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ARTICLE

The Effect of a Low-Cover Stratum—Woody Vines—on Vegetation Determinations Made During Wetland Delineations

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Abstract We examined the effect of a low-cover stratum—woody vines—on 1) the outcome of vegetation determinations made using the Prevalence Index (PI) and the Dominance Ratio (DR), and 2) agreement between vegetation and soils during wetland delineations in the United States. Different vine abundance measures—stem counts vs. percent cover—had no effect on the percentage of hydrophytic vegetation determinations made by either formula. Artificial increases and decreases to the woody vine stratum's minimum cover threshold of 5.0% also had no effect. However, in plots that contained borderline hydrophytic/nonhydrophytic vegetation, the percentage of hydrophytic vegetation determinations made by the DR decreased significantly when vine indicator status was artificially increased ($p=0.048$). The PI produced significantly fewer hydrophytic determinations in plots with nonhydric soils than in plots with hydric soils ($p<0.001$). The DR produced large percentages (81.8–100%) of hydrophytic determinations, regardless of soil type. Plots in which the DR and the PI differed had many commonalities, including nonhydric soils, nonhydrophytic PI/hydrophytic DR values, borderline hydrophytic vegetation, and an odd number of dominant species. During wetland delineations, the PI should be used in plant communities with low-cover strata, high species richness, or a high frequency of hydrophytes.

Keywords Dominance Ratio · Prevalence Index · Strata · Woody vines

Introduction

In the United States, jurisdictional wetlands are identified by the presence of three factors: hydrophytic vegetation, hydric soils, and wetland hydrology. All three factors are necessary to determine the limits of the wetland boundary. To be considered hydrophytic, vegetation must be dominated by >50% wetland plant species (Environmental Laboratory 1987). The U.S. Fish and Wildlife Service (FWS) has assigned five indicator status ratings to plant species based on the frequency with which they occur in wetlands: obligate (OBL) >99%, facultative wetland (FACW) 67–99%, facultative (FAC) 34–66%, facultative upland (FACU) 1–33%, or upland (UPL) <1% (Reed 1988). Species ranked as FAC, FACW, or OBL are considered hydrophytes and occur in wetlands with greater frequency than species ranked as FACU or UPL.

Two formulas, the Prevalence Index (PI) and the Dominance Ratio (DR), are used to make vegetation determinations. The PI is a weighted average that uses the wetland indicator status of plant species combined with either frequency (Wentworth et al. 1988) or cover values (Wakeley and Lichvar 1997) to determine whether hydrophytic vegetation is present. Field studies testing the PI method along gradually transitioning wetland to upland areas showed that the PI was reliable for identification of hydrophytic vegetation in three factor wetlands (Carter et al.

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1988). In contrast, the DR method was specifically designed for wetland delineation purposes, but a formula was never published. It originated in an interagency meeting leading to the development of the 1989 Federal Interagency Manual for Identifying and Delineating Jurisdictional Wetlands. The DR method is based on the concept of identifying the dominant species, which has long been used to describe patterns of community composition and to develop corresponding hypotheses regarding species' ecological responses (Preston 1948; MacArthur 1957; Whittaker 1965). During interagency discussions to develop the 1989 wetland delineation manual, the interagency committee discussed how to determine a plot's dominant species using a reliable and repeatable method, during delineations. From these discussions the 50/20 approach was developed (Charles Rhodes 2006, pers. comm.). It was agreed to use the two cover values of 50% and 20% to select the dominant species from each stratum. The calculation method was described in the Federal Interagency Manual (Federal Interagency Committee for Wetland Delineation 1989) and is recommended in the U.S. Army Corps of Engineers Wetland Delineation Manual, hereafter referred to as the 1987 manual (Environmental Laboratory 1987).

Previous studies have suggested that use of 50% and 20% of total cover values to select dominant species can give a species from a stratum with a low cover value undue influence on the results of vegetation determinations made by the DR (Wakeley and Lichvar 1997). Because woody vine cover is often sparse, District offices of the U.S. Army Corps of Engineers (USACE), including the Norfolk, Buffalo, and Detroit Districts, have reported that the vine stratum has this effect and can "tip" vegetation determinations in one direction or the other, between a nonhydrophytic or a hydrophytic determination, depending on the wetland indicator status of the woody vine species present. Plots that contain borderline hydrophytic/nonhydrophytic vegetation are most likely to be affected. In response to these concerns, we examined the effect of the woody vine stratum on the percentage of hydrophytic vegetation determinations produced by the two vegetation formulas—the PI and the DR—in all plots and in only plots that contained borderline vegetation.

