# *CHAPTER 3   CHARACTERIZATION OF PUGET SOUND BASIN PALUSTRINE WETLAND VEGETATION*

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## INTRODUCTION

Nineteen wetlands in the Puget Sound Basin in King County, Washington were studied for five years between 1988 to 1995.  An additional seven wetlands were studied infrequently over the same period.  Our study attempted to understand the character and structure of wetland plant communities and, in particular, if and how wetland communities respond to changing land use and hydrology.  The vegetation communities of each wetland were sampled and compared with land use and hydrologic conditions in the watershed.

Results from the early years of the study had shown that many plant species were found in only one or a few of the wetlands surveyed, suggesting that, regardless of size, wetland plant communities often have a few relatively uncommon species present (Cooke and Azous 1992).  Early work had also shown a hydrologic measure, mean annual water level fluctuation, was negatively correlated with plant richness in wetlands.  This chapter re-examines those earlier findings.

Plant richness and composition in wetlands was compared with wetland area, urbanization in the watershed and water level fluctuation.  Community structure was examined through analysis of species richness, composition and percent cover.  Ordination and classification analyses were used to identify distinct plant communities and examine relationships with the presence, abundance and distribution of invasive species.

Finally, the wetland indicator status of several common plant species, as assigned by Reed (1988, 1993), was examined.  Comparisons were made between the Reed indicator status and a status assigned using quantitative data on species occurrence and hydrologic regime collected for our study.

## METHODS

The wetlands surveyed were inland palustrine wetlands ranging in elevation from 50 m to 100 m above mean sea level and characterized by a mix of emergent, scrub-shrub, aquatic bed, and forested wetland vegetation classes.  Wetlands were selected so that approximately half would be affected by urbanization sometime after the baseline year.  Sites that remained unaffected by urbanization were expected to be the controls for those wetlands receiving urbanization treatment.  The wetlands were matched, wherever possible, as treatment (new urban disturbance) and control (no new urban disturbance) pairs on the basis of morphological characteristics and vegetation zones (Cooke et al.'s 1989a, b, c).

Unfortunately, not all of the watersheds developed as predicted.  Only six watersheds developed beyond 10% of the baseline developed area.  This hindered the ability to statistically compare differences in plant community structure due to stormwater and urbanization effects between control and treatment pairs.  Instead, differences in plant communities related to stormwater and urbanization effects were identified by correlating conditions found at the wetlands with watershed conditions and analyzing all wetlands as a continuum. Together, over the study period, the wetlands represented a spectrum of watershed development conditions and hydrologic regimes that we were able to analyze and compare with respect to the plant communities observed.

Wetland sizes were estimated through analysis of USGS 7.5 minute series topographic maps and ranged from 0.4 to 12.4 hectares. Geographic Information Analysis (GIS) was also used to delineate land use and impervious areas within the watersheds (Taylor 1993). Land use classifications included agricultural lands, single and multiple family residential housing, commercial and industrial development, transportation corridors, and any other development within a watershed that reduced forest cover.

Plant communities in each wetland were characterized during a two to three week period during the active growing season between July and August, during the years 1988, 1989, 1990, 1993, and 1995. Plant community composition and percentage cover were sampled in permanent plots adjacent to linear transects established across the hydrologic gradients of each wetland. Species cover was recorded using a cover class system based on the Octave Scale (Barbour et al. 1987, Gauch 1982). Detailed protocols for the vegetation field work are documented in Cooke et al. (1989a). The data set also includes seven additional wetlands that were surveyed during the years 1993, 1994 and 1995 as part of several related studies.

Species were identified using Hitchcock et al. (1969) and were verified with specimens from the University of Washington Herbarium. Using the Cowardin classification system (Cowardin et al. 1979), sample plots were assigned a category based on the dominant structure of the vegetation community, such as aquatic bed (PAB), emergent (PEM), scrub-shrub (PSS), forested (PFO), upland, or some transition zone between them (e.g., PEM/PSS). The Cowardin classification system was selected because it is widely used in functional assessments, wetland protection, and mitigation criteria (Washington State Department of Ecology 1993). In some cases zones changed over time and were re-categorized as required. Upland zones were not included in the analyses of richness or disturbance, but were included in all other analyses.

The vegetation survey data were used to calculate the frequency with which plant species were observed among the wetlands surveyed. We also calculated total plant species richness for individual wetlands, and the total and average plant richness found in the different vegetation community zones of each wetland. Species were categorized according to wetland indicator status (Reed 1988, 1993) and included obligate (OBL), facultative wetland (FACW), facultative (FAC) and facultative upland (FACU) species. The indicator status in Reed is assigned based on qualitative expert experience of how frequently a plant species is found growing in wetland conditions (Table 3-1).

Table 3-1. Indicator status categories for wetland plant species.

| Code | Designation | Wetlands Probability 1 |
|---|---|---|
| OBL | Obligate wetland | > 99 |
| FACW | Facultative wetland | 67 to 99 |
| FAC | Facultative | 34 to 66 |
| FACU | Facultative upland | 1 to 33 |
| UPL | Obligate upland | < 1 |
| NI | No indicator status | |

1Percent occurrence of plant found in a wetland

Community types were defined and described using ordination (DECORANA) and classification (TWINSPAN) comparisons (Hill 1979 a, b). Plant community data were tabulated in a two-way data matrix (species by cover). The classification method involved grouping similar vegetation units into categories (Cliffors and Williams 1973, Causton 1988). All of the species that composed more than 25 percent cover in the sample stations were included. Ordination was used to display the species data plots in graphical space where like-communities were plotted close together and dissimilar communities were plotted further apart (Hill 1979b, Gauch 1982). The frequency of species and the relative dominance of species were both described by the proportion of vegetation sampling plots in which the species were found.

Hydrologic measurements, including instantaneous water levels from staff gages and peak levels from crest gages, were recorded at least eight times annually while water was present in the wetlands (Reinelt and Horner 1990). Since we did not have a gage at each sample station, the hydrology at each vegetation sample station was calculated based on the elevation of the sample stations in relationship to the water levels measured at the wetland staff and crest gages. This method assumed that water levels were evenly distributed throughout the wetland varying only as elevation varied. In most cases this assumption was sufficiently accurate, however, the wetlands we studied were sometimes more hydrologically complex, so vegetation sample stations were field checked and eliminated if calculated water levels were inaccurate.

