Hatfield Marine Science Center
Dynamic Revetment Project
DSL permit # 45455-FP

Monitoring Report
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Submitted by:
George Boehlert, Director
Hatfield Marine Science Center
Oregon State University
george.boehlert@oregonstate.edu
541-867-0211

Editor:
Walt Nelson, US Environmental Protection Agency

Contributors:
Beach Profiles:
Jonathan Allan, Oregon Department of Geology and Mineral Industries
Erica Harris, Oregon Department of Geology and Mineral Industries

Birds and Marine Mammals:
Shawn Stephensen, US Fish and Wildlife Service

Fish:
Vincent Politano, Oregon State University
Heppell Laboratory, Oregon State University

Benthic Invertebrates and Vegetation:
Christina Folger, US Environmental Protection Agency
Walt Nelson, US Environmental Protection Agency
Abstract
The Hatfield Marine Science Center (HMSC) is an interagency campus in Newport, Oregon with a mission of research, education and outreach in marine sciences through collaborative partnerships. Located on a 49 acre site on Yaquina Bay, Oregon, it is adjacent to diverse habitats, many of which are subject to action of waves and tides. A Dynamic Revetment (gravel beach) was installed in November, 2011 on the shoreline along the northeastern edge of the HMSC to mitigate erosion that threatened HMSC critical infrastructure. Shoreline topographic and biological monitoring was initiated before and continued after the project completion. Monitoring of beach profiles along the project area showed that a Dynamic Revetment installed in 2007 had been successful in stabilizing further retreat of the beach. As of January 2012, the 2011 project also appears to have stabilized the shoreline, while rapid erosion has continued in the adjacent Reference beach area. For invertebrates, fish, and vegetation, only pre-installation comparisons of the project (DRP) and Reference beach have been conducted. For both invertebrates (infauna, beach wrack associates) and fish, there were statistically significant differences over the combined DRP and Reference beaches reflecting small scale ecological variability. Shoreline vegetation also displayed some differences in species composition in pre-installation sampling, but total shore vegetation cover did not differ significantly between the two beach areas. Visual counts of marine mammals and birds were conducted both pre- and post-installation. There were no marine mammals observed, and no birds were observed prior to the project. Variability among observation periods was extremely high, with many zero observations. There were no statistically significant differences in the number of birds observed based either on tide (high vs. low) or sample area (DRP vs. (Reference). Post-installation sampling for all the above parameters will continue.
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1.0 HMSC Beach and Shoreline Monitoring

1.1 Background

Stabilization of the Yaquina Bay shoreline along the northeastern edge of the Hatfield Marine Science Center (HMSC) campus has become necessary to halt erosion that threatens both HMSC critical infrastructure (seawater storage tank) and public access to the HMSC nature trail. The Hatfield Marine Science Center (HMSC) Estuary trail was constructed in 1988 and is unique to Newport since it provides the only trail for exploring the Yaquina Bay estuary from its banks, as well as being one of the longer accessible trails in the area for those with disabilities. Since the late 1990s/early 2000 the trail has experienced erosion from a combination of oceanographic processes including high frequency wind waves coupled with high tides and tidal currents associated with both the ebb and flood tide. The erosion eventually led to the partial closure of the trail in 2005.

In 2006, the Oregon Department of Geology and Mineral Industries (DOGAMI) assisted HMSC with the design of a “soft” form of coastal engineering to help mitigate the erosion. The design involved the construction of a gravel beach (also known as a dynamic revetment). The project was completed in March 2007 with the assistance of the Oregon Army National Guard IRT program and resulted in the stabilization of approximately 200 linear feet of shoreline. That shoreline has remained stable since project implementation. Erosion had been occurring at a lower rate to the south of the project area, but in the winter of 2009-2010, weather conditions resulted in rapid erosion of up to 13 ft along approximately 500 linear ft of shoreline. This erosion moved the shoreline to the edge of the nature trail in one location, and to within only 25 ft of portions of the seawater system infrastructure for HMSC. The seawater system supports the research of Oregon State University and the five federal and state agency programs co-located on site. The threat to critical public infrastructure required an additional erosion control effort utilizing the gravel shoreline technique.

