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MARINE RESOURCES OF THE ELWHA RIVER ESTUARY

CLALLAM COUNTY, WASHINGTON

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OF THE
ELWHA RIVER ESTUARY

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INTRODUCTION

The Elwha River is located on the Olympic Peninsula in northwest Washington State. The Elwha River has a north-south orientation and is 45 miles long with over 100 miles of tributary streams. It has a drainage area of 321 square miles, of which 267 square miles are within Olympic National Park. Two hydroelectric projects have been constructed on the Elwha River; Elwha Dam in 1913, about 5 miles upstream from the river mouth, and Glines Canyon Dam in 1926, about 7 miles upstream from the lower dam.

The Elwha River Ecosystem and Anadromous Fisheries Restoration Act (P.L. 102-495) authorizes the Secretary of the Interior to acquire and remove the two Elwha River hydroelectric projects, providing removal is necessary to achieve the goals of the Act and Congress appropriates the required funding. The Department of the Interior (Interior) documented and submitted its finding to Congress that removal of the dams was necessary to achieve the Act's goal of full ecosystem restoration (Department of Interior 1994). The National Park Service, as lead agency, along with the U.S. Fish and Wildlife Service, Bureau of Reclamation and Bureau of Indian Affairs, as cooperating agencies, are currently preparing the required documentation for compliance with the National Environmental Policy Act (NEPA).

Dam removal and restoration of the watershed is a major federal action that could cause significant impacts to the environment (Department of Interior 1994). Of particular concern is the project's potential effect on the Elwha River estuary located in the Strait of Juan de Fuca. An estimated 12 to 15 million cubic yards of sediment (clay, silt, gravel, cobble, and boulder) have accumulated in the reservoirs since the construction of the dams (Department of Interior 1994). The dam removal and sediment management alternatives being developed would result in different sediment quantities being released to the marine environment over a varying time periods. Other impacts would result by returning the Elwha River sediment supply of about 280,000 cubic yards per year to the coastal zone (Federal Energy Regulatory Commission 1993). Previous work failed to adequately consider the impacts of these higher sediment loads on the marine environment. The FERC and Interior reports both recommended further study to assess these impacts and to recommend potential measures to mitigate the impacts (Federal Energy Regulatory Commission 1993; Department of Interior 1994).

The seaweed or macroalgae community was identified during the scoping of this study as a particularly important resource because of its ecological functions. Existing biological information for the nearshore marine environment was found to be extremely limited or unsuited for use in describing the biological community near the Elwha River mouth because of the lack of site specificity. Of the information reviewed, the kelp distribution maps prepared by the Washington State Department of Natural Resources were the most useful for our purposes. Essentially all other sources of information that were reviewed consisted of regional data, a small number of data entries from field notebooks, or general observations taken over a period of years.

Druehl (1970) reported that Washington State has one of the most diverse and abundant kelp

community of any area worldwide. Previous surveys of these resources show that bull kelp (*Nereocystis luetkeana*) and giant kelp (*Macrocystis integrifolia*) are the dominant surface canopy kelps of Washington's Strait of Juan de Fuca and open coast. The Strait of Juan de Fuca contains 79% (3,061 hectares) of these kelp beds (Dept. of Natural Resources 1993). Other kelp surveys provide information for the Puget Sound region. When examining habitat changes over time, Levings and Thom (1994) found that kelp beds increased in Puget Sound by 53% between 1912 and 1978. However, lack of information prevented them from estimating trends for the hundreds of other macroalgae species present in the Sound.

The purpose of this study was to characterize the existing marine resources which dam removal could affect and to assess the impact of an increased sediment load on the estuary. It should be noted that the 1994 marine resources characterization of the study area was not intended or designed to establish a quantitative baseline against which post dam removal data would be compared. The characterization, however, would be used in the development of a plan of study for monitoring pre- and post-dam removal changes in substrate and its associated biological community. It is anticipated that permanent monitoring stations would be established in 1996, pending approval and funding of dam removal by Congress.

STUDY AREA

The Elwha River is found on the Olympic Peninsula of Washington State, and enters the Strait of Juan De Fuca at Freshwater Bay, about 10 miles east of the City of Port Angeles. The Lower Elwha S'Klallam Tribal lands are at the mouth of the river. These lands encompass about 340 acres and are in the river's historic floodplain. The river's mouth is near the eastern boundary of Freshwater Bay. The bay is crescent shape and defined by two prominent points, Observatory Point to the west and Angeles Point to the east. The coastal shoreline is steep with coarse sediments, like cobble, near the mouth of the river. Generally, this steepness decreases with increasing distance to the east and west of the river's mouth.

The study area includes the intertidal and shallow subtidal zone adjacent to, and including the Elwha River delta. This zone extends from about +8 to -50 feet MLLW beginning approximately 2 miles west of the Elwha River mouth and extending easterly for a distance of about 5 miles to Dry Creek (Figure 1). The boundaries of the study area were selected for three reasons. Firstly, the transport of coarse sediment (sand and gravel) from the Elwha River would occur mainly along the shore at water depths less than -20 feet MLLW once it enters the marine environment (Schwartz 1994). Secondly, higher turbidity from an increased quantity of fine sediment (clay and silt) could affect plants to -50 feet MLLW, the expected depth of abundant macroalgae growth. The extent of most macroalgae growth is about 100 feet and diminishes quickly with depth (Scagel 1972). Finally, the eastern boundary of the study area was selected because of the presence of actively eroding sea bluffs immediately east of Angeles Point. This area of erosion contributes turbidity and a significant quantity of sediment to the adjacent nearshore environment. The conditions of this area are not likely

to change significantly following dam removal.

METHODS

The intertidal and subtidal observations were collected during June 1994 through the first week of September 1994. The intertidal zone (about +8 feet to -2 feet MLLW) was surveyed by walking the beach during daylight hours at low tide, and collecting information on macroalgae, macroinvertebrates, fish within tide pools, and substrate. This survey was considered adequate for characterizing the mid to upper intertidal zone because of few marine algae and macroinvertebrates. Characterization of the low intertidal zone was included within our survey efforts of the shallow subtidal zone. The lower intertidal and shallow subtidal zones (0 to 50 feet MLLW) were sampled by conducting SCUBA surveys during daylight hours. As with the intertidal observations, the survey characterized the nearshore community of macroalgae and macroinvertebrates near the river's mouth. The study included sampling along seventy-eight 600-foot-long transects.

The study efforts were concentrated east of the river, nearer to shore, and closer to the river's mouth because of our expectations with sediment transport. Forty-nine transects were placed east of the river compared to 29 transects to the west. More transects were placed in shallow water (56 transects) than in deeper water (22 transects). The shallow transects covered from 0 to -30 feet MLLW with an average station depth of about -14 feet MLLW. The deeper transects ranged from -19 to -49 feet MLLW with an average depth of -31 feet MLLW.

The transects were not set randomly by design. Two starting points were arbitrarily selected in the field. One starting point was west of the river's mouth; the other was east. The transects were oriented perpendicular to the shoreline, and were spaced about 300 and 900 feet apart depending on whether the transects were shallow or deep, respectively. Some of the transects towards the perimeter of the study area were spaced further apart. Map 1 illustrates the location of each transect.

Each transect was marked with 11 sampling stations at 60 foot intervals including the two endpoints. A square yard quadrat was used at each station to record depth, substrate type (10 classes), total percent plant cover (4 classes), presence or absence of 22 species of marine algae, the number and species of 19 types of macroinvertebrates, and the geographic coordinates of the station. A preprinted form facilitated data collection by listing the marine algae, macroinvertebrates and substrate observed during the reconnaissance dives (Appendix A). Space was provided on the form to record species that were not listed. Substrate was classified according to the Washington State Department of Natural Resources' classification system, as modified from Dethier (1990). Percent cover was a subjective determination of four classes (0 to 24%, 25 to 49%, 50 to 74%, and 75 to 100%). For macroalgae, the data recorder identified dominant species. A dominant species was the species with the greatest aerial coverage. The data recorder often noted more than one dominant species when multiple canopy layers occurred within the quadrat. Besides the data collected within the quadrat, the survey team also recorded its general observations outside the quadrat. Throughout

this document, we use the terms quadrat and station synonymously.

The species and substrate maps were developed by converting the transect data to a grid with a cell size of 10,000 feet^2 as the map base. A grid is like latticework in that a map is divided into many discrete uniform units (i.e., the square holes in the lattice) called cells. A cell represents a specific geographic location with each cell representing 10,000 feet^2 of the study site. Each cell on the grid was expanded into adjacent empty cells using nearest neighbor analysis. A cell was expanded by three cells where a species was present or dominant and by five cells for substrate. When two cells were competing to expand into the same cell, the conflict was resolved based on the value of the majority of the surrounding cells. The depth or bathymetry map was created by interpolating the bathymetry values collected at each station. Interpolation was first completed by creating a triangulated irregular network (TIN) of the site. A TIN is a set of adjacent, non-overlapping triangles that connect each station. Depth contours were created from the TIN using bivariate quintic interpolation with five subdivisions of the TIN triangles. Environmental Systems Research Institute (1991b) provides a full discussion of creating and expanding grids and Environmental Systems Research Institute (1991a) describes the use of TIN and bivariate quintic interpolation.

RESULTS AND DISCUSSION

This section has descriptions of the intertidal and subtidal zones, the study's findings, and a discussion of the survey limitations. Descriptions of the intertidal and subtidal zones are intended to provide a qualitative overview of the resources that dam removal could affect. The findings section presents a quantitative view of the data and discusses pertinent literature about the resources found during the study. The study constraints are discussed in the survey limitations section. The data collection effort commonly identified 15 species of brown algae, 22 species of red algae, two species of green algae, one seagrass, 50 types of macroinvertebrates, and six types of fish. In total, twelve phyla were present on site representing about 150 species (Table 1). The most significant resource identified was the macrophyte community. This community was found over most of the area surveyed during the intertidal and subtidal surveys.

DESCRIPTION OF INTERTIDAL ZONE

The intertidal beaches east and west of the Elwha River mouth are markedly different. The survey identified four areas along the shore with differing geomorphology. These areas supported different plant and animal communities. Figure 2 shows these four areas that we labeled as directly east, further east, directly west, and further west of the river.

Directly east of the river, the beach consists of large cobbles and boulders with a small amount of gravel and sand. The slope of the beach is steep, which allows waves to more frequently reach the upper beach. This stretch of the beach is also more exposed to the ocean swell. As a consequence,

the marine plant and animal community utilizing the middle to upper intertidal zone is extremely sparse. The community in this zone is limited to species adapted to the abrasive action of the gravel and small cobbles moved by the breaking waves. Within the high intertidal zone, only amphipods were commonly found, primarily in the wrack. The primary intertidal marine life observed in the middle intertidal zone included limpets, the acorn and thatched barnacles, blue mussels, and periwinkles. The watered depressions underneath boulders provided habitat for clingfish and gunnels. Three species of algae (*Porphyra* sp., *Ulva* sp., and *Acrosiphonia coalita*) were found in this zone. The distribution of these species was patchy and was typically found in the more protected areas like cracks and spaces between larger rocks.