Each sample station was assigned an instantaneous water level and a maximum water level. Water level fluctuation (WLF) was computed as the difference between the peak level and the average of the current and previous instantaneous water levels for each four to six week monitoring period. Mean WLF was calculated by averaging all WLFs for a specific season, or the entire year. These data were averaged over the year and each of four seasons; the early growing (EG) (Mar 1-May 31), intermediate growing (IG) (June 1-August 30), senescence (Sept 1-Nov 15), and dormant (Nov 16-Feb 28) seasons.

The hydrologic data were used to compare the results of field measurements with Reed’s categorization of wetland indicator plants. A status was assigned to each species based on the hydrologic regime observed at the vegetation sampling stations. If a station was inundated at any time during the year to within 30 cm of the surface of the sample station the station was considered wet and the plant categorized as growing in wet conditions. Water levels to within 30 cm of the soil surface at the station were used in order to account for saturated soil conditions. All occurrences of individual species were evaluated and, based on the proportion in wet stations versus dry, categorized according to indicator status using Table 3-1.

## RESULTS

### *Community Structure and Composition*

Two hundred and forty-two plant species were identified in 26 wetlands over the study period (the list of species is provided in Appendix Table 3-1). Most were obligate (OBL) species (28%), followed by FAC (23%), FACU (22%), and FACW (16%) species. The remaining 11% had no assigned indicator status.

Forty-five species (19%) were found in only one (4%) of the wetlands surveyed. Over 38 percent of plant species were found in less than three wetlands (12%). The distribution of plants according to wetland indicator status was similar to the overall distribution. Forty percent of OBL, 35% of FAC, and 39 % of FACU species were also found in three or fewer wetlands. FACW species were generally more widely dispersed among wetlands, with all species observed in at least eight wetlands.

Most of the species observed were shrubs (35%), followed by herbs (25%) and ferns and horsetails (14%). Least commonly found were rushes (2%), sedges (3%), grasses (3%) and trees (13%). All of the exotic plant species identified in the study wetland plots were either herbs, shrubs, or rushes.

Rubus spectablilis, Rubus ursinus and Polystichum munitum were observed in all 26 wetlands, however, Spirea douglasii was considered to be the most dominant species as it occurred in 25 of 26 wetlands and covered greater than 64% of the sample station in more than 21% of the stations in which it was observed. Alnus rubra, Athyrium filix-femina, and Salix scoulerleriana were also found in 25 of 26 wetlands but rarely dominated the sample station. Phalaris arundinaceae, an invasive weed, was considered the second most dominant species, being found in 18 wetlands (69%) and dominating the sample station in 19% of the plots in which it was observed. Other invasive wetland species were Ranunculus repens found in 65% (17) of wetlands, and Juncus effusus, observed in 58% (15) of the wetlands. Lythrum salicaria, an exotic considered highly invasive, fortunately, was found in only one wetland. Table 3-2 shows some of the most common and least common plants we found categorized by occurrence and cover dominance.

Table 3-2. Species occurrence for different categories of plant type and cover dominance.

| Cover Dominance Category | High Occurrence (>80% wetlands) | Low Occurrence (<10% wetlands) |
|---|---|---|
| Usually dominant. Greater than 64% coverage in more than 19 percent of observations. | Phalaris arundinaceae<br>Spirea douglasii | Juncus supiniformis<br>Menyanthes trifoliata |
| Dominance in plots varies | Alnus rubra<br>Athyrium filix-femina<br>Kalmia microphylla<br>Lonicera involucrata<br>Polystichum munitum<br>Pteridium aquilinum<br>Ranunculus repens<br>Rhamnus purshiana<br>Rubus laciniatus<br>Rubus spectablilis<br>Rubus ursinus<br>Salix pedicellaris<br>Salix scoulerleriana<br>Salix sitchensis<br>Vaccinium parvifolium | Azola mexicana<br>Brasenia schribneri<br>Eriophorum chamissonis<br>Hippurus vulgaris<br>Hydrocotyl ranunculoides<br>Hydrophyllum tenuipes<br>Nymphaea odorata<br>Polygonum amphibium<br>Potentilla gramineus<br>Rhynchospora alba<br>Sparganium eurycarpum<br>Sagittaria latifolia<br>Scirpus acutus<br>Veronica americana |
| Always less than 1% coverage | no species | Mimulus guttatus<br>Myosotis laxa<br>Potamogeton diversifolius<br>Ranunculus acris<br>Rorippa curvisiliqua<br>Rumex obtusifolius<br>Trillium ovatum<br>Vaccinium ovatum<br>Vaccinium uliginosum<br>Vicia sativa |

*Plant Community Zone Characterization*

Twenty-four wetland vegetation community zones were encountered in the 26 study wetlands. These include the four Cowardin types PAB, PEM, PSS, PFO (Cowardin et al. 1979), an additional two zones called BOG and UPL (upland transition), and combinations of each. Table 3-3 lists the frequency of occurrence of each zone out of a total 465 vegetation stations sampled over the study. Shrub-scrub and forested wetlands were the most common vegetation zones sampled, 26 and 16 percent of the samples respectively. Emergent communities were 13 percent of the samples, and bogs (Sphagnum moss systems) 4.5 percent. Mixed communities were found in about one third of the stations sampled, though mosaic type communities, which include more than three mixed community types, were fairly rare.

Communities of the different vegetation zones were evaluated with respect to the dominant plants and their associated Reed indicator status. Most species found in PAB zones were obligate (74%) or FACW (17%). Six percent of species were FAC, and no FACU species were observed in PAB zones. As would be expected, PAB zones were dominated by obligate herbs (67%), followed by obligate and FACW shrubs (15%), FACW herbs (3%), and rushes (3%).

Species most frequently observed in PEM communities were obligate herbs (31%) followed by FACW shrubs (8%) and FACU (8%) shrubs. Many more FAC (15%) and FACU (17%) species were present in emergent areas than were observed in aquatic bed areas.

Scrub-shrub zones were more evenly distributed between obligate (21%), FACW (22%), FAC (27%) and FACU (23%) species. PSS zones were comprised of 14% obligate herbs and 15% FACW shrubs. FAC and FACU shrubs were about 11% of the species observed in PSS communities.

