Iona Beach Regional Park:
Strategies for Maintaining Native Ecological Communities

Raincoast Applied Ecology
March 2011
Acknowledgements

This project was managed and directed by Markus Merkens (Natural Resource Management Specialist, Metro Vancouver Parks).

Recommended citation:

Table of Contents

Summary ........................................................................................................................................... 1

Part 1 – Introduction and Background Information ................................................................. 2
  Study Area and Site History ........................................................................................................ 2
  Existing Information .................................................................................................................. 4
  Vegetation Mapping ................................................................................................................ 5
  Species at Risk ......................................................................................................................... 9
  Rare Ecological Communities ............................................................................................... 9
  Invasive Plants ....................................................................................................................... 10

Part 2 – Shoreline and Vegetation Change ............................................................................ 13
  Shoreline Change .................................................................................................................. 13
  Shoreline Processes .............................................................................................................. 16
  Shrub Expansion .................................................................................................................... 21
  Vegetation Succession .......................................................................................................... 21

Part 3 – Vegetation Management Strategies ..................................................................... 27
  Strategy 1 – Wood Debris Removal ...................................................................................... 27
  Strategy 2. Mowing and Sod Stripping .................................................................................. 29
  Strategy 3. Revegetation of Native Ecological Communities ........................................... 31
  Monitoring ............................................................................................................................. 33

References .................................................................................................................................... 34

Appendices
  Appendix 1. Historic air photos
  Appendix 2. Vegetation plot data
  Appendix 3. Particle size analysis
Summary

The purpose of this report is to describe the causes of vegetation change in Iona Beach Regional Park and to recommend vegetation management strategies for maintaining sparsely-vegetated and other native ecological communities. The 30 ha study area includes the western portion of Iona Beach Regional Park.

Many of the plant and animal species at risk in coastal ecosystems are associated with sparsely-vegetated ecological communities found in sand beaches and dunes. The primary threat to these communities is the development of more stable and densely vegetated communities through vegetation succession. In coastal BC, invasive plants and reduced sand supply or transport can accelerate vegetation succession by promoting vegetation establishment and growth. Scotch broom is an important cause of vegetation change in coastal sand ecosystems in the Georgia Basin.

Two federally designated bird species (Streaked Horned Lark and Coastal Vesper Sparrow) and one provincially ranked plant species (Vancouver wildrye) occur or historically occurred on Iona Island. Three ecological communities ranked by the BC Conservation Data Centre are also found in the study area. Two are red-listed communities associated with sandy beaches and dunes (Dune wildrye–beach pea Herbaceous Vegetation and Large-headed sedge Herbaceous Vegetation) while the third is found in brackish or marine wetlands on fine sediments (Seashore saltgrass Herbaceous Vegetation). Overall, rare ecological communities account for 5.0 ha (17%) of the study area.

There are two components to habitat change in Iona Beach Regional Park. First, the shoreline has moved seaward in response to sediment accretion. The rate of progradation ranged from 0.9 to 1.7 m/yr over the study period with an overall mean of 1.3 m/yr. Second, vegetation succession has led to the development of shrub and grass dominated ecological communities. Shrub vegetation increased from 300 m² in 1969, to 0.2 ha in 1979, 4.4 ha in 2004, and 5.2 ha in 2009.

The proposed goal of vegetation management in Iona Beach Regional Park is to maintain and restore native ecological communities through active management. Sparsely-vegetated coastal sand communities are the focus of vegetation management because they support ground-nesting birds, provincially-rare ecological communities, and invertebrates of high conservation value. However, beachgrass meadows and shrub-thicket communities are also appropriate in Iona Beach Regional Park.

Two vegetation management strategies are recommended: (1) log debris removal; (2) mowing and sod stripping to reduce shrubland development. The initial approach to vegetation management is to use test areas to assess the practicality and effectiveness of different management techniques.
Part 1 – Introduction and Background Information

The purpose of this report is to describe the causes of vegetation change in Iona Beach Regional Park and to recommend vegetation management strategies for maintaining sparsely-vegetated and other native ecological communities. Iona Beach is one of only two areas of coastal sand ecosystems in the Fraser Lowland\(^1\), and is regionally important for plants, invertebrates, birds, and other species associated with these unique ecosystems. This includes three provincially rare ecological communities and historical habitat for Streaked Horned Lark ((*Eremophila alpestris strigata*) and Coastal Vesper Sparrow (*Pooecetes gramineus affinis*) which are designated as Endangered in Canada (Environment Canada, 2008).

Most of the plant and animal species at risk in coastal sand ecosystems are associated with sparsely-vegetated ecological communities and the primary threat is the development of more stable and densely vegetated communities through natural or accelerated vegetation succession (Page et al., 2011). In coastal BC, invasive plants and reduced sand supply or transport contribute to accelerated vegetation succession. Scotch broom (*Cytisus scoparius*) is an important cause of vegetation change in coastal sand ecosystems in the Georgia Basin because it colonizes dry, nutrient-poor sand soils and rapidly develops a dense shrub thicket community. Expansion of Scotch broom, and to a lesser extent Himalayan blackberry (*Rubus armeniacus*), is the most visually obvious vegetation change at Iona Beach.

Study Area and Site History

The 30 ha study area encompasses the western portion of Iona Beach Regional Park (20 ha) and a portion of the North arm Jetty which is managed by Port Metro Vancouver (10 ha) (Figure 1). It does not include the adjacent intertidal mudflats or the channel of the Fraser River. Most of the study area is used for recreation including walking, beach activities, and bird watching. Park facilities include a parking area for 105 vehicles, a washroom building, picnic tables, information signs, and viewing platforms. There is minimal network of designated trails and most park visitors use the beach and adjacent foreshore to access the North Arm Jetty or the road edge to access the Iona Jetty. The North Arm Jetty includes a wood debris storage and processing facility where logs and other wood debris from the Fraser River is collected, chipped, and loaded onto barges. The wood debris processing facility has been present since the mid 1960s.

Iona Island has an interesting history which influences vegetation development and succession. Prior to dredging of the North Arm of the Fraser River in the first part of the last century, Iona Island

\(^1\) The other important site is Boundary Bay Regional Park.
Figure 1. Study area (in yellow) in relation to boundary of Iona Beach Regional Park (in pink). 2009 orthophoto base.
was a low-lying floodplain island composed of estuarine marshes and tidal channels. Some of the original vegetation structure such as tidal channels is visible in the 1952 air photo (see Appendix 1). After regular dredging was undertaken to improve navigation of the lower river, the marsh island was used for dredge spoil deposition. Fans of unvegetated sediment line the islands northern margin in the 1952 air photo. During the late 1950s, vegetation and topography Iona Island changed dramatically as the sewage treatment plant and associated ponds and outfall were constructed, and the causeway connected Iona and Sea islands. The plant was opened in 1963 and has been expanded six times in the past 50 years; in the mid 1980s, the North Marsh (pond) was constructed with disturbance to adjacent areas (Appendix 1).

