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SHORT COMMUNICATIONS

A Murky Ruling Threatens the Fate of Millions of US Wetlands

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Abstract

For decades, federal protections were extended to wetlands adjacent to "waters of the US" by the Clean Water Act. In its *Sackett v. EPA* ruling, however, the US Supreme Court redefined the meaning of "adjacent," eliminating protections to wetlands without a continuous surface connection to these waters (i.e., geographically isolated wetlands, GIWs). Yet it remains unclear how this continuous surface test will work in reality, where ecological connectivity often extends beyond physical connectivity. Here, we calculate the number of US wetlands that could be considered geographically isolated depending upon the distance threshold used to define isolation (ranging from 1 m to 100 m from the nearest hydrological feature). Overall, we estimate that 27–45% of wetlands, at minimum, could be considered geographically isolated using this range of distance thresholds. Over 3 million wetlands are within 1–100 m of the nearest hydrological feature, making them most vulnerable to losing prior protections from the Clean Water Act. The Midwest and Northeast have the largest share of potential GIWs within this range. Freshwater emergent wetlands and forested/shrub wetlands make up the majority of these vulnerable wetlands, though this varies by state. Roughly 47% of these wetlands are located in states without state-level protections for GIWs. Our analysis highlights the heterogeneity of risk to wetlands across the country and the scale of the uncertainty imposed by the updated Sackett definition. State-level protections that are robust to changes in federal protections are urgently needed to secure the country's wetlands from further pollution and destruction.

Keywords Wetland protection · US Supreme Court · Connectivity · Clean Water Act · Environmental Protection Agency · Wetland policy

Introduction

Wetlands perform essential functions within the landscape, such as water storage and filtration, carbon sequestration, and serving as critical habitat, providing hydrological, chemical, and biological benefits that sustain ecological and sociological well-being (Creed et al. 2017). In some wetland systems, such as riparian networks and floodplain swamps, the hydrological and ecological connectivity between upstream and downstream waters is obvious. Some wetlands are considered "geographically isolated"–surrounded by uplands without persistent surface water connections–but remain functionally connected to the natural landscape through the movements of plants and animals, as well as continuous groundwater and intermittent surface water flow paths. These geographically isolated wetlands (GIWs) support biodiversity and water cycle dynamics due to their unique hydrological regimes and serve as important refuges for rare and threatened species (Cohen et al. 2016). In the conterminous US, it has been estimated that upwards of 8.3 million wetlands (16 million acres) could be considered GIWs (Lane and D'Amico 2016).

The loss of a single GIW can be significant if it supports an endangered species, but the cumulative loss of many of these wetlands can cause regional consequences, reducing hydrological connectivity and increasing isolation. In addition to their ecological importance, these GIWs are economically valuable; it is estimated that ephemeral and seasonal-flowing streams provide an average of $14,400 per hectare in ecosystem services annually in the US (Hill et al. 2014), with wetlands outside of floodplains contributing an additional $102,000 per hectare each year (Adusumilli 2015). For centuries, humans have altered wetland connectivity for flood control, agricultural practices, and

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development, resulting in a loss of 53% of all wetlands in the conterminous US over a period of 200 years (Dahl 1990).

At the federal level in the US, protections for wetlands are secured under the Federal Water Pollution Control Act, also known as the Clean Water Act (CWA), which enables federal agencies to regulate pollutant discharges into "waters of the United States" (WOTUS) and establish surface water quality standards. Historically, most wetlands that border, neighbor, or are contiguous to WOTUS (i.e., "adjacent" wetlands) were considered to fall within the WOTUS jurisdiction and thus under protection by the CWA, though not without frequent legal challenges (Walsh and Ward 2022). A wide range of wetland regulations are also present at the state level, but less than half of all states have explicit protections for GIWs (Creed et al. 2017; McElfish 2022). For many of the country's small, GIWs, protections afforded by the CWA have been critical for filling these state regulatory gaps. Over the last decade, however, the WOTUS definition has been increasingly modified, raising concerns over the future protections of GIWs across the country.