Table 3-3. Plant community zone frequency of occurrence (descending order).

| Plant Community Zone | Frequency | Plant Community Zone | Frequency |
|---|---|---|---|
| PSS | 25.59% | PEM/PFO | 1.29% |
| PFO | 16.34% | PAB | 1.29% |
| PEM | 13.12% | PAB/PSS | 1.08% |
| PEM/PSS | 9.25% | PEM/UPL | 0.86% |
| UPL | 7.31% | PEM/BOG | 0.22% |
| PSS/PFO | 5.16% | PEM/PFO/UPL | 0.22% |
| BOG | 4.52% | PEM/PSS/PFO | 0.22% |
| PFO/UPL | 3.87% | PFO/PAB/PEM | 0.22% |
| PAB/PEM | 2.58% | PFO/PSS/UPL | 0.22% |
| PSS/UPL | 2.58% | PAB/PFO | 0.22% |
| BOG/PSS | 1.94% | PAB/PFO/UPL | 0.22% |
| PAB/PEM/PSS | 1.51% | UPL/PFO/PEM | 0.22% |

Shrubs made up about 36% of the species observed in PFO zones, and most of the shrubs observed were FAC (11%) or FACU (19 %) species. Upland tree species comprised about 17% of species observed in forested zones. FACW trees comprised less than 0.5% of the forested species observed. Thirteen percent of species observed in PFO zones were obligates, of which 9% were herbs.

A limited number of bog zones were also sampled. Obligate species made up 50% of the observations in bogs, and were mostly shrubs (21%) and herbs (18%). The remaining species found in bogs were primarily FACW shrubs (21%).

### *Wetland Plant Community Associations*

Wetland vegetation sample plots were classified into eleven community types using TWINSPAN (Hill 1979a), on the basis of species composition and percent cover (Figure 3-1). The communities include the categories and species listed in Table 3-4.

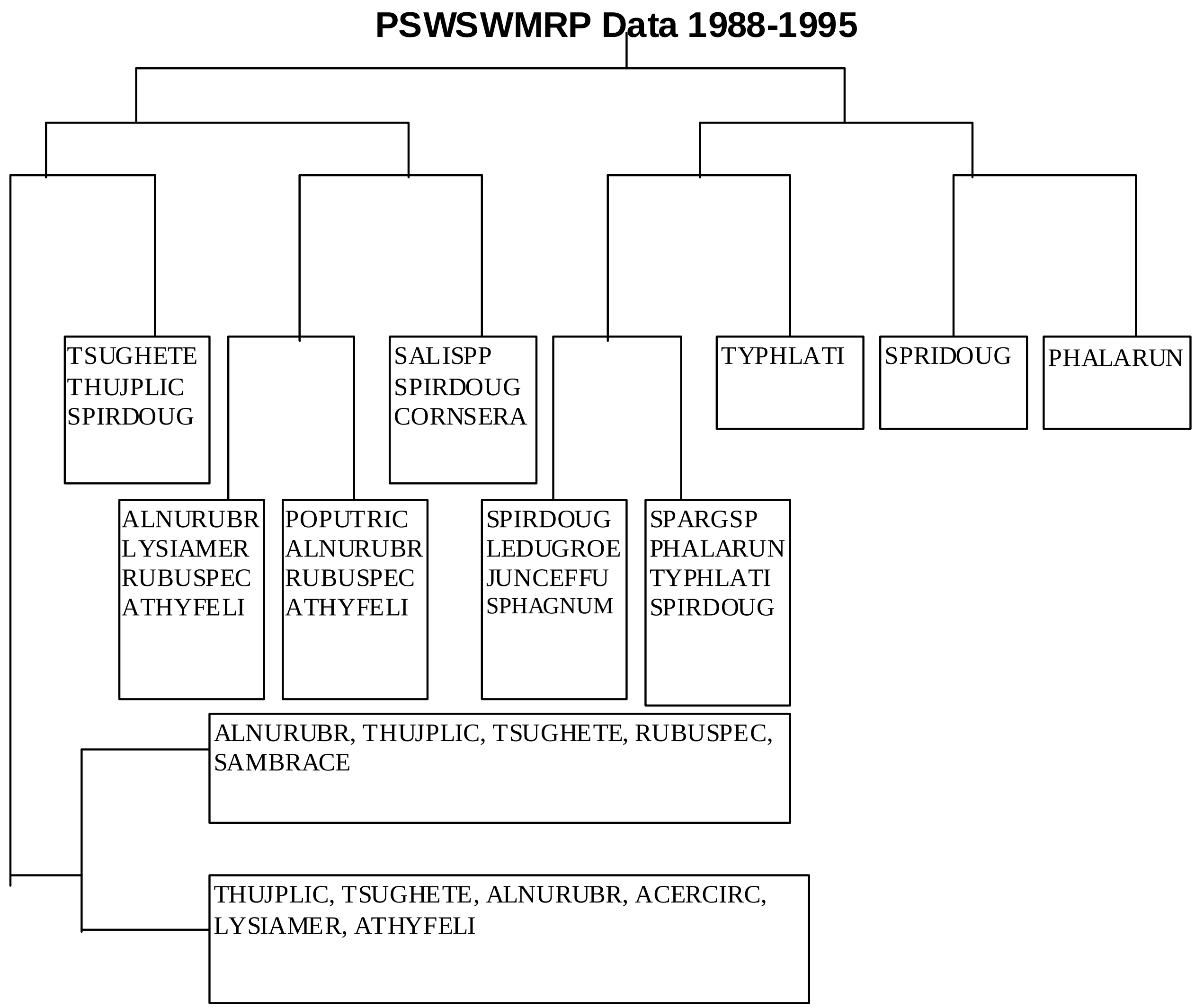


Figure 3-1 Classification of wetland community types present in the PSWSMRP study sites using TWINSPAN (Hill 1979a). (After Houck 1996).

All 24 of the community types listed in Table 3-3 are characterized by the dominant species associations shown in the of the TWINSPAN analysis (Figure 3-1), confirmed in the DECORANA analysis, and described in Table 3-4. These 11 basic community types were repeatedly observed in the study wetlands. Subdominant species changed and a single or a few uncommon species were sometimes present, but the dominant plant associations could be described by one of the eleven types. These communities may be used as a guide for understanding species composition and community structure in wetlands and are relevant to developing reference plant communities for palustrine wetlands in the Puget Basin.