Two changes related to the development of the Iona Island Sewage Treatment Plant influence the current structure of vegetation in the study area. First, large amounts of sand fill were placed on the western portion of the island to construct the treatment ponds, and a shoreline was constructed as the new western boundary of the island. Most of the fill was reworked dredge spoil from the Fraser River. The second change was the creation of a low-energy embayment between the North Arm Jetty and the Iona Jetty which was built around the sewage outfall. The embayment has influenced sediment transport and shoreline processes by efficiently trapping and storing sand. Beginning in the mid-1960s, the North Arm Jetty was also used to trap and store wood debris from the Fraser River. This use has continued to present.

**Existing Information**

There is relatively little information on the vegetation communities or other environmental values at Iona Beach other than Dawn Hanna’s (1998) study entitled *Restoration Case Study of Selected Habitats at Iona Beach Regional Park*. It describes available information on plant species observed in the park based on some field assessment and a review of background reports (including Summers and Gebauer’s (1996) wildlife management plan and Klinkenberg’s online information) and available species lists such as Tootchin (1994). Hanna focused on the conservation value of two habitats that are regionally rare, the sand dune habitat characterized by large-headed sedge (*Carex macrocephala*), and estuarine dune meadow habitat which is vegetated with seashore saltgrass (*Distichlis spicata*). It also notes the value of the area for other rare species including Streaked Horned Lark (now extirpated from Canada), and regionally uncommon bird species such as Savannah Sparrow (*Passerculus sandwichensis*), Snow Bunting (*Plectrophenax nivalis*), and Lapland Longspur (*Calcarius lapponicus*).

Pitfall trapping for invertebrates was undertaken by BC Ministry of Environment in 2010 but specimen identification has not been completed (J. Heron, pers. comm.).
Vegetation Mapping

Methods. Vegetation in the study area was mapped and sampled to assess relative conservation values and to better describe patterns and processes of vegetation change. A digital orthophoto (2009) was used as a base and mapping was undertaken in Arcview 3.2. As a first step, terrestrial and wetland vegetation was divided into five types based on vegetation structure: (1) shrub; (2) herbaceous; (3) bryophyte; (4) sparsely-vegetated; and (5) wetland. Vegetation composition and percent cover was measured in twenty-four 2 x 2 m plots in areas of representative vegetation (Figure 2). The plot-based sampling was not comprehensive because of the difficulty in identifying some grasses in the late summer. As well, bryophytes and lichens were not identified in detail. However, sampling did focus on the identification and mapping of rare ecological communities, which are ranked and tracked by the BC Conservation Data Centre. These included communities dominated by large-headed sedge, dune wildrye, and seashore saltgrass. For each of these ecological communities, field-based mapping using a handheld GPS was used because they could not be accurately mapped from available air photos.

Table 1 provides a summary of vegetation types and Figure 3 includes representative photos. In summary, grass- or sedge-dominated herbaceous vegetation accounts for 6.1 ha (20%) of the study area, sparsely-vegetated vegetation 5.7 ha (19%), shrublands 5.2 ha (17 ha), wetland (marsh) vegetation 3.8 ha (13%), and bryophyte vegetation 1.3 ha (4%). Developed lands including parking areas, mowed grasses, roads, and unvegetated areas disturbed by wood debris processing or storage account for 8.4 ha (28%).
Figure 2. Distribution of vegetation types in Iona Beach Regional Park. Vegetation plots are also shown.
### Table 1. Summary descriptions of vegetation types in Iona Beach Regional Park.

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>General Description</th>
<th>Representative Photo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shrub</td>
<td>Scotch broom in dense monotypic thickets or intermixed with Himalayan blackberry on southern end of study area; often with with grass-dominated understory; sometimes with bryophytes; generally a species-poor community because of competition from Scotch broom; 5.2 ha (17% of study area).</td>
<td></td>
</tr>
<tr>
<td>Herbaceous</td>
<td>Two herbaceous communities present in the study area: (1) dune wildrye (<em>Leymus mollis</em>)-dominated ecological community adjacent to beach; and (2) weedier mixed meadow community with forbs such as yarrow (<em>Achillea millefolium</em>), prickly sow thistle (<em>Sonchus asper</em>), sheep sorrel (<em>Rumex acetosella</em>), and non-native grasses; 6.1 ha (20% of study area).</td>
<td></td>
</tr>
<tr>
<td>Bryophyte</td>
<td>Variable and difficult to differentiate communities that are often transitional to large-headed sedge sparse vegetation, or Scotch broom dominated shrublands; <em>Racomitrium canescens</em> is frequently dominant, but <em>Polytrichum juniperinum</em>, <em>Tortula ruralis</em>, and <em>Cladonia</em> and <em>Cladina</em> lichens are often present; 1.3 ha (4% of study area).</td>
<td></td>
</tr>
<tr>
<td>Sparse-vegetation</td>
<td>Two communities occur within this vegetation type: (1) lower beach communities on newly deposited sand with sparse cover of dune wildrye, beach pea (<em>Lathyrus japonicas</em>), large-headed sedge (<em>Carex macrocephala</em>), and American searocket (<em>Cakile edentula</em>); and (2) older communities with large-headed sedge, occasionally with dune wildrye; 5.7 ha (19% of study area).</td>
<td></td>
</tr>
<tr>
<td>Wetland</td>
<td>Two wetland types were described: (1) a brackish marsh with seashore saltgrass (&gt;95% cover) and minor amounts of common silverweed (<em>Potentilla anserina</em>) and common orache (<em>Atriplex patula</em>) found in depressional areas between the shoreline; and (2) small area of freshwater marsh (likely occasionally brackish) found near the Iona Jetty with common rush (<em>Juncus effusus</em>), yellow-flag iris (<em>Iris pseudacorus</em>), and purple loosestrife (<em>Lythrum salicaria</em>); 3.8 ha (13% of study area).</td>
<td></td>
</tr>
</tbody>
</table>
Figure 3. Representative photos of vegetation types in Iona Beach Regional Park: shrublands (a-c), herbaceous communities (d-f), bryophyte communities (g-h), sparsely-vegetated communities (i-j), and wetland communities (k-l).
Species at Risk

Two federally designated bird species and one provincially ranked plant species occur or historically occurred on Iona Island:

**Streaked Horned Lark** (*Eremophila alpestris strigata*) is a rare subspecies of the Horned Lark that breeds in large coastal sand ecosystems and short-grass prairies in Oregon and Washington (Pearson and Altman, 2005). It is a specialist of sparsely-vegetated habitats, and occurred historically in both dunes and grasslands in southwestern BC. In the lower Fraser Valley, breeding records were concentrated on Sea Island, Iona Island, and Lulu Island in dredge spoil areas (it continues to use dredge spoil areas at the mouth of the Columbia River). Streaked Horned Lark is not currently known to occur in Canada and is listed as Endangered under Schedule 1 of SARA (Environment Canada, 2008). A joint recovery strategy for Streaked Horned Lark and Coastal Vesper Sparrow is currently in draft form (Environment Canada, 2008), and includes recommendations for restoring or creating new habitats through the use of dredge spoil including vegetation management.

