colonies covering much of the substrate along with the tufted red alga *Endocladia muricata*. In the damper portions of this barnacle zone (mostly between 2.8 to 4.9 m) were dense growths of the red algae *Halosaccion glandiforme*, *Odonthalia floccosa*, and *Rhodomela larix*; in the drier portions, the brown rockweed *Fucus distichus* formed a dense cover over the barnacles. The bay mussel *Mytilus edulis* was also abundant in scattered patches in this area and continued to some extent throughout lower intertidal areas. The littorine snail *Littorina sitkensis* and the limpets *Collisella* spp. and *Notoacmaea* spp. were the most abundant grazers at this level.

Below the *Fucus*/*Halosaccion* zone barnacle dominance shifted to the thatched barnacle *B. cariosus*. Algal dominance shifted to the brown laminarian alga *Alaria crispa*.* During spring and summer of 1974-1976 this species formed an extensive band (62 to 85 percent cover) from about +2.8 m (near MSL) to near MLLW with an understory of several reds (*O. floccosa*, *Rhodymenia* spp.,** *Polysiphonia* sp., *Pterosiphonia* sp., *Gigartina* spp.,*** and the filamentous green *Spongomorpha* sp. Encrusting species (*Ralfsia pacifica* and a coralline) covered much of the unoccupied

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* Called *A. ?praelonga* in Dames & Moore (1976).

** Includes forms called *Callophyllis* in Dames & Moore (1976).

*** Includes forms called *Iridaea* in Dames & Moore (1976).

rock surface. The Alaria plants in this zone were largely attached to the shells of B. cariosus (Figure 4-1) and died back to much lower coverage during fall 1974 (34.7 percent) and winter 1975 (3.4 percent).

In addition to the limpets, the chitons Katharina tunicata and Tonicella lineata were important grazers throughout this zone with young specimens of the green sea urchin Strongylocentrotus droebachiensis becoming increasingly common at lower levels. Major predators included the six-rayed starfish (Leptasterias ?hexactis) and the muricid snail Nucella lamellosa.

From near MLLW, the Alaria thinned sharply leaving as the dominants several species, especially O. floccosa, that had occurred largely in understory roles at higher levels. Below this relatively narrow zone the larger laminarians, especially Laminaria groenlandica, assumed a dominance that persisted well into the subtidal zone. The larger starfish predators such as Evasterias troschelii were much more abundant at this lowest intertidal zone and limited survival of mussels and barnacles.

Levels marked by fixed pins (+3.8 to 0.0 m MLLW) on the Gull Island transect were sampled five times in both 1977 (February 15, May 2 and 3, June 29 and 30, August 27 and 30, October 13) and 1978 (March 8, May 22 and 23, June 19, July 18, October 15). Sampling was in accordance with procedures described in Section 3.1.1 and 3.1.2. These data constitute a continuation of some types of data that were reported by Dames & Moore (1976) in their 1974 to 1976 studies. Thus, they permit examination of long-term fluctuations in distribution and abundance of some important species.

Density of faunal dominants at the various tide levels are given in Tables 4-1 and 4-2 while complete distribution data for all species are contained in Appendix Tables

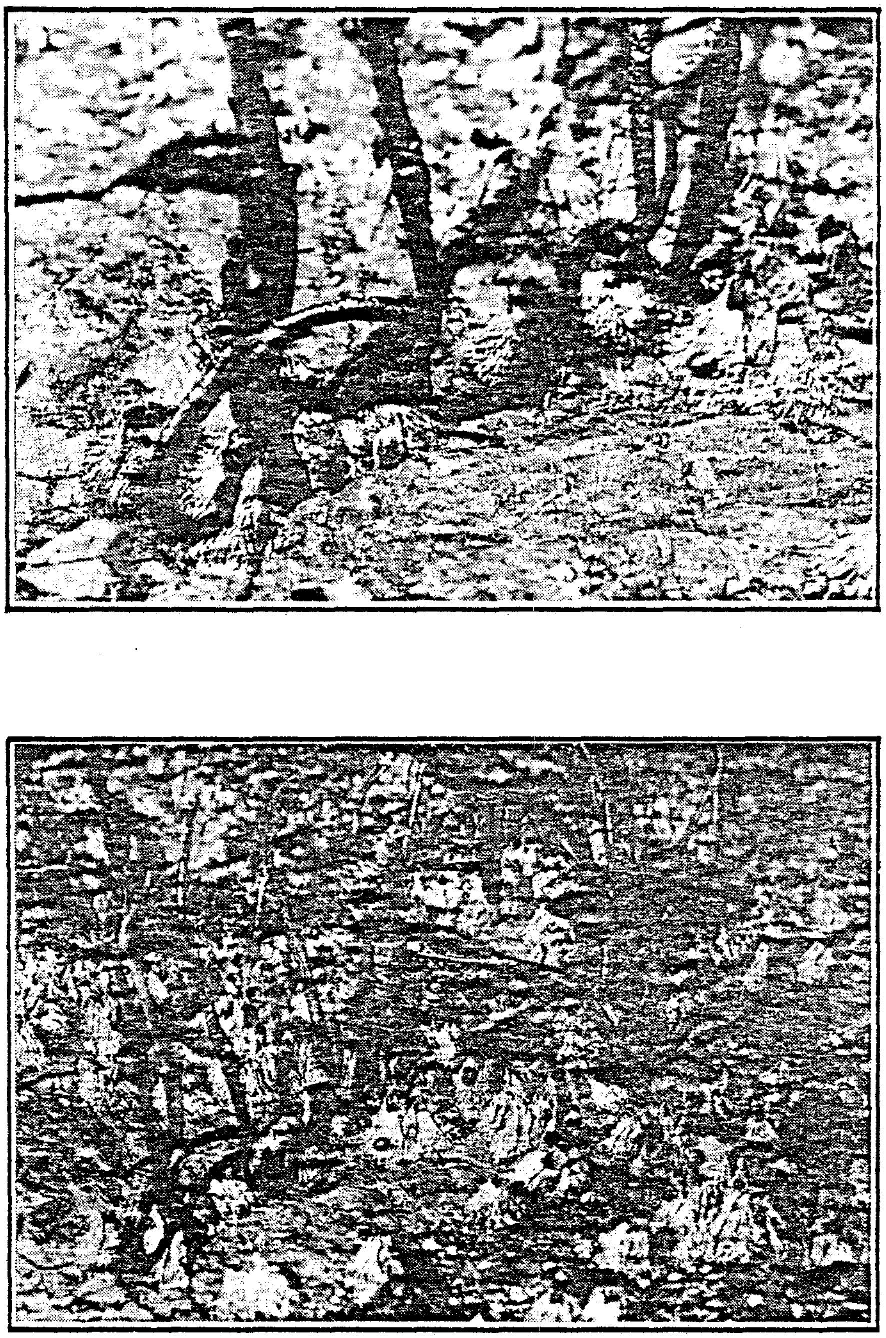

FIGURE 4-1

ATTACHMENT BY THE KELP <u>ALARIA CRISPA</u>
TO THE THATCHED BARNACLE <u>BALANUS CARIOSUS</u>

TABLE 4-1

GULL ISLAND INTERTIDAL INVERTEBRATE DOMINANTS, 1977

Level/Species	Date/Average Percent Cover or No./m^2				
	2/16/77	5/23/77	6/27-30/77	8/27-30/77	10/13/77
3.8 m					
(% Cover)					
Balanus cariosus	0	2.9	4.4	2.8	12.4
Balanus glandula	36.7	20.0	21.7	37.0	61.4
Mytilus edulis	21.7	27.1	19.7	24.0	24.0(a)
(#/m^2)					
Acmaeidae	48.0	76.4	276.0	238.4	192.0
Katharina tunicata	17.2	0	0	0	0
Littorina sitkana	P(b)	P	P	P	P
Nemertea	0	1.2	P	0	5.6(c)
Siphonaria thersites	0	0	4.8	0	0.8
1.5 m					
(% Cover)					
Balanus cariosus	14.6	31.0	22.1	33.0	41.0
Chthamalus dalli	4.5	0	3.4	2.7	17.0
Mytilus edulis	18.2	5.4	10.0	0.2	6.4
Rynchozoon bispinosum	1.2	0	2.5	1.2	0
(#/m^2)					
Acmaeidae(f)	7.0	5.6	42.0	112.0	132.8
Katharina tunicata	0	9.6	47.4	66.4	37.6
Leptasterias ?hexactis	6.5	2.4	21.1	21.6	21.6
Metridium senile(e)	0	0	17.1	52.0	28.0
Schizoplax brandtii	0	3.2	16.0	48.8	21.6
Siphonaria thersites	0	48.8	55.3	68.8	117.6
Tealia spp.(d)	8.4	0	0.6	1.6	0.8
0.5 m					
(% Cover)					
Balanus cariosus	4.1	3.2	4.2	26.2	16.0
Chthamalus dalli	0.7	0	2.3	0.8	3.4
Halichondria panicea	12.7	6.0	12.5	7.1	0.8
Mytilus edulis(a)	0	0	6.7	15.8	18.6
(#/m^2)					
Acmaeidae	0	218.0	75.0	241.6	354.4
Evasterias troschelii	1.6	1.6	0	0	0.8
Katharina tunicata	35.5	31.2	28.5	32.8	42.4
Leptasterias ?hexactis	2.4	12.0	1.5	0.8	14.4
Metridium spp.	0	3.2	2.5	21.6	32.8
Nemertea	0	9	1.0	0	2.4
Schizoplax brandtii	0	44.0	22.5	23.2	88.0
Strongylocentrotus drobachiensis	6.4	16.0	14.5	1.6	14.4
Tealia spp.	5.6	0.8	1.5	0	0.8
Tonicella lineata	15.5	12.8	11.0	5.2	19.2

(a) Adults and juveniles combined.
(b) P = present.
(c) Unidentified sp. and Emplectonema sp. combined.
(d) Includes T. crassicornis and Tealia sp. (juveniles).
(e) Includes M. senile and Metridium sp. (juveniles).
(f) Includes all Notoacmaea and Collisella spp.

TABLE 4-1

Sheet 2 of 2

Level/Species	Date/Average Percent Cover or No./m^2				
	2/16/77	5/23/77	6/27-30/77	8/27-30/77	10/13/77
0.2 m					
(% Cover)					
Balanus cariosus	P	0	0	1.4	8.2
Chthamalus dalli	0	0	5.3	0.5	0.4
Halichondria panicea	6.4	0	0	0.4	0
Hydrozoa(g)	1.6	2.0	0.8	0.3	5.8
Mytilus edulis	0	0	2.5	8.5	3.2
Rynchozoon bispinosum	P	0	1.4	0.3	0
(#/m^2)					
Acmaeidae	0	49.6	161.2	192.0	146.4
Anthozoa-unidentified	0	14.4	6.0	0	0
Cancer sp.(h)	0	0	3.2	0	0.8
Katharina tunicata	37.6	29.6	36.0	44.8	42.4
Leptasterias ?hexactis	1.2	0	3.3	0.8	0.8
Metridium spp.	0	1.6	63.3	46.4	57.6
Mopalia ciliata	3.6	0	1.3	1.6	1.6
Schizoplax brandtii	0	0.8	13.3	13.6	14.4
Siphonaria thersites	0	0.8	0	0	14.0
Strongylocentrotus drobachiensis	40.0	15.2	17.3	9.6	73.6
Tealia spp.	1.2	4.0	2.7	4.0	9.6
Tonicella lineata	22.4	7.2	22.0	27.2	32.0
0.0 m					
(% Cover)					
Balanus cariosus	0	0	0	0.2	9.1
Hydrozoa(g)	0.8	6.0	11.4	0.7	2.6
Mytilus edulis	0	P	18.4	36.8	18.8
Ritterella ?pulchra	0	3.7	5.4	5.7	0
(#/m^2)					
Acmaeidae	27.2	16.0	26.4	83.2	102.0
Anthozoa-unidentified	57.6	5.2	1.6	0	0
Cancer spp.	0	1.2	0	0	4.0
Crucigera zygophora	0	28.0	0.8	9.0	0
Evasterias troschelii	0	4.0	1.6	0	2.0
Katharina tunicata	39.2	8.0	31.2	38.4	30.0
Leptasterias ?hexactis	0	0	8.8	2.4	6.0
Metridium spp.	0	0	0	236.0	8.0
Mopalia ciliata	0	10.8	11.2	12.8	6.0
Nucella lamellosa	0	2.8	1.6	4.0	0
Paguridae	3.2	0	7.2	1.6	0
Pugettia gracilis	0	0	0.8	8.0	0
Schizoplax brandtii	0	4.0	3.2	0.8	20.0
Serpulidae	160.0	P	15.2	P	P
Strongylocentrotus drobachiensis	38.4	25.2	64.0	76.0	11.0
Tealia spp.	1.6	2.8	9.6	8.8	7.0
Tonicella lineata	26.4	62.8	53.6	54.4	8.0

(g) Includes all species.

(h) Includes *Cancer* sp. and *C. oregonensis*.

TABLE 4-2

Sheet 1 of 2

GULL ISLAND INTERTIDAL INVERTEBRATE DOMINANTS, 1978

Level/Species	Date/Average Percent Cover or No./m^2				
	3/8/78	5/23-24/78	6/19/78	7/18/78	10/15/78
3.8 m					
(% Cover)					
Balanus cariosus	1.2	24.0	3.2	3.5	2.7
Balanus glandula	44.2	0.3	33.8	44.4	49.0
Chthamalus dalli	1.3	2.0	0.7	1.1	0.5
Mytilus edulis	24.5	33.6	29.0	35.0	42.0
(#/m^2)					
Acmaeidae	170.8	300.0	277.6	256.0	221.0
Leptasterias ?hexactis	0	0	0	0	1.2
Littorina sitkana	P[a]	P	P	P	P
Nemertea[b]	1.3	0.3	0.6	2.7	5.6
Siphonaria thersites	0	0	13.1	8.0	0.8
1.5 m					
(% Cover)					
Balanus cariosus	30.3	28.4	33.3	33.3	52.5
Balanus glandula	0.4	0	1.2	5.5	9.6
Chthamalus dalli	9.3	18.6	12.5	14.3	8.7
Mytilus edulis	30.8	4.3	8.5	6.2	13.2
(#/m^2)					
Acmaeidae	160.7	400	429.3	298.0	24.0
Anthopleura artemisia	0	3.2	2.7	2	0
Cucumaria spp.	0	4	54	12.8	1.3
Katharina tunicata	5.3	13.6	19.3	11.3	13.3
Leptasterias ?hexactis	6	19.3	13.3	9.3	16.7
Metridium senile	18	40.8	57.3	108.3	14.7
Onchidella borealis	0	0	6.0	0.7	2.7
Schizoplax brandtii	0.7	7.2	10.0	0.7	8.7
Siphonaria thersites	6	99.2	240.7	28.0	21.3
0.5 m					
(% Cover)					
Balanus cariosus	15.2	40.0	59.2	61.7	66.2
Chthamalus dalli	1.0	4.7	0.9	0.8	0.8
Mytilus edulis	15.2	30.8	64.2	70.0	55.2
(#/m^2)					
Acmaeidae	253.4	637.3	612.0	448.0	302.0
Anthopleura artemisia	0.7	2.0	2.7	0.7	0
Easterias troschelii	0	1.3	0	0	1.3
Ischnochiton ?albus	10	0	0		
Katharina tunicata	27.3	48	10.0	14.0	28.0
Leptasterias ?hexactis	16.7	54.0	61.3	22.0	36.7
Metridium senile	11.3	6.7	12.3	6.0	40.0
Nemertea[b]	0	1.3	10.6	4.1	0
Nucella lamellosa	0	1.3	0	0	0.7
Onchidoris bilamellata	2.7	0.7	0	0	7.3
Schizoplax brandtii	5.3	18.7	11.3	2.3	2.0
Strongylocentrotus drobachiensis	2	4.7	0.7	0	3.3
Tonicella lineata	8.7	4	2.0	0.7	4.0

(a) P = present.

(b) Includes all species.

TABLE 4-2 Sheet 2 of 2

Level/Species	Date/Average Percent Cover or No./m^2				
	3/8/78	5/23-24/78	6/19/78	7/18/78	10/15/78
0.2 m					
(% Cover)					
Balanus cariosus	16.1	9.7	7.6	37.0	27.5
Balanus glandula	0.1	0.2	3.0	1.4	0.2
Chthamalus dalli	1.5	4.0	1.1	3.1	0.8
Mytilus edulis	11.5	16.0	25.0	32.5	51.7
Spirorbinae	P	2.8	0.9	1.7	0.4
(#/m^2)					
Acmaeidae	407.3	595.3	888.8	753.3	404.0
Anthopleura artemisia	0.7	0	0.8	3.3	1.3
Evasterias troschelii	0	0	0.8	3.3	22.0
Ischnochiton ?*albus*	93	0.7	0	0	0
Katharina tunicata	36.7	44.7	26.4	20.0	22.0
Leptasterias ?*hexactis*	15.3	20.7	15.2	8.0	6.7
Metridium senile	21.3	22.0	65.6	51.3	24.7
Mopalia ciliata	0.7	2.0	0.8	0	1.3
Nucella lamellosa	0	1.3	4.0	1.3	0.7
Onchidoris bilamellata	2.0	0.7	0	0	5.3
Schizoplax brandtii	10.7	20.0	17.6	9.3	4.0
Strongylocentrotus drobachiensis	34.7	35.3	16.0	7.3	6.0
Tealia crassicornis	2	2.0	1.6	0	0.7
Tonicella lineata	16.7	14.7	24.8	21.3	20.0
0.0 m					
(% Cover)					
Balanus cariosus	0	2.9	3.3	1.8	0
Hydrozoa$^{(b)}$	P	4.8	3.3	5.6	2.0
Mytilus edulis	31.0	17.3	37.5	20.5	44.5
Serpulidae	P	0	2.0	0	0.3
Spirorbinae	P	P	1.0	7.0	6.8
(#/m^2)					
Acmaeidae	2.4	200.7	117.0	73.3	190.0
Cancer oregonensis	0	0	2.0	2.7	8.0
Crucigera zygophora	0	0	P	24.0	22.7
Easterias troschelii	2	42	14.0	64.7	39.3
Katharina tunicata	27.3	50	66.0	44.0	36.0
Leptasterias ?*hexactis*	18	7.7	8.0	2.6	1.3
Metridium spp.	168.7	308.7	0	392.7	278.7
Mopalia ciliata	6.7	0	11.0	14.7	12.0
Nemertea$^{(b)}$	0	2.7	0	3.3	17.3
Nucella lamellosa	0	4.7	7.0	12.6	0
Ritterella ?*pulchra*	0	15.3	0	0	
Schizoplax brandtii	0	4.7	11.0	0	2.0
Strongylocentrotus drobachiensis	23.3	36.7	19.0	21.3	20.0
Tonicella lineata	33.3	44.7	60.0	84.0	56.0

+3.8 m, the "Fucus - Odonthalia" Zone

Algal sampling during 1977 and 1978 served to quantify the dominance of this level by the brown rockweed Fucus and the red Odonthalia floccosa,* at least during the period from fall through early spring (Figures 4-2 and 4-3**). During the period from late spring through the summer, however, standing crop of Halosaccion glandiforme increased to exceed that of Odonthalia in June of 1977 and all species in May through July of 1978. Peak cover and biomass of Halosaccion occurred in June in both years. Late summer decay of Halosaccion and continued health of Fucus caused Fucus to heavily dominate algal biomass in late summer of 1977. Peak biomass of Fucus (1,516 g/m^2) and of all algae at this level (1,720 g/m^2) occurred during August of 1977.

The acorn barnacle Balanus glandula was codominant in the use of the primary space (rock surface) at this level with mean coverage as high as 61.4 percent in October 1977 (Table 4-1). Lowest coverage (0.3 percent) in May 1978 (Table 4-2) was probably due in part to altered positioning of the transverse sampling line (at a lower contour) since there was a corresponding increase in coverage of the thatched barnacle B. cariosus. This latter species was typically subdominant to B. glandula at this level, preferring moist pockets and the shaded north side of the island. The bay mussel Mytilus edulis was the other major dominant in terms of occupation of primary space at +3.8 m with mean coverage ranging from a low of 19.7 percent (June 1977) to a high of 42.0 percent (October 1978).

Gastropod grazers (limpets, littorines, pulmonates) were the most abundant motile organisms at the +3.8-m level. The limpets (Notoacmaea, Collisella) were extremely abundant with densities of up to 300 per m^2 (all sizes included). The sharp jump in counts from May to June 1977 (Table 4-1) was due to inclusion in the latter and in subsequent counts of all sizes of limpets down to 1- to 2-mm juveniles. Recruitment of limpets apparently occurs in early summer (e.g. Table 4-2) with a gradual

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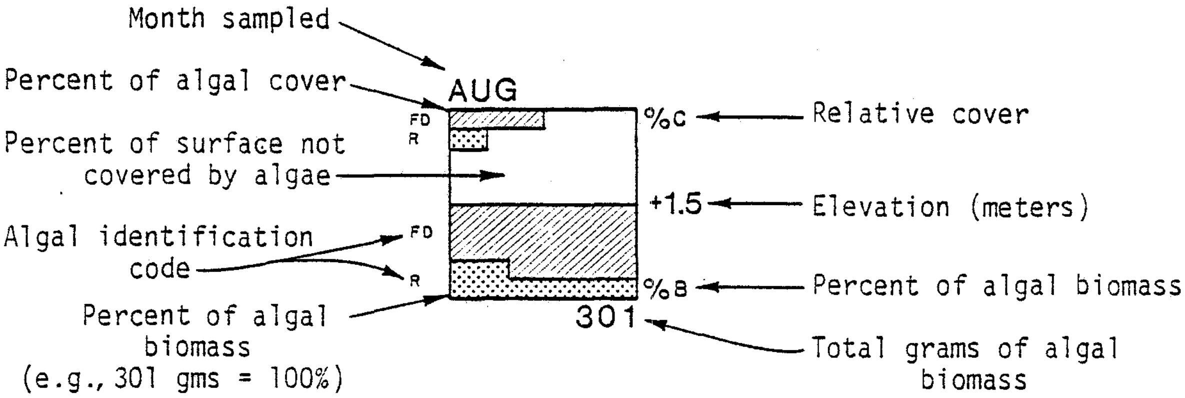
* Odonthalia at this level was inseparably mixed with varying amounts of Rhodomela larix and all numbers reported include both species.

** See Table 4-3 for key to abbreviations in Figures 4-2 and 4-3.

KEY TO FIGURES 4-2, 4-3, 4-4, AND 4-5



Each ☐ = 2 percent; each full column = 20 percent

In the example FD cover = 10 percent; biomass = 74 percent

R cover = 4 percent; biomass = 26 percent

In some instances, percent cover exceeded 100 because of species layering; this is indicated by expanding the boundaries of the percent cover box.

Major taxa indicated as follows:

░ = fleshy Rhodophyta
□ = coralline Rhodophyta
▓ = Chlorophyta
▨ = Phaeophyta

Note: On Figure 4-3 each ☐ = 1 percent cover and each full column = 10 percent; biomass was not measured.

TABLE 4-3

ALGAL IDENTIFICATION CODES

A	*Alaria crispa*
AC	*Agarum cribrosum*
AF	*Alaria fistulosa*
ART	Articulating corallines
AT	*Alaria taeniata*
CD	*Cladophora* spp.
CHL	Miscellaneous Chlorophyta
CO	Corallines (encrusting and articulating)
CR	*Codium ritteri*
CY	*Cymathere triplicata*
E	*Endocladia muricata*
EC	Encrusting corallines
F	*Fucus distichus*
G	*Gigartina* spp.
HG	*Halosaccion glandiforme*
HI	*Hildenbrandia* sp.
HS	*Hedophyllum sessile*
LJ	*Laminaria* spp. juveniles
LG	*Laminaria groenlandica*
M	*Monostroma* spp.
NL	*Nereocystis luetkeana*
OF	*Odonthalia floccosa*
OL	*Odonthalia lyalli*
O/R	*O. floccosa* and *Rhodomela larix*
PF	*Petalonia fascia*
PH	Miscellaneous Phaeophyta
POR	*Porphyra* spp.
PT	*Pterosiphonia* sp.
R	Miscellaneous Rhodophyta
RH	*Rhodymenia palmata*
RL	*Rhodymenia liniformis*
RP	*Ralfsia pacifica*
RX	*Rhodomela larix*
SC	*Scytosiphon lomentaria*
SCH	?*Schizymenia*
SO	*Soranthera ulvoidea*
SP	*Spongomorpha* spp.

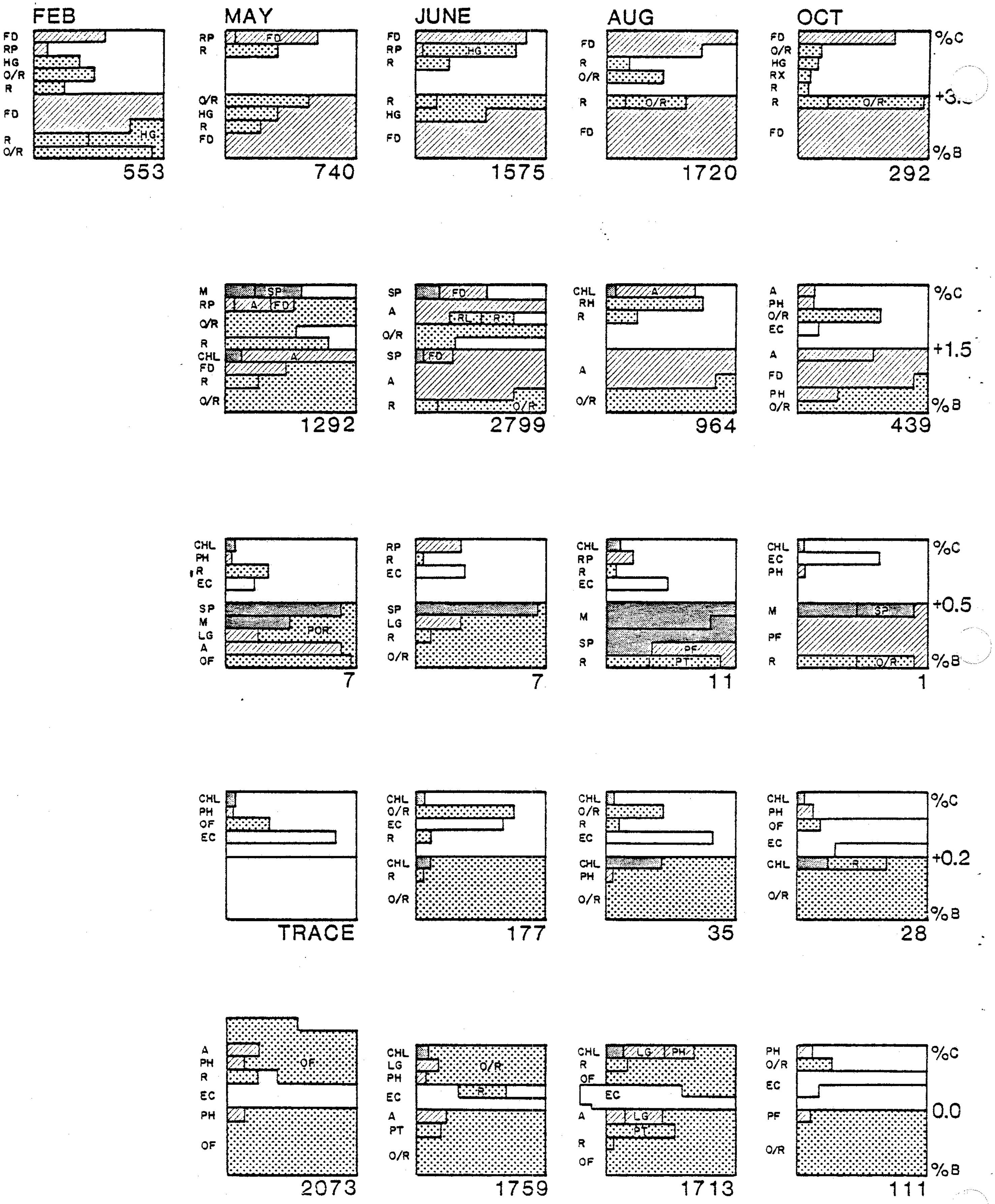


FIGURE 4-2

ZONATION, COVER AND BIOMASS OF ALGAE AT GULL ISLAND IN 1977

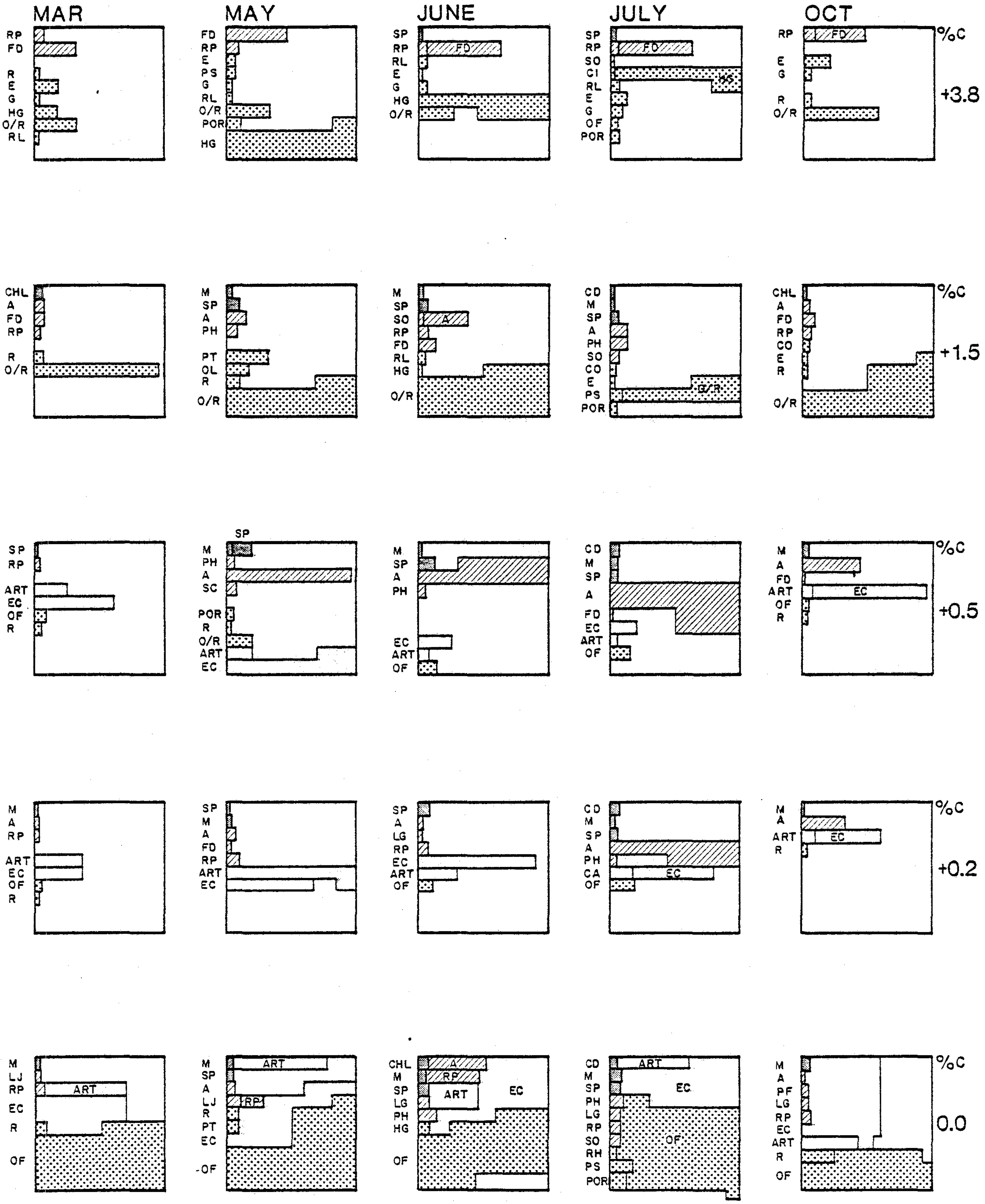


FIGURE 4-3

ZONATION AND COVER OF ALGAE AT GULL ISLAND IN 1978 decline in numbers by late summer continuing through the following spring. The periwinkle Littorina sitkana was also present in great number but was not counted. The pulmonate Siphonaria thersites was common (13.1 per m^2 in June 1978) in summer and fall, following June recruitment, but was absent during the winter and spring.

Predatory nemerteans, primarily Emplectonema ?gracile were the major representatives of higher trophic levels present. Their numbers tended to increase somewhat in late fall and winter, a period of apparent breeding activity.

+1.5 m, the "Alaria" Zone

This level, still on the sloping upper portion of "Gorilla Rock," lies within the broad "Alaria" zone described from the 1974 to 1976 studies (Dames & Moore 1976). Alaria crispa* did, in fact, grow rapidly from a few juveniles present in February 1977 to a position of dominance during June (25 percent cover; 1,951 g/m^2). However, by August Alaria cover had declined to 12.1 percent and biomass had dropped to 527.5 g/m^2. This decline in Alaria continued at this level with only a slight resurgence (to 3 percent cover) in early summer of 1978 (Figures 4-2, 4-3). In previous years, midsummer coverage of Alaria had ranged from 30 to 90 percent in this area (Dames & Moore 1976).

In 1978, as in previous years, the red algal turf of O. floccosa and Rhodomela larix was a dominant assemblage and better developed during the fall to spring period (Tables 4-4, 4-5). However, throughout 1978, these reds maintained a clear dominance over all other algae. Fucus was present in small amounts during most of 1977-1978 but achieved co-dominance with the reds only in fall of 1977, following the late summer decline in Alaria.

The thatched barnacle B. cariosus was more abundant at this level than at +3.8 m and ranked high in coverage among sessile fauna (14.6 to 52.5 percent, Tables 4-1, 4-2). During the winter months (e.g. February

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* Called A. ?praelonga in Dames & Moore (1976).

TABLE 4-4

GULL ISLAND ALGAL COVER AND BIOMASS BY MAJOR TAXON, 1977

	Level									
	3.8 m		1.5 m		0.5 m		0.2 m		0.0 m	
Month/Class	%	gm/m^2	%	gm/m^2	%	gm/m^2	%	gm/m^2	%	gm/m^2
February										
Chlorophyta	0	0	--		--		--		--	
Phaeophyta	13.7	206.4	--		--		--		--	
Rhodophyta										
encrusting	0	0	--		--		--		--	
other	21.2	346.0	--		--		--		--	
Total	34.9	552.4	--		--		--		--	
May										
Chlorophyta	0.3	2.9	11.5	32.8	1.6	1.8	1.1	0	0.4	0.1
Phaeophyta	14.4	537.4	10.2	229.2	1.1	1.7	1.4	0	8.5	65.3
Rhodophyta										
encrusting	0	--	0	--	3.1	--	14.8	--	25.0	--
other	8.0	199.8	66.9	1,029.8	3.4	3.7	9.7	--	99.1	2,012.0
Total	22.7	740.1	88.6	1,291.8	9.2	7.2	27.0	0	133.0	2,077.4
June										
Chlorophyta	0.3	1.2	3.8	37.7	0.5	1.4	1.3	4.3	1.8	13.3
Phaeophyta	18.0	1,048.7	32.8	2,087.0	7.3	0.5	15.7	0.1	7.7	83.4
Rhodophyta										
encrusting	0	--	0.5	--	5.9	--	9.8	--	21.0	--
other	21.1	525.2	36.5	674.4	2.5	5.5	6.2	172.9	63.3	1,662.3
Total	39.4	1,575.1	73.6	2,799.1	16.2	7.4	33.0	177.3	93.8	1,759.0
August										
Chlorophyta	0.3	3.4	1.3	1.9	2.0	7.3	1.3	3.0	3.0	14.0
Phaeophyta	34.4	1,516.3	13.6	527.6	4.7	1.8	9.6	0.5	10.8	161.5
Rhodophyta										
encrusting	0	--	0.2	--	7.4	--	11.2	--	32.0	--
other	12.1	200.5	18.8	434.5	3.8	1.8	6.8	31.8	61.7	1,537.8
Total	46.8	1,720.2	33.9	964.0	17.9	10.9	28.9	35.3	107.5	1,713.3
October										
Chlorophyta	0.1	--	0.4	--	0.8	0.2	0.7	1.4	0.5	0.6
Phaeophyta	14.6	237.1	4.5	255.2	0.8	0.7	2.5	0	2.6	2.3
Rhodophyta										
encrusting	0	--	2.7	--	9.8	--	31.0	--	18.0	--
other	10.3	57.8	13.4	183.5	3.1	0.2	16.3	26.5	11.8	107.8
Total	25.0	294.9	21.0	338.7	14.5	1.1	50.5	27.9	32.9	110.7

TABLE 4-5

GULL ISLAND ALGAL COVER (PERCENT) BY MAJOR TAXON, 1978

	Tide Level				
Month/Taxon	+3.8 m	+1.5 m	+0.5 m	+0.2 m	0.0 m
March					
Chlorophyta	0	0.4	0.1	0.1	0.1
Rhodophyta					
encrusting	0	0	6.4	3.6	18.7
other	7.3	10.0	3.5	4.0	52.0
Phaeophyta	3.8	1.2	0.2	0.3	1.0
Total	11.1	11.6	9.9	7.9	71.8
May					
Chlorophyta	0	1.0	1.8	0.5	0.6
Rhodophyta					
encrusting	0	0.4	13.0	11.5	23.5
other	27.3	28.4	4.3	6.8	55.3
Phaeophyta	5.1	2.1	10.9	1.2	3.1
Total	32.4	31.9	30.0	20.0	82.5
June					
Chlorophyta	0.2	0.7	2.1	0.5	1.1
Rhodophyta					
encrusting	0	0	2.4	9.0	26.3
other	19.8	35.7	2.1	3.8	55.0
Phaeophyta	6.3	5.6	17.5	0.7	9.8
Total	26.3	42.0	24.1	14.0	92.2
July					
Chlorophyta	0.3	0.7	1.0	1.0	1.6
Rhodophyta					
encrusting	0	0.1	1.9	6.3	29.2
other	15.6	14.2	1.7	3.5	67.2
Phaeophyta	6.3	3.3	30.1	16.4	2.8
Total	22.2	18.3	34.7	26.2	100.8
October					
Chlorophyta	0	0.1	0.3	0.1	0.4
Rhodophyta					
encrusting	0	0.3	8.7	5.1	35.8
other	8.7	31.8	1.9	1.2	35.9
Phaeophyta	4.6	2.0	4.5	3.3	1.3
Total	13.3	34.3	15.4	9.7	73.4

1977, March 1978) however, coverage by the blue mussel Mytilus edulis was greater. Another barnacle Chthamalus dalli was a major subdominant (0 to 18.6 percent cover) along with B. glandula which increased from near 0 to about 9.6 percent cover during the last half of 1978.

As at the higher level, the gastropod grazers were especially important at this level, maintaining a strong numerical dominance among mobile fauna. Limpets were again the most abundant (to 429.3 per m^2) with density fluctuations paralleling those described at the +3.8-m level. The large chiton Katharina tunicata was also an important grazer with densities reaching 66.4 per m^2 in August 1977. A smaller chiton Schizoplax brandtii was also among the dominants with peak density of $48.8/m^2$, also in August 1977. The final grazer of importance was the pulmonate Siphonaria thersites. This species, like the limpets, apparently recruits during early summer, reaching a peak density of 240.7 per m^2 in June 1978.

Several sea anemone species were also abundant at the +1.5-m level. Metridium senile reached a density of 108.3 per m^2 following successful recruitment in two successive summers while Tealia and Anthopleura artemisia were considerably less abundant. The starfish Leptasterias, a predator on small barnacles and mussels, was moderately abundant (to 21.6 per m^2) except during the winter surveys when its cryptic coloration and habits may have combined with poor lighting to bias counts.

+0.5 m and +0.2 m, the Rocky Bench

The two levels sampled on the rocky bench of "Gorilla Rock" lay in an area that, in the summers of 1974 through 1976, was virtually covered (25 to 100 percent) by a dense mat of Alaria crispa attached to B. cariosus shells (Dames & Moore 1976). Sometime prior to the sampling in February 1977, a major change occurred that affected the community structure throughout the remainder of the study. The coverage of barnacles on the bench (mostly B. cariosus) declined to near zero in the spring of 1977. At this time, there was almost a total absence of Alaria

(Table 4-1, Figures 4-2 and 4-3). New set of B. cariosus spat occurred during 1977 and, with rapid growth, accounted for 26 percent cover at +0.5 m by late August 1977. Balanus cariosus density continued to increase through 1978 (to 66 percent cover, Table 4-2) at the +0.5-m level. At the +0.2-m level starfish predation reduced coverage during early summer of 1978, but August cover was 37 percent (Table 4-2). A partial recovery of Alaria populations was associated with this recurrence of B. cariosus as coverage reached 30 percent at the +0.5-m level and 15.5 percent at the +0.2-m level in July.

Other algae were generally of little importance on the bench except for encrusting and articulating corallines which covered up to 30 percent of the rock surface in some areas (+0.2 m in October 1977, Table 4-4). The corallines occurred mainly in tidal channels, pools, and small pockets retaining water during emersion. Odonthalia floccosa was also common.

In addition to B. cariosus, the major sessile invertebrate on this bench was the mussel (M. edulis). Like the barnacles the mussels were virtually absent in the winter of 1976-77 but expanded their coverage later in 1977 (to 18.6 percent at +0.5 m) following a heavy set in early summer. During 1978 mussel coverage continued to increase on the bench (to 70 percent at +0.5 in July) despite heavy predation by starfish and snails.

Another sessile form, the sponge Halichondria panicea which, in association with B. cariosus, had been a notable member of the community under the Alaria canopy in earlier years, declined rapidly on the bench during the spring of 1977 and was virtually absent throughout the remainder of the study. This was probably a result of desiccation caused by lack of the protective shading by Alaria and loss of the protection from predation provided by the heavy stand of adult B. cariosus.

The species comprising the remainder of the community on the bench were similar to those in the "Alaria zone" at +1.5 m. Grazers were abundant; dominants included acmaeids (to 888/m^2) and the chitons

Katharina (to $66/m^2$), Tonicella lineata (to $62.8/m^2$), and Schizoplax brandtii (to $88/m^2$). The sea urchin Strongylocentrotus droebachiensis was also abundant in tidal channels and pools, especially at +0.2 m where peak densities of $26/m^2$ were reached in August 1977.

Density of the starfish Leptasterias increased significantly (all comparisons) between 1977 and 1978 (mean density at both levels: 3.4 in 1977; 25.7 in 1978), probably in response to increased availability of barnacle and mussel food items. The larger asteroid Evasterias troschelii was also present in much lower densities during sampling but probably moved on to the bench to feed during periods of inundation. Another predator on barnacles and mussels, the snail Nucella, was absent at both the 0.5- and 0.2-m levels in 1977, but became increasingly abundant (to $4/m^2$) at both levels in 1978. The increase in abundance of small Balanus and Mytilus, more suitable for predation, probably accounts to a large degree for the increased density of Leptasterias and Nucella at these levels. Anemones, primarily Tealia spp. and Metridium senile, were very common from the summer of 1977 on.

0.0 m, the "Odonthalia" Zone

The slopes of the relatively flat rock bench break steeply downward at about MLLW (Figure 2-2) marking a sharp break in biological assemblages. In the 1974-76 studies this break marked the lower edge of the Alaria zone. In 1977 and 1978, however, it was better characterized by the contrast between a thick growth of red algae and the relatively barren bench surface. Red algae, dominated by O. floccosa (to 75 percent), were by far the most abundant group of erect algae (Figures 4-2 and 4-3), while encrusting and articulating corallines covered much of the rock surface under the Odonthalia canopy. Smaller brown algae (juvenile Laminaria groenlandica, Petalonia fascia) were often common, but few adults of the larger species (L. groenlandica) survived at this level despite the relatively low degree of desiccation experienced.

Animals occupied a minor percentage of the primary substrate at this level. The hydroids Abietinaria turgida and the barnacle B. cariosus, combined for up to about 12 percent cover at times, while tunicates (e.g., Ritterella ?pulchra) and serpulid worms (e.g., Crucigera zygophora, Spirobinae) were less important (Tables 4-1 and 4-2). Mussels set heavily on the fronds of O. floccosa during the spring of 1977 and maintained from 17 to 44.5 percent cover subsequently. In terms of Mytilus biomass and relative cover, growth of individuals overrode the effects of mortalities due to predation and other causes. The anemones, including Metridium (to 392.7/m^2) and Tealia (to 9.5/m^2), were also abundant and occasionally occupied a significant amount of primary space.

Grazing pressure appeared intense. Four species of chitons, lead by K. tunicata (to 66/m^2) and T. lineata (to 84/m^2), limpets (to 200/m^2), and sea urchins (to 76/m^2) were the dominant grazers.

Two species of starfish (L. ?hexactis (to 18/m^2) and E. troschelii (to 64/m^2) were common at this level, probably exploiting primarily the recent set of mussels. Scavengers or omnivores occasionally seen at this level were the brachyurans, Cancer oregonensis (to 8.0/m^2) and Pugettia gracilis (to 8.0/m^2).

4.1.2 Seldovia Point

General ecological features of Seldovia Point intertidal and subtidal communities have been described by Dames & Moore (1976) based on the 1974 to 1976 studies. These characteristics are summarized here.

The uppermost edge of the macrophyte zone began at about +4 m or above depending on the exposure with patches of the rockweed Fucus distichus, and occasional tufts of Endocladia muricata. Vast numbers of the periwinkle Littorina sitkana were often present grazing on periphyton and Fucus. Acorn barnacles (Balanus glandula) were abundant along with a major predator on them, the snail Nucella sp.

At lower levels, Fucus was joined by increasing amounts of red algae including Halosaccion glandiforme, Rhodymenia spp.* and Gigartina papillata. Barnacles were joined by the mussel, Mytilus edulis, as a major occupant of primary space. The limpets, Collisella and Notoacmaea, were the most abundant grazers.

Below about +2.0 m the reds were clearly dominant to about the +1.5-m level or below. In this broad zone, seasonally dominated by the brown alga Alaria taeniata, occupied much of the boulder beach to near MLLW. The reds from the upper level were found as understory species in this area along with encrusting corallines in the wetter areas. Surge, or drainage, channels and permanently wetted areas had dense growths of the laminarian Hedophyllum sessile. The thatched barnacle B. cariosus was abundant throughout the Alaria zone and extended to below MLLW.

Several herbivores were conspicuous in this area. Limpets and the large chiton Katharina tunicata were found throughout, while the green urchin Strongylocentrotus droebachiensis occurred primarily in lower areas. A sharp reduction in algal cover and biomass occurred throughout this zone in fall and winter as the result of low light levels, damage from exposure during low tides, heavy seas, and possibly, intense herbivory. The six-ray starfish Leptasterias ?hexactis was an important predator on barnacles, mussels, and snails throughout the area. Under boulders in this area, typical assemblage included large numbers of a small sea cucumber, Cucumaria ?vegae, the isopods Gnorimosphaeroma oregonensis, Pentidothea wosnesenskii, gammarid amphipods, urchins, a predatory snail Volutharpa ampulacea, periwinkles, limpets, a sipunculid worm Golfingia margaritacea, and Leptasterias.

Near and below MLLW, A. taeniata gave way to A. fistulosa and Laminaria groenlandica, typically subtidal forms. The opportunistic green alga Monostroma covered substantial areas of the bench in the

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* Includes R. liniformis, called Callophyllis in Dames & Moore (1976), and R. palmata.

vicinity of MLLW and, along with Alaria, was a common food of the urchins. Large areas devoid of significant macroalgae attested to the efficiency of urchin herbivory. Other important herbivores included the limpets and chitons seen farther up the beach as well as the lined chiton, Tonicella lineata, a micro-grazer often found in association with crustose corallines.

From below MLLW to past the 18-m contour, lay an extensive multi-layered kelp bed. The floating canopy consisted of the bull kelp Nereocystis luetkeana and A. fistulosa. Under this were intermediate layers of L. groenlandica and the "sieve kelp" Agarum cribrosum, and a lower layer of foliose red algae such as Turnerella mertensiana,* Kallymenia and Callophyllis sp. On the substrate beneath these macroalgae were cushion-like patches of Codium ritteri and the encrusting corallines. This subtidal algal assemblage also experienced high seasonality with a major reduction in areal coverage in the fall and early winter. New growth began in early spring. Macroinvertebrates were common with echinoderms (urchins and starfish) among the most obvious forms.

Intertidal sampling was carried out four times (February 16, May 5 and 6, July 2 and 3, August 28 and 29) at four levels (+2.0, +1.5, +0.8, 0.0 m) on Seldovia Point during 1977 and five times (March 7, May 26, June 20, July 19, and October 19) at three levels (+2, +1.5, 0.0 m) during 1978. Subtidal sampling was conducted in five periods (February 10 and 12; May 10, 11, and 13; August 4 and 5; September 13; November 2 and 5) at three depths (6, 12, and 18 m) in 1977, and in three periods (June 1, 2, and 29; July 11 and 12, October 30 and 31; November 8) at three depths (-6, 9, and 12 m) in 1978. Sampling was in accordance with procedures described in Sections 3.1.1 and 3.1.2.

+2 m, the "Fucus" Zone

The upper level sampled during 1977-78 (+2.0 m) was in an area of large (0.3 to 2 m) boulders interspersed with areas of less stable

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* Includes forms called ?Schizymenia in Dames & Moore (1976).

cobbles and gravel. This variability in substrate was reflected in a high degree of patchiness in organism distributions. Moderate development of benthic species occurred on stable rock surfaces clear of gravel abrasion while few organisms were found in the finer materials unless the substrate was stabilized by proximity to larger boulders (e.g., under rock fauna).*

The dominant alga at the +2.0-m level was the rockweed F. distichus. This species showed a moderately strong seasonal pattern with a steady increase in coverage through the spring and early summer. Peak standing crop was reached in July in both 1977 (30.8 percent, 2,934 g/m^2) and 1978 (23.8 percent, 1,466 g/m^2) with a minimum value of 9 percent cover and 249 g/m^2 recorded in March 1978 (Figures 4-4 and 4-5, Appendix Tables 4-2-1 through 4-2-11). A variety of red algae, especially H. glandiforme, R. liniformis, and the opportunistic Porphyra sp. were also present, especially in the summer, but only exceeded 10 percent total coverage in June and July. Biomass contribution of red algae at this level was small to insignificant.

Sessile epifauna was very sparse at the +2.0-m level. Fairly dense barnacle cover (19.8 percent) was present in February 1977, but declined to less than 1 percent by late summer, remaining low throughout 1978 (Tables 4-6 and 4-7). Average cover of the mussel M. edulis was less than 2.6 percent throughout the study period. New set and growth of the small barnacle Chthamalus dalli covered up to 3.8 percent (July 1978) of the primary substrate.

Moreover, relatively few species of motile invertebrates were found at +2 m (Figure 4-6), and the only species present in large numbers were periwinkles (1,686/m^2, only counted in February 1977), the limpets (to 109/m^2), and the pulmonate Siphonaria thersites (to 61.2/m^2). All of these species are primarily grazers on the microflora coating rocks and

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* Sampling conventions adopted did not include counting of under-rock fauna or infauna unless they were visible without moving any substrate materials.

