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ESTIMATED EXTENT OF GEOGRAPHICALLY ISOLATED WETLANDS IN SELECTED AREAS OF THE UNITED STATES

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Abstract: In preparing a major report on geographically isolated wetlands, the U.S. Fish and Wildlife Service (FWS) initiated a study of the extent of these wetlands across the country. The FWS used geographic information system (GIS) technology to analyze existing digital data (e.g., National Wetlands Inventory data and U.S. Geological Survey hydrologic data) to predict the extent of isolated wetlands in 72 study areas. Study sites included areas where specific types of "isolated" wetlands (e.g., Prairie Pothole marshes, playas, Rainwater Basin marshes and meadows, terminal basins, sinkhole wetlands, Carolina bays, and West Coast vernal pools) were known to occur, as well as areas from other physiographic regions. In total, these sites represented a broad cross-section of America's landscape. Although intended to show examples of the extent of isolated wetlands across the country, the study was not designed to generate statistically significant estimates of isolated wetlands for the nation. As expected, the extent of isolated wetlands was quite variable. The study found that isolated wetlands constituted a significant proportion of the wetland resource in arid and semi-arid to subhumid regions and in karst topography. Eight study areas had more than half of their wetland area designated as isolated, while 24 other areas had 20–50 percent of their wetland area in this category. For most sites, isolated wetlands represented a greater percent of the total number of wetlands than the percent of wetland area. This was largely attributed to difference in wetland size, with most non-isolated wetlands being larger than the isolated wetlands. Forty-three sites had more than 50 percent of their total number of wetlands designated as isolated. The estimates of isolated wetlands presented in this study cannot be readily translated to wetlands that have lost Clean Water Act "protection" based on a recent U.S. Supreme Court ruling for several reasons, including the lack of written guidance on interpreting the Court's decision for identifying jurisdictional wetlands. The results of this GIS analysis present one perspective on the extent of geographically isolated wetlands in the country and represent a starting point for more detailed assessments.

Key Words: Carolina bays, coastal plain wetlands, Delmarva potholes, Gulf Coast Prairie, flatwood wetlands, geographically isolated wetlands, isolated wetlands, jurisdictional wetlands, playas, Prairie Pothole wetlands, Rainwater Basin wetlands, Sandhills wetlands, terminal basins, West Coast vernal pools

INTRODUCTION

Interest in "isolated wetlands" has risen due to recent changes in the federal wetland regulatory program. In a January 2001 ruling (Solid Waste Agency of Northern Cook County [SWANCC] vs. U.S. Army Corps of Engineers), the U.S. Supreme Court overturned the so-called "Migratory Bird Rule" that the U.S. Army Corps of Engineers (Corps) used to help identify potential areas of federal jurisdiction under the Clean Water Act. This decision stated that the Corps did not have the authority to regulate "isolated waters" solely on the basis of their use by migratory birds. In response to this decision, individual Corps districts have modified their procedures for making jurisdictional determinations. The net effect of these changes is a reduction in the level of regulation for "isolated waters" (including "isolated wetlands") and a lack of national consistency.

The U.S. Fish and Wildlife Service (FWS) recently published a web-based report on "geographically isolated wetlands" (Tiner et al. 2002a). These wetlands are vital habitats for wildlife, and despite their "isolation," they perform many of the valued functions that other wetlands perform (e.g., nutrient cycling, surface-water detention, and shoreline stabilization).

One of the basic questions about "isolated wetlands" is "How abundant are they and what percent of the nation's wetlands do they represent?" While there are no national estimates of isolated wetlands versus other wetlands, the FWS initiated a small-scale study to estimate the extent of these wetlands in a di-

verse set of landscapes across the country. Other agencies and organizations have generated similar statistics for particular areas. The purpose of this paper is to present the results of the FWS's study, summarize similar data from other sources, identify the vulnerability of geographically isolated wetlands, and offer some recommendations for improving the conservation of geographically isolated wetlands.

DEFINITION OF ISOLATED WETLAND

For this study, a definition of isolated wetland was chosen to facilitate identification of potentially isolated wetlands using geographic information system (GIS) technology. Such a definition could be used to extract information from available digital data sources for analysis. Other definitions, such as one based on hydrologic connectivity, including ground-water interactions, while vital to explaining wetland formation and function, were not workable within the constraints of existing information and technology. Also, the traditional view of "isolated wetlands" has been based on geographic isolation since it is more readily observed than hydrologic isolation. It is important to emphasize that the definition used in this study is not a regulatory definition, as many wetlands identified as "geographically isolated" in this study may be jurisdictional wetlands under various rules used by federal, state, and local agencies to administer their wetland resource regulatory programs.

A landscape-based or geographic definition of isolated wetland was adopted:

> "Geographically isolated wetlands" are wetlands with no apparent surface-water connection to perennial rivers and streams, estuaries, or the ocean. They are surrounded by dryland.

Please note that streamside wetlands where the stream disappeared underground or entered an isolated (no surface-water outflow) lake or pond, as in karst topography, were classified as isolated, as were wetlands associated with isolated waterbodies. This definition does not recognize infrequent and/or short duration connections caused by basin spillovers or catastrophic floods during abnormally wet periods, mainly because such connections are not readily determined through remote sensing or geographic information system (GIS) analysis. It does, however, acknowledge connections by ditches and intermittent streams as viable links since such features are readily observed and usually are represented in digital geospatial databases. Moreover, in many areas, these features likely provide seasonal connections to other waterbodies during years of average precipitation.

STUDY AREAS

Study areas were intended to address the range of environmental conditions found across the country. Given the focus on isolated wetlands, study sites intentionally included areas where such wetlands were suspected to represent a significant proportion of the area's wetlands (e.g., the Prairie Pothole Region, Nebraska's Rainwater Basin, and West Texas). However, study areas were also chosen in other physiographic regions to provide perspective on the possible extent of such wetlands elsewhere.

Since the analysis required using GIS technology, the following digital data were needed for potential study sites: 1) National Wetlands Inventory (NWI) digital data for wetlands, 2) U.S. Geological Survey (USGS) digital line graphs (DLGs) for hydrology (e.g., rivers, streams, lakes, ponds, estuaries, and oceans), and 3) USGS digital raster graphics (DRGs). Since NWI digital data were not available for most of the Southwest Region, potential study areas included areas where NWI maps and DLGs or DRGs were available.

Seventy-two study sites were selected by the FWS's Regional Wetland Coordinators based on the above criteria. Study areas were typically 4–8 quads (1: 24,000) in size to facilitate data processing. Two much larger areas (Horry County, South Carolina and Devils Lake, North Dakota) were evaluated as pilot areas to test study methods. Overall, study sites were located in 44 states, more than 20 ecoregions (Bailey 1995), and in each major watershed (Figure 1). Note that, while areas with extensive floodplains and coastal wetlands were generally avoided since their wetlands are typically not isolated, some of these sites were evaluated for national perspective.

Site selection was not random, and the study was not designed to generate a national estimate of the extent of geographically isolated wetlands. The study sites may or may not be representative of a particular physiographic region or ecoregion. To determine representativeness, additional study areas would have to be selected randomly and evaluated. The study sites do represent a range of environmental conditions and therefore provide some perspective on the variability of isolated wetlands across the country.

