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Proper Cover Classification Is Needed to Protect Palustrine Wetland Forest Structure and Functions

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Abstract

"Cover" is a technical concept used by scientists and regulators to describe plant communities in several ways that can be confused. The venerable Cowardin descriptive classification of wetland habitats requires that vegetation be assigned to categories based on the (external) cover Class of their tallest plants. Cowardin Classes are widely employed on National Wetlands Inventory maps across the United States and are used to communicate scientific, regulatory, and resource management information.

The term "cover" also is used for other regulatory purposes, notably the (internal) cover formed by individual species growing within layers of a plant community that determines dominants for the three-parameter methodology identifying federally regulated wetlands. Internal and external measures of cover, and the recorded data from which they are derived, may differ for an individual wetland sample plot. Both are meaningful, but if these distinct measures of cover are muddled, the result can be misclassification, misregulation, and inappropriate mitigation of impacts—especially in small wetlands.

Thus I review classifications of cover. Regulators and consultants must insure the accurate identification and reporting of internal and external cover when inventorying vegetation, delineating wetlands, and assessing impacts. Otherwise, environmental impacts will not be minimized, and post-disturbance wetland ecosystem recovery will be unlikely even where human mitigation is attempted.

Key Words: cover, forest cover, vegetation cover, canopy cover, Cowardin cover Class, Corps of Engineers 1987 Wetlands Delineation Manual, forested wetlands, National Wetlands Inventory, palustrine wetlands, wetland mitigation

Introduction

The habitat classification of wetland parcels according to the United States Fish and Wildlife Service descriptive classification system set forth by Cowardin *et al.* (1979) is commonly employed by the National Wetlands Inventory (NWI) to label polygons on its wetland maps within water regimes according to their physiognomic appearance---the Class based on *cover* formed by their tallest plants.[1] Cowardin wetland Classes are based on the common sense visual inspection of the uppermost layer of vegetation in the detail allowable by target map scale. Classes, in turn, can be further subdivided into Subclasses and Dominance Types. The system was refined by generations of ecologists and field biologists seeking a consistent language of nationwide applicability when describing communities of plants that share common traits for purposes such as communicating information, evaluating ecological processes, transferring

[1] Cowardin *et al*. (1979) also classify deepwater habitats and set forth a methodology for recognizing wetlands for wildlife management purposes. Cowardin definitions are *not* used for the identification and delineation of federally regulated wetlands, and National Wetlands Inventory maps are not adequate for identification of specific properties, pursuant to the Clean Water Act (P.L. 92-500, 86 Stat. 816) or the Rivers and Harbors Act of 1899 (30 Stat. 1151). The Cowardin document was adopted as a National Standard by the Federal Geographic Data Committee (FGDC-STD-004). It recently was updated, clarified, and reissued (FGDC 2013), and the threshold depth for deepwater habitats was increased from the former 2 m to 2.5 m (6.6 ft to 8.2 ft). The 1979 discussion of cover Classes remained virtually unchanged. Fill and excavation activities in all wetlands identified as Waters of the United States are federally regulated, whatever their wetland characteristics, Cowardin classification, successional stage, or level of disturbance.

knowledge from comparable sites, and predicting management outcomes. If Cowardin Classes are not understood, wetland protection will be lessened.

Cowardin Classification of Cover

Drawing on decades of prior Fish and Wildlife Service work describing wetlands (Martin *et al*. 1953, Shaw and Fredine 1956), Cowardin *et al*. (1979) presented a structural, hierarchical classification of wetlands and deepwater habitats based at the System level on water regimes and for vegetated wetlands at the Class level on plant physiognomy, with provisions for greater detail using various subclasses and other modifiers (Wilen & Golet 2018).[2]

> The basic life form layers, from highest to lowest—trees, shrubs, emergents, emergent mosses or lichens, and surface plants or submergents—are used to define Classes because they are relatively easy to distinguish, do not change distribution rapidly, and have traditionally been used for classification of wetlands and habitat assessment. … Use of life forms at the Class level has two major advantages: (1) extensive biological knowledge is not required to distinguish between various life forms, and (2) many life forms can be readily identified on a variety of remote sensing products. [FGDC 2013, p.19-20]

More than 7,500 Cowardin distinct classification codes have been found useful for wetland description and mapping (Dahl *et al*. 2015).

The Cowardin system provides an artificial key for first identifying systems in its Appendix E. For systems not influenced by tides or by ocean-derived salinity, the initial question is the percent area cover of vegetation. Thirty percent or greater vegetation cover identifies the

[2] A similar classification system has been adopted for use worldwide pursuant to the 1971 Ramsar Convention on Wetlands (a current version appears in Ramsar 2016, p. 45 ff).

Palustrine system, whatever the substrate (including streams and ponded waters). A second key addresses classes within the systems.

The Cowardin *et al.* schematic landscape cross-section (Figure 1) illustrates the relative location of several vegetation Classes and Subclass aquatic modifiers in the Palustrine System---nontidal wetlands not consisting of major lakes or rivers [FGDC 2013, p. 18]. This conceptual diagram illustrates vegetation as if only one structural layer exists above the land or water surface.

