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

Final Monitoring Report
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Summary

Stabilization of the Yaquina Bay shoreline along the northeastern edge of the Hatfield Marine Science Center (HMSC) campus in Newport, Oregon became necessary to halt erosion that threatened both HMSC critical infrastructure (seawater storage tank) and public access to the HMSC Nature Trail. A Dynamic Revetment (gravel beach) was installed in November, 2011 on 260 feet of shoreline to mitigate erosion. Shoreline topographic and biological monitoring was initiated before and has continued after the project completion. Monitoring of beach profiles indicated that as of January 2016 the 2011 Dynamic Revetment Project (DRP) has generally successfully stabilized the shoreline in the project area. Beach profile data also indicated that a 200-ft DRP constructed in 2007 continued to be successful in stabilizing further retreat of the shoreline. In both areas, some loss of gravel at the top of the shore profile due to overtopping of the beach during highest tides was noted, and some additional placement of gravel at these locations is recommended. As a result of the rapid erosion that continued through much of 2015 in the adjacent Reference beach area, an extension of the 2011 DRP project to the south was completed during February 2015. This extension converted the Reference area used for monitoring the 2011 project into an additional gravel beach area (DRP 2015), which clearly differed from its previous characteristics. However, given the highly eroded condition of the Reference area in 2013-2014, the transition may have actually improved conditions for some monitored parameters (e.g. wrack invertebrates).

Monitoring of beach wrack invertebrates, fish, and vegetation was conducted in 2015 for the fifth and last year. The Reference (DRP 2015) area had significantly higher abundance per unit dry wt versus both the DRP (2011) and DRP Reference (2007) samples. In contrast to previous years when the total amount of beach wrack was much sparser in the Reference area due to the eroded shore profile, there was little apparent difference in wrack accumulation along the shoreline. As has been a consistent pattern, fish were significantly more abundant in the Reference area compared to the DRP. However, this pattern was present in the pre-project sampling, and the Reference area may have a higher degree of physical habitat complexity. This was certainly true after the completion of the DRP 2015, where in addition to the root masses of trees that have been eroded onto the shore, six additional tree root masses were emplaced along the shoreline as an experiment. As has consistently been observed, vegetation coverage was significantly greater and presence of non-living substrata was significantly less in the Reference (DRP 2015) area as compared to the DRP. These differences are consistent with the pre-DRP 2011 project site differences, probably resulting from a low area of the shoreline which allows increased flooding and associated disturbance in the DRP back shore area. Fish and wrack invertebrates, such as beach hoppers, continue to utilize the DRP project area. Biological differences in fish and vegetation observed in the monitoring in 2015 tended to reflect differences in habitat that were present before the DRP 2011 project was implemented.

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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 became necessary in 2007 to halt erosion that threatened 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.

Among the range of solutions to coastal erosion, 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). 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. Gravel beaches are considered a “soft” form of coastal engineering to help mitigate erosion.

In 2006, the Oregon Department of Geology and Mineral Industries (DOGAMI) assisted HMSC with the design of a dynamic revetment project. 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 the northeastern shoreline of HMSC. That shoreline section has remained stable since dynamic revetment implementation. Erosion continued at a lower rate to the south of the 2007 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.

Therefore, 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). The monitoring program included comparisons between the 2011 DRP area and adjacent areas for various physical and biological parameters which provided potential reference conditions to assess possible impacts associated with the 2011 DRP. During 2013 and 2014, the erosion along the approximately 240 ft of shoreline to the south of the 2011 DRP continued unabated, creating highly eroded conditions that undermined and collapsed multiple sections of the HMSC estuary trail, and left steep vertical scarps on the shoreline with loss of high marsh vegetation. These changes have been documented in previous DRP monitoring reports. In conjunction with Oregon Dept. of State Lands and Oregon Dept. of Fish and Wildlife, a plan was developed to install an additional section of dynamic revetment including novel features along the eroding shoreline section. These features included a contouring of the shoreline to reestablish an appropriate beach slope following existing scalloped features in the shoreline, but most importantly, included installation of six trees with projecting root wads at the toe of the beach contour in the area where the cobble toe of a dynamic revetment was installed. The extension of the DRP was carried out in February 2015. This necessary response to highly damaging erosion meant that the conditions in the area to the south of the 2011 DRP, previously termed the "Reference" area, changed to those of an additional gravel beach. Because no equivalent sand intertidal area could be located, the decision was made to continue the biological sampling at existing locations. To reflect the change in conditions, the label for the "Reference" area was changed to "Reference (DRP 2015)" to reflect the transition. Thus, the report may make reference to DRP 2007, the original dynamic revetment to the north, DRP 2011, the second dynamic revetment installation which has been the primary subject of the monitoring reports, and Reference (DRP 2015) which represents the southernmost portion of shoreline within the area.

This report constitutes the fifth and final annual report on the monitoring program for the 2011 DRP, representing four full years after project completion.

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 24 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, such that the 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).

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.

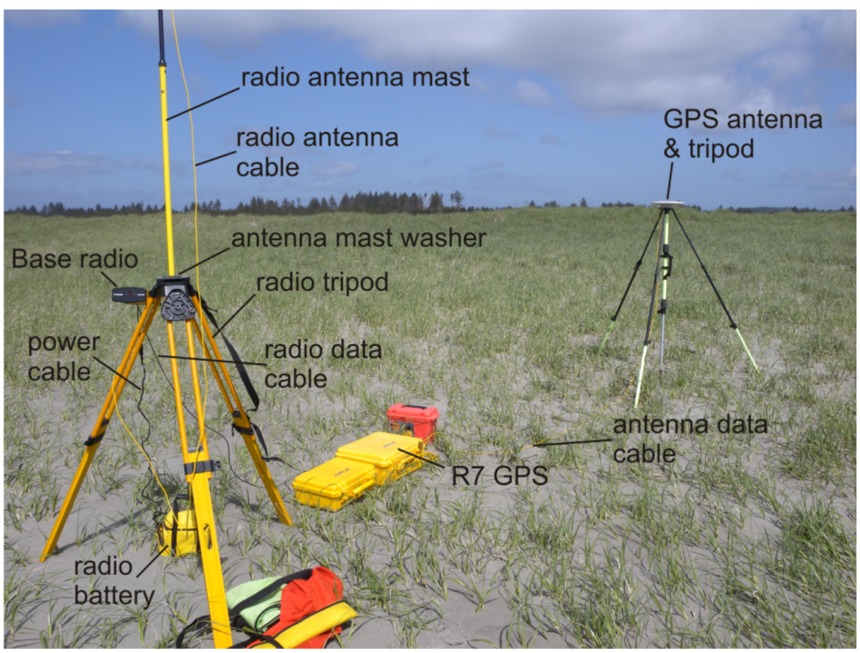

Figure 2.1. The Trimble R7 base station antenna in operation on the Clatsop Plains. Corrected GPS position and elevation information is transmitted by an HPB450 Pacific Crest radio to the R8 GPS rover unit.

2.2 Beach Profile Results

For the purposes of this study, we 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) to document changes on the original gravel beach constructed there in late 2006, while the remaining 10 lines were established in July 2011. An additional 3 transect lines were established in May 2014 (Table 2.1), expanding the monitoring network further to the south (Figure 2.2).

GPS Surveys were undertaken on the original profile 1-5 lines in May 2006, March 2007 and in September 2007 (Table 2.1). These data have been supplemented with high resolution terrain elevations extracted from a LIDAR dataset (8 points per m^2) collected by DOGAMI for the Northern Oregon coast in July 2009. Table 2.1 presents the times when all surveys of the beach were carried out.

Table 2.1: Dates when beach surveys and mapping efforts were undertaken

Measurement Date	Type	Transects
May 19 2006	RTK-DGPS	1-5
March 16 2007	RTK-DGPS	1-5
September 6 2007	RTK-DGPS	1-5
July 19 2009	Lidar	1-15
July 13 2011	RTK-DGPS	1-15
December 19 2011	RTK-DGPS	1-15
January 13 2012	RTK-DGPS	1-15
May 7 2012	RTK-DGPS	1-15
December 21 2012	RTK-DGPS	1-15
May 5 2013	RTK-DGPS	1-15
August 19 2013	RTK-DGPS	1-15
May 20 2014	RTK-DGPS	1-19
January 9 2015	RTK-DGPS	1-19
March 13 2015	RTK-DGPS	1-19
January 11 2016	RTK-DGPS	1-19

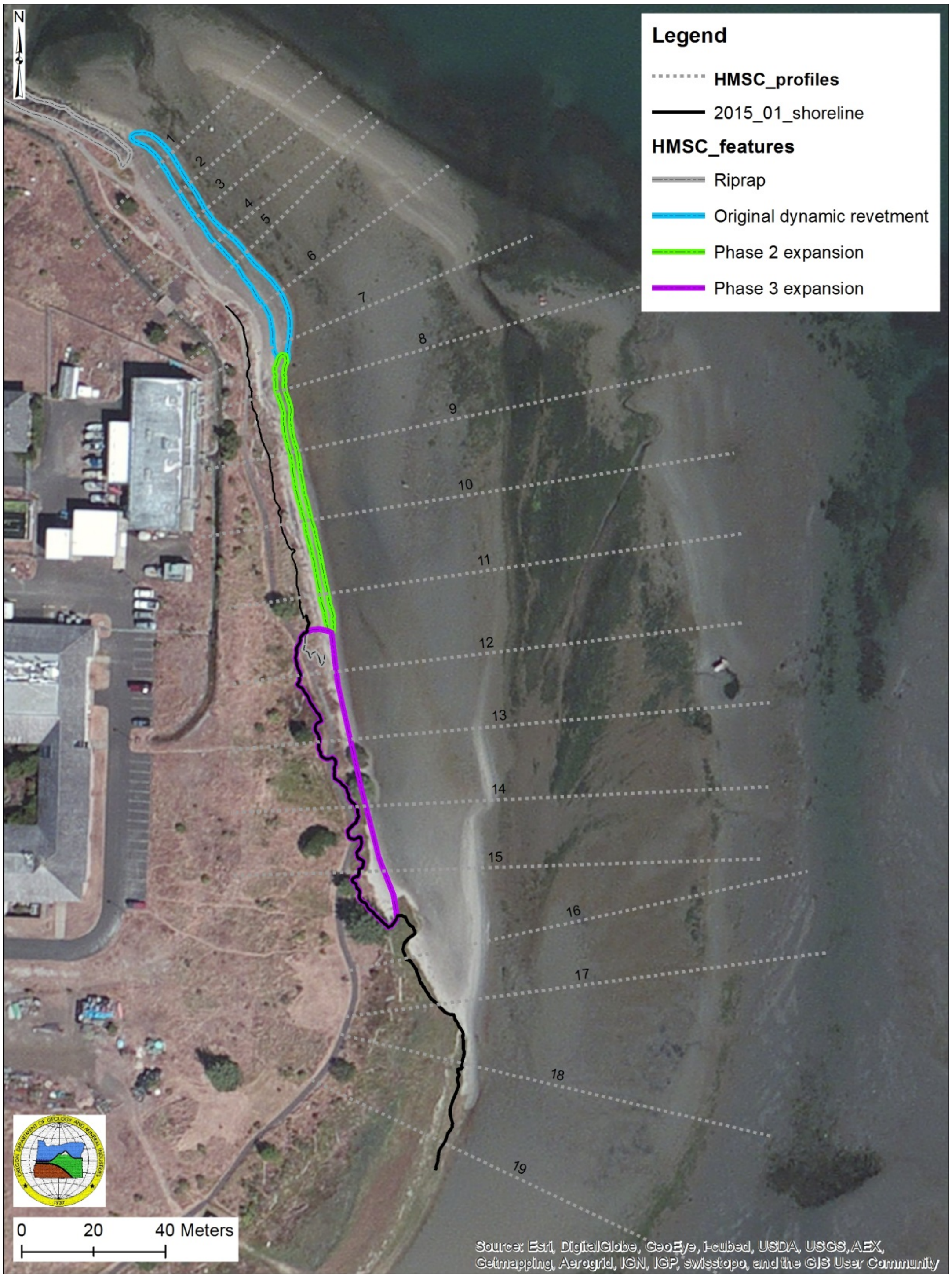

Figure 2.2: Location map showing the HMSC beach and shoreline monitoring network. Blue shaded dashed line denotes the cobble 'lag' toe of the original dynamic revetment (DRP 2007), green shaded dashed line denotes the cobble 'lag' toe for the expanded section (DRP 2011), purple represents the Reference (DRP 2015) area, and grey shaded dashed line denotes the location of rip rap rock. Solid black line depicts the most recent (January 2015) measurement of the erosion scarp.

Figure 2.3 presents the change over time as measured at the 2.4 m elevation contour for all the transect sites that span the original dynamic revetment (DRP 2007). Individual profile responses and time stacks (EDA plots) of changes taking place at selected contour elevations can be accessed online using the NANOOS Beaches portal: http://nvs.nanoos.org/BeachMapping. To view these data, select "Newport" in the regions section of the web portal. From there it is possible to obtain a close-up view of the HMSC campus and access the individual data plots.

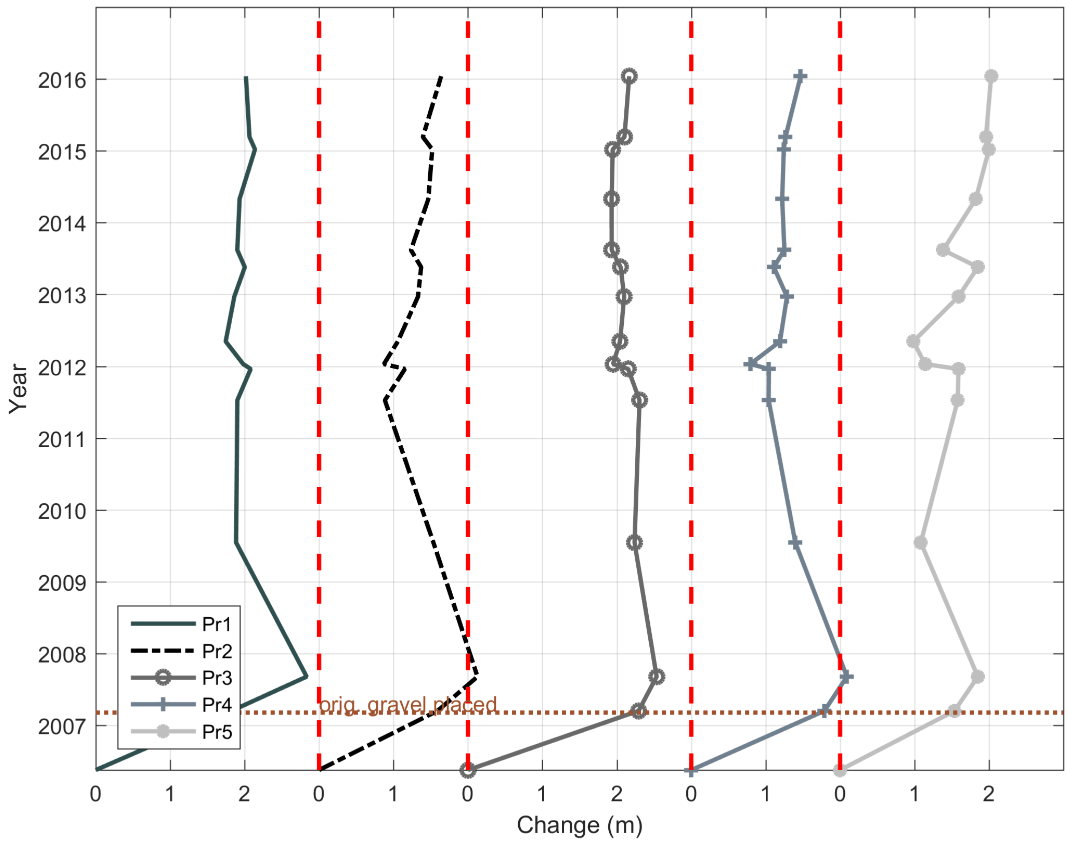

Figure 2.3: Transects 1 to 5 span the region where the original dynamic revetment/gravel beach was constructed. The zero line reflects the initial survey prior to construction of the gravel beach.

