B. Biota at Sites

1. Macrobiota

The macrobiota was examined visually at all sites. These observations are generally summarized in Table 3-2. Observations of macrofaunal abundance are summarized in Table 3-3. Observations of cover by plants and macrofauna are summarized in Table 3-4.

Total number of macrobiotic (both plants and animals) taxa observed, ranging from 0 on all of the shoals to 17 at NE Chisik Island, averaged 6.7 ± 5.2 taxa per site if shoals. Kalgin Island sites consistently had more species than the overall average (11.3 ± 1.0) whereas sites on the east and west sides of the inlet averaged lower (6.3 ± 4.8 and 7.6 ± 5.2 taxa per site, respectively). Sites with mixtures of boulder/cobble and soft substrate generally supported more taxa than sites where substrate was limited to sand or mud (10.4 ± 4.0 taxa vs 2.7 ± 3.0 taxa; Table 3-2 and Figure 3-33a). Moreover, the number of taxa per site generally declined with increasing latitude in both substrate categories (Figure 3-33b).

Taxa observed most commonly included: Baltic macoma *Macoma balthica* (14); the barnacle *Semibalanus balanoides* (13); the lugworm *Abarenicola pacifica* (10); sheet-like green algae *Ulva*/*Monostroma* (10); a filamentous brown alga *Pylaiella littoralis* (9); the rockweed *Fucus gardneri* (8); and a whelk *Nucella lima* (8) (Tables 3-3 and 3-4).

Total percent cover by plants and animals combined at the sites with stable hard substrate where cover was measured within quadrats ranged from 1 to 19 percent and averaged 6.9 percent (Table 3-2). Highest cover by plants and animals was observed at the NE Chisik Island site (17 percent), where the abundance of gravel and boulder/cobble allowed a variety of red and green algae to flourish on an otherwise muddy substrate.

Distribution of the most commonly observed macrofauna is shown in Figure 3-32. This figure clearly demonstrates that the larger organisms and greater biomass are concentrated below East and West Forelands. It also shows where macroinfaunal organisms were not found.

a) East Side of Middle and Upper Cook Inlet

The biota was examined visually at six sites on the east side of middle and upper Cook Inlet. These observations are summarized below.

Figure 3-32. Distribution and relative abundance of several important macroinfaunal organisms in middle and upper Cook Inlet during the CIRCAC reconnaissance survey in August-September 2000.

Table 3-2. Summary of general data and macrobiotic assemblage statistics at selected intertidal sites in upper Cook Inlet based on reconnaissance survey in August-September 2000.

Table 3-3. Summary of quantitative or qualitative data for macroinvertebrates at selected intertidal sites in upper Cook Inlet based on reconnaissance survey in August-September 2000.

Table 3-4. Summary of quantitative or qualitative cover data for macrobiota at selected intertidal sites in upper Cook Inlet based on reconnaissance survey in August-September 2000.

Figure 3-33. Relationship between number of macrobiotic taxa and latitude on the basis of substrate

1) Clam Gulch

While only four macrofaunal taxa were observed at Clam Gulch (Table 3-2), it was the most productive site observed on the east side of the inlet during this study. Razor clams (*Siliqua patula* - 5.2 per sq. m., Table 5), the dominant organism occurring at this site, have been (Lees and Houghton 1977; Lees et al. 1980; Pentec Environmental 1996) and continue to be sufficiently abundant to support a considerable sport fishery. Estimates of density for razor clams during these surveys have ranged from about 0.5 to 6.25 per sq. m. Mussels were common on the boulders and cobbles in the transition zone (3.8 percent cover). Both mussels and razor clams are potential sentinel species.

The two other species observed were barnacles (Table 3-3). The three species observed on boulders or cobbles at the toe of the beachface covered about 6 percent of the rock surface. Populations of the two bivalves were dominated by specimens more than one year old, indicating that winter conditions are sufficiently mild to allow them to overwinter and establish a breeding population.

2) Kalifornsky Beach

Fifteen macrobiotic taxa were observed at Kalifornsky Beach (Table 3-2). These included four plant and eleven invertebrate taxa (Tables 3-3 and 3-4). Lugworms (*Abarenicola pacifica*- 42.4 per sq. m.) and Baltic macomas (*Macoma balthica* – 2.4 per sq. m.) were the dominant infaunal organisms occurring at this site and productivity appears moderate. Both species could are potential sentinel species.