Gravel beaches have long been recognized as an effective form of natural coastal protection, minimizing the potential for inundation from wave overtopping as well as exhibiting a remarkable degree of stability in the face of sustained wave attack (van Hijum, 1974; Nicholls and Webber, 1988; Allan et al., 2005; Komar and Allan, 2010). The reason for this is due to their high threshold of motion and because of the asymmetry (shape) of shoaling waves and swash velocities on the beach face, which results in a greater propensity for onshore particle movement compared with sand-size particles, forming a steeply sloping beach face. Once formed, the porous gravel beach is able to disrupt and dissipate the incident-wave energy, even during intense storms. As a result of these characteristics, artificially constructed gravel beaches have been suggested as a viable approach for protection from coastal erosion, variously termed “cobble berms” or “dynamic revetments” when used in such applications. Once formed, the gravel beach is considered to be dynamic in that the gravels may be moved about by waves and currents, adopting a morphology that will reflect those assailing forces.

On November 10-11, 2011, an additional 260 ft of gravel beach was installed with the assistance of the Oregon Army National Guard. As a condition of the permit for installation, Oregon Department of State Lands required a monitoring program be put in place to assess both the geological performance and the biological impacts of the gravel beach installation (herein termed Dynamic Revetment Project or DRP). This report constitutes the first annual report on the
monitoring program. The majority of information provided in the present report represents pre-DRP installation monitoring data, with the exception of the first set of post-installation beach profiles and some data on bird utilization.

2.0 Physical Parameters
2.1 Beach Profile Survey Methodology
Beach profiles that are orientated perpendicular to the shoreline can be surveyed using a variety of approaches, including a simple graduated rod and chain, surveying level and staff, Total Station theodolite and reflective prism, Light Detection and Ranging (LIDAR) airborne altimetry, and Real-Time Kinematic Differential Global Positioning System (RTK-DGPS) technology. Traditional techniques such as leveling instruments and Total Stations are capable of providing accurate representations of the morphology of a beach, but are demanding in terms of time and effort. At the other end of the spectrum, high-resolution topographic surveys of the beach derived from LIDAR are ideal for capturing the 3-dimensional state of the beach, over an extended length of coast within a matter of hours. However, the LIDAR technology remains expensive and is impractical along small segments of shore, and more importantly, the high costs effectively limits the temporal resolution of the surveys and hence the ability of the end-user to understand short-term changes in the beach morphology.

Within this range of technologies, the application of RTK-DGPS for surveying the morphology of both the sub-aerial and sub-aqueous portions of the beach has effectively become the accepted standard [e.g. Ruggiero et al., 2005; Allan and Hart, 2008], and has been the surveying technique used in this study. The Global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of >30 satellites and their ground stations, originally developed by the US Department of Defense; in 2007 the Russian Government made their GLONASS satellite network available increasing the number of satellites to ~46 (as of February 2011). In its simplest form, GPS can be thought of as triangulation with the GPS satellites acting as reference points, enabling users to calculate their position to within several meters (e.g. using inexpensive off the shelf hand-held units), while survey grade GPS units are capable of providing positional and elevation measurements that are accurate to a centimeter. At least four satellites are needed mathematically to determine an exact position, although more satellites are generally available. The process is complicated since all GPS receivers are subject to error, which can significantly degrade the accuracy of the derived position. These errors include the GPS satellite orbit and clock drift plus signal delays caused by the atmosphere and ionosphere and multipath effects (where the signals bounce off features and create a poor signal). For example, hand-held autonomous receivers have positional accuracies that are typically less than about 10 m (−30 ft), but can be improved to less than 5 m (−15 ft) using the Wide Area Augmentation System (WAAS). This latter system is essentially a form of differential correction that accounts for the above errors, which is then broadcast through one of two geostationary satellites to WAAS enabled GPS receivers.

Greater survey accuracies are achieved with differential GPS (DGPS) using two or more GPS receivers to simultaneously track the same satellites enabling comparisons to be made between two sets of observations. One receiver is typically located over a known reference point and the position of an unknown point is determined relative to that reference point. With the more sophisticated 24-channel dual-frequency RTK-DGPS receivers, positional accuracies can be
improved to the sub-centimeter level when operating in static mode and to within a few centimeters when in RTK mode (i.e. as the rover GPS is moved about). In this study we used Trimble® 24-channel dual-frequency R7/R8 GPS receivers. This system consists of a GPS base station (R7), Zephyr Geodetic antenna (model 2), HPB450 radio modem, and R8 “rover” GPS (Figure 2.1). Trimble reports that both the R7/R8 and 5700/5800 GPS systems have horizontal errors of approximately ±1-cm + 1ppm (parts per million * the baseline length) and ±2-cm in the vertical [Trimble, 2011].