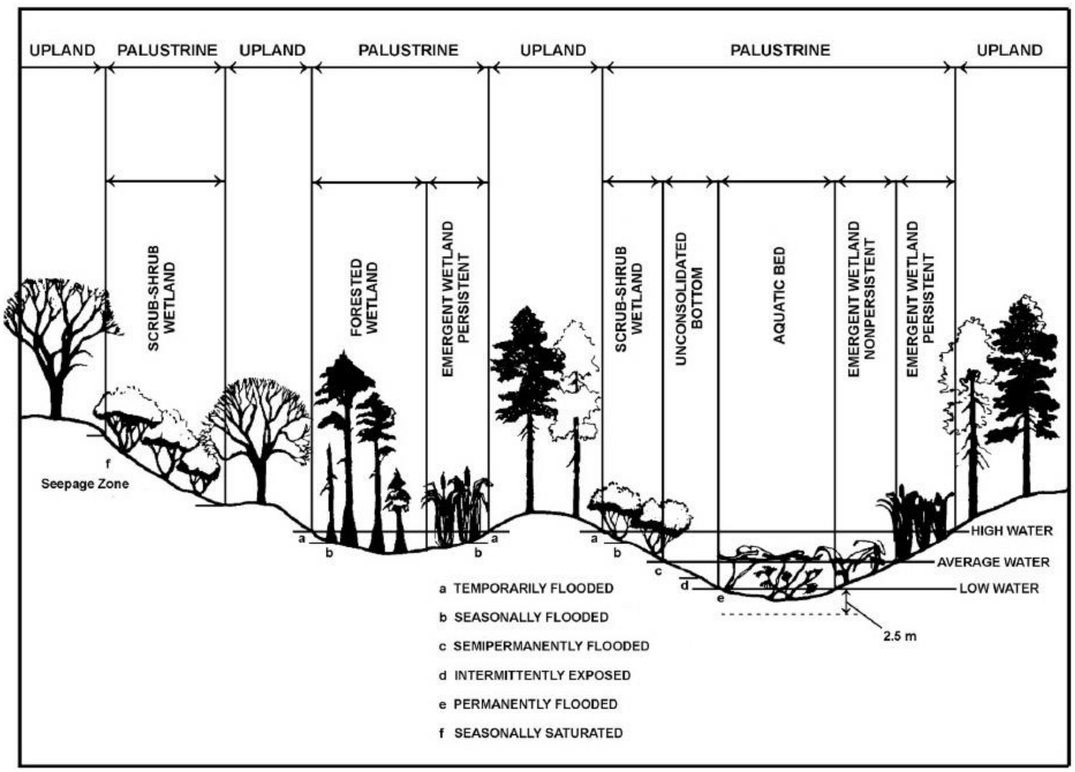

Figure 1. Landscape cross-section shows vegetated "distinguishing features and examples of habitats in the Palustrine System" (Cowardin *et al*. 1979, FGDC 2013). Soils information and plant root locations are not considered in this classification, only plant parts visible above ground or above water. There are no deepwater Classes in the Palustrine System; herbs, shrubs, and trees that emerge from the water represent their cover type (minimum

30%) irrespective of the depth of water from which they emerge. Palustrine Classes also include rock bottom, unconsolidated bottom, aquatic bed, and unconsolidated shore (which latter can be vegetated by pioneer plant species covering greater than 30% of the surface).

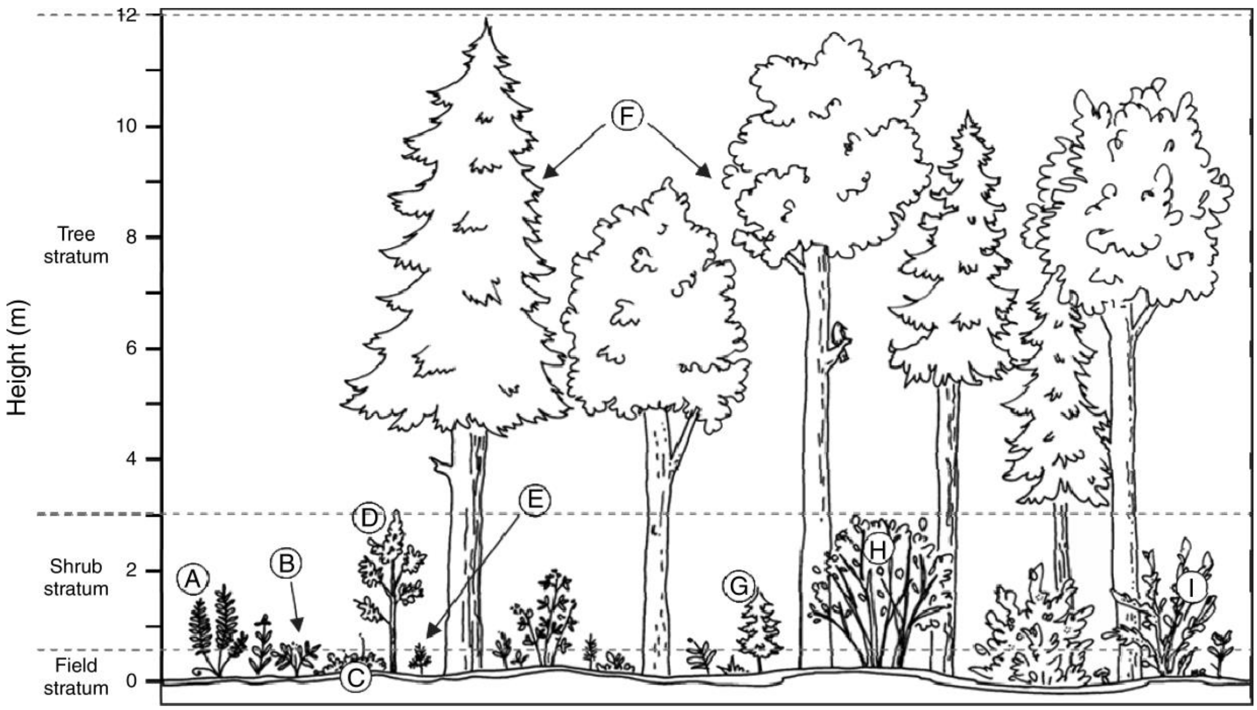

Figure 2. "An illustration of strata showing growth forms of individual plants as may be found in a plot (the ground stratum is not delineated). The field stratum is 0– 0.5 m; the shrub stratum is 0.5–3.5 m; and the tree stratum is 3.5–12 m. Assignment of individual plants to a stratum (circled letters) is based on height and growth form as follows. (A) A plant having an herbaceous growth form. Although projecting vertically into the shrub stratum, it is excluded from being recorded as part of the shrub stratum canopy cover because its stems die and regrow each year. (B) A plant having a dwarf-shrub growth form is recorded as part of the field stratum. If desired, a separate dwarf-shrub substratum can be recognized. (C) A moss, recorded as part of the ground stratum. (D) A plant having a tree growth form but at a sapling stage of life. This individual is recorded as part of the shrub stratum canopy. (E) A plant having a tree growth form but at a seedling stage of life. This plant is recorded as part of the field stratum canopy. (F) Mature trees, recorded as part of the tree stratum. (G) A sapling, as in (D). (H) A plant having a shrub growth form, recorded as part of the shrub stratum canopy cover. (I) A plant having an herb growth form and projecting into the shrub stratum; excluded from being recorded as part of the shrub stratum canopy (as in A)" [Jennings *et. al* 2009:183, Copyright by the Ecological Society of America].

