Rocky Shores
Inventory and Assessment

Summary Report for FY93 CZMA Grant:
Sensitive Shoreline Resources, Task B

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1. INTRODUCTION

During 1993 and 1994, the Oregon Department of Fish and Wildlife (ODFW) conducted a two-phase inventory of the natural resources of Oregon's rocky shores. The inventory supports planning work of the Oregon Ocean Policy Advisory Council (OPAC). Work conducted during 1993 (phase 1) focused on compiling coastwide rocky shore resource information into a report entitled "Oregon Rocky Shores Natural Resource Inventory". This report summarizes existing information as well as the results of a qualitative examination of rocky shores sites conducted by ODFW staff in spring and summer of 1993. In addition to the report, ODFW also conducted a low tide aerial photo survey of Oregon's rocky shores using color infrared film. The photo survey was designed to support future, more detailed, assessments of rocky shores. Both the report and photo survey were partially funded using a Coastal Zone Management section 309 grant.

During 1994 (phase 2), our rocky shores study focused on broadening our knowledge of rocky intertidal habitats and communities. This work was funded, in part, by a Coastal Zone Management section 309 grant entitled "Sensitive Shoreline Resources" (grant Task B, Rocky Shores Inventory and Assessment). The grant included the following work items:

1. Conduct detailed field surveys of rocky shore sites to ground-truth (verify) information and test interpretation techniques using the 1993 infrared aerial photos.
2. Develop horizontal controls for photos to be used for mapping, and apply stereo modeling to photos of selected sites through contract with Oregon State University.
3. Prepare summary report of rocky shores field work.
4. Prepare digital maps of selected rocky shore sites from data obtained through aerial photography and entered into a GIS data base.

The purpose of this report is to summarize the rocky intertidal field work and the photo interpretation and digitizing work conducted during 1994. This report is intended to fulfill grant work item 3, above.

1.1 Rocky Intertidal Field Work

One of the large gaps in the information base on Oregon's rocky shore resources is a consistent set of coastwide quantitative data describing rocky intertidal invertebrate and algal communities. Although three or four of Oregon's rocky intertidal sites have been studied intensively, the sites are clustered on just one part of the coast. In addition, the existing studies have focused principally on community ecology, rather broad-based intertidal community descriptions. The lack of descriptive community studies representing intertidal environments from all parts of the Oregon coast has reduced our ability to effectively manage intertidal resources.

In summer of 1994, ODFW and the University of Oregon Institute of Marine Biology (OIMB) conducted a quantitative descriptive study of the invertebrate and algal communities on 12 representative intertidal sites on the Oregon coast. This study was intended to begin to fill the gap in descriptive community information. The primary goal and objectives of the study were as follows:

Goal: Describe intertidal communities and habitats at representative sites along the Oregon coast.

Objectives

1) Describe and compare species assemblage composition and species diversity of intertidal sites (the spatial scale of sites is 100's to 1000's of meters).
2) Describe species assemblage composition and species diversity at the scale of 10's of meters within sites (meso-scale).
3) Relate meso-scale species assemblage composition and species diversity to habitat physical characteristics and to features mapped from aerial photos.

1.2 Aerial Photo Interpretation and Digitizing

In summer of 1993 ODFW contracted with an aerial photography firm to conduct an aerial photographic survey of Oregon's rocky shores. The photos were taken at tides below 0' Mean Lower Low Water (MLLW) using false color infrared film. We selected infrared film because it enhances our ability to see algae and vegetation on the photos, allowing us to readily distinguish the algae-covered rocky intertidal habitats. One of our tasks in describing rocky intertidal communities is to map intertidal habitats from the aerial photos (work item 4 of the 1994 grant). The habitat map information will be combined with community descriptions to develop a detailed description of the rocky intertidal environment at 12 sites along the coast.

2. METHODS

2.1 Rocky Intertidal Field Work

ODFW and OIMB staff selected 12 sampling sites along the Oregon coast to include in the study (Figure 1). The primary criteria for selecting the sites included: representing as many habitat types as possible, evenly spreading the sites along the entire coastline, and focusing on the largest rocky intertidal areas. We used a stratified-random sampling design to describe the rocky intertidal invertebrate and algal communities. Each sampling area was divided into four strata based on tidal elevation. The elevation strata were 0-0.5 meters, 0.5-1 meters, 1-2 meters, and 2-3

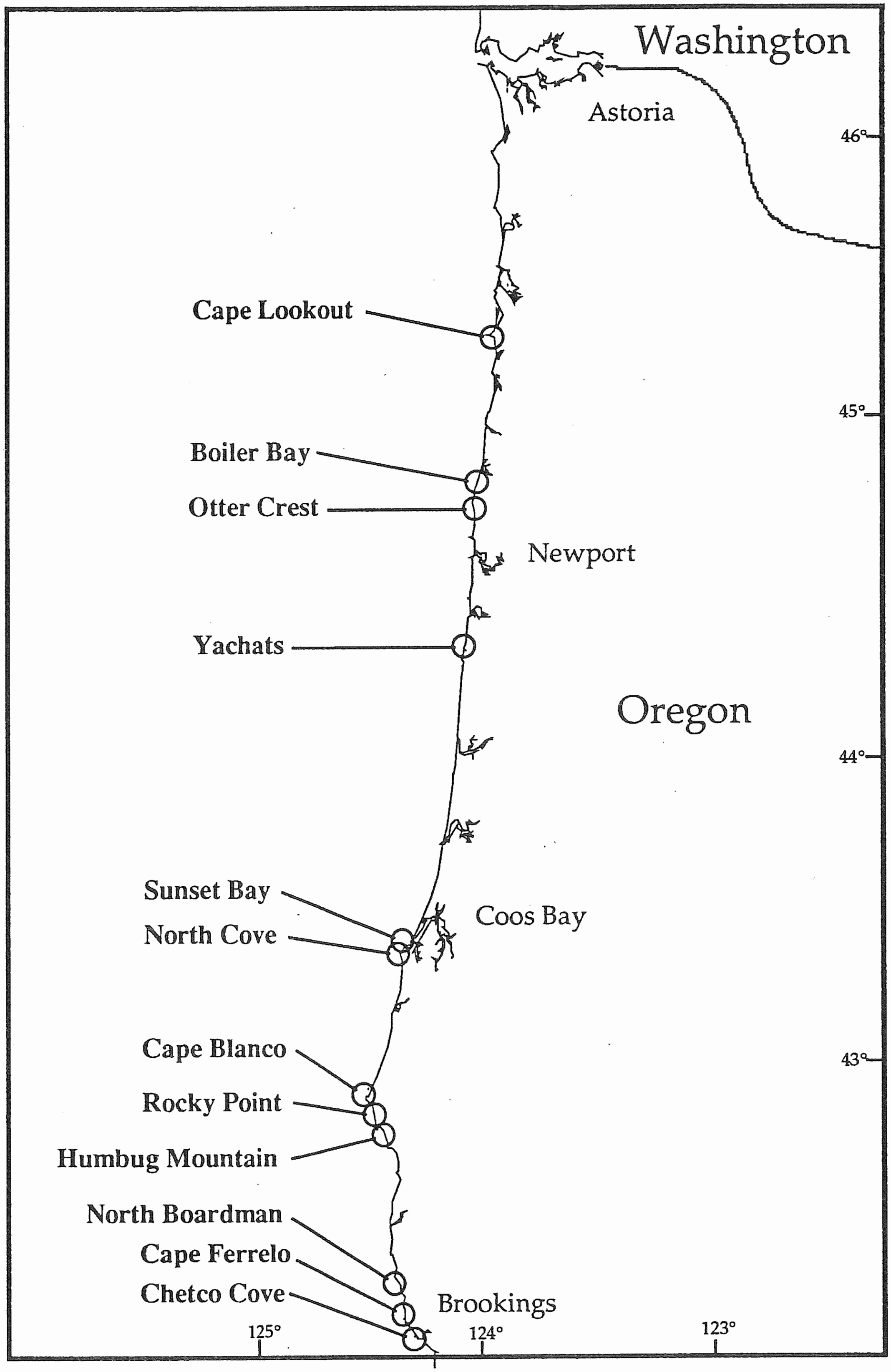

Figure 1. Location of rocky intertidal survey sites on the Oregon coast.

meters, using Mean Lower Low Water as 0. We attempted to sample at 6 randomly placed stations within each stratum. We conducted three sampling procedures at each station:

1. plots with point quadrats (one 10m x 1m plot with 80 random points per plot),
2. quadrats (three 0.5m x 0.5m quadrats per station), and
3. belt transects (one 20m x 1m belt transect per station).

