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Wetlands Regulatory Assistance Program (WRAP)

Examining Discrepancies Among Three Methods Used to Make Hydrophytic Vegetation Determinations for Wetland Delineation Purposes

Robert W. Lichvar and Jennifer J. Gillrich

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Abstract

Three methods for making vegetation determinations—the Prevalence Index (PI), the Dominance Ratio (DR), and the Hydrophytic Cover Index (HCI)—were compared using national wetland delineation data. The PI and the DR produced significantly fewer hydrophytic determinations (69%, $p < 0.01$, and 76%, $p = 0.04$) than the HCI (80%). The three methods disagreed 16% of the time. The HCI produced hydrophytic determinations only in plots where hydrophyte (Facultative, Facultative Wetland, and Obligate species) cover was greater than 50% of the total cover and never produced hydrophytic determinations in plots where hydrophyte cover was 50% or less. The PI disagreed with the HCI 12% of the time, producing nonhydrophytic determinations in plots where hydrophyte cover was greater than 50%. The DR disagreed with the HCI 9% of the time. Disagreements included nonhydrophytic determinations in plots where hydrophyte cover was greater than 50%, hydrophytic determinations in plots where hydrophyte cover was 50% or less, and a nonhydrophytic bias in plots dominated by even numbers of plant species. These results demonstrate that HCI determinations are more accurate and consistent than those of the PI and the DR. The HCI method is recommended for making vegetation determinations during wetland delineations in future revisions of the Corps delineation manual and its supplements.

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Preface

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The principal investigators were Robert W. Lichvar and Jennifer J. Gillrich, both of the Remote Sensing/Geographic Information Systems (RS/GIS) and Water Resources Branch, Cold Regions Research and Engineering Laboratory (CRREL), US Army Engineer Research and Development Center (ERDC), Hanover, NH. This study was conducted under the general supervision of Timothy Pangburn, Chief, RS/GIS and Water Resources Branch; Dr. Justin B. Berman, Chief, Research and Engineering Division; Dr. Lance Hansen, Deputy Director; and Dr. Robert E. Davis, Director.

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Acronyms and Abbreviations

CRREL	US Army Cold Regions Research and Engineering Laboratory
DR	Dominance Ratio
ERDC	Engineer Research and Development Center
FAC	Facultative
FACU	Facultative Upland
FACW	Facultative Wetland
HCI	Hydrophytic Cover Index
NAT	National Advisory Team for the Regionalization of the Corps of Engineers Wetland Delineation Manual
NTCWV	National Technical Committee on Wetland Vegetation
OBL	Obligate
PI	Prevalence Index
RS/GIS	Remote Sensing/Geographic Information Systems
UPL	Upland
USACE	US Army Corps of Engineers
WRAP	Wetland Regulatory Assistance Program

1 Introduction

In the United States, wetlands are delineated based on the presence of three factors, hydrophytic vegetation, hydric soils, and wetland hydrology, by using methods described in the *Corps of Engineers Wetland Delineation Manual* (hereafter the 1987 Manual) (Environmental Laboratory 1987) and the appropriate Regional Supplement (e.g., USACE 2010). To determine whether vegetation is predominantly hydrophytic or nonhydrophytic, plant species have traditionally been assessed using wetland indicator status ratings on *The National List of Plant Species that Occur in Wetlands* (hereafter the 1988 List) (Reed 1988) and a mathematical method for determining if vegetation is hydrophytic, either the Dominance Ratio (DR) or the Prevalence Index (PI). On the 1988 List, plant species are rated in five categories that range from Obligate (OBL) to Upland (UPL) (Table 1). The five categories originally represented the frequency with which plant species were thought to occur in wetlands, based on the literature and field experiences of botanists and wetland ecologists. The ratings have evolved into short ecological descriptions of how often a plant species is thought to occur in wetlands (Lichvar and Minkin 2008; Lichvar and Gillrich 2011; Lichvar et al. 2012). Plant species that are not listed on the 1988 List are considered UPL.

Table 1. Indicator values and short working definitions associated with the five wetland-indicator status ratings used on the National Wetland Plant List.