Figure 2.3 depicts the measured changes in the original gravel beach (Figure 2.4) area (blue dashed line in Figure 2.2). Examination of these data and results from the adjacent transects (6-12) confirm that the 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. This is characterized by the fact that there have been negligible changes to the gravel beach morphology in this area over time. Nevertheless, while the gravel beach is considered to be stable, there is some evidence of minor erosion taking place on the upper portion of the gravel beach where it merges with the sandy backshore. This response is entirely due to the occurrence of wind driven waves coupled with high tides, which enable the waves to reach to higher elevations on the profile (effectively exceeding the gravel beach) where they erode the sandy backshore. As noted in our original design, the gravel beach structure would need to have been built to a higher elevation to mitigate these effects, or combined with an artificial dune (*letter to HMSC by Allan, J.C. 2006*).

Figure 2.4: View looking northwest across the original gravel beach (DRP 2007). Photo depicts the effects of recent inundation by high tides along with some minor erosion of the top of the sandy beach *[Photo by J.C. Allan, January 11th 2016]*.

Further south between Transects 6-11 (Figure 2.5*,* green dashed line in Figure 2.2), the beach survey data indicate that the expanded gravel beach section (DRP 2011) is also stable, such that erosion of the beach and backshore has essentially ceased. Note that the degree of erosion that took place in this area is captured by the changes that took place between July 2009 and our first survey of the new gravel beach area undertaken in July 2011. In Figure 2.5 the baseline for our current monitoring efforts is the 2009 LIDAR. Despite the apparent stability of the gravel beach, our most recent survey undertaken on January 11th 2016 confirmed that the Transect 6 profile site is experiencing some erosion; this was noted in our previous report. As can be seen in Figure 2.6, the erosion is confined entirely to the upper part of the beach profile (located between the 2-3 m elevation). It is likely that the erosion at Transect 6 reflects the fact that this area of the beach may be feeding gravel to the areas adjacent to it (Figure 2.7). For example, Transect 5 shows clear evidence of it having gained gravel over the past few years. <u>As noted in our previous reports, we recommend that HMSC consider adding some additional gravel to this portion of the existing dynamic revetment in order to safe guard its volume</u>.

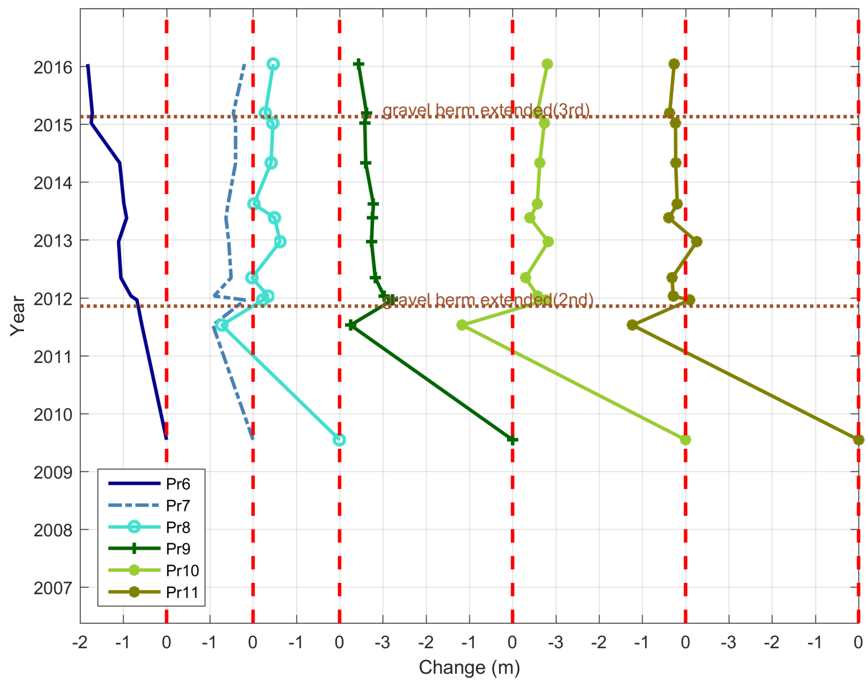

Figure 2.5: Transects 6 to 11 span the region where the expanded dynamic revetment/gravel beach (DRP 2011) was constructed. The zero line reflects the initial survey prior to construction of the gravel beach.

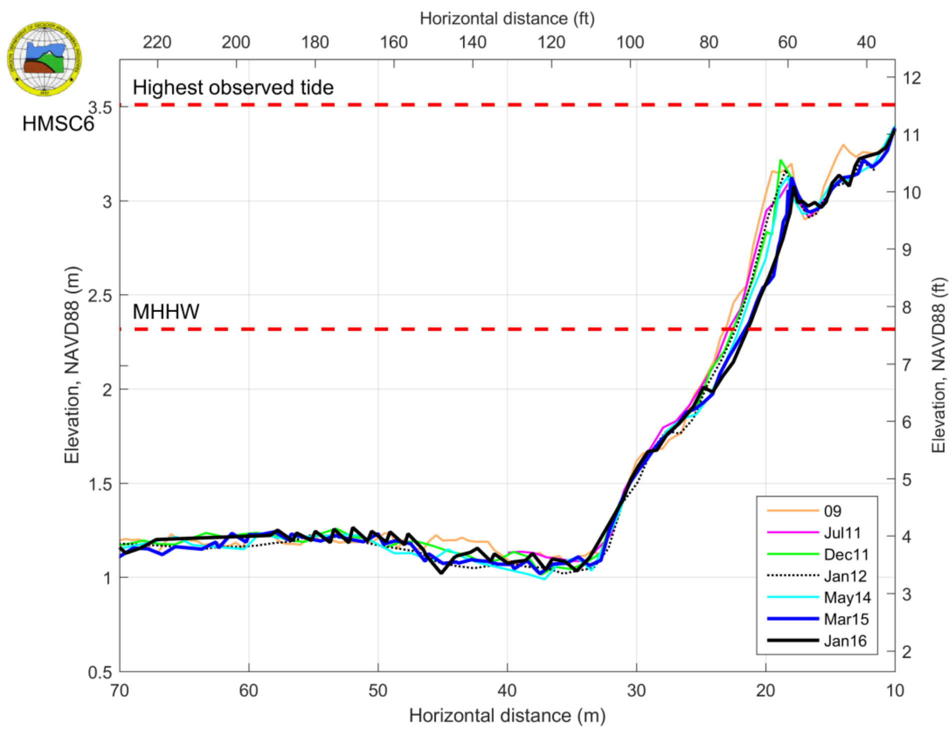

Figure 2.6: Measured profile changes at the Transect 6 profile site, showing evidence of erosion along the upper gravel beach face.

Figure 2.7: Erosion of the upper gravel beach and backshore occurring near the Transect 6 profile site [Photo by J.C. Allan, January 11th 2016].

Figure 2.8 depicts the measured changes taking place in the Reference (DRP 2015) area south of the phase 2 project area in January 2015; this latter area was also converted to a gravel beach in order to stem erosion taking place there. As can be seen from the various plots, the phase 3 area (Reference (DRP 2015)) experienced significant erosion between 2009 and 2015, with some areas having eroded by 9.6 to 11 m (respectively HMSC 13 and 12), decreasing to -3.4 m at Transect 14 and -5 m at Transect 15. In each of these cases, the rate of erosion was virtually unchanged between the period prior to and post gravel beach construction to its immediate south (phase 2, in Figure 2.2), which indicates that the erosion is independent of the recently constructed gravel beach. These changes reflected a complete landward translation of the entire beach profile (Figure 2.9), and based on assessments at the time, it was expected that the erosion would continue to occur in the south if left unchecked. Figure 2.10 provides a photo of the erosion of the Reference area, while the solid black line depicted in Figure 2.2 captures the spatial extent of the erosion along the length of the Reference area (and beyond) as at January 9th 2015. It is important to note that the erosion that took place adjacent to the south end of the phase 2 gravel beach was entirely a function of antecedent erosion that was taking place along the entire length of this shore, and was not related to any end effects associated with the phase 2 gravel beach. Accordingly, in the absence of the installation of a new gravel beach the shoreline would almost certainly have removed the estuary trail located between Transects 7 to 11. A view of the expanded gravel beach established in the Reference area in 2015 is given in Figure 2.11.

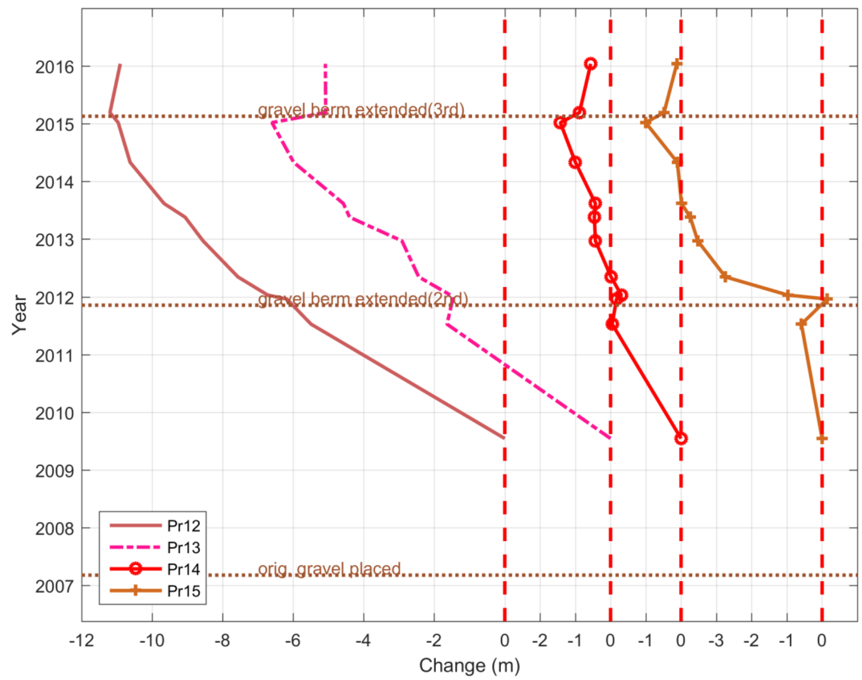

Figure 2.8: Transects 12 to 15 span the unprotected (Reference (DRP 2015)) region. The zero line reflects the initial survey prior to construction of the expanded gravel beach.

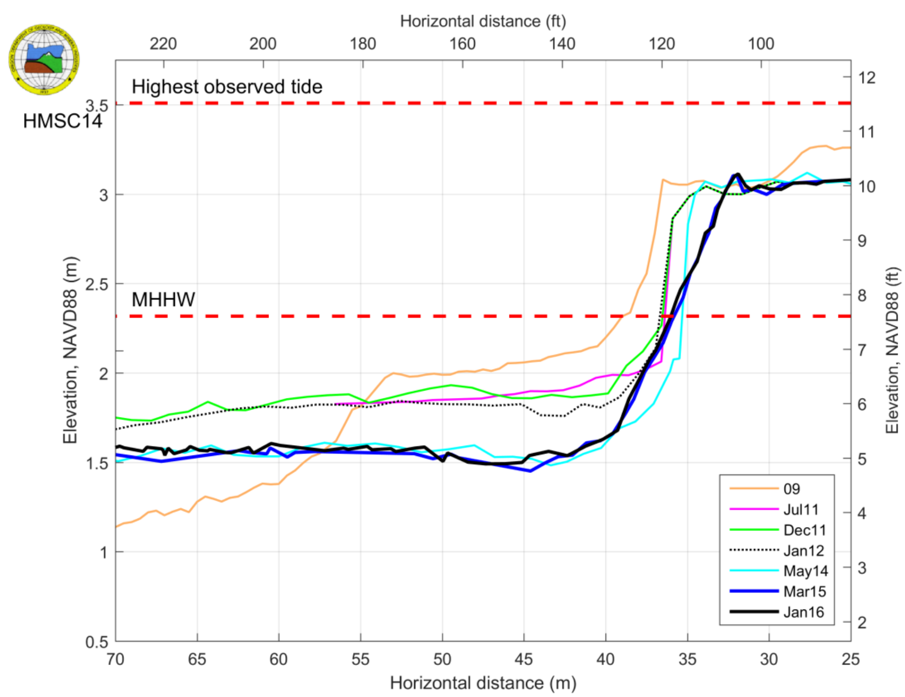

Figure 2.9: Measured profile changes at the Transect 14 profile site, showing the landward translation of the entire beach profile between 2009 and January 2015, when the beach was renourished with gravel.

Figure 2.10: Erosion taking place in the phase 3 (Reference (DRP 2015)) construction area, prior to the area having been renourished with gravel *[Photo by J.C. Allan, January 9th 2015]*.

Figure 2.11: Expanded dynamic revetment **(**Reference (DRP 2015)**)** *[Photo by J.C. Allan, January 11th 2016]*.

2.3 References

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3.0 Biological Parameters

3.1 Density of Benthic Invertebrates

3.1.1 Benthic Invertebrate Sampling Methods

A major change occurred during the final year of benthic invertebrate sampling, due to the replacement of the "Reference" beach by the gravel beach produced by the 2015 DRP. Additional intertidal sand beach with similar wave exposure to the "Reference" beach was not available. Therefore the decision was made to continue to sample the same spatial area as in previous reports. However, whereas the "Reference" beach in the past had consisted of severely eroded shoreline with vertical scarps of one meter to a sand beach, the 2015 DRP produced a gradually slopping gravel beach. Organic material accumulated along the high tide line of the new gravel beach in a much more homogeneous fashion than occurred in the "Reference" area previously. To make comparison of the 2015 collections to previous years possible, the designation of "Reference" has been changed in this report from "REF" to "REF (2015 DRP)".

Mixed algae and seagrass samples were collected on October 16, 2015 from the wrack line deposited by the previous high tide at five random locations from the Reference (2015 DRP) beach, the DRP beach (2011 DRP), and from the wrack line in the 2007 DRP area, termed DRP Reference. Figure 3.1 shows the typical algal wrack line along the DRP area. Samples of wrack were obtained by using scissors to cut segments of the wrack line which were rapidly placed in labeled plastic bags. Samples were placed in a walk in freezer until they could be thawed and sorted. The wrack samples consisted mostly of green macroalgae and the seagrass, *Zostera marina*. Wrack samples were processed by a combination of rinsing, sieving and picking through the wrack material under a dissecting microscope. 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 and counted. Densities for wrack associated organisms in higher taxonomic groupings are expressed per unit dry wrack biomass.

3.1.2 Invertebrate Results

Invertebrates associated with beach wrack were found within all three of the DRP project areas. Composition of wrack invertebrates was generally similar among the three areas. Invertebrate abundance was dominated (63%) by talitrid amphipod crustaceans (beach hoppers), and by insects (33%) (Table 3.1). A small number of isopod crustaceans, nematodes, arachnids, and oligochaetes were also found. Expressed as the number of individuals per g of plant dry-wt, there was a significant difference in density of wrack invertebrates among the three areas (One-way ANOVA, $p<0.002$). In contrast to previous years, pairwise multiple comparisons showed that the Reference (DRP 2015) area had significantly higher abundance per unit dry wt versus both the DRP (2011) and DRP Reference (2007) samples. There was no significant difference among areas in total invertebrates or insects. For talitrid amphipods, the normality test failed, and Kruskal-Wallis One Way ANOVA on Ranks was carried out instead. The Reference (DRP 2015) area had significantly higher abundance of talitrid amphipods versus both the DRP (2011) and DRP Reference (2007) samples.