We selected three different sampling methods because no one method adequately samples all the types of invertebrates or algae in the rocky intertidal community. The plots with point quadrats sampled percent cover of algae and encrusting invertebrates. The quadrats sampled density of common non-encrusting invertebrates and the belt transects sampled density of conspicuous, widely dispersed invertebrates. The methods were intended to give the best representation possible of the dominant taxa that compose intertidal communities, given limitations of sampling time. The methods did not fully sample species that occur rarely, species that occur under rocks or in sediments, or species that occur in interstitial spaces between rocks, within algal holdfasts, or between densely packed invertebrates. The total planned sampling size was 24 stations per site (includes a total of 24 plots, 72 quadrats, and 24 belt transects) divided into 6 stations per stratum. Appendix A provides details of the biological sampling procedures and Appendix B contains the field data forms.

During the biological sampling, we also recorded physical habitat features. The following three sampling methods were used:

1. elevation surveys to locate the sampling strata and to record the elevation of individual sampling stations,
2. video taping each plot and belt transect to provide a record of substrate types, and
3. recording substrate type associated with each sampling point in the plots and within each quadrat.

Elevations were measured with an optical surveyor's level and stadia rod. Appendix C describes details of the elevation surveying methods. Substrate type categories are described in Appendix A.

2.2 Aerial Photo Interpretation and Digitizing

The purpose of the photo interpretation and digitizing was to develop maps of rocky intertidal habitat features. Producing the maps required the following general steps:

1. geo-registering the aerial photos to a Universal Transverse Mercator (UTM) coordinate system,

2. stereo-modeling selected photo pairs to produce elevation contours of rocky intertidal areas,
3. interpreting the photos for selected physical and biological characteristics, and
4. digitizing the interpreted photos onto a GIS.

Geo-registration

ODFW contracted with Oregon State University, Department of Forestry to geo-register the aerial photos of rocky intertidal areas. This work involved defining planimetric control points on each photo and determining the UTM coordinates of each point. The steps in this process included:

1. locating features that are identifiable on both U. S. Geological Survey (USGS) 1:24000 orthophotos and our 1:7200 color infrared photos and using these features as common control points,
2. digitizing control points on the 1:24000 orthophotos or quad maps to obtain their UTM coordinates,
3. bridging the control points from the 1:24000 orthophotos to the 1:7200 photos using a digitizer, and
4. marking control points of the photos and developing computer files with the coordinates.

The bridging process allowed us to accurately orient the photos and digitize habitat features into the UTM coordinate system.

Stereo Modeling

ODFW contracted with Oregon State University, Department of Forestry, to stereo model photos of selected intertidal areas for the purpose of developing elevation contours. The Department of Forestry used an AP190 analytical stereo plotter to develop contours within the intertidal zone. The stereo models were leveled with the low-tide water surface on the photos to provide vertical reference. Where possible contour intervals were 1 meter and covered the area from 0 to 4 meters MLLW. The Department of Forestry recorded contours in digital format and we loaded them directly onto our GIS.

Photo Interpretation

We interpreted habitat characteristics on 1:1200 enlargements of the color infrared photos for the 12 study sites shown in Figure 1. The interpretation procedure involved first examining each photo using a set of criteria that define particular physical or biological characteristics (Appendix D). Polygons defining the habitat characteristics were then drawn on acetate overlays registered to the aerial photos. Habitat characteristics examined included:

- bedrock
- boulder (two size categories)
- cobble
- sand
- tide pools

- surge channels and crevices
- macroscopic intertidal algae
- mussel beds
- large surf grass beds (*Phyllospadix* spp.)
- selected kelp beds

Once completed, the 1:1200 photos and associated acetate overlays became the digitizing base for developing GIS habitat maps.

Digitizing

Intertidal site maps with habitat polygons were placed onto our GIS of marine resources. The methods involved first creating site maps using a commercial GIS software package. The map files were initially established in a "no projection metric" coordinate system. We created separate layers for each type of habitat characteristic within each map file and then digitized the habitat polygons onto their appropriate map layers. We then transformed the digitized map into the UTM coordinate system by bridging control from the 1:7200 photos to the 1:1200 digitizing base and conducting an "Affine Transformation". This transformation scales and positions the digitized image based on the control points and allowed us to merge the image with our coastal base map. Our Oregon coastal base map was developed by the Oregon Geographic Information Service Center from 7.5 minute USGS quad sheets.

3. RESULTS AND DISCUSSION

3.1 Rocky Intertidal Field Work

Table 1 lists the intertidal sites sampled and the total number of samples collected within each stratum at each site. Nearly all of the planned samples were completed. At several sites, the 2-3 meter stratum was sampled at a reduced rate or not at all because the stratum was either non-existent or so small and uniform that it could be adequately represented at a reduced sampling rate. Rocky Point had no samples at both the 2-3 meter the 1-2 meter strata because the site had no rocky intertidal area above 1 meter MLLW.

The 12 survey sites represented a variety of rocky intertidal habitat types. Three of the sites consisted primarily of low slope bedrock platform, five were primarily boulder habitat, and four had a mixture of platform and boulder habitat. We equally divided the sites between the north coast and south coast to reflect the possible shift in intertidal species between those two regions. Most of the larger intertidal sites on the Oregon coast are somewhat protected from wave action because they are located in large coves or on the north or south flanks of headlands. With the exception of Yachats and Boiler Bay, none of the sites had the extensive

Table 1. Total number of samples per site and stratum.

Site and Stratum	Plots	Quadrats	Belt Transects	Site and Stratum	Plots	Quadrats	Belt Transects
Cape Lookout				**Cape Blanco**			
0 - 0.5 meter	6	18	5	0 - 0.5 meter	6	18	6
0.5 - 1 meter	6	18	6	0.5 - 1 meter	6	18	6
1 - 2 meter	6	18	6	1 - 2 meter	6	18	6
2 - 3 meter	6	18	6	2 - 3 meter	6	18	6
Otter Crest				**Rocky Point**			
0 - 0.5 meter	4	12	4	0 - 0.5 meter	6	18	6
0.5 - 1 meter	5	15	5	0.5 - 1 meter	6	18	6
1 - 2 meter	4	12	4	1 - 2 meter	0	0	0
2 - 3 meter	0	0	0	2 - 3 meter	0	0	0
Boiler Bay				**Humbug Mountain**			
0 - 0.5 meter	4	12	4	0 - 0.5 meter	6	18	6
0.5 - 1 meter	4	12	4	0.5 - 1 meter	6	18	6
1 - 2 meter	4	12	4	1 - 2 meter	6	18	6
2 - 3 meter	6	18	6	2 - 3 meter	3	9	3
Yachats				**North Boardman**			
0 - 0.5 meter	6	18	2	0 - 0.5 meter	6	18	6
0.5 - 1 meter	5	15	2	0.5 - 1 meter	6	18	6
1 - 2 meter	6	18	6	1 - 2 meter	6	18	6
2 - 3 meter	6	18	6	2 - 3 meter	3	9	3
Sunset Bay				**Cape Ferrelo**			
0 - 0.5 meter	4	12	4	0 - 0.5 meter	5	15	5
0.5 - 1 meter	4	12	4	0.5 - 1 meter	6	18	6
1 - 2 meter	6	18	6	1 - 2 meter	6	18	6
2 - 3 meter	4	12	4	2 - 3 meter	6	18	6
North Cove				**Chetco Cove**			
0 - 0.5 meter	6	18	6	0 - 0.5 meter	6	18	6
0.5 - 1 meter	6	18	5	0.5 - 1 meter	6	18	6
1 - 2 meter	5	15	5	1 - 2 meter	6	18	6
2 - 3 meter	6	18	6	2 - 3 meter	3	9	3

Total Plots	241
Total Quadrats	723
Total Belt Transects	232

mussel bed communities that typically occur on open coast wave-exposed locations. The relative scarcity of mussel bed communities was one notable surprise of the survey. The typical intertidal habitat of Oregon is generally considered to be highly exposed areas with extensive mussel bed communities. We observed that, in terms of total surface area, there may actually be more semi-protected intertidal areas almost devoid of mussel beds in Oregon. This will be verified as we analyze the data.

