

Field-based assessment of wetland condition, wetland extent, and the National Wetlands Inventory in Kentucky, USA

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Abstract The economic and ecological importance of wetlands is well documented, but there are few studies that have assessed wetland condition and extent for the United States. Many states, including Kentucky, have had no statewide field evaluation of wetlands of any kind. The National Wetland Inventory (NWI) is the largest database for mapped wetlands in the United States and the most comprehensive source of wetland information for Kentucky, but its value for determining wetland condition is limited. Therefore, our objectives were to document wetland extent and condition and assess the agreement between the NWI and field-based wetland characteristics in Kentucky. We conducted field and remote-sensing based assessments of 352 wetlands across the state. NWI-mapped and field-assessed wetlands had similar large-scale patterns;

however, for individual wetlands, classification often disagreed. Based on our wetland assessment method, wetlands appear to be of moderate condition, although we found differences among basins, dominant vegetation types, and landscape positions and much variation as many sites scored very low and high. Our findings support previous work showing that rapid assessments are valuable for determining wetland condition for ambient monitoring and other applications. Also, our results provide the foundation for future status and trends studies and suggest an urgent need to update the NWI in Kentucky and elsewhere. We suggest that the NWI could be improved by using newer technology that increases wetland mapping accuracy and including predictions of wetland condition using the enhanced NWI approach.

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Introduction

There were an estimated 158 million hectares of wetlands in what is now the United States in the 1780 s (Frayer et al. 1983; Dahl 1990). Due to draining of wetlands for agricultural and other human uses, by the 1980 s over 50% of wetland area in the conterminous United States was lost (Pavelis 1987; Dahl and Allord

1996). Prior to colonization, 6% of Kentucky's statewide land cover consisted of wetlands, and by the 1990 s, wetland coverage was reduced by over 80% (Dahl 1990).

The National Wetlands Inventory (NWI) is the most extensive wetland mapping program in the United States and fulfills many of the federally legislated wetland mapping requirements (Lang and McCarty 2008). Beginning in 1974, wetlands were delimited primarily by aerial photograph interpretation at a small scale (1:250,000). More recently, local and regional updates of the NWI have relied on higher resolution and multispectral aerial and satellite imagery resulting in an inventory that is a patchwork of contemporary and dated NWI maps (Wilen and Bates 1995; Dahl 2011). The NWI data for Kentucky is up to 35 years old, with data for 85% of the state at least 25 years old and less than 3% of the area covered by data updated within the last 10 years (USFWS 2015).

The Emergency Wetlands Resources Act of 1986 requires the decadal publication of the "Status and Trends of Wetlands and Deepwater Habitats in the Conterminous United States" reports to document the extent and changes to wetlands (USFWS 2016). This established national ambient monitoring of wetlands (Dahl and Johnson 1991; Dahl 2006, 2011), but the program does not effectively assess the quality or condition of wetlands in a way that is useful to state or regional management (Dahl 2006). Recently, the NWIPlus has been used to develop regional enhancements of NWI that include functional assessment based on landscape position, landforms, and hydrology (Tiner 2003, 2005, 2014). However, this approach misses critical information on the effects of stressors on wetlands, especially those that are difficult to detect with remote sensing data. Wetland condition can deteriorate without wetland loss or change of type (Dahl 2006). To address this the National Wetland Condition Assessment (NWCA) was established to determine the condition of the wetlands of the United States (Leibowitz et al. 1991). At a regional scale, hydrogeomorphic wetland classifications have been developed and used to assess wetland functions (Brinson 1993; Ainslie et al. 1999; USACE 2010). Collectively, these approaches have made significant contributions to our knowledge of wetland condition and function (Wardrop et al. 2007).

Although federal monitoring programs have documented important trends in changes of wetland types,

acreages, and condition, knowledge at the state scale is variable, and in Kentucky it is limited. Site selection for national-scale monitoring is typically density weighted, and few sites are sampled in Kentucky (Leibowitz et al. 1991). Although western Kentucky harbors the largest number of wetlands in the state (Abernathy et al. 2010), there is a considerable amount of wetland area throughout the rest of state, which encompass different ecoregions and some wetland types not found in western Kentucky (Woods et al. 2002; Richter et al. in press). Our principle objective was to provide baseline data for ambient wetland monitoring in Kentucky. Specifically, we compared the information published in the NWI to field-collected wetland characteristics, including wetland type and size, and assessed reasons for discrepancies. We also used the Kentucky Wetland Rapid Assessment Method (KY-WRAM) to determine wetland condition of sites visited and describe the patterns of condition among wetland types and across river basins.

Description of study area

Large rivers form the borders of much of Kentucky, including the Ohio River to the north, the Mississippi River to the far west, the Big Sandy River basin to the east, and the Tennessee River to the southwest. Kentucky encompasses seven level III ecoregions: Southwestern Appalachians, Central Appalachians, Western Allegheny Plateau, Interior Plateau, Interior River Valleys and Hills, Mississippi Alluvial Plain, and Mississippi Valley Loess Plains (Woods et al. 2002). These ecoregions are distinguished by differences, including topographic relief and elevation, geology and soils, climate, vegetation composition, and land cover and land uses (Woods et al. 2002). Generally, elevation and topographic relief decreases from east to west. Minimum and maximum temperatures are similar across the state (minimum: -7 to -5 °C; maximum: 31 to 33 °C); however, the minimum number of frost free days (160–190) and minimum precipitation (107–130 cm) increases from east to west.

Most of eastern Kentucky is situated within the Southwest and Central Appalachians and Western Allegheny Plateau, which are more similar to one another than the other ecoregions. They are characterized by relatively high elevation (305–1262 m),

ugged topography and well-drained soils of low fertility. Thus, much of the land is not arable. These ecoregions have also experienced extensive surface and underground coal mining, and oil–gas production. Vegetation communities include mixed mesophytic and mixed oak forests.

The Interior Plateau Ecoregion is the largest ecoregion in the state and encompasses northern, central, and portions of western Kentucky. It is characterized by decreased topographic relief and elevation (105–457 m), broad terraces, floodplains/bottomlands, and knobs. The geology includes large areas of karst. Soils tend to have high fertility and the area is extensively farmed. Pastureland, cropland, and remnant woodlands of mixed deciduous and oak-hickory are common.

In western Kentucky, the Interior River Valleys and Hills, Mississippi Alluvial Plain, and Mississippi Valley Loess Plains ecoregions comprise a relatively small amount of land cover combined. Elevation and topographic relief is lower than elsewhere in the state (94–259 m), and soils are poorly drained and productive. Most major stream systems have been channelized. Historically, forested floodplains, swamps, and bottomlands were extensive, but most have been cleared and drained for agriculture. Because of the underlying geology, coal mining has also been a major land use in the Interior River Valleys and Hills Ecoregion. Natural vegetation communities include oak-hickory forests on drier sites and water-tolerant oaks, tupelos (*Nyssa aquatica* and *N. sylvatica*), and bald cypress (*Taxodium distichum*) in bottomlands.