Comparison of the number of wrack organisms per g of plant dry-wt over the five years of the sampling program is given in Figure 3.2. There has been considerable spatial and temporal variability in this parameter. The most striking difference was the high number of organisms within the wrack material within the DRP (2011) project area in the year following the project (2012). This difference was not seen in 2013-2015. Although there have been statistical differences among sites from year to year, there has been no consistent pattern of elevated or depressed numbers associated with any particular area. Taxonomic composition of the wrack fauna has been generally similar both from year to year, and among sampling areas (e.g. Table 3.1)

Figure 3.1. View of the DRP shoreline (October 15, 2015) showing the algal wrack line on the upper shore. [Photo by W.G. Nelson].

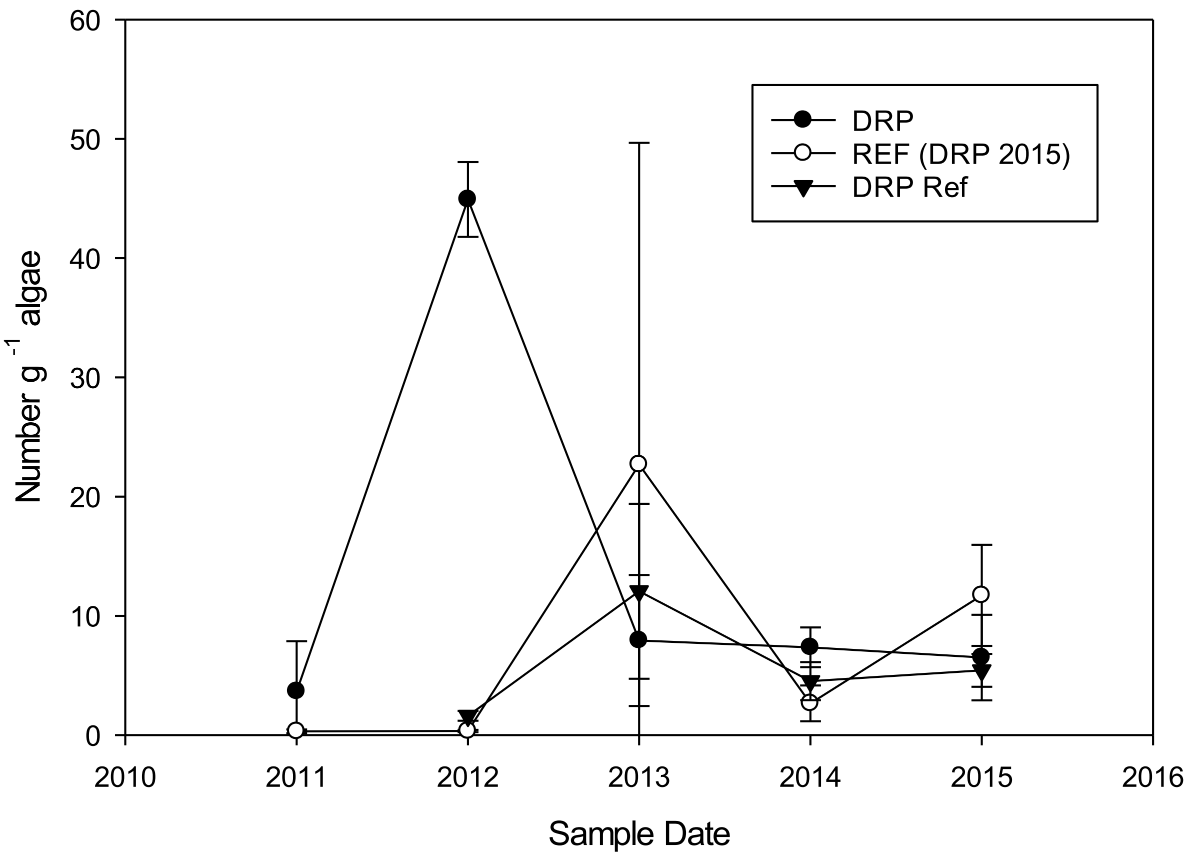


Figure 3.2. Comparison of the mean (±1 s d) number of wrack organisms per g of plant dry-wt over the five years of the sampling program. The DRP Ref (2007) area was added as a sampling area in 2012.

Table 3.1. Abundances (counts) of invertebrates collected in association with plant wrack deposited within the study area. DRP – 2011 project area, REF (DRP 2015) – Reference area converted to DRP 2015, DRP REF (2007) project area.

Sample	Amphipoda Talitridae	Isopoda	Oligo-chaeta	Nematoda	Insecta	Arach-nida	Total	algae dry wt (g)	#/g algae dry wt
DRP 1	13			1	63		77	7.9	9.8
DRP 2	14			3	12		29	9.1	3.2
DRP 3	25				66		91	8.3	11.0
DRP 4	21				11		32	7.0	4.6
DRP 5	16				7		23	5.8	4.0
Subtotal	**89**	**0**	**0**	**4**	**159**	**0**	**252**		
REF 1 (DRP 2015)	74				9		83	8.2	10.2
REF 2 (DRP 2015)	65	1		1	2		69	4.5	15.4
REF 3 (DRP 2015)	56			1	24		81	5.3	15.1
REF 4 (DRP 2015)	62				7		69	5.4	12.7
REF 5 (DRP 2015)	25	1		1	1		28	5.4	5.1
Subtotal	**282**	**2**	**0**	**3**	**43**	**0**	**330**		
DRP REF 1	19		1		5	1	26	5.1	5.1
DRP REF 2	20		10		10		40	7.2	5.5
DRP REF 3	24		6	1	13		44	6.7	6.6
DRP REF 4	26				4		30	4.5	6.6
DRP REF 5	25		1		17		43	13.2	3.3
Subtotal	**114**	**0**	**18**	**1**	**49**	**1**	**183**		

3.2 Fish

3.2.1 Fish Sampling Methods

On 7 occasions from January through November of 2015, intertidal fish were captured with a 50-ft (15.3 m) shore seine towed perpendicularly to the shore for a distance of 50-ft (15.3 m) at three permanent sites along the DRP shoreline and three permanent sites along the Reference shoreline, which is now the 2015 revetment extension, hereafter termed "DRP 2015" (Figure 3.3). This sampling was performed at spring high tide in order to sample as much of the high intertidal habitat as possible. Some months were not sampled due to the construction activities of the 2015 DRP, low volunteer availability, or poor weather conditions. All fish captured in the seine were held for no more than 15 minutes in a container of ambient bay water while they were measured and identified to the lowest possible taxonomic level before being released at the point of capture.

3.2.2 Fish Results

During seven months of sampling, a total of 8 species and 1248 individuals were captured (Table 3.2, Figure 3.3). Five species were represented by less than 10 individuals in the total collection (Table 3.2). This is comparable to the first full sampling year of the program. During the 2015 sampling year, 151 individuals representing 5 species were captured along the original DRP shoreline (sites 1-3) and 1097 individuals representing 5 species were collected from the DRP 2015 area, formerly the reference shoreline (sites 4-6) (Figure 3.4). Approximately 88% of the total number of individuals captured in 2015 was collected from the DRP 2015 shoreline sites, a figure comparable to that from 2014 (85%). That proportion was driven primarily by large catches of pacific staghorn sculpin and whitebait smelt in June and Novembe,r respectively (Figure 3.3). Whitebait smelt, pacific staghorn sculpin, and shiner perch remain the most abundant fishes captured (Table 3.2). One chum salmon was captured on the DRP shoreline during June, the only salmon captured during 2015 sampling. Statistical comparisons indicated that there was that there was a significant ($p<0.001$) interaction term of shoreline area with sampling date (Two-way ANOVA), and both main factors were also significantly different in mean abundance. Interpretation of the interaction term in this case is not entirely clear, in that abundance was higher in each month in the DRP 2015 area. The ANOVA showed that mean monthly catch was significantly greater in the DRP 2015 (reference) shoreline area than the catch in the DRP shoreline area ($p<0.001$).

Table 3.2. A list of the total number of individuals of each species captured in 2015, during seven months of sampling both the original DRP shoreline sites and the DRP 2015 shoreline sites.

Species	Common Name	Total
Leptocottus armatus	Pacific Staghorn Sculpin	717
Allosmerus elongatus	Whitebait Smelt	474
Cymatogaster aggregata	Shiner Perch	50
Gasterosteus aculeatu	Three-Spine Stickleback	1
Oncorhynchus keta	Chum Salmon	1
Oligocottus maculosus	Tidepool Sculpin	1
Engraulis mordax	Pacific Anchovy	1
Ophiodon elongatus	Lingcod	1
Unidentified Larval Fish		2
Grand Total		1248

3.2.3 Discussion

The overall catches on and near the DRP shorelines were lower this year compared to 2014, but the total catch was similar to 2012, the first full year of data collection for this program. The number of months sampled in 2015 is closer to 2012 than 2014, and this lower effort may have caused a lower total catch in 2015 (Figure 3.5). The DRP 2015 installation in February 2015 may have constituted a pulse disturbance event, but the catches in this area in June, July and November 2015 would indicate a relatively rapid recovery following gravel beach installation.

The results from the third year of post installation fish sampling were consistent with past results, in that more intertidal fish were captured along the Reference shoreline than the DRP shoreline (Figure 3.4). The difference between sites the DRP (sites 1-3) and DRP 2015 (sites 4-6) was primarily driven by large concentrations of pacific staghorn sculpin in June and whitebait smelt in November. More intertidal fish were caught within the DRP 2015 shoreline area (sites 4-6) this year than within the original DRP (sites 1-3). Seining directly onto the gravel beach in the DRP 2015 area was not possible due to root wad placement, and therefore was conducted on the sandy flats immediately adjacent to the gravel beach in this area. The higher efficiency of the seine on the sandy substrate may have contributed to the higher catches at sites 4-6, as noted in past reports. However, the higher abundances in sites 4-6 after the DRP 2015 could also indicate that fish generally prefer these sites more than sites 1-3 for a reason unrelated to the presence of a revetment, as this is the same pattern we have seen in each year of the program (Figure 3.6).

Throughout the study, there have been large month to month differences in fish abundance collected (Figure 3.7, 3.8), as well as interannual differences, e.g. 2014 in the Reference (DRP 2015) area. Higher abundance in the Reference (DRP 2015) area was a consistent pattern over the study period (Figure 3.6), due to factors described above and in previous reports.

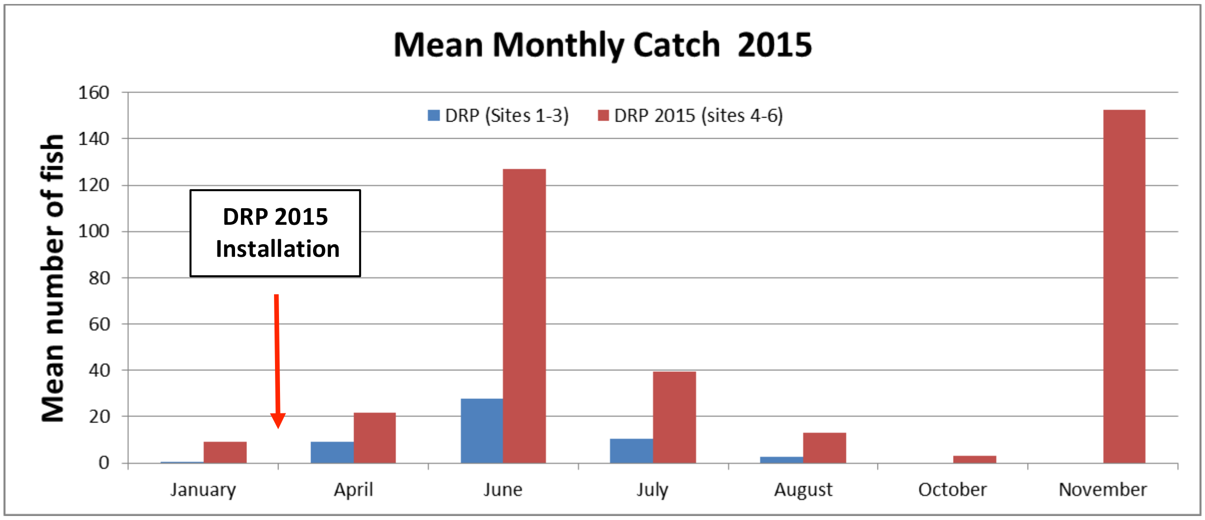


Figure 3.3: Total number of individuals captured in both the DRP shoreline sites and the DRP 2015 shoreline sites during 2015.

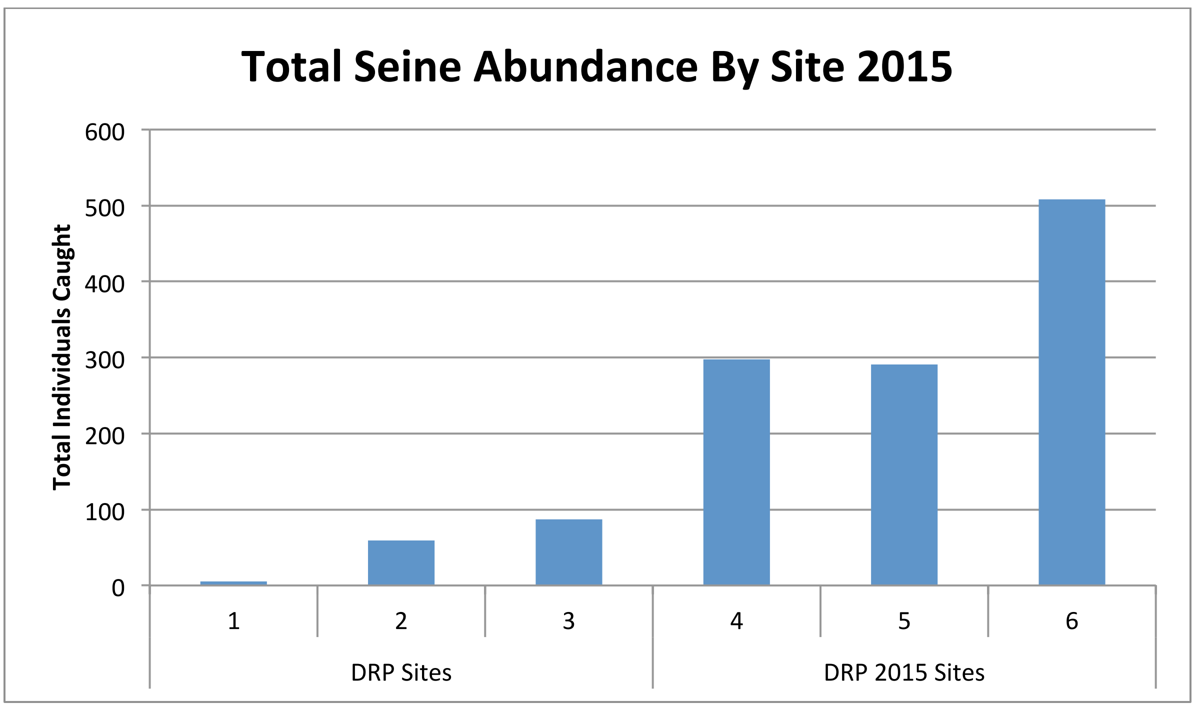


Figure 3.4: Total number of individuals caught at each sampling site in 2015. Sites 1-3 are within the DRP shoreline, sites 4-6 are in the DRP 2015 (Reference) shoreline.