METHODS

The study involved compiling existing information, creating new digital data, and geoprocessing digital data. A series of maps and area summaries were compiled (see Tiner et al. 2002a for details). Only the latter will be presented in this paper.

Figure 1. Distribution of study areas for estimating the extent of geographically isolated wetlands in the United States.

Data Sources

Three main data sources were used: 1) NWI digital data (http://wetlands.fws.gov), 2) DLG hydrology coverages (http://edc.usgs.gov/geodata/), and 3) DRGs (http://data.geocomm.com/catalog/index.html). The NWI polygon data served as the prime source of wetlands and deepwater habitat data; NWI linear and point data were not used. While NWI maps may show linear streams (on the USGS base map), this information typically has not been incorporated into the NWI digital data, so other sources were consulted. The DLG hydrology layer (typically 1:24,000) represented a consistent dataset for the analysis of wetland-stream connectivity and isolation. It was the major source of stream and other waterbody (e.g., rivers, lakes, estuaries, and oceans) data. Where DLG hydro data were not available, a hydro-line coverage was created from the DRG. In general, the DRGs were used as collateral data to aid in determining whether or not wetlands were isolated. Where DRGs were not available, U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) data were consulted (http://www.census.gov/geo/www/tiger/tigerua/ua_tgr2k.html). Aerial photos were reviewed when necessary and where they were readily available, but they were not routinely examined.

Buffering of Streams

Linking two digital data sources often creates problems due to differences in spatial accuracy (e.g., linear stream data may not intersect streamside wetlands). Joining NWI data with DLG hydro data, in some instances, caused a streamside wetland (NWI data) to be offset from its adjoining stream (DLG data). To remedy this situation, linear stream data were buffered. For the analysis, two stream buffer widths were used: 20 m and 40 m. The 20-m buffer represents the stream, so all wetlands within this zone were considered to be in contact with the stream. The 40-m buffer was selected in an attempt to capture other wetlands (especially headwater wetlands) that were not linked to stream systems due to a data gap between the DLG data and the NWI data. Recognizing that this buffering process may capture other wetlands that were clearly separated from a stream, a range of estimates for isolated wetlands was generated for each study area (see Scenarios for Data Presentation).

Data Compilation and Analysis

GIS technology was used to compile existing digital data and use such data to predict the extent of isolated wetlands for selected study sites. The following is a summary of GIS procedures used to compile and analyze these data. ArcInfo and ArcView software (http://www.esri.com) were used for this analysis.

(1) Gather digital data for each quad (NWI data, DLG hydrology layer, and DRG).
(2) Import selected DLG hydro.sdts file to an ArcInfo coverage (using sdts2cov.aml).
(3) "Select" perennial and intermittent streams from the DLG hydro layer and deepwater habitats from the NWI data.
(4) Buffer the selected hydro layer with a 20-m buffer.
(5) "Select" by theme (NWI and DLG) all NWI deepwater habitats intersecting the 20-m buffer.
(6) "Union" (ArcView geoprocess wizard) selected DLG hydro layer with selected NWI deepwater habitat data.
(7) Eliminate internal polygon lines in the unioned data by using the ArcView dissolve geoprocess.
(8) Take the NWI data (wetlands and deepwater habitats) and query to select all features intersecting the unioned 20-m buffer-selected deepwater habitat data.
(9) Build out the selection to include any wetland or deepwater habitat touching one that is within or contiguous to this buffered data (identified in Step 8; when complete, the build-out selection will highlight all features that are "not isolated").
(10) Reverse or switch the selection (this selects all features not selected in Step 9) and the highlighted features are "isolated wetlands and deepwater habitats."
(11) "Select" isolated wetlands and deepwater habitats at a distance of 20 m from the unioned 20-m buffer-selected deepwater habitat data; this step highlights wetlands within the "20–40 m buffer" (potentially isolated under two scenarios) for analysis.
(12) Compare results versus DRG (check for stream links to "isolated features"). Road-fragmented wetlands are culled out manually when viewing the DRGs. (Note: Aerial photos may be consulted when available.)
(13) Produce draft map and data summaries. (Note: Internal linework within wetland complexes is dissolved to generate statistics on wetland number.)
(14) Cull out isolated deepwater habitats from isolated wetlands by codes (e.g., L1 = lacustrine deepwater habitats; L2 = lacustrine littoral wetlands; all P = wetlands; for Riverine, UB and RB = unconsolidated bottom and rock bottom deepwater habitats, US and RS = unconsolidated shore and rocky shore wetlands).
(15) Generate final map and data summaries.

Road-Fragmented Wetlands

Wetlands may be fragmented by roads, railroads, and other types of development. Separations by roads and railroads were interpreted from DLG data or TIGER data. For the analysis, wetlands separated by roads and railroads with no connection to the neighboring stream were designated as "road-fragmented wetlands." These wetlands may or may not be connected to neighboring wetlands across the road via a culvert. Consequently, they may or may not be geographically isolated.

Scenarios for Data Presentation

Three scenarios were evaluated to present a range of estimates for the extent of isolated wetlands:

(1) narrow interpretation—wetlands >40 m from non-isolated waterbody and not "road-fragmented" were classified as isolated,
(2) slightly broader interpretation—wetlands > 20 m from a non-isolated waterbody and not "road-fragmented" were considered isolated, and
(3) broadest interpretation—wetlands > 20 m from a non-isolated waterbody and wetlands designated as "road-fragmented" were identified as isolated.

Scenario 1 yields the lowest number and area of isolated wetlands, whereas Scenario 3 generates the largest number and greatest area of potentially isolated wetlands. Note that, for this analysis, any wetland within 20 m of a stream was considered "non-isolated" or connected to the stream.

Small pieces of wetlands along outer boundaries of a study area were not evaluated and were designated as "map-edge" wetlands, since they could be connected to streams on adjacent quads. These wetlands represented only a minute fraction of a study area's wetlands.

STUDY LIMITATIONS

Source Data Limitations

The source data were compiled through remote-sensing techniques, primarily photointerpretation with limited field checking. Consequently, NWI maps and digital data do not show all wetlands, and USGS maps and digital data do not show all streams and other waterbodies. Both sources do, however, represent national datasets suitable for GIS analysis. Photo and map scales are constraints for wetland mapping, as is the difficulty of detecting certain wetland types or features (Tiner 1990, 1999). Small wetlands (less than 0.4 ha) are usually not shown on NWI maps (except for prairie potholes and perhaps a few other grassland areas). Even larger wetlands that are difficult to photointerpret (e.g., evergreen forested wetlands or wet flatwoods) may be missed or mapped inaccurately. Carolina bays may have a narrow strip of upland separating them from adjacent flatwood wetlands or pocosins, but this may be too narrow to depict on an NWI map. They were not identified as "isolated" for this study unless they were separated by upland on the NWI map. Wetlands classified as "isolated" may be connected to "non-isolated wetlands and waters" by a stream, seepage wetland, or overflow channel that was not shown on the USGS hydrology coverage. If evaluated in the field, such wetlands may or may not be considered "isolated" by the Corps, depending on their field-based evaluation methods. Other "isolated" wetlands, such as those in urban areas connected to streams by underground culverts or those in agricultural areas connected to streams by tile lines, were not detected through GIS analysis. All roads are not shown on the data sources, so more wetlands may be "road-fragmented" than identified in the current study. It is important to remember that the analysis was strictly a GIS process, and no field verification was done to evaluate the quality of the data sources. For a more in-depth discussion of limitations, see Tiner et al. (2002a).