Woody vines, or lianas, can be the most difficult vegetation stratum to sample during wetland delineations because vines often climb high into the canopy of their host, making species identification challenging. In most genera, a combination of leaves, twigs, and fruits is required for identification (Gleason and Cronquist 1991), making species identification most accurate late in the growing season. However, many high-climbing vines have no visible buds, fruit, or leaves at the ground level. Misidentification of congeners that have been assigned different indicator statuses could affect the results of vegetation determinations when the vegetation is borderline hydrophytic. For instance, in the northeast, *Smilax rotundifolia* L. (common greenbrier) has a wetland indicator status of FAC, whereas a similar-looking species with variable leaves, *S. bona nox* L. (bullbrier greenbrier), is considered FACU.

In this study, our goals were to examine the effect of a low-cover stratum—woody vines—on hydrophytic vegetation determinations made by the PI and the DR and on disagreements between the two formulas. We had three objectives: 1) to describe the woody vine stratum, including abundance, number of dominants, and indicator status ratings; 2) to explore the effect of measurement methods, minimum cover thresholds, and indicator status ratings on the percentage of hydrophytic vegetation determinations produced by the PI and the DR; and 3) to describe the vine stratum's effect on relationships between vegetation and soils.

We made four hypotheses. First, there is no significant difference in the frequency with which hydrophytes occur in the vine stratum when compared to the remaining three strata. Second, there is no significant difference in the percentage of hydrophytic vegetation determinations produced by the PI or the DR when a) the vine stratum is measured using percent cover and stem counts, b) minimum cover thresholds of 2%, 10%, and 15% are applied to the vine stratum, and c) the indicator status of species in the woody vine stratum is artificially increased or decreased by one rating category. Each part of this hypothesis (a–c) was tested in all plots and in only plots that contained borderline vegetation. Third, there is no significant difference in the percentage of plots that contain hydric soils and the percentage of plots that contain hydrophytic vegetation, as determined by either the PI or the DR. Last, there is no significant difference in the percentage of hydrophytic vegetation determinations produced by the PI and the DR, when plots with hydric soils are compared to plots with nonhydric soils.

Methods

Field Methods

To meet these objectives we collected data in two former FWS Wetland Plant Regions, the Northeast and the North Central. Potential sites in each region were identified based on input from local USACE District personnel, who suggested areas where woody vines were present. Final plot locations were selected based on the presence of woody vines at the wetland boundary. A total of 28 plots was sampled, 11 in uplands and 17 in wetlands. In the Northeast, six plots were located in Connecticut, two plots were located in southwestern New York, and nine plots were located in southeast Virginia. In the North Central Region, 11 plots were sampled across northern Indiana.

Vegetation data were collected according to sampling methods described in the 1987 Manual (Environmental Laboratory 1987). The data represent percent cover and stem counts of the vine stratum in 30-ft radius plots, percent cover of the tree stratum in 30-ft radius plots, and percent cover of the shrub and herb strata in 5-ft-radius plots. Field identifications were confirmed in the laboratory using Gleason and Cronquist (1991). Nomenclature follows Kartesz (2009). The depth and texture of each soil layer in the profile were measured, described, and recorded. The hue, value, and chroma of each layer were determined using Munsell Soil Color Charts (Gretag/Macbeth 2000). Wetland determinations were made according to procedures described in the 1987 manual (Environmental Laboratory 1987) and the regional supplements to the U.S. Army Corps of Engineers wetland delineation manual for the Atlantic and Gulf Coast Plain region (U.S. Army Corps of Engineers 2010) and the Northcentral-Northeast regions (U.S. Army Corps of Engineers 2009).

Calculating DR and PI

We used percent cover or stem count data and the following formula to calculate PI:

$$PI = \left(S_{obl} + 2S_{facw} + 3S_{fac} + 4S_{facu} + 5S_{upl}\right) / \left(S_{obl} + S_{facw} + S_{fac} + S_{facu} + S_{upl}\right)$$

where S = summed abundance. The worksheet that delineators use for field calculations provides a summary of this procedure in Online Resource 1. In each plot, we summed the absolute abundance of each species across strata. Each species' total abundance was multiplied by its wetland indicator status rating, a value ranging from 1 (OBL) to 5 (UPL). These values were summed and then divided by the total abundance of all species. Vegetation in plots with PI values less than or equal to 3.0 was considered hydrophytic. Vegetation in plots with plots with PI values greater than 3.0 was considered nonhydrophytic (U.S. Army Corps of Engineers 2010).