Within the low intertidal zone, the number of species and abundance of marine life increased markedly. The substrate was primarily cobbles and boulders, but contained more sand and gravel than occurred in the middle and upper beach. Most of the species observed in the middle to high intertidal zone were also found in the lower zone but in greater abundance. Other macroinvertebrates observed included Dungeness, red rock and hermit crabs, sculpins, whelks, and native littleneck and horse clams. The survey identified more than 35 species of marine plants, including such green algae as *Ulva* sp., *Enteromorpha* spp., and *Acrosiphonia coalita*, such red algae as *Iridaea cordata*, *Gigartina exasperata*, and *Mastocarpus* spp., and such brown algae as *Alaria marginata*, *Cymathere triplicata*, *Pterygophora californica*, and *Laminaria saccharina*.

Further east, a sequence of vertical sea bluffs border the beach. The presence of landslides and sites of active erosion suggests the bluffs are a significant source of sediments to the marine environment. Consequently, the substrate in this area is less coarse and consists of a mixture of silt, sand, gravel and cobble. The water offshore was consistently more turbid than the area closer to the river mouth. By the eroding bluffs, the marine plant and animal communities within the intertidal zone were sparse and less abundant than the communities found immediately to the west. Species observed included periwinkles, limpets, barnacles, and algae (*Porphyra* sp. and *Ulva* sp.). Substrate in the lower intertidal zone consisted primarily of cobble, silt and sand, and supported a plant community consisting mainly of *Porphyra* sp., *Mastocarpus* sp., *Alaria marginata*, and *Ulva* sp. Macroinvertebrates observed included the acorn barnacle, blue mussel, limpets, and periwinkles.

Directly west of the river, the substrate and marine community is very similar to that which was observed directly east of the river. Further west, the substrate is almost entirely sand with a small amount of gravel. The beach slope is moderately steep. The survey found no attached plants and very few macroinvertebrates. Amphipods were abundant in the wrack. A few shrimp, *Cragon* sp., were found in the wave wash. These observations are typical of exposed sand beaches. Few marine species can reside in this environment throughout the tidal cycle. The scope of the survey did not include efforts to determine which species move in and out of this zone with the tides.

DESCRIPTION OF SUBTIDAL ZONE

Substrate and the plant and animal communities observed in the nearshore subtidal zone was similar

to the adjacent intertidal zone. Again, the survey identified several areas that were different. Refer to Figure 2 for the location of these areas labeled as directly east, further east, directly west, west, and further west of the river.

Directly east of the river, the substrate between the -20 foot contour and the intertidal zone included cobbles and gravel with lesser amounts of boulders and sand. Between -20 and -50 feet in depth, the substrate was either gravel, sand, or mixed fines. Brown algae, collectively called kelp, dominate the marine plant community in this area. The more abundant species observed include *Alaria marginata*, *Cymathere triplicata*, *Pterygophora californica*, and *Nereocystis luetkeana* with *Desmarstia viridis* and *Costaria costata* being less abundant. Of the red algae, *Iridaea cordata*, *Mastocarpus* spp., and *Sarcodiotheca gaudichaudii* were the most frequently observed species. With a few exceptions, populations of macroinvertebrates were low. The survey team frequently encountered huge swarms of mysids, shrimp like crustaceans. Many small snails were found attached to the blades of many kelp species. Several species of chitons and limpets were also found on larger rocks at shallow depth, but only in small numbers. Bivalves (littleneck, horse, geoduck clams, cockles, and pink and rock scallop) were present in only low numbers, except in a few small isolated areas where horse and geoduck clams were locally abundant. Sea stars, including the sunflower, sun, blood, and bat star were present in low densities. Kelp, red rock, Dungeness, graceful, and hermit crabs were also found in low numbers. Fish observed included juvenile salmon, herring, sand lance, kelp greenling, several species of flatfish and sculpin, tube-snouts, clingfish, gunnels, dogfish shark, ratfish, and seaperch.

Further east, the substrate consisted primarily of finer sized sediment (sand, gravel and silt) due to the sediment contribution from nearby eroding sea bluffs. An increase in turbidity was also evident. Additionally, there was an increase in Ulva spp. and a decrease in the diversity and abundance of brown and red algae. Macroinvertebrate diversity and abundance continued to be low, but included more species, like ghost shrimp and Dungeness crab, that are adapted to the finer grained sediments.

Directly west of the river, the substrate and marine community is very similar to that which was observed directly east of the river shoreward of the -20 foot contour. The substrate is sand at greater depths. This is different from the coarser gravel and sand mix found at similar depths directly east of the river mouth. The marine plant community was clearly less abundant and consisted of fewer species. *Ulva* sp., and *Sarcodiotheca gaudichaudii* were the primary plant species observed in this area. The feather duster tube worm, blood star, snail, and several unidentified species of flatfish were also found in this zone.

West of the river, the substrate is almost entirely sand. Vegetation in this area was sparse, except the occurrence of diatoms, which formed a brown scum over large areas. *Ulva* sp. and *Zostera marina* were found at some locations. Nearly all hard surfaces, including shells, rock outcrops and tube worm casings, supported both brown and red algae, primarily *Cymathere triplicata*, *Pterygophora californica*, and *Botryoglossum farlowianum*. Macroinvertebrates observed in this area included Dungeness, decorator and hermit crabs, cragon shrimp, bivalves, including the basket cockle and horse and geoduck clams, the feather duster tube worm, several species of snails, and a yellow sponge. The fish most frequently encountered were flatfish, dogfish shark, and sculpins.

Further west of the river, the substrate becomes more diverse. Areas of just sand, gravel, hardpan, boulders, and mixed coarse substrates were common. Plant and animal communities observed in association with the sand, gravel and mixed coarse substrates were similar to those found near the river in areas of like substrate. The hardpan and boulder substrates were very rare east of the river mouth. These substrates supported dense communities of brown algae, including *Pterygophora californica*, *Nereocystis luetkeana*, *Laminaria saccharina*, and *Costaria costata*. Red algae, such as *Iridaea cordata*, *Mastocarpus* spp., and *Botryoglossum farlowianum*, were also very common on these substrates. Sea urchins, sea cucumbers and anemones were more abundant here than any other area surveyed during this study. They were usually found on the large boulders scattered throughout this area. Large populations of mysids were often present, especially in association with *Pterygophora californica*. Tube-snouts were the most abundant fish observed, followed by kelp greenling.

FINDINGS OF SURVEY

The frequency of fish and macroinvertebrates observed during the study was low. Of the 57 species that were present, only five species were found at more than 10 percent of the 820 quadrats. Table 2 summarizes the frequency of the fish and macroinvertebrates. The lack of fish and motile macroinvertebrates was largely a result of quadrat sampling which does not efficiently survey motile species. Most of the commercially or recreationally important macroinvertebrates like sea urchins, sea cucumbers, scallops, clams, crabs, and shrimp were found infrequently. Of these species, the red rock crab was found at 9 percent of the stations, yet the next most frequent species, the horse clam, was found in only 3.4 percent of the quadrats. Generally, the bed size of the species, not density, was well below that which is considered commercially harvestable (Table 3). Densities of geoduck averaged 0.275 geoducks per ft^2 (show-corrected) which is well over commercial minimum density of 0.037 geoducks per ft^2 but they were present in only 21 of 820 quadrats (Bradbury 1995a). Likewise, red sea urchins and giant sea cucumbers were found infrequently during the survey (2 and 10 quadrats respectively) at densities which averaged 0.111 individuals per ft^2. Typically, the commercial densities of the red sea urchin and giant sea cucumber are 0.03 urchins per ft^2 and 0.005 cucumbers per ft^2 (Bradbury 1995a). Clams were also very infrequently encountered during the survey. Littleneck, butter, horse clams were found at 0.1, 0.5, and 3.4 percent of the stations. Rough piddock and heart cockle distributions were also very limited being present at 2 and 10 of the 820 quadrats, respectively.

Others have examined the macroinvertebrate distribution and abundance near the Elwha River. Goodwin (1994) determined that geoducks exist in the Juan de Fuca Strait, but not in the high concentration found in Puget Sound or Hood Canal. Near Angeles Point, he identified three small geoduck beds but did not determine the bed densities. Two of these beds are east of Angeles Point and located offshore of the eroding bluffs. Bradbury (1995b) reported that red sea urchins are found in commercial quantities at an average depth of -55 feet MLLW directly off Angeles Point. Harvest of sea urchins offshore of Angeles Point totaled about 1,100,000 pounds which represents 45 percent of the statewide harvest during the 1992/93 season (Bradbury 1995b). High densities of sea urchins

were not found during our survey. This could be due to the limits of our study that did not exceed -49 feet MLLW and averaged -31 feet MLLW for the deeper transects or that commercial divers harvested the sea urchins before our survey. Sea urchin harvest occurs from November to February. Sea cucumbers occur widely in Puget Sound, Hood Canal, and the Strait of Juan de Fuca. Bradbury (1994c) found the harvest in Strait of Juan de Fuca accounts for about 30 percent (449,375 pounds) of the statewide sea cucumber harvest. The area between Whiskey Creek and Angeles Point accounts for about 12 percent of the Straits' sea cucumber harvest and 3 percent of the statewide harvest. Bradbury did not report this data with enough specificity for us to compare his sea cucumber results with our findings. Commercial divers harvest sea cucumbers between May and July so it is not likely that harvest occurred before our data collection effort. Clams in the intertidal zone are also an important resource. The State of Washington primarily surveys native littleneck and Manila clams (Cook 1995). Because these surveys cover a limited area, the State has little information on the widespread distribution of these resources. No quantitative information is available for our study area.

The abundance and diversity of macroalgae were most evident during the study. The survey recorded total vegetative cover in quartiles. The most frequent coverage was in the highest quartile, 75 to 100 percent plant coverage of the quadrat (Table 4). About 60 percent of the quadrats had macroalgae coverage that exceeded 50 percent (Map 1). The highest density of vegetation is east of the river and within the -20 foot MLLW contour. Thirty-one species were recorded as dominant, species covering the greatest area within a quadrat (Table 5). Of these, *Alaria marginata*, *Cymathere triplicata*, *Pterygophora californica*, and *Iridaea cordata* were consistently dominant. Except *Pterygophora californica*, all these species were more abundant east of the river (Maps 2-5). *Pterygophora californica* was more evenly distributed east and west of the river. A total of 40 species was recorded in the quadrats (Table 6). This table illustrates the great diversity of seaweed that was found during the survey. Almost half of these species (19) were found at more than 10 percent of the stations. Generally, the dominant algae were present most frequently.

Nereocystis luetkeana or bull kelp is one of two surface canopy kelps found in Washington. It is considered a priority habitat for Washington state because of its high resource value and potential commercial importance (Buckley 1995). Bull kelp was present in 1.5 percent of the quadrats sampled for this survey. The distribution map (Map 6) estimates the areal coverage to be about 87 acres. This data is inconsistent with the Washington Coastal Kelp Resources Inventory conducted by the Washington Department of Natural Resources between 1989 and 1992. This inventory estimated the average areal coverage of bull kelp to be about 780 acres. Our survey technique did not survey bull kelp accurately due to the quadrat size and the difficulty in setting transects in dense bull kelp beds. When sampling large canopy forming macroalgae, like *Nereocystis luetkeana* and *Macrocystis integrifolia*, Simenstad et. al. (1991) recommended large quadrat sizes of between 4 m^2 and 100 m^2. This recommended size is four to 100 times larger than the quadrant used on this survey. The smaller quadrat size prevented accurate representation of *Nereocystis luetkeana* density and extent. Map 7 illustrates the results of the Washington Coastal Kelp Resources Inventory. This map shows the areal extent of the bull kelp for 1992, the most recent year of the survey. For this year, the areal extent for all the beds in the state was about 5,625 acres of which 426 acres was in the study area. Given this

additional data, *Nereocystis luetkeana* can be considered one of the more important dominant macroalgae found during the study.