A description of each site is given below based on our observations while conducting the field work. We will develop quantitative descriptions of communities and habitats at each site as we analyze the field and photo interpretation data.

Cape Lookout

The rocky intertidal site on the south side of Cape Lookout consists of a sandstone and basalt boulder field that ends in vertical sea cliffs to the west and sandy beach to the east. The site faces directly south and is protected from spring northwest winds and swell but is very exposed to winter south winds. Boulders at the site range in size from 0.5 to 2 meters. There are extensive kelp and surf grass beds at the lower intertidal limit. A *Nereocystis* kelp bed lies just offshore. Intertidal habitat appears to have a very rich assemblage of algae and nudibranchs and appears more similar in habitat structure and, possibly, species composition to south Oregon coast sites than other north coast sites. Human use at the site is relatively low due to difficult public access. The area we sampled consisted of a nearly level boulder field and was about 400 meters west of the sandy beach.

Otter Crest

Otter Crest intertidal area consists of a nearly continuous low-slope shale bedrock platform extending from the high cliffs of Cape Foulweather to the small headland at Devil's Punch Bowl. There are some intertidal boulder fields at the site. The upper intertidal grades into sand beach along much of the shore. Overall, the site has a diversity of microhabitats due to the numerous crevices in the bedrock, small rocky outcroppings, and boulders, as well as the mix of basalt, soft sandstone, and shale rock types. The site has a west exposure but receives some protection from the full force of waves from shallow reefs and rocks just offshore. Human use is very high at the southern half of the site and decreases significantly toward the northern half. The upper intertidal habitat on the south half of the site is apparently influenced by both periodic sand burial and high human use. The area we sampled consisted primarily of low-relief shale bedrock platform with almost no boulders. The area sampled was dominated by the alga *Enteromorpha linza*. Boring clams such as *Adula* sp. and the anemone, *Anthopleura artemisia*, appeared to be much more common than at other sites.

Boiler Bay

Boiler Bay has a wide variety of wave exposure regimes and substrate types. It is a northwest facing cove that has some protection during winter south winds but has significant exposure to spring and summer seas. Protection from wave exposure increases toward the inner reaches of the cove. The inside is protected from both summer and winter waves. Substrate types include sloping basalt bedrock benches, low-slope fractured bedrock platforms, boulder fields with a variety of boulder sizes, and small coves and pocket beaches. The variety of intertidal habitat types make it a species-rich site. Only the semi-protected sloping bedrock benches were included in our survey. Common lower intertidal species included two species of *Phyllospadix* and numerous purple urchins. Mid to upper intertidal areas had some mussel beds.

Boiler Bay is the most studied intertidal area in Oregon. OSU researchers have performed numerous research projects over the years, primarily focusing on different aspects of intertidal community ecology. The primary purpose of including this site in the inventory was to obtain a verification of our sampling techniques. We will compare existing data from Boiler Bay with our results to help determine how well our methods represented the intertidal community.

Yachats

Intertidal areas along Yachats consist primarily of a series of fractured basalt and sandstone bedrock benches that rise about 1 to 4 meters above the surrounding beaches. The tops of the benches are in the mid to upper intertidal elevation ranges; most of the lower intertidal communities exists on vertical faces of the benches. There are also some lower intertidal bedrock platforms scattered among the high benches. Many of the lower areas receive significant sand scour. The entire intertidal area has a west exposure and no protection from wave action. Middle intertidal areas have large, well developed mussel beds. Much of the site receives a great deal of human use, including commercial mussel harvest. The area we sampled consisted both of high basalt benches and low basalt bedrock platforms. The lower intertidal zone had well-developed beds of the alga *Laminaria sinclairii*. These beds had an extensive holdfast network that provided habitat for a number of invertebrate species. Spaces between the holdfasts had sand-cementing tube worms and bryozoans.

Sunset Bay

Sunset Bay intertidal habitats consist of low-slope fractured sandstone bedrock platforms and some boulder fields. The bay and surrounding area consists of a series of small inlets and intertidal habitats that fall into a variety of wave exposure regimes. Most parts of the bay are relatively protected from wave action. Use of some of the intertidal areas by school groups and the general public is very intense. We sampled on the wave-protected south side of Sunset Bay in an area consisting of bedrock platforms in the upper intertidal and boulder fields in the lower intertidal.

North Cove

North Cove of Cape Arago consists of large sandstone boulder fields and low-slope bedrock platforms. It is the largest rocky intertidal site in Oregon. The main part of the cove is an extensive mid to low intertidal boulder field with some large rock outcroppings. It is very protected due to a line of offshore rocks (Simpson Reef) that form almost a continuous barrier to waves. There are sand and mud beaches at the upper reaches of the intertidal. North Cove is a very species-rich site, particularly its algal community. It is the only site in Oregon where significant beds of *Macrocystis integrifolia* are found. We sampled an area to the north of the main part of the cove. This area consisted of a mix of bedrock platform and boulders in the upper intertidal and a boulder field in the lower intertidal. It was more exposed to wave action than the main part of the cove. The outer edges of the site were bordered by surf grass beds.

Cape Blanco

Cape Blanco forms the westernmost point in Oregon. Rocky intertidal habitat extends around all sides of the cape, but our summer 1994 field work concentrated on the north side. This north facing site consists of sloping bedrock almost completely covered with a layer of 0.5 meter to 2 meter diameter boulders. In some areas, significant amounts of shell and sand fill the gaps between boulders. The eastern part of the site grades into a sandy beach. The western part of the site consists mostly of high relief bedrock, with large tide pools that can exceed 2 meters deep and rock outcroppings several meters high. In total the site has a significant amount of vertical relief, overhangs, crevices, and other microhabitats. Human use is relatively low due to its remote location. We sampled the central part of the site that consisted mostly of bedrock covered by boulders. Because the site is exposed to spring and summer waves, the rocks appeared wetter at any given elevation than more protected areas. It appeared that the distribution of many organisms in tidal zones was shifted upwards compared to nearby sites. Because lower tidal levels tend to be more diverse, the overall species richness of the Cape Blanco site appeared to be high, possibly due to the upward shift of lower intertidal communities. The algal cover was extremely lush and multilayered. We found several encrusting invertebrate species in the lower intertidal zone of Cape Blanco, such as the bryozoan *Costazia ventricosa*, that we did not observe at other sites.

Rocky Point

Rocky Point intertidal habitats include both low slope boulder areas and some higher relief bedrock and boulders areas. The site faces west but is probably less exposed to wave action than other west facing sites because it is in the large cove formed by Port Orford heads and Humbug Mountain. We sampled at a very low slope boulder and cobble area that graded into a sandy beach at about 1 meter of elevation. The boulders were mostly less than 0.5 meters in diameter and there was generally sand between the boulders. The site has a significant amount of human use and probably experiences disturbance due to clam digging, overturning boulders, and trampling. The boulders and cobbles are small enough that they probably also experience overturning by wave action. The site appeared less species rich than other sites on the south coast. One notable observation was that the black turban snail *Tegula funebralis* appeared much more abundant than at other sites sampled.