Species Designation	Indicator Status (abbreviation)	Indicator Value	% Occurrence in Wetlands (Reed 1988)	Ecological Description (Lichvar et al. 2012)
Hydrophyte	Obligate (OBL)	1	99	Almost always occur in wetlands
Hydrophyte	Facultative Wetland (FACW)	2	67–99	Usually occur in wetlands, but may occur in non-wetlands
Hydrophyte	Facultative (FAC)	3	34–66	Occur in wetlands and nonwetlands
Nonhydrophyte	Facultative Upland (FACU)	4	1–33	Usually occur in non-wetlands, but may occur in wetlands
Nonhydrophyte	Upland (UPL)	5	1	Almost never occur in wetlands

The DR is the method used most frequently to make vegetation determinations during wetland delineations. This method makes determinations based on the wetland indicator status ratings of the dominant plant species only; ratings of nondominant species are disregarded. It is described in detail in the 1987 Manual (Environmental Laboratory 1987), the Regional Supplements (e.g., USACE 2010), and the *Federal Manual for Identifying and Delineating Jurisdictional Wetlands* (Federal Interagency Committee for Wetland Delineation 1989). To determine the DR, vegetation is divided into the following strata: herbs, shrubs, vines, and trees. Saplings are treated as a separate stratum in some Corps regions. Three values are calculated for each stratum: total cover, 50% of total cover, and 20% of total cover. According to the 50/20 Rule, dominant species are those that compose at least 20% of the total cover of each stratum. (See the *Methods* section for a detailed description of the dominant selection process.) The numbers of hydrophytic dominants and total dominants are tallied across strata. The DR is the total number of dominant hydrophytes (FAC or wetter) divided by the total number of dominant plant species. There are two outcomes. Vegetation is considered hydrophytic when the DR is greater than 50% and nonhydrophytic when the DR is 50% or less.

The second method, the PI, is a weighted average that was originally calculated using frequency data from line-intercept sampling (Wentworth et al. 1988). The PI confirms the presence of hydrophytic vegetation, but it cannot objectively locate the wetland boundary using vegetation alone (Carter et al. 1988). Wakeley and Lichvar (1997) modified the PI, changing it to a plot-based method for wetland delineation purposes. To calculate PI in a plot, the total cover of all species in each rating category (OBL–UPL) is summed and multiplied by the indicator value (1–5) of that rating category (Table 1) and then divided by the total cover of all plant species in the plot. PI values range from 1.0 to 5.0. Vegetation with a PI value less than or equal to 3.0 is considered hydrophytic. Vegetation with a PI value greater than 3.0 is considered nonhydrophytic.

The DR and the PI have been the subject of much research because they produce conflicting vegetation determinations 16%–54% of the time (Wakeley et al. 1996; Wakeley and Lichvar 1997; Dewey et al. 2006). The DR's role in these discrepancies has been well documented. Vegetation simulations show that the DR exhibits an odd-hydrophytic, even-nonhydrophytic bias in determinations, depending on the number of dominant species in a plot (Lichvar et al. 2011). Another source of disagreement is the DR's use of strata. As the numbers of strata and dominant species in a plot increase, the probability of the DR producing a hydrophytic determination increases by more than 20% (Lichvar et al. 2011). In addition, low-cover strata, such as woody vines, can also cause discrepancies between the DR and the PI. Because all dominant species are treated equally, sparse dominants from low-cover strata can “tip” DR determinations from hydrophytic to nonhydrophytic (or the reverse) when the number of hydrophytic and nonhydrophytic dominants are similar (Gillrich et al. 2011).

The PI may also contribute to these discrepancies. In June 2011, the National Advisory Team for the Regionalization of the Corps of Engineers Wetland Delineation Manual discussed a report from the National Technical Committee on Wetland Vegetation (NTCWV) regarding discrepancies between the DR and the PI. The discussion revealed a belief that the PI sometimes produces nonhydrophytic vegetation determinations when greater than 50% of the vegetative cover is hydrophytic (NAT 2011). A preliminary investigation using randomly generated vegetation simulations suggested that PI determinations conflict with the actual percent cover of FAC, FACW, and OBL species in a plot 14.4% of the time. In 88.9% of the plots that disagreed, the PI produced a nonhydrophytic determination even though species rated FAC, FACW, and OBL represented over 50% of the total cover (Lichvar and Gillrich, unpublished data).