All plant taxa were growing on scattered boulders in the area. Plant cover was sparse and all but rockweed (*Fucus gardneri*) are considered ephemeral. Rockweed was represented only by young-of-year (YOY) plants. Similarly, most of the invertebrate taxa are associated with the rock. Most common among these were the predatory gastropods *Nucella lima*, *Onchidoris bilamellata*, and *Volutharpa ampullacea*, and their barnacle prey, *Semibalanus balanoides*. Populations of two of the snails were dominated by specimens more than one year old, indicating that winter conditions are sufficiently mild to allow them to overwinter and establish a breeding population.

3) Boulder Point

The biota at Boulder Point was very sparse; only three invertebrate taxa were observed in the lower intertidal (Table 3-2) and productivity appears quite low. These included two ephemeral species, *viz*., gammarid amphipods (mainly *Anisogammarus pugettensis* under boulders) and the barnacle *Semibalanus balanoides* (Tables 3-3 and 3-4). Large sea anemones (probably *Urticina crassicornis*) were observed in protected crevices between boulders. None of the species observed at this site appeared to be suitable for use as a sentinel species.

The sea anemones were large enough to represent overwintering populations. All other taxa were ephemeral colonizers. This indicates that conditions are generally too harsh to allow most taxa to overwinter and establish breeding populations.

4) Bishop Beach

The biota on the mud flat at Bishop Beach was very impoverished; only one invertebrate taxon was actually observed and surficial clues were observed for two others (possibly chironomid flies and enteropneusts; Tables 3-2 and 3-3). Productivity appears relatively low. A light diatom film covered much of the surface of the mud (Table 3-4). However, we observed light foraging in the area by shorebirds and evidence of flatfish foraging during the previous high tide.

Baltic macomas (*Macoma balthica*) were the dominant organism occurring at this site (Table 3-3). It appeared to be the only species suitable for use as a sentinel species. The size of these clams suggests they live at least a couple of years at this location but their density suggests it is not a highly suitable or stable area.

5) Moose Point

Although the number of taxa observed at Moose Point (10 taxa; Table 3-2) was above average, the biota was very sparse, and productivity appears relatively low. Habitat diversity is the likely explanation for the anomalously high level of species richness. Four plant taxa were observed (Table 3-4). Most notably, small patches of rockweed (*Fucus gardneri*), a potentially perennial species, were scattered sparsely on the larger boulders but the only plants observed were YOY. The animals observed included the large isopod, *Saduria ?entomon*, and chironomid flies, both of which burrowed into the soft mud in the channel, gammarid amphipods (mainly *Anisogammarus pugettensis*) on or under boulders in the lower intertidal, and juvenile specimens of barnacles (*Semibalanus balanoides*), periwinkles (*Littorina sitkana*), and limpets (Lottiidae, unid.) on the boulders in the outer low intertidal flat (Table 3-3). All species were juveniles or considered ephemeral. No species appeared to be suitably abundant at this site for use as a sentinel species. This indicates that conditions are generally too harsh to allow any taxon to overwinter and establish breeding populations.

6) Chickaloon Bay

The biota had low species richness on the mud flat at Chickaloon Bay (3 taxa; Table 3-2) but productivity appears relatively high. The biota observed included a blue-green algal mat (Table 3-4) and two burrowing invertebrates. With an estimated density of over 450 clams per sq. m., Baltic macomas (*Macoma balthica*) were the dominant organism occurring at this site (Table 3-3) and appeared to be the only species that could be used for sentinel species. The other invertebrate was a large burrowing nereid worm, *Laonnates* sp. The size of the clams and worms suggests they live at least a couple of years at this location and their density suggests the area is relatively stable.

b) Middle of Middle and Upper Cook Inlet

The biota was examined visually at seven sites in the middle of Cook Inlet between Tuxedni Bay and Granite Point. These observations are summarized below.

1) Shoal South of Kalgin Island

Approximately 0.5 nm of shoal was examined visually during the brief visit to one of the exposed shoals south of Kalgin Island. A shovel was used to dig holes and the surface of the sand was scanned for visual clues of burrowing organisms. Other than a small group of seals that was hauled out on the shoal when we approached by helicopter, no organisms were observed during this extensive examination of the exposed portion of the shoal by three observers searching independently. This indicates that conditions on the upper portions of the shoals are generally too harsh to allow any long-lived taxon to overwinter and establish breeding populations. The routine, deep scouring (up to 2 feet during a spring tide flood or ebb) described above in the geomorphological section for this site is the likely reason this site is uninhabitable for long-lived macrofauna.