Zostera marina (eelgrass) and *Phyllospadix scouleri* were the only two seagrasses found during the study. Like kelp, seagrasses are also a priority habitat for Washington State and are believed to be declining (Levings and Thom 1994). Eelgrass was found in low abundance during the survey. It was the dominant vegetative cover in eight quadrats (1 percent) and was present at 5.6 percent of the stations (46 quadrats). Map 8 illustrates the distribution of eelgrass, which is more abundant west of the river, though still relatively sparse.

The survey also collected information on bathymetry and substrate. Map 9 illustrates the bathymetry of the study area. This map shows that the beach close to the river's mouth is steep and becomes more gradual with increasing distance from the mouth. We recorded eight substrate types in the study site (Table 7). Of these types, mixed coarse, sand, gravel, or mixed fine substrates were found most frequently and collectively represent 93 percent of the total observations. Map 10 shows the distribution of substrate types. The distributions of the dominant macroalgae corresponds to the distribution of the sediment type. This is evident when comparing species richness for the different substrate types. Species richness, the number of different species found in an area, is considered one measure of ecological diversity. Figure 3 shows the species richness of macroalgae for different substrate types. Generally, species richness for macroalgae increased with an increase in substrate coarseness. Figure 3 shows that at least four species were found in 50 percent of the quadrats classified as sand substrate compared to nine species associated with gravel and mixed coarse substrates. The figure does not include cobble, boulder, and hardpan substrates because of the few quadrats found with these substrates (29 for cobble, 12 for boulder, and 5 for hardpan).

Existing studies of the kelp community indicate it provides important recruitment and nursery habitats for juvenile marine fish. Levings and Thom (1994) reported that Pacific herring use macroalgae for spawning and that density of young-of-the-year copper rockfish was higher in Nereocystis beds than in other habitats. They also found that juveniles of pink, coho, and sockeye salmon were associated with kelps beds at Discovery Passage, a migration route out of the Strait of Georgia for young salmon. Simenstad et. al. (1991) identified several macroalgae assemblages important to sympatric species of invertebrates (red rock crab, Dungeness crab), fish (buffalo sculpin, pile perch, white spotted greenling, kelp perch, striped sea perch, bay pipefish, crescent gunnel, pinpoint gunnel, chum salmon, shiner perch, tube-snout), and wildlife (American widgeon, black brant, gadwell). Emmett et. al. (1991) identified marine algae as important to the early life stages of Pacific herring and three-spine stickleback and juvenile and adult lingcod. After surveying the shoreline in the Strait of Juan de Fuca, the San Juan Islands, and Puget Sound, Doty and Norris (1992) concluded that kelp beds are a seasonally important habitat for young-of-the-year copper, quillback, and black rockfish. Buckley (1995) anecdotally documented the use of kelp by sand lance, lingcod and true cod near the Elwha River during some of these state surveys. Macroalgae, specifically *Nereocystis luetkeana*, *Macrocystis sp.*, and *Fucus distichus*, is also very important when it breaks loose from its holdfast and forms large drifting mats. These drift mats are especially important for splitnose rockfish recruitment and growth from June to November (Buckley et. al. 1995).

Swarms of mysids were frequently observed during our survey in close association with the kelp beds, particularly *Pterygophora californica.* Little information is available that describes the significance of kelp beds in the mysids life cycle, yet some investigators have anecdotally documented the association. Garner (1990), Duffus (1995), Calambokidis (1995) have observed gray whales commonly feeding on mysids in kelp beds. While surveying for marine fish, Buckley (1995) and Doty (1995) observed swarms of mysids in kelp beds yet they observed few mysids outside the beds. These observations suggest an association between kelp beds and mysids.

SURVEY LIMITATIONS

The survey was designed to collect information on which to characterize the area potentially affected by dam removal and the resultant release of sediments. The survey was not designed to establish a quantitative baseline from which to compare post dam removal data. For our objectives, it was important that the survey cover as much area as possible and to concentrate our sampling efforts effort in areas of greater risk. Because of this emphasis, the survey design had some limitations. Some of these limitations concern the survey technique. Static sampling techniques, like quadrats, do not efficiently survey motile species. Also, no information was collected on seasonal or diel use of the site. Abundance or biomass, except total percent vegetative cover, was not measured because of the need to cover a large area. The mapping effort was limited to the GPS accuracy of 12 to 40 meters. Other limitations, pertain to the consistency of the survey data. We recognized there was observer bias from the sixteen divers that participated in the survey. Giving divers underwater visual keys and pairing divers experienced in macroalgae identification with those less experienced helped reduce this bias. Because of the limited expertise of some divers in identifying marine algae and macroinvertebrates, the taxonomic classifications used for this study may not be as rigorous as other studies.

CONCLUSION

The study limitations preclude a rigorous analysis of the data, particularly concerning macroalgae associations or determining with reliability the effect of depth or sediment type on the macroalgae community supported. However, the survey accomplished the original goals of the project. These goals included the characterization of the macroalgae and macroinvertebrate community within the study area and mapping the location of these resources. The results of this study will be used to assess impacts during the NEPA process and to formulate a monitoring plan that will establish a quantitative baseline to measure post dam removal effects. This survey suggests that the macroalgae community, particularly the kelps, should be emphasized in the monitoring plan.

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Table 1.

Elwha River Intertidal and Subtidal Survey Species Occurrence List

Scientific Name	Common Name
Phylum Anthophyta: Flowering Plants	
Phyllospadix scouleri	Surf Grass
Zostera marina	Eelgrass
Phylum Bacillariophyta: The Diatoms	
Class Bacillariophyceae (Schizonema/Berkeleya sp.)	Diatoms
Phylum Chlorophyta: The Green Algae	
Acrosiphonia coalita (Spongomorpha coalita)	Sponge Shape
Cladophora sp.	
Enteromorpha sp.	
Phyllospadix sp.	Surf Grass
Ulva spp.	Sea Lettuce
Phylum Phaeophyta: The Brown Algae	
Agarum fimbriatum	
Alaria marginata	Wing Kelp
Costaria costata	
Cymathere triplicata	
Desmarestia ligulata	Thick Desmarestia
Desmarestia viridis	Thin Desmarestia
Egregia menziesii	Feather Boa Kelp
Fucus gardneri	Rock Weed

Scientific Name	Common Name
Hedophyllum sessile	
Laminaria groenlandica	
Laminaria saccharina	Oar Weed
Laminaria setchellii	
Macrocystis integrifolia	Giant Kelp
Nereocystis luetkeana	Bull Kelp
Pleurophycus gardneri	
Pterygophora californica	
Scytosiphon lomentaria	Leather Tube
Phylum Rhodophyta: The Red Algae	
Bangia fuscopurpurea	Dark Hair
Bonnemaisonia nootkana	
Botryoglossum farlowianum	
Callithamnion pikeanum	
Callophyllis edentata	
Callophyllis flabellulata	
Callophyllis sp.	
Coralline Articulated	
Coralline Crustose	
Cryptopleura sp.	
Delesseria sp.	
Erthrophyllum delesserioides	
Gigartina cristata	
Gigartina exasperata	Turkisk Towel
Gigartina papillata	

Scientific Name	Common Name
Halosaccion glandiforme	Sea Sack
Halymenia sp.	
Hymenena flabelligera	
Iridaea cordata	Iridescent Algae
Iridaea splendens	
Mastocarpus papillatus	
Mastocarpus sp.	
Microcladia borealis	
Odonthallia kamehatalensis	
Odonthalia washingtoniensis	
Plocamium sp.	
Porphyra nereocystis	
Porphyra perforata	
Porphyra sp.	
Prionitis lanceolata	
Prionitis sp.	
Ptilota filicina	
Ptilota sp.	
Rhodoglossum sp.	
Rhodoptilum sp.	
Rhodymenia pertusa	
Sarcodiotheca furcata	
Sarcodiotheca gaudichaudii	
Smithora naiadum	

Scientific Name	Common Name
Phylum Annelida: The Segmented Worms (i.e. Polychate Worms)	
Thelepus crispus	Spaghetti Worm
Phylum Arthropoda: The Crustaceans (i.e. Barnacles, Crabs, and other Small Crustaceans)	
Balanus amphitrite	
Balanus glandula	Acorn Barnacle
Balanus nubilis	Giant Barnacle
Semibalanus cariosus	Thatched Barnacle
Cancer magister	Dungeness Crab
Cancer productus	Red Rock Crab
Hemigrapsus nudus	Purple Shore Crab
Oregonia gracilis	Decorator Crab
Pagurus sp.	Hermit Crab
Pugettia producta	Kelp Crab
Callianassa californiensis	Ghost Shrimp
Crangon sp.	Crangon
Idotea sp.	Rockweed or Eelgrass Isopod
Order Mysidacea	Mysids
Phylum Bryozoa: The Bryozoans or Moss Animals	
Phylum Bryozoa	Bryozoans
Phylum Cnidaria: The Cnidarians or Coelenterates (i.e. Sea Anemonies & Jellies)	
Cnidopus ritteri	
Ptilosarcus gurneyi	Sea Pen
Urticina (Tealia) crassicornis	Red and Green Anemone
Class Hydrozoa	Hydroids

Scientific Name	Common Name
Class Scyphoza	Scyphozoan
Haliclystus stejnegeri	Stalked Jellyfish
Phylum Cordata (i.e Fish)	
Agonus acipenserinus	Sturgeon Poacher
Ammondytes hexapterus	Pacific Sand Lance
Aulorhynchus flavidus	Tube-Snout
Clupea harengus pallasi	Pacific Herring
Family Cottidae	Sculpin
Family Pholididae	Gunnel
Family Pleuronectidae	Flounder
Family Salmonidae	Salmon, Trouts, and Chars
Gobiesox maeandricus	Northern Clingfish
Hexagrammos sp.	Greenling
Hydrolagus colliei	Spotted Ratfish
Raja binoculata	Big Skate
Sebastes sp.	Rockfish
Squalus acanthias	Spiny Dogfish
Phylum Echinodermata. The Spiny-skinned Animals (i.e. Sea Stars, Urchins & Cucumbers)	
Amphipholis squamata	Brittle Star
Cucumaria miniata	Orange Cucumber
Dermasterias imbricata	
Eupentacta quinquesemita	White Sea Cucumber
Henricia leviuscula	Blood Star
Leptasterias hexactis	Six-rayed Sea Star

