Importance of Vegetation for Identifying Wetlands in the Lower Mainland Fraser Valley region of British Columbia, Canada using Prevalence Index, Hydrophytic Cover Index, and Dominance Ratio

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INTRODUCTION

The Lower Mainland Fraser Valley (LMFV) in British Columbia (BC), Canada is a complex and high stakes environment for wetland identification (Figure 1). High precipitation, subdued topography, and complex site history combine to present formidable challenges to wetland identification and management. Over the last 100+ years, the LMFV has undergone intense and rapid changes. Originally the land was a natural assortment of bogs, swamps and upland forests, which was then cleared for agriculture, and now is undergoing accelerating urban development. Land use competition is intense. Stakes are high: identification of wetlands can make or break development deals. Wetlands are protected in BC by the Water Sustainability Act, and administration is usually through municipal governments and bylaws. Jurisdictional wetlands are identified and mapped as part of a development permitting process.

Figure 1. Outlined in yellow, the Lower Mainland Fraser Valley (LMFV) in British Columbia, Canada is a highly urbanized area extending from Vancouver (West), to Hope (East), and to the USA border (South) (Google Maps 2021). The LMFV is unceded land and includes traditional territories of the Musqueam, Tsleil'waututh, Squamish, Kwikwetlem, Stó:lō, Chehalis, Katzie, Kwantlen, Tsawwassen, and Semiahmoo nations (MetroVancouver 2021).

Wetlands are defined as "areas where soils are water-saturated for a sufficient length of time such that excess water and resulting low soil oxygen levels are principal determinants of vegetation and soil development. Wetlands will have a relative abundance of hydrophytes in the vegetation community and/or soils featuring 'hydric' characters" (MacKenzie and Moran 2004, p. 6). We assess wetlands in our region with methods similar to those described by the US Army Corps of Engineers (USACE 1987) where wetland identification is based on vegetation, soils, and wetland hydrology. Ideally, all three aspects should be considered fully when determining wetland or upland status. Unfortunately, for many sites in the LMFV it is difficult to get sufficiently detailed information on wetland hydrology and soils. Long term, detailed records of hydrology are typically unavailable for operational wetland assessments, and extensive drainage disturbance has altered the natural hydrology significantly throughout the LMFV. Soil mapping covers many areas, but mainly at a scale of 1:50,000. It often lacks the detail needed for wetland identification. Disturbance and drainage have also drastically altered soil profiles (Figure 2). Redoximorphic soil features are often relicts that are no longer diagnostic for hydric soils (Bedard-Haughn 2001; Lavkulich, pers. com. 2019).

Figure 2. Soils within the Lower Mainland Fraser Valley are often highly disturbed, as shown in this soil profile. Multiple changes to site use, including clearing and drainage for agricultural use, development as a golf course, and commercial development have occurred in this location. This has resulted in new anthropogenic soil horizons (such as the buried sand and buried organic layers) and has altered soil development processes.

Many LMFV plant communities are dominated by a small number of aggressive, seral species (Figure 3), which has led some wetland managers to conclude that vegetation is unreliable as a wetland indicator in the LMFV. They suggest that emphasis should be on soils. Given the above-mentioned problems with wetland hydrology and soil information, that would leave us with many sites that have no sufficient criteria for wetland identification. Furthermore, several studies covering a range of vegetation, soil, and climate conditions in the United States (e.g., see

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Lichvar and Gillrich 2014; Segelquist et al. 1990; Scott et al. 1989; Wentworth et al. 1988) have shown strong correlations between hydrophytic vegetation and hydric soils.

The purpose of this paper is to assess the effectiveness of vegetation, expressed as Hydrophytic Cover Index (HCI), Prevalence Index (PI), and the Dominance Ratio (DR) for identifying wetland sites. Our focus is on individual sample quadrats rather than on wetland or upland map units. We also compare HCI, PI and DR, including PI at two hydrophyte thresholds and comment on some important plant species for further consideration in the LMFV.