**Coastal Vesper Sparrow** (*Pooecetes gramineus affinis*) (Endangered under Schedule 1) is a similar ground-nesting open grassland species that bred historically on Iona Island (Environment Canada, 2008). It is now a very rare summer visitor in the Fraser Lowlands, and the only known extant breeding population is located on Vancouver Island about 20 km south of Nanaimo at the Nanaimo Airport. It is listed as Endangered under Schedule 1 of SARA.

**Vancouver wildrye** (*Leymus x vancouverensis* hybrid) is a hybrid of *Leymus mollis* and an unknown species, possibly *Leymus triticoides*. It is locally abundant in sand dunes, spits, and beaches in the Georgia Basin. This taxa has replaced older collections of *Leymus triticoides* in coastal BC. It is currently ranked S2S3 (Imperilled/vulnerable) by the BC Conservation Data Centre.

Rare Ecological Communities

Three ecological communities ranked by the BC Conservation Data Centre occur in the Iona Beach study area. Two are red-listed communities associated with sandy beaches and dunes, while the third is found in brackish or marine wetlands on fine sediments. Overall, they account for 5.0 ha (17%) of the study area (see Figure 4 for their distribution).

**Dune wildrye–beach pea Herbaceous Vegetation.** This is the dominant native beachgrass community on many coastal sites including sand and gravel beaches and some estuary sites. It more common in the Georgia Basin than on the west coast Vancouver Island. It is rarely floristically diverse and often only supports dune wildrye and beach pea, but is occasionally inter-mixed prickly
sow-thistle, yarrow, and a variety of non-native grasses. It is currently red-listed in BC (S1S2). It is relatively abundant at Iona Beach (2.5 ha) and is found between the sparsely-vegetated habitats of the shoreline and the shrub-dominated communities (Figure 4). It also found along the margin of the Fraser River.

**Large-headed sedge Herbaceous Vegetation.** This is species-poor and sparsely-vegetated community found on upper and mid elevation beach sites and dunes throughout coastal BC. It is often only with large-headed sedge present, or occasionally mixed (or transitional) to dune wildrye. It is red-listed in BC (S1S2). This community is found on a linear band paralleling the beach (1.6 ha total area) (Figure 4). At the southern end it often transitions into beach meadow dominated by dune wildrye. In other areas, it is transitional a *Racomitrium* moss dominated community that develops on stable, acidic beach sands.

**Seashore saltgrass Herbaceous Vegetation.** This is a wetland community is found in saline or brackish water in sandy or silty substrates. It is described as an “estuary ecosystem occurring in the lowest vegetated tidal zone on imperfect to poorly-drained, fine sand to silt textured marine sediments. These sites are flooded daily for prolonged periods. Vegetation is typically dominated by seashore saltgrass but high cover of coast silverweed and common orache occurs on some sites in the study area” (Stacey and Filatow, 2009). It is blue-listed in BC (S2S3). It is found in a depressional area (0.9 ha) behind the beach where it receives some tidal inflow (see Figure 4).

Another interesting ecological community found in the study area is *American searocket Sparse Vegetation*. This is relatively common and widespread sparsely-vegetated community found in the lower beach habitats. It often contains species found in more established communities but plant cover is sparse. Common species in the lower beach at Iona Island Regional Park are dune wildrye, beach pea, large-headed sedge, and *American searocket*; silver burweed was also observed occasionally. It is currently unranked by the BC Conservation Data Centre.

**Invasive Plants**

Eighteen non-native plants were identified during the vegetation survey (Appendix 2). They include three shrubs (Scotch broom, Himalayan blackberry, cutleaf evergreen blackberry (*Rubus laciniatus*)), several grasses (orchardgrass (*Dactylis glomerata*), sweet vernalgrass (*Anthoxanthum odoratum*), velvet grass (*Holcus lanatus*), brome species (*Bromus spp.*), etc), and a range forbs.

---

2 Subnational (provincial) ranks are defined as: S1 (Critically Imperiled); S2 (Imperiled); S3 (Vulnerable); S4 (Apparently Secure). Red-listed species or ecological communities are Extirpated, Endangered, or Threatened in British Columbia. Blue-listed species or ecological communities are of Special Concern (formerly Vulnerable) and Yellow-listed species are secure.
including hairy cat’s ear (*Hypochaeris radicata*), lance-leaved plantain (*Plantago lanceolata*), St. John’s wort (*Hypericum perforatum*), yellow iris, and purple loosestrife.

Scotch broom is the most important invasive plant in the Iona Beach study area because of its ability to rapidly establish in sparsely-vegetated or grassland plant communities, and exclude native species. It is present in most coastal sand ecosystems in the Georgia Basin and is forms the dominant ecological community at Goose and Witty’s spits on southeastern Vancouver Island, and Hook Spit on Sidney Island.

Scotch broom has several characteristics that make it a successful invader of coastal sand ecosystems: it is a prolific producer of long-lived seed; it fixes nitrogen in nutrient-poor sand soils; and it is tolerant of summer drought once established. It forms dense stands that compete for light and moisture with native plants, and it accelerates succession by stabilizing the surface of the sand and increasing soil fertility. However, it is important to note that Scotch broom most often colonizes sites that have been previously stabilized by native bryophytes, and is less successful in open sand areas because of seedling mortality from summer drought.

Invasive grasses are also common in all Georgia Basin coastal sand ecosystems. Species commonly observed include cheatgrass (*Bromus tectorum*), soft brome, rip-gut brome (*Bromus rigidus*), velvetgrass, orchardgrass, sweet vernal grass, silver hairgrass (*Aira caryophyllea*), and early hairgrass (*Aira praecox*). Most are found on stabilized sites with some soil development, however, cheatgrass and hairgrass species often occur on open sand. None are considered an important driver of successional change in coastal sand ecosystems but contribute to the development of grass-dominated meadows and organic-enriched soils over time.
Figure 4. Distribution of three rare ecological communities in Iona Beach Regional Park.
Part 2 – Shoreline and Vegetation Change

There are two components to habitat change in Iona Beach Regional Park. First, the shoreline has moved seaward (prograded) in response to sediment accretion. Second, vegetation succession has led to the development of shrub and grass dominated ecological communities in areas that were previously sparsely-vegetated. Part 2 of this report uses a series of historic air photos from 1952–2009 and other information to describe these changes, and to relate them to physical and ecological processes. Historic air photos were scanned and orthorectified in Global Mapper to provide a consistent dataset for comparison (see photos in Appendix 1). A photo from 1949 was the earliest air photo available for the study area but could not be orthorectified because of the lack of sufficient points of comparison.

Shoreline Change

Shoreline change was assessed using the historical shoreline location from 1952–2009. In addition, four transects approximately 350 m apart along the western shore of the park were used to quantify the rate of shoreline change (Figure 5). The location of the shoreline was delineated using the distinct transition from the intertidal mudflats to the toe of the lower beach. It is slightly seaward (west) of the high water mark and includes the entire beach.

