

# Changes in historical Iowa land cover as context for assessing the environmental benefits of current and future conservation efforts on agricultural lands

Alisa L. Gallant, Walt Sadinski, Mark F. Roth, and Charles A. Rewa

Conservationists and agriculturists face unprecedented challenges trying to minimize tradeoffs between increasing demands for food, fiber, feed, and biofuels and the resulting loss or reduced values of other ecosystem services, such as those derived from wetlands and biodiversity (Millenium Ecosystem Assessment 2005a, 2005c; Maresch et al. 2008). The Food, Conservation, and Energy Act of 2008 (Pub. L. 110-234, Stat. 923, HR 2419, also known as the 2008 Farm Bill) reauthorized the USDA to provide financial incentives for agricultural producers to reduce environmental impacts via multiple conservation programs. Two prominent programs, the Wetlands Reserve Program (WRP) and the Conservation Reserve Program (CRP), provide incentives for producers to retire environmentally sensitive croplands, minimize erosion, improve water quality, restore wetlands, and provide wildlife habitat (USDA FSA 2008a, 2008b; USDA NRCS 2002). Other conservation programs (e.g., Environmental Quality Incentives Program, Conservation Stewardship Program) provide incentives to implement structural and cultural conservation practices to improve the environmental performance of working agricultural lands. Through its Conservation Effects Assessment Project, USDA is supporting evaluation of the environmental benefits obtained from the public investment in conservation programs and practices to inform decisions on where further investments are warranted (Durancik et al. 2008; Zinn 1997).

Participation in USDA conservation programs is voluntary. Thus, the interests of participating producers and the loca-

tion and physical nature of their lands substantially drive implementation of specific conservation practices at local scales. Local conservation decisions may focus on the field or farm scale without consideration of landscape context, past human activities, and conservation needs across broader spatial and temporal scales (Burger 2006). However, effective assessment of environmental benefits derived from conservation programs and practices requires this broader context to allow for understanding net benefits at meaningful ecological scales and for strategic planning that accounts for landscape linkages elemental for long-term conservation success (Lowrance et al. 2006; Robertson et al. 2007). Relatively local perspectives provide inherently limited information useful for landscape-scale strategic planning likely to increase conservation value or for use in comprehensive assessment of conservation program benefits. For example, outcomes from WRP and CRP practices in Iowa are intended to mitigate statewide environmental impacts of intensive agriculture—impacts that substantially have altered the landscape physically, chemically, and biologically (Gleason et al. 2008). These alterations have reduced the breadth of ecosystem services (Millenium Ecosystem Assessment 2005b) the Iowa landscape currently provides compared to preagricultural times. The nature and locations of historical anthropogenic changes have been dictated by development potential and constraints related to climate and landscape characteristics and conditions. Current and future success of WRP and CRP practices also depends upon these characteristics and conditions, but the full value of the programs further relates to hydrologic and habitat linkages and ecological coherence at broader scales. This information might or might not concern a WRP or CRP participant interested in reducing agricultural runoff into local wetlands. Thus, evaluating the environmental benefits of various conservation programs and practices requires the ability to compare current condi-

tions with what was and what could be at spatiotemporal scales relevant to specific improvement goals.

For goals related to biodiversity, program assessments have emphasized local or landscape-scale habitat quantity and quality (Evans et al. 2009; Frazer and Galat 2008; Gleason et al. 2008; Rewa 2007), but ultimately, habitat quantity, quality, and connectivity at regional and broader scales sufficient for wildlife populations to persist is critical for long-term conservation success. For example, the current or potential set of species inhabiting wetlands and uplands is a function of the quantity and quality of requisite habitat patches available and the interconnectedness of those patches (Santelmann et al. 2006) within ecologically meaningful landscape distances. Characteristics of habitat patches are a function of land cover and land use, which reflect climatic, geomorphic, hydrologic, biogeochemical, and biological conditions and human activities. Meaningful landscape distances can extend a few hundred meters from wetlands for some amphibians or beyond state or even continental boundaries for migratory birds. Therefore, we should interpret the current presence or absence of a given species at program enrollment sites within the multifaceted context of historical and current landscape conditions and the species' life-history requirements that dictate presence not only in a specific wetland or field, but also within the larger relevant landscape mosaic. We also should consider spatial relations of conservation sites to each other within and across landscape mosaics in terms of how they contribute to habitat conditions. Beyond assessing benefits of current conservation practices, forecasting future landscape conditions to plan strategically for facilitating persistent occupancy of species or other conservation goals and outcomes (Rustigian et al. 2003; Santelmann et al. 2004, 2006) is also dependent upon this context.

Settlement and agricultural development in Iowa increased at a rapid rate during the second half of the 1800s (Waisanen

**Alisa L. Gallant** is an eco-geographer with the U.S. Geological Survey's Earth Resources Observation and Science Center, Sioux Falls, South Dakota. **Walt Sadinski** is a research ecologist and **Mark F. Roth** is a biologist with the U.S. Geological Survey's Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. **Charles A. Rewa** is a biologist with the USDA Natural Resources Conservation Service, Beltsville, Maryland.

and Bliss 2002), with extensive draining of wetlands in the 1900s (Jaynes and James 2007), often in response to federal, state, and local programs enacted to encourage wetland drainage (Bishop 1981; Bishop et al. 1998). Most of Iowa is in the US Corn Belt, and it ranks first among states in the production of corn and soybeans (USDA NASS 2009) and corn ethanol (Secchi and Babcock 2007). Recently, high prices for these commodities reduced financial incentives for landowners to enroll or stay enrolled in land retirement programs, as evidenced by substantial losses of acreage in the CRP throughout the US Midwest (Stubbs 2007). This likely will result in more marginal lands planted in corn and soybeans and greater use of fertilizers and pesticides to improve crop yields (USDA NASS 2009). In conjunction with historical and ongoing loss of wetlands and (rare remaining patches of) native vegetation, these increases add to the complex set of anthropogenic stressors acting to suppress multiple ecosystem services across the Iowa landscape. Given Iowa's central location within the Mississippi River Basin and along the Mississippi River flyway, these impacts extend well beyond Iowa, such as to ecosystem services related to Gulf hypoxia or migratory bird populations that rely on habitat in the central North American landscape to persist. Thus, WRP and CRP enrollments in Iowa are important for conservation regionally, nationally, and internationally and require assessments of outcomes within the context of interacting landscape-level factors across space and time.

Our assessment of the benefits of WRP and CRP efforts in Iowa largely will be based upon their contributions to habitat quantity, quality, and use for birds and amphibians at various scales, as surrogates for other biodiversity and related ecosystem services. We report here a retrospective analysis of land-cover changes in Iowa as an initial step in our assessment process, intended to help describe the context necessary for subsequent evaluation of the nature and likely spatial impacts on bird and amphibian distributions and to inform our understanding of the full range of potential benefits from WRP and CRP efforts in Iowa.

## METHODOLOGY

**General Land Cover.** We compiled maps of Iowa's presettlement landscape to compare with the current landscape. Maps produced for the General Land Office (GLO), which contracted surveys of Iowa from 1832 to 1859 to promote private ownership and settlement (Miller 1995), were the key source of historic information. Surveyors described, measured, and mapped components of the landscape encountered along section boundaries of the Public Land Survey System (PLSS) (Stewart 1935). Surveyors were required to keep notes on timber, undergrowth, streams, springs, ponds, swamps, stone quarries, peat beds, minerals and ores, soil quality, and other landscape features they

observed along transects. Although no formal quantitative reports on the accuracy of surveys were produced, by 1850 examiners regularly were conducting field checks along a subset of transects in Iowa to assess the quality of survey results (Stewart 1935). The township maps created from surveyor sketches have since been digitized and edge matched, with land-cover labels the surveyors used assigned to the digitized polygons (Anderson 1996). These maps were available by county from the Iowa Department of Natural Resources (IDNR 2010). We acquired the county GLO maps and merged them into a statewide land-cover map.