Scientific Name	Common Name
Mediaster aequalis	Vermilion Sea Star
Orthasterias koehleri	Long-rayed Sea Star
Parastichopus californicus	Giant Sea Cucumber
Patiria miniata	Webbed Star
Pisaster ochraceus	Purple Sea Star
Pycnopodia helianthoides	Sunflower Star
Solaster stimpsoni	Sun Star
Strongylocentrotus droebachiensis	Green Sea Urchin
Strongylocentrotus franciscanus	Rea Sea Urchin
Strongylocentrotus purpuratus	Purple Sea Urchin
Phylum Mollusca: The Molluscs (i.e. Chitons, Limpets, Nudibranchs, Scallops, Clams, and Snails)	
Collisella sp.	
Cryptochiton stelleri	Giant Pacific Chiton (Gumboot)
Diodora aspera	Keyhole Limpet
Katharina tunicata	Black Chiton
Tonicella lineata	Lined Chiton
Aeolidea papillosa	Sea Mouse
Dirona albolineata	Frosted Nudibranch
Hermissenda crassicornis	Opalescent Nudibranch
Chlamys hastata	Pink Scallop
Clinocardium nuttallii	Heart Cockle
Hinnites giganteus	Purple Hinged Rock Scallop
Macoma nasuta	Bent-nosed Clam
Mytilus edulus	Blue Mussel

Scientific Name	Common Name
Panopea generosa	Geoduck
Protothaca staminea	Native Littleneck
Saxidomus giganteus	Butter Clam
Tresus capax	Horse (Gaper) Clam
Zirfaea pilsbryii	Rough Piddock
Calliostoma annulatum	Ringed Top Shell
Calliostoma ligatum	Top Shell
Ceratostoma foliatum	Leafy Hornmouth
Fusitriton oregonensis	Hairy Triton
Littorina sitkana	Sitka Periwinkle
Nucella lamellosa	Purple Whelk (smooth form)
Olivella biplicata	Purple Olive Shell
Polinices lewisii	Moon Snail
Phylum Porifera: The Sponges	
Halichondria sp.	Bread Crumb Sponge
Haliclona sp.	Haliclona
Ophlitaspongia pennata	Red Sponge
Phylum Urochordata: The Sea Squirts	
Pyura haustor	Warty Sea Squirt
Styela montereyensis	Long-stalked Sea Squirt

Table 2.

Elwha River Subtidal Survey
Fish and Macroinvertebrate Frequency

Scientific Name	Common Name	Frequency[1]	Percent[2]
Class Gastropoda	Snail	188	22.9
Diodora spp.	Limpet	144	17.5
Phylum Porifera	Sponge	93	11.3
Eudistylia vancouveri	Feather Duster Worm	88	10.7
Class Scyphozoa	Jelly Fish	87	10.6
Urticina (Tealia) crassicornis	Red and Green Anemone	76	9.3
Cancer productus	Red Rock Crab	74	9.0
Phylum Bacillariophyta	Diatom	71	8.6
Pagurus spp.	Hermit Crab	51	6.2
Oregonia gracilis	Decorator Crab	46	5.6
Balanus spp.	Barnacle	41	5.0
Class Crustacea	Shrimp	39	4.8
Katharina tunicata	Black Chiton	31	3.8
Phylum Bryozoa	Bryozoan	30	3.7
Pycnopodia helianthoides	Sunflower Star	30	3.7
Pugettia producta	Kelp Crab	29	3.5
Subclass Opisthobranchia	Nudibranch	29	3.5
Tresus capax	Horse (Gaper) Clam	28	3.4
Panopea generosa	Geoduck	21	2.6
Class Amphineura	Chiton	20	2.4
Henricia leviuscula	Blood Star	18	2.2
Cancer magister	Dungeness Crab	14	1.7

Scientific Name	Common Name	Frequency[1]	Percent[2]
Schizobranchia insignis	Plume Worm	12	1.5
Nucella lamellosa	Purple Whelk	11	1.3
Parastichopus californicus	Giant Sea Cucumber	10	1.2
Clinocardium nuttallii	Heart Cockle	10	1.2
Family Pleuronectidae	Flounder	8	1.0
Solaster stimpsoni	Sun Star	8	1.0
Cucumaria miniata	Orange Sea Cucumber	6	0.7
Phylum Urochordata	Sea Squirts	6	0.7
Amphipholis squamata	Brittle Star	5	0.6
Callianassa californiensis	Ghost Shrimp	5	0.6
Strongylocentrotus droebachiensis	Green Sea Urchin	5	0.6
Family Pholididae	Gunnel	5	0.6
Ptilosarcus gurneyi	Sea Pen	5	0.6
Samidomus giganteus	Butter Clam	4	0.5
Class Bivalva	Clam[3]	4	0.5
Cryptochiton stelleri	Gumboot Chiton	4	0.5
Gobiesox maeandricus	Northern Clingfish	3	0.4
Class Crustacean	Crab[3]	3	0.4
Dirona albolinea	Frosted Nudibranch	3	0.4
Class Crustacean	Isopod	3	0.4
Tonicella lineata	Lined Chiton	3	0.4
Strongylocentrotus purpuratus	Purple Sea Urchin	3	0.4
Family Cottida	Sculpin	3	0.4
Hexagrammmos spp.	Greenling	2	0.2
Strongylocentrotus franciscanus	Red Sea Urchin	2	0.2

Scientific Name	Common Name	Frequency[1]	Percent[2]
Zirfaea pilsbryii	Rough Piddock	2	0.2
Chlamys hastata	Pink Scallop	2	0.2
Leptasterias hexactis	Six-rayed Sea Star	2	0.2
Thelepus crispus	Spaghetti Worm	2	0.2
Squalus acanthias	Spiny Dogfish	1	0.1
Protothaca staminea	Native Littleneck	1	0.1
Polinices lewisii	Moon Snail	1	0.1
Hemigrapsus nudus	Purple Shore Crab	1	0.1
Class Echinoidea	Sea Urchin	1	0.1
Eupentacta quinquesemita	White Sea Cucumber	1	0.1

[1] The number of quadrats with at least one specimen
[2] The total number of quadrats with at least one specimen divided by the total number of quadrats surveyed
[3] Frequency and percent calculations do not include specimens that were identified to a lower taxonomic level

Table 3.

Elwha River Subtidal Survey
Selected Macroinvertebrate Density (number/ft^2)

Common Name	Minimum Density	Average Density	Maximum Density	Number of Quadrats
Butter Clam	0.111	0.167	0.333	4
Dungeness Crab	0.111	0.135	0.333	14
Geoduck	0.111	0.206	0.667	21
Ghost Shrimp	0.111	0.200	0.556	5
Giant Sea Cucumber	0.111	0.111	0.111	10
Green Sea Urchin	0.111	0.111	0.111	5
Heart Cockle	0.111	0.144	0.444	10
Horse Clam	0.111	0.198	1.111	28
Littleneck Clam	0.111	0.111	0.111	1
Orange Sea Cucumber	0.111	0.111	0.111	6
Purple Sea Urchin	0.111	0.111	0.111	3
Red Rock Crab	0.111	0.134	0.333	74
Red Sea Urchin	0.111	0.111	0.111	2
Rough Piddock	1.111	1.667	2.222	2
White Sea Cucumber	0.111	0.111	0.111	1

Table 4.

Elwha River Subtidal Survey
Macroalgae Percent Cover

Cover	Frequency	Percent
75 to 100%	303	39.5
50 to 74%	173	22.5
25 to 49%	131	17.1
0 to 24%	161	21.0

Table 5.

Elwha River Subtidal Survey
Dominant Macroalgae Frequency

Scientific Name	Frequency[1]	Percent[2]
Alaria marginata	232	28.3
Cymathere triplicata	135	16.4
Pterygophora californica	128	15.6
Iridaea cordata	65	7.9
Mastocarpus sp.	37	4.5
Costaria costata	35	4.3
Red Foliate	35	4.3
Laminaria saccharina	31	3.8
Desmarestia viridis	25	3.0
Laminaria groenlandica	24	2.9
Desmarestia ligulata	23	2.8
Botryoglossum farlowianum	21	2.6
Erthrophyllum delesserioides	21	2.6
Sarcodiotheca gaudichaudii	18	2.2
Laminaria setchellii	17	2.1
Ulva spp.	14	1.7
Nereocystis luetkeana[3]	12	1.5
Porphyra sp.	10	1.2
Zostera marina	8	1.0
Gigartina exasperata	5	0.6
Corallina spp.	4	0.5
Scytosiphon lomentaria	3	0.4

Scientific Name	Frequency[1]	Percent[2]
Egregia menziesii	2	0.2
Odonthalia washingtoniensis	2	0.2
Agarum fimbriatum	1	0.1
Bangia fuscopurpurea	1	0.1
Bonnemaisonia nootkana	1	0.1
Callophyllis edentata	1	0.1
Hymenena flabelligera	1	0.1
Microcladia borealis	1	0.1
Prionitis lanceolata	1	0.1

[1] The number of quadrats with at least one specimen
[2] The total number of quadrats with at least one specimen divided by the total number of quadrats surveyed
[3] Nereocystis luetkeana was not sampled accurately with our method

Table 6.

Elwha River Subtidal Survey
Macroalgae Frequency

Scientific Name	Frequency[1]	Percent[2]
Alaria marginata	461	56.2
Iridaea cordata	428	52.1
Lithothamnion spp.	378	46.0
Cymathere triplicata	328	40.0
Pterygophora californica	310	37.8
Red Foliate	289	35.2
Mastocarpus sp.	241	29.4
Ulva spp.	227	27.6
Erthrophyllum delesserioides	210	25.6
Desmarestia viridis	184	22.4
Sarcodiotheca gaudichaudii	176	21.4
Costaria costata	145	17.7
Desmarestia ligulata	113	13.8
Botryoglossum farlowianum	111	13.5
Laminaria groenlandica	107	13.0
Porphyra sp.	107	13.0
Laminaria saccharina	105	12.8
Gigartina exasperata	94	11.4
Laminaria setchellii	79	9.6
Nereocystis luetkeana[3]	73	8.9
Corallina spp.	63	7.7
Scytosiphon lomentaria	55	6.7

Scientific Name	Frequency[1]	Percent[2]
Odonthalia washingtoniensis	47	5.7
Zostera marina	46	5.6
Callophyllis edentata	36	4.4
Microcladia borealis	24	2.9
Prionitis lanceolata	16	1.9
Ptilota filicina	11	1.3
Hymenena flabelligera	10	1.2
Egregia menziesii	9	1.1
Pleurophycus gardneri	5	0.6
Agarum fibriatum	4	0.5
Bonnemaisonia nootkana	4	0.5
Gigartina perforata	3	0.4
Acrosiphonia coalita	2	0.2
Halosaccion glandiforme	2	0.2
Bangia fuscopurpurea	1	0.1
Callophyllis flabelligera	1	0.1
Fucus gardneri	1	0.1
Smithora naiadum	1	0.1

[1] The number of quadrats with at least one specimen
[2] The total number of quadrats with at least one specimen divided by the total number of quadrats surveyed
[3] Nereocystis luetkeana was not sampled accurately with our method

Table 7.