After a long history of regulatory pivots throughout the Obama, Trump, and Biden Administrations (Keiser et al. 2022), the ruling by the US Supreme Court in the case of *Sackett v. EPA* has managed to halt the swing of the policy pendulum while leaving many questions unanswered. Writing for the majority opinion, Justice Samuel Alito argued that the CWA only applies to wetlands with a "continuous surface connection to bodies that are 'waters of the United States'" and concluded that GIWs are not covered by the CWA's extended protections to wetlands that are "adjacent" to waters of the US (Sackett v. EPA 2023). Justice Brett Kavanaugh criticized Justice Alito's definition for its interpretation of the statutory "adjacent" terminology as effectively "adjoining," arguing "By narrowing the Act's coverage of wetlands to only adjoining wetlands, the Court's new test will leave some long- regulated adjacent wetlands no longer covered by the Clean Water Act" (Sackett v. EPA 2023).

The new ruling defines a wetland under WOTUS jurisdiction as (1) having a continuous surface connection with an existing surface water, and (2) being practically indistinguishable from an ocean, river, stream, or lake where the continuous connection is defined. Many have critiqued this decision with near unanimous agreement that it is not scientifically justified and is legally unprecedented relative to past CWA amendments (Sullivan et al. 2020; Ward 2023). Concerns expressed by environmental scientists and legal experts (e.g., Gardner 2023; Sullivan et al. 2020; Ward 2023) warrant a comprehensive and quantitative estimate of the amount and extent of wetlands that are now vulnerable to exclusion under the latest ruling. Recent reports have estimated that 63% of wetlands could be impacted by the Sackett ruling (e.g., Kihslinger et al. 2023), though the methodology underpinning these estimates are not provided. These estimates are critical to understand the potential effects this decision has on the nation's water quality, in addition to motivating state and local governments to bolster existing protections where federal rulings fall short. Here, we expand upon the previous estimates of Lane and D'Amico (2016) to determine to what extent GIWs across the entire US may fall outside federal or state protections.

Methods

We conducted a national-scale assessment for the United States to identify potential GIWs, focusing specifically on the continuous surface connection requirement, to define those wetlands that are beyond a given straight-line distance from existing water bodies. The second requirement that a wetland must be "practically indistinguishable" cannot be definitively assessed at a national scale with existing datasets, and thus we evaluate a range of distances as one approach to address this issue in our analysis. Our analysis therefore reflects the minimum number of wetlands at risk from the Sackett ruling. Although existing wetland protections at the state level can expand upon federal protections to GIWs in some cases, all GIWs in this analysis are similarly considered across states regardless of existing protections. Such state rule protections may now be vulnerable to legal challenges or changes given the new Sackett definition (e.g. North Carolina Farm Act 2023). However, we characterize these risks by distinguishing between states with existing, limited, or no protections for GIWs at the state level (Table 1) based on a review of state wetland policies by Creed et al. (2017).

The National Wetland Inventory (NWI) maintained by the US Fish and Wildlife Service (2023) and the National Hydrography Dataset (NHD) maintained by the US Geological Survey (2023) were used for the assessment. The NWI is the most comprehensive geospatial dataset (1:24,000 scale) of wetlands in the US, representing the combined mapping efforts of states, federal agencies, tribal governments, regional and local governments, and nonprofit organizations. Data are available for over 35 million wetlands classified as "estuarine and marine deepwater," "estuarine and marine wetland," "freshwater emergent wetland," "freshwater forested/shrub wetland," "freshwater pond," "lake," "riverine," and "other." The "other" category includes farmed wetlands, saline seeps, or other miscellaneous types (Federal Geographic Data Committee 2013). The NHD is mapped at 1:24,000 scale and includes line and area features for flow networks and waterbodies, respectively. Both the

Table 1 Level of regulatory protection provided to geographically isolated wetlands by state.
Adapted from Creed et al. (2017)

Existing	Limited	None
California	Illinois	Alaska
Colorado	Indiana	Alabama
Connecticut	Massachusetts	Arkansas
Florida	Michigan	Arizona
Hawaii	New Hampshire	Delaware
Maryland	Nevada	Georgia
Maine	New York	Iowa
Minnesota	Texas	Idaho
Nebraska	Vermont	Kansas
New Jersey	West Virginia	Kentucky
New Mexico		Louisiana
Ohio		Missouri
Oregon		Mississippi
Pennsylvania		Montana
Rhode Island		North Carolina*
Tennessee		North Dakota
Virginia		Oklahoma
Washington		South Carolina
Wisconsin		South Dakota
Wyoming		Utah

* Reclassified from original source due to legislative changes in 2023.

