BEAVER HERBIVORY BEHAVIOR AND ITS IMPACT ON HABITAT
RESTORATION IN THE SOUTH SLOUGH NATIONAL ESTUARINE
RESEARCH RESERVE

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North American beavers (*Castor canadensis*) are ecological engineers that improve biodiversity and can improve the health of riparian ecosystems. Beavers are generalist herbivores with some evidence of species preference, utilizing woody material for both food source and dam construction. In the South Slough National Estuarine Research Reserve, Charleston, Oregon, a restoration project is underway to restore the Wasson creek tributary. The creek has become inundated with invasive reed canary grass (*Phalaris arundinacea*) severely reducing riparian biodiversity. To better understand how the beaver population at South Slough are utilizing the estuary, trail cameras were installed to record beaver activity and tree surveys up to 40m perpendicular to the stream bank were conducted to determine herbivory preference by recording species, size, distance from the streams edge and form of beaver herbivory present at Wasson creek (restoration site), Anderson creek (20-year post-restoration site), and Tom’s creek (reference site). The surveys showed preference for sitka willow (*Salix sitchensis*), red alder (*Alnus rubra*) and cascara (*Rhamnus purshiana*) trees. Beaver herbivory focused individuals with a diameter at breast height (DBH) equal to or under 30cm. The distance measurements showed herbivory of preferred species at all intervals along the 40m transects perpendicular to stream ban. However, beavers did go long distances away from the stream to seek out non-preferred species. These findings suggest that this beaver population will seek out specific preferred tree species, making it likely the beavers will utilize the Sitka willows planted for habitat restoration. Trail camera footage showed high levels of activity in Anderson and Tom’s creeks with some activity at Wasson creek, suggesting the improved
conditions of Wasson creek post-restoration may encourage immigration from the other creeks.

Trail cameras also revealed that beavers will climb trees to seek out specific branches high up on the trees.

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Introduction

The North American beaver (*Castor canadensis*) is the largest rodent in North America, it is semi aquatic and known for its unique large oblong tail that is utilized in dam construction. *C. canadensis* is the only extant species on the North American continent and is often viewed as a pest due to the impact their dams have on human property. North American beavers (*C. canadensis*) were hunted for many years for their pelts and use of their musk as castoreum which was widely used in perfumes, food additives and tincture in the early 1900s. Both factors contributed to a significant population decline in the early 1900s which has since rebounded; they are now classified as a species of least concern by the International Union for Conservation of Nature’s (IUCN) Red List of Threatened Species (Cassola 2016). *C. canadensis* is now widely distributed across the Northern United States and Canada, and is the official national animal of Canada and the state mammal of Oregon and New York.

North American beavers (*C. canadensis*) have continuously growing incisors that are adapted to digest plant material as their primary food source. *C. canadensis*’ diet consists of a mix of herbaceous and woody plant material and are known to be generalists with some evidence of species preference (Vorel et al. 2015). In addition to feeding on woody plants, beavers utilize branches, and will fell entire trees for use in dam and lodge construction. Dams and lodges are thought to be for the purpose of predator evasion and shelter, *C. canadensis* will utilize woody material, as well as mud, rocks, and grass to build these structures. In the creation of dams beavers are able to dramatically alter the landscape of their habitat, making them both habitat engineers and keystone species (Law et al. 2017, Schulte & Dietland 1999). The presence of beavers tends to have positive impacts on fish, insect, bird, and vegetation biodiversity.
Because beavers introduce dead wood into water systems they create habitat for both fish and insects, this in turn causes an improved habitat for amphibians, reptiles and birds that utilize both the fish and insects. Additionally, beaver’s use of woody plant material curates greater diversity in plant life, prevents soil erosion, increases mineral sediment deposits in streams, enhances nutrient retention and biological uptake, and overbank flow to name a few. (Rosell & Campbell-Palmer 2002) For this project I studied the North American beaver’s herbivory behavior at Wasson creek, Anderson creek and Tom’s creek in the South Slough National Estuarine Research Reserve, and the impact it has on the planned restoration of Wasson creek.