Given the history of disagreement between the DR and the PI and the inaccuracies associated with each method, NTCWV recently recommended testing the Hydrophytic Cover Index (HCI) to determine if it exhibits the inaccuracies of the PI or the DR (NTCWV 2011). The HCI has its origin in the basic vegetation rule described in the 1987 Manual (hereafter the Basic Rule) (Environmental Laboratory 1987). This hydrophytic vegetation criterion states that hydrophytic vegetation is present when greater than 50% of the dominant plant species are rated FAC, FACW, or OBL (Environmental Laboratory 1987). The HCI is calculated by dividing the summed cover of the species rated FAC, FACW, and OBL by the total cover of all species in the plot. Recent work suggests that the HCI produces repeatable, consistent vegetation determinations regardless of plot size, plot shape, or the ability to identify all plant species present (Lichvar and Gillrich 2014).

In our study, we had three objectives. The first objective was to use a national delineation data set to compare all determinations produced by the HCI, the PI, and the DR. To meet this objective, we tested the hypothesis that there is no significant difference in the percentage of hydrophytic determinations produced by the HCI, the PI, and the DR in a national data set of wetland delineation plots. The second objective was to compare the percentage of hydrophytic vegetation determinations produced by the three methods in plots where hydrophyte cover was greater than 50% and less than or equal to 50%. Here, we tested the hypothesis that there is no significant difference in the percentage of hydrophytic vegetation determinations produced by the three methods in two subsets of plots where (a) hydrophytes (plant species rated FAC, FACW, and OBL) represented 50% or less of the total cover and (b) hydrophytes represented greater than 50% of the total cover. The third objective was to determine if the HCI is subject to any of the biases or inaccuracies associated with the DR or the PI. To meet this objective, we tested the hypothesis that there is no significant difference in the percentage of hydrophytic vegetation determinations produced by the HCI, the PI, and the DR in two subsets of plots in which (a) even and (b) odd numbers of plant species are selected as dominants.

2 Methods

To test these hypotheses, we used data collected in nine Corps regions during the development and field testing of the Regional Supplements to the Army Corps of Engineers Wetland Delineation Manual (Berkowitz 2011). These delineation data were collected between 2004 and 2009 by teams of wetland resource professionals representing the US Army Corps of Engineers (USACE), the Natural Resources Conservation Service, the Environmental Protection Agency, the US Fish and Wildlife Service, and a variety of state and local agencies. Using procedures described in the 1987 Manual and in the appropriate Regional Supplement, the regional teams collected vegetation data at 232 sites in 637 plots. At each site, plots were located on either side of the wetland boundary or along a wetland-to-upland transect. Most often, nested circular plots with 9 m (30 ft) and 2 m (5 ft) radii, as described in the 1987 Manual (Environmental Laboratory 1987), were used to collect percent areal cover data. Occasionally, herb cover was collected in nested 1 m^2 plots as described in the appropriate Regional Supplement (e.g., USACE 2010). Vegetation was identified to the species level, and wetland ratings were assigned according to the 1988 List (Reed 1988). Plots were not used if the percent cover was not recorded or if more than 20.0% of the vegetation was not identified to species. For more information on these data, see Berkowitz (2011).

3 Data Analysis

With regard to the first hypothesis, we calculated the HCI, the PI, and the DR for each plot in the national data set (n = 637) and tallied the number of plots that contained hydrophytic vegetation as determined by each method. To calculate the HCI, we used the wetland ratings, the percent cover data from each plot, and the following equation:

$$HCI = (S_{obl} + S_{facw} + S_{fac})/(S_{obl} + S_{facw} + S_{fac} + S_{facu} + S_{upl}) \times 100$$

where S is the summed percent areal cover. Plots with HCI values greater than 50% were determined to contain hydrophytic vegetation. Plots with HCI values of 50% or less were determined to contain nonhydrophytic vegetation.

To calculate the PI, we used wetland ratings, the percent areal cover data from each plot, and the following equation:

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

where S is the summed percent areal cover. Plots with PI values greater than 3.0 were determined to contain nonhydrophytic vegetation. Plots with PI values of 3.0 or less were determined to contain hydrophytic vegetation (Environmental Laboratory 1987; USACE 2010).

