DEPARTMENT OF NATURAL RESOURCES

Wetland Hydrology Monitoring

2018-2022

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Abstract

The Minnesota Wetland Hydrology Network (WHyN) was established by the Minnesota Department of Natural Resources (DNR) to collect long-term data on hydrologic regimes of reference condition wetlands. Wetlands vary in depth, duration, frequency, and timing of water levels, leading to variation in vegetation, function, and ecosystem services. Some wetlands depend on groundwater, and therefore can be impacted by groundwater use. Long-term data can help characterize normal hydrologic regimes for wetlands, which can then inform regulatory decisions related to groundwater impacts, landscape alterations, and wetland restoration. While existing projects in the upper Midwest provide important information on long-term wetland hydrology, none span the range of wetland types and geographic extent of wetland coverage in Minnesota. WHyN aims to fill this gap with long-term monitoring of multiple types of wetlands across the state. We have established 25 monitoring sites by installing shallow monitoring wells and conducting baseline vegetation surveys. The initial four years of the project involved refining hydrologic monitoring methods for wetlands in response to several challenges. Initial results suggest that wetlands within a category may be characterized by similarities in temporal variation in water levels and sensitivity to precipitation. The final network will include 60 monitoring sites. We expect that long-term data from WHyN will aid in developing guidelines for impacts to wetland hydrology.

Introduction

Wetlands in Minnesota and throughout the United States support diverse flora and fauna and provide integral ecosystem services. The hydrologic regimes of wetlands, including the frequency, depth, duration, and timing of water saturation and inundation, influence the composition of wetland plant communities (Seabloom et al. 1998, Aldous and Bach 2014, Mushet et al. 2022). Minnesota has many different types of wetlands that vary in vegetation, soil properties, geomorphic setting, water source, and hydrologic regime (Shaw and Fredine 1956, Brinson 1993, MN DNR 2003, 2005a, 2005b, Eggers and Reed 2015). General hydrologic characteristics, such as an average inundation depth and duration, are expected to characterize different wetland types (USACE 2019) (Table 1). However, the full range of hydrologic conditions that are associated with any given wetland type are not known. Long-term data from unimpacted, reference condition wetlands can help inform the conditions necessary to maintain and restore the hydrology and plant communities of impacted wetlands. For example, wetlands often have a hydrologic connection with groundwater and may therefore be influenced by nearby groundwater use, such as municipal supply or agricultural irrigation (MN DNR 2016). While the MN DNR and other agencies have long-term monitoring from lakes, streams, and groundwater to assist with assessment of groundwater use impacts, such foundational data for wetlands are lacking. Therefore, MN DNR is establishing a monitoring network to measure long-term trends of wetland hydrology. This long-term data will aid the characterization of normal wetland hydrologic regimes and thus help identify deviations that could cause ecological impacts. This objective addresses the need for “thresholds for negative impacts to surface waters”, as described in Minnesota Statutes (MN DNR 2016).

The Minnesota DNR received an EPA Wetland Program Development Grant in late 2018 to establish the first 20 sites of the Wetland Hydrology Network (WHyN). In 2021, MN DNR received a grant from the LCCMR to expand the network to 40 more sites, five of which were installed in 2022. Here, we describe the methods used to establish the first 25 sites and present initial results. Data collected from WHyN will be used to develop hydrographs (ranges of observed water levels over time) for different wetland types. Because wetlands within the network have relatively high-quality plant communities and relatively unimpacted hydrology, the hydrographs may be used to guide wetland restoration (USACE 2019) and modeling that would inform regulatory water use decisions (MN DNR 2016). Further, data collected from the network can be used to address fundamental questions about wetland hydrology, including:

- How do hydrologic conditions vary across wetland community types?
- How do hydrologic conditions in each of the wetland community types vary by Minnesota ecological province?
- How do hydrologic conditions in wetlands relate to weather, climate, and nearby land-use?

Wetland community types that will be represented in WHyN include shallow open water/deep marshes, shallow marshes, marshes with sedge mats, fens, bogs, fresh meadows, shrub and wooded swamps, and floodplain forest. Most of these wetland types are defined in Eggers and Reed (2015). We expect that wetlands will vary in depth, duration, timing, and frequency of water saturation and inundation (Table 1). Ecological provinces that will be represented in WHyN include Prairie Parkland/Tallgrass Aspen Parkland, Eastern Broadleaf Forest, and Laurentian Mixed Forest. We expect differences in climate and geology across ecological provinces will cause variation in wetland hydrology (Table 2). We expect that increasing frequencies of extreme precipitation events (MCAP 2022) will lead to broader hydrologic regimes, including higher water levels of short duration following heavy snow and rain storms and more frequent periods of low water levels during droughts.

Table 1. Wetland community types, dominant or characteristic vegetation, and current knowledge about growing season hydrology under normal or wetter-than-normal weather conditions.

Wetland community type	Description	Vegetation	Expected Hydrology
floodplain forest	Occur in river floodplains. Alluvial, mineral soils are dynamic and do not develop hydric features typical of other wetland types. Dominated by hardwood trees, with sparse shrub layer and herbaceous ground layer. Circular 39 type 1.[1,3]	Silver maple (*Acer saccharinum*), American elm (*Ulmus americana*), river birch, green ash (*Fraxinus pennsylvanica*), black willow (*Salix nigra*), swamp white oak (*Quercus bicolor*), box elder (*Acer negundo*), plains cottonwood (*Populus deltoides*)[1,2]	Temporarily inundated during flooding for ~14-28 days (exceptions to upper limit). Water depth depends on site.[3,4]
fresh meadow	Nearly continuous vegetative cover on well-developed peat, muck, or mineral soils. May be dominated by sedges (sedge meadow) or grasses and forbs (wet to wet-mesic prairie or fresh wet meadow). Often transitional between aquatic communities and upland. Circular 39 type 1 or 2.[1,3]	Sedge-dominated: tussock sedge (*Carex stricta*), lake sedge (*Carex lacustris*), water sedge (*Carex aquatilis*), and/or other sedges. Grass/forb dominated: Canada bluejoint (*Calamagrostis canadensis*), prairie cord-grass (*Spartina pectinata*), big bluestem (*Andropogon gerardii*), narrow reedgrass (*Calamagrostis stricta*), switch grass (*Panicum virgatum*), native forbs.[1, 5-7]	Water table within 12 in. of surface for ≥ 28 consecutive days, two periods of ≥ 14 consecutive days, or (for organic soils) from the start of the growing season to at least July 1st (later for groundwater-fed or lacustrine fringe). Inundation ≤ 6 in. for < 14 consecutive days at the start of the growing season or after extreme precipitation events. Extended inundation ≤ 6 in. in hollows between hummocks.[3,4]
fen	Open peatlands influenced by groundwater. Dominated by graminoids and low shrubs. Can have variable forb cover and sphagnum moss. Water chemistry varies and influences plant community composition. Circular 39 type 2.[3,5-8]	Wiregrass sedge (*Carex lasiocarpa*), lesser panicled sedge (*Carex diandra*), prairie sedge (*Carex prairea*), cottongrasses (*Eriphorum* spp.), bog willow (*Salix pedicellaris*), leatherleaf (*Chamaedaphne calyculata*), bog rosemary (*Andromeda glacophylla*), marsh cinquefoil (*Potentilla palustris*), shrubby cinquefoil (*Dasiphora fructicosa*), northern marsh fern	Same as fresh meadow, organic soils, when peat surface is considered ground surface. Greater water depth and duration when mineral soil is considered ground surface.

Wetland community type	Description	Vegetation	Expected Hydrology
		(*Thelypteris palustris*), northern bog violet (*Viola nephrophylla*), marsh St. John's wort (*Triadenum fraseri*), willowherbs (*Epilobium* spp.), Canada bluejoint (*Calamagrostis canadensis*) clustered muhly grass (*Muhlenbergia glomerata*)[5-7]	
shallow marsh	Dominated by emergent aquatic species. Submerged and floating plants may be present. Plant species are similar to deep marsh, but hydrology differs. Circular 39 type 3.[1-3]	Reeds, whitetop, rice cutgrass (*Leersia oryzoides*), carex (*Carex* spp.), giant bur-reed (*Sparganium emersum*), bulrushes (*Cyperaceae* family), spikerushes (*Eleocharis* spp.), cattails (*Typha* spp.), arrowheads (*Sagittaria* spp.), smartweeds (*Polygonum* spp.)[1,2]	Inundation ≤ 6 in. for ≥ 28 consecutive days during growing season. With extreme precipitation events, inundation > 6 in. and ≤ 18 in. for < 28 consecutive days.[1-4]
deep marsh/ shallow open water	The deepest wetland community types. Contain emergent, submerged, and floating aquatic species. Emergent abundance less than or equal to others in deep marsh and restricted to borders in shallow open water. Circular 39 type 4 or 5.[1-3]	*Potamogeton* spp., naiads (*Najas* spp.), coontail (*Ceratophyllum demersum*), water milfoils (*Myrophyllum* spp.), waterweeds (*Elodea* spp.), duckweeds (*Lemnoideae* subfamily), water lilies (*Nymphaeaceae* family), spatterdocks (*Nuphar* spp.), wild celery (*Vallisneria americana*), muskgrasses (*Chara* spp.), cattails (*Typha* spp.), reeds, bulrushes (*Cyperaceae* family), spikerushes (*Eleocharis* spp.), wild rice (*Zizinea* spp.)[3]	In deep marsh, inundation of 6-48 in. throughout growing season unless drought. In shallow open water, permanent to nearly permanent depth of 48-80 in. Usually less than 10 ft of inundation.[1-4]
marsh with sedge mat	Floating mat with vegetation similar to fens and hydrology similar to marshes.[1,2,8]	Wiregrass sedge (*Carex lasiocarpa*) and/or few-seeded sedge (*Carex oligosperma*). May also have other sedges, Canada bluejoint (*Calamagrostis canadensis*), northern marsh fern (*Thelypteris palustris*), and various forbs.[1, 2] *Sphagnum* cover typically < 25% and often absent.[5-7]	Same as shallow marsh or deep marsh.[3,4]

Wetland community type	Description	Vegetation	Expected Hydrology
shrub/wooded swamp	Dominated by woody vegetation. Circular 39 type 6 or 7.[1,3]	Shrub swamps: alders (*Alnus* spp.), willows (*Salix* spp.), dogwoods (*Cornus* spp.), buttonbush (*Cephalanthus occidentalis*), and meadowsweet (*Spirea* spp.). Non-native buckthorns (*Rhamnus cathartica* and *Frangula alnus*) can be present. Wooded swamps: tamarack (*Larix laricina*), black spruce (*Picea mariana*), northern white cedar (*Thuja occidentalis*), red maple (*Acer rubrum*), silver maple (*Acer saccharinum*), black ash (*Fraxinus nigra*), green ash (*Fraxinus pennsylvanica*), yellow birch (*Betula alleghaniensis*), quaking aspen (*Populus tremuloides*), balsam poplar (*Populus balsamifera*), plains cottonwood (*Populus deltoides*), and black willow (*Salix nigra*). Vernal pool wooded swamps also have American elm (*Ulmus americana*) and yellow-bud hickory (*Carya cordiformis*).[1-3]	Same as fresh meadow, organic soils.[4]
bog	Saturated, acidic, peat soils with low concentrations of minerals and essential nutrients. Vegetation can be woody, herbaceous, or both. Nearly continuous sphagnum moss (*Sphagnum* spp.). Trees may be scattered and often stunted. Circular 39 type 8.[1-3]	Sedges (Cyperaceae family), cottongrass (*Eriophorum* spp.), and heath shrubs (Ericaceae family), including leatherleaf (*Chamaedaphne calyculata*), Labrador tea (*Rhododendron tomentosum* and *R. groenlandicum*), cranberries (*Vaccinium* subg. *Oxycoccus*), black spruce (*Picea mariana*), and tamarack (*Larix laricina*).[1-3]	Same as fresh meadow, organic soils, when peat surface is considered ground surface.[4] Greater water depth and duration when mineral soil is considered ground surface.

1. (Eggers and Reed 2015) 2. (Bourdaghs 2012) 3. (Shaw and Fredine 1956) 4. (USACE 2019) 5. (MN DNR 2005a) 6. (MN DNR 2005b) 7. (MN DNR 2003) 8. (Cohen et al. 2020)

Table 2. Characteristics of Minnesota's ecological provinces that are expected to influence wetland hydrology

Ecological Province	Climate	Geology	Wetland features
Prairie Parkland and Tallgrass Aspen Parkland[1]	MAT: 2-9°C ET > Precip MAP: 46-84 cm	Thick mantle drift deposited by glaciers. Deep-water sediments deposited by Glacial Lake Agassiz in northern portion.	Floodplain forests, fresh meadows, and marshes were historically common and those that remain tend to be disturbed; wooded swamps are uncommon; limited peat development; some peatland communities in the northern portion or associated with groundwater discharge or floating mats
Eastern Broadleaf Forest[2]	MAT: 3-8°C ET ≈ Precip MAP: 60-90 cm	Thick glacial drift deposits that are highly calcareous. Deep river valleys. Southeastern portion not covered by ice in last glaciation and has deep river valley, exposed bedrock, and older drift.	Extensive floodplain forests; fresh meadows and marshes are common; limited peat development except in northern portion; wet forests are uncommon; groundwater discharge or formation of floating mats can support some peatland communities, which are at their range edge
Laurentian Mixed Forest[3]	MAT: 1-4°C ET < Precip for most of province MAP: 53-81 cm	Rugged lake-dotted terrain with thin glacial deposits over bedrock. Hummocky or undulating plains with deep glacial drift. Large, flat, poorly drained peatlands.	Extensive peat development; wooded swamps, fresh meadows, and marshes are common; narrower floodplain forests than other two provinces

1. (MN DNR 2005a) 2. (MN DNR 2005b) 3. (MN DNR 2003) Abbreviations: MAT = mean annual temperature range, ET = evapotranspiration, Precip = precipitation, MAP = mean annual precipitation range

Methods

Site Selection

The first twenty sites established for WHyN are primarily within the Prairie Parkland and Eastern Broadleaf Forest ecological provinces, with two in the Laurentian Mixed Forest Province (Figure 1). A monitoring site must be located on land where long-term operation of hydrology equipment is possible, so public lands were targeted.

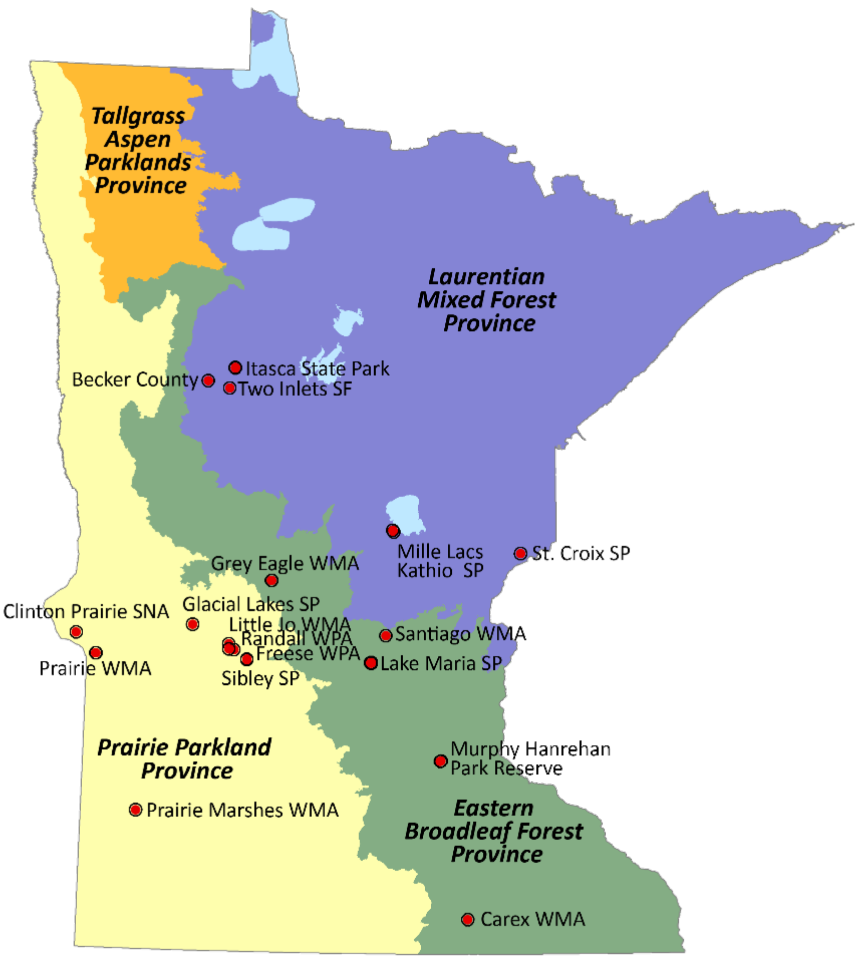

Figure 1. Map of land management units hosting WHyN sites. Abbreviations are: SF = state fores, SNA = scientific and natural area, SP = state park, WMA = wildlife management area, WPA = waterfowl production area.

To assess hydrology as close to natural conditions as possible, we selected wetlands free from human manipulation, such as ditching, and outside impacts from groundwater withdrawals. To assess wetland vegetation types that reflected high floristic quality and were representative of wetland targets set by restoration and land managers, we selected wetlands with low non-native invasive vegetation coverage. Additionally, the project goals include assessing hydrology within a single wetland type. Many wetland basins contain multiple wetland types across ground surface elevation gradients (Eggers and Reed 2015). We aimed to select basins that were either a single type or that had a large area of the target wetland community type, which is typically where hydrology equipment was installed.

We are establishing up to three site replicates of each wetland community type (*N* = 8) in each ecological province (*N* = 3) for a total of 60 sites (Table 3). Some wetland community types, such as shrub and wooded swamp or bogs will have lower replication in the Prairie/Tallgrass Aspen Parkland province. Some land management units (e.g., a state park) contain more than one site of different wetland community types.

Table 3. Established sites for each wetland community type in each ecological province. Italicized site names are newly installed and do not have data in this report. Crossed out sites were removed. When the network is fully established, we anticipate 3 sites in each box of the matrix.

Expected water regime	Wetland community type (Eggers and Reed)	Hydrogeomorphic class	Prairie/Tallgrass Aspen Parkland sites	Eastern Broadleaf Forest sites	Laurentian Mixed Forest sites
Temporarily to seasonally flooded	floodplain forest	riverine floodplain flat			
Seasonally flooded	fresh wet meadow Sedge meadow	depression/flat	Prairie WMA 1 Clinton 1	Lake Maria 2 Grey Eagle 2 Santiago 1	
Saturated	fen	depression/ peatland	Sibley State Park 3	Lake Maria 3 Grey Eagle 1 Murphy 2	Becker 1
Seasonally Flooded	shallow marsh	depression	Glacial Lakes 1 Prairie WMA 2 Sibley State Park 1	Lake Maria 1	Becker 2 (Two Inlets)
Semi-Permanently Flooded to Intermittently Exposed	marsh with sedge mat	depression	Little Jo 1 Randall 1	Carex 1	Itasca 1
Semi-Permanently Flooded to Intermittently Exposed	deep marsh/shallow open water	depression	Prairie Marshes 1 ~~Sibley State Park 2~~ Freese 1	Murphy 1	
Temporarily to Seasonally Flooded	shrub/wooded swamp	depression/flat			Mille Lacs 2 St. Croix 1
Saturated	Organic Flat, Open and Coniferous bogs	organic flat/peatland			Mille Lacs 1

Hydrology Equipment

As the project has progressed, we have learned how to design hydrology monitoring stations suited to our project goals. We have therefore changed the equipment installed at many of the established wetland sites over the course of the project. As of spring 2022, we have equipped all sites with the finalized hydrology monitoring station design (Figure 2). This design consists of an OTT Orpheus Mini Water Level Logger (OTT) that collects water level data every 15 minutes. This is a datalogger and submersible pressure transducer, powered by Lithium-ion AA batteries. The transducer is covered by a 4 in. x 4 in. square of landscaping fabric to prevent sediment build-up and housed in a 2 in. diameter slotted PVC pipe, which is buried 2-3 ft below substrate within the wetland, although sometimes shallower if substrate is too restrictive. The slotted PVC has 0.010 in. openings which prevent sediment build-up and is anchored to a fence post for stability. In some cases, rather than anchoring to a fence post, the PVC pipe is anchored within a 4-6 in. diameter steel case with a lock to protect the equipment from prescribed burns. The datalogger is either housed within a cylindrical steel case that can be placed in nearby upland or on the same fencepost as the PVC pipe, or in a mounted steel box in nearby upland. When the datalogger is placed in nearby upland, it is connected to the transducer with buried conduit.

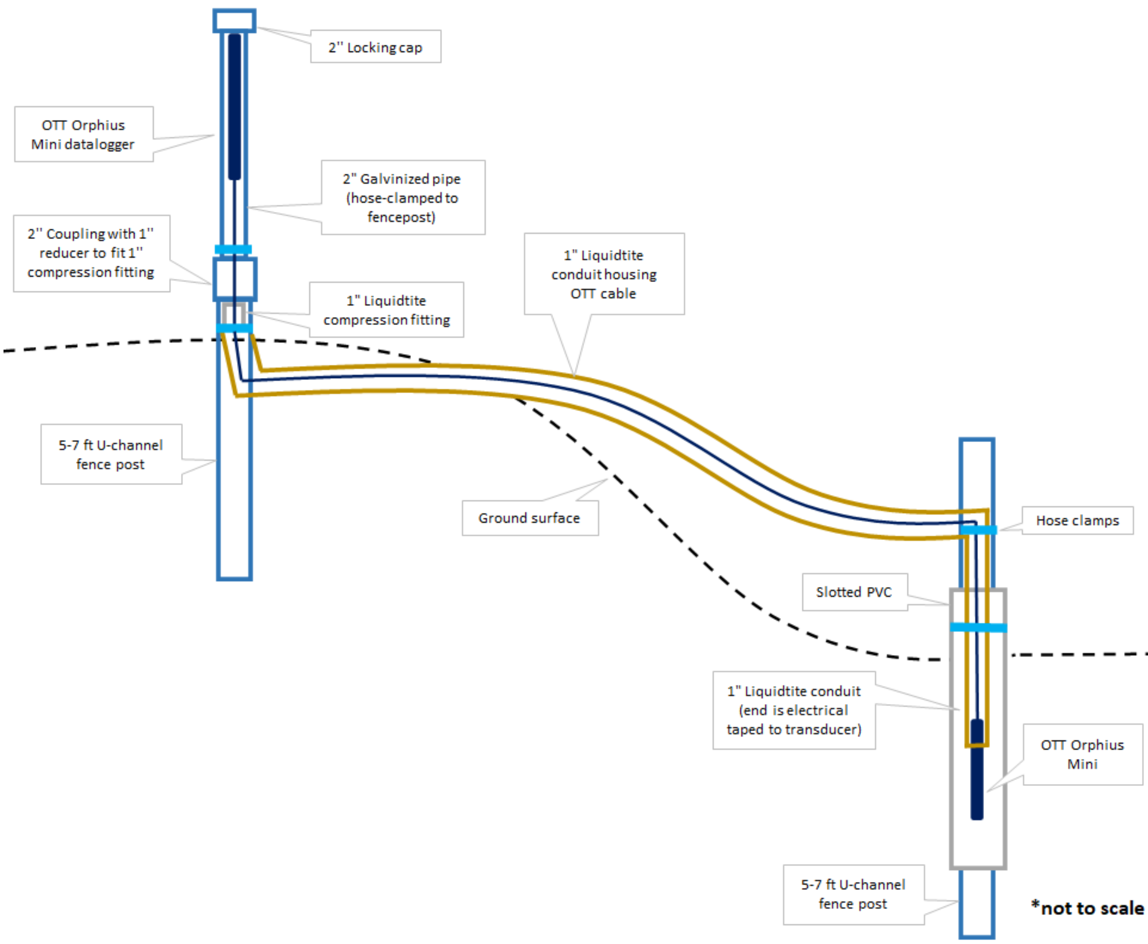

Figure 2. Current wetland hydrology equipment design.

The steel boxes housing loggers at the established wetland sites are artifacts of the initial hydrology equipment design, which required a larger container (Figure 3). This design was implemented at 14 sites and later replaced with the current design (Figure 2). Because we will no longer need such a large container, we will house loggers at future sites in cylindrical steel cases with locks. The previous hydrology equipment design consisted of a Design Analysis Waterlog gas purge bubbler system (bubbler) connected to a datalogger, powered by a 12-volt gel cell battery, which is recharged using a solar panel with a voltage regulator. This design is standard for MN DNR stream gage monitoring. However, because the orifice lines at all but a few sites were placed on top of substrate, we only collected data on inundation and not saturation. In addition, OTTs have newer groundwater monitoring technology that was not available at the beginning of our project, and that makes water elevation measurements more precise in mucky and highly vegetated areas. OTTs also require less equipment in the field than bubblers. Like bubblers, OTTs do not need to be barometrically corrected. These benefits led to our current hydrology equipment design (Figure 2).

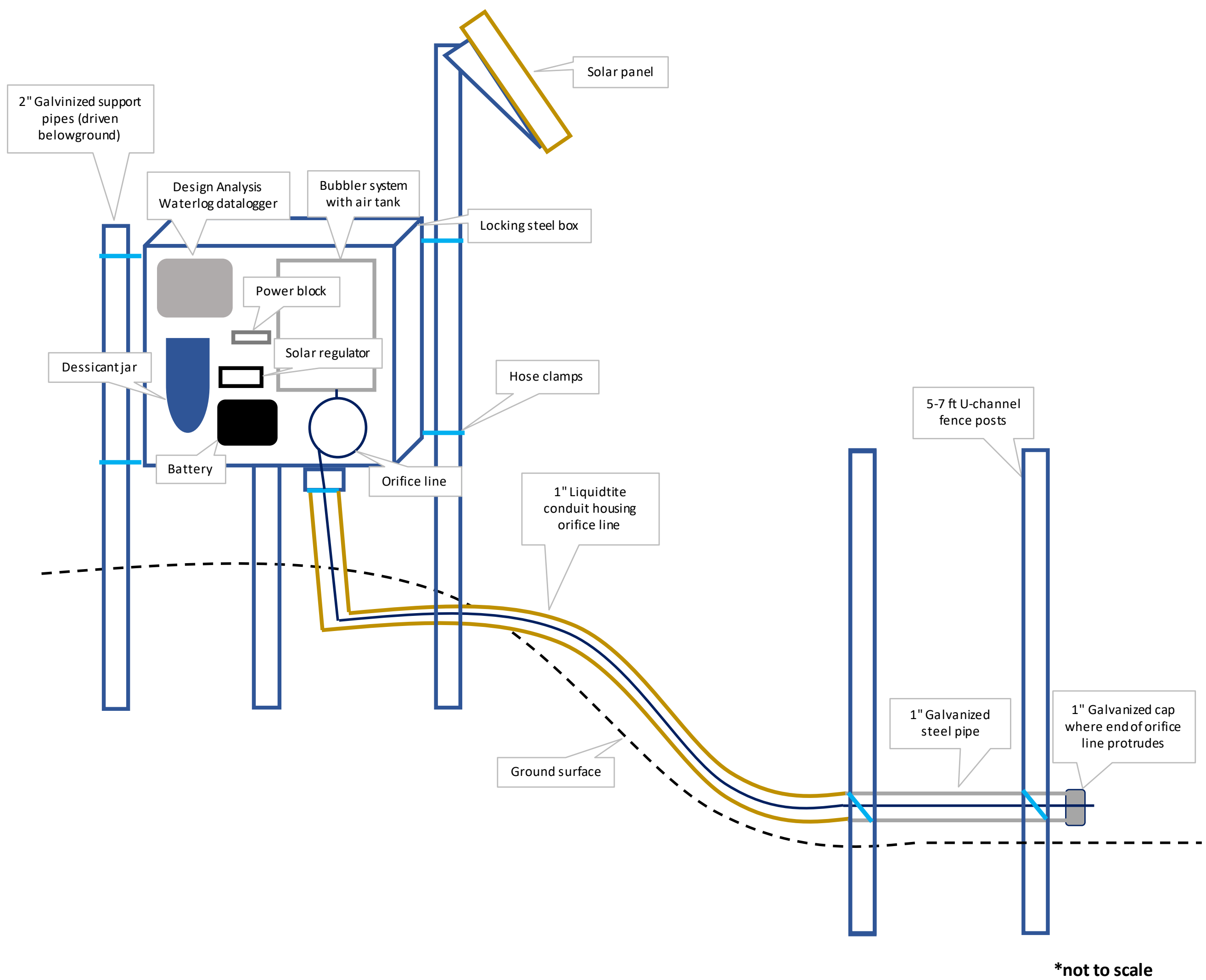

Figure 3. Previous wetland hydrology equipment design.

Wetland sites are visited twice per year. During visits, algae and fine soil deposits inside PVC pipes are cleaned out. Permanent survey benchmarks (e.g., a nail in a tree, a large boulder) are used to estimate elevation of the water level at the PVC pipe (i.e., measured stage), elevation of the ground at the PVC pipe, and the elevation of the top of the PVC pipe. The PVC pipe and associated equipment are reset or stabilized if movement has occurred. Finally, data are downloaded from dataloggers and, if needed, the water elevation is reset to match the measured stage. Ground elevation had an error of approximately ± 0.1 ft. Water levels relative to the ground inherit this error, plus additional measurement error of approximately ± 0.01-0.03 ft.

Hydrological Data

Hydrological data are uploaded to the Minnesota DNR's hydrological database, Water Information Systems by KISTERS (WISKI). The data are reviewed and approved by an experienced DNR hydrologist before being made publicly available through WISKI's KIWIS app. A public-facing portal will eventually be developed and accessible through the WHyN website. In the meantime, please contact report authors for instructions on how to access data. Water level data from dataloggers are compared to measured stages and corrected when necessary.

Uninterpretable data are removed, and comments are added to explain gaps in the water level records. Uninterpretable data may be caused by equipment malfunctions, water levels below equipment elevation, or vegetation or debris interference. For the winters of 2019-2020 and 2020-2021, hydrology equipment was removed from wetlands to prevent freezing and damage. It is now being left in to capture hydrological conditions on the edeges of the growing season but freezing may induce equipment malfunction.

Vegetation Survey

To describe the wetland community type of a site and to gather baseline data that can be used to evaluate wetland change over time, we conducted vegetation surveys at the established sites. Surveys were completed in late July and August of 2020 and 2021.