Table 3-4. Wetland community type descriptions (Houck 1996).

| Descriptive Name | Cowardin Community Type 1 | Community Name 2 | Dominant Species |
|---|---|---|---|
| Coniferous forest | PFO<br>PFO/UPL<br>PAB/PFO/UPL<br>UPL | Tsuga-Thuja | Tsuga heterophylla<br>Thuja plicata<br>Spirea douglasii<br>Gaultheria shallon<br>Polystichum munitum |
| mixed coniferous-deciduous forest with shrub understory | PFO<br>PSS/PFO<br>PEM/PFO<br>PEM/UPL<br>PEM/PFO/UPL | Tsuga-Thuja-wet | Tsuga heterophylla<br>Thuja plicata<br>Acer macrophyllum<br>Acer circinatum<br>Lysichitum americanum |
| mixed coniferous-deciduous forest with little understory | PSS/UPL | Alnus-Thuja | Alnus rubra<br>Thuja plicata<br>Tsuga heterophylla<br>Rubus spectabilis<br>Sambucus racemosa |
| deciduous forest | PFO/PSS/UPL<br>PFO/PSS | Populus | Populus balsamifera<br>Alnus rubra<br>Rubus spectabilis<br>Athyrium filix-femina |
| deciduous forest | PEM/PSS/PFO<br>PFO/PAB/PEM | Alnus | Alnus rubra<br>Rubus spectabilis<br>Cornus sericea<br>Lysichitum americanum<br>Athyrium filix-femina |
| mixed shrub scrub | PAB/PSS<br>PAB/PFO | Salix-Spirea | Salix spp.<br>Spirea douglasii<br>Cornus sericea<br>Cornus sericea<br>Lonicera involucrata |
| bog | BOG, BOG/PSS | poor fen-shrub | Rhododendron groenlandicum (Ledum g.),<br>Sphagnum<br>Spirea douglasii |
| mixed emergent | PAB/PEM/PSS<br>BOG/PEM | poor fen-marsh | Phalaris arundinacea<br>Typha latifolia<br>Rhododendron groenlandicum<br>Sparganium spp<br>Spirea douglasii |
| emergent | PAB, PAB/PEM | Typha | Typha latifolia<br>Solanum dulcmara<br>Lemna minor |
| emergent | PEM | Phalaris | Phalaris arundinaceae<br>Solanum dulcmara<br>Urtica dioica |
| scrub-shrub | PSS | Spirea | Spirea douglasii<br>Salix sitchensis<br>S. Alba |

[1]- Community type used in Table 3-3 [2]- Community name used in Figure 3-2

*The Abundance and Distribution of Invasive Plant Species*

Patterns of invasive plant species distribution, dominance and abundance were compared among and within the wetland study sites (Houck 1996). The frequency of invasive species was found to be highly dependent on the conditions present, which varied for different species. For example, Phalaris arundinaceae, Rubus procerus and Solanum dulcamara were more abundant in urbanized watersheds, while Typha latifolia and Juncus effusus were generally more abundant in less urbanized watersheds (Houck 1996). Houck examined water level fluctuation, depth of flooding, and duration of inundation and found that only duration of flooding was associated with the abundance of some invasive species. Typha latifolia and Juncus effusus were generally more abundant in permanently flooded conditions, while Rubus procerus was found in sites where flooding seldom occurred.

Invasive species were most abundant in aquatic bed and emergent marsh communities. The species most frequently observed were Phalaris arundinaceae and Typha latifolia (Figure 3-2). Very few invasive species were found in coniferous forested communities in either the wetland or upland zones.

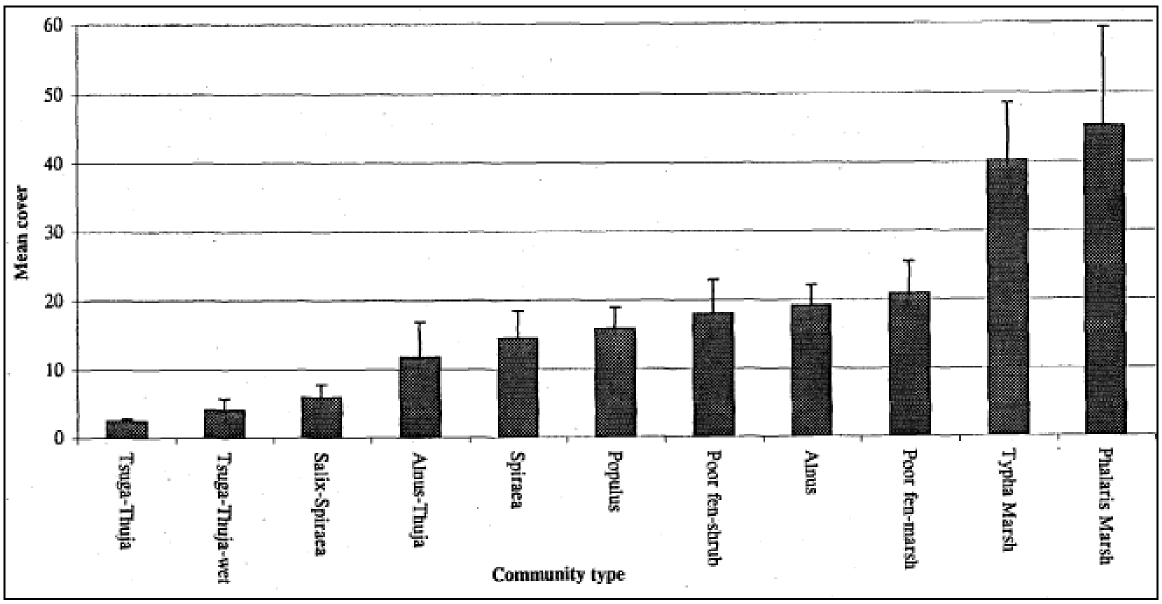


Figure 3-2. Abundance of invasive species within the community types found in the PSWSMRP study sites. Error bars are one standard error (Houck 1996).

*Community Richness*

At the completion of the study, total plant richness ranged from 35 to 109 species across the wetlands surveyed. Twelve of the wetlands had between 60 and 84 species. Seven had less than 60 species and seven had between 85 and 109 species.

Plant richness varied widely between and among the Cowardin vegetation types. Emergent type richness contained from two species to 33 and averaged 19 species per station overall. Scrub-shrub types ranged from four to 27 species and averaged 11 species per station. Forested types had from five to 31 species and averaged 19. Aquatic bed types had the fewest species, from one to eight and averaging about four among the sample stations. The highest total plant richness was found in wetlands with the largest number of Cowardin community types (Fisher's r to z (Frz), R = 0.41, p = 0.0001).

Plant richness in wetlands and in the Cowardin et al. (1979) vegetation Aquatic bed was compared with wetland area, impervious area in the watershed and water level fluctuation. Total plant richness of a wetland was found to have no significant relationship to wetland area (Figure 3-3), nor did average wetland plant richness within community types, such as PEM and PSS, have any relationship to wetland area.