To calculate the DR, we selected dominant species based on cover values, according to the 50/20 rule (Environmental Laboratory 1987; Federal Interagency Committee for Wetland Delineation 1989). We calculated the total cover in each plot by summing the absolute cover values for all species. In each vegetative stratum (e.g., tree) with an absolute cover value of at least 5%, we ranked the plant species in descending order by absolute cover values. The 50% and 20% thresholds for each stratum were determined by multiplying the total cover by 0.50 and 0.20, respectively. The dominant species in each stratum were those selected from the top of this list until the cumulative cover exceeded 50%. If several species on the list had the same cover value, they were all selected. If any species with an absolute cover value greater than or equal to 20% of the total cover in the stratum had not been selected, it was also considered dominant. We applied wetland ratings (Reed 1988), divided the total number of hydrophytic dominants by the total number of dominants, and then multiplied by 100 to yield the DR. Plots with DR values less than or equal to 50% were determined to contain nonhydrophytic vegetation. Plots with DR values greater than 50% were determined to contain hydrophytic vegetation (Environmental Laboratory 1987; USACE 2010).

To test the second hypothesis regarding discrepancies among the three methods in plots where hydrophyte cover was greater than 50% or less than or equal to 50% of the total cover, we divided the data into two subsets of plots. The two subsets were plots in which more than 50% of the total cover was composed of plant species rated FAC, FACW, and OBL (n = 512) and plots in which 50% or less of the total cover was composed of plant species rated FAC, FACW, and OBL (n = 125). In each plot, we summed the absolute percent cover of species rated FAC, FACW, and OBL. We also summed the absolute percent cover of all species and multiplied by 0.5. If the summed hydrophyte cover was greater than half of the total cover, the plot was put in the first subset of plots. If the summed hydrophyte cover was less than or equal to half of the total cover, the plot was put in the second subset. In both subsets of plots, we tallied the number of plots that contained hydrophytic vegetation, according to each of the three methods.

To address the third hypothesis, we divided the data into two subsets of plots: those in which an odd number (1, 3, 5, 7, 9, 11, or 13) of plant species were selected as dominants (n = 306) and those in which an even number (2, 4, 6, 8, 10, or 12) of plant species were selected as dominants (n = 331). In both subsets, we tallied the number of plots that contained hydrophytic vegetation, according to each of the three methods.

When expected and observed values were large, we used Pearson Chi-Square tests and SYSTAT 12 statistical software (Systat Software, Inc. 2007) to test for differences in the percentages of hydrophytic vegetation determinations produced by the three methods. When expected and observed values were low (less than 5), we used Fisher’s Exact tests. Fisher’s Exact tests are designed for use with categorical data. In contrast to the Chi-Square test, 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. Because they are more conservative and less likely to reject a null hypothesis when it is true, Fisher's Exact tests have greater statistical power than Chi-Square tests (Bowman and Shetty 2007).

4 Results

Results from the first hypothesis test indicate that the PI (69%) and the DR (76%) produced significantly smaller percentages of hydrophytic vegetation determinations than the Hydrophytic Cover Index (HCI) (80%) produced (Table 2a). The p-values (hereafter p) of 0.01 and 0.04, respectively, demonstrated strong evidence against the null hypothesis. Overall, the three methods produced conflicting hydrophytic vegetation determinations in 105 plots (16%) of the 637 wetland delineation plots collected in nine Corp Regions. The PI disagreed with the HCI in 74 plots (12%) (Table 2b[i] and 2b[ii]). The DR disagreed with the HCI in 57 plots (9%). The total disagreement among the three methods (16%) is less than the sum of the individual disagreements (12% + 9% = 21%) because in 29 plots (5% of the data), determinations made by the PI and the DR agreed with each other but conflicted with those made by the HCI.

Tests of the second hypothesis showed that the HCI produced no hydrophytic vegetation determinations (0%) in plots where plant species rated FAC, FACW, and OBL represented less than or equal to 50% of the total cover. The PI determinations were similar (2%, $p = 0.50$). However, the DR produced a significantly larger percentage of hydrophytic determinations (10%, $p < 0.01$) than the HCI. In plots where plant species rated FAC, FACW, and OBL represented greater than 50% of the total cover, all of the vegetation determinations produced by the HCI (100%) were hydrophytic. Both the PI (86%, $p < 0.01$) and the DR (91%, $p < 0.01$) produced significantly smaller percentages of hydrophytic determinations in these plots.

With regard to the third hypothesis, the DR and the PI produced significantly smaller (70%, $p < 0.01$) percentages of hydrophytic vegetation determinations than the HCI (81%) in plots containing an even number of dominant plant species. When an odd number of plant species was dominant, 80% of the vegetation determinations made by the HCI were hydrophytic. The DR produced a similar percentage (81%, $p = 0.84$). However, the PI produced a significantly smaller percentage of hydrophytic determinations (69%, $p < 0.01$) when compared to the HCI.