Humbug Mountain

A large strip of intertidal boulder habitat lines the south face of Humbug Mountain. The site is very protected from wave action during the spring and summer northwest winds. The overall slope of the boulder field is moderate, grading from 4 meters to 0 meters MLLW over the 60 meter width of the intertidal zone. The boulders are rather large, ranging from 0.5 to 4 meters or more in diameter. The intertidal habitat has high vertical relief due to the size of the boulders. The boulder field ends at a cliff on the northwest end of the site and a sandy beach on the southeast end of the site. A *Nereocystis* kelp bed forms almost a continuous strip along the coast just offshore. The site is remote and receives very little human use. We sampled the middle portion of the site about 400 meters northwest of the sandy beach. The intertidal area at Humbug Mountain appeared dryer at any given elevation than more exposed sites due to the protection from waves. Because of this, organisms appeared to be shifted downward in elevation strata. This was especially evident in the algal species on the tops of boulders. The very low tidal zones appeared particularly rich in invertebrate species. For example we observed a large variety of sea stars including *Solaster dawsoni*, all 3 species of *Henricia, Dermasterius imbricata, Evasterias troschelii,* and *Pycnopodia helianthoides*.

North Boardman

North Boardman is the largest intertidal area in a series of intertidal platforms and boulder fields from Crook Point to Cape Ferrelo. The North Boardman site consists of a series of low rock ridges in the lower intertidal and a boulder field in the upper intertidal. The boulders grade into a cobble beach above the intertidal zone. The site has west exposure but is somewhat protected from wave action by large rock outcroppings on the outer fringe of the intertidal platform and by Mack Reef to the northwest. The combination of ridges, outcroppings, and boulders makes for a very complex series of microhabitats. Because the site is remote, it receives very little human use. This site is probably one of the most species rich in Oregon, especially in the lower intertidal. The lower intertidal algal community consisted of a rich covering of the brown alga *Alaria* sp., *Laminaria* sp., *Egregia* sp., *Cystoseira* sp., *Hedophyllum* sp., and numerous red algae species. There was a diversity of encrusting sponges, hydrozoans, and bryozoans in the lower intertidal, as well as many species of nudibranchs and sea stars.

Cape Ferrelo

Cape Ferrelo intertidal habitat consists of boulder fields with a wide variety of boulder sizes from less than 0.5 meters to over 10 meters in diameter. The site we sampled had south and west exposure and consisted of two separate coves with large boulders partially protecting them from wave action. The wide variety of boulders made for a variety of crevices, vertical surfaces, overhangs, and other microhabitats. The lower intertidal zone had a rich growth of *Alaria* sp., *Laminaria* sp., *Egregia* sp., *Cystoseira* sp., *Hedophyllum* sp., *Odonthalia floccosa*, and some *Nereocystis luetkeana*. There were also numerous sea star species (including more *Dermasterius imbricata* than seen at other sites), and anemone species (including

Urticina crassicornis, U. coriacea, and *U. lofotensis*). The limpet *Acmea mitra* was more common here than other sites, and it was the only site where we saw the gastropod *Tegula brunnea*. Many mid to upper intertidal boulders were nearly covered with *Petrocelis* sp., an encrusting red alga.

Chetco Cove

Chetco Cove is a south facing cove just north of the mouth of the Chetco River. The site is completely protected from spring and summer northwest winds due to its orientation and is partially protected from winter south winds by the north jetty of the Chetco River. The intertidal habitat consists of low relief bedrock platform, with some boulders. There are numerous tide pools in the lower intertidal. The upper intertidal grades into a sand and cobble beach. Access to the site is, for the most part, known only to locals so the site receives relatively little human use. Dominant lower intertidal algal species included *Prionitis lanceolata* and the introduced *Sargassum muticum*. These species appeared more abundant here than at the other sites. The invertebrate community appeared less species rich than other sites but included some species not commonly seen intertidally in Oregon, such as the tunicate *Clavelina huntsmani* and the brachiopod *Terebratalia transversa*.

3.2 Aerial Photo Interpretation and Digitizing

Aerial Photo Control and Stereo Modeling

The Oregon State University Department of Forestry completed horizontal control of 150 rocky shore photos. These photos represent all sections of the Oregon coastline with significant amounts of rocky intertidal area. Each photo has 5 to 8 control points, concentrated primarily on the low elevation shoreline areas. High elevation areas were avoided to minimize photo registering errors caused by photo scale differences at different elevations. The control points are in the UTM coordinate system and their units are in meters. we have found the horizontal error of the control points to be generally 10 meters or less.

OSU Department of Forestry completed stereo modeling of 22 photo pairs. These photos represent most of the sites sampled during the summer 1994 field work. This work provided elevation contours for the rocky intertidal portion of the photos. Rocky intertidal areas were difficult to contour because many are nearly level and contain numerous high-relief geologic features. These features were too small to be individually contoured on the 1:7200 photos. This small scale vertical variation often made it difficult represent the gentle slope of a site. The contours represent general elevation change within a site but do not represent all of the vertical variation within the intertidal area. Figure 2 shows an example of elevation contours at one of the sites.

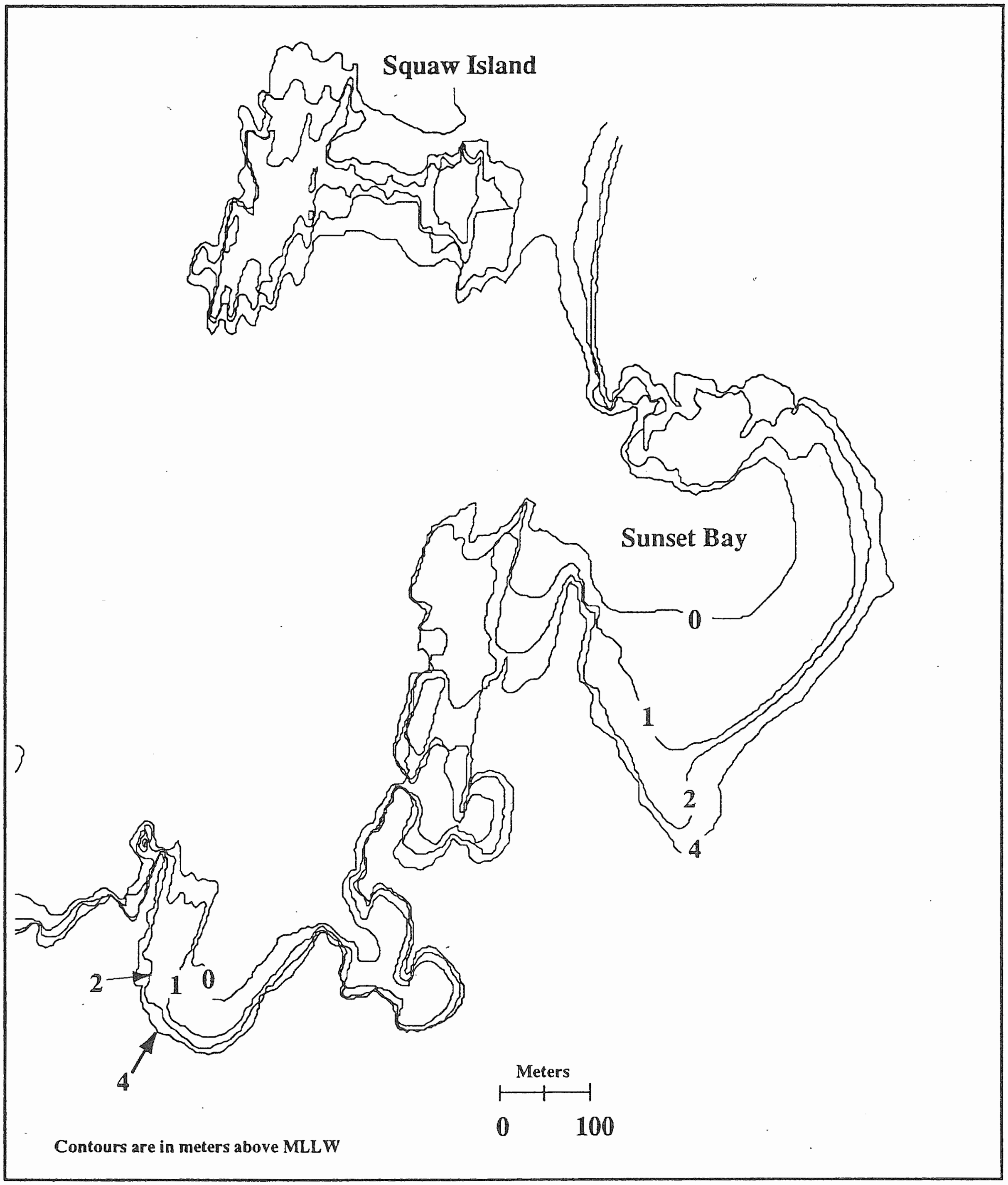

Figure 2. Example rocky intertidal contour map. The area depicted is Sunset Bay and vicinity, Cape Arago, Coos County, Oregon.