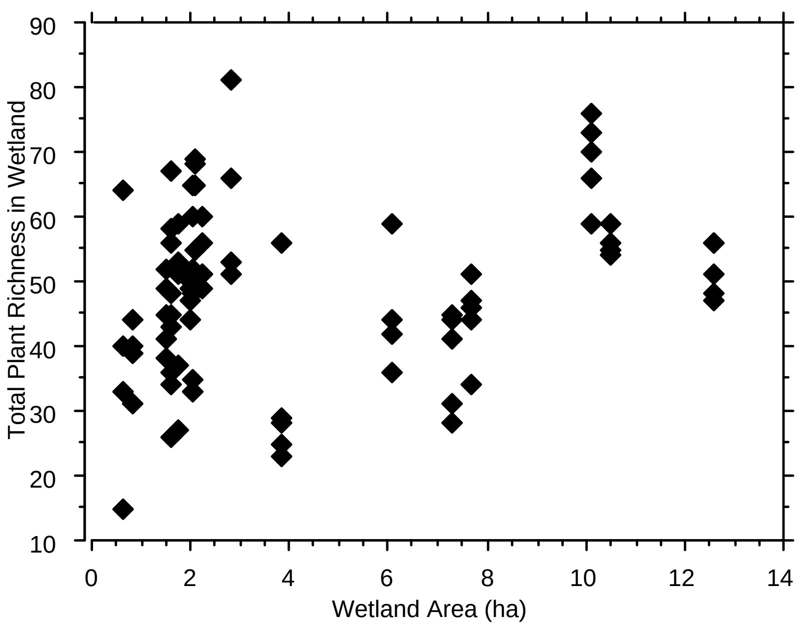


Figure 3-3. Plant richness and wetland area.

The percent of impervious area within the watershed was negatively correlated with average plant richness in the emergent zones and scrub-shrub community types (Figure 3-4). On average both types exhibited significantly lower species richness as the amount of impervious area in the watershed increased (Frz, PEM: R = 0.55, p = 0.002; PSS: R = 0.57, p = 0.001).

All years of data were examined for the relationship between mean annual WLF and plant richness with the following results. Total plant richness found in wetlands was unrelated to the degree of WLF. Average plant richness within the forested community type was also found to be unrelated to mean annual WLF. However, in both the emergent and scrub-shrub types, average plant richness was negatively correlated with mean annual WLF. Figure 3-5 shows plant richness in the these community types related to mean annual WLF for all years of data and all wetlands. The results showed a significant relationship in both types for all years combined (Frz, PEM: R = -0.38, p =

0.006; PSS: R=-0.5, p = .0001). When years were examined singly, both the emergent and scrub-shrub types showed significant negative correlations between plant richness and water WLF for three of the five years.

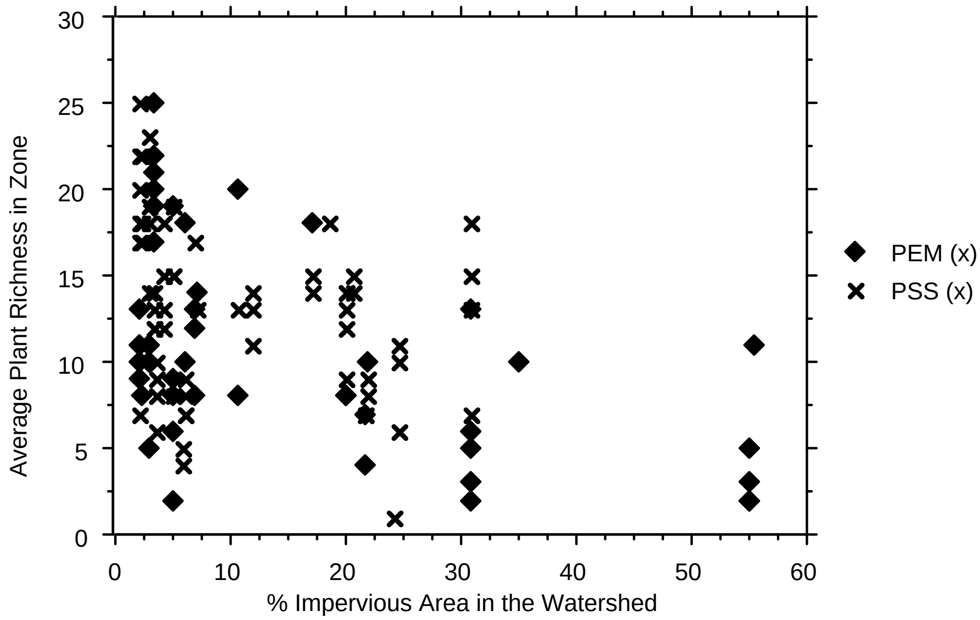


Figure 3-4. Richness in the emergent and scrub-shrub communities and impervious area in the watershed.

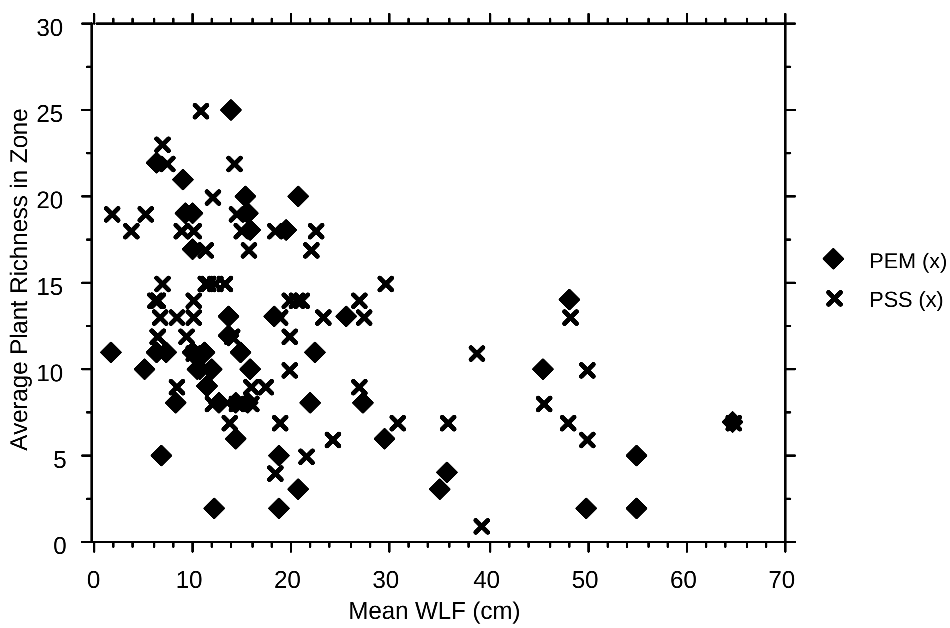


Figure 3-5. Plant richness in the emergent and scrub-shrub communities related to mean annual WLF.