Table 2. Chi-Square test and Fisher's Exact test results comparing the percentage of hydrophytic vegetation determinations produced by the Hydrophytic Cover Index (HCI), the Prevalence Index (PI), and the Dominance Ratio (DR). Data were collected (as described in Berkowitz [2011]) during field testing of the Regional Supplements to the Army Corps of Engineers *Wetland Delineation Manual*. df represents degrees of freedom. X^2 is the chi-squared test statistic.

Hypotheses	Plots with Hydrophytic Vegetation						n	χ^2	df	p
	HCI		PI		DR					
	%	No.	%	No.	%	No.				
(a) In all plots across nine Corps Regions										
$HCI_{hydrophytic} = PI_{hydrophytic}$	80	512	69	442			637	20.45	1	<0.01
$HCI_{hydrophytic} = DR_{hydrophytic}$	80	512			76	481	637	4.39	1	0.04
(b) In a subset of plots where (i) hydrophyte* cover ≤ 50% of the total cover†										
$HCI_{hydrophytic} = PI_{hydrophytic}$	0	125	2	2			125	2.02	1	0.50
$HCI_{hydrophytic} = DR_{hydrophytic}$	0	125			10	13	125	13.71	1	<0.01
(ii) hydrophyte cover > 50% of the total cover										
$HCI_{hydrophytic} = PI_{hydrophytic}$	100	512	86	440			512	77.45	1	<0.01
$HCI_{hydrophytic} = DR_{hydrophytic}$	100	512			91	468	512	45.98	1	<0.01
(c) In a subset of plots where (i) an even number of plant species are selected as dominant										
$HCI_{hydrophytic} = PI_{hydrophytic}$	81	247	70	214			306	9.57	1	<0.01
$HCI_{hydrophytic} = DR_{hydrophytic}$	81	247			70	213	306	10.12	1	<0.01
(ii) an odd number of plant species are selected as dominant										
$HCI_{hydrophytic} = PI_{hydrophytic}$	80	265	69	228			331	10.88	1	<0.01
$HCI_{hydrophytic} = DR_{hydrophytic}$	80	265			81	268	331	0.09	1	0.84

* FAC, FACW, and OBL species.

† Fisher's Exact tests were used.

5 Discussion

These delineation data collected in nine Corps regions suggest that the HCI is a better metric for assessing vegetation than either the PI or the DR. Nationally, the three formulas disagreed 16% of the time. The PI (69%, $p < 0.01$) and the DR (76%, $p = 0.04$) produced significantly fewer hydrophytic vegetation determinations than the HCI (80%) (Table 2a). These results suggest that the HCI is a more accurate and consistent indicator of hydrophytic vegetation than the other methods. The HCI is more accurate because it correctly identified the presence or absence of hydrophytic vegetation in all of the wetland delineation plots ($n = 637$). All HCI determinations were hydrophytic in the subset of plots in which hydrophytes—plant species rated FAC, FACW, and OBL—composed greater than 50% of the total cover. Conversely, the HCI produced no hydrophytic determinations in plots where hydrophytes represented 50% or less of the total cover. Neither the PI nor the DR was able to correctly identify the vegetation in all plots as hydrophytic or nonhydrophytic. The HCI accurately identifies hydrophytic and nonhydrophytic vegetation because it originated from the 1987 Manual's Basic Rule, a method used to determine if hydrophytic vegetation is present. The Basic Rule states that vegetation is hydrophytic when greater than 50% of the dominant plant species are rated FAC, FACW, or OBL (Environmental Laboratory 1987). The HCI is similar in that it determines that vegetation is hydrophytic when more than 50% of the total cover (dominants and nondominants) in a plot are made up of hydrophytes.

The HCI is also a consistent indicator of hydrophytic vegetation. The HCI is a simple formula that does not weight cover values, as the PI does, or use complicated rules for selecting dominant species, as the DR does, to determine if vegetation is hydrophytic. The HCI uses only the percent cover values and wetland ratings of the plant species in a plot to make vegetation determinations, dividing the percentage of hydrophytic cover by the total cover. Since there is no manipulation of the data in this calculation, the HCI produces consistent results. In these data, the HCI consistently determined that 80%–81% of the vegetation in all plots was hydrophytic, regardless of whether the number of dominant species was odd or even (Table 2a and Table 2c). These results suggest that the HCI will be as accurate and consistent as the wetland ratings assigned to each plant species and as each investigator's ability to estimate percent areal cover.