Wild plants, however, typically overlap and grow together, giving rise to a practical need for rules for assigning plants to and excluding plants from strata (layers). The number of strata to be recognized and size of woody plants making up a layer when identifying wetlands differs from region to region among recent supplements to the *Corps of Engineers Wetlands Delineation Manual* (EL 1987). The most concise graphic illustration of strata that I have found is reproduced here by permission as Figure 2.

Cowardin wetland Classes are precisely defined based on the proportion of the ground covered by the aggregation of tallest live plants abundant in or above any wetland substrate:

> If living vegetation (except pioneer species) ***covers 30 percent or more*** of the **substrate**, we distinguish ***Classes*** on the basis of ***the life form of the plants that constitute the uppermost layer*** of vegetation and that possess an ***areal coverage 30 percent or greater***. For example, an area with 50 percent areal coverage of trees over a shrub layer with a 60 percent areal coverage would be classified as Forested Wetland; an area with 20 percent areal coverage of trees over the same (60 percent) shrub layer would be classified as Scrub-Shrub Wetland. When trees or shrubs alone cover less than 30 percent of an area but in combination cover 30 percent or more, the wetland is assigned to the Class Scrub-Shrub. When ***trees and shrubs cover less than 30 percent*** of the area ***but the total cover*** of vegetation (except pioneer species) is ***30 percent or greater***, the wetland is assigned to the appropriate Class for the ***predominant life form below the shrub layer.*** [FGDC 2013, p. 19-20, ***emphasis added***]

Thus bare ground, impounded water, stream channels, shrubs, herbaceous plants, lichens, and/or mosses may be found beneath a tree canopy in a forested wetland. The Cowardin 30% threshold cover for identifying wetland forest or scrub is relatively conservative. The US Department of Agriculture Forest Service threshold for mapping forest is 10% tree cover. In Forest Service usage (Brohman & Bryant 2005, as recommended in USACE 2012, p. 22) low density forest has 10 to

25% tree cover (sparse canopy); moderate density forest, 25 to 60% tree cover (open canopy); and high density forest, 60 to 100% tree cover (closed canopy).[3]

The Corps three-parameter wetland identification/delineation methodology itself is specifically described as not having been designed for wetland classification (EL 1987, p.7). Thus users of the 1987 *Corps Manual* are advised to become familiar with the older Cowardin system as a means for *classifying* wetlands. The basic Cowardin cover classification of wetland vegetation can aid in scientific description, assessment of impacts, and design of compensatory mitigation to replace lost functions when damage to wetlands cannot be avoided.

Assigning the correct Cowardin external cover Class to a sample wetland plot is a task distinctly different from estimating its internal cover and boundaries. Cowardin physiognomic classification is not dependent on the species composition of plants growing in a wetland, although the kinds of

[3] The undated Army Corps Baltimore District's online "Regulatory Sourcebook," however, on pages 7 and 8 defines wetland types (a) with woody vegetation covering at least 20% of the ground as forest (trees are >5 m or 16.4 ft tall) or scrub-shrub (shrubs are <5 m tall) rather than the Cowardin 30% threshold and Cowardin 6 m (20 ft) break between trees and shrubs as PFO or PSS, and (b) as persistent emergent vegetation only when exhibiting 80% minimum total herbaceous cover as PEM. These definitions to me appear seldom if ever to have been used in practice by anyone. If they were applied, they would decrease significantly the size of wetlands identified as PEM and increase the size of PFO and PSS. They are described as "official" guidance regarding policies and procedures, despite their misattribution of their unidentified source to Cowardin *et al*. 1979 (https://www.nab.usace.army.mil/Missions/RegulatoryA/Jurisdictional-Determinations/). The Pennsylvania Department of Environmental Protection (PADEP 2017a) characterizes the percentage of tree canopy in a "zone of influence" within 91 m (300 feet) surrounding any wetland as optimal (60% or more tree cover), suboptimal (≥30% but <60%), or marginal (<30%) in recognition of typically valuable buffering of wetland ecosystems by trees.

plants present are very significant for establishing that the study plot in which they are rooted qualifies as a wetland per the 1987 *Corps Manual*.[4]

For at least a decade the Army Corps of Engineers has directed that the Cowardin physiognomic Class be reported for the wetland polygons identified in applications for permits and jurisdictional determinations (Riley 2008), although the most recent guidance drops all reference to Cowardin (Jackson 2016). No supplemental guidance has been provided suggesting any modification of the Cowardin cover classification when using it for Corps regulatory purposes.

No mention of the Cowardin cover classification system (or even the word palustrine) appears in the ten recent regional supplements which supersede sections of the 1987 *Corps Manual*. Those supplements incorporate detailed methodological advances resulting from a quarter-century of wetland science aimed at recognizing wetlands in dissimilar ecosystems. They do not update or supersede any sections of the 1987 *Corps Manual* that refer to Cowardin classification. They are silent as to how users might document Cowardin Classes. Consequently, their field data forms do not prompt recording the field information necessary for designating Cowardin Classes.[5] Corps vegetation forms instead emphasize identifying, quantifying, and assigning to aboveground strata

[4] *Dominant* plants are defined quite differently for purposes of Cowardin classification from the definition used when identifying and delineating Corps wetlands, inasmuch as (a) "Cowardin dominants" do not need to be rooted in the wetland substrate and (b) their species identification is immaterial at the Class level. "Dominant: Species that are most numerous, or form the bulk of the biomass, and therefore have the greatest effect or influence on the ecological community, generally controlling the presence, abundance, or type of other species. Dominant Life Form: That life form of plants (e.g., tree, shrub, moss) that constitutes the uppermost layer of vegetation at a site and possesses at least 30 percent areal cover. The dominant life form determines the Class of vegetated wetlands in this classification" (FGDC 2013:58). "**Dominant**: The species making up the majority of spatial cover" (Dahl *et al*. 2015).