TABLE 4-6

Sheet 1 of 2

SELDOVIA POINT INTERTIDAL INVERTEBRATE DOMINANTS, 1977

Level/Species	Date/Average Percent Cover or No./m^2 2/16/77	5/5-6/77	7/2-3/77	8/28-29/77
+2 m				
(% Cover)				
Balanus glandula	19.8	2.3	1.2	0.5
Mytilus edulis	2.6	1.7	2.6	1.7
(#/m^2)				
Acmaeidae	10.0	99.6	81.5	66.8
Anthozoa[c]	<6	2.8	0.4	1.6
Leptasterias ?hexactis	0	0	6.7	1.6
Littorina sitkana	1,685.7	P	P	P
Nucella emarginata	2.4	4.0	0	0.4
Pagurus hirsutiusculus	0	0	4.4	2.0
Pentidothea wosnesenskii	2.4	P[a]	0	8.8[b]
Siphonaria thersites	0.4	0	2.2	16.8
1.5 m				
(% Cover)				
Balanus cariosus	0.6	0.1	2.9	2.4
Chthamalus dalli	2.6	0.5	2.4	1.8
Halichondria panicea	1.2	0.3	3.7	0.8
Rhynchozoon bispinosum	0	P	2.7	5.4
(#/m^2)				
Acmaeidae	7.2	58.0	43.2	54.7
Anthozoa[c]	0	0	1.6	4.4
Cucumaria vegae	1.6	P	6.4	P
Katharina tunicata	0	0.5	2.0	1.3
Leptasterias ?hexactis	0	0.	6.0	4.4
Metridium sp.	0	0	0.4	5.3
Pagurus hirsutiusculus	0	0	P	1.8
Schizoplax brandtii	0	0.5	3.2	0.4
Siphonaria thersites	P	5.7	22.0	17.8
0.8 m				
(% Cover)				
Balanus cariosus	14.0	17.4	13.1	21.2
Chthamalus dalli	3.0	0.1	1.4	7.1
Halichondria panicea	0	10.4	2.3	8.2
Rhynchozoon bispinosum	0.4	0.3	1.7	11.7
Schizobranchia insignis	0	0	2.8	0.7
(#/m^2)				
Acmaeidae	6.4	25.5	53.9	15.2
Anthozoa[d]	0.8	0.5	1.6	1.6
Cucumaria vegae	0	P	11.6	P
Katharina tunicata	23.2	17.0	20.0	32.8
Leptasterias ?hexactis	0	1.5	4.4	3.6
Pagurus beringanus	0	0	6.0	4.0
Pugettia gracilis	0	0	1.6	11.6
Schizoplax brandtii	0.8	4.0	0.4	0.4
Tealia spp.	4.0	1.0	0.4	0

(a) P = present.
(b) Identification in this period is uncertain.
(c) Includes all anthozoan species at this level except *Metridium* sp.
(d) Includes all anthozoan species at this level except *Tealia* spp.

TABLE 4-6

Sheet 2 of 2

Level/Species	Date/Average Percent Cover or No./m^2			
	2/16/77	5/5-6/77	7/2-3/77	8/28-29/77
0.0 m.				
(% Cover)				
Balanus cariosus	17.1	15.2	11.8	27.5
Halichondria panicea	2.8	0	1.1	0.5
Schizobranchia insignis	6.8	0.8	0.1	0.6
(#/m^2)				
Acmaeidae	3.6	13.3	20.0	10.8
Katharina tunicata	7.5	12.9	6.0	3.2
Leptasterias ?hexactis	1.2	0.4	1.6	3.6
Metridium senile	0	0	0	7.6
Mopalia ciliata	0	3.1	7.2	15.2
Pagurus beringanus	0	0	5.6	0.4
Pugettia gracilis	0.4	1.8	0	10.0
Strongylocentrotus drobachiensis	0.4	13.3	37.2	10.0
Tonicella lineata	2.0	4.4	8.4	5.6

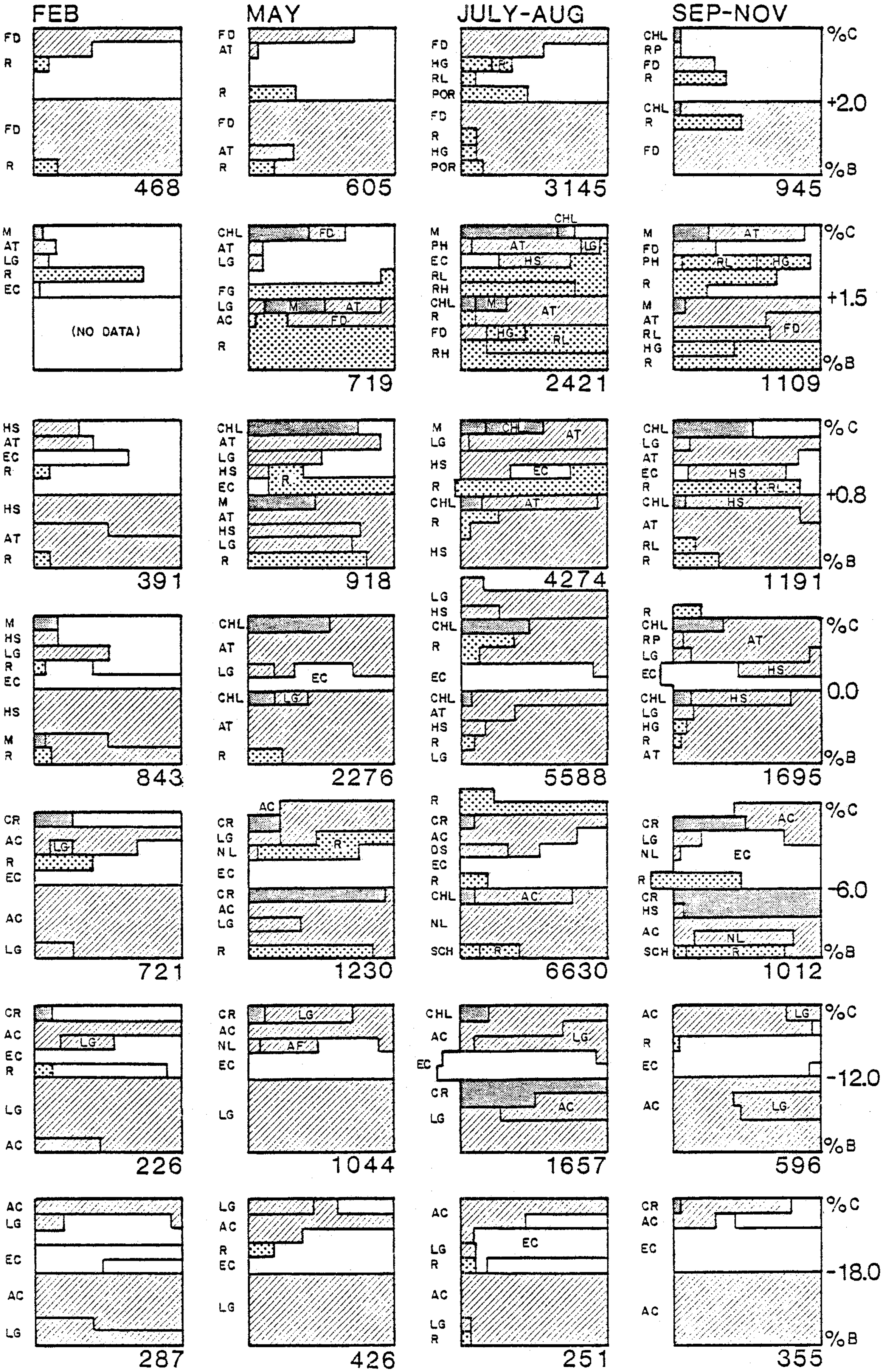
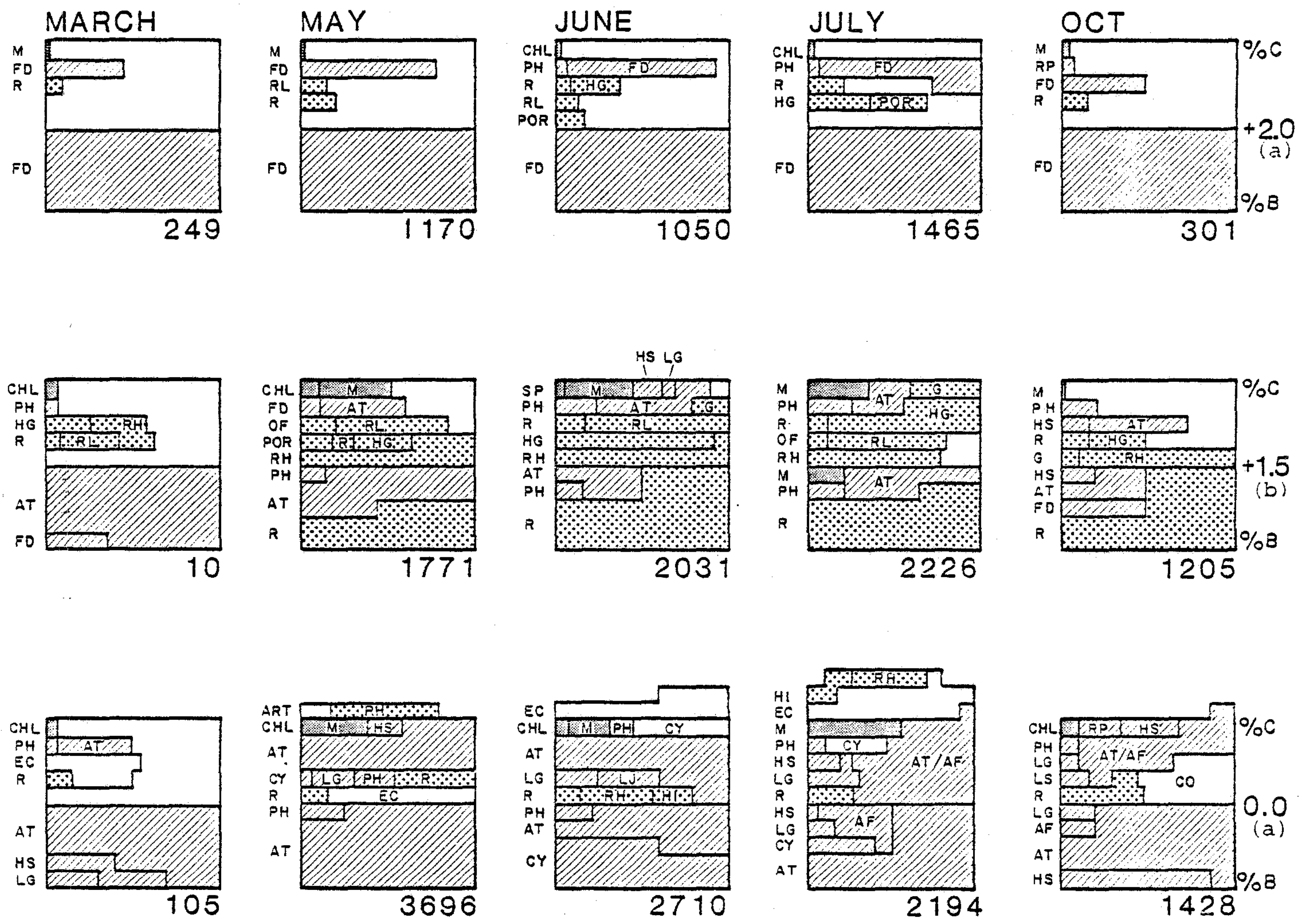


FIGURE 4-4

ZONATION, COVER AND BIOMASS OF ALGAE AT SELDOVIA POINT IN 1977



(a) Only phaeophytes were weighed at this level.

(b) Only phaeophytes were weighed at this level in March. Chlorophytes were only weighed in July.

FIGURE 4-5

ZONATION, COVER AND BIOMASS OF ALGAE AT SELDOVIA POINT IN 1978

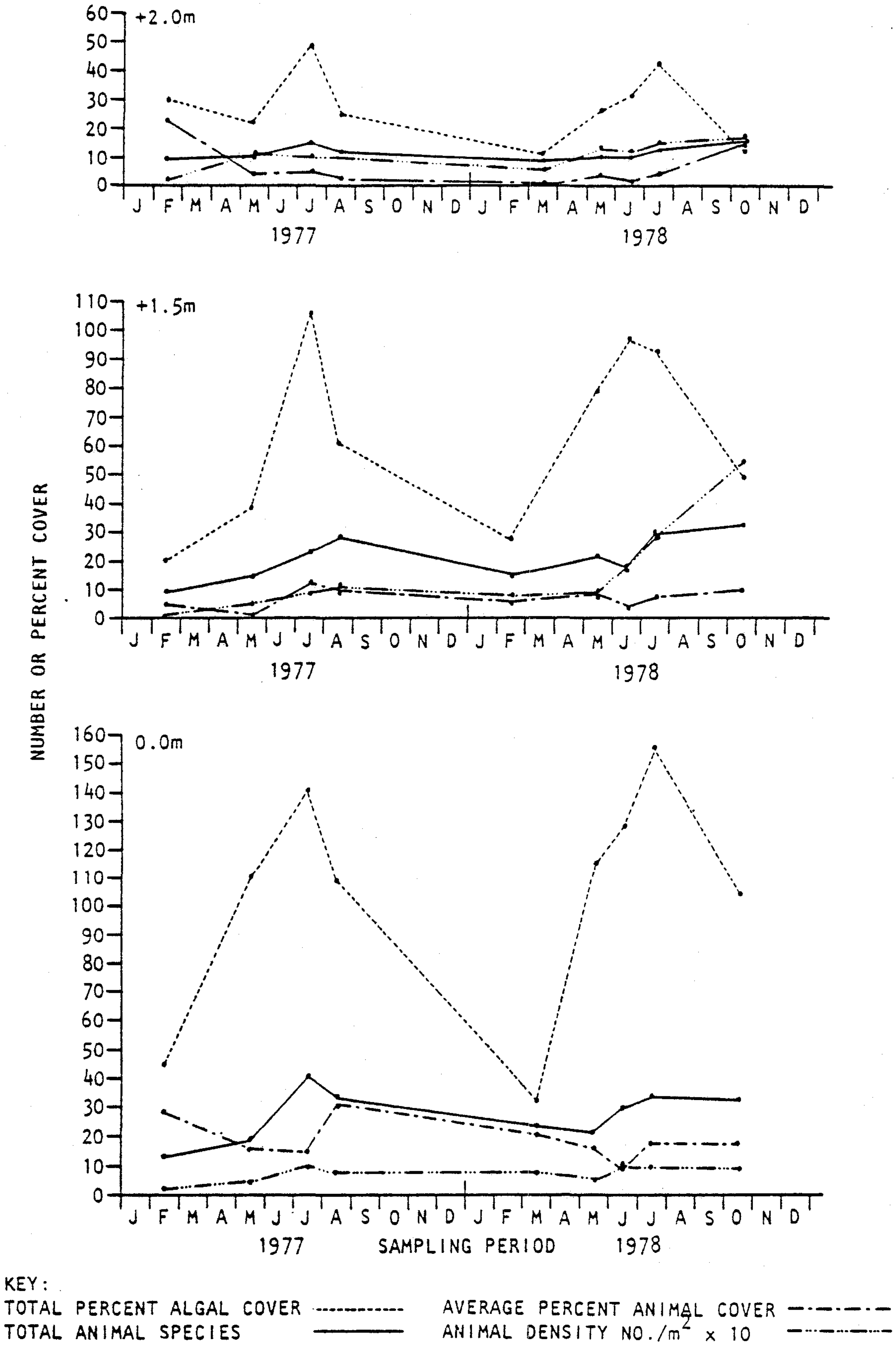


FIGURE 4-6

TRENDS IN COMMUNITY PARAMETERS AT SELDOVIA POINT IN 1977-1978 plants of this level. The starfish Leptasterias, a predator on these gastropods as well as on barnacles and mussels, was seen only occasionally (to 6.7/m^2 in July 1977) but more undoubtedly went unnoticed under larger boulders. Nucella emarginata, a predator on barnacles, was also not overly abundant (to 4.0/m^2 in July 1977) and was only seen in 4 of 9 sample periods, Tables 4-6 and 4-7).

A large disparity existed at this level between the density of the most abundant species (limpets and pulmonates) and that of the next most abundant forms (Tables 4-6 and 4-7).

+1.5 m, the "Rhodymenia" Zone

At the +1.5-m level the red algae R. palmata, R. liniformis, and H. glandiforme visually dominated a fairly narrow but distinct band of shoreline. At this level the substrate was predominantly boulders and cobbles containing more stable substrate than at higher levels. This, plus the greater immersion time, permitted development of a more diverse and productive community than that found at higher levels.

Total algal cover was near 100 percent in midsummer (June, July) with total standing crop exceeding 2,000 g/m^2 (Tables 4-8 and 4-9, Figures 4-4 and 4-5). Reduction in standing crop began by August and winter levels were very low, probably less than 100 g/m^2. The three dominant red algae were approximately equal in abundance during most of the year, but R. liniformis seemed to decline more quickly in the fall than the other species.

Some areas sampled at the +1.5-m level were transitional with the "Alaria" zone below and contained significant amounts of A. taeniata. Average standing crop of Alaria was only 9.3 g/m^2 with less than 1 percent cover in March 1978 but increased to 798 g/m^2 with 9.6 percent cover by May. Green algae, primarily Monostroma sp. contributed up to 15.6 percent cover (July 1977). However, standing crop did not exceed 100 g/m^2 except in July 1977 when it reached 161 g/m^2, still less than 7 percent of the total biomass.

TABLE 4-7

SELDOVIA POINT INTERTIDAL INVERTEBRATE DOMINANTS, 1978

	Date/Average Percent Cover or No./m^2				
Level/Species	3/7/78	5/26/78	6/20/78	7/19/78	10/19/78
+2 m					
(% Cover)					
Balanus cariosus	0.1	0.2	0	0	0.6
Balanus glandula	0.3	0.3	0.3	0.4	0.6
Chthamalus dalli	0.3	1.8	0.7	3.8	0.2
Mytilus edulis	0.2	1.5	0.3	0.6	0.2
(#/m^2)					
Acmaeidae	44.4	100.8	66.8	108.8	99.6
Anthozoa(a)	4	1.2	0.4	1.2	2.4
Cucumaria vegae	0	0	1.2	0	0
Nucella emarginata	0	0	0.0	3.2	0
Pagurus hirsutiusculus	0	0.8	4.0	0.4	0
Siphonaria thersites	13.2	22.8	54.8	40.0	61.2
1.5 m					
(% Cover)					
Balanus cariosus	0.5	0.6	1.5	0.5	1.7
Balanus glandula	0	0.1	0	0	6.0
Chthamalus dalli	4.9	0	0.8	0.4	1.3
Mytilus edulis	0.2	2.6	0.1	0.2	0.2
Rhynchozoon bispinosum	0.3	0	2.5	5.9	9.0
(#/m^2)					
Acmaeidae	37.6	44.8	52.8	65.2	91.6
Anthozoa(b)	3.2	0	0.4	0	8.0
Cucumaria vegae	0.8	P(c)	47.6	27.2	2.0
Katharina tunicata	1.6	0.4	2.4	2.0	3.6
Leptasterias ?hexactis	0	2.4	4.4	5.6	36
Metridium spp.	0.8	2.4	3.2	15.6	0
Nemertea(a)	0.4	2.8	1.6	0.4	3.6
Nucella sp.	4.0	0	1.2	0.8	0.4
Pagurus spp.(a)	0	2.8	2.4	4.8	9.6
Pentidotea wosnesenskii	0.4	4.8	P	0	P
Schizoplax brandti	0	2.4	9.2	2.4	0.4
Siphonaria thersites	28.4	16.4	35.6	157.6	395.6
0.0 m					
(% Cover)					
Balanus cariosus	18.3	12.7	6.8	12.4	5.0
Chthamalus dalli	0	0.1	0	0.3	10.4
Rhynchozoon bispinosum	0	0.3	0.4	1.4	0.6
Schizobranchia insignis	2.1	P	0.8	1.3	0.1
(#/m^2)					
Acmaeidae	14.8	13.2	14	36.0	7.0
Anthozoa(b)	4.4	1.2	0	2.0	1.0
Katharina tunicata	19.2	26.8	10.4	17.2	32
Leptasterias ?hexactis	2.4	2.0	0.4	4.4	0.5
Metridium spp.	0.4	2.0	1.6	5.2	0
Mopalia ciliata	1.6	3.2	2.8	0	6
Nemertea(a)	0	0.4	4	7.2	4.5
Pagurus beringanus	1.2	0	32	2.4	0
Pentidotea wosnesenskii	1.2	0.6	0	0	P
Strongylocentrotus drobachiensis	14.0	8.8	16.4	1.6	5.0
Tonicella lineata	1.6	3.6	9.2	7.6	2.5

(a) Includes all species.
(b) Unidentified spp., includes Tealia crassicornis.
(c) P = present.

TABLE 4-8

SELDOVIA POINT ALGAL COVER AND BIOMASS BY CLASS, 1977

	Level													
	+2 m		+1.5 m		+0.8 m		0.0 m		-6 m		-12 m		-18 m	
Month/Class	%	gm/m^2	%	gm/m^2	%	gm/m^2	%	gm/m^2	%	gm/m^2	%	gm/m	%	gm/m
February														
Chlorophyta	0.2	0.7	0.8	--	0.3	--	2.7	6.8	4.8	1.8	1.9	--	0	0
Rhodophyta														
encrusting	0	--	1.2	--	13.3	--	27.3	--	38.1	--	31.3	--	28.0	--
other	1.8	15.1	14.5	--	2.3	9.2	1.2	14.1	8.1	--	1.8	8.3	0.1	--
Phaeophyta	27.7	452.5	3.8	--	14.0	381.8	12.7	821.8	36.3	719.5	30.2	226.0	23.3	282.4
Total	29.7	468.3	20.3	--	29.9	391.0	43.9	842.7	87.3	731.3	65.2	234.3	51.4	282.4
May														
Chlorophyta	0.3	0.3	8.1	60.9	14.7	79.9	10.5	64.2	3.7	228.1	1.9	40.9	0	0
Rhodophyta														
encrusting	0	--	0	--	2.5	--	27.8	--	45.0	--	72.4	--	45.5	--
other	6.4	17.4	22.3	455.5	21.8	142.6	12.1	86.6	23.8	207.9	15.8	5.3	3.1	T(a)
Phaeophyta	15.7	587.3	8.4	202.8	31.2	677.2	58.6	2,123.2	42.2	713.2	49.9	1,009.7	39.4	425.8
Total	22.4	605.0	38.3	719.2	70.2	899.7	109.0	2,274.0	114.7	1,149.0	140.0	1,055.9	88.0	425.8
July-August														
Chlorophyta	1.8	1.5	15.6	160.8	10.9	102.3	9.3	47.8	1.7	116.4	3.4	490.9	0	0
Rhodophyta														
encrusting	0	--	4.8	--	8.1	--	38.1	--	49.3	--	46.8	--	41.4	--
other	15.3	205.6	64.3	1,395.6	25.4	269.7	9.2	86.8	28.7	409.5	T	3.9	2.1	41.4
Phaeophyta	31.1	2,937.6	19.5	884.7	56.7	3,901.8	83.9	5,453.3	46.4	6,103.8	56.5	1,162.1	26.8	248.7
Total	48.2	3,144.7	104.2	2,421.1	101.1	4,273.8	140.0	5,587.9	126.1	6,629.7	106.8	1,656.9	70.1	250.8
September-November														
Chlorophyta	0.5	0.6	4.6	19.8	10.9	37.8	6.7	35.4	9.3	787.9	0	0	0.6	--
Rhodophyta														
encrusting	0	--	0.1	--	2.0	--	32.0	--	62.0	--	58.8	--	63.3	--
other	6.6	83.1	37.0	574.9	17.2	193.5	3.8	39.4	12.6	242.9	0.8	0.02	2.8	0
Phaeophyta	19.2	861.6	20.0	514.2	51.1	1,760.1	66.1	1,620.1	31.1	986.0	38.6	596.2	22.0	355.2
Total	26.3	945.3	61.7	1,108.9	81.2	1,991.4	108.6	1,694.9	115.0	2,016.8	98.2	596.2	88.1	355.2

(a) T = Trace.

TABLE 4-9

SELDOVIA POINT ALGAL COVER AND BIOMASS BY CLASS, 1978

	Tide Level					
	+2 m		+1.5 m		+0.0 m	
Month/Taxon	%	gm/m^2(a)	%	gm/m^2	%	gm/m^2(a)
March						
Chlorophyta	0.1	--	1.4	--	1.1	--
Rhodophyta						
encrusting	0	--	0.8	--	17.8	--
other	2.0	--	23.7	--	3.7	--
Phaeophyta	9.2	249.2	1.4	10.0	10.0	105.3
Total	11.3	249.2	27.3	10.0	32.6	105.3
May						
Chlorophyta	0.6	--	11.2	--	8.1	--
Rhodophyta						
encrusting	0	--	0.1	--	18.6	--
other	6.7	--	24.4	--	2.9	--
Phaeophyta	18.7	1,169.8	13.2	859.6	62.1	3,696.0
Total	26.0	1,169.8	79.2	859.6	115.2	3,696.0
June						
Chlorophyta	0.4	--	8.3	--	6.5	--
Rhodophyta						
encrusting	0	--	0.1	--	28.2	--
other	12.0	--	63.7	1,623.5	16.7	--
Phaeophyta	18.8	1,050.0	24.0	407.5	77.4	2,709.6
Total	31.2	1,050.0	96.1	2,031.0	128.8	2,709.6
July						
Chlorophyta	0.8	--	7.1	--	11.5	--
Rhodophyta						
encrusting	0	--	1.4	--	34.2	--
other	16.7	--	68.0	1,498.5	22.8	--
Phaeophyta	24.9	1,465.6	15.3	639.8	86.7	2,194.2
Total	41.6	1,465.6	91.8	2,225.8	155.2	2,194.2
October						
Chlorophyta	0.1	--	0.9	--	1.7	--
Rhodophyta						
encrusting	0	--	0.7	--	26.6	--
other	2.3	--	29.0	840.6	15.2	--
Phaeophyta	10.0	301.2	19.0	364.6	61.0	1,427.5
Total	12.4	301.2	49.6	1,205.2	104.5	1,427.5

(a) Only phaeophytes were weighed at +2 m and 0.0 m.

The very dense algal growth at +1.5 m was probably closely related to the limited occupation of primary space by sessile animals and the grazers. Three species of barnacles, B. glandula, B. cariosus, and C. dalli, contributed up to 9 percent coverage, often on boulder tops or under overhangs unsuitable for algal growth. The mussel M. edulis was not abundant in the area although some large boulders nearby supported nearly 100 percent cover. The starfish Leptasterias may have contributed somewhat to low numbers of barnacles and mussels. Increased coverage of barnacles in October 1978 was paralleled by increased density of Leptasterias to $36/m^2$, the maximum recorded at this level. The encrusting bryozoan Rhynchozoon bispinosum covered up to 9 percent of the surface (October 1978), mostly on overhanging surfaces.

The most abundant herbivores were the pulmonate S. thersites (to $396/m^2$) and the limpets (to $92/m^2$). Numbers of both appeared to increase markedly in late summer and fall due to recruitment of a new generation. Although usually considered to be microherbivores, these animals, especially Siphonaria, were clearly consuming material from the fronds of Rhodymenia and Halosaccion in October 1978. The large chiton Katharina tunicata, while not abundant (to $3.6/m^2$), was a significant grazer at this level. The isopod Pentidotea wosnesenskii was usually present and occasionally abundant (but not counted) attached to algae or under boulders and, along with the hermit crab Pagurus hirsutiusculus (to $9.6/m^2$), was an important scavenger at this level. Anemones, especially Metridium sp. (to $15.6/m^2$) were another scavenging group found here.

+0.8 m, the "Alaria" Zone

The +0.8-m level was only sampled in 1977. It lay approximately in the middle of the broad lower section of cobble bench that was characterized during the summer months by an abundance of the brown alga Alaria taeniata. Development of Alaria peaked in 1977, with 38 percent cover (July) and a biomass of 1,333 g/m^2 (August). The sampling area was laterally crossed by several surge or runoff channels where the laminarian Hedophyllum sessile was strongly dominant. The holdfast of this species was virtually always in a permanently wetted area while that of Alaria was typically on an emergent rock or B. cariosus shell. Coverage by H. sessile in individual quadrats occasionally reached 100 percent with biomass equivalent to 10 kg/m^2. Average coverage peaked at 36 percent in July with an average biomass of 3,185 g/m^2 (Tables 4-8 and 4-9).

At the +0.8-m level, coverage of the primary substrate by sessile animals was much greater than at +1.5-m level. This was attributable primarily to large B. cariosus (13.1 to 21.2 percent cover, Table 4-6), although the green sponge Halichondria panicea (to 10.4 percent) and the encrusting bryozoan R. bispinosum (to 11.7 percent) were also important. Acmaeids (to $53.9/m^2$) and Katharina (to $32.8/m^2$) lead the grazers in abundance; Siphonaria was completely absent. Scavengers and predators remained much as at the 1.5-m level except that Pagurus beringanus (to $6/m^2$) and Pugettia gracilis (to $11.6/m^2$) largely replaced Pagurus hirsutiusculus and Pentidotea.

0.0 m, the lower "Alaria" Zone*

Rock surfaces in the upper portion of this sampling area were typical of the broad "Alaria" band described at the +0.8-m level, but the lower portions of the irregular bench were transitional, supporting many more typically subtidal species (e.g., Alaria fistulosa, Cymathere triplicata, Nereocystis luetkeana, Strongylocentrotus, Henricia tumida, Trichotropis cancellata and unidentified tunicates).

Encrusting coralline algae accounted for a relatively constant percent coverage of the primary substrate (17.8 to 34.2 percent) over the 2-year study period (Tables 4-8, 4-9). Total coverage by non-encrusting algae varied more widely on a seasonal basis at this level than at any other level (e.g., from 14.8 percent in March to 121.1 percent in July 1978; Figure 4-6). Laminarians accounted for greater than 90 percent of

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* The fixed pin at this level was actually at about +0.3 m (+1 ft) on a rock ridge. However, most of the sampling occurrd at lower elevations (to about -0.3 m); hence, the approximate average level of 0.0 m was used.

algal biomass at this level with the remaining portion about equally split between reds and greens. Average algal biomass peaked at 5,588 g in July 1977 and 3,696 g (phaeophytes only) in May 1978 (Tables 4-8 and 4-9).

Alaria taeniata (to 54.9 percent cover, 3,501 g/m^2) was the dominant species throughout most of the study. Temporary dominance by H. sessile (February 1977), Laminaria groenlandica (July 1977) and Cymathere (June 1978) (Figures 4-5, 4-6) was probably due, in part, to differences in the precise orientation of the sample transverse between sampling periods.

The thatched barnacle B. cariosus was the dominant sessile animal at MLLW with coverage ranging from a low of 5 percent to a high of 27.5 percent. Sand tubes of the sabellid polychaete Schizobranchia insignis formed cushion-like aggregations covering 6.8 percent of the primary substrate in February 1977 and from 0.1 to 2.1 percent during the remainder of the study.

Major herbivores from higher levels (Acmaeidae to 36/m^2; K. tunicata to 32/m^2) were joined by the green sea urchin S. drobachiensis (to 37.2/m^2). As in previous years, these grazers were effective at reducing algal cover. Some areas, especially slightly below MLLW where high densities of urchins were found, were virtually devoid of macroalgae. In October 1978 many K. tunicata had "captured" fronds of A. taeniata between their mantle and the rock and were systematically eating through the midrib. Many plants in the vicinity had been truncated in this fashion, usually fairly close to the stipe. The chitons Mopalia ciliata (to 15.2/m^2) and Tonicella lineata (to 9.2/m^2) were important grazers on the microflora of this level. Predation by the grazers and the starfish Leptasterias ?hexactis (to 4.4/m^2) probably was a major factor in limiting recruitment of B. cariosus. Most B. cariosus at this level were adults that were several years old. The sea anemones Metridium senile, Tealia spp., and Cribrinopsis were common (to 7.2/m^2).

In general, the abundance of dominant animal species tended to fluctuate less widely at this level than at the higher levels sampled (Figure 4-6). Moreover, no one or two animals were vastly more abundant than all others as occurred with limpets and *Siphonaria* at higher levels.

4.2 ROCKY HABITATS - WEST SIDE

4.2.1 Scott Island

No previous detailed ecological surveys of Scott Island have been conducted. Based on aerial surveys, Dames & Moore (1977) reported that the islands off the entrance to Iniskin Bay supported "light to moderate algal cover." From field surveys, they also described in moderate detail the assemblages on "Rocky Point", which juts into Iniskin Bay about 1.8 km NNE of Scott Island, and the algal assemblage on the west and southwest side of Scott Island itself. The latter site is generally the same location described below. Upper intertidal levels had abundant cover by the rockweed *Fucus distichus* and barnacles. Intermediate levels had an abundance of several "pioneer" species, e.g., *Rhodymenia palmata*, *R. liniformis*,* *Halosaccion glandiforme*, *Odonthalia*, and *Porphyra*. Laminarians were uncommon since observations did not extend below MLLW.

Three levels on the Scott Island transect were sampled four times (April 23-24, June 23, July 21, September 16) during 1978.

The "*Fucus*" Zone

The upper level sampled on Scott Island was intentionally located on irregular bedrock at an elevation supporting maximum development of the "*Fucus*" zone. *Fucus* achieved its maximum coverage (54 percent) in April and remained at about 50 percent until September when it dropped to 37.1 percent. Maximum biomass (2,292 g) was recorded in July (Table 4-10). No other erect alga was very abundant on the sloping rocks of the true "*Fucus*" zone but the encrusting brown ?*Ralfsia pacifica* was common (to 38 percent cover). However, the sampling transverse at this level included a fairly broad (2 to 4 m) runoff channel where continuous wetting permitted development of a biota typical of considerably lower levels. Several red algae were sufficiently abundant in this area to

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*Called *Callophyllis* in Dames & Moore (1977).

TABLE 4-10

SCOTT ISLAND ALGAL COVER AND BIOMASS BY MAJOR TAXON, 1978

	Zone					
	"Fucus"		"Rhodymenia"		"Laminarian"	
Month Taxon	%	gm/m$^{2(b)}$	%	gm/m^2	%	gm/m^2
April						
Chlorophyta						
encrusting	0.2	--	1.0	--	0.9	--
other	0.6	--	9.4	9.9	5.9	2.7
Encrusting reds & browns(a)	22.1	--	0.4	--	0.1	--
Phaeophyta	54.0	1,491.6	13.3	224.6	13.0	214.5
Rhodophyta						
encrusting corallines	1.3	--	0.1	--	0.7	--
other	21.2	137.2	58.1	1,587.1	21.8	268.2
Total	99.4	1,628.8	82.3	1,821.6	42.4	485.4
June						
Chlorophyta						
encrusting	0.7	--	7.0	--	0.8	--
other	1.0	--	10.9	75.3	12.2	106.4
Encrusting reds & browns	49.9	--	18.3	--	3.4	--
Phaeophyta	49.7	2,150.8	6.7	555.1	43.9	2,197.7
Rhodophyta						
encrusting corallines	0.6	--	5.8	--	8.1	--
other	19.2	--	124.0	4,635.0	67.9	1,726.6
Total	121.1	2,150.8(b)	172.7	5,265.4	136.3	4,030.7
July						
Chlorophyta						
encrusting	0.7	--	5.3	--	1.3	--
other	2.5	--	1.4	--	7.6	--
Encrusting reds & browns	17.1	--	10.3	--	1.7	--
Phaeophyta	59.0	2,292.2	11.7	517.4	62.1	1,169.0
Rhodophyta						
encrusting corallines	4.4	--	0.5	--	10.6	--
other	29.7	--	125.2	4,368.1	71.1	3,473.7
Total	113.4	2,292.2(b)	154.4	4,885.5	154.4	4,642.7
September						
Chlorophyta						
encrusting	0.2	--	10.2	--	1.3	--
other	1.7	--	1.6	--	3.2	15.7
Encrusting reds & browns	30.8	--	9.2	--	2.9	--
Phaeophyta	37.6	1,374.0	7.3	115.1	23.7	448.2
Rhodophyta						
encrusting corallines	4.9	--	0.3	--	14.4	--
other	22.9	--	88.7	1,404.1	55.2	1,345.0
Total	98.1	1,374.0	117.3	1,519.2	100.7	1,808.9

(a) Includes _Ralfsia pacifica_ and other unidentified encrusting rhodophytes and phaeophytes.

(b) Only phaeophytes weighed at this level.

contribute a total coverage of about 55 percent when averaged over the entire sampling period. These include Rhodomela ?lycopodioides and Odonthalia floccosa (to 18.2 percent), and encrusting corallines (to 4.9 percent), but an unidentified red algal film contributed considerably.

The fauna was poorly developed in the "Fucus" zone. Although among the most important, the barnacles B. glandula and C. dalli contributed marginally to cover (Table 4-11). The important micrograzers included acmaeids (up to $24.4/m^2$), Littorina sitkana, and pulmonate snail Siphonaria thersites (up to $11.2/m^2$). Important predators and scavengers included the whelk N. emarginata (to $23.6/m^2$) and the hermit crab P. hirsutiusculus (to $37/m^2$). Invertebrate populations were generally dominated by juveniles; adults were fairly uncommon.

The "Rhodymenia" Zone

Below the "Fucus" zone, the bedrock dropped off slowly and then formed a conspicuous hogback parallel to the shoreline. At this level, the appearance of the biota was strongly dominated by the red algae R. pacifica (up to 64.3 percent) and R. liniformis (up to 74.2 percent). Maximum biomass for red algae was 4.6 kg/m^2 in June (Table 4-10). Other plants that contributed significantly to the vegetative assemblage at this level included Fucus (up to 10.9 percent and 516.3 g/m^2), the red algae Gigartina papillata (up to 17.1 percent), and Halosaccion glandiforme (14.8 percent). Several encrusting algae contributed slightly to cover.

The fauna at this level was quite impoverished. Only two sessile forms appeared commonly (Table 4-11); neither appeared to contribute appreciably. Motile forms were likewise sparse. None of the species exceeded a density of $7.5/m^2$. Highest densities were observed in September.

TABLE 4-11

SCOTT ISLAND INTERTIDAL INVERTEBRATE DOMINANTS

	Date/Average Percent Cover or No./m^2			
Level/Species	4/24/78	6/23/78	7/21/78	9/16/78
	"Fucus" zone			
(% Cover)				
Balanus glandula	10.3	10.2	4.1	0.9
Chthamalus dalli	0	1.6	6.3	5.8
Halichondria panicea	0.3	1.0	3.8	4.6
(#/m^2)				
Acmaeidae	23.6	24.4	16.8	18.0
Cerithiopsis sp.	0	0	0	5.0
Littorina sitkana	P	P	P	P
Nucella emarginata	23.6	12.8	5.2	18.5
Pagurus beringanus	0	5.2	0.4	18.5
Pagurus hirsutiusculus	23.2	12.4	21.2	37.0
Pagurus unid. juv.	0	4.8	0	0
Schizoplax brandtii	2.0	0.8	0	9.0
Siphonaria thersites	3.6	11.2	9.6	7.0
Volutharpa sp.	4.0	0	0	0
	"Transition" zone			
(% Cover)				
Halichondria panicea	3.5	0.9	2.6	2.5
Rhynchozoon bispinosum	0	0.8	3.1	2.1
(#/m^2)				
Acmaeidae	1.2	2.9	1.3	4.7
Lacuna sp.	0	1.7	0	--
Pagurus beringanus	0	0	0	3.3
Pagurus hirsutiusculus	0	0	1.3	7.3
	"Rhodymenia" zone			
(% Cover)				
Halichondria panicea	0.05	1.0	0.3	0.5
Modiolus modiolus	0.3	1.6	0.7	4.8
(#/m^2)				
Acmaeidae	2.0	1.6	1.2	5.3
Leptasterias sp.	1.2	1.2	6.0	5.3
Pagurus beringanus	0.4	1.6	4.8	8.0
Telmessus cheiragonus	0	2.0	0.8	0
Tonicella lineata	0	3.2	0.4	7.3

The Laminarian Zone

Below the hogback at the outer edge of the "Rhodymenia" zone, a 30 m wide bedrock terrace strewn with small boulders and shallow tide pools supports a light crop of Laminaria and other seaweeds. Highest algal standing stocks were observed in July (4642.7 g/m^2), when red algae contributed 3473.7 g/m^2. The kelp Laminaria groenlandica was a dominant plant (up to 43.3 percent cover and 1873.4 g/m^2) but the red algae Rhodymenia pacifica (38 percent cover) and R. liniformis (up to 20 percent cover) were at least as important. Encrusting coralline algae covered an increasing proportion of bottom during the study (from 0.7 percent to 14.4 percent). The kelp Alaria taeniata became important by July but disappeared by September. Other important species included Fucus (up to 9.1 percent cover and 324 g/m^2), Monostroma (up to 7.2 percent), Gigartina papillata (up to 5.7 percent) and Spongomorpha (up to 5.2 percent).

The fauna at this level was rather impoverished but included some representatives of the subtidal fauna. The main suspension feeders were the sponge Halichondria panicea (up to one percent) and the horse mussel Modiolus modiolus (up to 4.8 percent). Micrograzers included limpets (up to 5.3/m^2) and the lined chiton Tonicella lineata (7.3/m^2). The only common predator/scavengers were the starfish Leptasterias ?hexactis, the hermit crab Pagurus beringanus and the helmet crab Telmessus cheiragonus (Table 4-11).

4.2.2 Knoll Head

No previous studies of this area are known. The area was selected because the predominantly rocky stretch of coastline is structurally complex and is intermediate in the degree of exposure between Scott Island and White Gull Island.

Three levels on the Knoll Head transect were sampled three times (June 21, July 20 and September 17) during 1978. Weather precluded sampling during the April survey.

The "Fucus" Zone

The upper level sampled was located on top of a rock logback in an area of maximum development of the "Fucus" zone. Fucus maintained coverage of about 45 percent in June and July but declined to 37 percent in September. Maximum biomass at this level (1896.3 g/m^2) was observed in July (Table 4-12). Other important algae at this level included an unidentified encrusting green alga (to 4.7 percent), the red algae Rhodomela ?lycopodioides (to 25.7 percent) and an unidentified red algal film (to 23.8 percent) and the brown encrusting alga ?Ralfsia pacifica (to 14.2 percent). Rhodomela and articulated corallines were abundant in the tide pools. Red algae contributed an average of about 39 percent over the entire sampling period, largely due to an unidentified red algal film.

The fauna at this level, generally typical of the "Fucus" zone elsewhere on the west side, was quite sparse. Dominant sessile forms were B. glandula and C. dalli. Motile organisms included the grazing snail L. sitkana, which was abundant and was observed laying eggs in June. Other grazers included a few limpets (Acmaeidae) and very few chitons. The predaceous gastropod Nucella emarginata was very common, particularly juveniles.

The "Transition" Zone

An expanse of rather smooth bedrock was located below the "Fucus" zone. The appearance of this zone was dominated by the red algae Rhodymenia palmata (up to 68 percent) and R. liniformis (up to 26.5 percent). Maximum biomass for red algae was observed in July (2658.1 g/m^2; Table 4-12). Fucus also contributed appreciably to cover and biomass (up to 31.8 percent and 992.2 g/m^2). Two opportunistic species, the red Porphyra sp. (3.6 percent) and the green Monostroma fuscum (11.0 percent) were common at this level in June, but declined during the remaining periods. Small plants of Alaria taeniata and Laminaria groenlandica were observed. The red Gigartina papillata were fairly common in all surveys (up to 18.1 percent).

TABLE 4-12

KNOLL HEAD ALGAL COVER AND BIOMASS BY MAJOR TAXON, 1978

	Zone					
	"Fucus"		"Transition"		"Rhodymenia"	
Month Taxon	%	gm/m^{2}(b)	%	gm/m^{2}	%	gm/m^{2}
June						
Chlorophyta						
encrusting	3.0	--	7.8	--	0.8	--
other	0.8	--	24.3	257.1	28.5	235.3
Encrusting reds & browns(a)	14.2	--	33.4	--	12.9	--
Phaeophyta	54.4	1,528.7	30.0	992.2	6.4	51.2
Rhodophyta						
encrusting corallines	0.8	--	1.7	--	6.3	--
other	11.9	--	89.2	2,393.1	119.9	3,724.7
Total	85.1	1,528.7	186.4	3,642.4	174.8	4,011.2
July						
Chlorophyta						
encrusting	0.4	--	4.3	--	2.8	--
other	0.1	--	5.1	26.2	4.5	20.5
Encrusting reds & browns	24.2	--	45.3	--	32.5	--
Phaeophyta	46.8	1,896.3	34.9	724.8	10.7	66.1
Rhodophyta						
encrusting corallines	1.0	--	3.3	--	15.4	--
other	39.2	--	94.7	2,658.1	120.9	3,397.9
Total	111.7	1,896.3	188.6	3,409.1	186.8	3,484.5
September						
Chlorophyta						
encrusting	4.7	--	12.0	--	3.1	--
other	0.3	--	1.1	--	1.6	--
Encrusting reds & browns	23.8	--	13.0	--	20.3	--
Phaeophyta	37.5	1,093.8	24.2	633.9	6.3	368.4
Rhodophyta						
encrusting corallines	1.0	--	0.4	--	3.8	--
other	16.9	--	94.4	2,238.4	99.6	2,176.8
Total	84.2	1,093.8	145.1	2,872.3	134.7	2,545.2

(a) Includes *Ralfsia pacifica* and other unidentified encrusting Rhodophyta and Phaeophyta.

(b) Only Phaeophyta weighed at this level.

Very few animals were found at this level (Table 4-13). The only taxa consistently observed were the sponge Halichondria (up to 4.3 percent cover), amphipods, the hermit crabs Pagurus beringanus (up to $3.2/m^2$) and P. hirsutiusculus (up to $4.8/m^2$), the snail Lacuna (up to $2.7/m^2$) and an encrusting bryozoan Rhynchozoon bispinosum (up to 7.6 percent cover). Most of these were most common in September, but densities were quite low for all invertebrates.

The "Rhodymenia" Zone

The substrate at a lower level is similar to that in the "Transition" zone. The biota at this level was much like that at the "Transition" zone except that R. palmata dominated more completely and Fucus was only found on the highest prominences. This level supported the lushest development of algae biomass (up to 4.01 kg/m^2 by June) (Table 4-12), mainly from the contribution of R. palmata.

The fauna was sparsely developed (Table 4-13). The only reliable components were the encrusting bryozoan R. bispinosum (up to 4.8 percent cover), the small starfish Leptasterias ?hexactis (up to $2/m^2$) and a small pink social ascidian Dendrodoa sp. (up to $3.3/m^2$). Most invertebrates were most common in September.

In the low surge channels surrounding this terrace, a fairly dense assemblage of laminarians (L. groenlandica, L. saccharina and Alaria sp.) and the red alga Constantinea simplex was observed. Large areas devoid of macroalgae were present although herbivores were scarce. The horse mussel Modiolus modiolus was present in the lowest channels although beds were not dense; shell debris indicated recent mortality. Large Tealia and Cribrinopsis were common in protected areas under boulders. Several starfish (Henricia leviusculus, Solaster stimpson; and Leptasterias ?hylodes were observed. Other species seen included the thatched barnacle B. cariosus, the lined chiton Tonicella lineata and a greenling (Hexagrammos sp.).

TABLE 4-13

KNOLL HEAD INTERTIDAL INVERTEBRATE DOMINANTS

	Date/Average Percent Cover or No./m^2		
Level/Species	6/21/78	7/20/78	9/17/78
	"*Fucus*" zone		
(% Cover)			
Balanus glandula	15.8	10.5	6.5
Chthamalus dalli	2.3	7.1	8.4
Halichondria panicea	0	1.3	0.6
(#/m^2)			
Acmaeidae	13.0	46.7	30.0
Lacuna sp.	0.2	0	P
Nucella emarginata	26.0	18.7	28.8
Pagurus hirsutiusculus	0	9.3	16.0
	"Transition" zone		
(% Cover)			
Halichondria panicea	4.3	1.3	0.2
Rhynchozoon bispinosum	0.4	2.0	7.6
(#/m^2)			
Acmaeidae	2.7	2.7	0
Lacuna sp.	2.7	2.7	P
Leptasterias ?hexactis	2.0	0	1.6
Pagurus hirsutiusculus	0.7	0.7	4.8
	"*Rhodymenia*" zone		
(% Cover)			
Rhynchozoon bispinosum	0.5	1.0	4.8
(#/m^2)			
Acmaeidae	2.0	0	3.2
?*Dendrodoa* sp.	0.2	3.3	0
Leptasterias ?hexactis	0.7	1.3	2.0
Oregonia gracilis	0	0	3.3
Pagurus beringanus	0	0	3.3

General

Several fairly strong seasonal and spatial patterns were apparent. At the levels dominated by Rhodymenia, biomass was highest in June and declined substantially thereafter. Fucus attained maximal development in July. Plant biomass generally was highest in areas dominated by Rhodymenia, especially at the lowest level sampled. Phaeophyta, mainly represented by Fucus, became increasingly less important at lower levels (Table 4-12).

4.2.3 White Gull Island

There are no known prior studies of the intertidal or subtidal benthic communities of White Gull Island.

The "Fucus" Zone

The upper level sampled on White Gull Island was on an irregular rock bench in the midst of the "Fucus" zone (Section 2.7). Coverage by the rockweed Fucus distichus increased from 13 to 28 percent from June to September 1978 with maximum biomass (993.8 g/m^2) in July. Several red algae including Rhodomela ?lycopodioides (to 4.6 percent), identified polysiphonous forms (Rhodomelaceae; to 1.4 percent) and encrusting corallines (to 1.8 percent) were also common, primarily in small tide pools and moist crevices (Table 4-14).

The fauna at this level, typical of the "Fucus" zone elsewhere on the west side, was somewhat sparse. Balanus glandula (to 36.0 percent cover in July; Table 4-15) and Chthamalus dalli (to 3.9 percent cover in July) were the only significant sessile forms. Nucella emarginata were numerous (to 63.6, mostly juveniles, in August) and preying on the barnacles. The most common grazers were the limpets (Acmaeidae, to 27.2/m^2) and the periwinkle, Littorina sitkana. Periwinkles were laying eggs at this level during the June survey. The hermit crab Pagurus hirsutiusculus increased in abundance through the study period from 4.8/m^2 in June to 18.8/m^2 in September.

TABLE 4-14

WHITE GULL ISLAND ALGAL COVER AND BIOMASS BY MAJOR TAXON, 1978

	Zone			
	"Fucus"		"Transition"	
Month Taxon	%	gm/m$^{2(b)}$	%	gm/m^{2}
June				
Chlorophyta				
encrusting	0.7	--	11.7	--
other	0.1	--	26.2	--
Encrusting reds & browns(a)	23.2	--	28.4	--
Phaeophyta	13.1	546.9	60.6	979.1
Rhodophyta				
encrusting corallines	1.2	--	2.8	--
other	8.0	--	33.9	548.0
Total	46.3	546.9	163.6	1,527.1
July				
Chlorophyta				
encrusting	0.9	--	1.1	--
other	--	--	5.2	28.6
Encrusting reds & browns	14.1	--	10.0	--
Phaeophyta	23.8	993.8	73.1	2,682.7
Rhodophyta				
encrusting corallines	1.0	--	10.3	--
other	7.0	--	44.4	784.2
Total	46.8	993.8	144.1	3,495.5
September				
Chlorophyta				
encrusting	0.2	--	0.9	--
other	--	--	0.4	--
Encrusting reds & browns	6.7	--	3.2	--
Phaeophyta	28.2	869.0	41.5	1,104.8
Rhodophyta				
encrusting corallines	1.8	--	4.5	--
other	4.8	--	19.4	293.1
Total	41.7	869.0	69.9	1,379.9

(a) Includes *Ralfsia pacifica* and other unidentified Rhodophyta and Phaeophyta.

(b) Only Phaeophyta weighed at this level.

TABLE 4-15

WHITE GULL ISLAND INTERTIDAL INVERTEBRATE DOMINANTS

Level/Species	Date/Average Percent Cover or No./m^2 6/22/78	7/22/78	9/16/78
	"Fucus" zone		
(% Cover)			
Balanus cariosus	0.1	0.1	0.6
Balanus glandula	20.5	36.0	27.9
Chthamalus dalli	1.4	3.9	2.0
Halichondria panicea	0.4	0.5	0.3
(#/m^2)			
Acmaeidae	16.0	27.2	27.2
Littorina sitkana	A	--	P
Nucella emarginata	10.4	7.6	63.6
Pagurus hirsutiusculus	4.8	14.4	18.8
	"Transition" zone		
(% Cover)			
Balanus cariosus	3.1	1.4	0.9
Balanus glandula	0.6	0.5	5.2
Chthamalus dalli	2.9	18.6	18.1
Halichondria panicea	16.7	12.9	12.9
Rhynchozoon bispinosum	2.1	4.6	3.3
(#/m^2)			
Acmaeidae	18.2	10.4	39.6
Cucumaria ?vegae	7.1	9.2	0.9
Leptasterias ?hexactis	3.1	8.4	12.4
Metridium senile	0.9	0.8	5.8
Nucella emarginata	2.2	16.4	27.6
Pagurus beringanus	2.7	0.4	3.6
Pagurus hirsutiusculus	5.8	11.2	17.3
Schizoplax brandtii	11.1	4.4	3.6

The "Transition" Zone

Below the upper rock bench of the "*Fucus*" zone, the beach at the White Gull transect dropped to a lower bench with numerous boulders, tide pools, and channels. On the shoreward part of this bench, no quantitative sampling was done, but exposed upper rock surfaces were dominated by *Fucus* and obvious green layers of *Spongomorpha* and *Monostroma*. In shaded areas the green sponge *Halichondria panicea* formed thick mats, occasionally covering barnacles and generally reinforcing the green appearance of the area. In the channels, *Alaria taeniata* and *Laminaria groenlandica* were abundant along with the reds *Rhodymenia palmata* and encrusting corallines. The most obvious animals present were hermit crabs, *Pagurus* spp., encrusting bryozoans, probably *Rhynchozoon bispinosum*, and hydroids.