To convert a space-based positioning system to a ground-based local grid coordinate system, a precise mathematical transformation is necessary. While some of these adjustments are accomplished by specifying the map projection, datum and geoid model prior to commencing a field survey, an additional transformation is necessary whereby the GPS measurements are tied to known ground control points. This latter step is called a GPS site calibration; GPS measurements are calibrated to ground control points with known vertical and horizontal coordinates using a rigorous least-squares adjustments procedure. Performing the calibration is initially undertaken in the field using the Trimble TSC2 GPS controller and then re-evaluated in the office using Trimble’s Business Office software (v2.5).

![Figure 2.1. The Trimble R7 base station antenna in operation on the Clatsop Plains. Corrected GPS position and elevation information is transmitted by an HPB450 Pacific Crest radio to the R8 GPS rover unit.](image)

Survey control at HMSC was provided by occupying two benchmarks established by National Geodetic Survey (NGS – Hamilton and 943 5380 tidal), and by the Coastal Field Office of DOGAMI (hmsc-crk & hmsc-pth). Coordinates assigned to these monuments were derived using a combination of approaches that included the Online Positioning User Service (OPUS) maintained by the NGS (http://www.ngs.noaa.gov/OPUS/) and the Oregon Real Time GPS Network (http://www.theorgn.net/) established by the Oregon Department of Transportation.
2.2 Beach Profile Lines and Initial Results

For the purposes of this study, DOGAMI staff established 15 beach profile transect lines along the estuary trail (Figure 2.2), which extends from the HMSC wharf in the northwest, southward approximately 290 m (~950 ft). Of these, 5 of the lines were originally established in May 2006 (1-5), while the remaining 10 lines were established in July 2011. GPS Surveys were undertaken on the original 1-5 lines in May 2006 and March 2007. These data have been supplemented with high resolution terrain elevations extracted from a LIDAR dataset (8 points per m²) collected by DOGAMI for the Northern Oregon coast in 2009. GPS surveys of the entire network were completed in July and December 2011, and most recently on January 13, 2012. Future surveys will be confined to mid-late winter (~February/March) and in late summer (~September).

Examination of the time history of beach and shoreline changes occurring between the HMSC profile lines 1 through 6, indicate that the initial dynamic revetment design (shaded blue dashed line in Figure 2.2), which included placement of gravel on the beach face and a lower cobble “lag” berm located at the juncture between the sandy beach and the inter-tidal mudflats, has been successful in stabilizing further retreat of the beach. While some southward migration of the gravel has occurred through time, particularly in the vicinity of the HMSC lines 5 through 7, the amount of gravel loss is small and presently does not exceed the 2006 pre-construction elevation. Nevertheless, given that there has been a small amount of gravel lost, we recommend that HMSC consider adding some additional gravel to this portion of the existing dynamic revetment in order to safeguard its volume.

In contrast to the area covered by the existing dynamic revetment, there has been significant beach and shoreline erosion (up to 5.5 meters) south of the structure (lines 7 through 15), which occurred between 2009 to 2011. As can be seen from the beach profile plots (Section 2.4), the erosion reflects a complete landward translation of the entire beach profile. As a result, this southern area is actively eroding and without immediate intervention, would almost certainly have continued into the future. With the recent completion of the expanded gravel beach/dynamic revetment (shown as the shaded green dashed line in Figure 2.2), the expectation is that the erosion will likely slow or stop completely in the area covered by profiles 6-11. There is one caveat to this in that the amount of gravel placed is less than ideal (i.e. not enough) and lies at a much steeper angle when compared with the original structure such that the expectation is for some of that gravel to be redistributed to the south, where it will spread out on the unprotected beach to the south, as well as be transported down the beach profile. To the south in the unprotected areas, we fully expect erosion to continue and our recent survey of the beach on January 13, 2012 reinforces this perception. Finally, an issue that remains in this area is risk from overtopping and flooding (as evident by the accumulation of an eel grass wrack line west of the estuary trail), which will remain a problem for the estuary trail.