*Wetland Indicator Status*

All 242 plant species found during our study were assigned an indicator status based on the hydrologic regimes observed at the study sample stations. Since upland zones represented only 18% of the stations sampled, it was expected that many transitional species would look wetter than indicated by Reed. However, for most species, the hydrology based assignments for indicator status matched Reed's assignments. Of the 93 that did not match, approximately 42% were eliminated because the number of observations was considered to be too low (less than 10) for an accurate assessment or because the water depths measured at the wetland gage did not accurately reflect the water depths at the vegetation sample stations. In addition, 27 species were eliminated as they were observed growing in conditions that were within 10% of the maximum and minimum range of observed frequency assigned by Reed (Table 3-1) and within the margin of error for measuring water levels. The remaining 27 species were selected as candidates for a change in the indicator status assigned by Reed and are shown in Table 3-5.

Interestingly, several species listed in the table are categorized as obligates by Reed but were found in wet zones in fewer than 88% of our observations. Most were observed in at least 25 sample stations. This study, however, was not able to measure hydrology at each plot but only calculate it based on events measured at the wetland gage station with respect to the elevation of the vegetation sample station. The remaining differences between the Reed categories and the hydrologically based categories may be due to the presence of hydrologic conditions not accounted for by our methods. Nevertheless, the number of observations and frequency of inundation recorded warrant a review of the species listed in Table 3-5.

Table 3-5. Comparison of indicator assignments for some plant species.

| Plant Species | Form | Weed | Reed Wetland Indicator | Status Assigned Using PSWSMRP Study Data | Percent of Observations Plant Was Wet | Number of Observat ions |
|---|---|---|---|---|---|---|
| *Epilobium ciliatum (watsonii)* | herb | no | FAC | FACW | 0.83 | 144 |
| *Acer circinatum* | shrub | no | FACU | FAC | 0.58 | 180 |
| *Dicentra formosa* | herb | no | FACU | FAC | 0.48 | 23 |
| *Dryopteris expansa (austriaca)* | fern | no | FACU | FAC | 0.62 | 143 |
| *Epilobium angustifolium* | herb | no | FACU | FAC | 0.6 | 15 |
| *Hypericum formosum* | herb | no | FACU | FAC | 0.65 | 17 |
| *Rubus procerus (discolor)* | shrub | exotic | FACU | FAC | 0.64 | 115 |
| *Sambucus racemosa* | shrub | no | FACU | FAC | 0.54 | 205 |
| *Stellaria media* | herb | no | FACU | FAC | 0.65 | 40 |
| *Tsuga heterophylla* | tree | no | FACU | FAC | 0.56 | 211 |
| *Rubus laciniatus* | shrub | exotic | FACU | FACW | 0.72 | 116 |
| *Carex hendersonii* | sedge | no | none | FAC | 0.33 | 21 |
| *Carex exsiccata (vesicaria)* | sedge | no | OBL | FACW | 0.85 | 13 |
| *Carex obnupta* | sedge | no | OBL | FACW | 0.67 | 72 |
| *Hypericum anagalloides* | herb | no | OBL | FACW | 0.8 | 25 |
| *Juncus acuminatus* | rush | no | OBL | FACW | 0.87 | 30 |
| *Ludwigia palustris* | herb | no | OBL | FACW | 0.75 | 24 |
| *Lycopus americanus* | herb | no | OBL | FACW | 0.74 | 50 |
| *Lycopus uniflorus* | herb | no | OBL | FACW | 0.7 | 44 |
| *Mimulus guttatus* | herb | no | OBL | FACW | 0.82 | 11 |
| *Myosotis laxa* | herb | no | OBL | FACW | 0.8 | 43 |
| *Salix pedicellaris* | shrub | no | OBL | FACW | 0.73 | 26 |
| *Scirpus atrocinctus* | shrub | no | OBL | FACW | 0.74 | 65 |
| *Scirpus microcarpus* | shrub | no | OBL | FACW | 0.74 | 42 |
| *Solanum dulcamara* | herb | no | OBL | FACW | 0.71 | 212 |
| *Veronica americana* | herb | no | OBL | FACW | 0.74 | 108 |
| *Veronica scutellata* | herb | no | OBL | FACW | 0.69 | 80 |

## DISCUSSION

Wetland management regulations in the Puget Sound lowlands, for the most part, classify wetlands on the basis of area, the number and type of vegetation communities, and the presence of threatened or endangered species (King County 1990, Toshach 1991). Although one might rationalize that larger wetlands are more diverse ecosystems, we found that in the case of plants, wetland area is not directly related to the rarity or richness of the plant community.

Other factors, such as hydrologic regime and the kinds and frequency of disturbance, appeared to be more critical in determining the diversity and character of the wetland plant communities we studied. Generalized classifications of vegetation structure, such as forested, scrub-shrub and emergent, lend no insight into the presence or absence of unusual plant species, plant associations or the biodiversity value of a wetland to a region.  Our results suggest that selecting for wetland size and certain types of wetland plant communities will not insure protection of regional wetland values and functions.

Eleven distinct wetland plant communities were identified that are typical of the region. These communities were mostly found in mixed assemblages interspersed throughout individual wetlands.  Most of the wetlands studied were characterized by several wetland plant community types with transition zones between them.  In general, when several community types were present, plant richness was higher within individual communities, as many species were observed to transition between community types.

The presence of these zones is highly dependent on the hydrologic gradients at work in a wetland.  Wetlands with the richest and most diverse plant communities were typically characterized by more complex hydrology and more variable morphology, providing many surfaces at different gradients for plant species to inhabit.  Wetlands with simpler vegetation communities were more frequently topographically uniform, resulting in simpler hydrologic patterns.  These differences may be traced, to some extent, to patterns of disturbance, including water level fluctuation.

It is important to focus our management efforts toward understanding the conditions required for wetland plant and animal diversity and to comprehensively mitigate the functions lost when wetlands are disturbed.  In addition to preserving large wetlands with diverse hydrologic zones, we should consider addressing land use and development constraints to limit the extent of increases in water level fluctuations occurring in wetlands due to increased impervious area.  Limiting other types of disturbance and monitoring invasive species presence also provide reasonable tools for maintaining species richness and regional biodiversity.