[5] The small blank for "NWI classification" normally is filled with "none" for wetlands not mapped by NWI.

those plant species rooted within user-defined plots for each layer, and to assigning the proper regional hydrophytic status rankings to each species. Corps districts and Pennsylvania DEP continue to direct applicants to supply also the Cowardin Class for each wetland, in addition to the documentation recorded on data forms and relied upon to establish wetland presence and limits. Appropriate minimum area for Class designation has never been specified for regulatory purposes, although photographs in Plates 8 and 54 of Cowardin et al. (1979) imply that polygons normally would not be mapped separately for individual trees. Mixes of cover types can be recorded.

In Pennsylvania there is now an incentive to misassign small wetlands to Cowardin physiognomic Classes---specifically, to describe forested wetlands as herbaceous.[6] Thus it is important to review how the concepts underlying the Cowardin system describe vegetated wetlands in contrast to the concepts of the 1987 *Corps Manual*. Some professionals may find Cowardin physiognomic classification difficult to apply; others appear to misapply it by misinterpreting basic technical procedures. Misclassification can lead to improperly designed plans for impact avoidance and impact mitigation as well as to litigation (for examples, see Schmid 2019), all of which can be minimized by careful attention to methodology and the common sense underlying the Cowardin system.

Forested wetland vegetation is more slowly established or reestablished following disturbance than a cover of herbaceous wetland plants. Forest structure typically is more complex than herbaceous

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[6] PADEP (2014) would specifically adopt the Cowardin Class designations for use when compensating for wetlands damaged in Pennsylvania. Impacts requiring mitigation include "conversion of a forested wetland system to a non-forested state through chemical, mechanical or hydrologic manipulation that results in a maintained state of vegetation" (PADEP 2017b). Less mitigation is required for damaging herbaceous wetlands than for forested wetlands. There is also an incentive for misclassifying scrub-shrub wetlands as herbaceous, because replanting of shrubs is deemed proper for temporarily disturbed wetlands, as opposed to mere reseeding of native herbaceous species.

communities, and forested wetland functions are not replaced by restored wetlands where succession is arrested at an herbaceous stage (Schmid & Co., Inc. 2014a). Little is known about the restoration of soils in forests, either wetland or upland (Lovett *et al*. 2018). Even beneath restored herbaceous wetlands, soil development requires decades to centuries to approximately recover biogeochemical functions such as the denitrification performed under undisturbed reference conditions nearby (Ballantine & Schneider 2009, Hossler *et al*. 2011, Moreno-Mateos *et al*. 2012, 2015) or the capture of human-generated carbon dioxide (Griscom *et al*. 2017). As the US Army Corps of Engineers and US Environmental Protection Agency observed in 2008 rulemaking regarding compensatory mitigation for losses of aquatic resources:

> We understand that different functions often develop at different rates after aquatic resource restoration, establishment, or enhancement activities are implemented, because of the ecosystem development processes that occur. … It is important to understand that temporary impacts may result in permanent changes to, or losses of, specific functions. As an incentive for timely mitigation, district engineers may determine that additional compensation for temporal losses is not necessary if the mitigation project is initiated prior to or concurrent with the permitted impacts, except in the case of resources with long development times, (e.g., forested wetlands). [33 CFR 325 and 332, 40 CFR 230; 73 FR70:19638]

Measuring Cover during Wetland Investigation

Two basic vegetation *cover* measurements are required in the context of wetland assessment. I discuss first the familiar measurement of *internal cover for wetland identification and delineation* using Corps methodology. Then I discuss the contrasting measurement of *Cowardin external cover*, which apparently is less well known. The procedures address different characteristics of a plant community and yield two distinct, complementary descriptions of the vegetation plot, stand, polygon, or patch sampled.

The Corps-specified set of cover measurements is *internal* to the vegetation under study. It is derived from the identified species making up the plant community and must be measured in the field. It is recorded for the aggregate extent (or shadow cast onto the ground by vertical light) of individuals in each plant species within each layer of concern rooted in the study plot or patch under maximum leaf-out conditions for each species. This is the kind of cover discussed at length in the regional supplements to the 1987 *Corps Manual*. It applies to each of the kinds of plants *present* (those plants exhibiting stems rooted) within the homogeneous sample area where the diagnostic plant species, soil characteristics, and hydrologic indicators are being recorded. This is a fundamental determination whenever applying the three-parameter approach for wetland identification using the 1987 *Corps Manual* and its regional supplements.[7] Plot sizes are to be recorded for each layer in a wetland being sampled, typically with larger plots evaluated for the tree stratum than for other strata. The supplements caution that overhanging plants rooted in different soil or hydrologic conditions outside the homogeneous sample plot under study are not to be recorded on Corps data forms or considered when quantifying internal cover for the rapid dominance, 50/20 dominance, or prevalence index tests for hydrophytic vegetation (or the FAC-neutral test for hydrology), especially near wetland boundaries where such data are typically sampled (for example, USACE 2012, p. 22).[8]

[7] Other measures of species abundance are authorized for use to identify dominant species (such as basal area or stem density), but absolute areal cover of the aggregated individual plants of each species within each relevant layer (not the relative cover within any stratum) is the normal attribute commonly estimated visually and recorded on the Corps vegetation data form for every sample. Basal area measurements cannot be used for determination of prevalence index, but necessitate resampling for absolute cover if a prevalence index is needed (USACE 2012, p. 23-31, 148).

[8] Others, such as Fehmi (2010), would include overhanging plants when quantifying "species cover," for purposes of analysis not including wetland delineation.

Formal rules are provided for designating the minimum absolute cover among species recorded as present when identifying the dominant plant species in each layer.[9] Internal cover measurements are made by visual estimates of each species by structural layer. There is an extensive literature on the use of pin frames and other methods, some plotless, for more precise yet tedious quantification of absolute internal cover. There is no single best method for estimating or measuring internal cover in the field, which can be a difficult task in structurally complex, species-rich communities (Mueller-Dombois & Ellenberg 1974, as recommended in USACE 2012, p. 22). The internal cover measurements recorded on data forms often total more than 100% wherever plants overlap within or among strata.[10] When calculating dominants among the species present to identify hydrophytic vegetation, any merely overhanging plants judged to be rooted outside the wetland properly are excluded.