The transverse sampled on the seaward edge of this bench was in an area containing a great diversity of microhabitats from deep pools to exposed ridges. Biota in this area was highly dependent on the exposure of the substrate to waves, sunlight, and water drainage. Density and coverage figures given are averaged over all microhabitats sampled, and high standard deviations reflect the patchiness of this environment.

Upper rock surfaces elevated from the bench 0.5 to 1.0 m and with convex or sloped surfaces retaining little moisture, had a biota dominated by *Fucus* (to 18.8 percent), the opportunistic *Porphyra* (to 9.2 percent in June), *B. glandula* (to 5.5 percent with new set in September), and *C. dalli* (to 18.1 percent). *Littorina*, small chitons (e.g., *Schizoplax brandtii*, to 11.1/m^2), and limpets (to 39.6/m^2) were the most abundant grazers. At lower levels, sides of rock channels with some protection from desiccation had dense growth of *R. palmata* (to 21.2 percent) and *A. taeniata* (to 40.2 percent), often in fairly narrow bands. *Rhodymenia liniformis* (to 11.1 percent) and *Gigartina papillata* (to 2.4 percent) were also common in these areas. In the tide pools, *L. groenlandica* was the dominant brown alga (to 13.6 percent). Several typical tide pool species of red algae (corallines, to 11.3 percent; *Ahnfeltia plicata*, to

0.1 percent) were present. The fauna was richer in and near the pools than on the upper rock surfaces.

The green sponge H. panicea (to 16.7 percent), Balanus cariosus (to 3.1 percent), and the encrusting bryozoan R. bispinosum (to 4.6 percent) were the most important sessile animals. Hermit crabs (especially P. hirsutiusculus, to 17.3/m^2) were abundant in the pools along with the anemone Metridium senile, which jumped in density from 0.8/m^2 in June to 5.8/m^2 with a new set in late summer. The small sea cucumber Cucumaria ?vegae was abundant (to 9.2/m^2) in silty crevices and among the larger barnacles.

Predatory snails (N. emarginata, to 27.6/m^2) and starfish (Leptasterias ?hexactis, to 12.4/m^2) ranged throughout this sampling level, probably in response to barnacle density, but generally sought moister areas during low tide periods.

Below MLLW the bench dropped sharply to nearly vertical. This face was heavily covered with corallines and other encrusting forms. Rhodymenia palmata was fairly common to at least -1.2 m but did not form the dense cover seen along the margins of pools and channels on the bench.

4.3 GROWTH RATES AND PRIMARY PRODUCTION OF SOME DOMINANT LAMINARIAN KELPS

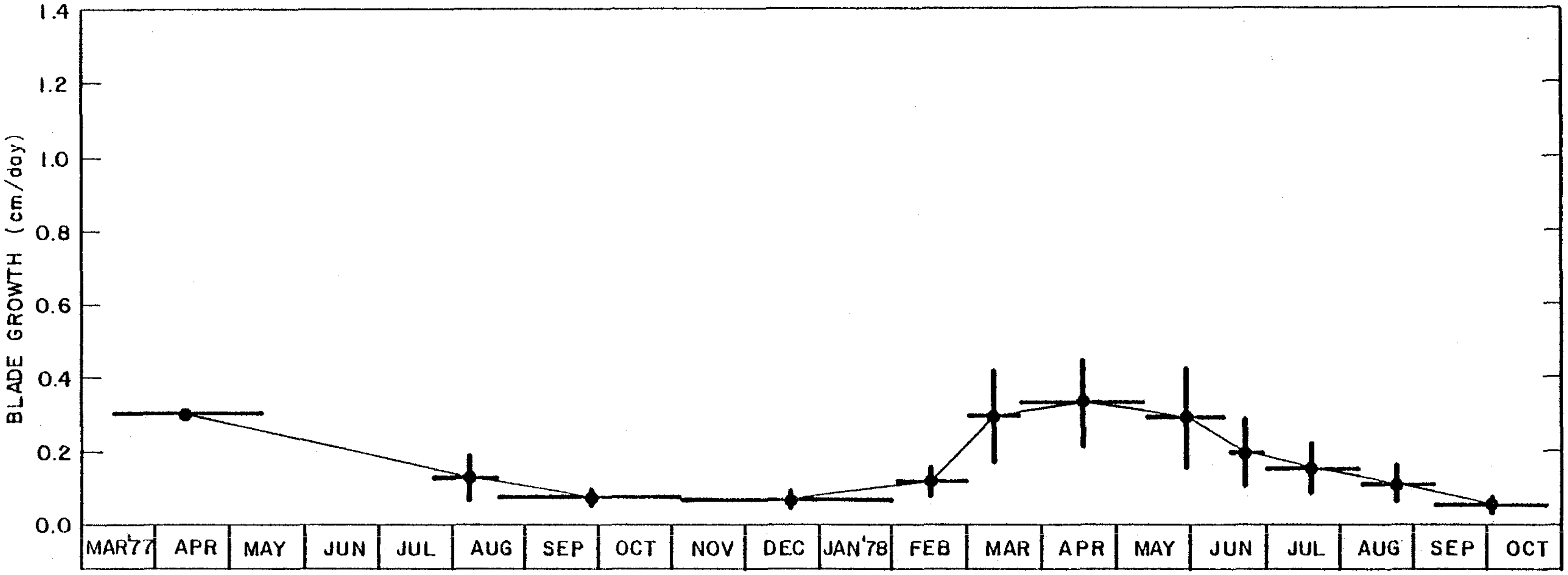
Growth rates for three species of laminarian algae were examined in order to assist in calculation of primary production rates. The species studied, namely, Agarum cribrosum, Alaria fistulosa and Laminaria groenlandica, are among the dominant species in the floral assemblages in Kachemak Bay and along the outer Kenai Peninsula. Other dominants in Kachemak Bay include, in the intertidal zone, Fucus distichus, Alaria taeniata, A. crispa and Hedophyllum sessile, and, subtidally, Nereocystis luetkeana.

Growth rates were successfully measured almost continuously for individual plants of Agarum cribrosum, Alaria fistulosa and Laminaria groenlandica from March 1977 through October 1978. Alaria fistulosa is a large species that forms heavy surface canopies; adult plants attain a length of at least 20 meters. Densities seldom exceed one plant/m^2, but biomass may approach 5 kg/m^2. Agarum and L. groenlandica are smaller plants that form a dense understory; adult plants attain a length of one and two meters, respectively. Densities of adult plants frequently exceed 20 plants/m^2, and biomass can approach 5 kg/m^2 in Kachemak Bay.

4.3.1 Average Growth Rates for Agarum cribrosum

Thirty-eight plants of Agarum cribrosum were labelled during this program. At least one growth observation was obtained from 33 of them. Records extending for over a year were obtained for four plants and for at least eight months for 15 plants.

Growth rates for Agarum cribrosum (Figure 4-7) are lowest in fall and early winter (September through January) and highest in spring (April). Average rates ranged from 0.05 cm/day in September and October 1978 to 0.33 cm/day in April 1978. Growth rates generally exceeded 0.2 cm/day in March, April, May and part of June, but fell below 0.12 cm/day (into the lower quartile) from August through mid-February, slightly



MEAN BLADE GROWTH (cm)	0.300	(~0.21)	0.128	0.072	0.068	0.118	0.291	0.327	0.291	0.194	0.149	0.106	0.052
S*			0.066	0.025	0.030	0.045	0.130	0.118	0.138	0.094	0.067	0.052	0.024
SE			0.022	0.010	0.013	0.011	0.033	0.026	0.032	0.023	0.016	0.013	0.007
n	2		9	6	5	16	16	20	19	17	19	16	12
DAYS	61	(69)	37	77	88	30	21	51	35	13	40	32	47
GROWTH INCREMENT (cm)	18.3	(14.5)	4.7	5.5	6.0	3.5	6.1	16.7	10.2	2.5	6.0	3.4	2.4

*S = STANDARD DEVIATION; SE = STANDARD ERROR; n = NUMBER OF PLANTS MEASURED

FIGURE 4-7

SEASONAL PATTERNS IN GROWTH FOR <u>AGARUM CRIBROSUM</u> AT JAKOLOF BAY over half of the year. During the periods of slowest growth, nearly all tagged plants grew at a slow rate rather than ceasing growth completely (Appendix 4.3.1).

Individual growth rates appeared to vary more during periods of peak growth than during slow growth (Figure 4-7). However, despite the high variability, growth rates differed significantly between periods of slow growth and fast growth. For example, the hypothesis that growth rates in the September-October 1978 period were slower than growth rates observed in the March through May 1978 period was tested using an approximate "t" test for independent means (Sokal and Rohlf, 1969). The difference was highly significant ($P < 0.001$; one-tailed test).

In contrast, a comparison of average growth rates in the same season of consecutive years indicates strong uniformity. For instance, comparisons of growth rates for the July-August periods in 1977 and 1978, or the September-October periods of the same years, indicate no significant difference between those periods (Student's t-test, $P > 0.10$ in both cases).

The hypothesis that growth rate is correlated with plant size was tested for three observation periods, namely, 22 July to 18 August 1977, 30 January to 1 March 1978 and 24 March to 12 May 1978 (Appendix 4.3.1). For this analysis, stipe length was used as an index of plant size. The data and regression equations for the last two periods are shown in Figure 4-8. The correlations were not significant for any of the periods ($P \gg 0.1$ in all three cases).

Average blade growth increments were calculated for each observation period by multiplying its average daily growth rate by the number of days in the period (Figure 4-7). These increments were summed over a year to compute an annual mean rate of blade elongation. From March 1977 through February 1978, the estimate of average blade growth was 58.6 cm and from November 1977 through October 1978, it was 56.8 cm.

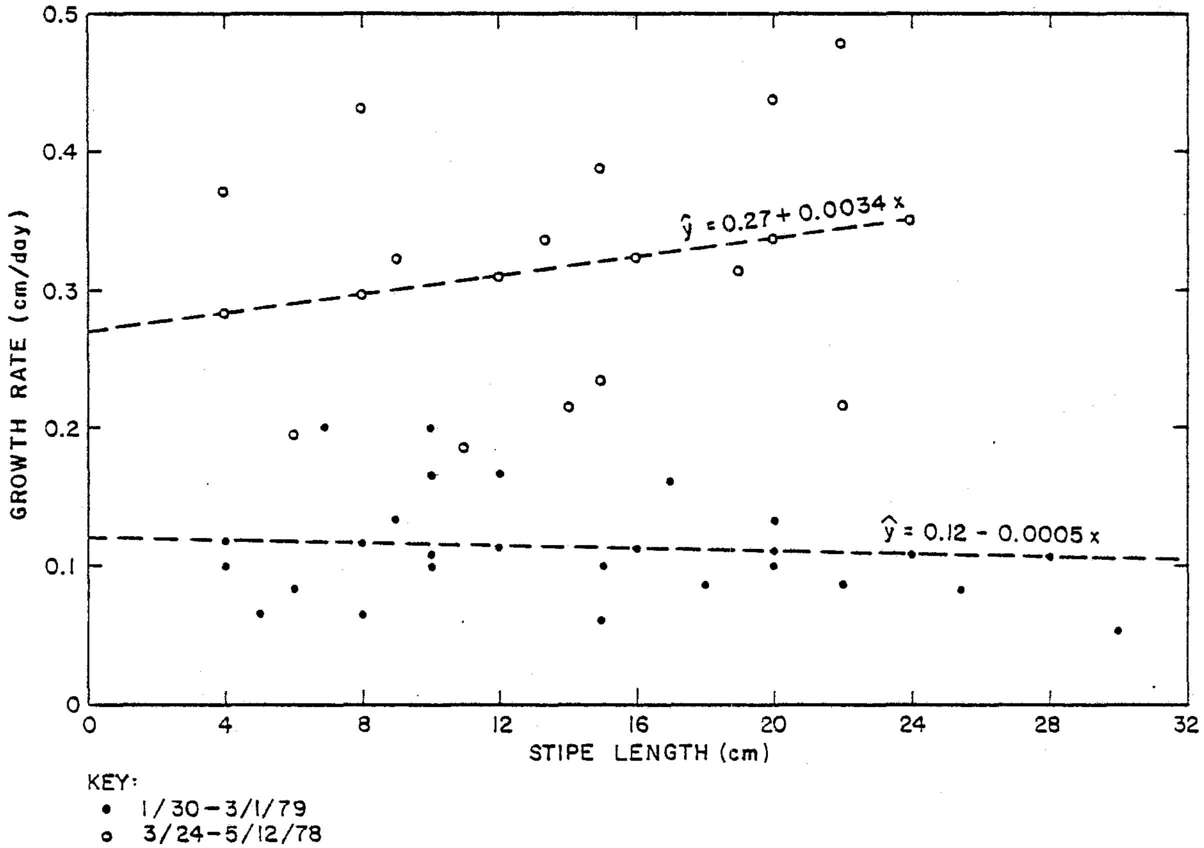


FIGURE 4-8

RELATIONSHIP BETWEEN STIPE LENGTH AND GROWTH RATE
FOR *AGARUM CRIBROSUM*
DURING TWO OBSERVATION PERIODS

The tagged plants of Agarum were generally distributed among five locations. The physical characteristics of these sites differed in several respects, e.g. light levels, exposure to tidal currents and turbulence, and silt deposition. The hypothesis that average growth rates were the same at each location was tested using the non-parametric Friedman two-way analysis of variance. A summary of the available data (Table 4-16) suggests that the plants at the shallowest site (Rocky Finger, 10 feet deep) grew more slowly than at the deepest site (Lower Transect, 25 feet deep). Two combinations of the data were tested, namely, 1) sites 1, 2 and 3 for the periods extending from 2/1/78 to 10/26/78, and 2) sites 1, 2, 3 and 4 for the periods extending from 3/22/78 to 10/26/78. In both tests, the probability that the site was unimportant to growth rates was low (for combination 1, $P = 0.085$; for combination 2, $P < 0.05$). Generally, plants grew faster at site 1, but the other sites exhibited no strong patterns.

Stipe lengths were recorded on several occasions to permit an evaluation of the efficacy of using that parameter for determining age structure and to examine growth rates of the stipe. These data, summarized in Table 4-17, evoke a degree of puzzlement because they do not provide clear indication of stipe growth. For plants with records covering between six and nine months, the mean change in stipe length was an increase of 0.77 ± 2.31 cm ($n = 13$). In this group of plants, stipe length increased in six, decreased in three, and did not change in four. For the entire group of plants with at least two measurements, nine increased in length, eight decreased and six did not change (Table 4-17). The maximum increase in length was six cm and the maximum decrease was four cm. Certainly, we recognized that measuring the length of the contorted stipes of Agarum presented problems, but the data seems fairly convincing that stipe growth is slow and irregular.

Knowledge of the annual turnover rate (i.e. the rate at which blade tissue is replaced) is useful in the calculation of primary productivity. It can be calculated for either blade length or weight. In terms of length, it is estimated as the ratio of the annual blade growth increment to the average blade length. Average blade length for tagged Agarum on

TABLE 4-16

AVERAGE RATES OF BLADE GROWTH (CM/DAY) FOR AGARUM CRIBROSUM FOR SPECIFIC SITES AND PERIODS AT JAKOLOF BAY

Site Number	Site Name		1977			1978						
			7/25-8/18	8/18-11/3	11/3 2/1/78	2/1-3/1	3/1-3/22	3/22-5/12	5/12-6/16	6/16-8/8	8/8-9/9	9/9-10/26
1	Lower Transect, 25 m Rock (-25 feet; high current velocity on both ebb and flow)	$\bar{x}$	0.188	0.091	0.091	0.119	0.301	0.444	0.360	0.272	0.143	0.072
		s	--	--	--	0.059	0.080	0.089	0.185	--	0.067	--
2	East of N-S Finger Transect (-15 feet; high current velocity on flow)	$\bar{x}$	--	--	--	0.104	0.326	0.389	0.320	0.180	0.078	0.053
		x	--	--	--	0.021	0.069	0.084	0.087	0.052	0.016	--
3	E-W Finger Transect, 30 m Boulder (-15 feet; moderate current veolcity on flow)	$\bar{x}$	--	--	--	0.139	0.234	0.297	0.296	0.131	0.097	0.043
		s	--	--	--	0.049	0.106	0.104	0.186	0.049	0.046	0.020
4	West of N. End of N-S Finger Transect (-20 feet; low current velocity)	$\bar{x}$	--	--	--	--	--	0.206	0.275	0.167	0.141	0.032
		s	--	--	--	--	--	0.017	0.090	--	--	0.011
5	Rocky Finger (-10 feet; moderate current velocity on flow)	$\bar{x}$	0.117	0.059	0.054	0.083	--	--	--	0.165	--	0.069
		s	0.068	0.031	--	0.027	--	--	--	--	--	--

TABLE 4-17

CHANGES IN STIPE LENGTH FOR INDIVIDUAL PLANTS OF *AGARUM CRIBROSUM* AT JAKOLOF BAY
STIPE LENGTH (CM) AT DATE OF OBSERVATION

Plant Designation	3/12	5/12	7/22	8/18	10/31	11/3	1/30	3/22	5/12	8/8	9/9	10/26	Overall Change
AG4			6				4						-2
AG14							4	4					0
AG19							6				7		+1
AG38							5	6		7	8	8	+3
AG41							9	7	7.5	8	10.5	9	0
AG17			10				10						0
AG10							7				12.5	13	+6
AG37							10	9		9	12.5	12	+2
AG39							12	10		12	13.5	10	-2
AG40							10	8		11	12	13	+3
AG42											12	11	-1
AG1			12				12						0
AG2	13	13											0
AG45											15	13.5	-1.5
AG35							15	13.5					-1.5
AG43							17	15			16	15	-2
AG12					15		10	11					-4
AG44							15	15		14	16		+1
AG36							20	19				20	0
AG16							20	22					+2
AG11						22	22	20					-2
AG31											23	24	+1
			31	32	35								+4

30 January was 28.9 ± 8.8 cm (n = 18). That date was selected because it is near the beginning of the growth period and average plant size is near its minimum. Using an average annual growth increment of 57.7 cm, the turnover rate in terms of length is two for the average plant. Since growth rates do not appear to vary with plant size, at least for mature plants, turnover rates apparently range from 1.2 for larger plants to over six for plants with blades less than six cm long.

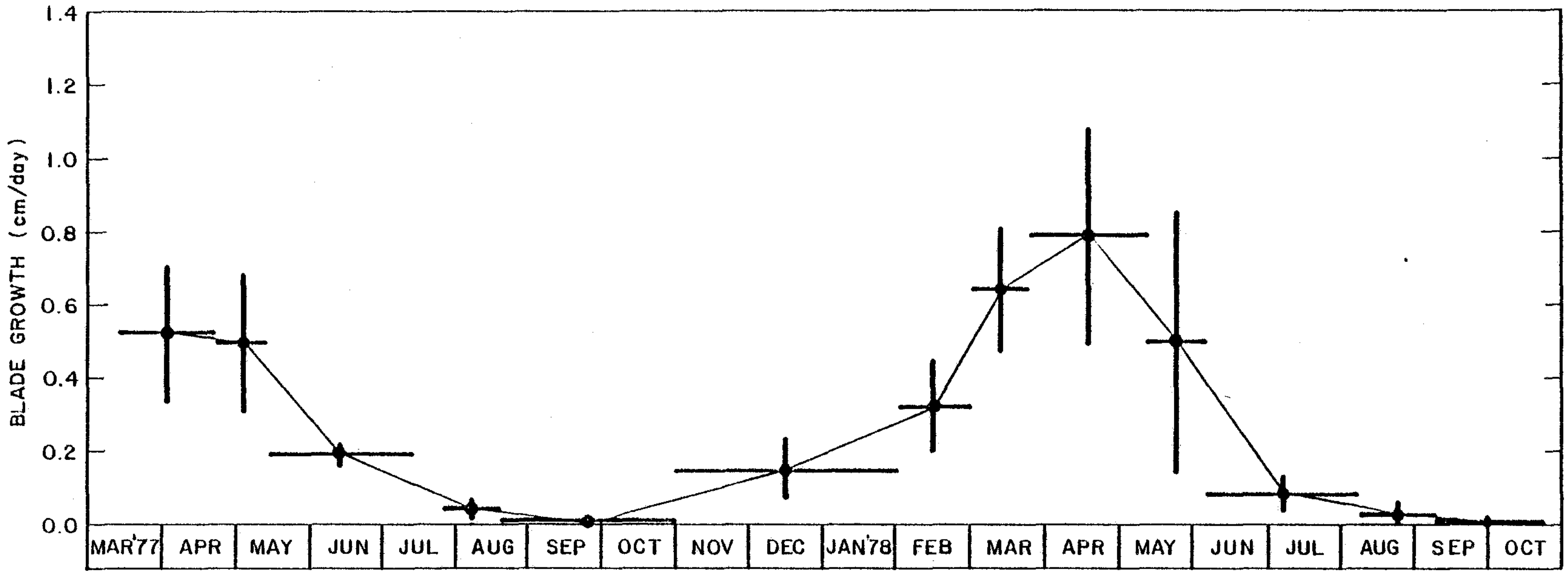
These ratios do not pertain to the turnover rate in terms of weight. Because both width and thickness of the blade increase with greater length, weight increases at an exponential rate for a given linear increase in blade length.

4.3.2 Average Growth Rates for *Laminaria groenlandica*

Forty-three plants of *Laminaria groenlandica* were labelled during this program. At least one growth observation was obtained from 42 of them. Records extending for over a year were obtained for only one plant, but thirteen produced records for at least eight months and 23 for over six months.

Growth rates for *L. groenlandica* are lowest in late summer and fall (August, September and October) and highest in spring (March and April) (Figure 4-9). Average rates ranged from 0.005 cm/day in August through October 1977 to 0.79 cm/day in April 1978. Growth rates exceeded 0.4 cm/day from March through late May, and fell below 0.2 cm/day (the lower quartile) from June through early January, i.e., more than seven months. During the periods of slowest growth, 18 of the tagged plants apparently ceased growth for one to three months (Appendix 4.3.2).

Individual growth rates appeared to vary more during periods of peak growth than during slow growth (Figure 4-9). However, despite the high variability during periods of rapid growth, growth rates differed significantly between periods of slow and rapid growth. For example, the hypothesis that growth rates were slower in the August through October 1978 period than in the March through May 1978 period was tested



MEAN BLADE GROWTH (cm)	0.525	0.497	0.195	(0.125)	0.054	0.005	0.151	0.328	0.645	0.789	0.499	0.083	0.031	0.010
s*	0.188	0.192	0.027		0.028	0.007	0.081	0.125	0.171	0.296	0.357	0.051	0.039	0.017
SE	0.050	0.051	0.009		0.009	0.003	0.041	0.024	0.036	0.063	0.078	0.012	0.009	0.005
n	14	14	10		10	6	4	28	22	22	21	18	18	12
DAYS	41	20	61	(13)	24	74	91	30	21	51	25	63	32	47
GROWTH INCREMENT (cm)	21.5	9.9	11.9	1.6	1.3	0.4	13.7	9.8	13.5	40.2	12.5	5.2	1.0	0.5

*S = STANDARD DEVIATION; SE = STANDARD ERROR; n = NUMBER OF PLANTS MEASURED

FIGURE 4-9

SEASONAL PATTERNS IN GROWTH FOR <u>LAMINARIA GROENLANDICA</u> AT JAKOLOF BAY using an approximate "t" test for independent means (Sokal and Rohlf, 1969). The difference was highly significant ($P < 0.0005$; one-tailed test).

A comparison of average growth rates in the minimum growth period of consecutive years indicates strong uniformity. For instance, comparison of growth rates for the September through October periods in 1977 and 1978 indicates no significant difference ($P > 0.25$). However, comparison of the maximum growth periods indicates that, although the growth patterns are similar, maximum growth rates can differ significantly between years ($P < 0.025$, two-tailed t-test).

Average blade growth increments were computed for each observation period by multiplying its average daily growth rate by the number of days in the period (Figure 4-9). These increments were summed over a year to compute an annual mean rate of blade elongation. From March 1977 through February 1978, the estimate of average blade growth was 83.6 cm, and from November 1977 through October 1978, it was 96.4 cm.

The hypothesis that growth rate is correlated with plant size was tested for two observation periods, namely, January through March 1978 and September through October 1978 (Appendix 4.3.2). The data and regression equations are shown in Figure 4-10. The correlations were not significant for either period ($P > 0.1$ in both cases).

The tagged plants were generally distributed among four locations. The physical characteristics of these sites differed mainly in the degree of exposure to tidal currents and the extent to which they extended above the surrounding rock substrate into the water column. All locations were at approximately the same depth and not exposed to siltation. A summary of the data (Table 4-18) suggests that plants on the 10 meter boulder grew more rapidly than the other sites, but the hypothesis is not supported statistically. The data used comprised a block covering from 1/30/78 to 10/26/78 for the 0 meter, 10 meter and 25 meter boulder areas. The hypothesis that average growth rates varied with respect to

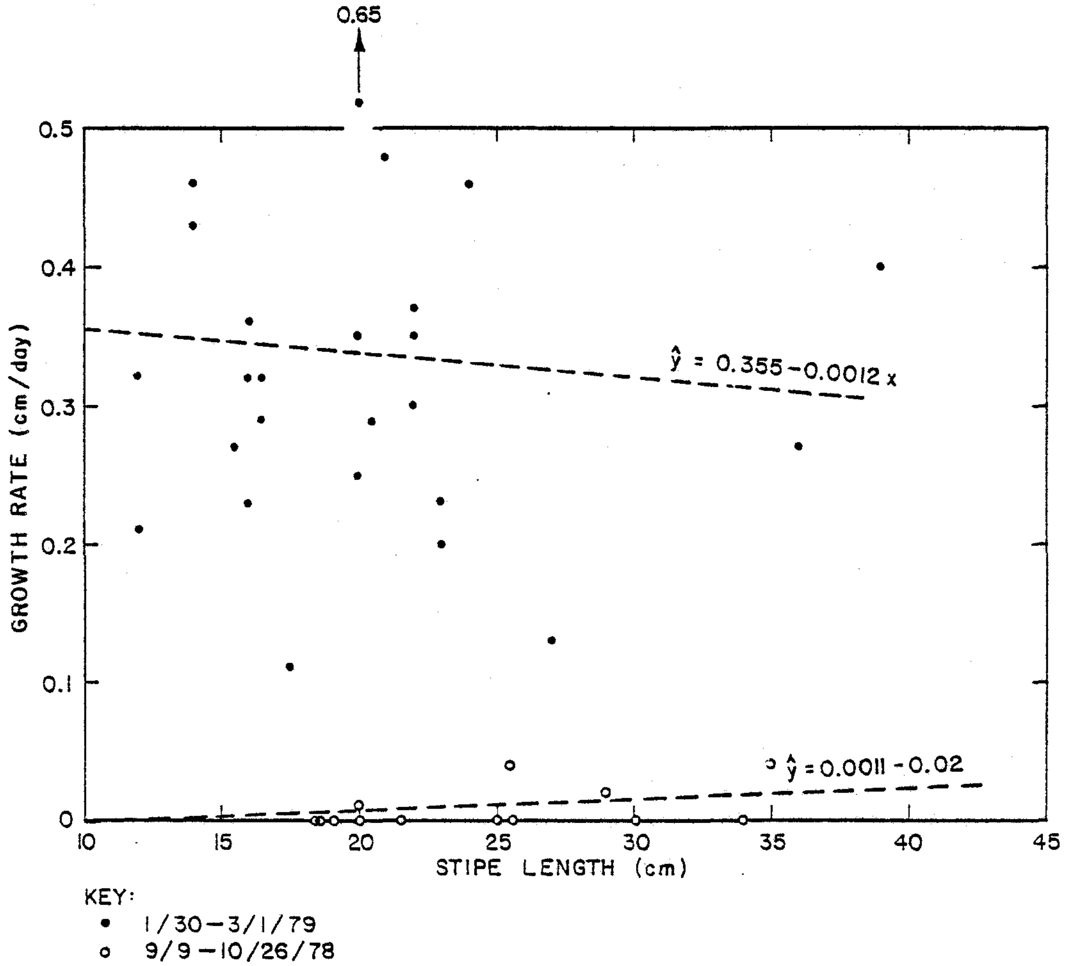


FIGURE 4-10

RELATIONSHIP BETWEEN STIPE LENGTH AND GROWTH RATE FOR <u>LAMINARIA GROENLANDICA</u> DURING TWO OBSERVATION PERIODS

TABLE 4-18

AVERAGE RATES OF BLADE GROWTH (CM/DAY) FOR *LAMINARIA GROENLANDICA* FOR SPECIFIC SITES AND PERIODS AT JAKOLOF BAY

	1977					1978							
	4/22	5/12	7/12	8/18	11/3	1/30	3/1	3/22	5/12	6/6	8/8	9/9	10/26
N. of Metridium Rock (Low; laminar flow, high velocity)	--	0.663	0.213	--	--	0.151	0.253	--	0.556	--	--	--	--
0 Meter Boulder (Moderate, turbulent flow, high velocity)	--	0.603	0.156	0.042	0.007	--	0.328	0.631	0.524	0.712	0.085	0.022	0.009
10 Meter Boulder (High, laminar flow, moderate velocity)	--	--	--	--	--	--	0.446	0.691	1.075	0.552	0.084	0.042	0.022
25 Meter Boulder (Moderate, laminar flow, moderate velocity)	0.514	0.450	0.200	0.067	0.000	--	0.299	0.644	0.588	0.320	0.095	0.025	0.000

location was not statistically significant (P = 0.237, non-parametric Friedman two-way analysis of variance).

Stipe lengths were recorded on several occasions to permit evaluation of that parameter in determining age structure and to examine growth rates of the stipe. These data, summarized in Table 4-19, indicate the occurrence of seasonal patterns in stipe growth. Positive growth of the stipe appears to occur during the period when rates of blade growth are high (2/1 through 8/8), whereas it appears that negative growth (shrinkage) occurs during the period of minimal growth (8/8 through 1/30). The hypothesis that rate of stipe growth was greater during the period 1/30 through 3/22/78 than in 9/9 through 10/26/78 was tested with a t-test, and found to be highly significant ($P < 0.005$). Figure 4-11).

Twenty-two plants had stipe length measured on both 1/30 or 2/1 and 9/9 (Table 4-19). Initial stipe length ranged from 12 cm to 39 cm, and the change in length over that period ranged from -0.5 cm to +25 cm and averaged 7.85 cm. The hypothesis that stipe length and its rate of growth are related was tested with a correlation coefficient. The negative correlation observed between the initial stipe length (x) and its subsequent growth ($\hat{Y} = 16.145 - 0.416x$; (Table 4-11) was not significant ($r = -0.303$, $P > 0.1$).

The relationship between the simultaneous increase in length of stipe and blade (Figure 4-12) was tested with a correlation coefficient. The hypothesis that growth of the two structures was directly related was significant ($r = 0.87$, $P < 0.0005$). The regression equation suggests that they grow about three times as fast as stipes. Furthermore, the data suggest that growth of both structures is influenced by plant location; plants on the 10 meter rock appeared to grow faster than elsewhere. This boulder extends about 1.5 meters above the surrounding seafloor and all plants tagged were on top of it. Because of its small size, however, few plants were tagged.

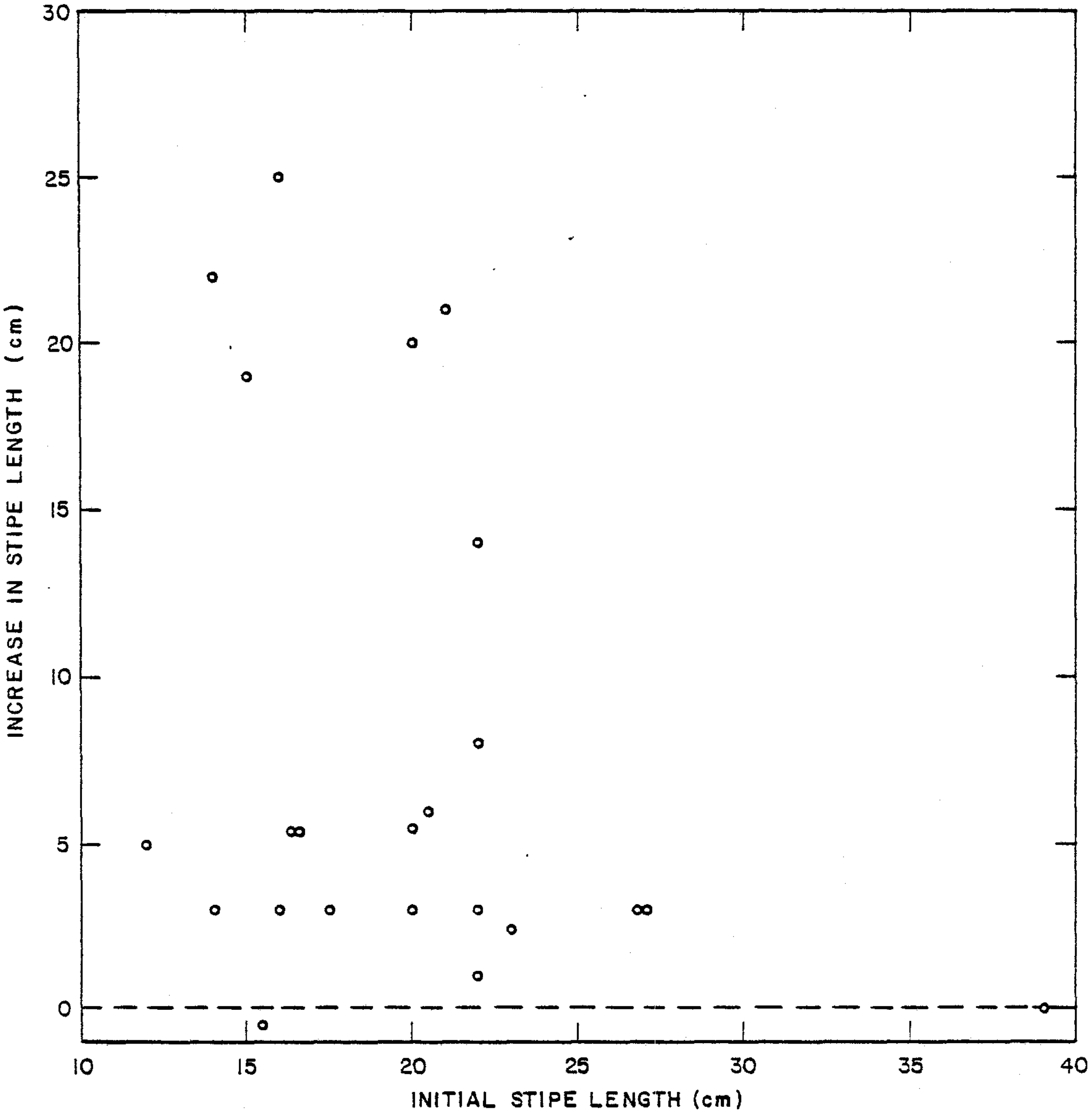


FIGURE 4-11

RELATIONSHIP BETWEEN INITIAL STIPE LENGTH
AND SUBSEQUENT STIPE GROWTH FOR *LAMINARIA GROENLANDICA*
FROM 1/30/78 TO 9/9/78

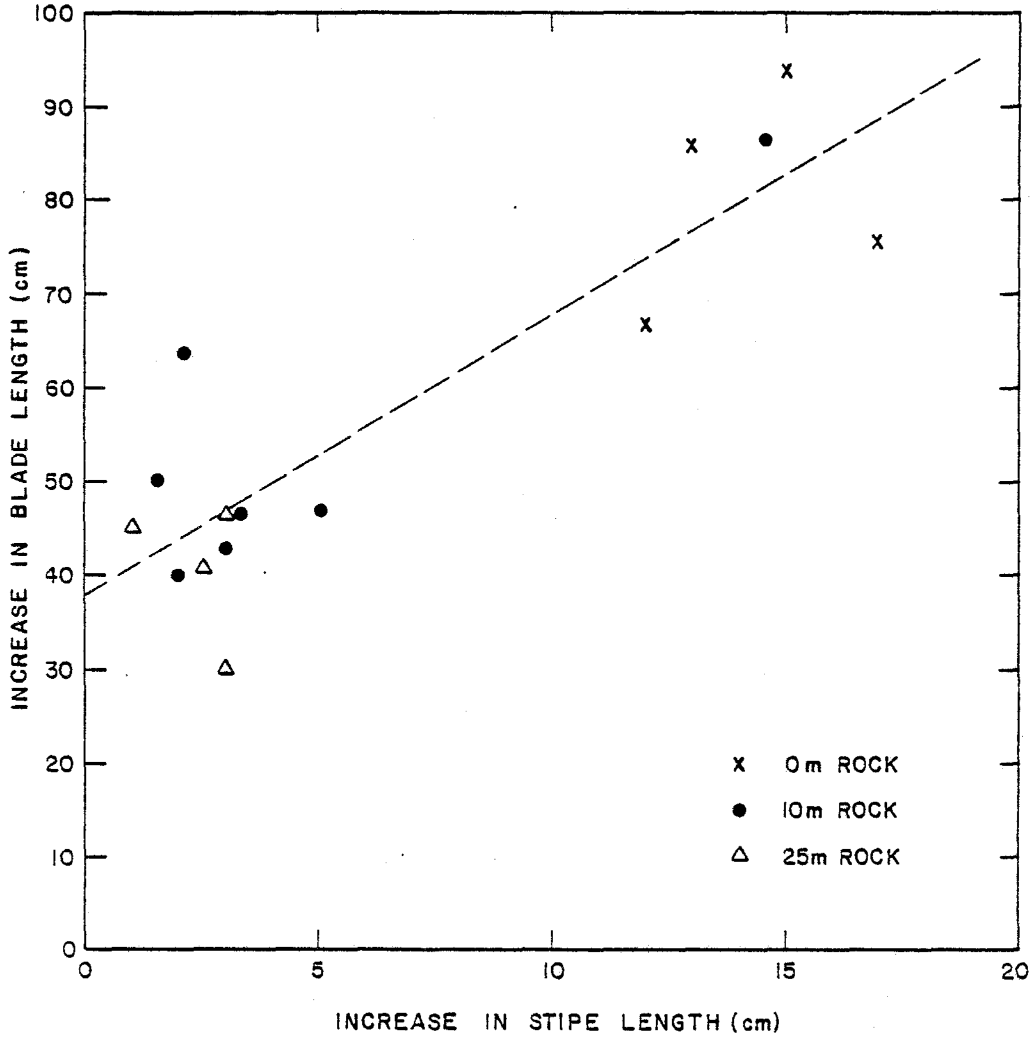


FIGURE 4-12

RELATIONSHIP BETWEEN INCREASE
IN LENGTH OF STIPE AND BLADE FOR LAMINARIA GROENLANDICA
FROM 3/22/78 TO 9/9/78

TABLE 4-19

CHANGES IN STIPE LENGTH FOR INDIVIDUAL PLANTS OF *LAMINARIA GROENLANDICA* AT JAKOLOF BAY

Plant Designation	10/31	1/30	2/1	3/22	6/9	8/8	9/9	10/26	Overall Change
NO4	35	36							+ 1
NO6		15.5					15		- 0.5
NO7	23	22					23		0
NO8	37	39					39		+ 2
NO9			14	20	29		35	36	+22
L17	31	27					30		- 1
L19	22	20							- 2
L34		16		17	17	18	19	18	+ 2
L38		22		27	33		36		+14
L40		20		25.5	34		40		+20
L41		22		23	26		28	28	+ 6
L42		21		30	36		42		+21
L43		20					23	23	+ 3
L44		22		23		25	25	24	+ 2
L45			16	24	38.5	45	41		+25
L46		27		27			30	30	+ 3
L47		20		22.5	23		25.5	25	+ 5
L48		23		24	26		25.5	24	+ 1
L49			15	21	28		34	33	+18
L51			16.5	18		21	22		+ 5.5
L52			17.5	18		20	20.5	20	+ 2.5
L53			20.5	23.5		27	26.5	31	+10.5
L54			16.5	19		20		22	+ 5.5
L55			24	27					+ 3
L56			12	14			17	15	+ 3
L57			16	16					0
L58			14	13			17	17	+ 3
L420			12	18	31				+19
$\bar{X}$	-0.8		3.0	6.3	2.8	-0.3	-0.2		6.9
s	2.4		2.8	4.8	--	1.9	1.6		8.2
Rate/day	-0.009		0.061	0.079	0.047	-0.010	-0.001		

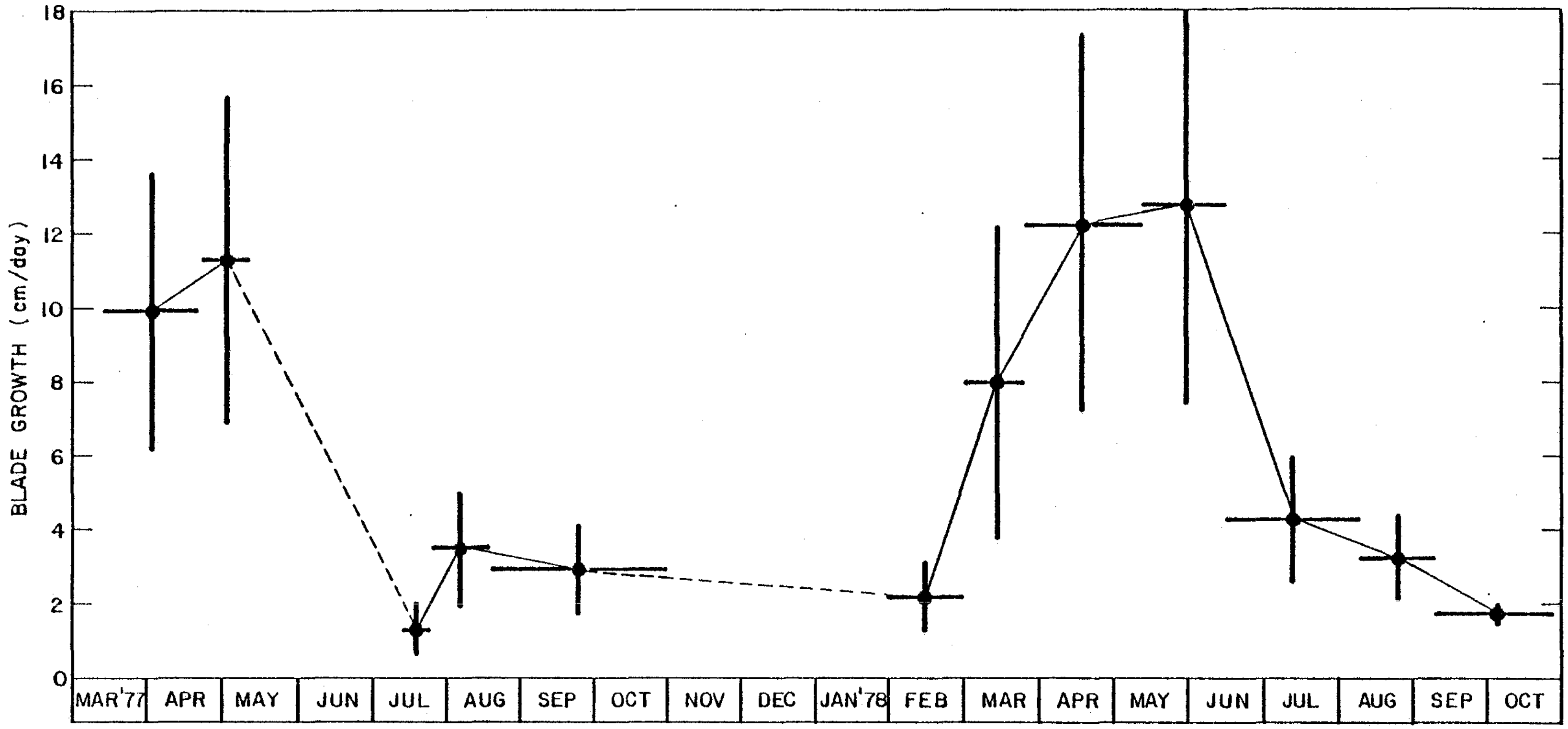
4.3.3 *Alaria fistulosa*

4.3.3.1 Average Growth Rates

Fifty-six plants of *Alaria fistulosa* were labelled during this program. At least one growth observation was obtained from 42 of them. The longest records were obtained for two plants extending from 02/01/78 to 10/26/78. Seven additional plants were followed for over seven months. The average length of observation was for 105 days. This is a reflection of the high mortality rates of this genus in Alaska which, although generally considered to be perennial, is virtually annual. In addition to high natural mortality, handling activities associated with tagging and measurements seemed to increase mortality rates. This resulted mainly from weakening the attachment by the holdfast. Blade damage resulted in some loss of growth markers. However, since growth occurs mainly in the meristem (between the blade and stipe), and that structure was not handled, we have no reason to suspect that tagging affected growth rates. Additionally, plant loss was greater during 1977 because the front of sea urchins grazed through the tagging area and extirpated virtually all the *Alaria*.

Growth rates for *A. fistulosa* were lowest during fall and mid-winter, but increased rapidly to a peak in spring (April-May) (Figure 4-13). Average rates ranged from 1.36 cm/day in July 1977 to 12.79 cm/day in May-June 1978. Growth rates generally exceeded 6.4 cm/day (half the maximum rate) in March through June, but fell below 4.24 cm/day (into the lower quartile) during the remaining months, i.e. two-thirds of the year. The slowest rate of growth observed for an individual plant was 0.84 cm/day for the month of February and the most rapid was 18.77 cm/day from late May to early June (Appendix 4.3.3).

Individual growth rates appeared to vary more during periods of peak growth than during slow growth (Figure 4-13). However, despite high variability, growth rates differed significantly between periods of slow and rapid growth. For example, the hypothesis that growth rates in



MEAN BLADE GROWTH (cm)	9.93	11.31	(6.34)	1.36	3.48	> 2.94	(2.58)	2.21	7.98	12.35	12.79	4.28	3.28	1.70
S*	3.37	4.44		0.67	1.57	1.22		0.95	4.21	4.99	5.15	1.65	1.17	0.29
SE	1.42	1.81		0.24	0.50	0.70		0.25	1.12	1.21	1.33	0.52	0.39	0.15
n	7	6		8	10	3		14	14	17	15	10	9	5
DAYS	40	20	61	13	24	74	93	28	23	49	35	53	32	47
GROWTH INCREMENT (cm)	397.2	226.2	(326.7)	17.7	83.5	217.6	239.9	61.9	183.5	605.2	447.7	226.8	105.0	79.9

* S = STANDARD DEVIATION; SE = STANDARD ERROR; n = NUMBER OF PLANTS MEASURED

FIGURE 4-13

SEASONAL PATTERNS IN GROWTH FOR ALARIA FISTULOSA AT JAKOLOF BAY the September-October 1978 period were slower than those observed in the May-June 1978 period was tested using an approximate "t" test for independent means (Sokal and Rohlf 1969). The difference was highly significant ($p < 0.005$; one-tailed test).

In contrast, a comparison of average growth rates in the same season of consecutive years indicates strong uniformity. For instance, comparison of the growth rates for the April-May 1977 and March-May 1978 periods, and the July-August 1977 and June-August 1978 periods indicate no significant differences in growth rates between these respective periods (Student's t-test, $P > 0.10$ in both cases).

The hypothesis that growth rate is correlated with plant size was tested for six observation periods, namely, 12 March to 22 April, 1977, 22 April to 12 April 1977, 12-22 April, 1977, 30 January to 1 March 1978, 16 June to 8 August 1978, and 8 August to 9 September, 1978 (Appendix 4.3.3). For this analysis, stipe length was used as an index of plant size. The data and regression equations for two periods are shown in Figure 4-14. The correlations was significant only for the 16 June to 8 August period ($p < 0.05$; $P > 0.10$ for the other periods).

Average blade growth increments were calculated for each observation period by multiplying its average daily growth rate by the number of days in the period (Figure 4-13). These increments were summed over a year to compute an annual mean rate of blade elongation. From March 1977 through February 1978, the estimate of average blade growth was 1630.7 cm, and from November 1977 through October 1978 it was 1950 cm.

The tagged plants of Alaria were generally distributed among three locations. These locations differed mainly in depth, but somewhat in water quality. Sufficient data for comparison were only obtained at "Upper Boulders, Finger Reef" and at "5 m on E-W Finger Line". At the former, depth was about -2 m below MLLW, tidal currents strong and water possibility warmer and more turbid during low slack tide. At the latter site, depth was about -5 below MLLW. The hypothesis that average

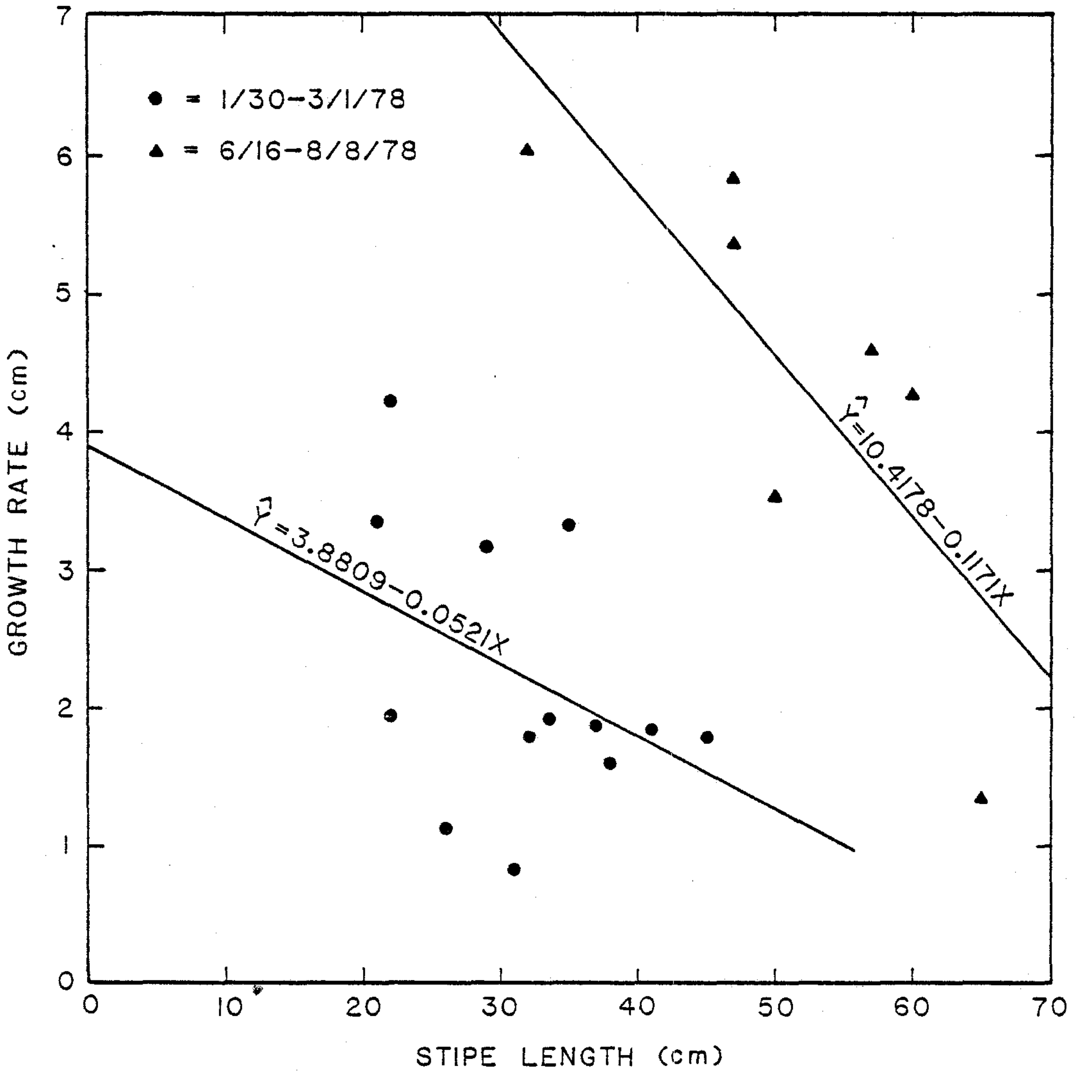


FIGURE 4-14

RELATIONSHIP BETWEEN STIPE LENGTH AND GROWTH RATE FOR <u>ALARIA FISTULOSA</u> AT JAKOLOF BAY growth rates were the same at each location was tested using the Mann-Whitney U Test. A summary of the available data (Table 4-20) supports that hypothesis but the data are weak. Comparisons between these locations for two periods (2/1 - 3/1/78 and 3/1 - 3/24/78) indicated that growth rates were not significantly different.