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Appendix Table 3-1. List of plant species and frequency found among 19 Puget lowland palustrine wetlands.

| Plant Species | Number of Wetlands | Percent of All Wetlands | Plant Species | Number of Wetlands | Percent of All Wetlands |
|---|---|---|---|---|---|
| Adiantum pedatum | 1 | 0.04 | Rorippa calycina | 5 | 0.19 |
| Agrostis scabra | 1 | 0.04 | Rosa pisocarpa | 5 | 0.19 |
| Aira caryophyllea | 1 | 0.04 | Sium suave | 5 | 0.19 |
| Anthoxanthum odoratum | 1 | 0.04 | Utricularia minor | 5 | 0.19 |
| Arbutus menziesii | 1 | 0.04 | Agrostis gigantea (alba) | 6 | 0.23 |
| Asaurum caudatum | 1 | 0.04 | Crataegus monogyna | 6 | 0.23 |
| Berberis aquifolium | 1 | 0.04 | Fraxinus latifolia | 6 | 0.23 |
| Brasenia schribneri | 1 | 0.04 | Galium aparine | 6 | 0.23 |
| Carex athrostachya | 1 | 0.04 | Hypericum formosum | 6 | 0.23 |
| Carex stipata | 1 | 0.04 | Ludwigia palustris | 6 | 0.23 |
| Chenopodium alba | 1 | 0.04 | Rubus leucodermis | 6 | 0.23 |
| Cladina rangiferina | 1 | 0.04 | Smilacena racemosa | 6 | 0.23 |
| Convolvulus sepium | 1 | 0.04 | blue-green algae | 6 | 0.23 |
| Cornus canadensis | 1 | 0.04 | Anaphalis margaritacea | 7 | 0.27 |
| Echinochloa crusgalii | 1 | 0.04 | Festuca rubra | 7 | 0.27 |
| Festuca pratensis | 1 | 0.04 | Galium cymosum | 7 | 0.27 |
| Fragaria virginiana | 1 | 0.04 | Glyceria borealis | 7 | 0.27 |
| Goodyeara oblongifolia | 1 | 0.04 | Holodiscus discolor | 7 | 0.27 |
| Hippurus vulgaris | 1 | 0.04 | Juncus bufonius | 7 | 0.27 |
| Hydrocotyl ranunculoides | 1 | 0.04 | Lycopus americanus | 7 | 0.27 |
| Hydrophyllum tenuipes | 1 | 0.04 | Myosotis laxa | 7 | 0.27 |
| Juncus supiniformis | 1 | 0.04 | Potamogeton natans | 7 | 0.27 |
| Lamium purpurea | 1 | 0.04 | Rumex crispus | 7 | 0.27 |
| Lythrum salicaria | 1 | 0.04 | Carex lenticularis | 8 | 0.31 |
| Melilotus alba | 1 | 0.04 | Dactylis glomerata | 8 | 0.31 |
| Nymphaea odorata | 1 | 0.04 | Geranium robertianum | 8 | 0.31 |
| Poa palustris | 1 | 0.04 | Glyceria elata | 8 | 0.31 |
| Poa pratensis | 1 | 0.04 | Juncus acuminatus | 8 | 0.31 |
| Potamogeton diversifolius | 1 | 0.04 | Juncus ensifolius | 8 | 0.31 |
| Potamogeton gramineus | 1 | 0.04 | Rhododendron groenlandicum (Ledum g.) | 8 | 0.31 |
| Ranunculus acris | 1 | 0.04 | Nuphar polysepalum | 8 | 0.31 |
| Rhinanthus crista-galli | 1 | 0.04 | Oplopanax horridus | 8 | 0.31 |
| Ribes bracteosum | 1 | 0.04 | Potentilla palustris | 8 | 0.31 |
| Rorippa curvisiliqua | 1 | 0.04 | Ribes lacustre | 8 | 0.31 |
| Rosa nutkana | 1 | 0.04 | Stachys cooleyae | 8 | 0.31 |
| Rosa rugosa | 1 | 0.04 | Symphoricarpos albus | 8 | 0.31 |
| Rumex acetosella | 1 | 0.04 | Tiarella trifoliata | 8 | 0.31 |
| Sagittaria latifolia | 1 | 0.04 | Carex hendersonii | 9 | 0.35 |
| Scirpus acutus | 1 | 0.04 | Circium arvense | 9 | 0.35 |
| Solanum nigrum | 1 | 0.04 | Dicentra formosa | 9 | 0.35 |
| Stellaria longifolia | 1 | 0.04 | Rosa gymnocarpa | 9 | 0.35 |
| Tanacetum vulgare | 1 | 0.04 | Scirpus atrocinctus | 9 | 0.35 |
| Trifolium pratense | 1 | 0.04 | Sorbus scopulina | 9 | 0.35 |
| Vaccinium ovatum | 1 | 0.04 | Sphagnum spp. | 9 | 0.35 |
| Vicia sativa | 1 | 0.04 | Salix pedicellaris | 10 | 0.38 |
| Adenocaulon bicolor | 2 | 0.08 | Scirpus microcarpus | 10 | 0.38 |
| Alnus sinuata | 2 | 0.08 | Agrostis capillaris (tenuis) | 11 | 0.42 |
| Alopecurus pratensis | 2 | 0.08 | Callitriche heterophylla | 11 | 0.42 |
| Azola mexicana | 2 | 0.08 | Epilobium angustifolium | 11 | 0.42 |
| Bromus ciliatus | 2 | 0.08 | Lycopus uniflorus | 11 | 0.42 |

Appendix Table 3-1 continued. List of plant species and frequency found among 19 Puget lowland palustrine wetlands.