Methods

Wetland distribution and site selection

We used NWI data (<http://www.fws.gov/wetlands/data/Data-Download.html>) and ArcGIS v. 10.0 (ESRI 2011) to calculate wetland area for all of the palustrine wetlands in Kentucky, with the exclusion of excavated (i.e., unconsolidated bottom) and aquatic bed wetlands. NWI data were downloaded in November 2013 and acquired in an Albers equal-area map projection, which is appropriate for area-based estimates. We calculated total area, mean area, and frequency of wetlands in each basin and by dominant NWI

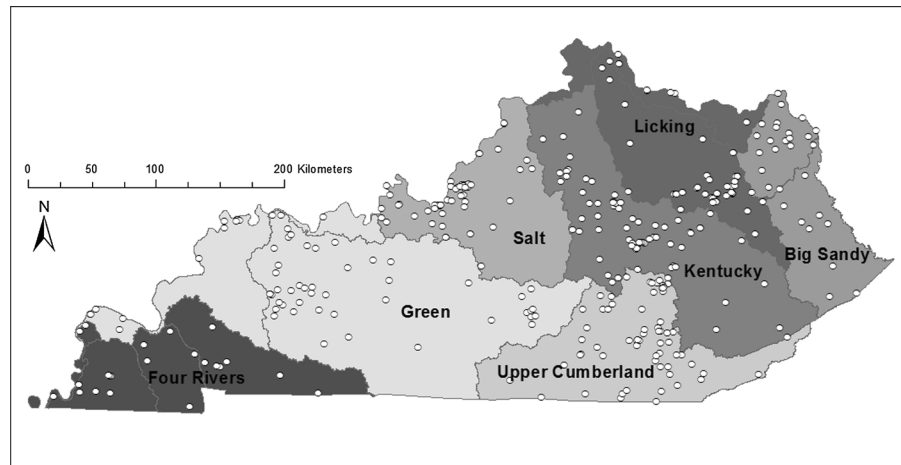
vegetation class, including palustrine forested, palustrine scrub-shrub, palustrine emergent and combinations of these classes where they co-occurred (Cowardin et al. 1979).

From May 2011 to October 2014, we field sampled 352 wetlands (Fig. 1), of which 61% were probability-selected and 39% were target-selected. Probabilistic sampling sites were selected from the NWI database of palustrine wetlands using a Generalized Random Tessellation Stratified (GRTS) spatially balanced survey method (Stevens and Olsen 2004), which randomly selected wetlands in proportion to wetland density. Site selection was further stratified by forest, scrub-shrub, and emergent NWI vegetation class for each of the seven major river basins in Kentucky: Four Rivers, Green, Salt, Upper Cumberland, Kentucky, Licking, and Big Sandy. Four Rivers includes portions of the Lower Cumberland, Tennessee, Mississippi, and Lower Ohio watersheds. The Big Sandy basin includes the Big Sandy, Little Sandy, and Tygarts Creek watersheds. Wetlands associated with tributaries to the Ohio River main-stem were combined with the nearest large river basin for site selection.

Our goal was to sample 30 wetlands in each basin, except in the Licking and Four Rivers basins, which were not sampled as intensively due to logistical constraints. A randomized list of approximately 200 NWI wetland points was generated per basin and was evaluated in order for inclusion in the study until the desired sample size was met. Points were eliminated if a wetland was not present within 60 m of the point (i.e., did not meet the criteria for a federally jurisdictional wetland; USACE 1987), we failed to receive landowner permission, or points were too close together based on KY-WRAM criteria (i.e., with boundaries <762 m apart). Approximately 30% of randomly-selected points were eliminated because we found no evidence of a wetland when inspected visually using aerial imagery (USDA NAIP 2012 and 2014, 1 m resolution) and USGS topographic maps (1:24,000), or during field-based reconnaissance.

In addition to the GRTS-based probabilistic sampling, we used a targeted approach, to sample non-riparian terrene wetlands that tend to be missed by NWI. During sampling it became apparent that low and high quality wetlands were scarce, thus wetlands expected to be of low or high quality were added to the sample to strengthen the condition gradient.

Fig. 1 Field-sampled wetlands (N = 352) from 2011 to 2014 across the seven major river basins of Kentucky



Vegetation and LLWW classification

Each site was assigned to one or more dominant vegetation categories following the NWI classification system (Cowardin et al. 1979). Categories included palustrine emergent (PEM), scrub-shrub (PSS), forested (PFO), aquatic bed (PAB), unconsolidated bottom (PUB), and combinations thereof, and were considered dominant when present at $\geq 40\%$ contiguous cover of the wetland area (or $>30\%$ when three or more categories were present). Although PAB and PUB wetlands were excluded a priori during site selection, several wetlands originally classified as PEM, PSS, or PFO were determined to be partially or completely PUB or PAB during field assessments. We added one category, palustrine farmed wetlands (Pf), for actively farmed sites that had wetland soils and hydrology, but did not necessarily have existing wetland vegetation. All wetlands were field-classified according to the NWI system. Duplicate assessments were made for quality assurance purposes.

We also classified each site using the NWIplus classification (Tiner 2014) based on landscape position, landform, water flow path, and water body type. We used a dichotomous key to classify each wetland as Lentic, Lotic river, Lotic stream, Terrene headwater, Terrene riparian, or Terrene non-riparian (Tiner 2014). We used Federal Emergency Management Agency (FEMA) maps, and the National Hydrography Dataset (<http://nhd.usgs.gov>), and field reconnaissance to determine flow path and water body type. We used US Army Corps of Engineers (USACE) Wetlands Delineation Manual (1987, 2012) wetland

hydrology indicators to determine if sites were likely to flood on average at least every other year, an important criterion for NWIplus classification.

Wetland condition

The Kentucky Wetland Rapid Assessment Method (KY-WRAM) is a site specific, primarily field-based, assessment of the condition of natural wetlands that incorporates stressors and natural features. The scoring range of 0–100 is categorized into one of three groups: Category one (poorest condition; 0–41 points), Category two (moderate condition; 42–70 points), and Category three (best condition; 71–100 points). KY-WRAM consists of six metrics: wetland size and distribution (up to nine points), buffers and intensity of surrounding land use (up to 12 points), hydrology (up to 29 points), habitat alterations and habitat structure development (up to 20 points), special wetlands (up to 10 points), and vegetation and habitat features (up to 20 points). At each site, a KY-WRAM evaluation was performed by at least one, but usually two field crew members, and mean scores were calculated. Each wetland assessment area included up to 20 ha (Form and Guidance Manual: <http://water.ky.gov/waterquality/Pages/KY-WRAM.aspx>), which was centered on the sampling point for larger wetlands. The size of field-assessed wetlands was estimated from site visits, and each site was placed in one of seven size categories: 0 to <0.04 ha, 0.04 to <0.12 ha, 0.12 to <1.21 ha, 1.21 to <4 ha, 4 to <10.12 ha, 10.12 to <20.23 ha, or ≥ 20.23 ha.