These results also show that PI is a consistent but inaccurate indicator of hydrophytic vegetation compared to the HCI. Prior work has shown that the PI is a more consistent and reliable indicator of hydrophytic vegetation than the DR (Lichvar et al. 2011), particularly when species richness is high and low-cover strata are present (Gillrich et al. 2011). As in previous work, PI determinations in this study were very consistent, 69%–70% hydrophytic, in all plots, regardless of whether the number of dominant species was odd or even (Table 2a and Table 2c). However, compared to the HCI, the PI was a less accurate indicator because it consistently underestimated the percentage of delineation plots that contained hydrophytic vegetation.

Overall, the PI produced an incorrect vegetation determination in 12% of these data, or 74 plots. In the subset of 125 plots in which 50% or less of the total cover was composed of hydrophytes, the PI determined that two plots contained hydrophytic vegetation (Table 2b[i]). PI determinations were least reliable in the subset of 512 plots where FAC, FACW, and OBL species represented more than 50% of the total cover. The PI determined that only 440 plots contained hydrophytic vegetation (Table 2b[ii]). The PI's lack of accuracy in these 72 plots can be explained by several factors. First, the PI assigns large weighted values to nonhydrophytes (Table 1). Because the PI is a weighted average, species rated FACU (4) and UPL (5) carry more weight in the formula and have a greater effect on the outcome than species rated FAC (3), FACW (2), or OBL (1). Second, in plots where the PI makes an incorrect vegetation determination, species rated FAC are often abundant. Although FAC species are hydrophytes, they are also assigned a fairly high weighted value (3) by the PI. In one example from the Western Mountains, Valleys, and Coast region, absolute percent cover by wetland rating category was as follows: OBL = 0%, FACW = 3%, FAC = 116%, FACU = 23%, and UPL = 7%. Although most (80%) of the cover in this plot was hydrophytic, the PI produced a nonhydrophytic determination of 3.2. Because this plot contained a large percentage of FAC species, the PI value for the hydrophytes alone was $[(0 \times 1) + (3 \times 2) + (116 \times 3)]/119 = 3.0$, the break point between hydrophytic and nonhydrophytic vegetation. When the low to moderate cover values of species rated FACU and UPL are weighted and added to the calculation, the break point is overridden (3.2).

In contrast, vegetation determinations produced by the DR were neither as consistent nor as accurate as the HCI. The DR was a less accurate indicator because it either underestimated or overestimated the percentage of delineation plots that contained hydrophytic vegetation. For instance, in the subset of the data in which hydrophytes represented more than 50% of the total cover, only 91% of DR determinations were hydrophytic, significantly fewer than those produced by the HCI (100%, $p < 0.01$) (Table 2b[ii]). Yet, in the subset of plots where hydrophytes represented 50% of the total cover or less, 10% of DR determinations were hydrophytic, significantly more than those produced by the HCI (0%, $p < 0.01$). Overall, the DR produced an incorrect vegetation determination in 57 plots, or 9% of these delineation data (Table 2b). In 44 of the 57 plots (77%), the DR determined that vegetation was nonhydrophytic when more than 50% of the total cover was composed of hydrophytes. Conversely, in the remaining 13 plots, the DR produced hydrophytic determinations when hydrophytes composed less than or equal to 50% of the total cover.

The odd-even bias that is built into the DR method offers an explanation for the patterns observed in these data. Vegetation simulations demonstrate that the selection of an even number of dominant species in combination with binomial probability creates a nonhydrophytic bias in DR determinations (Lichvar et al. 2011). If all wetland ratings are equally likely to occur, when two species are selected as dominants, there is a low (36%) probability that a DR determination will be hydrophytic. The results of this study corroborate previous work, showing that, in the subset of plots dominated by an even number of plant species, the DR produced significantly fewer hydrophytic determinations (70%, $p < 0.01$) than the HCI (81%) (Table 2c[i]). A plot from the Great Plains region provides an example of the nonhydrophytic bias associated with an even number of dominant species. The plot contained the following cover: *Phalaris arundinacea* L. (reed canary grass) = 50% (FACW), *Poa pratensis* L. (Kentucky blue grass) = 25% (FACU), *Persicaria amphibia* (=*Polygonum amphibium*) (L.) S.F. Gray p.p. (water smartweed) = 20% (OBL), and *Spartina pectinata* Bosc ex Link (freshwater cord grass) = 15% (FACW). According to the 50/20 Rule, two grasses, *Poa pratensis* and *Phalaris arundinacea*, are dominants. The DR produced a nonhydrophytic determination (50%) even though 77% of the cover and three of the four species were hydrophytic.