2) SE Kalgin Island

A broad variety of organisms was observed at this complex location (13 taxa; Table 3-2) and productivity appears moderately high. The macrobiota included three ephemeral algae (Table 6-4) and nine invertebrates, a number of which were unique to this location (Table 3-2). A lugworm (*Abarenicola pacifica*) was abundant in the lower portion of the nearshore sand flat (40 worms per sq. m.). On the inner bank of the bar, juvenile razor clams (*Siliqua patula*) were the dominant organism. The upper portions of the bar were depauperate. The predominant large infaunal organisms in the outermost portion of the bar included the sand dollar (*Echinarachnius parma*) and juvenile specimens of the surf clam (*Macromeris polynyma*). The epibiota on the boulder/cobble outcrops at the outer edge of the bar was dominated by several species of algae and sea anemones (*Urticina crassicornis*) and included the large snail *Fusitriton oregonense*.

Razor and surf clams and lugworms all appear to be potential sentinel species, even though only juvenile clams were observed. The size of the worms suggests they live a couple of years at this location and their density suggests the area is relatively stable. However, the size of the clams on the sand bar suggests they do not live at this location to establish mature populations.

3) Oldmans Bay, Kalgin Island

The mud flat and boulders at this site, supporting a moderately rich biota of infauna and epibiota (12 taxa; Table 3-2), appears to be moderately productive. The biota included eight invertebrate and four algal taxa (Tables 3-3 and 3-4). The boulders scattered on the mud flat (glacial erratics) supported the richest epibiota observed at sites examined during this survey. This biota comprised species typical for hard substrate, including adult rockweed (*Fucus gardneri*), which was common to abundant on the boulders, periwinkles (*Littorina sitkana*) and whelks (*Nucella lima*), which were common, and a sparse cover of the barnacle *Semibalanus balanoides*. The macroinfauna was also well developed. Softshell clams and Baltic macomas (*Mya arenaria* and *Macoma balthica*) were among the dominant organisms at this site. A lugworm (*Abarenicola pacifica*) was also common.

Moderately high abundance in adult populations of softshell clams, Baltic macomas, and lugworms appear to provide several potential sentinel species. The presence of adult populations of both plants and several species of epi- and infaunal invertebrates, all long-lived, indicates this is a stable site, protected from major disturbances by wave action, currents, or ice scour. The absence of the blue mussel is puzzling in view of the occurrence of adult populations of several other typical epibiotic dominants.

4) Shoal West of Kalgin Island

Because of earlier experience on other shoals and instability of the sediments on this shoal, only a small areas was examined visually during the brief visit to one of the exposed shoals west of Kalgin Island. The surface of the sand was scanned for visual clues of burrowing organisms. No organisms were observed during this examination. This indicates that conditions on the upper portions of the shoals are generally too harsh to allow any long-lived taxon to overwinter and establish breeding populations. The routine, deep scouring (up to 2 feet during a spring tide flood or ebb) described above in the geomorphological section for this site is the likely reason this site is uninhabitable for long-lived macrofauna.

5) NE Kalgin Island

The mud flat in the lee of the spit at the northeastern corner of Kalgin Island exhibited moderate species richness (9 taxa; Table 3-2) and appears moderately productive. The biota included four algal and five invertebrate taxa (Tables 3-3 and 3-4). Macroalgae cover over 6 percent of the mud flat. Three organisms are epifaunal. The remainder are infaunal or algae residing on the mud flat. The lugworm (*Abarenicola pacifica*) was relatively quite abundant (Table 3-3). Baltic macomas (*Macoma balthica*) were abundant at this site and softshell clams (*Mya arenaria*) were common.

Moderate abundance in adult populations of softshell clams, Baltic macomas, and lugworms appear to provide several potential sentinel species. The presence of adult populations of several species of infaunal invertebrates, all long-lived, indicates this is a moderately stable site. The combination of substrate (mud), geomorphology, and biota suggest the site is protected from major disturbances by wave action, currents, or ice scour.

6) NW Kalgin Island

Despite the generally moderate level of species richness (11 taxa; Table 3-2), the biota at this site is relatively impoverished and the area does not appear very productive. The biota was predominantly epibiotic, comprising primarily ephemeral species or young-of-year specimens of typical epifaunal taxa (Table 3-3). Plants covered over 11 percent of the substrate in the lower intertidal zone. Rockweed was present but only YOY specimens (Table 3-4). The macroinfauna generally was relatively poorly developed. Juvenile razor clams (*Siliqua patula*) and lugworms were observed but they were too small and fragile to be suitable for use as a sentinel species. This site does not appear to be suitable for tissue monitoring.

The paucity of adult populations of either epibiotic or infaunal taxa suggests this site is relatively exposed to harsh environmental conditions. This is supported by the orientation of the site, which is exposed directly to waves, currents, and ice coming from upper Cook Inlet.