Land cover and uses surrounding wetlands

Land uses for each site were quantified within a 1000-m buffer (Mack 2006) around each wetland point using ArcGIS (ESRI 2011) and the Kentucky 2005 Land Cover (Anderson Level II, 30-m \times 30-m resolution; KLC 2005). The Kentucky land cover map has lower accuracy for forest types and development classes than for some other land uses (Harp et al. 2006), but should be superior to the NLCD because it is based on training samples that come exclusively from within Kentucky. For each buffer, a land use comprising $\geq 25\%$ of pixels was considered a dominant land use. We report on land use in two ways, the percentage of wetland sites possessing each dominant land use within 1000 m, and the average percent area of each land use within 1000 m of each assessed wetland.

Statistical analyses

We used the NWI-based estimates of wetland frequency and area to report descriptive statistics on patterns among the dominant vegetation classes and river basins. We tested for differences in the mean ranks of wetland area among basins using a Kruskal–Wallis test followed by Nemenyi multiple comparisons. We tested for differences in median ranks of wetlands among vegetation classes with an Independent-Samples Median test. We calculated the percent of wetlands within each NWI-based vegetation class (e.g., PFO, PEM, PSS) that disagreed with our field-based classification and used a Pearson χ^2 test to determine if the misclassifications were statistically significant.

To compare KY-WRAM scores among locations, we used ANOVA, including basin and landscape position as fixed factors, and blocked on sampling method (probability vs. targeted). The KY-WRAM dataset met the assumptions for parametric tests, including a normal distribution and homogeneous group variances. We used Tukey's tests to compare pairwise differences among the basins and landscape position types. We also compared condition between the three dominant NWI vegetation classes, as determined by field sampling (PFO, PEM, and PUB) using ANOVA, with blocking on sampling method. We conducted this analysis separately from the ANOVA with basins and landscape position because there were

more than 25 vegetation classes or combinations of classes among our sampled wetlands, most of which occurred infrequently. In fact, only the three types listed above occurred at more than 10 wetlands, and so we limited our analysis of vegetation classes to these. Finally, we conducted separate two-sample t-tests to compare KY-WRAM scores of field-classified forested wetlands and field-classified emergent wetlands that were similarly classified by NWI to those that disagreed with NWI. We limited these analyses to forested and emergent wetlands due to low sample sizes of other NWI classes.

Results

Wetland distribution

Across Kentucky, the NWI included 39,024 total palustrine wetland polygons, which were dominated by PFO, PEM, and PSS as single classes or in combination. Palustrine wetlands encompassed approximately 133,024 ha (PFO, PEM, PSS and their combinations totaled 131,816 ha). The mean (\pm SE) area of NWI palustrine polygons was 3.4 ± 0.11 ha (3.8 ± 0.13 ha for PFO, PEM, PSS and their combinations), but the distribution of wetland areas was highly skewed such that most NWI-mapped palustrine wetlands were relatively small and the median wetland size was 0.38 ha (0.46 ha for PFO, PEM, PSS, and their combinations) (Table 1). The Four Rivers basin had the highest mean area, total area, and frequency of wetlands, followed by the Green River basin. The distribution of wetlands, follows a general west to east pattern, with more and larger wetlands occurring in the westernmost portion of Kentucky. The mean ranks of wetland area were significantly different among basins ($H_6 = 4874$, $P < 0.001$). The mean ranks of wetland area indicated that the Four Rivers basin had the largest wetlands, followed by the Green River and Upper Cumberland basins, but the latter comparison had a statistically non-significant difference in ranks. The Kentucky and Licking basins had similar mean ranks, which were significantly greater than the Big Sandy and Salt river basins. The Big Sandy River basin had the lowest mean rank of wetland size.

Of all NWI-mapped palustrine wetlands that had a single dominant vegetation class, forested wetlands had the highest frequency and mean area in all basins,

Table 1 Mean area (± 1 SE ha), in bold, total area (ha), in italics, and number of palustrine wetlands in major rivers basins of Kentucky, by vegetation class, as indicated by the National Wetlands Inventory data

Basin	PEM	PSS	PFO	PEM/PSS	PEM/PFO	PSS/PFO	Total
Four rivers 1,134,800 ha	1.0 \pm 0.05 <i>3234.3</i>	2.4 \pm 0.18 <i>3968.3</i>	13.3 \pm 0.73 <i>73,272.4</i>	10.6 \pm 1.88 <i>979.2</i>	10.5 \pm 2.29 <i>198.7</i>	14.0 \pm 2.61 <i>1038.1</i>	7.7 \pm 0.39 <i>82,741.9</i>
Green 2,957,400 ha	0.9 \pm 0.10 <i>3141.5</i>	1.7 \pm 0.10 <i>2236.3</i>	5.5 \pm 0.23 <i>30,842.4</i>	8.6 \pm 2.13 <i>326.0</i>	3.5 \pm 1.71 <i>10.4</i>	14.5 \pm 9.76 <i>276.1</i>	3.5 \pm 0.13 <i>36,840.0</i>
Salt 1,075,500 ha	0.2 \pm 0.01 <i>530.0</i>	0.6 \pm 0.05 <i>244.6</i>	1.8 \pm 0.15 <i>1875.8</i>	0.0 <i>0.0</i>	0.0 <i>0.0</i>	0.8 <i>0.8</i>	0.7 \pm 0.04 <i>2651.3</i>
Upper Cumberland 1,342,100 ha	0.6 \pm 0.03 <i>666.9</i>	1.6 \pm 0.11 <i>793.5</i>	2.9 \pm 0.20 <i>3108.8</i>	1.2 \pm 0.25 <i>48.6</i>	3.5 <i>3.5</i>	3.3 \pm 0.76 <i>42.7</i>	1.6 \pm 0.08 <i>4664.4</i>
Kentucky 1,804,100 ha	0.3 \pm 0.01 <i>552.5</i>	1.0 \pm 0.07 <i>479.0</i>	1.5 \pm 0.07 <i>1356.4</i>	0.9 \pm 0.40 <i>5.3</i>	1.0 \pm 0.40 <i>4.9</i>	0.0 <i>0.0</i>	0.8 \pm 0.03 <i>2398.1</i>
Licking 1,259,800 ha	0.3 \pm 0.02 <i>404.9</i>	0.7 \pm 0.06 <i>268.4</i>	1.2 \pm 0.05 <i>1212.8</i>	0.0 <i>0.0</i>	0.0 <i>0.0</i>	0.0 <i>0.0</i>	0.7 \pm 0.02 <i>1886.1</i>
Big Sandy 892,300 ha	0.4 \pm 0.03 <i>343.9</i>	0.9 \pm 0.09 <i>113.9</i>	1.3 \pm 0.13 <i>228.9</i>	2.8 \pm 1.27 <i>5.6</i>	0.0 <i>0.0</i>	0.0 <i>0.0</i>	0.3 \pm 0.01 <i>1842.6</i>
Total	0.6 \pm 0.03 <i>8874.0</i>	1.7 \pm 0.07 <i>8104.0</i>	7.3 \pm 0.28 <i>111,897.6</i>	7.7 \pm 1.12 <i>1364.8</i>	7.8 \pm 1.73 <i>217.5</i>	12.7 \pm 2.50 <i>1357.7</i>	107 <i>5272</i>