Because a DR formula has never been published, we calculated the DR using the indicator status of the dominant plant species in each stratum and instructions in the 1987 Manual (Environmental Laboratory 1987). The worksheet that delineators use for field calculations provides a summary of this procedure in Online Resource 1. A stratum was considered present if it constituted at least 5% of the plot's total cover. In each stratum, dominant plant species were selected using the 50/20 approach. Plant species were ranked in descending order by absolute abundance values, and the 50% and 20% thresholds were determined by multiplying the stratum's total cover by 50% and 20%, respectively. If a single species exceeded the 50% threshold, that species was considered dominant. When no species exceeded the 50% threshold, dominant species were those selected from the top of this list until their cumulative abundance exceeded the 50% threshold. In addition, if any species had an absolute abundance value greater than or equal to the 20% threshold and had not yet been selected, it was also considered dominant. Species with equal abundance values were treated equally as dominants or nondominants. The regional wetland indicator status of each dominant species was obtained from the National List of Plant Species that Occur in Wetlands (Reed 1988). Species listed as OBL, FACW, or FAC were considered hydrophytes. To determine the percentage of hydrophytic vegetation in the plot, the dominant hydrophytes from each of the strata were summed, divided by the summed total of all dominant species, and multiplied by 100. Vegetation in plots with DR values greater than 50.0% was considered hydrophytic. Vegetation in plots with DR values less than or equal to 50.0% was considered nonhydrophytic (Environmental Laboratory 1987; U.S. Army Corps of Engineers 2010).

Data Analysis

Histograms were used to describe the structure of the vine stratum and to determine its potential effect on hydrophytic vegetation determinations made using the DR and the PI. We presented these results in a table showing the frequency with which dominant species occurred in the vine stratum and in all remaining strata, and the frequency of five woody vine stratum cover classes.

We used Fisher's exact tests and SYSTAT 12 statistical software (SYSTAT 2007) to compare the proportion of plots that contained hydrophytic vegetation according to each formula. Like the Chi-Square test, Fisher's exact tests are designed for use with categorical data; however, they are not based on the assumption of a large sample size. Instead of calculating a test statistic using the observed and expected values for each category as the Chi-Square test does, Fisher's exact tests calculate a test statistic by counting all possible outcomes exactly, including interactions greater and less than those actually observed. When compared to Chi-Square tests, Fisher's exact tests have greater statistical power because they are more conservative and less likely reject a null hypothesis when it is true (Bowman and Shetty 2007).

To examine the effect of different vine measurement methods on vegetation determinations made by the DR and the PI, we compared the percentage of hydrophytic vegetation determinations produced when the woody vine stratum was measured using percent cover and stem counts, in all plots and in only plots containing borderline vegetation. We defined borderline vegetation as follows: excluding the woody vine stratum, there are either equal numbers of dominant hydrophytes and nonhydrophytes, or one more dominant hydrophyte than nonhydrophyte (i.e., three hydrophytes and two nonhydrophytes). To examine the effect of the 5.0% minimum cover threshold requirement on hydrophytic vegetation determinations made by the DR, we compared the percentage of hydrophytic vegetation determinations produced by the standard 5.0% threshold to the percentages obtained using cover thresholds of 2.0%, 10.0%, and 15%, in all plots and in only plots containing borderline vegetation. The 15% threshold essentially removed the woody vine stratum from vegetation calculations, enabling us to observe this effect on vegetation determinations. Although the PI does not use cover thresholds, we also applied these thresholds to PI calculations so that we could compare their effects on both formulas.

To examine the effect of the woody vine stratum on the percentage of hydrophytic determinations made by the vegetation formulas, we increased (FAC to FACU) or decreased (FAC to FACW) the indicator status of each species in the woody vine stratum by one rank and then calculated the DR and PI. The percentages of hydrophytic vegetation determinations made using these two modified ranking systems were compared to the percentage of hydrophytic determinations produced by the standard ratings (Reed 1988) in all plots and in only plots containing borderline vegetation.

To examine agreement between the vegetation determinations and the presence/absence of hydric soils, we compared the percentage of plots determined to contain hydric soils to the percentages of hydrophytic vegetation determinations produced by the PI and the DR. We also compared the percentage of hydrophytic determinations made by each formula in plots with hydric soils and in plots with nonhydric soils.