Results of the analysis are shown in Figure 5 and Table 2. The shoreline can be divided into two segments: (1) a northern segment encompasses the shoreline of the North Arm Jetty; and (2) a southern segment in the eastern end of the bay. Shoreline location in the northern segment has been more variable with periods of both accretion and erosion. However, overall shoreline change is less than the southern segment (<1.0 m/yr). The variability of shoreline location along the North Arm Jetty is influenced by the movement of lobes of sediment that are transported episodically from the northwest (see Figure 5 for example from 2004). In some cases, these lobes of sand act as small spits which migrate into the shallow intertidal zone. This process forms linear depressions behind the new shoreline location which are colonized by salt-tolerant wetland vegetation (Figure 6). The southern segment has a less variable shoreline location and a more consistent rate of progradation.

The rate of shoreline change ranged from 0.9 to 1.7 m/yr over the study period with an overall mean of 1.3 m/yr (Table 2). The rate of change is approximately 1.0 m/yr in front of the park building. Despite relatively consistent rates of progradation of Iona’s shoreline over the study period, the location of the shoreline was more variable in the more northern segment.
Figure 5. Shoreline change in the Iona Beach Regional Park area between 1952 and 2009. Inset graphs show mean and variability of shoreline change over time.
Figure 6. Depressional wetland formed by the deposition of sand seaward of the old shoreline location (from right to left). Some seashore saltgrass and American bulrush (*Schoenoplectus pungens*) is visible around the margin of the wetland.

Table 2. Shoreline change in Iona Beach Regional Park: 1952–2009 (57 years).

<table>
<thead>
<tr>
<th>Date</th>
<th>No. of Years</th>
<th>Transect 1</th>
<th>Transect 2</th>
<th>Transect 3</th>
<th>Transect 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1952</td>
<td>0</td>
<td>na</td>
<td>na</td>
<td>97.4</td>
<td>105.1</td>
</tr>
<tr>
<td>1963</td>
<td>11</td>
<td>32.5</td>
<td>109.0</td>
<td>140</td>
<td>114.2</td>
</tr>
<tr>
<td>1969</td>
<td>6</td>
<td>53.8</td>
<td>113.5</td>
<td>190.7</td>
<td>132</td>
</tr>
<tr>
<td>1974</td>
<td>5</td>
<td>60.9</td>
<td>101.3</td>
<td>183.7</td>
<td>100.8</td>
</tr>
<tr>
<td>1976</td>
<td>2</td>
<td>62.4</td>
<td>113.8</td>
<td>170.3</td>
<td>88.6</td>
</tr>
<tr>
<td>1979</td>
<td>3</td>
<td>64.5</td>
<td>120.5</td>
<td>152.6</td>
<td>113.9</td>
</tr>
<tr>
<td>1984</td>
<td>5</td>
<td>66.0</td>
<td>112.5</td>
<td>169.4</td>
<td>128.3</td>
</tr>
<tr>
<td>1991</td>
<td>7</td>
<td>81.7</td>
<td>126.7</td>
<td>154.5</td>
<td>173.5</td>
</tr>
<tr>
<td>1997</td>
<td>6</td>
<td>84.6</td>
<td>126.9</td>
<td>178.3</td>
<td>136.6</td>
</tr>
<tr>
<td>2004</td>
<td>7</td>
<td>99.8</td>
<td>146.0</td>
<td>148.1</td>
<td>135.5</td>
</tr>
<tr>
<td>2009</td>
<td>5</td>
<td>106.5</td>
<td>155.2</td>
<td>193.6</td>
<td>158.6</td>
</tr>
</tbody>
</table>

Shoreline Change (m) | 74.0 m | 46.2 m | 96.2 m | 53.5 m
Mean change / year (m) | 1.4 m/yr | 1.3 m/yr | 0.8 m/yr | 0.8 m/yr
Variability (SD) | 1.1 m/yr | 2.6 m/yr | 5.7 m/yr | 5.4 m/yr
Figure 7. Example of pulsed shoreline change along the North Arm Jetty as lobes of sediment are moved episodically from the northwest. Most of the sediment is medium sand transported during infrequent large storms. Between the two lobes is a section of shoreline erosion.

Shoreline Processes

As described in the previous section, the shoreline of Iona Beach has progressed seaward over the past 60 years. Sediment (primarily sand) is moved along the shore of the North Arm Jetty in a southeastern direction by two processes: (1) longshore drift caused by wave action in the direction of prevailing winds; and (2) aeolian transport caused by wind. Longshore drift is the incremental movement of sediment along the beach by the swash and backwash of waves in the direction of the prevailing wind. On Iona Beach, the prevailing wind is from the southwest which moves sediment to the northeast. Two large sediment lobes visible in 2004 (Figure 7) are representative of pulsed sediment transport caused by longshore drift.

Wind (aeolian) movement of sand and fine sediment also occurs on the beach face and adjacent backshore. Finer sands (i.e., < 1 mm) are reworked from the foreshore and transported within the
sparsely-vegetated backshore by winds >6 m/s where they accumulate in the presence of vegetation or log debris. These structural features form small incipient (or embryo) dunes that are often seasonal in nature. Small incipient dunes (<0.5 m in height) are visible on the beach and backshore at Iona Beach (Figures 8 and 9). The lack of larger dunes indicates that wind movement of sand is a less-important process in Iona Beach than longshore drift. This also suggests that wind-transported sediment is not an important influence on vegetation development or succession in Iona Beach except for the portion of the backshore immediately adjacent to the beach.

Figure 8. Small incipient dunes have formed around vegetation and wood debris along the North Arm Jetty. Photo from August 2010.

Sand Size. Seven surface sediment samples were collected from the beach and incipient dunes to characterize the size of surface sediment. Each sample was sieved in a series of sieves (#4, #8, #12, #20, #50, and #100), and sediment statistics were calculated using Gradistat (Blott and Pye, 2001).

Sediment was characterized as “very well sorted medium sand” with a mean diameter (arithmetic) of 356 microns (see Appendix 3 for analysis results). If all samples were combined, 15% was very coarse sand, 2% was coarse sand, 89% was medium sand, and 8% was fine sand. In contrast, the mean diameter of sand particles in Wickaninnish Beach dunes on the west coast of Vancouver
Island is 206 microns (Beaugrand, 2010). The larger mean particle size of sand in the Iona Beach study reduces wind movement and the formation of dunes.

**Wood Debris.** Wood debris is common in beaches in BC. It is largely composed of logs and smaller debris that originates in the transport or storage of wood by the forest industry. Recent research has shown that wood debris increases the accretion of coastal sediments in the backshore by providing sites for wind-transported sand to be deposited (Walker and Barrie, 2007; Eamer and Walker 2010). Many of the incipient dunes observed along the Iona Beach backshore developed around wood debris (see Figure 9). However, while wood debris does contribute to shoreline stabilization, there is no physical evidence to suggest it contributes to vegetation succession at Iona Beach by reducing sand movement through the backshore. As discussed previously, wind-related sand movement at Iona Beach is relatively limited.