Basins are listed from west to east. Total basin area is listed under the basin name and includes all NWI palustrine wetlands. Shared letters in the right-most column indicate no statistically significant difference in the mean rank of wetland size among basins

PEM emergent wetland, PSS scrub-shrub wetland, PFO forested wetland

except in the Big Sandy, where emergent wetlands had the greatest mean and total area ($P < 0.001$ for all tests). Emergent wetlands had higher total area than scrub-shrub wetlands ($H_2 = 9387$, $P < 0.001$); however, scrub-shrub wetlands were larger than emergent wetlands ($H_2 = 11,271$, $P < 0.001$).

Overall, >50% of all NWI-mapped palustrine wetlands and field-sampled sites were less than 1.21 ha (Table 2). Very few NWI-mapped wetlands (0.5%) were less than 0.04 ha, whereas wetlands of this size were a considerable part (11%) of the field-assessed sites. The greatest number of wetlands in a single size category for both NWI-mapped (58%) and field-assessed wetlands (26%) was 0.12 to 1.21 ha. Most size classes had a similar proportion of wetlands between NWI and field-visited wetlands; however, wetlands in the 0.1–1.2 ha size category accounted for almost 60% of NWI wetlands, but only 26% of field-assessed wetlands.

Of the probability-selected sites, the Salt ($N = 47$), Upper Cumberland ($N = 37$), Green ($N = 37$), Big Sandy ($N = 30$), and Kentucky ($N = 29$) river basins had the highest number of sites sampled, whereas the Licking ($N = 20$) and Four Rivers ($N = 16$) river basins had the fewest sampled sites. For the target-selected sites, the Licking ($N = 36$), Kentucky ($N = 35$), and Upper Cumberland ($N = 29$) river basins had the highest number of sites sampled, and the Salt ($N = 6$), Four Rivers ($N = 13$) and Green ($N = 17$) river basins had the fewest sites sampled. No target-selected sites were sampled in the Big Sandy river basin.

Of the 352 wetlands sampled in the field, there were 37 lotic river, 143 lotic stream, 17 terrene headwater, 54 terrene riparian, 85 terrene non-riparian, and 16 lentic wetlands sampled. Of the 37 lotic river wetlands, 10 were also considered as farmed wetlands according to the Natural Resources Conservation

Service (R. Toor, personal communication). Sampled wetlands encompassed the three main vegetation classes; however, the most frequently sampled wetland vegetation community was forest ($N = 150$), followed by emergent ($N = 68$). Although not a vegetation community, unconsolidated bottom wetlands were also sampled in relatively high numbers ($N = 37$), with 38% of these in the Big Sandy river basin ($N = 14$). Of the field-sampled sites, public-owned properties accounted for 22% of probability-selected and 68% of target-selected sites, whereas private ownership accounted for 78% of probability-selected and 31% of target-selected sites.

Vegetation and LLWW classification

Of the 352 field-sampled wetlands, 270 sites (77%) had been mapped by the NWI. The 82 sites that did not occur in NWI were target-selected, and accounted for 60% of targeted sites (40% of targeted sites occurred in NWI). More than half (55%) of unmapped sites were terrene non-riparian wetlands ($N = 45$); almost two-thirds were less than 0.1 ha; and almost two-thirds were emergent, forest, or a combination of the two.

A large proportion of field-based classifications disagreed with NWI vegetation class (50% of probability-selected sites) (Table 3). All NWI-classified scrub-shrub sites were assigned a different vegetation class based on field surveys, most frequently as forest (66% of probability-selected sites). Wetlands that were classified as emergent in NWI were most frequently field-classified as forested wetlands (28%). Most wetlands mapped by the NWI as forest were found to be forested during field sampling (78%); however, those found to be another type were most frequently emergent (9%). When considering emergent and forested types alone there was a significant

Table 2 Percent (and total number) of NWI-mapped palustrine wetlands and field-assessed sites by KY-WRAM size class category

Size class (ha)	NWI	Cumulative percent	Field sites	Cumulative percent
<0.04	0.5% (176)	0.5	11% (38)	11
0.04 to <0.12	14% (5631)	15	14% (48)	25
0.12 to <1.21	58% (22,709)	73	26% (93)	51
1.21 to <4.05	16% (6208)	89	15% (52)	66
4.05 to <10.12	6% (2381)	95	12% (44)	78
10.12 to <20.23	2% (914)	97	8% (29)	86
≥20.23	3% (1005)	100	14% (48)	100

Table 3 The percent of probability-selected sites ($N = 126$) where the dominant vegetation class, as observed in the field, differed from the NWI classification

NWI classification	Field-based classification								Total disagreement
	PEM	PSS	PFO	PEM/PSS	PEM/PFO	PFO/PSS	Pf	PUB	
PEM	38.4	0.0	27.4	9.6	5.5	1.4	2.7	12.3	61.6
PSS	0.0	0.0	65.7	5.7	8.6	11.4	0.0	2.9	100
PFO	8.7	1.4	78.3	0.0	2.9	0.0	0.0	1.4	21.7
PEM/PSS	0.0	0.0	50.0	0.0	0.0	0.0	0.0	50.0	100
PEM/PFO	–	–	100.0	–	–	–	–	–	100

Bold values on the diagonal indicate percent of similarly classified sites

frequency of disagreement for both emergent and forested wetlands between NWI mapped and field sampled wetlands ($X^2 = 50.81$; $df = 2$; $P < 0.001$).

Landscape disturbance

The most frequently encountered dominant land uses in the area buffering wetlands were deciduous forest (196 wetlands, 56% of sites, mean land cover = 55%), pasture or hay (98 wetlands, 28% of sites, mean land cover = 52%), and cultivated crops (48 wetlands, 14% of sites, mean land cover = 51%) (Table 4). Deciduous forest was a dominant land use (i.e., comprised at least 25% of 1000-m buffer surrounding wetlands) across all river basins. Pasture/hay was a dominant land use for the Kentucky, Licking, Salt, and Upper Cumberland river basins. In the Four Rivers and Green river basins, cultivated crops was a dominant land use. Wetlands dominated by woody plants (i.e., a combination of shrub and tree species) occurred frequently in the Four Rivers basin.