But then the field investigator must look up (or down) and quantify the *uppermost external canopy* cover to ascertain the Cowardin Class of the wetland as a whole, which for a small wetland may little resemble its internal cover measurements. A 1987 *Corps Manual* wetland may or may not be assignable to any Cowardin vegetated wetland Class.

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[9] Pennsylvania would request also the visual estimate and reporting of *relative* cover of *invasive* species present when assessing wetlands (PADEP 2014), but the discussion here is confined to absolute cover.

[10] Internal, absolute species cover will always be larger than zero when describing a vegetated wetland. It may be less than 100% for one species or layer and for several layers or species in combination. By convention, internal cover of a single species within a single layer or of one individual plant is limited to 100%, however many layers of leaves and branches of that species of plant may block the observer's view of the sky. A third parameter, "leaf cover" can be measured to ascertain the total percentage of area occupied by all (one-sided) layers of plant parts down to the ground or water surface and can greatly exceed 100% for individual plants, single species, or combinations of species (Fehmi 2010). Leaf cover is related to leaf area index, an important indicator of plant ecophysiology (Bréda 2003). Leaf cover is prohibitively time-consuming to measure and thus seldom discussed or recorded in the context of wetland assessment.

Unlike the National Wetlands Inventory map conventions, the Corps has not specified a minimum plot size for reporting Cowardin Classes when requesting permits to fill wetlands within a jurisdictional polygon. In Pennsylvania wetland boundaries are to be drawn to +/- 15 cm (0.5 foot) horizontal accuracy (http://www.nab.usace.army.mil/Portals/63/docs/Regulatory/Pubs/checklist.pdf), and tallies of wetland area are to be reported to the accuracy of 40 square meters (a 21-foot square or 0.01 acre) for permit applications (PADEP 2017b). In principle, it would be possible to report the areas covered by individual trees within a marsh individually as PFO, if their replacement is differently regulated. Compared with the scientific attention devoted over several decades to explaining field evidence for the three parameters of wetland identification (hydrophytic vegetation, hydric soils, prolonged hydrology), detailed attention to the application of Cowardin Classes to regulated wetlands has been greatly neglected by regulators and consultants.

In contrast to Corps wetland identification and delineation methodology, the Cowardin system is based on the *external* ground cover of the subject wetland polygon's vegetation as a whole, which can never exceed 100%. It is a simple appraisal based on the physiognomy, the growth form, of the tallest vegetation layer(s) projected vertically.[11] Tree and shrub roots typically extend outward from the trunk at least as far as the "drip line" at the edge of the foliage, so 30% canopy cover is indeed a conservative measure of the spatial extent of Cowardin Class dominance. The assessor records how much of the sky is covered by each layer when all leaves are fully expanded in order to ascertain the

[11] Thus investigators must be careful to correct for non-vertical attributes of foliage if using convex mirrors or fish-eye lenses to measure or record external canopy cover. Fehmi (2010) labels external cover as "aerial cover".

uppermost layer's external cover shading the ground beneath the wetland.[12] (That is more practical than looking down on trees unless there is some handy way for the observer to become elevated above a tree canopy or a camera-carrying drone is included with field equipment.) When using aerial photographs, one obviously looks down to see how much ground is covered by the canopy of a patch under study. (The observer always must compensate mentally for seasonally missing or undersized foliage and for leaf-off periods.)

Similar to internal cover estimates, external cover typically is estimated visually. There are various kinds of densitometers available for more precise and repeatable but time-consuming measurements of forest cover in the field, and an extensive literature

[12] Neither Figure 1 nor the text definition from Cowardin quoted above nor subsequent U.S. Fish and Wildlife Service publications such as Dahl *et al*. (2015) requires that there be any trees rooted in a wetland or sample plot classified as forest. The only mention in the Cowardin system of rooted plants is to rooted emergent herbs, to distinguish them from floating aquatic herbs such as duckweed (*Lemna* spp.) and water hyacinth (*Eichhornia crassipes*). Thus I have been astonished to find professionals who insist upon confusing rootedness with external cover. They claim to have been so instructed by regulators. The simplest and most straightforward statement of this key distinction I have been able to find is that from the description of vegetation surveying methodology used for many years in North Carolina (Peet *et al*. 1998). Their use of the term "presence" for the "internal" version and reservation of "cover" for the "external" version avoids potential confusion:

> We define "presence" as the occurrence of a species (based on emergence of a stem or stems) within a quadrat, where the species must be "rooted" in the quadrat. … "Cover" is here defined as the percentage of ground surface obscured by the vertical projection of all aboveground parts of a given species onto that surface. No species may exceed 100% cover, though the sum of cover estimates across all species often exceeds 100%. In this case [that is, when quantifying external cover rather than ascertaining internal presence], the plant need not be rooted in the area under consideration. [Peet *et al*. 1998, p. 265]

describes their use (Huynh 2005, Korhonen *et al*. 2006, Paletto & Tosi 2009, Barbour *et al*. 1999).

The external cover of the uppermost layer of a patch or stand of vegetation cannot exceed 100%. Total external cover of the ground or water surface by (other than early successional, pioneer) plants must be at least 30% for a wetland to be placed in any Cowardin vegetation cover Class (or "vegetated" Subclass), by definition.

External measurements of cover are widely used by foresters and range managers as well as by the National Wetlands Inventory. Similarly, woody canopy cover is to be recorded while characterizing the riparian vegetation of wadeable streams when computing an Index of Biological Integrity (Barbour *et al*. 1999).[13] PADEP (2017a) states that assessors using its Level 2 rapid assessment methodology to determine wetland condition "should be able to accurately estimate the percentage of ground cover using aerial photography. The assessor should then verify this initial classification based on such photography when conducting the field portion of the assessment" by using visual estimation. Plant succession, beavers, forest fires, hurricanes, and human activities often lead to changes in actual vegetation subsequent to the taking of aerial photographs. During a recent field investigation of more than 350 selected wetlands in Kentucky, Guidugli-Cook *et al.* (2017) found that more than 50% of their wetlands mapped as emergent herbaceous by NWI were in fact dominated by forest cover, while more than 20% of NWI-mapped forested wetlands were dominated by herbs at the time of field inspection.