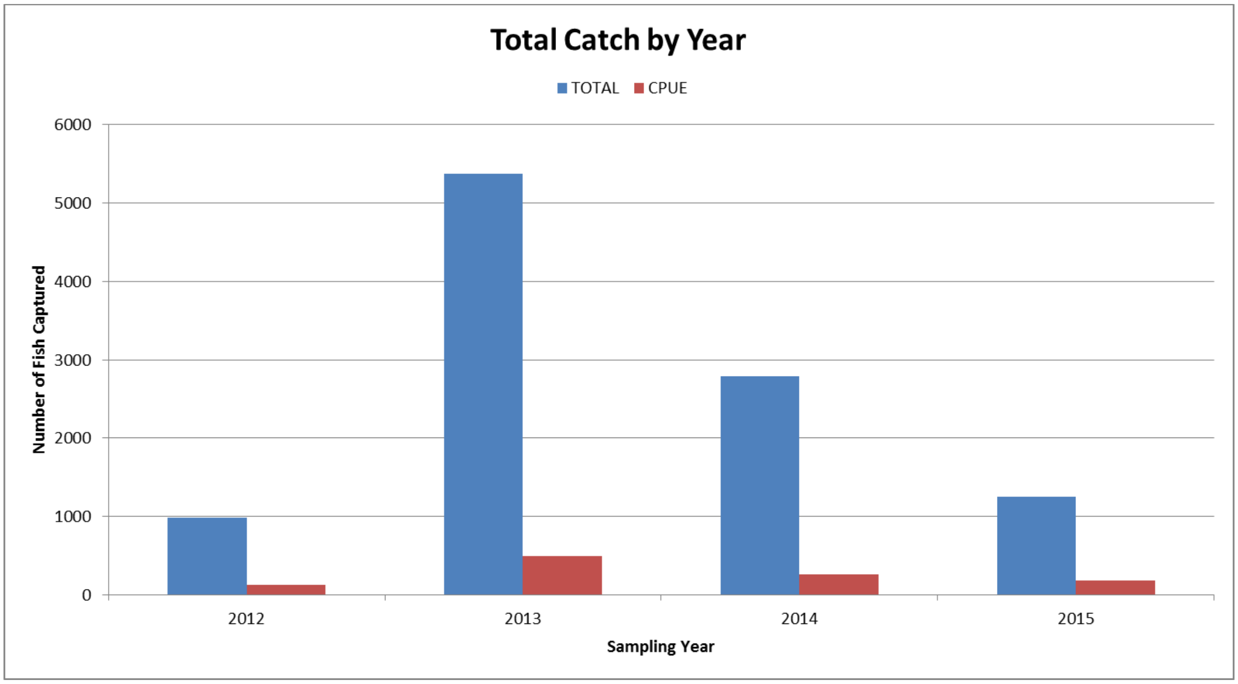


Figure 3.5: Total number of individuals caught for each sampling year 2012-2015 shown as total catch and catch per unit effort (defined as the number of months sampled).

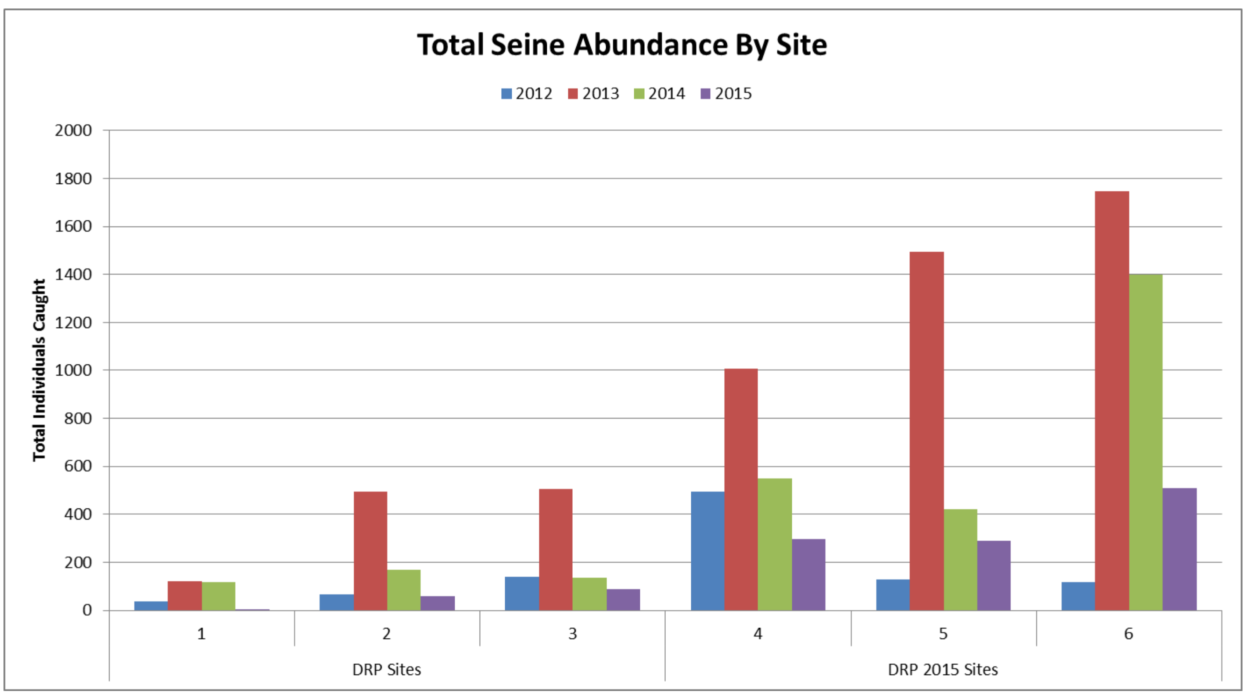


Figure 3.6: Total number of individuals caught at each sampling site from 2012-2015. Sites 1-3 are within the DRP shoreline, sites 4-6 are in the DRP 2015 (Reference) shoreline.

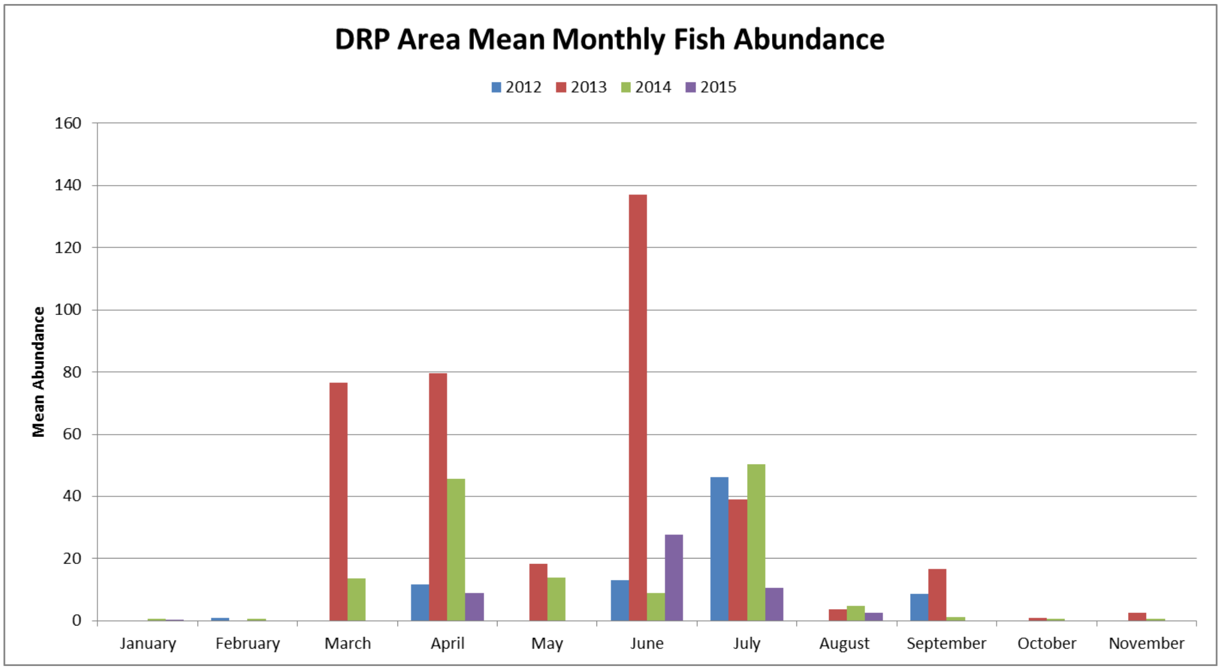


Figure 3.7: Mean number of individuals caught monthly at the DRP area sampling site from 2012-2015. Note that some months were not sampled in some years.

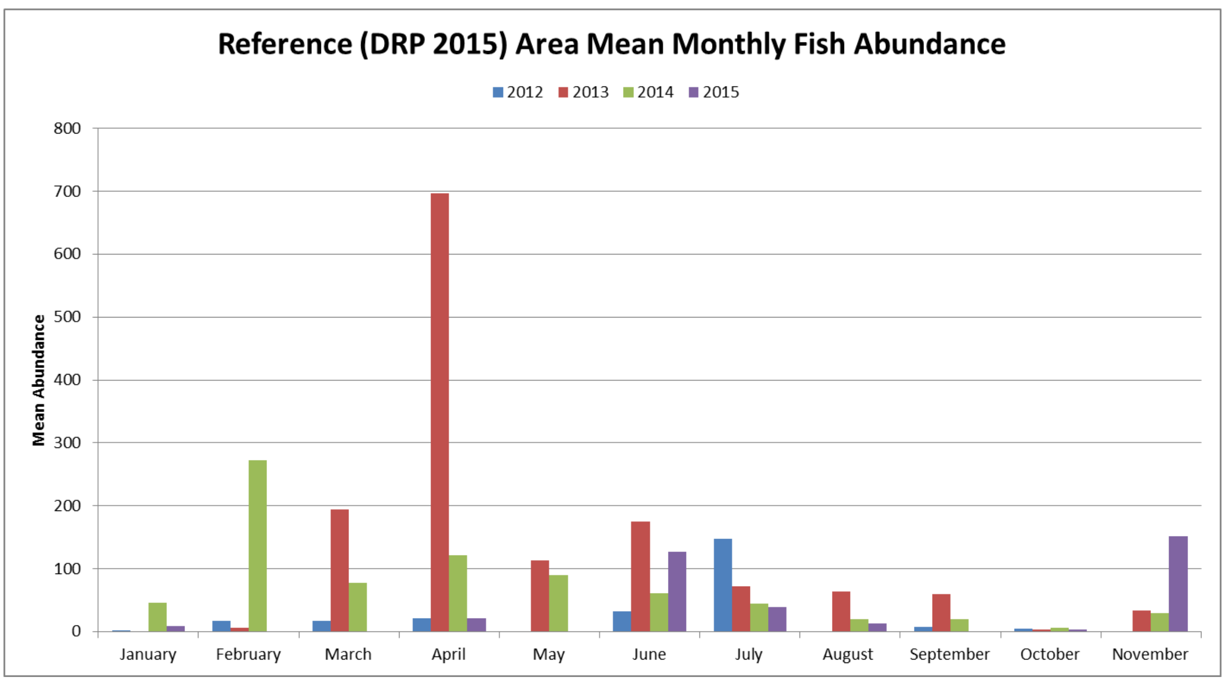


Figure 3.8: Mean number of individuals caught monthly at the Reference (DRP 2015) area sampling site from 2012-2015. Note y axis scale differs from Figure 3.4 and some months were not sampled in some years.

3.3 Vegetation

3.3.1 Vegetation Methods

To assess possible changes in shoreline vegetation following DRP installation, sampling was initially focused on the approximately 1 to 10 m wide strip of land between the paved HMSC estuary trail and the shoreline. This area contains mixed vegetation community types including high marsh, dune and terrestrial plants and shrubs. Six 1-m^2 quadrats were established within the DRP and Reference areas in October 2011 (Figure 3.9) and a labeled PVC stake was placed to mark the quadrat center. A Trimble R8 Global Navigation Satellite System (GNSS) unit was used to establish horizontal and vertical positions of the center of each plot by performing a Real Time Kinematic (RTK) survey with the Oregon Real time GNSS Network (ORGN) network. Over the monitoring period to date, sample quadrats Reference 1 through 5 were lost to erosion. New replacement quadrats were established inland of the original plots and designated as quadrats 1A and then 1B (replacement quadrat 1A also eroded away during the next year, so quadrat 1B was established), 2A, 3A, 4A and 5A. Differences in plots due to relocation were discussed in the 2014 Monitoring Report.

Vascular plant presence or absence (usually at the species level) was visually assessed by scanning one 0.25 -m^2 quadrat within each 1-m^2 quadrat (Figure 3.10, 3.11). Plant percent cover was assessed by visually evaluating the percentage that each plant species contributed to the overall plant community present within the 1-m^2 quadrat. Percent cover estimates also considered non-plant substrata such as open or bare ground and detrital material. Photographs of each quadrat were taken from several perspectives.

3.3.2 Vegetation Results

The plant taxa recorded in the 0.25-m^2 quadrats (Table 3.3) were very similar to those recorded in the 1-m^2 quadrats (Table 3.4). Based on the 1 m^2 quadrats, a total of thirty plant taxa were identified in the 12 plots (Table 3.4), 29 vascular plants plus lichen. Ten plant taxa were found in both areas, six taxa were only observed within the DRP area, and 14 were only observed within the Reference area. Within the 0.25-m^2 quadrats, a grass, *Festuca rubra* (red fescue), was the most frequently occurring taxon in the DRP, while the most frequently occurring species in quadrats in the Reference area included *Schedonorus phoenix* (tall fescue), *Spergularia* spp (sea-spurreys, sandspurrys), *Achillea millefolium* (yarrow) and *Juncus breweri* (Brewer's rush*)*.

Estimates of percent coverage of plants gave generally similar results to those obtained from the presence-absence data (Table 3.4). Although there was a higher coverage of living plant material (92% vs. 69%), and conversely a lower percentage of non-living coverage in the Reference area, the difference was not statistically significant (t-test, p=0.06). The grass *F. rubra* had the largest percent coverage in the DRP. *Elymus mollis* (American dunegrass) and *Spergularia* spp. were the next most abundant in terms of percent cover in the DRP. *Carex pansa* (sand dune sedge), *Ammophila arenaria* (European beachgrass), and *Juncus breweri* were the most extensive in the Reference area quadrats. Dominant species were generally similar to the 2014 survey in both DRP and Reference plots.

The lower average vegetation cover at the DRP sites has been a consistent result during the monitoring, and was present in the pre-project samples (Figure 3.12). DRP quadrats 1-3 occur at lower elevation than most other sample locations, and as described in previous reports, there is also a topographic low spot in the shoreline near beach profile 9 (Figure 3.1), which allows the back shore area to be more frequently flooded by fall and winter King tides. This increased flooding has transported gravel from the DRP back into some of the vegetation plots, and there were also heavy deposits of seaweed wrack consisting mostly of the green alga *Ulva* spp.

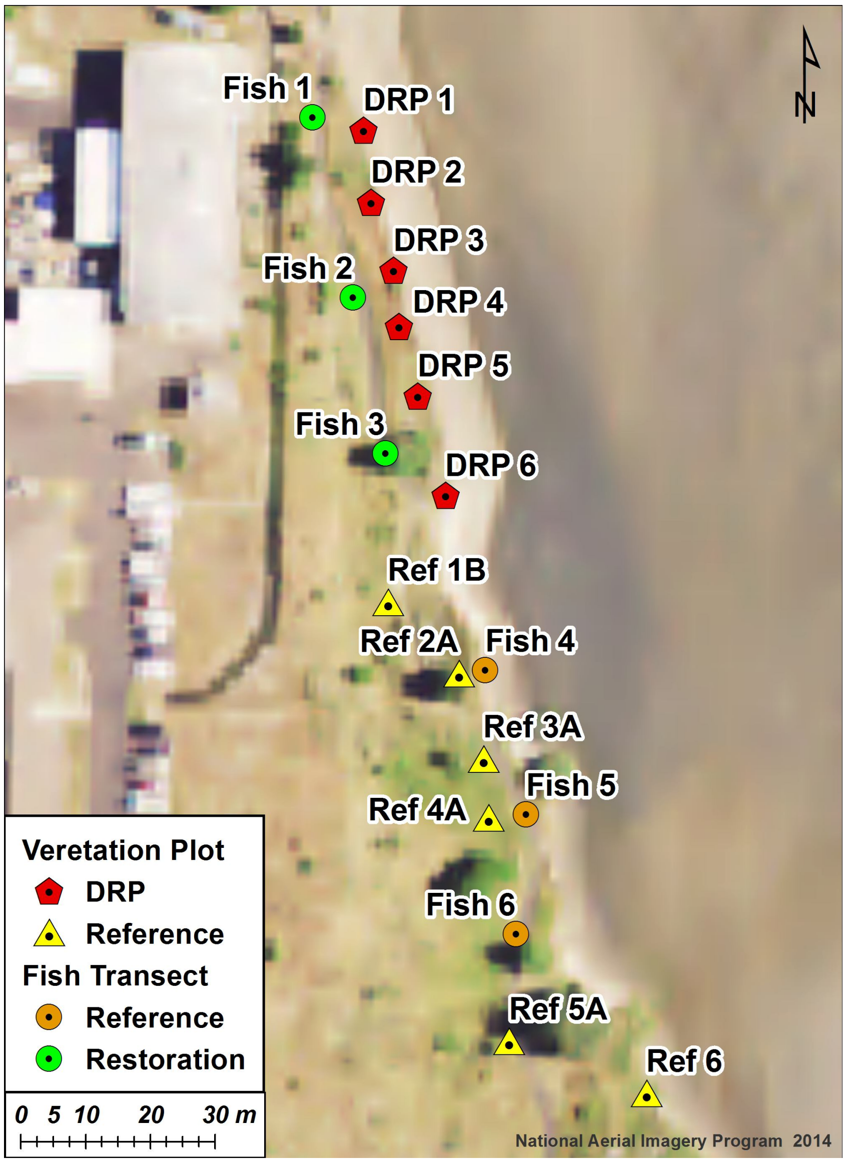


Figure 3.9: Vegetation plots in DRP (red symbols, DRP 1-6) and Reference (yellow symbols, Ref 1-6) survey areas. Locations of fish sampling transects are shown as green (DRP, Fish 1-3) and orange (Reference, Fish 4-6) symbols.