Figure 3. It can be challenging to identify wetlands in the Lower Mainland Fraser Valley as the plant communities, soil, and hydrology are highly disturbed. Since 1949 this site has gone through multiple major changes as described in Figure 2. The current plant community is highly disturbed and contains an abundance of weedy and aggressive species.

METHODS

Thirty-four quadrats were randomly selected from 17 wetland assessment project sites in the LMFV. Sample quadrats were from jurisdictional wetland assessments. Field work was carried out at various times between March to early September from 2019 through 2021. Several sites were revisited during June through August or during November through January to gather supplemental information. Plant species and their percentage cover were recorded from 0.01 ha (0.025 acre) plots. Plant names are from the standard list for British Columbia (Meidinger et al. 2009). Vascular plant hydrophyte classes are mainly those from the Western Mountains, Valleys and Coast Region from the U.S. Army Corps of Engineers (USACE) wetland plant list (2020). A few species not listed were classified based on various sources such as Fletcher et al. (2019) and Klinka et al. (1989). Classes for mosses and lichens are based on information provided in MacKenzie and Moran (2004) and Klinka et al. (1989). Plant hydrophyte classes and their corresponding weights for PI calculations are shown in Table 1. Calculations for HCI, PI and DR were carried out following the methods in Lichvar and Gillrich (2014) and USACE (2010, 1987).

Soil pits were located within each vegetation quadrat. Soil data collected included parent material, Munsell colors, texture, % coarse fragments, redoximorphic features, root depth and abundance, presence of a water table or seepage, and thickness for each soil layer in the upper 60 to 100 cm (ca. 24 – 40 in.). Depth to significant mottling (redox masses and pore linings) or gleying (redox depletion), depth to water table, presence, thickness and degree of decomposition of surface organic layers, and actual soil moisture regime (ASMR) were recorded. Definition of ASMR is from Klinka et al. (1989). Soil classification was determined at the subgroup level in the Canadian System of Soil Classification (SCWG 1998). Equivalents in the USDA Soil Taxonomy (Soil Survey Staff 1975) were approximated. Hydric soils were originally defined based on MacKenzie and Moran (2004), and modified by adding detailed criteria for gleying, mottling, and degree of organic matter decomposition (see Standish and Alards-Tomalin 2022). However, for the purposes of this paper, hydric soils are defined by hydric soil criteria in USDA (2018).

Wetland hydrology was assessed from wetland hydrology indicators (USACE 2010) and focused on estimated frequency and duration of inundation or soil upper soil profile saturation,

connectivity, and observable features listed in USACE (2010). No hydrologic data, for example from monitoring wells, was available.

Hydrophyte class	**Symbol**	**Frequency of occurance in the wetlands**	**Weight (for PI)**
Obligate	OBL	Almost always occurs in wetlands	1
Faculative Wetand	FACW	Usually occurs in wetlands but may occur in noon-wetlands	2
Faculative	FAC	Occur in wetlands & non-wetlands	3
Faculative Upland	FACU	Usually in non-wetlands but may occur inwetlands	4
Upland	UPL	Almost never occurs in wetlands	5

Table 1. Hydrophyte classes, symbols and weights used for Prevalence Index (PI) calculation. (USACE 2010).

True wetland status for each quadrat was determined based on soils, wetland hydrology, and site history. Sites that were unclear with respect to their soil features or wetland hydrology were revisited on more than one occasion (different seasons and, in some cases, different years). Site history was investigated through local knowledge and analysis of historical remote sensing imagery.

Data was summarized and edited using MS Excel and PCORD v.7.2 (Peck 2016). Some univariate statistics were computed with "Omni" (Szczepanek et al. 2022).

Accuracy of vegetation indices for recognizing true wetland status is expressed as the percentage of true positive or true negative wetland determinations. HCI, PI at two thresholds (PI = 3.0 or PI3.0 and PI = 3.5 or PI3.5), and DR using the 50/20 rule were compared. Inspection of LMFV data along with literature survey and data from Biogeoclimatic Ecosystem Classification site series for the region (Green and Klinka 1994) suggested a PI of < 3.5 as an alternative PI threshold. Differences in accuracy and hydrophyte community determination were analyzed using McNemar's test for paired proportions (Zar 2010). PI at the two thresholds and DR were also compared based on the percentage of quadrats with hydrophytic plant communities, referred to as the percentage of "hydrophyte determination" by Lichvar and Gillrich (2014).