The South Slough National Estuarine Research Reserve (SSNERR) is a system of estuarine creeks and rivers comprising the South Slough Watershed which is part of the greater Coos Watershed in Coos Bay, Oregon. The watershed was designated in 1974 as the first National Estuarine Research Reserve System (NERRS) as part of the 1972 Coastal Zone Act for the purpose of research, education, and coastal stewardship. NOAA and Oregon DSL work in collaboration with the Coquille Indian Tribe, Confederated Tribes of the Coos, Coos Watershed Association and Partnership for Coastal watersheds amongst other stakeholders to manage the slough. SSNERR is currently being managed by the Oregon Department of State Land (DSL) in conjunction with the National Oceanic and Atmospheric Administration (NOAA). The drainages of focus for current research and management are the restoration site Wasson, the 20-year post-restoration site Anderson, and the reference site Tom’s. The Wasson creek drainage was historically clear cut for use as cattle pasture, causing dramatic changes for the marsh. The introduction of cattle brought with it significant changes to the flora and topography of the
drainage; the soil became compacted, streams were redirected, and invasive reed canary grass (*Phalaris arundinacea*) was introduced. (State of Oregon 2017)

To restore the Wasson drainage Oregon DSL plans to mow, treat with herbicide, then manually remove most of the grass from the lower portion of the drainage with earth moving machinery. However, the ground in the upper Wasson drainage is not compact enough for earth moving equipment, so there is ongoing discussion about the best means of removing the invasive reed canary grass (*Phalaris arundinacea*) in the upper creek with both controlled burns and grazing as potential options. Once the grass is removed reintroduction of riparian trees including sitka willows (*Sagittaria latifolia*), red osier dogwood (*Cornus sericea*), and pacific crabapple (*Malus fusca*) will begin along the creek bed to shade out the remaining grass and seeds and reduce its regrowth (Figure 1). (Management Plan for South Slough 2017)

<table>
<thead>
<tr>
<th>Species</th>
<th>Quantity</th>
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</thead>
<tbody>
<tr>
<td>Small-fruited bulrush (<em>Scirpus microcarpus</em>)</td>
<td>3800</td>
</tr>
<tr>
<td>Slough sedge (<em>Carex obnupta</em>)</td>
<td>3800</td>
</tr>
<tr>
<td>Soft rush (<em>Juncus effusus</em>)</td>
<td>3800</td>
</tr>
<tr>
<td>Tufted hairgrass (<em>Deschampsia cespitosa</em>)</td>
<td>3800</td>
</tr>
<tr>
<td>Common three-square (<em>Schoenoplectus pungens</em>)</td>
<td>3800</td>
</tr>
<tr>
<td>Gumweed (<em>Grindelia integrifolia</em>)</td>
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<tr>
<td>Pacific silverweed (<em>Potentilla anserina</em> ssp. <em>Pacifica</em>)</td>
<td>3700</td>
</tr>
<tr>
<td>Common camas (<em>Camassia quamash</em>)</td>
<td>600</td>
</tr>
<tr>
<td>Wapato (<em>Sagittaria latifolia</em>)</td>
<td>As available</td>
</tr>
<tr>
<td>Willow (<em>Salix sp.</em>)</td>
<td>5200</td>
</tr>
<tr>
<td>Red osier dogwood (<em>Cornus sericea</em>)</td>
<td>2800</td>
</tr>
<tr>
<td>Red elderberry (<em>Sambucus racemosa</em>)</td>
<td>2550</td>
</tr>
<tr>
<td>Indian plum (<em>Oemleria cerasiformis</em>)</td>
<td>2550</td>
</tr>
<tr>
<td>Oregon ash (<em>Fraxinus latifolia</em>)</td>
<td>2550</td>
</tr>
<tr>
<td>Pacific crabapple (<em>Malus/Pyrus fusca</em>)</td>
<td>2650</td>
</tr>
<tr>
<td>Nootka rose (<em>Rosa nudkana</em>)</td>
<td>100</td>
</tr>
<tr>
<td>Oceanspray (<em>Holodiscus discolor</em>)</td>
<td>800</td>
</tr>
<tr>
<td>Tiger lily (<em>Lilium columbianum</em>)</td>
<td>200</td>
</tr>
<tr>
<td>Sitka spruce (<em>Picea sitchensis</em>)</td>
<td>700</td>
</tr>
<tr>
<td>Western red cedar (<em>Thuja plicata</em>)</td>
<td>600</td>
</tr>
<tr>
<td>Western hemlock (<em>Tsuga menziesii</em>)</td>
<td>600</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>40,800</strong></td>
</tr>
</tbody>
</table>