7) Shoal North of Kalgin Island

Approximately 0.5 nm of shoal was examined visually during the brief visit to one of the exposed shoals north of Kalgin Island. A shovel was used to dig holes and the surface of the sand was scanned for visual clues of burrowing organisms. Other than roosting gulls and a small group of seals that was hauled out on the shoal when we approached by helicopter, no organisms were observed during this extensive examination of the exposed portion of the shoal by three observers searching independently. This indicates that conditions on the upper portions of the shoals are generally too harsh to allow any long-lived taxon to overwinter and establish breeding populations. The routine, deep scouring (up to 2 feet during a spring tide flood or ebb) described above in the geomorphological section for this site is the likely reason this site is uninhabitable for long-lived macrofauna.

8) Middle Ground Shoal

As on all other shoals examined, no animals were observed during an extensive examination of the exposed portion of the shoal.

c) West Side of Middle and Upper Cook Inlet

The biota was examined visually at eleven sites on the west side of middle and upper Cook Inlet. These observations are summarized below.

1) NE Chisik Island

The geologically complex flat at the northwest corner of Chisik Island supported the richest biota observed at any of the sites examined during this survey. The flats appeared to support varied epibiotic and infaunal assemblage including both algae and invertebrates. Seventeen taxa, including nine algae and eight invertebrates, were observed either in the mud or on the boulder/ cobble/pebble substrate at this site (Tables 3-2, 3-3, and 3-4). Dominant organism in the mud habitat included the lugworm (*Abarenicola pacifica*, 1.6 worms per sq. m.) and the spoonworm *Echiurus echiurus alaskanus*. Baltic macomas (*Macoma balthica*) were common in this habitat and numerous recently broken shells of the basket cockle *Clinocardium nuttallii* were scattered on the flats, suggesting they are common as well. Most of the algae occurred on the mud flat, covering about 19 percent of the surface (Tables 3-2 and 3-4); sheet-like green algae (*Ulva/Monostroma* unid.) were the most abundant. The spoonworm was very abundant in the mixed gravel/mud deposits on the low ridge. The boulders scattered on the low intertidal ridge supported several typical epifaunal species and a few algae. The algae included individual plants of rockweed (*Fucus gardneri*), a perennial, and the ephemeral red alga, *Porphyra* sp. Predominant invertebrates included the barnacle *Semibalanus balanoides*, a common predator on barnacles, the whelk *Nucella lima*, and large limpets.

The populations of lugworms, Baltic macomas, and spoonworms contain large proportions of adults and are sufficiently abundant to be considered as potential sentinel species. The presence of adult populations of several epibiotic and infaunal organisms suggest this site is relatively stable and not exposed to excessive physical disturbance. The absence of blue mussels is puzzling.

2) North Tuxedni Bay

The mud flat at this site, supporting a moderately rich infaunal biota (10 taxa; Table 3-2), appears to be moderately productive. The biota included five invertebrates and five algae (Table 3-3 and 3-4). Lugworms (9.1 per sq. m.), Baltic macomas (*Macoma balthica*), and softshell clams (*Mya arenaria* and *M. truncata*, 0.5 per sq. m. combined) were the dominant macrofaunal organisms at this site. The sipunculid ?*Phascolosoma agassizii*) was also a common burrower in the mud.

The abundance of the three clams and the lugworm indicates that any could be considered as potential sentinel species. Adults of each of these species, all of which live several years, were common. This indicates that sediment conditions at the site are relative stable.

3) Polly Creek

Because of a history of previous studies at this site, it was only visited during this survey to collect tissue samples for hydrocarbon analysis. Razor clams (*Siliqua patula*), the dominant organisms occurring at this site, have been (Lees and Houghton 1977; Lees et al. 1980; Pentec Environmental 1996) and continue to be sufficiently abundant to support a considerable commercial and sport fishery. Estimates of density for razor clams during these surveys has ranged from about 2.5 to 5.25 per sq. m. They have exhibited considerable stability in abundance and provide a good candidate for a sentinel species at this site.

In 1996, boulders scattered on the sand flat supported considerable cover by a mixture of barnacle species and age classes (total of about 75 percent). The predatory snail, *Nucella lima*, was common. Rockweed and juvenile and adult mussels were sparse.