We selected 15 points at each site to collect vegetation data using the Generalized Randomized Tessellation Stratified (GRTS) algorithm (Figure 4). The GRTS algorithm creates a random and spatially balanced sample design. First, a polygon of five acres or less was drawn around each wetland basin in ArcGIS using LiDAR hill shade, 2019 Color Infrared Imagery, and 2019 True Color Imagery. Gradients that commonly correlate with shifts in vegetation (e.g., elevation gradients) were intentionally included in polygons to capture wetland areas most likely to change over time. Areas without vegetation (e.g., open water) were sometimes excluded from polygons. Then, polygons were imported into the statistical program R (R Core Team 2021) and the spsurvey package was used to apply the GRTS algorithm (Dumelle et al. 2022). In addition to 15 sample points, we selected 10 oversample points, which were used to replace inaccessible or non-target sample points, including disturbances by animals that lacked vegetation, moats with water greater than 1.4 m, uplands, and deer beds.

We aimed to collect data within one meter of the sample points and were largely successful; the average distance to sample points averaged well below 1 m for 19 of 22 surveys. We used ArcGIS Collector software on iPads with a Trimble R2 sub-meter GNSS unit and SBAS or MNCORS Virtual Reference System as our correction source to navigate to target points on pre-loaded maps. To verify our accuracy, we recorded a waypoint where 1 m^2 quadrats were placed. Quadrat locations were not permanently marked in the field.

At each sample point, we placed a 1 m^2 quadrat with a 0.1 m^2 nested quadrat around vegetation (or floating on water) so that the outer corner of the nested quadrat was positioned on the marked waypoint and pointing east (Figure 4). In each quadrat, we recorded presence/absence of every species rooted within the quadrat, noting whether any were rooted within the nested quadrat. For woody species, we estimated the percent foliar cover to the nearest 1% from 0%-10% and to the nearest 5% from 10%-100%. Data tables were entered with the Survey123 app and stored in ArcGIS Collector. No specimens were collected as part of the vegetation surveys.

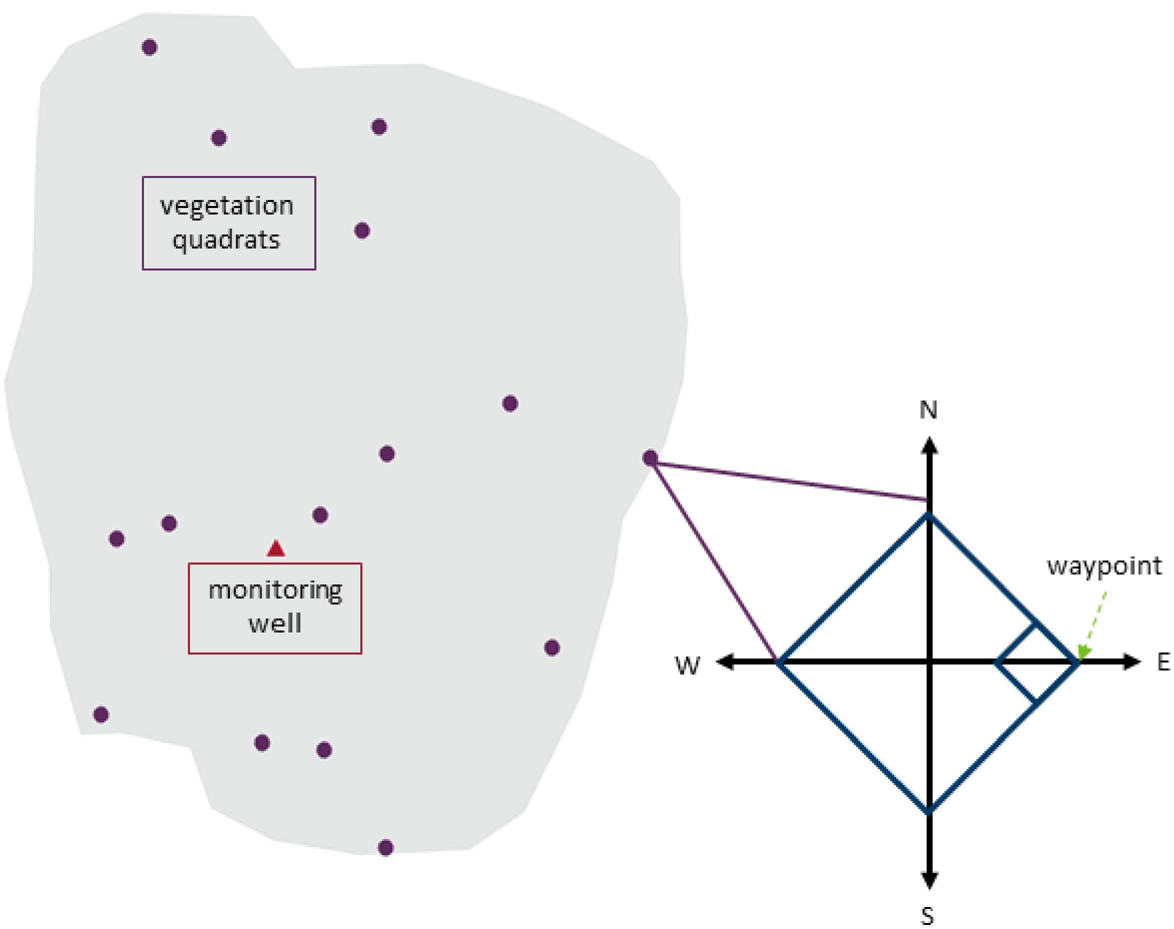

Figure 4. Schematic of vegetation survey. Gray polygon represents wetland boundary, which encompasses monitoring well. Purple points are randomly placed vegetation quadrats. Close-up schematic on right shows quadrat placement.

Data Analysis

To characterize the vegetation at each wetland site, we used the MN DNR's vascular plant checklist, MNTaxa (MN DNR 2015), to assign taxa statuses of native or non-native and the US Army Corps of Engineers National Wetland Plant List (USACE 2020) to assign wetland indicator status. We calculated the proportion native as the frequency of native species (number of quadrats per site) divided by the frequency of all species at the site categorized as native/non-native. We calculated the taxonomic richness for each site (number of different types of taxa), encompassing all taxa identified to the genus level and below. We used the Shannon index to calculate taxonomic diversity. The Shannon index is equal to $-\sum_{i=1}^{R} p_i \ln p_i$, where R is the taxonomic richness and p_i is the proportion of quadrats with taxon i (Oksanen et al. 2022). Larger values of the Shannon index indicate greater richness and/or evenness (similarity in p_i across taxa). We also divided the Shannon index by the log-transformed richness to calculate taxonomic evenness (Oksanen et al. 2022). We pooled plant surveys by wetland type and displayed the top ten most common taxa in each with labels corresponding to wetland indicator status.

To evaluate wetland hydrology trends, we summarized site-level hydrology during the growing season. We first identified growing season dates for each site by extracting daily minimum temperature from nearby weather stations in the Global Historical Climatology Network (Menne et al. 2012). Because air temperature is not a direct measurement of the growing season, we calculated the seven-day rolling average of the daily minimum temperature (hereafter, "rolling temperature") to reduce the influence of extreme values. We used January 1-July 31 as the potential window for the start of the growing season and August 1-December 31 as the potential window for the end of the growing season. We identified the start of the growing season as the first date after the last rolling temperature below 0^{o}C and the end of the growing season as the last date before the first rolling temperature below 0^{o}C (USDA 2021). We used the closest weather station (within 50 km of the wetland site) that had complete data for at least 90% of the dates. For wetland site/year combinations that used different weather stations for the start and end of the growing season (n = 3), weather stations were within 5 km of one another.

We defined saturation as water levels above -1 ft, where negative values indicate water levels below ground elevation. We defined inundation as water levels above ground elevation. We calculated the maximum number of consecutive days with average daily water levels indicating saturation or inundation for each wetland site and growing season. We also calculated the maximum daily average water level maintained for 14 consecutive days for each wetland site and growing season. Missing data (e.g., from equipment malfunctions or water levels below the transducer) were omitted from daily averages. We calculated the coefficient of variation (standard deviation divided by mean) for water levels of each wetland in each year.

We obtained precipitation data from the Minnesota State Climatology Office website (MN DNR 2022). For each wetland, we obtained historical monthly total precipitation with the Wetland Delineation Precipitation Data Retrieval Tool and daily precipitation with the Nearest Station Precipitation Data Retrieval Tool, allowing a maximum of 3 missing days per month. We then calculated the cumulative 30-day sum of daily precipitation and the 30^{th} and 70^{th} percentiles of historical monthly total precipitation for data collected for the 40-year time span of 1976-2015 to display alongside hydrographs. For each wetland in each growing season, we calculated cumulative precipitation for the water year (October 1 – September 30). We also calculated the Pearson's correlation coefficient for daily maximum water level and 30-day cumulative precipitation for each wetland in each growing season.

We constructed target hydrographs by depicting the time series of each wetland in each year, grouped by wetland type. In other publications (Wheeler et al. 2004, Annen and Larson 2022), target hydrographs contain information about normal and abnormal water levels. However, because most wetlands in our network had incomplete data for at least one year, and because the dataset only contains a maximum of four years, there is not yet enough data to determine normal and abnormal water levels for a given wetland type.

Analyses were performed in R version 4.0.5 (R Core Team 2021). We used the vegan package to calculate taxonomic diversity (Oksanen et al. 2022), the rnoaa package to extract weather data (Chamberlain 2021), the tidyverse packages for calculations and visualizations (Wickham et al. 2019). Methods and results for each wetland monitoring site can be found in the appendix.

Results

Vegetation Characteristics

The wetland sites in WHyN are dominated by native plant taxa (Table 4). The fresh meadow in Clinton Prairie SNA had the lowest native plant dominance, with native taxa making up 74% of frequency-weighted taxa (Table 4). The deep marsh/shallow open water wetlands in Murphy Hanrehan Park Reserve and Freese WPA, the fens in Murphy Hanrehan Park Reserve, Sibley Stat Park, and Becker County, the fresh meadow at Lake Maria State Park, and the marsh with sedge mat at Carex WMA only had native taxa out of those categorized (Table 4). Taxonomic richness ranged from six taxa in the deep marsh/shallow open water at Freese WPA to 50 taxa in the shallow marsh at Glacial Lakes State Park. The taxonomic diversity similarly varied from 1.3 in the deep marsh/shallow open water at Freese WPA to 3.6 in the shallow marsh at Glacial Lakes State Park. The deep marsh/shallow open water at Freese WPA also had the lowest taxonomic evenness (0.74) while the fresh meadow at Clinton Prairie SNA had the highest (0.93) (Table 4).

Table 4. Vegetation characteristics of WHyN sites.

Wetland type	Ecological province	Land management unit	Proportion native	Richness	Diversity	Evenness
deep marsh/ shallow open water	Eastern Broadleaf Forest	Murphy Hanrehan Park Reserve	1.00	16	2.3	0.84
deep marsh/ shallow open water	Prairie Parkland	Freese WPA	1.00	6	1.3	0.74
deep marsh/ shallow open water	Prairie Parkland	Prairie Marshes WMA	0.97	18	2.4	0.82

Wetland type	Ecological province	Land management unit	Proportion native	Richness	Diversity	Evenness
deep marsh/ shallow open water	Prairie Parkland	Sibley State Park	0.98	12	2.1	0.85
fen	Eastern Broadleaf Forest	Grey Eagle WMA	0.99	32	3.0	0.86
fen	Eastern Broadleaf Forest	Lake Maria State Park	0.99	35	3.2	0.91
fen	Eastern Broadleaf Forest	Murphy Hanrehan Park Reserve	1.00	35	3.2	0.90
fen	Laurentian Mixed Forest	Becker County	1.00	20	2.7	0.90
fen	Prairie Parkland	Sibley State Park	1.00	28	3.0	0.91
fresh meadow	Eastern Broadleaf Forest	Grey Eagle WMA	0.92	31	3.1	0.91
fresh meadow	Eastern Broadleaf Forest	Lake Maria State Park	1.00	34	3.2	0.91
fresh meadow	Prairie Parkland	Clinton Prairie SNA	0.74	43	3.5	0.93
fresh meadow	Prairie Parkland	Prairie WMA	0.82	14	2.3	0.86
marsh with sedge mat	Eastern Broadleaf Forest	Carex WMA	1.00	40	3.3	0.90
marsh with sedge mat	Prairie Parkland	Little Jo WMA	0.98	25	2.9	0.90
marsh with sedge mat	Prairie Parkland	Randall WPA	0.97	43	3.4	0.91

Wetland type	Ecological province	Land management unit	Proportion native	Richness	Diversity	Evenness
shallow marsh	Eastern Broadleaf Forest	Lake Maria State Park	0.99	26	3.0	0.92
shallow marsh	Laurentian Mixed Forest	Becker County	0.90	43	3.4	0.89
shallow marsh	Prairie Parkland	Glacial Lakes State Park	0.88	50	3.6	0.92
shallow marsh	Prairie Parkland	Prairie WMA	0.88	21	2.8	0.92
shallow marsh	Prairie Parkland	Sibley State Park	0.93	20	2.7	0.89

The most common taxon in deep marsh/shallow open water was common coontail (*Ceratophyllum demersum*) (Figure 5), a submersed aquatic species that is not dominant in any of the other wetland types. Deep marsh/shallow open water plant communities shared some common taxa with shallow marsh wetlands (Figure 9), including common bladderwort (*Utricularia vulgaris*), turion duckweed (*Lemna turionifera*), and bluejoint (*Calamagrostis canadensis*). Lake sedge (*Carex lacustris*), the most common species in shallow marsh wetlands, was also dominant in fens (Figure 6), fresh meadows (Figure 7), and marshes with sedge mats (Figure 8). Fens and marshes with sedge mats had 80% overlap in their dominant plant species. Fresh meadows had three facultative wetland (FACW) taxa and seven obligate wetland (OBL) taxa whereas other wetland types had at least nine OBL taxa.

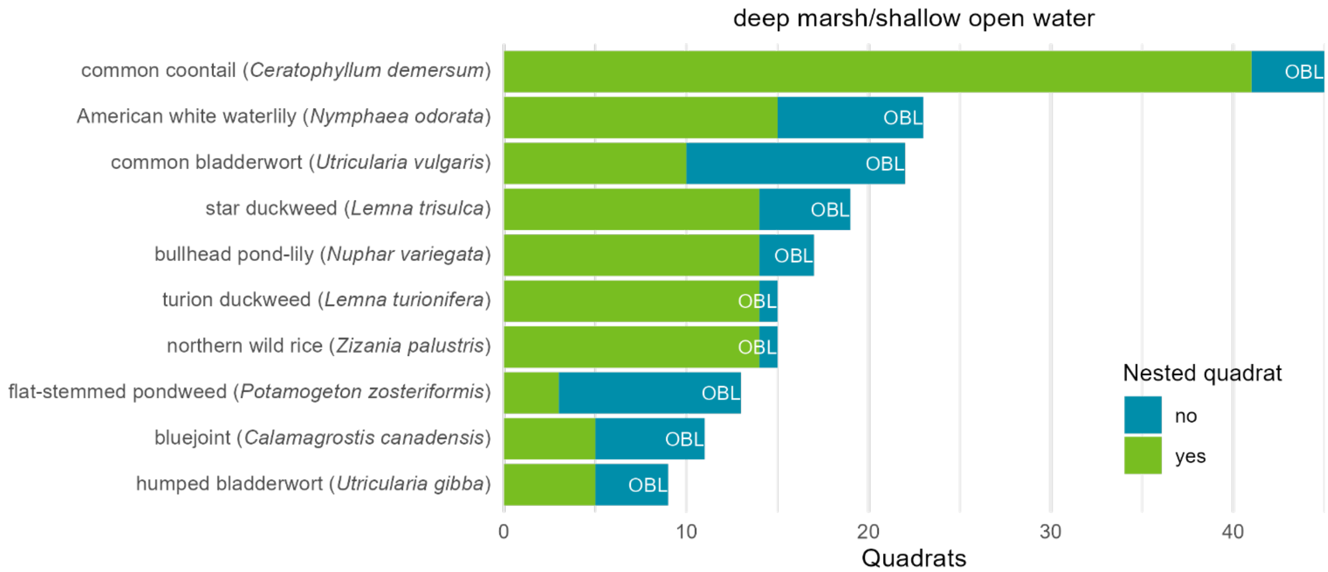

Figure 5. Frequencies of top ten most common taxa from pooled plant surveys in deep marsh/shallow open water wetlands (OBL = obligate wetland).

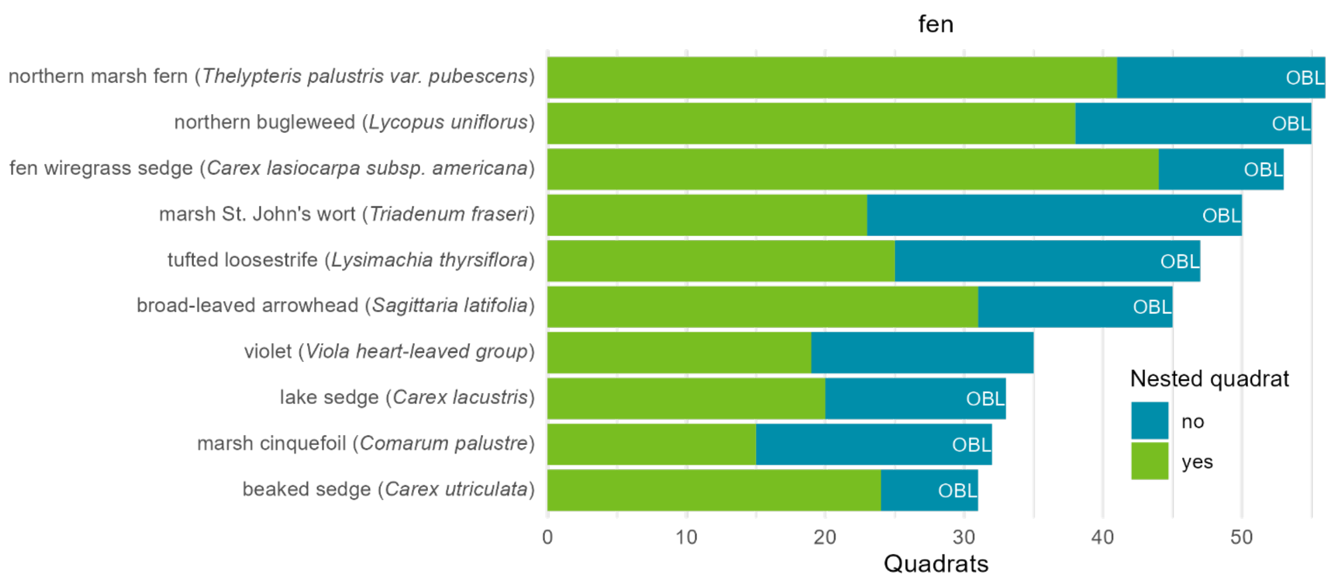

Figure 6. Frequencies of top ten most common taxa from pooled plant surveys in fen wetlands (OBL = obligate wetland).

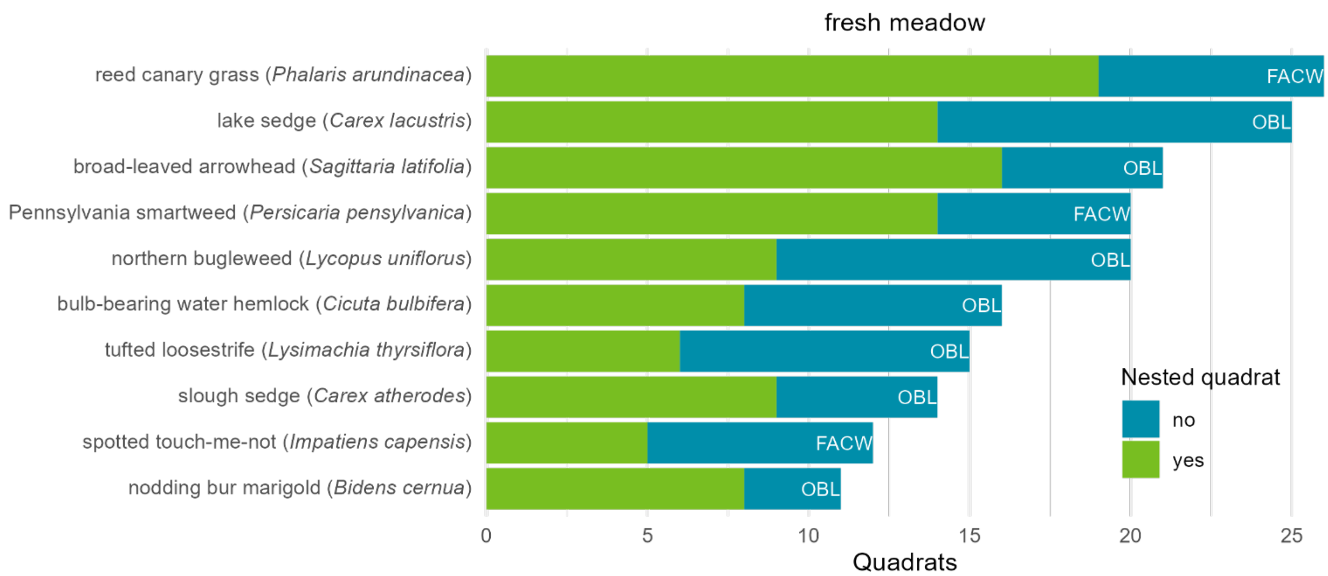

Figure 7. Frequencies of top ten most common taxa from pooled plant surveys in fresh meadow wetlands (OBL = obligate wetland, FACW = facultative wetland).

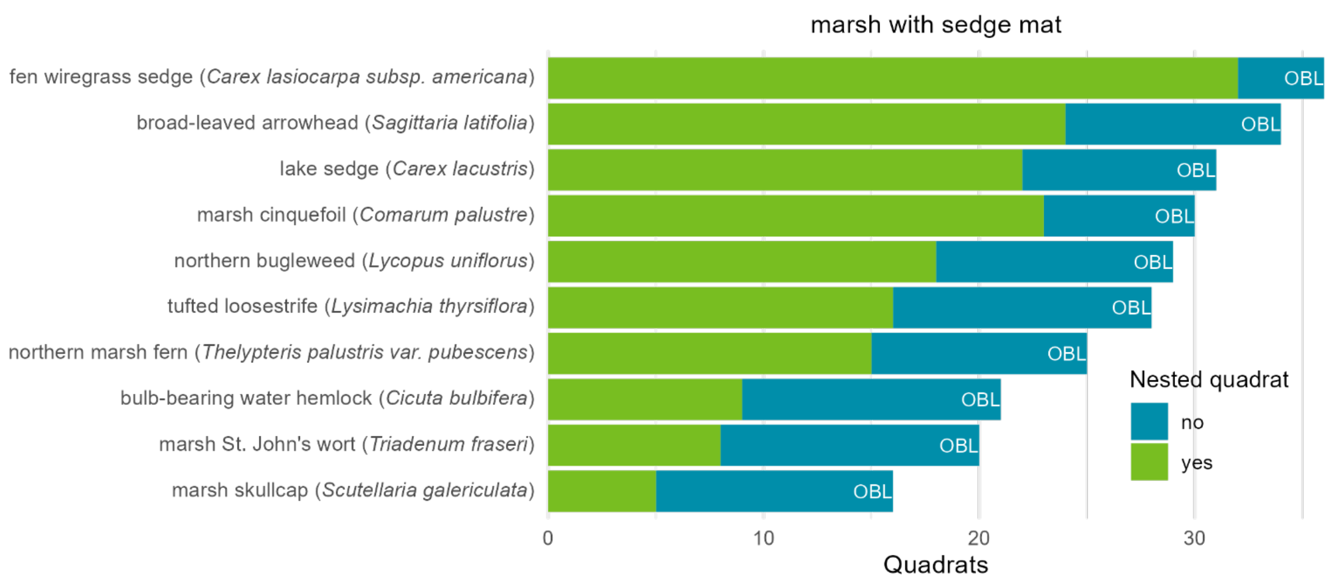

Figure 8. Frequencies of top ten most common taxa from pooled plant surveys in marshes with sedge mats (OBL = obligate wetland).

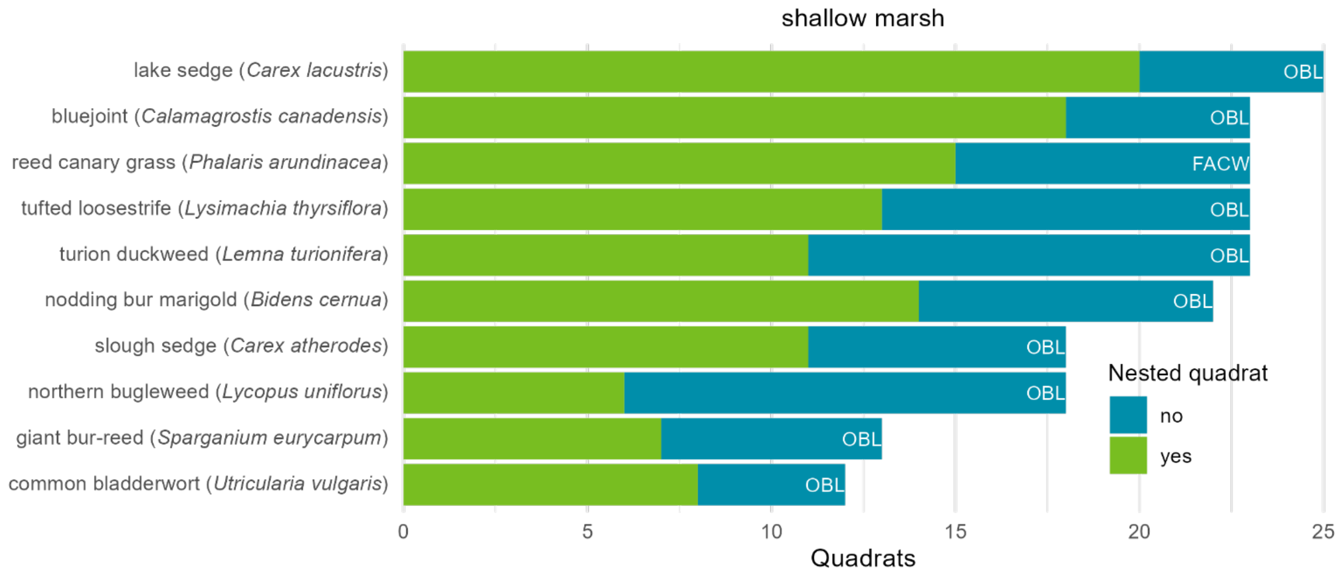

Figure 9. Frequencies of top ten most common taxa from pooled plant surveys in shallow marsh wetlands (OBL = obligate wetland, FACW = facultative wetland).

Hydrology

Deep marsh/shallow open water

Deep marshes/shallow open water wetlands were inundated for as many days as they were saturated, and the maximum water levels maintained for at least 14 days were within the range expected for deep marshes (Murphy Hanrehan Park Reserve, Prairie Marshes WMA) and shallow open water (Freese WPA) (Table 5). All three deep marshes/shallow open water wetlands had positive correlations between 30-day cumulative precipitation and daily maximum water levels in 2022. Negative correlations in 2020 and 2021 potentially indicate a lag in response time between precipitation and water levels.

Table 5. Hydrology summaries of deep marsh/shallow open water wetlands. For year, asterisks indicate values are based on incomplete data (e.g., equipment was installed or turned on during this growing season, final measurements were made before the end of the growing season). Sat. (saturation) is the number of days during the growing season that water levels exceeded 1 ft belowground. Inun. (inundation) is the number of days during the growing season that water levels exceeded ground elevation. Max level is the maximum water level (ft) maintained in the wetland for at least 14 days during the growing season. CV is the coefficient of variation. Total precip. is the cumulative water year precipitation. Precip. corr. is the correlation between cumulative 30-day precipitation and daily maximum water level with 95% confidence intervals in parentheses.

Land management unit	Year	Sat.	Inun.	Max level	CV	Total precip.	Precip. corr.
Murphy Hanrehan Park Reserve (EBF)	2020*	88	88	3.7	0.06	35.04	0.33 (0.13, 0.5)
Murphy Hanrehan Park Reserve (EBF)	2021	215	215	3.3	0.2	25.79	-0.03 (-0.16, 0.1)
Murphy Hanrehan Park Reserve (EBF)	2022*	177	177	2.4	0.29	23.91	0.67 (0.58, 0.75)
Freese WPA (PP/TAP)	2020*	72	72	5.2	0.02	23.71	-0.64 (-0.76, -0.48)

Freese WPA (PP/TAP)	2021	189	189	5.4	0.09	25.3	-0.29 (-0.41, -0.15)
Freese WPA (PP/TAP)	2022	169	169	5.1	0.11	27.43	0.57 (0.45, 0.66)
Prairie Marshes WMA (PP/TAP)	2019*	93	93	3	0.04	47.23	0.66 (0.53, 0.76)
Prairie Marshes WMA (PP/TAP)	2020*	69	69	2.5	0.09	29.82	-0.65 (-0.77, -0.49)
Prairie Marshes WMA (PP/TAP)	2021*	138	138	2.5	0.56	24.59	-0.4 (-0.53, -0.25)
Prairie Marshes WMA (PP/TAP)	2022*	132	132	2.9	0.39	25.89	0.73 (0.64, 0.8)

Fen

Fens exceeded the expectations for inundation of less than 6 in. for less than 14 consecutive days (Table 6). Instead, fens were inundated for many days during the growing season, with maximum levels maintained for at least 14 days ranging from 2.2 ft (Lake Maria State Park, Becker County, and Sibley State Park in 2021) to 4.7 ft (Murphy Hanrehan Park Reserve in 2020). The observed water levels may be higher than expected because we measured ground surface at the mineral soil, not the peat surface. The fen at Lake Maria State Park had a relatively high coefficient of variation in 2021 (1.36), but no correlation with precipitation. All the fens had positive correlations between precipitation and water levels in 2022.

Table 6. Hydrology summaries of fen wetlands. Column meanings are the same as in Table 5.