![Figure 9. Incipient dunes associated with wood debris in the Iona Beach backshore.](image)

The distribution and abundance of surface wood debris accumulations was mapped using three methods (Figure 10). First, the boundary of concentrated wood debris patches was mapped using the 2009 ortho photo. Second, the distribution of wood debris (pieces >1 m long and 20 cm in diameter) were recorded in eleven transects using a hand-held GPS. Third, wood debris was measured in three 10 m x 10 m plots to quantify the size and density of wood debris. The length
Figure 10. Distribution and abundance of wood debris in Iona Beach Regional Park in 2010. Debris plots and transects are shown in relation to polygons (in light orange) showing concentrations of wood debris.
and diameter of wood pieces was measured within and adjacent to the plot was measured, and this was used to calculate overall wood volume.

Both orthophoto mapping and transect based assessment methods showed that wood debris forms a relatively continuous band along the foreshore (Figure 10). It generally coincides with the occurrence of sparsely-vegetated ecological communities. Wood debris also occurs landward of the wetland complex (see Transects T5, T6, and T7 in Figure 10), but is not found on the northern portion of the study area (Transects T9, T10, and T11) because of an active wood debris removal project in 2009.

The average volume of wood debris in the plots was 7.5 m³/plot (range: 5.0–8.9 m³/plot; mean: 0.075 m³/m²). This is substantially less than the density of wood measured in a wood debris raft in the Beach Grove Lagoon in 1999 (0.17 m³/m²) (Page et al., 1999). The mean length of wood pieces in the plots at Iona Beach was 2.8 m (range: 1.0–8.2 m) and the mean diameter was 29 cm.

Figure 11. Example of wood debris accumulation in Iona Beach Regional Park.
Shrub Expansion

Similar to shoreline change, historic air photos (1952–2009) were used to assess vegetation change in the study area. The assessment focused on quantifying the development of more stable shrub-dominated vegetation which can be identified in older air photos, and are an indicator of the overall loss of sparsely-vegetated plant communities. Shrub thickets in Iona Beach Regional Park are predominantly composed of Scotch broom, with lesser amounts of Himalayan blackberry near the base of the Iona Jetty. Very little tree establishment has occurred.

Shrub vegetation increased from 0.03 ha in 1969, to 0.2 ha in 1979, 4.4 ha in 2004, and 5.2 ha in 2009. Figure 12 shows the distribution of shrub vegetation in 2004 and 2009. Between 2004 and 2009, substantial areas of Scotch broom-dominated shrub thicket were removed from the eastern edge of the park near the parking area by volunteer-based restoration projects. However, shrub areas continue to expand, particularly adjacent to the Iona Jetty. Based on the current trends, shrub-dominated communities are expected to expand substantially over the next 10 years as existing patches coalesce to form continuous thickets.

Vegetation Succession

The primary threat to native ecological communities in Iona Beach Regional Park is the development of more stable and densely vegetated communities, particularly Scotch broom-dominated shrub thickets, through vegetation succession. While succession\(^3\) is a natural process in coastal sand ecosystems and results in assemblage of younger and older communities on most sites, there is evidence that the rate of succession has accelerated in many coastal sand ecosystems in BC. Accelerated succession has also been observed in sand ecosystems in western Europe where it may be a response to atmospheric nitrogen deposition (Jones et al., 2004). In BC, invasive plants, reduced sand supply, and atmospheric nitrogen deposition may contribute to accelerated succession.

The process of vegetation succession at Iona Beach was described based on observations of community development at the site, as well as other coastal sand ecosystems in the Georgia Basin (see Figure 12 for a schematic depiction of successional patterns). The initial phase is species-poor and sparsely-vegetated lower beach community that develops on newly deposited sand substrates. At Iona Beach, this community is characterized by dune wildrye, beach pea, and large-headed sedge, with smaller amounts of American searocket. This community develops into either a beach meadow community dominated by dune wildrye, or a sparsely-vegetated community vegetated

---

\(^3\) Succession is the orderly change in the composition and structure of an ecological community over time caused by the replacement of species in response to environmental and climate factors.
Figure 12. Distribution of shrub vegetation in Iona Beach Regional Park in 2004 and 2009. Note broom removal areas.
almost entirely with large headed sedge. Soil and moisture characteristics likely cause these vegetation differences. As beach meadow communities age, they often become both more diverse but also weedier with species such as yarrow, velvetgrass, common tansy (Tanacetum vulgare), and St. John’s wort establishing. Eventually Himalayan blackberry and/or Scotch broom establish.

In sites with large-headed sedge, there is often a gradient of stability with sites closest to the shore maintained as sparsely-vegetated communities by wind-transported sand and sites away from the shore becoming progressively more stable and more vegetated. In coastal BC, succession from sparsely-vegetated communities is often initiated by pioneering bryophytes (e.g., Racomitrium canescens, Dicranum spp., Tortula ruralis, etc) which facilitate the establishment of perennial grasses, forbs, and some shrubs (Figure 13). Bryophytes are able to colonize open sand if sand movement by wind is relatively minimal. Soil acidification caused by leaching may also be a factor in promoting bryophyte colonization of beach sands.

The bryophyte community often develops into shrub vegetation because shrub seedlings establish in bryophyte mats where summer moisture stress and nutrient loss is reduced (Parker, 2002). Biological nitrogen fixation from bryophytes may also be an important factor promoting succession to shrub communities. Parker (2002) found bryophyte crusts dominated by Racomitrium mosses facilitated Scotch broom establishment in glacial outwash prairies in central Washington by providing “safe sites” for seedling germination and growth. Scotch broom invasion in other Georgia Basin sites such as Goose and Witty’s spits also appears to be supported by bryophyte crusts, particularly by reducing moisture stress during the first growing season. Where the bryophyte mat was removed at Goose Spit as part of restoration activities (see Figure 15), broom seedlings germinated but often failed to survive drought conditions in late summer.
Figure 13. Replacement of a bryophyte-dominated community (with Racomitrium moss, large-headed sedge, lance-leave plantain, and hairy-cat’s ear) with a Scotch broom shrub community at Iona Beach. Note the Scotch broom seedings growing through the bryophyte mat in the foreground.

Accelerated Succession. Sparsely-vegetated communities are prevalent in coastal sand ecosystems because dry, nutrient-poor soils are difficult for many plants to colonize. Disturbance to the ground surface by the movement of sand by wind and coastal processes also limits the development of stabilizing vegetation. However, these attributes can be modified by anthropogenic factors resulting in accelerated succession.