4) No-name Creek Beach

This site was only surveyed briefly because of its history of commercial harvesting in previous years. Even during the brief survey, six taxa were identified (Table 3-2), including four infaunal taxa and two epibiotic taxa (Table 5). All species were relatively small, however, and density was not high so productivity is probably moderate. Baltic macomas were common in the mud flat at the inner edge of the flats. Razor clams (*Siliqua patula*) were not observed to be common at this site but the abundance of large shells of both razor and surf clams suggests that live specimens are common farther offshore. Both mud and razor clams probably could be used as sentinel species at this site.

Large boulders on the flats supported the barnacle *Semibalanus balanoides* and its predatory snail, *Nucella lima*. The beach appears to collect a considerable amount of debris and thus may be susceptible to floating oil.

5) Redoubt Creek

Thirteen macrofaunal taxa were observed in the mud and sand flats and large boulders at Redoubt Creek Beach (Table 3-2) and productivity is probably moderate. The biota comprised nine invertebrate taxa and four algal taxa (Tables 3-3 and 3-4). Four of the invertebrates were infaunal. Among these, the Baltic macoma (*Macoma balthica*) was dominant occurring in the mud flats. The lugworm, *Abarenicola pacifica,* and the nereid, *Laonnates* sp., both burrowers, were also common in some areas at this site. The inner portion of the sand bar did not appear to support any clams. In view of the adult size and abundance of the species listed above, all could potentially be used as sentinel species at this site.

The large boulders (glacial erratics) in the sand flat support a typical epibiotic assemblage. Rockweed (*Fucus gardneri*) is located like a halo around the base of most of the boulders just above the pool of water in the depression (probably a scour basin) surrounding many of the boulder. Mussels were sparse under rockweed at and just below the low-tide water line in the pools surrounding many of the boulders. This was the only site other than Clam Gulch where mussels were observed during this reconnaissance. It was also the only site other than Oldmans Bay that supported adult rockweed plants. Above the rockweed band, the boulders were inhabited with sparse barnacles (*Semibalanus balanoides*), a predatory snail (*Nucella lima*), and periwinkles (*Littorina sitkana*). In view of the size and abundance of the mussels, they could potentially be used as a sentinel species for this location.

6) Harriet Point North

Fourteen macrobiotic taxa were identified in the complex habitat mix (boulder/cobble beachface and sand and mud flats) on the north side of Harriet Point (Table 3-2) but productivity appears relatively low. These taxa included ten invertebrates and four algae (Tables 3-3 and 3-4). Four of the invertebrate taxa were infaunal. Surf clams (*Macromeris* (=*Spisula*) *polynyma*) were the most common bivalve in the small sand flat but YOY razor clams were also present. In the mud flat, basket cockles (*Clinocardium nuttallii*) and the bivalve *Yoldia* sp. were present in low numbers. Two large snails and the hermit crab, *Pagurus ochotensis*, occurred sparsely on the mud flat. The surf clam was the only species sufficiently common to use as a sentinel species during this survey but razor clams and cockles are also possible candidates.

The boulder/cobble and glacial erratics habitat on the beachface supported a relatively limited epibiotic assemblage typical of the upper portions of the inlet. Barnacle cover (*Semibalanus balanoides*, ≤50 percent; Table 3-4) was the highest observed at any site examined during this reconnaissance. This also was one of only a few locations where barnacles exhibited multiple year classes and formed populations where combined density and growth forced the individuals in the barnacle crust to assume a chimney-like form. Two grazing snails (a periwinkle, *Littorina sitkana*, and limpets) and two predatory snails (*Nucella lima* and *Buccinum ?baeri* were common. Sparse algal cover juvenile rockweed (*Fucus gardneri*), the red alga, *Palmeria ?hecatensis*, and the sheet-like green algae, *Ulva/Monostroma* sp. indicate failure of algae to overwinter. Thus, this site presents a seeming paradox regarding stability. Populations of barnacles and grazing and predatory snails comprise multiple year classes but perennial algae such as rockweed do not. Mussels are also lacking. The paucity of infaunal organisms and the dominance by YOY individuals suggests the soft habitats are unstable.

7) Old Cannery Creek

The extensive fine sand and mud flats at this site, southwest of the Drift River, was impoverished (3 taxa; Table 3-2) and productivity appeared very low. The predominant biotic form is the extensive blue-green algal mat that covers most of the surface of the flat, starting about 300 feet from the high-tide wrack line (Table 3-4). Baltic macomas (*Macoma balthica*) and gammarid amphipods were the only animals observed at this site and both were uncommon (Table 3-3). It is likely that, farther offshore (i.e., >1750 feet), Baltic macomas become sufficiently abundant to become useful as a sentinel species.