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[13] "Canopy Cover: Note the general proportion of open to shaded area which best describes the amount of cover at the sampling reach or station. A densitometer may be used in place of visual estimation." [Barbour *et al*. 1999, Section 5.1.7] Kauffman *et al*. (1999) and Somerville & Pruitt (2004) also discuss stream cover measurement.

External cover is not the only significant attribute of vegetation that can be affected by overhanging plants. Another is the quantity of biomass present in a sample plot, as discussed in comprehensive texts (*e.g.*, Bonham 2013). Figure 3 appears in USDI-BLM (1996, p. 111, a reference recommended in USACE 2012, p. 22). As noted above, "Cowardin dominant" species that are "responsible for the bulk of the biomass, and therefore have the greatest effect or influence on the ecological community, generally controlling the presence, abundance, or type of other species" in a quadrat may or may not be rooted within that quadrat. "Cowardin dominant" trees or shrubs must be close enough, of course, to provide at least 30% external canopy cover above the palustrine wetland in question for it to be classed as forest or scrub-shrub.

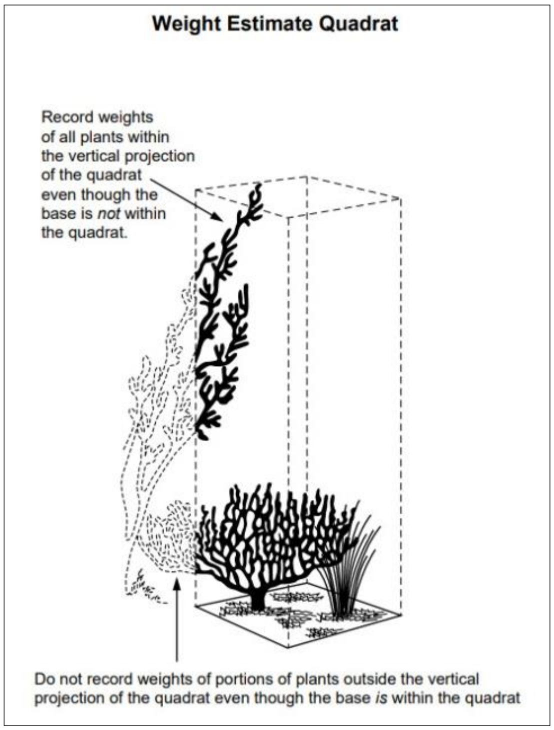

Figure 3. Measurement of biomass per unit area (USDI-BLM 1996, p. 111).

External cover and biomass measurements, when consistently applied, enable the abundance of plants to be evaluated in comparable terms. Cover measurements are discussed at length in most textbooks on vegetation, and are standard characteristics of plant communities recorded during field and airphoto investigations for many purposes. The authoritative USDA Forest Service guide to vegetation classification and mapping cited above (Brohman & Bryant 2005, as recommended in USACE 2012, p. 22) precisely defines terms for what I label internal and external cover in concert with federal agency usage without any mention of rootedness:

> **vegetation cover** [external]**.** ***Vegetation that covers or is visible at or above the land or water surface***; a subcategory of earth cover. The percentage of the ground covered by ***a vertical projection of the outermost perimeter*** of the natural spread of the foliage of plants (FGDC 1997 [rev. 2008]).
> **canopy cover** [external]**.** (1) ***The proportion of ground***, usually expressed as a percentage, that is ***occupied by the perpendicular projection down on to it of the aerial parts of the vegetation*** or the species under consideration. The additive ["internal"] cover of multiple strata or species may exceed 100 percent (FGDC 1997 [rev. 2008]). (2) The ***percentage of ground covered by a vertical projection of the outermost perimeter*** of the natural spread of foliage of plants. Small openings in the canopy are included (SRM 1989 [rev. 1998], USDA NRCS 1997 [rev. 2017]). Canopy ["external"] cover is synonymous with canopy closure (Helms 1998). For woody plants, canopy cover is synonymous with crown cover (USDA NRCS 1997 [rev. 2017], Helms 1998).
> **canopy closure.** The proportion of ground, usually expressed as a percentage, that is occupied by ***the perpendicular projection downward of the aerial parts of the vegetation of one or more species***. It usually refers to ***the tree life form of the uppermost canopy, as seen from above, and cannot exceed 100 percent.*** [Brohman & Bryant 2005, ***emphasis added*** *and references updated*]

The concept of external vegetation cover is illustrated in diagrams of the U.S. Bureau of Land Management (USDI-BLM 1996, as recommended in USACE 2012, p. 22). Canopy cover consists of both shades of gray in the vertically illuminated shadow beneath the plant in Figure 4.

A recent review of palustrine wetland communities in Pennsylvania that focused on rare plants used a somewhat different physiognomic classification from that of Cowardin but offered no explanation for its modifications. Its herbaceous wetland group is defined by aggregate non-woody cover greater than 25% with woody plant cover less than 25% (Western Pennsylvania

Conservancy 2011). Its shrubland group of communities has greater than 25% cover of woody plants less than 5 m (16.4 ft) tall, with taller trees less than 25%. It labels as woodland any wetland vegetation with tree (5 m or taller) cover 25% to 60%, and as forest any having tree

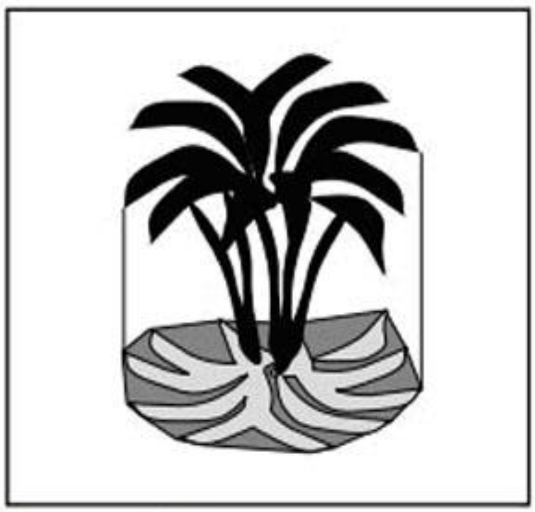

Figure 4. Canopy cover beneath a vertically illuminated plant (USDI-BLM 1996, p. 25). Individual plants in fact can exhibit multiple layers of internal cover, and the internal cover formed by multiple kinds of plants growing together in the wild can be challenging to describe accurately.