Wetland condition

The mean (\pm SE) KY-WRAM score across all field-sampled wetlands of Kentucky was 54.3 ± 1.0 (Fig. 2), and scores ranged from 5 to 92. KY-WRAM scores did not differ statistically between probability (mean = 54.1 ± 1.3) and target-sampled wetlands (mean \pm SE = 54.7 ± 1.5) ($F_{1,339} = 0.07$, $P = 0.78$). The mean KY-WRAM score differed among basins ($F_{6,339} = 10.97$, $P < 0.001$), with wetlands in the Four Rivers basin having the highest condition scores, and wetlands in the Big Sandy basin having the lowest condition scores; the other five basins had relatively similar scores for condition (Fig. 3).

Wetland condition also differed among landscape positions ($F_{5,339} = 5.56$, $P < 0.001$; Fig. 4). Specifically, on average, lentic wetlands scored the highest, terrene headwater wetlands scored the lowest (Fig. 4). There were some differences in condition scores between lotic and terrene wetland types. It appears lotic riverine wetlands tended to score higher than terrene wetlands, except for in the Green River basin. Lotic stream wetlands tended to score higher than terrene non-riparian wetlands, although this may not hold for the Upper Cumberland and Licking River basins. Also, terrene non-riparian wetlands tended to score lower than other wetlands, except perhaps in the Upper Cumberland and Kentucky River basins, where terrene riparian wetlands had lower scores (Fig. 5). Lotic wetlands in the Four Rivers basin appear to have the highest condition scores, whereas, terrene non-riparian wetlands in the Big Sandy River basin appear to have the lowest condition scores overall. The mean KY-WRAM score differed among the dominant vegetation classes ($F_{2,251} = 57.46$, $P < 0.001$; Fig. 6), with forested wetlands having higher scores than emergent and unconsolidated bottom wetlands. Actively farmed wetlands ($N = 12$) had low condition scores (mean \pm SE = 24.5 ± 1.6). There was no difference in the condition of field-classified forested sites that were also mapped as forested by NWI (mean \pm SE = 63 ± 1.7) compared with those classified as emergent or scrub-shrub by NWI (mean \pm SE = 61 ± 2.3 ; $t_{111} = 0.95$, $P = 0.17$). Likewise, there was no difference in the condition of field-classified emergent sites that were also classified as emergent by NWI (mean \pm SE = 39 ± 2.6) compared with those classified as forested (there were none classified as scrub-shrub) by NWI (mean \pm SE = 46 ± 2.5 ; $t_{36} = 1.23$, $P = 0.11$).

Table 4 Land use category index value and average percent area (± 1 SE) of each category within 1000 m of probability-selected points by river basin for all study sites

Land use category	Index value	Four Rivers	Green	Salt	Upper Cumberland	Kentucky	Licking	Big Sandy	Statewide
Woody Wetlands	1	27.0 \pm 4.3	5.6 \pm 0.9	6.2 \pm 1.4	0.0 \pm 0.0	0.2 \pm 0.0	0.5 \pm 0.1	0.1 \pm 0.0	0.9
Emergent Wetlands	1	2.7 \pm 0.7	3.5 \pm 0.7	0.5 \pm 0.1	0.0 \pm 0.0	0.1 \pm 0.0	0.1 \pm 0.0	0.0 \pm 0.0	2.2
Deciduous Forest	1	27.8 \pm 4.0	34.2 \pm 3.0	40.6 \pm 2.9	55.0 \pm 3.1	32.4 \pm 3.0	49.9 \pm 3.6	56.3 \pm 4.0	46.8
Evergreen Forest	1	2.1 \pm 0.5	2.5 \pm 0.5	1.2 \pm 0.2	0.8 \pm 0.1	1.9 \pm 0.5	2.1 \pm 0.4	1.7 \pm 0.3	0.3
Mixed Forest	1	0.0 \pm 0.0	0.4 \pm 0.2	0.2 \pm 0.0	6.7 \pm 1.3	3.0 \pm 1.0	6.2 \pm 1.3	2.0 \pm 0.4	4.3
Grassland/Herbaceous	1	0.8 \pm 0.4	2.3 \pm 0.6	1.5 \pm 0.3	5.6 \pm 0.8	3.4 \pm 1.0	2.1 \pm 0.4	8.3 \pm 1.4	2.3
Scrub-Shrub	1	0.5 \pm 0.1	0.7 \pm 0.2	0.3 \pm 0.1	1.1 \pm 0.2	1.0 \pm 0.1	1.2 \pm 0.2	1.5 \pm 0.3	1.1
Open Water	1	7.6 \pm 2.0	4.1 \pm 0.9	3.7 \pm 1.1	1.0 \pm 0.5	0.9 \pm 0.2	4.5 \pm 1.3	4.3 \pm 2.0	2.0
Pasture/Hay	3.41	3.4 \pm 1.9	8.7 \pm 2.0	16.7 \pm 3.0	18.3 \pm 2.8	36.2 \pm 3.2	22.5 \pm 3.7	12.2 \pm 2.7	21.8
Developed, Open Space	6.92	2.2 \pm 0.5	3.1 \pm 0.3	12.0 \pm 1.8	5.5 \pm 0.5	7.4 \pm 0.6	4.8 \pm 0.6	5.3 \pm 0.7	4.8
Cultivated Crops	7	25.1 \pm 4.0	33.9 \pm 3.8	6.8 \pm 1.7	1.7 \pm 0.9	3.9 \pm 0.8	3.4 \pm 1.1	2.5 \pm 0.9	10.9
Developed, Low Intensity	7.55	0.4 \pm 0.1	0.7 \pm 0.2	6.6 \pm 1.3	2.5 \pm 0.6	4.8 \pm 0.9	1.9 \pm 0.3	3.3 \pm 0.6	1.5
Barren Land	8.32	0.1 \pm 0.1	0.1 \pm 0.0	0.3 \pm 0.1	0.7 \pm 0.2	0.8 \pm 0.6	0.2 \pm 0.0	6.7 \pm 0.4	0.4
Developed, Medium Intensity	9.42	0.1 \pm 0.1	0.3 \pm 0.1	2.7 \pm 0.6	0.7 \pm 0.3	3.2 \pm 0.8	0.5 \pm 0.2	1.5 \pm 0.5	0.5
Developed, High Intensity	10	0.0 \pm 0.0	0.1 \pm 0.0	0.9 \pm 0.3	0.2 \pm 0.1	0.7 \pm 0.2	0.1 \pm 0.0	0.2 \pm 0.1	0.2

Statewide percent area is shown for reference

Discussion

Our study is the first statewide assessment of wetland status and condition, particularly for wetlands associated with lotic systems in Kentucky. This provides baseline data for monitoring including status and trends research, evaluation of compensatory mitigation success, and identification of reference sites. Additionally, this is the first comparison of NWI and field-sampled wetlands in Kentucky for agreement of vegetation classification and size distribution estimates.