Elwha River Subtidal Survey
Substrate Types

Substrate Type	Frequency	Percent
Mixed Coarse	339	42.5
Sand	213	26.7
Gravel	122	15.3
Mixed Fine	64	8.0
Cobble	29	3.6
Boulder	14	1.8
Bedrock	12	1.5
Hardpan	5	0.6

Figure 1. Elwha River Subtidal Survey - Study Area

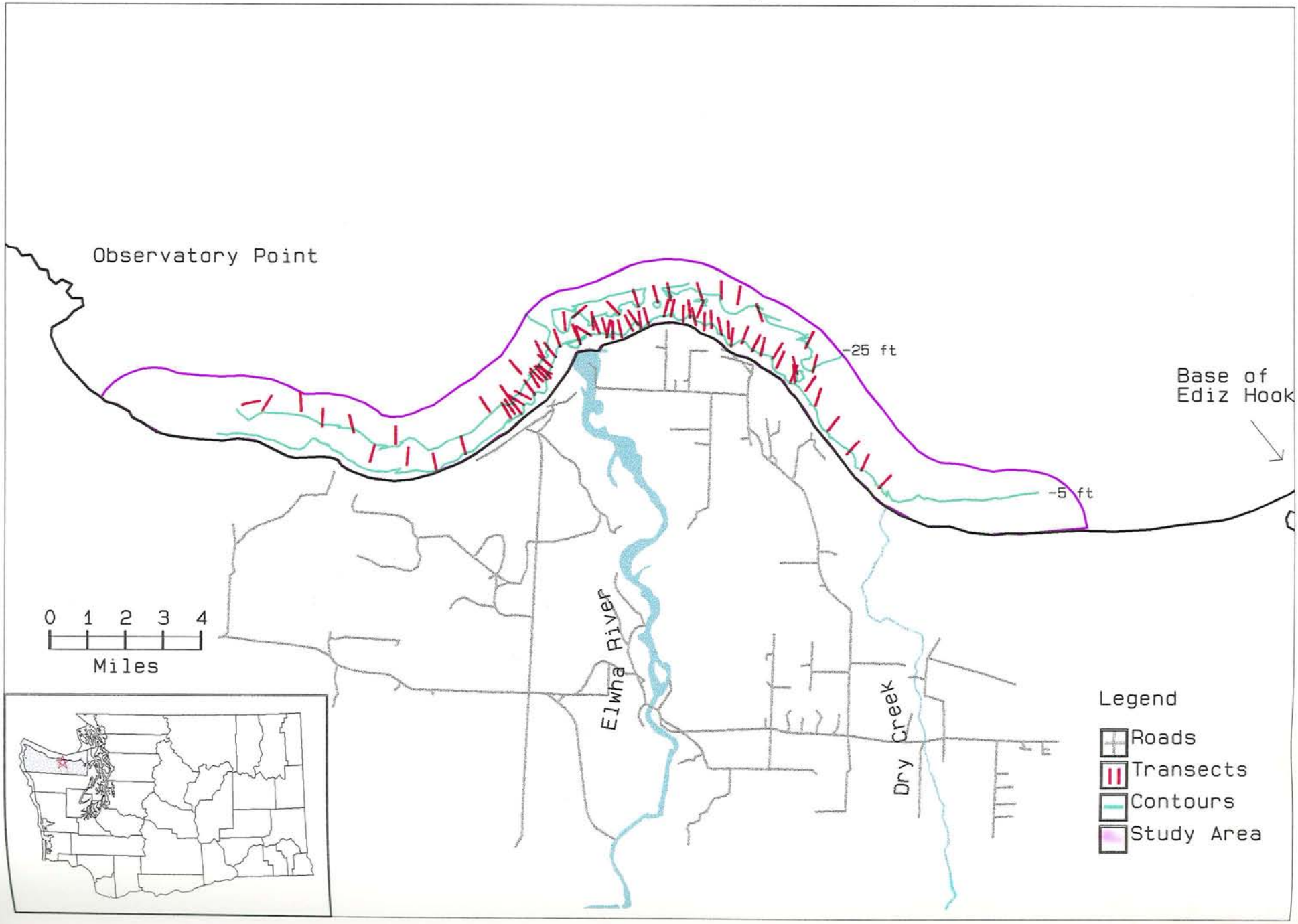
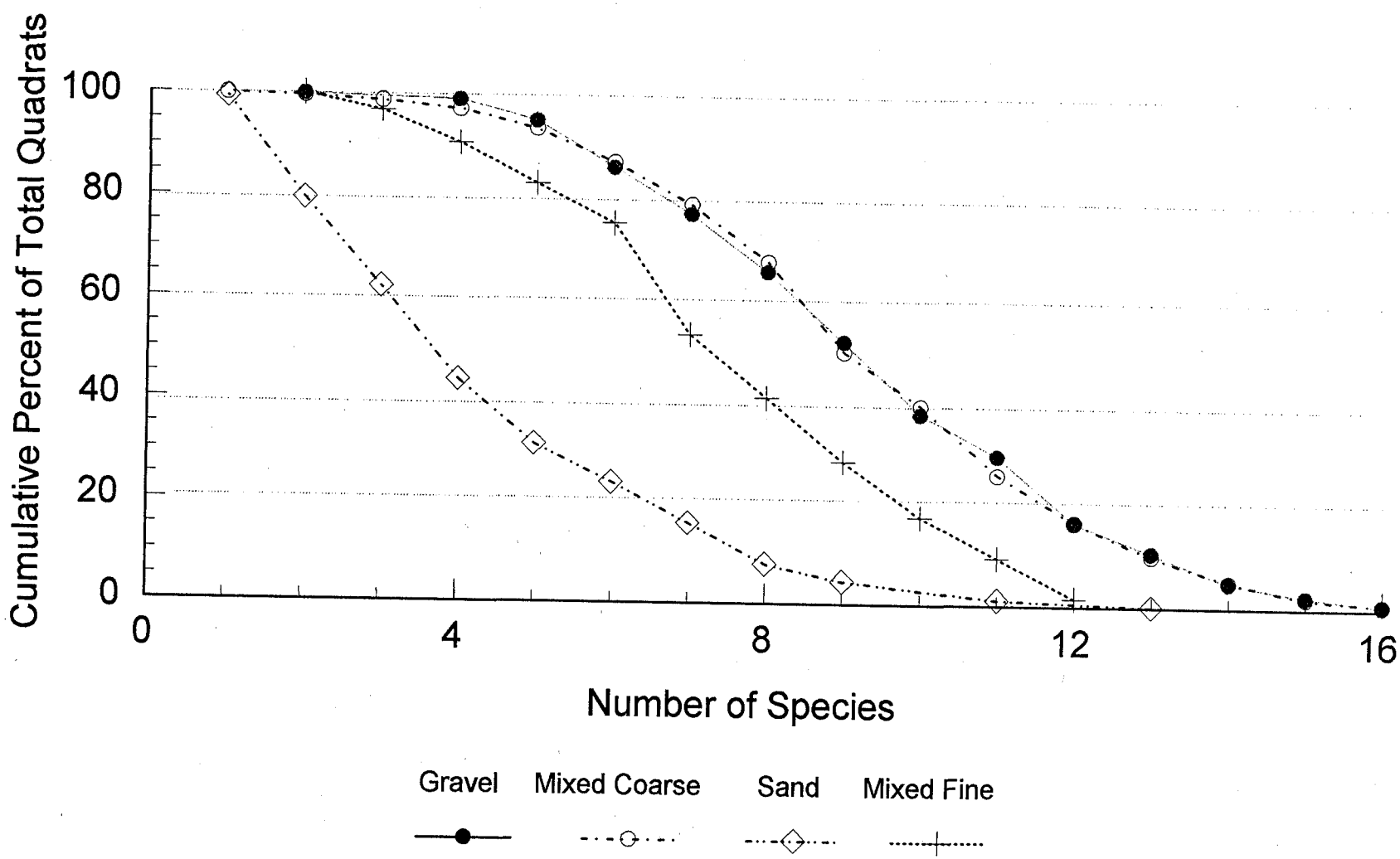
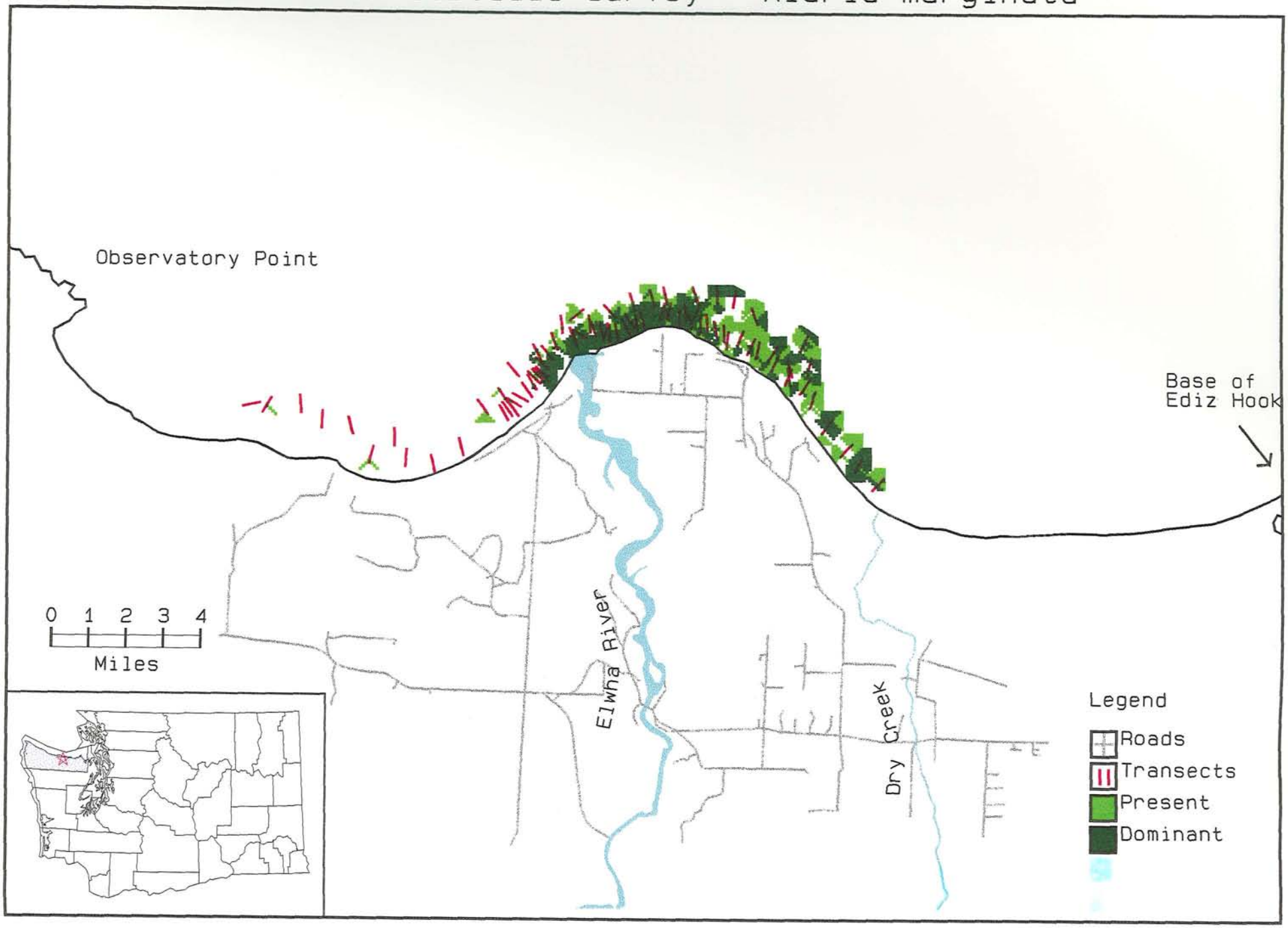