Included in Figure 2.2 are various shorelines derived from aerial photography (essentially the vegetation/beach juncture) and from GPS and LIDAR surveys (erosion scarp features) of the beach. These lines demonstrate the ongoing changes (predominantly erosion) that have taken place along the estuary trail. Where the original dynamic revetment/gravel beach was constructed in the north, the structure is doing its job with little to no evidence of erosion having
taken place; some minor erosion has occurred adjacent to the profile 6 line as gravels were redistributed toward the south.

Figure 2.2. Location map showing the HMSC beach and shoreline monitoring network. Blue shaded dashed line denotes the cobble ‘lag’ toe of the original dynamic revetment, green shaded dashed line denotes the cobble ‘lag’ toe for the expanded section and grey shaded dashed line denotes the location of rip rap rock.
2.3 References
2.4 Beach Profile Survey Results
3.0 Biological Parameters

3.1 Density of Benthic Invertebrates

3.1.1 Benthic Invertebrate Sampling Methods

To characterize initial conditions for infaunal invertebrates, five replicate 7.6-cm diameter core samples were collected within three elevation zones on both the Reference and DRP beaches prior to DRP implementation on October 15, 2011. Replicates were collected at random within the elevation zones, which consisted of 1-m bands of the upper beach, mid beach, and low beach. The upper beach zone is located just below the vertical beach scarp, the low zone is located at the bottom of the beach slope, and the mid beach zone is established at the mid-point between these two limits. Mixed algae and seagrass samples were collected from the wrack line at five random locations from the Reference beach and five locations from the DRP beach. All samples were frozen after collection and thawed just prior to processing.

Sediment cores were processed on a 1-mm sieve and the organisms were preserved in 70% denatured alcohol. The wrack samples consisted mostly of the green macroalgae *Ulva* sp. and the seagrass, *Zostera marina*. Wrack samples were processed by a combination of rinsing, sieving and picking the wrack material in plastic tubs. The algae/seagrass biomass material was saved for each replicate and dried in an oven at 70°C for 5 days. The final dry weight of each wrack sample was determined.

Organisms were sorted, identified to family and enumerated. Densities for wrack associated organisms are expressed per unit dry wrack biomass.

3.1.2 Invertebrate Results

For the pre-installation sampling, benthic infaunal invertebrates in the intertidal sand beach within the study area were highly patchy, both between the DRP and Reference area, and among the vertical zones on the beach (Table 3.1.1). Most of the invertebrates recorded in the DRP area were cirolanid isopods found in the mid-intertidal zone. In the Reference area, the majority of invertebrates were gammaridean amphipods found in the lower beach zone. Virtually no gammarideans were found in either in other Reference area beach zones or in the DRP area. A few talitrid amphipods were found in both sample areas, but were mostly restricted to the upper beach zone. A two-way ANOVA on total invertebrate abundance with the factors of sample area and beach zone showed a highly significant interaction term, confirming that there is a significant variability in total abundance that must be explained by both differences in beach zone and sample area.
Table 3.1.1. List of benthic infaunal invertebrates collected from the intertidal sand within the study area prior to DRP emplacement.

<table>
<thead>
<tr>
<th>Sample Area</th>
<th>Beach Zone</th>
<th>Replicate</th>
<th>Talitridae</th>
<th>Gammaridae</th>
<th>Corophiidae</th>
<th>Cirolanidae</th>
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<td>27</td>
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</table>

Invertebrates associated with beach wrack on the intertidal sand beach were dominated by amphipod crustaceans in both the DRP and reference areas (Table 3.1.2). Cirolanid isopods and a small number of insects were collected in both areas. Only one polychaete was found on wrack samples. Expressed as a number of individuals per g dry-wt basis, there were approximately 12
times more wrack invertebrates in the DRP area, and this difference was statistically significant (Mann Whitney U-test, p=0.016).

Table 3.1.2. List of invertebrates collected in association with plant wrack deposited within the study area prior to DRP emplacement.