Geographically Isolated Wetlands vs. Jurisdictional Wetlands

There was no attempt to identify regulated wetlands from non-regulated wetlands due to "isolation." Federal and state agencies apply criteria other than "geographic isolation" to determine whether a wetland is isolated or not (e.g., "adjacency"). They also apply varied criteria for determining whether a given plant community is wetland or not, and those criteria may differ from what the scientists consider "wetlands" and from what is mapped as wetland by the NWI. Consequently, even wetlands designated as "non-isolated" wetlands in this study may not be regulated because their "connection" may be through a non-regulated wetland (i.e., an area not meeting all the requirements for a jurisdictional wetland determination). Also, where agency guidance is not explicit (i.e., lack of standardized methods for evaluation), interpretations will likely differ, making an assessment of impacts of regulatory policy changes very difficult to predict accurately. It is virtually impossible to make any assertions regarding how many geographically isolated wetlands (or even non-isolated wetlands, for that matter) may or may not be regulated by various levels of government, given that: 1) there are no published standards for making such determinations, 2) inconsistencies exist among and within regulatory agencies for identifying so-called "jurisdictional wetlands," and 3) at the federal level, isolated wetlands that are near navigable waters or their tributaries may be considered "adjacent" wetlands subject to the Corps jurisdiction.

Number of Wetlands

To determine the number of wetlands in a given study area, internal linework within a "wetland complex" (i.e., a wetland with more than one covertype delineated) had to be dissolved. This process worked well for discrete basins but was less effective for wetlands crossed by roads. The roads created additional wetland polygons, and they were treated as separate wetlands, although other interpretations may be equally valid. The ratio given for the number of isolated wetlands versus non-isolated wetlands presented in this study should be considered conservative. Study findings do not represent absolute numbers but are intended to show tendencies and provide some relative estimates of the abundance or scarcity of isolated wetlands in particular landscapes. Also, NWI point or linear data were not used, since such data are not consistent among regions. In some areas like the Prairie Pothole Region, these wetlands comprise a large number of the area's wetlands, although they typically do not account for much of the total wetland area.

GIS Analysis

When performing GIS analyses, rules must be developed for making consistent evaluations. As noted above, there are limitations to the source data used for assessing the extent of geographically isolated wetlands by GIS technology, but there also are constraints based on rules for data interpretation. In determining whether or not a given wetland was isolated, the FWS employed rather strict rules, such as if a wetland did not have a stream connection in the dataset and was separated from a non-isolated wetland by a road, it was classified as a "road-fragmented" wetland. Such wetlands were not included as isolated in two scenarios but were considered isolated in the broadest interpretation used in this study. In karst topography, perennial streams that disappeared underground were considered isolated. More detailed investigations might reveal that such streams resurface some distance (e.g., kilometers) downstream and may thereby be considered non-isolated by some definitions. Clearly, other interpretations are possible for a host of situations encountered. The results of the FWS's GIS analysis present one perspective on the extent of geographically isolated wetlands and represent a starting point for more detailed assessments, as needed.

Interpretation of the Results

Reference to "isolated" wetlands in the results should be interpreted as "potentially isolated." Determination of geographically isolated wetlands, in many cases, requires field verification to ensure that the designated wetland does not have some form of surface-water outflow. In urban areas, it is quite possible that numerous "isolated wetlands" are connected to streams via underground culverts. The same may be true for impounded wetlands near rivers and streams.

RESULTS

A series of tables summarize study findings for various regions of the United States. The tables list for each study area the size of the study area, the wetland area (based on NWI mapping), the percent of the study area represented by wetlands, the number of wetlands, the percent of the wetland area that was predicted as being isolated (range of three scenarios), the percent of the number of wetlands that were predicted as isolated (range of scenarios), the area of deepwater habitat, the percent of the study area classified as deepwater habitat, and the percent of the deepwater habitat area that was predicted as being isolated. While the tables report information on the number of wetlands and the percent of the number of wetlands that are isolated, there is no detailed discussion of these percentages. In general, the percent of the number of individual wetlands that are isolated is much greater than the percent of the total wetland area designated as isolated (typically more than twice). This is attributed to the overall smaller size of isolated wetlands in most study sites. The percent of isolated deepwater habitats can also been determined from reviewing the tables. In most cases, this percentage was zero or less than one percent, with a few noteworthy exceptions (e.g., Lincoln County, WA; Blackwater-Florence, AZ; Oklahoma City, OK; Mustang Bayou, TX; Tahoka, TX; Goose Lake, IL; Harrisburg, IL; Grand Sable Lake, MI; Big Lake, MN; Lake Alexander, MN; Crystal Lake, FL; Dade City, FL; Baton Rouge, LA; Newton, NJ; Edgemere, PA; Altona, NE; Kenai, AK).

Results by Region

Northeast. Seventeen study sites were examined in the Northeast (Table 1). Eleven sites were located in the glaciated portion of the region (Northampton, Porcupine Mountain, Conway, Epping, Boonton, Newton, Eastern Lake Ontario, Millbrook, Edgemere, Lake Como, and Bread Loaf). Three sites in the coastal zone were Delmarva Potholes, Atsion, and Cape May. The rest of the study areas were located in more mountainous terrain of the non-glaciated portion of the Appalachians (Distant, Savage River, and Frederick).

In the glaciated portion of the region, the percent of wetlands in the study areas ranged from 0.5 percent (Bread Loaf) to 15.9 percent (Boonton). The percent of wetland area that was predicted to be isolated ranged from 5.1 percent (Boonton—in the New York City-Newark metropolitan area) to 28.2 percent (Millbrook).

On the Coastal Plain, the percent of wetland in the study areas was much greater than in study areas elsewhere in the Northeast: 15.0 percent in the Delmarva Potholes to 41.5 percent in Atsion (the New Jersey Pine Barrens). Two of the Coastal Plain sites had low percentages (less than 6%) of their wetland areas classified as isolated (Atsion and Cape May), while the Delmarva Potholes sites had 35–39 percent of its wetland area designated as isolated. The latter area is atypical of the Coastal Plain due to the great abundance of pothole-like depressional forested and scrub-shrub wetlands on broad interfluves.

Southeast. Wetlands in 14 study areas, including all of Horry County, South Carolina, were examined (Table 2). Five sites were located on the Coastal Plain (Dublin, Horry County, New Orleans, Dade City, and Crystal Lake), with the latter two sites occupying karst topography. Two sites (Baton Rouge and Hazen) were on or proximate to the Mississippi Alluvial Plain. Other sites were from hilly to mountainous areas, with two sites (Charlotte and Holly Springs) on the Gulf-Atlantic Rolling Plain and five sites (Earlysville, Rainelle, Bee Spring, Trinity, and Acworth) from the Eastern Highlands (all except Bee Spring from the Appalachians).