Figure 1: Table showing the quantity of each species being utilized by Oregon Department of State Land to revegetate Wasson Creek (Brickner 2017)
**Purpose**

The purpose of this study was to learn how this beaver population is utilizing the South Slough estuary in order for management agencies to tailor their revegetation plans for the Wasson creek to the population’s needs. My plan was to survey the riparian zone of the Wasson, Anderson, and Tom’s drainage and determine the current beaver herbivory activity and establish species preference to adjust the amount and type of riparian trees needed to support the beaver population while allowing enough trees to shade out the invasive grass. I planned to also utilize trail cameras to get a better idea of how the beaver population is utilizing the resources in the area, and if the current dams are being actively maintained. I anticipated minimal if any beaver activity in the Wasson creek drainage, and that the beavers that are utilizing the estuary show preference for sitka willow (*Sagittaria latifolia*) and red alder (*Alnus rubra*) trees over other riparian trees and shrubs.

**Site Description**

The Wasson Creek drainage system is the focus of this project, it is the site in the South Slough National Estuarine Research Reserve that is being actively restored. Wasson Creek is situated on the southern portion of the Winchester arm of the estuary, it runs parallel to the Anderson creek and both are adjacent to the Tom’s creek drainage. All three drainage systems are sub-basins contributing to Winchester creek, the largest tributary of the South Slough watershed. The drainages are predominantly freshwater with the influence of saltwater most pronounced in the summer when the freshwater input is low. The estuary experiences mild tidal cycles with two high tides and two low tides per day, however circulation patterns in the estuary are complex and poorly understood. (State of Oregon 2017) The South Slough watershed lies
along the South Slough geologic syncline and channels into the Coos bay, this means the eastern and western slopes are geologically distinct. The Wasson creek drainage is in the eastern part (Winchester arm) of the estuary which is composed of highly-erodible Quaternary marine terraces of sand, silt and clay, while the western (Sengstacken arm) portion of the estuary is composed of hard impermeable sandstone. Despite the degradation to the Wasson creek drainage the water quality of the estuary is within healthy parameters of salinity, oxygen, pH, chlorophyll, nutrient, and specific conductivity. (Management Plan for South Slough 2017)

The Anderson creek drainage, like Wasson creek, was invaded by reed canary grass (*Phalaris arundinacea*) but was restored in 2001. The restoration process included reconstruction of the pilot channel, which had become downcut restricting salmonid and beaver habitat and increased turbidity. The invasive reed canary grass was then removed, large felled conifers were introduced to the pilot channel and riparian trees, shrubs and sedges were replanted. In the 20 years since its restoration Anderson creek has deterred the return of the reed canary grass, and now has a thriving beaver and salmonid population. The creek is now primarily comprised of mixed conifers, riparian deciduous trees, shrubs and sedges, while it has more dense creek bed canopy the creek is still relatively homogenous with sitka willows (*Salix sitchensis*) and red alders (*Alnus rubra*) dominating the site. This site is used as an indicator of the likely conditions of Wasson creek post-restoration. (Cornu 2005)

The Tom’s creek drainage is the restoration management’s reference site; it was never invaded by reed canary grass from cattle grazing, and is one of the least disturbed sites in the estuary. It is classified as a bulrush and sedge saltwater marsh and is a watershed sub-basin that drains the eastern side of the South Slough syncline. Tom’s creek is an open expansive saltwater
marsh with narrow shallow tidal channels with a maximum depth of -2.2m. The creek's tidal waters have a tidal amplitude of 2.0m and a mean salinity of 4-20psu with temperatures ranging from 8-18°C. The tidal habitat is surrounded by an upland forest of mixed conifers and deciduous trees over 70 years old. (Rumrill 2006) The Tom’s creek drainage has served as the reference site for the restoration of both Anderson and Wasson creeks amongst others in the estuary, by utilizing historic aerial photos of the creek to estimate creek channel characteristics. (Cornu 2005)