We obtained recent land-cover information from the 2001 National Land

**Table 1**

**General Land Office (GLO) land-cover classes (with parenthetical enumeration of member polygon types) and the categories to which they were reclassified for comparison with the National Land Cover Database (NLCD).**

GLO map classes	Reclassified categories
Developed (city, village)	Developed
Barren (barrens, sandbars)	Barren
Brush/shrubs (rough, brush, thicket, willows*)	Shrub/scrub
Field (field, Indian field†)	Cultivated cropland
Grasslands (prairie, opening)	Grassland/herbaceous
Windfall (windfall)	Forest
Forest/woodland (scattering trees, timber/scattering/barrens, timber/scattering/openings, timber barrens, oak barrens, part prairie/part timber, timber, grove)	Forest
Drainage courses (ravine, drain)	Other‡
Island (island within a large river)	Other‡
Water (lake)	Water
Wetlands (swale, meadow§, marsh, bayou, bog, pond, pool, slough, swamp/marsh, swamp, spring, wetland)	Wetlands
River (river#)	Water (large rivers were excluded from the analysis)

\* Willows may signify wetlands, but only one very tiny polygon in the GLO maps was labeled as willow, so assignment of this class to the "brush/shrub" category rather than the "wetland" category had no measurable effect on the analysis results at the precision we used.

† Although we may be misinterpreting the characteristics represented by an "Indian field," only two tiny polygons were labeled as this class, and their total area had no measurable effect on the analysis results at the precision we used.

‡ The GLO descriptions and current aerial photographs provided insufficient information to map this GLO class to the NLCD. We labeled these polygons as "other" and excluded them from the analysis.

§ There were eight meadow polygons. We checked them against current digital orthophoto quarter quadrangles, and all appeared to be located in high-moisture areas along drainages and swales.

# Only major rivers demarking the east and west state borders were mapped as "river." Streams within the state borders were not distinguished by GLO surveyors.

Cover Database (NLCD) (Homer et al. 2007), <http://www.mrlc.gov/nlcd.php>. This provided a thematic land-cover map developed at 30 m (98 ft) spatial resolution from data collected by Landsat sensors. We intentionally selected a national product rather than a state land-cover map, such as the 2002 Iowa land-cover product developed by the Iowa Department of Natural Resources (Iowa Geological Survey 2004), because we are working to develop an integrated approach for Iowa that can be applied to other regions. The NLCD represents the most current midresolution national product completed for Iowa as of this writing and has undergone a formal accuracy assessment (Wickham et al. 2010). The accuracy assessment was performed across an area much larger than Iowa (note that all standard error values provided here and in the Results section pertain to this larger extent and are not tailored for Iowa) and provided an overall accuracy rate of 89% ( $\pm 1.1\%$ ) at the most general level of land-cover classes and 82% ( $\pm 2.7\%$ ) for the more detailed level (Wickham et al. 2010). We aggregated the land-cover classes to the general level for our assessment, with the exception of distinguishing cropland from hay/pasture, which are more detailed agricultural classes. Therefore, the map we used had an overall accuracy (for the larger assessment area) somewhat less than 89%.

We aggregated land-cover classes from the GLO classification scheme to derive classes comparable with those used for the NLCD (table 1). We anticipated locational and distortional errors in the GLO land-cover features because maps were derived from paper (an unstable medium) field sketches based on chain measurements and visual observations conducted in the 1800s. Therefore, we summarized findings at ecoregional and state levels rather than performing a direct, map-to-map comparison of GLO and NLCD polygons.

**Wetland Comparisons.** Because NLCD source data are not optimal for detecting wetlands (Gallant 2009), we acquired digital maps from the National Wetlands Inventory (NWI) for better information on locations of contemporary wetlands (Wilens and Bates 1995). NWI source data were aerial photographs from a single date in time. Achieving continuous spatial cov-

erage across the United States required a mosaic of photos from the 1970s, 1980s, 1990s, and 2000s (Gallant 2009). The photos used to delineate wetlands in Iowa were from 1980 to 1985. Thus, our wetland comparisons were between conditions spanning from 1832 to 1859 and from 1980 to 1985.

GLO maps best represent land cover along PLSS transects because surveyors measured cover type extents by chain. They used ocular approximations to sketch land cover further away from transects into field notebooks (Stewart 1935). Wetlands were delineated in entirety if they intersected transects but not described otherwise (figure 1a). In contrast, NWI wetland maps were derived from aerial photographs and provided spatially continuous geographic information (figure 1b). We calibrated the two products so we could compare them quantitatively.

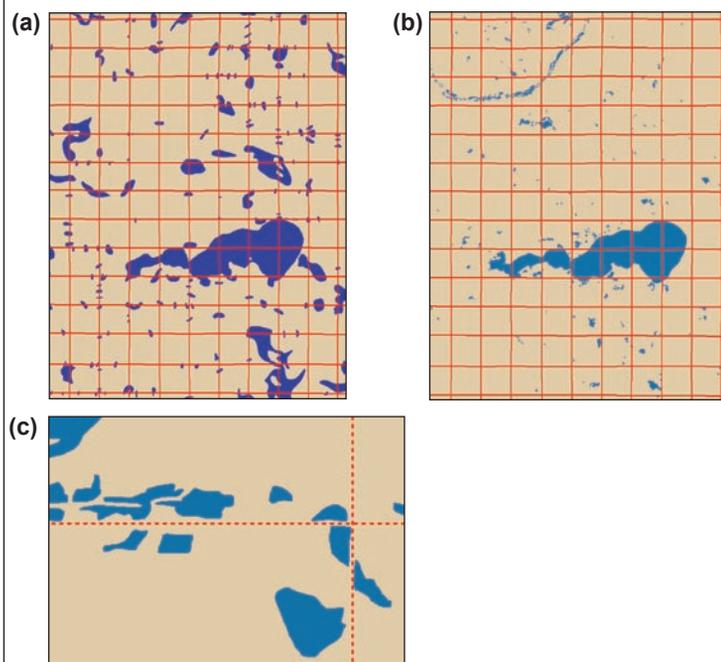
The PLSS essentially is a rectangular system of transects based on a statute

mile that divide the landscape into square townships 6 mi (9,656 m) on a side. Townships are subdivided into 1 mi<sup>2</sup> (259 ha) sections. We considered the GLO surveys along section lines as a land-cover sampling technique comparable with the line-intercept method used for vegetation sampling (Canfield 1941; Coulloudon et al. 1999; Hormay 1949). We used only north-south GLO transects for sampling wetlands to avoid double-sampling wetlands at intersections of north-south and east-west transects. We summarized the proportion of landscape covered by wetlands on GLO and NWI maps as a percent of the total transect length intersected by wetlands.

Transects of the Public Land Survey System were used to site Iowa's road network. Although these roads still intersect wetlands, recontouring near roads and hydrologic modifications to reduce flooding altered some original wetland patterns, as is visible in NWI maps (figure 1c). In

**Figure 1**

Comparison of wetlands mapped from GLO surveys (a) versus by the NWI (b) for an approximate 13 by 10 township area in Iowa. GLO surveyors mapped only wetlands encountered along transects. The NWI mapped wetlands across the entire landscape with air photos as the source of information. Recontouring of the landscape to accommodate roads has altered drainage patterns and interrupted wetland flow, as evidenced by the discontinuous polygons near the road intersection from the NWI dataset (c, red dashed lines are roads); culverts sometimes, but not always, link such wetlands, though this may occur only during periods of moderate to high water levels.



addition, there is inconsistency in how wetlands adjacent to roads are mapped by the NWI: some wetlands are delineated as separate polygons on either side of a road (as in figure 1c) and others are delineated as if the road did not exist. In the former case, roads (i.e., transects) that cross culverts technically intersect wetlands, but we have no consistent way to know where culverts exist and, therefore, no consistent means to sample wetland intersections by roads with the NWI dataset. To avoid problems caused by roads when sampling the distribution of current wetlands, we offset the GLO transects eastward by 0.25 mi (402 m). This was the furthest distance we could move transects to avoid the main road network while also avoiding potential farm service roads (and related physical disruption of wetlands), often at half-mile intervals. Had we not offset the transects from the current road system, we would have underrepresented NWI wetlands because of the artificial discontinuities in wetland surfaces created by the roads. We also wanted to retain the north-south orientation of the GLO transects to sample NWI wetlands both to control for potential directional influences of landscape characteristics on wetland shape and orientation (i.e., whatever bias was inherent in the transect orientation of the GLO wetlands would likewise be imposed on sampling NWI wetlands) and to keep transect lengths comparable within ecoregions for both wetland datasets.

Minimum polygon areas depicted on GLO maps were approximately 0.45 ha (1.11 ac). To render the NWI comparable, we removed all polygons smaller than 0.45 ha. We also excluded all riverine systems from both GLO and NWI maps from this comparison because the only riverine features digitized from GLO surveyor maps were along the Mississippi river bordering the east side of Iowa and the Missouri and Big Sioux rivers bordering the west side. Surveyors otherwise ignored interior riverine features.