The Coastal Plain sites, like their Northeast counterparts, had large percentages of their areas represented by wetlands, ranging from 18 percent (Crystal Lake) to 44 percent (Horry County). Within these areas, the predicted extent of isolated wetlands varied from a low around two percent (New Orleans) to a high approaching 45 percent (Crystal Lake). The two sites in Florida's karstlands (Crystal Lake and Dade City) had 41–45 percent of their wetland areas designated as isolated. The Dublin and Horry County sites contain many Carolina bays, with 20–24 percent and 5–9 percent of their total wetland areas classified as isolated. The latter area contained extensive floodplain and flatwood wetlands.

The Baton Rouge and Hazen sites on the Mississippi alluvial plain had 10 and 21 percent of their area

Table 1. Estimates of geographically isolated wetlands and deepwater habitats for selected areas in the Northeast. (Source: Tiner et al. 2002a).

State(s)	Study Area	Size of Study Area (hectares)	Wetland Area (ha)	% of Study Area in Wetlands	Number of Wetlands	% of Wetland Area Predicted as Isolated	% of Wetland Number Predicted as Isolated	Deepwater Habitat Area (ha)	% of Study Area in Deepwater Habitats	% Deep-water Habitat Area Predicted as Isolated
MA	Northampton[1]	57206	3130	5.5	951	17.2–21.6	44.4–53.8	640	1.1	0.0
MD	Frederick[3]	59723	966	1.6	1076	16.8–17.7	43.2–47.9	322	0.5	0.0
MD	Savage River[3]	59594	560	0.9	569	19.5–22.0	55.0–60.6	217	0.4	0.0
MD/DE	Delmarva Potholes[2]	59879	8974	15.0	3670	35.4–38.8	76.7–80.7	301	0.5	0.0
ME	Porcupine Mtn[1]	54766	7047	12.9	1691	16.7–17.7	65.7–67.4	5137	9.4	1.1
NH	Conway[1]	55718	2395	4.3	813	12.3–15.5	38.1–40.6	1433	2.6	0.9
NH	Epping[1]	56637	7332	12.9	3390	13.9–16.0	61.8–65.5	527	0.9	0.0
NJ	Atsion[2]	59452	24666	41.5	236	1.0–1.1	48.7–51.3	224	0.4	0.0
NJ	Boonton[1]	58487	9290	15.9	907	5.1–7.3	41.9–49.0	1490	2.5	0.0
NJ	Cape May[2]	59978	18363	30.6	1257	3.8–5.3	65.2–72.3	20340	33.9	0.3
NJ	Newton[1]	58375	6076	10.4	1495	17.9–19.1	63.9–66.7	2205	3.8	4.4
NY	E. Lake Ontario[1]	56036	4302	7.7	1294	20.1–22.1	64.5–67.6	10389	18.5	0.0
NY	Millbrook[1]	57620	3022	5.2	3445	24.7–28.2	62.1–66.7	367	0.6	0.0
PA	Distant[3]	58511	126	0.2	163	17.3–18.3	39.9–44.2	951	1.6	0.0
PA	Edgemere[1]	58156	5529	9.5	1147	14.7–16.1	55.9–58.8	1374	2.4	2.4
PA	Lake Como[1]	57716	1987	3.4	1321	15.5–18.1	41.9–45.6	1004	1.7	0.0
VT	Bread Loaf[3]	55820	283	0.5	245	13.8–17.4	37.1–40.8	2	0	0.0

[1] Glaciated.
[2] Coastal zone.
[3] Mountainous non-glaciated.

Table 2. Estimates of geographically isolated wetlands and deepwater habitats for selected areas in the Southeast. (Source: Tiner et al. 2002a.)

State(s)	Study Area	Size of Study Area (hectares)	Wetland Area (ha)	% of Study Area in Wetlands	Number of Wetlands	% of Wetland Area Predicted as Isolated	% of Wetland Number Predicted as Isolated	Deepwater Habitat Area (ha)	% of Study Area in Deep-water Habitats	% Deep-water Habitat Area Predicted as Isolated
AL	Trinity[3]	63649	9092	14.3	1393	7.4–9.0	62.3–67.6	1736	2.7	0.0
AR	Hazen[2]	63391	6269	9.9	659	7.4–9.1	48.9–56.0	175	0.3	0.0
FL	Crystal Lake[1]	66517	12033	18.1	1175	44.6–44.9	74.2–77.0	1669	2.5	88.1
FL	Dade City[1]	67969	13826	20.3	4136	41.0–42.1	88.9–90.2	571	0.8	48.2
GA	Acworth[1]	64097	1117	1.7	764	25.6–29.2	63.2–68.2	1036	1.6	0.0
KY	Bee Spring[3]	61520	506	0.8	1601	46.1–47.6	88.1–90.2	430	0.7	0.0
LA	Baton Rouge[2]	66633	13771	20.7	793	4.8–6.5	63.3–72.5	874	1.3	4.1
LA	New Orleans[1]	66864	15666	23.4	304	1.7–2.6	24.0–28.6	44089	65.9	0.1
MS	Holly Springs[1]	63535	4136	6.5	1575	5.3–5.7	56.2–59.2	324	0.5	0.0
NC	Dublin[1]	63630	14608	23.0	1292	20.7–24.2	74.8–79.1	651	1.0	0.0
NC/SC	Charlotte[1]	63177	992	1.6	1137	17.1–21.2	39.7–45.7	145	0.2	0.0
SC	Horry County[1]	300449	132349	44.1	7639	5.1–9.1	63.3–70.6	6032	2.0	0.0
VA	Earlysville[1]	60878	520	0.9	733	14.4–16.5	34.0–37.9	318	0.5	0.0
WV	Rainelle[3]	61010	244	0.4	763	34.8–41.0	60.3–65.4	303	0.5	0.0

[1] Coastal plain.
[2] Mississippi alluvial plain.
[3] Appalachian mountains.

mapped as wetland. Less than 10 percent of their wetland areas was classified as isolated.

Sites in hilly and mountainous terrain had much lower amounts of wetland, with most sites having less than two percent of their area identified as wetland. The percent of wetland area classified as isolated varied considerably, from 5–6 percent (Holly Springs) to 46–48 percent (Bee Spring). The former area contained many floodplain wetlands, whereas the latter had an abundance of ponds that were designated as isolated.

Midwest. All but two of the 12 Midwest study areas were covered by the Wisconsin glacier more than 15,000–20,000 years ago (Table 3). The exceptions were Harrisburg and Trenton, and they had 5–6 percent of their areas inventoried as wetlands and 11–15 percent of their wetland area designated as isolated.

The Prairie Pothole Region encompasses part of this region, and two pothole study sites were evaluated: Devils Lake and Clark. They had 11–15 percent of their areas mapped as wetlands. Of these, 49–98 percent was isolated, with the greater percent attributed to the Clark study area. The presence of Devils Lake and its tributaries accounted for the lower percent of isolated wetland area in the Devils Lake study area. The Clark site, with its lack of streams, is probably more representative of the Pothole Region.