<table>
<thead>
<tr>
<th>Invertebrate Family</th>
<th>Replicate</th>
<th>DRP</th>
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<tr>
<td>Total</td>
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<td>84</td>
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3.2 Fish

3.2.1 Fish Sampling Methods:
During September and October of 2011, intertidal fish were captured with a 50 ft shore seine towed perpendicularly to the shore in a southeast direction for a distance of 50 ft at three permanent sites within the DRP shoreline and three permanent sites within the adjacent reference shoreline (Figure 3.3.1). This sampling was performed at spring high tide in order to be able to sample as much of the high intertidal habitat as possible. All fish captured in the seine were held for no more than 15 minutes in a bucket of ambient bay water while they were measured and identified to the lowest feasible taxonomic level before being released at the point of capture. Any injured or ill fish were treated by Dr. Tim Miller-Morgan, an aquatic veterinarian with Oregon State University (OSU) stationed at HMSC.

3.2.2 Fish Results
Shore seining was carried out on September 12 and 28, and October 12 and 26, 2011. A total of seven species and 189 individuals were captured (Table 3.2.1). Five species were represented by less than 10 individuals in the total collection. No salmonids were recorded. Fifty-seven individuals from six different species were captured in the DRP area (Sites 1-3, labeled “Restored” on Figure 3.1.1) and 132 individuals from four different species were captured in the adjacent Reference area (Sites 4-6). Sixty-nine percent of the total number of individuals captured in 2011 were harvested from the reference sites (Figure 3.2.1). That proportion was driven primarily by a large catch of shiner perch in Site 4 of the reference shoreline (Figure 3.2.2).

3.2.3 Discussion
The 2011 sampling provides baseline data against which post-DRP installation data can be compared. However, such comparisons will need to consider seasonality in fish assemblages in the Yaquina estuary. For the pre-DRP installation sampling, a large proportion of individuals
were captured at sites 4 and 5 within the Reference area shoreline. We attribute this to the presence of a patch of intertidal fish habitat in the form of exposed tree roots that occur near these transects. This is the only such complex habitat within the entire sampling area and contrasts markedly to the sandy habitat of the remaining shoreline. Thus, it is possible that a large component of future catch may continue to come from these transects, although the effect of the cobble and gravel beach must also be considered.

Table 3.2.1: A list of the number of individuals of each species captured during shore seining in 2011.

<table>
<thead>
<tr>
<th>Species</th>
<th>Common Name</th>
<th>Number Caught</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Allosmerus elongatus</em></td>
<td>whitebait smelt</td>
<td>7</td>
</tr>
<tr>
<td><em>Atherinopsis californiensis</em></td>
<td>jacksmelt</td>
<td>2</td>
</tr>
<tr>
<td><em>Cymatogaster aggregata</em></td>
<td>shiner perch</td>
<td>149</td>
</tr>
<tr>
<td><em>Gasterosteus aculeatua</em></td>
<td>threespine stickleback</td>
<td>1</td>
</tr>
<tr>
<td><em>Leptocottus armatus</em></td>
<td>pacific staghorn sculpin</td>
<td>24</td>
</tr>
<tr>
<td><em>Oligocottus snyderi</em></td>
<td>fluffy sculpin</td>
<td>5</td>
</tr>
<tr>
<td><em>Platichthys stellatus</em></td>
<td>starry flounder</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 3.2.1: Total number of species and total number of individuals caught at each site in 2011, “Restored” = DRP.
3.3 Vegetation

3.3.1 Vegetation Methods

In order to assess possible changes in shoreline vegetation following DRP installation, sampling was focused on the approximately 1 to 10 m wide strip of land east of the paved HMSC estuary trail and adjacent to the upper intertidal mudflat northeast of the EPA building (Figure 3.3.1). This area contains mixed vegetation community types including high marsh, dune and terrestrial plants and shrubs. A rapid vegetative assessment was done by Dr. Chris Janousek of US EPA on August 20, 2011 and results of this survey were previously submitted to DSL.

A quantitative survey using 1-m² quadrats was done on October 19, 2011. The survey consisted of randomly tossing the quadrat at approximate intervals of 10-15 m in the vegetation zone in both the DRP area and the Reference area for a total of twelve 1-m² plots (Figure 3.1.1), six per zone. A labeled PVC stake was placed in the center of the 1-m² quadrat and photographs were taken from several perspectives (3.3.2). Using a Trimble R8 GNSS unit, horizontal and vertical positions were measured in the center of each plot by performing an RTK survey with the ORGN network. The elevation data has not yet been processed, but approximate elevations may be obtained by reference to the profiles in Section 2.4.