Land management unit	Year	Sat.	Inun.	Max level	CV	Total precip.	Precip. corr.
Grey Eagle WMA (EBF)	2019*	93	93	3.7	0.06	39.3	0.38 (0.19, 0.54)
Grey Eagle WMA (EBF)	2020*	129	129	3.1	0.04	30.29	0.79 (0.71, 0.85)
Grey Eagle WMA (EBF)	2021	120	120	3	0.11	24.72	-0.57 (-0.68, -0.43)
Grey Eagle WMA (EBF)	2022	177	177	3.9	0.13	33.38	0.71 (0.63, 0.78)
Lake Maria State Park (EBF)	2020*	128	128	2.3	0.13	28.91	0.3 (0.13, 0.45)
Lake Maria State Park (EBF)	2021	167	70	2.2	1.36	24.22	0.14 (-0.01, 0.28)
Lake Maria State Park (EBF)	2022*	155	155	2.9	0.14	31.28	0.25 (0.1, 0.39)
Murphy Hanrehan Park Reserve (EBF)	2020*	87	87	4.7	0.05	35.11	0.55 (0.38, 0.68)
Murphy Hanrehan Park Reserve (EBF)	2021	192	192	4.2	0.13	25.83	-0.12 (-0.26, 0.02)
Murphy Hanrehan Park Reserve (EBF)	2022*	177	177	3.2	0.16	23.97	0.73 (0.65, 0.79)
Becker County (LMF)	2021*	158	158	2.2	0.26	18.73	0.13 (-0.03, 0.28)
Becker County (LMF)	2022*	144	144	3.4	0.16	30.65	0.7 (0.6, 0.77)
Sibley State Park (PP/TAP)	2021	146	146	2.2	0.18	24.86	-0.17 (-0.32, -0.01)
Sibley State Park (PP/TAP)	2022	169	169	3.1	0.1	28.59	0.61 (0.5, 0.7)

Fresh meadow

Fresh meadows met the expectation of saturation for at least 28 consecutive days (Table 7). Except for Grey Eagle WMA in 2020, inundation lasted longer than expected, and the maximum water levels maintained for at least 14 days were greater than expected in the fresh meadows (less than 6 in. for less than 14 consecutive days). The fresh meadow at Grey Eagle WMA had negative coefficients of variation because of negative average daily water levels. Three of the four fresh meadows had positive correlations between precipitation and water levels while the fourth (Prairie WMA) had negative correlations in both 2020 and 2021.

Table 7. Hydrology summaries of fresh meadow wetlands. Column meanings are the same as in Table 5.

Land management unit	Year	Sat.	Inun.	Max level	CV	Total precip.	Precip. corr.
Grey Eagle WMA (EBF)	2019*	93	28	0.3	-4.88	39.32	0.39 (0.2, 0.55)
Grey Eagle WMA (EBF)	2020*	106	0	-0.4	-0.51	30.33	0.4 (0.24, 0.53)
Grey Eagle WMA (EBF)	2022*	119	72	0.8	-5.81	33.43	0.77 (0.69, 0.83)
Lake Maria State Park (EBF)	2021	173	99	1.7	0.41	24.28	0.24 (0.09, 0.37)
Lake Maria State Park (EBF)	2022*	156	156	1.8	0.21	31.4	0.54 (0.42, 0.64)
Clinton Prairie SNA (PP/TAP)	2022*	63	61	1.1	0.54	25.09	0.71 (0.55, 0.81)
Prairie WMA (PP/TAP)	2020*	39	39	1.5	0.25	21.9	-0.88 (-0.94, -0.79)
Prairie WMA (PP/TAP)	2021*	116	60	1.4	0.66	22.93	-0.41 (-0.55, -0.24)
Prairie WMA (PP/TAP)	2022*	150	144	2.8	0.57	24.05	0.67 (0.57, 0.75)

Marsh with sedge mat

The hydrology of the monitored sedge mats was consistent with expectations for deep marsh and shallow open water: inundation lasted for many days of the growing season with maximum water levels maintained for at least 14 days ranging from 2.2 ft (Carex WMA in 2021 and 2022) to 5 ft (Little Jo WMA in 2020) (Table 8). In 2019, 2020 and 2022, the sedge mats at Carex WMA and Little Jo WMA had strong positive correlations between precipitation and water levels, but these were not observed in 2021.

Table 8. Hydrology summaries of marsh with sedge mat wetlands. Column meanings are the same as in Table 5.

Land management unit	Year	Sat.	Inun.	Max level	CV	Total precip.	Precip. corr.
Carex WMA (EBF)	2019*	88	88	2.5	0.07	41.46	0.86 (0.79, 0.91)
Carex WMA (EBF)	2020*	129	129	2.6	0.06	38.47	0.87 (0.83, 0.91)
Carex WMA (EBF)	2021	191	191	2.2	0.17	28.34	0.16 (0.02, 0.3)
Carex WMA (EBF)	2022	176	176	2.2	0.15	30.51	0.6 (0.49, 0.68)
Little Jo WMA (PP/TAP)	2020*	129	129	5	0.02	23.63	0.71 (0.62, 0.79)
Little Jo WMA (PP/TAP)	2021	177	177	4.6	0.09	24.99	-0.04 (-0.19, 0.1)

Little Jo WMA (PP/TAP)	2022	169	169	5.1	0.09	27.33	0.63 (0.52, 0.71)
Randall WPA (PP/TAP)	2021	189	189	3.6	0.18	25.19	-0.19 (-0.33, -0.05)
Randall WPA (PP/TAP)	2022	169	169	5	0.18	27.15	0.49 (0.37, 0.6)

Shallow marsh

The shallow marshes were inundated for as many days as they were saturated, except for Glacial Lakes State Park in 2021 (Table 9). The maximum water levels maintained for at least 14 days were mostly higher than those expected (less than 6 in. during normal precipitation conditions), with values ranging from 0.4 ft (Glacial Lakes State Park in 2020) to 4.9 ft (Becker County in 2022). In 2020, the shallow marsh at Glacial Lakes had the largest magnitude coefficient of variation across all wetlands and a negative average water level. The shallow marshes at Becker County in 2021, Prairie WMA in 2020 and 2021 and at Sibley State Park in 2021 had negative correlations between precipitation and water levels. All wetlands had positive correlations in 2022.

Table 9. Hydrology summaries of shallow marsh wetlands. Column meanings are the same as in Table 5.

Land management unit	Year	Sat.	Inun.	Max level	CV	Total precip.	Precip. corr.
Lake Maria State Park (EBF)	2020*	128	128	2	0.25	28.9	0.15 (-0.03, 0.31)
Lake Maria State Park (EBF)	2021*	39	39	1.1	0.21	24.24	0 (-0.32, 0.31)
Lake Maria State Park (EBF)	2022*	55	43	1.6	1.96	31.46	0.54 (0.39, 0.67)
Becker County (LMF)	2021*	135	135	4.4	0.16	18.77	-0.75 (-0.81, -0.66)
Becker County (LMF)	2022*	111	111	4.9	0.11	28.32	0.71 (0.6, 0.79)
Glacial Lakes State Park (PP/TAP)	2020*	58	34	0.4	-1.53	20.54	0.5 (0.36, 0.62)
Glacial Lakes State Park (PP/TAP)	2021	44	31	0.5	-0.89	22.98	-0.1 (-0.24, 0.05)
Glacial Lakes State Park (PP/TAP)	2022	168	168	2.2	0.43	26.22	0.72 (0.64, 0.79)
Prairie WMA (PP/TAP)	2020*	120	120	2.7	0.24	21.89	-0.62 (-0.72, -0.49)
Prairie WMA (PP/TAP)	2021	144	144	2.2	0.34	22.93	-0.23 (-0.38, -0.07)
Prairie WMA (PP/TAP)	2022	177	177	3.7	0.34	24.02	0.66 (0.57, 0.74)
Sibley State Park (PP/TAP)	2020*	129	129	3	0.07	24.07	0.65 (0.53, 0.74)
Sibley State Park (PP/TAP)	2021	94	94	2.8	0.5	24.85	-0.82 (-0.88, -0.75)
Sibley State Park (PP/TAP)	2022	169	169	3.4	0.16	28.53	0.62 (0.52, 0.71)

Target hydrographs

The hydrographs for each wetland type in 2020 (Figure 10), 2021 (Figure 11), and 2022 (Figure 12) can inform expected wetland water levels under low disturbance in those years. Most of the variation in water level arises from variation among wetlands, which differ in location, rather than temporal variation. In some cases, different wetlands within a type have very similar time series despite differences in average water level value (e.g., fens in 2020 and 2022, marshes with sedge mats in 2021).

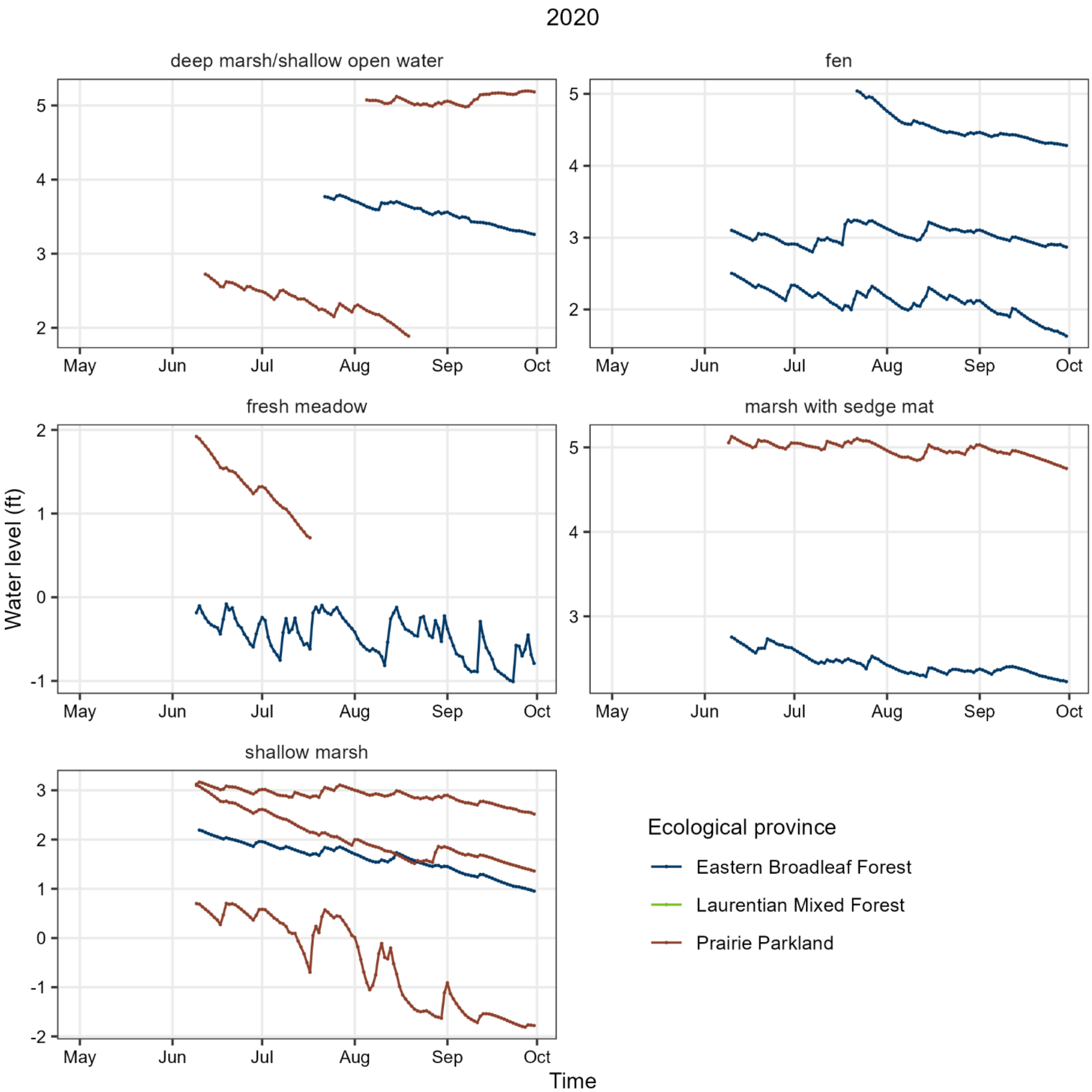

Figure 10. Hydrographs for each wetland type in 2020. Each line is a separate land management unit.

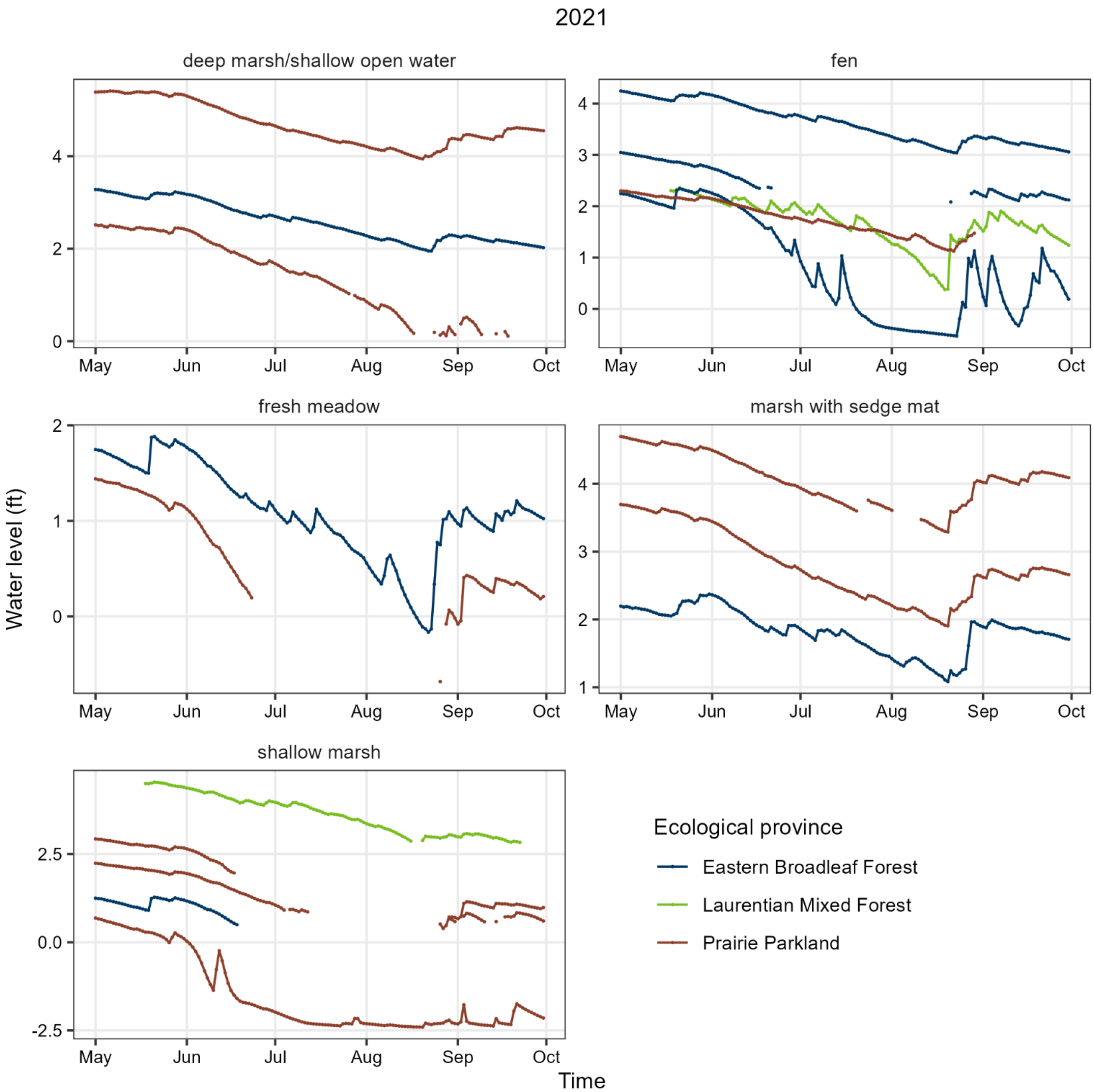

Figure 11. Hydrographs for each wetland type in 2021. Each line is a separate land management unit.

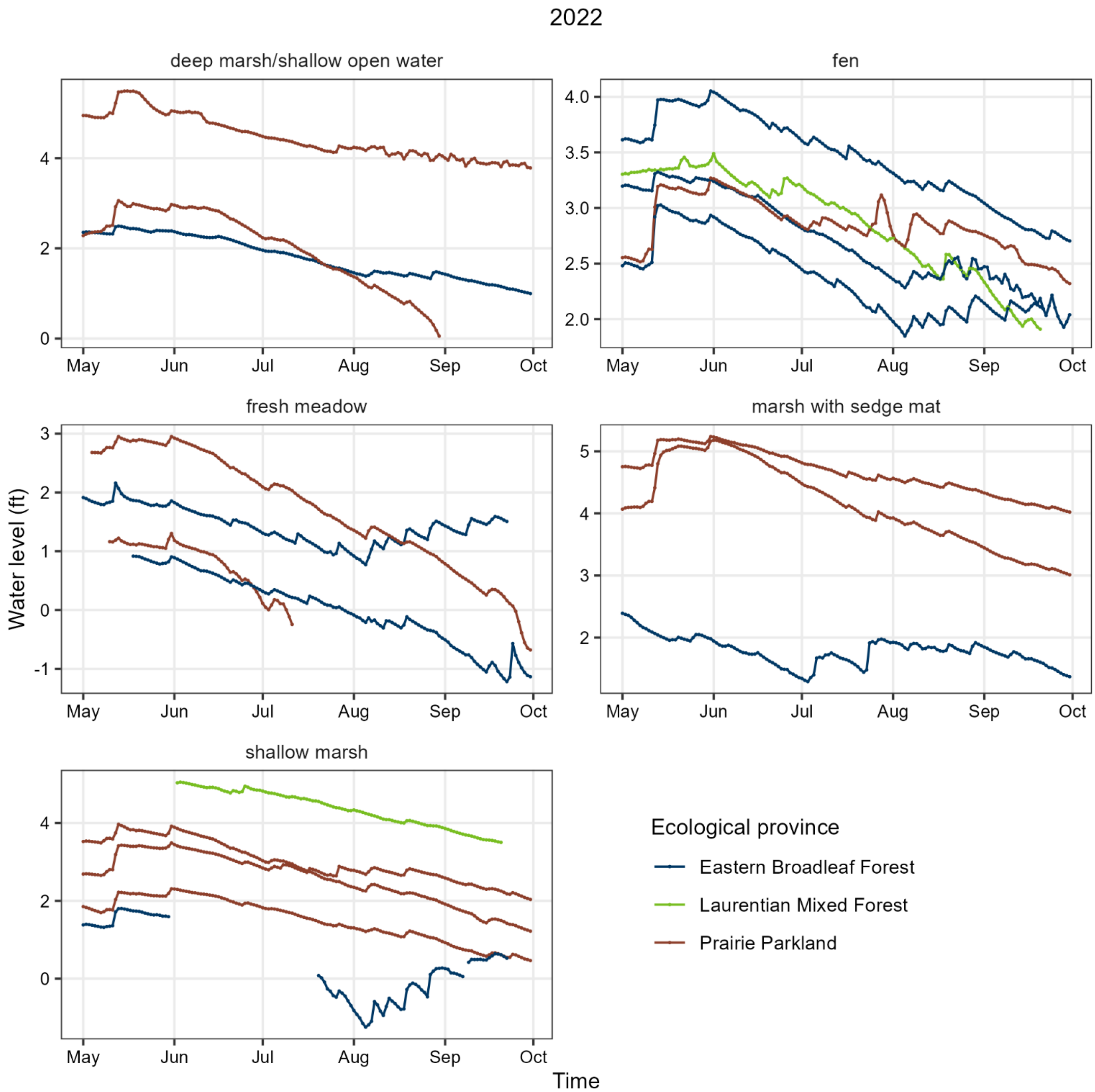

Figure 12. Hydrographs for each wetland type in 2022. Each line is a separate land management unit.

Discussion

Over the first few years of WHyN, we have installed 25 sites and collected at least one year of data from 20 sites. Our sites have diverse plant communities, dominated by native species, and hydrology that typically exceeds expected depths and duration of saturation/inundation, even during years of drought (2021, 2022). We have also learned valuable lessons to improve data collection, that we will apply to WHyN moving forward. The continued development of the network will aid in informing threshold water levels for management and policy. So far, we do not have enough data to inform general wetland water level thresholds (MN DNR 2016). Preliminary target hydrographs suggest that patterns of water level over time may be more characteristic of a wetland type than the absolute water level values. Further, precipitation appears to be a primary driver of hydrology for multiple wetland types and can produce similar patterns across types.

The wetland types are a useful tool for simplifying a wide variety of plant community types. However, this tool has limitations. A single category may contain wetlands that are relatively different in plant diversity or composition. For example, the wetland at Freese WPA, which is predominantly shallow open water, set the lower limit of multiple plant diversity metrics, while the other wetlands in the category of deep marsh/shallow open water were predominantly deep marsh and had higher plant diversity metrics. In addition, we categorized wetlands by the dominant plant community type, but wetlands contain multiple communities. For instance, the wetlands at Clinton Prairie SNA and Glacial Lakes State Park had multiple wetland communities within the vegetation survey, leading to relatively high plant diversity metrics for their assigned wetland categories. Finally, wetland vegetation, and possibly the wetland community type, can vary over time. For example, the sedge mat at Randall WPA was dry during vegetation sampling, so there was higher cover of annual plant species than would be expected in wetter years.

Key lessons learned during the development of WHyN may help guide future wetland hydrology efforts. First, we tried multiple types of equipment, eventually settling on a set-up that can be applied across a range of wetland types, that protects equipment from the elements, and that tends to provide accurate data (Figure 2). In a handful of wetlands (fen and shallow marsh in Sibley State Park, fresh meadow in Clinton Prairie SNA), we have observed unusual data patterns that we have yet to reconcile. However, we expect that updating equipment could help resolve these issues as they do not appear to be driven by natural processes. Some challenges we have already solved with equipment modification include missing water levels belowground (solution: installing slotted PVC wells that go belowground), water pooling in the bottom of wells or casings (solution: suspending transducers above the bottom of these enclosures), and vegetation or muck interfering with water level measurements (solutions: switching equipment from bubblers to OTTs and covering transducers with landscaping fabric). We also found that most variation in water level arises from variation among wetlands, which differ in location, rather than temporal variation. It is therefore also important to ensure we have representative wetlands in each wetland type category and multiple replicates before summarizing by wetland type.

WHyN builds upon a current and long-term wetland monitoring efforts in the upper Midwest. For example, the Wisconsin Department of Natural Resources monitored the hydrology of southern sedge meadows and wet-mesic prairies in Wisconsin in 2020 and 2021 (Kolb and Jarosz 2022). They compared their data to the same wetland hydrology standards we considered (USACE 2019) and found that many of the wet-mesic prairie sites did not meet the expected inundation durations while many of the sedge meadows did. Part of their results can be explained by wells that were too shallow – a problem we also encountered. Additionally, wet-mesic prairies tend to be drier than sedge meadows and the wetland community types monitored in WHyN. Between 2008 and 2013, the Minnesota Pollution Control Agency conducted a monitoring study of six wetlands with varying levels of human impact in central and southern Minnesota (MPCA 2015). Less impacted wetlands tended to have more gradual changes in water levels, while more impacted wetlands tended to have steeper changes in water levels, following precipitation events. The data from WHyN can be compared to more impacted wetlands to evaluate the generality of this result.

Long-term monitoring of bogs and fens at Marcell Experimental Forest (northern Minnesota) has shown variation in water table elevation trends among the different wetlands (Stockstad et al. 2021). We also found notable variation among wetlands within each category, emphasizing the importance of geographic replication and long-term monitoring to characterize the wide range of water levels observed in wetlands. In addition, long-term monitoring of prairie pothole wetlands at the Cottonwood Lake Study Area in North Dakota has demonstrated how hydrogeomorphology of wetlands affects how water levels, vegetation, and animal communities shift with changing climate (Mushet et al. 2022). Therefore, the continued monitoring of diverse wetlands across Minnesota can inform management across biological strata in the context of changing climate. Finally, long-term monitoring of reference wetlands in Anoka County, MN, demonstrates the utility of wetland monitoring for wetland delineations (Annen and Larson 2022).

We are in the process of adding more sites to WHyN with a grant from the LCCMR. We expect the additional sites will add greater geographic and plant community variation to our network that can help inform the range of hydrological conditions that occur in wetlands across Minnesota.

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M. D. Caceres, S. Durand, H. B. A. Evangelista, R. FitzJohn, M. Friendly, B. Furneaux, G. Hannigan, M. O. Hill, L. Lahti, D. McGlinn, M.-H. Ouellette, E. R. Cunha, T. Smith, A. Stier, C. J. F. T. Braak, and J. Weedon. 2022. vegan: Community Ecology Package.

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Appendix: Site Descriptions

By 2022, 21 sites were established at 13 land management units, which consist of state forests, wildlife management areas (WMA), scientific and natural areas (SNA), state parks, park reserves, and waterfowl production areas (WPA). Each site is named by the land management unit and then numbered, starting with one. We present methods and available data for each site.

Becker County 1

Methods

We monitored a fen in Becker County, which is in the Laurentian Mixed Forest province (Fig. A1A). The monitored wetland is not within a specific land management unit, but is 4.3 miles east of Tamarack National Wildlife Refuge (Fig. A2). We installed OTT equipment on May 18, 2021 (Fig. A1B). The transducer was originally mounted to a fence post and on October 19, 2021, we put the transducer into a slotted PVC well mounted to a fence post (Fig. 2) (Fig. A1C). We conducted a vegetation survey on August 2, 2021 (Fig. A1D).

Figure A1: (A) View of Becker County 1, taken on June 1, 2022. (B) Fence post supporting OTT transducer following installation on May 18, 2021. (C) Installation of slotted PVC well on October 19, 2021. (D) Vegetation survey on August 2, 2021.

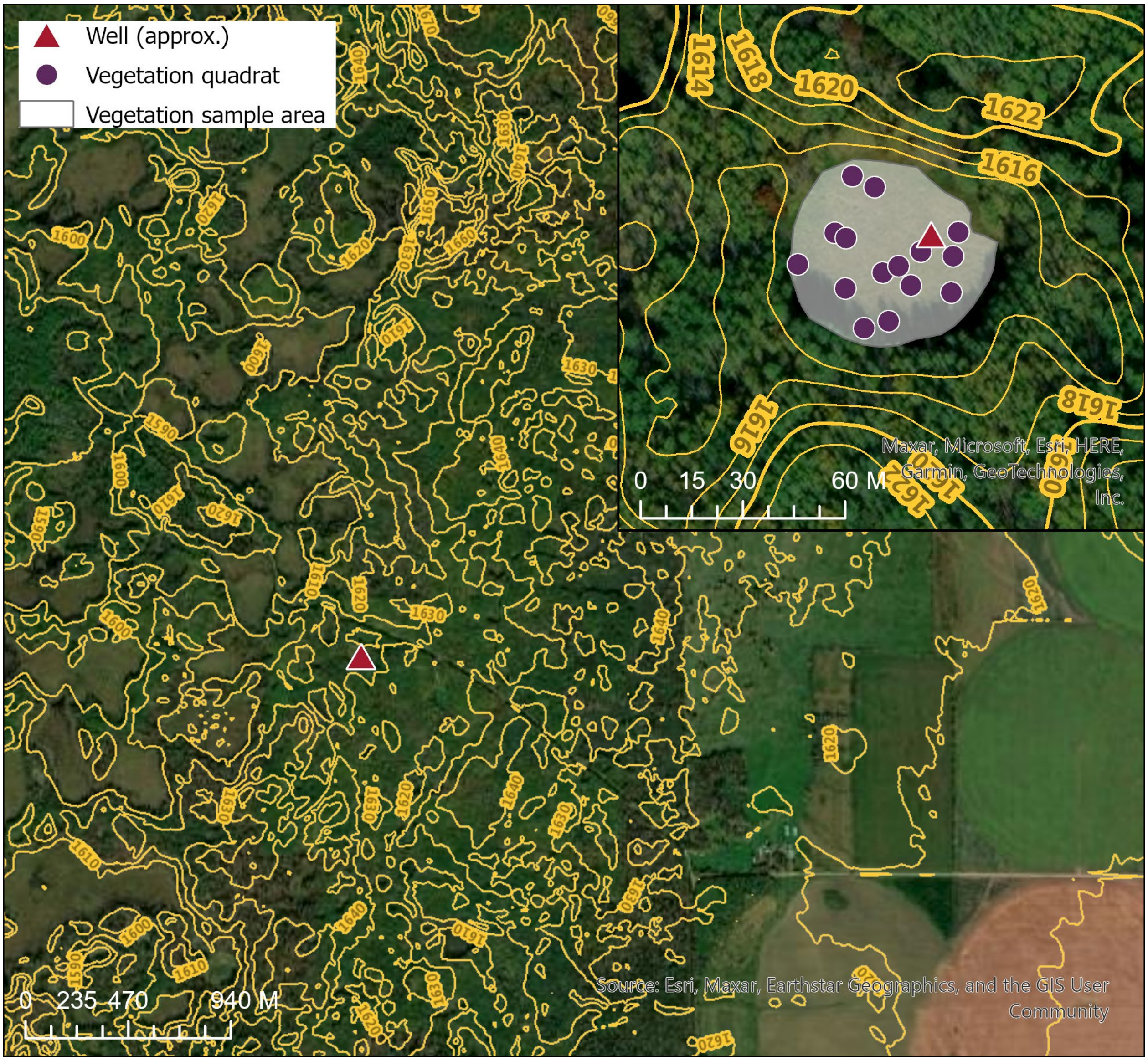

Figure A2: Map of Becker County 1 data collection sites. The yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data.

Results

We identified 20 plant taxa at the fen in Becker County, with a diversity of 2.7 and evenness of 0.9. The fen is dominated (present in > 75% of the quadrats) by beaked sedge (*Carex utriculata*), lake sedge (*Carex lacustris*), tufted loosestrife (*Lysimachia thyrsiflora*), fen wiregrass sedge (*Carex lasiocarpa subsp. americana*) (Fig. A3).

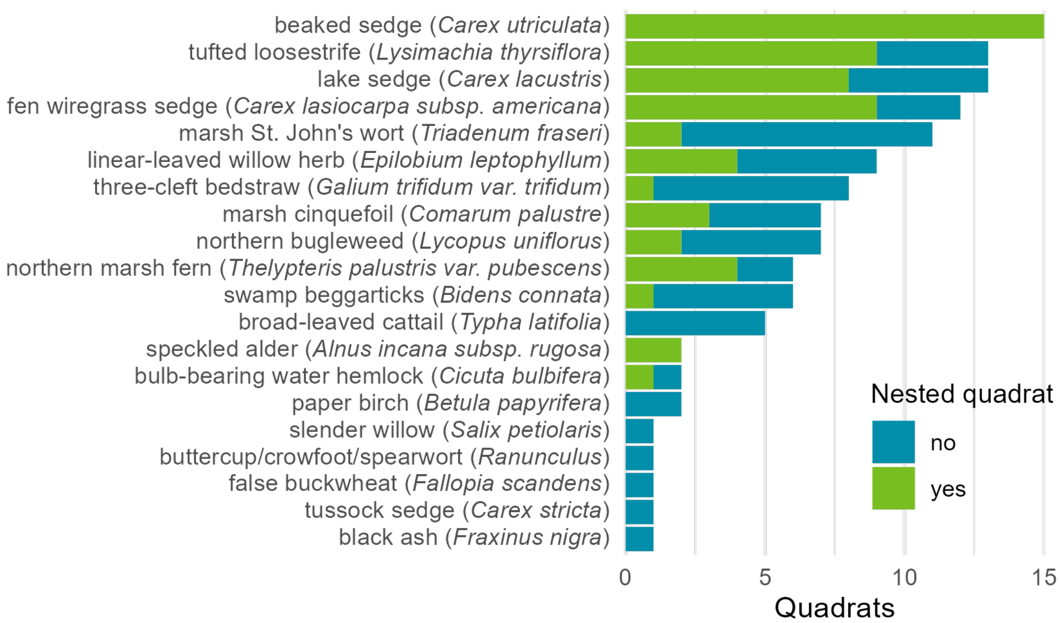

Figure A3: Plant community of Becker County 1.