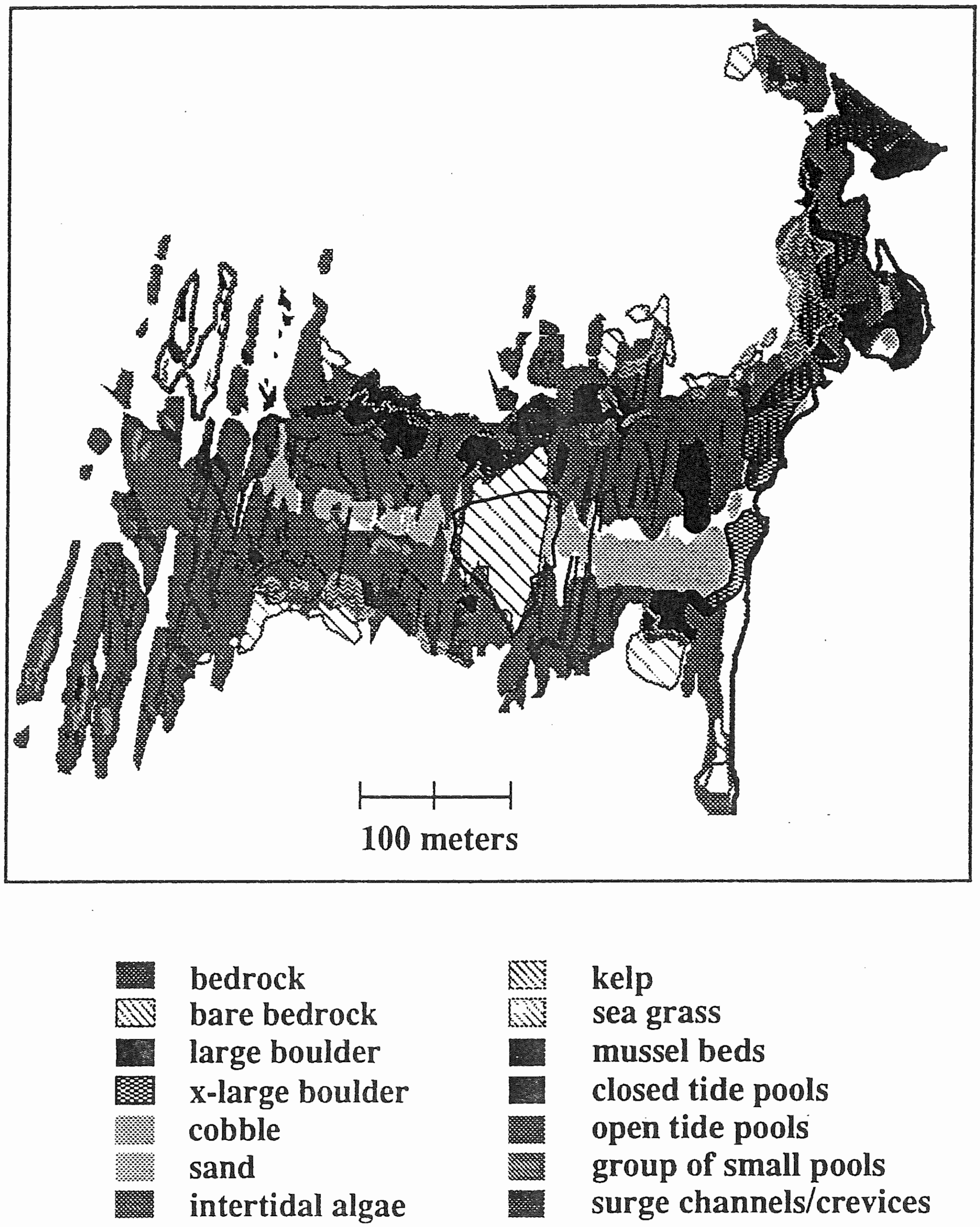

Figure 3. Example rocky intertidal habitat map. The site depicted is Squaw Island on the north side of Sunset Bay, Cape Arago.

Photo Interpretation and Digitizing

We have completed interpretation of intertidal habitat characteristics on a total of twenty-eight 1:1200 photo enlargements. Figure 3 is an example of a map of intertidal habitats at one of the sites.

4. FUTURE DATA ANALYSIS PLANS

The data collected during the summer 1994 field work lend themselves to a wide variety of analytical procedures. We plan to focus our analyses on large scale comparisons of sites and elevation strata. We will generate species diversity measures for strata and sites including Shannon-Weiner diversity index, species richness, and species evenness indices. We will conduct Analysis of Variance (ANOVA) statistical tests to examine differences in the diversity measures among sites and strata. ANOVA will also be employed to examine differences in density or percent cover of key invertebrate and algal species by site and stratum. We will use hierarchical clustering methods to define algal and invertebrate species assemblages. The clustering will be done by site, stratum, site/stratum combination, and key habitat type. The combination of these analyses will help us formulate conclusions about major differences among sites along the coast, among strata within a site, and among similar strata at different sites.

The digitized habitat data will be used for two purposes: to determine regional significance of different habitat features on the coast and to determine correlations between habitat features and species assemblages. The habitat feature polygons at each site will be analyzed by hierarchical cluster analysis and other means to determine which combinations of features co-occur most frequently. We will determine which habitat features occur most frequently, which features are rare, and whether there are differences between north and south coast habitat features.

The description of habitat features in the areas sampled during the summer 1994 field work will be used to draw inferences about the relationship between physical habitat and species present.

Appendix A: Rocky Intertidal Survey Sampling Procedures

This appendix describes details of the procedures for conducting the rocky intertidal survey. Biological sampling consisted of 3 types of procedures: plots with point quadrats, quadrats, and belt transects (Figure 4). Physical sampling included elevation surveys (see Appendix C) and recording substrate types on data forms and video tape. The sampling procedures are summarized below.

Sampling Teams

Sampling personnel were divided into a north coast and south coast groups, each possessing 4 two-person teams. During each day of sampling, 3 teams conducted plot and quadrat sampling and 1 team conducted elevation surveys and video work. The team leaders did the belt transects.

Biological Sampling

Plots: The plots were designed for determining percent cover of algae and encrusting invertebrates. Eighty (80) random points were sampled for cover type (all layers) within 1m x 10m plots running approximately parallel to the elevation contours. The plots were located randomly within each elevation stratum and laid out using two parallel measuring tapes.

Sampling Procedure:
1) The sampling teams located sampling stations according to methods outlined in Appendix C.
2) At the selected location, teams extended two parallel 20m measuring tapes one meter apart staying within the elevation stratum to define the plot boundaries (the first 10m formed the plot; the entire 20m formed the belt transect).
3) A $0.25m^2$ sampling grid* was placed on the inside of the first tape at the 0m mark. Four points on the sampling grid were selected randomly to sample all layers of cover species (algae or invert.) at each point. The sampling team moved the quadrat 0.5m along the plot, randomly to the left or right transect tape (determined from the random number chart), and sampled four more random points. This procedure was continued until the 9.5-10m mark was reached on the measuring tapes (the quadrat was laid out a total of 20 times to locate all 80 sampling points in the plot).

* The $0.25m^2$ sampling grid consisted of a square frame 0.5 m on edge made from PVC pipe. The frame was divided up into a grid with each grid cell 0.1 m on edge. Fishing line was strung on the frame to create the grid.

Quadrats: The quadrats were designed to sample non-encrusting invertebrates. Invertebrates were identified and counted within three $0.25m^2$ square quadrats selected at a random location within each plot.

Sampling Procedure: Sampling teams used a pre-developed list of random numbers to locate the quadrats at the plot points selected from the list. All visible invertebrates within the quadrat were identified and counted. Littorine and Lacuna snails, small limpets, small chitons, and *Balanus* and *Chthamalus* barnacles were estimated by order of magnitude (1's, 10's, 100's).