NWI and NHD are available as separate geodatabases or shapefiles for each state. A custom analysis workflow at this spatial scale was used to quantify the amount and areal coverage of GIWs by state. The NWI and NHD are not without accuracy limitations, which primarily include errors of omission/commission–the prevalence of which may vary by region–based on constraints of the data used to create each layer (Matthews et al. 2016; Hafen et al. 2020). However, both datasets represent the best estimate of surface water coverage in the US, and an assessment of potential GIWs is informative regardless of the limitations.

Several data preprocessing steps were required before comparing NWI and NHD features, building on similar methods as Lane and D'Amico (2016). First, NWI classes that were not considered relevant for estimating GIWs were removed. These included wetlands that were connected to existing surface waters by definition alone: estuarine and marine deepwater, estuarine and marine wetland, and riverine. Excluded wetlands totaled 11,239,007 polygons, or 31.8% of all NWI features. Second, wetland polygons that were considered part of the same wetland complex were combined based on spatial proximity. All wetland polygons that overlapped after applying a buffer distance of 0.5 m were combined into one wetland feature, where the majority wetland class among the combined polygons was assigned to the new feature. Third, all wetlands with surface area less than 0.25 acres were excluded from analysis ($n = 11{,}875{,}618$, or 33.6% of all NWI features). This threshold was used to identify "small" wetland features that would typically fall outside the scope of local, state, or federal level protections, thus not requiring permits for activities that can alter, degrade, or eliminate their function. Recognizably, this size threshold can vary by state or smaller regulatory jurisdictions. For example, Florida uses a threshold of 0.5 acres (Florida Administrative Code Rule 62–340), whereas Indiana uses a threshold of 0.1 acres (Indiana Rule 327 IAC 17). As such, the 0.25 minimum acreage criteria represents a generic de minimis threshold that acknowledges most states do not protect small wetlands. Further, the minimum mapping unit (or target mapping unit) for the NWI has varied over time, though the current minimum is 0.5 acres for most locations with some allowances for special mapping projects (Federal Geographic Data Committee 2009). Therefore, the percentage of wetlands smaller than 0.25 acres noted above, as well as those less than half an acre, is likely an underestimate of the actual total. For the NHD layers, only relevant feature types were retained, which included canals/ditches, streams/rivers (perennial, intermittent, ephemeral), coastlines, and artificial paths from the flowlines layer and lakes/ponds, reservoirs, and estuaries from the waterbodies layer. We made no distinction between potentially ephemeral/intermittent and perennial streams in the NHD flowlines layer. The decision to include all stream classifications is an acknowledgement of the uncertainty of these classifications at the NHD scale (i.e., field-based assessments are needed to accurately characterize flow regimes) and that their inclusion provides us with a more conservative estimate of GIWs. Their inclusion also implicitly assumes that ephemeral/intermittent streams are within WOTUS, which is another area of current debate that our analysis does not address.

Our analysis was conducted using the open source R statistical programming language (version 4.2.3; R Core Team 2023). A custom workflow was developed to iteratively download the NWI and NHD spatial layers for each state to identify GIWs based on the Euclidean distance of wetland features to NHD features. The simple features package, "sf" (Pebesma and Bivand 2023), provided the core functions for the spatial analyses, including use of the st_read() function for importing relevant layers from the state geodatabases and calculating distances between features using the st_nearest() function. For the latter analysis, the NWI layer for each state was compared separately to the flowline and waterbody layer from the NHD, resulting in an index of NHD features that were nearest to each NWI feature. The distance between the NWI features and the nearest NHD feature were estimated using the st_distance() function and the minimum distance to either a flowline or waterbody feature was estimated for each wetland. The final datasets included tabular information for each state, where each row was an individual wetland, with columns for the wetland attribute, acreage of the wetland, latitude and longitude (WGS 1984) of the wetland centroid, distance of the wetland in meters to the nearest NHD feature, the state abbreviation, and wetland type. All geospatial analyses were conducted using the Albers equal area projection with a North American Datum of 1983.