Vascular plant presence or absence (usually at the species level) was visually assessed by scanning one 0.25 -m² quadrat within each 1-m² quadrat (Figure 3.3.2). Plant percent cover was assessed by visually evaluating the percentage that each plant species contributed to the overall

Figure 3.2.2: Total number of individuals of each species caught at each site in 2011. Sites 1-3 are within the DRP area, sites 4-6 are in the Reference area.
plant community present within the 1-m² quadrat. Percent cover estimates also considered non-plant material such as open or bare ground and detrital material.

Figure 3.3.1. Vegetation plots in DRP (red symbols) and Reference (yellow symbols) survey areas. Locations of fish sampling transects are shown as green (DRP) and orange (Reference) symbols.
3.3.2 Vegetation Results
A total of twenty-four plant taxa were identified in the 12 plots (Table 3.3.1). There was a trend at the site for the plant communities to transition from dune species to mid-elevation marsh to low marsh traveling from north to south across the study area. This vegetation change corresponds to a slight change in site elevation moving from north to south. Elevation differences between the DRP area and the Reference area can be seen in the beach profiles in Section 2.4 by comparing profiles HMSC 8-11 versus HMSC 9-15. Eleven vascular plant taxa were found in both areas, four taxa were only observed within the DRP area, and nine taxa were only observed within the Reference area. A grass, *Festuca rubra* (red fescue), was the most frequently occurring taxon in both areas. There was a greater frequency of occurrence of non-living substrate within the quadrats in the DRP area.
Table 3.3.1. Frequency of occurrence (presence/absence) of plant taxa and non-living material in the DRP and Reference areas, n = 6 quadrats per area.

<table>
<thead>
<tr>
<th>Plant Taxon</th>
<th>DRP</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Festuca rubra</em></td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><em>Atriplex</em> spp.</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td><em>Spergularia macrotheca</em></td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td><em>Elymus mollis</em></td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td><em>Achillea millefolium</em></td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><em>Grindelia stricta</em></td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><em>Daucus</em> sp.</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><em>Cackile maritima</em></td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td><em>Heracleum</em> sp.</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td><em>Digitalis</em> sp.</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td><em>Symphyotrichum subspicatum</em></td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td><em>Taraxacum</em> sp.</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td><em>Cytisus scoparius</em></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><em>Deschampsia cespitosa</em></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><em>Anaphalis margaritacea</em></td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Carex pansa</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Juncus breweri</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Schedonorus phoenix</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Distichlis spicata</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Holcus lanatus</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Juncus balticus ssp. ater</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Sarcocornia perennis</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Trifolium spp.</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><em>Lupinus</em> sp(p).</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woody Debris</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Bare ground/sand</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Dead plant matter</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Estimates of percent coverage of plants give generally similar results to those obtained from the presence-absence data (Table 3.3.2). There was greater total coverage of vascular plants within quadrats from the Reference area, and conversely greater presence of debris and bare space in the DRP versus Reference area (12.5 vs 0.8 %). However, the difference in total cover was not statistically significant (Mann-Whitney Rank Sum Test, p>0.05). The percent coverage data gives a better indication of the differences in plant dominance in the two areas. The grass *Festuca rubra* had the largest percent coverage in both areas, but in the DRP *Elymus mollis* (American dunegrass) and *Atriplex* spp. (saltbush) were the next most abundant, compared to
Carex pansa (sand dune sedge), Sarcocornia perennis (chickenclaws), and Schedonorus phoenix (tall fescue) which were most extensive in the Reference area quadrats.

Table 3.3.2. Mean and standard deviation of percent coverage of plant taxa and non-living material in the DRP and Reference areas, n = 6 quadrats per area.