Belt transect: The belt transects were designed for sampling conspicuous, widely dispersed invertebrates. There was one 1mX20m belt transect at each station consisting of the plot, described above, and a 10mx1m extension of the plot.

Sampling Procedure: Sampling personnel walked the belt transect defined by the measuring tapes and recorded all large seastars and other conspicuous species. The search procedure included moving aside large clumps of algae and looking in crevices. Rocks were not turned over, and algae were not systematically searched.

Physical Characteristic Sampling

Elevation Surveys: see Appendix C.

Substrate Types: Sampling teams recorded the substrate type at each point sampled in the plot. They estimated the cover of each physical feature in the quadrats by counting quadrat grid cells. The substrate types included:

sand	< 4mm (1/8")
gravel	4 - 64mm (1/8" - 2.5")
cobble	64 - 305mm (2.5" - 12")
small boulder	30.5cm - 1.25m (1' - 4')
large boulder	> 1.25m (4')
tidal pools (impounded pools only)	

Video Record: Sampling personnel video taped the plots and belt transects to record habitat characteristics.

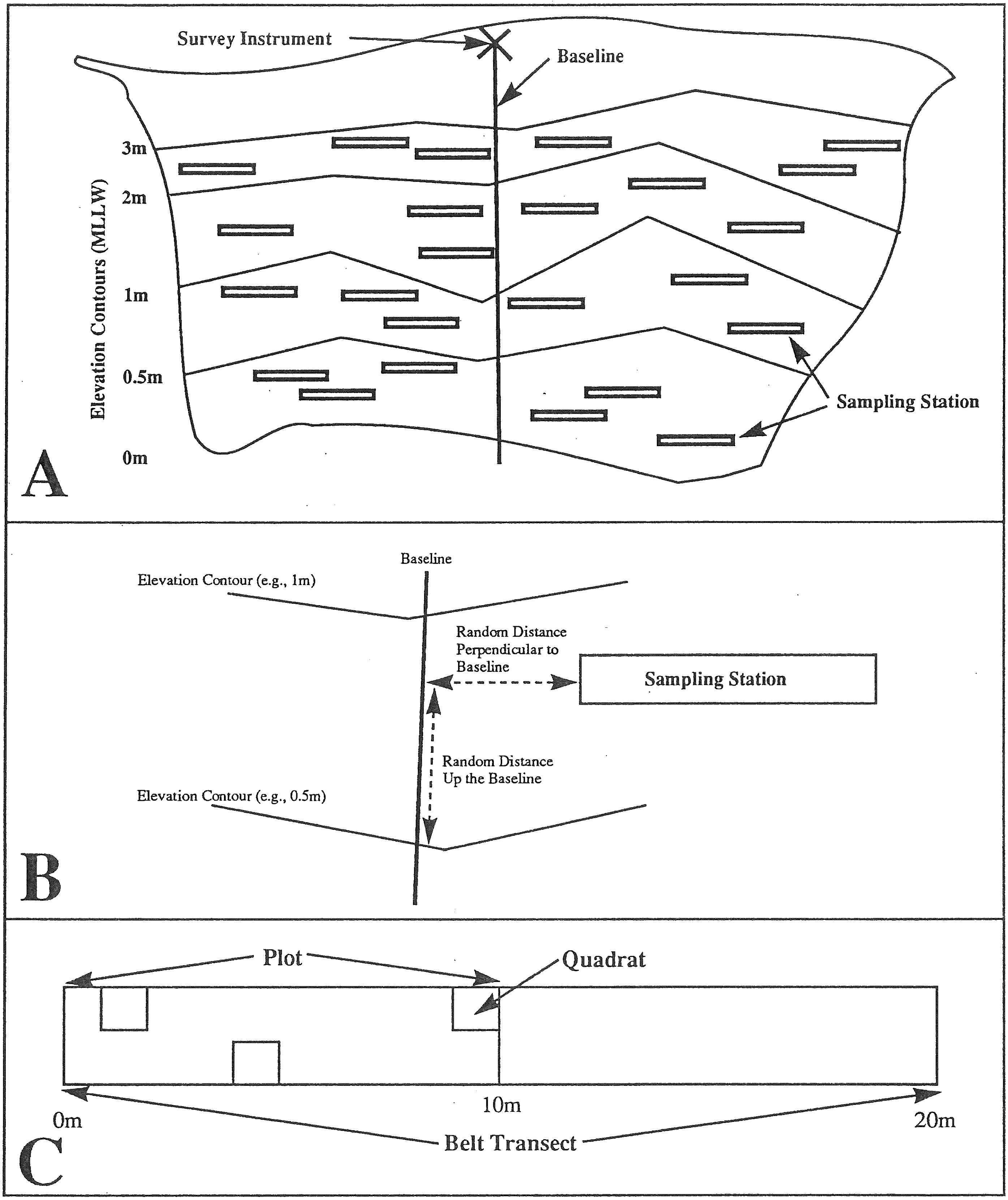

Figure 4. Schematic representation of sampling design (see text for further explanation). A. Typical layout of sampling stations at an intertdial site. B. Method of randomly locating a sampling station with respect to elevation contours and the baseline. C. Individual sampling station showing relationship among the 1m x 10m plot (80 points were sampled randomly within each plot), the 1m x 20m belt transect, and the 3 quadrats.

Appendix B: Rocky Intertidal Survey Field Data Forms

Observer: low intertidal **Plot** 1 2 3 4 5 6

Recorder: Date: Site: Stratum: Points 1-40 41-80

Ceramium sp.	
Cryptosiphonia woodii	
Dilsea californica	
Endocladia muricata	
Gelidium sp.	
Gigartina canaliculata	
Hymenena/Cryptopleura	
Iridaea heterocarpa	
I. splendens	
Mastocarpus sp.	
Microcladia borealis	
Neorhodomela larix	
Odonthalia floccosa	
O. sp. (com. unknown)	
Plocamium cartilag.	
P. violaceum	
Polysiphonia sp.	
Prionitis sp.	
Ptilota filicina	
fleshy crust (other)	
"Petrocelis" crust	
Bossiella sp.	
Calliarthron sp.	
Corallina sp.	
Corallina vancouver.	
coralline crust	
Analipus japonicus	
Egregia menziesii	
Fucus gardneri	
Hedophyllum sessile	
Laminaria setchellii	
Acrosiphonia coalita	
Cladophora sp.	
Ulva/Monostroma	
Phyllospadix scouleri	
P. torreyi (narrow)	
INVERTS	
A. elegantissima	
A. xanthogrammica	
Spirorbis	
Mytilus californianus	
small Mytilus	
Balanus	
Pollicipes	
Semibalanus	
unident. barnacles	
S. purpuratus	
bare rock	
SUBSTRATUM	
bedrock	
large boulder (>4')	
small boulder (1 - 4')	
cobble (2.5" - 1')	
gravel (<2.5")	
sand	
tidepool	

Site: Stratum:

Observer/Recorder: Plot number:

Quadrat
A B C

Anthozoa		tot.	**nudibranchs**		tot.
A. elegantissima			Rostanga		
A. xanthogrammica			Archidoris montere.		
A. artemesia			Diaulula sandiegen.		
Epiactis prolifera					
U. crassicomis					
U. coriacea			**bivalves**		
			Mytilus califomianus		
			sm. Myt. (1, 10, 100)		
Polychaeta			piddock siphons		
Pista elongata					
Thelepus cripsus			**bamacles**		
Eudistylia			Pollicipes polymer.		
Serpula			Chtham. (1, 10, 100)		
Spirorbis (1, 10, 100)			Balanus (1, 10, 100)		
			Semibalanus cario.		
Chitons					
Nuttalina			**Isopoda/ Amphipoda**		
Mopalia muscosa			Idotea spp.		
M. lignosa					
Katharina			amphip. (1, 10, 100)		
Tonicella					
small chitons			**Decapoda**		
			shrimps		
limpets			large hermit crabs		
Lottia digitalis			small hermit crabs		
L. strigatella			Petrolisthes spp.		
L. pelta			Pugettia producta		
L. asmi			P. gracilis		
Tectura persona					
T. scutum					
T. fenestrata					
Acmaea mitra					
sm. limpets (<5 mm)			**Asteroidea**		
			Leptasterias		
			Pisaster		
snails					
Littorina (1, 10, 100)					
Lacuna spp.			**Echinoidea**		
Tegula			S. purpuratus		
Nucella emarginata					
N. lamellosa					
N. canaliculata					
Ocenebra lurida			**Phys. charac. (record # of squares)**		
Calliostoma ligatum			bedrock		
Amphissa			large boulder (>4')		
Alia			sm. boulder (1 - 4')		
small round snails			cobble (2.5" - 1')		
small conical snails			gravel (<2.5")		
			sand		
			tidepool		