RESULTS/DISCUSSION

OVERVIEW OF VEGETATION AND SOILS

A total of 102 plant species were recorded from the quadrats. Species richness ranged from 2 to 27, averaging 9 per quadrat. Heterogeneity of plant communities is shown by its high Whittaker's β-diversity (βw = 11). The most common species, in decreasing order of abundance and frequency, are reed canary grass (*Phalaris arundinacea*), salal (*Gaultheria shallon*), Labrador tea *(Rhododendron groenlandicum*), salmonberry (*Rubus spectabilis*), black cottonwood (*Populus trichocarpa*), western hemlock (*Tsuga heterophylla)*, red alder (*Alnus rubra*) highbush huckleberry (*Vaccinium corymbosum*), Himalayan blackberry (*Rubus armeniacus*), and step moss (*Hylocomium splendens*). About 15% of species are trees, 20% shrubs, 55% herbs (including forbs, graminoids, and ferns), and 10% bryophytes, mainly mosses. FAC and FACU make up 76% of the species. Presence of individual hydrophyte classes is OBL 18%, FACW 21%, FAC 20%, FACU 40%, and UPL 1%. One-third of the sample quadrats are in the intermediate PI range described by Wentworth et al. (1988) of 2.5 to 3.5. The 95% confidence interval for mean PI is 2.5-3.1 and for HCI is 50-72.

Based on hydric soils and wetland hydrology indicators, twenty-two quadrats (65%) were identified as true wetlands and 12 (35%) as true uplands. Wetland vs. upland plant community composition was compared using Multi Response Permutation Procedure (MRPP). MRPP is a nonparametric, multivariate test for differences among groups (McCune and Grace 2002; Mielke 1991; Peck 2016). It showed no significant difference (p = 0.29) in community composition.

About 65% of soils are mineral soils in the Gleysolic and Podzolic orders in the Canadian System of Soil Classification (SCWG 1998). Equivalents in the USA system (Soil Survey Staff 1975) include Aqualfs, Aquents, Aquepts, Haplorthods and Fluvents. Organic soils (Histosols) comprise about 35%. Actual Soil Moisture Regime (ASMR sensu Klinka et al. 1989) ranged from slightly dry to very wet; more than 40% were wet. Soil drainage classes ranged from moderately well drained to very poorly drained. All soils have had superficial to severe disturbance to their profiles. Some of them have also been altered by onsite or offsite drainage. USDA (2018) hydric soils included Histosol (A6), Loamy Gleyed Matrix (F2), Redox Dark Surface (F6), Sandy Redox (S5), Histic Epipedon (A2) and Loamy Mucky Mineral (F1).

COMPARISON OF HCI, PI, AND DR

All hydrophyte indices underestimated the number of true wetlands. Accuracy for determination of wetlands and uplands for HCI, PI3.0, PI3.5, and DR is shown in Table 2. HCI has the greatest accuracy for identifying wetlands followed by DR, PI3.5 and PI3.0. HCI is significantly different (@ αcrit = 0.05) from PI at both thresholds and from DR. PI at both thresholds and DR are not significantly different from each other.

///////////	Wetland Accuracy %	Upland Accuracy %	p – values (McNemar's Test)			
Hydrophyte Index			**HCI**	**$PI_{3.0}$**	**$PI_{3.5}$**	**DR**
HCI	91	50	//////////	0.043	0.043	0.024
$PI_{3.0}$	73	75	//////////	//////////	0.17	0.11
$PI_{3.5}$	82	75	//////////	//////////	//////////	0.061
DR	86	67	///////////	///////////	//////////	//////////

Table 2. Accuracy and p-values comparing HCI, PI3.0, PI3.5 and DR.