For the other study areas, Ericsburg had the greatest percent of its area covered by wetlands (44%), with forested wetlands predominating. This area is characterized as "conifer bog needleleaf forest" in the National Atlas (U.S. Geological Survey 1970), and only a small percent of Ericburg's wetland area was deemed isolated (8–9%). The percent of wetland area identified as isolated varied considerably among the other study areas, ranging from 5–6 percent (Goose Lake) to 50–54 percent (Bluffton).

Interior West. Eleven sites were evaluated in this region, which extended from Montana to Kansas and west to Utah and Idaho (Table 4). This region included arid and semi-arid (subhumid) areas and the Rocky Mountains. All the study sites had relatively low percentages of their areas mapped as wetlands—less than two percent for more than half of the sites. While the wetland area may be low, the percent that was isolated was large for several areas. This region contained study sites in Nebraska's Rainwater Basin and Sandhills (Hill Lake) and the Great Basin (Four Mile Flat), areas noted for their geographically isolated wetlands. These study areas had 46 percent or more of their wetland area designated as isolated. The Four Mile Flat site contains two terminal basins, and all of its wetlands were considered isolated. The Rainwater Basin study area had 84–85 percent of its wetlands classified as isolated. Other areas with a very large percent of their wetland area mapped as isolated were Black Thunder (80–81%) and Olathe-Kansas City (46–49%). Most of the isolated wetlands in these two areas were palustrine emergent wetlands (wet meadows) and ponds with aquatic vegetation, respectively.

Southwest. Like the Interior West, arid and semi-arid climates predominated this region. As expected, most of the study sites had low percentages of their area occupied by wetlands (less than 3% for most and less than 1% for four sites; Table 5). The Southwest Region contained the Southern High Plains, an area noted for high concentrations of playas. These wetlands are typically isolated, and the two West Texas study sites (Tokio and Tahoka) had all of their wetlands (playas) mapped as isolated. Besides these two sites, four other sites had more than 20 percent of their wetlands classified as isolated: three sites in Texas (Laguna Park, Mustang Bayou, and St. Charles Bay) and one site in New Mexico (Carlsbad Caverns). Most of the isolated wetlands in the latter two Texas sites within the Gulf Coast Prairie were palustrine emergent wetlands.

Pacific Coast and Alaska. Six study sites were evaluated on the Pacific Coast (three in California, two in Oregon, and one in Washington), and three sites were assessed in Alaska (Table 6). California's Birds Landing study area included the Jepson Prairie, known for its West Coast vernal pool wetlands. This site had only three percent of its wetlands designated as isolated due to the presence of extensive estuarine wetlands in the four-quad study area. Of the California sites, Sacramento had the greatest percent of wetlands designated as isolated (40–48%). Palustrine emergent wetlands predominated the isolated types. The Coquille River site in Oregon had six percent of its area occupied by wetlands due to the presence of extensive floodplain wetlands. Eight to ten percent of its wetland area was classified as isolated. The Clackamas River site had only one percent as wetlands, yet had 16–20 percent of its wetlands designated as isolated. The Lincoln County study area contained the area called "Channeled Scablands" where isolated wetlands were expected to be abundant and 78 percent of the wetland area was mapped as isolated. Most of the isolated wetland area was represented by palustrine emergent wetlands, with isolated ponds also common.

For two of the Alaska study sites, the percent of total study area was extremely large: 45–46 percent for Mt. McKinley and Charley River, respectively. However, the percent of their wetland area that was isolated was low (i.e., less than 5%). In contrast, Kenai had about 20 percent of its area in wetland, with 24–25 percent of the wetland area designated as isolated.

Table 3. Estimates of geographically isolated wetlands and deepwater habitats for selected areas in the Midwest. (Source: Tiner et al. 2002a.)

State(s)	Study Area	Size of Study Area (hectares)	Wetland Area (ha)	% of Study Area in Wetlands	Number of wetlands	% of Wetland Area Predicted as Isolated	% of Wetland Number Predicted as Isolated	Deepwater Habitat Area (ha)	% of Study Area in Deepwater Habitats	% Deepwater Habitat Area Predicted as Isolated
IL	Goose Lake[1]	58542	2828	4.8	829	4.5–6.5	41.5–46.9	3428	5.9	1.3
IL	Harrisburg[2]	61244	3649	6.0	1588	10.9–12.4	71.2–76.0	255	0.4	14.8
IN	Bluffton[1]	53729	936	1.6	906	50.1–53.8	79.8–84.2	34	0.1	0.0
IN	Mongo[1]	57852	7548	13.1	3707	24.9–27.7	78.6–81.3	1284	2.2	0.0
IA	Allison[1]	56821	1979	3.5	966	10.6–11.8	45.0–52.2	172	0.3	0.0
MI	Grand Sable Lake[1]	53199	6482	12.2	473	15.3–16.0	85.0–85.6	20592	38.7	1.8
MN	Big Lake[1]	54394	9109	16.8	2982	29.9–35.4	84.1–86.1	1685	3.1	24.2
MN	Ericsburg[1]	51469	22742	44.2	2033	7.7–9.2	81.1–83.7	399	0.8	0.0
MN	Lake Alexander[1]	53691	11442	21.3	3471	22.7–33.9	90.0–92.8	2299	4.3	19.6
MO	Trenton[2]	59133	3066	5.2	4126	12.6–15.1	45.7–52.8	285	0.5	0.0
ND	Devils Lake[3]	374843	55050	14.7	42327	49.3–51.3	97.0–97.6	16087	4.3	0.1
SD	Clark[3]	54875	6019	11.0	4106	98.1–98.2	93.8–94.6	0	0	0.0

[1] Glaciated.
[2] Non-glaciated.
[3] Glaciated Prairie Pothole Region.

Table 4. Estimates of geographically isolated wetlands and deepwater habitats for selected areas in the Interior West. (Source: Tiner et al. 2002a.)

State	Study Area	Size of Study Area (hectares)	Wetland Area (ha)	% of Study Area in Wetlands	Number of Wetlands	% of Wetland Area Predicted as Isolated	% of Wetland Number Predicted as Isolated	Deepwater Habitat Area (ha)	% of Study Area in Deep-water Habitats	% Deep-water Habitat Area Pre-dicted as Isolated
CO	Cherry Creek Lake	59557	730	1.2	943	13.9–16.7	31.6–36.8	425	0.7	0.0
ID	Wood River	56091	849	1.5	967	5.2–6.3	29.7–33.4	106	0.2	0.0
KS	Olathe-Kansas City	90335	986	1.1	2866	45.9–49.0	70.1–71.1	508	0.6	0.0
MT	Hoodoo Hill	50999	719	1.4	846	20.0–21.1	47.3–53.0	70	0.1	0.0
NE	Altona	57426	384	0.7	364	20.2–24.7	42.6–50.6	55	0.1	21.3
NE	Hill Lake	57218	2389	4.2	1006	46.2–47.2	66.2–73.8	0	0	0.0
NE	Rainwater Basin	58816	1906	3.2	1076	84.1–84.6	64.4–67.7	25	0	0.0
NV	Four Mile Flat	59788	4212	7.0	10	100	100	0	0	0.0
UT	Green River	44377	2950	6.6	304	3.0–3.4	18.1–20.7	948	2.1	0.0
UT	Rockport Lake	58486	1400	2.4	632	3.5–7.5	23.9–36.7	448	0.8	0.0
WY	Black Thunder	55910	905	1.6	887	80.3–80.7	41.4–43.7	0	0	0.0

Palustrine scrub-shrub wetland was the dominant isolated wetland type in the Alaskan study areas.