The state tabular data with the distance of each wetland feature to the nearest NHD feature were used to quantify the amount and extent of GIWs using a range of thresholds. In total, 35,291,995 wetlands were assessed, where the distance to NHD features ranged from 0 to 26 km. A range of distances for each NWI feature to the nearest NHD feature were used to develop an expectation of the amount and extent of GIWs at risk in each state. The Supreme Court decision that wetlands must have a “continuous surface connection” to existing navigable waters does not provide specificity or quantitative guidance on how this should be defined; it implies a zero distance between a wetland and WOTUS boundary, yet measurements on the ground could vary depending upon low- and high-water marks of navigable waterways (Gardner 2023). The range of values used to quantify potential GIWs in our analysis varied from 1 to 100 m (at 10 m intervals) to take into account this uncertainty in the current definition, as well as the uncertainty in the mapping products used in the analysis. Our range provides estimates for identifying GIWs using this strict zero distance threshold, as well as estimates under more modest thresholds given boundary uncertainties (cf. Wade et al. 2022) and up to the approximate distance that was challenged in the *Sackett v. EPA* case. This range also provides more flexibility in assessing potential GIWs across states, given Lane and D’Amico’s (2016) prior estimates that were focused at discrete 10-, 30-, and 300-m buffer intervals. Further, the criterion that a wetland must be “practically indistinguishable” from an existing surface water is not clearly defined, and using a range of straight line distances allows for some differences in interpretation of this ruling. Recognizably, natural hydrologic flows are determined through complex interactions between topography, soil infiltration, groundwater influences, and seasonal weather patterns. A straight-line distance does not fully account for these factors, but provides a reasonable approximation in the absence of incorporating additional datasets to more accurately define water flow between hydrologic features. Based on these ranges, the amount and extent of GIWs in each state were quantified, including an assessment of GIWs by wetland type (i.e., freshwater emergent, freshwater forest/shrub, etc.).

We further characterize vulnerable wetlands according to their overlap with existing protected areas. We identified wetlands within protected areas by intersecting the wetland centroids with polygons in the Protected Area Database (PAD-US) maintained by the US Geological Survey Gap Analysis Project (2022). This database is a comprehensive inventory of protected areas, including public and private lands, that are categorized by “GAP status” indicating how they are being managed for conservation purposes. Each feature is assigned an integer of 1 to 4 for the GAP status, with decreasing protections for higher numbers. We focus attention to identifying wetlands within protected areas with a GAP status of 1 or 2; those with GAP status 1 have permanent protections and mandated management plans for biodiversity, and those with GAP status 2 are similar but may receive uses or management practices that degrade the quality of natural communities (e.g., suppression of natural disturbances). Any wetlands within GAP 3 or 4 protected areas are grouped together with wetlands outside protected areas in our analysis given their weaker protections; protected areas in GAP status 3 may be subject to extractive uses (e.g., logging, mining) and those in GAP status 4 have no mandated biodiversity protections.

Results

We estimate that 7.74 million wetlands (45% of all wetlands included) could be considered geographically isolated using the 1 m distance threshold. This represents nearly 41 million acres, or 16% of the total wetland area evaluated (Fig. 1a). Under a greater threshold (100 m), the number of GIWs could reduce to 4.68 million (27%), covering 27.4 million acres (6%). Protections for the 3.06 million wetlands (18%) within this distance range are the most vulnerable under an interpretation of the recent Sackett ruling. Nearly half of these wetlands (47–48%) are located in states without existing protections for GIWs, while 15–16% are in states with some limited protections in place. These GIWs are most prevalent in the northern Midwest, southeastern, and northeastern states (Fig. 1b)–a pattern that remains consistent regardless of distance threshold used (see Online Resource). For example, approximately 51–76% of wetlands in North and South Dakota could be considered geographically isolated (depending on the distance threshold), representing 26–38% of each state’s wetland area. GIWs represent 28–55% of all wetlands in Florida and South Carolina (10–35% of their wetland area), and in the northeast, Delaware and Maryland have some of the highest representation of GIWs (26–60% of their wetlands, 12–50% of their wetland area). Notably, our estimates of the area of GIWs are far larger than the 16 million acres estimated previously by Lane and D’Amico (2016). This discrepancy may be due to differences in distance thresholds used, as well as nearly a