Conversely, selection of an odd number of dominants in combination with binomial probability creates a hydrophytic bias in DR determinations

(Lichvar et al. 2011). If all wetland ratings are equally likely to occur, when three species are selected as dominants, there is a high (65%) probability that a DR determination will be hydrophytic even when the percent cover of FAC, FACW, and OBL species in a plot is 50% or less. A plot from the Arid West region provides an example. The plot contained five species: *Solidago altissima* L. (tall goldenrod) = 25% (FACU), *Juncus mexicanus* Willd. ex J.A. & J.H. Schultes (Mexican rush) = 15% (FACW), *Potentilla anserina* L. (common silverweed) = 15.0% (OBL), *Bromus arvensis* L. (field brome) = 10% (FACU), and *Equisetum laevigatum* A. Braun (smooth scouring rush) = 5% (FACW). Three species, *S. altissima*, *P. anserina*, and *J. mexicanus*, were selected as dominants, making the DR = 67%. Yet, only 50% of the cover in this plot was hydrophytic. Therefore, it is not considered hydrophytic.

6 Conclusions

Given these results, we recommend the Hydrophytic Cover Index (HCI) method for making vegetation determinations during wetland delineations. The HCI method significantly outperformed both the PI and DR methods with respect to the accuracy and consistency of hydrophytic vegetation determinations. All HCI determinations are hydrophytic in plots where hydrophyte cover is greater than 50% of the total cover. None of the HCI determinations are hydrophytic in plots where hydrophyte cover is less than or equal to 50% of the total cover. The HCI is a better method because it is a simple formula that does not weight percent cover values or select a few dominant species to represent the entire plot. Instead, the HCI outcome is influenced only by the percent cover values and wetland indicator status ratings of the plant species present.

Vegetation determinations made by the PI and the DR are less accurate and less consistent than the HCI because they are affected by weighted values and the number of dominant species. The PI and the DR produced incorrect vegetation determinations 16% of the time in these national delineation data. Most often, they produced nonhydrophytic determinations in plots where hydrophyte cover represented more than 50% of the total cover. Occasionally they produced hydrophytic vegetation determinations in plots where hydrophyte cover was less than or equal to 50%. Therefore, in future revisions of the Corps delineation manual and its supplements, we recommend the HCI method for making vegetation determinations during wetland delineations.

References

Berkowitz, J. F. 2011. Recent advances in wetland delineation—Implications and impact of regionalization. *Wetlands* 31:593–601.

Bowman, C., and H. N. Shetty. 2007. Crosstabulation (One-way, Two-way, and Multiway). In *SYSTAT12: Statistics I,* 220–226. San Jose, CA: SYSTAT Software, Inc.

Carter, V., M. K. Garrett, and P. T. Gammon. 1988. Wetland boundary determination in the Great Dismal Swamp using weighted averages. *Water Resources Bulletin* 24:297–306.

Dewey, J. C., S. H. Schoenholtz, J. P. Shepard, and M. G. Messina. 2006. Issues related to wetland delineation of a Texas, USA bottomland hardwood forest. *Wetlands* 26:410–429.

Environmental Laboratory. 1987. *Corps of Engineers Wetlands Delineation Manual*. Technical Report Y-87-1. Vicksburg, MS: Environmental Laboratory, US Army Engineer Waterways Experiment Station. http://el.erdc.usace.army.mil/elpubs/pdf/wlman87.pdf (accessed 19 November 2010).

Federal Interagency Committee for Wetland Delineation. 1989. *Federal Manual for Identifying and Delineating Jurisdictional Wetlands*. Cooperative Technical Publication. Washington, DC: US Army Corps of Engineers, US Environmental Protection Agency, US Fish and Wildlife Service, and U.S.D.A. Soil Conservation Service. http://www.wetlands.com/pdf/89manv3b.pdf.

Gillrich, J. J., B. P. Allen, and R. W. Lichvar. 2011. The effect of a low-cover stratum—woody vines—on vegetation determinations made during wetland delineations. *Wetlands* 31:865–873.