Figure 3. Elwha River Subtidal Survey - Macroalgae Species Richness by Substrate

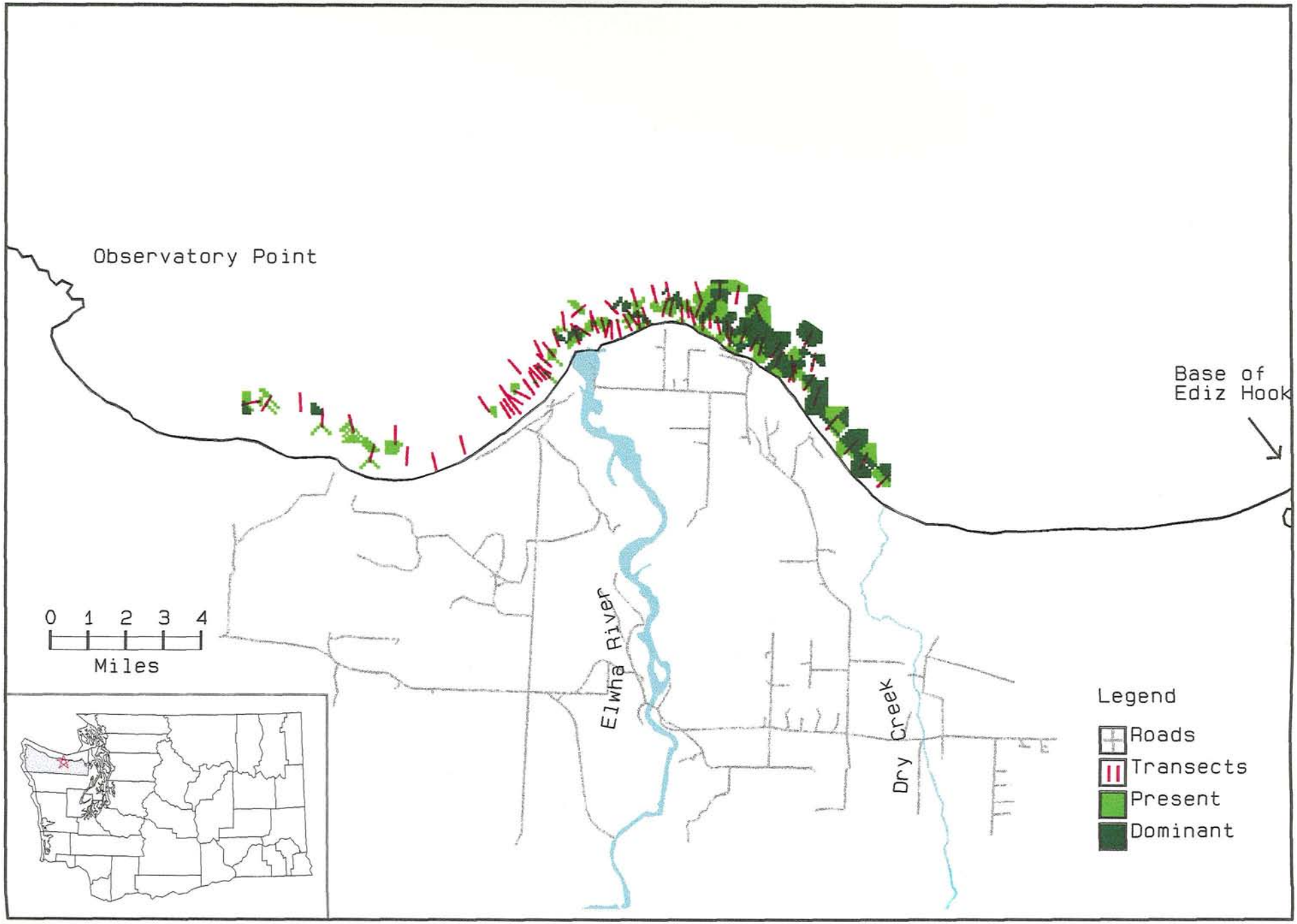


Map 1. Elwha River Subtidal Survey - Vegetation Cover

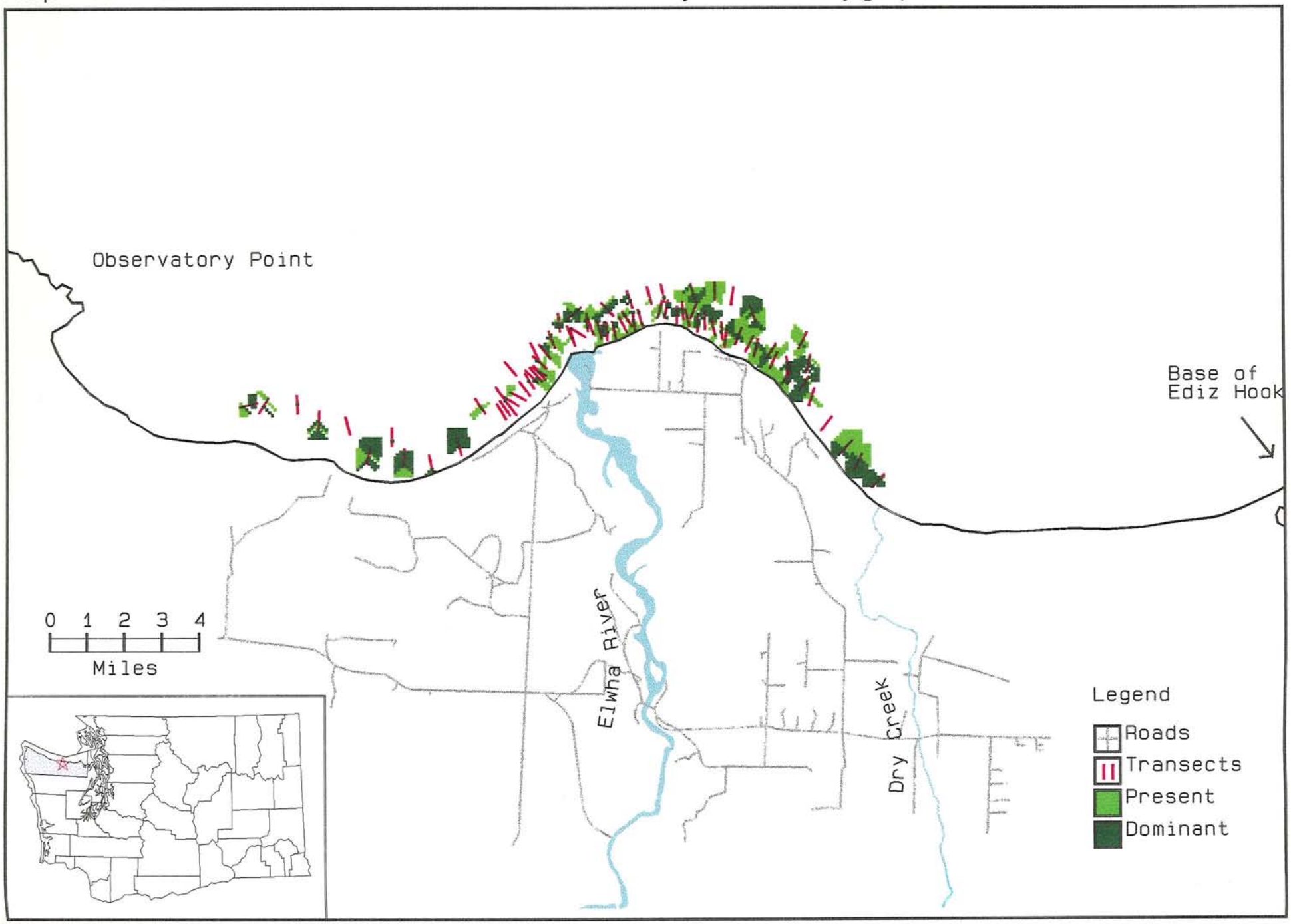
Map 2. Elwha River Subtidal Survey - Alaria marginata



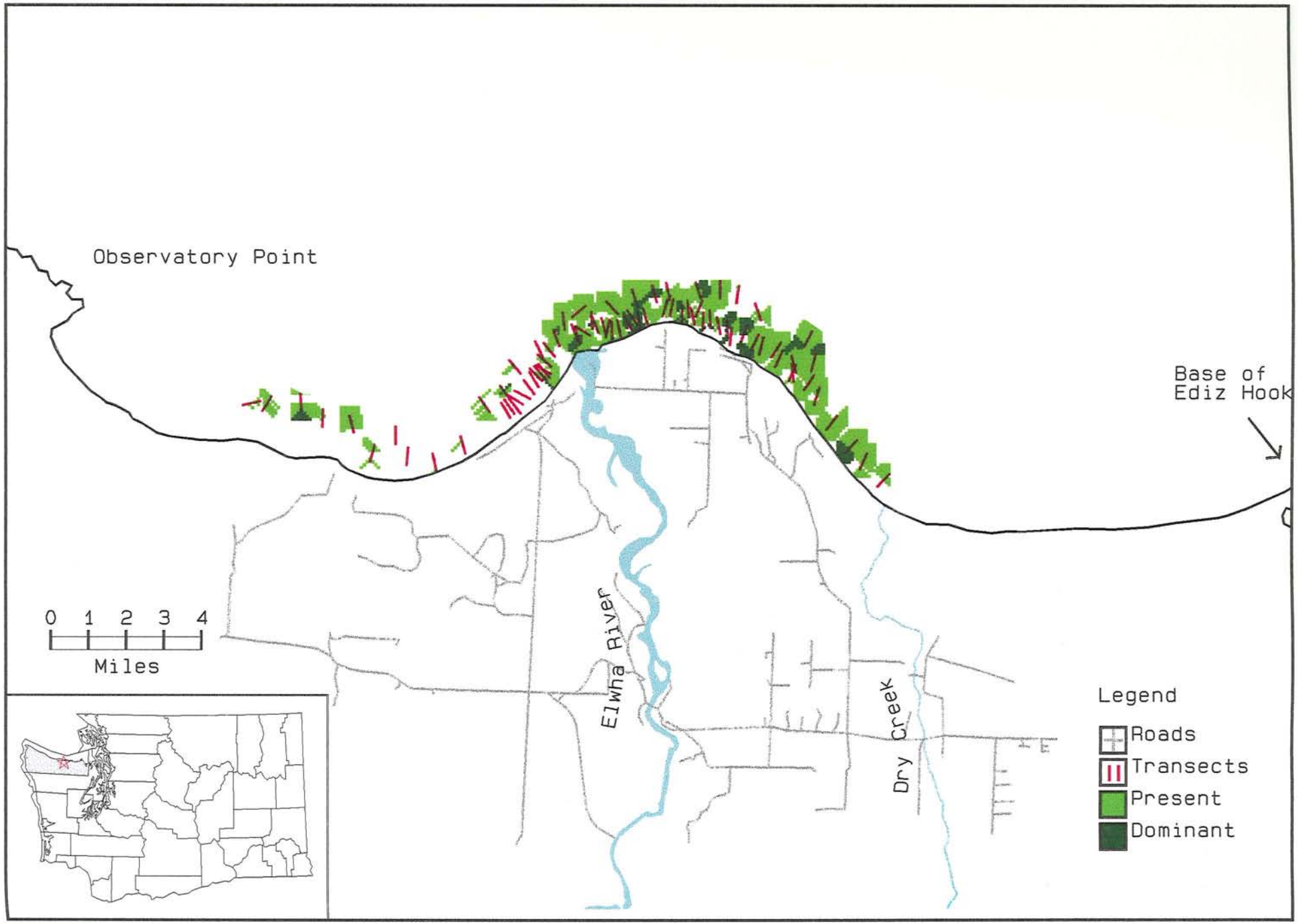
Map 3. Elwha River Subtidal Survey - Cymathere triplicata