The average size of NWI-mapped palustrine wetlands and field-assessed wetlands in our study were similar, and fell within the relatively small 1.21 to 4 ha KY-WRAM size category. Other studies have found

that most wetlands were relatively small (<1.0 ha), including in coastal prairie wetlands (Enwright et al. 2011), depressional wetlands in Minnesota (Genet and Olsen 2008), across eight states of the southeast, including Virginia and Florida (Lane et al. 2012), and across three regions of the U.S., including North Dakota, Washington, and Illinois (Ernst et al. 1995). Although average wetland sizes were similar between the NWI-mapped and field-assessed wetlands, the distribution of sizes differed. For example, almost 75% of NWI-mapped wetlands were ≤ 1.21 ha, whereas the same cumulative percentage of field-assessed wetlands ranged up to 10.12 ha. Additionally, only 11% of NWI-mapped wetlands were >10.12 ha, compared with 34% of field-assessed sites. NWI also appears to miss many of the smallest

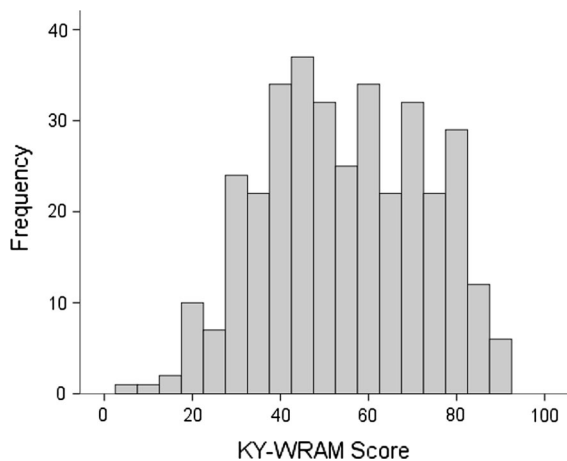


Fig. 2 Frequency of Kentucky Wetland Rapid Assessment Method total scores for all sites sampled from 2011 to 2014. The KY-WRAM ranges from 0 to 100 possible points, but the lowest possible score is 5 because all wetlands receive points in some metrics

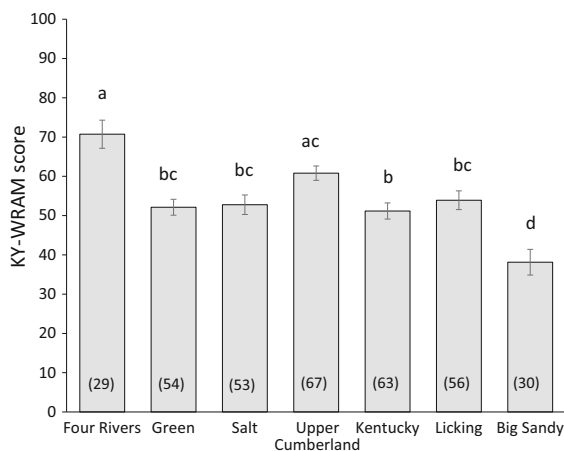


Fig. 3 Mean KY-WRAM scores (± 1 SE) of field-sampled wetlands among the seven major river basins of Kentucky. Sample sizes are in parentheses at the bottom of each bar. Shared letters above each bar indicate no statistically significant differences between basins

wetlands: 11% of field assessed sites were <0.04 ha, whereas only 0.5% of NWI wetlands fell within that size class. This is likely because of limited resolution of imagery used to create NWI maps and that many of these smallest wetlands were within forest, thus difficult to detect with remote sensing.

Most of the wetlands we encountered in the field that were not mapped in NWI were small (<0.3 ha on average), forested, and in upland settings, a pattern

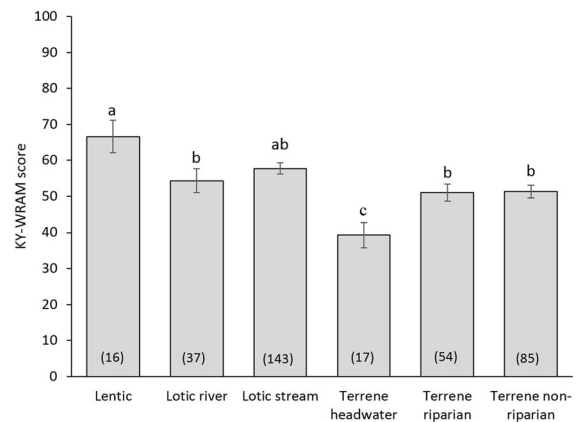


Fig. 4 Mean KY-WRAM scores (± 1 SE) of field-sampled wetlands among six landscape position classes, as determined by NWIPlus system. Sample sizes are in parentheses at the bottom of each bar. Shared letters above each bar indicate no statistically significant differences between basins

which has been described elsewhere (Stolt and Baker 1995; Dahl 2006). Although not widely known to be an issue with the NWI, Stolt and Baker (1995) also found several large riverine and flats wetlands that did not appear in the NWI. Given this, and the fact that our field-sampled sites included a much higher proportion of large wetlands compared with the NWI, it appears that the NWI underestimates the size of large, riverine wetlands.

Despite the extensive loss of Kentucky's historic wetlands ($>80\%$), the patterns of wetland distribution are similar to those of the past. For example, wetland area and stream order were historically and continue to be positively related (USGS 1973, 1990), and so there remains a higher frequency and larger total wetland area in the Green and Four Rivers basins, due largely to their association with higher order streams and the associated flat topography (USGS 1973, 1990).

The broad scale wetland characteristics documented by our field surveys generally reflected overall NWI characteristics. For example, NWI showed the majority of wetlands were palustrine and forested, scrub-shrub, emergent, and unconsolidated bottom. Specifically, forested wetlands were the most frequent type (43%), followed by emergent (19%), unconsolidated bottom (11%), and scrub-shrub wetlands (2%). This is similar to national NWI patterns, where forested wetlands were the predominant freshwater wetland class (almost 50%), followed by emergent (26%), scrub-shrub (18%), and ponds (6%) (Dahl

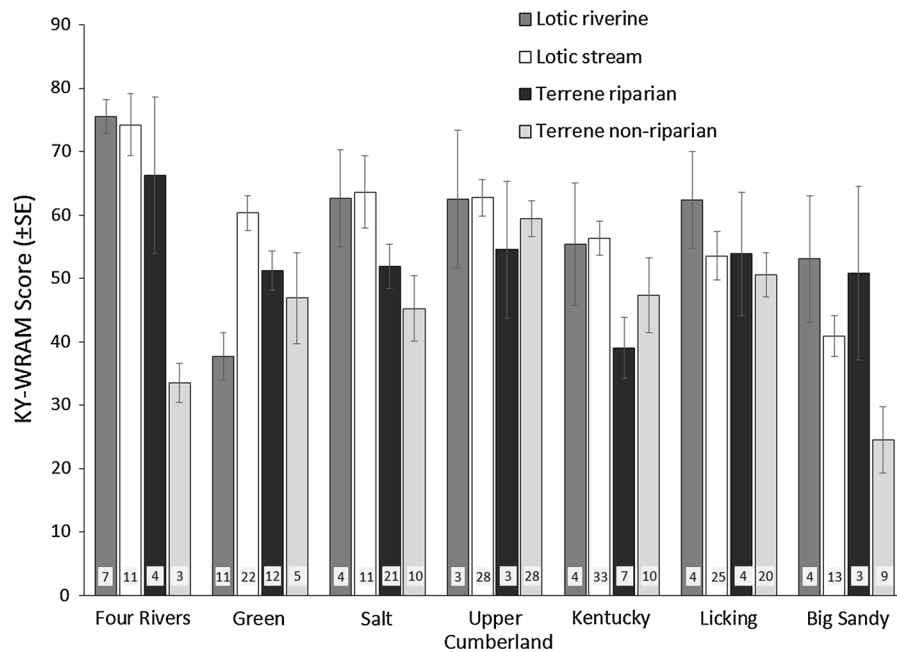


Fig. 5 KY-WRAM scores among the seven river basins and grouped by NWIPlus classification. The number at the bottom of each bar indicates sample size