<table>
<thead>
<tr>
<th>Plant Species</th>
<th>DRP</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Total Vascular Plants</td>
<td>87.5</td>
<td>15.1</td>
</tr>
<tr>
<td>Festuca rubra</td>
<td>29.7</td>
<td>16.3</td>
</tr>
<tr>
<td>Elymus mollis</td>
<td>24.2</td>
<td>33.2</td>
</tr>
<tr>
<td>Atriplex spp.</td>
<td>13.3</td>
<td>11.3</td>
</tr>
<tr>
<td>Spergularia macrotheca</td>
<td>7.8</td>
<td>18.2</td>
</tr>
<tr>
<td>Grindelia stricta</td>
<td>5.0</td>
<td>7.7</td>
</tr>
<tr>
<td>Cackile maritima</td>
<td>3.8</td>
<td>8.0</td>
</tr>
<tr>
<td>Achillea millefolium</td>
<td>0.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Heracleum sp.</td>
<td>0.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Cytisus scoparius</td>
<td>0.5</td>
<td>1.2</td>
</tr>
<tr>
<td>Digitalis sp.</td>
<td>0.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Daucus sp.</td>
<td>0.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Deschampsia cespitosa</td>
<td>0.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Symphyotrichum subspicatum</td>
<td>0.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Anaphalis margaritacea</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Taraxacum sp.</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Carex pansa</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Sarcocornia perennis</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Schedonorus phoenix</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Juncus breweri</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Distichlis spicata</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Juncus balticus ssp. ater</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Lupinus sp(p)</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Holcus lanatus</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Trifolium spp.</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total Non-living</td>
<td>12.5</td>
<td>15.1</td>
</tr>
<tr>
<td>Woody debris</td>
<td>8.3</td>
<td>14.4</td>
</tr>
<tr>
<td>Bare ground/sand</td>
<td>4.2</td>
<td>10.2</td>
</tr>
<tr>
<td>Dead plant matter</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
3.4 Birds and Marine Mammals
3.4.1 Bird and Marine Mammal Methods
The survey for birds and marine mammals included assessments at both the control and study areas. Formal surveys were initiated October 18, 2011 and data reported here include surveys through January 19, 2012. Additional pre-DRP construction surveys were conducted on September 21 and 23. Surveys were conducted within one hour of predicted high tide (preferably when the water was in the study and control areas) and at low tide (when the study and control areas were entirely exposed) and both surveys were conducted on the same day whenever possible. Observers identified birds to species wherever possible. Observers conducted counts along the HMSC nature trail at the south end of the DRP area and south end the Reference area for a minimum of 3 minutes in each area. Sampling protocol was that birds flying overhead would not be recorded unless they are hovering over the area to feed (e.g., Belted Kingfisher). Observers also recorded bird or marine mammal activity as coded in Table 3.4.1.

Table 3.4.1. Bird/marine mammal activity codes.

<table>
<thead>
<tr>
<th>Code</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>Foraging – birds/marine mammals are feeding or capturing prey</td>
</tr>
<tr>
<td>H</td>
<td>Hovering – birds hovering in air while searching for prey</td>
</tr>
<tr>
<td>L</td>
<td>Loafing – birds/marine mammals are loafing, resting, or sleeping</td>
</tr>
<tr>
<td>P</td>
<td>Preening – birds are preening feathers</td>
</tr>
<tr>
<td>S</td>
<td>Swimming – birds/marine mammals swimming through the study or control area</td>
</tr>
<tr>
<td>O</td>
<td>Other – explain activity in detail</td>
</tr>
</tbody>
</table>

3.4.2 Bird and Marine Mammal Results
There were no marine mammals recorded in the study period.

No birds were observed in either the Reference or the DRP area prior to DRP installation (Table 3.4.2). Post installation, a total of 22 birds was observed in the DRP area, and 120 birds were observed in the Reference area. At low tide, only 1 bird was observed in the DRP area, and 14 were observed in the Reference area. The majority of birds observed in the Reference area (100) were observed swimming at high tide. Variability among observation periods was extremely high, with many zero observations. An analysis of the bird count data using two-way ANOVA for the factors tide and sample area found no significant difference in the number of birds observed based either on tide (p=0.29) or sample area (p=0.34).

American Coot was dominant numerically in both sample areas. They were observed foraging on vegetation stranded at the high tide line in the DRP area post installation, and were observed swimming along the shoreline in the Reference area. A Western Gull was also observed foraging in the DRP area, while Brant geese and Scaup sp. were observed swimming in the reference area.
Table 3.4.2. List of bird species observed in the DRP and adjacent Reference area. Project construction occurred on November 10-11, 2011. Activity codes as in Table 3.4.1.