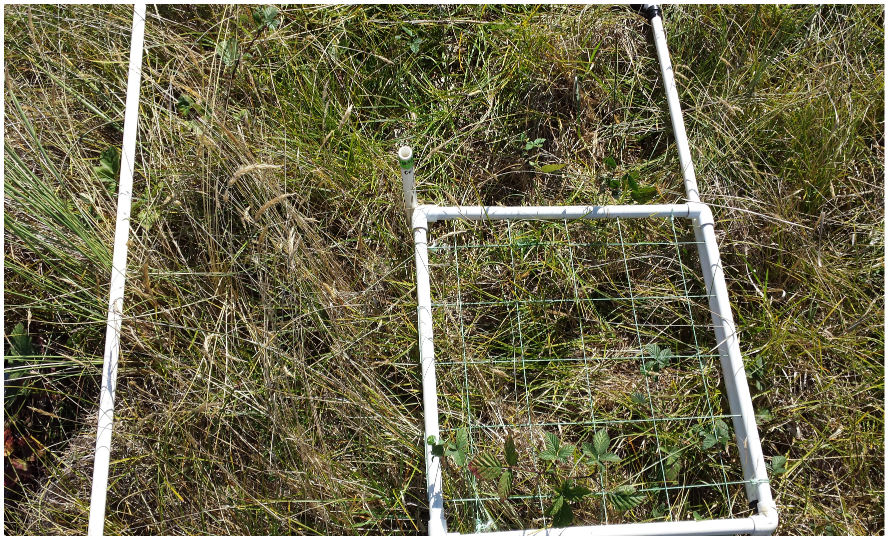


Figure 3.10: Close up of 1-m^2 quadrat used to determine plant presence-absence with the 0.25-m^2 quadrat used to determine percentage cover of vegetation. [Photo by C. Folger]

Figure 3.11: Vegetation monitoring Quadrat DRP 2, October 2015. View to northeast. . [Photo by C. Folger]

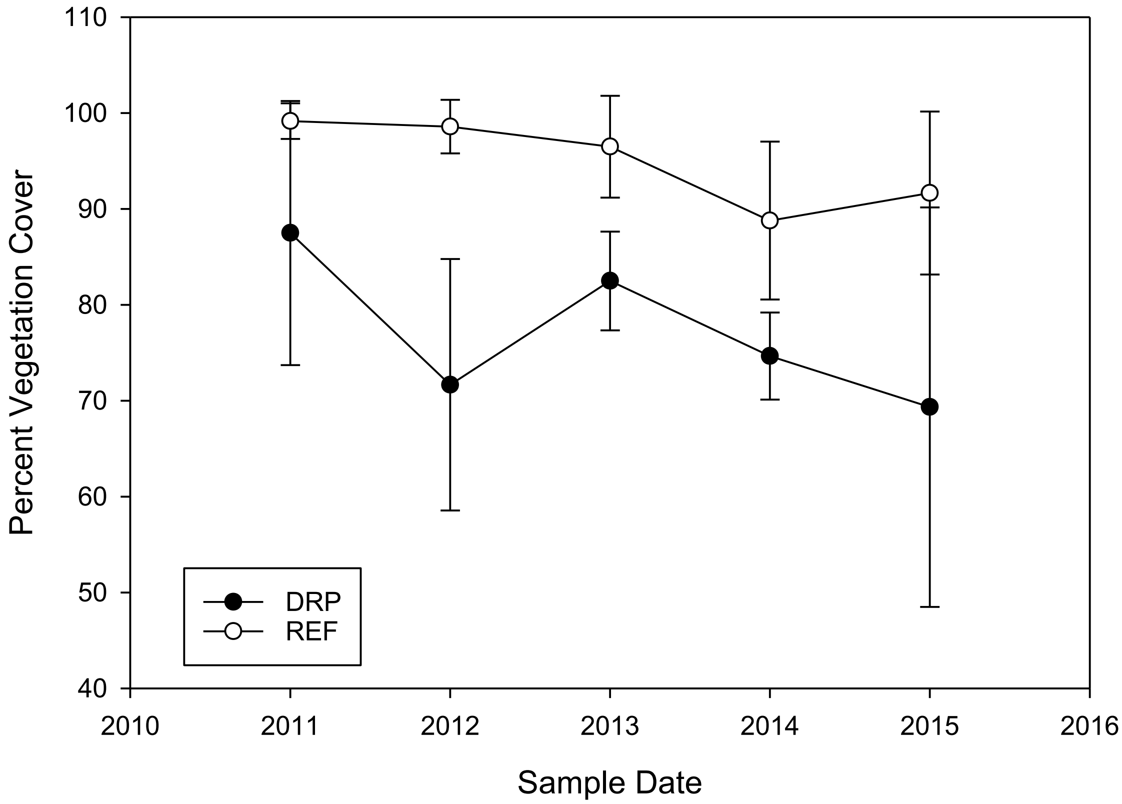
Table 3.3. Frequency of occurrence (presence/absence) of plant taxa in the DRP and Reference areas, n = 6 (0.25-m^2) quadrats for DRP and for Reference.

Plant Taxon	DRP	Reference
Festuca rubra	5	0
Rumex acetocella	3	1
Schedonorus phoenix	2	4
Spergularia spp	2	4
Daucus carota	2	2
Taraxacum sp	2	2
Grindelia stricta	2	1
Elymus mollis	2	0
Achillea millefolium	1	4
Carex pansa	1	2
Angelica lucida	1	1
Digitalis purpurea	1	1
Lichen spp	1	0
Atriplex spp	1	0
Stellaria spp	1	0
Cytisus scoparius	1	0
Juncus breweri	0	4
Vicia nigricans	0	3
Plantago maritima	0	2
Ammophila arenaria	0	2
Deschampsia cespitosa	0	1
Distichlis spicata	0	1
Sarcocornia perennis	0	1
Trifolium spp	0	1
Lupinus sp	0	1
Rubus spp	0	1
Unknown weed	0	1

Table 3.4. Mean percent coverage of plant taxa and non-living material in the DRP and Reference areas, n = 6 (1-m^2) quadrats for DRP and for Reference.

Plant Taxon	DRP	Reference
Festuca rubra	20.7	0.0
Elymus mollis	12.5	0.0
Spergularia spp	10.8	7.0
Schedonorus phoenix	6.0	8.3
Grindelia stricta	5.8	0.8
Rumex acetocella	5.3	1.7
Atriplex spp	2.2	0.0
Carex pansa	1.7	16.3
Taraxacum sp	1.3	2.8
Daucus carota	0.8	1.7
Digitalis purpurea	0.5	0.8
Stellaria spp	0.5	0.0
Cytisus scoparius	0.5	0.0
Lichens	0.3	0.0
Achillea millefolium	0.2	1.7
Angelica lucida	0.2	0.8
Ammophila arenaria	0.0	13.3
Juncus breweri	0.0	13.0
Deschampsia cespitosa	0.0	7.5
Plantago maritima	0.0	4.2
Sarcocornia perennis	0.0	3.3
Vicia nigricans	0.0	2.7
Distichlis spicata	0.0	1.7
Rubus spp	0.0	1.7
Baccharis pilularis	0.0	0.8
Unknown weed	0.0	0.5
Cynosurus sp	0.0	0.3
Anaphalis margaritacea	0.0	0.3
Trifolium spp	0.0	0.2
Lupinus sp	0.0	0.2
Total Non-living		
Dead plant matter	12.8	3.3
Woody debris	6.7	0.0
Gravel from revetment	4.2	0.0
Ulva spp	4.2	0.0
Bare ground/sand	2.8	5.0

Figure 3.12. Comparison of mean (± 1 s d) percent vegetation cover over the period of the DRP monitoring study between the DRP and the Reference vegetation areas.



4.0 Current Status of Erosion in the Study Area

As described in more technical detail in Section 2.2, as of February, 2016, the 2015 DRP project has largely stabilized shoreline erosion within the project area. Both the 2007 and 2011 DRP shoreline sections appear mostly stable. "King" tides occurring from November – February coupled with east wind driven wave action have continued to roll back the shoreline vegetation, and steep vertical scarps at the vegetation edge are the norm along this shore section. Erosion in the unprotected Reference area in the period 2009-2014 has been as great as 11 m (36 ft). The effect of erosion during 2014 can be seen in comparison of Figures 4.1 through 4.4, taken from a similar spot on the HMSC Nature Trail. Erosion in 2014 continued to create vertical banks of collapsed sod, with salt march vegetation collapsing and being eroded away (Compare Figures 4.5 and 4.6). Erosion has begun to accelerate for low salt marsh habitat beyond the southern edge of the currently proposed new project area, which has not been exposed to erosion before (Figure 4.7).

Figure 4.1: View of collapsed section of HMSC nature trail, February 3, 2015. [Photo by W. Nelson]

Figure 4.2: View of dynamic revetment project February 18, 2015 showing gravel grading to cobble at the toe of the beach slope. Six trees with root masses exposed were emplaced along the lower margin of the project. [Photo by W. Nelson]

Figure 4.3: Close up view looking north along the dynamic revetment project February 18, 2015. The terminus of the 2011 dynamic revetment is seen in the upper center of the photo, located opposite the white sign. [Photo by W. Nelson]

Figure 4.4: View looking north along the dynamic revetment project October 15, 2015. Vegetation has recovered along the upper edge of the project, and the beach face has accumulated a tidal wrack line of organic material. [Photo by W. Nelson]

Figure 4.5: View to the north along the dynamic revetment project October 15, 2015. Sand has accumulated in the vicinity of the tree stumps sufficiently to bury the cobble toe of the project in some spots. [Photo by W. Nelson]

Figure 4.6: View at the northern end of the 2015 dynamic revetment project October 28, 2015 during king tides. Water levels surged over the top of the project berm and inundated the HMSC nature trail. [Photo by W. Nelson]

Figure 4.7: View of the 2011 dynamic revetment project on January 21, 2016 during king tides, showing over topping of the project with a drain channel for water returning to the estuary as the tide falls. [Photo by C. Folger]

Figure 4.8. View of the 2015 dynamic revetment project on January 21, 2016 during king tides, showing scouring of gravel at the top of the project associated with a drain channel for water returning to the estuary after over topping of the project. Gravel was moved down the beach and bare earth was exposed. [Photo by C. Folger]

Figure 4.9. Close-up view of the 2015 dynamic revetment project on January 22, 2016 during king tides, showing scouring of gravel at the top of the project associated with a drain channel for water returning to the estuary after over topping of the project. [Photo by W. Nelson]

5.0 Disclaimer and Acknowledgements

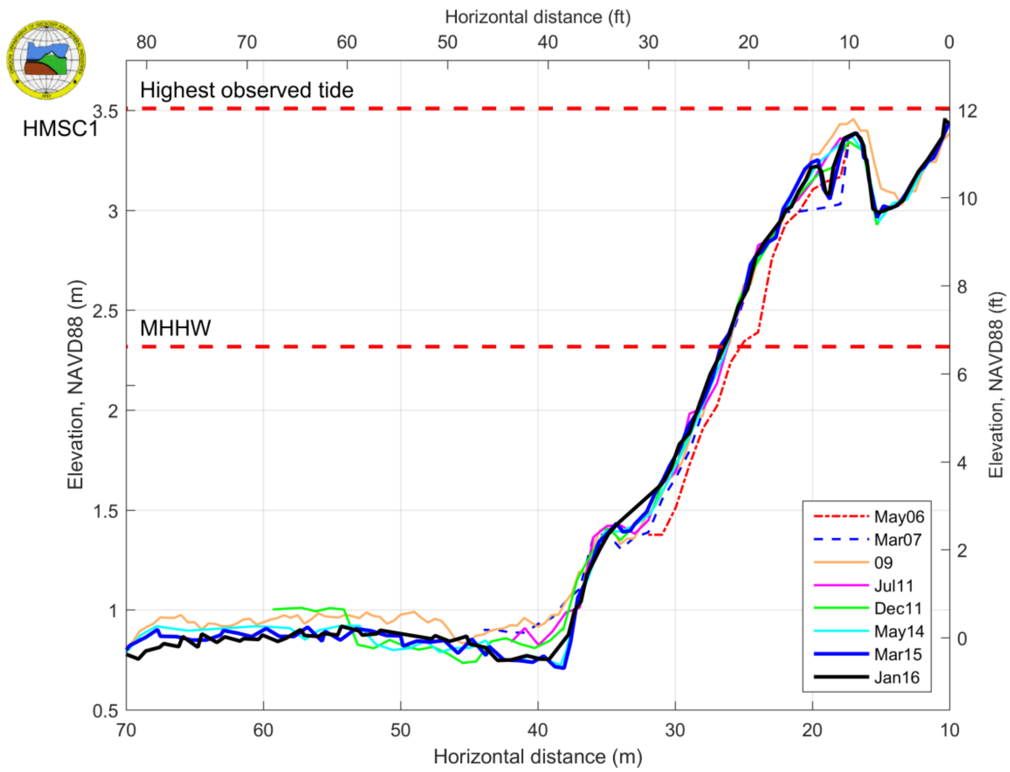
5.1 Disclaimer

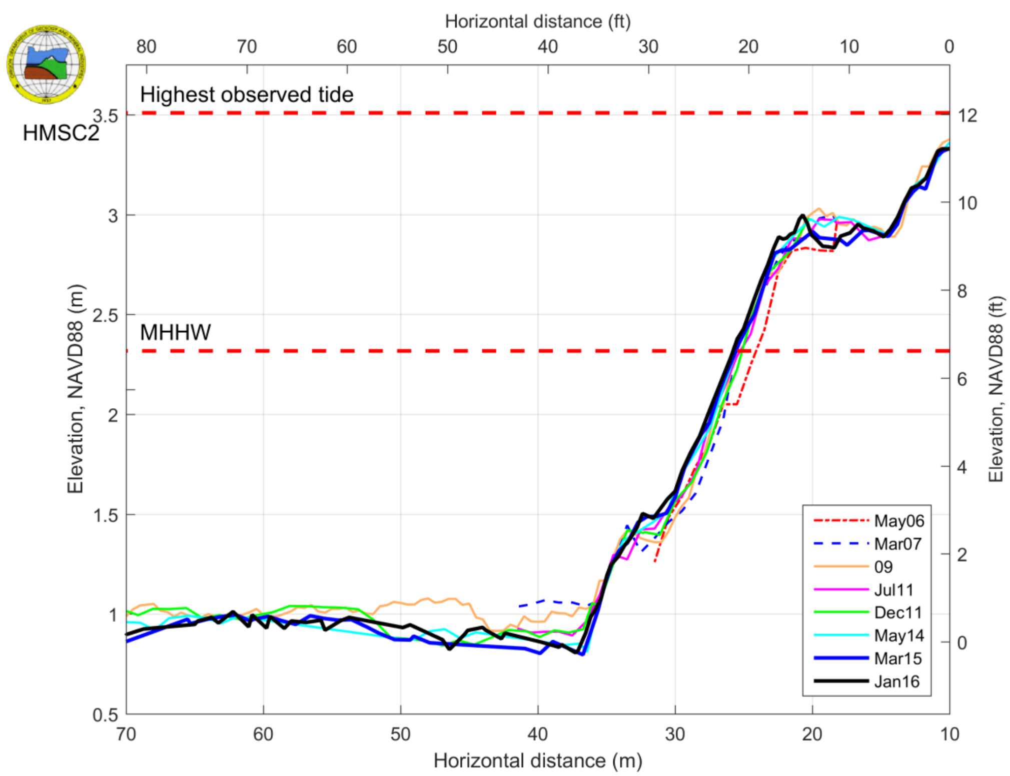
The information in this document contained in sections 3.1 and 3.3 has been subjected to review by the National Health and Environmental Effects Research Laboratory of US EPA and approved for publication. Approval does not signify that the contents reflect the views of the Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