The forest surrounding the Wasson drainage is comprised primarily of douglas fir (*Pseudotsuga menziesii*) but is also mixed with sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and cedars (*Chamaecyparis lawsoniana* and *Thuja plicata*). Wasson creek’s riparian zone has been invaded by reed canary grass (*Phalaris arundinacea*), outcompeting most other plant species, but scattered red alder (*Alnus rubra*), cascara (*Rhamnus purshiana*), and sitka spruce (*Picea sitchensis*), and some shrub species remain. The basin of the drainage is flat with compacted soil and small streams lacing across what was once marshland. Currently the basin is so invaded by reed canary grass that the streams are rarely visible in the summer and fall. The water flow through the drainage is minimal with many locations of little to no flow. Once in the upper riparian zone biodiversity increases, and several species of shrub are abundant primarily Himalayan blackberry (*Rubus armeniacus*), trailing blackberry (*Rubus ursinus*), salmonberry (*Rubus spectabilis*), salal (*Gaultheria shallon*), red huckleberry (*Vaccinium parvifolium*), evergreen huckleberry (*Vaccinium ovatum*), and pacific rhododendron (*Rhododendron macrophyllum*). Several sites in the estuary had been used for commercial timber harvesting and clear cutting, reducing the density of old growth and homogenizing much
of the forest. Regional weather is consistent with coastal Oregon with cool moist winters and mild summers, with average precipitation around 56in per year. (Management Plan for South Slough 2017, Rumrill 2006)

Image 1: South Slough watershed and reserve boundary map (State of Oregon 2017)
Image 2: Mapping of non-native vegetation at Wasson creek, showing the extent of the reed canary grass inundation. (Management Plan for South Slough 2017)

<table>
<thead>
<tr>
<th>Camera</th>
<th>Site</th>
<th>Map Location</th>
<th>Site Description</th>
<th>Site Photo</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Wasson</td>
<td><img src="image1" alt="Map Location A" /></td>
<td>Facing red alder with evidence of recent herbivory, adjacent to mudslip upstream from a dam.</td>
<td><img src="image2" alt="Site Photo A" /></td>
</tr>
<tr>
<td>B</td>
<td>Wasson</td>
<td><img src="image3" alt="Map Location B" /></td>
<td>Facing dam under large sitka spruce</td>
<td><img src="image4" alt="Site Photo B" /></td>
</tr>
<tr>
<td>Camera</td>
<td>Site</td>
<td>Map Location</td>
<td>Site Description</td>
<td>Site Photo</td>
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<td>--------</td>
<td>--------------</td>
<td>------------------------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>C</td>
<td>Toms</td>
<td><img src="image" alt="Map C" /></td>
<td>Facing open channel near possible lodge</td>
<td><img src="image" alt="Site C" /></td>
</tr>
<tr>
<td>D</td>
<td>Anderson</td>
<td><img src="image" alt="Map D" /></td>
<td>Facing beaver slide near heavy willow herbivory and resprouting</td>
<td><img src="image" alt="Site D" /></td>
</tr>
<tr>
<td>E</td>
<td>Toms</td>
<td><img src="image" alt="Map E" /></td>
<td>Facing possible lodge, next to signs of heavy herbivory and beaver slide</td>
<td><img src="image" alt="Site E" /></td>
</tr>
<tr>
<td>F</td>
<td>Anderson</td>
<td><img src="image" alt="Map F" /></td>
<td>Facing stream with evidence of beaver paw marks in mud, and possible dam</td>
<td><img src="image" alt="Site F" /></td>
</tr>
</tbody>
</table>

Figure 2: List of trail cameras, their location and what is being observed.
Image 3: Wasson creek and dam

Image 4: Anderson Creek and dam

Image 5: Toms creek and dam
**Methods**

To assess the beaver population’s herbivory, surveys of beaver herbivory on trees in the riparian zone were conducted. The surveys consisted of 6 transects of both the upper and lower Wasson drainage, as well as the Tom’s reference site and the Anderson post-restoration site.

Each of the 4 survey sites were broken into 100m quadrants using GIS and Avenza Maps software as seen in images 6-9. The starting point for the transect was determined based on an initial beaver herbivory point within the 100m quadrant, if no herbivory was found the transect starting point was placed at the edge of the quadrant. At the Toms site it was decided to place two transects in the first quadrant as the third quadrant is exceptionally marshy and would be difficult to access by foot (image 9). Once the starting point was established, 50 meter measuring tapes were fastened by the same point flag and rolled out 40m in opposite directions, noting the azimuth of both transects. Each transect was then divided into 5m quadrants, in each quadrant the nearest tree and trees with herbivory were recorded. All recordings included species, diameter at breast height (DBH) in centimeters, form of herbivory (none, stripped, gnawed, girdled, or felled), interval along transect (0-5m, 5-10m,... 35-40m), location within the estuary (Lower, Mid, or Upper quadrant), GPS coordinates, and a photo of the herbivory when present. To create consistency across all of the data Survey 123 was used and data exported to ArcGIS online, the surveys were done at the beginning of September as fall is the most active season for beavers (ODFW 2009).