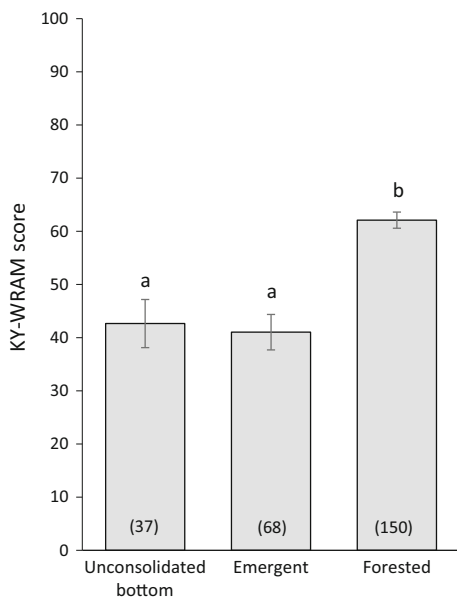


Fig. 6 Mean KY-WRAM scores (± 1 SE) among the three dominant NWI classes as determined by field-based classification. Sample sizes are in parentheses at the bottom of each bar. Shared letters above each bar indicate no statistically significant differences between basins

2011). The dominant wetland types in nearby regions such as the Mid-Atlantic and the Southern Blue Ridge of Virginia were also palustrine forested, emergent, and scrub-shrub (Tiner and Finn 1986; Stolt and Baker 1995). In the Upper Great Lakes region of Michigan, palustrine forested wetlands accounted for more than two-thirds of wetlands (Kudray and Gale 2000). Wetlands remaining in agricultural or other human land use settings were typically forested, possibly because they were too wet to farm, as with other regions (e.g., Choptank River Watershed in Maryland; Lang and McCarty 2009).

During site scouting we excluded 30% of potential sites because jurisdictional wetlands were not present. KY-WRAM was intended for use as a regulatory tool, so we selected wetlands that fit USACE jurisdictional criteria (i.e., all three indicators present under normal conditions: hydric soils, hydrophytic vegetation, and hydrology); however, NWI requires only one of three indicators. Therefore, it is difficult to infer the proportion of sites excluded that were not jurisdictional wetlands, but would have been considered wetlands in the NWI. Other studies have found similar

levels of disagreement between NWI and other approaches such as USACE-delineated and hydrogeomorphic-delineated wetlands (Wu et al. 2014: >20% disagreement; Dvoretz et al. 2012: 31% disagreement). Older studies show a lower rate of disagreement between NWI and USACE (<10%; Stolt and Baker 1995; Kudray and Gale 2000). This suggests that the age of NWI maps, differences in wetland delineation criteria, and mapping errors all contribute to high rates of disagreement, but the relative contributions of these factors are not fully understood.

We also found disagreement between NWI and current field conditions in the classification of dominant vegetation. In our study, disagreement was especially high for scrub-shrub wetlands: of all NWI-mapped scrub-shrub wetlands, zero were classified as such in the field. Additionally, nearly two-thirds of wetlands mapped as emergent by NWI were found to be a different vegetation class. Maxa and Bolstad (2009) also noted a high rate of disagreement of shrub wetlands when comparing LiDAR mapped wetlands versus Wisconsin Wetlands Inventory Maps, which used similar mapping techniques as NWI. Ecological succession may explain much of our results, as trees small enough to be considered scrub-shrub decades ago have matured since NWI maps were last updated, leading to gains of forest and losses of scrub-shrub wetlands (Stolt and Baker 1995; Dahl 2006). Further, the majority of sites we sampled (>50%) that were mapped by NWI as emergent were found to be forested during field sampling. Given that it has been approximately 30 years since NWI maps were last updated for Kentucky (1980–1987), it is plausible that wetlands previously dominated by emergent vegetation or early-successional tree species and not by true shrubs (e.g., buttonbush and alder) at the time of mapping have developed into forest communities. Although NWI maps and field-assessed sites agreed more frequently for forested wetlands than other types, a large proportion of NWI mapped forested wetlands disagreed with field sampling as well (>20%), with more than half of these being emergent wetlands in the field. This may be due to clearing for timber harvest or agriculture resulting in conversion to emergent wetlands, a pattern documented nationally in USFWS Wetlands Status and Trends reports (Dahl 2011). In contrast with our findings, other studies have reported that forested wetlands were the most inaccurately

classified wetland type (Dahl 1990; Kudray and Gale 2000; Dvoretz et al. 2012).

Given the large amount of disagreement between NWI-mapping and our field-assessments of wetlands in Kentucky in relation to wetland presence, vegetation classification, size distribution, and omission of small, forested non-riparian terrene wetlands, we believe these maps should be used with caution and that there is an urgent need for the NWI to be updated to reflect current wetland conditions. Future NWI and other mapping efforts may be improved by using recent remote-sensing and image processing techniques, extensive ground-truthing and imagery training, and frequent map updates. For example, high-resolution digital elevation data from light detection and ranging (LiDAR) and radio detection and ranging (RADAR) systems combined with high-resolution multispectral satellite data would likely improve the accuracy of mapping wetland woody vegetation (Bergen et al. 2009).

We found that land uses surrounding field-sampled wetlands for each river basin were reflective of statewide and ecoregion land uses. Statewide, the majority of wetlands were surrounded by forest, with fewer wetlands surrounded by hay/pasture and row crops. Historically, forested floodplains and bottomlands were common in the Green River and extensive in the Four Rivers basins; however, we found woody wetlands to be a dominant land use only in the Four Rivers basin and only a small component of the Green River basin (6%).