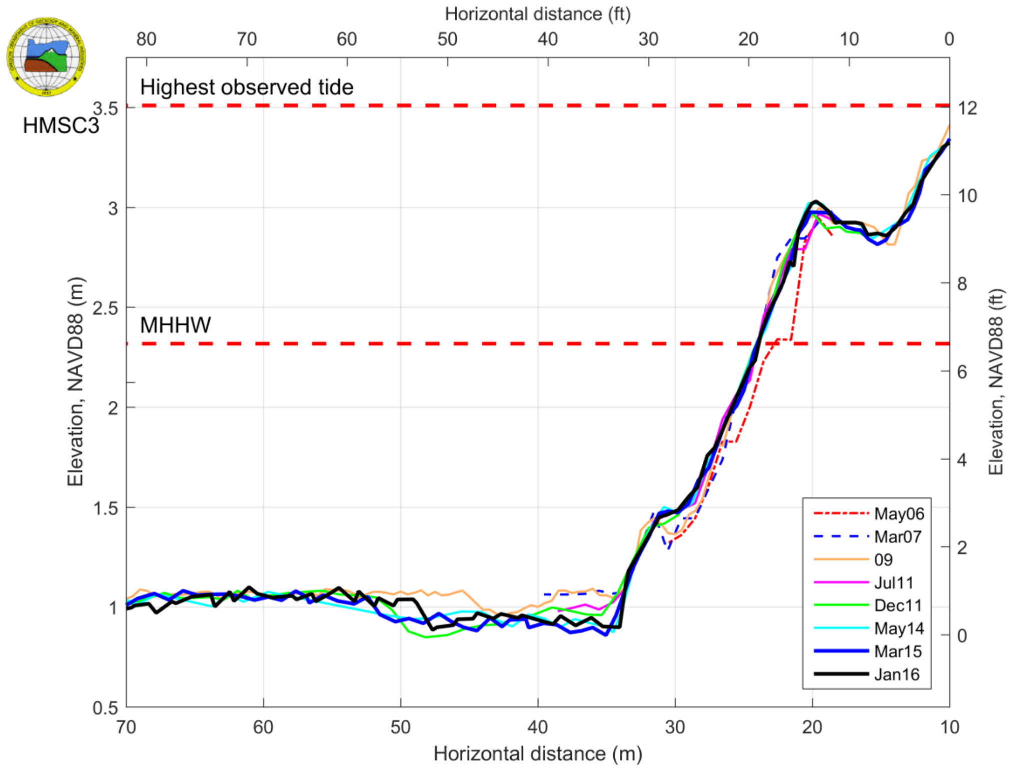
5.2 Acknowledgements

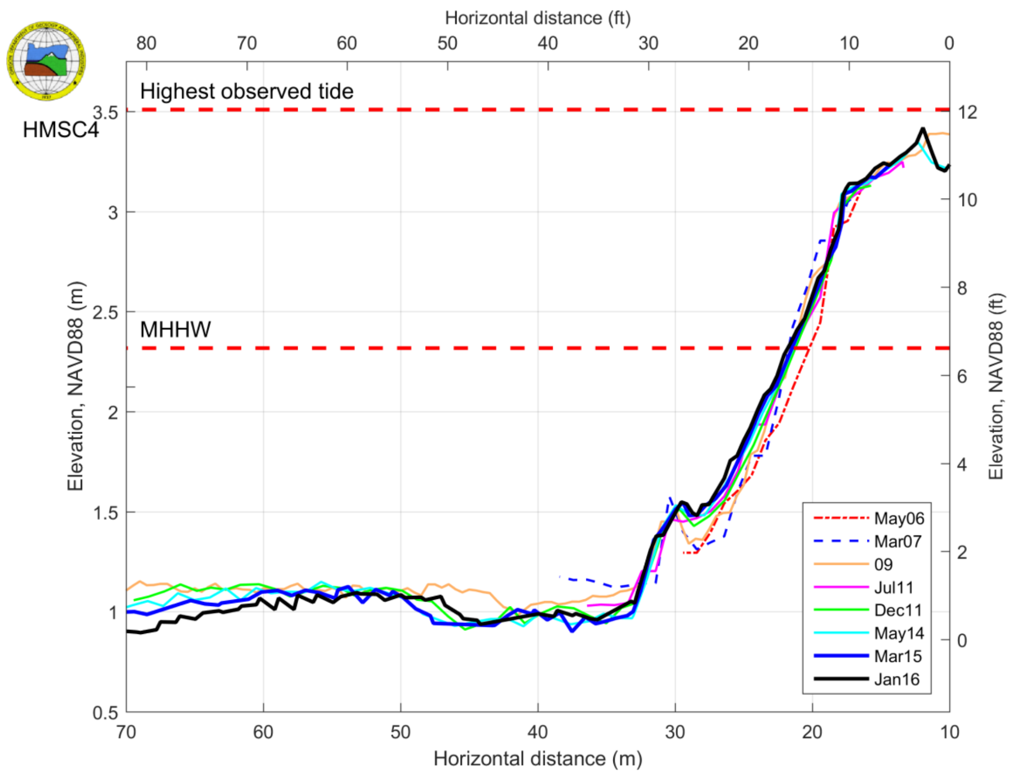
Pat Clinton of US EPA provided GIS assistance in the production of the plot locations given in Figure 3.9. Maryann Bozza of HMSC, Oregon State University provided coordination of the monitoring groups, and provided editing and review of this report. Dr. Lauri Ruiz-Greene provided a technical review of sections 3.1 and 3.3. The Oregon State University Marine Team, a student marine science group, provided volunteers to assist with fish sampling throughout the project. Vince Politano was instrumental in initially setting up the fish sampling program.

Appendix 1: Beach Profile Survey Graphs






HMSC3
Horizontal distance (ft)
Highest observed tide
MHHW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
May06
Mar07
09
Jul11
Dec11
May14
Mar15
Jan16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Horizontal distance (ft)
Highest observed tide
MHHW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
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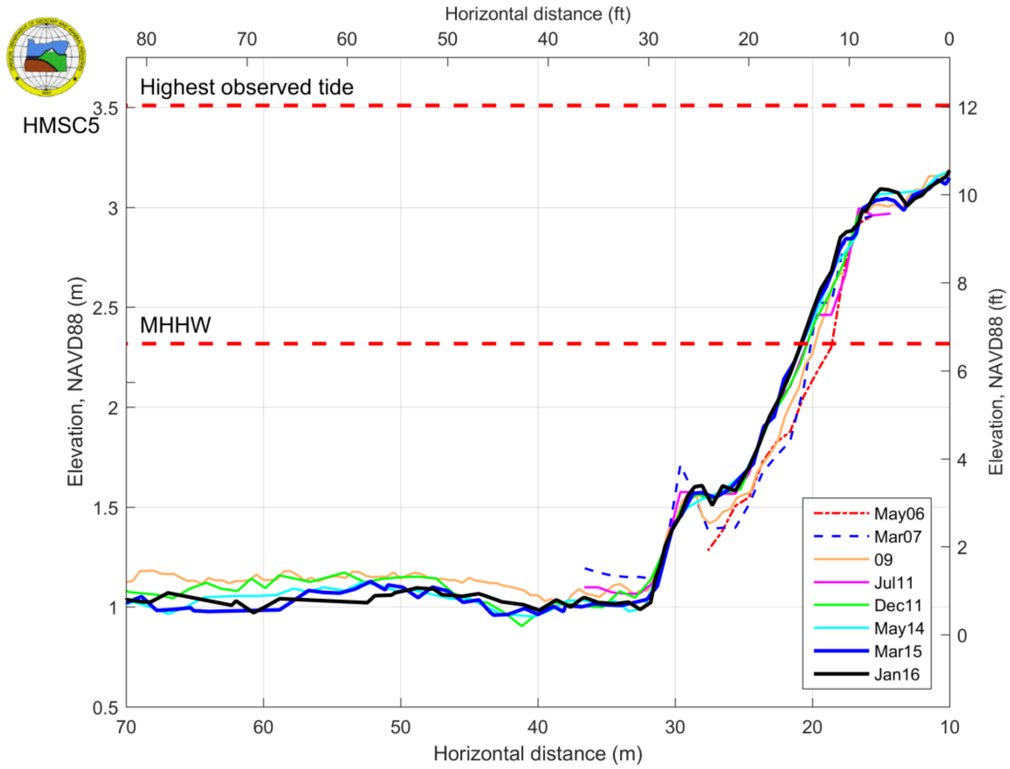
09
Jul11
Dec11
May14
Mar15
Jan16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Horizontal distance (ft)
Highest observed tide
MHHW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
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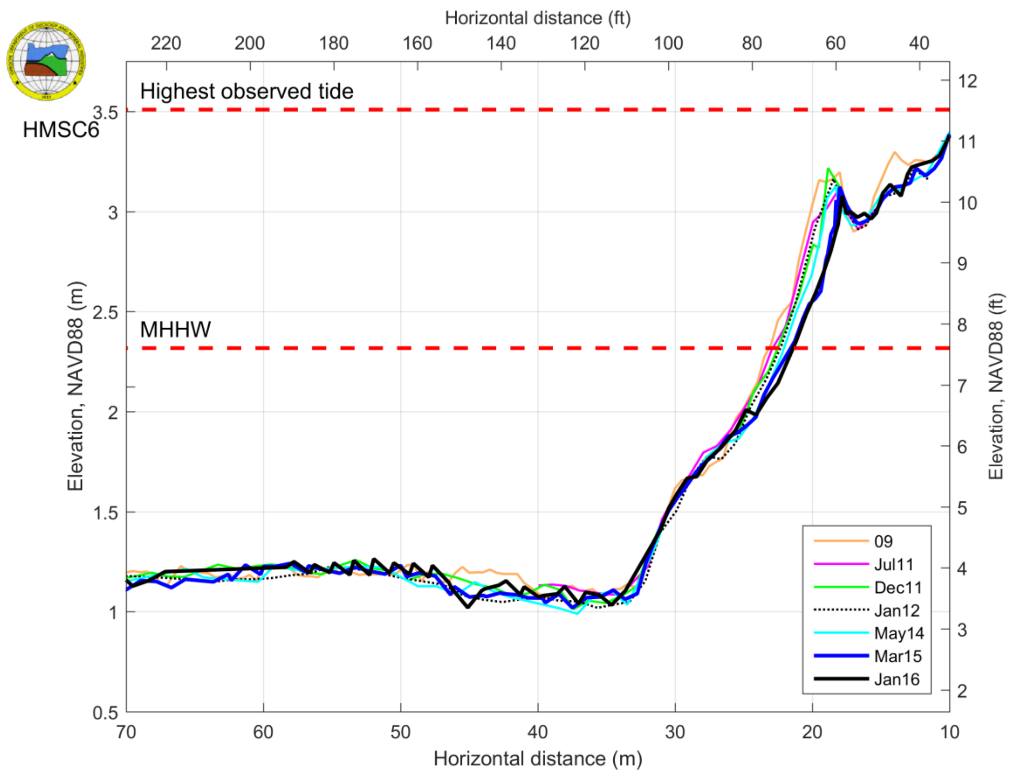
Jul11
Dec11
May14
Mar15
Jan16