It was assumed that bark stripped above a reasonable height for a beaver to reach was created by porcupines rather than beavers and was excluded. When two forms of herbivory
were present on the same tree only the most severe form was recorded with felled more severe than girdled, girdled more severe than gnawed, and gnawed more severe than stripped.

Game cameras were then placed at sites with particularly dense or fresh herbivory, with 2 cameras facing each site from different angles at each creek (Figure 2). 6 total cameras were set up and maintained from September 7, 2021 to May 14, 2022. Images were manually analyzed for activity.

Once the data was collected it was processed using RStudio to graphically analyze the beaver population's herbivory preference based on size, species and distance from the stream. The Oregon DSL will then use this information to strategically plant riparian shade trees throughout the Wasson Creek drainage to prevent or limit reed canary grass growth. Dr. Benjamin Dittbrenner founder of Beavers Northwest, and Jen Vanderhoof president of Beavers Northwest were consulted about the findings of the trail cameras and beaver behavior. The Oregon State University Statistical Consultation program also provided guidance on the analysis of this data.
Image 7: Wasson creek upper section with 100m quadrant overlay and with transect start points

Image 8: Anderson creek with 100m quadrant overlay and with transect start points

Image 9: Toms creek with 100m quadrant overlay and with transect start points
Results

The following figures show the relationships between the size, type of beaver herbivory, tree species, and the trees distance from the stream edge. This data was collected from 3 individual sites, the future restoration site “Wasson”, the post-restoration site “Anderson”, and the reference site “Toms”. Per the recommendations from the OSU statistical consultation a statistical hypothesis test was not conducted due to a lack of independence and data bias based on the selection of transect location, instead the data was used for trend visualization. The tree species recorded includes: red alder (Alnus rubra or “ALNRUB”), Port Orford cedar (Chamaecyparis lawsoniana or “CHALAW”), salal (Gaultheria shallon “GAUSA”), pacific wax myrtle (Myrica californica or “MYRCAL”), sitka spruce (Picea sitchensis or “PICSIT”), douglas fir (Pseudotsuga menziesii or “PSEMEN”), cascara (Rhamnus purshiana or “RHAPUR”), pacific rhododendron (Rhododendron macrophyllum or “RHOMAC”), sitka willows (Salix sitchensis or “SALSIT”), red elderberry (Sambucus racemosa or “SAMRAC”) western redcedar (Thuja plicata or “THUPLI”), western hemlock (Tsuga heterophylla or “TSUHET”). Abbreviations for the tree species listed are consistent with the format utilized by the Oregon DSL management team. For the purposes of this study some species traditionally classified as shrubs but measuring more than 2cm DBH have been classified as trees and counted towards the analysis of beaver interactions with trees.
Figure 3: Size distribution of sampled trees and the form of herbivory present at the South Slough survey sites.

Figure 3 shows all trees with herbivory present have a DBH under 40cm, with the exception of two outlying occurrences of herbivory on larger sitka spruces (PICSIT) one with a DBH of 162.7cm, and one with a DBH of 77.8cm both at Wasson creek. Additionally, the largest felled tree recorded was a cascara (RHAPUR) with a DBH of 17.7cm off transect at Tom's creek.
In figure 4 we can see the beavers in South Slough showed more discriminatory size preference for some species than others. In the case of sitka spruce (PICSIT) there appears to be a preference for gnawing larger trees between 80cm and 160cm DBH, while preference was shown towards smaller trees of red alder (ALNRUB), cascara (RHAPUR), and sitka willow (SALSIT) across all herbivory forms. Girdling was not observed on any of the transects, but was grossly observed at the Toms site to a red alder (image 18).
In figure 5 we observed trees with all 4 types of herbivory in all quadrants of the transect, rather than clustered along the stream edge, however only red alder (ALNRUB), cascara (RHAPUR), and sitka willow (SALSIT) showed consistent herbivory at every interval of every form of herbivory.
Figure 6: Frequency of each observed species of tree at Wasson creek.