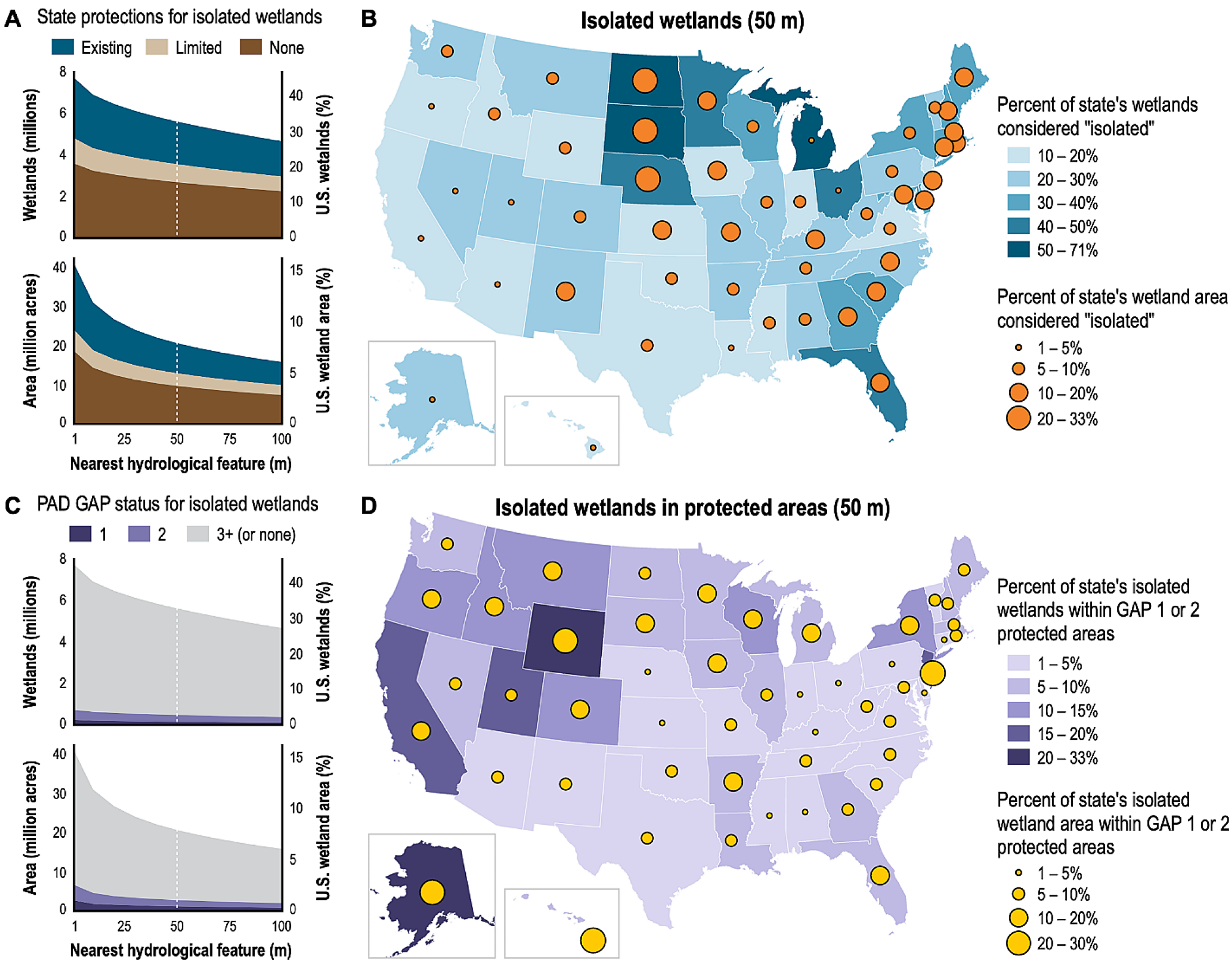

Fig. 1 (**A**) The share of US wetlands that could be classified as "geographically isolated" using different definitions of isolation depending upon their proximity to the nearest hydrological feature (1 to 100 m), and distinguished between wetlands in states with existing, limited, or no protections for geographically isolated wetlands. Dotted line indicates the average distance threshold investigated (50 m), which is used in (B). (**B**) Proportion of each state's total number of wetlands and total wetland area that could be considered geographically isolated using a 50 m distance threshold. (**C**) The share of geographically isolated wetlands that are within protected areas with a PAD GAP status of 1 or 2. (**D**) Proportion of each state's total number and area of geographically isolated wetlands that are located within a GAP 1 or 2 protected area

decade of updates to the wetland area mapped in the NWI dataset.

Overall, 9% of all wetlands considered in this analysis (and 16% of the total wetland area) are within protected areas with strict biodiversity protection mandates (GAP status 1 or 2). This pattern is also reflected in the share of GIWs within GAP 1 or 2 protected areas; depending on the distance threshold, 8–9% of GIWs are within these protected areas, which represents 13–16% of the total area of GIWs (Fig. 1c). However, there is a significant spatial bias that reflects the well-known bias of the US protected area network toward western and more remote states (Fig. 1d). For example, 22–26% and 32–35% of GIWs are within GAP 1 or 2 protected areas in Wyoming and Alaska, respectively, which have some of the largest protected areas in the country. For most states, however, only a small portion of their GIWs are within these protected area boundaries, with little variation between distance thresholds (see Online Resource).

The majority of wetlands at risk are freshwater emergent wetlands (e.g. marshes, wet prairies) (Fig. 2a). These wetlands make up 45–58% of all wetlands classified as geographically isolated under the different distance thresholds. Freshwater forested or shrub wetlands (e.g. swamps, hammocks, wet flatwoods), however, have the greatest area at risk: 57–66% of the total GIW area consists of these wetlands. For each state, we examined which wetlands have a disproportionately greater share of their wetlands classified as geographically isolated, as well as how much each wetland type contributes to the state's total number of GIWs