We examined plots in which vegetation determinations made by the DR and the PI differed, and we described the pattern of disagreement, including common characteristics that might be associated with disagreement. Finally, we calculated the probability that the DR would produce a hydrophytic vegetation determination and compared this likelihood with the actual vegetation determinations produced by the DR. Binomial probability was calculated as described in Lichvar et al. (2011), using the frequency with which hydrophytes occurred in these data and the number of dominant species in each plot.

Results

The data showed that the woody vine stratum was characterized by very few dominant species and low cover values. In 46.4% of the study plots, the woody vine stratum contributed one dominant to plots with up to seven dominant plant species (Table 1). In 78.5% of the plots, vine cover was 10% or less. There was no difference in the frequency with which hydrophytes occurred in the vine stratum (82.4%) and in the three remaining strata (71.9%)—trees, shrubs, and herbs ($p=0.664$, Table 2).

When all plots were tested, stem counts enabled the woody vine stratum to meet the 5.0% minimum threshold more often (78.6%) than percent cover (50.0%), but the percentage of hydrophytic vegetation determinations produced by the two methods were not significantly different, regardless of which formula was used ($p=1.000$) (Table 2). Increases and decreases to the minimum cover threshold had no significant effect on the percentage of hydrophytic vegetation determinations produced by the PI ($p=1.000$) or the DR ($p=0.419$, 1.000). Likewise, increasing and decreasing vine species' indicator status rating category had no significant effect on the percentage of hydrophytic vegetation determinations produced by the PI ($p=1.000$) or the DR ($p=0.165$, 1.000).

When the subset of plots containing borderline hydrophytic vegetation was tested, differences in the percentage of hydrophytic vegetation determinations produced by vine stem counts and percent cover data were not significant, regardless of whether the PI ($p=1.000$) or the DR ($p=0.470$) was used (Table 2). Increasing and decreasing the minimum cover thresholds had no significant effect on the percentage of hydrophytic vegetation determinations produced by the PI ($p=1.000$) or the DR ($p\geq0.200$, $p=1.000$). However, artificial increases to the vine stratum's indicator status rating category (FAC to FACU) significantly reduced the percentage of hydrophytic vegetation determinations made by the DR ($p=0.048$), from 100.0% to 20.0% ($n=5$). The percentage of hydrophytic vegetation determinations made by the PI was unaffected ($p=0.524$).

Hydric soils occurred in 60.7% of the study plots. The DR determined that a significantly larger percentage of plots (92.9%) contained hydrophytic vegetation ($p=0.010$, Table 2). In contrast, there was no significant difference between the percentage of plots that contained hydric soils and the percentage of plots that the PI determined contained hydrophytic vegetation (75.0%) ($p=0.391$). In a subset of plots with nonhydric soils ($n=11$), the PI produced a significantly smaller percentage of hydrophytic vegetation determinations (36.4%) than it did in a subset of plots with hydric soils ($n=17$, 100.0%) ($p<0.001$). There was no significant difference in the percentage of hydrophytic vegetation determinations made by the DR in subsets of

Table 1 a) Frequency with which dominant species occurred in the woody vine stratum and in the tree, shrub, and herb strata. The 50/20 Rule and absolute cover values were used to select dominant species from all strata that met the minimum cover threshold of 5.0% b) Frequency of five woody vine cover classes

Number of Dominant Species								
a)	Zero	One	Two	Three	Four	Five	Six	Seven
Vine Frequency	50.0	46.4	3.6	0.0	0.0	0.0	0.0	0.0
Tree, Shrub, Herb Frequency	0.0	0.0	3.6	32.1	21.4	17.9	14.3	10.7
Woody Vine Cover Classes								
b)	0.1–5.0%	5.1–10.0%	10.1–15.0%	15.1–20.0%	<20.1%			
Frequency	57.1	21.4	14.3	3.6	3.6			

Table 2 Results from Fisher's exact tests comparing the proportions of hydrophytic vegetation determinations produced by the Dominance Ratio and the Prevalence Index and the proportions of hydrophytes among strata. Significance marked as: p<0.05*, p<0.01**