| Plant Species | Number of Wetlands | Percent of All Wetlands | Plant Species | Number of Wetlands | Percent of All Wetlands |
|---|---|---|---|---|---|
| Claytonia lanceolata | 2 | 0.08 | Rubus parviflorus | 11 | 0.42 |
| Cornus nuttallii | 2 | 0.08 | Scutellaria lateriflora | 11 | 0.42 |
| Elytrigia repens (Agropyron repens) | 2 | 0.08 | Sparganium emersum | 11 | 0.42 |
| Eriophorum chamissonis | 2 | 0.08 | Torreyochloa pauciflora (Puccinellia p.) | 11 | 0.42 |
| Glecoma hederacea | 2 | 0.08 | Veronica scutellata | 11 | 0.42 |
| Gnaphalium uliginosum | 2 | 0.08 | Equisetum hyemale | 12 | 0.46 |
| Gymnocarpium dryopteris | 2 | 0.08 | Equisetum telmateia | 12 | 0.46 |
| Hercaleum lanatum | 2 | 0.08 | Holcus lanatus | 12 | 0.46 |
| Hypochaeris radicata | 2 | 0.08 | Menziesia ferruginea | 12 | 0.46 |
| Impatiens noli-tangere | 2 | 0.08 | Polygonum hydropiper | 12 | 0.46 |
| Lolium mulitflorum | 2 | 0.08 | Typha latifolia | 12 | 0.46 |
| Lotus corniculatus | 2 | 0.08 | Bidens cernua | 13 | 0.5 |
| Menyanthes trifoliata | 2 | 0.08 | Carex arcta | 13 | 0.5 |
| Pinus monticola | 2 | 0.08 | Galium trifidum | 13 | 0.5 |
| Polygonum amphibium | 2 | 0.08 | Ilex aquifolia | 13 | 0.5 |
| Rhynchospora alba | 2 | 0.08 | Picea sitchensis | 13 | 0.5 |
| Rumex obtusifolius | 2 | 0.08 | Sorbus americana | 13 | 0.5 |
| Salix hookeriana | 2 | 0.08 | Berberis nervosa | 14 | 0.54 |
| Smilacena stellata | 2 | 0.08 | Carex utriculata =(rostrata) | 14 | 0.54 |
| Sparganium eurycarpum | 2 | 0.08 | Maianthemum dilatatum | 14 | 0.54 |
| Streptopus roseus | 2 | 0.08 | Salix alba | 14 | 0.54 |
| Taraxacum officinale | 2 | 0.08 | Tolmiea menziesii | 14 | 0.54 |
| Trfolium repens | 2 | 0.08 | Corylus cornuta | 15 | 0.58 |
| Vaccinium uliginosum | 2 | 0.08 | Juncus effusus | 15 | 0.58 |
| Vallisneria americana | 2 | 0.08 | Lemna minor | 15 | 0.58 |
| Actea rubra | 3 | 0.12 | Prunus emarginata | 15 | 0.58 |
| Alisma plantago-aquatica | 3 | 0.12 | Stellaria media | 15 | 0.58 |
| Carex exsiccata (vesicaria) | 3 | 0.12 | Trillium ovatum | 15 | 0.58 |
| Circium vulgare | 3 | 0.12 | Cornus sericea (stolonifera) | 16 | 0.62 |
| Cytisus scoparius | 3 | 0.12 | Geum macrophyllum | 16 | 0.62 |
| Dulichium arundinaceum | 3 | 0.12 | Oenanthe sarmentosa | 16 | 0.62 |
| Elodea canadensis | 3 | 0.12 | Acer macrophyllum | 17 | 0.65 |
| Lolium perenne | 3 | 0.12 | Carex obnupta | 17 | 0.65 |
| Mimulus guttatus | 3 | 0.12 | Ranunculus repens | 17 | 0.65 |
| Montia siberica | 3 | 0.12 | Rubus procerus (discolor) | 17 | 0.65 |
| Nasturtium officinale | 3 | 0.12 | Urtica dioica | 17 | 0.65 |
| Phleum pratense | 3 | 0.12 | Equisetum arvense | 18 | 0.69 |
| Ribes sanguineum | 3 | 0.12 | Glyceria grandis | 18 | 0.69 |
| Nastutium officinale | 3 | 0.12 | Luzula parviflora | 18 | 0.69 |
| Taxus brevifolia | 3 | 0.12 | Phalaris arundinaceae | 18 | 0.69 |
| Utricularia vulgaris | 3 | 0.12 | Populus balsamifera | 18 | 0.69 |
| Viola glabella | 3 | 0.12 | Blechnum spicant | 19 | 0.73 |
| Azolla filiculoides | 4 | 0.15 | Carex deweyana | 19 | 0.73 |
| Eleocharis ovata | 4 | 0.15 | Malus fusca (Pyrus f.) | 19 | 0.73 |
| Eleocharis palustris | 4 | 0.15 | Salix sitchensis | 19 | 0.73 |
| Hieracium pratense | 4 | 0.15 | Acer circinatum | 20 | 0.77 |
| Hypericum anagalloides | 4 | 0.15 | Lysichitum americanum | 20 | 0.77 |
| Iris pseudacorus | 4 | 0.15 | Polypodium glycyrrhiza | 20 | 0.77 |

Appendix Table 3-1 continued. List of plant species and frequency found among 19 Puget lowland palustrine wetlands.

| Plant Species | Number of Wetlands | Percent of All Wetlands | Plant Species | Number of Wetlands | Percent of All Wetlands |
|---|---|---|---|---|---|
| Kalmia microphylla | 4 | 0.15 | Pseudotsuga menziesii | 20 | 0.77 |
| Linnaea borealis | 4 | 0.15 | Salix lucida var. lasiandra | 20 | 0.77 |
| Mentha arvensis | 4 | 0.15 | Solanum dulcamara | 20 | 0.77 |
| Myosotis scorpioides | 4 | 0.15 | Thuja plicata | 20 | 0.77 |
| Petasites frigidus | 4 | 0.15 | Tsuga heterophylla | 20 | 0.77 |
| Physocarpus capitatus | 4 | 0.15 | Veronica americana | 20 | 0.77 |
| Plantago lanceolata | 4 | 0.15 | Oemleria cerasiformis | 21 | 0.81 |
| Plantoga major | 4 | 0.15 | Gaultheria shallon | 22 | 0.85 |
| Populus tremuloides | 4 | 0.15 | Sambucus racemosa | 22 | 0.85 |
| Solidago canadensis | 4 | 0.15 | Dryopteris expansa (austriaca) | 23 | 0.88 |
| Spirodela polyrhiza | 4 | 0.15 | Epilobium ciliatum (watsonii) | 23 | 0.88 |
| Streptopus amplexifolius | 4 | 0.15 | Lonicera involucrata | 24 | 0.92 |
| Vaccinium oxycoccos | 4 | 0.15 | Pteridium aquilinum | 24 | 0.92 |
| Agrostis oregonensis | 5 | 0.19 | Rhamnus purshiana | 24 | 0.92 |
| Amelanchier alnifolia | 5 | 0.19 | Rubus laciniatus | 24 | 0.92 |
| Betula papyrifera | 5 | 0.19 | Vaccinium parvifolium | 24 | 0.92 |
| Circaea alpina | 5 | 0.19 | Alnus rubra | 25 | 0.96 |
| Convolvulus arvensis | 5 | 0.19 | Athyrium filix-femina | 25 | 0.96 |
| Digitalis purpurea | 5 | 0.19 | Salix scoulerleriana | 25 | 0.96 |
| Drosera rotundifolia | 5 | 0.19 | Spirea douglasii | 25 | 0.96 |
| Hedera helix | 5 | 0.19 | Polystichum munitum | 26 | 1 |
| Lonicera ciliosa | 5 | 0.19 | Rubus spectablilis | 26 | 1 |
| Ribes divaricatum | 5 | 0.19 | Rubus ursinus | 26 | 1 |