Based on the absence of a discernable beachface, and the fine nature of the sediment, it is likely the area is highly depositional and unable to support long-lived infaunal organisms. The paucity of biota at this site indicates it is unstable. However, the low gradient created by this prograding shoreline means that we probably did not descend to a suitably low elevation, despite moving out across the flats nearly 1800 feet.

8) West Foreland South

The mud and sand flats at this site southwest of the West Foreland supported six macrobiotic organisms (Table 3-2) but productivity appears moderate. The only alga observed was the blue-green algal mat, which was well developed on the relatively narrow mud flat on the inner portion of the flat (Table 3-4). The invertebrates included two infaunal taxa and three epibiotic taxa (Table 3-3). Baltic macomas (*Macoma balthica*) were the dominant invertebrate in both the limited mud and extensive sand flats at this site, appearing to achieve densities of at least 1000 animals/sq. m. in some areas (Table 3-3). Other invertebrates included gammarid amphipods and the large isopod

Saduria entomon. Baltic macoma appears to be the only potential sentinel species at this site.

Only a few large glacial erratics exist at this site. The barnacle *Semibalanus balanoides* was sparsely distributed on the face of these boulders. A hydroid formed a halo around the boulders near the surface of the water in the surrounding scour pool.

9) West Foreland North

Eight taxa were observed in the boulder/cobble and mud flat habitats northwest of the West Foreland (Table 3-2). Productivity appeared low. The biota, including one alga and seven invertebrates, was very sparse. The only infaunal animals observed were the Baltic macoma (*Macoma balthica*), a small shrimp (*Crangon* sp.), the large isopod *Saduria entomon*, and a species of predatory snail. Abundance of all species was low.

In addition, the epibiota in the boulder/cobble habitat was impoverished. Rockweed (*Fucus gardneri*) and the barnacle *Semibalanus balanoides* each covered about 1% of the surface on the larger boulders. No other alga was observed. The only other epibiotic invertebrates observed were the periwinkle (*Littorina sitkana*) and a gammarid amphipod (*Anisogammarus pugettensis*). All populations comprised primarily YOY individuals.

No suitable species appeared to be available for use as a sentinel species at this site, where the conditions in all habitats appears to be quite harsh.

10) Nikolai Creek

Only three taxa were observed on the extensive mud flat at Nikolai Creek (Table 3-2), but productivity appears to be moderate. The biota comprised one alga and two infaunal invertebrates (Tables 3-3 and 3-4). The blue-green algal complex formed an extensive mat. Baltic macomas (*Macoma balthica*) and a burrowing polychaete worm (the nereid ?*Laonnates* sp.) were the dominant organisms occurring at this site. The worm, whose burrows honeycomb the mud, provided the most biomass by far. However, because it is not a filter feeder, it probably does not provide the high bioaccumulation advantage exhibited by bivalves. The clam became more abundant with increasing distance offshore and, although not easily collected, it could be used as a sentinel species. Based on the development of the blue-green algal turf and the abundance and size of the worm *Laonnates*, this site appears to be relatively stable.

11) Beluga River SW

Three macroinfaunal taxa were observed on the sand beachface and mud flat south of Beluga River (Table 3-2), where productivity appeared to be moderate. The Baltic macoma (*Macoma balthica*) was the dominant organism at this site, occurring in abundance in the lower muddy sediments (Table 3-3). In addition, lugworms (*Abarenicola pacifica*) were common in the same area. Based on tracks in the surface of the beach, young specimens of the large isopod *Saduria entomon* were common on the sandy lower reaches of the beachface.

The Baltic macoma appears to be the only potential sentinel species at this site. The site appears sufficiently stable to support large populations of both Baltic macomas and lugworms but sufficiently harsh to discourage many other potential infaunal species.

2. Infauna

a) Macroinfauna Statistical Analyses

The qualitative data (absent, sparse, common, abundant) for macrobiota were transformed into ordinal values (0-3) for the seven most commonly observed macroinfauna species (Table 3-5). The data were then submitted for cluster analyses as a Bray-Curtis dissimilarity index or a Jaccard presence/absence index.

From the clustering of the presence/absence data (Figure 3-34), the results show a simple breakdown of sites based on the presence of either the Baltic macoma (*Macoma balthica*) or the razor clam (*Siliqua patula*); essentially a dichotomy of muddy versus sandy sites. The mud sites then break down into subgroupings based on the presence or absence of various accompanying species, lugworms (*Abarenicola pacifica*), softshell clams (*Mya arenaria*), or one of the three rarer species, burrowing spoonworms (*Echiurus*), sipunculids (?*Phascolosoma agassizii*) or nereid polychaete worms (*Laonnates*).