Several factors likely increase the rate of vegetation succession in Iona Beach Regional Park:

- rapid progradation of the shoreline reduces sediment movement into the backshore trapping sand near the shore;
- the combination of wood debris and the presence of depressional wetland areas prevent sand from moving further into the backshore;
- relative to dune areas on the west coast of Vancouver Island where sand is finer and more easily moved by wind, sand at Iona Beach is relatively coarse and not easily transported by
wind. This reduces sand movement into backshore areas and limits dune formation to small incipient dunes around wood debris or vegetation in the backshore; and

- invasive plants such as Scotch broom and non-native grasses colonize dry, nutrient-poor sand soils which facilitate further vegetation establishment. Scotch broom is able to fix nitrogen which allows it to establish and thrive in infertile soils found in Iona Beach Regional Park.
Figure 14. Schematic depiction of vegetation succession in Iona Beach Regional Park. There are three pathways identified by the blue, orange, and red arrows between the boxes. Both the blue and orange pathways end in the development of a shrub community dominated by Scotch broom.
Part 3 – Vegetation Management Strategies

The proposed goal of vegetation management in Iona Beach Regional Park is to maintain and restore native coastal ecological communities through active management. Sparsely-vegetated coastal sand communities are the focus of vegetation management because they support ground-nesting birds, provincially-rare ecological communities, and invertebrates of high conservation value. Indeed, Iona Beach Regional Park could become important recovery habitat for Streaked Horned Lark or Coastal Vesper Sparrow with active management. However, other native ecological communities such as beachgrass meadows and shrub thickets are also appropriate objectives for vegetation management.

Three vegetation management strategies are presented in this part of the report: (1) log debris removal; (2) mowing and sod stripping to create sparsely-vegetated communities; and (3) test plantings of native beachgrass, shrubs, or seeded native species in treated areas. Each strategy is described in more detail below and the boundaries of proposed treatment areas are shown in Figure 16.

The initial approach to vegetation management is to use test areas to assess the practicality and effectiveness of different management strategies. As well, test areas are useful for demonstrating habitat restoration activities to park users or naturalists who may be resistant to vegetation change in parks. Test areas are shown in Figure 16.

Strategy 1 – Wood Debris Removal

While this study has concluded that wood debris plays a minor role in vegetation succession in Iona Beach Regional Park, debris removal is recommended as a management strategy for two reasons. First, wood debris traps sand in the backshore which promotes progradation and shoreline stabilization. Second, wood debris removal from the North Arm Jetty in 2009 (north of the park) successfully created large areas of sparsely-vegetated communities that are now dominated with native species. This suggests that wood debris removal in Iona Beach Regional Park would also result in the restoration of sparsely-vegetated communities.

Proposed Location. Wood debris should be removed from backshore the central portion of the park. Figure 16 shows a 0.9 ha area from which debris could be removed over the long term. Debris removal should be tested in a 1,300 m² test area to refine methods and assess impacts. A temporary access road for debris removal is also shown.
Figure 16. Proposed vegetation management areas in Iona Beach Regional Park.
Timing. Debris removal can be undertaken at any time of the year but is recommended for late-winter (February–April) prior to vegetation development. This allows vegetation such as large-headed sedge to quickly regrow in the first growing season.

Methods. Wood debris should be removed using a conventional tracked excavator with a hydraulic thumb. Approximately 80–90% of the wood debris should be removed; large and more stable pieces should be left. Debris should be removed under the direction of a biologist or environmental monitor to reduce damage to vegetation or other environmental values. Spill response equipment and other measures to mitigate construction phase impacts should be used.

Debris would be hauled to central location for loading. Conventional trucks with dump boxes (“dump trucks”) or trucks with detachable bins (“big bin”) should be used to transport the debris to the debris processing facility on the North Arm Jetty.

Cost. The estimated cost for wood debris removal from the 1,300 m² test area is $6,500 ($2,400 for excavator use; $1,500 for trucking; $1,000 for disposal; $1,600 for field supervision).

Strategy 2. Mowing and Sod Stripping

As shown in Figure 12, the manual removal of Scotch broom has been successful in reducing shrub cover to the north and south of the park building. Most of this restoration work has been undertaken by volunteers using hand-tools. While it has been successful on a small-scale, this approach has two main disadvantages. First, it is time-consuming and labour-intensive and relative to the amount of Scotch broom in Iona Beach Regional Park only a small amount has been cleared. Indeed, despite ongoing restoration efforts to remove broom since 2005, the overall area of broom in Iona Beach Regional Park has increased from 4.4 ha to 5.1 ha. Second, Scotch broom is a persistent species with a long-lived seedbank and will frequently re-establish after pulling or cutting. In some cases, soil disturbance associated with pulling can promote seedling establishment.

The recommended method for removing Scotch broom-dominated shrublands is to mow above-ground vegetation using a tractor-mounted mower and then strip off the upper 5 cm of soil with a rubber-tired backhoe or bobcat. The upper soil layer contains most of the seedbank, as well as invasive grasses and most of the organic matter in the soil profile.

As background, mowing and sod stripping was used successfully to restore sparsely-vegetated ecological communities in Island View Beach Regional Park and at Goose Spit as part of recovery for Sand-verbena Moth (Page, 2004). Several methods were tested and the best method for restoring sparsely-vegetated habitat was cutting or mowing Scotch broom plants combined with surface scalping of mosses, grasses, and their associated seedbank (see Figure 15). One of the key
advantages to this method is that it removes the accumulated seedbank as well as the grass and bryophyte mat which facilitates Scotch broom establishment. Most broom seedlings that germinate in the first 2–5 years after sod stripping do not survive late summer drought. Sod stripping has also been used to restore stabilized dunes in the Netherlands (van Til and Kooijman, 2007). Their research found that the native plant community re-established after sod cutting and invertebrates including rare butterflies and beetles increased in abundance.

**Proposed Location.** Two areas are proposed for mowing (see Figure 16): a 1.9 ha area in the northern portion of the study area, and a smaller area to the south of the park building. A test area for sod stripping is proposed for a 1,600 m² that is densely vegetated with Scotch broom and non-native grasses (Figure 16).
**Timing.** Mowing of Scotch broom should be undertaken during flowering to reduce resprouting, however, this may conflict with both bird nesting and higher park activity in early summer. Mowing should be undertaken concurrently between September 30 and April 30. Sod stripping can be undertaken at any time of year but areas should be assessed for ground-nesting birds prior to implementation.

**Methods.** Mowing should be undertaken with either a boom-mounted flail mower attached to a rubber-tired tractor, or a front mounted mulching mower that cuts and shreds all vegetated to the ground-surface (mulching mower). Brush-cutting may also be required around the margin of the work area or near obstacles such as trees, fences, or large wood debris.

Sod-stripping should be undertaken with a bobcat or a rubber-tired backhoe. The upper 5 cm of sod and soil should be stripped and stockpiled. This material should either be buried on site (minimum 1 m cover) or trucked off-site to be for use as fill.

**Cost.** The estimated cost for mowing for mowing and brushcutting (1.8 ha) is $2,800 ($2,400 for mowing and $400 for field supervision).

Estimated cost for sod stripping in the $3,800 ($2,000 for sod stripping; $1,200 for trucking and disposal; and $400 for field supervision). Costs are reduced if material can be disposed of on-site.