The median water level in the fen in Becker County was 1.7 ft in 2021 and 3 ft in 2022 (Fig. A4). The wetland was saturated within 1 ft of the ground surface for 158 days during the 2021 growing season and 144 days during the 2022 growing season. It was inundated for 158 days during the 2021 growing season and 144 days during the 2022 growing season. The maximum water level maintained for at least 14 days during the growing season was 2.2 ft in 2021 and 3.4 ft in 2022.

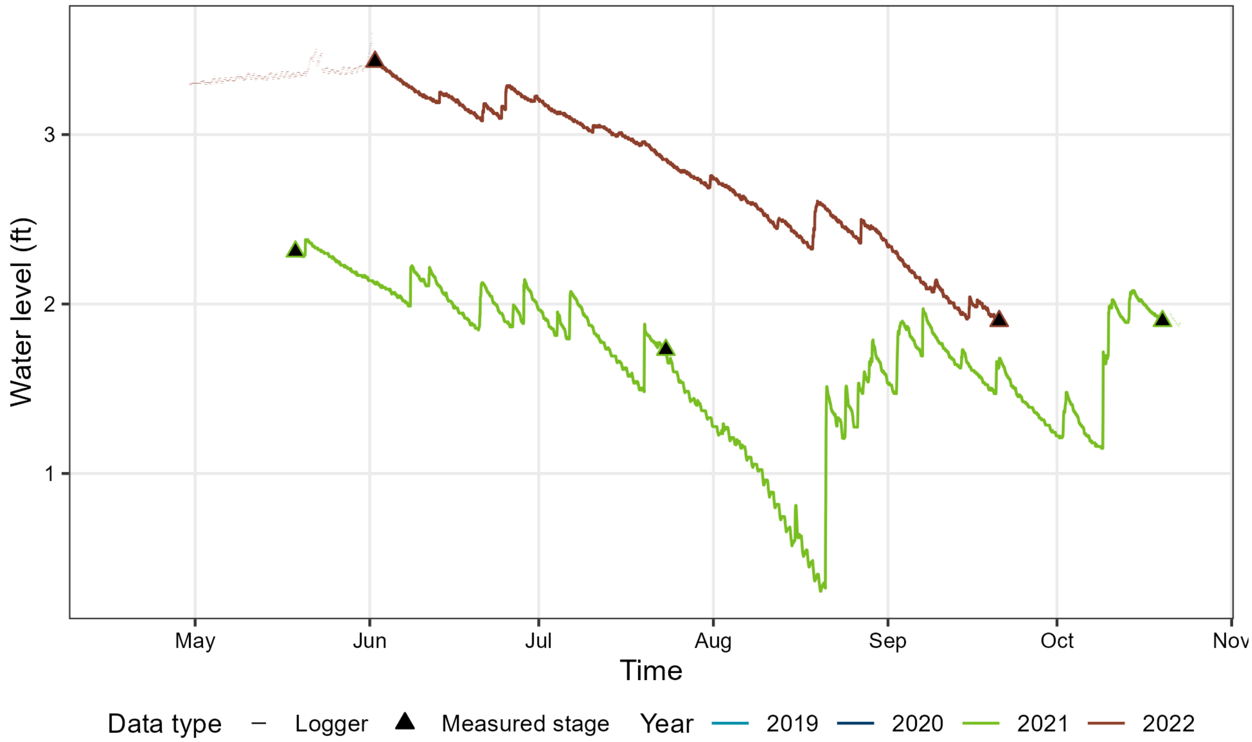

Figure A4: Hydrograph from Becker County 1.

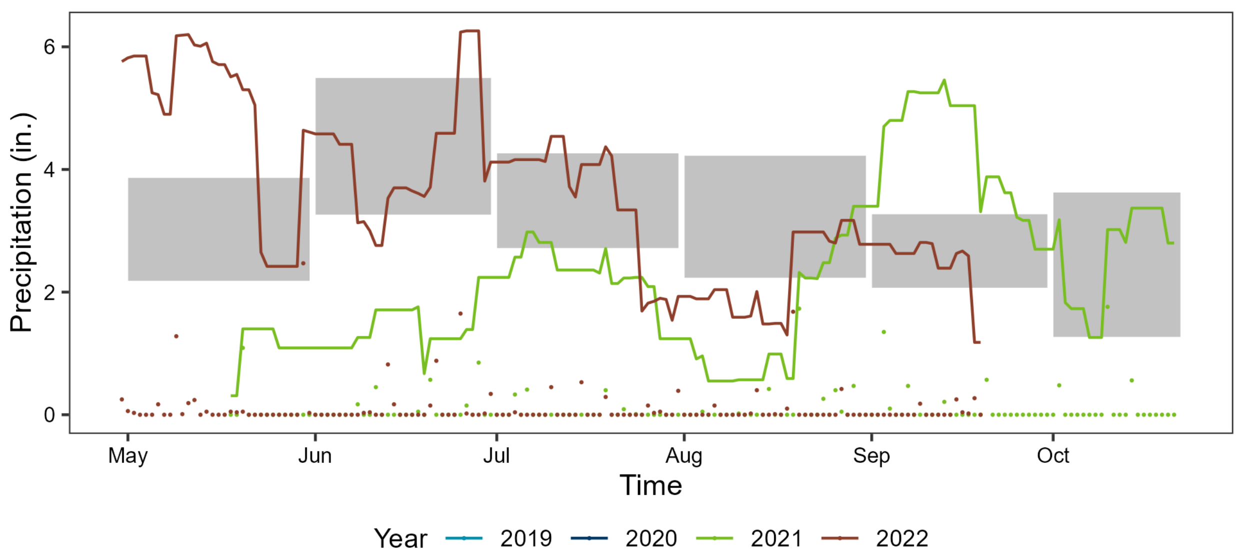

Figure A5: Precipitation at Becker County 1. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Becker County 2

Methods

We monitored a shallow marsh in Becker County, which is in the Laurentian Mixed Forest province (Fig. A6A). The monitored wetland is in the center of the Two Inlets State Forest (Fig. A7). We installed OTT equipment and began collecting data on May 18, 2021 (Fig. A6B). The transducer was originally aboveground and mounted to a fence post, which prevented the measurement of some water levels in 2021. On October 19, 2021, we put the transducer into a slotted PVC well mounted to a fence post (Fig. 2) and moved it further into the wetland (Fig. A6C). On June 1, 2022, we replaced the steel pipe housing the logger with a smaller pipe mounted to a fence post (Fig. A6A). A channel connects the monitored shallow marsh to a neighboring wetland wetland to the southwest (Fig. A6D, Fig. A7). We conducted a vegetation survey on August 3, 2021.

Figure A6: (A) View of Becker County 2 with newer steel pipe housing logger intalled and older housing on the ground, taken June 1, 2022. (B) Original monitoring equipment set-up with transducer mounted directly to fence post, taken October 19, 2021. (C) OTT transducer within PVC well and installed further into the wetland, taken on October 19, 2021. (D) Channel connecting the monitored shallow marsh to a neighboring wetland, taken on August 2, 2021.

Figure A7: Map of Becker County 2 data collection sites. The yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data.

Results

We identified 43 plant taxa at the shallow marsh in Becker County, with a diversity of 3.4 and evenness of 0.89. The shallow marsh is dominated (present in > 75% of the quadrats) by tufted loosestrife (*Lysimachia thyrsiflora*) (Fig. A8).

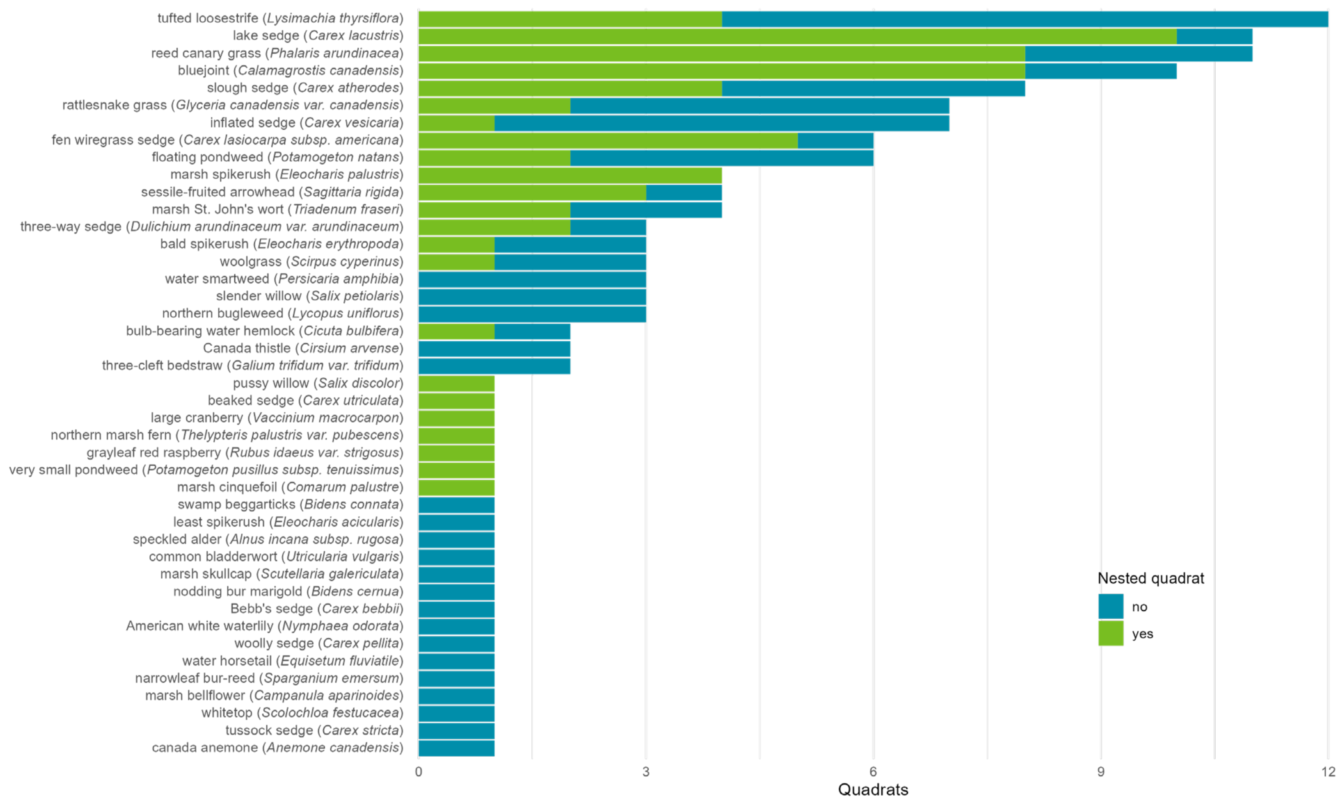

Figure A8: Plant community of Becker County 2.

The median water level in the shallow marsh in Becker County was 3.6 ft in 2021 and 4.4 ft in 2022 (Fig. A9). The wetland was saturated within 1 ft of the ground surface for 135 days during the 2021 growing season and 111 days during the 2022 growing season. It was inundated for 135 days during the 2021 growing season and 111 days during the 2022 growing season. The maximum water level maintained for at least 14 days during the growing season was 4.4 ft in 2021 and 4.9 ft in 2022.

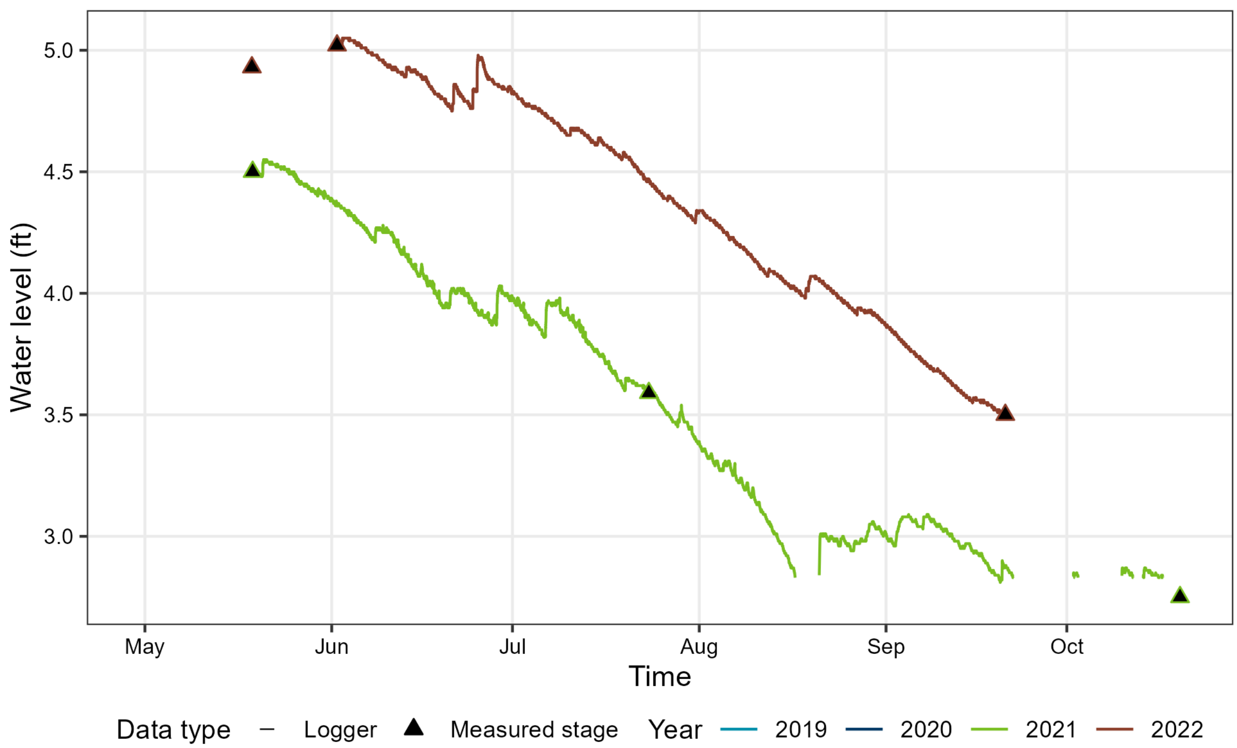

Figure A9: Hydrograph from Becker County 2.

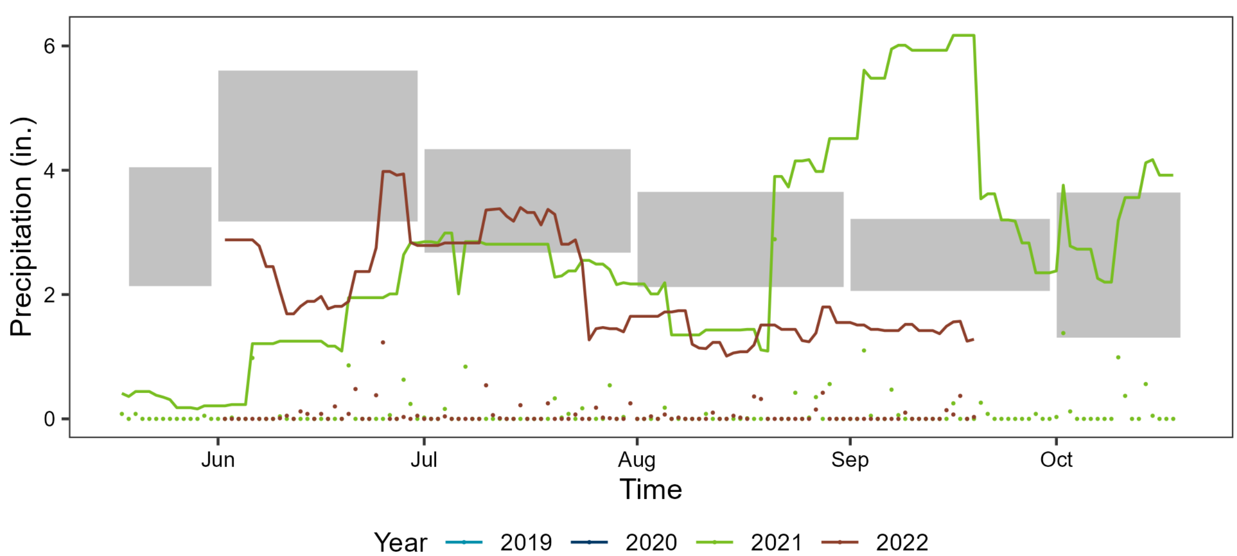

Figure A10: Precipitation at Becker County 2. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Carex WMA 1

Methods

We monitored a sedge mat in Carex WMA (Freeborn County), which is in the Eastern Broadleaf Forest province (Fig. A11A). The well is installed on the southwest edge of the wetland and vegetation data were collected in the center of the wetland, where the sedge mat community is well represented (Fig. A12). The first set of hydrological equipment (bubbler, Fig. 3) was installed and began collecting data on July 18, 2019. We switched the equipment to an OTT (Figure AY) on April 26, 2022. The equipment is installed on the edge of a vegetation transition (Fig. A11B), but has the same water depth as the dominant sedge mat community (where the survey occurred, Fig. A12). There is a box housing the logger in a nearby upland area (Fig. A11C). The wetland is part of a larger wetland complex that expands throughout the WMA (Fig. A12). It is separated from the adjacent wetland by a pervious earthen berm, on the northwest side of the wetland, through which water drains (Fig. A11D). The equipment was shut down during the winter of 2019-2020, turned back on slightly late in the growing season of 2020 (June 10) due to COVID-19 restrictions on field work, and remained on through the winter of 2020-2021. We conducted a vegetation survey on July 31, 2020.

Figure A11: (A) View of Carex WMA 1 on July 14, 2022. (B) Well (bottom center of photo) on July 14, 2022. (C) Upland box housing logger on July 18, 2019. (D) Outlet on April 26, 2022.

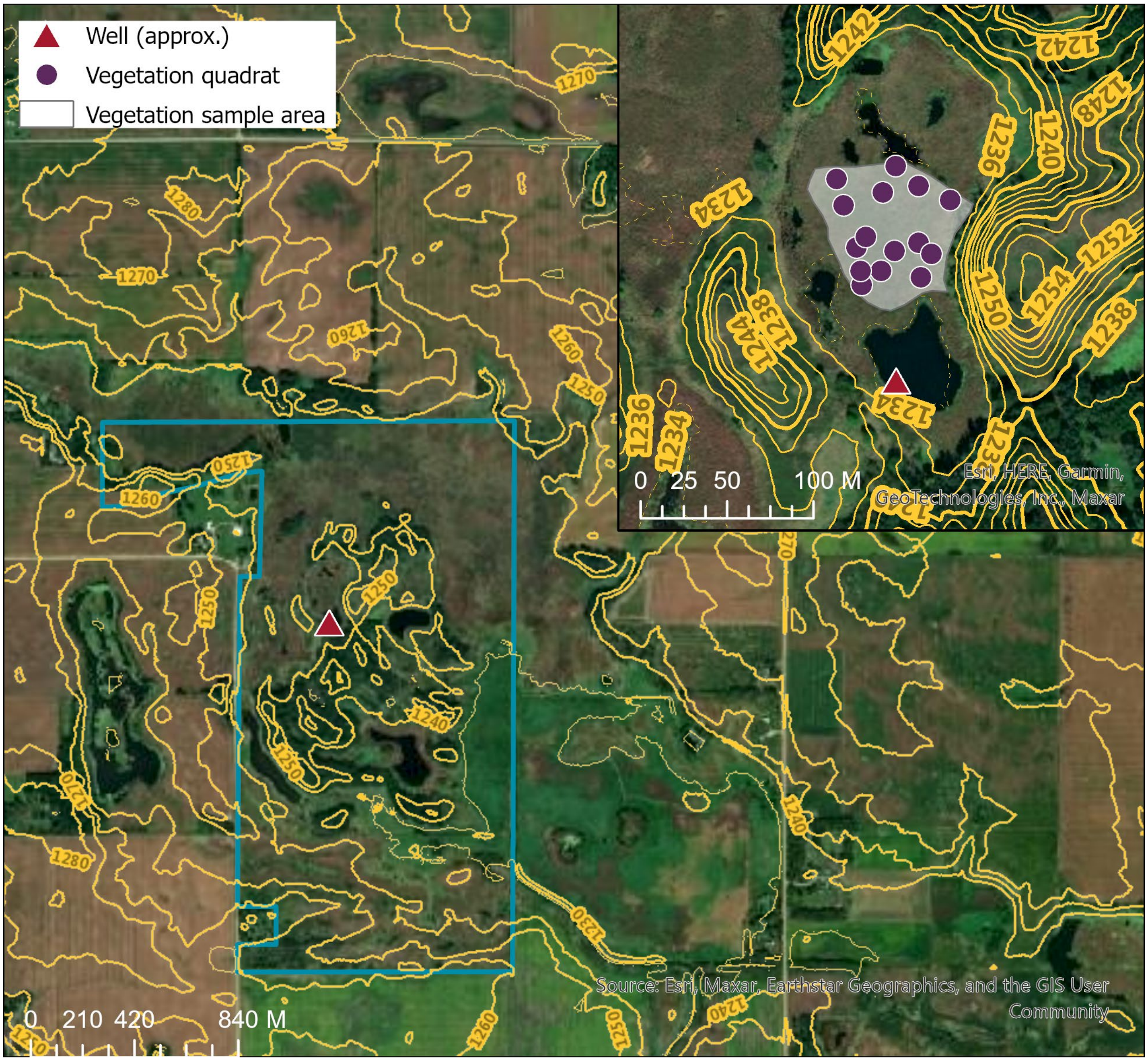

Figure A12: Map of Carex WMA 1 data collection sites. The blue line shows the boundaries of Carex WMA and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data.

Results

We identified 40 plant taxa at the sedge mat in Carex WMA, with a diversity of 3.3 and evenness of 0.9. The sedge mat is dominated (present in > 75% of the quadrats) by fen wiregrass sedge (*Carex lasiocarpa subsp. americana*), broad-leaved arrowhead (*Sagittaria latifolia*), marsh cinquefoil (*Comarum palustre*), slender willow (*Salix petiolaris*) (Fig. A13).

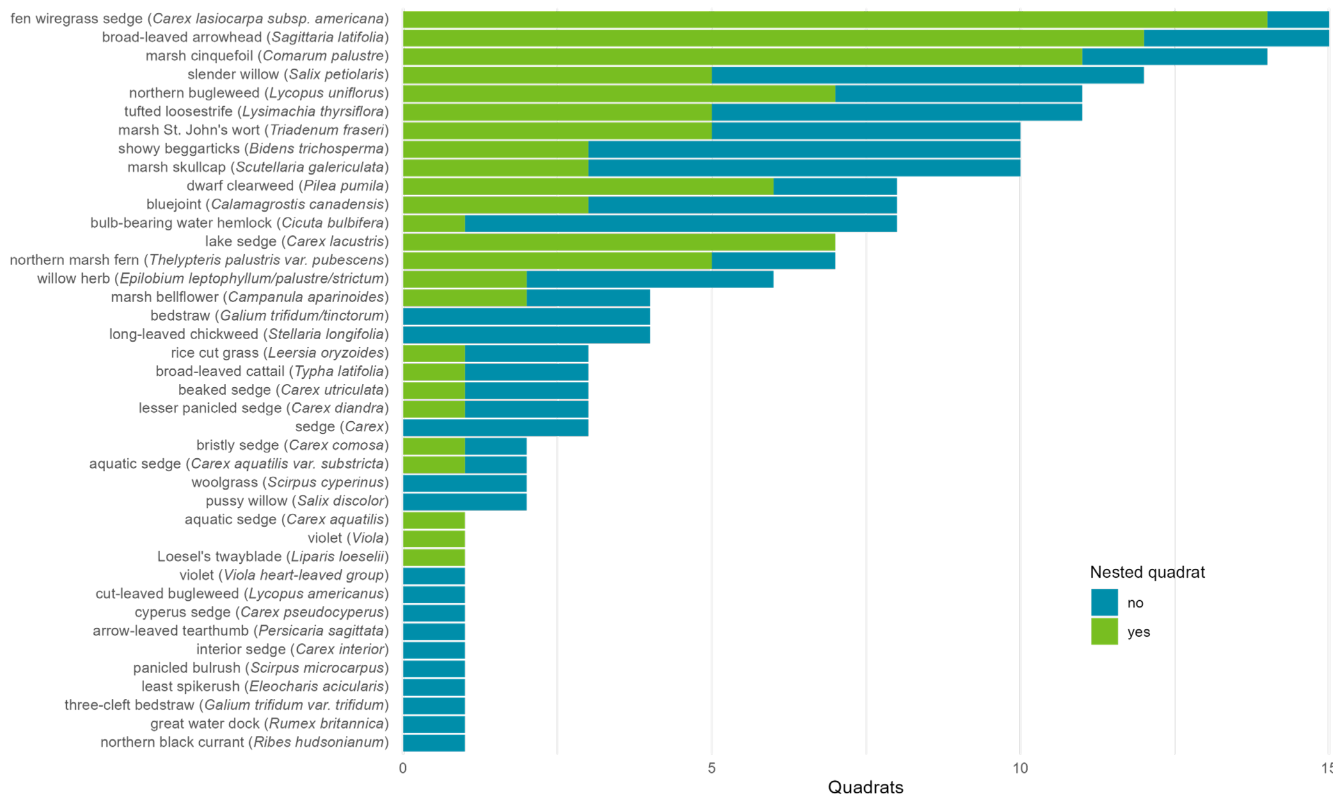

Figure A13: Plant community of Carex WMA 1.

The median water level in the sedge mat in Carex WMA was 2.4 ft in 2020, 1.8 ft in 2021, and 1.8 ft in 2022 (Fig. A14). The wetland was saturated within 1 ft of the ground surface for 129 days, 191 days, and 176 days during the 2020, 2021, and 2022 growing seasons, respectively. It was inundated for 129 days, 191 days, and 176 days during the 2020, 2021, and 2022 growing seasons, respectively. The maximum water level maintained for at least 14 days during the growing season was 2.6 ft in 2020, 2.2 ft in 2021, and 2.2 ft in 2022.

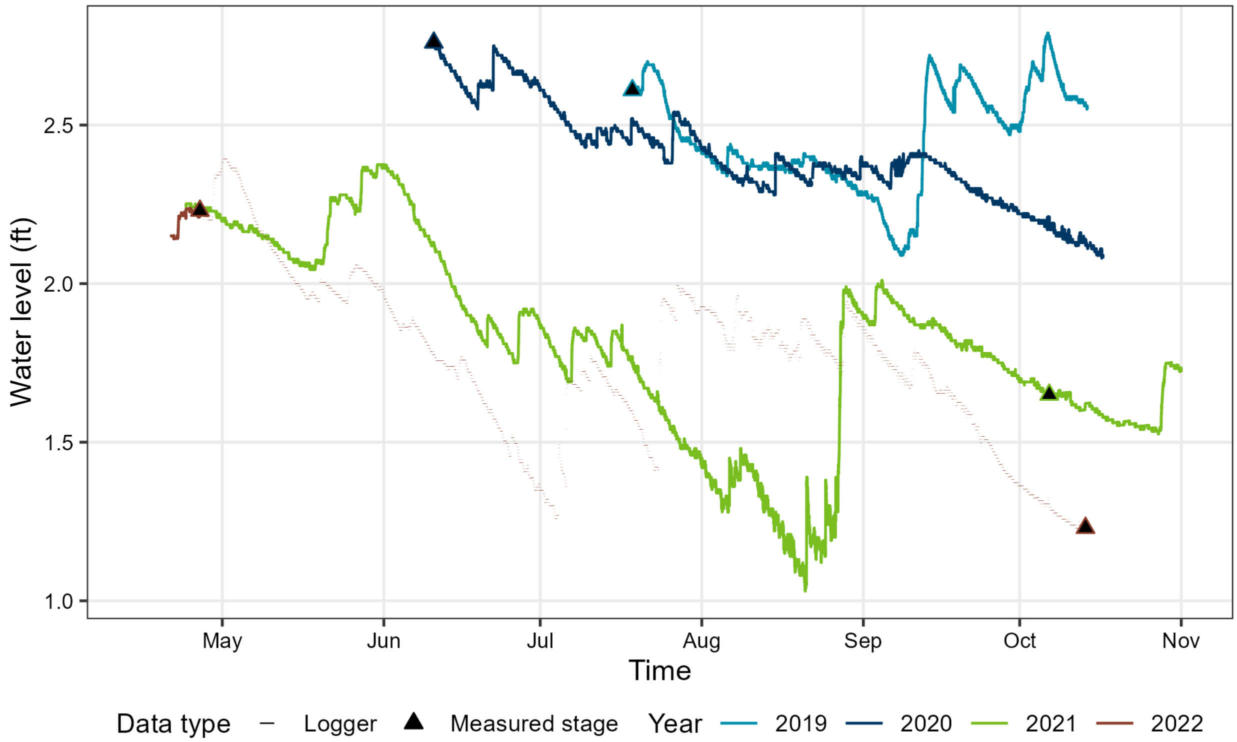

Figure A14: Hydrograph from Carex WMA 1.