Changing to a quantitative dissimilarity index (Bray-Curtis) as the input for clustering produced essentially the same results but gives more information regarding the degree of

Table 3-5. Macroinfaunal data from upper Cook Inlet sites, where 0 = absent, 1 = sparse, 2 = common, 3 = abundant.

Location	*Mya*	*Phascolo-soma*	*Macoma*	*Abareni-cola*	*Echiurus*	*Siliqua*	*Laonnates*
Chickaloon Bay			2				
Nikolai Creek			1				3
Redoubt Creek			2	3			
West Foreland North			1				
Bishop Creek Beach			1				
Old Cannery Creek			1				

West Foreland South			3				
Beluga River SW			3	1			
Kalifornsky Beach			1	3			
NE Chisik Island			3	3	3		
Oldmans Bay, Kalgin Is.	2		3	2			
Light Point, NE Kalgin Island	2		2	3			
No. Tuxedni Bay Spit	3	2	3	2			
Harriet Point North						1	
Clam Gulch						3	
SE Kalgin Is.				3		1	
NW Kalgin Is.				1		1	

Figure 3-34. Clusters of dominant macroinfaunal species at intertidal sites based on qualitative (presence/absence) data from upper Cook Inlet sites.

Figure 3-35. Station clusters of intertidal sites based on qualitative (presence/absence) data of dominant macroinfaunal species at upper Cook Inlet sites.

similarity within the stations' subgroupings (Figure 3-35). Here the mud/sand dichotomy is subjugated to the abundance of the dominant species. The SE Kalgin site, with (qualitatively) abundant lugworms and sparse razor clams, clustered with the site subgroup dominated by lugworm- rather than with the razor clam. Likewise, the clustering algorithm moves the Beluga River site into the subgroup dominated by Baltic-macoma, ignoring its sparse lugworm population. The species cluster (Figure 3-36) was less informative.

The overall clustering results simply suggest that the macroinfaunal species are consistently found at sites that meet their living requirements: Macomas prefer muddy sites, lugworms prefer sandy mud and razor clams need sand. This mud/sand dichotomy is reflected in both clusters. When quantitative data are used, the results reflect finer distinctions in the assemblages that are lost in the presence/absence data. If more data were available, it is likely that additional subgroups would be formed that reflect the unique proportions of dominant species in response to a gradient in sediment characteristics.

b) Analysis of Infaunal Cores

The full replicate-cores data set is available on the CIRCAC website, *www.circac.org*. Average species abundance for each site is presented in Appendix D. Table 3-6 represents the common pertinent species used in the cluster analyses along with average species richness and average number of individuals from the full data set. Note that some sites have none of the selected species and were dropped from further statistical analyses.

Contrary to typical intertidal infaunal data sets, the data from the infaunal cores represent very sparse assemblages except for those from North Tuxedni Bay and NE Chisik Island sites. The average site had 2.1 species with 33.8 individuals per core with a maximum of 10.2 species and 246.6 individuals (modes at 0.8 and 0.2, respectively). For analytical purposes, most sites were nearly empty with many species being represented by a single individual from the five replicate cores. For this reason, the statistical analyses were kept to simple cluster analyses, eschewing higher-order multivariate techniques. The task of the cluster analyses was to reduce the data set to pertinent species and provide a graphical structure to assist in categorizing and interpreting the data.

Keep in mind that the perceived paucity of biota only represents the assemblage at the "practical sampling" location selected for a site and not necessarily the site as a whole. The goal of this program was to find potential monitoring locations (thus the "practical sampling") and to characterize the biota of the upper inlet. Higher abundance of infauna

Figure 3-36. Station clusters of intertidal sites in upper Cook Inlet inhabited by macroinfauna based on qualitative species abundance.

Table 3-6 Average abundance of infauna in core samples from intertidal sites in middle and upper Cook Inlet, Aug-Sept 2000.

may indeed occur at these sites, as was sometimes suggested in the macroinfauna data from the "nature hikes", but not at the particular locations or with the level of replication by which we sampled.

One of the sediment features observed at Moose Point was an infill of seasonal mud - isolated, eroding, and nearly devoid of life. The only organisms observed in this mud were chironomid flies, the isopod *Saduria*, and one polychaete worm (*Scolelepis*). The remainder of site is ice-scoured, hard-packed substrate with few signs of life.As noted above, the sparseness of the data set made the analyses very sensitive to small changes. The data for several sites contained values representing a single individual from a single replicate, the addition or deletion of which may shift the similarity of one station to a different station group. One method to attenuate some of the sensitivity was to use a Jaccard index of presence/absence (binary) data as the input data. This method produced grouping results very similar to the usual quantitative Bray-Curtis dissimilarity data index. Interpretations were based on a cross-validated assessment between both methods of clusters.