Comparison	Hypothesis	n	Chi^2	df	p
i) Indicator rating differences among strata					
Vines vs. Trees, shrubs, herbs	$Vine_{hydrophytes}$ =3 $strata_{hydrophytes}$	342	0.404	1	0.664
ii) Vine stratum effect on vegetation determinations in all plots					
a) Abundance measure	$PI_{stemcounts}=PI_{percent\ cover}$	22	0.008	1	1.000
Abundance measure	$DR_{stemcounts}=DR_{percent\ cover}$	22	0.365	1	1.000
b) Increase threshold	$PI_{5\%}=PI_{15\%}$	26	0.000	1	1.000
Increase threshold	$PI_{5\%}=PI_{10\%}$	26	0.000	1	1.000
Decrease threshold	$PI_{5\%}=PI_{2\%}$	26	0.000	1	1.000
Increase threshold	$DR_{5\%}=DR_{15\%}$	26	1.486	1	0.419
Increase threshold	$DR_{5\%}=DR_{10\%}$	26	0.221	1	1.000
Decrease threshold	$DR_{5\%}=DR_{2\%}$	26	0.221	1	1.000
c) Increase 1 category	$PI_{Reed\ (1988)}=PI_{increase}$	14	0.190	1	1.000
Decrease 1 category	$PI_{Reed\ (1988)}=PI_{decrease}$	14	0.243	1	1.000
Increase 1 category	$DR_{Reed\ (1988)}=DR_{increase}$	14	3.394	1	0.165
Decrease 1 category	$DR_{Reed\ (1988)}=DR_{decrease}$	14	0.000	1	1.000
Vine stratum effect on vegetation determinations in borderline plots					
a) Abundance measure	$PI_{stemcounts}=PI_{percent\ cover}$	7	0.343	1	1.000
Abundance measure	$DR_{stemcounts}=DR_{percent\ cover}$	7	1.714	1	0.470
b) Increase threshold	$PI_{5\%}=PI_{15\%}$	8	0.000	1	1.000
Increase threshold	$PI_{5\%}=PI_{10\%}$	8	0.000	1	1.000
Decrease threshold	$PI_{5\%}=PI_{2\%}$	8	0.000	1	1.000
Increase threshold	$DR_{5\%}=DR_{15\%}$	8	3.692	1	0.200
Increase threshold	$DR_{5\%}=DR_{10\%}$	8	2.286	1	0.467
Decrease threshold	$DR_{5\%}=DR_{2\%}$	8	1.067	1	1.000
c) Increase 1 category	$PI_{Reed\ (1988)}=PI_{increase}$	5	1.667	1	0.524
Decrease 1 category	$PI_{Reed\ (1988)}=PI_{decrease}$	5	0.476	1	1.000
Increase 1 category	$DR_{Reed\ (1988)}=DR_{increase}$	5	6.667	1	0.048*
Decrease 1 category	$DR_{Reed\ (1988)}=DR_{decrease}$	5	0.000	1	1.000
iii) Patterns of agreement between vegetation and soils					
Veg. vs. hydric soils	$DR_{\%hydrophytic}=Soils_{\%hydric}$	28	8.114	1	0.010*
Veg. vs. hydric soils	$PI_{\%hydrophytic}=Soils_{\%hydric}$	28	1.310	1	0.391
iv) hydrophytic vegetation determinations on hydric and nonhydric soils					
% hydrophytic veg.	$PI_{hydric\ soils}=PI_{nonhydric\ soils}$	28	14.424	1	<0.001**
% hydrophytic veg.	$DR_{hydric\ soils}=DR_{nonhydric\ soils}$	28	3.329	1	0.146
% hydrophytic veg.	$PI_{hydric\ soils}=DR_{hydric\ soils}$	17	0.000	1	1.000
% hydrophytic veg.	$PI_{nonhydric\ soils}=DR_{nonhydric\ soils}$	11	4.701	1	0.092

plots with nonhydric soils (81.8%) and hydric soils (100.0%) (p=0.146).

The DR and the PI disagreed in 17.9% of the study plots. In all of these plots, hydric soil indicators were absent, the PI determined that vegetation was nonhydrophytic, and the DR determined that vegetation was hydrophytic (Table 3). An odd number of plant species was dominant in four of the five plots. The probability of the DR producing a hydrophytic vegetation determination in these plots ranged from 68.8% to 89.9%.

Discussion

Vine Stratum Effect on Vegetation Determinations

In the species-rich plant communities we studied, the low-cover woody vine stratum had little effect on vegetation determinations made by the PI. In all plots and in only plots containing borderline vegetation, the percentage of hydrophytic vegetation determinations produced by the PI was unaffected by the use of different vine abundance measures, cover thresholds, or indicator status ratings (Table 2). Mathematically, each species' contribution to the final PI value is weighted based on its absolute cover and its wetland indicator status. Because the woody vine stratum constituted less than 10% of the cover in 78.5% of the study plots (Table 1), our manipulations had no significant effect on final index values. These results suggest that, in wetland boundary plots, strata with low cover, like the woody vine stratum, are unlikely to exert excessive influence on vegetation determinations made using the PI.