The average KY-WRAM score for all wetlands studied was 54, a score which is considered “Category Two” for an individual wetland. Category Two wetlands are considered to be of moderate quality and support some wetland functions, but are degraded to a level below reference condition. Terrene headwater wetlands, the Big Sandy River basin, and emergent and unconsolidated bottom wetlands scored, on average, at the upper end of Category One, which is the category that includes the most degraded wetlands. The average KY-WRAM score for the Four Rivers river basin approached Category Three (i.e., least-disturbed). Otherwise, the average KY-WRAM score for all the other wetland classes we described above were in Category Two. Even though most of the wetlands in Kentucky have been lost to historical disturbances, the remaining wetlands are on average of

moderate quality, although there is substantial variation in scores with a number of high quality and low quality wetlands in our sample (Figs. 2, 5, 6).

KY-WRAM scores indicate that wetlands in the Four Rivers river basin have experienced the least amount of degradation overall, whereas wetlands of the Big Sandy basin have experienced the highest levels of degradation. Given that the Four Rivers river basin is located within the floodplain of several major rivers, including the Mississippi River, and the topography is much flatter than that of the rest of Kentucky, wetlands in this area remain wetter for longer and many rarely dry completely. We suspect that widespread high water tables have served to impede conversion of wetlands to various land uses, such as agriculture, and have resulted in wetlands having less disturbance. In fact, this basin had the lowest amounts of developed land of the basins in Kentucky. However, *terrene non-riparian* wetlands in this basin scored lower than all other wetland types in all other basins (except the same type in the Big Sandy), possibly because they are located in upland settings that may be vulnerable to human land use, such as agriculture. In contrast, the Big Sandy river basin, located in the Central Appalachians and Western Allegheny Plateau ecoregions, has been an area of intensive coal extraction and had the highest amounts of barren land adjacent to sites in our study. In fact, most of the wetlands randomly selected in this basin were former coal sediment ponds, which were mainly *terrene non-riparian* wetlands and scored lower than wetlands of any other type, and lowered the average for the entire basin. Because the Green River basin also has a history of coal mining, we expected that mining would have a negative impact, as in the Big Sandy; however, we observed almost no barren land surrounding the wetlands we surveyed and higher condition scores, which suggests less mining has occurred near these wetlands, or that natural vegetation on mined areas in this basin has had more time to regenerate. It is also possible that differences in topography between the basins make wetlands in the Big Sandy River basin, which is highly-dissected and steeply-mountainous, more susceptible to impacts than those in the Green River basin, which has a relatively level terrain.

Lentic and *terrene headwater* wetlands had the highest and lowest condition scores, respectively, but because of their relatively low samples sizes it is difficult to know if this is a meaningful trend. This

uncertainty is reinforced by the fact that over half of *terrene headwater* wetlands sampled were target-selected and in the Kentucky River basin, which may have skewed condition scores. Lotic stream wetlands tended to have higher condition scores than the *terrene* wetland types, except *terrene riparian*. Lotic and *terrene riparian* wetlands are situated within 100-year floodplains, which may deter human land uses and result in higher condition, but more work is needed to fully understand this pattern.

Our data suggest that forested wetlands are in better condition overall than emergent and unconsolidated bottom wetlands. In Kentucky, the climax community is deciduous forest, so the presence of forest may indicate an extended time since disturbance, at least since alterations to the vegetation community, such as logging or mowing. Other studies have also found that forested wetlands were less disturbed compared to other vegetation classes (Kayastha et al. 2012; Lane et al. 2012). Interestingly, we found that field-sampled forested wetlands that had been mapped as emergent or scrub-shrub by the NWI were not in poorer condition than wetlands mapped as forested by the NWI. Many of these wetlands appear to have changed into forested habitat through ecological succession, but more detailed vegetation studies are needed to test if there are functional differences between persisting forested wetlands and those that have only recently developed into a forested vegetation class.

Restoration and construction of wetlands can help mitigate environmental functions lost with previous removal of Kentucky's wetlands, but these rarely attain reference functions (Moreno-Mateos et al. 2012). Thus, we argue that protection of existing wetlands in Kentucky should be the primary focus of wetland conservation efforts. A substantial portion of the state's wetlands occurred on public lands, but most (>75%) were on privately owned lands. This corresponds with a national estimate that almost 75% of wetlands are privately owned (USEPA 2001). Although many of the private wetlands were owned by natural resource companies, most were on small farms, which was expected given the importance of agriculture in Kentucky (Kentucky Farm Bureau 2015). We suggest that efforts to protect wetlands in Kentucky should include incentives for landowners, and farmers in particular, to protect and restore wetlands on their property.

Because wetlands associated with streams and rivers (i.e., floodplains) are putatively the most common wetland type in Kentucky, they were the focus of this study. Given this, there is a need for a more comprehensive assessment of the extent and condition of less frequent wetland types, such as terrene non-riparian (depressions and flats), terrene headwater, slopes, and lentic wetlands. Moreover, given the discrepancies between wetlands mapped by the NWI and current field characteristics, updates to NWI maps are necessary to reflect the current extent and classification of wetlands in Kentucky, especially for wetland types that were often unmapped, such as non-riparian terrene wetlands. Additionally, to further assess wetland condition in Kentucky, it will be necessary to determine the degree to which wetland function is degraded by anthropogenic activities. Tiner (2005) and Fizzell (2007), for example, have utilized the NWIPlus and historic soil survey data to remotely assess the potential loss of wetland functions at the watershed scale. As Tiner (2005) suggested, the NWIPlus has its limitations and should be used for preliminary identification of potential losses and that field checking should be conducted, especially for wetlands with hydroperiod variation that could affect functions. Using the NWIPlus to assess wetland function loss of Kentucky's wetlands would add to our understanding of wetland ecology, especially if these assessments include extensive field verification.

Conclusions

Our study is the first statewide assessment of wetlands in Kentucky. We documented baseline wetland condition and characteristics that will be essential for monitoring wetland status and trends. Additionally, this is the first study to utilize the KY-WRAM, which proved effective for determining condition for a large number of wetlands of a variety of wetland types, landscape settings, and regions in Kentucky, over a relatively short amount of time. Our findings support previous work showing that rapid assessments, especially when developed within the area of interest, are valuable tools for determining wetland condition for ambient monitoring and other assessment purposes.

A limited number of studies have evaluated the agreement between NWI-mapped and field-assessed wetland classification and characteristics. This is the

first study of its kind for Kentucky and its surrounding states. Given the age of the NWI maps for Kentucky, it is not surprising that we found a large amount of disagreement between the NWI and field-assessments; however, this comparison was valuable in illustrating the need for an updated NWI and its limitations in detecting particular wetland types such as non-riparian terrene. Given the relatively rapid rate of forest succession from emergent and scrub-shrub wetlands, particularly those that were previously-logged forested wetlands, NWI updates should be scheduled to occur at a frequency that maintains its accuracy, perhaps every 10–15 years in this region. As an additional improvement, future NWI and other mapping efforts should include enhancements introduced by the NWIPlus, which provide landscape, landform, and hydrology information for each wetland. This would be useful for predicting wetland functions and losses. Lastly, for enhanced distinction of vegetation classes, newer mapping techniques, such as LiDAR, should be explored.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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