<table>
<thead>
<tr>
<th>DATE</th>
<th>TIDE</th>
<th>SPECIES</th>
<th>COUNT</th>
<th>ACTIVITY</th>
<th>SPECIES</th>
<th>COUNT</th>
<th>ACTIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/21/2011</td>
<td>High</td>
<td>None</td>
<td>0</td>
<td>None</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>9/23/2011</td>
<td>High</td>
<td>None</td>
<td>0</td>
<td>None</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>10/18/2011</td>
<td>High</td>
<td>None</td>
<td>0</td>
<td>None</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>10/19/2011</td>
<td>High</td>
<td>None</td>
<td>0</td>
<td>None</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>10/25/2011</td>
<td>High</td>
<td>None</td>
<td>0</td>
<td>None</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>11/3/2011</td>
<td>High</td>
<td>None</td>
<td>0</td>
<td>None</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>11/7/2011</td>
<td>High</td>
<td>None</td>
<td>0</td>
<td>None</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>11/17/2011</td>
<td>High</td>
<td>None</td>
<td>0</td>
<td>None</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>11/29/2011</td>
<td>High</td>
<td>None</td>
<td>0</td>
<td>None</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>12/15/2011</td>
<td>High</td>
<td>Killdeer</td>
<td>3</td>
<td>L</td>
<td>Western Meadowlark</td>
<td>6</td>
<td>L</td>
</tr>
<tr>
<td>1/6/2012</td>
<td>High</td>
<td>American Coot</td>
<td>18</td>
<td>F</td>
<td>American Coot</td>
<td>2</td>
<td>S</td>
</tr>
<tr>
<td>1/6/2012</td>
<td>High</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Black Brant</td>
<td>2</td>
<td>S</td>
</tr>
<tr>
<td>1/19/2012</td>
<td>High</td>
<td>None</td>
<td>0</td>
<td>American Coot</td>
<td>93</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>1/19/2012</td>
<td>High</td>
<td>-</td>
<td>-</td>
<td>Scaup sp.</td>
<td>3</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>10/18/2011</td>
<td>Low</td>
<td>None</td>
<td>0</td>
<td>None</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>10/24/2011</td>
<td>Low</td>
<td>None</td>
<td>0</td>
<td>None</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>10/25/2011</td>
<td>Low</td>
<td>None</td>
<td>0</td>
<td>None</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>11/3/2011</td>
<td>Low</td>
<td>None</td>
<td>0</td>
<td>None</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>11/7/2011</td>
<td>Low</td>
<td>None</td>
<td>0</td>
<td>None</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>11/17/2011</td>
<td>Low</td>
<td>None</td>
<td>0</td>
<td>None</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>11/29/2011</td>
<td>Low</td>
<td>None</td>
<td>0</td>
<td>None</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>12/15/2011</td>
<td>Low</td>
<td>Western Gull</td>
<td>1</td>
<td>F</td>
<td>None</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1/6/2012</td>
<td>Low</td>
<td>None</td>
<td>0</td>
<td>American Coot</td>
<td>14</td>
<td>L</td>
<td></td>
</tr>
</tbody>
</table>
4.0 Current Status of Erosion in the Study Area

As suggested in Section 2.2, as of February 6, 2012, the DRP shoreline appears stable while erosion has continued to occur in the Reference area immediately to the south of the DRP. “King” tides occurring from November – February have continued to roll back the shoreline vegetation, and steep vertical scarps at the vegetation edge are the norm along this shore section. The HMSC nature trail has been undermined and erosion has nearly spanned the width of the trail at one point. Spring high tide on February 6, 2012 occurred together with a steady east wind which provided optimal conditions for erosion.

Figure 4.1. View north showing the shoreline in the reference area in the foreground and the DRP project area in the background. High tide, February 6, 2012. Wind waves generated by east wind can be shown impacting the shore. Collapsed areas of HMSC nature trail are visible in the middle of the photograph.
Figure 4.2. View of collapsed section of HMSC nature trail, February 3, 2012.

Figure 4.3. View of collapsed section of HMSC nature trail, February 6, 2012 showing waves continuing to erode shoreline in this area.
Figure 4.4. View to the south of edge of DRP project and the reference shoreline, February 3, 2012. Note sections of marsh sod eroded onto shoreline in middle distance. Erosion at the upper edge of the DRP project can be seen.

Figure 4.5. View of upper edge at south end of DRP showing shoreline erosion at the marsh edge. The marsh bank is undercut by approximately 1 ft in this picture. Integrity of the DRP project edge may be impacted if erosion cuts back behind the gravel shoreline.