Figure 7: The relationship between the abundance of herbivory and the availability of each species of tree observed at Wasson creek.
Figure 8: Frequency of observed tree species at Anderson creek

Figure 9: The relationship between the form of herbivory and the availability of each species of tree observed at Anderson creek
Based on figures 6-11 we can conclude that the beaver native to the South Slough reserve show preference for specific species of trees. In figures 6, 8, and 10 we can see that the most abundant species is not always the most utilized. For example, figure 6 shows sitka spruce (PICSIT) as one of the most abundant species at Wasson creek, but 85.71% of observed sitka
spruce had no observed herbivory. The species with the highest percentage of herbivory was wax myrtle (MYRCAL) with 100% observed herbivory at Wasson (figure 7) and Toms (figure 11), but was not observed at Anderson creek. However, both Wasson and Toms had very little abundance of wax myrtle with only one individual at Wasson and 3 at Toms (figures 6 and 10). At Anderson creek the highest percentage of observed herbivory was sitka willow (SALSIT) with 91.75% observed herbivory from a total of 97 individual trees (figure 9). At Tom’s creek there was 1 sitka willow with stripping observed but sitka willows were absent from Wasson creek. Additionally red alder (ALNRUB) had a 100% observed herbivory at Tom’s (figure 11) from 3 observed individuals while Anderson (figure 9) had 30 individuals with a 60% observed herbivory and Wasson (figure 7) had 8 individuals with 37.50% observed herbivory. Surprisingly, cascara (RHAPUR) appeared to be at the top of the list of favorites at the sites where it was present, at Wasson there were 18 individuals with 50% herbivory observed and Tom’s had 25 individuals with a 32% herbivory, but was absent from Anderson creek.

The collective data shows each site has a preferred species, and auxiliary species that are common amongst all 3 sites. Additionally, this preferred species is not always the most abundant species which could suggest the beavers are actively seeking out specific species of trees. Sampling was also indiscriminate of age of herbivory so we cannot assess if beavers are returning to trees with existing herbivory.
Image 10: Trail camera footage from camera F at Anderson of beaver moving large tree limb through the water.

Image 11: Trail camera footage from camera F at Anderson of beaver utilizing grass.
Image 12: Trail camera footage from camera B at Wasson of beaver coming out of stream up steep embankment.

Image 13: Trail camera footage from camera A at Wasson of beaver climbing red alder, same tree had evidence of herbivory 4ft. < from the ground (images 14 &15).
Image 14 and 15: Evidence of beaver herbivory in a red alder tree, approximately 4ft or more from the ground. This tree was the focal point of camera A at Wasson creek.

Image 16: Trail camera footage from camera E at Toms of beaver possibly eating a branch.
Image 17: Trail camera footage from camera E at Toms of possible juvenile beaver.

Image 18: Photo of girdled red alder at Tom's creek.
Discussion

The results of this study show size and species have more correlation to beaver herbivory than perpendicular distance from a stream. However, different patterns emerged at each site, which can likely be attributed to the abundance of vegetation available. At Wasson creek there is far less tree density and diversity than Anderson and Tom’s creek. Because of the difference in riparian tree abundance we see more variety in the species being utilized at Toms and Anderson as well as more frequency in beaver activity. There is evidence of elevated herbivory rates of sitka willow (SALSIT) and red alder (ALNRUB) when available, supporting the conclusion that beavers show preference amongst tree species. Additionally, there was ample evidence of cascara (RHAPUR) herbivory at the sites where it was present. While this would be understandable where riparian tree cover is sparse like Wasson creek, it is unexpected at sites with riparian tree abundance and diversity like Tom’s creek. This suggests that further research is needed in order to properly understand the beavers utilization of cascara in this estuary.

The data collected showed minimal patterns in the trees observed with herbivory and their distance perpendicular to the stream’s edge. Felled trees were found up to 40m away from a stream and as close as <5m. This implies that beavers prefer specific species evoking a willingness to traverse the terrain, sometimes at an incline, to seek out the species they desire. From looking at figure 5 we can see that the tree species that have already been established as preferential species; cascara (RHAPUR), sitka willow (SALSIT), and red alder (ALNRUB) were the species that showed consistent herbivory at all intervals along the transect while other species did not. This conclusion is supported by Vorel et al (2015) where it was found that Eurasian beavers foraging behavior showed plasticity with consistency in preference for Salix spp. and
*Populus spp.* However, the study found the beavers would travel as far as 200m for preferred species. It is reasonable to assume that this behavior is similar in the North American beaver.