DISCUSSION

Examination of 72 study areas across the United States produced highly variable results regarding the amount of wetlands and the percent of wetlands predicted as geographically isolated. While there are estimates of isolated wetlands from numerous sources, only a few are based on GIS analysis. The FWS conducted a few watershed studies in the Northeast that produced information on geographically isolated wetlands (Tiner et al. 1999, 2000, 2001, 2002b), while Ducks Unlimited conducted a specific study to predict the possible impacts of the SWANCC decision on wetlands in areas important for waterfowl (Petrie et al. 2001). The results of these studies are summarized in Table 7. Four states have also prepared estimates of wetlands that may be adversely affected by the SWANCC ruling.

Despite some differences in study methods, the results of various studies are comparable to those obtained from the present study. The data presented in Table 7 from the Ducks Unlimited study (Petrie et al. 2001) are for "no buffer" and "100-m buffer" (i.e., distance from a navigable water or tributary) scenarios. Their data suggest that isolated wetlands do not encompass significant area either in the Mississippi alluvial valley or along portions of the Atlantic Coastal Plain, whereas they predominate in the Prairie Pothole Region of the Dakotas and the Gulf Coast Prairie Region (coastal Texas-Louisiana). Isolated wetlands also appear to be quite extensive in the Great Lakes Region based on their limited sample (four-1:24,000 quads). The wide range of values for their Mid-Atlantic Coast study area is due to their inclusion of sites with considerable tidal wetlands and floodplain wetlands (e.g., Rock Point, Leonardtown, Mardela Springs, and St. Michaels) and one site within the Delmarva Potholes region (i.e., Millington). The former sites had 4–13 percent of their wetland area designated as potentially isolated ("at risk"), whereas the latter area had 43–46 percent classified as such. Petrie et al. (2001) reported that Texas biologists believed that nearly 100 percent of the playas would be without Clean Water Act Section 404 protection. The Tokio and Tahoka sites of the subject study were located in an area of heavy concentration of playas, and 100 percent of their wetlands were classified as isolated (Table 5).

Studies conducted by the FWS's Northeast Region provided data for five watersheds: Casco Bay (Maine), Nanticoke River (Maryland and Delaware), Coastal Bays (Maryland), Cannonsville Reservoir (New York), and Neversink Reservoir (New York) (Tiner et al.

Table 5. Estimates of geographically isolated wetlands and deepwater habitats for selected areas in the Southwest. (Source: Tiner et al. 2002a.)

State	Study Area	Size of Study Area (hectares)	Wetland Area (ha)	% of Study Area in Wetlands	Number of Wetlands	% of Wetland Area Predicted as Isolated	% of Wetland Number Predicted as Isolated	Deepwater Habitat Area (ha)	% of Study Area in Deepwater Habitats	% Deep-water Habitat Area Predicted as Isolated
AZ	Blackwater-Florence	32355	155	0.5	41	3.3–4.2	31.7–36.6	5	0	100.0
NM	Carlsbad Caverns	65379	102	0.2	154	24.4–25.4	21.4–22.7	0	0	0.0
NM	Valle Grande	62629	218	0.3	218	12.3–13.0	43.6–47.7	0	0	0.0
OK	Oklahoma City	63010	1760	2.8	1180	17.1–18.8	63.4–65.8	559	0.9	3.0
TX	Laguna Park	65693	410	0.6	1155	24.8–27.4	53.9–58.5	293	0.4	0.0
TX	Mustang Bayou	67299	5114	7.6	2147	22.0–29.1	77.5–88.5	1499	2.2	6.3
TX	St. Charles Bay	68017	14138	20.8	2656	22.0–22.6	46.6–47.7	20116	29.6	0.0
TX	Tahoka	48520	1272	2.6	446	100	100	310	0.6	100.0
TX	Tokio	48506	997	2.1	392	100	100	0	0	0.0

1999, 2000, 2001a, 2002b). The Maine and New York watersheds are located in the glaciated portion of the Northeast. Geographically isolated wetlands ranged from low occurrence in two reservoir watersheds in mountainous terrain (Catskill Mountains) to moderate levels of abundance in the Casco Bay watershed. The other watersheds were situated on the Atlantic Coastal Plain. The extent of isolated wetlands in these watersheds was similar to that of the current study's New Jersey Coastal Plain sites (Atsion and Cape May; Table 1), although the percent of wetland number was much lower. One possible explanation for the latter difference could be that extensive ditching of wetlands on the Delmarva Peninsula has connected formerly isolated wetlands to tributary streams. Other explanations could be differences in topography, soils, and other features between study sites or more extensive examination of data for the watershed characterizations.

At least four states have produced estimates of isolated wetlands, waters, or wetlands unprotected by the SWANCC decision: Nebraska, Wisconsin, Indiana, and Illinois. The Nebraska Game and Parks Commission prepared estimates of isolated wetlands for different regions by reviewing NWI data and deriving estimates based on the best professional judgment from the state's wetland experts (LaGrange 2001; T. LaGrange, pers. comm. 2002). They estimated the percent of wetland area represented by isolated wetlands as follows: Rainwater Basin—90 percent, Central Table Playas—95 percent, Southwest Playas—95 percent, Todd Valley Playas—95 percent, Sandhills—60 percent, and Loup/Platte River Sandhills—50 percent. These estimates are comparable to the numbers produced from the present study (e.g., 84–85% for Rainwater Basin study site and 46–47% for the Hill Lake, Sandhills study site). Petrie et al. (2001) reported that 60 percent of Nebraska's wetlands were isolated. The Wisconsin Department of Natural Resources (2001) analyzed its wetland inventory data to assess the potential implications of the SWANCC decision on wetland protection in the state. Their summary statistics on protected vs. unprotected wetland area for each county predicted that 70 percent of the state's wetlands would be unprotected. A later assessment, employing GIS analysis methods proposed by the Association of State Wetland Managers (2001), revealed that 404,858–526,316 hectares of wetlands (approximately 24% of Wisconsin's wetlands) would be at risk (Scott Hausmann, pers. comm. 2002). Using these same GIS techniques, the Indiana Department of Environmental Management determined that 9–31 percent of Indiana's water area (deepwater habitats and wetlands) and 32–85 percent of the state's waters (by number) would be considered isolated (James Robb, pers. comm.

Table 6. Estimates of geographically isolated wetlands and deepwater habitats for selected areas on the Pacific Coast and in Alaska. (Source: Tiner et al. 2002a.)