Wetlands generally are associated with hydric soils. The USDA Natural Resources Conservation Service (USDA NRCS) and other agencies use the presence of hydric soils as a criterion for determining where wetland restoration could be

implemented. Historical distributions and extents of wetlands in Iowa were estimated previously based on the distribution of hydric soils (Wangpakapattanawong 1996), as represented in the State Soil Geographic Database (STATSGO) (USDA NRCS 2011a). We used the distribution of hydric soils in Iowa as a second approach to assess past distributions and extents of wetlands in Iowa, but we obtained soils data from the more recent and finer-resolution Soil Survey Geographic Database (SSURGO) (USDA NRCS 2011b). The minimum area delimited on SSURGO maps varies from approximately 0.4 to 4.0 ha (0.99 to 9.88 ac), depending upon source information, compared to approximately 1,000 ha (2,471 ac) for STATSGO (USDA NRCS 2011c). We used the SSURGO data to compile a statewide raster map of the percentage of hydric soils per 30 m (98 ft) pixel.

**Ecoregion Framework.** We used an ecoregion framework for summarizing and interpreting data. Ecoregions represent geographic areas of relative homogeneity with respect to climate, geology, topography, soils, hydrology, land cover, and land use (Omernik 1994). Thus, ecoregions provide interpretive strata for partition-

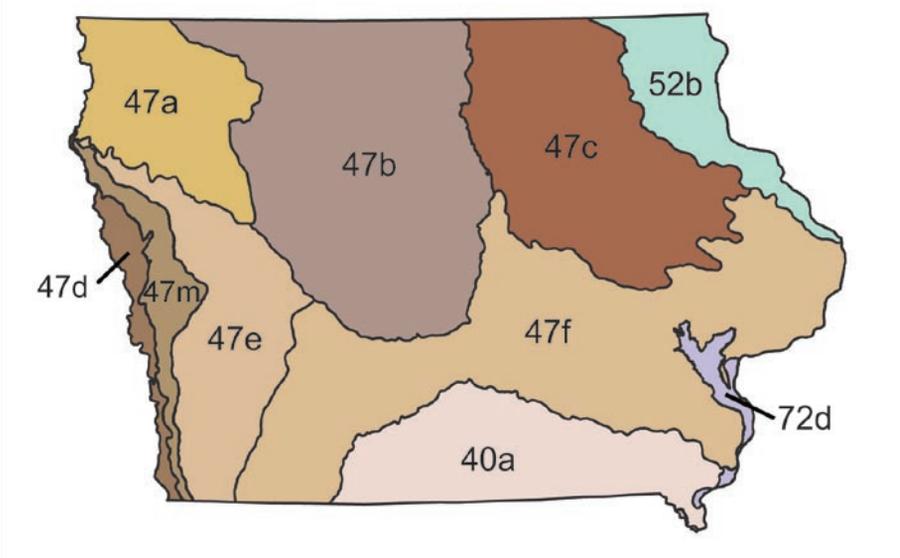
ing environmental variability, enabling more ecologically meaningful estimates of measured response variables and comparisons of estimates within and across regions. The environmental characteristics of each region dictate the potential of the region to support various land uses, so the framework is applicable for understanding legacies of past use as well as current and future patterns of uses (Gallant et al. 2004). We used level IV ecoregions of the hierarchic framework (figure 2) developed by Chapman et al. (2001), which integrates with a three-tiered North American ecoregion framework (Commission for Environmental Cooperation Working Group 1997).

## RESULTS

**General Land Cover.** Our comparison of land cover documented by GLO surveyors in the mid-1800s with recent land cover represented in the NLCD demonstrated wholesale changes in the Iowa landscape (figure 3). Grasslands occupied approximately 80% of Iowa's land area in the mid-1800s, but only about 5% ( $\pm 3.6\%$ ) as of 2001. Approximately 65% of recent grasslands occurred where grasslands existed in the mid-1800s,

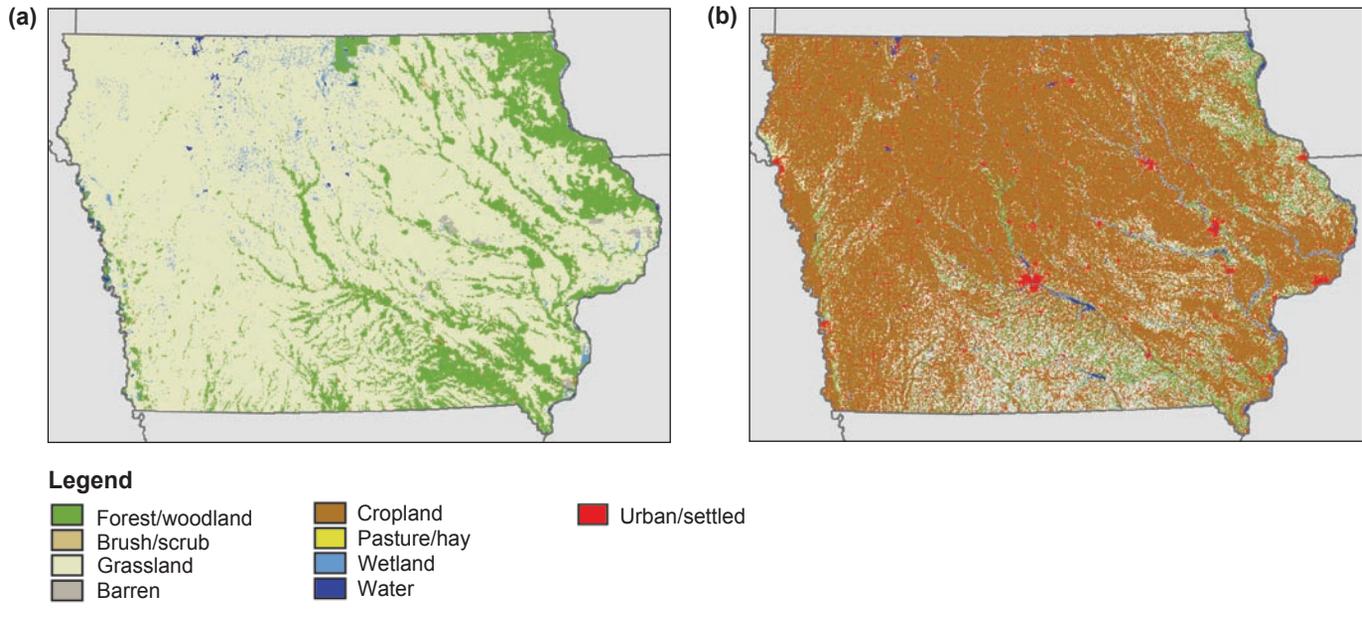
**Figure 2**

Level IV ecoregion framework used for summary and interpretation of information (Chapman et al. 2001): 40a=Loess Flats and Till Plains, 47a=Loess Prairies, 47b=Des Moines Lobe, 47c=Iowan Surface, 47d=Missouri Alluvial Plain, 47e=Steeply Rolling Loess Prairies, 47f=Rolling Loess Prairies, 47m=Western Loess Hills, 52b=Paleozoic Plateau/Coulee Section, 72d=Upper Mississippi Alluvial Plain.



**Figure 3**

Iowa land cover in the mid-1800s (a) and as of 2001 (b). Note that polygons reclassified to “other” from the General Land Office (GLO) dataset (see table 1) are much too small to depict at this map scale.



but about a third occurred in areas that were woodlands in the past. Nearly 75% of the grasslands in the mid-1800s were converted to cropland, based upon the NLCD, and about 10% were converted to pasture or hay production. Together, croplands (65%  $\pm$  1.2%) and hay/pasture (13%  $\pm$  5.7%; note the standard error is high, but the cover type was most typically confused with cropland) dominated Iowa's contemporary landscape.

Woodlands were the second most extensive vegetation type in the mid-1800s, covering about 18% of the surface area. That area had decreased to 7% ( $\pm$ 3.7%) of the 2001 landscape. All other land-cover types mapped during the 1800s covered very small proportions ( $\leq$ 1%) of the landscape, whereas 7% ( $\pm$ 9.4%) of the state was developed (residential, commercial, industrial, or roads) by 2001, primarily in areas that used to be grasslands. The large standard error for developed lands mapped by the NLCD prompted us to consult additional sources to gauge potential accuracy of this class in Iowa. A map of land cover developed from Landsat sensor data by the Iowa Department of Natural Resources for 2002 had 3% of the area mapped as comparable classes, although no accuracy assessment was available (Iowa Geological Survey Department of Natural Resources

2004). We estimated proportion of Iowa covered by census block polygons from the Bureau of Census for 2000 (Radeloff et al. 2005) as 2% of the landscape for areas having population densities  $\geq$ 50 people per km<sup>2</sup>, although this approach missed roads and industrial or commercial areas having low population densities. We used a map of boundaries for incorporated cities (Iowa Department of Transportation 2002) and found that the area covered 4% of Iowa, but recognized that this would not include roads or unincorporated areas that would qualify as “developed” lands outside city boundaries. Together, these additional sources indicated that at least several percent of the Iowa landscape was urbanized, and it is not unreasonable that including roads and industrial and commercial areas could result in an estimate comparable with that from the NLCD.