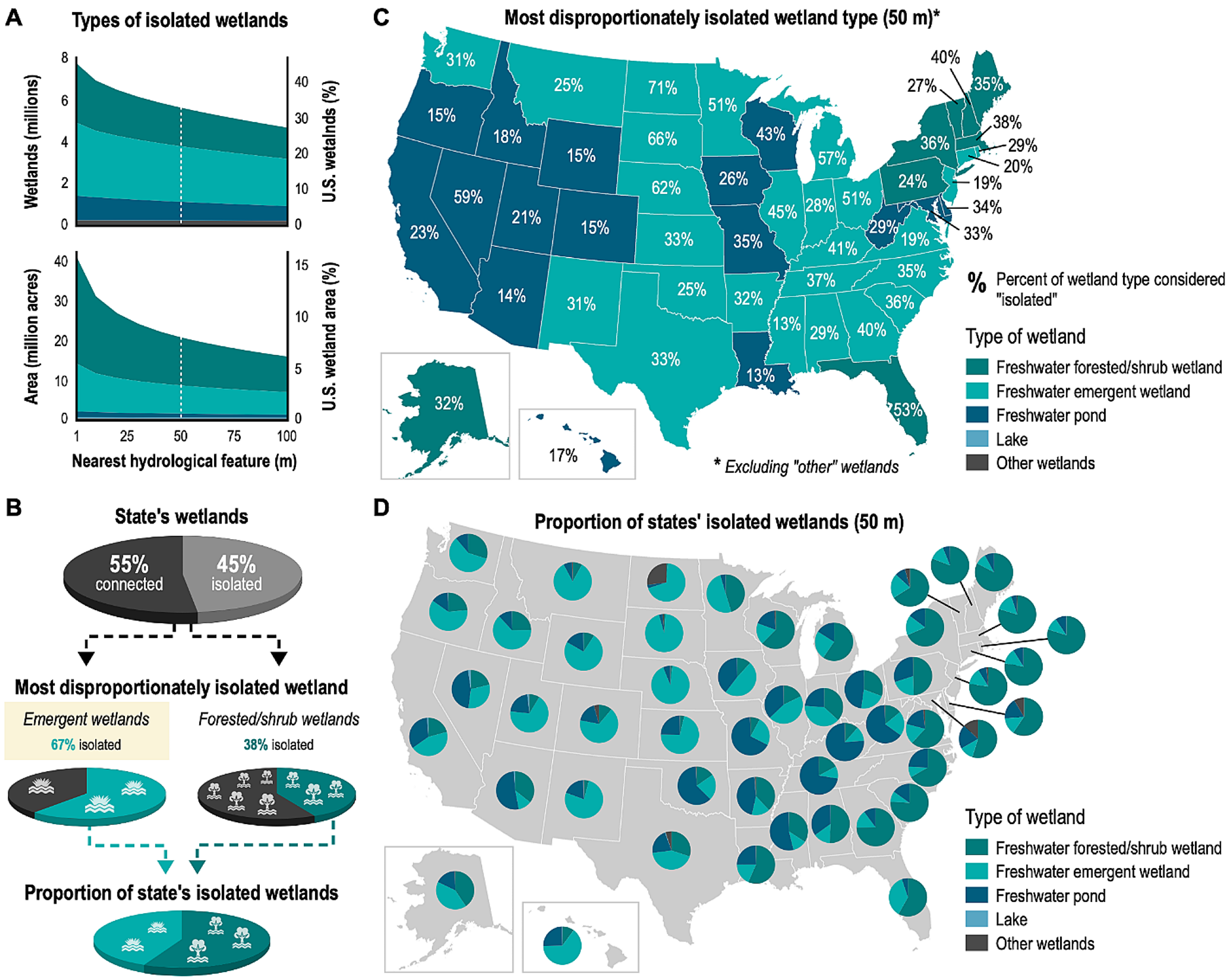

Fig. 2 (**A**) The share of US wetlands that could be classified as "geographically isolated" using different definitions of isolation depending upon their proximity to the nearest hydrological feature (1 to 100 m) according to the type of wetland. Dotted line indicates the average distance threshold investigated (50 m), which is used in (C) and (D). (**B**) Diagram illustrating the process for characterizing states' geographically isolated wetlands according to wetland type. (**C**) The type of wetland in each state (excluding "other" wetlands) with the greatest proportion considered isolated, using a 50 m distance threshold. Percentages show the percent of the respective wetland type that is considered isolated for each state. (**D**) The proportion of each state's total number of geographically isolated wetlands according to the type of wetland, using a 50 m distance threshold

(Fig. 2b). We found a high degree of variability between states; although emergent wetlands are the most disproportionately isolated type of wetland for most states, freshwater ponds and forested/shrub wetlands are the most isolated type in the west and northeast, respectively (Fig. 2c), though there is considerable variation depending upon the distance threshold (see Online Resource). This is often in contrast to each states' total number of GIWs within each type (Fig. 2d). For example, although emergent wetlands constitute just 9% of all GIWs in North Carolina, these isolated wetlands represent 28–52% of all emergent wetlands in the state–the highest of all wetland types. Overall, there is a noticeable pattern in the number of GIW types across the country; forested/shrub wetlands constitute most of the share of isolated wetlands along the east coast, while freshwater ponds are more frequent in the central US and Appalachia, and emergent wetlands in the northern and western states (Fig. 2d). Notably, 86–95% of "other" wetlands (e.g. farmed wetlands, saline seeps) could be considered geographically isolated—the highest share of any wetland type—but make up less than 2% of all wetlands in the country.