Stipe lengths were recorded on several occasions to permit an evaluation of the efficiency of using that parameter for determining age structure, and to examine growth rates of the stipe. These data, summarized in Table 4-21, are rather ambiguous. All plants examined for over three months showed increases in stipe length. However, several plants examined for shorter periods exhibited substantial decreases in stipe length. The explanation of this is unclear; problems in measurement should not be ruled out.

4.3.3.2 Primary Production

The equations used to calculate annual primary production (AP) for the large kelp Alaria fistulosa incorporates data for growth, density and length-weight data were used to construct a horizontal life table. The growth data are based on patterns described above; rates used from October to January are probably somewhat conservative.

The two density levels used are based on estimates from (1) a fixed transect in a shallow area with fairly high density of both adult and juvenile plants (Dames & Moore 1976), and (2) on a lower, more general average from quadrats and band transects spread throughout the area (Table 4-22). Generally, densities of juveniles were scarce to absent during fall and mid-winter, increased rapidly during April to a peak in May, and then decreased rapidly through the summer. Adults were present all year, but densities were lowest in March-May and highest in July and August.

These data suggest the general shape of the survivorship curve and were used as a basis for Figure 4-15. The generality of the curves

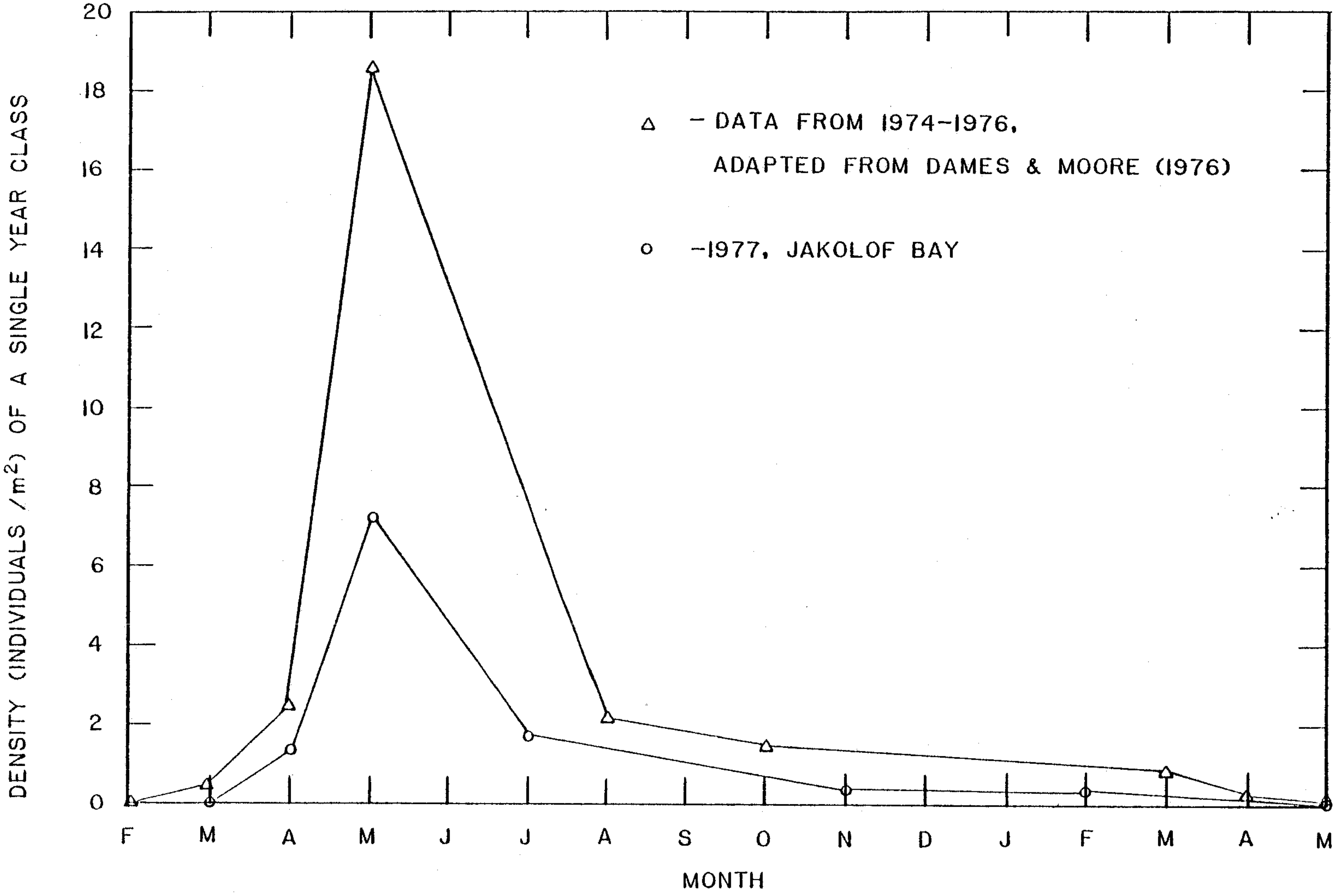


FIGURE 4-15

GENERALIZED SURVIVORSHIP

CURVES FOR ALARIA FISTULOSA AT JAKOLOF BAY

TABLE 4-20

AVERAGE PATES OF BLADE GROWTH (CM/DAY) FOR <u>Alaria fistulosa</u> FOR SPECIFIC SITES AND PERIODS IN JAKOLOF BAY

		02/02 - 03/01	03/01 - 03/24	03/24 - 06/16	06/16 - 08/08	08/08 - 09/09	09/09 - 10/26
5 m on E-W Finger Line (5 m deep)	$\bar{x}$	2.23	6.84	9.95	5.96	3.49	1.45
	s	1.15	4.30	6.18	4.90	1.59	--
Upper Boulder Finger Reef (2 m deep)	$\bar{x}$	2.18	8.94	13.23	4.17	2.38	2.19
	s	0.79	4.45	--	--	--	--
E.of E-W Finger Line (5 m deep)	$\bar{x}$	--	--	15.94	5.23	4.32	1.28
	s	--	--	1.41	--	--	0.56

TABLE 4-21

CHANGES IN STIPE LENGTH FOR INDIVIDUAL PLANTS OF *Alaria fistulosa* AT JAKOLOK BAY

Plant Designation	Stipe Length (cm) at Date of Observation											Overall Change
	03/13	04/22	05/12	07/15	08/18	10/31	02/01	03/22	08/08	09/09	10/26	
AL68										15	22	+ 7
AL26				17	19							+ 2
AL24				17		28						+11
AL22				18	10							- 8
AL15				20	11	37						+17
AL25				21	36							+15
AL21				21		41						+20
AL32							21			50	52	+31
AL30							22		47	45		+23
AL18		27	29	35								+ 8
AL23							28			33		+ 5
AL19		29	30									+ 1
AL 4							29				53	+24
AL27							30	29				- 1
AL38							31	30				- 1
AL 6									32	26	25	- 7
NO 9	32.5	31	33									+0.5
NO 6	34	39	43									+ 9
NO 3	35	35	36									+ 1
NO 4	37.5	34										-3.5
AL50									38	29		- 9
AL31							38		60	62		+23
NO 8	39	35	40									+ 1
NO 2	39	38	40									+ 1
AL58										39	40	+ 1
AL36							41		65			+24
AL33							45	43				- 2
AL 7									47	33		-14
NO 5	48	47	51									+ 3
AL51									52	53		+ 1
AL63									65	74		+ 9
$\bar{x}$	0.29		2.63	--	0.00	--	--	1.3	--	2.25		
s	3.08		1.51		11.17			0.6		3.40		

TABLE 4-22

DENSITY DATA (INDIVIDUALS/m^2) FOR *Alaria fistulosa* AT JAKOLOK BAY, 1974-1977

Data from fixed transect, 1974-1976, adapted from Dames & Moore (1976):

	08/74	10/74	03/75	05/75	08/75	10/75	04/76	07/76
Juveniles	--	--	0.24	18.72	0.96	0.12	2.48	4.52
Adults	2.40	1.64	0.96	0.12	2.24	1.60	0.24	1.96

Data from random areas at Jakolof Bay study site:

	02/77	03/77	04/77	05/77	07/77	11/77
Juveniles	0	0	1.33	7.19	0.32	0
Adults	0.69	0.027	0.025	0.12	1.81	0.33

appears acceptable based on our impressions of growth and survivorship for Alaria in Kachemak Bay. However, density levels, while representative of a well-developed kelp bed, are undoubtedly rather high for Kachemak Bay as a whole, as A. fistulosa has been observed mainly in high current areas between 1.5 m and 12 m depths (personal observation).

The length-weight relationship (Figure 4-16) is based on plants collected from the study site. The correlation is highly significant for plants up to 10 m in length ($r = 0.96$, $P << 0.001$). The regression equation, exponential because increased length is accompanied by increased blade width and thickness, was used to calculate fresh weights of a hypothetical, uneroded plant at various lengths up to 12 m. The linear increase in the plant weight: plant length ratio associated with increasing length (Figure 4-17) is probably mainly due to increasing width. Although we observed that larger plants had wider blades, in the absence of data showing this relationship at lengths greater than 10 m, we felt it was inappropriate to assume that the ratio continued increasing. This choice also precluded using the regression equation for plant lengths appreciably larger than 11 m. Therefore, plant weights for plants longer than 12.0 m were calculated by multiplying their length by 2.2 g/cm, the length-weight ratio for 11 m long plants.

Alaria spp. are virtually annuals in Alaska (personal observation for three species). This feature permitted treating the population as a cohort simplifying the production computations. Therefore, we assumed that the plants recruited on 1 May ($m = o$) at a length of 30 cm ($L_o = 30$ cm). (This was a statistical assumption; Table 4-22 indicates the occurrence of juveniles in numerous months before and after May, but definitely, juvenile density was highest then.) Based on these assumptions, the hypothetical, uneroded length of a plant at the end of a specific month was taken as:

$$L_m = t_m \bar{G}_m + L_{m-1},$$

where t_m is the number of days in the month and G_m is the observed

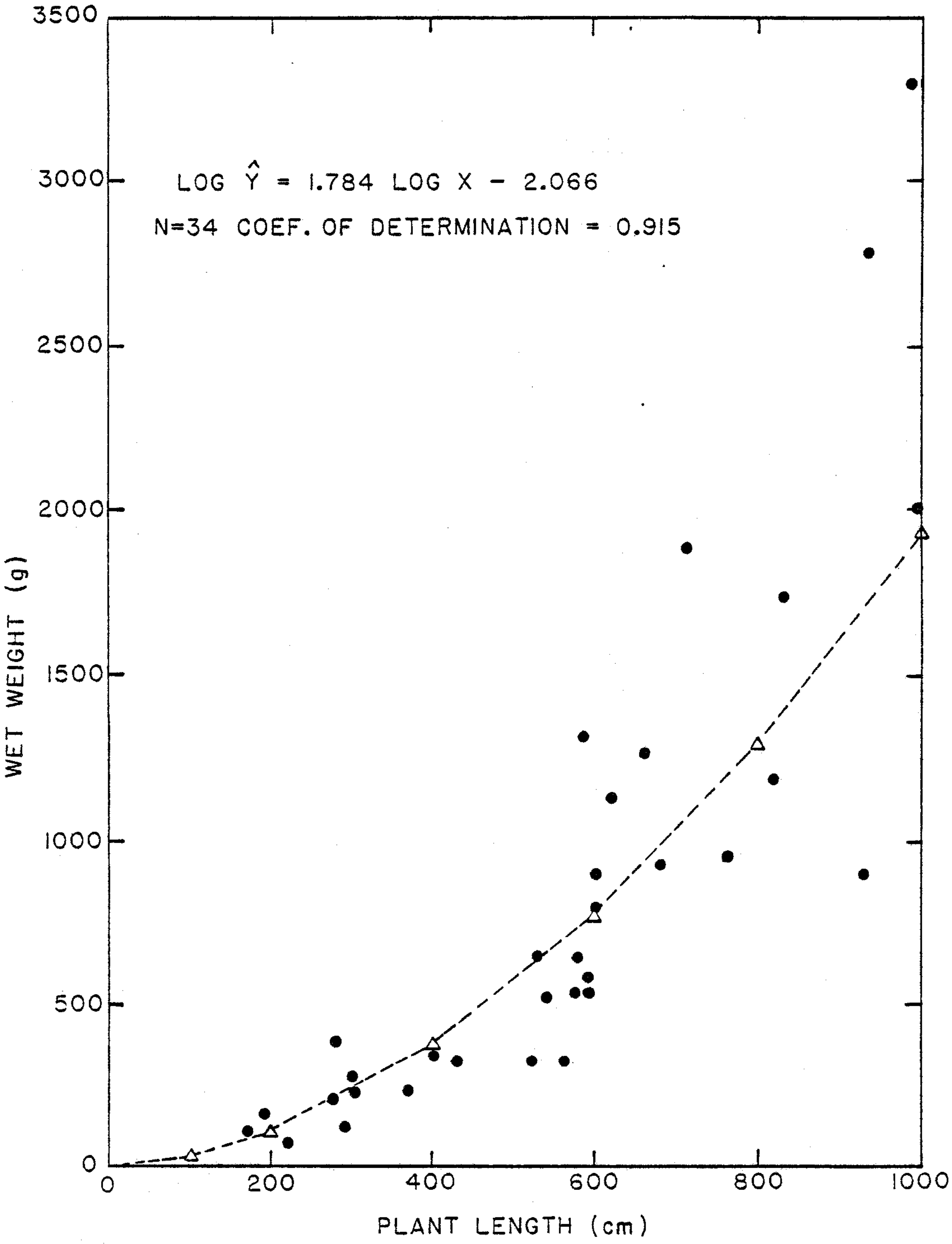


FIGURE 4-16

LENGTH-WET WEIGHT RELATIONSHIP
FOR *ALARIA FISTULOSA* AT JAKOLOF BAY
FOR PLANTS COLLECTED ON 12, 15 AND 25 JULY, 1977

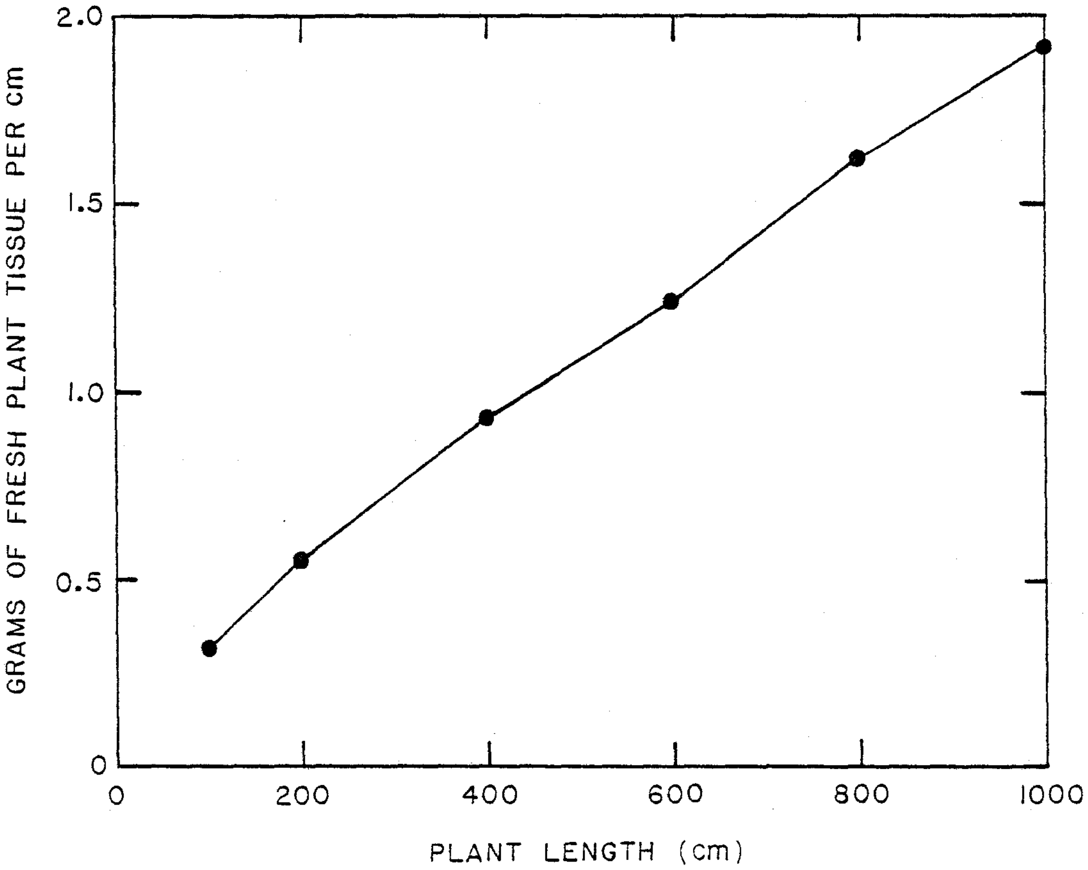


FIGURE 4-17

RELATIONSHIP BETWEEN PLANT LENGTH AND LENGTH: WET WEIGHT RATIO FOR *ALARIA FISTULOSA* FROM JAKOLOF BAY average daily growth rate for that month. Calculations of L_m must be accomplished consecutively.

The monthly increment in fresh tissue weight (T_m) for an average individual was taken as the difference between individual plant weight in consecutive months, i.e., $W_m - W_{m-1}$, where

$$W_m = 10^{1.784 \log L_m - 2.066}.$$

For the total population, monthly tissue production (MP_m) involves a simple relationship between T_m, plant density (D_m) and the shape of the survivorship curve during that month ($D_m - D_{m-1}$):

$$MP_m = T_m ((D_m + D_{m-1})/2) = T_m \bar{D}_m.$$

Data for May in Table 4-23 are used as an example. Given an average plant length and weight of 30 cm and 3.7 g on 30 April and an average observed growth rate of 12.5 cm/day for May, the average plant will have grown about 388 cm to an uneroded length of 418 cm by the end of May. The length-weight regression equation predicts a plant that long would weigh 408 g. Since the initial size of the average plant was about 4 g, the tissue increment per plant is 404 g. Multiplying this increment by average plant density for May

$$(D_1 + D_o)/2 = (5.6 + 7.19)/2 = 6.395 \text{ plants/m}^2$$

gives an estimate of 2577 g tissue produced/m^2 in May.

The calculations of primary production for A. fistulosa are summarized in Table 4-23. These indicate that over 80 percent of the plant tissue produced by this species is produced during May, June, and July, when estimates of carbon fixation range up to 13.77 gC/day in the densely populated areas. Annual averages range from 1.17 gC/m^2/day in the study area to 3.05 gC/m^2/day in the high density area.

TABLE 4-23

ESTIMATES OF PRIMARY PRODUCTION FOR THE KELP ALARIA FISTULOSA FOR THE JAKOLOF BAY STUDY SITE

	A	M	J	J	A	S	O	N	D	J	F	M	A	Annual Production By Cohort
Average Growth Rate (cm/day)-G_m	--	12.5	10.0	6.0	3.8	2.5	2.0	2.0	2.0	2.0	2.0	5.5	10.0	
Indiv. Length (cm) at end of month - L_m	30	418	718	904	1022	1097	1159	1219	1281	1343	1399	1570	1870	
Indiv. Weight (g) at end of month - W_m	3.7	408	1070	1614	2008	2279	2514	2682	2818	2955	3078	3454	4114	
Monthly Increment in Fresh Tissue Weight (g) - T_m		404	662	544	394	271	235	168	136	137	123	376	660	
CONSERVATIVE ESTIMATE OF PRODUCTION														
Density at end of month (plants/m^2) - D_m	7.19	5.60	1.81	1.40	1.05	0.75	0.45	0.40	0.35	0.33	0.30	0.19	0	
Production (g/m^2/month) by														
Plants remaining		2262	1198	762	414	203	106	67	48	45	37	71	0	
Plants lost to area		321	1254	112	69	41	35	4	3	1	2	21	63	
Monthly Fresh Tissue Production (g/m^2/month) - MP_m		2583	2452	874	483	244	141	71	51	46	39	92	63	7,139
											Dry weight/m^2			1,428[1]
											g C/m^2			428[2]
HIGH DENSITY AREA ESTIMATE OF PRODUCTION														
Density at end of month (plants/m^2) - D_m	18.72	13.00	7.80	2.24	1.80	1.50	1.40	1.25	1.10	1.00	0.90	0.30	0	
Production (g/m^2/month) by														
Plants remaining		5252	5164	1219	709	407	329	210	150	137	111	113	0	
Plants lost to area		1155	1721	1512	87	41	12	13	10	7	6	113	99	
Monthly Fresh Tissue Production (g/m^2/month) - MP_m		6407	6885	2731	796	448	341	223	160	144	117	226	99	18,577
											Dry weight/m^2			3,715[1]
											g C/m^2			1,115[2]

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[1] Assuming a dry tissue weight/wet weight ratio of 0.2 (Mann, 1972).

[2] Assuming a g C/dry weight ratio of 0.3 (Mann, 1972).

These estimates probably indicate the correct order of magnitude of tissue production for Alaria stands around Kachemak Bay, but several factors could alter them substantially. The model is quite sensitive to changes in life history features in May and June such as:

- initial density
- the temporal relationship between peak density and growth rates
- the shape of the survivorship curves
- growth rates

Environmental factors or disturbances altering any of these features in March or April (period of maximal germination) through June could probably have significant influence on the annual production of this species.

4.4 RESULTS - SOFT SUBSTRATES

At the two sand beaches and the mud flat studied the respective faunas were distinctly different. Sampling efforts were essentially equal in each survey. Twenty-two species were identified from the sand beach at Deep Creek (Table 4-24), where the fauna was dominated by the gammarid amphipod Eohaustorius eous. Thirty species were identified from the sand beach at Homer Spit (Table 4-24), where the fauna was dominated by the polychaete Scolelepis sp. A. Forty species were identified from the mud flat at Chinitna Bay (Table 4-25), where the fauna was dominated by the clams Maxoma balthica, Mya arenaria, M. truncata and Mya priapus. Mya spp. are possibly present at commercially harvestable densities. Although unmeasured, the mud flat also supported appreciable standing crops of benthic diatoms and filamentous brown and green algae in the summer.

4.4.1 Biological Assemblage of the Sand Beach at Deep Creek

The infaunal assemblage at the Deep Creek site was sampled three times during the period covered by this report, namely on 4 February,

TABLE 4.24. FREQUENCY OF OCCURRENCE OF TAXA FROM SANDY INTERTIDAL SITES ON THE EAST SIDE OF LOWER COOK INLET IN 1977

Taxa	Deep Creek	Homer Spit
PLATYHELMINTHES		
Turbellaria, unid.	0	1
ANNELIDA - Polychaeta		
Abarenicola sp.	1	0
Capitella capitata	3	1
Chaetozone setosa	1	0
Eteone nr. *longa*	3	2
Magelona pitelkae	0	1
Nephtys ?*ciliata*	2	3
Nephtys sp. (juv.)	0	1
Paraonella platybranchia	3	3
Sabellidae, unid.	0	1
Scolelepis p. A	3	3
Scoloplos armiger	3	1
Spionidae, unid.	0	1
Spiophanes ?*bombyx*	0	1
Typosyllis sp.	0	1
ARTHROPODA - Crustacea		
Anisogammarus cf. *confervicolus*	2	0
Archaeomysis grebnitzkii	2	1

Taxa	Deep Creek	Homer Spit
Atylidae, sp.A	1	0
Crangon ?alaskensis elongatus	0	1
Eohaustorius eous	3	3
Gammaridae sp.A	1	0
Gammaridea, red striped	0	1
Lamprops carinata	0	1
Lamprops quadriplicata	1	1
Lamprops sp.	0	1
Lysianassidae, unid.	1	2
Oedocerotidae, unid.	1	0
Paraphoxus milleri	1	2
Paraphoxus sp.	2	1
Synchelidium sp.	1	0
MOLLUSCA - Gastropoda		
Littorina sitkana	0	1
MOLLUSCA - Pelecypoda		
Mytilus edulis	0	1
Protothaca staminea	0	1
Spisula polynyma	0	3
CHORDATA - Pisces		
Ammodytes hexapterus	0	3
Total Number of Species	22	30

TABLE 4.25. PERIOD OF OCCURRENCE OF TAXA FROM MUD FLAT SITE AT GLACIER SPIT, CHINITNA BAY IN 1977

TAXON	
NEMERTEA, unid.	7[a]
ANNELIDA	
Abarenicola pacifica	4
Ampharete acutifrons	4,7
*A*phroditoidea, unid	4
Axiothella rubricincta	7
Capitella capitata	4,7
Eteone nr. *longa*	4,7
E. nr. *pacifica*	7
Glycinde polygnatha	4
Harmothoe imbricata	4,7
Malacoceros sp	4,7
Maldanidae, unid.	7
Nephtys sp	4,7
Nephtys sp (juvenile)	4,7
Oligochaeta, unid.	7
Paraonella platybranchia	7
Paraonidae, unid.	4
Phyllodoce groenlandica	4,7
Polydora caulleryi	4,7
Polygordius sp	7
Potamilla sp	4,7
Scoloplos armiger	4,7
Spio ?*filicornis*	7
?*Spio* sp	4
Spionidae, unid.	7
ECHIURA	
Echiurus echiurus alaskensis	4,7

TAXON	
ARTHROPODA	
Acarina, unid.	7
Cyclopoida, unid.	7
Crangon sp	7
Harpacticoida, unid.	7
Insecta (larva)	7
Ischyrocerodidae, unid.	7
Pontoporeia femorata	7
Saduria entomon	4
Tritella ?*pilimana*	4,7
MOLLUSCA	
Aglaja diomedea	7
Clinocardium nuttallii	4,7
Cylichna sp	7
Macoma balthica	4,7
Macoma sp	4
Mya arenaria	4,7
M. *priapus*	4,7
M. *truncata*	4,7
Mya spp. (juveniles)	4,7
Pseudopythina sp	4,7

---

[a] Number refers to month of sampling period; 4 = April, 7 = July

7 April and 29 July 1977. A total of 17 taxa, including eight polychaete and nine crustacean taxa, was identified during the sampling period (Table 4-24).

Quantitatively, the infauna was dominated heavily by gammarid amphipods, especially the haustoriid *Eohaustorius eous* (Table 4-26). Relative abundance was remarkably uniform seasonally. An unidentified member of the amphipod family Gammaridae (Gammaridae sp. A) was quite abundant in the July survey. The remaining species were only of marginal numerical importance. Most notable among these were the polychaetes *Eteone* nr. *longa* and *Scolelepis* sp. A, and the gammarid *Paraphoxus milleri*. The raw data for these samples, by core, level and survey, are presented in Appendix 4.4.1 through 4.4.3 and species summaries in Appendix 4.4.4 through 4.4.6.

4.4.1.1 Zonation

To examine zonation, the species at each level were assigned, by survey, to "importance" categories according to their density and frequency of occurrence (see METHODS section). Species composition was then compared among the sampling levels. According to these criteria, the upper level was dominated by *Eteone* and *Eohaustorius*, the middle two levels by *Eohaustorius* and the lower level by *Scolelepis* and *Eohaustorius* (Table 4-27). Only the latter species was important at all levels.

The relationship between elevation and density was examined, but only the increase of *Eohaustorius* at lower elevations departed significantly from random ($P < 0.02$). In contrast, *Eteone* was more abundant at the upper levels than below, but the pattern was not statistically significant. In addition, densities in July appeared to be quite variable for several species. It appears that the middle level is near the upper limit for *Scolelepis* and *Paraphoxus* at this beach. The paucity of statistically significant elevation-related density differences among the species observed is probably mostly a consequence of too few samples, or a high degree of patchiness, as well as the changes in the beach shape and the corresponding movement of the animal populations in relation to the sampling levels.

TABLE 4-26. OVERALL DENSITY (NO./M^2) OF COMMON SPECIES AT DEEP CREEK SITE

Taxa	2/77 Density	%	4/77 Density	%	7/77 Density	%
Polychaeta		(17.6)[a]		(12.9)		(13.4)
Capitella ?capitata	9.6	1.8	-	-	9.6	0.8
Eteone nr. *longa*[b]	44.6	8.6	9.6	1.6	9.6	0.8
Nephtys ?ciliata[b]	-	-	9.6	1.6	9.6	0.8
Paraonella platybranchia	15.9	3.0	9.6	1.6	12.7	1.0
Scolelepis sp. A[b]	15.9	3.0	35.0	5.4	92.3	7.4
Scoloplos armiger[b]	6.4	1.2	15.9	2.7	31.8	2.6
Gammaridea		(81.3)		(84.7)		(84.6)
Anisogammarus cf. *confervicolus*	6.4	1.2	6.4	1.0	-	-
Eohaustorius eous	404.2	78.3	461.5	78.8	648.4	51.9
Gammaridae, sp. A	-	-	-	-	388.3	31.2
Paraphoxus milleri[b]	9.6	1.8	28.6	4.9	19.1	1.5
Mysidacea						
Archaeomysis grebnitzkii	3.2	0.6	-	-	3.2	0.2

---

[a] Parenthetic number are total percentages in major taxa

[b] Also common in sandy infaunal samples collected at 200 ft. depths in the middle of Lower Cook Inlet and at Homer Spit

[c] Also found at Homer Spit

TABLE 4-27. IMPORTANT SPECIES AT EACH LEVEL AT DEEP CREEK

Species	Sampling Level 1	2	3	4
Polychaetes				
Capitella capitata		Frequent		
Eteone nr *longa*	Dominant	Frequent		
Paraonella platybranchia		Frequent	Sub-dominant	Frequent
Scolelepis sp. A		Seasonal	Sub-dominant	Dominant
Scoloplos armiger			Sub-dominant	Frequent
Crustaceans				
Anisogammarus cf *confervicolus*	Frequent			Frequent
Eohaustorius eous	Dominant	Dominant	Dominant	Dominant
Gammaridae sp. A		Seasonal	Seasonal	Seasonal
Paraphoxus milleri		Frequent	Sub-dominant	Sub-dominant

Field observations indicate patterns of vertical distribution in the sediment for some of the species. All of the gammarid amphipods appear to live within 5 cm of the water-sand interface. On the other hand, the polychaetes *Scolelepis* and *Nephtys* are generally encountered at least 15 cm below the interface during low tides.

4.4.1.2 Seasonal Patterns

Several seasonal patterns were apparent. Overall density increased from February to July (Table 4-26). Within this general pattern, two trends were discerned. Gammaridae sp. A increased strongly in abundance during the summer. Several other species, i.e., *Eohaustorius* and the polychaetes *Scolelepis* and *Scoloplos*, increased during the survey, but not significantly (respectively, $P > 0.65$, > 0.05 and > 0.20, based on a Friedman X_r^2 analysis of variance computed with pooled data for each level and tested among surveys). In contrast, *Eteone* nr. *longa* decreased in abundance but not significantly ($P > 0.05$). These trends appear strong and the lack of significance appears to be mainly a consequence of too few samples.

4.4.1.3 Biomass

In terms of biomass, the fauna at Deep Creek was generally dominated by polychaetes in April but by gammarid amphipods in July (Table 4-28). Specifically, in order of importance, the dominant polychaetes were *Scoloplos*, *Eteone*, *Nephtys* and *Scolelepis* in April, and *Scoloplos*, *Scolelepis*, *Nephtys* and *Abarenicola* in July. Dominant gammarids were *Eohaustorius* in April, and in July, Gammaridae sp. A and *Eohaustorius*. Overall, *Eohaustorius* dominated in terms of biomass in April and Gammaridae sp. A in July; *Eohaustorius* was next most important in July.

Generally, biomass levels were relatively low and consequently strongly affected by large, uncommon species such as *Nephtys*, or spatially and temporally patchy species such as Gammaridae sp. A. However, two general trends appeared real. During both surveys, there was a tendency for biomass to be greater at lower levels, mainly reflecting the patterns

TABLE 4.28. DISTRIBUTION OF WHOLE WET AND ESTIMATED DRY WEIGHTS IN SAMPLE SETS AT DEEP CREEK IN 1977 (WEIGHTS IN GRAMS)

Level	April				Survey Total		July				Survey Total	
	1	2	3	4	Wet Weight	Dry Weight[a]	1	2	3	4	Wet Weight	Dry Weight
Polychaeta	(0.360)[b]	(0.010)	(0.120)	(0.444)	(0.934)	(0.155)	(0.064)	(0.641)	(0.324)	(0.388)	(1.417)	(0.221)
Abarenicola pacifica	0	0	0	0	0	–	0	0.127	0	0	0.127	0.027
Capitella capitata	0	0	0	0	0	–	0	0.027	0	0.005	0.032	0.006
Cirratulidae, unid.	0	0	0	0	0	–	0	0	0.008	0	0.008	0.001
Eteone nr *longa*	0.260	0	0	0	0.260	0.051	0.020	0.008	0	0	0.028	0.006
Nephtys caeca	0	T	0	0.183	0.183	0.035	0	0	0.070	0.080	0.150	0.029
Paraonella platybranchia	0	T	T	0	T	T	0.001	–	–	0.001	0.002	T
Polychaeta, unid.	0	T	0	0	T	T	–	–	–	–	–	–
Scolelepis sp A	0	0	0.010	0.163	0.173	0.025	0.043	0.032[c]	0.01	0.140	0.226	0.032
Scoloplos armiger	0.100	0	0.110	0.098	0.308	0.044	0	0.447	0.235	0.162	0.844	0.120
Gammaridea[d]	(0.106)	(0.095)	(0.125)	(0.324)	(0.650)	(0.128)	(0.246)	(3.094)	(0.725)	(0.659)	(4.724)	(0.922)
Eohaustorius eous	0.033	0.095	0.125	0.291	0.544	0.107	0.126	0.234	0.315	0.239	0.914	0.179
Paraphoxus milleri	0.033	T	0	0.013	0.046	0.009	0	0.010	0.020	0.030	0.060	0.012
misc. gammarids	0.040	0	0	0.020	0.060	0.012	0.120	2.850	0.390	0.390	3.750	0.731
Total	0.466	0.105	0.245	0.768	1.584	0.283	0.310	3.825	1.049	1.047	6.231	1.143
Biomass (g/m^2)	5.93	1.34	3.12	9.78			3.95	48.70	13.36	13.33		
Average biomass (g/m^2)					5.04	0.901					19.84	3.638

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[a] Based on conversion factors indicated in Thorson (1957)

[b] Parenthetic values are total wet whole weight for major taxa

[c] Only data for 9 cores

[d] Gammarid weights for July are estimates based on July abundance and wet weight/number ratio in April; samples were lost in the mails before weighing

of the dominant species. Furthermore, there was a strong increase in biomass between April and July. This reflected an increase in biomass in the dominant species, particularly Eohaustorius and Scoloplos, as well as the appearance of several additional species during this period (Table 4-28).

4.4.1.4 Size Structures

Observations on size structure were attempted for the gammarid Eohaustorius eous and the polychaete Scolelepis to provide insight into growth rates, life cycle and eventually permit estimation of secondary production.

It was possible to examine the size structure of Eohaustorius by measuring its length (from the tip of the rostrum to the base of the telson) with an ocular micrometer (Appendix 4.4.7). The length-frequency histograms represent pooled samples for all four levels (Figure 4-18). Based on these data, it appears that at least two age classes occurred in the population. The younger class appeared less abundant than the older one, but this may be an artifact of the mesh size of the sieve used to screen the samples. However, reproductive potential of haustoriids is reported to be fairly low (Sameoto 1969a and b).

A comparison of the April and July modes for the young age class suggests that growth was rather slow. The modal size of the older age class appears to have decreased during the same period, perhaps due to size specific predation or post spawning mortality of larger individuals. The difference in size structure is highly significant ($P < 0.005$, Kolmogorov-Smirnov two-sample test).

Size data were collected for two other gammarid amphipods but are unsatisfactory for one of several reasons. Average lengths for Paraphoxus milleri were 4.4 ± 1.7 mm in April (n = 8) and 7.7 ± 3.6 mm in July (n = 6) but the sample sizes were very small. Gammaridae sp A, very common in July, had an average length of 2.5 ± 0.7 mm (Appendix 4.4.8), but no comparative data were available from April.

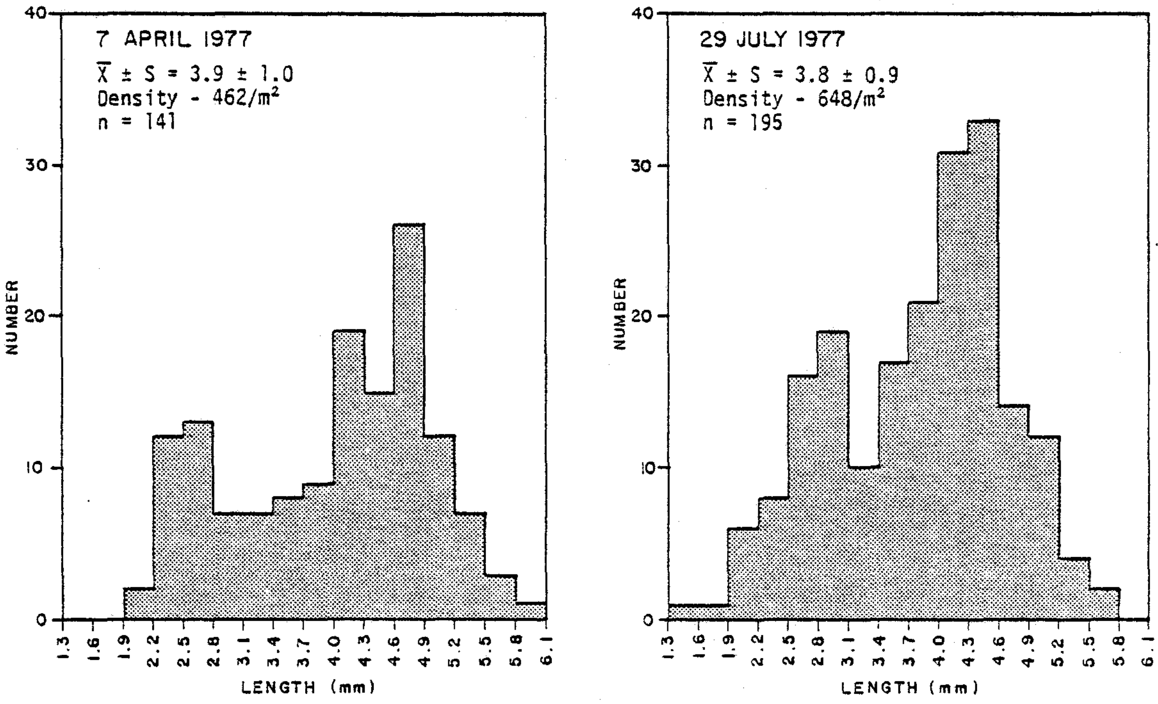

FIGURE 4-18

LENGTH FREQUENCY HISTOGRAMS
FOR EOHAUSTORIUS EOUS FROM DEEP CREEK, 1977

Generally, useful measurements were not obtainable for Scolelepis because of its fragility and absence of hard parts useful in size measurements. To date, we have been unable to obtain a single whole worm. However, it is our impression based on visual examination of the samples that, on the average, worms were small in winter or spring, and large in the summer.

4.4.1.5 Numerical Parameters

Patterns in the numerical parameters were rather straight forward and consistent during the study. Generally, abundance, species richness and species diversity increased during the period of the survey (Table 4-29). Also, the first two parameters were generally higher at the lower elevations.

The significance of the observed increase in abundance from February to July was tested separately for each level on unpooled data (Appendix 4.4.1 through 4.4.3) by means of the Kruskal-Wallis one-way analysis of variance. The differences were found to be highly significant ($P < 0.01$) at levels 1, 2 and 3, but did not depart from random at level 4 ($P > 0.3$).

When abundance was tested in the same manner for differences among levels, highly significant differences ($P < 0.01$) were found for all sample sets. In February and April, abundances were higher at lower elevations. In contrast, the two intermediate elevations (levels 2 and 3) had the higher densities in July.

The other abundance parameters presented (total number of organisms collected per level and number per m^2) are both derived directly from the raw data. Thus, the patterns are identical, i.e., exhibiting general increases with season and, during each survey, with lower elevation.

Species richness was evaluated statistically by comparing the number of species in each core (unpooled data) among levels and surveys; again the Kruskal-Wallis one-way analysis of variance was used. The differences observed among surveys at a given level were significant at

TABLE 4.29. SUMMARY OF NUMERICAL PARAMETERS FOR THE SANDY INTERTIDAL ASSEMBLAGE AT DEEP CREEK

	Abundance			Species Richness		Species Diversity	Evenness		
Elevation (ft)	Total per Level	$\bar{x} \pm s$ per Core	per m^2	Total per Level	$\bar{x} \pm s$ per Core	H	N/S	E	Grams Wet Weight per m^2
				4 February 1977					
0	18	1.8 ± 1.9	229.2	4	1.3 ± 0.7	1.32	4.5	0.62	-
-1	21	2.1 ± 1.6	267.4	3	1.2 ± 0.4	0.70	7.0	0.54	-
-2	39	3.9 ± 1.7	496.6	6	1.7 ± 0.8	1.05	6.5	0.35	-
-3	84	8.4 ± 4.3	1069.5	7	2.0 ± 0.7	0.69	12.0	0.23	-
Overall	162			9			18.0		
$\bar{x} \pm s$		4.1	515.7		1.6	0.9 ± 0.30		0.44 ± 0.18	-
				7 April 1977					
0	10	1.0 ± 0.9	127.3	5	0.8 ± 0.6	1.50	2.0	0.57	5.93
-1	31	3.1 ± 3.2	394.7	5	1.2 ± 0.8	0.64	6.2	0.31	1.34
-2	35	3.5 ± 2.8	445.6	6	1.3 ± 0.9	0.96	5.8	0.32	3.12
-3	108	10.8 ± 4.8	1375.1	7	2.6 ± 1.3	0.95	15.4	0.28	9.78
Overall	184			10			18.4		
$\bar{x} \pm s$		4.6	585.7		1.5	1.01 ± 0.36		0.37 ± 0.13	5.04
				29 July 1977					
0	39	3.9 ± 2.3	496.6	5	2.0 ± 0.9	1.15	7.8	0.44	3.95*
-1	173	17.3 ± 16.3	2202.7	12	3.9 ± 1.4	1.72	14.4	0.27	48.70
-2	101	10.1 ± 4.9	1286.0	11	3.4 ± 1.3	1.56	9.2	0.27	13.36
-3	84	8.4 ± 6.2	1069.5	9	2.7 ± 1.3	1.61	9.3	0.34	13.33
Overall	391			16			24.4		19.84
$\bar{x} \pm s$		9.9	1263.7		3.0	1.51 ± 0.25		0.33 ± 0.08	

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* Biomass for gammarids in July based on average weight/specimen in April; animals lost in mails.

level 1, highly significant at levels 2 and 3, but not significant (P >0.5) at level 4. At levels 1 and 3, fewest species per core were encountered in April, but at all levels, greatest species richness occurred in July. The total number of species encountered in each survey also increased during the study (Table 4-29). In February and April, there was a fairly well-defined increase in species richness at the lower sampling levels, but this pattern was not apparent in July.

Species diversity (H) generally increased from February to July, but was quite variable among the levels within each period. However, neither the patterns of variation with season nor with elevation were significant.

Evenness parameters generally indicated that species were less equitably distributed at lower elevations and in the later surveys. This is mainly a reflection of large increases in the density of populations of a rather limited number of species at lower elevations and through time. However, in all surveys, over 50 percent of the species were represented by three or fewer specimens. None of the patterns was statistically significant.

Species-area curves were constructed for each level and survey to provide insight into rates of species acquisition in the samples and the suitability of the sampling program. In most cases, the curves for specific levels show signs of becoming asymptotic (Figure 4-19). Only at levels 2, 3 and 4 in July does it appear that a substantial number of additional species might have been obtained by further sampling. Such patterns emphasize the low species richness and high N/S ratios reported above.

Composite species-area curves were constructed for each survey by tabulating, by level, the cumulative number of species identified. In all cases, the rate of "accrual" was fairly slow and uniform. This is probably a reflection of the intensity of the physical gradients. It is not surprising, however, that July, the mildest period sampled, initially

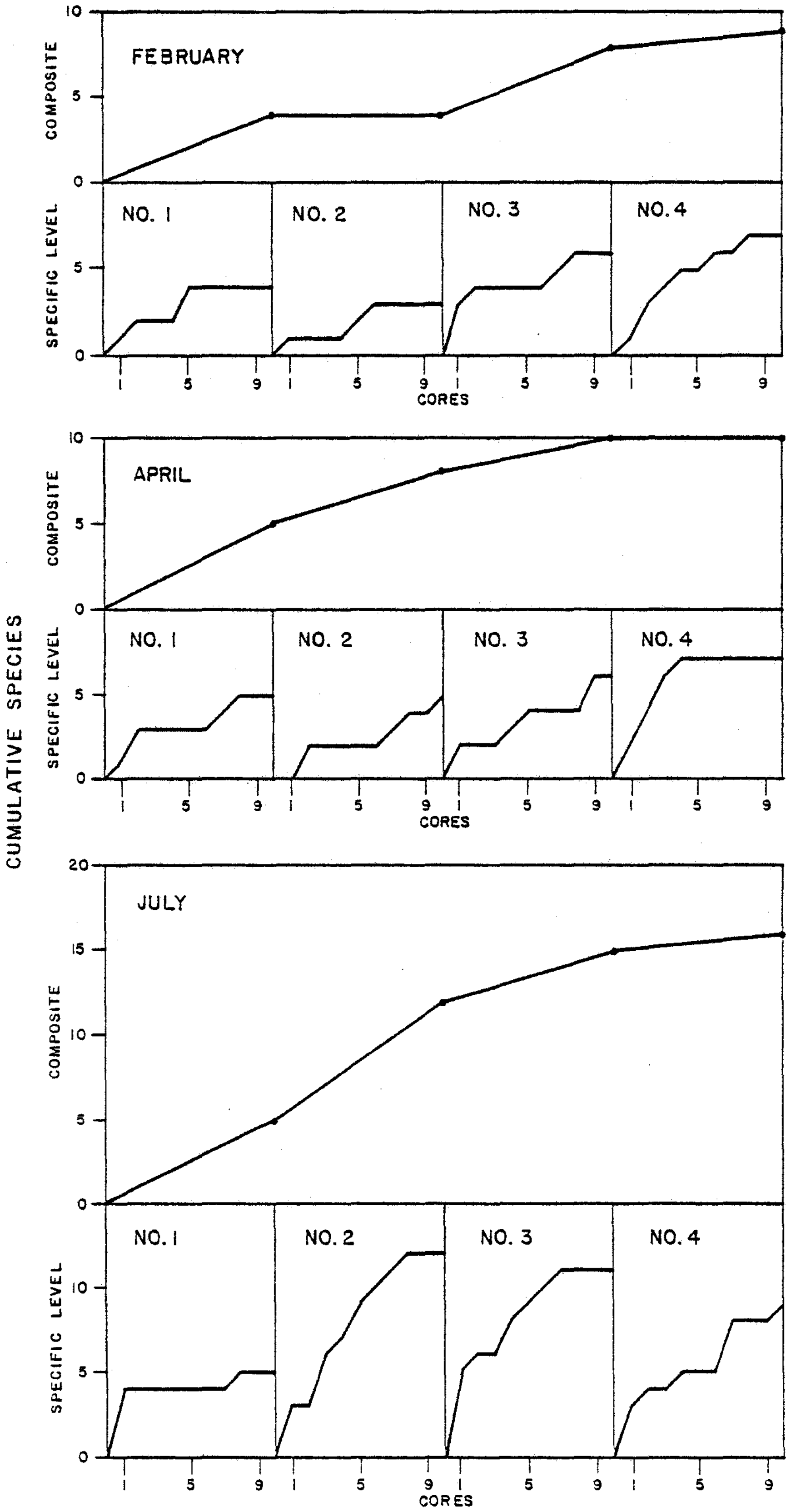

FIGURE 4-19 - SPECIES/AREA CURVES FOR DEEP CREEK produced the most rapid rate of "accrual" (the steepest slope). During that period, many less tolerant species were able to expand their local distribution to shallower levels.

4.4.2 Biological Assemblage of the Sand Beach at Homer Spit

The infaunal assemblage at the Homer Spit station was sampled three times during the period covered by this report, namely on 17 February, 7 March and 28 July 1977. A total of 25 taxa, including 11 polychaete, 8 crustacean, and two molluscan (Table 4-24), was identified from the core samples.

Quantitatively, the infauna was dominated heavily by polychaetes, especially Paraonella platybranchia and Scolelepis sp. A (Table 4-30). Relative abundance of all groups was fairly uniform. Gammarid amphipods were substantially less important, with Eohaustorius and Paraphoxus the most abundant. The redneck clam (Spisula) and a fish (sand lance, Ammodytes) were encountered in low numbers in each survey. The raw data for these samples, by core, level and survey, are presented in Appendix 4.4.9 through 4.4.11 and species summaries in Appendix 4.4.12 through 4.4.14.

4.4.2.1 Zonation

To examine zonation, the species at each level were assigned, by survey, to "importance" categories according to their density and frequency of occurrence (see METHODS section). Species composition was then compared among the sampling levels. According to these criteria, the upper two levels were dominated by Scolelepis, level 3 by Scolelepis, Paraonella and Paraphoxus and the lower level by Scolelepis (Table 4-31). Paraonella and Scolelepis were important at all levels, and the latter dominated throughout.

The relationship between elevation and density was examined, with the Kruskal-Wallis analysis of variance. Scolelepis was significantly more dense at lower elevations ($P < 0.001$). The density pattern of Paraonella, high toward the middle of the beach and lower at the upper

TABLE 4.30. OVERALL DENSITY (NO./M^2) OF COMMON SPECIES AT HOMER SPIT SITE

Taxa	2/77 Density	%	3/77 Density	%	7/77 Density	%
Polychaeta		(75.8)[a]		(84.8)		(78.1)
Eteone nr. *longa*[b,c]	6.4	1.0	0	0	3.2	0.3
Nephtys ?ciliata	6.4	1.0	9.5	1.0	3.2	0.3
Paraonella platybranchia	146.4	24.2	38.2	7.3	213.3	20.4
Scolelepis Sp. A[b,c]	273.7	45.2	385.2	73.3	547.5	52.3
Gammaridea		(16.8)		(12.7)		(5.8)
Eohaustorius eous	19.1	3.1	12.7	2.4	28.7	2.7
Paraphoxus milleri[b,c]	44.6	7.3	50.9	9.7	19.1	1.8
Pelecypoda						
Spisula polynyma[b]	12.7	2.1	3.2	0.6	6.4	0.6
Pisces						
Ammodytes hexapterus[b]	12.7	2.1	6.4	1.2	3.2	0.3

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[a] Parenthetic values are percent of the overall total individuals within the major taxon indicated

[b] These species were also common in sandy infaunal samples collected at 200' depths in the middle of Lower Cook Inlet

[c] Also found at Deep Creek

TABLE 4.31. IMPORTANT SPECIES AT EACH LEVEL AT HOMER SPIT

Species	Sampling Level (m) 30	75	100	135
Polychaetes				
Nephtys ?ciliata		Frequent		
Paraonella platybranchia	Frequent	Frequent	Dominant	Frequent
Scolelepis Sp. A	Dominant	Dominant	Dominant	Dominant
Crustaceans				
Eohaustorius eous		Sub-dominant	Sub-dominant	Frequent
Lamprops carinata				Seasonal
L. quadriplicata	Seasonal			
Paraphoxus milleri	Frequent		dominant	Sub-dominant
Pelecypods				
Spisula polynyma (juv.)				Sub-dominant
Fishes				
Ammodytes hexapterus			Frequent	

and lower levels, was also highly significant ($P < 0.01$).

4.4.2.2 Seasonal Patterns

The seasonal patterns apparent in Table 10 are not statistically significant even though the differences are large in some cases. The density of the polychaete _Scolelepis_, for example, increased two-fold from February to July. The cumaceans _Lamprops_ spp. became abundant in July.