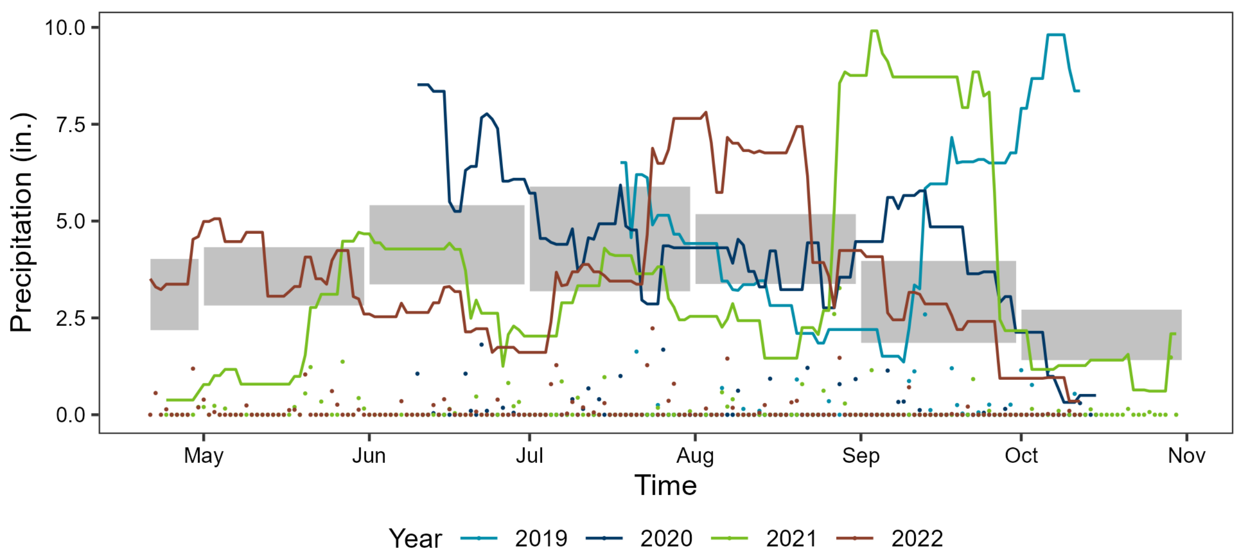

Figure A15: Precipitation at Carex WMA 1. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Clinton Prairie SNA 1

Methods

We monitored a fresh meadow in Clinton Prairie SNA (Big Stone County), which is in the Prairie Parkland province (Fig. A16A). The wetland is in the center of the SNA (Fig. A17). An OTT was installed and began collecting data on September 22, 2020, but the data showed unusual jumps. Unusual data patterns may have been due to a pinch in the cable connecting the transducer to the logger or water pooling in the bottom of the casing. We replaced the OTT with a new one of the same model on May 10, 2022. The set-up differs from Fig. 2 because the transducer is housed in 6 in. steel casing that rises approximately 4 ft above ground (Fig. A16B), rather than a slotted PVC. This design was used to protect the equipment from prescribed burns. The transducer can collect data on water levels down to approximately 1 ft below ground. We are going to lower the transducer in spring 2023 and place it within a slotted PVC that is protected with steel casing. The logger is housed in the top of the steel casing (Fig. A16C). The well is on the southern edge of the wetland and vegetation data were collected throughout the wetland (Fig. A17). Water appears to flow southward from the wetland, but there is no obvious outlet. The vegetation in this SNA has been monitored by Minnesota Biological Survey botanists prior to this project. We conducted a vegetation survey on August 2, 2021 (Fig. A16D).

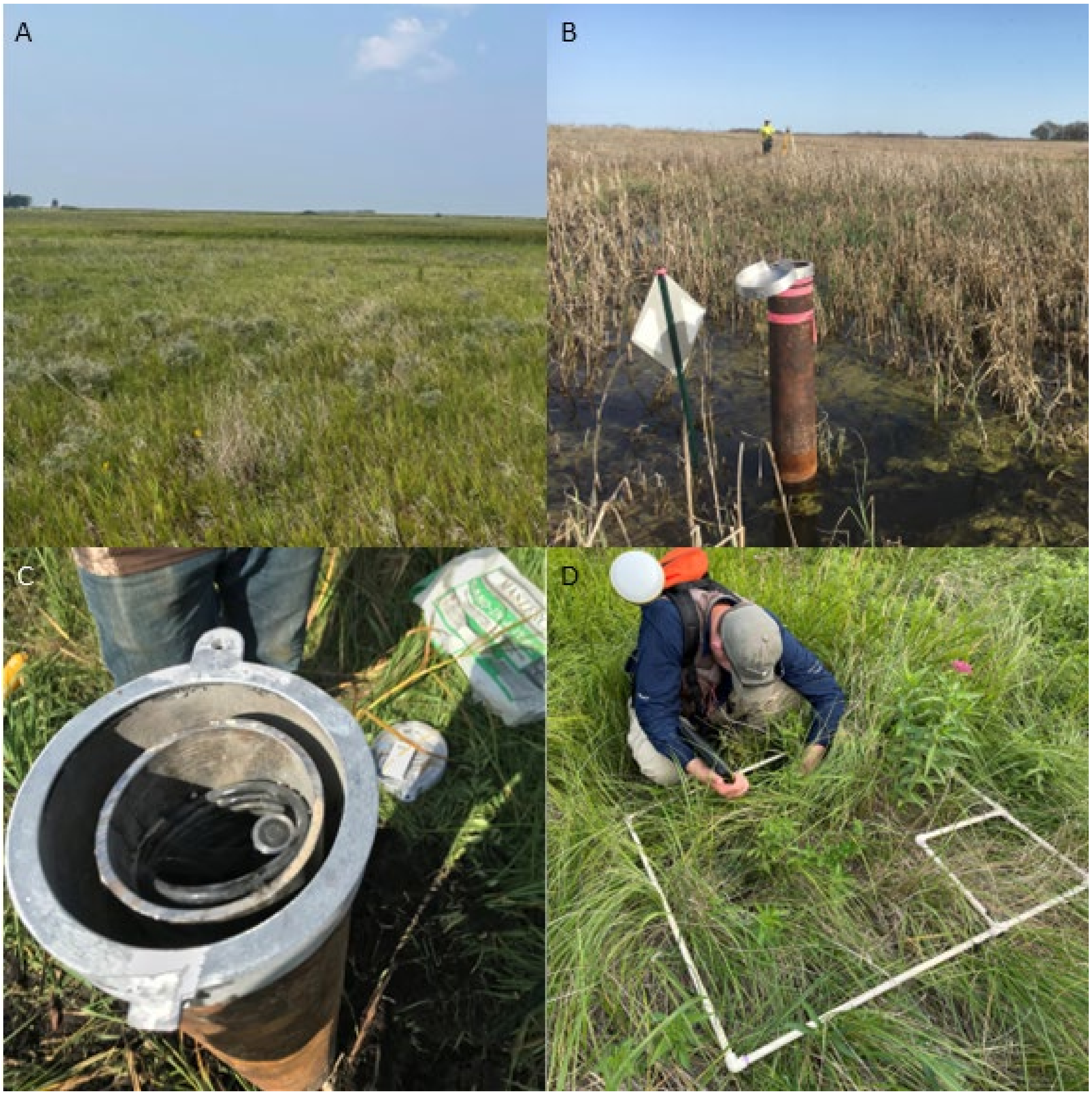

Figure A16: (A) View of Clinton Prairie SNA 1 on August 2, 2021. (B) Well with inundation on May 10, 2022. (C) Inside of well on September 22, 2020. (D) Quadrat used for vegetation survey on August 2, 2021.

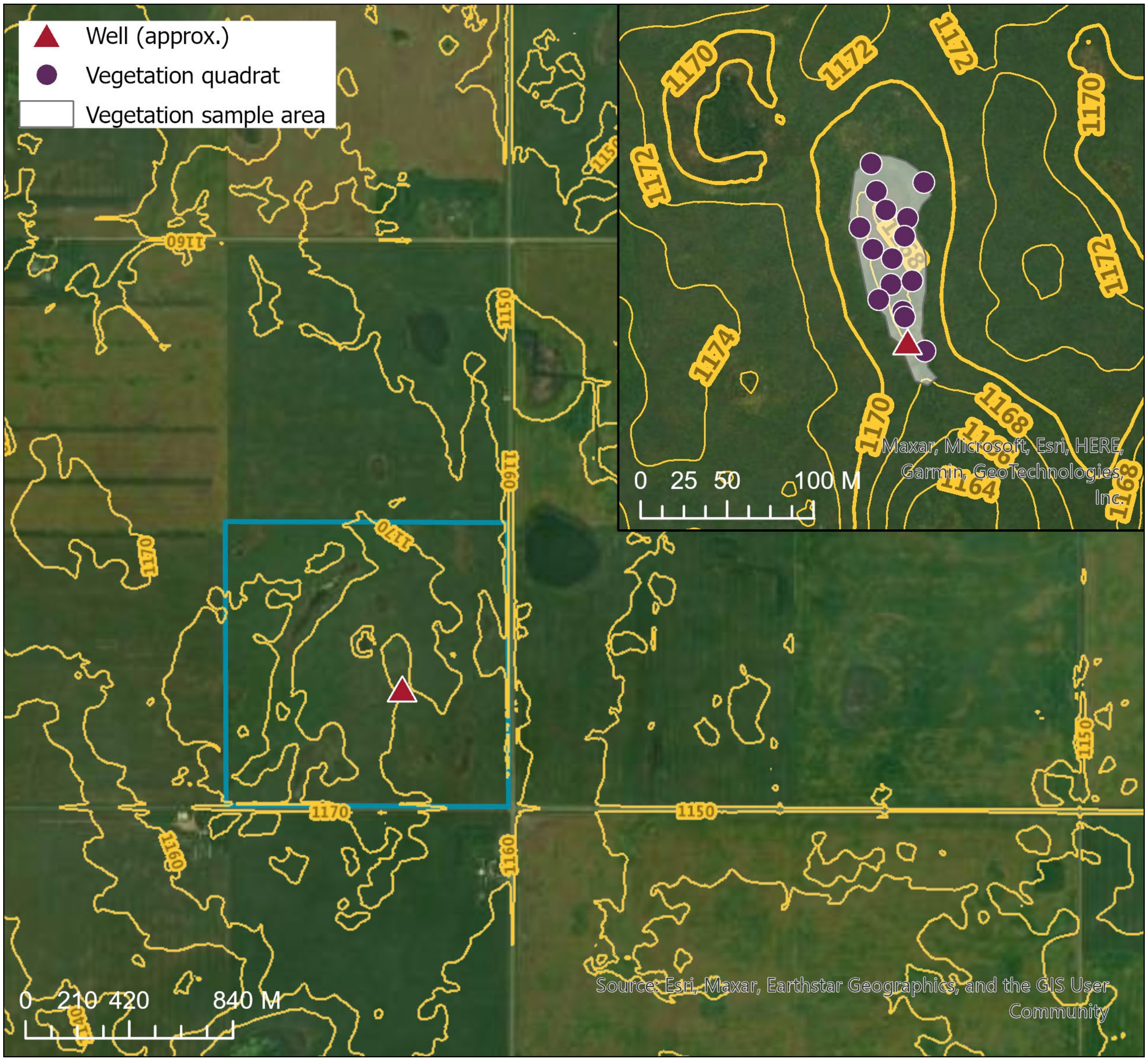

Figure A17: Map of Clinton Prairie SNA 1 data collection sites. The blue line shows the boundaries for Clinton Prairie SNA and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data.

Results

We identified 43 plant taxa at the fresh meadow in Clinton Prairie SNA, with a diversity of 3.5 and evenness of 0.93. The fresh meadow has no dominant (present in > 75% of the quadrats) taxa (Fig. A18).

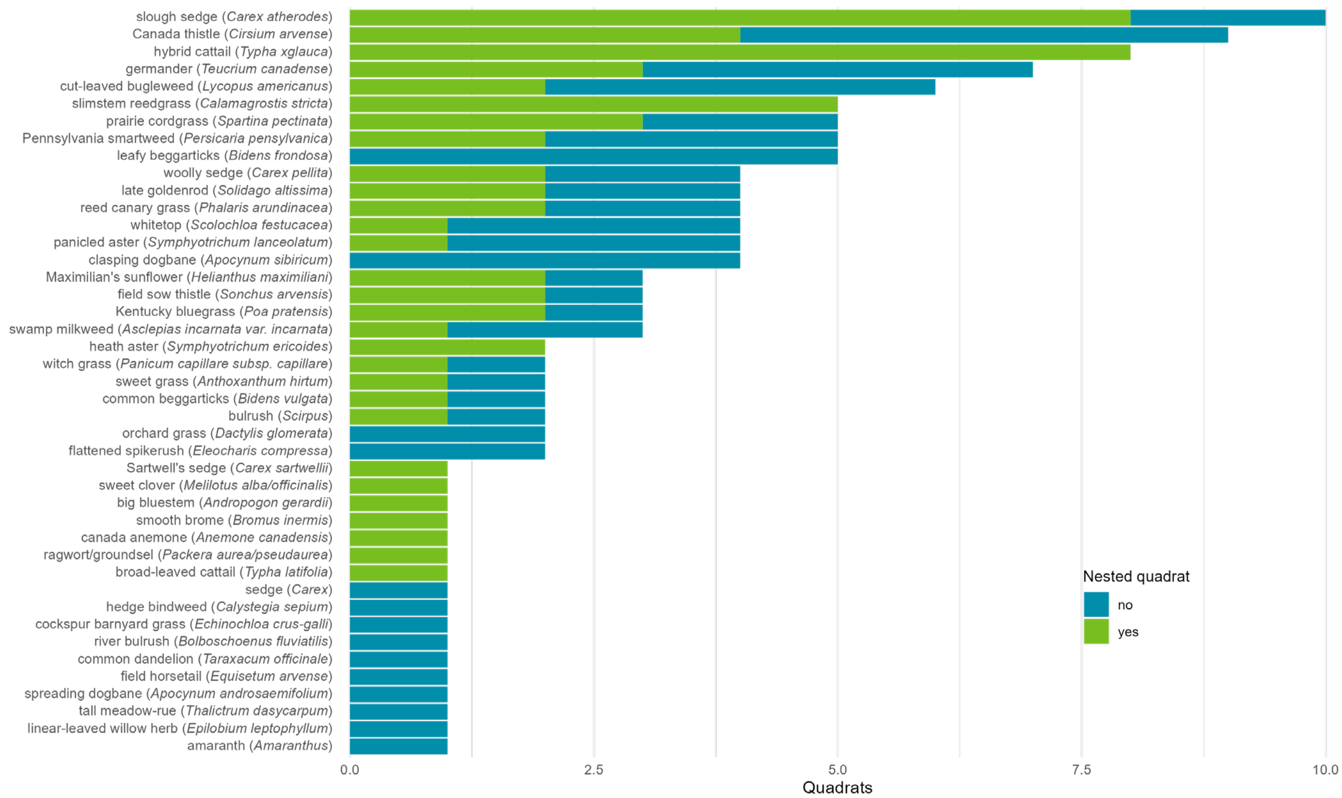

Figure A18: Plant community of Clinton Prairie SNA 1.

We did not analyze the water levels in this wetland in 2020 and 2021 due to equipment malfunctions. Note that the 2022 data are incomplete. The median water level in the fresh meadow in Clinton Prairie SNA was 1 ft in 2022 (Fig. A19). The wetland was saturated within 1 ft of the ground surface for 63 days during the 2022 growing season. It was inundated for 61 days during the 2022 growing season. The maximum water level maintained for at least 14 days during the growing season was 1.1 ft in 2022.

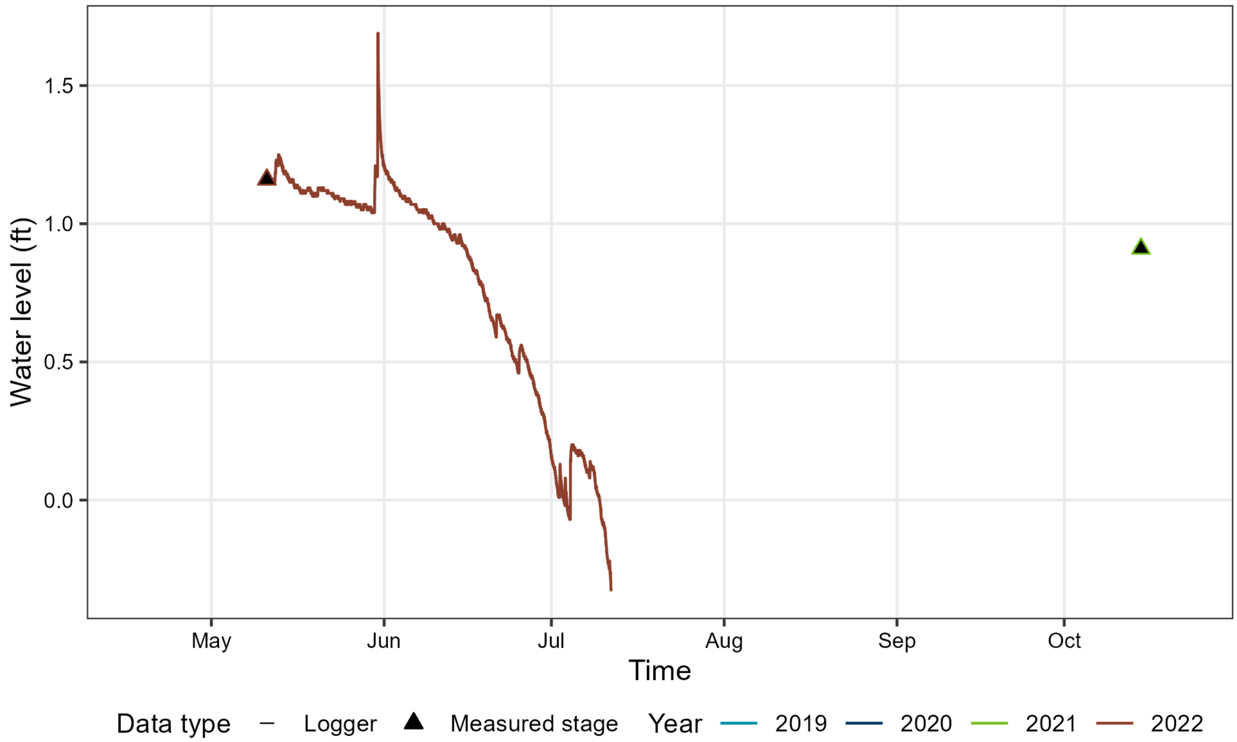

Figure A19: Hydrograph from Clinton Prairie SNA 1.

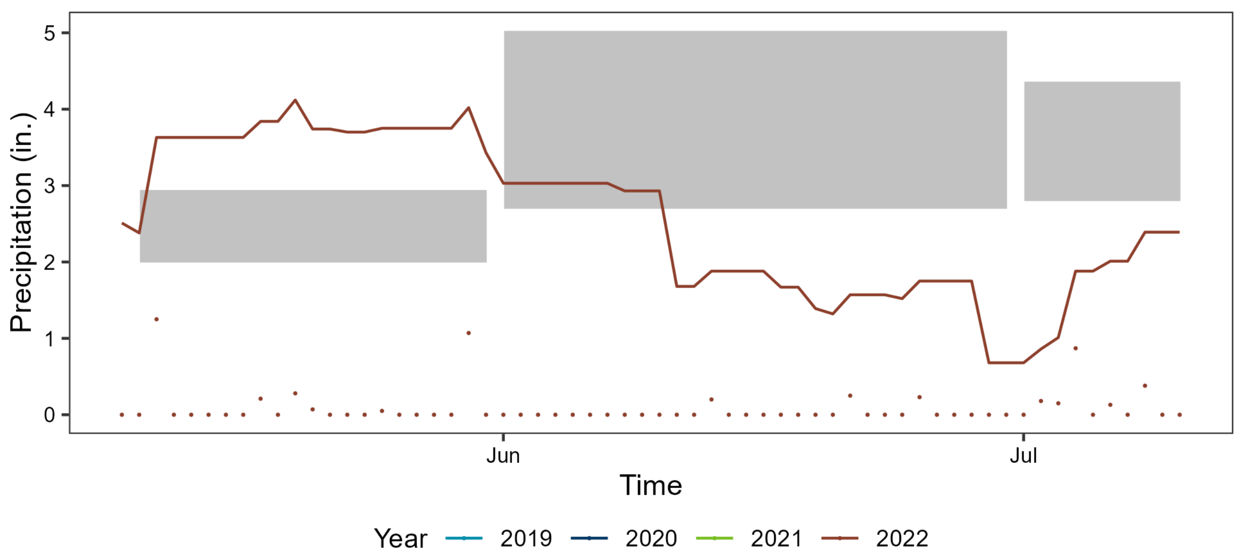

Figure A20: Precipitation at Clinton SNA 1. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Freese WPA 1

Methods

We monitored a deep marsh/shallow open water in Freese WPA (Kandiyohi County), which is in the Prairie Parkland province (Fig. A21A). We installed an OTT on August 5, 2020. The equipment is located on the northeast side of the wetland (Fig. A22). The transducer was mounted to a fencepost without a PVC well, but it was placed inside a slotted PVC in May 2022. The transducer does not reach belowground, but we do not expect water levels to decline belowground in this location. The logger is housed in a 6 in. steel casing (Fig. A21B), which we painted green to reduce visibility (Fig. A21C). The transducer is located within cattails that are on the edge of the open water (Fig. A21D). We conducted a vegetation survey on August 18, 2020. During this survey, we collected water depth measurements. We used the difference between the survey point on the edge of the wetland and the deepest point in the open water to translate the hydrograph to deeper water levels.

Figure A21: (A) View of Freese WPA 1 on August 18, 2020. (B) Installation of the steel casing housing the logger on August 5, 2020. (C) Steel casing housing the logger on August 5, 2020. (D) View of the open water relative to the logger housing on March 31, 2021.

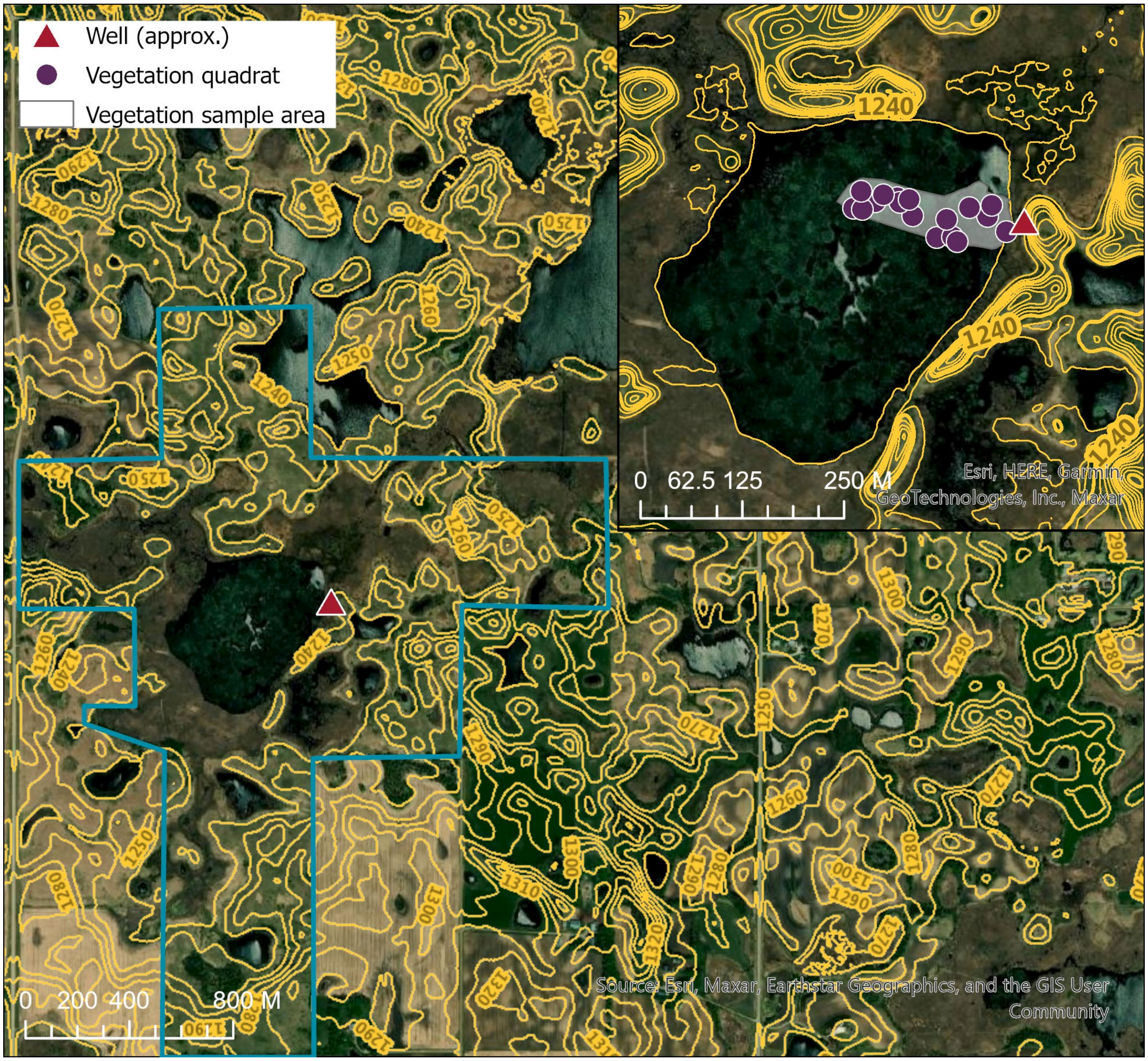

Figure A22: Map of Freese WPA 1 data collection sites. The blue line shows the approximate boundaries for Freese WPA and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data.

Results

We identified 6 plant taxa at the deep marsh/shallow open water in Freese WPA, with a diversity of 1.3 and evenness of 0.74. The deep marsh/shallow open water is dominated (present in > 75% of the quadrats) by common coontail (*Ceratophyllum demersum*), bullhead pond-lily (*Nuphar variegata*) (Fig. A23).

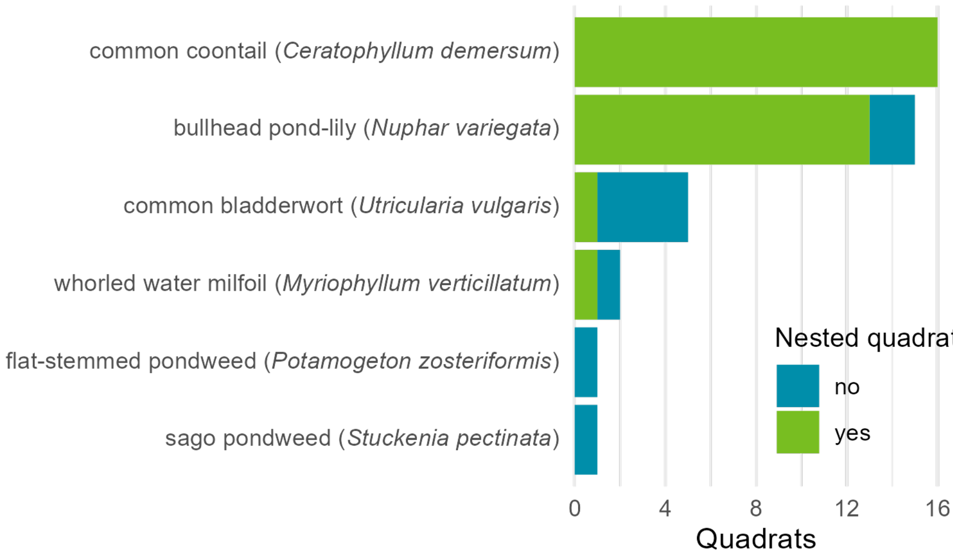

Figure A23: Plant community of Freese WPA 1.

The median water level in the deep marsh/shallow open water in Freese WPA was 5.1 ft in 2020, 4.6 ft in 2021, and 4.2 ft in 2022 (Fig. A24). The wetland was saturated within 1 ft of the ground surface for 72 days, 189 days, and 169 days during the 2020, 2021, and 2022 growing seasons, respectively. It was inundated for 72 days, 189 days, and 169 days during the 2020, 2021, and 2022 growing seasons, respectively. The maximum water level maintained for at least 14 days during the growing season was 5.2 ft in 2020, 5.4 ft in 2021, and 5.1 ft in 2022.

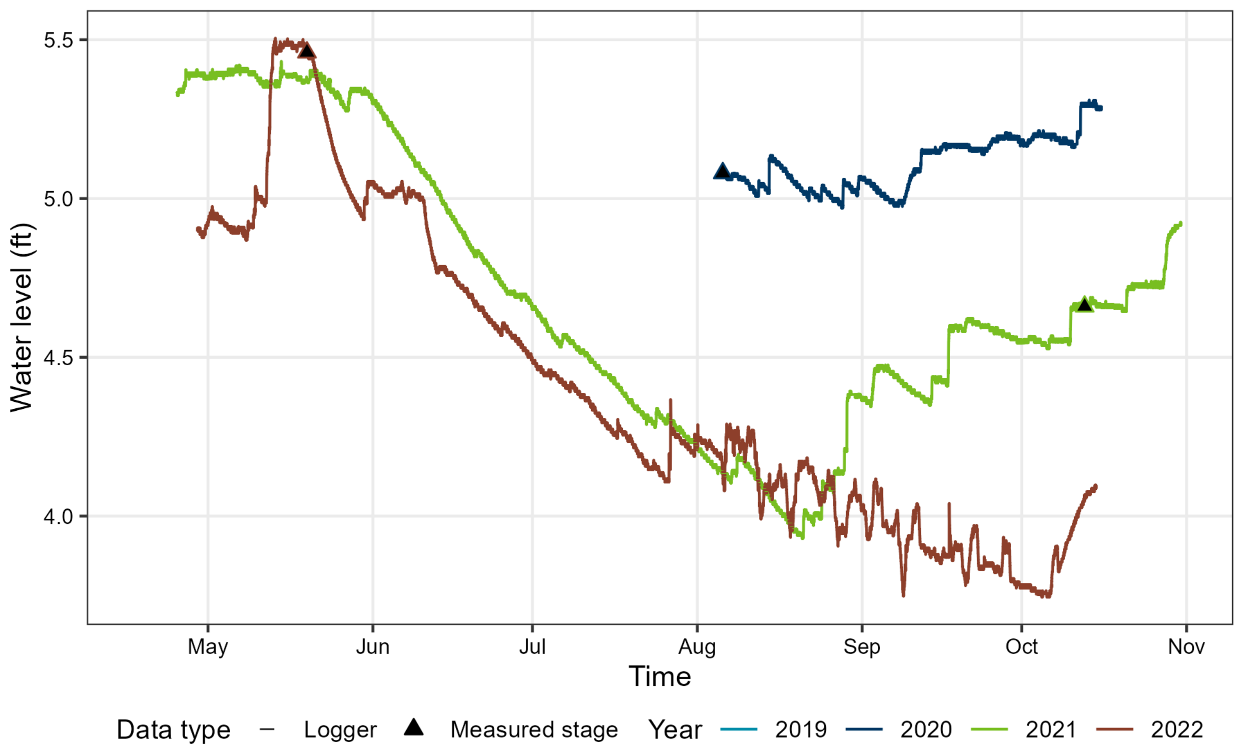

Figure A24: Hydrograph from Freese WPA 1.