**Strategy 3. Revegetation of Native Ecological Communities**

Active revegetation will be required to establish native ecological communities in areas that are treated with mowing and sod stripping. Natural re-establishment of large-headed sedge and other native species is expected to occur in wood debris removal areas and no active planting is recommended.

There are four main techniques for revegetating treatment areas following mowing and sod stripping: (1) allowing natural establishment from the existing seedbank or regrowth from deep roots; (2) reseeding with desirable native species; (3) replanting with plant materials salvaged from adjacent areas or prior to disturbance; or (4) replanting from commercially available nursery grown stock. Each method is suitable for the creation of different ecological communities. Test plots are recommended to review effectiveness, cost, and practicality prior to more wide-scale implementation.

Four 20 x 20 m (400 m²) revegetation test plots are proposed (Figure 16) in the sod stripping area:
1. **No planting / natural regeneration.** One test plot should not be planted for at least two growing seasons after mowing and sod stripping to evaluate natural regeneration and establishment from the seedbank.

2. **Native beachgrass meadow.** Rooted sprigs of dune wildrye should be planted from material harvested or salvaged from adjacent areas. Planting should be completed before May 1.

3. **Shrub Thicket.** Container-grown (1 gallon) stock from commercial nurseries should be planted in an intermixed thicket. Recommended species are Nootka rose (*Rosa nootkana*) (30%), snowberry (*Symphoricarpus albus*) (30%), oceanspray (*Holodiscus discolor*) (10%), red flowering currant (*Ribes sanguineum*) (10%), thimbleberry (*Rubus parviflorus*) (10%), and black hathorne (*Crataegus douglasii*) (10%).

4. **Seeding of Native Species.** Seed from locally collected species should be distributed on one test plot to review regeneration success. Potential species include large-headed sedge, dune wildrye, red fescue (*Festuca rubra*), Puget gumweed (*Grindelia integrifolia*), common yarrow, and beach pea.

**Proposed Location.** The proposed for revegetation test plots is within areas treated with both mowing and sod stripping (see Figure 16).

**Timing.** All planting should be complete by May 15 to increase root development prior to the onset of summer drought. Supplemental watering may be required during the first growing season to improve establishment success.

**Methods.**

**Native beachgrass meadow.** Large clumps of dune wildrye should be harvested from healthy stands within or adjacent to Iona Beach Regional Park. Clumps should be carefully separated into single sprigs with intact roots. Sprigs should be planted 10 cm deep using a narrow spade at a density of 5 per square meter (2,000 sprigs for 400 m² test plot).

**Shrub Thicket.** Container grown plants should be planted at an average spacing of 1.2 m on centre (350 plants for 400 m² test plot). Plants should be intermixed but planted in groups of 3 to 10 of the same species. Care must be taken to ensure the crown of the root ball is below the surface of the soil. Grid or other uniform planting methods should be avoided.

**Seeding of Native Species.** Seed should be collected from plants within Iona Beach Regional Park and distributed by hand on to the surface of the test plot. Hand trampling and surface raking should be used to increase germination success.

**Cost.** The overall cost of the revegetation test plots is $4,800. This includes:
• $1,200 in labour and materials to harvest and plant dune wildrye sprigs;
• $3,200 for materials and plant materials for shrub thicket plantings ($2,100 in plant costs (350 plants x $6/unit) and $1,100 in planting); and
• $400 in labour and materials for seed collection and seeding.

**Monitoring**

The success of the vegetation management strategies should be evaluated using three monitoring approaches:

1. Photodocumentation of before, during, and after vegetation management should be undertaken. Permanent photo monitoring points (posts or other structures) should be installed but more general photos are also effective at documenting vegetation change. Permanent plots described below should also be photodocumented from each corner looking towards the centre.

2. Permanent vegetation plots (10 m x 10 m with fixed corner posts) should be used to quantify vegetation change. The abundance (% cover or number of plants) and composition (species richness) should be measured before and after implementation. Scotch broom regeneration should be measured by counting seedlings at the end of the growing season during the first 3 years.

3. More general observations and photos are also effective at assessing success such as mowing effectiveness, plant health, exposure of sand, and wildlife use (butterflies, bird use, etc).
References


Appendices
### Appendix 2. Iona Beach Regional Parks Vegetation Plots (August 2010) (non-native species are denoted with an asterisk).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cytisus scoparius*</td>
<td>0.1</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubus armeniacus*</td>
<td></td>
<td>2.5</td>
<td>0.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Grasses and Forbs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achillea millefolium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agrostis sp.*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aira praecox*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anthoxanthum odoratum*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aster sp. (non-native)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aster subspicatus</td>
<td>0.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atriplex patula</td>
<td></td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bromus sp.*</td>
<td>0.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cakile edentula*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carex macrocephala</td>
<td>0.1</td>
<td>2.5</td>
<td>75</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cirsium vulgare*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distichlis spicata</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epilobium ciliatum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Festuca rubra</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geranium sp.*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grass unidentified*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypericum perforatum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypochaeris radicata*</td>
<td>0.1</td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iris pseudacorus*</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juncus effusus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lathyrus japonicus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leymus mollis</td>
<td>20</td>
<td>40</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lupinus polyphyllus (?)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lythrum salicaria*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantago lanceolata*</td>
<td>0.1</td>
<td>0.1</td>
<td>15</td>
<td>7.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potentilla egedii</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rumex acetosella*</td>
<td>1</td>
<td>1.5</td>
<td>2.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schoenoplectus americanus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sonchus asper*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vulpia myuros*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total Cover**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.7</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>99</td>
<td>5</td>
<td>75</td>
<td>2.5</td>
<td>63</td>
<td>60</td>
<td>26</td>
<td>100.1</td>
<td>45</td>
<td>125</td>
<td>0.5</td>
<td>3</td>
<td>5.2</td>
<td>72.1</td>
<td>25</td>
<td>40.5</td>
<td>85.2</td>
<td>92.4</td>
<td>100.1</td>
<td>2.8</td>
<td></td>
</tr>
</tbody>
</table>
### Particle size analysis results based on Gradistat for sand samples from Iona Beach Regional Park (August 2010).