Samples were collected in March immediately following a large storm to attempt to examine the effects of that disturbance. Generally, it appeared that the storm had little effect. However, a comparison of density of species between the February and March surveys provides some insight on vertical distribution within the sediment. Density reductions were noted for several species (e.g., _Eteone_, _Eohaustorius_, _Spisula_ and _Ammodytes_) but only _Paraonella_ was reduced significantly ($P < 0.05$; Table 4-30) and only at the 100 m level. That reduction following storm surf suggests that these species live near the surface of the sediment. In contrast, the density of _Scolelepis_, which usually lives at least 15 cm below the surface, increased from February to March.

4.4.2.3 Biomass

In terms of biomass, the fauna at Homer Spit was strongly dominated by polychaetes in both March and July (Table 4-32). _Scolelepis_ was by far the most important species at every level and in both surveys. _Paraphoxus_ was the most important gammarid.

Biomass was relatively low but appeared only slightly affected by large, uncommon species. Two trends were fairly clear. Spatially, biomass increased markedly at lower elevation. Temporally, biomass increased sharply from April to July. Both patterns are mainly reflections of increases in _Scolelepis_. Gammarids showed little change by location or between periods.

TABLE 4.32. DISTRIBUTION OF WHOLE WET AND ESTIMATED DRY WEIGHTS IN SAMPLE SETS AT HOMER SPIT IN 1977 (WEIGHTS IN GRAMS)

	March				Survey Total		July				Survey Total	
Sampling Level:	30m	75m	100m	135m	Wet Weight	Dry Weight[a]	30m	75m	100m	135m	Wet Weight	Dry Weight
Polychaeta	(0.080)[b]	(0.810)	(2.571)	(2.350)	(5.811)	(0.831)	(0.247)	(1.529)	(1.657)	(6.224)	(9.657)	(1.448)
Abarenicola pacifica	0	0	0	0	0	-	0	0.015	0	0	0.015	0.003
Capitella capitata	0	0	0	0	0	-	0	0	0.010	0.060	0.070	0.013
Magelona pitelkai	0	0	0	0.030	0.030	0.006	0	0	0	0	0	-
Nephtys sp.	0	0.020	0.005	0	0.025	0.005	0.184	1.140	-	0	1.324	0.255
Paraonella platybranchia	0	-	0.005	0	0.005	0.001	0.012	0.010	0.023	0.015	0.060	0.011
Sabellidae, unid.	0	0	0.005	0	0.005	0.001	0	0	0	0	0	-
Scolelepis sp A	0.080	0.790	2.556	2.240	5.666	0.807	0.048	0.364	1.624	6.149	8.185	1.166
Spio sp	0	0	0	0.080	0.080	0.011	0	0	0	0	0	-
Spiophanes bombyx	0	0	0	0	0	-	0.003	0	0	0	0.003	T
Gammaridea	(0.010)	(0.085)	(0.039)	(0.075)	(0.209)	(0.041)	(0.029)	(0.035)	(0.098)	(0.029)	(0.191)	(0.038)
Eohaustorius eous	0	0.005	0.009	0.005	0.019	0.004	0.009	0.005	0.018	0.009	0.041	0.008
Paraphoxus milleri	0.010	0.050	0.030	0.070	0.160	0.031	0.020	0	0.020	0.020	0.060	0.012
misc. gammarids	0	0.030	0	0	0.030	0.006	T	0.030	0.060	0	0.090	0.018
Total	0.090	0.895	2.610	2.425	6.020	0.872	0.276	1.564	1.755	6.253	9.848	1.486
Biomass (g/m²)	1.15	11.40	33.23	30.88			3.51	19.91	22.35	79.62		
Average biomass (g/m²)					19.17	2.78					31.35	4.73

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[a] Based on conversion factors indicated in Thorson 1957

[b] Parenthetic values are total wet whole weight for large taxa

4.4.2.4 Size Structures

Size data were collected for the gammarid amphipods Paraphoxus milleri and Eohaustorius eous, but the sample sizes were too small to provide satisfactory comparisons. The average size of Paraphoxus was 6.2 ± 1.1 mm in March (n = 7) and 6.1 ± 1.5 mm in July (n = 5). Data are not available for Eohaustorius in March, but average length was 3.8 ± 0.5 mm in July (n = 5).

4.4.2.5 Numerical Parameters

Patterns in the numerical parameters were fairly straight-forward and consistent during the survey. Basically, abundance, species richness and species diversity increased during the survey and, except for species diversity, at lower elevations (Table 4-33). Among the evenness parameters, N/S also increased during the study and at lower elevations, whereas E declined during the study and at lower elevations.

The significance of the observed increases from February to July was tested separately for each level on unpooled data (Appendix 4.4.9 through 4.4.11) using the Kruskal-Wallis analysis of variance. The seasonal increases in abundance were significant ($P < 0.05$) at the 30 m, 75 m and 135 m levels, but did not depart from random at the 100 m level. Similar analysis of abundance patterns among levels during a survey indicated that the increase in density at lower elevations observed in each survey were highly significant ($P < 0.01$).

Species richness was examined similarly by comparing the number of species per core among levels and surveys with the Kruskal-Wallis test. The seasonal changes observed at specific levels were significant at the 30 m ($P < 0.01$), 75 m and 135 m levels (for both, $P < 0.05$). Generally, there was a decline from February to March, and an increase by July at each level. Only in March were the observed differences among levels significantly different from random ($P < 0.01$). In both February and March, the average number of species per core was highest at the 100 m level. These patterns were fairly well reflected by the total number of

TABLE 4.33. SUMMARY OF NUMERICAL PARAMETERS FOR THE SANDY INTERTIDAL ASSEMBLAGE AT HOMER SPIT

	Abundance			Species Richness		Species Diversity	Evenness		
Sampling Level (m)	Total per Level	$\bar{x}$ ± s per Core	per m^2	Total per Level	$\bar{x}$ ± s per Core	H	N/S	E	Grams Wet Weight per m^2
				17 February 1977					
~30	12	2.4 ± 1.7	305.6	4	2.0 ± 1.2	1.25	3.0	0.60	
~75	8	1.6 ± 1.5	203.7	5	1.4 ± 1.5	1.52	1.6	0.57	
100	33	6.6 ± 2.1	840.4	7	3.8 ± 1.3	1.89	4.7	0.53	
135	42	8.4 ± 3.2	1069.6	7	3.0 ± 1.6	1.77	6.0	0.49	
Overall	95			14			6.79		
$\bar{x}$ ± s		4.8	604.8		2.6	1.61 ± 0.28		0.55 ± 0.05	
				7 March 1977					
30	9	0.9 ± 1.1	114.6	3	0.6 ± 0.7	0.71	3.0	0.55	
75	25	2.5 ± 1.6	318.3	6	1.7 ± 0.8	1.60	4.2	0.51	
100	48	4.8 ± 3.0	611.2	8	2.3 ± 1.2	1.58	6.0	0.37	
135	83	8.3 ± 6.3	1056.9	6	2.0 ± 0.8	0.75	13.8	0.28	
Overall	165			12			13.8		
$\bar{x}$ ± s		4.1	525.3		1.7	1.16 ± 0.50		0.43 ± 0.13	
				28 July 1977					
30	64	6.4 ± 5.1	814.9	12	3.3 ± 2.2	2.25	5.8	0.43	
75	47	4.7 ± 2.2	585.7	9	2.9 ± 1.2	2.16	5.1	0.50	
100	75	7.5 ± 2.9	955.0	9	3.0 ± 0.7	1.69	8.3	0.36	
135	144	14.4 ± 5.2	1833.6	10	3.3 ± 1.4	1.26	16.0	0.27	
Overall	330			16			20.6		
$\bar{x}$ ± s		8.3	1047.3		3.1	1.84 ± 0.46		0.39 ± 0.10	

species per level and the overall number of species per survey (Table 4-33). However, the pattern for species richness was rather confused in July.

Species diversity was, on the average, highest at each level, and overall, in July. However, the relationships among levels in a specific survey were confused.

Evenness patterns generally indicated that the species were less equitably distributed at the lower levels and in the later surveys. The decrease in evenness with lower elevation is a reflection of the relatively moderate increase in species richness in comparison with the increase in density. The average decrease in evenness during the study is a reflection of substantial density increases among a fairly stable suite of species.

Species-area curves were constructed for each level and survey to provide insight into rates of species acquisition in the samples and the suitability of the sampling program. Generally, the curves for specific levels showed signs of becoming asymptotic (Figure 4-20). However, it appears that a substantial number of species could have been added by additional sampling at the 30 m and 135 m levels in July. This pattern accentuates the finding of low species diversity and high N/S ratios.

Composite species-area curves were constructed for each survey by tabulating by level the cumulative number of species identified. In February and March, the rate of "accrual" was fairly slow and uniform at each level. This seems to indicate a strong gradient for physical factors. This interpretation is amplified by the composite curve for July, when conditions were comparatively very mild. In this case, the rate of "accrual" is initially rapid, i.e., most of the species observed were identified at the upper level, and the subsequent rate is quite slow. Although this suggests that the mild conditions have allowed a number of species previously restricted to lower levels to expand into higher elevations, examination of the species lists from the intertidal levels does not support this hypothesis.

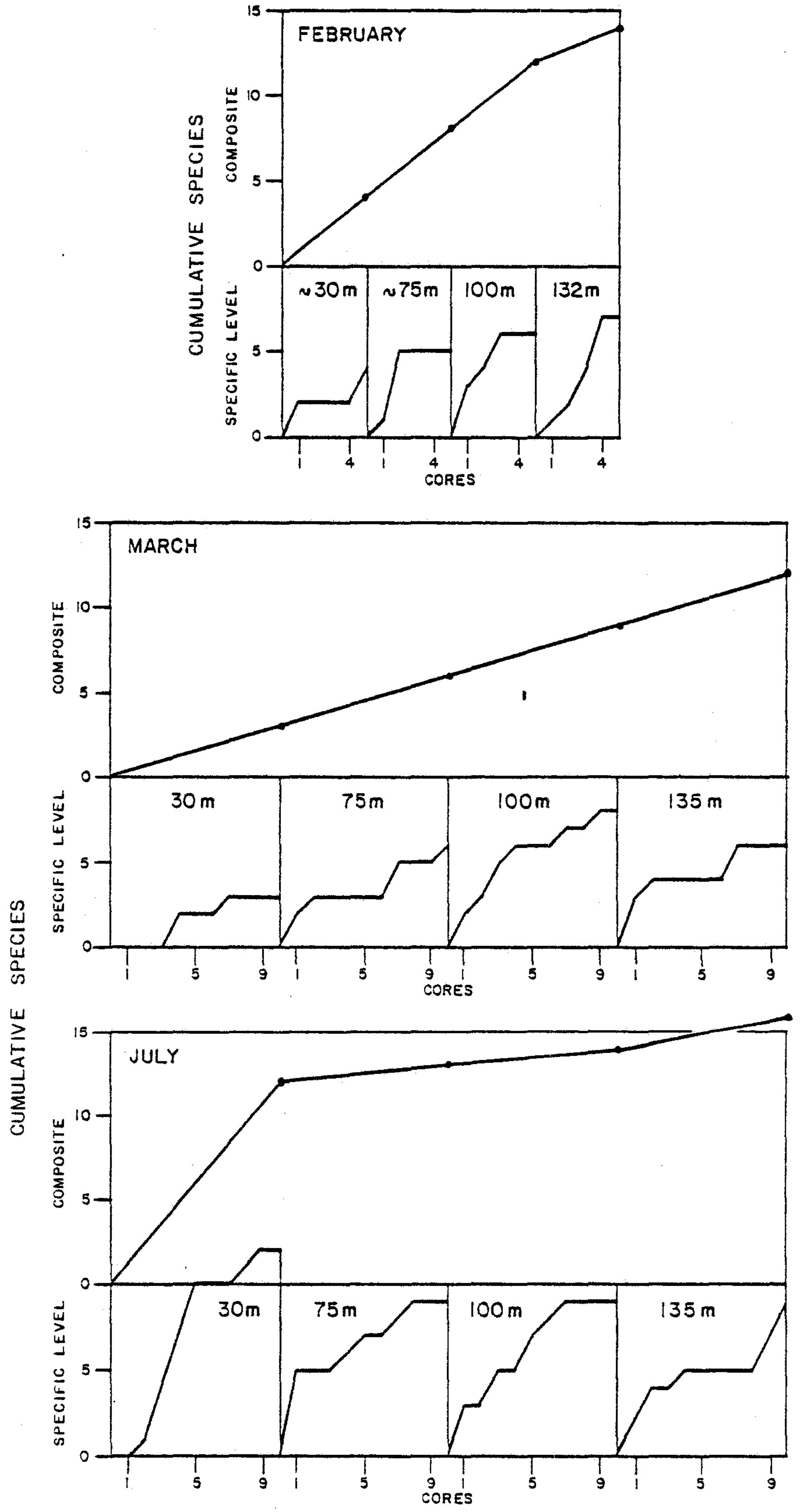

FIGURE 4-20 - SPECIES/AREA CURVES FOR HOMER SPIT

4.4.3 Biological Assemblage of the Mud Flats at Glacier Spit, Chinitna Bay

The infaunal assemblage at Glacier Spit, Chinitna Bay, (Figure 2-5) was sampled twice during the period covered by this report, namely on 6 April, and 30 July, 1977. A total of 45 taxa, including 22 annelids, nine arthropods, and nine molluscs, was identified in the core samples (Table 4-25). Twenty of these taxa, including 67 percent of the molluscs and 50 percent of the annelids, were observed in both sample sets. Only one arthropod taxon occurred in both surveys; in fact, that species, a caprellid amphipod, Tritella pilimana, was the only crustacean of any importance.

In terms of abundance and biomass, the fauna was dominated heavily by pelecypods, especially Macoma balthica and Mya spp., (Table 4-34). Relative abundance was uniform between surveys. Furthermore, these clam species comprised at least 90 percent of the whole wet weight in the samples, while the remaining taxa contributed little. Several other species, especially the polychaete worms Nephtys, Potamilla, and Spio, and the clams Clinocardium and Pseudopythina, contributed at least marginally to density. Raw abundance data by core are presented in Appendix 4.4.15 and 4.4.16, and biomass data by core in Appendix 4.4.17 and 4.4.18. These types of data are summarized, by species, in Appendices 4.4.19, 4.4.20, and 4.4.21. Size and weight data for several species are in Appendix 4.4.22 through 4.4.30.

4.4.3.1 Seasonal Patterns

Several seasonal patterns are apparent in the Chinitna Bay samples. The average number of specimens per core, and thus the other abundance parameters, decreased from April to July (Table 4-35; $P << 0.001$, with Student's t-test). However, within this general pattern, two strong trends were discerned. Density of polychaetes and the caprellid increased dramatically between surveys ($P << 0.005$, Wilcoxin matched-pairs signed ranks t-test). In contrast, most of the clams became substantially less abundant ($P > 0.05$) during the same period.

TABLE 4.34. OVERALL DENSITY (NO./M^2) AND BIOMASS[a] OF COMMON TAXA AT THE GLACIER SPIT, CHINITNA BAY SITE

	4/6/77				7/30/77			
	Density (no./m^2)	%	Biomass (g/m^2)	%	Density	%	Biomass	%
Echiurida								
Echiurus echiurus	38.2	0.6	22.82	1.0	41.4	0.8	31.80	0.8
Polychaeta		(9.5)[b]		(1.6)		(31.0)		(2.0)
Ampharete acutifrons	12.8	0.2	0.05	T	28.7	0.6	-	-
Capitella capitata	15.9	0.2	0.07	T	111.4	2.2	-	-
Eteone nr *longa*	38.2	0.6	0.55	T	121.0	2.4	0.73	T
Harmothoe imbricata	9.5	0.1	0.77	T	63.7	1.3	8.13	0.2
Malacoceros sp	15.9	0.2	0.04	T	38.2	0.8	0.05	T
Nephtys sp (adults & (juvenile)	331.0	5.0	27.92	1.2	324.7	6.5	59.94	1.5
Phyllodoce groenlandica	15.9	0.2	1.58	0.1	28.7	0.6	4.07	0.1
Polydora caulleryi	15.9	0.2	0.03	T	54.1	1.1	0.05	T
Potamilla sp	117.8	1.8	2.13	0.1	245.1	4.9	4.86	0.1
Scoloplos armiger	3.2	T	0.01	T	38.2	0.8	0.04	T
Spio filicornis	0	0	0	0	448.8	9.0	0.98	T
Crustacea		(0.1)		(T)		(4.9)		(T)
Tritella ?pilimana	3.2	T	T	T	187.8	3.8	T	T
Pelecypoda		(88.8)		(97.6)		(62.8)		(97.3)
Clinocardium nuttallii (juv. & adults)	213.3	3.2	1.53	0.1	105.0	2.1	201.8	5.0
Macoma balthica	4672.8	71.0	502.93	21.7	2654.7	53.4	461.55	11.4
Mya sp	804.8	12.2	1755.53	75.7	213.3	4.3	3257.53	80.7
Pseudopythina sp	144.7	2.2	1.94	0.1	140.1	2.8	6.6	0.2

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[a] Based on whole preserved weights

[b] Parenthetic numbers are total percentages in major taxa

TABLE 4.35. SUMMARY OF NUMERICAL PARAMETERS FOR THE MUDDY INTERTIDAL ASSEMBLAGE AT GLACIER SPIT, CHINITNA BAY

	Abundance			Species Richness		Species Diversity	Evenness		
Elevation (ft)	Total per Level	$\bar{x} \pm s$ per Core	per m^2	Total per Level	$\bar{x} \pm s$ per Core	H	N/S	E	Grams Wet Weight per m^2
				6 April 1977					
+3.6	428	42.8 ± 16.7	5450	16	4.7 ± 2.6	0.85	26.8	0.16	4163.66
+2.5	435	43.5 ± 8.4	5539	16	6.6 ± 1.6	1.12	27.2	0.22	2975.03
+0.9	642	64.2 ± 18.7	8175	15	7.0 ± 1.3	1.41	42.8	0.22	1144.08
-1.2	563	56.3 ± 17.3	7156	20	6.7 ± 2.0	1.40	28.2	0.22	996.46
Overall	2068			25			82.7		
$\bar{x} \pm s$		51.7	6580		6.3	1.20 ± 0.27		0.21 ± 0.03	2319.81
				30 July 1977					
+3.6	250	25.0 ± 6.2	3183	20	6.4 ± 2.4	1.81	12.5	0.17	3743.89
+2.5	395	39.5 ± 13.7	5030	24	9.8 ± 2.5	2.82	16.5	0.27	3974.22
+0.9	441	44.1 ± 14.9	5615	25	10.1 ± 3.1	2.88	17.6	0.28	4858.09
-1.2	475	47.5 ± 13.9	6048	25	10.2 ± 3.3	2.54	19.0	0.22	3576.88
Overall	1561			36			43.4		
$\bar{x} \pm s$		39.0	4969		9.1	2.51 ± 0.49		0.24 ± 0.05	4038.27

4.4.3.2 Zonation

To examine zonation, the species at each level were assigned, by survey, to "importance" categories according to their density and frequency of occurrence (see METHODS section). Species composition was then compared among the sampling levels. According to these criteria, all levels were numerically dominated by a small pink clam Macoma balthica, and a polychaete Nephtys was subdominant at each (Table 4-36). Additionally, the polychaete Eteone occurred frequently at all levels. Other species that were important at all levels sampled were a tubicolous polychaete Potamilla and the clams Clinocardium, Mya spp. (unidentified juvenile specimens) and a commensal clam Pseudopythina. The eastern soft shell clam, Mya arenaria, was only important at the two upper levels and M. priapus at the lower two levels. Several other species became more important at lower levels, including the worm Spio, the caprellid Tritella, and the clams Clinocardium and Mya spp. (juveniles).

Consistent patterns of vertical distribution in the sediment were evident from field observations for several species (Figure 4-21). The caprellid lives on filamentous algae at the water-mud interface, (Benedict, personal communication), whereas most of the other species live in the sediments. Most of the polychaetes live near the sediment surface. However, Potamilla constructs tubes extending well into the sediment, and Nephtys adults live in burrows with at least two openings that extend to a depth of at least 15 cm into the sediment. Echiurus (Figures 4-21 and 4-22) constructs U-shaped burrows that may extend down into the sediment at least 30 cm. Pseudopythina appears to live in these burrows as a commensal, sometimes occurring attached to the spoonworm by byssus threads. The scaleworm Harmothoe is a commensal and appears in burrows with Nephtys, Echiurus and Mya. Juveniles of Macoma, Mya and Clinocardium live in the surface sediments. Adult Clinocardium live with the anterior margin of the shell right at the water-mud interface. Macoma and Mya burrow deeper as they grow larger, a trait which provides considerable protection from predators, physical stress and disruption. Adult Macoma balthica (Figures 4-21 and 4-22) generally live within 5 cm of the sediment surface. Adults of Mya spp. burrow

TABLE 4.36. IMPORTANT SPECIES AT EACH LEVEL AT GLACIER SPIT, CHINITNA BAY

	Elevation (ft)			
Species	+3.6	+2.5	+0.9	-1.2
Echiurus echiurus		Frequent	Frequent	
Polychaetes				
Capitella capitata		Frequent	Frequent	Frequent
Eteone nr *longa*	Frequent	Frequent	Frequent	Frequent
Harmothoe imbricata			Frequent	
Nephtys sp	Sub-dominant	Sub-dominant	Sub-dominant	Sub-dominant
Phyllodoce groenlandica				Frequent
Polydora caulleryi		Frequent		
Potamilla sp	Frequent	Frequent	Sub-dominant	Frequent
Spio ?*filicornis*		Seasonal	Seasonal	Frequent
Caprellidea				
Tritella ?		Seasonal	Seasonal	Frequent
Pelecypods				
Clinocardium nuttallii	Frequent	Frequent	Sub-dominant	Sub-dominant
Macoma balthica	Dominant	Dominant	Dominant	Dominant
Mya arenaria	Frequent	Frequent		
M. priapus			Frequent	Frequent
Mya spp (juv)	Frequent	Frequent	Sub-dominant	Dominant
Pseudopythina sp	Frequent	Frequent	Sub-dominant	Frequent

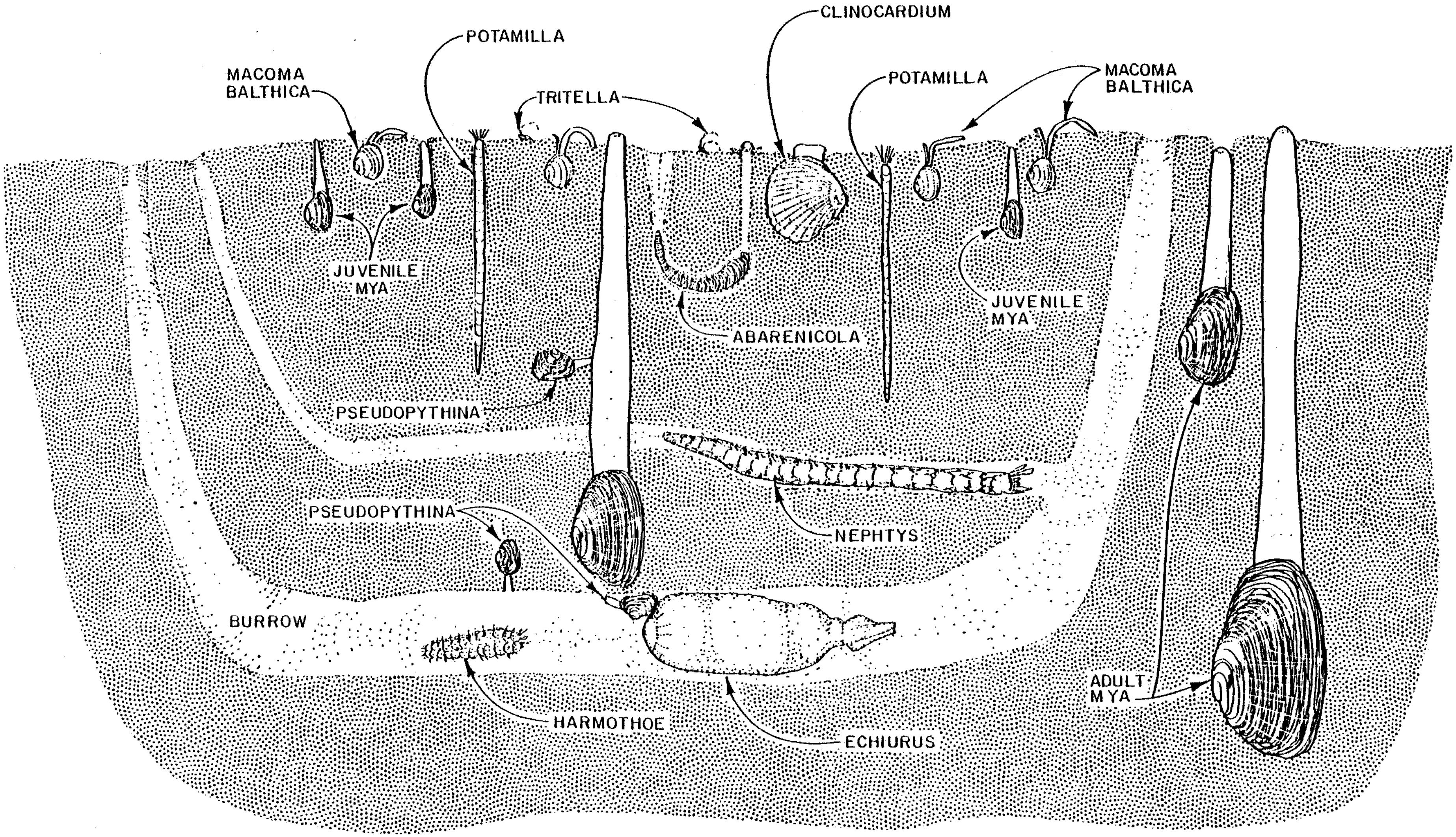

FIGURE 4-21 - DISTRIBUTION OF MAJOR ORGANISMS IN THE FAUNAL ASSEMBLAGE ON THE MUD FLAT AT GLACIER SPIT, CHINITNA BAY

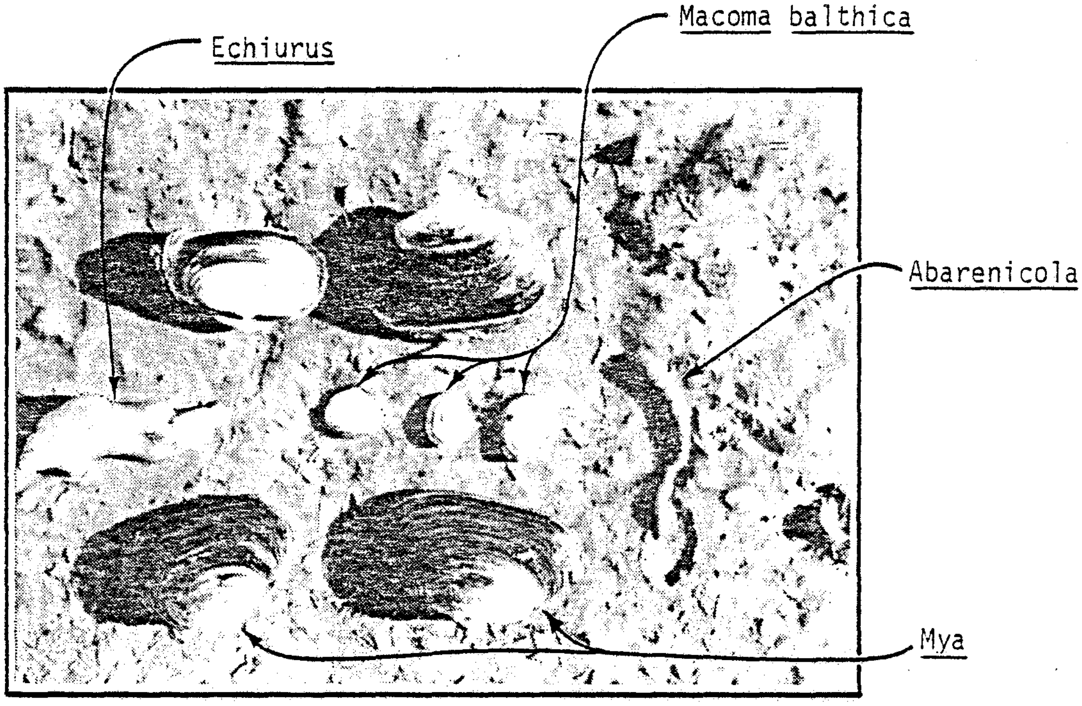

FIGURE 4-22

SEVERAL DOMINANT SPECIES IN THE MUD FLAT ASSEMBLAGE AT GLACIER SPIT, CHINITNA BAY down to at least 30 cm into the sediment and form semi-permanent burrows communicating vertically with the surface (Figures 4-21 and 4-22).

These patterns result in a substantial vertical distribution of the biomass in the upper 30 cm of the sediment. Furthermore, the burrowing habit of Mya spp. and Echiurus results in a fair degree of porosity in the upper 30 cm of the mud flats (Figures 4-21, 4-22 and 4-23). In Figure 4-23, the large holes were formed by adult Mya spp., and the smaller holes by Macoma balthica, polychaetes and Echiurus.

4.4.3.3 Biomass

During the survey, biomass (compared in Tables 4-35 and 4-37), generally increased significantly on the average and for most species examined (P = 0.005; Wilcoxin T-test). Among the major species, only Macoma exhibited a decline in biomass. Clam species contributed over 90 percent to both the wet and dry weight estimates for the mud flat examined. Data in Appendix 4.4.17 and 4.4.18 indicate that adult Mya arenaria and M. priapus are particularly important. Echiurus and polychaetes contribute less than two percent each to standing stocks. Among the polychaetes, Nephtys contributes most. Clinocardium displayed the highest rate of increase in biomass, and the magnitude of change was probably due mainly to growth.

4.4.3.4 Biology Of Macoma balthica

Observations on size structure were made for all of the clams collected to provide insight into growth rates and life cycles as well as to assist in estimation of secondary production (Appendix 4.4.22 through 4.4.30). The most useful data were for Macoma balthica and Mya spp. In all cases, the measurement used was shell length.

Length-frequency histograms for Macoma balthica from a 1976 collection and for both 1977 sampling periods covered by this report are included in Figure 4-24. These histograms also indicate the mean size

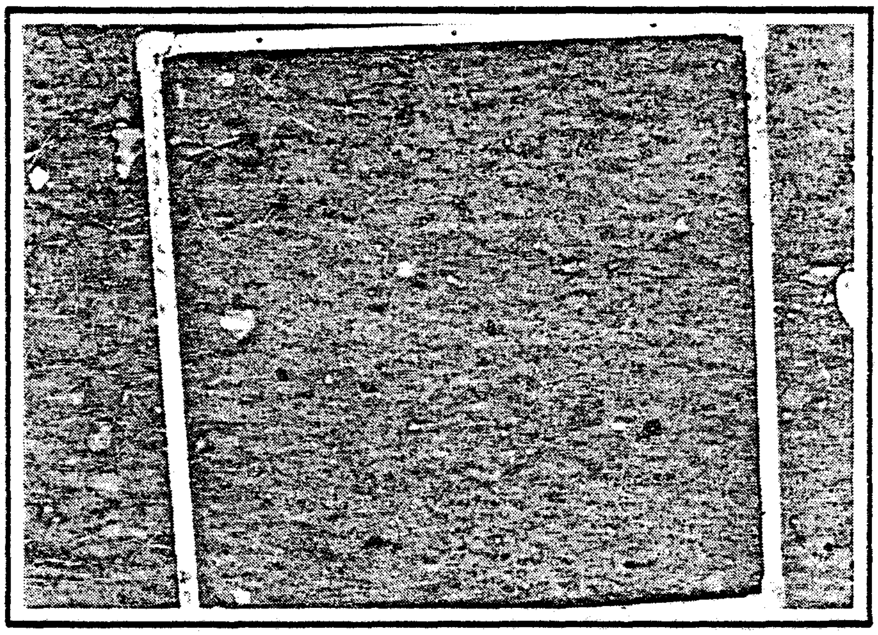

FIGURE 4-23

SURFACE OF THE MUD FLAT AT BRUIN BAY IN KAMISHAK BAY, LOWER COOK INLET, SHOWING THE POROSITY AS A CONSEQUENCE OF BIOLOGICAL ACTIVITY

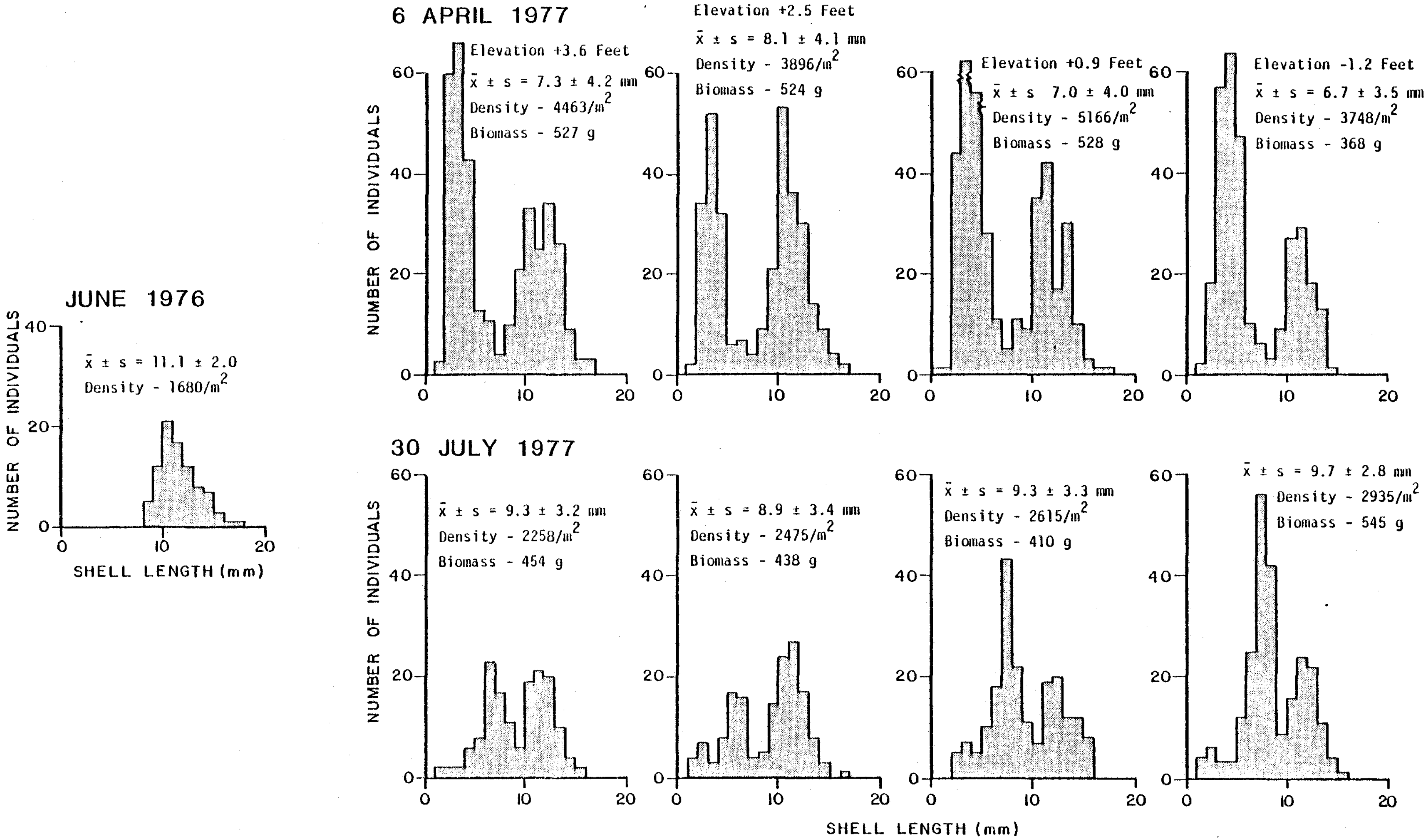

FIGURE 4-24

PATTERNS IN SIZE, ABUNDANCE AND BIOMASS FOR MACOMA BALTHICA

CHINITNA BAY

TABLE 4.37. SUMMARY OF BIOMASS DATA FOR THE MUDFLAT ASSEMBLAGE, GLACIER SPIT, CHINITNA BAY IN 1977

	Average Whole Wet Weight (g/m^2)		Conversion Factor	Estimated Dry Tissue Weight (g/m^2)	
	April	July		April	July
Echiurus	22.82	31.80	14%[a]	3.19	4.45
Polychaetes	35.06	78.99	14%[b]	4.91	11.06
Clams					
Clinocardium	1.53	201.8	5%[a]	0.08	10.09
Macoma balthica	502.93	461.55	5.75%[b]	28.92	26.54
Mya spp	1755.53	3257.53	6.6%[b]	115.86	215.00
Pseudopythina	1.94	6.6	5.4%[c]	0.10	0.36
Total	2319.81	4038.27		153.06	267.5

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[a] Estimates based on examination of Thorson (1957)

[b] Based on conversions published in Thorson

[c] Average for pelecypods in Thorson

of the distribution, its standard deviation, and estimates for density and whole wet weight per m^2, where available. This comparison reveals several important features about the population structure of Macoma. Generally, all levels exhibited similar size structures during the same sampling period. In April 1977, members of the 0-year class were considerably more numerous than those in the older mode. By July, the difference was substantially reduced, particularly at the +3.6 foot and +2.5 foot levels, where the two modes were nearly equal in abundance. The 0-year class remained more numerous at the two lower levels in July. Except at the lowest level, the older mode was also reduced substantially between April and July. The decline of both modes resulted in the large reduction in overall density observed at all levels by July. These density reductions ranged from 22 percent at the -1.2 foot level to 49 percent at the +3.6 and +0.9 foot levels and averaged 39 percent. All reductions were significant ($P < 0.01$ in all cases; Kruskal-Wallis analysis of variance).

Growth was apparent in both modes (Figure 4-24). The 0-year class increased from between 3 and 4 mm in April to between 6 and 7 mm in July. The larger mode probably includes several year classes, so changes in the modal mean do not accurately reflect age-specific growth rates.

Above MLLW, biomass (wet whole weight) decreased between April and July. However, a substantial increase was observed at the -1.2 foot level. This was apparently a consequence of growth, combined with a relatively limited reduction in density.

The comparison of these histograms to the one for 1976 is quite revealing. The conspicuous absence of a 0-year class in 1976 is very probably a consequence of the relative harshness of the previous winter. Notable also was the substantially lower density in early summer.

4.4.3.5 Biology Of Mya spp.

Size structures for Mya spp. are not clearly definable because of the relatively low density of the adults and the confusion caused by the

0-year classes (juveniles) of three species. Specimens smaller than about 20 mm are very difficult to assign to species and have therefore been tabulated separately (Appendix 4.4.24). As a consequence, the number of specimens in the 0-year class for each species is unknown. However, the juvenile/adult ratio for Mya spp. averaged 28.7 and ranged from 1.4 to 88.0 in April, in contrast to July, when it averaged 0.7 and ranged from 0.1 to 1.3 (Table 4-38). Basically, the reduction in this ratio is a result of a considerable decrease in the abundance of juvenile Mya. Most of the loss appears to be a consequence of mortality; the slight increase in density of adults clearly doesn't account for the total reduction in juveniles. It appears, however, that growth of the juveniles was fairly rapid between April and July. Average shell length for the juvenile mode increased from 4.2 ± 1.0 mm in April to 11.9 ± 6.5 mm in July (Appendix 4.4.24). Contrasting the virtual absence of specimens larger than 6.5 mm in April to the fact that 78 percent of the juveniles in July were larger than 6.5 mm (Figure 4-25) supports a hypothesis that the increase in size was due to growth and not solely differential mortality, at least initially.

Average shell length of adult Mya arenaria and M. priapus increased between April and July, but the sample sizes were small (Appendix 4.4.25 and 4.4.26). Using Students' t-test, the increase from 67.0 mm to 73.7 mm for M. arenaria was not significant ($P > 0.10$), but for M. priapus, the increase from 26.9 mm to 46.5 mm was significant ($P < 0.05$). It seems imprudent to assume, without more direct evidence, that the latter increase is due solely to growth.

Additional information on the distribution and density of adult Mya spp. was obtained by counting siphon holes in a series of haphazard 1/16 m^2 quadrats at each sampling level (Table 4-39). Generally, this method produced more conservative density estimates than the core method, probably because the clams become distinguishable to species somewhat before they are large enough to produce a readily distinctive siphon hole. In fact, the quadrat data are probably more reliable than the core data for large clams because of the larger sampling area involved (0.0625 m^2 vs. 0.0078 m^2), the larger number of samples collected (25

TABLE 4.38. DISTRIBUTION OF ADULT AND JUVENILE MYA SPP. IN THE INTERTIDAL ZONE AT GLACIER SPIT, CHINITNA BAY IN 1977

	Average Number per Core							
	April				July			
Tidal Elevation (ft)	+3.6	+2.5	+0.9	-1.2	+3.6	+2.5	+0.9	-1.2
Adults								
Mya arenaria	0.7	0.5	0	0.3	0.5	0.5	0.4	0.1
M. priapus	0	0.2	0.1	0.1	0.2	0.1	0.6	0.5
M. truncata	0	0	0	0.1	0	0	0.3	0.2
Total adults	0.7	0.7	0.1	0.5	0.7	0.6	1.3	0.8
Juvenile *Mya* spp	1.2	1.0	8.8	11.9	0.1	0.4	0.6	1.0
Juvenile/adult ratio	1.7	1.4	88.0	23.8	0.1	0.7	0.5	1.3

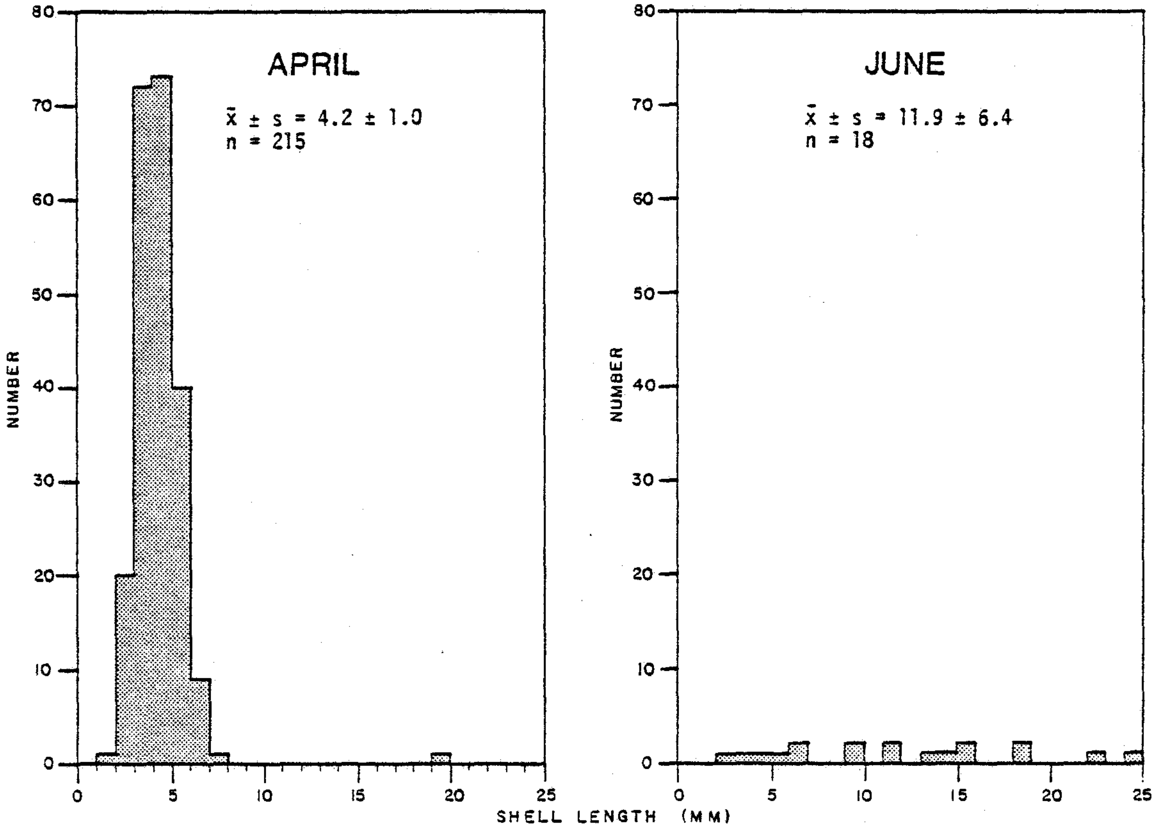

FIGURE 4-25

SHELL LENGTH FREQUENCY HISTOGRAMS
FOR JUVENILES OF MYA SPP.
FROM GLACIER SPIT, CHINITNA BAY IN 1977

TABLE 4.39. DISTRIBUTION AND DENSITY OF ADULT <u>MYA</u> SPP. BASED ON HAPHAZARD CASTS OF A 1/16m^2 QUADRAT

	Elevation (ft)							
	6 April 77				30 July 77			
Number per 1/16m^2 quadrat	+3.6	+2.5	+0.9	-1.2	+3.6	+2.5	+0.9	-1.2
0	1	1	0	3	0	0	0	2
1	2	2	0	4	2	4	2	4
2	6	3	3	5	2	2	4	1
3	5	6	3	3	3	1	3	5
4	8	5	4	4	4	2	6	6
5	1	2	3	3	4	6	1	0
6	1	1	3	2	1	3	2	5
7	0	2	3	1	2	1	2	1
8	0	1	1	0	2	2	2	1
9	0	0	1	0	1	2	2	0
10	0	1	0	0	3	1	0	0
11	0	0	2	0	1	0	1	0
12	1	1	0	0	0	1	0	0
13	0	0	2	0	0	0	0	0
$\bar{x}$	3.4	4.2	6.0	2.9	5.5	5.2	4.8	3.6
s	2.3	2.8	3.3	2.0	3.0	3.0	2.7	2.2
No./m^2	53.8	67.8	96.0	46.7	87.7	83.2	76.2	57.6
Overall mean				66.0/m^2				76.4/m^2
Estimated number of adults/m^2, based on core data	101.8	101.8	38.2	63.6	114.8	127.4	216.4	114.7
Overall mean				76.4/m^2				143.3/m^2

4.4.3.6 Other Size And Density Data

Size data for the basket cockle (Appendix 4.4.28) indicate that average size increased markedly from April to July ($P < 0.001$; Kolmogorov-Smirnov two sample test). As in the case of *Mya*, a sharp reduction in density occurred over the same period (Table 4-40). It appears that the intertidal population is dominated by young specimens.

TABLE 4-40

DENSITY OF THE BASKET COCKLE *CLINOCARDIUM NUTTALLII*
IN THE INTERTIDAL ZONE AT GLACIER SPIT, CHINITNA BAY

Elevation (ft.)	April	July
+3.6	63.7	38.2
+2.5	50.9	76.4
+0.9	432.9	165.5
-1.2	345.8	178.2
$\bar{x} \pm s$	223.3 ± 195.0	114.6 ± 68.1

Similarly, size data for the small commensal clam *Pseudopythina* sp. (Appendix 4.4.30) indicate a weak increase in average size ($P < 0.10$) from 3.2 mm to 5.0 mm. Average density was remarkably constant during this period (Table 4-41). This is probably a consequence of its apparent commensalism with burrowing species such as *Echiurus*, a behavior pattern that affords it considerable protection from severe predation pressures at the water-sediment interface. Highest densities appeared to occur at about MLLW.

TABLE 4-41

DENSITY OF THE COMMENSAL CLAM *PSEUDOPYTHINA* SP.
IN THE INTERTIDAL ZONE AT GLACIER SPIT, CHINITNA BAY

Elevation (ft.)	April	July
+3.6	89.1	89.1
+2.5	203.7	114.6
+0.9	229.2	216.5
-1.2	56.6	140.1
$\bar{x} \pm s$	144.7 ± 84.6	140.1 ± 55.0

4.4.3.7 Numerical Parameters

Numerical parameters used to describe the assemblage exhibited few strongly consistent patterns. Abundance, species richness and species diversity generally increased from upper to lower elevations in each survey (Table 4-35). However, abundance decreased at all levels between April and July ($P \ll 0.001$). Species richness and species diversity all increased markedly during the same period. These patterns in abundance and species richness corresponded in a reduction in the average number of specimens per species (N/S). In spite of a seasonal decline in abundance, biomass increased substantially at all but the highest level. The seasonal change in biomass progressed from a 10 percent reduction at the +3.6 foot level, through a 34 percent increase at +2.5 feet, to 325 percent and 259 percent increases at the +0.8 foot and -1.2 foot levels.

Species-area curves were constructed for each level and survey to provide insight into rates of species acquisition in the samples and the suitability of the sampling program. Generally, the curves for specific levels appeared to be leveling off, but none was asymptotic after 10 samples (Figure 4-26). This pattern was more apparent in July. However, it seems obvious that additional sampling effort only would have added a number of uncommon species to the lists compiled at each level during the respective sampling periods. This pattern accentuates the finding of high N/S ratios and low species diversity.

The composite species-area curves also generally tended to level off, but definitely were not asymptotic. This is to be expected because the sampling levels extend across an elevation gradient and new species are expected to be encountered at the lower levels. In fact, the number of new species appearing below the upper level was greater in July, but seems rather modest for both sampling periods. This suggests a relative homogeneity in composition of the mud flat assemblage in the area examined.

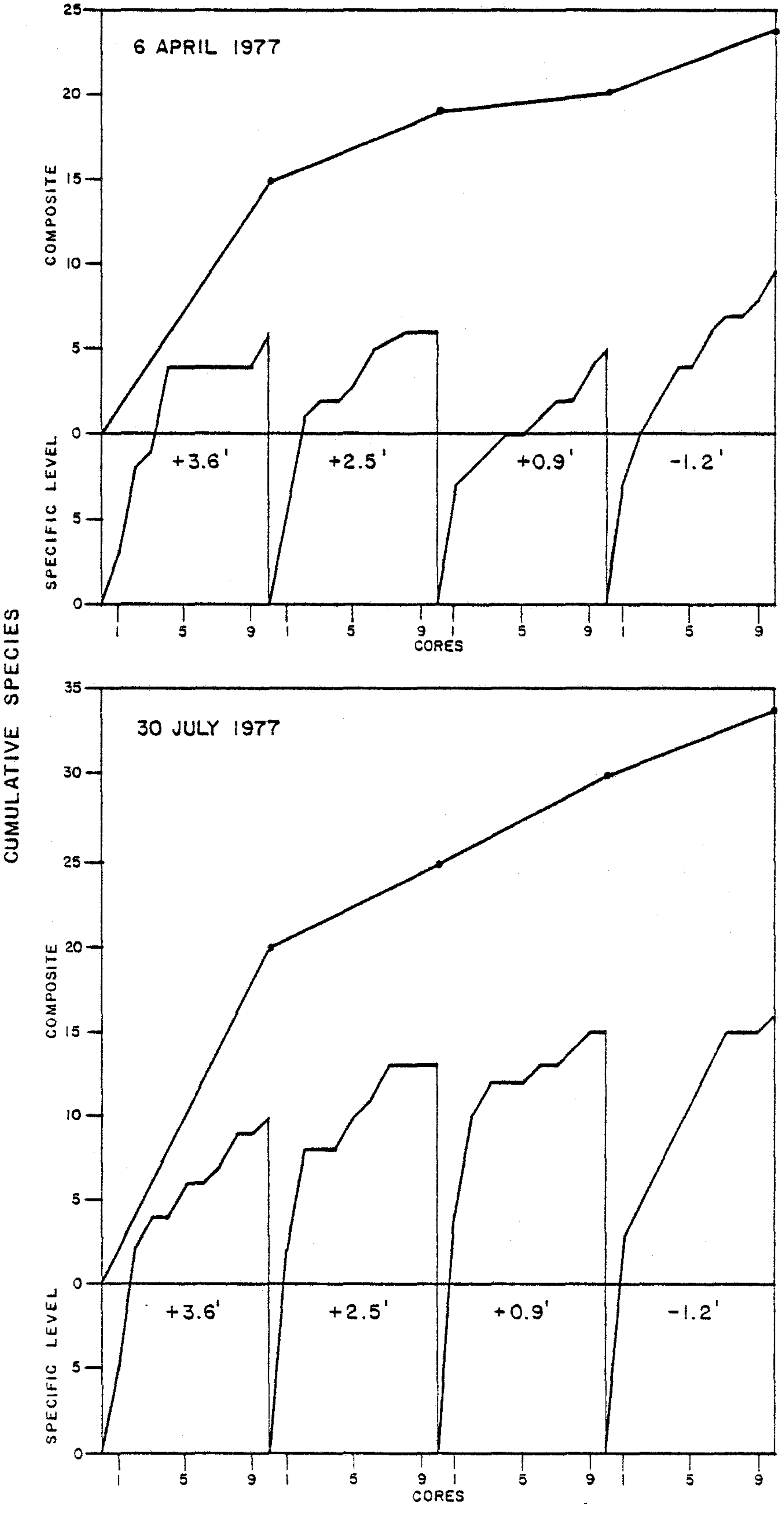

FIGURE 4-26 - SPECIES/AREA CURVES FOR GLACIER SPIT, CHINITNA BAY

5.0 DISCUSSION

This discussion is preliminary; major habitats have not been accorded equal effort at this time.