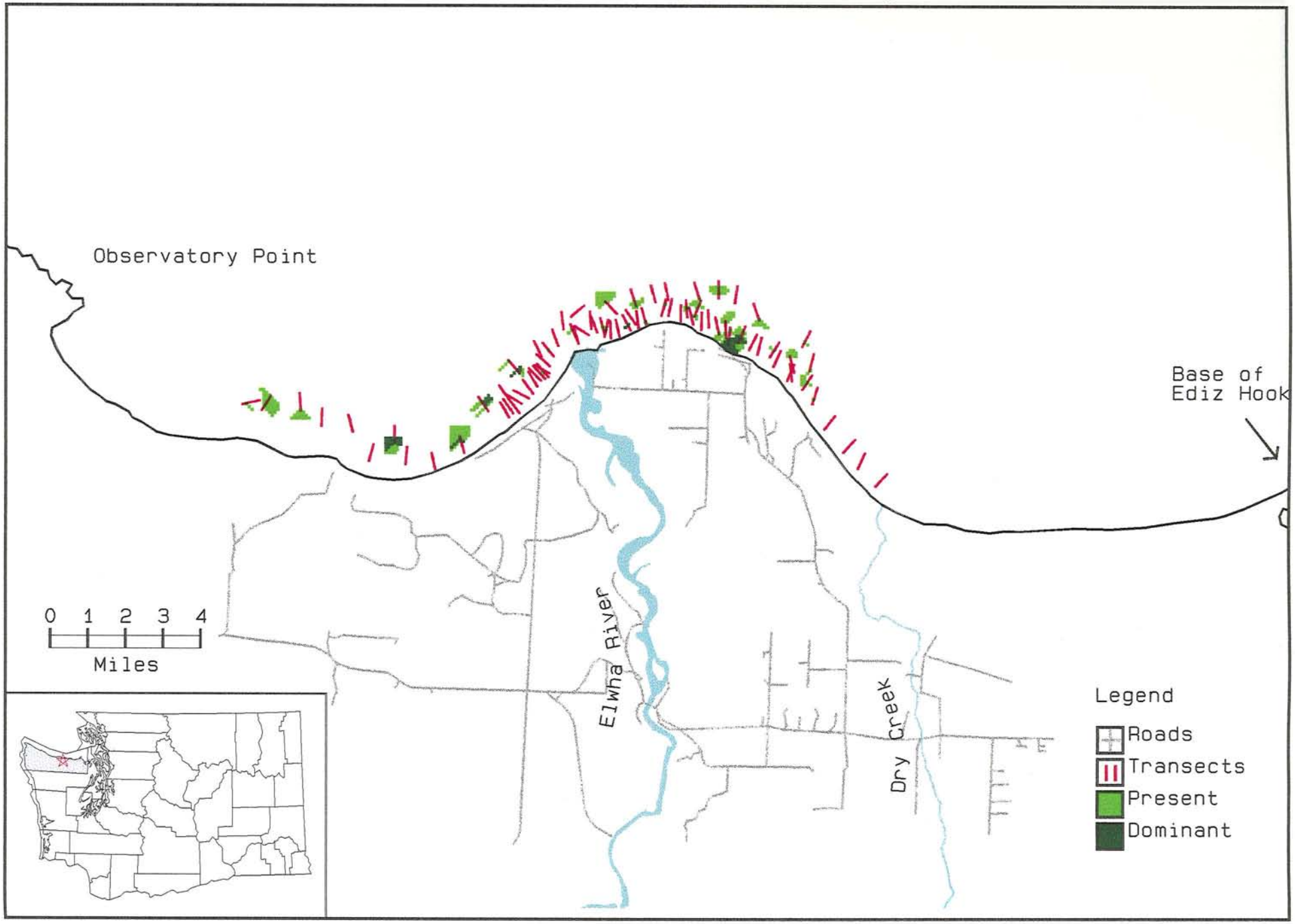
Map 4. Elwha River Subtidal Survey - Pterygophora californica



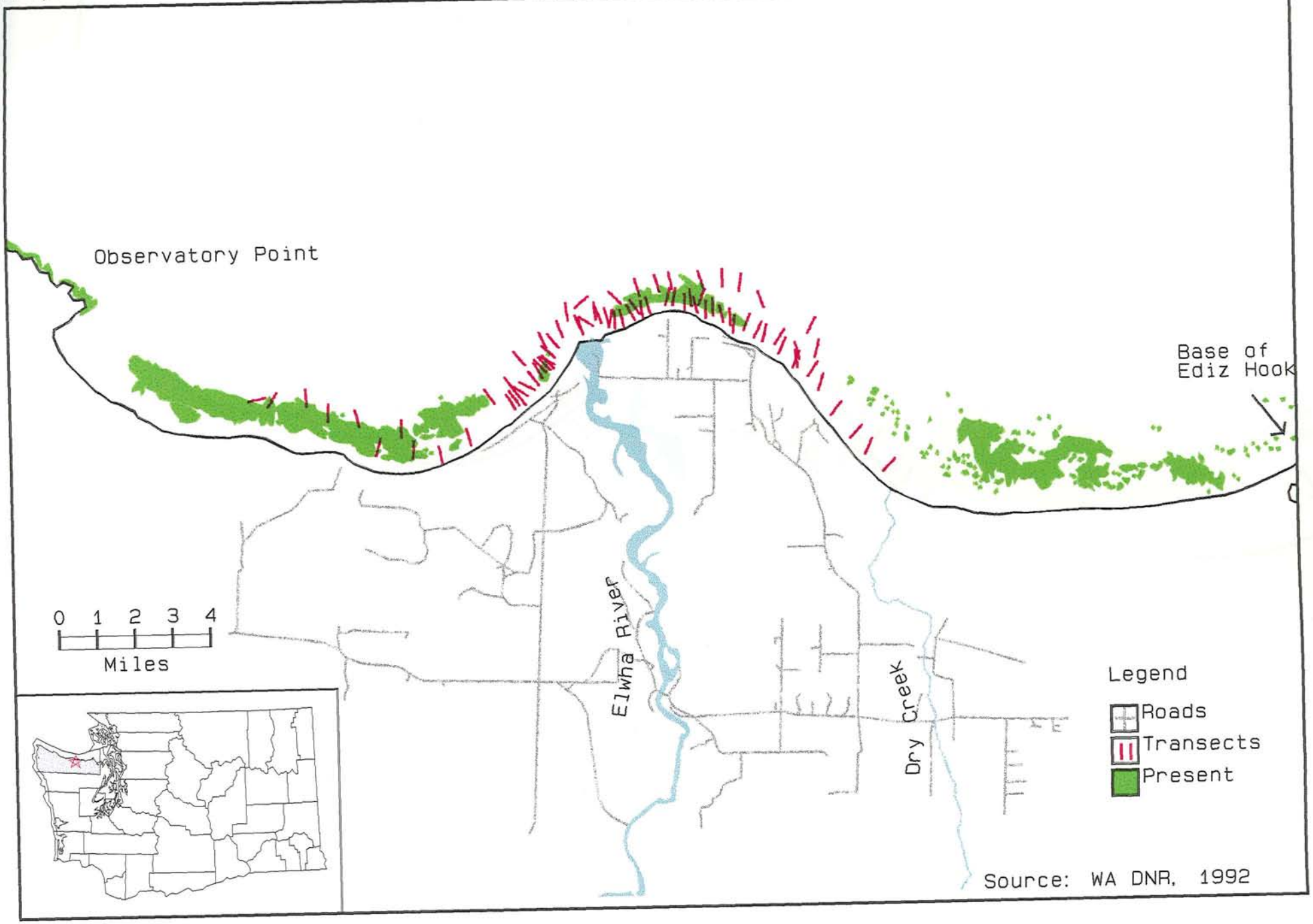
Map 5. Elwha River Subtidal Survey - Iridaea cordata



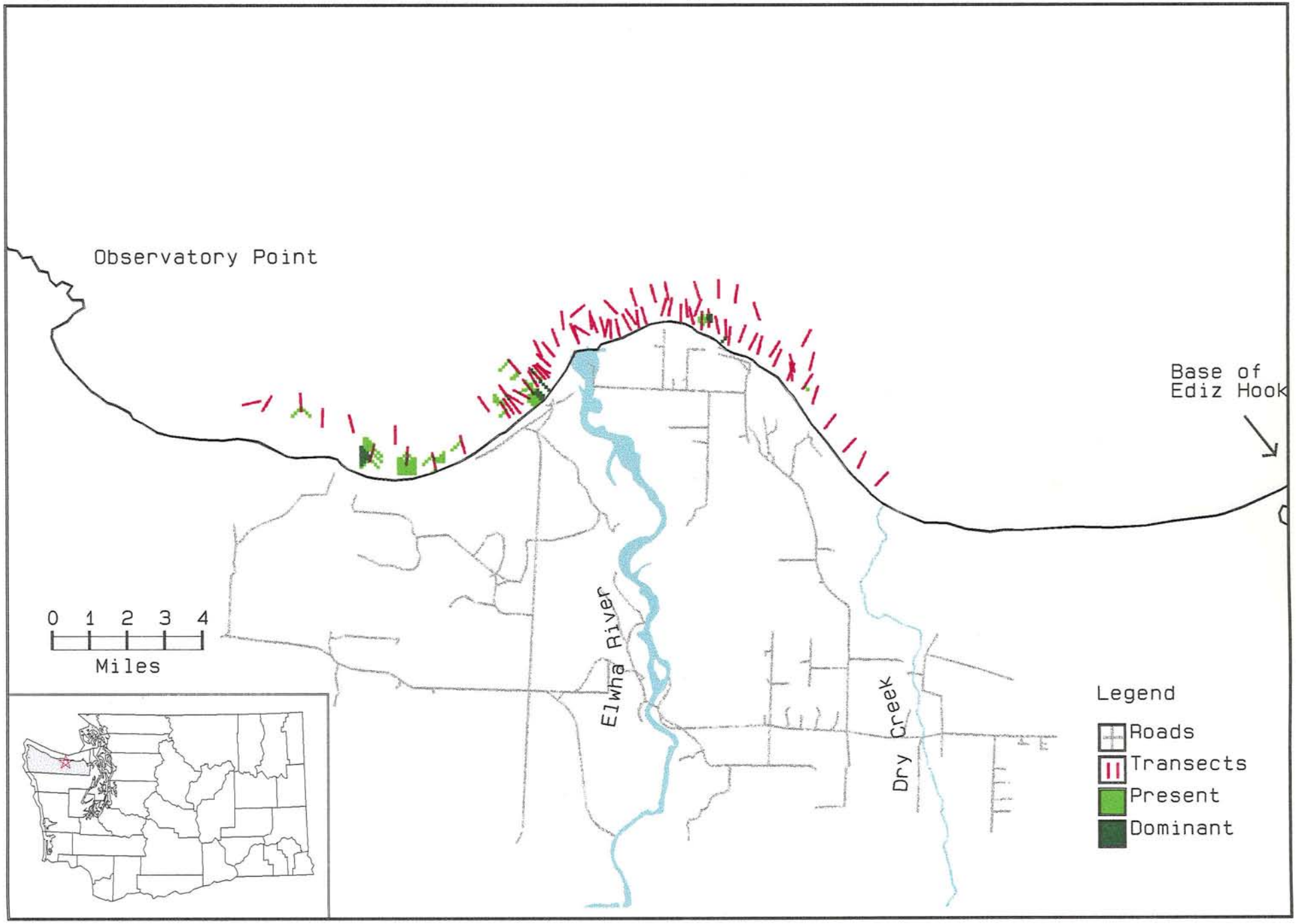
Map 6. Elwha River Subtidal Survey - Nereocystis luetkeana