The level of beaver herbivory present at both Anderson and Tom’s creek suggest the sites are inhabited by thriving beaver populations. This gives reason to believe that with the restoration of Wasson creek and an influx of resources adequate to sustain beaver herbivory, there is likely to be an increase in the beaver population and herbivory at the Wasson site post restoration (Epps et al. 2021, Epps Interview Feb 23, 2022). Additionally, camera footage from Camera E at Tom’s creek showed juvenile beaver’s inhabiting a lodge near the camera (image 17). The footage supports the suggestion that the beaver population at Tom’s creek is thriving but also means the juveniles may emigrate from the populus creeks to neighboring creeks such as Wasson if conditions are appropriate. While this may seem problematic during the early stages of vegetation establishment in restoration projects, an increase in the beaver populations after the vegetation is established at Wasson creek could have long-term habitat restoration and maintenance benefits. The Anderson Creek reference site reflects the potential future conditions at Wasson. Beaver populations at Anderson Creek created habitat diversity without depleting the resources needed to both sustain the beaver population and prevented reed canary grass reestablishment.

Considering the revegetation species prescribed for the Wasson creek restoration plan (Brickner 2017), my surveys revealed abundant herbivory of sitka willow (*SALSIT*) in both Tom’s and Anderson creeks. The Wasson creek restoration plan prescribes 5200 sitka willows to be planted at the Wasson site. Our herbivory findings suggest that this number of planted willows should be ample to support revegetation and beaver activity at the site. However, the
revegetation plan does not prescribe planting red alder (ALNRUB), a species showing abundant beaver herbivory preference at all of the study sites. The Wasson Creek restoration plan anticipates that sufficient numbers of red alder will naturally seed-in. The addition of red alder to the revegetation plan may be advisable since it is actively utilized by the beavers in this estuary and may alleviate some of the herbivory stress from other species. (Interview with Dr. Benjamin Dittbrenner March 2, 2022) In addition, increasing desirable species could attract more beavers to the Wasson site and facilitate continued improvements to the biodiversity of the site. (Rosell & Campbell-Palmer 2022)

Increasing habitat engineers such as beavers at restoration sites has shown improved riparian health and may help facilitate the recovery of the Wasson site. Beaver dams and beaver dam analogues have been used throughout the Pacific Northwest to improve riparian watershed health. (Interview with Jennifer Vanderhoof March 2, 2022) Beavers bring with them an influx of biodiversity and improved fish stocks, vegetation diversity, soil quality, and invertebrate and amphibian populations. Rosell and Campbell-Palmer (2022) assert that beaver-influenced environments provide a great expanse and increased variety of living opportunities for a wide range of plant species, which increases the feeding and breeding opportunities for insects; with a greater abundance of standing and submerged dead wood habitat enhancing the process and significantly altering invertebrate densities. Increases in invertebrate densities then lead to increases in amphibian, reptile, and bird populations. A wide variety of fish populations are also known to benefit from the foraging and shelter provided by dams including salmonid species such as those found in the South Slough estuary (Law et al 2017, Rosell & Campbell-Palmer 2022).
On Camera A at Wasson creek on September 10, 2021 at 12:52am an adult beaver was observed in the tree limbs of a red alder. We can only assume the observation means the individual was climbing in the tree. While video footage of the behavior was not recorded, evidence of beaver herbivory was observed in the same tree between 3-5ft off the ground on September 4, 2021 at 3:41pm (images 14 &15). The only logical conclusion is the beaver climbed the tree to gnaw on the branches. When speaking with Dr. Benjamin Ditbrenner and Jennifer Vanderhoof about the matter they both suggested that previous evidence of beavers climbing trees has been observed but dismissed due to beavers morphology and possible alternative explanations. Further research into the beavers ability to climb trees may provide greater insight into their utilization of resources in watersheds.