5.1 ECOLOGICAL STRUCTURE AND FUNCTION AT GULL ISLAND

Patterns in zonation at Gull Island are primarily related to differences in slope and elevation. The bedrock substrate was quite uniform. The main additional microhabitat resulting from physical conditions was provided by the small tidepools, particularly on the lower bench (0.5- to 0.0-m levels). The various biological assemblages found at the different levels studied acted strongly to modify physical conditions. Heavy cover of the primary substrate by mussels, barnacles, or algae resulted in reduced desiccation rates and higher species diversity ensued. This phenomenon was particularly notable in areas dominated by _Alaria crispa_, _Balanus cariosus_ and _Odonthalia_ spp.

Our observations suggest a strong dependence by _A. crispa_ on _B. cariosus_ (Figure 4-1). This became most obvious between summer of 1976 and spring of 1977 at the 0.5- and 0.2-m levels on the lower bench. This area was heavily covered by _A. Crispa_ in the spring and summer of 1974, 1975, and 1976 (Dames & Moore 1976). During this period, quantitative data on relative cover were only collected for undisturbed quadrats, so information on the organisms under the _Alaria_ canopy is lacking. However, data collected in winter when the _Alaria_ canopy was absent indicate that adult _B. cariosus_ covered a substantial proportion of the primary substrate during that season. Since this barnacle requires several years to reach maturity, it is reasonable to surmise that the same population of mature individuals existed under the _Alaria_ canopy in the summers of 1974 through 1976. However, in the winter and spring surveys of 1977, _B. cariosus_ cover was considerably reduced at these levels, and _A. crispa_ failed to develop a canopy in the summer of 1977 and 1978. This was accompanied by a reduction in relative cover of the sponge _Halichondria panicea_, a frequent associate of _B. cariosus_.

Algal assemblages at all levels exhibited strong seasonal patterns in development, primarily in response to environmental conditions. Germination was most prevalent in the spring, and was accompanied by rapid growth in both new and overwintering plants. Highest development (greatest relative cover, biomass, and species diversity) of the algal assemblages was observed during the summer. Deterioration of the assemblages appeared to accompany fall storms. Poorest development of the algal assemblages was observed in the winter. Important environmental parameters appeared to be sunlight, nutrient availability, length and time of emersion, and wave action.

Invertebrate grazers, mainly chitons and limpets, also appeared to exert an important influence on the development of the algal assemblage. This influence is probably exercised mainly on microscopic gametophytes and juvenile sporophytes, rather than on adult sporophytes.

The main suspension feeders (Balanus spp. and Mytilus) were found mainly in the upper portions of the intertidal zone. This is probably a response to limitations on the upward distribution of invertebrate predators imposed by tidal emersion and the accompanying desiccation.

5.2 ECOLOGICAL STRUCTURE AND FUNCTION AT SELDOVIA POINT

The heterogeneous nature of the beach at Seldovia Point provided several microhabitats for benthic flora and fauna. Sampling during 1977 and 1978 focused on the most prevalent and obvious of these: the exposed upper and lateral surfaces of the rock bench, cobbles, and boulders. These surfaces supported an algae-herbivore dominated assemblage described in Section 4.1.2. Primary productivity was high, as indicated by the strong annual cycle in macrophyte standing crop and the high abundance of microherbivores (limpets, chitons, and pulmonate snails). A major fraction of the macrophyte production is exported to other communities in the form of frayed or broken fronds, dissolved or fine-particulate exudates, and metabolites or fecal pellets of macroherbivores (e.g., urchins) within the intertidal community. Plants that are fed upon by macroherbivores are usually weakened to the point where a major portion of the plant is carried away by wave action, leaving only some of the stipe, holdfast, or lower frond (e.g., Katharina grazing on Alaria in October 1978). These broken portions thus provide organic detritus to other primarily subtidal communities.

As is typical of most rocky littoral situations, there was strong competition for primary substrate among plants and sessile filter or suspension feeders. Micrograzers (limpets and small chitons) and macrogazers (urchins, Katharina) appear to exert some control over algal standing crop. Sessile animals and the micrograzers themselves are preyed upon by a variety of starfish, prosobranch snails, and nudibranchs. Sea ducks, gulls, and sea otters may take a variety of these larger forms including barnacles, mussels, snails, and urchins.

Import of plant material from the subtidal community appeared to contribute somewhat to the energy base of detritivores in the mid and upper intertidal areas although no quantitative measurements were made. Portions of Agarum, Codium, Desmarestia, and other typically subtidal plants were frequently seen being eaten by urchins, Pentidotea, littorines, etc.

The undersides of rocks where water circulated freely were usually well covered by sessile filter feeding animals such as barnacles, bryozoans, hydroids, and serpulid worms (Spirorbinae). Primary productivity was very low because of low light levels, but predators such as Leptasterias, Nucella, and the nudibranch Onchidoris bilamellata foraged activity on the sessile fauna. Limpets often moved to shaded undersides of boulders seeking refuge from desiccation during periods of emersion.

Areas directly under and between boulders, where water movement was reduced sufficiently to allow accumulation of gravel, sand, and organic debris, had a completely different fauna from that on the rocks or boulders. This microhabitat supported an assemblage of detritivores living mostly off algal and other organic material trapped in the area. These included a small burrowing sea cucumber, Cucumaria vegae, the polychaete Cirratulus cirratus, and perhaps urchins. Hermit crab (Pagurus and Elassochirus), gammarid amphipod, and isopod scavengers were also present, taking advantage of the natural food trap afforded by these kinds of areas.

5.3 ECOLOGICAL STRUCTURE AND FUNCTION AT ROCKY INTERTIDAL SITES IN KAMISHAK BAY

The rocky intertidal sites examined in Kamishak Bay were all composed mainly of bedrock, with little boulder cover. Algal assemblages were dominated by *Fucus* at the upper levels and by red algae (*Rhodymenia pacifica* and *R. liniformis*) at the lower levels. Laminarian kelps were only important in tidal channels and pools, and subtidally, to a depth of about 3 m. Standing stocks of red algae and *Fucus* were moderately high in mid-summer.

Intertidal invertebrate assemblages were poorly developed. Generally, densities of typical intertidal dominants were low and populations comprised mainly juvenile specimens. This condition is attributed primarily to winter ice conditions.

Subtidal invertebrate assemblages are fairly well developed, but of dramatically different species composition than in Kachemak Bay. Encrusting forms with Arctic and Bering Sea affinities predominate, covering high proportions of the available rock surface. Dominant taxa include bryozoans, tunicates, sponges and barnacles, all of which are suspension feeders. Grazers are not common. Major predators are snails and starfish. Demersal fish are much less abundant than the substrate type would permit.

5.4 PRIMARY PRODUCTION BY MACROPHYTES

This subject will be discussed in the final report, now in preparation.

5.5 SAND BEACH ASSEMBLAGES

The biological assemblages observed on the sand beaches exhibited many fundamental similarities in composition and structure. Many of the species were important at both sites, including the polychaetes *Eteone* nr. *longa*, *Nephtys* ?*ciliata*, *Paraonella platybranchia* and *Scolelepis* sp. A, and the gammarid amphipods *Eohaustorius eous* and *Paraphoxus milleri* (Table 4-24). Age structure data are not available for any for these species, but most appear to live for two years or less. Reporting on five species of haustoriids, Sameoto (1969a, 1969b) indicates ranges in longevity of 12 to 17 months; most were annuals. Hedgpeth (1957) reported that most sand beach organisms are annuals.

Many of the families, genera, and in some cases, the species, are characteristic components of unconsolidated intertidal assemblages in the Pacific and Atlantic Oceans (e.g., Withers 1977).

Many of the seasonal and elevational patterns observed for numerical parameters were similar for the two beaches (Tables 4-29 and 4-33). Levels of density, average number of species, species diversity, evenness and biomass were uniformly rather low at both locations. Sand beaches are generally characterized by low values for these parameters (Dexter 1969, 1972). At both beaches abundance, species diversity and biomass parameters generally increased from winter to summer, agreeing with the pattern described by Hedgpeth (1957), and from higher to lower elevations as reported by Johnson (1970). In addition, the average number of specimens per species increased from winter to summer, which was accurately reflected by decreases in the evenness index (E) over the same period. Keith and Hulings (1965) found similar patterns on sand beaches on the Texas Gulf Coast.

In spite of the basic similarities, some faunal dissimilarities imply important differences between the areas. Specifically, the fauna at Deep Creek was dominated numerically by gammarid amphipods, *viz.* *Eohaustorius*, Gammaridae sp. A and *Paraphoxus* (Table 4-16). In contrast, the fauna at Homer Spit was dominated by polychaetes such as *Scolelepis*, and gammarids were only of marginal importance (Table 4-30). In terms of biomass, the fauna at Deep Creek was again dominated by *Eohaustorius* in both surveys whereas at Homer Spit, it was dominated by *Scolelepis*.

Furthermore, the fauna at Homer Spit was somewhat richer than that examined at Deep Creek, biomass was appreciably greater, and the range of organisms, including a clam and a fish, was broader. Withers (1977) reported that the polychaete fauna on Welsh beaches was better developed in sheltered areas. Furthermore, he noted that, on exposed beaches, "only a very reduced fauna of crustaceans and small polychaetes was found." These facts lead to the impression that the fauna at Deep Creek was responding to a more rigorous environment and was more typical of exposed intertidal beaches. This impression was amplified by the strong dominance at Deep Creek by a haustoriid amphipod, a family often characteristic of exposed sandy beaches (Barnard 1969), the importance of another amphipod, Anisogammarus, and a mysid Archaeomysis, both typically intertidal species (Kozloff 1973). In contrast, the fauna at Homer Spit was characterized by increased importance of polychaetes, and the consistent appearance of characteristically subtidal forms such as the redneck clam (Spisula) and the sand lance (Ammodytes).

Pronounced annual variations in the abundance of organisms are characteristic of sand beaches (Hedgpeth 1957). The increases in abundance, species richness, species diversity and biomass observed in this study in spring and summer are a consequence of a combination of reduced environmental stress, growth, and recruitment. Higher species richness indicates that several species are attempting to colonize the intertidal zone during this relatively mild period. Size structures, when available, indicated that many juvenile specimens were present, and growth was also apparent for at least one species (Eohaustorius).

It is probable that several factors are responsible for lower levels of abundance, species richness and biomass in the winter. Increased wave action undoubtedly raises mortality rates for species living near the water-sand interface. March samples from Homer Spit taken immediately after a storm suggested that density of some polychaetes was reduced. However, densities of Eohaustorius and Paraphoxus were not appreciably affected, and Scolelepis, which lives buried deeply in the sand, increased substantially during this period. Keith and Hulings (1965) reported that sand faunas on the Texas Gulf Coast were not

Sand

appreciably affected by the waves of Hurricane Cindy in 1963. Low winter temperatures undoubtedly reduce metabolic rates and feeding activities, thus slowing growth and reproductive activities. Woodin (1974) states that many polychaetes die after spawning and this may account in part for the seasonal variations in density observed at both beaches. Increased sediment instability associated with storms is likely to reduce success rate in recruitment, but this may be of little importance in winter.

The precise role of predation in the sand beach assemblages is, at present, still unclear. Predation presence appears low, but has not been assessed in detail. The only infaunal predator recognized so far is the polychaete Nephtys (Kozloff 1973, Green 1968), which probably feeds on Scholelepis. Pressure from shorebirds appears minimal, even during the peaks of migration. Several species are known to feed on amphipods on sandy beaches (Sameto 1969a; Dave Erikson, personal communication). Species observed on local sandy beaches include Semipalmated Plovers (Calidris pusilla), Rock Sandpipers (C. ptilacnemis), Dunlin (C. alpina), Western Sandpipers (C. mauri), and Sanderlings (C. alba). However, most prefer other habitats. Glaucous-winged Gulls (Larus glaucescens) and Mew Gulls (L. canus) are commonly observed foraging on the exposed low-tide terrace; they appear to capture the large polychaete Nephtys, amphipods, the helmet crab Telmessus, the sand lance Ammodytes, and also occasionally larger clams. When the low-tide terrace is underwater, several species of diving ducks (e.g., Greater Scaup (Aythya marila), Oldsquaw (Clangula hyemalis), White-winged Scoter (Melanitta deglandi), Surf Scoters (M. perspicillata), and Black Scoters (M. nigra) move in to feed. Apparently spring is the period of greatest utilization by sea ducks, but even then usage is minor. Predation pressure from birds is somewhat reduced in the winter.

Several demersal fishes and epifaunal invertebrates, all potential predators, have been collected on the low-tide terrace during periods of submergence. The fish included Pacific staghorn sculpin (Leptoccottus armatus), brown Irish lord (Hemilepidotus spinosus), starry flounder (Platichthys stellatus), butter (Isopsetta isolepis) and English sole

(Parophyrys vetulus), Dolly Varden trout (Salvelinus malma), steelhead trout (Salmo gairdneri), sand lance and sandfish (Trichodon trichodon) (personal observation). The epifaunal invertebrates were mainly crustaceans, such as Dungeness, tanner, and helmet crabs and gray shrimp (Crangon sp.). Our subtidal observations indicate most of the fish and infaunal invertebrates move into deeper water during the winter months. Virnstein (1977) has shown that crabs and fish can exert strong control on infaunal population of polychaetes and clams on soft substrates. He further points out that the importance of predation cannot be determined without experimental manipulation.

The importance of competition as a factor influencing composition of the sand beach faunas and the distribution and abundance of their component species is difficult to assess based on the existing data. Sand beaches are strongly influenced by various physical stresses and thus are typical of physically controlled habitats as defined by Sanders (1968), wherein biological interactions such as competition and predation are thought to be relatively unimportant. Slow moving or juvenile organisms that live near the water-sand interface may be strongly influenced by storm surf or temperature extremes during low tides. The large decrease in the density of Paraonella noted after a winter storm may be evidence of this. Furthermore, Hedgpeth (1957) suggests that food supplies are not limiting on sand beaches. Combining these possibilities with observed low species richness and densities, it therefore seems plausible to consider interspecific competition inconsequential.

However, both Virnstein (1977) and Woodin (1974) point out the danger of ignoring biological interactions in physically controlled habitats. Interspecific competition in protected intertidal soft substrates has been shown for several species (e.g., Woodin 1974, Fenchel 1975, and Ronan 1975), but not on exposed sand beaches. The dominance of environmental stress in these habitats must be examined from the viewpoint of juveniles as well as adults of each species, as most adults live in more protected circumstances on soft substrates. For instance, recruiting juveniles of the polychaete Scolelepis face a much more rigorous environment near the water-sand interface than the deeply buried adults. It appears that the adults migrate vertically in the sand, moving upward to richer food concentrations during calm weather and downward in response to physical stresses and disturbances. Under such circumstances, it is possible that intraspecific competition for food and space could occur at the deeper, more protected levels, especially during the winter. However, as Scolelepis appears to be the only deep burrowing deposit feeder found on exposed sand beaches, interspecific competition seems unlikely.

The trophic structure of the sand beaches is not well understood, but a tentative food web is indicated in Figure 5-1. The main source of energy for the assemblage appears to be detritus, which the primary consumers ingest mainly for the adhering bacteria. The two major categories of detritivores recognized in the sand beach assemblages are suspension feeders and deposit feeders. The former, including a mysid Archaeomysis and the clams Spisula, Siliqua, and Tellina lutea, feed on organic particles in suspension or at the water-sand interface. However, a greater proportion of the energy appears to pass through polychaetes and gammarid amphipods. The gammarid amphipods Eohaustorius and Paraphoxus are probably selective deposit feeders, burrowing to feed on sand grains and organic particles of specific sizes. The polychaete Scolelepis, which ingests large quantities of sand, is probably a nonselective deposit feeder.

The primary consumer groups appear to contribute to both marine and terrestrial systems by serving as forage items for birds and fish. The most important linkages seem to go to fish and shorebirds. Based on the low standing stocks, low levels of observed bird predation (even during spring migration), and the relative inaccessibility of a major biomass component (the deep burrowing polychaete Scolelepis) to the major shorebirds (which feed chiefly at or near the sediment surface), it appears that the sand beach habitat contributes only minimally to bird productivity of Lower Cook Inlet. Its importance to the subtidal forms (fish, crabs, and shrimp) is unclear at present. However, productivity appears to be low in comparison with mud beaches.

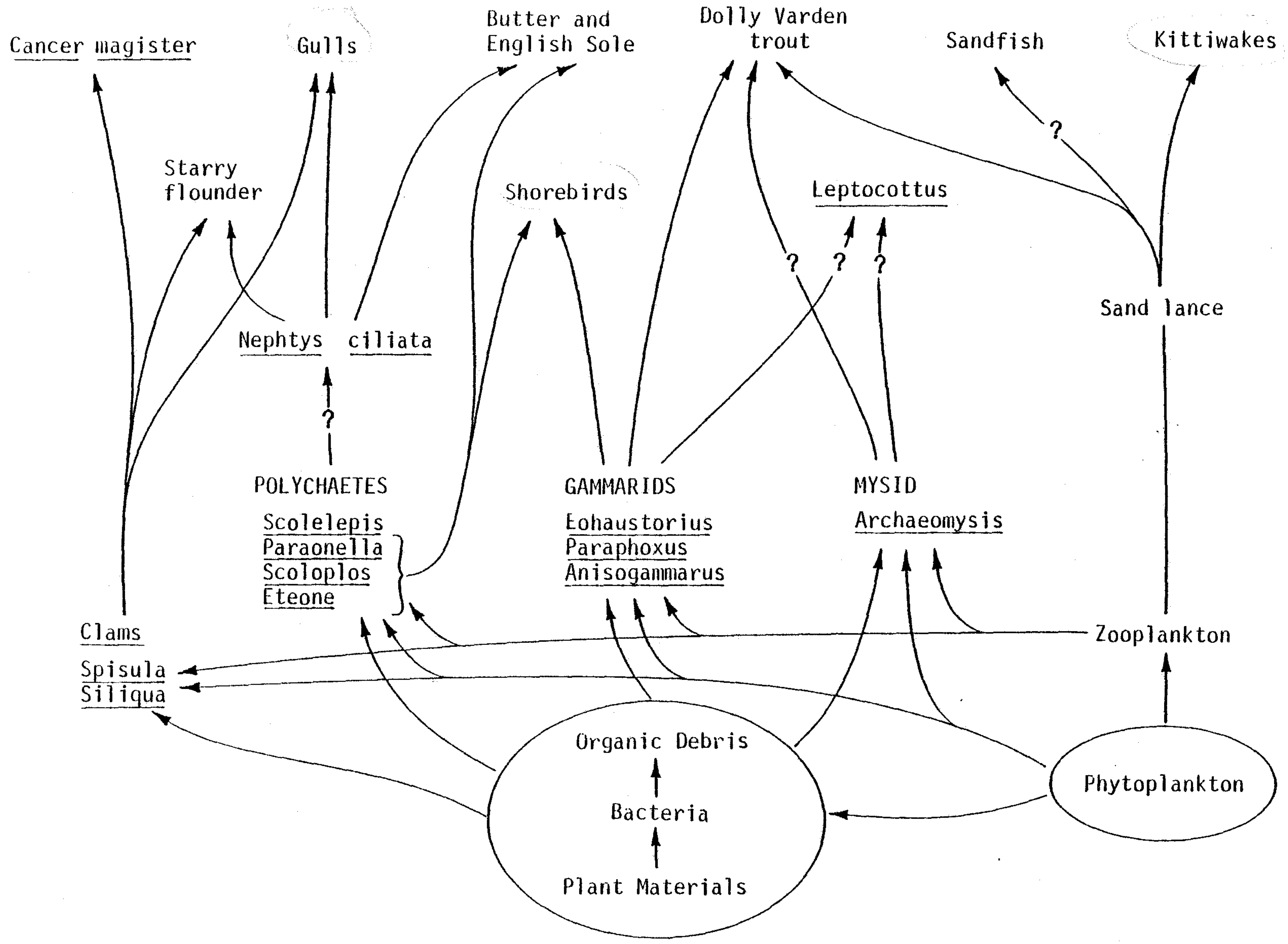

FIGURE 5-1 - GENERALIZED FOOD WEB FOR SAND BEACHES AT HOMER SPIT AND DEEP CREEK

A comparison of infaunal data from several sand beaches on the east side of Lower Cook Inlet suggests that the sand beach assemblages are quite variable spatially and possibly temporally (Table 5-1). Only 17 percent of the species were found at more than three of the stations. Only Eohaustorius and Paraphoxus were found on all occasions. Temporal patchiness cannot be examined because of differences in sampling areas and methods at Homer Spit and Deep Creek. Samples for 1976 were collected with a much smaller, shorter core tube than in 1977, and fewer samples were collected in 1976, so deep burrowing forms such as Scolelepis, and uncommon or patchy species were not sampled adequately in that survey.

Two patterns seem rather well-defined. Overall, polychaetes decrease and crustaceans increase in importance on the beaches moving from Homer to Deep Creek. As noted above, this seems to reflect a gradient in physical energy, with Deep Creek being subjected to stronger, more consistent current action, as well as higher turbidity, colder temperatures, lower salinities and more ice.

Further insight into this physical stress gradient is provided by comparing the species composition of Homer Spit and Deep Creek with that of a subtidal sand habitat at the A.R.Co. C.O.S.T. well site in the middle of Lower Cook Inlet (∿60 m deep). There is a surprising but definite resemblance between the intertidal sand assemblages and that described for unstable subtidal sand substrates (Table 5-2; Dames & Moore 1978). Forty-five percent of the species considered important at Deep Creek and eighty percent of those at Homer Spit were also common at the C.O.S.T. well site. The polychaete Scolelepis and a gammarid amphipod Paraphoxus were frequently considered dominants at all locations. Other species that were common at all locations include the polychaetes Eteone nr. longa, Nephtys ?ciliata, and Scoloplos armiger. It is tempting to speculate, in view of the physical gradient, that the faunal differences observed between the various sites represent sequences in the successional development of a sandy substrate, as suggested by Johnson (1970). This could not be shown without experimental manipulation, however.

TABLE 5-1. SPECIES COMPOSITION AND DENSITY (NO./M^2) AT SAND BEACHES ON THE EAST SIDE OF LOWER COOK INLET. BEACHES ARE ARRANGED FROM SOUTH TO NORTH.

TAXA	Homer Spit 1977	Homer Spit 1976	Bishops Beach 1976	Whiskey Gulch 1976	Deep Creek 1977	Deep Creek 1976	Clam Gulch 1976
Polychaeta	(78%)	(29%)	(38%)	(16%)	(13%)	(16%)	(10%)
Abarenicola sp	0	0	0	0	6.4	0	0
Capitella capitata	25.5	0	0	0	9.6	0	0
Chaetozone setosa	0	0	0	0	6.4	0	0
Eteone nr *longa*	3.2	0	0	0	9.6	37.8	0
Magelona ?sacculata	0	0	113.6	0	0	0	0
Nephtys ?ciliata	22.3	37.9	37.9	21.6	9.6	0	0
Paraonella platybranchia	213.3	0	0	0	12.7	75.8	75.8
Scolelepis sp A	547.5	0	0	32.5	92.3	0	12.6
Scoloplos armiger	0	75.8	0	0	31.8	75.8	0
Spio filicornis	0	0	0	0	0	75.8	25.3
Spiophanes bombyx	3.2	75.8	75.8	0	0	0	0
Crustacea	(6%)	(59%)	(63%)	(84%)	(85%)	(84%)	(90%)
Anisogammarus confervicolus	0	0	0	10.8	0	0	0
Anonyx sp	0	0	0	10.8	0	0	0
Archaeomysis grebnitzkii	0	0	0	0	3.2	0	0
Atylidae, unid.	0	0	0	0	3.2	0	0
Crangon alaskensis elongata	12.7	0	0	0	0	0	0
Cumacea, unid.	0	151.5	0	10.8	0	0	0
Eohaustorius eous	28.7	37.9	75.8	151.5	648.4	1363.6	947.0
Gammariidae, unid.	0	0	0	0	388.3	0	12.6
Hippomedon sp	0	151.5	227.3	0	0	0	0
Lamprops carinata	60.5	0	0	0	0	0	0

TAXA	Homer Spit 1977	Homer Spit 1976	Bishops Beach 1976	Whiskey Gulch 1976	Deep Creek 1977	Deep Creek 1976	Clam Gulch 1976
Crustacea, cont.							
Lamprops quadriplicata	79.6	0	0	0	19.1	0	0
Lamprops sp	3.2	0	0	0	0	0	0
Paraphoxus milleri	19.1	37.9	75.8	108.2	19.1	37.8	25.3
Synchelidium sp	12.7	0	0	0	6.4	0	0
Pelecypoda	(0.6%)	(18%)					
?*Macoma* sp	0	37.9	0	0	0	0	0
?*psephidia lordii*	0	37.9	0	0	0	0	0
Spisula polynyma	6.4	0	0	0	0	0	0
Pisces	(0.3%)						
Ammodytes hexapterus	3.2	0	0	0	0	0	0

TABLE 5-2. COMPARISON OF DENSITIES (NUMBER/M^2) FOR IMPORTANT SPECIES AT VARIOUS SITES ON UNSTABLE SAND HABITATS IN LOWER COOK INLET

	Deep Creek	Homer Spit	ARCO site Ocean Ranger	ARCO site Control
Polychaetes				
Capitella capitata	6.4	0	0	0
Chaetozone setosa	0	0	5.0	5.4
Eteone nr *longa*	21.3	3.2	0.6	92.9
Nephtys ?ciliata	6.4	6.4	12.2	35.7
Ophelia limacina	0	0	45.0	125.0
Paraonella platybranchia	12.7	132.6	0	0
Polygordius sp	0	0	7.8	407.1
Scolelepis sp A	47.7	402.1	423.9	160.7
Scoloplos armiger	18.0	2.1	61.7	33.9
Sphaerosyllis pirifera	0	0	0	25.0
Spiophanes bombyx	0	1.1	185.6	2410.7
Streptosyllis nr *latipalpa*	0	0	7.2	12.5
Crustaceans				
Anisogammarus confervicolus	4.3	0	0	0
Archaeomysis grebnitzkii	1.1	0	0	0
Eohaustorius eous	504.7	20.2	0	0
Gammaridae sp A	129.4	0	-	-
Orchomene cf *pacifica*	0	0	3.9	17.9
Paraphoxus milleri	19.1	38.2	56.1	14.3
Clams				
Astarte sp	0	0	0.6	25.0
Glycymeris subobsoleta	0	0	2.2	50.0
Liocyma fluctuosa	0	0	31.7	58.9
Spisula polynyma	0	7.4	0.6	3.6
Tellina nuculoides	0	0	19.4	44.6
Gastropods				
Propebela spp	0	0	16.1	7.1
Sand dollars				
Echinarachnius parma	0	0	22.2	17.9
Fish				
Ammodytes hexapterus	0	7.4	C	C
Overall Average Density	788	726	1017	3852

5.6 MUD FLAT ASSEMBLAGES

Our studies so far have indicated that, in contrast to sand beaches, the mud flat off Glacier Spit, Chinitna Bay, supports a large standing crop of suspension and deposit feeders, has higher species richness, and appears to be highly productive. However, spatial, seasonal and annual variability were considerable, being influenced strongly by weather conditions and predation. Species richness, species diversity and biomass were greatest in the summer, whereas abundance was lowest in summer (Table 4-35). This apparent paradox is attributable to the large reduction in the abundance of juveniles of the clams Macoma balthica and Mya spp. between April and July; most other species increased in abundance during the same period (Table 4-34).

The fauna was dominated heavily by the clams Mya spp. and Macoma balthica, which comprised more than 50 percent of the individuals and 90 percent of the wet biomass and dry tissue weight in both surveys (Tables 4-34 and 4-37). Macoma was by far the most abundant, but contributed only 10 to 15 percent of the biomass. Three other visually conspicuous species of marginal importance were an echiurid Echiurus echiurus alaskanus, a large polychaete Nephtys sp., and the basket cockle Clinocardium nuttallii, all of which also contributed marginally to biomass.

Ten species exhibited densities exceeding 100 individuals/m^2 in at least one survey. These included, in order of importance, Macoma, Mya spp., Nephtys, Spio, Potamilla, Clinocardium, Pseudopythina, Tritella, Eteone, and Capitella (Table 4-34). All of the worms except Nephtys increased in abundance substantially from April to July, whereas that worm and all of the clams became less abundant. All of the species exhibiting increased abundance are thought to be annuals, at least in this habitat. In contrast, all of the species that declined, including Nephtys, appear to be perennials (Thorson 1957).

The species that appear to represent the mature stage, or highest level of development, of this mud flat assemblage are the clams Mya, Macoma, Pseudopythina, the polychaete Nephtys and the echiurid Echiurus.

The present rarity of adult *Clinocardium* in the intertidal zone suggests that it does not survive harsh winters at these elevations in this location. However, long-time resident Wayne Byers indicated that adult cockles were abundant on these flats prior to the uplift resulting from the 1964 earthquake (personal communication). *Mya* spp. and *Echiurus* construct semi-permanent burrows which impart a characteristic appearance to the mud flats on the west side of Lower Cook Inlet (Figure 4-23).

The richness of this mud flat assemblage is indicated by the density and biomass of its constituent species, particularly the dominants. For instance, in April, when the population was dominated by the 0-year class, *Macoma* densities ranged from 4250/m^2 to 5350/m^2 (Appendix 4.4.15) and whole wet weight ranged from 340 g/m^2 to 550 g/m^2 (Appendix 4.4.17). Such densities are among the highest recorded for *Macoma* (Green 1968, Tunnicliffe and Risk 1977), and this is particularly notable in view of the high percentage of animals at least one year old during the summer (Figure 4-24).

The contrasting seasonal patterns of abundance for the major clams and the polychaetes seem to indicate differences in reproductive cycles. Density of the three main clam taxa decreased markedly from April to July. Moreover, the 0-year class strongly dominated the age structures for *Macoma*, *Mya* spp. and *Clinocardium* in the April samples but was strongly reduced in all cases by July. The implication is that recruitment occurs in late summer, fall or winter. This hypothesis is partially supported for *Macoma* by data from the Irish Sea for reproductive condition from Chambers and Milne (1975), and for *Mya truncata* by Thorson (1957). Surprisingly, however, Chambers and Milne (1975) observed heavy recruitment in July, four months after the local adult population was spawned out.

Myren and Pella (1977) found no seasonal changes in density for larger specimens of *M. balthica* at Valdez. The data for large specimens of *Macoma* and *Mya* spp. from Glacier Spit generally support that finding, and suggested that the adult size classes are much more stable than the 0-year class.

Density of the polychaete populations increased considerably from April to July. The July samples were strongly dominated by newly settled specimens, as was the case on the sand beaches. This pattern suggests late spring or early summer spawning.

It seems probable that both physical and biological factors are important in determining the density of the organisms living in the mud flats at Glacier Spit. Physical conditions are severe, especially near the water-sediment interface where temperature and salinity fluctuate widely and ice scouring and crushing can be substantial. In addition, predation pressures and intra- and interspecific competition for food and space are probably intense, especially in the spring, when maximum densities of young clams are concentrated in the upper few centimeters of sediment and high numbers of migratory birds exploit the mud flats. In addition, predation by adult clams on larval, metamorphosing and settling juvenile clams is probably intense during major periods of recruitment.

mud f.

Predation seems to exert a strong influence on the density of several species, such as Macoma balthica, Mya spp. and Echiurus. A broad variety of predators exploit the mud flats (Figure 5-2). Diving ducks (scoters, scaup and Oldsquaw), gulls and shorebirds appear to be major predators on clams and polychaetes. Diving ducks and shorebirds are most abundant during spring migration and seem to concentrate on Macoma and Mya. Judging from the reductions of nearly 50 percent and 70 percent in the densities of Macoma and Mya, respectively, these predators are fairly effective. The changes in size structure indicate that juveniles, located near the sediment surface, are most frequently utilized. Gulls were observed foraging on the mud flats during both day and night low tides, and their egesta and shell debris indicate that they feed mainly on barnacles, Clinocardium, and crabs; large worms such as Nephtys are probably also taken frequently.

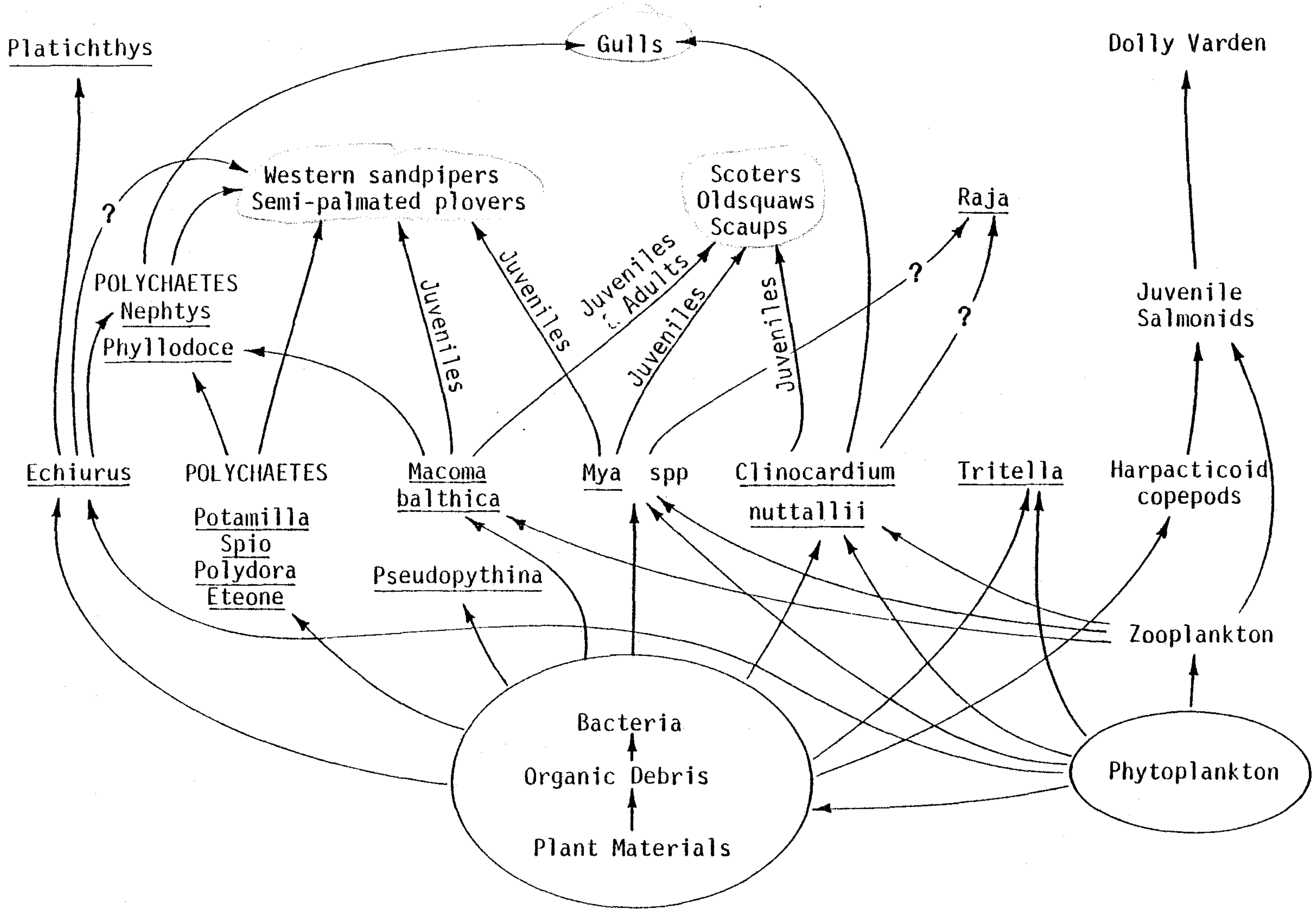

FIGURE 5-2 - GENERALIZED FOOD WEB FOR MUD FLAT AT GLACIER SPIT

The only resident predator of any importance observed in the study area was the polychaete Nephtys sp. The population of this perennial included specimens up to 10 cm in length, but was strongly dominated by the small, younger animals. The importance of this species is poorly understood. The few feeding observations made were for adults, and most had empty alimentary canals. The small number of feeders had all fed on adult Echiurus; one specimen contained two prey. Based on available prey and habits, it seems probable that juvenile Nephtys feeds on juvenile Echiurus and small polychaetes.

Gastropod predators, particularly small opisthobranchs, are frequently common locally on mud substrates and on more temperate mud flats. However, they were very uncommon during this survey.

Data are presently not available to describe the function of several predators, but some speculation is permissible based on other studies or observations. Excavations and shell remains observed while diving in Cottonwood Bay suggest that skates (Raja) may move into shallow bays and feed on Clinocardium. Starry flounder are reported to feed on Echiurus in the Bering Sea (Feder, personal communication). Other potential predators important to macrofaunal forms include Dungeness (Cancer magister) and tanner crab, rock sole (Lepidopsetta bilineata), and Pacific staghorn sculpin.

As indicated above, competition for food and space may be important in determining densities and growth rates of several species, particularly the clams Macoma and Mya spp. The feeding activities of dense adult clams may strongly reduce success of recruits attempting to settle, so that suitable space is limiting for larvae. Furthermore, food and space are somewhat synonymous for Mya and Macoma and, at high densities, available food may become limiting.

Several types of mud flats have been observed in southcentral Alaska; all are dominated by clams and generally they differ sharply from those described or observed in Washington (Kozloff 1973) or California (Ricketts and Calvin 1962). Species richness is rather lower, reflecting the absence or paucity of a number of higher taxa. Southcentral Alaskan mud flats generally lack burrowing shrimp (e.g., *Callianassa* and *Upogebia*), gammarid amphipods and isopods, deposit feeding or predatory gastropods (e.g., *Hydrobia* or *Aglaja*) and commensal fish (e.g., *Clevelandia*).

Southcentral Alaskan mud flats appear to have greater affinity to similar habitats on the Atlantic Ocean, which also support high densities of *Macoma balthica* and/or *Mya* spp. These species dominate on many mud flats in Lower Cook Inlet, and the burrow building *Echiurus* is frequently an important structural component. On some mud flats, such as the Dayville flats in Valdez (Feder, personal communication) and Mud Bay in Homer (personal observation), *Mya* and *Echiurus* are uncommon, reducing the permeability of the sediments.

A number of mud flats support beds of eelgrass (*Zostera marina*), but intertidal stands are frequently limited by winter ice.

The generalized trophic structure proposed for the mud flat (Figure 5-2) appears to be based on detrital material from marine and terrestrial systems. It is considerably more diverse than that for sand beaches. Griffiths (personal communications) indicates that the bacterial flora observed in the water column on the west side of the inlet suggests that terrestrial plants may be a major source of organic debris. The detritus, associated inorganic particles, bacteria and protozoans are ingested by suspension and deposit feeders (Jørgenson, 1966), but mainly the bacteria and protozoans are digested and assimilated (Johannes and Satomi 1966). Nearly all of the infaunal animals collected at Glacier Spit were detritivores; both suspension and deposit feeders were common but suspension feeders seem to dominate. Non-selective deposit feeders such as *Abarenicola* were uncommon.

Nearly all the predators observed were transients representing other systems, and were mainly effective only in spring and summer. However, several overwintering duck species are heavily dependent on mud flats. The fish, crabs and ducks move onto the intertidal flats during high tides, and the shorebirds move in during low tides. Commercially, the most important of these interactions appears to be that of juvenile salmon and harpacticoid copepods (Sibert et al. 1977, Kaczynski et al. 1973). The consequence of this concept is that a very large proportion of the tissue produced on the flats is exploited by predators from other systems. This is a particularly important concept on the west side of the Inlet because of 1) the richness of the mud flats, 2) the large proportion of mud flat habitat in the intertidal zone and, 3) the potential susceptibility of this assemblage to oil pollution.

A preliminary assessment of secondary production can be made using data for density, growth and biomass data and the predation hypotheses. Nearly all species exhibited sizeable changes in density between April and July. With the notable exception of *Macoma*, most species exhibited relatively large increases in standing crops. For *Macoma*, density decreased nearly 50 percent concurrent with a small decrease in standing crop. Average size of all the populations appeared to increase during this period. During this same period, it is probable that predation pressures were intense. Despite predation, whole wet weight increased during this four month period from 2.3 kg/m^2 to 4.0 kg/m^2. The 74 percent increase in biomass during a period of intense predation indicated moderately high net production.

5.7 FAUNAL COMPOSITION OF GRAVEL UPPER BEACHES AND SCOURED BOULDER FIELDS

Gravel/cobble upper beaches and scoured boulder fields were frequently associated with the soft substrates and so were examined qualitatively to develop a general idea of their faunal composition and structure. These areas were quite impoverished, a condition which Kozloff (1973) reports is normal. However, particularly during summer, the lower levels of gravel and cobble substrate characteristic of upper beach areas throughout much of Lower Cook Inlet appear to support moderate densities of two scavengers, namely, the gammarid amphipod *Anisogammarus confervicolus* and the isopod *Gnorimosphaeroma oregonensis*. These organisms are most abundant in areas where ground water from the upper beach seeps onto the beach. There, they aggregate mainly under large cobbles that rest in a manner allowing water to stand or pass gently under them. Generally, these species should be considered as cryptic rather than infaunal as they do not appear to live interstitially in the gravel. Nematodes appear to be the common infaunal form.

These species are also characteristic of the scoured boulder/cobble fields occurring at about MLLW. However, these areas are not subject to the continuous grinding that occurs in the gravel beach, and therefore are capable of supporting young populations of pioneer species such as barnacles (Balanus spp.) and mussels (Mytilus edulis). Generally, these populations do not survive a harsh winter, but annual replacement appears to be fairly reliable. The last two winters have been quite mild, however, so many such areas in Lower Cook Inlet support two year classes of barnacles and mussels.

These species appear to occupy positions low in the food web, and are probably mainly dependent upon phytoplankton (barnacles and mussels), or plant and animal debris (isopods and amphipods). However, casual observations suggest that a number of invertebrate, bird and fish species heavily utilize these resources for food. The nudibranch Onchidoris bilamellata and the snail Nucella emarginata compete for the barnacle and mussel resources. Onchidoris appears to be more successful in the less stable areas.

[illegible]

Shorebirds, mainly sandpipers, turnstones and plovers, put considerable predation pressure on these habitats, particularly during spring migration, when utilization is intense. The Rock Sandpiper, a ? winter resident, appears to be particularly important. Our observations during the winter suggest that this species is using these resources during both day and night ? low tides. The occurrence of night feeding by shorebirds in winter does not appear well known. However, the energetics argument appears strong, considering the combination of short day length, available low (feeding) tides, the possibility of reduced prey density and higher metabolic rates for resident birds during winter months.

Several invertebrate and fish species have been collected in beach seine hauls just below these habitats and it can be assumed that many of these probably feed there. The main invertebrates are adult and juvenile Dungeness crabs (Cancer magister), adult helmet crabs (Telmessus cheiragonus) and gray shrimp (Crangon alaskensis). Juvenile Dungeness crabs are fairly common in the boulder/cobble field during the summer. The main fish species observed include the sand lance (Ammodytes hexapterus), Pacific staghorn sculpin (Leptocottus armatus), starry flounder (Platichthys stellatus), and flathead sole (Hippoglossoides elassodon). Specific food habits have not been investigated in this area.

5.8 PRELIMINARY DISCUSSION OF THE POTENTIAL EFFECTS OF OIL POLLUTION

The two major potential types of oil pollution of concern in Lower Cook Inlet are catastrophic spills of crude oil and chronic pollution by refined petroleum or refinery effluents. Chronic pollution is a concern chiefly on the eastern shore of the Inlet since most onshore facilities are planned for that side (Warren, 1978). This would result from increased boat traffic to supply and support facilities and, in the event of development and production, from the operation of various onshore facilities related to treatment and transfer of oil and gas. During the exploration phase, chronic pollution from boat activities should be minimal, but during development and production, it could become significant. General sites being considered for construction of onshore facilities include the western tip of the southern Kenai Peninsula, between Port Graham and Port Chatham, and Anchor Point, just north of Kachemak Bay. Facilities could include crude oil terminals, production treatment facilities, and liquification and terminal facilities for natural gas. Suitable sites on the southern Kenai are located on or near very productive embayments and estuaries. The Anchor Point site would include an important river mouth and wetland.

A regional assessment of coastal morphology has been used to predict behavior of oil spills in Lower Cook Inlet and to develop a classification of the susceptibility of local coastal environments to oil spills (Hayes, Brown and Michel, 1977). This classification is based primarily on geological features and sediment characteristics as they relate to interactions with crude oil. It provides a useful starting point in assessing potential impacts from oil pollution, but it is necessary to temper the assessments with the idea that the major incentive for investigating potential effects of oil pollution is protection of biological assemblages. A point sometimes overlooked is that a ranking of biological assemblages by either importance or susceptibility to oil pollution does not always agree closely with the classification based on geological characteristics proposed by Hayes et al. (1977).

For the purposes of their assessment, Hayes et al. (1977) divided the 1216 km of examined shoreline into erosional, neutral and depositional categories (45, 38 and 17 percent, respectively). Because of the complex structure of the beaches, it is difficult to subdivide these categories into bedrock, boulder fields, gravel, sand or mud. The upper beach face in Lower Cook Inlet (Figures 2-4 and 2-6) is most commonly composed of gravel, or a mixture of gravel, sand, cobbles, and boulders. However, adjacent low-tide terraces are usually mud, sand, boulders or bedrock. The distinct difference in substrate between upper beach face and low-tide terrace on most beaches in Lower Cook Inlet makes it somewhat difficult to apply the Hayes assessment of environmental susceptibility locally. For instance, most flat fine-grained sandy beaches [given a susceptibility ranking of 3 on a scale of 1 (low) to 10 (high)], are bordered by a beach front of gravel or mixed sand and gravel (susceptibility rankings of 7 and 6, respectively). This problem is further complicated by assessment of biological susceptibility. Gravel or mixed sand and gravel beaches generally support only impoverished assemblages of small crustaceans and are therefore probably of lower importance than sand beaches which often support important populations of razor clams. Furthermore, it is important to consider the levels of tolerance or susceptibility to contamination of the organisms in an assemblage, and the importance of the assemblage to other assemblages or systems. Clearly then, several factors must be integrated to develop a satisfactory assessment of susceptibility.

5.8.1 Sand Beaches

Beaches with sandy low-tide terraces border about 50 percent of Lower Cook Inlet. They are concentrated on exposed portions of the Inlet, especially in its northeastern quadrant. Hayes et al. (1977) indicated that since these beaches are generally flat and hard-packed, they are relatively impenetrable to oil and thus have a fairly low susceptibility ranking. However, oil stranding during a falling tide may penetrate into the sediment (especially the water-soluble, toxic fractions) and come into contact with the infaunal forms (Anon. 1975). Furthermore, extensive burial of stranded oil can occur, increasing the residence time on polluted beaches. Such burial can induce anaerobic conditions, delaying microbial degradation.

The biological assemblages most commonly observed on sand beaches in Lower Cook Inlet are dominated by burrowing polychaetes, small crustaceans (gammarid amphipods and mysids) and razor clams. All are known to be somewhat sensitive to crude and petroleum products. Generally, standing stocks are low and the contribution of sand beaches to other systems appears low. However, beaches supporting dense clam populations are important to sport and commercial clamming enterprises. Recovery of the worm and crustacean populations would be rapid following contamination, but for clam populations, recovery would be very slow, possibly requiring decades.

5.8.2 Gravel And Sand Upper Beaches

As pointed out above, gravel or mixed sand and gravel upper beaches border a large proportion of the shoreline in Lower Cook Inlet. Hayes et al. (1977) indicate that oil arriving on such beaches can penetrate to considerable depths, especially on gravel, or can be buried, and thus residence periods can be great. Clean-up would be difficult without large-scale removal of sediments. Such beaches are therefore highly susceptible (ranking of 7 and 6, respectively) to oil pollution. In the Straits of Magellan, oil from the Metula spill formed thick asphalt pavement on low-tide terraces of mixed sand and gravel (Hayes et al. 1977); this formation was highly resistant to degradation.

(on gravel)

The biological assemblage most frequently observed is impoverished, mainly including nematodes, one gammarid amphipod and one isopod species. The sensitivity of these species to crude oil is unknown, but, as they are all short lived, they probably could recovery fairly rapidly. However, widespread contamination could lead to a lengthy recovery period since both the gammarid and the isopod are brooders, having no pelagic larvae. Recolonization would depend upon migration rates. Our observations so far suggest that this assemblage supports limited secondary production and contributes little to other systems.

5.8.3 Scoured Boulder Fields

The extent of scoured boulder fields on the low-tide terrace is unclear, but they may be located primarily on spits and below eroding scarps. Hayes et al. (1977) do not specifically rank this type of habitat, and the basic sediment is often mixed sand and gravel. Therefore, many of the same considerations apply.

These boulder fields support a more diverse biotic assemblage, however, because of the high proportion of solid substate. Nevertheless, most of the animals are pioneer species and the populations are largely dominated by young organisms. These conditions are a consequence of scouring and abrasion. Juvenile barnacles and mussels are often dominant species and although production may be moderate, biomass is low. The contribution of this assemblage is not great, although overwintering Rock Sandpipers appear to feed in such areas. Because of their small size, many of the animals in this habitat would be susceptible to smothering by crude oil. However, natural scouring could be expected to facilitate clean-up and recovery would probably be rapid (perhaps within two years).

5.8.4 Mud Flats

Mud flats, variously referred to by Hayes et al. (1977), as muddy tidal flats, protected estuarine tidal flats and rias, border about 35 percent of the total shoreline of Lower Cook Inlet and nearly half of its western shoreline. The two types of mud flats described are 1) exposed muddy tidal flats, such as are observed in association with the wavecut sandstone platforms in southern Kamishak Bay, and 2) protected estuarine flats, which are "primarily drowned glaciated river valleys (rias)" such as Chinitna Bay (Hayes et al. 1977). Because of the difference in exposure and probable residence time, exposed flats were considered to be moderately susceptible to oil pollution (rank of 5) and protected flats to be highly susceptible (rank of 9; Hayes et al. 1977). These investigators described the flats as impermeable to oil. In fact, we believe that permeability may vary considerably, depending on the faunal components. Where the flats are dominated by *Macoma balthica*, but *Mya* spp. and *Echiurus* are absent, the flats indeed appear impermeable. Mud Bay, at Homer, and Dayville Flats, at Valdez, are examples of this type of flat. Shaw et al. (1977), in fact, reported low uptake and rapid loss of crude oil on Dayville Flats. Griffiths (personal communication) suggests that Shaw's findings may have been influenced by low densities of bacteria and organic debris, which have a direct relationship to uptake rates. However, where *Mya* and *Echiurus* are common, their burrows, with densities of up to 100/m^2 and extending up to 45 cm into the sediment, may increase the rate of oil penetration into the sediment, and allow oil to be stored at deep, anoxic levels. All mud flats observed to date on the west side of Cook Inlet are of this type.

Because of anoxic conditions near the sediment surface, and the low energy regime of the protected estuaries, residence time could extend up to 10 years in some of these areas (Hayes et al. 1977).

The fauna, dominated by longevous clam and polychaete species, includes several species that have been shown to be sensitive to oil contamination. For instance, Shaw et al. (1976) reported significant mortality in *Macoma balthica* in response to low dosages of Prudhoe Bay crude oil in elegant field experiments on Dayville Flats. Hampson and Sanders (1969) reported considerable mortality of M. arenaria and many polychaete species in West Falmouth, Mass., after exposure to high doses of fuel oil. Feder et al. (1976) observed anomalous increases in the density of harpacticoid copepods on Dayville Flats, but the causes and ramifications are not clear.