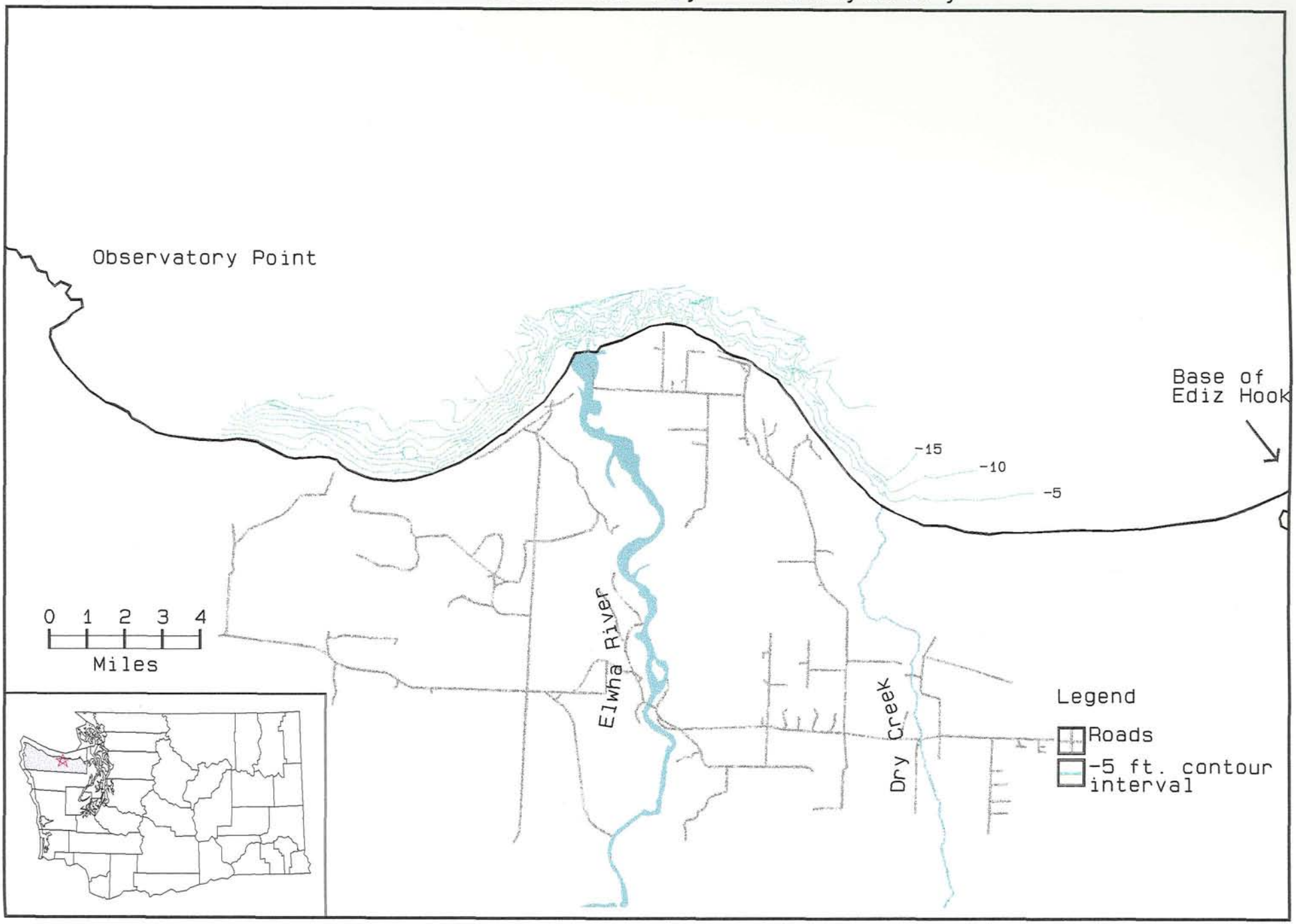
Map 7. Elwha River Subtidal Survey - Nereocystis luetkeana



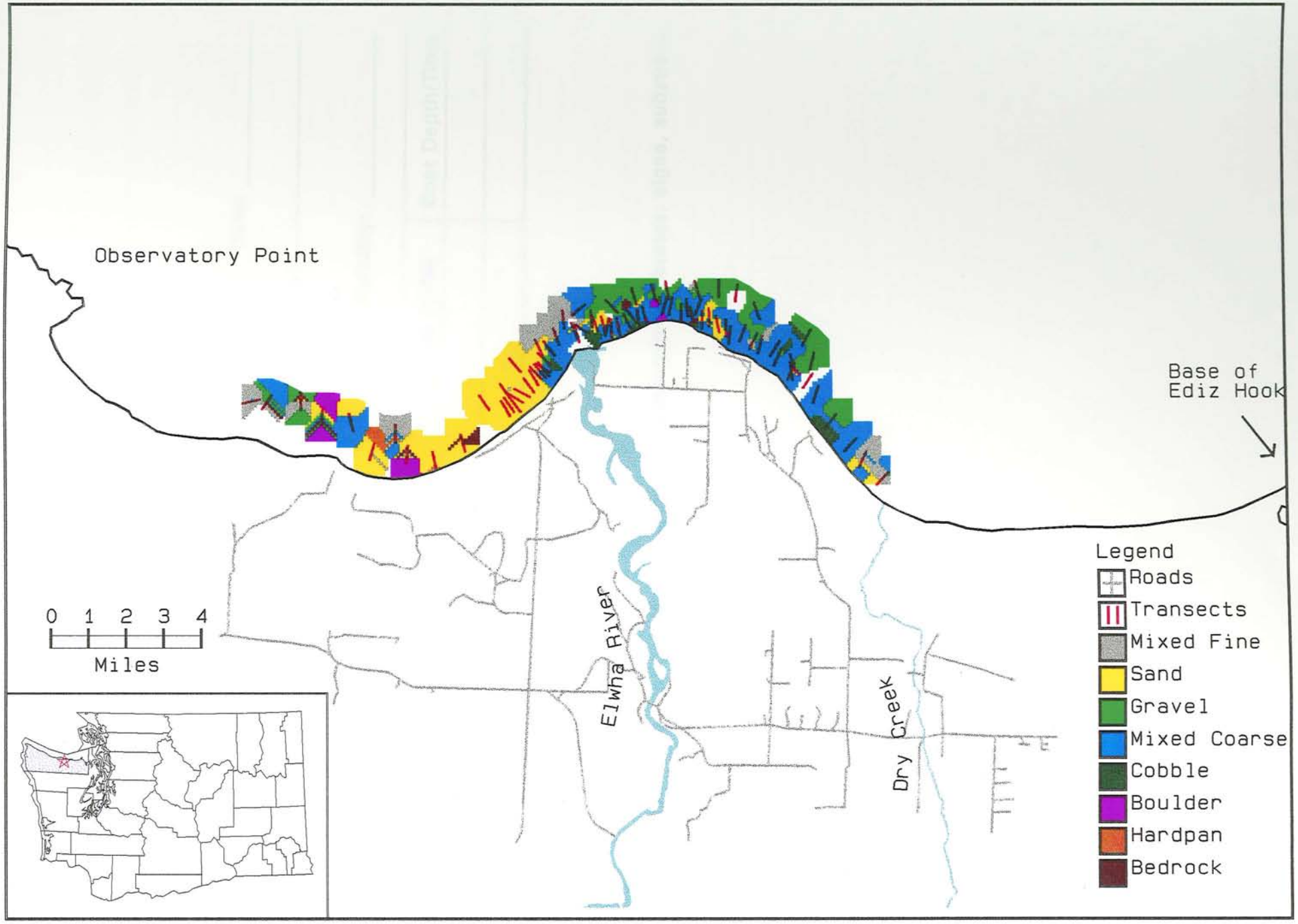
Map 8. Elwha River Subtidal Survey - Zostera marina



Map 9. Elwha River Subtidal Survey - Bathymetry



Map 10. Elwha River Subtidal Survey - Substrate



Appendix A.

Transect ID: _____ Length: _____ Date: _____

Divers: _____
(circle data recorder)

Quadrat Size: _____ Visibility: _____

	Latitude (GPS)	Longitude (GPS)	Boat Depth/Time
Shallow End			
Deep End			

General Oberservations (fish, crusteaceans, macroinvertebrates, algae, substrate, etc.):

TRANSECT ID: START TIME: FINISH TIME:	NEAR SHORE										OFFSHORE
	1	2	3	4	5	6	7	8	9	10	11
Depth											
Veg. Cover (25% increments)	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
Brown Algae (D=dominant; X=present)											
Alaria marginata											
Cymathere triplicata											
Pterygophora california											
Laminaria setchelii											
Laminaria groenlandia											
Costaria costata											
Nereocystis luetkeana											
Desmarestia ligulata											
Desmarestia viridis											
Scytosiphon lomentaria											
Red Algae (D=dominant; X=present)											
Iridaea cordata											
Mastocarpus sp.											
Erthrophyllum delesseriodes											
Gigartina exasperata											
Botryoglossum farlowianum											
Sarcodiotheca gandchandii											
Coralline Crustose											
Corralline Articulated											
Microcladia borealis											
Porphyra sp.											
Red Foliate											
Green Algae – Ulvoids											
Macroinvertebrates (count if < 20; estimate higher densities with 21–50, >50)											
Green Sea Urchin											
Giant Sea Cucumber											
Geoduck											
Horse Clam											
Heart Cockle											
Dungeness Crab											
Decorator Crab											
Kelp Crab											
Red Rock Crab											
Hermit Crab											
Sunflower Star											
Sun Star											
Blood Star											
Sabellid Tube Worm (leatherlike)											
Terebellid Tube Worm (calcareous)											
Black Chiton											
Limpet											
Nudibranch											
Snail											
Substrate											
BOulder–Cobble–MCoarse–Gravel–Sand Bedrock–Hardpan–MFine–Mud											

**** RECORD GENERAL OBSERVATIONS ON THE REVERSE SIDE UPON FINISHING TRANSECT ****