HMSC6
Horizontal distance (ft)
Highest observed tide
MHHW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
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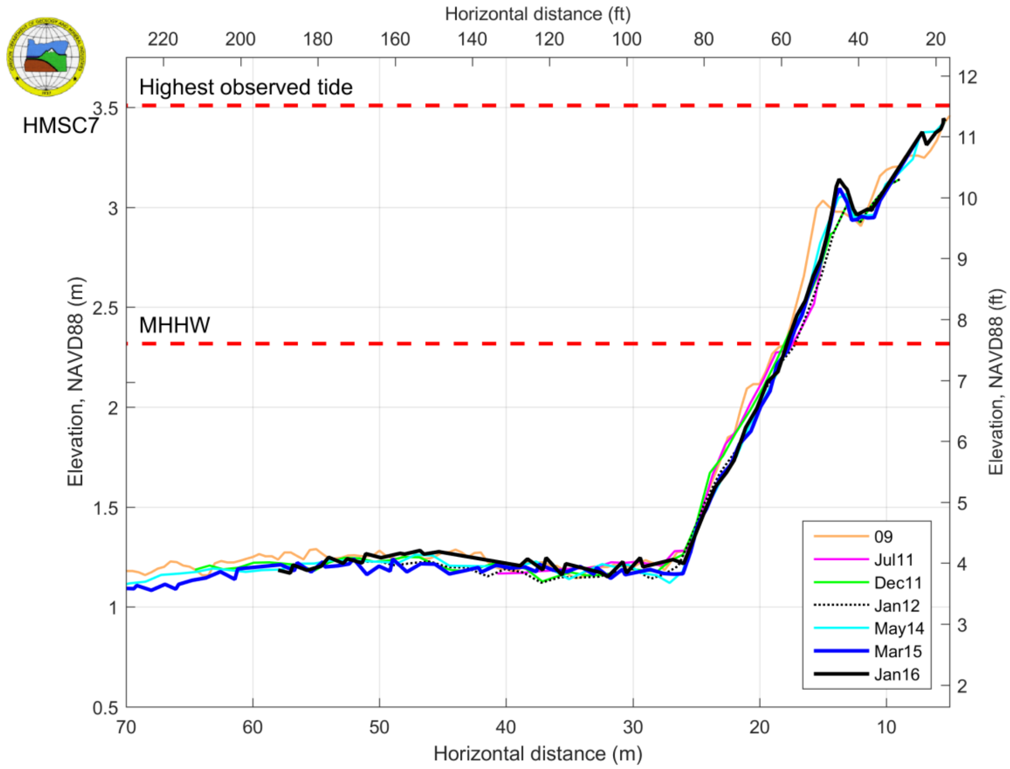
Jul11
Dec11
Jan12
May14
Mar15
Jan16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Horizontal distance (ft)
Highest observed tide
MHHW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
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Jul11
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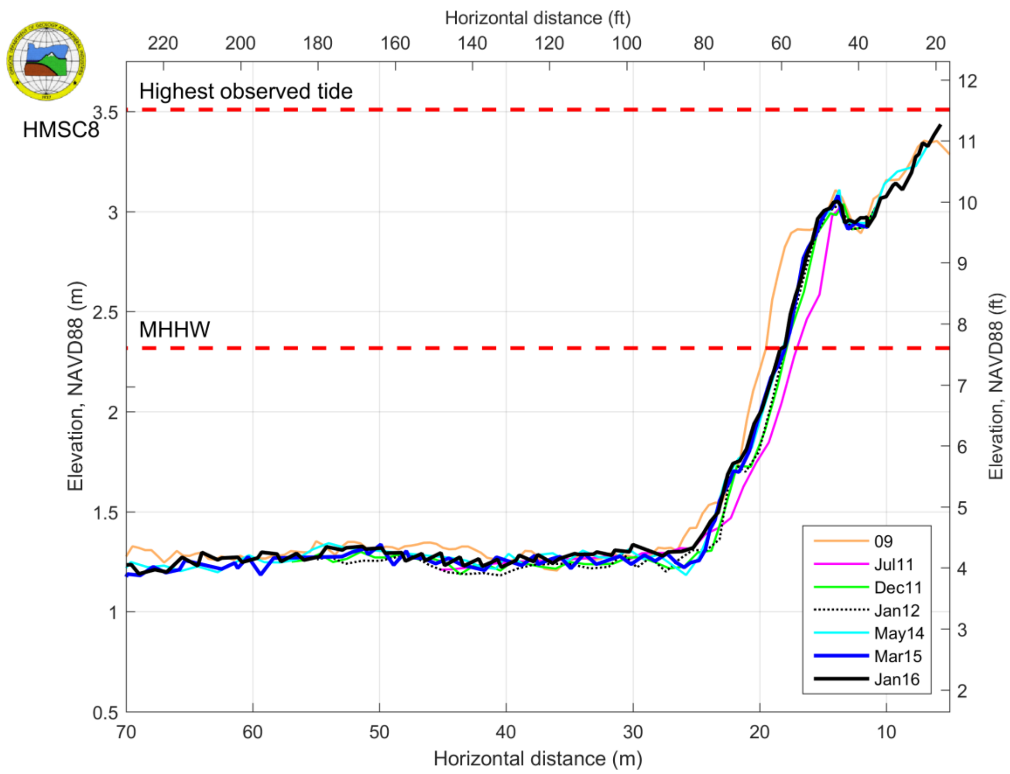
Jan12
May14
Mar15
Jan16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Horizontal distance (ft)
Highest observed tide
MHHW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
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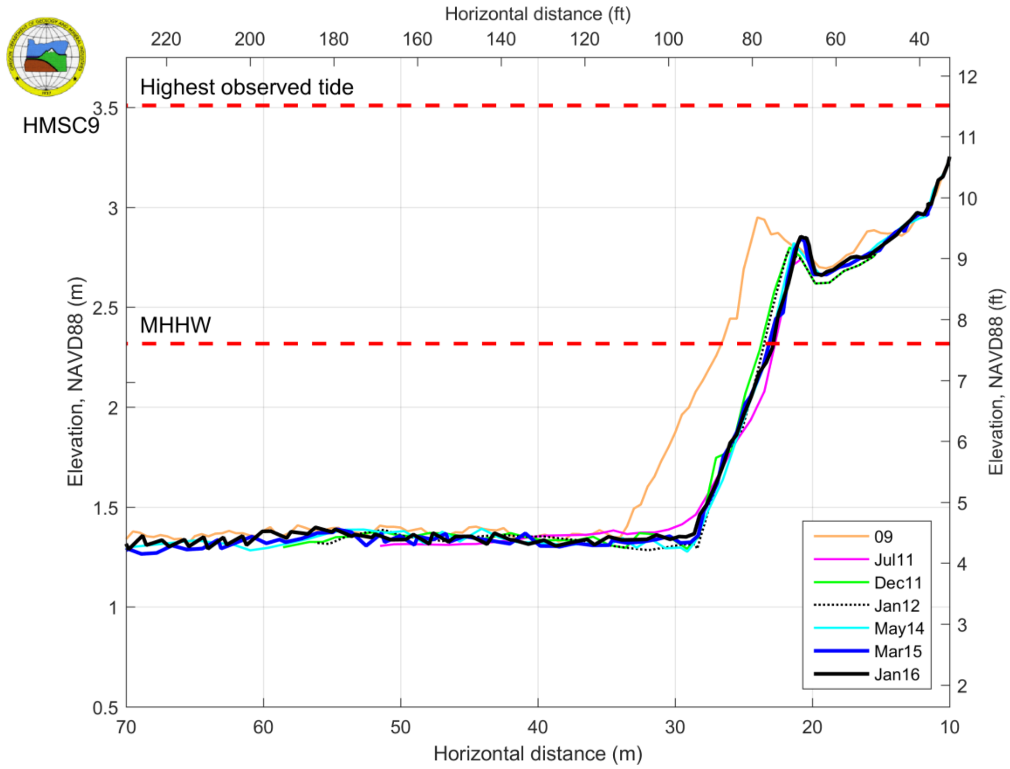
Jan12
May14
Mar15
Jan16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Highest observed tide
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Elevation, NAVD88 (ft)
Horizontal distance (m)
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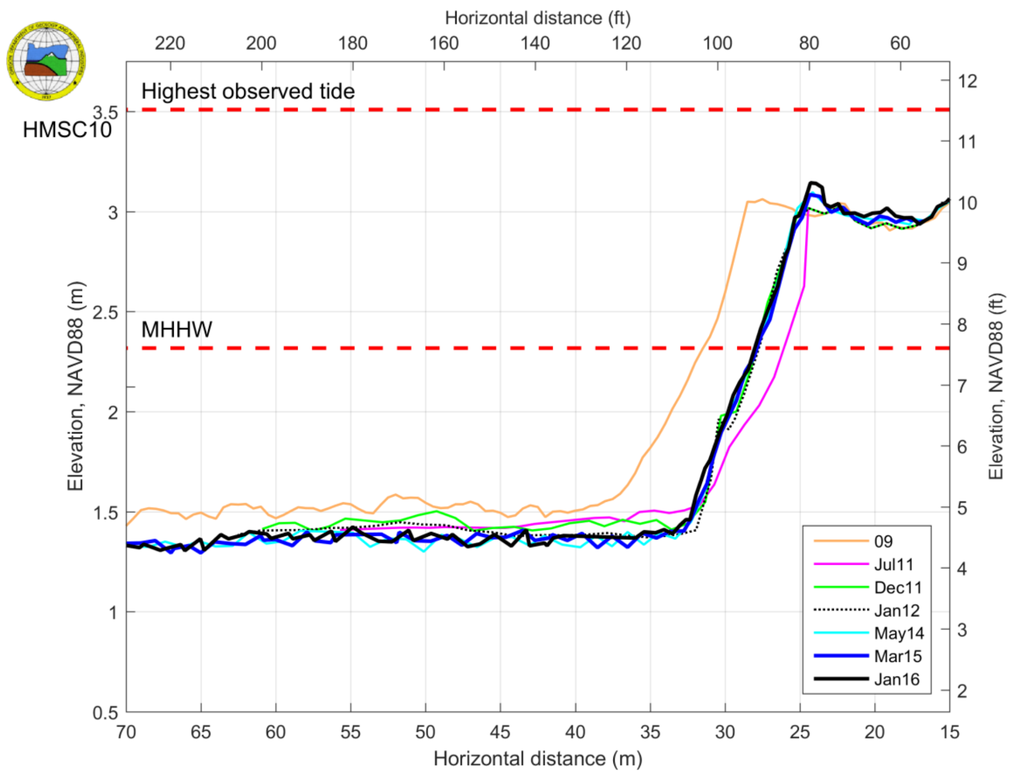
Jan12
May14
Mar15
Jan16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Highest observed tide
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Elevation, NAVD88 (ft)
Horizontal distance (m)
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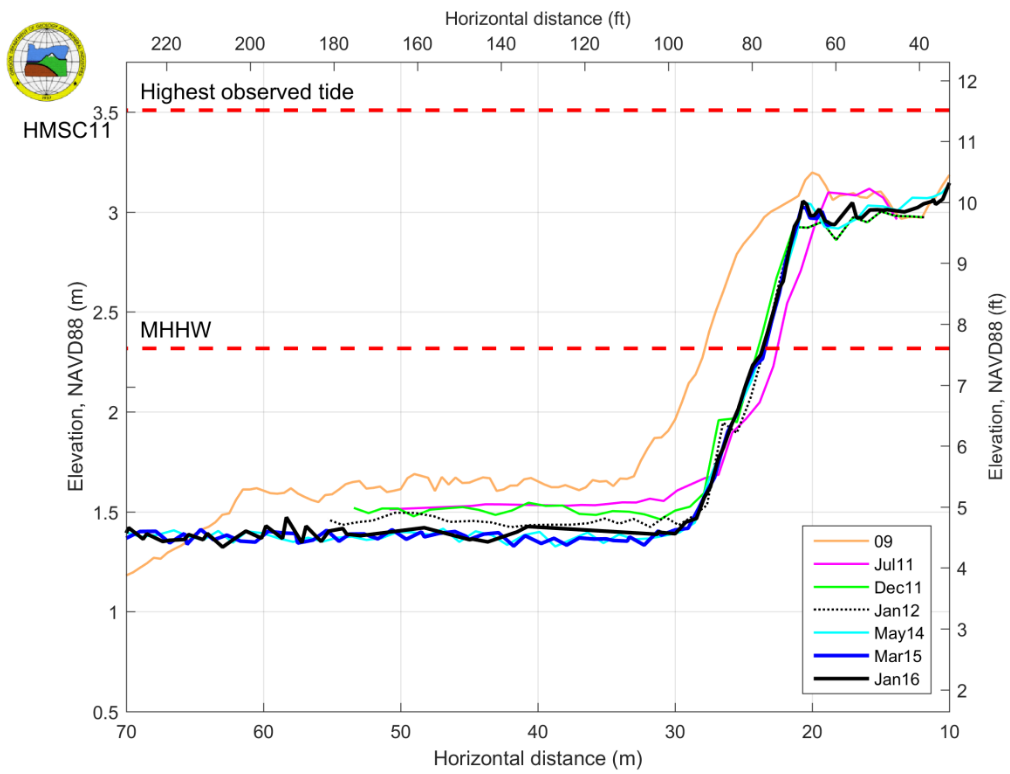
Mar15
Jan16



HMSC11
Horizontal distance (ft)
Highest observed tide
MHHW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
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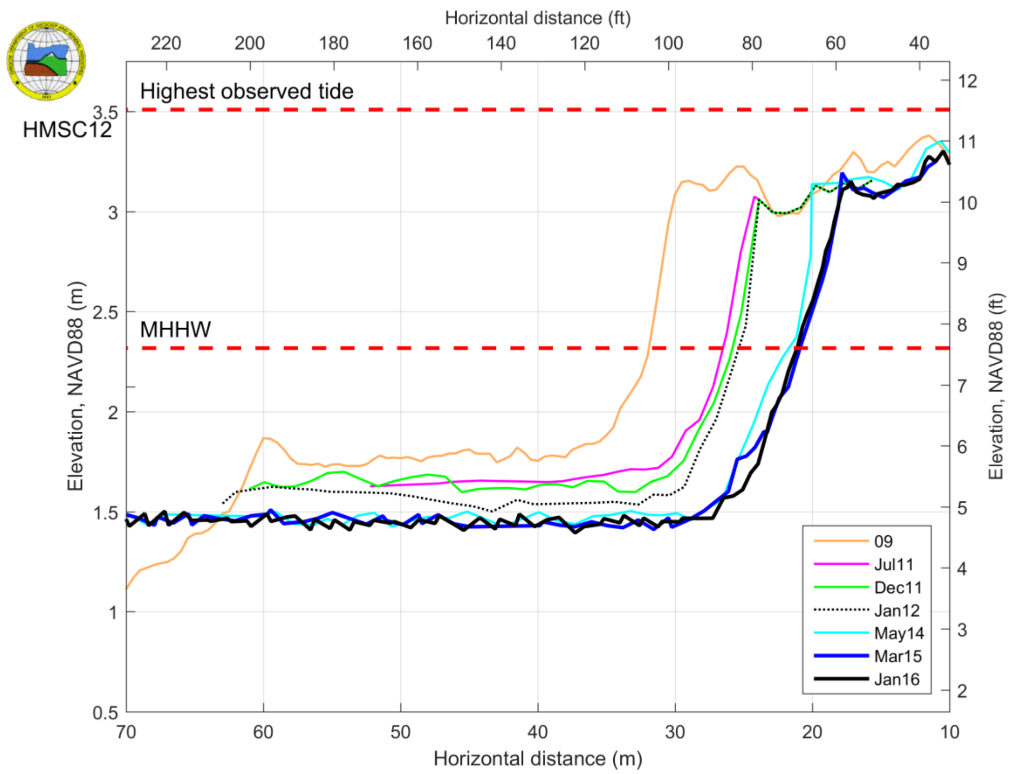
Jan12
May14
Mar15
Jan16