Because it appears that most of the tissue produced on the mud flats is utilized by transient predators from other systems, the condition of the mud flats is of considerable concern and importance. Animals particularly reliant on continued high productivity of the mud flats include 1) smolts of at least two species of salmon in spring (Sibert et al. 1977), 2) Western Sandpipers on spring migration, and 3) ducks, especially scoters, scaup and Oldsquaw, all year long. Only ducks and gulls appear to depend on adult or long-lived animals.

Recovery rates following contamination are subject to several conditions. Obviously, local conditions (orientation of estuary, time of year, tidal phase, porosity of the flat) are of importance. If appreciable quantities of oil penetrate deeply into the sediment, however, it is probable that full recovery will require at least 10 years. The dominant clam species all live at least 6-10 years (Chambers and Milne 1975, Feder and Paul 1974). Ducks appear to feed mainly on adult Macoma. Shorebirds, in contrast, feed mainly on young-of-year Macoma, Mya, annual polychaetes and harpacticoid copepods, which could recover fairly quickly if the sediments were uncontaminated. Based on the predictions of Hayes et al. (1977), it is probable that the exposed flats would recover in several years, but that the estuaries could require at least a decade.

6.0 CONCLUSIONS

The conclusions given herein are preliminary and abbreviated. More complete conclusions will be presented in the final report in preparation in which all the data will be presented and discussed.

6.1 ROCKY HABITATS

- Seaweed assemblages on the east side of the Inlet are strongly dominated by brown algae, mainly Fucus in the mid-intertidal zone and other kelps from the lower intertidal down to at least 70 foot depths. In contrast, on the west side of the Inlet, seaweed assemblages are mainly dominated by red algae (esp. Rhodymenia spp.) except at the upper level (mid-intertidal zone dominated by Fucus); kelps dominate from the lowest intertidal level down to a depth of about 10 feet, where significant algae growth closes.

- Intertidal invertebrate assemblages are diverse and well-developed on the east side of the Inlet, and include numerous mature specimens of long-lived species. In contrast, intertidal invertebrate assemblages on the west side of the Inlet are improverished and mainly composed of juvenile specimens of pioneer species.

- Subtidal invertebrate assemblages are well-developed, diverse and composed of long-lived forms on both sides of the Inlet, but are strongly dissimilar in composition and appearance. The fauna on the east side, dominated by sea urchins, snails, and starfish, show close affinities to southeast Alaska, British Columbia and Washington. In contrast, the fauna on the west side of the Inlet, dominated by bryozoans, tunicates, sponges and barnacles, shows close affinities with the Bering and Beaufort Seas.

- Rocky intertidal biotas exhibit strong seasonal changes on both sides of the Inlet, greatest development is in mid-summer and poorest in late winter. Ice is an important factor on the west side of the Inlet.

- Rocky subtidal biotas on the east side of the Inlet also exhibit significant seasonal changes, but such patterns are undescribed for the west side.
- Patterns of vertical zonation are clearly defined on rocky substrates on both sides of the Inlet.
- Primary production by macrophytes appears to be quite high in the southeastern quadrant of Lower Cook Inlet, and substantially lower on the west side of the Inlet. Most of the plant material is exported to other assemblages.

6.2 SAND BEACHES

- Faunas on sand beaches are dominated by polychaete worms (e.g., *Scolelepis* sp.) and gammarid (e.g., *Eothaustorius eous*). Proportions vary with exposure to wave action.
- Biomass is low and secondary production appears low.
- Patterns in vertical zonation are vague.
- Seasonal patterns in species composition and abundance are well defined; both parameters peak in mid-summer.

6.3 MUD BEACHES

- Faunas on mud beaches are dominated by clams (e.g., *Macoma balthica* and *Mya* spp.) Composition and proportions appear to vary with degree of consolidation of the sediment surface.
- Biomass is high and secondary production appears to be high.

- Patterns of vertical zonation are vague.

- Seasonal patterns in species composition and abundance are well-defined; both parameters peak in mid-summer.

- Mud flat faunas appear to be an important food resource for several species of shorebirds, diving ducks, and gulls, as well as some important fish (e.g., salmonid fry). A large proportion of the tissue produced in the mud flat assemblage is utilized by transient predators from other widespread assemblages (e.g., migratory shorebirds or ducks, or wide-ranging fish and crabs).

6.4 NEEDS FOR FURTHER STUDY

Needs for further study will be addressed in the final report.

6.5 SUMMARY OF JANUARY THROUGH MARCH QUARTER

Work during this quarter has all been related to preparation of the annual and final report, verification of digital data and processing the remaining digital data.

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APPENDIX 4.3.1 DATA FOR STIPE LENGTH/GROWTH RATE (CM/DAY) RELATIONSHIPS FOR *AGARUM CRIBROSAM* AT JAKOLOF BAY

Stipe	Growth Period Ending												
Length (cm)	4/22	5/12	7/12	8/18	10/31	1/30	3/1	3/22	5/12	6/16	8/8	9/9	10/26
4				0.185									
4							0.100	0.286	0.373	0.250	0.150	0.063	
5				0.148	0.041		0.089						
5							0.067						
6								0.143	0.196				
6						0.068	0.083	0.486		0.120			
7											0.211		
7											0.092		
7						0.114	0.200	0.569		0.080	0.333		
7							0.133	0.214					
8							0.067						
8											0.133		
8												0.078	0.032
8									0.262	0.124			0.053
8													
9				0.185									
9							0.167	0.262	0.224	0.179	0.167		
9							0.200	0.429	0.431	0.571			
10							0.167	0.214				0.094	0.064
10							0.100	0.190				0.141	0.095
10													
10				0.037	0.095	0.054	0.107						
11	0.361			0.037	0.041	0.032	0.054		0.184				
11											0.208		
12.5												0.141	
12												0.172	
12											0.083	0.156	0.021
12												0.047	0.053
13	0.238												
14									0.216	0.179	0.250	0.125	0.043
14							0.061	0.273	0.337	0.280			
15							0.161	0.391	0.388	0.600		0.078	0.074
15							0.100	0.143	0.235	0.250	0.100		
16												0.094	0.021
20							0.133	0.286	0.314	0.292	0.050	0.094	0.053
20							0.100						
22								0.405	0.480	0.417	0.125	0.078	
22						0.071	0.089	0.239	0.439	0.320			
23				0.111									
23												0.0	0.032
25.5							0.083						

APPENDIX 4.3.2 DATA FOR STIPE LENGTH/GROWTH RATE (CM/DAY) RELATIONSHIPS FOR *LAMINARIA GROENLANDICA* AT JAKOLOF BAY

Stipe	Growth Period Ending													
Length (cm)	3/12	4/22	5/12	7/12	8/18	10/31	1/30	3/1	3/22	5/12	6/16	8/8	9/9	10/26
12								0.32						
12								0.21						
14										0.31				
14								0.46						
14								0.43	0.78	0.47				
15								0.61						
15.5								0.27						
16								0.29	0.57					
16								0.32						
16								0.36						
16								0.23						
16.5								0.29						
16.5								0.32						
17											0.49	0.05		0
17													0.05	0
17.5								0.11						
18										0.57			0	0
18										0.11				
19									0.67					
20								0.35		1.28				0.01
20								0.65					0.02	0
20								0.25						
20.5								0.29						
21								0.48		1.00			0.03	
22						0.12		0.30						
22								0.35						
22								0.37						
22.5										0.67				
23						0.19		0.23		1.02		0.08		0.0
23								0.20		0.67				
23.5										0.61				
24								0.46		1.10	0.59			
25													0	0
25.5											1.08			0
25.5														0.04
26												0.08		
27				0.20				0.13		0.78	1.51		0	
27										0.69				
28												0.19		0.02
29													0.12	
30											0.88			0
31											0.64			
33													0.04	
34													0.04	0
35														0.043
36								0.27					0	
38.5												0.06		
39								0.40						
41													0.11	

APPENDIX 4.3.3

DATA FOR STIPE LENGTH/GROWTH RATE (CM/DAY) RELATIONSHIPS FOR
ALARIA GISTULOSA AT JAKOLOF BAY

Stipe	Growth Period Ending														
Length (cm)	3/12	4/22	5/12	7/12	7/22	8/18	10/31	1/30	3/1	3/22	5/12	6/16	8/8	9/9	10/26
15					0.86										
15					2.86										
15															1.67
17					1.29										
17					1.29										
18					1.71										
19						2.89									
20					0.86	3.59									
21									3.36						
21					0.86										
21					1.14										
22									1.96						
22									4.21						
26									1.14						
27			14.6												
28							4.31								
28								1.95							
29				0.98											
29									3.18						
31									0.84	2.17					
32									1.30						
32													6.05	3.97	1.45
33		14.78												1.62	
33.5									1.93						
34		3.58													
35		10.25	6.60						3.34						
37.5		11.45													
37									1.89						
38									1.61						
39		12.90	14.5											4.13	1.64
39		6.75	5.0												
40			11.95				2.54								
41							1.97		1.86						
45									1.80	4.46					
47													5.83	2.63	
47		9.80	15.20										5.37	1.72	
50													3.53		
53															2.19
57													4.60	4.50	
60													4.27		
62														4.78	
65													1.35		1.53

APPENDIX 4.4.1. ABUNDANCE DATA FOR CORE SAMPLES FROM DEEP CREEK BEACH; 4 FEBRUARY 1977.

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x}$ ± s	Total
Level 1 (Upper)												
ANNELIDA - Polychaeta												
Capitella capitata	0	0	0	0	1	0	1	0	0	0	0.2 ± 0.4	2
Eteone nr. *longa*	1	0	1	2	0	0	0	1	2	2	0.9 ± 0.9	9
ARTHROPODA - Gammaridae												
Anisogammarus cf *confervicolus*	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	1
Eohaustorius eous	0	2	1	0	2	1	0	0	0	0	0.6 ± 0.8	6
S	1	1	2	1	3	1	1	1	1	1		
N	1	2	2	2	4	1	1	1	2	2		

Extralimital Species: *Halichondria panicea* on Sabellid tube, *Mytilus edulis* on boulder

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x}$ ± s	Total
Level 2												
ANNELIDA - Polychaeta												
Capitella capitata	0	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	1
Eteone nr. *longa*	0	0	0	0	1	0	1	1	0	0	0.3 ± 0.5	3
ARTHROPODA - Gammaridea												
Eohaustorius eous	3	1	2	1	0	0	1	2	6	1	1.7 ± 1.8	17
S	1	1	1	1	1	1	2	2	1	1		
N	3	1	2	1	1	1	2	3	6	1		

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x}$ ± s		Total
						Level 3							
ANNELIDA - Polychaeta													
Eteone nr. *longa*	0	1	0	0	0	0	0	0	0	0	0.1	0.3	1
Paraonella platybranchia	0	0	0	0	0	0	1	1	2	0	0.4	0.7	4
Scolelepis Sp. A	0	0	0	0	0	0	0	1	0	0	0.1	0.3	1
Scoloplos armiger	1	0	0	0	0	0	0	0	0	1	0.2	0.4	2
ARTHROPODA - Gammaridae													
Eohaustorius eous	1	4	2	5	5	1	6	2	1	3	3.0	1.9	30
Paraphoxus milleri	1	0	0	0	0	0	0	0	0	0	0.1	0.3	1
S	3	2	1	1	1	1	1	3	2	2			
N	3	5	2	5	5	2	7	4	3	4			
						Level 4 (lower)							
ANNELIDA - Polychaeta													
Eteone nr. *longa*	0	0	1	0	0	0	0	0	0	0	0.1	0.3	1
Paraonella platybranchia	0	0	0	0	0	1	0	0	0	0	0.1	0.3	1
Scolelepis Sp. A	0	1	0	0	1	0	1	0	1	0	0.4	0.5	4
ARTHROPODA - Gammaridea													
Anisogammarus cf *confervicolus*	0	0	0	0	0	0	0	1	0	0	0.1	0.3	1
Eohaustorius eous	4	5	10	16	11	6	9	1	6	6	7.4	4.2	74
Paraphoxus milleri	0	1	0	0	0	0	0	0	1	0	0.2	0.4	2
ARTHORPODA - mysidacea													
Archaecmysis grebnitzkii	0	0	0	1	0	0	0	0	0	0	0.1	0.3	1
S	1	3	2	2	2	2	2	2	3	1			
N	4	7	11	17	12	6	10	3	8	6			

APPENDIX 4.4.2. ABUNDANCE DATA FOR CORE SAMPLES FROM DEEP CREEK BEACH; 7 APRIL 1977.

TAXA	1	2	3	4	5	6	7	8	9	10	x̄ ± s	Total
Level 1 (Upper)												
ANNELIDA - Polychaeta												
Eteone nr. *longa*	1	0	1	0	0	0	0	0	1	0	0.3 ± 0.5	3
Scoloplos armiger	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	1
ARTHROPODA - Gammaridea												
Anisogammarus cf *confervicolus*	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Eohaustorius eous	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	1
Paraphoxus milleri	0	2	0	0	2	0	0	0	0	0	0.4 ± 0.8	4
S	1	2	1	0	1	0	1	1	1	0		
N	1	3	1	0	2	0	1	1	1	0		
Level 2												
ANNELIDA - Polychaeta												
Capitella capitata	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Nephtys ?ciliata	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	1
Paraonella platybranchia	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	1
ARTHROPODA - Gammaridea												
Eohaustorius eous	0	1	2	0	1	4	10	4	4	1	2.7 ± 3.0	27
Paraphoxus milleri	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	1
S	0	2	1	0	1	1	2	2	1	2		
N	0	2	2	0	1	4	11	5	4	2		

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x}$ ± s	Total
Level 3												
ANNELIDA - Polychaeta												
Paraonella platybranchia	0	0	0	1	0	0	0	1	0	0	0.2 ± 0.4	2
Scoloplos armiger	0	0	0	0	0	0	0	0	2	0	0.2 ± 0.6	2
Scolelepis Sp. A	0	0	0	0	0	0	0	0	1	0	0.1 ± 0.3	1
ARTHROPODA - Gammaridea												
Eohaustorius eous	3	7	2	3	0	0	0	3	2	8	2.8 ± 2.8	28
?Ischyroceridae, unid.	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	1
Paraphoxus milleri	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
S	2	1	1	2	1	0	0	2	3	1		
N	4	7	2	4	1	0	0	4	5	8		
Level 4 (Lower)												
ANNELIDA - Polychaeta												
Nephtys ?ciliata	0	0	2	0	0	0	0	0	0	0	0.2 ± 0.6	2
Scoloplos armiger	0	1	1	0	0	0	0	0	0	0	0.2 ± 0.4	2
Scolelepis Sp. A	1	1	1	1	0	0	0	2	2	1	0.9 ± 0.7	9
ARTHROPODA - Gammaridea												
Anisogammarus cf. *confervicolus*	0	0	0	1	0	0	0	0	0	0	0.1 ± 0.3	1
Eohaustorius eous	15	7	3	8	13	4	3	16	13	7	8.9 ± 5.0	89
Gammaridea, unid.	0	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	1
Lysianassidae, unid.	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	1
Paraphoxus milleri	0	1	0	1	0	0	0	0	0	1	0.3 ± 0.5	3
S	2	4	5	4	1	2	1	2	2	3		
N	16	10	8	11	13	5	3	18	15	9		

APPENDIX 4.4.3. ABUNDANCE DATA FOR CORE SAMPLES FROM DEEP CREEK BEACH; 29 JULY 1977.

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x}$ ± s	Total
					Level 1 (Upper)							
ANNELIDA - Polychaeta												
Eteone nr. *longa*	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	1
Paraonella platybranchia	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Scolelepis Sp. A	1	1	0	1	0	1	0	0	0	1	0.5 ± 0.5	5
ARTHROPODA - Gammaridea												
Eohaustorius eous	2	7	0	4	1	3	1	4	2	4	2.8 ± 2.0	28
Gammaridae, Sp. A	1	0	1	1	1	0	0	0	0	0	0.4 ± 0.5	4
S	4	2	1	3	2	2	1	2	1	2	2.0 ± 0.9	
N	5	8	1	6	2	4	1	5	2	5	3.9 ± 2.3	
					Level 2							
ANNELIDA - Polychaeta												
Abarenicola Sp.	0	0	1	0	0	0	1	0	0	0	0.2 ± 0.4	2
Capitella capitata	0	0	0	0	0	0	0	1	0	1	0.2 ± 0.4	2
Eteone nr. *longa*	0	0	0	2	0	0	0	0	0	0	0.2 ± 0.6	2
Paraonella platybranchia	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	1
Scolelepis Sp. A	1	0	1	1	2	1	1	2	1	1	1.1 ± 0.6	11
Scoloplos armiger	0	0	1*	1*	1	1	0	0	0	0	0.4 ± 0.5	4
ARTHROPODA - Gammaridea												
Eohaustorius eous	4	8	6	2	11	6	9	3	2	1	5.2 ± 3.4	52
Gammaridae Sp. A	46	0	0	0	1	0	30	14	0	3	9.4 ± 16.1	94

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x}$ ± s	Total
					Level 2 Cont.							
Lamprops quadriplicata	0	0	0	0	0	0	1	0	1	0	0.2 ± 0.4	2
Oedocerotidae Sp.	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	1
Paraphoxus milleri	0	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	1
Synchelidium Sp.	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	1
ARTHROPODA - Mysidacea												
Archaeomysis grebnitzkii	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	1
S	3	1	5	4	6	4	5	4	3	4	3.9 ± 1.4	
N	51	8	10	6	17	9	42	20	4	6	17.3 ± 16.3	
					Level 3							
ANNELIDA - Polychaeta												
Chaetozone setosa	0	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	1
Nephtys ?ciliata	0	0	0	0	0	0	1*	0	0	0	0.1 ± 0.3	1
Paraonella platybranchia	0	1*	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Scolelepis Sp. A	0	0	0	1	0	1	0	2	0	0	0.4 ± 0.7	4
Scoloplos armiger	1	1*	0	0	0	0	1*	1	1*	0	0.5 ± 0.5	5
ARTHROPODA - Gammaridea												
Atylidae Sp. A	0	0	0	1	0	0	0	0	0	0	0.1 ± 0.3	1
Eohaustorius eous	12	9	2	6	15	6	5	7	4	4	7.0 ± 4.0	70
Gammaridae Sp. A	3	0	1	2	0	2	3	0	0	0	1.1 ± 1.3	11
Lamprops quadriplicata	1	0	0	1	1	0	0	0	1	0	0.4 ± 0.5	4
Paraphoxus milleri	1	0	0	0	0	0	0	1	0	0	0.2 ± 0.4	2
Synchelidium Sp.	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	
S	5	3	2	5	3	4	4	4	3	1	3.4 ± 1.3	
N	18	11	3	11	17	10	10	11	6	4	10.1 ± 4.9	

TAXA	1	2	3	4	5	6	7	8	9	10	x̄ ± s	Total
					Level 4 (Lower)							
ANNELIDA - Polychaeta												
Capitella capitata	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	1
Nephtys ?ciliata	0	1*	0	0	1	0	0	0	0	0	0.2 ± 0.4	2
Paraonella platybranchia	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	1
Scolelepis Sp. A	0	0	0	1	2	2	2	0	0	2	0.9 ± 1.0	9
Scoloplos armiger	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	1
ARTHROPODA - Gammaridea												
Eohaustorius eous	3	7	9	6	1	0	19	2	2	4	5.3 ± 5.6	53
Gammaridae Sp. A	1	0	0	0	2	3	0	2	0	5	1.3 ± 1.7	13
Paraphoxus milleri	1	0	0	2	0	0	0	0	0	0	0.3 ± 0.7	3
S	3	2	1	3	4	2	4	2	1	4	3.3 ± 2.4	
N	5	8	9	9	6	5	23	4	2	12	7.8 ± 6.4	

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* Fragment

APPENDIX 4.4.4. DENSITY OF ORGANISMS IN INFAUNAL SAMPLES BY LEVEL AT DEEP CREEK, 4 FEBRUARY 1977

	Density (No./m^2)			
TAXA Station No.:	1	2	3	4*
ANNELIDA - Polychaeta				
Capitella capitata	25.5	12.7	0	0
Eteone nr. *longa*	114.6	38.2	12.7	12.7
Paraonella platybranchia	0	0	50.9	12.7
Scolelepis Sp. A	0	0	12.7	50.9
Scoloplos armiger	0	0	25.5	0
ARTHROPODA - Gammaridea				
Anisogammarus cf. *confervicolus*	12.7	0	0	12.7
Eohaustorius eous	76.4	216.4	381.9	942.2
Paraphoxus milleri	0	0	12.7	25.5
ARTHROPODA - Mysidacea				
Archaeomysis grebnitzkii	0	0	0	12.7
Total Number of Specimens:	18	21	39	84

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* Lowest level on beach

APPENDIX 4.4.5. DENSITY OF ORGANISMS IN INFAUNAL SAMPLES BY LEVEL AT DEEP CREEK, 7 APRIL 1977

	Density (No./m^2)			
TAXA Station No.:	1	2	3	4*
ANNELIDA - Polychaeta				
Capitella capitata	0	12.7	0	0
Eteone nr. *longa*	38.2	0	0	0
Nephtys ?*ciliata*	0	12.7	0	25.5
Paraonella platybranchia	0	12.7	25.5	0
?*Scolelepis* Sp. A	0	0	12.7	114.6
Scoloplos armiger	12.7	0	25.5	25.5
ARTHROPODA - Gammaridea				
Anisogammarus cf. *confervicolus*	12.7	0	0	12.7
Eohaustorius Sp.	12.7	343.7	356.4	1133.0
Gammaridea, unid.	0	0	12.7	25.5
Paraphoxus Sp.	50.9	12.7	12.7	38.2
Total Number of Specimens:	10	31	35	108

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* Lowest level on beach

APPENDIX 4.4.6. DENSITY OF ORGANISMS IN INFAUNAL SAMPLES BY LEVEL AT DEEP CREEK, 29 JULY 1977

	Density (No./m^2)			
TAXA Station No.:	1	2	3	4*
ANNELIDA - Polychaeta				
Abarenicola Sp.	0	25.5	0	0
Capitella capitata	0	25.5	0	12.7
Chaetozone setosa	0	0	12.7	0
Eteone nr. longa	12.7	25.5	0	0
Nephtys ?ciliata	0	0	12.7	25.5
Paraonella platybranchia	12.7	12.7	12.7	12.7
Scolelepis Sp. A	63.7	140.1	50.9	114.6
Scoloplos armiger	0	50.9	63.7	12.7
ARTHROPODA - Gammaridea				
Atylidae Sp. A	0	0	12.7	0
Eohaustorius eous	356.6	662.1	891.3	674.8
Gammaridae Sp. A	50.9	1196.8	140.1	165.5
Lamprops quadriplicata	0	25.5	50.9	0
Paraphoxus milleri	0	12.7	25.5	38.2
Synchelidium Sp.	0	12.7	12.7	0
ARTHROPODA - Mysidacea				
Archaeomysis grebnitzkii	0	12.7	0	0
Total Number of Specimens:	39	173	101	83

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* Lowest level on beach

APPENDIX 4.4.7. POOLED SIZE DATA FOR *EOHAUSTORIUS EOUS* AT DEEP CREEK IN 1977

Size Class (mm)	4/7/77	7/29/77
1.3 - 1.5		1
1.6 - 1.8		1
1.9 - 2.1	2	6
2.2 - 2.4	12	8
2.5 - 2.7	13	16
2.8 - 3.0	7	19
3.1 - 3.3	7	10
3.4 - 3.6	8	17
3.7 - 3.9	9	21
4.0 - 4.2	19	31
4.3 - 4.5	15	33
4.6 - 4.8	26	14
4.9 - 5.1	12	12
5.2 - 5.4	7	4
5.5 - 5.7	3	2
5.8 - 6.0	1	
Mean length (mm)	3.9	3.8
s	1.0	0.9

APPENDIX 4.4.8. LENGTH DATA FOR UNID. GAMMARIDAE WITH DARK EYE AND COARSE ANTENNAE, DEEP CREEK, 29 JULY 77

	1	2	3	4	Total
1.5		3			3
1.6		2			2
1.7		1	1	1	3
1.8		2			2
1.9	1	3			4
2.0	1	3		3	7
2.1		3			3
2.2		9	3	2	14
2.3		8	1	1	10
2.4		1	1	2	4
2.5	1	8	2	1	12
2.6		2	1		3
2.7		5		1	6
2.8		7			7
2.9		4			4
3.0		1		1	2
3.1		1			1
3.2		3		1	4
3.3		3			3
3.4		3			3
3.5		1	1		2
3.6		1			1
3.7		2			2
7.0		1			1

$n = 103$

$\bar{x} = 2.52$

$s = 0.69$

APPENDIX 4.4.9. SAMPLE DATA FOR HOMER SPIT BEACH; 17 February 1977.

TAXA	1	2	3	4	5	$\bar{x} \pm s$	Total
Cores* near 30m level							
ANNELIDA - Polychaeta							
Eteone nr. *longa*	0	0	0	0	1	0.2 ± 0.4	1
Paraonella platybranchia	2	1	0	0	1	0.8 ± 0.8	4
Scolelepis Sp. A	1	1	1	1	2	1.2 ± 0.4	6
ARTHROPODA - Mysidacea							
Archaeomysis grebnitzkii	0	0	0	0	1	0.2 ± 0.4	1
Total	3	2	1	1	5		
Cores* near 75m level							
ANNELIDA - Polychaeta							
Nephtys ?ciliata	0	1	0	0	0	0.2 ± 0.4	1
Scolelepis Sp. A	1	0	0	2	0	0.6 ± 0.9	3
Spionidae, unid.	0	1	0	0	0	0.2 ± 0.4	1
Typosyllis Sp.	0	1	0	0	0	0.2 ± 0.4	1
ARTHROPODA - Gammaridea							
Eohaustorius eous	0	1	0	0	1	0.4 ± 0.5	2
Total	1	4	0	2	1		

TAXA	1	2	3	4	5	x ± s	Total
	Cores* from 100m level						
ANNELIDA - Polychaeta							
Magelona pitelkai	0	1	0	0	0	0.2 ± 0.4	1
Paraonella platybranchia	1	4	3	0	4	2.4 ± 1.8	12
Scolelepis Sp. A	1	2	1	5	2	2.2 ± 1.6	11
ARTHROPODA - Gammaridea							
Eohaustorius eous	0	0	1	0	0	0.2 ± 0.4	1
Gammaridae, unid. (red-striped)	0	0	1	0	1	0.4 ± 0.5	2
Paraphoxus milleri	1	0	1	1	1	0.8 ± 0.4	4
PISCES							
Ammodytes hexapterus	0	0	1	1	0	0.4 ± 0.5	2
Total	3	7	8	7	8		
	Cores* from 132m level						
ANNELIDA - Polychaeta							
Magelona pitelkai	0	0	0	1	0	0.2 ± 0.4	1
Paraonella platybranchia	0	0	2	2	3	1.4 ± 1.3	7
Scolelepis Sp. A	8	2	5	6	2	4.6 ± 2.6	23
ARTHROPODA - Gammaridea							
Gammaridae, unid. (red-striped)	0	2	2	0	0	0.8 ± 1.1	4
Paraphoxus milleri	0	0	0	1	2	0.6 ± 0.9	3
MOLLUSCA - Gastropoda							
Littorina sitkana	0	0	2	0	0	0.4 ± 0.9	2
MOLLUSCA - Pelecypoda							
Spisula polynyma	0	0	0	2	0	0.4 ± 0.9	2
Total	8	4	11	12	7		

APPENDIX 4.4.10. SAMPLE DATA FOR HOMER SPIT BEACH; 7 MARCH 1977

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x} \pm s$	Total
						Cores* from 30m level						
ANNELIDA - Polychaeta												
Nephtys ?ciliata	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	1
Scolelepis Sp. A	0	0	0	1	2	0	0	3	1	0	0.7 ± 1.1	7
ARTHROPODA - Gammaridea												
Paraphoxus milleri	0	0	0	1	0	0	0	0	0	0	0.1 ± 0.3	1
Total	0	0	0	2	2	0	1	3	1	0		
						Cores* from 75m level						
ANNELIDA - Polychaeta												
Nephtys ?ciliata	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	1
Paraonella platybranchia	0	0	0	0	0	0	1	1	0	2	0.4 ± 0.7	4
Scolelepis Sp. A	0	1	1	0	1	4	1	3	2	0	1.3 ± 1.3	13
ARTHROPODA - Gammaridea												
Anonyx Sp.	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	1
Eohaustorius eous	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Paraphoxus milleri	1	0	0	0	1	1	0	0	2	0	0.5 ± 0.7	5
Total	2	1	1	0	2	5	3	4	4	3		

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x}$ ± s	Total
Cores* from 100m level												
ANNELIDA - Polychaeta												
Nephtys ?ciliata	0	0	0	0	0	0	0	0	1	0	0.1 ± 0.3	1
Paraonella platybranchia	0	1	0	2	1	1	2	0	1	0	0.8 ± 0.8	8
Sabellidae, unid.	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	1
Scolelepis Sp. A	2	1	1	4	4	1	5	0	7	5	3.0 ± 2.3	30
Scoloplos armiger	0	0	0	0	0	0	2	0	0	0	0.2 ± 0.6	2
ARTHROPODA - Gammaridea												
Eohaustorius eous	0	0	0	1	1	0	0	0	0	0	0.2 ± 0.4	2
Paraphoxus milleri	1	0	2	0	0	0	0	0	0	0	0.3 ± 0.7	3
MOLLUSCA - Pelecypoda												
Mytilus edulis (juv.)	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	1
Total	3	2	5	7	6	2	9	0	9	5		
Cores* from 135m level												
ANNELIDA - Polychaeta												
Magelona pitelkai	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Scolelepis Sp. A	19	1	6	16	4	12	3	5	1	4	7.1 ± 6.3	71
ARTHROPODA - Gammaridea												
Eohaustorius eous	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Paraphoxus milleri	1	0	1	0	1	0	0	1	0	3	0.7 ± 0.9	7
MOLLUSCA - Pelecypoda												
Spisula polynyma (juv.)	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	1
CHORDATA - Pisces												
Ammodytes hexapterus	0	0	0	0	0	0	1	1	0	0	0.2 0.4	2
Total	21	2	7	16	5	12	5	7	1	7		

APPENDIX 4.4.11. SAMPLE DATA FOR HOMER SPIT BEACH; 28 July 1977

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x} \pm s$	Total
					Cores* from 30m level							
PLATYHELMINTHES												
Turbellaria, unid.	0	0	0	1	0	0	0	0	0	0	0.1 ± 0.3	1
ANNELIDA - Polychaeta												
Nephtys Sp. (juv.)	0	0	0	1	1	1	0	1	0	0	0.4 ± 0.5	4
Paraonella platybranchia	0	0	0	3	3	4	5	0	0	0	1.5 ± 2.0	15
Scolelepis Sp. A	0	0	2	0	2	4	1	1	4	1	1.5 ± 1.5	15
Spiophanes ?bombyx	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	1
ARTHROPODA - Crustacea												
Crangon ?alaskensis elongata (juv.)	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	1
Lamprops carinata	0	0	0	0	1	1	0	2	1	0	0.5 ± 0.7	5
L. quadriplicata	0	0	0	0	6	2	2	5	1	0	1.6 ± 2.2	16
Eohaustorius eous	0	0	1	0	1	0	0	0	0	0	0.2 ± 0.4	2
Gammaridae, unid.	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	1
Paraphoxus milleri	0	1	0	0	0	0	0	0	1	0	0.2 ± 0.4	2
MOLLUSCA - Pelecypoda												
Protothaca staminea	0	0	0	0	0	0	0	0	1	0	0.1 ± 0.3	1
Total	0	1	4	5	15	12	8	10	8	1		

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x} \pm s$	Total
Cores* from 75m level												
ANNELIDA - polychaeta												
Capitella capitata	0	0	0	0	0	0	1	4	0	0	0.5 ± 1.3	5
Nephtys ?ciliata	1	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	1
Nephtys Sp. (juv.)	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Paraonella platybranchia	2	4	2	1	3	1	0	0	0	0	1.3 ± 1.4	13
Scolelepis Sp. A	1	4	1	2	0	3	1	0	1	2	1.5 ± 1.3	15
ARTHROPODA - Crustacea												
Crangon ?alaskensis elongata (juv.)	0	0	0	0	1	0	0	0	1	0	0.2 ± 0.4	2
Eohaustorius eous	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	1
Lamprops carinata	1	0	0	1	0	0	0	0	0	0	0.2 ± 0.4	2
L. quadriplicata	0	0	0	0	2	1	1	0	0	0	0.4 ± 0.7	4
Lamprops Sp.	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	1
Synchelidium Sp.	0	0	0	1	0	0	0	0	0	0	0.1 ± 0.3	1
Total	6	9	3	5	6	6	3	5	2	2		
Cores* from 100m level												
ANNELIDA - Polychaeta												
Capitella capitata	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	1
Nephtys Sp. (juv.)	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	1
Paraonella platybranchia	3	4	3	4	0	4	3	1	1	6	2.9 ± 1.8	29
Scolelepis Sp. A	6	2	2	3	3	2	3	1	5	7	3.4 ± 2.0	34

TAXA	1	2	3	4	5	6	7	8	9	10	$\bar{x} \pm s$	Total
Cores* from 100m level Cont.												
ARTHROPODA - Crustacea												
Eohaustorius eous	1	0	0	1	0	0	1	1	0	0	0.4 ± 0.5	4
Lamprops carinata	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	1
Paraphoxus milleri	0	0	0	0	0	1	0	0	0	1	0.2 ± 0.4	2
Synchelidium Sp.	0	0	0	0	2	0	0	0	0	0	0.2 ± 0.6	2
PISCES												
Ammodytes hexapterus	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	1
Total	10	6	7	8	6	7	8	3	6	14		
Cores* from 135m level												
ANNELIDA - Polychaeta												
Capitella capitata	0	2	0	0	0	0	0	0	0	0	0.2 ± 0.6	2
Eteone nr. *longa*	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	1
Paraonella platybranchia	0	1	0	2	2	0	4	1	0	0	1.0 ± 1.3	10
Scolelepis Sp. A	14	3	8	9	12	7	11	16	8	20	10.8 ± 4.9	108
ARTHROPODA - Crustacea												
Crangon ?alaskensis elongata	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	1
Eohaustorius eous	0	0	0	0	0	0	0	0	1	1	0.2 ± 0.4	2
Lamprops carinata	1	1	0	0	0	1	2	0	4	2	1.1 ± 1.3	11
L. quadriplicata	0	2	0	0	0	0	1	1	1	0	0.5 ± 0.7	5
Paraphoxus milleri	0	0	0	1	0	1	0	0	0	0	0.2 ± 0.4	2
MOLLUSCA - Pelecypoda												
Spisula polynyma	0	0	0	0	0	0	0	0	2	0	0.2 ± 0.6	2
Total	15	9	8	12	14	9	18	18	16	25		

APPENDIX 4.4.12. DENSITY OF ORGANISMS IN INFAUNAL SAMPLES BY LEVEL AT HOMER SPIT BEACH; 17 FEBRUARY 1977

TAXA	Density (No./m^2)			
	30m	75m	100m	132m*
ANNELIDA - Polychaeta				
Eteone nr. *longa*	25.5	0	0	0
Magelona pitelkai	0	0	25.5	25.5
Nephtys ?ciliata	0	25.5	0	0
Paraonella platybranchia	101.9	0	305.6	178.3
Scolelepis Sp. A	152.8	76.4	280.1	585.7
Spionidae, unid.	0	25.5	0	0
Typosyllis Sp.	0	25.5	0	0
ARTHROPODA - Gammaridae				
Eohaustorius eous	0	50.9	25.5	0
Gammaridae, unid. (red-striped)	0	0	50.9	101.8
Paraphoxus milleri	0	0	101.8	76.4
ARTHROPODA - Mysidacea				
Archaeomysis grebnitzkii	25.5	0	0	0
MOLLUSCA - Gastropoda				
Littorina sitkana	0	0	0	50.9
MOLLUSCA - Pelecypoda				
Spisula polynyma	0	0	0	50.9
PISCES				
Ammodytes hexapterus	0	0	50.9	0

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* lowest level on beach

APPENDIX 4.4.13. DENSITY OF ORGANISMS IN INFAUNAL SAMPLES BY LEVEL AT HOMER SPIT BEACH; 7 MARCH 1977

TAXA	Density (No.m^2) 30m	75m	100m	135m*
ANNELIDA - Polychaeta				
Magelona pitelkai	0	0	0	12.7
Nephtys ?ciliata	12.7	12.7	12.7	0
Paraonella platybranchia	0	50.9	101.9	0
?Sabellidae, unid.	0	0	12.7	0
Scolelepis Sp. A	89.1	165.5	382.0	904.0
Scoloplos armiger	0	0	25.5	0
ARTHROPODA - Gammaridea				
Anonyx Sp.	0	12.7	0	0
Eohaustorius eous	0	12.7	25.5	12.7
Paraphoxus milleri	12.7	63.7	38.2	89.1
MOLLUSCA - Pelecypoda				
Mytilus edulis (juv.)	0	0	12.7	0
Spisula polynyma	0	0	0	12.7
PISCES				
Ammodytes hexapterus	0	0	0	25.5

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* lowest level on beach

APPENDIX 4.4.14. DENSITY OF ORGANISMS IN INFAUNAL SAMPLES BY LEVEL AT HOMER SPIT BEACH; 28 JULY 1977

	Density (No./m^2)			
TAXA	30m	75m	100m	135m*
PLATYHELMINTHES				
Turbellaria, unid.	12.7	0	0	0
ANNELIDA - Polychaeta				
Capitella capitata	0	63.7	12.7	25.5
Eteone nr. *longa*	0	0	0	12.7
Nephtys ?ciliata	0	12.7	0	0
Nephtys Sp. (juv.)	50.9	12.7	12.7	0
Paraonella platybranchia	191.0	165.5	369.2	127.3
Scolelepis Sp. A	191.0	191.0	432.9	1375.1
Spiophanes ?bombyx	12.7	0	0	0
ARTHROPODA - Crustacea				
Crangon ?alaskensis elongata	12.7	25.5	0	12.7
Eohaustorius eous	25.5	12.7	50.9	25.5
Lamprops carinata	63.7	25.5	12.7	140.1
L. quadriplicata	203.7	50.9	0	63.7
Lamprops Sp.	0	12.7	0	0
Paraphoxus milleri	25.5	0	25.5	25.5
Synchelidium Sp.	12.7	12.7	25.5	0

TAXA	Density (No./m^2) 30m	75m	100m	135m*
MOLLUSCA - Pelecypoda				
Protothaca staminea	12.7	0	0	0
Spisula polynyma	0	0	0	25.5
PISCES				
Ammodytes hexapterus	0	0	12.7	0

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* lowest level on beach

APPENDIX 4.4.15. ABUNDANCE DATA FOR CORE SAMPLES FROM THE +3.6 FOOT LEVEL AT GLACIER SPIT, CHINITNA BAY INTERTIDAL AREA; 6 APRIL 1977

TAXA	Number Per Core Sample										x ± s	Estimated no./m^2
ECHIURIDAE												
Echiurus echiurus	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
ANNELIDA - Polychaeta												
Abarenicola pacifica	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
Capitella capitata	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	12.7
Eteone nr *longa*	0	0	1	0	0	0	0	0	2	0	0.3 ± 0.7	38.2
Glycinde polygnatha	0	0	0	0	1	0	0	0	0	1	0.2 ± 0.4	25.5
Harmothoe imbricata	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
Malacoceros sp	0	0	0	0	2	0	0	0	0	0	0.2 ± 0.6	25.5
Nephtys sp	1	0	2	0	0	0	1	1	0	0	0.5 ± 0.7	63.7
Nephtys sp (juv.)	0	1	1	0	3	1	1	0	0	0	0.7 ± 0.9	89.1
Paraonidae, unid.	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Phyllodoce groenlandica	0	0	0	0	2	0	0	0	0	0	0.2 ± 0.6	25.5
Potamilla sp	0	1	4	0	0	0	0	0	0	0	0.5 ± 1.3	63.7
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (juv.)	0	1	0	1	2	0	0	0	0	1	0.5 ± 0.7	63.7
Macoma balthica	25	31	26	46	45	32	41	22	32	65	36.5 ± 13.0	4647.3
Mya arenaria	0	0	0	0	2	1	1	2	0	1	0.7 ± 0.8	89.1
Mya sp	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	12.7
Mya spp (juv.)	0	0	0	1	8	0	2	0	0	1	1.2 ± 2.5	152.8
Pseudopythina sp	0	1	1	0	1	0	0	0	0	4	0.7 ± 1.3	89.1
No. of Individuals	27	36	35	48	67	34	47	25	34	75		
No. of Species	3	6	5	3	10	3	4	3	2	8		

ABUNDANCE DATA FOR CORE SAMPLES FROM THE +2.5 FOOT LEVEL AT GLACIER SPIT, CHINITNA BAY INTERTIDAL AREA; 6 APRIL 1977

TAXA	Number Per Core Sample										x ± s	Estimated no./m^2
ECHIURIDAE												
Echiurus echiurus	1	0	1	1	0	1	1	1	2	0	0.8 ± 0.6	101.9
ANNELIDA - Polychaeta												
Aphroditoididae	1	0	0	0	0	0	1	0	0	1	0.3 ± 0.5	38.2
Capitella capitata	0	2	0	0	0	0	0	0	0	0	0.2 ± 0.4	25.5
Eteone nr *longa*	0	1	0	0	1	1	0	1	0	0	0.4 ± 0.5	50.9
Glycinde polygnatha	0	0	1	1	0	0	0	1	0	0	0.3 ± 0.5	38.2
Harmothoe imbricata	0	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	12.7
Nephtys sp	2	1	1	0	0	1	0	0	1	1	0.7 ± 0.7	89.1
Nephtys sp (juv.)	2	2	2	0	0	0	2	1	1	1	1.1 ± 0.9	140.1
Polydora caulleryi	0	0	0	0	1	0	0	0	1	0	0.2 ± 0.4	25.5
Potamilla sp	0	2	1	1	0	0	1	0	0	1	0.6 ± 0.7	76.4
ARTHROPODA - Isopoda												
Saduria entomon	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	12.7
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (juv.)	0	1	1	0	0	0	1	0	1	0	0.4 ± 0.5	50.9
Macoma balthica	40	33	29	32	35	35	32	53	22	38	34.9 ± 8.1	4443.6
Mya arenaria	0	1	0	1	0	0	0	1	1	1	0.5 ± 0.5	63.6
M. priapus	0	0	0	0	0	1	0	0	1	0	0.2 ± 0.4	25.5
Mya sp fragment	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
Mya spp (juv.)	1	3	0	0	3	0	0	2	0	1	1.0 ± 1.2	127.3
Pseudopythina sp	0	6	4	2	0	0	0	1	3	0	1.6 ± 2.1	203.7
No. of Individuals	47	52	40	38	40	40	38	62	33	45		
No. of Species	5	9	7	6	4	6	6	9	8	6		

ABUNDANCE DATA FOR CORE SAMPLES FROM THE +0.9 FOOT LEVEL AT GLACIER SPIT, CHINITNA BAY INTERTIDAL AREA; 6 APRIL 1977

TAXA	Number Per Core Sample										x ± s	Estimated no./m^2
ECHIURIDAE												
Echiurus echiurus	0	0	0	0	0	0	0	0	1	0	0.1 ± 0.3	12.7
ANNELIDA - Polychaeta												
Ampharete acutifrons	1	0	0	0	0	0	0	0	0	1	0.2 ± 0.4	25.5
Capitella capitata	1	0	1	0	0	0	0	0	0	0	0.2 ± 0.4	25.5
Eteone nr *longa*	0	0	0	1	0	1	0	0	1	0	0.3 ± 0.5	38.2
Harmothoe imbricata	0	0	0	0	0	0	0	0	1	0	0.1 ± 0.3	12.7
Malococeros sp	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
Nephtys sp	1	0	1	1	2	2	3	1	1	1	1.3 ± 0.8	165.5
Nephtys sp (juv.)	2	3	3	6	0	2	2	3	3	5	2.9 ± 1.7	211.7
Phyllodoce groenlandica	0	0	1	0	0	0	0	0	0	1	0.2 ± 0.4	25.5
Polydora caulleryi	0	0	0	0	0	0	2	0	0	0	0.2 ± 0.6	25.5
Potamilla sp	1	2	2	6	2	1	6	2	2	1	2.5 ± 1.9	318.3
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (juv.)	1	3	3	3	8	3	4	3	4	2	3.4 ± 1.8	432.9
Macoma balthica	37	37	38	37	50	38	57	29	64	33	42.0 ± 11.2	5347.6
Mya priapus	0	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	12.7
Mya sp	1	0	1	0	0	0	0	0	0	0	0.2 ± 0.4	25.5
Mya spp (juv.)	1	1	4	9	13	7	13	6	13	21	8.8 ± 6.3	1120.5
Pseudopythina sp	0	1	0	0	0	0	6	1	4	6	1.8 ± 2.5	229.2
No. of Individuals	46	47	54	63	75	54	93	45	94	72		
No. of Species	8	6	7	6	5	7	7	6	9	9		

ABUNDANCE DATA FOR CORE SAMPLES FROM THE -1.2 FOOT LEVEL AT GLACIER SPIT, CHINITNA BAY INTERTIDAL AREA; 6 APRIL 1977

TAXA	Number Per Core Sample										x ± s	Estimated no./m^2
ECHIURIDAE												
Echiurus echiurus	1	0	0	0	0	0	0	0	1	0	0.2 ± 0.4	25.5
ANNELIDA - Polychaeta												
Ampharete acutifrons	0	0	1	0	0	0	0	0	0	1	0.2 ± 0.4	25.5
Capitella capitata	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Eteone nr *longa*	0	1	0	0	0	1	0	0	0	0	0.2 ± 0.4	25.5
Glycinde polygnatha	0	0	0	0	0	1	1	0	1	0	0.3 ± 0.5	38.2
Malacoceros sp	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
Nephtys sp	3	1	1	1	1	0	2	0	0	0	1.0 ± 1.0	127.3
Nephtys sp (juv.)	5	1	0	0	5	4	3	0	0	1	2.1 ± 2.1	267.4
Phyllodoce groenlandica	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Polydora caulleryi	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Potamilla sp	0	0	0	1	0	1	0	0	0	0	0.2 ± 0.4	38.2
Scoloplos armiger	0	0	0	0	0	0	0	0	1	0	0.1 ± 0.3	12.7
?*Spio* sp	0	0	1	0	0	0	0	0	0	1	0.2 ± 0.4	38.2
ARTHROPODA - Amphipoda												
Tritella pilimana	0	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	12.7
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (juv.)	1	2	8	4	0	3	4	4	5	1	2.7 ± 1.7	343.8
Macoma balthica	31	32	52	33	28	44	39	40	23	31	33.4 ± 6.5	4252.6
Macoma sp	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
Mya arenaria	1	0	0	0	0	1	1	0	0	0	0.3 ± 0.5	38.2
Mya priapus	0	0	0	1	0	0	0	0	0	0	0.1 ± 0.3	12.7
Mya truncata	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	12.7
Mya spp (juv.)	13	12	13	6	5	35	9	17	2	8	11.9 ± 9.8	1515.2
Pseudopythina sp	0	1	0	0	0	0	1	1	1	1	0.5 ± 0.5	63.6
No. of Individuals	57	51	76	46	39	91	61	62	34	46		
No. of Species	8	7	6	6	3	9	8	4	7	9		

APPENDIX 4.4.16. ABUNDANCE DATA FOR CORE SAMPLES FROM THE +3.6 FOOT LEVEL AT GLACIER SPIT, CHINITNA BAY INTERTIDAL AREA; 30 JULY 1977

TAXA	Number Per Core Sample										x ± s	Estimated no./m²
ECHIURIDAE												
Echiurus echiurus	0	1	1	0	0	0	0	0	0	0	0.2 ± 0.4	25.5
ANNELIDA - Polychaeta												
Ampharete acutifrons	0	0	1	1	0	0	0	0	1	0	0.4 ± 0.5	51.0
Capitella capitata	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Eteone nr *longa*	1	1	1	0	1	0	1	0	0	0	0.5 ± 0.5	63.8
Eteone nr *pacifica*	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Harmothoe imbricata	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Malococeros sp	0	0	0	0	0	0	1	0	0	1	0.2 ± 0.4	25.5
Nephtys sp	0	2	0	1	3	1	0	1	2	1	1.1 ± 1.0	140.1
Nephtys sp (juv)	1	0	2	1	0	0	1	1	1	1	0.8 ± 0.6	102.0
Polydora caullervi	0	0	1	0	0	0	0	0	1	0	0.2 ± 0.4	25.5
Potamilla sp	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	12.7
Scoloplos armiger	0	1	0	0	0	0	0	0	0	1	0.2 ± 0.4	25.5
Spio filicornis	1	3	1	1	0	0	1	3	0	0	1.0 ± 1.2	127.6
ANNELIDA - Oligochaeta	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
ARTHROPODA - Crustacea												
Crangon sp	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
Tritella ?pilimana	0	0	0	0	1	0	0	0	1	0	0.2 ± 0.4	25.5
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (adult)	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	12.7
(juv)	0	0	0	0	0	0	0	1	1	0	0.2 ± 0.4	25.5
Macoma balthica	14	20	22	14	21	18	15	21	17	15	17.7 ± 3.1	2253.6
Mya arenaria	1	0	0	0	2	0	0	1	1	0	0.5 ± 0.7	63.8
M. priapus	0	0	0	0	1	0	1	0	0	0	0.2 ± 0.4	25.5
Mya sp (frag & juv.)	0	0	1	0	1	0	1	0	0	0	0.3 ± 0.5	38.2
Pseudopythina sp	0	2	3	0	0	0	1	1	0	0	0.7 ± 1.1	89.1
No. of Individuals	18	33	33	18	30	19	22	31	25	21		
No. of Species	5	10	9	4	6	2	7	8	7	6		

ABUNDANCE DATA FOR CORE SAMPLES FROM THE +2.5 FOOT LEVEL AT GLACIER SPIT, CHINITNA BAY INTERTIDAL AREA; 30 JULY 1977

TAXA	Number Per Core Sample										x ± s	Estimated no./m^2
ECHIURIDAE												
Echiurus echiurus	1	0	0	0	2	0	1	1	0	0	0.5 ± 0.7	63.8
ANNELIDA - Polychaeta												
Capitella capitata	1	8	0	0	6	0	0	0	0	0	1.5 ± 3.0	191.3
Eteone nr *longa*	1	4	3	2	3	0	0	1	0	0	1.4 ± 1.5	178.6
Eteone nr *pacifica*	2	0	0	0	0	0	0	0	0	0	0.2 ± 0.6	25.5
Harmothoe imbricata	1	0	1	0	1	0	0	1	0	0	0.4 ± 0.5	50.9
Malococeros sp	0	3	0	0	0	0	0	0	0	0	0.3 ± 0.9	38.3
Maldanidae (juv.)	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Nephtys sp (adults)	4	0	0	0	2	1	0	0	3	1	1.1 ± 1.4	140.3
(juv.)	1	8	2	4	0	1	0	1	1	2	2.0 ± 2.4	255.1
Phyllodoce groenlandica	0	0	0	0	0	0	2	0	0	0	0.2 ± 0.6	25.5
Polydora caulleryi	3	0	1	1	0	1	0	3	0	1	1.0 ± 1.2	127.5
Potamilla sp	4	1	0	4	0	1	2	0	0	0	1.2 ± 1.6	153.1
Scoloplos armiger	0	0	0	0	0	1	0	1	0	0	0.2 ± 0.4	25.5
Spio filicornis	6	4	4	5	3	1	1	9	3	2	3.8 ± 2.4	484.7
Spionidae, unid.	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	12.7
ARTHROPODA - Crustacea												
Crangon sp	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	12.7
Cyclopoida	0	0	0	0	0	0	0	1	0	1	0.2 ± 0.4	25.5
Harpacticoida	0	4	0	0	0	0	0	0	0	0	0.4 ± 1.3	50.9
Ischyroceridae	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	12.7
Tritella ?pilimana	0	6	0	3	0	2	0	0	3	7	2.1 ± 2.6	267.9
Insecta (larvae)	0	1	0	0	1	0	0	0	0	1	0.3 ± 0.5	38.3

+2.5 Foot Level Cont.