In general, cluster analyses of the infaunal cores reflected subtler differences among the sites than did the macroinfaunal data (i.e., muddy versus sandy species). Working with a broader species list, the infaunal analyses tended to cluster stations into east side/west side groups with the west side sites additionally being separated by their physical exposures.

Figures 3-37 and 3-38 present the station and species clusters from the Jaccard binary data. Figures 3-39 and 3-40 present the same clusters using the Bray-Curtis data. Two indicator markings were added to each cluster figure. A vertical dotted line identifies the subjective break point in the cluster process that subsequently defines individual cluster groups. The groups are further delineated by horizontal dotted lines betweern labels of stations/species on the left side of the figure. The original data sets have been reordered to reflect the cluster groupings and are presented in Tables 3-7 and 3-8 with added notes on particle grain size, physical exposure and east/west location. From these tables, patterns emerge.

In both Tables 3-7 and 3-8, note on the bottom of the tables that the stations tend to cluster into east and west locations (albeit with a couple of stray east side stations). Also note that the west stations have additionally clustered into low/moderate versus strong physical exposures. From the Jaccard analyses, the low/moderate exposure west side sites are distinguished by two species, the polychaete worm, *Eteone longa*, and the clam, *Macoma balthica,* both of which prefer muddy substrates. The strong exposure west side sites are missing these species but have instead the polychaete worms *Leitoscoloplos pugettensis* and *Nephtys caeca* occupying their sandy sediments.

Two unique species-rich sites were sampled on the west side: the north entrance spit of Tuxedni Bay (actually the Crescent River delta) and NE Chisik Island. Both located in the mouth of Tuxedni Bay, they are exposed to substantial volumes of suspended sediments, probably relatively rich in organic matter, from the outflow of rivers within

Tuxedni Bay and the Crescent River. The north spit is a semi-protected environment with a complex assemblage of long-lived species that is well used by feeding marine birds. An eroding delta of the Crescent River, its sediments are a mix of sand and mud atop hard-packed clay. However, just across the mouth of Tuxedni Bay, the assemblage of the NE Chisik site represents a unique mix of both low and high exposure-adapted species. This site is subjected to strong physical disturbance and transport forces seasonally and yet apparently replenished with adequate amounts of sediments, nutrients, and faunal recruitment from nearby sheltered habitats within Tuxedni Bay. In fact, this site has more mud than the nearby protected spit site, suggesting a larger input from within the bay versus long-shore transport from the northern coasts. However, the site's exposure to physical disturbances (storm waves and ice scour) is apparently sufficient to preclude the establishment of the longer-lived macroinfauna (such as *Mya*) found living just across the entrance channel.

The shoals are highly dynamic environments with no established infauna. The few infaunal species found on the shoals are likely transitory species blown in from nearby disturbed habitats. For example, the *Eteone* worms on South Shoal are also found upstream in their more typical low-exposure environs at Oldmans Bay. *Leitoscoloplos* worms like those found at West Foreland North were also found on North Shoal. The South Shoal was an outlier station, clustering late in the hierarchy while North Shoal most closely resembled the neighboring West Foreland North site.

Four of the east side stations are more problematic to characterize. South of the East Foreland, beaches tend to be more current-swept with moderate physical exposure (Kalifornsky Beach and Clam Gulch). These sandy sites have modest infaunal abundance. North of the Foreland, the eastern sites are either muddy with low physical exposure (Bishops Creek Beach) or characterized by seasonally transitory (unstable) mud and (Moose Point). However, these sites are still only sparsely populated by infauna. In the cluster analyses, the eastern sites were often the most dissimilar as evidenced by being the last to join the subgroups. In summary, from the list of sites surveyed in this study, there was no "typical" east side site; they were all unique.

Figure 3-37. Station cluster of intertidal sites in upper Cook Inlet based on presence/absence data of species in infaunal cores using Jaccard similarity index.

Figure 3-38. Species cluster of infauna in intertidal cores from upper Cook Inlet based on presence/absence data using Jaccard similarity index.

Figure 3-39. Species cluster of infauna in intertidal cores from upper Cook Inlet based on abundance data using Bray-Curtis dissimilarity index.

Figure 3-40. Station cluster of intertidal sites in upper Cook Inlet based on abundance of infaunal species in intertidal cores using Bray-Curtis dissimilarity index.

What about epibiota? – a quick summary maybe