cover greater than 60%. Individual community names within groups reflect principal plant species. It also recognized transitional zones between cover classes.[14]

[14] The underlying Western Pennsylvania Conservancy report elected not to disturb the key Cowardin concepts discussed above. "Canopy: the branches and leaves of plants that form the uppermost layers of vegetation in a community. A canopy is said to be closed (or have 100% cover) when the ground and lower strata are completely hidden when viewed from above the canopy during the growing season. Cover: the percentage of the ground surface that is covered or shaded by the leaves or stems of a plant species or a group of plant species during the growing

Figure 5 is a simple diagram that applies the Cowardin cover classification to typical wetlands common in palustrine ecosystems in the Eastern Mountains and Piedmont Region of the United States. Figure 5 depicts palustrine wetlands such as herbaceous, skunk-cabbage (*Symplocarpus foetidus*) dominated depressions with hydric soils surrounded by non-wetland woods often

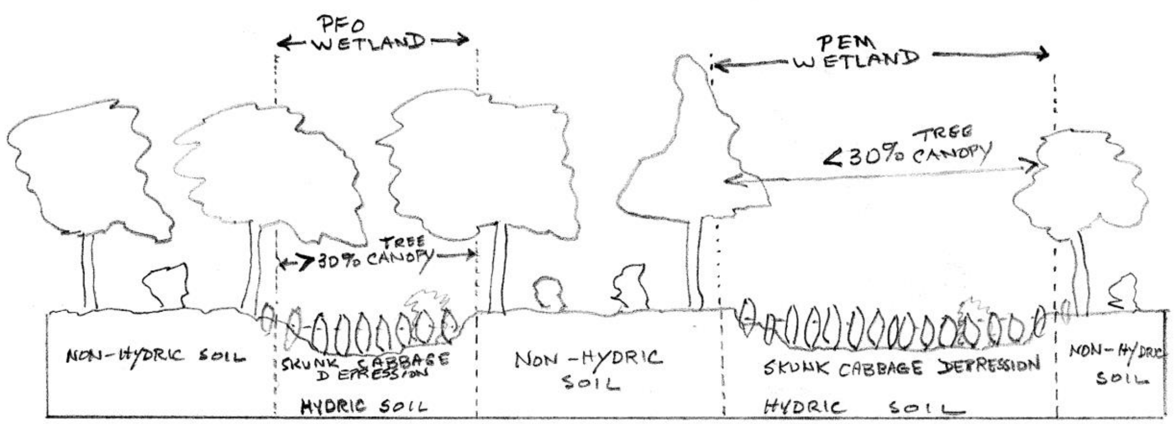

Figure 5. Landscape section showing Cowardin Classes of emergent-supporting palustrine wetland depressions in a matrix of non-wetland forest. PEM = palustrine emergent herbaceous vegetation; PFO = palustrine forest, whether evergreen, deciduous, or mixed. Current hydrology is assumed to be present with sufficient frequency and duration to support hydrophytes and to generate one or more field indicators of hydric soil. Such conditions typically are encountered along headwater streams in the Eastern Mountains and Piedmont and Northeastern Forest Regions, where riparian wetlands form relatively narrow bands. They also can arise at vernal pools.

dominated by red maple (*Acer rubrum*), green ash (*Fraxinus pennsylvanicum*), pin oak (*Quercus palustris*), eastern hemlock (*Tsuga canadensis*), and other facultative hydrophytic trees.

season. Dominant: a species with the greatest abundance, percent cover, or influence in a community or stratum" (Zimmerman *et al*. 2012).

Sampling points are to be sited near wetland boundaries when documenting wetland delineations, not in the center of polygons (USACE 2012, p. 43). If both wetland depressions in Figure 5 are accurately recorded as having no trees in the standard tree sampling plot of 9 m (30-foot) radius around the soil sample pit, after the plot shapes have been properly modified to include only plants growing under the representative wetland soil and hydrologic conditions, then their 1987 *Corps Manual* supplement data forms will not contain overhanging trees among the species listed as present.[15]

On the right side of Figure 5, the concave palustrine wetland has a tree canopy less than 30%, shrub cover less than 30%, trees and shrubs combined less than 30%, and non-pioneer herbaceous cover greater than 30%. Thus it is classed as a palustrine emergent wetland (PEM) in the Cowardin system. On the left side, the depression has a tree canopy greater than 30%, the minimum Cowardin threshold for forest. This depression is assigned to the forested wetland Class (PFO), although no trees may appear on its Corps vegetation data form for the wetland sample plots. Nothing printed on the current standard data forms records Cowardin classification, although the large biomass of overhanging trees would exert a major influence on the microclimate, species composition, nutrient cycling, energy flow, habitat quality, and organic matter accumulation in such a forested wetland depression or vernal pool. In my experience field delineators rarely would have any opportunity to excavate the roots of overhanging, typically facultative-hydrophytic trees in an attempt to establish whether they extended into an adjacent wetland. Similar situations are often encountered along incised headwater streams where the entire riparian corridor lies beneath a tree canopy, and both the

[15] As discussed above, those data forms were not designed to address or document Cowardin Classes.

stream and any adjacent wetlands are confined by steep banks inside the forest canopy of non-wetland trees on non-hydric soils. Both the stream channels and the emergent herbaceous wetlands beneath the overhanging tree canopy are properly classed as PFO wetlands. They are often missed entirely during National Wetland Inventory mapping in Pennsylvania, because they are hidden by the overhanging trees on aerial photographs.

In Figure 5 all the surrounding forests are diagrammed as non-wetlands, assuming localized wetland boundary points set near where soil, hydrology, and/or vegetation parameters change. If the surrounding adjacent forest were to consist instead of hydrophytic species on currently wet hydric soils, or hydrophytic trees were found within the topographic depressions, the correct Cowardin Class designations would remain the same for each depression as shown already in Figure 5. Absent minimum Cowardin Class size guidance, delineators would have no need to separate the herbaceous wetland depression at left from a surrounding wetland forest matrix, inasmuch as both would be regulated waters. The same would apply to a small vernal pool beneath the wetland forest canopy.