TAXA	Number Per Core Sample										x ± s	Estimated no./m^2
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (adult)	0	0	0	1	0	0	1	1	0	1	0.4 ± 0.7	50.9
(juv.)	0	1	0	0	0	0	0	1	0	0	0.2 ± 0.4	25.5
Macoma balthica	10	28	29	20	22	17	18	21	15	14	19.4 ± 6.0	2470.1
Mya arenaria	1	1	0	1	0	0	1	1	0	0	0.5 ± 0.5	63.8
M. priapus	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Mya spp (frag. & juv.)	1	0	0	1	0	2	0	0	1	1	0.6 ± 0.7	76.5
Pseudopythina sp	3	1	3	0	0	0	0	2	0	0	0.9 ± 1.2	114.6
No. of Individuals	39	72	43	42	42	27	27	46	26	31		
No. of Species	12	15	7	9	10	8	8	12	5	9		

ABUNDANCE DATA FOR CORE SAMPLES FROM THE +0.9 FOOT LEVEL AT GLACIER SPIT, CHINITNA BAY INTERTIDAL AREA; 30 JULY 1977

	Number Per Core Sample											Estimated
TAXA											x ± s	no./m^2
ECHIURIDAE												
Echiurus echiurus	0	1	1	0	0	1	0	0	2	0	0.5 ± 0.7	63.8
ANNELIDA												
Ampharete acutifrons	1	0	1	1	0	0	0	0	0	0	0.3 ± 0.5	38.3
Capitella capitata	1	0	1	0	0	11	0	0	0	0	1.3 ± 3.4	165.8
Eteone nr longa	0	2	1	1	0	4	0	0	2	0	1.0 ± 1.3	127.6
Harmothoe imbricata	2	1	0	2	0	1	1	2	1	0	1.0 ± 0.8	127.6
Malacoceros sp	1	2	0	0	0	0	0	0	0	0	0.3 ± 0.7	38.3
Nephtys sp (adult)	2	1	1	1	0	2	2	2	1	4	1.2 ± 0.8	153.1
(juv.)	2	1	0	0	0	1	1	1	0	0	0.6 ± 0.7	76.5
Oligochaeta, unid.	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Phyllodoce groenlandica	0	0	0	0	0	0	0	0	1	1	0.2 ± 0.4	25.5
Polydora caulleryi	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Polygordius sp	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Potamilla sp	6	2	6	8	4	2	5	2	0	1	3.6 ± 2.6	459.2
Scoloplos armiger	2	0	0	0	0	0	0	0	0	0	0.2 ± 0.6	25.5
Spio filicornis	14	2	6	2	1	5	12	0	1	1	4.4 ± 4.9	560.2
ARTHROPODA												
Acarina	0	0	0	0	0	1	0	0	0	0	0.1 ± 0.3	12.7
Cyclopoida	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Pontoporeia femorata	0	0	0	0	0	0	0	1	0	0	0.1 ± 0.3	12.7
Tritella ?pilimana	10	0	0	0	0	4	3	0	9	0	2.6 ± 3.9	331.6

+0.9 Foot Level Cont.

TAXA	Number Per Core Sample										x ± s	Estimated no./m^2
MOLLUSCA												
Clinocardium nuttallii (adult)	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	12.7
(juv.)	1	0	2	5	0	0	3	0	1	0	1.2 ± 1.7	152.8
Cylichna sp	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Macoma balthica	31	22	15	14	23	22	19	24	9	26	20.5 ± 6.4	2610.3
Mya arenaria	0	1	0	1	1	0	1	0	0	0	0.4 ± 0.5	50.9
M. priapus	0	2	1	0	0	0	2	1	0	0	0.6 ± 0.8	76.4
M. truncata	0	0	2	1	0	0	0	0	0	0	0.3 ± 0.7	38.2
Mya spp (frag. & juv.)	1	0	1	2	1	1	2	1	0	1	1.0 ± 0.7	127.6
Pseudopythina sp	0	1	2	2	0	7	1	2	2	0	1.7 ± 2.0	216.5
No. of Individuals	76	40	41	40	31	62	52	36	29	34		
No. of Species	14	13	13	11	5	12	10	7	10	6		

ABUNDANCE DATA FOR CORE SAMPLES FROM THE -1.2 FOOT LEVEL AT GLACIER SPIT, CHINITNA BAY INTERTIDAL AREA; 30 JULY 1977

TAXA	Number Per Core Sample										x ± s	Estimated no./m^2
ECHIURIDAE												
Echiurus echiurus	1	0	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
ANNELIDA - Polychaeta												
Ampharete acutifrons	0	0	0	0	0	1	0	0	1	0	0.2 ± 0.4	25.5
Axiothella rubrocincta	0	1	0	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Capitella capitata	1	0	1	0	0	0	3	0	0	1	0.6 ± 1.0	76.5
Eteone nr *longa*	2	0	0	1	1	0	3	1	0	1	0.9 ± 1.0	114.8
Harmothoe imbricata	1	0	1	0	0	0	1	1	0	1	0.5 ± 0.5	63.8
Malacoceros sp	0	0	0	0	0	1	2	0	0	1	0.4 ± 0.7	51.0
Nephtys sp	0	1	0	2	0	2	1	2	2	1	1.1 ± 1.1	140.3
Nephtys sp (juv.)	2	6	2	3	0	6	3	0	2	1	2.5 ± 2.1	318.9
Paraonella platybranchia	0	0	0	0	0	0	2	0	0	0	0.2 ± 0.6	25.5
Phyllodoce groenlandica	0	2	0	1	0	0	0	0	1	1	0.5 ± 0.7	63.8
Polydora caulleryi	1	1	0	0	0	1	1	0	0	0	0.4 ± 0.5	50.9
Potamilla sp	3	5	4	3	0	1	2	5	3	4	3.0 ± 1.6	382.0
Scoloplos armiger	1	0	0	0	0	1	0	0	0	0	0.2 ± 0.4	25.5
Spio filicornis	4	13	10	3	0	5	4	3	6	3	5.1 ± 3.8	650.5
NEMERTEA, unid.	0	0	0	1	0	0	0	1	0	0	0.2 ± 0.4	25.5
ARTHROPODA												
Acarina	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
Pontoporeia femorata	0	0	0	0	0	0	1	0	0	0	0.1 ± 0.3	12.7
Tritella ?pilimana	7	1	0	0	0	0	1	0	0	1	1.0 ± 2.2	127.6

-1.2 Foot Level Cont.

TAXA	Number Per Core Sample										x ± s	Estimated no./m^2
MOLLUSCA												
Aglaja diomadea	0	0	0	0	0	0	0	0	0	1	0.1 ± 0.3	12.7
Clinocardium nuttallii (adult)	0	0	1	0	0	0	0	0	0	0	0.1 ± 0.3	12.7
(juv.)	2	2	1	0	1	3	2	1	0	1	1.3 ± 0.9	165.5
Macoma balthica	50	19	30	21	28	27	23	20	18	22	25.8 ± 9.4	3285.0
Mya arenaria	0	0	0	0	1	0	0	0	0	0	0.1 ± 0.3	12.7
M. priapus	0	0	0	2	0	2	0	0	0	1	0.5 ± 0.8	63.8
M. truncata	0	0	0	0	1	1	0	0	0	0	0.2 ± 0.4	25.5
Mya spp (frag. & juv.)	2	1	1	0	1	2	3	0	0	1	1.1 ± 0.1	140.1
Pseudopythina sp	0	0	1	0	0	2	4	2	0	2	1.1 ± 1.3	140.1
No. of Individuals	77	52	53	37	33	55	56	36	33	43		
No. of Species	13	10	10	8	5	12	15	9	6	14		

APPENDIX 4.4.17. BIOMASS DATA (GRAMS WHOLE WET WEIGHT) FOR CORE SAMPLES FROM GLACIER SPIT, CHINITNA BAY, 6 APRIL 1977

TAXA	1	2	3	4	5	6	7	8	9	10	x̄ ± s	Biomass/m
					+3.6 Level							
ECHIURA												
Echiurus echiurus	0	0.377	0	0	0	0	0	0	0	0	0.038 ± 0.119	4.838
ANNELIDA - Polychaeta												
Abarenicola pacifica	0	0	0	0	0	0	0	0	0	0.024	0.002 ± 0.008	0.255
Capitella capitata	0	0	0	0	0.007	0	0	0	0	0	0.001 ± 0.002	0.127
Eteone nr *longa*	0	0	T	0	0	0	0	0	0.090	0	0.009 ± 0.028	1.146
Glycinde sp	0	0	0	0	0.001	0	0	0	0	0.047	0.005 ± 0.015	0.637
Harmothoe imbricata	0	0	0	0	0	0	0	0	0	0.007	0.001 ± 0.002	0.127
Malacocerus sp	0	0	0	0	0.001	0	0	0	0	0	T	T
Nephtys sp	0.005	0	0	0.14	0.726	0.054	0.139	0.10	0.005	0	0.017 ± 0.222	2.165
Nephtys sp (juv.)	0	0	T	0	T	T	T	0	0	0	T	0.026
Paraonidae, unid.	T	0	0	0	0	0	0	0	0	0	T	T
Phyllodoce groenlandica	0	0	0	0	0.017	0	0	0	0	0	0.002 ± 0.005	0.255
Potamilla sp	0	0.001	0	0	0.063	0	0	0	0	-	0.006 ± 0.020	0.764
ARTHROPODA - Crustacea												
Arthropod frag.	0	0	0	0.002	0	0	0	0	0	0	T	0.025

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m
					+3.6' Level Cont.							
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (juv.)	0	0.005	0	0.005	0.02	0	0	0	0	0.005	0.004 ± 0.006	0.509
Macoma balthica	4.32	4.69	2.31	4.59	4.00	3.48	3.33	2.55	5.50	7.88	4.3 ± 1.6	547.5
Mya arenaria	0	0	0	0	24.11	71.07	62.84	107.77	0	14.22	28.0 ± 38.8	3565.1
Mya spp (juv.)	0	0	0	0.005	0.05	0	0.01	0	0	0.01	0.008 ± 0.016	1.02
Mya sp (frag.)	0	0	0	0	0	0	3.03	0	0	0	0.3 ± 1.0	38.2
Pseudopythina sp	0	0.006	0.005	0	0.03	0	0	0	0	0.02	0.006 ± 0.011	0.76
Total	4.33	5.08	2.32	4.74	29.03	74.60	69.35	110.42	5.60	22.21	32.75 ± 38.35	4169.5
					+2.5' Level							
ECHIURA												
Echiurus echiurus	0.135	0	0.690	1.24	0	0.90	0.025	0.360	0.291	0	0.364 ± 0.439	46.35
ANNELIDA - Polychaeta												
Aphroditoidae, unid.	0.002	0	0	0	0	0.126	0	0	0.095	0	0.022 ± 0.047	2.801
Capitella capitata	0	0.001	0	0	0	0	0	0	0	0	T	T
Eteone nr *longa*	0	0.022	0	0	0.012	0.010	0	0.004	0	0	0.005 ± 0.008	0.637
Glycinde sp	0	0	0.075	0.006	0	0	0	0.030	0	0	0.011 ± 0.024	1.401
Harmothoe imbricata	0	0	0	0	0	0.029	0	0	0	0	0.003 ± 0.009	0.382

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m
					+2.5' Level Cont.							
Nephtys caeca	0.42	0.890	0.146	0	0.322	0.494	0	0	0.177	0.09	0.254 ± 0.285	32.34
Nephtys sp (juv.)	0.038	0.007	0.0 0	0	0	0	0.002	0.005	0.003	0.005	0.007 ± 0.011	0.891
Polydora caulleryi	0	0	0	0	0.003	0	0	0	0.002	0	T	0.06
Potamilla sp	0	0.017	0.040	0.008	0.022	0	0.003	0	0	0.034	0.012 ± 0.015	1.528
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (juv.)	0	0.005	0.01	0	0	0	0.01	0	0.01	0	0.004 ± 0.005	0.509
Macoma balthica	5.12	4.91	3.28	2.49	6.45	3.93	3.67	4.20	3.55	4.90	4.2 ± 1.1	534.7
Mya arenaria	0	51.61	0	7.17	0	0	0	62.62	39.20	9.86	17.0 ± 24.4	2164.5
M. priapus	0	0	0	0	0	7.05	0	0	6.10	0	1.3 ± 2.8	165.5
Mya sp (frag.)	0	0	0	0	0	0	0	0	0	0.84	0.08 ± 0.27	10.19
Mya spp (juv.)	0.01	0.02	0	0	0.02	0	0	0.005	0	0.6	0.07 ± 0.19	8.91
Pseudopythina sp	0	0.07	0.02	0.22	0	0	0	0.01	0.02	0	0.034 ± 0.07	4.33
Total	5.73	57.55	4.27	11.13	6.83	12.54	3.71	67.23	49.45	16.33	23.48 ± 24.55	2989.33

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m
						+0.9' Level						
ECHIURA												
Echiurus echiurus	0	0	0	0	0	0	0	0	1.099	0	0.110 ± 0.348	14.006
ANNELIDA - Polychaeta												
Ampharete acutifrons	0.010	0	0	0	0	0	0	0	0	0.001	0.001 ± 0.003	0.127
Capitella capitata	0.001	0	0	0	0	0	0	0	T	0	0.0001 ± 0.0003	0.013
Eteone nr *longa*	0	0	0	0.004	0	0.003	0	0	0.001	0	0.001 ± 0.001	0.127
Glycinde sp	0.020	0.005	0	0	0	0	0	0	0.050	0.070	0.015 ± 0.025	1.910
Harmothoe imbricata	0	0	0	0	0	0	0	0	0.195	0	0.020 ± 0.062	2.546
Malacocerus sp	0	0	0	0	0	0	0	0	0	0.001	0.0001 ± 0.0003	0.013
Nephtys sp	0.040	0	0.575	0.450	0.35	0.238	-	-	0.245	0.093	0.288 ± 0.189	29.03
Nephtys sp (juv.)	0.001	0.006	0.006	0.012	0	0.004	0.239	0.051	0.040	0.020	0.009 ± 0.013	1.146
Phyllodoce groenlandica	0	0.409	0.007	0	0	0	0	0.011	0	0.035	0.046 ± 0.128	5.857
Polydora caulleryi	0	0	0	0	0	0	0.004	0	0	0	0.0004 ± 0.001	0.051
Potamilla sp	0.046	0.012	0.020	0.182	0.030	0.005	0.032	0.011	0.061	0.012	0.041 ± 0.053	5.220
Spionidae, unid.	0	0	0	0	0	0	0	0	0	0.002	T	0.025
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (juv.)	0.1	0.01	-	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02 ± 0.03	2.55
Macoma balthica	3.58	4.89	4.16	5.19	3.82	3.94	6.64	1.70	5.01	3.92	4.3 ± 1.3	547.5

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m
+0.9' Level Cont.												
Mya priapus	0	0	0	0	0	2.37	0	0	0	0	0.2 ± 0.7	25.5
Mya sp (frag.)	4.29	0	33.83	0.96	0	0	0	0	0	0	3.91 ± 10.6	497.8
Mya spp (juv.)	0.005	0.01	0.03	0.07	0.14	0.075	0.10	0.06	0.10	0.17	0.07 ± 0.06	8.9
Pseudopythina sp	0	0.01	0	0	0	0	0.03	0.02	0.02	0.06	0.014 ± 0.02	1.78
Total	8.09	5.35	38.63	6.89	4.36	6.65	7.06	1.86	6.83	4.39	9.01 ± 10.56	1147.37
-1.2' Level												
ECHIURA												
Echiurus Echiurus	0.001	0	0	0	0	0	0	0	2.05	0	0.205 ± 0.648	26.101
ANNELIDA - Polychaeta												
Ampharete acutifrons	0	0	0.002	0	0	0	0	0	0	0.003	0.0005 ± 0.001	0.064
Capitella capitata	0	0	0	0	0	0	T	0	0	0	T	T
Eteone nr *longa*	0	0.001	0	0	0	0.006	0	0.009	0	0	0.002 ± 0.003	0.255
Glycinde sp	0.001	0	0	0	0	0.004	0.055	0	0.005	0	0.007 ± 0.017	0.891
Malacocerus sp	0	0	0	0	0	0	0	0	0	T	T	T
Nephtys caeca	0.419	-	0.506	0.682	0.178	0	0.496	0.270	0.095	0	0.356 ± 0.302	45.327
Nephtys sp (juv.)	0.012	0.910	0	0	0.005	0.011	0.006	0	0	0.001	0.004 ± 0.005	0.509
Phyllodoce groenlandica	0.015	0	0	0	0	0	0	0	0	0	0.002 ± 0.005	0.191

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m
-1.2 Level Cont.												
Polydora caulleryi	0	0.001	0	0	0	0	0	0	0	0	0.0001 ± 0.0003	0.013
Potamilla sp	0	0	0	0.028	0.001	0.012	0.043	0	0	0	0.008 ± 0.015	1.019
Scoloplos armiger	0	0	0	0	0	0	0	0	0.004	0	0.0004 ± 0.001	0.051
?*Spio* sp	0	0	0.004	0	0	0	0	0	0	0	0.0004 ± 0.001	0.051
ARTHROPODA - Crustacea												
Tritella pilimana	0	0	0	0	0	0.005	0	0	0	0	0.0005 ± 0.002	0.064
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (juv.)	0.005	0.01	0	0.01	0	0.1	0.01	0.02	0.02	0.05	0.02 ± 0.03	2.55
Macoma balthica	2.55	3.54	0	4.48	1.19	2.30	3.67	5.21	1.40	2.54	2.7 ± 1.6	342.3
Mya arenaria	0.99	0	0	0	0	11.15	0.68	0	0	0	1.3 ± 3.5	163.2
M. priapus	0	0	0	0.03	0	0	0	0	0	0	0.003 ± 0.01	0.382
M. truncata	0	0	0	0	0	0	24.34	0	0	0	2.4 ± 7.7	309.9
Mya spp (juv.)	0.13	0.14	0	0.13	0.07	0.32	0.05	0.13	0.02	0.07	0.11 ± 0.09	13.5
Pseudopythina sp	0	0	0	0	0	0	0.02	0.01	0.01	0.02	0.006 ± 0.009	0.76
Total	4.12	4.60	0.51	5.36	1.44	13.91	29.37	5.65	3.60	2.68	7.12 ± 8.63	906.9

APPENDIX 4.4.18. BIOMASS DATA (GRAMS WHOLE WET WEIGHT) FOR CORE SAMPLES FROM GLACIER SPIT, CHINITNA BAY, 30 JULY 1977

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m
+3.6' Level												
ECHIURA												
Echiurus echiurus	0	1.52	0.65	0.01	0	0	0	0	0	0	0.22 ± 0.05	27.76
ANNELIDA												
Ampharete acutifrons	0.01	0	T	T	0	0	0	0	0.01	0	T	T
Capitella capitata	0	T	0	0	0	0	0	0	0	0	T	T
Eteone nr *longa*	0.014	0.007	T	0	T	0	T	0	0	0	0.002 ± 0.005	0.267
Eteone nr *pacifica*	0	0.008	0	0	0	0	0	0	0	0	0.001 ± 0.003	0.102
Harmothoe imbricata	0	0.17	0	0	0	0	0	0	0	0	0.017 ± 0.054	2.165
Hirudinea, unid.	0	0.015	0	0	0	0	0	0	0	0	0.002 ± 0.005	0.19
?*Malacocerus* sp	0	0	0	0	0	0	T	0	0	T	T	T
Nephtys sp	0	0.49	0	0.20	0.52	0.35	0	0.31	0.65	1.39	0.39 ± 0.42	49.78
Nephtys sp (juv.)	T	0	0.005	T	0	0	0.265	T	–	0.003	0.027 ± 0.084	3.48
Oligochaeta, unid.	0	0	0	0	0	0	0	0	0	T	T	T
Polydora caulleryi	0	0	T	0	0	0	0	0	T	0	T	T
Potamilla sp	0	0	0	0	0.0	0	0	T	0.002	0	0.001 ± 0.003	0.153
Scoloplos armiger	0	T	0	0	0	0	0	0	0	0.005	0.001 ± 0.002	0.064
Spio filicornis	0.004	T	T	T	0	0	T	T	0	0	0.001 ± 0.002	0.122

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m
					+3.6' Level Cont.							
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii	0	0	0	0	0	0	0	3.70	0	0	0.37 ± 1.17	47.1
C. nuttallii (juv.)	0	0	0	0	0	0	0	0.18	0.01	0	0.02 ± 0.05	2.4
Macoma balthica	2.90	4.65	3.45	4.64	3.25	3.80	2.70	4.34	2.98	2.97	3.6 ± 0.70	454.6
Mya arenaria	67.95	0	0	0	78.77	0	0	54.77	9.00	0	21.0 ± 32.4	2680.2
M. priapus	0	0	0	0	7.27	0	1.94	0	0	0	0.9 ± 2.3	117.3
Mya spp (juv.)	0	0	0.19	0	0	0	0	0	0	0	0.02 ± 0.06	2.4
Mya sp (frag.)	0	0	0	0	8.11	0	2.03	0	0	0	1.0 ± 2.6	127.3
Pseudopythina sp	0	0.39	0.02	0	0	0	0.005	0.005	0	0	0.0 ± 0.12	5.3
Total	70.88	7.25	4.32	4.85	97.93	4.15	6.94	63.31	12.65	4.37	27.67 ± 35.45	3522.6
					+2.5' Level							
ECHIURA												
Echiurus echiurus	1.27	0	0.38	0	1.60	0	0.1	0.795	0	0	0.415 ± 0.600	52.776
ANNELIDA												
Capitella capitata	T	0.007	0	0	0.005	0	0	0	0	0	0.001 ± 0.003	0.166
Eteone nr *longa*	0.007	0.014	0.05	T	0.02	0	0	0.01	0	0	0.010 ± 0.016	1.30
Eteone nr *pacifica*	T	0	0	0	0	0	0	0	0	0	T	T

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m
+2.5' Level Cont.												
Harmothoe imbricata	0.24	0	0.34	0	0.326	0	0	0.08	0	0	0.099 ± 0.145	12.55
?Maldanidae (juv.)	0	T	0	0	T	0	0	0	0	0	T	T
Malococerus sp	0	T	0	0	0	0	0	0	0	0	T	T
Nephtys sp	0.404	0	0	0	0.394	0.84	0	0	0.84	0.14	0.26 ± 0.34	33.33
Nephtys sp (juv.)	-	0.012	0.02	0.02	T	0.02	0	T	0.014	-	0.009 ± 0.009	1.12
Phyllodoce groenlandica	0	0	0	0	0	0	0.384	0	0	0.08	0.046 ± 0.121	5.908
Polydora caulleryi	T	0	T	T	0	T	0	T	0	T	T	T
Potamilla sp	0.055	0.026	0	0.11	0	T	0.02	0	0	0	0.021 ± 0.036	2.687
Scoloplos armiger	0	0	0	0	0	T	0	T	0	0	T	T
Spio filicornis	0.018	T	0.01	0.01	0.016	T	T	0.03	0.007	T	0.009 ± 0.010	1.21
?Spionidae, unid.	0	0	0	0	T	0	0	0	0	0	T	T
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (adult)	0	0	0	7.79	0	0	3.32	9.83	0	7.01	2.8 ± 3.9	355.9
C. nuttallii (juv.)	0	0.005	0	0	0	0	0	0.34	0	0	0.04 ± 0.11	4.4
Macoma balthica	1.85	5.15	4.76	3.93	4.28	1.95	2.89	2.86	2.27	4.46	3.4 ± 1.2	438.0
Mya arenaria	81.07	19.35	0	68.66	0	0	8.05	13.06	0	0	19.0 ± 30.3	2421.7
M. priapus	0	9.39	0	0	0	0	0	0	0	0	0.9 ± 3.0	119.6
Mya spp. (juv.)	T	0	0	0	0	0.14	0	0	0.36	0	0.05 ± 0.12	6.4

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m
						+2.5' Level Cont.						
Mya sp (frag.)	0	0	0	4.50	0	0	0	5.75	0	49.21	5.9 ± 15.3	757.1
Pseudopythina sp	0.27	0.02	0.06	0	0	0	0	0.24	0	0	0.06 ± 0.11	7.5
Total	85.18	33.97	5.62	85.02	6.64	2.95	14.76	33.00	3.49	60.90	33.16 ± 32.93	4221.7
						+0.9' Level						
ECHIURA												
Echiurus echiurus	0	1.09	0.23	0	0	0.950	0	0	1.65	0	0.314 ± 0.590	40.036
ANNELIDA												
Ampharete acutifrons	T	0	T	T	0	0	0	0	0	0	T	T
Capitella capitata	0.015	0	T	0	0	0.015	0	0	0	0	0.003 ± 0.006	0.382
Eteone nr *longa*	0	0.007	T	0.005	0	0.033	0	0	0.023	0	0.007 ± 0.012	0.866
Harmothoe imbricata	0.030	0.285	0	0.03	0	0.05	0.022	0.40	0.03	0	0.083 ± 0.141	10.530
Malacocerus sp	T	0.002	0	0	0	0	0	0	0	0	T	0.032
Nephtys sp	0.986	0.383	0.065	0.930	0	1.614	0.844	0.36	1.75	0.35	0.728 ± 0.607	92.717
Nephtys sp (juv.)	0.006	-	0	0	0	-	-	-	0	0	0.001 ± 0.002	0.076
Oligochaeta, unid.	0	0.07	0	0	0	0	0	0	0	0	0.007 ± 0.022	0.891
Phyllodoce groenlandica	0	0	0	0	0	0	0	0	0.645	T	0.072 ± 0.215	9.125
Polydora caulleryi	0	0	0.007	0	0	0	0	0	0	0	0.001 ± 0.002	0.089

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m
+0.9' Level Cont.												
Polygordius sp	T	0	0	0	0	0	0	0	0	0	T	T
Potamilla sp	0.155	0.07	0.10	0.21	0.105	0.018	0.06	0.09	0	0.002	0.081 ± 0.067	10.313
Scoloplos armiger	T	0	0	0	0	0	0	0	0	0	T	T
Spio filicornis	0.037	0.008	0.009	0.01	T	0.010	0.017	0	0.004	0.014	0.011 ± 0.011	1.389
Spionidae, unid.	0	0.008	0	0	0	0	0	0	0	0	0.001 ± 0.003	0.102
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (adult)	0	0	0	0	25.50	0	0	0	0	0	2.6 ± 8.1	324.6
C. nuttallii (juv.)	0.15	0	0.007	4.00	0	0	0.01	0	0.005	0	0.02 ± 0.05	3.1
Macoma balthica	4.79	4.35	1.57	2.23	3.68	2.81	4.38	4.50	0.28	3.59	3.2 ± 1.5	409.6
Mya arenaria	0	39.16	0	23.00	20.80	0	11.29	0	0	0	9.4 ± 13.9	1199.8
M. priapus	0	41.22	17.78	0	0	0	5.35	19.89	0	0	8.4 ± 10.0	1072.5
M. truncata	0	0	24.54	14.75	0	0	0	0	0	0	3.9 ± 8.6	501.1
Mya spp (juv.)	0	0	0.04	0.14	0	0.54	0	0	0	0	0.2 ± 0.3	30.8
Mya sp (frag.)	28.34	0.79	0	40.97	0.65	0	10.87	9.67	0	0	9.1 ± 14.4	1162.4
Pseudopythina sp	0	0.005	0.03	0.005	0	0.17	0.005	0.59	0.01	0	0.08 ± 0.19	10.4
Total	34.51	87.38	44.38	86.28	50.74	6.21	32.83	35.50	4.40	3.96	38.62 ± 30.39	4917.36

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m
						-1.2' Level						
ECHIURA												
Echiurus echiurus	0.520	0	0	0	0	0	0	0	0	0	0.052 ± 0.164	6.621
ANNELIDA												
Ampharete acutifrons	0	0	0	0	0	T	0	0	T	0	T	T
Axiothella rubrocincta	0	T	0	0	0	0	0	0	0	0	T	T
Capitella capitata	0.001	0	0.001	0	0	0	0.001	0	0	–	0.0003 ± 0.0004	0.038
Eteone nr *longa*	0.012	0	0	0.002	0	0.01	0.009	0.001	0	0.003	0.004 ± 0.005	0.471
Harmothoe imbricata	0.003	0	0.046	0	0	0	0.507	0.008	0	0.007	0.057 ± 0.159	7.270
Malococerus sp	0	0	0	0	0	–	T	0	0	T	T	T
Nephtys sp	0.597	0.345	0.170	0.675	0	0.61	0.060	1.263	0.070	1.38	0.462 ± 0.510	58.836
Nephtys sp (juv.)	–	0.014	–	–	0	0.018	–	0	–	–	0.003 ± 0.007	0.407
Paraonalla platybranchia	0	0	0	0	0	0	T	0	0	0	T	T
Phyllodoce groenlandica	0	0.015	0	0.003	0	0	0	0	0.074	0.003	0.010 ± 0.023	1.210
Polydora ?caulleryi	0.002	T	0	0	0	T	T	0	0	0	0.0002 ± 0.001	0.045
Potamilla sp	0.104	0.196	0.012	0.053	0	0.043	0.014	0.028	0.010	0.034	0.049 ± 0.060	6.290
Scoloplos armiger	0.002	0	0	0	0	0.003	0	0	0	0	0.001 ± 0.001	0.064
Spio filicornis	0.022	0.020	0.02	T	0	0.011	0.005	0.007	0.007	0.004	0.010 ± 0.008	1.229

TAXA	1	2	3	4	5	6	7	8	9	10	x ± s	Biomass/m
-1.2' Level Cont.												
ARTHROPODA - Crustacea												
Tritella ?pilimana	T	T	0	0	0	0	0	0	0	T	T	T
MOLLUSCA - Pelecypoda												
Clinocardium nuttallii (adult)	0	0	2.10	0	0	0	0	0	0	0	0.2 ± 0.7	26.7
C. nuttallii (juv.)	0.25	0.04	0.005	0	0.44	1.20	1.15	0.005	0	0.005	0.3 ± 0.5	39.4
Macoma balthica	6.52	3.03	6.88	3.93	4.89	5.04	2.86	3.49	2.33	3.80	4.3 ± 1.5	544.5
Mya arenaria	0	0	0	0	85.56	0	0	0	0	0	8.6 ± 27.1	1089.2
M. priapus	0	0	0	25.47	0	34.08	0	0	0	23.70	8.3 ± 13.7	1059.8
M. truncata	0	0	0	0	34.58	17.47	0	0	0	0	5.2 ± 11.7	662.6
Mya spp (juv.)	0.01	0.04	1.40	0	0.81	0.25	0.43	0	0	0.19	0.3 ± 0.5	39.8
Mya sp (frag.)	2.29	0	0	0	0	0	0	0	0	0	0.2 ± 0.7	29.2
Pseudopythina sp	0	0	T	0	0	0.01	0.07	0.01	0	0.15	0.03 ± 0.05	3.2
Total	10.33	3.70	10.63	30.13	126.28	58.75	5.11	4.81	2.49	29.28	28.15 ± 38.77	3584.5

APPENDIX 4.4.19. SUMMARY OF DENSITY OF ORGANISMS IN INFAUNAL SAMPLES BY LEVEL AT GLACIER SPIT, CHINITNA BAY, 6 APRIL 77

	Number per m²			
TAXA	+3.6'	+2.5'	+0.9'	-1.2'
ECHIURA				
Echiurus echiurus	12.7	101.9	12.7	25.5
ANNELIDA - Polychaeta				
Abarenicola pacifica	12.7	0	0	0
Ampharete acutifrons	0	0	25.5	25.5
Aphroditoididae, unid. (?*Peisidice*)	0	38.2	0	0
Capitella capitata	12.7	25.5	25.5	12.7
Eteone nr *longa*	38.2	50.9	38.2	25.5
Glycinde polygnatha	25.5	38.2	0	38.2
Harmothoe imbricata	12.7	12.7	12.7	0
Malacoceros sp	38.2	0	12.7	12.7
Nephtys sp	63.7	89.1	165.5	127.3
Nephtys sp (juv)	89.1	140.1	211.7	267.4
Paraonidae, unid.	12.7	0	0	0
Phyllodoce groenlandica	25.5	0	25.5	12.7
Polydora caulleryi	0	25.5	25.5	12.7
Potamilla sp	63.7	76.4	318.3	38.2
Scoloplos armiger	0	0	0	12.7
?*Spio filicornis*	0	0	0	38.2
MOLLUSCA - Pelecypoda				
Clinocardium nuttallii	63.7	50.9	432.9	345.8
Macoma balthica	4647.3	4443.6	5347.6	4252.6
Macoma sp	0	0	0	12.7
Mya arenaria	89.1	63.6	0	38.2
M. priapus	0	25.5	12.7	12.7
M. truncata	0	0	0	12.7
Mya spp. (juv)	152.8	127.3	1120.5	1515.2
Pseudopythina sp	89.1	203.7	229.2	56.6
ARTHROPODA - Crustacea				
Saduria entomon	0	12.7	0	0
Tritella pilimana	0	0	0	12.7

APPENDIX 4.4.20. SUMMARY OF DENSITY OF ORGANISMS IN INFAUNAL SAMPLES BY LEVEL AT GLACIER SPIT, CHINITNA BAY, 30 JULY 77

	Number per m^2			
TAXA	+3.6'	+2.5'	+1.9'	-1.2'
ECHIURA				
Echiurus echiurus	25.5	63.8	63.8	12.7
NEMERTEA, unid	0	0	0	25.5
ANNELIDA - Oligochaeta, unid.	12.7	0	12.7	0
ANNELIDA - Polychaeta				
Ampharete acutifrons	51.0	0	38.3	25.5
Axiothella rubrocincta	0	0	0	12.7
Capitella capitata	12.7	191.3	165.8	76.5
Eteone nr longa	63.8	178.6	127.6	114.8
E. nr pacifica	12.7	25.5	0	0
Harmothoe imbricata	12.7	50.9	127.6	63.8
Malacoceros sp	25.5	38.3	38.3	51.0
Maldanidae, unid.	0	12.7	0	0
Nephtys sp	140.1	140.3	153.1	140.3
Nephtys sp (juv.)	102.0	255.1	76.5	318.9
Paraonella platybranchia	0	0	0	25.5
Phyllodoce groenlandica	0	25.5	25.5	63.8
Polydora caulleryi	25.5	127.5	12.7	50.9
Polygordius sp	0	0	12.7	0
Potamilla sp	12.7	153.1	459.2	382.0
Scoloplos armiger	25.5	25.5	25.5	25.5
Spio filicornis	127.6	484.7	560.2	650.5
Spionidae, unid.	0	12.7	0	0
ARTHROPODA				
Acarina, unid.	0	0	12.7	12.7
Crangon sp	12.7	12.7	0	0
Harpacticoidea, unid.	0	25.5	0	0
Ischyroceridae, unid.	0	50.9	0	0
Pontoporeia femorata	0	12.7	12.7	12.7
Tritella ?pilimana	25.5	267.9	331.6	127.6

TAXA	Number per m^2 +3.6'	+2.5'	+0.9'	-1.2'
MOLLUSCA				
Aglaja diomedea	0	0	0	12.7
Clinocardium nuttallii (adult)	12.7	50.9	12.7	12.7
C. nuttallii (juv)	25.5	25.5	152.8	165.5
Cylichna sp	0	0	12.7	0
Macoma balthica	2253.6	2470.1	2610.3	3285.0
Mya arenaria	63.8	63.8	50.9	12.7
M. priapus	25.5	12.7	76.4	63.8
M. truncatus	0	0	38.2	25.5
Mya spp (juv)	12.7	50.9	76.4	127.3
Pseudopythina sp	89.1	114.6	216.5	140.1

APPENDIX 4.4.21. SUMMARY OF BIOMASS DISTRIBUTION AMONG ORGANISMS AND LEVELS AT GLACIER SPIT, CHINITNA BAY IN 1977

	Grams wet weight per m^2							
	6 April				30 July			
TAXA	+3.6'	+2.5'	+0.9'	-1.2'	+3.6'	+2.5'	+0.9'	-1.2'
ECHIURA	(0.1%)	(1.6%)	(1.2%)	(2.9%)	(0.8%)	(1.3%)	(0.8%)	(0.1%)
Echiurus echiurus	4.84	46.35	14.01	26.10	27.76	52.78	40.04	6.62
ANNELIDA - Polychaeta	(0.1%)	(1.2%)	(4.0%)	(5.3%)	(1.6%)	(1.4%)	(2.5%)	(2.1%)
Ampharete acutifrons	0	0	0.13	0.06	T	0	T	T
Capitella capitata	0.13	T	0.01	T	T	0.17	0.38	0.04
Eteone nr *longa*	1.15	0.64	0.13	0.26	0.27	1.30	0.87	0.47
Glycinde polygnatha	0.64	1.40	1.91	0.89	0	0	0	
Harmothoe imbricata	0.13	0.38	2.55	0	2.17	12.55	10.53	7.27
Malacoceros sp	T	0	0.01	T	T	T	0.03	T
Nephtys sp	2.17	32.34	29.03	45.33	49.78	33.33	92.72	58.84
Nephtys sp. (juv)	0.26	0.89	1.15	0.51	3.48	1.12	0.08	0.41
Phyllodoce groenlandica	0.26	0	5.86	0.19	0	5.91	9.13	1.21
Polydora caulleryi	0	0.06	0.05	0.01	T	T	0.09	0.05
Potamilla sp	0.76	1.53	5.22	1.02	0.15	2.69	10.31	6.29
Scoloplos armiger	0	0	0	0.05	0.06	T	T	0.06
?*Spio filicornis*	0	0	0	0.05	0.12	1.21	1.39	1.23
ARTHROPODA - Crustacea	(0)	(T)	(0)	(T)	(T)	(T)	(T)	(T)
Pontoporeia femorata	0	0	0	0	0	0	T	T
Tritella ?*pilimana*	0	0	0	0.06	T	T	T	T
MOLLUSCA - Pelecypoda	(99.6%)	(96.6%)	(94.5%)	(91.8%)	(97.6%)	(97.4%)	(95.8%)	(97.5%)
Clinocardium nuttallii (adult)	0	0	0	0	47.1	355.9	324.6	26.7
C. nuttallii (juv)	0.51	0.51	2.55	2.55	2.4	4.4	3.1	39.4
Macoma balthica	547.5	534.7	547.5	382.0	454.6	438.0	409.6	544.5

	Grams wet weight per m^2							
	6 April				30 July			
TAXA	+3.6'	+2,5'	+0.9'	-1.2'	+3.6'	+2.5'	+0.9'	-1.2'
Mya arenaria	3565.1	2164.5	0	178.3	2680.2	2421.7	1199.8	1089.2
M. priapus	0	165.5	25.5	0.38	117.3	119.6	1072.5	1059.8
M. truncatus	0	0	0	343.8	0	0	501.1	662.6
Mya spp. (juv.)	1.02	8.91	8.9	14.01	2.4	6.4	30.8	39.8
Mya spp. (frags)	38.2	10.19	497.8	0	127.3	757.1	1162.4	29.2
Pseudopythina sp	0.76	4.33	1.78	0.89	5.3	7.5	10.4	3.2

APPENDIX 4.4.22. SHELL LENGTH (MM) DATA FOR *MACOMA BALTHICA* FROM GLACIER SPIT, CHINITNA BAY ON 6 APRIL 1977

	Frequency				Overall	
Size Class	+3.6'	+2.5'	+0.9'	-1.2'	f	%
0.0 - 0.9			1		1	0.07
1.0 - 1.9	3	2	1	1	7	0.5
2.0 - 2.9	60	34	44	19	157	11.2
3.0 - 3.9	66	52	97	57	272	19.4
4.0 - 4.9	43	32	73	64	212	15.1
5.0 - 5.9	13	6	28	47	94	6.7
6.0 - 6.9	11	7	11	10	39	2.8
7.0 - 7.9	4	4	5	6	19	1.4
8.0 - 8.9	10	9	11	3	33	2.4
9.0 - 9.9	21	21	9	9	60	4.3
10.0 - 10.9	33	53	35	27	148	10.6
11.0 - 11.9	25	36	42	29	132	9.4
12.0 - 12.9	34	30	17	18	99	7.1
13.0 - 13.9	24	14	30	13	81	5.8
14.0 - 14.9	9	9	10	1	29	2.1
15.0 - 15.9	3	4	3		10	0.7
16.0 - 16.9	3	2	1		6	0.4
17.0 - 17.9			1		1	0.07
n	362	315	419	304	1400	
$\bar{x}$	7.31	8.10	6.96	6.74	7.26	
s	4.23	4.09	4.03	3.51	4.02	

APPENDIX 4.4.23. SHELL LENGTH (MM) DATA FOR MACOMA BALTHICA FROM GLACIER SPIT, CHINITNA BAY ON 30 JULY 1977

	Frequency				Overall	
Size Class	+3.6'	+2.5'	+0.9'	-1.2'	f	%
2.0 - 2.9	2	4	5	4	15	1.9
3.0 - 3.9	2	8	7	6	23	2.9
4.0 - 4.9	2	4	5	3	14	1.8
5.0 - 5.9	7	11	10	3	31	3.9
6.0 - 6.9	10	20	18	12	60	7.5
7.0 - 7.9	27	18	43	25	113	14.2
8.0 - 8.9	19	12	22	56	109	13.7
9.0 - 9.9	12	6	11	42	71	8.9
10.0 - 10.9	6	15	7	9	37	4.7
11.0 - 11.9	19	32	19	16	86	10.8
12.0 - 12.9	22	29	20	24	95	11.9
13.0 - 13.9	22	17	12	22	73	9.2
14.0 - 14.9	11	9	12	11	43	5.4
15.0 - 15.9	5	3	8	4	20	2.5
16.0 - 16.9	3			1	4	0.5
17.0 - 17.9		1			1	0.1
n	169	189	199	238	795	
$\bar{x}$	9.28	8.92	9.33	9.73	9.76	
s	3.19	3.37	3.25	2.83	3.16	

APPENDIX 4.4.24. SHELL LENGTH (MM) DATA FOR MYA SPP. (JUVENILES) FROM GLACIER SPIT, CHINITNA BAY

6 April 1977							30 July 1977			
+3.6'	+2.5'	+0.9'	+0.9'	-1.2'	-1.2'	-1.2'	+3.6'	+2.5'	+0.9'	-1.2'
2.6	3.9	2.2	2.5	6.4	3.4	3.8	13.8	3.8	9.0	5.0
5.1	3.3	4.1	5.4	5.2	3.8	1.9		2.9	11.4	9.9
4.3	4.0	3.2	5.0	6.0	3.3	2.0		11.6	18.1	22.9
3.2	3.6	4.6	3.6	4.2	2.6	3.5		18.2		24.1
2.5	4.9	4.5	4.0	5.2	4.3	3.5				15.3
3.9	3.7	3.8	5.3	3.9	6.4	4.9				6.6
4.1	3.1	3.6	3.2	4.4	5.9	2.2				15.7
4.3	3.1	3.7	4.0	3.7	6.5	4.7				6.8
3.5	2.4	3.8	3.8	5.1	4.0	3.3				4.6
3.6		3.3	2.5	4.7	5.8	3.1				14.3
3.4		3.5	2.7	3.0	5.7	4.3				
3.8		4.0	4.3	3.9	5.2	4.6				
		3.4	6.0	2.2	4.3	4.5				
		4.9	4.3	5.4	5.6	3.0				
		5.2	5.4	3.9	5.7	3.9				
		2.5	4.5	4.7	4.9	4.4				
		5.5	3.9	5.8	4.8	4.8				
		4.9	5.0	5.8	4.3	4.6				
		2.3	4.3	5.7	4.9	5.0				
		4.5	3.4	4.4	5.2	5.9				
		6.2	4.1	6.0	5.6	2.5				
		3.5	4.0	3.4	5.0	3.5				
		2.4	5.0	3.6	4.5	5.0				
		6.2	4.2	4.8	5.0	3.2				
		4.2	4.6	3.2	3.4	4.1				
		5.4	4.1	5.2	4.1	3.6				
		3.6	3.6	4.1	3.6	2.5				
		4.0	3.9	5.2	4.7	5.7				
		3.4	3.8	5.7	3.9	4.6				
		4.5	3.6	4.3	3.6	3.9				
		3.0	4.0	4.5	2.2	19.3				
		5.8	4.8	3.3	4.3					
		5.6	3.3	4.0	5.0					
		3.5	3.9	4.4	3.8					
		4.8	3.7	4.6	5.0					
		4.1	4.7	3.6	3.3					
		3.7	4.0	4.3	4.5					
		3.2	4.0	4.0	6.2					
		5.3								
		3.2								
		2.5								
		4.7								
		5.1								
		2.4								
		4.3								
		3.8								
		4.8								
		2.7								
		3.9								
		4.7								

$\bar{x}$ = 4.17
s = 0.99
n = 215

$\bar{x}$ = 11.89
s = 6.41
n = 18

APPENDIX 4.4.25. SHELL LENGTH AND WEIGHT MEASUREMENTS FOR <u>MYA ARENARIA</u> AT GLACIER SPIT, CHINITNA BAY

6 April 1977

+3.6'			+2.5'			+0.9'			-1.2'		
Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)
90.5	55.00	21.31	56.9	9.86	4.19	-	-	-	27.0	0.99	0.51
93.3	62.84	25.54	-	39.20	14.23				-	11.15	5.66
58.7	12.25	6.02	49.3	7.17	3.63				24.3	0.68	0.35
56.6	11.86	5.97	97.7	51.61	20.41						
91.3	52.77	19.56									
97.8	71.07	25.43									
60.4	14.22	6.50									

Average shell length ($\bar{x}$ ± s) = 67.0 ± 26.6
Wet tissue weight: whole wet weight ratio = 0.40

30 July 1977

107.2	67.95	25.81	60.5	13.06	5.87	64.0	20.80	9.83	100.8	85.56	32.41
59.6	9.0	6.78	-	19.35	6.15	80.0	39.16	17.99			
88.8	54.77	21.61	47.9	8.05	4.00	56.9	23.00	6.82			
-	60.60	23.73	95.7	81.07	27.80	57.0	11.29	5.08			
65.8	18.17	9.91	-	68.66	28.0						

Average shell length ($\bar{x}$ ± s) = 73.7 ± 19.9
Wet Tissue weight:whole wet weight ratio = 0.40

APPENDIX 4.4.26. SHELL LENGTH AND WEIGHT MEASUREMENTS FOR *MYA PRIAPUS* AT GLACIER SPIT, CHINITNA BAY

6 April 1977

+3.6'			+2.5'			+0.9'			-1.2'		
Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)
-	-	-	-	7.05	2.85	31.2	2.37	1.07	7.3	0.03	-
			42.2	6.10	2.69						

Average shell length ($\bar{x} \pm s$) = 26.9 ± 17.8
Wet tissue weight:whole wet weight ratio = 0.43

30 July 1977

+3.6'			+2.5'			+0.9'			-1.2'		
Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)
22.1	1.94	0.91	46.0	9.39	3.66	62.8	19.89	11.41	59.1	23.70	9.16
42.3	7.27	3.44				-	23.44	7.44	60.4	24.38	9.92
						53.9	17.77	7.42	25.0	1.09	0.57
						54.8	17.78	7.65	61.3	19.48	8.12
						35.7	3.91	1.64	53.9	14.60	5.36
						27.5	1.44	0.71			

Average shell length ($\bar{x} \pm s$) = 46.5 ± 14.6
Wet tissue weight:whole wet weight ratio = 0.42

APPENDIX 4.4.27. SHELL LENGTH AND WEIGHT MEASUREMENTS FOR MYA TRUNCATA AT GLACIER SPIT, CHINITNA BAY

+3.6'			+2.5'			+0.9'			-1.2'		
Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)
6 April 1977											
-	-	-	19.6	0.60	-	-	-	-	63.3	24.34	8.57
30 July 1977											
-	-	-	-	-	-	-	14.75	8.16	-	17.47	13.70
						-	13.87	7.82	54.6	34.58	16.39
						-	10.74	4.91			

Wet tissue weight:whole wet weight ratio = 0.44

APPENDIX 4.4.28. SHELL LENGTH (MM) DATA FOR <u>CLINOCARDIUM</u> <u>NUTTALLII</u> FROM GLACIER SPIT, CHINITNA BAY

6 April 1977				30 July 1977					Frequency	
+3.6'	+2.5'	+0.9'	-1.2'	+3.6'	+2.5'	+0.9'	-1.2'	Size Class	4/6/77	7/30/77
2.0	1.6	9.2	1.9	9.6	1.8	8.7	9.6	1-3	62	16
1.5	2.1	2.5	2.6	2.3	11.5	2.3	3.4	4-6	0	2
2.0	2.4	10.8	2.1	27.1	39.9	2.3	7.4	7-9	1	4
1.9	2.8	2.0	2.0		27.9	5.8	3.4	10-12	1	5
1.7		2.1	2.1		31.3	1.6	2.2	13-15	0	1
		1.8	2.2		33.6	2.2	11.8	16-18	0	0
		1.9	1.9			4.0	12.6	19-21	0	0
		2.0	1.9			2.1	12.7	22-24	0	0
		2.0	2.0			1.9	14.0	25-27	0	2
		2.0	1.5			2.2	10.9	28-30	0	0
		1.8	1.6			2.0	1.9	31-33	0	2
		2.0	2.2			2.0	2.3	34-36	0	0
		1.8	2.2			47.2		37-39	0	1
		1.6	2.4					40-42	0	0
		1.8	1.8					43-45	0	0
		1.9	2.2					46-48	0	1
		1.8	2.5							
		2.2	1.8							
		2.3	3.0							
		2.1	2.2							
		1.8	2.4							
		1.6	2.5							
		2.0	1.9							
		1.9	1.9							
		1.7								
		2.2								
		2.1								
		1.8								
		1.7								
		2.4								
		2.3								

$\bar{x}$	2.25	10.63
s	1.46	12.25
n	64	34

APPENDIX 4.4.29. SHELL LENGTH AND WEIGHT MEASUREMENTS FOR CLINOCARDIUM NUTTALLII AT GLACIER SPIT, CHINITNA BAY

+3.6'			+2.5'			+0.9'			-1.2'		
Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)	Shell Length (mm)	Whole Wet Weight (g)	Wet Tissue Weight (g)
6 April 1977											
2.0	0.005	-	1.6	0.002	-	9.2	0.1	-	1.9	0.004	-
			2.1	0.01	-				1.9	0.004	-
			2.4	0.01	-						
			2.8	0.01	-						
30 July 1977											
9.6	0.18	-	1.8	0.005	-	8.7	0.15	-	2.2	0.005	-
2.3	0.01	-	11.5	0.34	-	2.0	0.005	-	11.8	0.44	-
27.1	3.70	0.96	39.9	9.83	3.0	47.2	25.50	9.73	1.9	0.005	-
			27.9	3.32	1.30				2.3	0.005	-
			31.3	7.01	2.23				-	2.10	-
			33.6	7.79	2.49						

Wet tissue weight:whole wet weight ratio = 0.34

APPENDIX 4.4.30. SHELL LENGTH (MM) DATA FOR PSEUDOPYTHINA SP. FROM GLACIER SPIT, CHINITNA BAY

6 April 1977						30 July 1977					
+3.6'	+2.5'	+0.9'	-1.2'	Size Class	Number	+3.6'	+2.5'	+0.9'	-1.2'	Size Class	Number
1.5	3.6	1.9	3.8	1.0-1.9	8	12.9	11.9	2.5	3.3	1.0-1.9	0
1.7	1.9	2.1	4.9	2.0-2.9	16	11.2	2.7	2.3	3.5	2.0-2.9	11
2.5	3.4	2.1	2.0	3.0-3.9	13	2.7	3.0	4.2	3.8	3.0-3.9	12
2.4	4.7	2.0	3.3	4.0-4.9	10	4.4	4.3	3.3	4.4	4.0-4.9	10
4.1	3.7	2.9	4.0	5.0-5.9	0	2.9	4.2	2.4	4.6	5.0-5.9	1
3.5	4.2	3.4		6.0-6.9	0	2.9	6.1	4.3	3.9	6.0-6.9	2
3.4	2.6	2.7		7.0-7.9	0	3.3	3.6	4.0	5.4	7.0-7.9	0
2.9	3.7	4.7		8.0-8.9	0		11.7	4.0	3.7	8.0-8.9	1
1.8	2.4	3.8		9.0-9.9	0		6.7	3.8	2.0	9.0-9.9	1
	2.7	3.0		10.0-10.9	0			9.2	10.0	10.0-10.9	1
	11.9	1.7		11.0-11.9	1			4.5	2.1	11.0-11.9	3
	1.8	2.0		12.0-12.9	0			2.1		12.0-12.9	1
	4.1	2.0		13.0-13.9	0			3.1		13.0-13.9	0
	4.2	2.8		14.0-14.9	0			16.2		14.0-14.9	0
	2.2	4.3						2.0		15.0-15.9	0
	1.6	3.4						3.7		16.0-16.9	1
		3.2						8.9			
		4.4									

	6 April 1977	30 July 1977
$\bar{x}$	3.18	5.04
s	1.60	3.37
n	48	44