HMSC12
Horizontal distance (ft)
Highest observed tide
MHHW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
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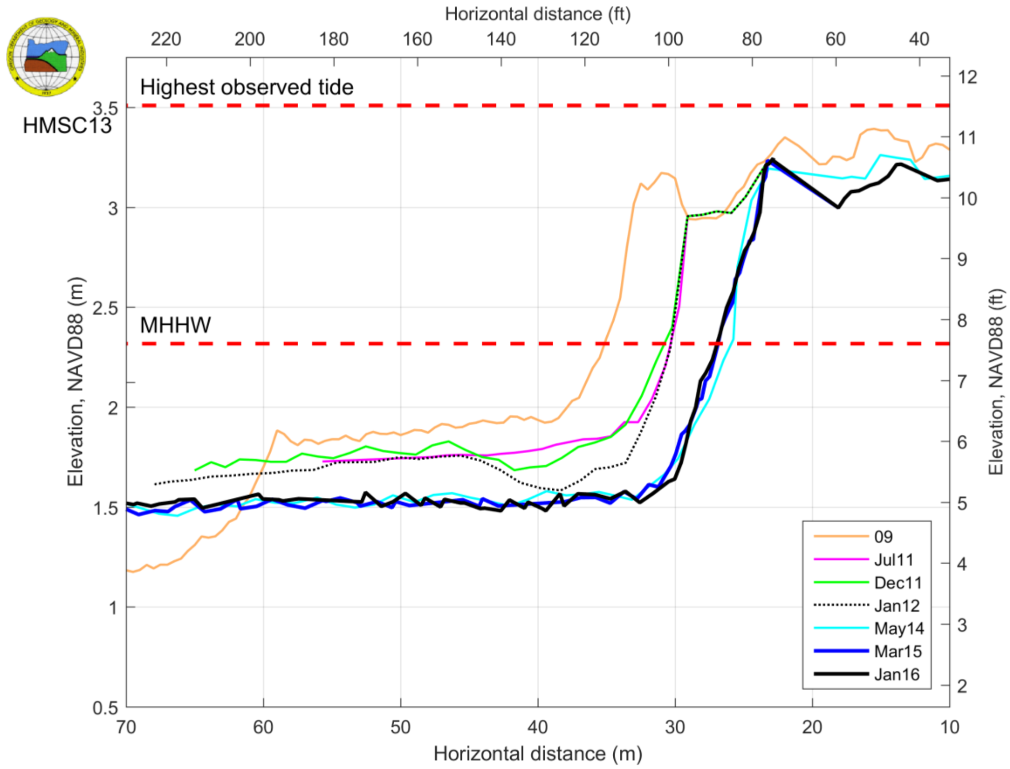
Jan12
May14
Mar15
Jan16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Horizontal distance (ft)
Highest observed tide
MHHW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
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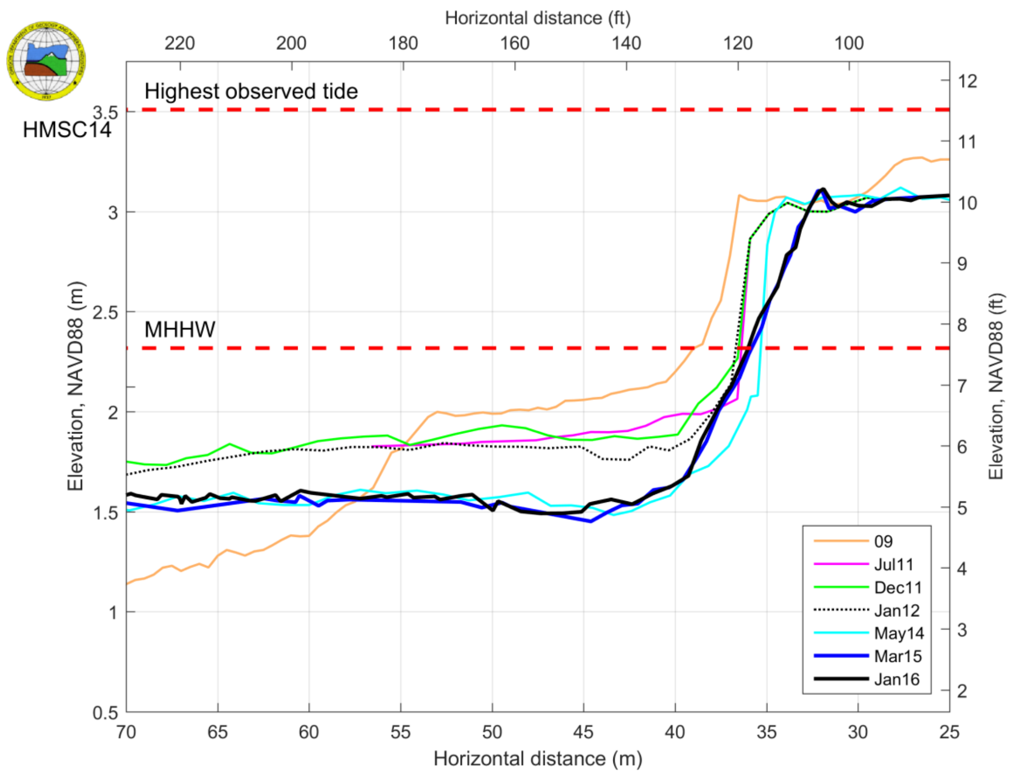
Jan12
May14
Mar15
Jan16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Horizontal distance (ft)
Highest observed tide
MHHW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
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Jul11
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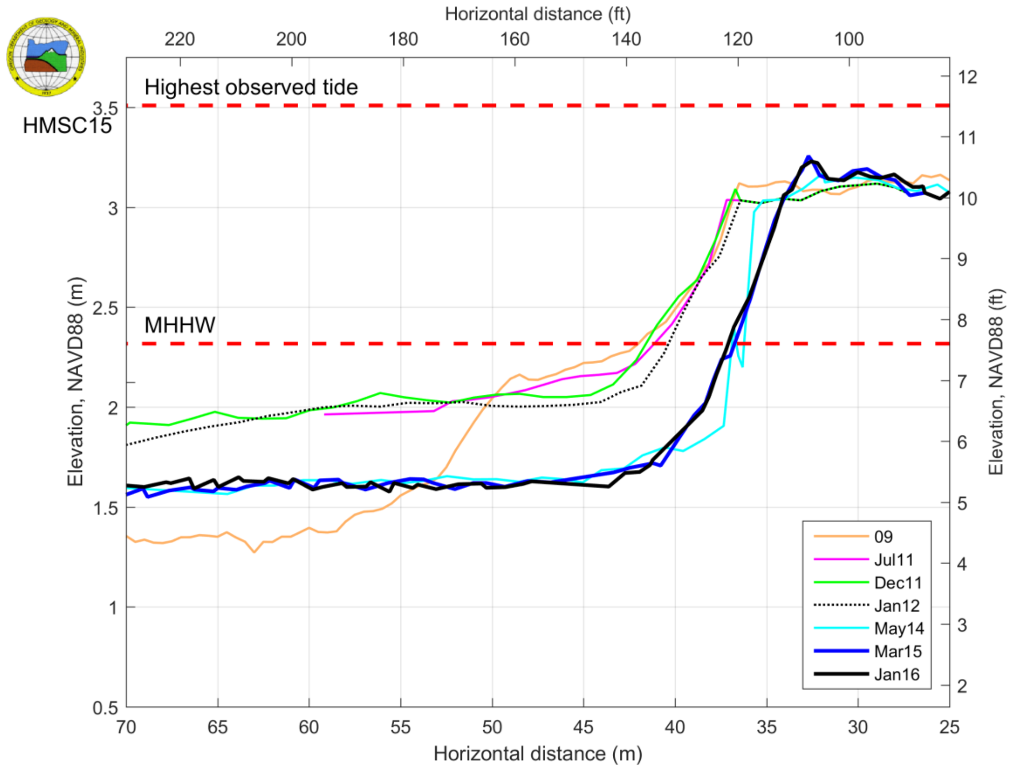
Jan12
May14
Mar15
Jan16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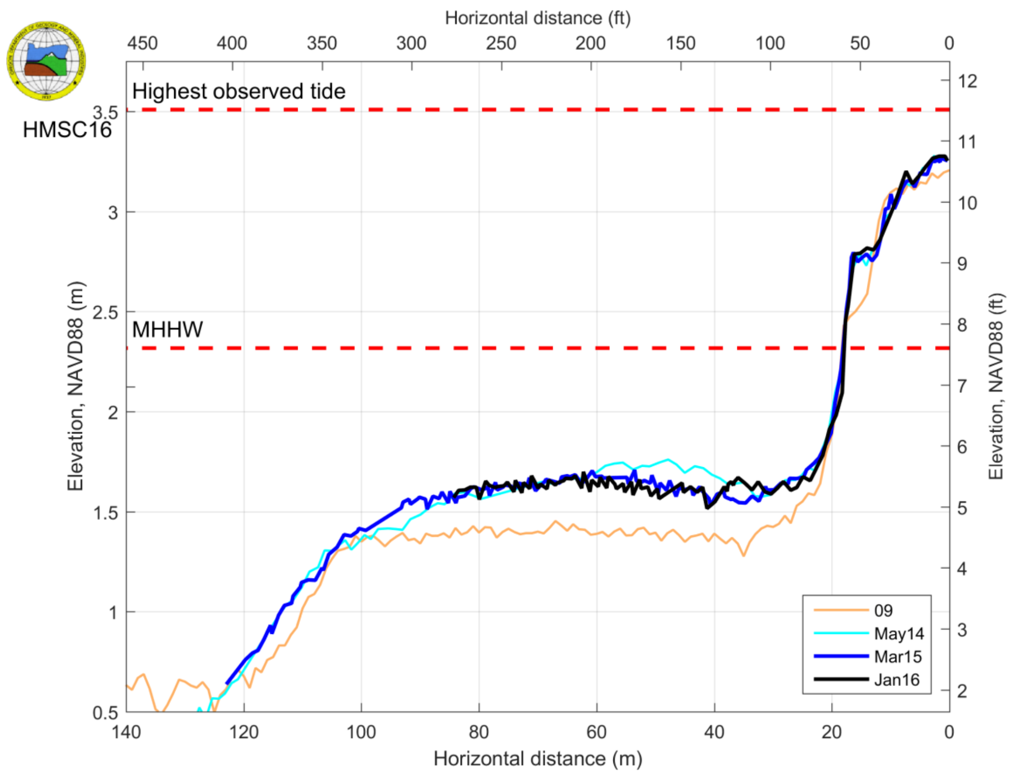
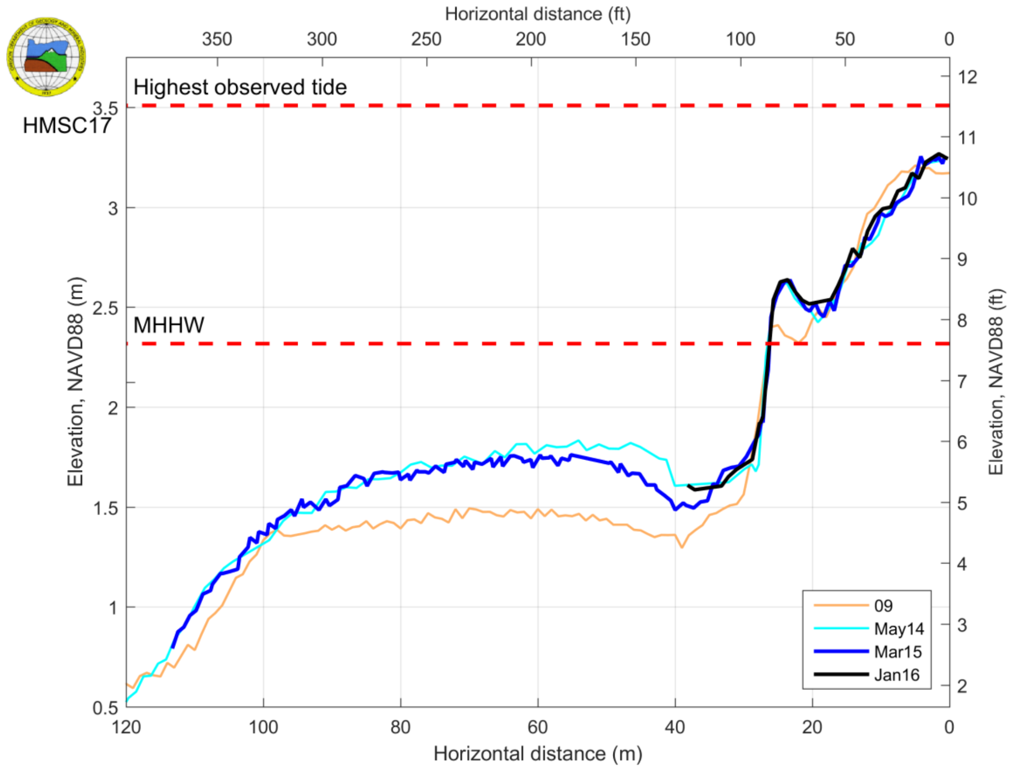
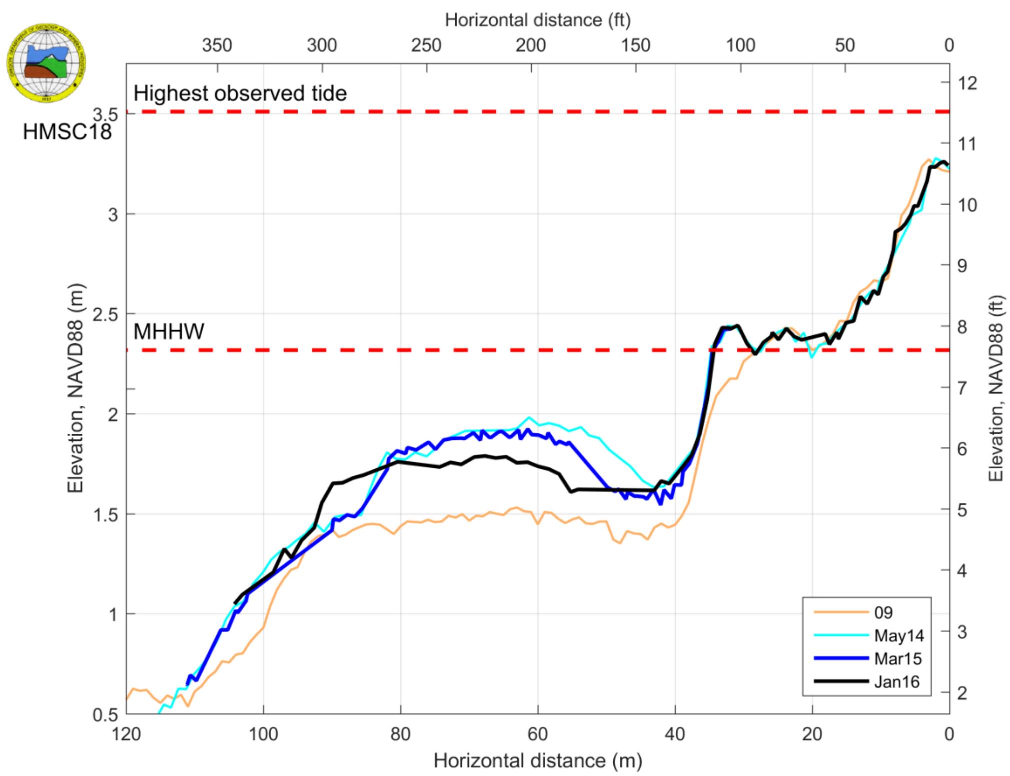
Horizontal distance (ft)
Highest observed tide
MHHW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
09
Jul11
Dec11
Jan12
May14
Mar15
Jan16

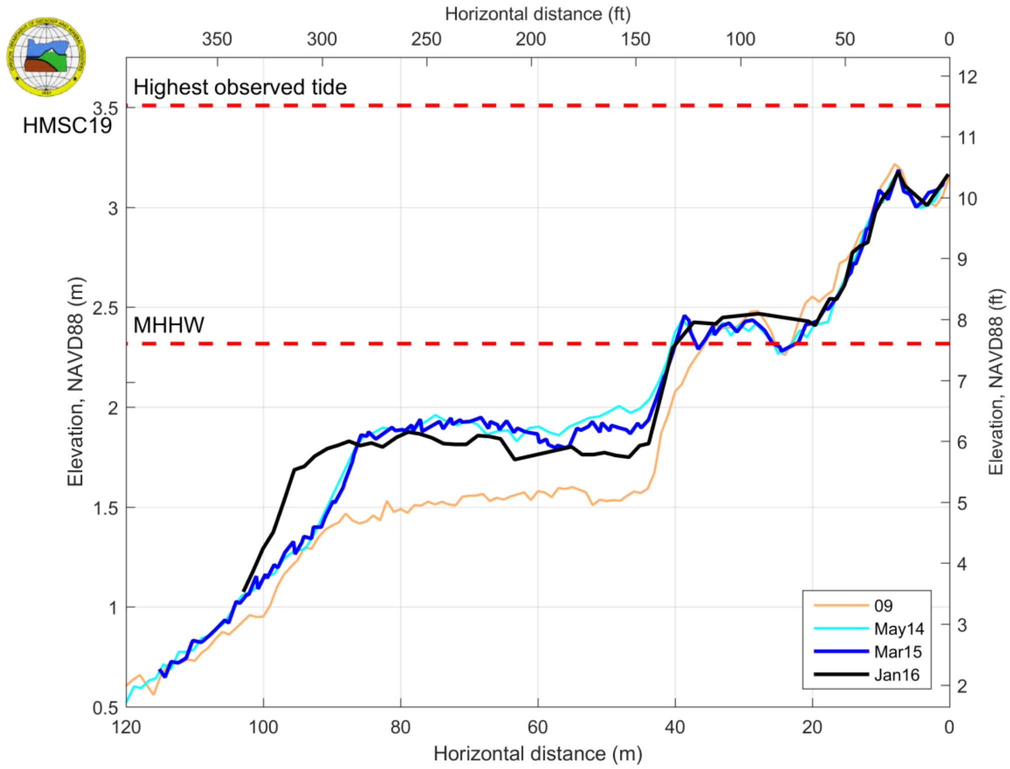

HMSC16
Horizontal distance (ft)
Highest observed tide
MHHW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
09
May14
Mar15
Jan16



HMSC17
Horizontal distance (ft)
Highest observed tide
MHHW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
09
May14
Mar15
Jan16



HMSC18
Horizontal distance (ft)
Highest observed tide
MHHW
Elevation, NAVD88 (m)
Elevation, NAVD88 (ft)
Horizontal distance (m)
09
May14
Mar15
Jan16


HMSC19
Horizontal distance (ft)
350
300
250
200
150
100
50
0
Highest observed tide
MHHW
Elevation, NAVD88 (m)
3.5
3
2.5
2
1.5
1
0.5
Elevation, NAVD88 (ft)
12
11
10
9
8
7
6
5
4
3
2
09
May14
Mar15
Jan16
120
100
80
60
40
20
0
Horizontal distance (m)