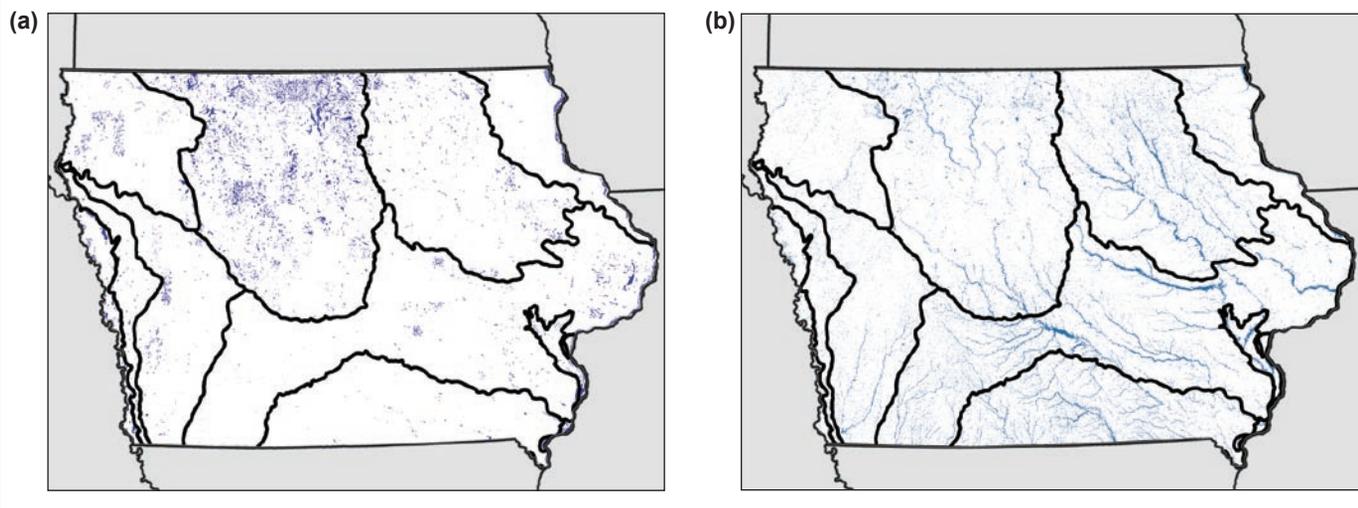
**Wetland Comparisons.** Wetlands intersected approximately 2% of the GLO and NWI transects, but the geographic distributions of these wetlands differed between data sets (figure 4, table 2). GLO wetlands occurred mostly in the Des Moines Lobe (ecoregion 47b), Missouri Alluvial Plain (47d), and Upper Mississippi Alluvial Plain (72d) ecoregions, with a relatively moderate amount in the Iowan Surface (47c) ecoregion. Wetlands were distributed less

densely in other western ecoregions and in eastern portions of the Steeply Rolling Loess Prairies (47e) ecoregion. Wetlands were relatively absent in the Paleozoic Plateau/Coulee Section (52b) ecoregion, the Loess Flats and Till Plains (40a) ecoregion, and most of the Rolling Loess Prairies (47f) ecoregion. The distribution of hydric soils developed from the SSURGO database depicts similarly strong regional patterns showing potentially suitable conditions for wetlands (figure 5), with hydric soils being most pervasive in ecoregions 47b and 47d (these two ecoregions ranked second and third in the GLO survey dataset in proportion of land surface covered by wetlands, [table 2]), but also notable in ecoregions 47c and 72d. In contrast, recent wetlands identified from the NWI were distributed more evenly across Iowa (figure 4b).

The size distribution of wetlands also appears to have changed considerably. Wetland fragments that intersected transects ranged from 112 to 463 m (367 to 1,519 ft) in median length per ecoregion in the GLO survey dataset and from 49 to 125 m (161 to 410 ft) in the NWI dataset (figure 6), although intercept lengths of 201 to 400 m (659 to 1,312 ft) were encountered most frequently in both the GLO and NWI datasets. The comparative

**Figure 4**

Iowa wetlands in the mid-1800s (a), based upon data from General Land Office (GLO) surveys, and in the 1980s (b), represented by data from the National Wetlands Inventory (NWI).

**Table 2**

Comparison of the percent ecoregion area covered by wetlands, as represented by three datasets. The two right columns indicate change in percent surface area covered by wetlands, estimated by comparing General Land Office (GLO) data with National Wetlands Inventory (NWI) data and comparing State Soil Geographic Database (SSURGO) data with NWI data.

Ecoregion	GLO (%)	NWI (%)	SSURGO (%)	GLO - NWI (change in %)	SSURGO - NWI (change in %)
40a	0.2	2.4	24.3	2.2	-21.9
47a	0.8	0.6	15.9	-0.2	-15.3
47b	5.6	1.8	46.6	-3.8	-44.8
47c	1.1	1.8	25.3	0.7	-23.5
47d	4.7	2.7	47.3	-2.0	-44.6
47e	0.7	0.7	10.2	0.0	-9.5
47f	0.6	2.7	17.6	2.1	-14.9
47m	0.6	0.6	1.7	0.0	-1.1
52b	0.6	3.6	4.3	3.0	-0.7
72d	7.6	13.5	40.1	5.9	-26.6

distributions of intercepted wetland lengths between these data sets show decreased wetland surface area in the Des Moines Lobe ecoregion over time, but an increase for most other ecoregions, resulting in the more homogenized distribution of wetlands previously noted (figure 7). Wetland surface area increased most in ecoregions 40a, 47f, 52b, and 72d. Accounting for these shifts in wetland distributions, the total Iowa surface area covered by wetlands and water based upon the GLO and NWI datasets is nearly equivalent (less than 0.2% change). However, the SSURGO data on the extent of hydric soils suggest 25% of

the total Iowa surface could have been wetlands compared to the 2% surface area mapped as wetlands by the NWI.

To understand wetland gains in some ecoregions, we used modifiers in the descriptor fields of the NWI dataset to distinguish wetlands coded as diked, impounded, excavated, or having artificial substrate from all other wetland types (figure 8, table 3). Created wetlands accounted for 85% of the total number of wetlands and 79% of the total wetland surface area in the Western Loess Hills (47m) ecoregion. Sixty-six percent of wetlands in ecoregion 40a were created, typically by impound-

**Table 3**

Proportion of total number and area of wetlands coded by National Wetlands Inventory (NWI) as being diked, impounded, excavated, and/or having artificial substrate, stratified by ecoregion. Note that all NWI wetlands were used for this summary (in our earlier comparison with General Land Office [GLO] survey results, we eliminated NWI wetlands smaller than 0.45 ha [1.11 ac] to calibrate the two datasets).

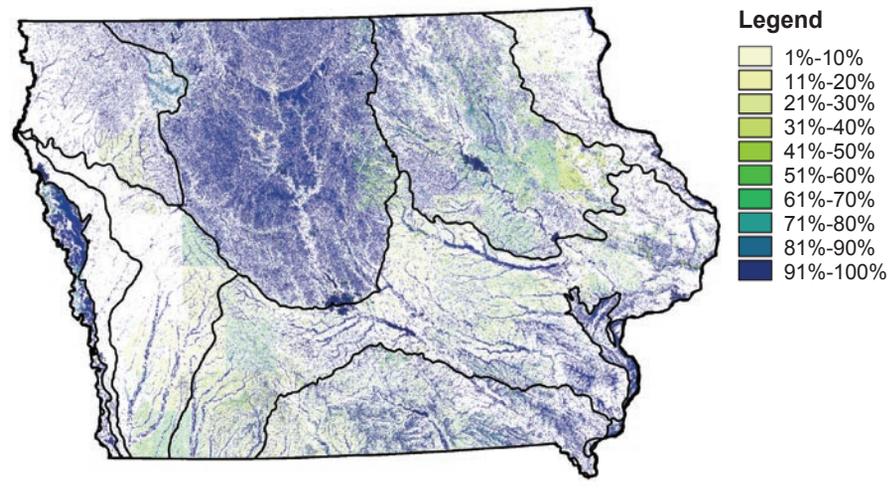
Ecoregion	% number of wetlands	% area of wetlands
40a	66	37
47a	17	15
47b	10	16
47c	12	15
47d	16	20
47e	55	41
47f	52	37
47m	85	79
52b	53	60
72d	28	44

ment, and composed 37% of the surface area of wetlands in that ecoregion. The Loess Prairies (47a), along with ecoregions 47b, 47c, and 47d, had the smallest proportions of created wetlands.