In most of the study plots, the woody vine stratum also had little effect on vegetation determinations made by the DR. The percentage of hydrophytic vegetation determinations produced by the DR was not significantly affected by different vine abundance measures, artificial increases or decreases to minimum cover thresholds, or artificial increases or decreases to vine indicator status (Table 2). These results appear to conflict with previous studies, which document variability in the percentage of hydrophytic vegetation determinations produced by the DR, particularly in plots with fewer than five dominant species (Wakeley and Lichvar 1997; Lichvar et al. 2011). There are two explanations for the DR's unexpected consistency. First, the DR is calculated using the indicator status of dominant species only. Since the woody vine stratum contributed just one dominant to plots with up to seven dominant species (Table 1), in most plots our artificial manipulations, such as increasing or decreasing the minimum cover threshold or vine indicator status had little effect on the overall ratio of hydrophytic dominants to total dominants. Second, in the Lichvar et al. (2011) study, simulations represented vegetation from a wide range of landscape positions—from xeric uplands to permanently flooded wetlands. All wetland indicator status categories from UPL to OBL were equally likely to occur. Hydrophytes occurred with a frequency of 60.0%. In contrast, these data were obtained from a single landscape position, wetland boundaries, where OBL and UPL species occurred extremely infrequently. Hydrophytes, mainly FAC and FACW species, occurred with a frequency of 71.9% (Fig. 1). Given this high frequency, in most plots, our cover threshold and indicator status manipulations simply added or removed a hydrophytic dominant to a ratio that was already predominately hydrophytic.

Vegetation determinations made by the DR were affected by our artificial manipulations of the woody vine stratum in a small percentage of the study plots. Slightly less than a third of the plots contained borderline hydrophytic/nonhydrophytic vegetation. Excluding the woody vine stratum, the dominant plant species in these plots consisted of either equal numbers of hydrophytes and nonhydrophytes or one more hydrophyte than nonhydrophyte (i.e., three hydrophytes and two nonhydrophytes). When we artificially increased vine species' indicator status ratings (e.g., FAC to FACU) in plots with borderline vegetation, the percentage of

Table 3 Factors associated with plots in which the Prevalence Index (PI) and the Dominance Ratio (DR) differed. PI calculations were based on all strata and percent cover. DR calculations were based on the indicator status (Reed 1988) of dominant species. The 50/20 Rule was used to select dominant species from all strata that met the minimum cover threshold of 5.0%. The probability of the DR producing a hydrophytic vegetation determination was calculated according to Lichvar et al. (2011), using the frequency with which hydrophytes occurred in these data, 71.9% (Fig. 1)

Plot	Probability of Hydrophytic DR	Total Dominants	Hydrophytic Dominants	DR	PI	Borderline Vegetation	Hydric Soil Indicators
5-CT	89.8%	7	4	57.1	3.1	Yes	none
8-CT	80.8%	3	2	66.7	3.2	Yes	none
9-IN	86.1%	3	2	66.7	3.2	Yes	none
15-IN	68.6%	4	3	75.0	3.2	No	none
28-VA	80.8%	3	2	66.7	3.2	Yes	none