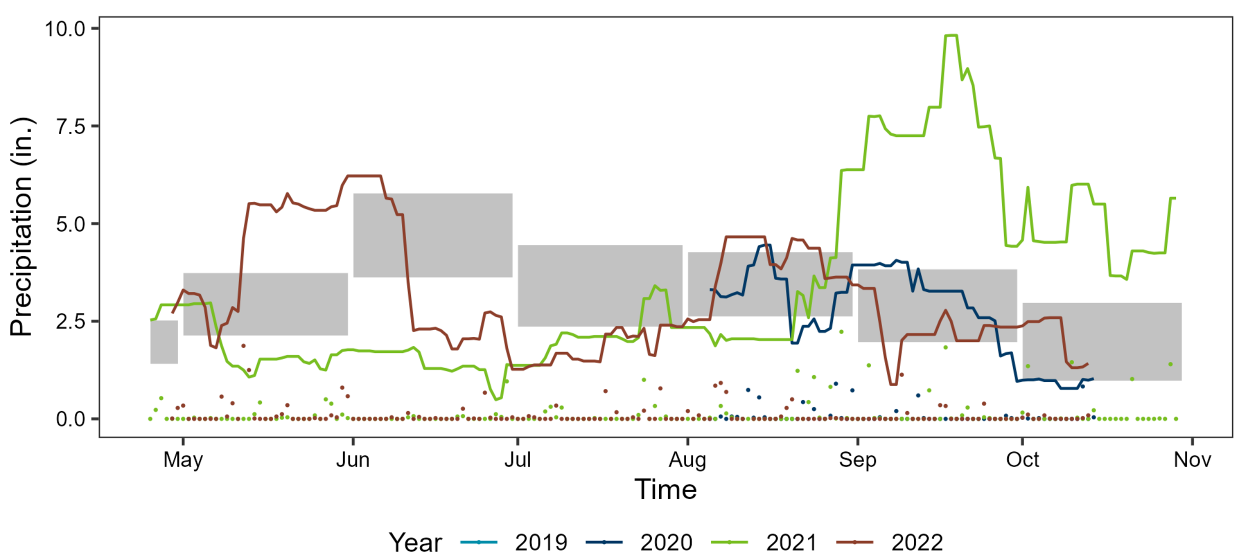

Figure A25: Precipitation at Freese WPA 1. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Glacial Lakes State Park 1

Methods

We monitored a shallow marsh in Glacial Lakes State Park (Pope County), which is in the Prairie Parkland province (Fig. A26A). The monitored shallow marsh is in the northwest portion of the park (Fig. A27). The original hydrology equipment (Fig. 3) was installed on October 15, 2019 and began collecting data on June 9, 2020. There's a steel box housing the logger on the upland (Fig. A26B). The bubbler was installed in a steel pipe in the wetland (Fig. A26C). This set-up has been replaced with an OTT housed inside of a slotted PVC pipe (Fig. 2), which was installed on May 18, 2022 (Fig. A26D). We conducted a vegetation survey on August 12, 2020.

Figure A26: (A) View of Glacial Lakes State Park 1 on October 14, 2021. (B) Steel box housing logger with well in the distance, taken on June 9, 2020. (C) Well housing bubbler (now a PVC pipe with an OTT transducer), taken on June 9, 2020. (D) Inundation at Glacial Lakes State Park 1 on May 18, 2022.

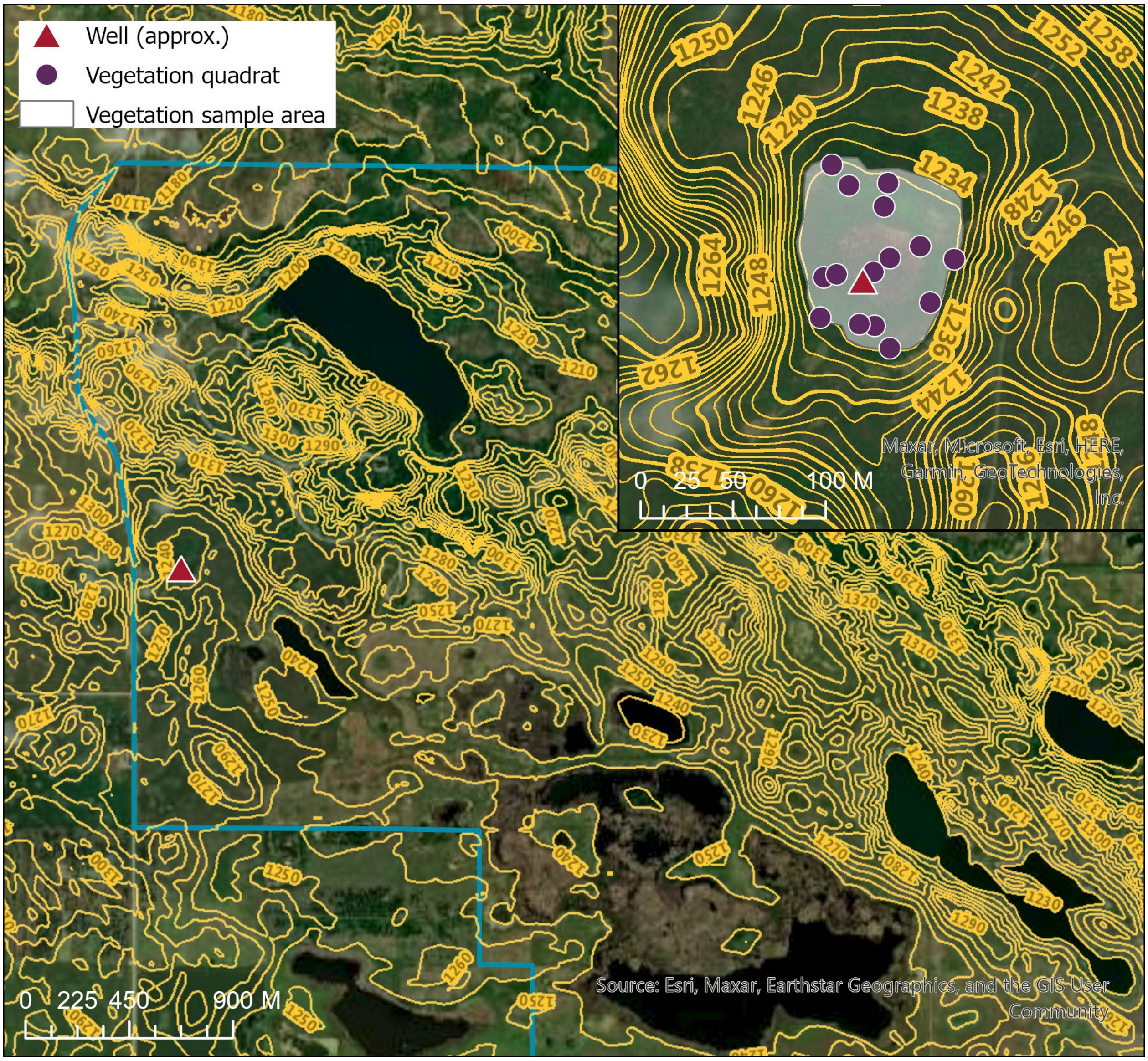

Figure A27: Map of Glacial Lakes State Park 1 data collection sites. The blue line shows the boundaries for Glacial Lakes State Park and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data.

Results

We identified 50 plant taxa at the shallow marsh in Glacial Lakes State Park, with a diversity of 3.6 and evenness of 0.92. The shallow marsh has no dominant (present in > 75% of the quadrats) taxa (Fig. A28).

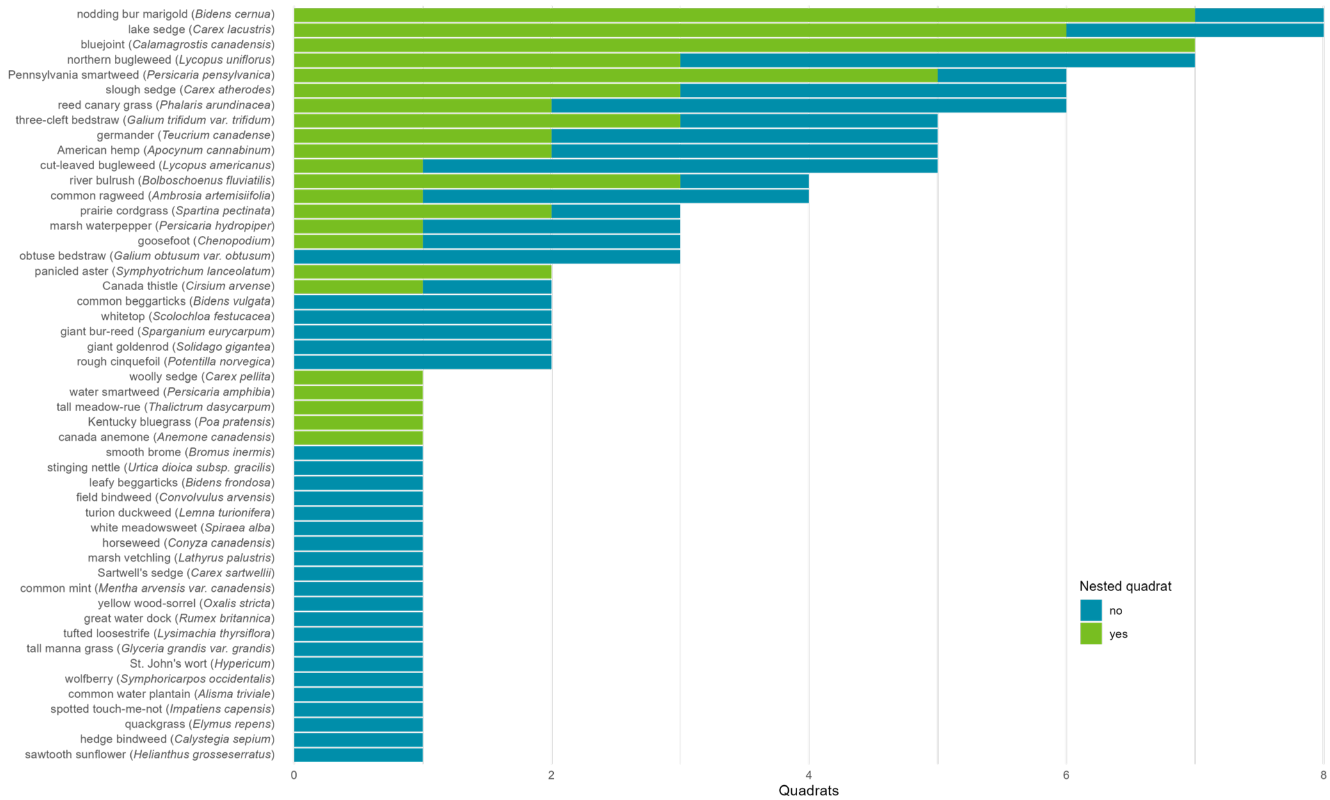

Figure A28: Plant community of Glacial Lakes State Park 1.

The median water level in the shallow marsh in Glacial Lakes State Park was -0.5 ft in 2020, -1.9 ft in 2021, and 1.4 ft in 2022 (Fig. A29). The wetland was saturated within 1 ft of the ground surface for 58 days, 44 days, and 168 days during the 2020, 2021, and 2022 growing seasons, respectively. It was inundated for 34 days, 31 days, and 168 days during the 2020, 2021, and 2022 growing seasons, respectively. The maximum water level maintained for at least 14 days during the growing season was 0.4 ft in 2020, 0.5 ft in 2021, and 2.2 ft in 2022.

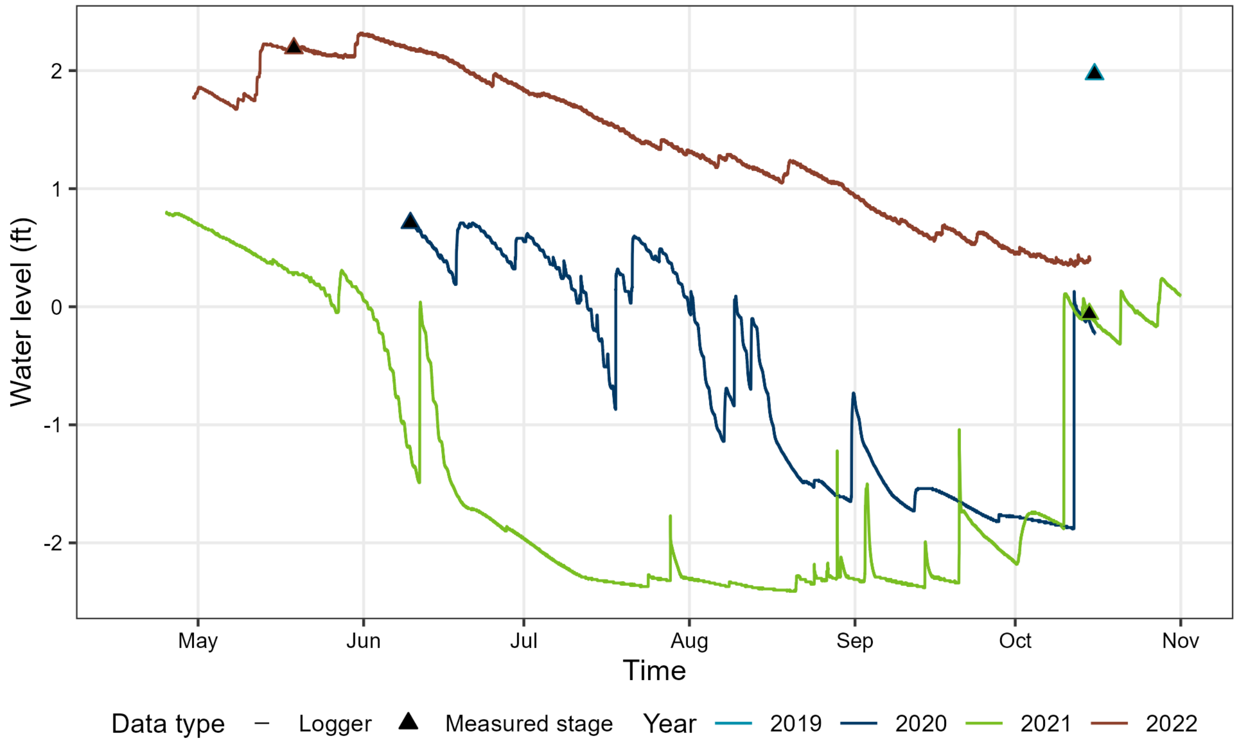

Figure A29: Hydrograph from Glacial Lakes State Park 1.

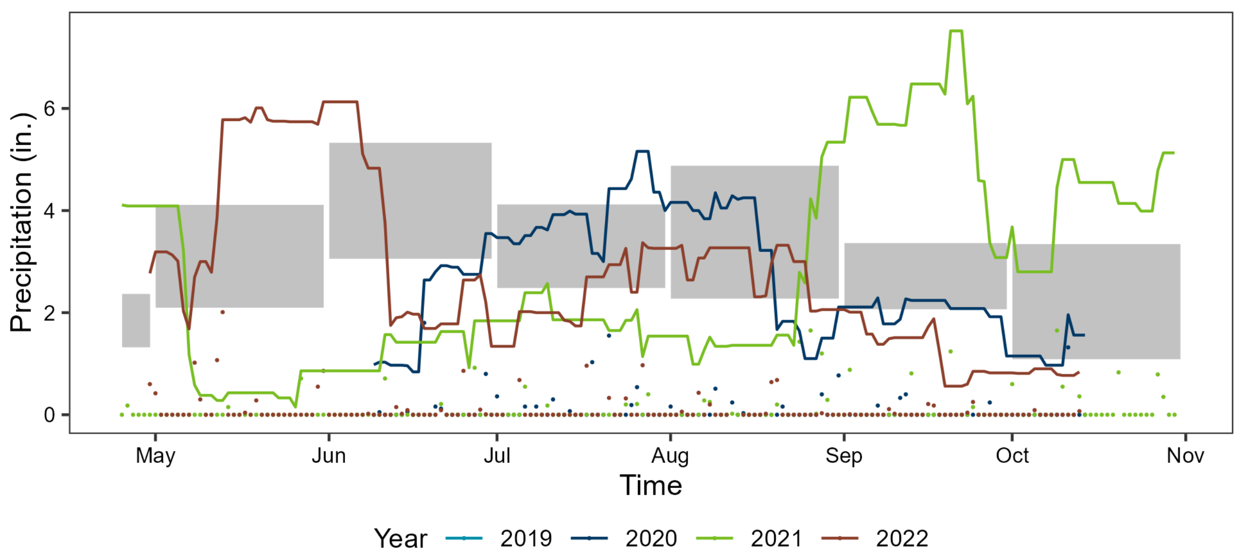

Figure A30: Precipitation at Glacial Lakes State Park 1. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Grey Eagle WMA 1

Methods

We monitored a fen in Grey Eagle WMA (Todd County), which is in the Eastern Broadleaf Forest province (Fig. A31A). Grey Eagle WMA 1 is located in the center of the WMA, just southwest of Grey Eagle WMA 2 (Fig. A32). Grey Eagle WMA 1 has a floating mat of vegetation surrounded by a moat. We installed bubbler equipment (Fig. 3) in the moat on June 25, 2019 (Fig. A31B) and OTT equipment (Fig. 2) in the vegetation mat on October 19, 2021 (Fig. A31C). The two sets of equipment are approximately 25 ft apart. The bubbler was originally mounted to a fence post, but was installed into a slotted PVC on August 19, 2021 (Fig. A31D). The bubbler equipment was removed from the water to avoid freeze damage from September 25, 2019 to June 9, 2020. The loggers for both sets of equipment are housed in a steel box located on nearby upland. The water elevations for the two sets of equipment have been equal. We present data from the bubbler until the OTT was installed, and then the data are from the OTT. We conducted a vegetation survey on August 11, 2020.

Figure A31: (A) View of Grey Eagle WMA 1 looking towards the hydrology equipment on May 18, 2022. (B) Fence posts supporting bubbler equipment, taken on June 9, 2020. (C) Conduit leading to (not visible) OTT equipment on May 18, 2022. (D) PVC well housing bubbler equipment, taken on October 19, 2021.

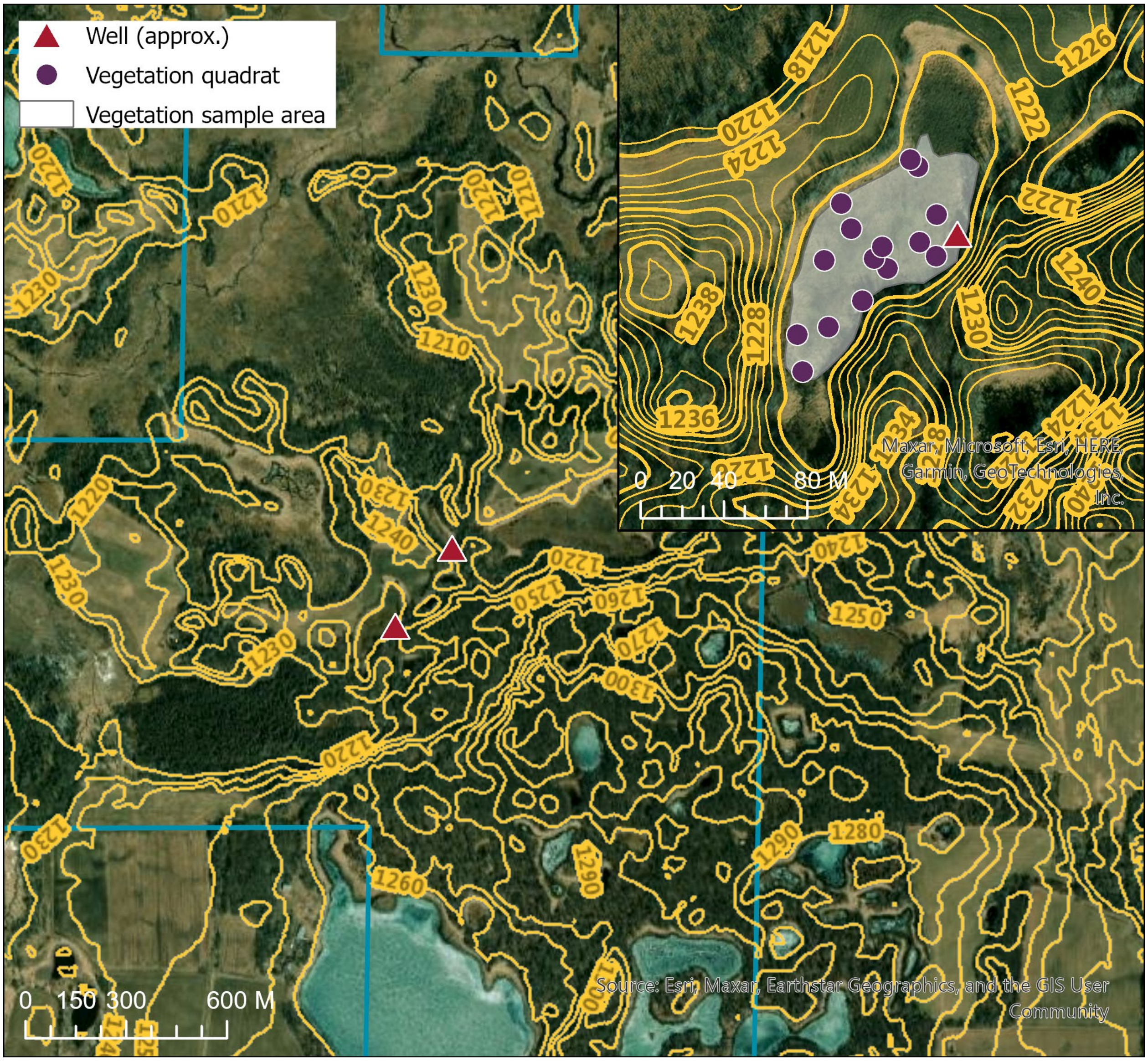

Figure A32: Map of Grey Eagle WMA 1 data collection sites. The blue line shows the boundaries for Grey Eagle WMA and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data. Grey Eagle WMA 1 is just southwest of Grey Eagle WMA 2.

Results

We identified 32 plant taxa at the fen in Grey Eagle WMA, with a diversity of 3 and evenness of 0.86. The fen is dominated (present in > 75% of the quadrats) by fen wiregrass sedge (*Carex lasiocarpa subsp. americana*), northern marsh fern (*Thelypteris palustris var. pubescens*) (Fig. A33).

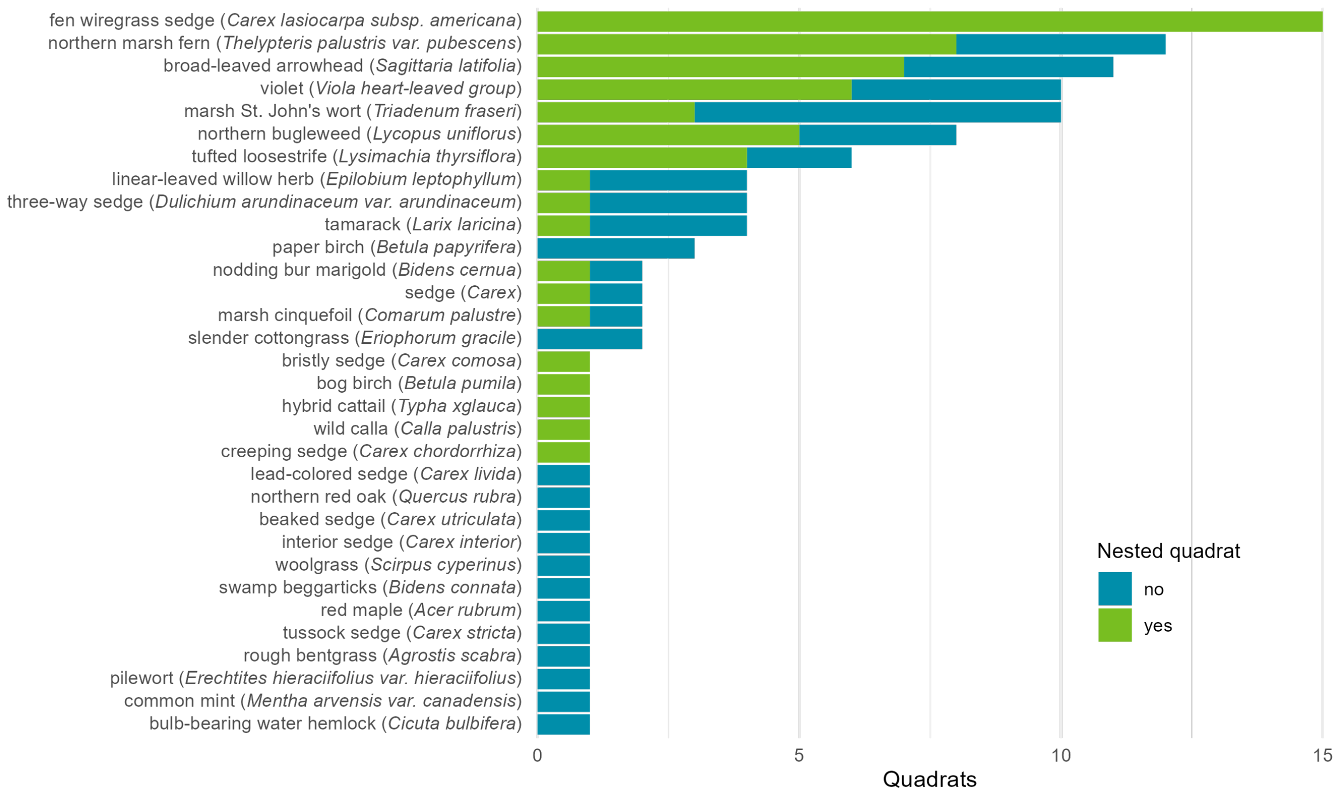

Figure A33: Plant community of Grey Eagle WMA 1.

The median water level in the fen in Grey Eagle WMA was 3 ft in 2020, 2.6 ft in 2021, and 3.5 ft in 2022 (Fig. A34). The wetland was saturated within 1 ft of the ground surface for 129 days, 120 days, and 177 days during the 2020, 2021, and 2022 growing seasons, respectively. It was inundated for 129 days, 120 days, and 177 days during the 2020, 2021, and 2022 growing seasons, respectively. The maximum water level maintained for at least 14 days during the growing season was 3.1 ft in 2020, 3 ft in 2021, and 3.9 ft in 2022.

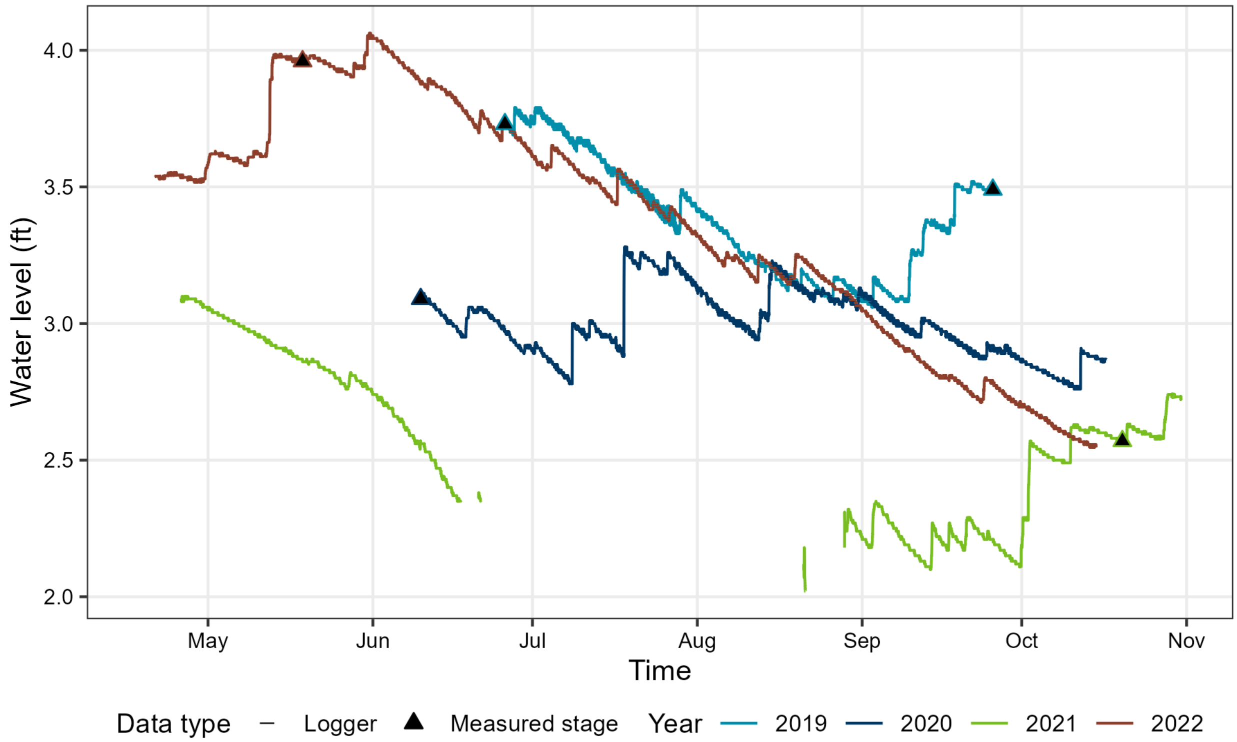

Figure A34: Hydrograph from Grey Eagle WMA 1.