Site, date:

Belt transects

Observer:

species	stratum, plot #	tot.	stratum, plot #	tot.	stratum, plot #	tot.	stratum, plot #	tot.
Anthozoa								
A. xanthogrammica								
A. elegan. (>5 cm disk)								
Urticina coriacea								
U. crassicornis								
ribbon worms								
Tubulanus polymorph.								
chitons								
Cryptochiton stelleri								
Katharina tunicata								
limpets, abalone								
Acmaea mitra								
Diodora								
Haliotis (ruf. or wal.)								
snails								
Calliostoma ligatum								
Ceratostoma foliatum								
nudibranchs								
Anisodoris nobilis								
Archidoris monterensis								
Cadlina luteomarginata								
Diaulula sandiegensis								
Dirona albolineata								
Hermissenda								
Janolus fuscus								
Rostanga pulchra								
Triopha catalinae								
Asteroidea								
Asterina (=Patiria)								
Dermasterias								
Evasterias troschelii								
Henricia (red)								
H. sp. (mottled)								
H. sp. (red + lav.)								
Leptasterias								
Pisaster ochraceus								
Pycnopodia								
Solaster stimpsoni								
S. dawsoni								
Echinoidea								
S. purpuratus								
S. franciscanus								
Codium fragile								
Laminaria setchellii								
Nereocystis								

Video Data Date ____________ Name ________________

Site ____________________

Stratum	Plot	Tape #	Start Video Count	End Video Count	Notes
0-0.5m	1				
	2				
	3				
	4				
	5				
	6				
0.5-1m	1				
	2				
	3				
	4				
	5				
	6				
1-2m	1				
	2				
	3				
	4				
	5				
	6				
2-3m	1				
	2				
	3				
	4				
	5				
	6				

Appendix C: Elevation Surveying and Sample Station Location Procedures

This appendix describes the methods of laying out sampling stations and surveying elevations. The procedures include establishing a baseline from which all measurements are taken, establishing a control height for the elevation surveying, randomly placed sampling stations in each stratum, and surveying the elevation of plots and quadrats.

A. Establishing Baseline

The baseline ran perpendicular to the shore across all elevation strata. Random sampling station locations were measured from the baseline.

1) Sampling team leaders pre-located baseline starting point on 1:1200 aerial photos prior to survey. These starting points were at a central location at each intertidal site, above the intertidal zone, at a conspicuous landmark that was recognizable both on the photo and in the field.
2) The survey team set up surveyor's level near the starting point.
3) Survey personnel extended a tape from the starting point (0m on the tape) to the water's edge approximately perpendicular to shore.
4) The survey team recorded the compass bearing on the baseline and sketched it on the aerial photo and graph paper.

B. Tidal Elevations

The tidal elevations measured in the field provided the basis for establishing elevations of strata and plots. A tidal elevation curve was plotted for each site using tidal prediction software prior to sampling. These curves provided elevations necessary to calibrate the surveys.

1) The survey team took an initial elevation reading at the water's surface at or near the baseline survey tape (if waves were making it difficult to establish water's surface, the reading was taken at a protected area near the tape).
2) The time, height, and distance out the baseline tape was recorded. Using the tidal height curve, the survey team computed the height of instrument (H.I.) by adding the rod height to the tidal height at the time of the reading (subtracted if it was a negative tide). All elevation readings after that point in time were based on the instrument height established under this procedure.
3) The survey instrument's horizontal angle ring was set on 0 while sighting down the baseline. All angles were measured from the baseline.
4) The survey rod holder moved forward or back along the baseline tape to find the 0m and 0.5m elevations. These were marked on the tape.

5) The survey team recorded the tape measure reading at the two elevations and computed the distance between elevations. This represented the width of the stratum.
6) Steps 4 and 5 were repeated for the 0.5-1, 1-2, and 2-3m strata after the first plots were located and teams began sampling.
7) The water's surface was re-measured several times during the day to verify the H.I.

C. Locating Sampling Stations

Sampling stations were located randomly within the strata following the procedure outlined below. A random number chart was prepared before the survey to provide random numbers for the procedures below.

1) From the random number chart, the random digit column was selected that correspond to the stratum width. From the appropriate column, random distances were selected for each of three sampling teams. In addition, a random distance perpendicular to the baseline was selected from the random numbers that correspond to the along-shore length of the stratum. These random numbers were used to pinpoint each sampling station. The survey team record these on the sampling site tracking form.
2) Each sampling team moved up the baseline according to the first random number selected above. The teams stretched a measuring tape perpendicular to the left or right of the baseline and measured the distance designated by the second random numbers selected above.
3) The survey team measured the elevation of one 'average' point at each station to ensure that it was in the correct stratum. At this point the sampling teams can start sampling their plots (see Appendix A). If the plot was not in the stratum, or more than 50% of the plot could not be sampled (due to deep pools, etc.), the plot was rejected and the sampling team proceed backward or forward along the tape to an appropriate area.
4) The above procedure was repeated to establish 6 sampling stations per elevation stratum.

D. Plot and Quadrat Elevations

1) The survey team measured the elevations of each plot by surveying the 0m, 5m, and 10m plot locations at a point halfway between the parallel tapes that define the plot.
2) The horizontal angles at each of these readings was also recorded. The survey team sketch the plot location and recorded the plot number on graph paper.
3) Using the random quadrat location numbers, the survey team located the three quadrats in each plot and identified them as quadrat A, B, and C.
4) The survey team measured the elevation at the center of each quadrat.

Appendix D: Photo Interpretation Guidelines for Intertidal Habitat Features

This appendix describes criteria and procedures for interpreting intertidal habitat features on the 1:1200 color infrared photo series.

Bedrock

Description

Bedrock generally encompassed large areas of intertidal habitat. This was the base substrate on many photos. Bedrock looked smooth on the photos in most cases. Some bedrock appeared rough on the photos, like boulders, but lacked the shadows that are characteristic of boulders. Some bedrock had crevices or channels in it, making it more recognizable. In many areas, bedrock was obscured with boulders covering it. These areas were mapped for both bedrock and boulder.

Interpretation Procedures

Polygons were drawn outlining the bedrock areas (where bedrock abuts a cliff, we used the toe of the cliff as the edge of the bedrock). Minimum size for polygons was set at about 0.5cm^2 on the photos. Individual polygons were separated by at least 3mm on the photos.

Boulder

Description

Two sizes of boulders were mapped: Large boulders (3'9") and extra-large boulders (5'5"). The transparent scale chart (Figure 5) illustrates the sizes. Boulders smaller than "large" could not be discerned very well on the photos and were mapped with cobble. Some boulders were so densely covered with vegetation that it was difficult to recognize them as boulders. In most cases, dark orange areas that appeared lumpy in texture and had shadows on the photos were boulders. Boulder size was verified with the aid of the magnifying glass.

Interpretation Procedures

We determined boulder size using the scale chart (Figure 5). A polygon was drawn around each discontinuous boulder field. Some boulder fields had patches of boulders that differed in size from the others. If a patch accounted for at least 30% of the total area, a separate polygon was drawn around it.

Cobble-Small Boulder

Description

Cobble areas appeared grainy on the photos, and sometimes had small boulders. Large or extra-large boulders sometimes occurred in cobble habitat. These boulders were mapped if the areas meet the minimum size requirements for boulder habitat (see scale chart for boulder polygon size, Figure 5).