<table>
<thead>
<tr>
<th>Sample 313</th>
<th>Sample 362</th>
<th>Sample 314</th>
<th>Sample 315</th>
<th>Sample 374</th>
<th>Sample 375</th>
<th>Sample 312</th>
</tr>
</thead>
<tbody>
<tr>
<td>METHOD OF MEANS</td>
<td>LOGARITHM (µm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MEAN (µm)</td>
<td>339.7</td>
<td>348.3</td>
<td>324.599</td>
<td>325.4</td>
<td>327.4</td>
<td>324.717</td>
</tr>
<tr>
<td>Q10 (µm)</td>
<td>301.7</td>
<td>304.18</td>
<td>300.792</td>
<td>302.3</td>
<td>303.8</td>
<td>304.4</td>
</tr>
<tr>
<td>D50 (µm)</td>
<td>324.5</td>
<td>324.566</td>
<td>325.3</td>
<td>325.1</td>
<td>325.5</td>
<td>324.1</td>
</tr>
<tr>
<td>D90 (µm)</td>
<td>47.746</td>
<td>48.605</td>
<td>48.333</td>
<td>47.969</td>
<td>48.739</td>
<td>49.418</td>
</tr>
<tr>
<td>D10 (µm)</td>
<td>1.056</td>
<td>1.092</td>
<td>1.098</td>
<td>1.109</td>
<td>1.124</td>
<td>1.109</td>
</tr>
<tr>
<td>Q10 (µm)</td>
<td>29.3</td>
<td>28.8</td>
<td>29.13</td>
<td>29.4</td>
<td>29.4</td>
<td>29.4</td>
</tr>
<tr>
<td>% COARSE SAND</td>
<td>1.517</td>
<td>1.517</td>
<td>1.517</td>
<td>1.517</td>
<td>0.044</td>
<td>1.516</td>
</tr>
<tr>
<td>% MEDIUM SAND</td>
<td>1.729</td>
<td>1.729</td>
<td>1.729</td>
<td>1.729</td>
<td>1.729</td>
<td>1.729</td>
</tr>
<tr>
<td>% FINE SAND</td>
<td>1.140</td>
<td>1.140</td>
<td>1.134</td>
<td>1.138</td>
<td>1.143</td>
<td>1.143</td>
</tr>
<tr>
<td>% V. FINE SAND</td>
<td>0.512</td>
<td>0.512</td>
<td>0.512</td>
<td>0.512</td>
<td>0.512</td>
<td>0.512</td>
</tr>
<tr>
<td>% COARSE SILT</td>
<td>0.532</td>
<td>0.532</td>
<td>0.532</td>
<td>0.532</td>
<td>0.532</td>
<td>0.532</td>
</tr>
<tr>
<td>% MEDIUM Silt</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>% V. MEDIUM Silt</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>% FINE Silt</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>% V. FINE Silt</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

### Additional Data
- **Mode 1 (µm):** 327.5
- **Mode 2 (µm):** 327.5
- **Mode 3 (µm):** 327.5
- **Mode 4 (µm):** 327.5
- **Mode 5 (µm):** 327.5
- **Mode 6 (µm):** 327.5
- **Mode 7 (µm):** 327.5
- **Mode 8 (µm):** 327.5
- **Mode 9 (µm):** 327.5
- **Mode 10 (µm):** 327.5
- **Mode 11 (µm):** 327.5
- **Mode 12 (µm):** 327.5
- **Mode 13 (µm):** 327.5
- **Mode 14 (µm):** 327.5
- **Mode 15 (µm):** 327.5
- **Mode 16 (µm):** 327.5
- **Mode 17 (µm):** 327.5
- **Mode 18 (µm):** 327.5
- **Mode 19 (µm):** 327.5
- **Mode 20 (µm):** 327.5
- **Mode 21 (µm):** 327.5
- **Mode 22 (µm):** 327.5
- **Mode 23 (µm):** 327.5
- **Mode 24 (µm):** 327.5
- **Mode 25 (µm):** 327.5
- **Mode 26 (µm):** 327.5
- **Mode 27 (µm):** 327.5
- **Mode 28 (µm):** 327.5
- **Mode 29 (µm):** 327.5
- **Mode 30 (µm):** 327.5
- **Mode 31 (µm):** 327.5
- **Mode 32 (µm):** 327.5
- **Mode 33 (µm):** 327.5
- **Mode 34 (µm):** 327.5
- **Mode 35 (µm):** 327.5
- **Mode 36 (µm):** 327.5
- **Mode 37 (µm):** 327.5
- **Mode 38 (µm):** 327.5
- **Mode 39 (µm):** 327.5
- **Mode 40 (µm):** 327.5

- **% Coarse Gravel:** 0.0%
- **% Medium Gravel:** 0.0%
- **% Fine Gravel:** 0.0%
- **% Coarse Sand:** 0.0%
- **% Medium Sand:** 0.0%
- **% Fine Sand:** 0.0%
- **% Coarse Silt:** 0.0%
- **% Medium Silt:** 0.0%
- **% Fine Silt:** 0.0%
- **% Coarse Clay:** 0.0%
- **% Medium Clay:** 0.0%
- **% Fine Clay:** 0.0%
SAMPLE STATISTICS

SAMPLE IDENTITY: 
SAMPLE TYPE: Unimodal, Very Well Sorted 
TEXTURAL GROUP: Slightly Gravelly Sand 
SEDIMENT NAME: Slightly Very Fine Gravelly Medium Sand

GRADE SIZE DISTRIBUTION

| MODE 1:  | 327.5 | 1.616 |
| MODE 2:  | 325.0 | 1.621 |
| MODE 3:  | 350.6 | 1.731 |
| D10:     | 301.3 | 1.512 |
| D50:     | 325.0 | 1.621 |
| D90:     | 350.6 | 1.731 |
| (D90 / D10): | 1.164 | 1.145 |
| (D90 - D10): | 49.30 | 0.219 |
| (D75 / D25): | 1.099 | 1.088 |
| (D75 - D25): | 30.80 | 0.137 |

| GRAVEL: 0.5% | COARSE SAND: 1.9% |
| SAND: 99.5%  | MEDIUM SAND: 88.9% |
| MUD: 0.0%    | FINE SAND: 7.7%   |
| V FINE SAND: 0.0% |

D10: V FINE SAND: 0.0%
MEDIAN or D50: V COARSE GRAVEL: 0.0%
D90: COARSE GRAVEL: 0.0%
(D90 / D10): MEDIUM GRAVEL: 0.0%
(D90 - D10): FINE GRAVEL: 0.1%
(D75 / D25): V FINE GRAVEL: 0.3%
(D75 - D25): V FINE SILT: 0.0%

METHOD OF MOMENTS

| MEAN (μ): | 356.6 | 324.6 | 1.623 |
| SORTING (σ): | 287.2 | 1.405 | 0.490 |
| SKEWNESS (Sk): | 9.819 | 2.789 | -2.789 |
| KURTOSIS (K): | 132.3 | 21.04 | 21.04 |

FOLK & WARD METHOD

<table>
<thead>
<tr>
<th>GEOMETRIC</th>
<th>LOGARITHMIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>325.0</td>
<td>1.621</td>
</tr>
<tr>
<td>1.156</td>
<td>0.210</td>
</tr>
<tr>
<td>-0.386</td>
<td>0.386</td>
</tr>
<tr>
<td>3.232</td>
<td>3.232</td>
</tr>
</tbody>
</table>

GRAIN SIZE DISTRIBUTION

Class Weight (%)

Particle Diameter (µm)

0 100 1000 10000 100000

0.0 10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0

0.0 1.0 3.0 5.0 7.0

5.0 3.0 1.0 -1.0 -3.0 -5.0 -7.0

0.0 100 1000 10000

Arithmetic Geometric Logarithmic