Discussion

Environmental policy should be based upon the best available and most broadly accepted scientific standards, definitions, and recommendations. The Sackett ruling affects vital ecological systems and services that the US relies upon for public health, environmental sustainability, and economic success. An impactful federal policy definition, such as "WOTUS," should at a minimum reference scientifically accepted assessments. The undefined "continuous surface water connection" standard referenced in the SCOTUS majority opinion falls short of providing national to local legal interpretations and policy guidance for ecologically and economically vital wetlands of the US. Although federal guidance states that the NWI and NHD datasets are insufficient for spatial descriptions of WOTUS, primarily due to errors of omission and commission (USEPA 2020a), this argument is ultimately a red herring. These datasets represent the most comprehensive, national-scale source of information on surface water coverage in the US (Ward 2023), and an objective assessment of wetlands at risk with these data remains highly informative regardless of the data limitations. Technological advances are on the horizon, however, that may be able to provide more robust wetland maps in the near future, such as the Wetland Intrinsic Potential tool (Halabisky et al. 2023). It is imperative that our estimates are updated as additional data and mapping tools arise. Future studies should expand upon our analysis to more comprehensively assess the extent of wetlands at risk from all components of the new WOTUS definition, including more refined or place-based de minimis activity thresholds to most accurately characterize GIWs in different states.

Recognizably, the WOTUS definition has changed before and will likely change again. Yet state and local governments should not be reliant upon federal policy to comprehensively protect the varied wetland types represented across the US (Creed et al. 2017; Sulliván 2023). State and local governments should take this opportunity to strengthen, expand, or initiate protections for habitats that are threatened by anthropogenic harm and may now fall outside federal protections. However, the opposite approach is now being taken. At the state level, wetland protections are already aligning with this new federal policy. For example, the North Carolina legislature overruled a gubernatorial veto through a supermajority vote in both chambers to repeal existing state-level protections for GIWs just one month after the Sackett opinion was published (North Carolina Farm Act 2023). Local protections risk further contraction to this federal standard given continuing economic growth and development pressures.

It is unclear how the Sackett ruling will impact environmental protection regulations in states like Florida, where delegation of Sect. 404 wetland permitting was transferred from the Environmental Protection Agency (USEPA 2020b) to the state Department of Environmental Protection and is currently being challenged in the case of *Center for Biological Diversity et al. v. Wheeler et al.* (US District Court for the District of Columbia 2024). Our analyses attempted to categorize risks at the state level, where existing, limited, or no GIW protections could be readily discerned. However, wetland protection standards under more local governance models should not be discounted as important public policy. In the Tampa Bay region of Florida, for example, definitions of "waters of the state and/or county" provide an additional backstop to limiting impacts to isolated freshwater wetlands that provide important migratory bird habitat functions across state jurisdictions, while also being conduits for direct aquifer recharge of regional and state drinking water supplies. Likewise, Maine specifically recognizes and manages unique, GIW types that are identified and valued as rare ecosystems under state policies. Despite some states having more protective regulatory frameworks for GIWs, the Sackett ruling may increase their exposure to future legal challenges, creating additional economic and litigious burdens on the state.

Scientific consensus remains that wetlands, no matter their size or interconnectivity, are vital to biodiversity and human well-being. While we strive to limit our impacts to these systems through various policies (e.g. "WOTUS" or "no net loss" in the US), globally our efforts are failing (Convention on Wetlands 2021). The Sackett ruling is already leading to cascading policy effects at the state-level (e.g., North Carolina Farm Act 2023), and further erosion of local protections may be on the horizon (McElfish 2022). Our analyses reinforce that collective protections at the federal, state, and local level are needed to reverse wetland attrition within the US and to help meet global goals to sustain social and ecological systems.

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Author Contributions BAS conceptualized the study. BAS, MWB, KFW, and ES contributed to the methodology. BAS and MWB analyzed the data. BAS, MWB, KFW, JL, and ES contributed to writing and reviewing the manuscript.

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Data Availability All data used for analyses are available from their respective sources. R code for replicating this analysis is available from GitHub (https://github.com/tbep-tech/wetlands-eval). The complete dataset, with files for each state, is hosted on the Knowledge Network for Biocomplexity (https://doi.org/10.5063/F1W37TSF).

Declarations

Competing Interests The authors have no relevant financial or non-financial interests to disclose.

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