Small, emergent-dominated, vegetated wetland depressions as portrayed on the left in Figure 5 typically would not be visible from aerial photographs and frequently are omitted from National Wetlands Inventory maps, requiring careful fieldwork for their accurate identification and delineation. The somewhat larger wetland on the right might be recognizable from aerial photos and might appear on an NWI map, but many are not (Figures 6 through 8).

Figure 6. May 2014 Google Earth aerial photograph of a palustrine emergent wetland in Pennsylvania dominated by herbs. Arrow indicates the camera location for Figure 8. Red dot indicates red maple tree in Figure 8. Small white dot identifies a white pine tree with scrub understory within the PEM. Orange dot locates a PFO about 0.03 acre (0.01 ha) in size (lighting is not vertical; shadow extends beyond its canopy). The outlined polygon includes 1.5 acres (0.6 ha) of mostly PEM. The precise limits of Cowardin PEM with respect to PFO and PSS here are problematic, if the intent is to mitigate or otherwise regulate the classes differently. To the northeast and southwest the outlined wetland is bounded by PFO; to the southeast, by upland forest. This wetland and the associated perennial stream are not shown on NWI or USGS topographic quadrangles or national hydrographic mapping. The 1975 printed Wyoming County soil survey slightly overmaps a 4.5-acre (1.8 ha) patch of Norwich (very poorly drained) and Chippewa (poorly drained) soils here and accurately shows this unnamed perennial stream tributary to Whitelock Creek.

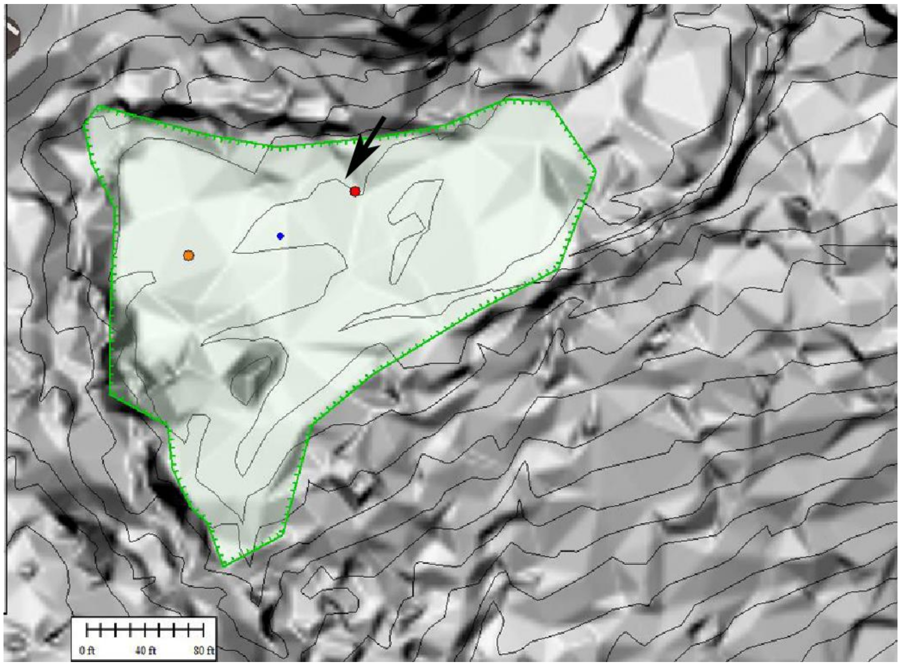

Figure 7. Topographic map of the same area as Figure 6. Two-foot contours and slope shading are from 2006-2008 LiDAR aerial photography (Pennsylvania Spatial Data Access, maintained online by Pennsylvania State University). Toothed green line is the same polygon as in Figure 6. Figure 6 white dot is here shown in blue for contrast. Arrow indicates camera location for Figure 8.

Figure 8. View southwest on 20 November 2018 from a red maple in the foreground (red dot in preceding figures) across the wetland shown in Figures 6 and 7. Dominant hydrophytic herbs are narrowleaf cattail (*Typha angustifolia*) and woolgrass (*Scirpus cyperinus*). Wetland white pine (*Pinus strobus,* white/blue dot in preceding figures) with scrub understory is silhouetted within the marsh to right of maple. A larger PFO stand (orange dot in preceding figures) is obscured in this view by pines at right, whose cover extends more than 20 feet (6 m) beyond the limit of snow. PFO extends right and left of the area shown here. Forest on slopes in background to the left of maple is not wetland.

Conclusions

State and federal regulators of proposed impacts on aquatic resources in Pennsylvania too often remain oblivious to errors of cover classification, wetland boundary delineation, and other aspects of environmental inventory, failing to require wetland boundary point flagging that is visible in the field, to inspect and verify delineated wetland boundaries and kinds on construction sites, and to demand accurate and consistent data in permit applications to damage streams and wetlands prior to granting permit approvals (Schmid 2019). Mistakes in reporting simple, basic Cowardin Classes of wetlands are now commonplace in Pennsylvania. When consistent, accurate wetland inventory information is not required of applicants by State or federal regulators in Pennsylvania on behalf of the public prior to permit approval, compliance with regulatory "requirements" is precluded (Schmid & Co., Inc. 2014a, 2014b, 2016). Permit conditions for restoration and compensatory mitigation that on paper may appear protective of resources in fact are not.

Temporary damages to aquatic resources may require many years for recovery, if restoration is even possible. The structural and functional losses in wetlands damaged by human activities worldwide are incurring "recovery debt" (Moreno-Mateos *et al*. 2015, 2017) that rarely is recovered completely despite human efforts at mitigation (Jones *et al*. 2018). This problem is exacerbated wherever damaged forested wetlands go unrecognized and unmitigated, while their biological structure and especially their biogeochemical functions require many decades or centuries to recover, even where post-construction restoration is attempted (Ballantine & Schneider 2009, Moreno-Mateos *et al*. 2012, Jones *et al*. 2018). Regulators could provide accurate guidance regarding Cowardin Classes and could maximize environmental protection by inspecting the sites of proposed damage and making all applicants follow the rules. Future generations would be appreciative.

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