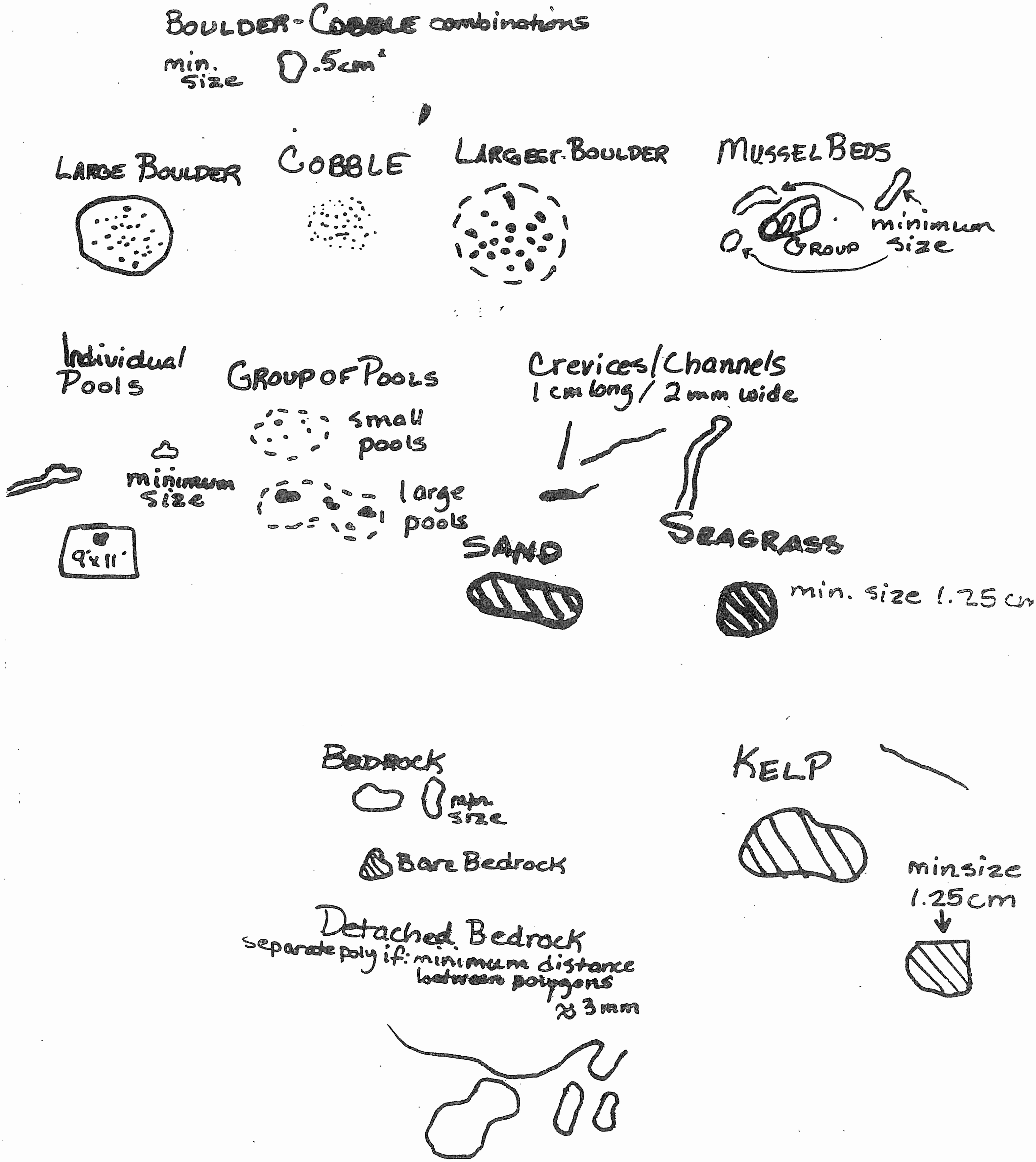

Figure 5. Scale chart showing minimum sizes of polygons for various intertidal habitat features. This chart was placed on clear acetate so it could be overlain on the 1:1200 photos as a guide for interpretation of habitat features.

Interpretation Procedures
Polygons were drawn around the cobble fields.

NOTE: An area that had a mixture of different rock sizes had overlapping polygons drawn in different colors, representing the overlap of different features.

Sand

Description
Sand appeared smoother than cobble on the photos (it did not look grainy). It was also yellow to tan or white on the photos, while cobble was usually gray. It was usually a large patch, but was sometimes visible beneath boulders. If it occurred in a boulder or bedrock habitat, it was mapped if the size of the sand area polygon was greater than $2cm^2$ on the photos.

Interpretation Procedures
Polygons were drawn around the sand areas.

Intertidal Algae (Macro algae)

Description
These appeared as red, pink and purple intertidal areas on the photos. Intertidal algal areas were usually large and mostly followed the outline of the bedrock or boulder habitat.

Interpretation Procedures
A polygon was drawn around the entire colored area to represent the extent of intertidal macro algae.

Mussel Beds

Description
Large dense mussel beds appeared brown and grainy under a magnifying glass on the photos. Small or sparse beds were usually not visible. Mussel beds were not always easy to recognize.

Interpretation Procedures
Polygons were drawn around the mussel beds. The minimum size for mussel bed polygons is indicated on the scale chart (Figure 5).

Tide Pools

Description
Pools usually appeared as deep blue or black areas on the photos. Sometimes shadows and pools looked similar. Careful inspection with a magnifying glass

helped to distinguish them. Large pools (minimum size 9'x9') were usually mapped individually. If there were a few large pools close together they were mapped as a group. Small pools were always mapped as a group. See scale chart for size reference (Figure 5). Pools that were mapped as a group were assigned I.D.'s that included specific information about the pools.

Interpretation Procedures

For individual pools, we drew a polygon around each pool. A group of small pools was mapped by drawing a tight polygon around the pools (minimize the amount of empty space beyond the pools). We numbered each group polygon, starting with 01. The pool sampling grid (transparent grid made from graph paper) was placed on the polygon and the number grid cells that covered the polygon were counted. This represented the total area. Then, the grid cells that covered only tide pools were counted. The tide pool grid cell number divided by the total area gave % pool area in the polygon. We also, counted the number of pools in the polygon. These figures were made part of the polygon I.D. as follows:

photo id. polygon number.%pools.pool count

example: 4307n.01.34.08

The I.D. was written on the acetate next to the group polygon.

Surge Channels and Crevices

Description

Channels were a minimum of 2mm wide on the photo. They could be any length. Crevices were less than 2mm wide. They usually appeared as dark lines in the bedrock. Crevices were too narrow to map as a channel so they were mapped as a line. The minimum length for a crevice was set as 1cm on the photos.

Interpretation Procedures

Channels were marked by tracing the whole channel so that it was an open polygon. Crevices were marked by single lines tracing the shape of the feature.

Surf Grass (*Phyllospadix* sp.)

Surf grass appeared very light pink and has a "washed out" or fuzzy appearance on the photos. It was not always easy to discern. The minimum polygon size was set as $2cm^2$ on the photo.

Interpretation Procedures

Polygons were drawn around the surf grass areas.

Kelps

Kelps, other than *Nereocystis*, that were located seaward of the rocky intertidal area were mapped, if noticeable. Taxa that make up these beds included, for example, *Laminaria, Alaria, Egregia,* and *Cystoseira*. Minimum size for polygons was set as $2cm^2$ on the photo.

Interpretation Procedures

Polygons were drawn around the kelp areas.

Other Considerations

In many cases, there were slabs of bedrock with algae cover that were detached from the mainland, appearing as small rock islands. It became questionable whether or not to include them in the mainland habitat when there was a large percentage of water surrounding them. A graph paper grid was placed on the area to estimate the rock-to-water ratio. If the ratio was greater than 50%, the rocks were included in the mainland habitat. If it was less than 50%, they were mapped as a group in a separate polygon.

Some rock surfaces that were higher than the intertidal zone but still located within intertidal habitat polygons. They appeared pure gray or white in color on the photos, with no pink coloration. They were mapped as separate polygons and not included in the intertidal area.