State	Study Area	Size of Study Area (hectares)	Wetland Area (ha)	% of Study Area in Wetlands	Number of Wetlands	% of Wetland Area Predicted as Isolated	% of Wetland Number Predicted as Isolated	Deepwater Habitat Area (ha)	% of Study Area in Deepwater Habitats	% Deepwater Habitat Area Predicted as Isolated
CA	Birds Landing	60752	8622	14.2	403	3.1–3.4	53.6–58.6	663	1.1	0.0
CA	La Mesa	48709	689	1.4	260	10.9–11.3	22.3–24.6	907	1.9	0.0
CA	Sacramento	60424	848	1.4	646	40.1–47.6	66.3–72.0	410	0.7	0.0
OR	Clackamas River	54393	672	1.2	598	15.9–20.5	43.3–48.2	414	0.8	0.0
OR	Coquille River	56499	3516	6.2	1110	8.4–9.6	47.2–49.1	17965	31.8	0.0
WA	Lincoln County	104427	1684	1.6	3124	78.1–78.4	94.5–95.3	79	0.1	70.0
AK	Charley River	65427	30317	46.3	384	3.7–3.8	63.3–66.4	255	0.4	0.0
AK	Kenai	57616	11397	19.8	1254	23.4–24.9	96.3–96.7	6044	10.5	2.7
AK	Mt. McKinley	69102	31353	45.4	323	4.7–5.1	82.7–83.9	8	0	0.0

2002). The Indiana assessment used DLGs at 1: 100,000 for determining the hydrologic connection of wetlands. These digital data do not include a large number of small tributary streams, so the projected estimates are likely much greater than reality. Two of the subject study's sites were located in Indiana (Bluffton and Mongo), and they had an estimated 25–54 percent of their wetland area identified as isolated and 71–84 percent of the wetland number predicted as isolated (Table 3). The Illinois Department of Natural Resources (2001) estimated that isolated wetlands represent 12 percent of the state's remaining wetland area. The Goose Lake and Harrisburg study areas were located in Illinois (Table 3). The former area had 5–7 percent of its wetland area designated as isolated, while the latter had 11–12 percent identified as such.

PROBLEMS IDENTIFYING GEOGRAPHICALLY ISOLATED WETLANDS ON-THE-GROUND

While we can define geographically isolated wetlands and identify wetlands that are clearly not geographically isolated, verifying that a given wetland or part of a wetland is geographically isolated can be problematic for individual projects. Consider the following.

(1) Although the surface-water connection of many wetlands to rivers and streams is rather obvious on satellite imagery, aerial photographs, and various maps, many wetlands that appear to be geographically isolated through such analyses may, in fact, be linked to downhill or even downstream wetlands through connections such as seepage slopes, intermittent streams, or periodic overflow channels or drainageways. Given this, field evaluation is required to determine whether wetlands that appear to be isolated on maps and photos, for example, are truly geographically isolated from others. Recognizing this fact, will the Corps of Engineers require field inspection of the entire wetland complex (extending beyond an applicant's property) to determine whether a wetland is isolated or not? Also, what constitutes a valid hydrologic connection to "navigable waters" for asserting federal jurisdiction? How will this be addressed in a consistent manner across the country?

(2) Headwater or outflow wetlands in broad flat terrain, such as the Atlantic-Gulf Coastal Plain, may be linked to perennial streams and rivers through flatwood wetlands. Some of these flatwood wetlands may not satisfy all the regulatory criteria for being a jurisdictional wetland based on current wetland delineation practices (Environmental Laboratory 1987 and guidance memoranda). From the

Table 7. Estimates of geographically isolated wetlands from other studies for selected areas in ten states.

State	Study Area	Size of Study Area (ha)	Wetland Area (ha)	% of Study Area in Wetlands	Number of Wetlands	% of Wetland Area Predicted as Isolated	% of Wetland Number Predicted as Isolated	Source
AR	Mississippi Valley	63000*	na	na	na	1–10**	17–75**	Petrie et al. 2001
DE	Nanticoke Watershed	126964	31319	25	3947***	3***	30***	Tiner et al. 2001
IL	Great Lakes	29000*	na	na	na	24–29**	81–88**	Petrie et al. 2001
IN	Great Lakes	29000*	na	na	na	22–49**	84–92**	Petrie et al. 2001
ME	Casco Bay Watershed	315077	15056****	5	8126	17	52	Tiner et al. 1999
MD	Coastal Bays Watershed	76696	14751	19	1494***	2***	24***	Tiner et al. 2000
MD	Mid-Atlantic Coastal Plain	90000*	na	na	na	4–46**	52–93**	Petrie et al. 2001
MD	Nanticoke Watershed	83692	25967	31	1378***	3***	29***	Tiner et al. 2000
ND	Prairie Potholes	40500*	na	na	na	61–98**	87–99**	Petrie et al. 2001
NY	Cannonsville Reservoir Basin	117377	2309	2	1888	5	15***	Tiner et al. 2002b
NY	Neversink Reservoir Basin	24097	186	1	247	1	2***	Tiner et al. 2002b
SD	Prairie Potholes	41000*	na	na	na	55–78**	88–97**	Petrie et al. 2001
TX	Gulf Coast Prairie	67500*	na	na	na	41–100**	79–100**	Petrie et al. 2001
TX	Playa Region	na	na	na	na	100	100**	Petrie et al. 2001

* Approximate.
** Estimated vulnerability.
*** Excludes ponds.
**** Excludes marine wetlands.
na = not available.

Corps regulatory perspective then, such outflow or headwater wetlands may not be sufficiently connected to tributaries of perennial watercourses to warrant jurisdiction. Regulatory criteria for making wetland determinations should be re-evaluated to ensure that all areas viewed as wetlands by the scientific community are recognized as "waters of the United States" (National Research Council 1995), since they are an integral part of the nation's surface water system.

(3) There is considerable information on the subsurface hydrologic linkage of geographically isolated wetlands to other wetlands and to local stream systems (see hydrologic flow paths in numerous illustrations in Tiner 2003). Is such information sufficient to link this class of wetlands to "waters of the United States" and include them in the regulatory review process established under the Clean Water Act?

VULNERABILITY OF GEOGRAPHICALLY ISOLATED WETLANDS

Geographically isolated wetlands represent a significant portion of the nation's wetlands, and many are biologically rich and/or productive habitats vital to sustaining America's biodiversity. In many areas, especially arid and semi-arid regions and karst regions, they are the predominant wetland type. Because of their position on the landscape (i.e., surrounded by upland), they have always been vulnerable to adverse impacts from human development, especially in agricultural and urban/suburban areas (e.g., filling, drainage, and contamination from agricultural and urban runoff). The impacts of the SWANCC decision on the future of these wetlands are variable and debateable. It must also be recognized that other policies and regulations at various levels of government (federal, state, and local) may provide some protection for isolated wetlands, and these mechanisms are not affected by the SWANCC ruling.

The degree to which geographically isolated wetlands were being protected before the SWANCC decision has not been reported. Since Corps districts develop their own procedures for regulating wetlands and for interpreting the Corps wetland delineation manual (Environmental Laboratory 1987), the regulation of isolated wetlands was likely quite varied prior to the SWANCC decision and probably remains so. In places where geographically isolated wetlands were being regulated (e.g., individual Section 404 permits required), the SWANCC ruling will likely have a significant impact because such areas may no longer be subject to federal regulation unless defined as "adjacent wetlands" or jurisdictional areas meeting other criteria. Where such wetlands were not being regulated, there will be little or no effect from this decision. The effect of SWANCC also depends on how the Corps, the Environmental Protection Agency (EPA), and other courts interpret the decision. If they decide that all isolated wetlands will no longer be regulated under the Clean Water Act, no matter what their role in water quality and maintaining the biological, physical, and chemical integrity of the nation's water, then the impact would be significant. If, instead, they decide that they can no longer use the Migratory Bird Rule solely to justify regulating a geographically isolated wetland as "waters of the United States," but use other criteria, then the impact could be much less. In this case, they might use flood storage, water-quality renovation, and ground-water contributions that ultimately support streamflow and aquatic life as the reasons to regulate certain activities in isolated wetlands.