**Considerations and Implications.** Our comparative analysis of historical and recent data sets produced a relatively novel description of how and where humans have changed the Iowa landscape since

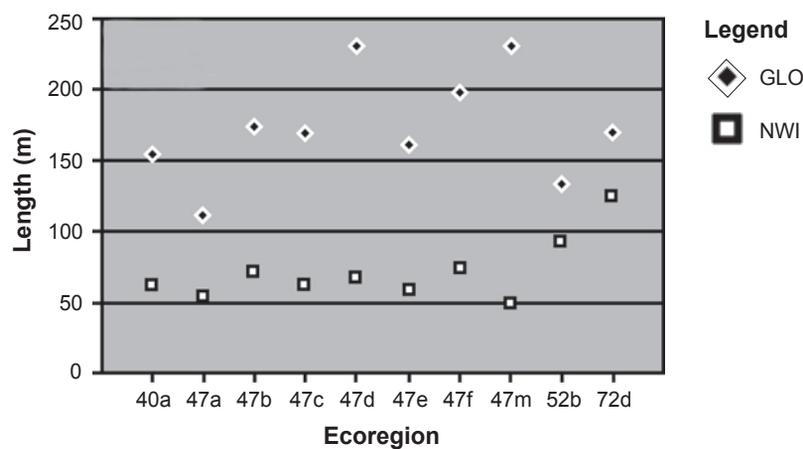
**Figure 5**

Percent of surface area of 30 m cells covered by hydric soils, as mapped with the State Soil Geographic Database (SSURGO) and overlain by ecoregion boundaries (see “SSURGO” column in table 2).



**Figure 6**

Comparison of median interception lengths by ecoregion for wetlands that intersected transects in our General Land Office (GLO) and National Wetlands Inventory (NWI) analyses.



the mid-1800s. We recognize that using this information requires necessary caution because of inherent limitations of the datasets. We compared datasets developed for different purposes and by different methods and we lacked sufficient data to describe the statistical uncertainties associated with our estimates. The GLO surveyors produced land-cover data aimed at facilitating settlement, not generating a statewide land-cover map. Although the GLO required and performed quality assurance on surveyors' data, they did so to determine if the surveyors deserved payment (Stewart 1935), not to provide a

systematic assessment of data accuracy. We also lacked formal accuracy assessments for land characteristics represented in the NWI and SSURGO datasets. Nevertheless, these three datasets, along with the NLCD, were the best available for our purposes and enabled complementary analyses of the Iowa landscape. With these limitations in mind, our results are similar to the collective results of others who described how EuroAmerican settlers changed the landscape of the midwestern United States (Bishop 1981; Bishop et al. 1998; Dahl and Allord 1996; Rayburn and Schulte 2009; Smith 1998).

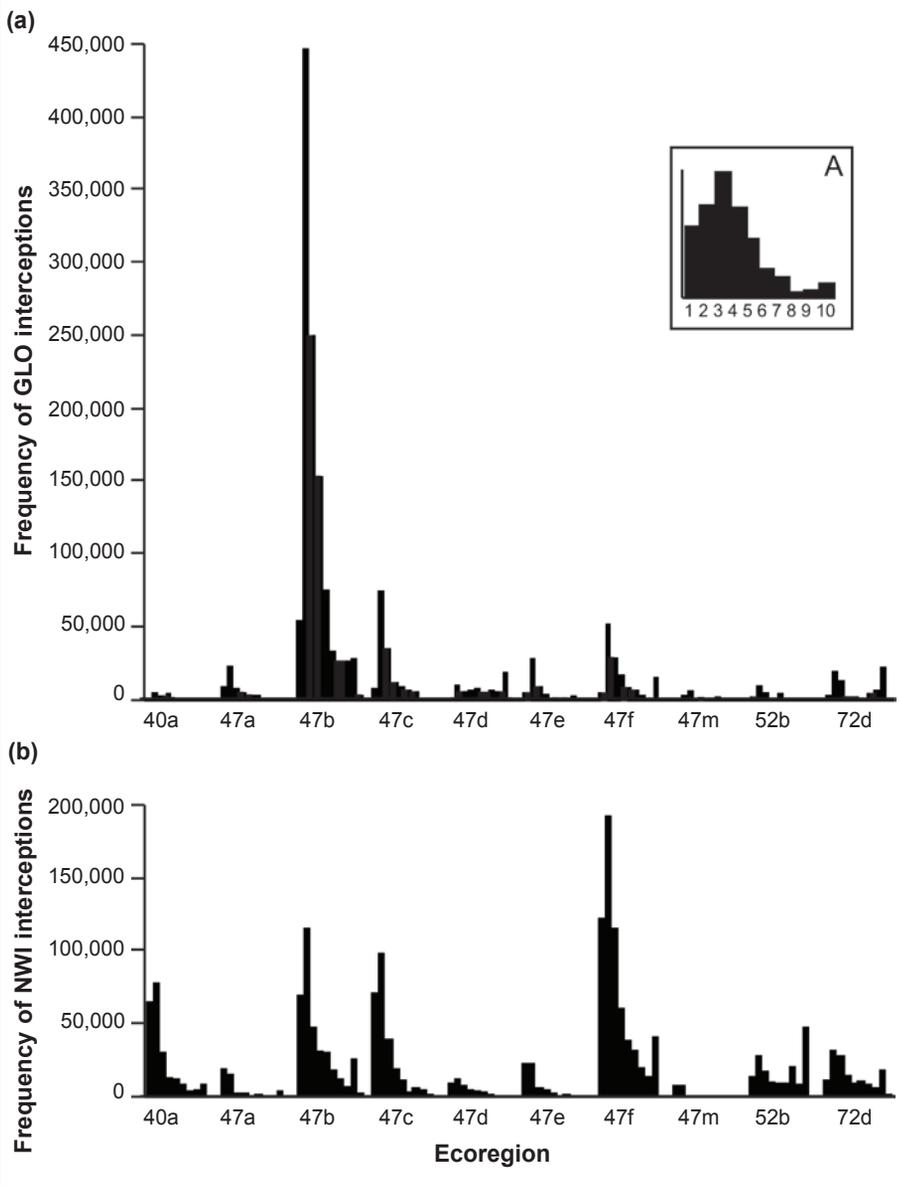
Our description of geographic changes in the Iowa landscape provides a coarse biotic and abiotic context for assessing the potential and realized benefits of current WRP and CRP conservation activities at local, ecoregional, and broader spatial scales. The descriptions of fundamental changes in habitat mosaics and the distribution of wetland loss and gain across ecoregions, for example, provide useful information for this purpose and also for planning the locations of future conservation activities. However, we do not propose that the mid-1800s landscape necessarily provides plausible reference conditions for today's conservation sites or goals, regardless of uncertainties in the datasets. Land-cover conversions and management practices might or might not have altered biotic and abiotic landscape characteristics irrevocably. For our purposes, knowledge of the landscape prior to extensive agriculture provides a coarse filter for understanding regional landscape patterns and species distributions and can be useful for considering whether conservation expectations are realistic based upon past and recent conditions.

The contemporary Iowa landscape is managed extensively for agricultural production and bears little resemblance to the grassland-, woodland-, and wetland-covered landscape of the mid-1800s. Such extensive land conversion reflects widespread similar agricultural conversions elsewhere in the United States (Waisenan and Bliss 2002) and around the world (Ramankutty and Foley 1999). These conversions have been described as the major cause of the net global losses of grasslands (White et al. 2000), wetlands (Baldassarre and Bolen 1994), and habitat (Stuart et al. 2004) and of reductions in various related ecosystem services (Millennium Ecosystem Assessment 2005b). Extensive draining of wetlands also has likely effected shifts in regional climate, such as increasing the magnitude and duration of temperature extremes (Marshall et al. 2003).