As shown in Table 2, HCI, PI and DR are closely comparable. Accuracy for PI3.5 is somewhat lower than for HCI but similar to findings from Scott et al. (1989). DR and PI3.5 results are more similar to HCI than PI3.0. HCI performs relatively poorly for predicting uplands which is not surprising as it was designed as part of a 3-factor test for identifying wetlands and not for identifying wetlands solely based on vegetation . That, as well as the lack of statistical significance between PI thresholds, could be due to lack of statistical power resulting from our small and variable sample, especially regarding upland sites. DR performed relatively well, with accuracy intermediate between PI and HCI.

The above results compare wetland status determined from vegetation to that determined from soils and wetland hydrology. They are not necessarily comparable to results reported in Lichvar and Gillrich (2014), who used vegetation alone to rank HCI, PI3.0 and DR. Our ranking from greatest to least hydrophytic vegetation determinations agreed with Lichvar and Gillrich (2014):

HCI, PI3.5 , DR, and PI3.0. HCI was significantly different from other hydrophyte indices ($p \le 0.05$) but differences among DR and PI at both thresholds were not significant.

Comparing the agreement of positive hydrophytic determinations, quadrat by quadrat, to HCI PI3.5 had the greatest degree of agreement followed by DR and then PI3.0. Differences among HCI, DR and PI were significant (@ $p \le 0.01$). Differences between the two PI thresholds were not significant ($p = 0.23$).

IMPORTANCE OF FACULTATIVE UPLAND (FACU) SPECIES

Since many of our quadrats are dominated by FACU and FAC species, they pose a relatively great challenge to wetland identification using vegetation. The PI vs. HCI graph (Figure 4) shows five quadrats in red triangles with PI > 3.0 (indicating uplands) and HCI ≥ 50 (indicating wetlands). All of them have 90% or more combined FAC and FACU % cover. FAC species, such as black cottonwood, Himalayan blackberry, and creeping buttercup (Ranunculus repens) have a percent cover of 35 to 80%. All are from young, seral, deciduous forests with a history of moderate to severe soil and hydrological disturbance. Four of the five quadrats represent true wetlands. Several other quadrats that are within ± 5% of PI = 3.0 or HCI = 50 have about 50% FAC species cover. Three quadrats from disturbed bog forests have 40% or more salal (a FACU species) cover. As mentioned above, 40% of all our species are FACU species. The remaining species are distributed roughly equally among OBL, FACW and FAC. Because of its weighting process, PI is relatively sensitive to a high percentage of FAC and FACU species. That likely explains the tendency of PI toward misidentifying those wetlands as uplands, especially for PI3.0.

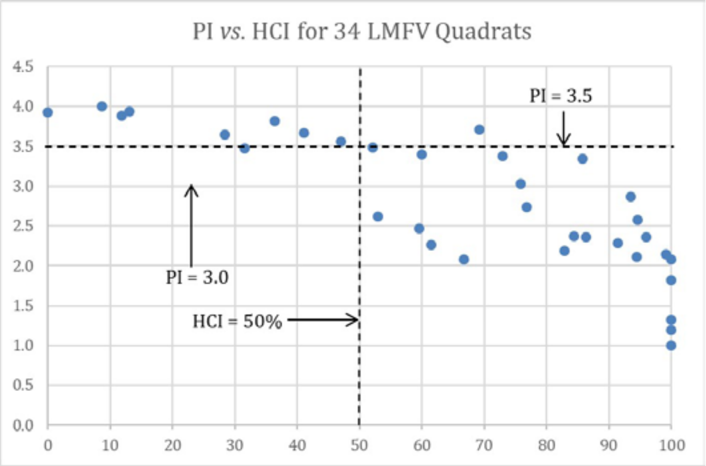

Figure 4. PI vs. HCI for 34 vegetation quadrats. 5 quadrats (red triangles) have PI > 3.0 (indicating uplands) and HCI > 50 (indicating wetlands). HCI and PI agree for those 5 quadrats if PI3.5 is used as a threshold instead of PI3.0.