**Future Consideration and Lessons Learned for Future Consideration**

Some of the difficulties faced with this project were battery and memory card life for the infrared trail cameras, and utilization of Survey 123. In the first 2-3 months of the trail camera placement images of low bater no infrared were consistently recorded within a few days of their placement, after changing the type of rechargeable battery being used we concluded that the rechargeable batteries did not have sufficient charge to sustain the cameras for the entire month. Once the rechargeable batteries were replaced with disposable batteries the error messages did not recur. Additionally there was evidence of bear interference with Camera A at Wasson creek which rendered the camera unusable until the monthly maintenance period when it was remounted. Little to no footage was recorded by Camera D at Anderson which was likely a result of poor placement.
Throughout the 1-week period of field surveys, 4 separate surveys on Survey123 were created. When the surveys were shared between the Oregon State University license and the NOAA license Oregon DSL was using the survey became corrupted and could not be opened or edited forcing a new survey to be made when any alterations to the survey was needed. In the future I would create and test the survey prior to the study date, and potentially utilize other software or handwritten data sheets to avoid this issue. However despite the survey becoming corrupted the mobile devices it had been downloaded onto were still able to record the data, and I was able to retrieve the data via ArcGIS. While the data was accessible through GIS, the multiple Survey123 surveys meant there was significant formatting required to blend the 4 surveys into a cohesive spreadsheet for analysis. Additionally Rstudio was utilized to analyze the data, per the recommendation of the individuals I consulted with at Oregon DSL and through the Oregon State University Statistical Consultation program. While this proved to be a very useful tool, the learning curve to understand the software was quite difficult and coursework teaching its use was not offered in the MNR curriculum. While online resources were able to provide guidance I think it would be immensely beneficial for future MNR students if the statistical courses offered in their curriculum included ones with R/Rstudio and GIS training.

This information provided in this study will be communicated via written format and powerpoint presentation to the Oregon State University graduate committee and will be submitted to the OSU Kerr Library Scholar archive. A short synopsis of the information gathered and restoration recommendations will be provided to the Oregon DSL and NOAA management committees for utilization in the Wasson creek restoration program.
**Restoration Recommendations**

Based on the information collected from this study, my recommendation is in addition to relying on natural establishment, add red alder (*Alnus rubra*) to the list of species prescribed for revegetation (figure 1). Adding the species will likely alleviate some of the herbivory pressure on the sitka willows (*Salix sitchensis*), improve canopy shade in the creek bed and possibly help to limit the growth of reed canary grass. Post restoration riparian surveys would be appropriate to ensure the species adequately colonizes the creek.

The survey has demonstrated that distance of trees perpendicular from the stream had little to no influence on beaver selection, so revegetation placement is unlikely to impact the amount of saplings utilized by beaver. Since size is an important factor in tree selection, it is likely that the beavers will utilize the willow saplings that are planted. Effectiveness of tree guards (Vexar) was not studied, but may be a useful tool for minimizing herbivory before the trees establish.

While the restoration plan includes introduction of large wood structures into the creek's main channels to create pooling, these structures are prone to degradation. Beaver dams and their maintenance could provide similar, if not more dynamic hydrologic and ecologic functions. My recommendation is to consider introducing individual beavers to the creek after vegetation is established, from neighboring creeks, allowing beavers to establish faster than they would with natural immigration. While this may not be feasible with budget constraints, it would be ecologically beneficial.
Lastly, continued surveys of beaver activity at the Wasson site with continued dam and herbivory monitoring may be an important indicator of the effectiveness of restoration. It is important for all parties involved with the management of the South Slough to maintain a positive mindset towards the presence of beavers as it is immensely beneficial to the ecology of the reserve.

**Reconnecting the restoration project with indigenous cultures**

As a site of indigenous and euro-american settlements it is important to continue to honor South Slough’s heritage. The South Slough team has so far done an exceptional job of celebrating its diverse history by incorporating anthropogenic history into management decisions. Doing so has given the reserve the opportunity to continually enhance their culture of inclusiveness and cultural integrity. This can greatly serve the management of beavers at Wasson creek by including traditional and local ecological knowledge in the decision making and restoration process. The Coquille, Confederated Tribes of the Coos, Lower Umpqua, and Siuslaw Indians currently working with the Oregon Department of State Land and NOAA may be able to provide traditional knowledge of the history of beavers at Wasson creek and how their populations were impacted by euro-american settlers to paint a clearer picture of the future needs of the beaver at the site.
Citations


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