Landscape changes of the magnitude described here eliminated and altered large quantities of historical wetland-upland habitats across Iowa. Avian and amphibian population declines have been linked to such conversion of grasslands and forests

**Figure 7**

Size distribution of intercepted wetland lengths by ecoregion based upon General Land Office (GLO) and National Wetlands Inventory (NWI) data. Histograms for each ecoregion in Iowa for both GLO (a) and NWI (b) data show the number of wetland intercepts in each of 10 size classes (inset A), where class 1 = 1 to 200 m (3.3 to 656.2 ft), class 2 = 201 to 400 m (659.4 to 1,312.3 ft), class 3 = 401 to 600 m (1,315.6 to 1,968.5 ft), ..., class 10 = 1800 to 2000 m (5,905.5 to 6,561.7 ft).



to agriculture, draining of wetlands, exposure to toxic agricultural chemicals, and other related factors (Alford and Richards 1999; Bernstein et al. 1990; Brennan and Kuvlesky 2005; Fletcher and Koford 2003; Herkert et al. 1996; Lannoo 2005; Murphy 2003; Nedland et al. 2007; Stuart et al. 2004). Given the wholesale extent of similar changes to habitat in Iowa over the past 150+ years, concomitant changes in the composition and distribution of biodi-

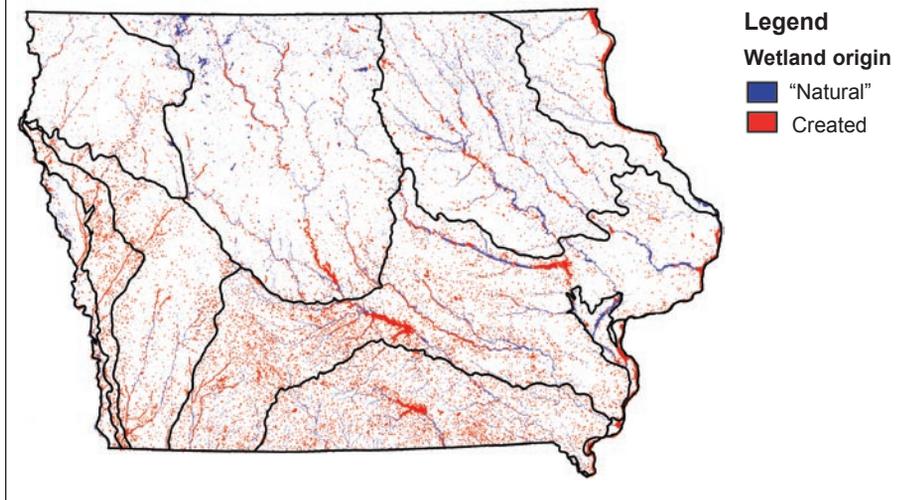
versity have occurred over time and even affected the composition of native vegetation in remaining grasslands (Smith 1998). Our results should help inform planning for and assessing WRP and CRP practices in Iowa. For example, most wetland losses were in ecoregions that contained wetlands in the mid-1800s and most created wetlands were in ecoregions that did not contain many wetlands during that period, an observation also noted by Bishop (1981).

Our coarse analysis suggested that 47% of the Des Moines Lobe ecoregion once was covered by wetlands, a finding comparable with the estimate of Miller et al. (2009) and with the earlier calculation of wetland loss provided by Wangpakapattanawong (1996). This is dramatically different from the current extent of wetlands in the Des Moines Lobe. Coupled with equally dramatic losses of grasslands in the Des Moines Lobe, this suggests that a larger landscape view is important to establish conservation goals and understand possible outcomes.

Another example of how our results could inform assessments of the WRP and CRP in Iowa relates to the types and distributions of recent wetlands in Iowa based upon the NWI data. Wetland area actually increased in portions of Iowa that contained relatively few wetlands historically, but the extent to which most of these created wetlands function similarly ecologically to the natural wetlands eliminated across the state over time at regional or local scales is not clear. For example, prairie-pothole type wetlands characteristic of the historically wetland-rich Des Moines Lobe ecoregion formed naturally in poorly drained glacial till and moraine (Chapman et al. 2001), which resulted in certain ranges of water chemistry, hydroperiods, and other wetland characteristics suitable to support a certain range of biodiversity. In contrast, many of the created wetlands are in ecoregions characterized by well-drained loess sediments that tend to be highly erodible (40a, 47f) (Chapman et al. 2001). An assessment of wadeable flowing waters in Iowa highlighted ecoregional differences in pH, nutrients, suspended solids, total dissolved solids, conductance, turbidity, hardness, and other attributes (Wilton 2004), underscoring regional variation in aquatic habitat with implications for the extent to which these habitats support biodiversity. The vast majority of created wetlands in Iowa are small impoundments. The morphology of many created wetlands can be substantially different from that of naturally-formed wetlands, further dictating different ranges of wetland characteristics, such as steepness of bank slope, water depth, and hydroperiod, that support biodiversity.

**Figure 8**

Ecoregional distribution of created versus “natural” wetlands based upon National Wetlands Inventory (NWI) data.



Inter-wetland linkages also are important for understanding mitigation and restoration opportunities at regional and local scales. The abundance and richness of bird and amphibian species have shown positive associations with wetland complexes (as opposed to geographically isolated wetlands) and hydroperiod heterogeneity, as well as with the configuration character of the wetland-upland matrix (Brodman 2008; Fairbairn and Dinsmore 2001; Lehtinen et al. 1999; Lehtinen and Galatowisch 2001; Vos and Stumpel 1995), emphasizing the importance of considering diverse wetland characteristics at broader scales than individual wetlands and how certain ecoregions are better suited to support complexes based upon historical evidence. This is especially important within the context of the historical nature of intervening uplands and habitat connectivity essential to support diverse wildlife populations at meaningful landscape scales.

All told, the sheer magnitude, as well as the nuances, of statewide and regional-scale shifts in the quantity, quality, and interconnectedness of historical Iowa land cover should be accounted for in evaluating the effectiveness of WRP and CRP conservation efforts across spatiotemporal scales. Consider assessments of current and future program enrollments within the Des Moines Lobe ecoregion. A southern lobe of the globally important Prairie Pothole

Region of North America (Johnson et al. 2005), this region historically was grassland that contained a high density of presumably very productive wetlands. The vast majority of these wetlands were drained to enable the extensive agriculture practiced there today. Conservation program benefits in this area need to be assessed at the site scale, but also at the ecoregion scale relative to the historical physical, chemical, and biological connectivity within the Prairie Pothole Region. In addition, measured and projected benefits of program investments in the Des Moines Lobe ecoregion should be considered relative to the benefits derived from program investments in other ecoregions of Iowa and the ecosystem services they do or could provide. All of this requires a multidisciplinary assessment integrated across methods and scales that facilitates understanding how these changes in fundamental landscape conditions over time and space relate to changes in ecosystem services of interest.

Given the magnitude of changes in the Iowa landscape since the mid-1800s, emerging stressors such as climate change and production of biofuel crops increase interest in maximizing the effectiveness of current and future WRP and CRP conservation actions in Iowa. On the global biodiversity front, many amphibian and bird populations have declined or are considered at risk (IUCN 2011) because of factors such as habitat loss, agricultural

practices that result in nutrient enrichment and exposure to toxicants, and disease, among others (Stuart et al. 2004). Our results complement those of others that allude to the strong influence of land conversion and land use on biodiversity across the Iowa landscape. We suggest that evaluating current conservation program benefits to biodiversity-related and other ecosystem services could be enhanced through assessments that consider and establish ecological context across spatial and temporal scales. This approach would facilitate calibration of local measurements and support more informed strategic thinking about long-term regional conservation goals. In addition, such assessments could help to better understand impacts of emerging elements of global change not observed historically, such as climate change and the production of biofuels.

## CONCLUSIONS

Our retrospective analysis of Iowa provided a coarse, yet information-rich description of the dramatic ways humans have altered the Iowa landscape since the mid-1800s. This description of these spatial and temporal changes in the amount and distribution of grasslands, woodlands, and wetlands in particular provides important context for evaluating the environmental benefits of current and future USDA conservation program enrollments and practices across Iowa in terms of past and future conditions and local and broader scales.

## ACKNOWLEDGEMENTS

This research was supported through interagency agreements between the US Geological Survey and the USDA Natural Resources Conservation Service in support of the Conservation Effects Assessment Project (IAG 67-3A75-8-12 and IAG 67-3A75-9-88) and by funds from the US Geological Survey's Amphibian Research and Monitoring Initiative. The authors appreciate critical input for this research from Monica Monk, Jennifer Anderson-Cruz, Mark Lindflott, Martin Adkins, and others at the Iowa State Office of the USDA Natural Resources Conservation Service, Des Moines, Iowa. Dave Otis from the US Geological Survey Iowa Cooperative Fish and Wildlife Research Unit, Ames, Iowa; Denis White from US Environmental Protection Agency Western Ecology Division, Corvallis, Oregon; and Roger Auch from the US Geological Survey Earth

Resources Observation and Science Center, Sioux Falls, South Dakota, provided valuable reviews on an earlier version of this paper.