NOTEWORTHY SPECIES TO CONSIDER

With few exceptions, we found the USACE plant list for the Western Mountains, Valleys, and Coast Region (2020) complete and accurate for use in the LMFV. The list covers many more taxa (about 1750) than the British Columbia list (about 350) in MacKenzie and Moran (2004).

Most species used in wetland identification are vascular plants but mosses are potentially useful. For example, Lichvar et al. (2009) used mosses to delineate wetlands in Alaska where diagnostic vascular species were rare or absent. There are several LMFV species that are relatively easy to identify and have potential hydrophyte diagnostic value for some communities. Feather mosses such as Oregon beaked moss (*Eurhynchium oreganum*) and lanky moss (*Rhytidiadelphus loreus*) are associated with upland forests. Step moss is a common upland forest floor moss but it also occurs on elevated microsites in bogs. It occurred equally in about 25% of upland and wetland sample quadrats. Several Sphagnum species, such as poor-fen peat-moss (*S. angustifolium*), common red peat-moss (*S. capillifolium*), and common brown peat moss (*S. fuscum*), are associated with wetlands. Common green peat-moss (*Sphagnum girgensohnii*) is often associated with small, wet, micro depressions in upland forests.

Figure 5. Skunk cabbage *(Lysichiton americanus*) is an herbaceous hydrophyte that can be missed or its percent cover underestimated during wetland surveys in winter. During the summer, skunk cabbage is very obvious, but swamp ecosystems in the LMFV can be misidentified as upland if visited during late fall or winter months. Pressure of land development deals often results in site visits and assessments during the fall or winter when this important hydrophyte isn't easily visible.

Figure 6: Many wetland sites across the LMFV have highly disturbed plant communities and are dominated (60-85% cover) by reed canary grass (RCG). RCG grows on a wide range of sites, including wetlands, borderline wetlands and non-wetlands.

Figure 7. Salal dominates the understory at this site in Burns Bog, Delta, BC, Canada. Using the standard hydrophyte classification for salal (FACU) hydrophyte indices often end up identifying the site to be non-hydrophytic when it is clearly a wetland from its hydrological and soil features.

Three vascular species that are often abundant in plant communities in the LMFV deserve special attention: skunk cabbage (*Lysichiton americanus*), reed canary grass and salal. Skunk cabbage is an important obligate hydrophyte indicator in many swamp ecosystems. If wetland assessments are conducted during the fall or winter, skunk cabbage may be undetected or its abundance significantly underestimated (Figure 5). Underrepresentation of this important hydrophyte can potentially lead to misidentification of wetland sites.

Reed canary grass (RCG) is a widespread and invasive FACW species, occurring mainly on disturbed sites in the LMFV. It was the most constant and abundant species in our sample. RCG dominates with a percent cover often in the 60% - 85% range on many sites, including wetlands, borderline wetlands, and non-wetlands (Figure 6). It reproduces rapidly both vegetatively and from seed and often forms a thick surface sod that inhibits establishment of other species (Tu 2004). Once established, it tends to dominate. Human disturbance creates ideal conditions for RCG to disperse and establish. Moving water is an important seed dispersal mechanism, so wetland sites in riparian or flooded areas can be easily colonized and taken over. Disturbed sites with damaged plant communities are particularly susceptible to being colonized, whether they are wetlands or not. Seven of the 34 quadrats in our sample have a cover of 55% or more of RCG. Four quadrats are wetlands and three are uplands that were misidentified from HCI, DR and PI as wetlands. Reed canary grass was slightly more abundant on our true upland quadrats (median = 82% cover) rather than on true wetlands (median = 58% cover). All of those quadrats are in sites affected by a high degree of onsite and adjacent offsite disturbance. To ensure accurate wetland status determination for these sites, careful attention to soil and site history is needed, further supporting the need to consider three factors in wetland identification in disturbed areas.