In places of arid and semi-arid regions where urban development is minimal, the effect of reducing protection through the Clean Water Act may be minimal (Petrie et al. 2001). Isolated wetlands in these areas, especially agricultural areas, may be protected through the Swampbuster provision of the Food Security Act (e.g., a voluntary farm subsidy program) and by various set-aside programs of the U.S. Department of Agriculture (e.g., Wetland Reserve Program and Conservation Reserve Program). However, since changes in one law or regulation often put pressure on other laws, regulations, or policies, the SWANCC decision could lead to heightened efforts to weaken other wetland conservation measures. This may pose the greatest potential threat to geographically isolated wetlands nationwide.

Geographically isolated wetlands in areas experiencing urban and suburban growth may bear the brunt of the SWANCC decision. Wetlands fragmented from other wetlands by roads could be in jeopardy unless they are considered "adjacent wetlands." Again, it is difficult to say anything firm about the impacts since it is unknown to what degree various isolated wetlands (e.g., woodland vernal pools) were regulated beforehand without doing a comprehensive survey of individual Corps districts and/or their staff.

Regardless of the SWANCC decision, geographically isolated wetlands will undoubtedly remain among the nation's most vulnerable wetlands. The fact that they are breeding grounds or prime habitats for so many types of wildlife (e.g., waterfowl, amphibians, and turtles) and their high vulnerability to conversion make it imperative that government agencies, environmental organizations, and others seek ways to improve their protection (see Strategies below).

STRATEGIES FOR CONSERVING GEOGRAPHICALLY ISOLATED WETLANDS

The scientific community recognizes the ecological importance of geographically isolated wetlands (see other papers in this special issue of *Wetlands*). With the SWANCC ruling, many geographically isolated wetlands lost some level of federal government review that helped protect them from certain forms of alteration (e.g., dredging and filling). Many other isolated wetlands may not have received any federal protection from current regulatory programs even before this decision. While strengthening current wetland regulations is one means of protecting these wetlands, regulations alone likely will not protect the biological resources that make many geographically isolated wetlands unique and vital natural resources. For example, many salamanders (*Ambystoma*) breed in woodland vernal pools but spend their juvenile and adult lives as fossorial organisms in adjacent upland forests. Protecting the vernal pool alone will not protect these species, since they require upland forests to complete their life cycle. Both adjacent forests and the vernal pools are needed. Perhaps, natural resource management agencies can promote existing programs or establish new ones to support wetland and forest conservation/management in such areas. This might be accomplished through existing federal and state programs that encourage habitat management on privately owned forests (private forest stewardship). Another option might be to create a fish and wildlife stewardship program that landowners can join by signing an agreement to conserve their vernal pools and the adjacent forest (including application of best management practices for timber harvest). This program could be similar to the FWS's Partners for Fish and Wildlife Program, with an emphasis on preservation and management of existing habitat and restoration of degraded habitat. Participants in this stewardship program could be given an annual subsidy or a tax credit based on the amount of land enrolled in this set-aside/forest management program. Other programs might include acquisition of priority areas (or easements on properties) where geographically isolated wetlands are particularly abundant. These and similar types of non-regulatory natural resource conservation tools may have the best chances for conserving these vital biological resources in the absence of protection through government regulations.

CONCLUSIONS

Geographically isolated wetlands occur throughout the country. Their extent varies with many factors, including climate, topography, surficial geology, glacial history, tectonic events, and human impacts. An analysis of more than 70 sites by the FWS and other agencies has uncovered a wide range of conditions across the country regarding isolated wetlands. Geographically isolated wetlands appear to be more extensive in arid and semi-arid to subhumid parts of the country and in areas of karst topography. Among the areas of the coterminous United States where such wetlands predominate are the Southern High Plains (e.g., Texas Panhandle), the Great Basin (e.g., terminal salt flats), Prairie Pothole Region of the Upper Midwest (e.g., North and South Dakota), Nebraska's Rainwater Basin, the Texas Gulf Coast Prairie, eastern Washington's Channeled Scablands, and north-central Florida (karst topography). Although only a limited number of sites in Alaska were evaluated, extensive areas of isolated wetland may exist on the North Slope and on discontinuous permafrost (Jon Hall, pers. comm. 2002). Wetlands along the Atlantic-Gulf Coastal Plain appear to be mostly linked to adjacent rivers or estuaries. However, many flatwood wetlands may not be recognized as "jurisdictional wetlands" based on current field criteria for determining regulatory wetlands. This may cause numerous depressional wetlands identified as "non-isolated wetlands" in this study to be classified as "isolated" from the regulatory perspective. This is not a trivial matter given that a large portion of the wetlands in the coterminous United States is located in this region.

The SWANCC ruling has lessened the amount of "protection" afforded to "isolated wetlands," since regulatory changes are being made to reduce the scope of federal jurisdiction. Translating the data reported on geographically isolated wetlands in this paper to predict the specific impact of the SWANCC decision, however, is not possible because the federal regulatory agencies have not developed uniform standards for making jurisdictional determinations. Moreover, it is virtually impossible to assess the magnitude of the decision on wetland protection without the following: 1) explicit written guidance from the regulatory agencies on the interpretation of the SWANCC decision, 2) an evaluation of the consistency in application of the Corps manual for wetland delineation (e.g., to determine if wetlands connected by wet flatwoods are considered "jurisdictional" or not), and 3) an analysis of wetland protection provided from other programs and policies (e.g., state wetland programs, definition of "adjacent wetlands," and the Swampbuster provision of the Food Security Act).

Without question, the SWANCC decision has raised concern and public awareness about "isolated wetlands." Rather than serve as a catalyst for weakening environmental protection, it is hoped that this ruling will generate public concern for these wetlands and spur various levels of government to devise alternatives to strengthen wetland conservation and protection. The state of Wisconsin has provided a leadership role in this effort by passing environmental legislation that specifically addresses isolated wetlands. Legislation has recently been filed in the U.S. Congress to clarify federal jurisdiction on waters of the United States (i.e., Clean Water Authority Restoration Act of 2002, Senate bill 2780 and House of Representatives bill 5194). Federal regulatory agencies need to develop written standards for identifying ''jurisdictional'' wetlands beyond the technical guidance offered in the Corps wetland delineation manual (Environmental Laboratory 1987). ''Quality assurance'' mechanisms should also be devised to ensure consistent application of these standards within and across Corps districts and U.S. Environmental Protection Agency regions. Finally, government agencies and nongovernment organizations should initiate nonregulatory conservation strategies to promote wetland conservation and work with private landowners to encourage stewardship of isolated wetlands and their wildlife. Many of these ''geographically isolated wetlands'' are among the nation's most important biological resources.

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