Lichvar, R. W., and J. J. Gillrich. 2011. *Final Protocol for Assessing Wetland Indicator Status Ratings During the National Wetland Plant List Update.* ERDC/CRREL TN-11-1. Hanover, NH: US Army Engineer Research and Development Center. http://wetland_plants.usace.army.mil/.

Lichvar, R. W., and J. J. Gillrich. 2014. *Field Testing New Plot Designs and Methods for Determining Hydrophytic Vegetation during Wetland Delineations in the United States*. ERDC/CRREL TN-14-1. Hanover, NH: US Army Engineer Research and Development Center.

Lichvar, R., and P. Minkin. 2008. *Concepts and Procedures for Updating the National Wetland Plant List*. ERDC/CRREL TN-08-03. Hanover, NH: US Army Engineer Research and Development Center. http://wetland_plants.usace.army.mil/.

Lichvar, R. W., J. J. Gillrich, and W. R. Ochs. 2011. Discrepancies in hydrophytic determinations produced by three vegetation formulas used for wetland delineations. *Wetlands* 31:603–611.

Lichvar, R. W., N. C. Melvin, M. L. Butterwick, and W. N. Kirchner. 2012. *National Wetland Plant List Indicator Rating Definitions.* ERDC/CRREL TR-12-1. Hanover, NH: US Army Engineer Research and Development Center. http://wetland_plants.usace.army.mil/.

National Advisory Team for the Regionalization of the Corps of Engineers Wetland Delineation Manual (NAT). 2011. Personal Communication. Discussion of a report from the NTCWV. 7 June. Fort Collins, CO: Fort Collins Science Center.

National Technical Committee on Wetland Vegetation (NTCWV). 2011. Personal Communication. Annual Meeting—Vegetation Sampling, Hydrophytic Vegetation Discussions. 18 May (teleconference). Hanover, NH: US Army Engineer Research and Development Center.

Reed, P. B. 1988. *National List of Plant Species that Occur in Wetlands.* Biological Report 88(26.11). Washington, DC: US Department of the Interior, Fish and Wildlife Service.

Systat Software, Inc. 2007. SYSTAT 12 for Windows®. San Jose, CA: Systat Software, Inc.

Wakeley, J. S., and R. W. Lichvar. 1997. Disagreements between plot-based prevalence indices and dominance ratios in evaluations of wetland vegetation. *Wetlands* 17:301–309.

Wakeley, J. S., S. W. Sprecher, and R. W. Lichvar. 1996. Relationships among wetland indicators in the Hawaiian rain forest. *Wetlands* 16:173–184.

Wentworth, T. R., G. P. Johnson, and R. L. Kologski. 1988. Designation of wetlands by weighted averages of vegetation data: A preliminary evaluation. *Water Resources Bulletin* 24:389–396.

US Army Corps of Engineers. 2010. *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Western Mountains, Valleys, and Coast Region (Version 2.0),* ed. J. S. Wakeley, R. W. Lichvar, and C. V. Noble. ERDC/EL TR-10-3. Vicksburg, MS: US Army Engineer Research and Development Center.

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Three methods for making vegetation determinations—the Prevalence Index (PI), the Dominance Ratio (DR), and the Hydrophytic Cover Index (HCI)—were compared using national wetland delineation data. The PI and the DR produced significantly fewer hydrophytic determinations (69%, $p < 0.01$, and 76%, $p = 0.04$) than the HCI (80%). The three methods disagreed 16% of the time. The HCI produced hydrophytic determinations only in plots where hydrophyte (Facultative, Facultative Wetland, and Obligate species) cover was greater than 50% of the total cover and never produced hydrophytic determinations in plots where hydrophyte cover was 50% or less. The PI disagreed with the HCI 12% of the time, producing nonhydrophytic determinations in plots where hydrophyte cover was greater than 50%. The DR disagreed with the HCI 9% of the time. Disagreements included nonhydrophytic determinations in plots where hydrophyte cover was greater than 50%, hydrophytic determinations in plots where hydrophyte cover was 50% or less, and a nonhydrophytic bias in plots dominated by even numbers of plant species. These results demonstrate that HCI determinations are more accurate and consistent than those of the PI and the DR. The HCI method is recommended for making vegetation determinations during wetland delineations in future revisions of the Corps delineation manual and its supplements.

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