Salal is a species of wide ecological amplitude. In the LMFV it is often most abundant at the extremes of soil moisture – the wettest sites and the driest sites. Salal is considered a FACU species in the Western Mountains Valleys and Coast region (USACE 2020). It occurs in 9 of 34 quadrats (26%) in our sample and ranges in abundance from 2% to 90% cover. Its greatest abundance is in bogs, along with shore pine (Pinus contorta var. contorta) and Labrador tea. In bogs that have experienced surface disturbance or adjacent drainage alteration, salal often dominates the understory (Figure 7), limiting the presence of FACW and OBL species such as Labrador tea, western bog laurel (Kalmia microphylla), bog blueberry (Vaccinium uliginosum), and bog cranberry (Oxycoccus oxycoccus). Even when such hydrophytic species are present, they are often hidden beneath a canopy of salal. Under those circumstances, hydrophyte indices may indicate uplands even though the site is a wetland.

SUMMARY AND CONCLUSION

The aim of our study was to determine if vegetation is an accurate indicator for identifying wetlands in the LMFV. We also wanted to compare the accuracy of HCI, PI at two thresholds, and DR. We found the accuracy of three different vegetation indices (HCI and PI and DR) for identifying wetlands was more or less similar to that reported by others, such as Lichvar and Gillrich (2014) and Scott et al. (1989). Accuracy for identifying wetlands using PI3.0, (the most commonly used PI threshold) was relatively low (76%). HCI (91%), DR (86%), and PI3.5 (82%) were more accurate in identifying true wetlands. PI3.5 accuracy for uplands was less than for wetlands, but the difference (82% - 75% = 7%) is relatively small. HCI accuracy for uplands is relatively poor (50%). Based on our results, along with other larger and more general studies (for example, Lichvar and Gillrich 2014; Scott et al. 1989) we conclude:

- Vegetation using HCI, PI or DR can identify LMFV wetlands with an accuracy of about 80 to 90%.
- Accuracy of using vegetation alone for identifying uplands is relatively poor, 75% for PI at both thresholds, 67% for DR and 50% for HCI. However, differences in upland accuracy may reflect our small sample size for uplands.
- PI with a threshold of 3.0 gives poorer results for wetland identification than HCI or DR.
- PI performance is improved if a higher wetland-upland threshold is used. A PI threshold of 3.5 worked relatively well for our sample; in some cases, it worked as well as HCI.
- Considering accuracy for both wetlands and uplands, PI3.5 and DR performed somewhat better than HCI.
- HCI was the most accurate hydrophyte index for identifying wetlands. We agree with De Steven (2015) and Lichvar and Gillrich (2014) that HCI has some advantages over other hydrophyte indices. Its strengths include accuracy for identifying wetlands and relative simplicity of calculations. Unlike PI, it does not require hydrophyte class weights, which are somewhat arbitrary.
- HCI's disadvantage, at least for our data, is that it misidentifies uplands as wetlands more often than other indices.
- LMFV plant communities are often dominated by FAC and FACU species, resulting in a relatively high potential for misclassifications and borderline determinations. PI, because of its weighting procedure, is potentially sensitive to the predominance of FAC and FACU species.
- Species-poor sites dominated by species such as reed canary grass or salal demand special attention to site and soil conditions.
- Wetland assessments should be scheduled for times when important herbaceous hydrophyte indicator species (such as skunk cabbage) are observable.

Reservations about using vegetation to determine wetland status in the LMFV seem to be ungrounded. Vegetation has been shown to accurately identify wetlands here and elsewhere, especially when used in a 3-factor approach (hydrophytic vegetation, hydric soils, and signs of wetland hydrology). Based on our observations, the link between hydric conditions and hydrophytic vegetation is strong, even in plant communities that are frequently dominated by a small number of aggressive, seral species. All of the hydrophyte indices we used performed more or less equally well when identifying wetlands, although PI at the commonly used threshold of 3.0 performed relatively poorly. We suspect that choice among HCI, PI and DR may be less crucial for wetland identification and delineation in the Lower Mainland Fraser Valley than other issues, such as correct plant species identification, and sampling design and layout. Nonetheless, disturbed sites will continue to be a challenge for wetland delineators and the 3-factor test appears to be useful for verification while the vegetation tests provide a good initial read on the likelihood for a given site to be wetland or non-wetland.

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