## REFERENCES

- Alford, R.A., and S.M. Richards. 1999. Global amphibian declines: A problem in applied ecology. *Annual Review of Ecology and Systematics* 30:133–165.
- Anderson, P.F. 1996. GIS Research to Digitize Maps of Iowa 1832–1859 Vegetation from General Land Office Township Plat Maps. Final report to Iowa Department of Natural Resources.
- Baldassarre, G.A., and E.G. Bolen. 1994. *Waterfowl Ecology and Management*. New York: John Wiley and Sons.
- Bernstein, N.P., K.K. Baker, and S.R. Wilmot. 1990. Changes in a prairie bird population from 1940 to 1989. *The Journal of the Iowa Academy of Science* 97(4):115–120.
- Bishop, R.A. 1981. Iowa's wetlands. *The Proceedings of the Iowa Academy of Science* 88(1):11–16.
- Bishop, R.A., J. Joens, and J. Zohrer, J. 1998. Iowa's wetlands, present and future with a focus on prairie potholes. *The Journal of the Iowa Academy of Science* 105(3):89–93.
- Brennan, L.A., and W.P. Kuvlesky, Jr. 2005. North American grassland birds: An unfolding conservation crisis? *Journal of Wildlife Management* 69(1):1–13.
- Brodman, R. 2008. A 14-year study of amphibian populations and metacommunities. *Herpetological Conservation and Biology* 4(1):106–119.
- Burger, L.W., Jr. 2006. Creating wildlife habitat through federal farm programs: An objective-driven approach. *Wildlife Society Bulletin* 34(4):994–999.
- Canfield, R.H. 1941. Application of the line interception method in sampling range vegetation. *Journal of Forestry* 39:388–394.
- Chapman, S.S., J.M. Omernik, J.A. Freeouf, D.G. Huggins, J.R. McCauley, C.C. Freeman, G. Steinauer, R.T. Angelo, and R.L. Schleppe. 2001. *Ecoregions of Missouri and Iowa*. Reston, VA: U.S. Geological Survey.
- Commission for Environmental Cooperation Working Group. 1997. *Ecological Regions of North America - Toward a Common Perspective*. Montreal, Canada: Commission for Environmental Cooperation.
- Coulloudon, B., K. Eshelman, J. Gianola, N. Habich, L. Hughes, L., C. Johnson, M. Pellant, P. Podboray, A. Rasmussen, B. Robles, P. Shaver, J. Spehar, and J. Willoughby. 1999. *Sampling Vegetation Attributes*. Interagency Technical Reference 1734-4. Denver, CO: Cooperative Extension Service, U.S. Forest Service, Natural Resource Conservation Service, and Bureau of Land Management.
- Dahl, T.E., and G.J. Allord. 1996. History of wetlands in the conterminous United States. *In National Water Summary on Wetland Resources*, eds. J.D. Fretwell, J.S. Williams, and P.J. Redman, 19–26. Water-Supply Paper 2425. Washington, DC: U.S. Geological Survey.
- Durancik, L.F., D. Bucks, J.P. Dobrowolski, T. Drewes, S.D. Eckles, L. Jolley, R.L. Kellogg, D. Lund, J.R. Makuch, M.P. O'Neill, C.A. Rewa, M.R. Walbridge, R. Parry, and M.A. Weltz. 2008. The first five years of the Conservation Effects Assessment Project. *Journal of Soil and Water Conservation* 63(6):185A–197A.
- Evans, K.O., W. Burger, M.D. Smith, and S. Riffell. 2009. Conservation Reserve Program, CP33-Habitat Buffers for Upland Birds. Bird Monitoring and Evaluation Plan, 2006–2008. Final report. Starkville, MS: Mississippi State University.
- Fairbairn, S.E., and J.J. Dinsmore. 2001. Local and landscape-level influences on wetland bird communities of the prairie pothole region of Iowa, USA. *Wetlands* 21(1):41–47.
- Fletcher, Jr., R.J., and R.R. Koford. 2003. Changes in breeding bird populations with habitat restoration in northern Iowa. *American Midland Naturalist* 150:83–94.
- Frazer, S., and D. Galat. 2008. Ecological monitoring insights from the Wetlands Reserve Program in Missouri. CEAP Conservation Insight. USDA Natural Resources Conservation Service. [ftp://ftp-fc.sc.egov.usda.gov/NHQ/nri/ceap/MO\\_WRP\\_021108.pdf](ftp://ftp-fc.sc.egov.usda.gov/NHQ/nri/ceap/MO_WRP_021108.pdf).
- Gallant, A.L. 2009. What you should know about land-cover data. *Journal of Wildlife Management* 73(5):796–805.
- Gallant, A.L., T.R. Loveland, T.L. Sohl, and D.E. Napton. 2004. Using an ecoregion framework to analyze land-cover and land-use dynamics. *Environmental Management* 34(S1):89–110.
- Gleason, R.A., M.K. Laubhan, and N.H. Euliss, Jr. 2008. Ecosystem services derived from wetlands conservation practices in the United States Prairie Pothole Region with an emphasis on the U.S. Department of Agriculture Conservation and Wetlands Reserve Programs. Professional Paper 1745. Reston, VA: U.S. Geological Survey.
- Herkert, J.R., D.W. Sample, and R.E. Warner. 1996. Management of midwestern grassland landscapes for the conservation of migratory birds. *In Management of Midwestern Landscapes for the Conservation of Neotropical Migratory Birds*, ed. F.R. Thompson, 89–116. U.S. General Technical Report 187. St. Paul, MN: Department of Agriculture North Central Forest Experiment Station.
- Homer, C., J. Dewitz, J. Fry, M. Coan, N. Hossain, C. Larson, N. Herold, A. McKerrow, N. VanDriel, Jr., and J. Wickham. 2007. Completion of the 2001 National Land Cover Database for the conterminous United States. *Photogrammetric Engineering and Remote Sensing* 73(4):337–341.
- Hormay, A.L. 1949. Getting better records of vegetation changes with the line interception method. *Journal of Range Management* 2(2):67–69.
- IDNR (Iowa Department of Natural Resources). 2010. Natural Resources Geographic Information Systems Library. <http://www.igsb.uiowa.edu/nrgislibx>.
- Iowa Department of Transportation. 2002. Incorporated cities of Iowa, 2000. [ftp://ftp.igsb.uiowa.edu/gis\\_library/IA\\_State/Admin\\_Political\\_Boundary/incorporated\\_cities\\_2000.zip](ftp://ftp.igsb.uiowa.edu/gis_library/IA_State/Admin_Political_Boundary/incorporated_cities_2000.zip).
- Iowa Geological Survey. 2004. Land cover for the State of Iowa in the Year 2002. *In The Iowa Geological Survey's Geographic Information Systems Bi-Monthly Department Newsletter*. June 2004.
- Iowa Geological Survey Department of Natural Resources. 2004. Land cover of the state of Iowa in the Year 2002. Iowa City, IA. [ftp://ftp.igsb.uiowa.edu/gis\\_library/IA\\_State/Land\\_Description/Land\\_Cover\\_2002/lc\\_2002.zip](ftp://ftp.igsb.uiowa.edu/gis_library/IA_State/Land_Description/Land_Cover_2002/lc_2002.zip).
- IUCN (International Union for Conservation of Nature). 2011. The IUCN Red List of Threatened Species. <http://www.iucnredlist.org>.
- Jaynes, D.B., and D.E. James. 2007. The extent of farm drainage in the United States. *In Proceedings of the Annual Meeting of the Soil and Water Conservation Society*, Tampa, Florida, July 21, 2007. Ankeny, IA: Soil and Water Conservation Society.
- Johnson, W.C., B.V. Millett, T. Gilmanov, T., R.A. Woldseth, G.R. Guntenspergen, G.R., and D.E. Naugle. 2005. Vulnerability of northern prairie wetlands to climate change. *BioScience* 55(10):863–872.
- Lannoo, M.J., 2005. *Amphibian Declines - The Conservation Status of United States Species*. Berkeley, CA: University of California Press.
- Lehtinen, R.M., and S.M. Galatowitsch. 2001. Colonization of restored wetlands by amphibians in Minnesota. *American Midland Naturalist* 145(2):388–396.
- Lehtinen, R.M., S.M. Galatowitsch, and J.R. Tester. 1999. Consequences of habitat loss and fragmentation for wetland amphibian assemblages. *Wetlands* 19(1):1–12.
- Lowrance, R., T.M. Isenhardt, W.J. Gburek, F.D. Shields, Jr., P.J. Wigington, Jr., and S.M. Dabney. 2006. Landscape management practices. *In Environmental Benefits of Conservation on*