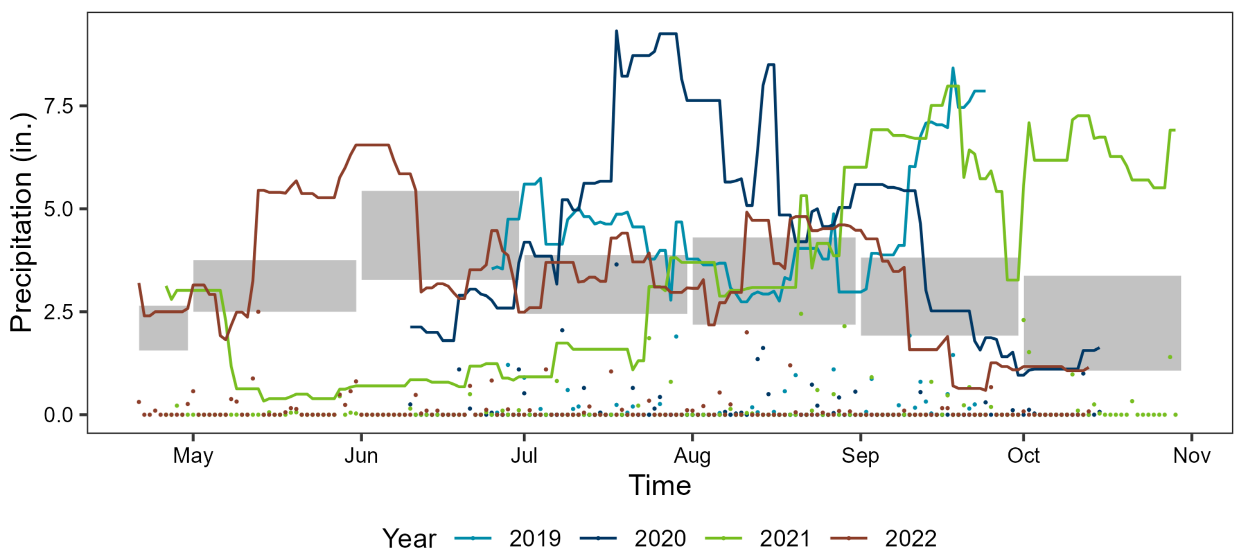

Figure A35: Precipitation at Grey Eagle WMA 1. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Grey Eagle WMA 2

Methods

We monitored a fresh meadow in Grey Eagle WMA (Todd County), which is in the Eastern Broadleaf Forest province. The fresh meadow is just northeast of Grey Eagle WMA 1 (Fig. A37). We installed bubbler equipment on June 25, 2019 (Fig. A36B) and replaced the bubbler with an OTT (Fig. 2) on May 18, 2022 (Fig. A36C). The bubbler equipment deviated from Fig. 3 because the orifice line was housed in a steel casing, which rose 2 ft above the ground. The bottom of the steel casing had a sand-point, which allowed it to be driven into the ground so that the orifice line could detect water levels belowground. Screened holes above the sand-point allowed water into the casing (Fig. A51C). Both sets of equipment were installed approximately 3 ft below the ground. The bubbler was removed from the water between September 25, 2019, and June 9, 2020 to prevent freeze damage. The logger died over the winter of 2020-2021 and the logger was not communicating correctly with the transducer in 2021, leading to replacement of the bubbler and cable on October 19, 2021. We conducted a vegetation survey on August 11, 2020.

Figure A36: (A) A view of Grey Eagle WMA 2 (note well in lower left corner) on June 9, 2020. (B) Steel casing housing bubbler orifice line, taken on June 9, 2020. (C) Installation of OTT equipment on May 18, 2022. (D) A view of Greay Eagle WMA 2 with inundation on May 18, 2022.

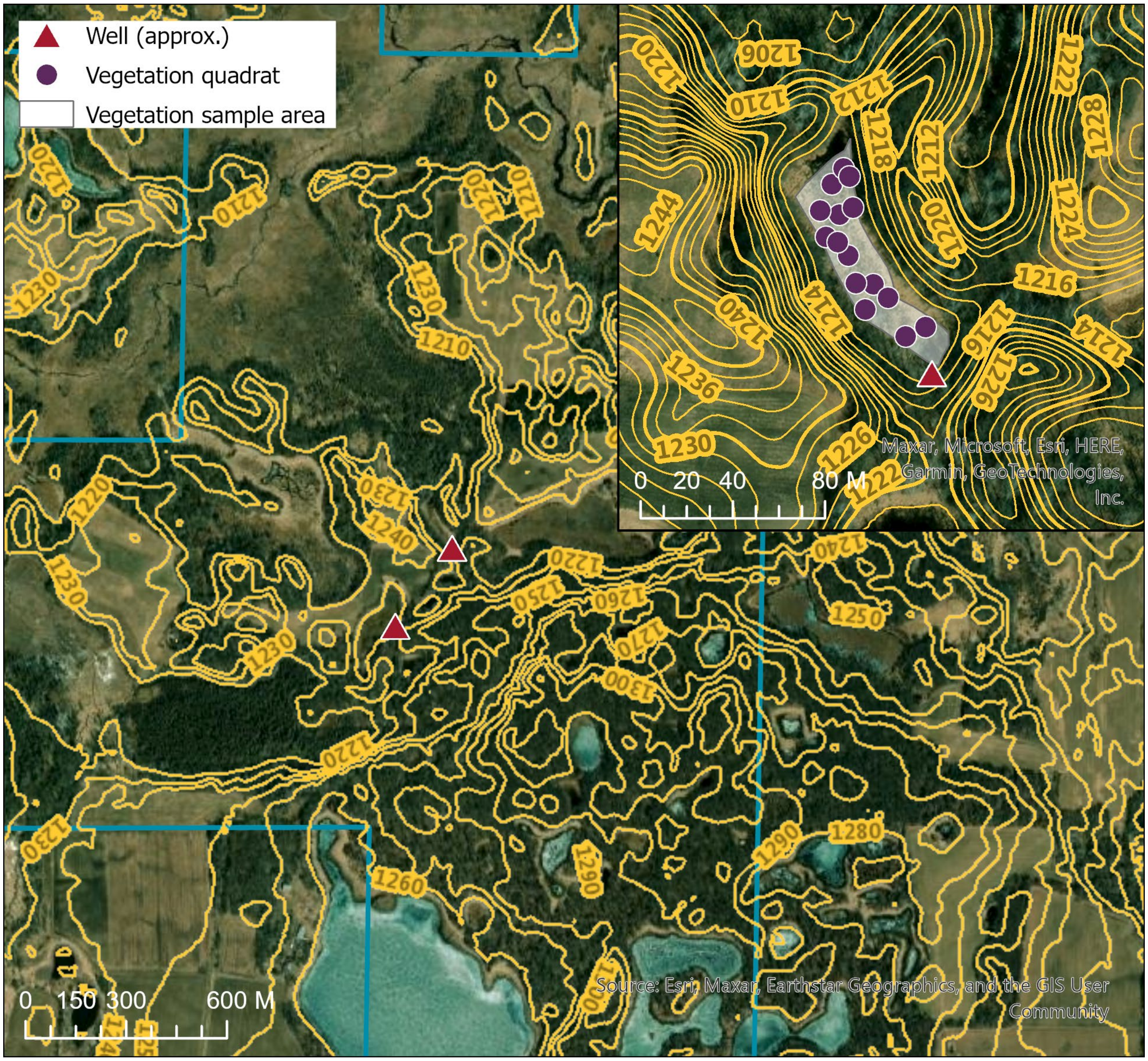

Figure A37: Map of Grey Eagle WMA 2 data collection sites. The blue line shows the boundaries for Grey Eagle WMA and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data.

Results

We identified 31 plant taxa at the fresh meadow in Grey Eagle WMA, with a diversity of 3.1 and evenness of 0.91. The fresh meadow is dominated (present in > 75% of the quadrats) by bulb-bearing water hemlock (*Cicuta bulbifera*), lake sedge (*Carex lacustris*) (Fig. A38).

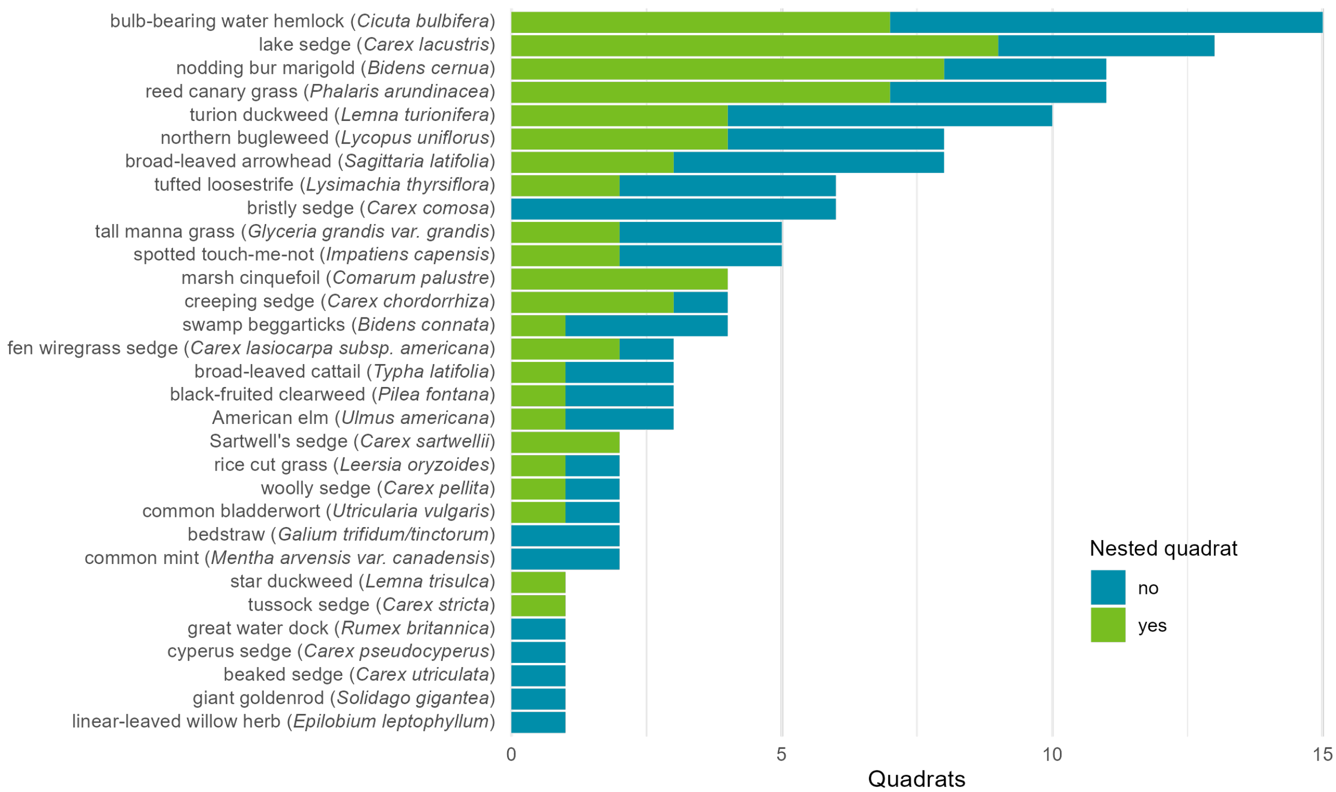

Figure A38: Plant community of Grey Eagle WMA 2.

The median water level in the fresh meadow in Grey Eagle WMA was -0.5 ft in 2020 and -0.1 ft in 2022 (Fig. A39). The wetland was saturated within 1 ft of the ground surface for 106 days during the 2020 growing season and 119 days during the 2022 growing season. It was inundated for 0 days during the 2020 growing season and 72 days during the 2022 growing season. The maximum water level maintained for at least 14 days during the growing season was -0.4 ft in 2020 and 0.8 ft in 2022.

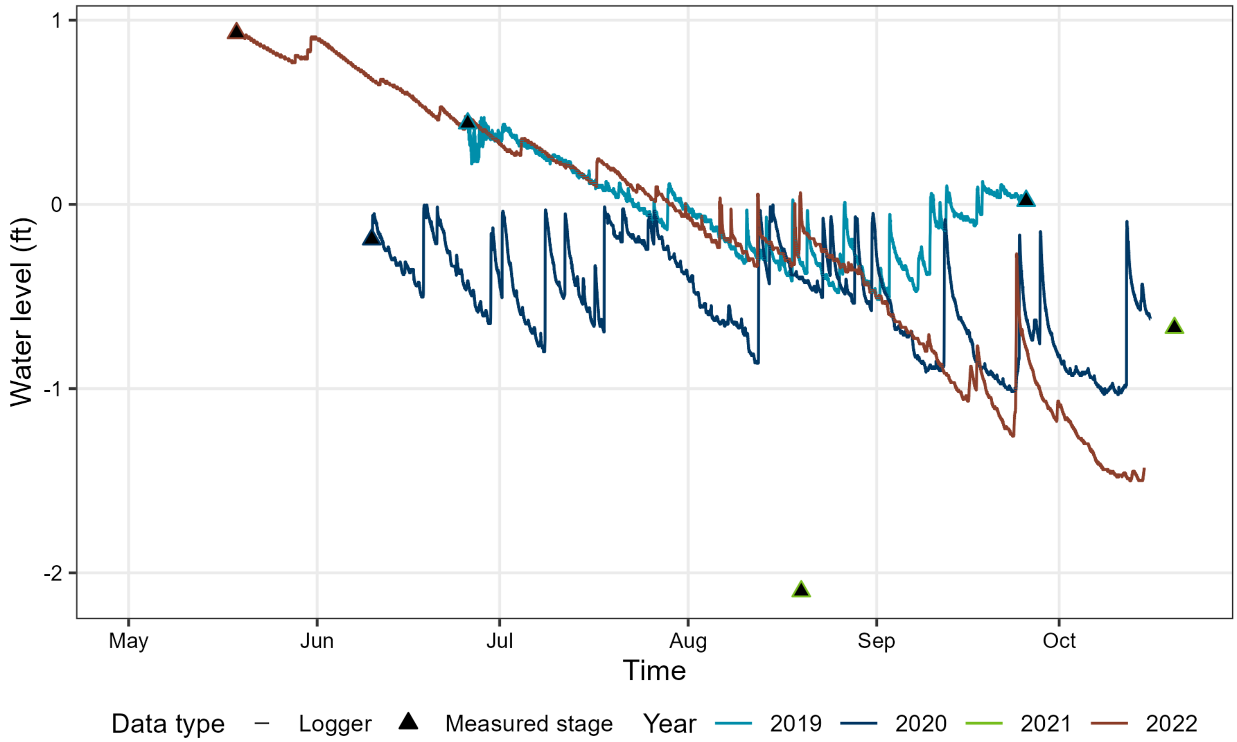

Figure A39: Hydrograph from Grey Eagle WMA 2.

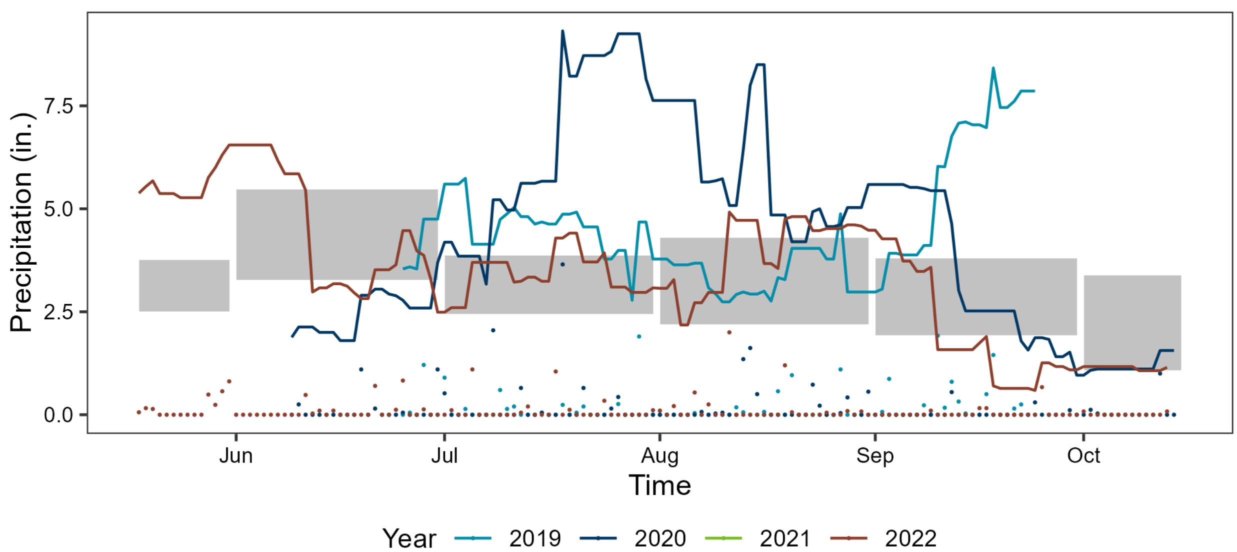

Figure A40: Precipitation at Grey Eagle WMA 2. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Lake Maria State Park 1

Methods

We monitored a shallow marsh in Lake Maria State Park (Wright County), which is in the Eastern Broadleaf Forest province (Fig. A41A). Lake Maria State Park 1, along with the other monitored wetlands, is located in the northeast portion of the park (Fig. A42). We installed bubbler equipment (Fig. 3) in Lake Maria State Park 1 on September 24, 2019 and began collecting data on June 10, 2020 (Fig. A41B). On July 15, 2021, we installed a new bubbler in a PVC well adjacent to the original equipment, approximately 0.4 ft below ground, in order to capture water levels below the ground (Fig. A41C). However, we still did not capture water levels during the summer of 2021 because they were below the orifice line. On May 26, 2022, we replaced the bubbler equipment with OTT equipment, which was installed approximately 1.4 ft below ground (Fig. A41D). We conducted a vegetation survey on August 13, 2020.

Figure A41: (A) View of Lake Maria State Park 1 on June 10, 2020. (B) Fence posts supporting first set of bubbler equipment, facing steel housing with loggers, taken on March 31, 2021. (C) New bubbler equipment in PVC well, installed adjacent to original equipment (fence post on left), taken on July 15, 2021. (D) PVC well housing OTT equipment, taken on July 13, 2022.

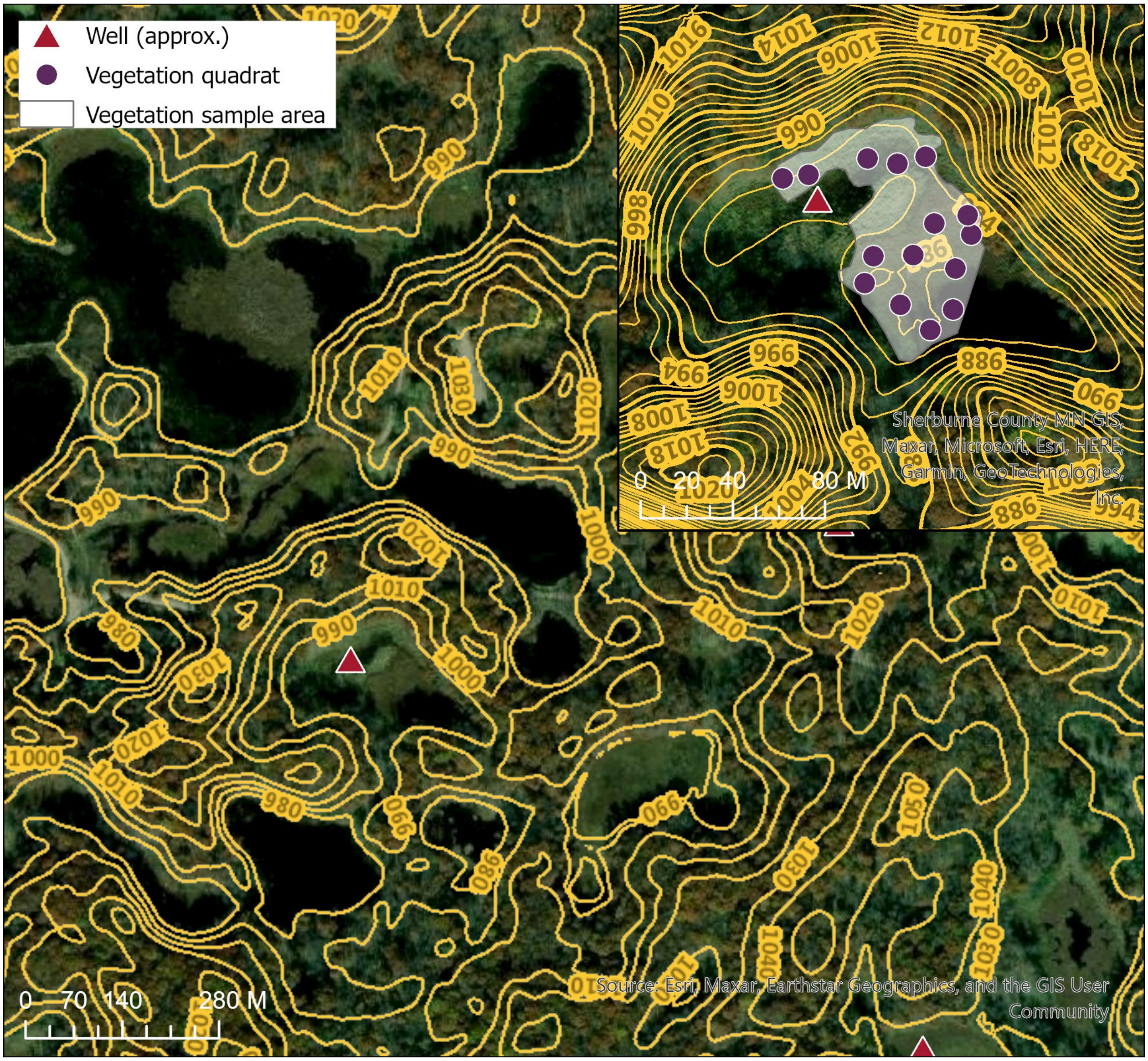

Figure A42: Map of Lake Maria State Park 1 data collection sites. The blue line shows the boundaries for Lake Maria State Park and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data.

Results

We identified 26 plant taxa at the shallow marsh in Lake Maria State Park, with a diversity of 3 and evenness of 0.92. The shallow marsh is dominated (present in > 75% of the quadrats) by broad-leaved arrowhead (*Sagittaria latifolia*) (Fig. A43).

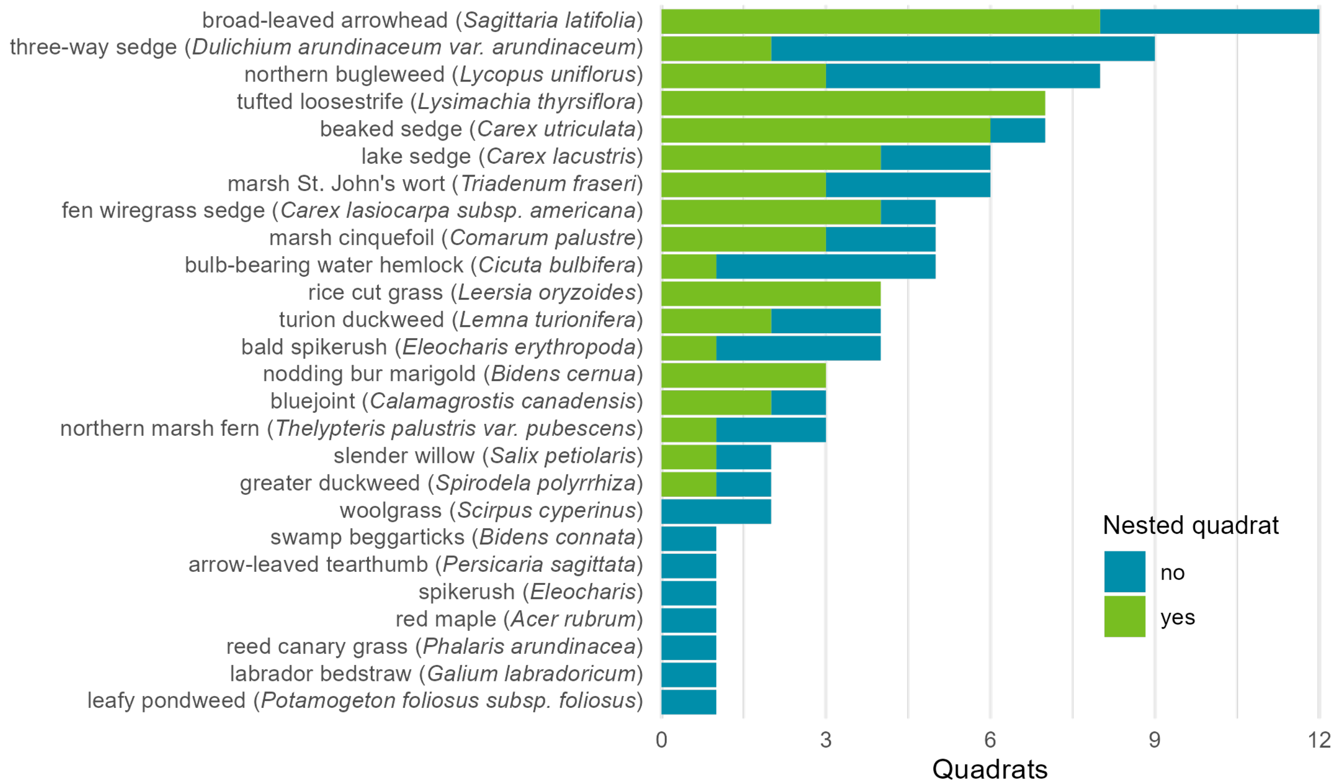

Figure A43: Plant community of Lake Maria State Park 1h.

The median water level in the shallow marsh in Lake Maria State Park was 1.6 ft in 2020, 1 ft in 2021, and 0.5 ft in 2022 (Fig. A44). The wetland was saturated within 1 ft of the ground surface for 128 days, 39 days, and 55 days during the 2020, 2021, and 2022 growing seasons, respectively. It was inundated for 128 days, 39 days, and 43 days during the 2020, 2021, and 2022 growing seasons, respectively. The maximum water level maintained for at least 14 days during the growing season was 2 ft in 2020, 1.1 ft in 2021, and 1.6 ft in 2022.

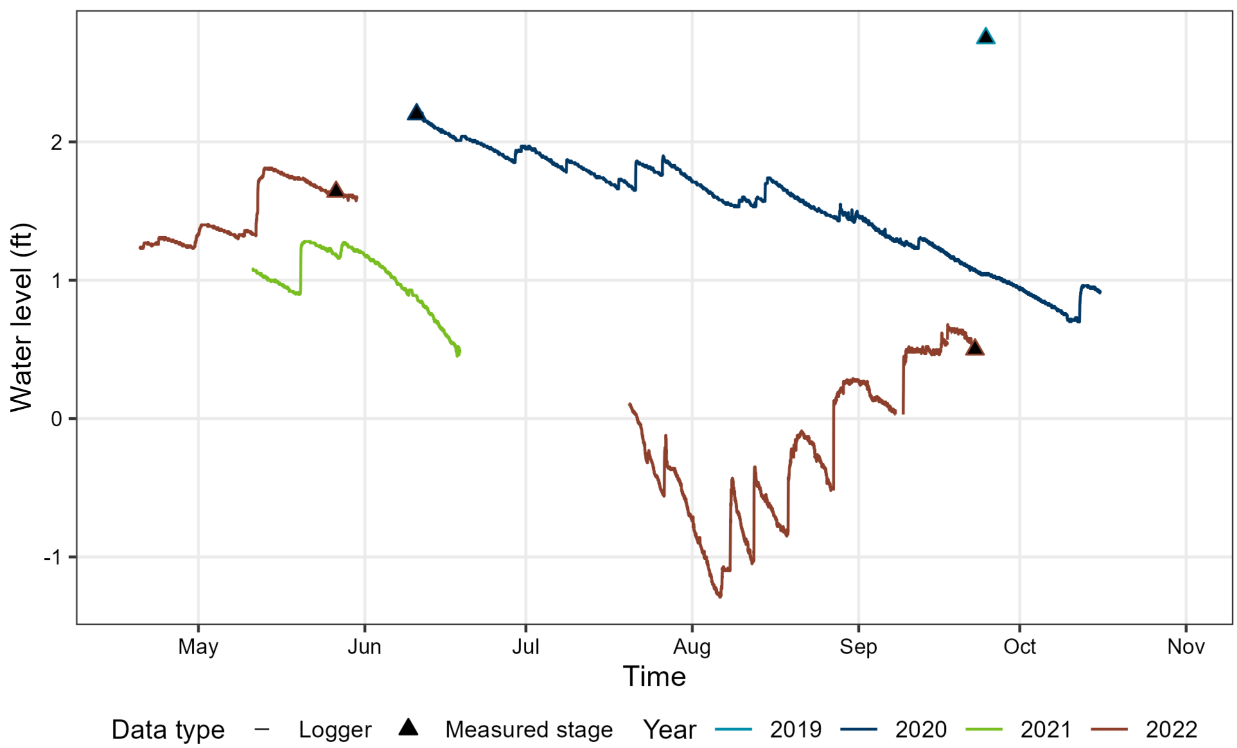

Figure A44: Hydrograph from Lake Maria State Park 1.

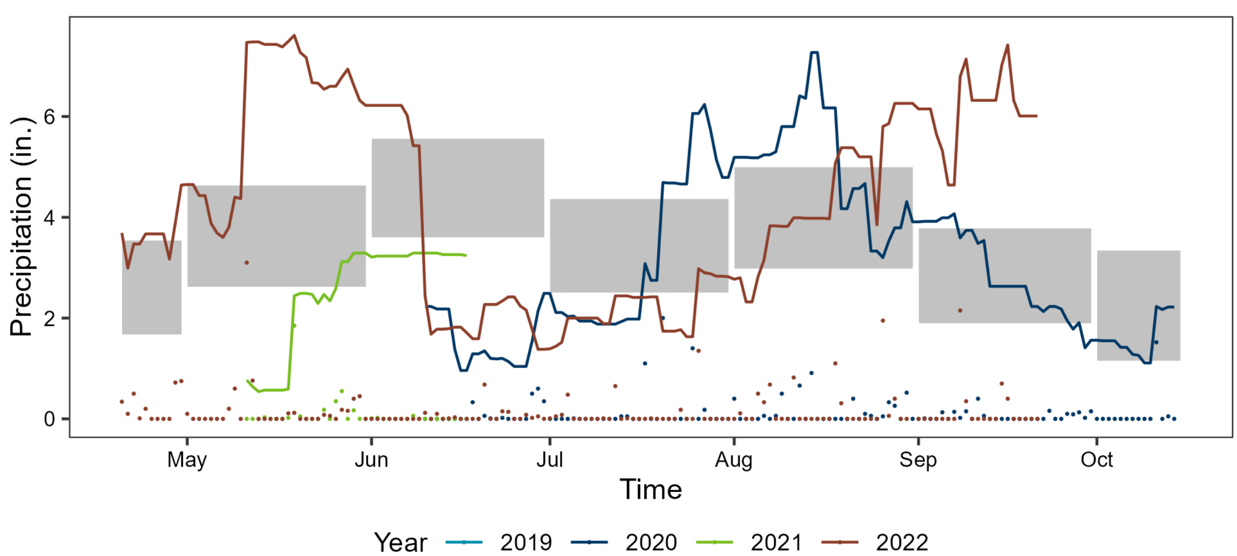

Figure A45: Precipitation at Lake Maria State Park 1. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Lake Maria State Park 2

Methods

We monitored a fresh meadow in Lake Maria State Park (Wright County), which is in the Eastern Broadleaf Forest province. Lake Maria State Park 2 (Fig. A46A), along with the other monitored wetlands, is located in the northeast portion of the park (Fig. A47). The wetland has wet meadow vegetation with an interior portion where shrubs and trees are growing. We installed bubbler equipment (Fig. A46B), housed in a steel sand-point well, in Lake Maria State Park 2 on September 24, 2019 and began collecting data on June 10, 2020. We replaced the bubbler equipment with OTT equipment on May 26, 2022 (Fig. A46C). Both sets of equipment were placed approximately 3 ft belowground. The data collected in 2020 had an unusual pattern and were deemed unreliable. Equipment may have malfunctioned. We conducted a vegetation survey on August 13, 2020.