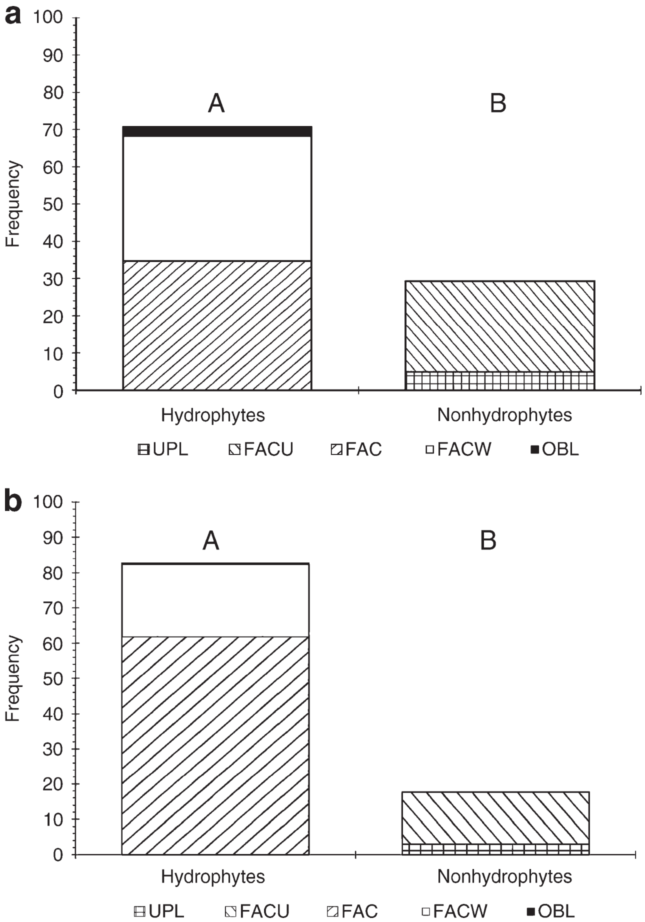

Fig. 1 Frequency of occurrence of wetland indicator status categories (Reed 1988) among strata including **a**) trees, shrubs and herbs, and **b**) the woody vine stratum. Values indexed with the same letter are not significantly different from one another

hydrophytic determinations made by the DR decreased from 100.0% to 20.0% (p=0.048) (Table 2). The response was significant, since 61.8% of the vine species in this study were FAC indicators that became FACU (Fig. 1). Decreasing the indicator status of the vine stratum (e.g., FAC to FACW) had no effect because DR determinations were already 100.0% hydrophytic. This significant response suggests that in wetland boundary plots, strata with low cover, like the woody vine stratum, may exert excessive influence on DR determinations. However, the small sample size (n=5) necessitates a cautious interpretation of these results. Additional studies or vegetation simulations that examine the effect of other low-cover stratum in a variety of wetland types are needed to corroborate these results.

Patterns of Agreement Between Vegetation and Soils

The data also provided evidence that the PI is a more precise vegetation indicator than the DR in plant communities characterized by a high frequency of hydrophytes. In this study, hydrophytic plant species occurred along wetland boundaries about three times as often as non-hydrophytic species (Fig. 1). The PI not only agreed with soils more often than the DR, it also distinguished between nonhydrophytic and hydrophytic plant communities better than the DR, producing significantly fewer hydrophytic vegetation determinations in plots with nonhydric soils (36.4%) than in plots with hydric soils (100.0%) (p<0.001, Table 2). Most likely, the PI distinguished nonhydrophytic vegetation better than the DR because it is calculated using the abundance of all plant species, not just the presence of dominants. In contrast, vegetation determinations made by the DR disagreed significantly with hydric soils. The total percentage of hydrophytic determinations made by the DR, 92.9%, was significantly greater than the percentage of plots with hydric soils, 60.7% (p=0.010) (Table 2). The DR also produced similar percentages of hydrophytic vegetation determinations in plots with hydric (100.0%) and nonhydric soils (81.8%). These data suggest that the DR consistently overshot the boundary between hydric and nonhydric soils, determining that the boundary between hydrophytic and nonhydrophytic vegetation was located much farther into adjacent non-wetlands, when compared to the PI. Although there was no difference in the percentage of hydrophytic determinations that the DR and the PI produced on nonhydric soils, the lack of statistical significance (p=0.092) between these percentages is most likely due to the small number of plots in this subset of the data (n=11).

Patterns of Disagreement Between the Vegetation Formulas

Other studies suggest that the PI and the DR disagree from 16 to 54.3% of the time (Wakeley et al. 1996; Wakeley and Lichvar 1997; Dewey et al. 2006). In this study the formulas disagreed in 17.9% of the plots, within the range of previously reported values. Because the number of plots that disagreed was small (n=5), we will not draw conclusions from these observations. Instead, we describe the pattern of disagreement in these data as it relates to prior work.

In this study, the vegetation formulas disagreed only in plots that lacked hydric soils (Table 3). In all of these plots, the DR disagreed with soils and the PI, determining that vegetation was hydrophytic. This pattern is not unusual. In 80,000 vegetation simulations, the hydrophytic DR/non-hydrophytic PI pattern occurred much more often than the reverse (Wakeley and Lichvar 1997). It has been described by Wakeley et al. (1996) in Hawaiian rainforests and by Dewey et al. (2006) in Texas bottomland forests. Data from these FAC-dominated plant communities suggested that the DR was biased toward hydrophytic vegetation determinations and disagreed with soils more often than the PI.