- Cropland: The Status of Our Knowledge, eds. M. Schnepf and C. Cox. Ankeny, IA: Soil and Water Conservation Society.
- Maresch, W., M.R. Walbridge, and D. Kugler. 2008. Enhancing conservation on agricultural landscapes: A new direction for the Conservation Effects Assessment Project. *Journal of Soil and Water Conservation* 63(6):198A–203A.
- Marshall, C.H., R.A. Pielke, Sr., and L.T. Steyaert. 2003. Crop freezes and land-use change in Florida. *Nature* 426(6 November):29–30.
- Millennium Ecosystem Assessment. 2005a. Ecosystems and human well-being: Biodiversity synthesis. Washington, DC: World Resources Institute, <http://www.millenniumassessment.org/documents/document.354.aspx.pdf>.
- Millennium Ecosystem Assessment. 2005b. Ecosystems and human well-being: Synthesis. Washington, DC: Island Press, <http://www.millenniumassessment.org/documents/document.356.aspx.pdf>.
- Millennium Ecosystem Assessment. 2005c. Ecosystems and human well-being: Wetlands and water synthesis. Washington, DC: World Resources Institute, <http://www.millenniumassessment.org/documents/document.358.aspx.pdf>.
- Miller, M.C. 1995. Analysis of Historic Vegetation Patterns in Iowa Using General Land Office Surveys and a Geographic Information System. Master's thesis. Ames, IA: Iowa State University.
- Miller, B.A., W.G. Crumpton, A.G. van der Valk. 2009. Spatial distribution of historical wetland classes on the Des Moines Lobe, Iowa. *Wetlands* 29(4):1146–1152.
- Murphy, M.T. 2003. Avian population trends within the evolving agricultural landscape of eastern and central United States. *Auk* 120(1):20–34.
- Nedland, T.S., A. Wolf, A., and T. Reed. 2007. A reexamination of restored wetlands in Manitowoc County, Wisconsin. *Wetlands* 27(4):999–1015.
- Omernik, J.M. 1994. Ecoregions: A spatial framework for environmental management. In *Biological Assessment and Criteria, Tools for Water Resource Planning and Decision Making*, eds. W.S. Davis and T.P. Simon, 49–62. Boca Raton, FL: Lewis Publishers.
- Radeloff, V.C., R.B. Hammer, S.I. Stewart, J.S. Fried, S.S. Holcomb, and J.F. McKeefry. 2005. The wildlife urban interface in the United States. *Ecological Applications* 15(3):799–805.
- Ramankutty, N., and J.A. Foley. 1999. Estimating historical changes in global land cover: Croplands from 1700 to 1992. *Global Biogeochemical Cycles* 13(4):997–1027.
- Rayburn, A.P., and L.A. Schulte. 2009. Integrating historic and contemporary data to delineate potential remnant natural woodlands within Midwestern agricultural landscapes. *Natural Areas Journal* 29(1):4–14.
- Rewa, C.A. 2007. Fish and wildlife benefits associated with wetland establishment practices. In *Fish and Wildlife Response to Farm Bill Conservation Practices*, ed. J.B. Haufler, 71–82. Technical Review 07-1. Bethesda, MD: The Wildlife Society.
- Robertson, G.P., L.W. Burger, Jr., C.L. Kling, and D.J. Mulla. 2007. New approaches to environmental management research at landscape and watershed scales. In *Managing Agricultural Landscapes for Environmental Quality: Strengthening the Science Base*, eds. M. Schnepf and C. Cox, 27–50. Ankeny, IA: Soil and Water Conservation Society.
- Rustigian, H.L., M.V. Santelmann, and N.H. Schumaker. 2003. Assessing the potential impacts of alternative landscape designs on amphibian population dynamics. *Landscape Ecology* 18:65–81.
- Santelmann, M., K. Freemark, J. Sifneos, and D. White. 2006. Assessing effects of alternative agricultural practices on wildlife habitat in Iowa, USA. *Agriculture, Ecosystems and Environment* 113:243–253.
- Santelmann, M.V., D. White, K. Freemark, J.I. Nassauer, J.M. Eilers, K.B. Vache, B.J. Danielson, R.C. Corry, M.E. Clark, S. Polasky, R.M. Cruse, J. Sifneos, H. Rustigian, C. Coiner, J. Wu, and D. Debinski. 2004. Assessing alternative futures for agriculture in Iowa, U.S.A. *Landscape Ecology* 19:357–374.
- Secchi, S., and B.A. Babcock. 2007. Impact of high crop prices on environmental quality: A case of Iowa and the Conservation Reserve Program. Working Paper 07-WP 447. Ames, IA: Iowa State University Center for Agricultural and Rural Development.
- Smith, D.D. 1998. Iowa prairie: Original extent and loss, preservation and recovery attempts. *The Journal of the Iowa Academy of Science* 105(3):94–108.
- Stewart, L.O. 1935. *Public Land Surveys*. Reprinted 1976, Minneapolis, MN: The Meyers Printing Co.
- Stuart, S.N., J.S. Chanson, N.A. Cox, B.E. Young, A.S.L. Rodrigues, D.L. Fischman, and R.W. Waller. 2004. Status and trends of amphibian declines and extinctions worldwide. *Science* 306:1783–1786.
- Stubbs, M. 2007. Land conversion in the Northern Plains. Congressional Research Service Report for Congress, April 5, 2007, order number RL33950. Washington, DC: Congressional Research Service.
- USDA FSA (USDA Farm Service Agency). 2008a. Conservation Reserve Program State Acres for Wildlife Enhancement (SAFE). Fact Sheet, January 2008. Washington, DC: USDA.
- USDA FSA. 2008b. Conservation Reserve Program (CRP) Benefits: Water Quality, Soil Productivity and Wildlife Estimates. Fact Sheet, March 2008. Washington, DC: USDA.
- USDA NASS (USDA National Agricultural Statistics Service). 2009. 2007 Census of Agriculture, Volume 1, Geographic Area Series, Part 51, AC-07-A-51. Washington, DC: USDA.
- USDA NRCS (USDA Natural Resources Conservation Service). 2002. Restoring America's Wetlands: The Wetlands Reserve Program, <http://www.nrcs.usda.gov/programs/wrp/pdfs/wrpweb.pdf>.
- USDA NRCS. 2011a. U.S. General Soil Map (STATSGO2). <http://soils.usda.gov/survey/geography/statsgo>.
- USDA NRCS. 2011b. Soil Survey Geographic (SSURGO) Database. <http://soils.usda.gov/survey/geography/ssurgo>.
- USDA NRCS. 2011c. <http://soildatamart.nrcs.usda.gov/USDGSM.aspx>.
- Vos, C.C., and A.H.P. Stumpel. 1995. Comparison of habitat-isolation parameters in relation to fragmented distribution patterns in the tree frog (*Hyla arborea*). *Landscape Ecology* 11:203–214.
- Waisanen, P.J., and N.B. Bliss. 2002. Changes in population and agricultural land in conterminous United States counties, 1790 to 1997. *Global Biogeochemical Cycles* 16:1137.
- Wangpakapattana Wong, P. 1996. Extent of Historical Wetlands of the Prairie Pothole Region, North Central Iowa. Master's thesis, Iowa State University.
- White, R., S. Murray, and R. Rohweder. 2000. Pilot Analysis of Global Ecosystems: Grassland Ecosystems. Washington, DC: World Resources Institute.
- Wickham, J.D., S.V. Stehman, J.A. Fry, J.H. Smith, and C.G. Homer. 2010. Thematic accuracy of the NLCD 2001 land cover for the conterminous United States. *Remote Sensing of Environment* 114(6):1286–1296.
- Wilens, B.O., and M.K. Bates. 1995. The US Fish and Wildlife Service's National Wetlands Inventory project. *Vegetatio* 118(1/2):153–169.
- Wilton, T.F. 2004. Biological Assessment of Iowa's Wadeable Streams. Project Report. Des Moines, IA: Iowa Department of Natural Resources.
- Zinn, J. 1997. Conservation Reserve Program: Status and Policy Issues. Congressional Research Service Report for Congress 96-760 ENR. Washington, DC: National Council for Science and the Environment.