The literature suggests two explanations for the hydrophytic DR/nonhydrophytic PI pattern observed in this study: the effect of sparse dominants from low-cover strata on plots with borderline vegetation and the DR's odd-even bias. The 50/20 approach, the dominant selection process used in the DR, may be one cause of disagreement between the vegetation formulas, since it enables sparse species from low-cover strata to be selected as dominants and exert influence on hydrophytic vegetation determinations (Wakeley and Lichvar 1997). There are two reasons that several sparse dominants may be selected from the same low-cover stratum. First, cover values of several sparse species may be required to reach the 50% threshold and satisfy 50/20 requirements. Second, strata protocols require that species with equal cover values be treated equally. For instance, in a plot with 105.0% total cover, if the woody vine stratum consists of three species with 3, 2, and 2% cover, the 50/20 approach selects all three as dominants. In a plot with borderline hydrophytic/nonhydrophytic vegetation, these sparse dominants could "tip" a vegetation determination in one direction or the other.

In this study, four of the five plots in which the DR and the PI disagreed contained borderline vegetation (Table 3). In these plots, vegetation determinations could be "tipped" by dominants from a low-cover stratum. For instance, a plot from Portage, IN, was dominated by one hydrophyte, *Fraxinus pennsylvanica* Marsh. (green ash) (FACW), and one nonhydrophyte, *Quercus alba* L. (white oak) (FACU), in the tree stratum. In this plot the presence of the vine *Smilax rotundifolia* (FAC) resulted in the DR determining that the vegetation was 66.7% hydrophytic. However, the PI determined that vegetation was nonhydrophytic (3.2), and the plot lacked hydric soil indicators. In this instance, selecting a dominant species from the woody vine stratum, a stratum with fairly low cover (9.1% of the total cover), may be one cause of the disagreement between the PI and the DR. The extremely large percentage of hydrophytic vines in this dataset, 82.4% (Fig. 1), suggests that vegetation determinations are more likely to be "tipped" towards hydrophytic in these study regions.

The DR's odd-even bias offers a second explanation for the hydrophytic DR/nonhydrophytic PI pattern of disagreement we observed. Selection of a few dominant species, in combination with binomial probability, causes a staggered bias in vegetation determinations produced by the DR, depending on whether the number of dominants is even or odd (Lichvar et al. 2011). The DR is most likely to produce hydrophytic determinations in plots with an odd number of dominant species and nonhydrophytic determinations in plots with an even number of dominants. The PI, which bases vegetation determinations on the indicator status and abundance data of all species, does not display this pattern. Interestingly, in four of the five plots in which the formulas disagreed there was an odd number of dominant species. In these plots, either three or seven species were dominant and there was a very high probability of the DR producing a hydrophytic vegetation determination, 80.8–89.8% (Table 3), since hydrophytes occurred with a frequency of 71.9% (Fig. 1). In addition to contributing to disagreement between the vegetation formulas, the odd number of dominant species may also explain the large percentage of hydrophytic vegetation determinations, 81.8%, made by the DR in plots with nonhydric soils.

As mentioned previously, the pattern described here is not the only pattern of disagreement between the vegetation formulas. Other work suggests that hydrophytic PI/nonhydrophytic DR disagreements occur when the number of dominant species is small (Wakeley and Lichvar 1997), particularly when there is an even number of dominants (Lichvar et al. 2011). In unpublished data from AK, disagreement between the formulas occurred most often on hydric soils with scrub-shrub vegetation. The majority of plots that disagreed were dominated by two plant species, one from the shrub stratum and one from the herb stratum (Lichvar et al. 2011a).

Recommendations

Either percent cover or stem counts can be used to measure the abundance of the woody vine stratum. Since both methods produce the same results, percent cover, the more expedient method, should be used. Limits should be placed on the time allocated to vine sampling because in most situations, low-cover strata, like the woody vine stratum, have little effect on most vegetation determinations.

Because DR determinations are susceptible to being "tipped" by sparse dominants from low-cover strata, the DR should not be used in plots that contain borderline vegetation, such as equal numbers of hydrophytic and nonhydrophytic dominants, or one more hydrophytic than nonhydrophytic dominant. In species-rich plant communities characterized by a high frequency of hydrophytes, the DR is a less accurate vegetation indicator than the PI. The DR is less able to distinguish nonhydrophytic from hydrophytic vegetation near the wetland boundary and frequently disagrees with hydric soil indicators.

We recommend that the PI be used for vegetation determinations in plant communities characterized by high species richness, high frequency of hydrophytes, or low-cover strata. Vegetation determinations made by the PI are not significantly affected by low-cover vegetative strata, such as the vine stratum. These data suggest that the PI is a more precise indicator than the DR because it agrees more consistently with hydric soil indicators and is better able to distinguish between nonhydrophytic and hydrophytic plant communities located along wetland boundaries.

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