Figure A46: (A) View of the Lake Maria State Park 2 on June 10, 2020. (B) Steel well housing bubbler equipment, taken on October 21, 2021. (C) PVC well housing OTT equipment, taken on May 26, 2022. (D) Manual measurement of water level, taken on October 21, 2021.

Figure A47: Map of Lake Maria State Park 2 data collection sites. The blue line shows the boundaries for Lake Maria State Park and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data.

Results

We identified 34 plant taxa at the fresh meadow in Lake Maria State Park, with a diversity of 3.2 and evenness of 0.91. The fresh meadow is dominated (present in > 75% of the quadrats) by broad-leaved arrowhead (*Sagittaria latifolia*), lake sedge (*Carex lacustris*), northern bugleweed (*Lycopus uniflorus*) (Fig. A48).

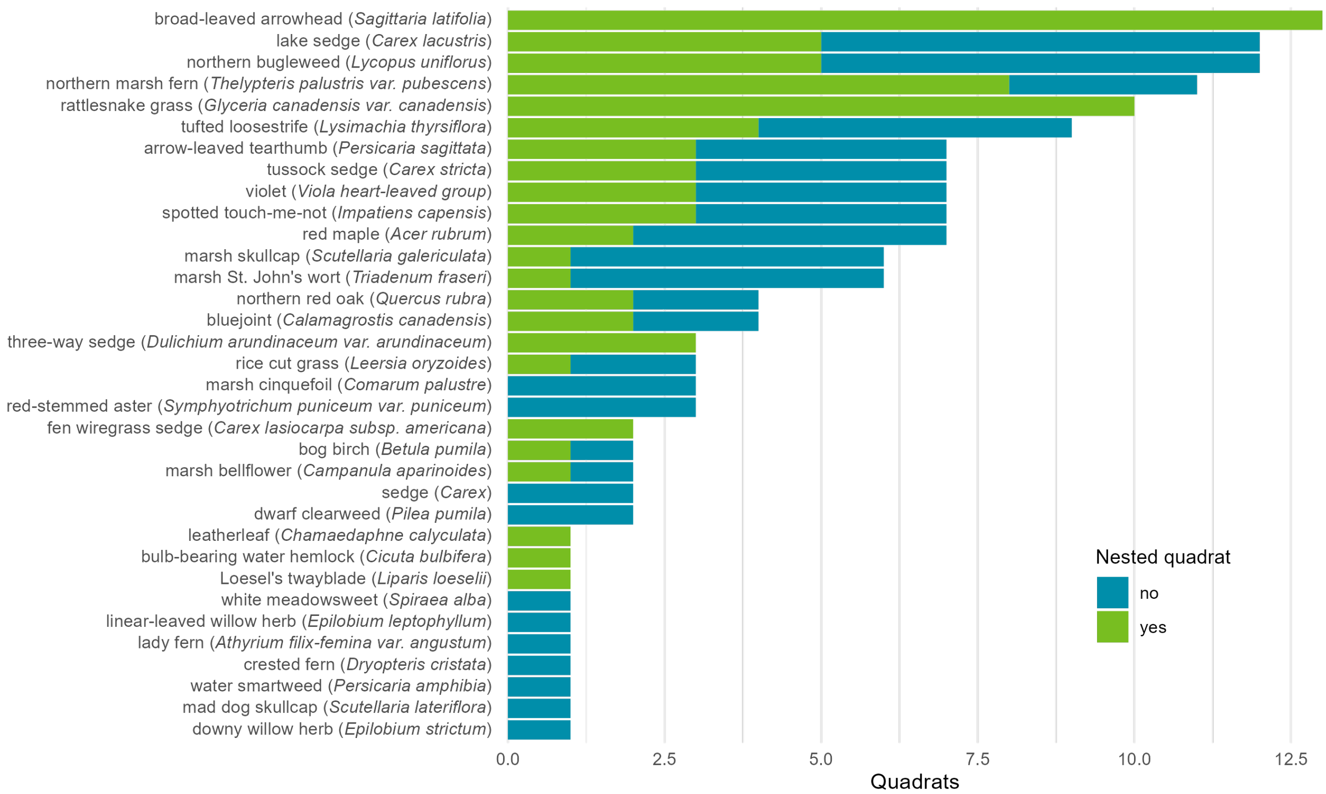

Figure A48: Plant community of Lake Maria State Park 2.

The median water level in the fresh meadow in Lake Maria State Park was 1 ft in 2021 and 1.5 ft in 2022 (Fig. A49). The wetland was saturated within 1 ft of the ground surface for 173 days during the 2021 growing season and 156 days during the 2022 growing season. It was inundated for 99 days during the 2021 growing season and 156 days during the 2022 growing season. The maximum water level maintained for at least 14 days during the growing season was 1.7 ft in 2021 and 1.8 ft in 2022.

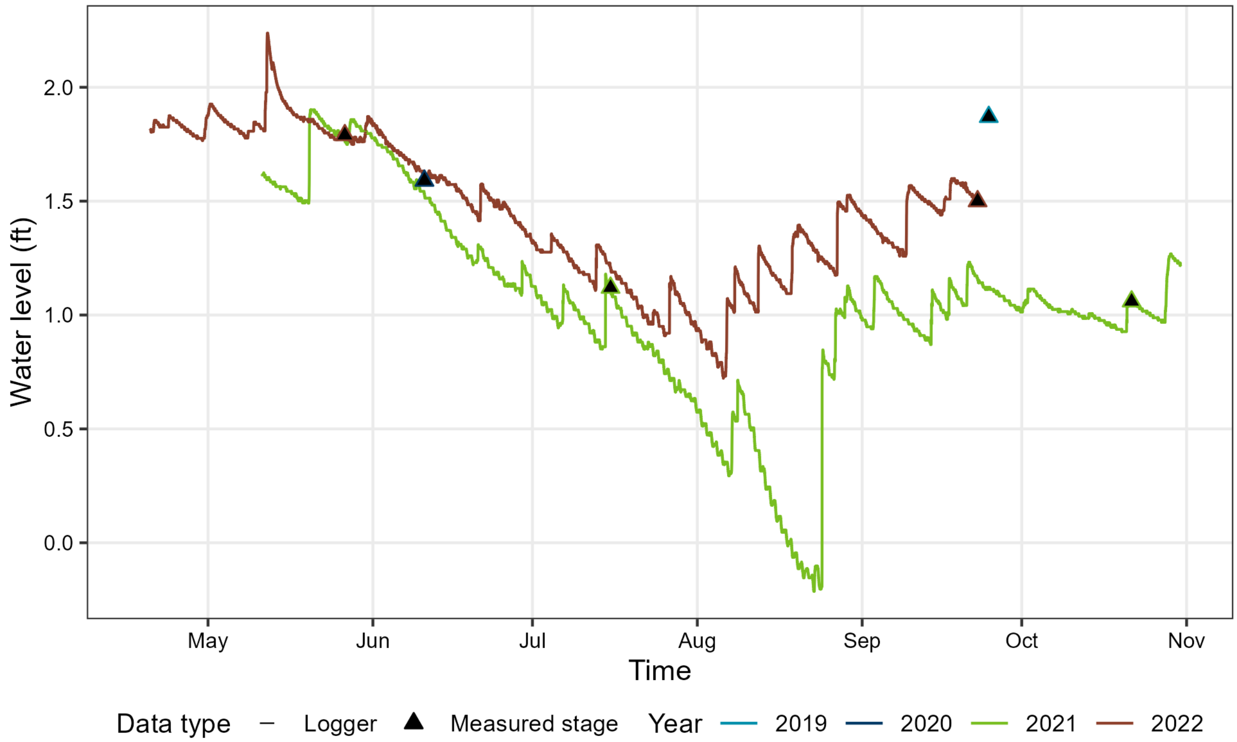

Figure A49: Hydrograph from Lake Maria State Park 2.

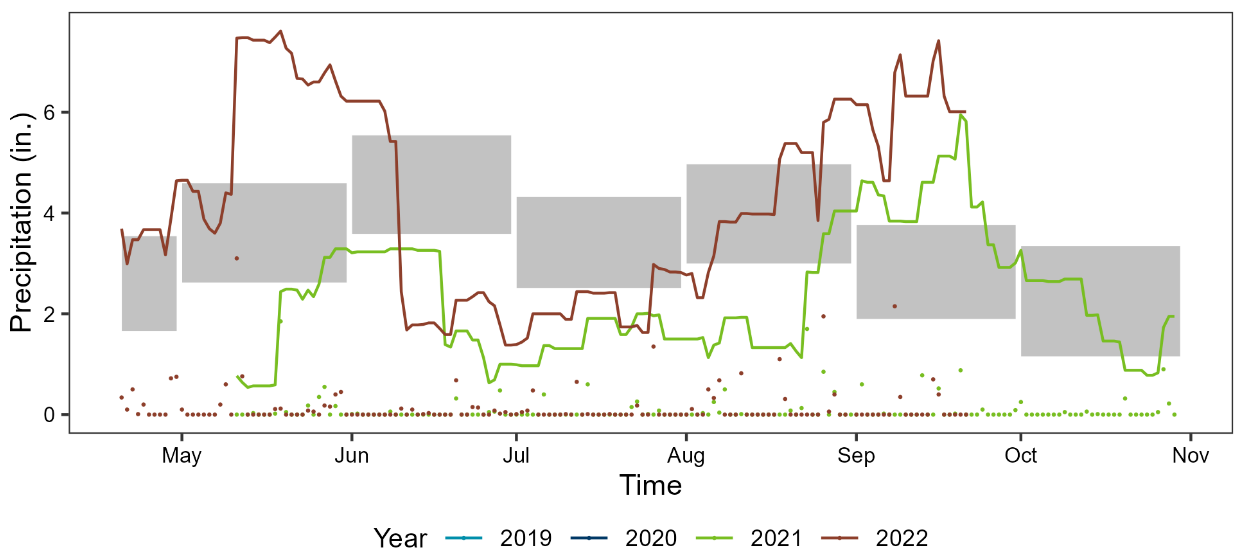

Figure A50: Precipitation at Lake Maria State Park 2. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Lake Maria State Park 3

Methods

We monitored a fen in Lake Maria State Park (Wright County), which is in the Eastern Broadleaf Forest province. Lake Maria State Park 3 (Fig. A51A), along with the other monitored wetlands, is located in the northeast portion of the park (Fig. A52). We installed bubbler equipment (Fig. A51B) on the periphery of the fen (in fresh meadow vegetation) on September 24, 2019 and began collecting data on June 10, 2020. The orifice line was housed in a sand-point steel well and reached approximately 3 ft belowground (Fig. A51C). Water was ponding in the base of the well, likely because it was within a clay layer. On October 20, 2021, the orifice line was elevated to prevent it from sitting in the ponded water. On May 26, 2022, we replaced the bubbler with OTT equipment (Fig. 2), with the tranducer placed approximately 2 ft below the ground (Fig. A51D). On September 22, 2022, we installed additional OTT equipment in the center of the wetland, where there is the dominant fen community. Water elevations measured at the two OTTs were equal and we use the water depth in the fen vegetation for the hydrograph. We conducted a vegetation survey on August 19, 2020.

Figure A51: (A) View of Lake Maria State Park 3 on June 10, 2020. (B) Steel well housing bubbler transducer (right side of photo) in the wet meadow, taken on March 31, 2021. (C) Sand-point on the bottom of steel well, taken on May 26, 2022. (D) PVC well housing OTT transducer, taken on August 11, 2022.

Figure A52: Map of Lake Maria State Park 3 data collection sites. The blue line shows the boundaries for Lake Maria State Park and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data.

Results

We identified 35 plant taxa at the fen in Lake Maria State Park, with a diversity of 3.2 and evenness of 0.91. The fen is dominated (present in > 75% of the quadrats) by broad-leaved arrowhead (*Sagittaria latifolia*) (Fig. A53).

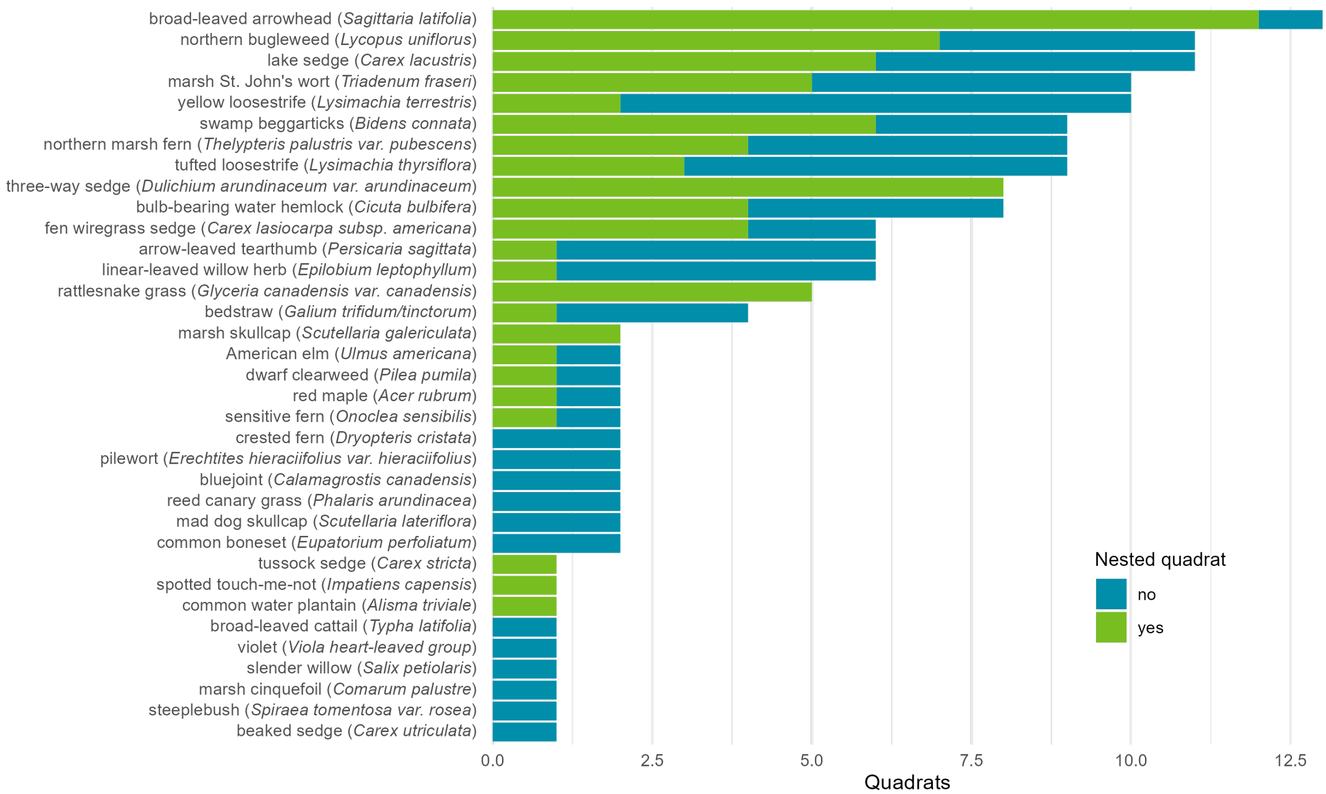

Figure A53: Plant community of Lake Maria State Park 3.

The median water level in the fen in Lake Maria State Park was 2.1 ft in 2020, 0.5 ft in 2021, and 2.4 ft in 2022 (Fig. A54). The wetland was saturated within 1 ft of the ground surface for 128 days, 167 days, and 155 days during the 2020, 2021, and 2022 growing seasons, respectively. It was inundated for 128 days, 70 days, and 155 days during the 2020, 2021, and 2022 growing seasons, respectively. The maximum water level maintained for at least 14 days during the growing season was 2.3 ft in 2020, 2.2 ft in 2021, and 2.9 ft in 2022.

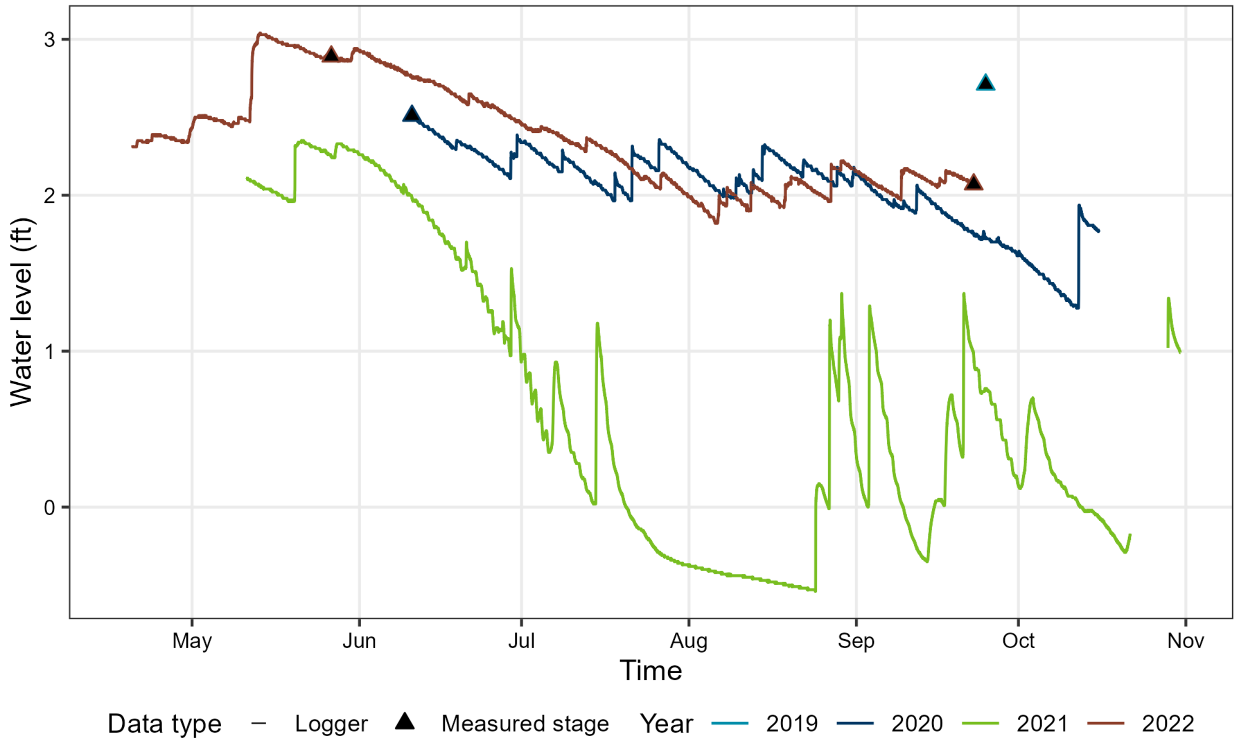

Figure A54: Hydrograph from Lake Maria State Park 3.

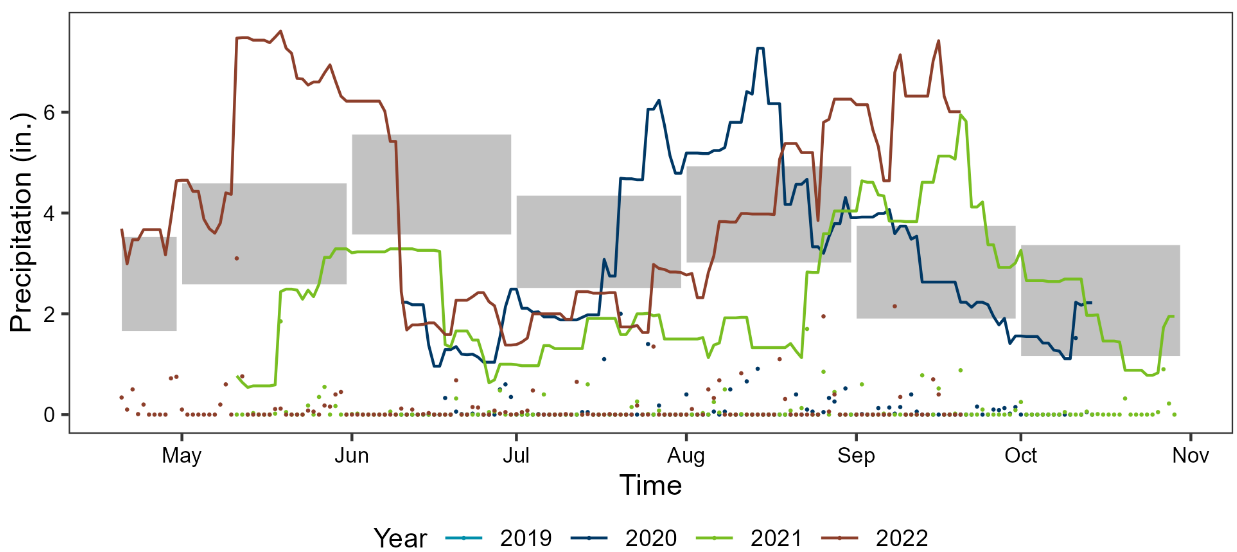

Figure A55: Precipitation at Lake Maria State Park 3. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Little Jo WMA 1

Methods

We monitored a sedge mat in Little Jo WMA (Pope County), which is in the Prairie Parkland province (Fig. A56A). Little Jo WMA 1 is part of a wetland complex (Fig. A56B) and is located in the northern portion of the WMA (Fig. A57). We installed bubbler equipment (Fig. 3) on October 15, 2019, and began collecting data on June 9, 2020 (Fig. A56C). We replaced bubbler equipment with OTT equipment (Fig. 2) on May 19, 2022 (Fig. A56D). The bottom of the PVC well housing the bubbler equipment was placed approximately 0.6 ft below the ground. Both sets of equipment were installed on the edge of the wetland, on what seems to be a submerged mat. The vegetation surrounding the equipment is similar, but not identical to the dominant vegetation in the wetland (where the survey occurred, Fig. A57). We measured water elevation at the equipment and in the dominant sedge mat community and found that they were equal. We therefore translated the hydrographs to represent water levels in the sedge mat community. We conducted a vegetation survey on August 12, 2020.

Figure A56: (A) View of Little Jo WMA 1, taken on June 9, 2020. (B) View of connection between the monitored wetland (on left) and a neighboring wetland (on right), taken on May 19, 2022. (C) Fence post supporting bubbler equipment (center of photo), taken on May 19, 2022. (D) PVC well housing OTT equipment, taken on May 19, 2022.

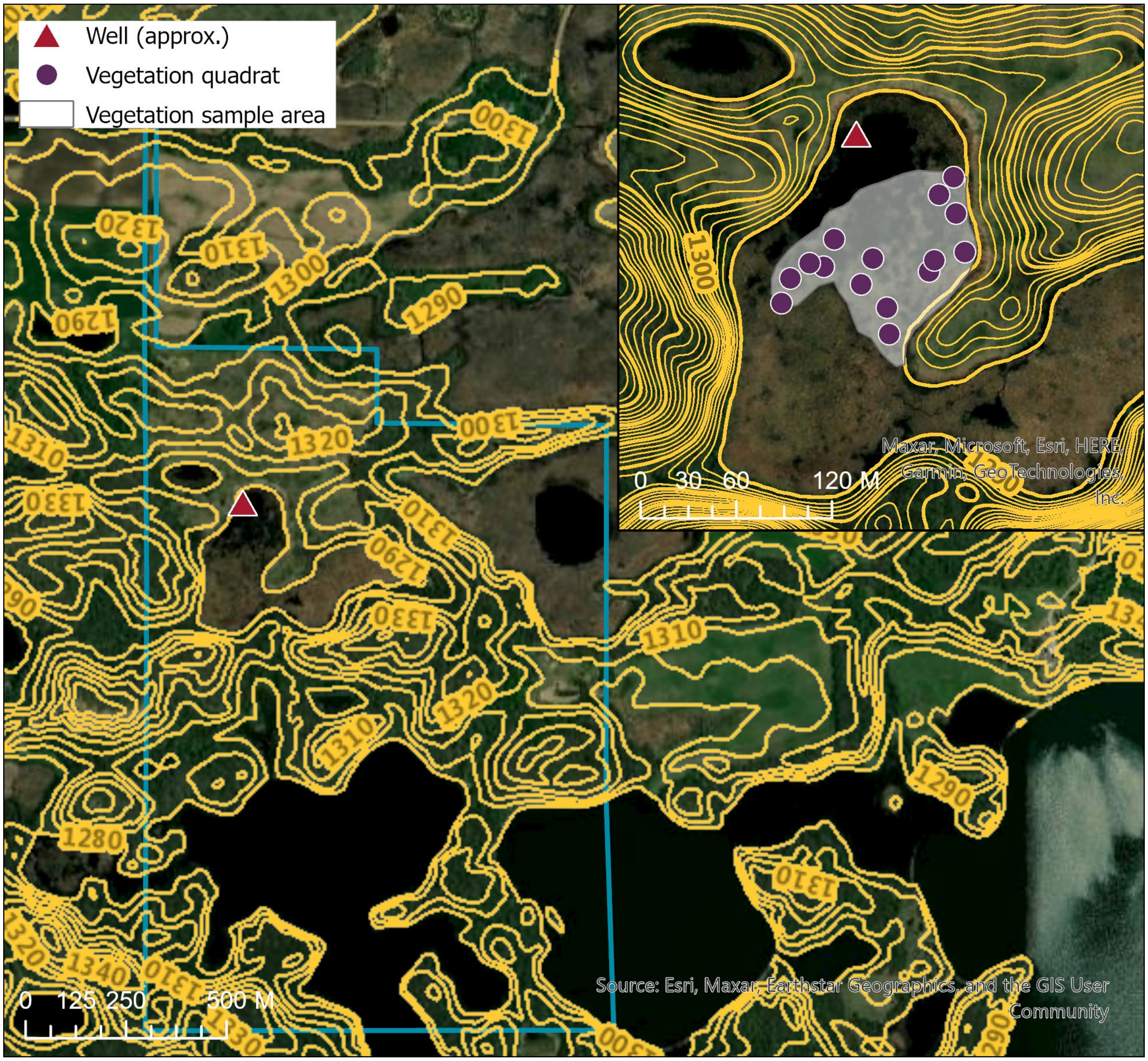

Figure A57: Map of Little Jo WMA 1 data collection sites. The blue line shows the boundaries for Little Jo WMA and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data.

Results

We identified 25 plant taxa at the sedge mat in Little Jo WMA, with a diversity of 2.9 and evenness of 0.9. The sedge mat is dominated (present in > 75% of the quadrats) by fen wiregrass sedge (*Carex lasiocarpa subsp. americana*), lake sedge (*Carex lacustris*), marsh cinquefoil (*Comarum palustre*), northern marsh fern (*Thelypteris palustris var. pubescens*) (Fig. A58).

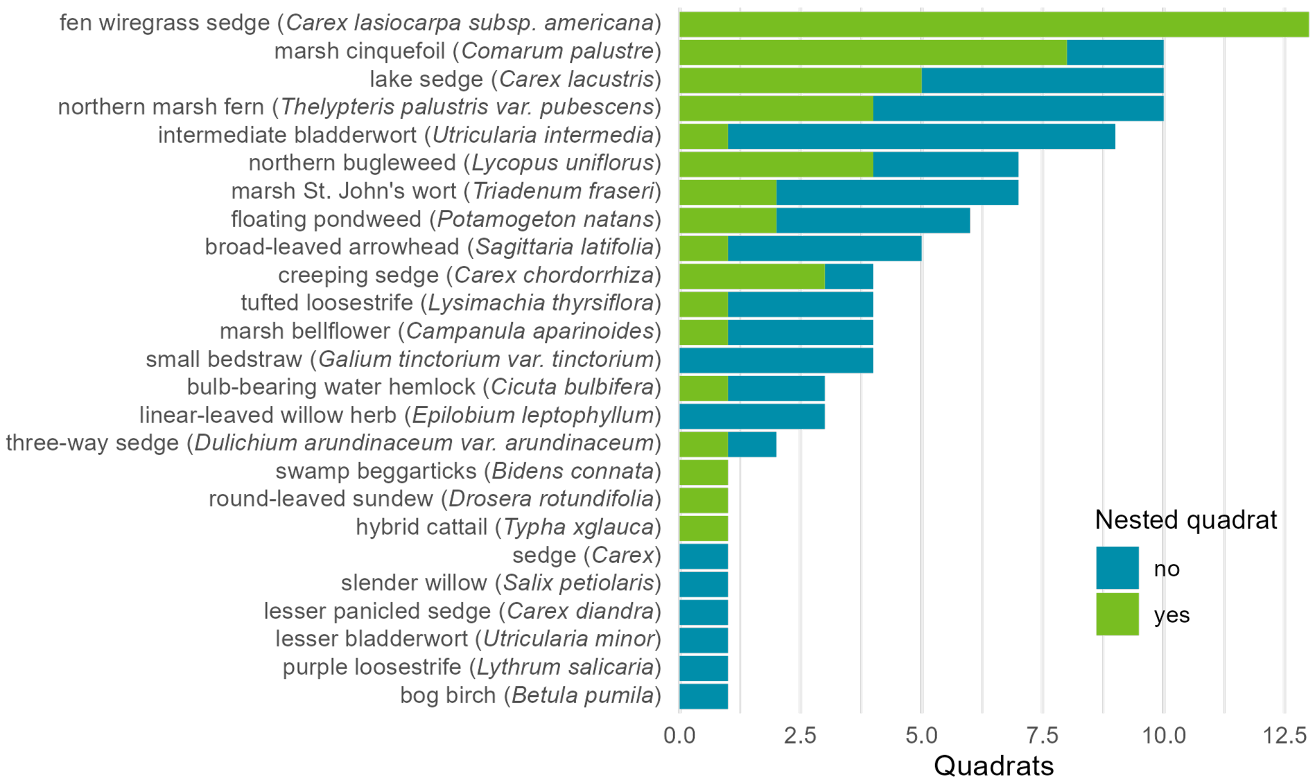

Figure A58: Plant community of Little Jo WMA 1.

The median water level in the sedge mat in Little Jo WMA was 5 ft in 2020, 4.1 ft in 2021, and 4.6 ft in 2022 (Fig. A59). The wetland was saturated within 1 ft of the ground surface for 129 days, 177 days, and 169 days during the 2020, 2021, and 2022 growing seasons, respectively. It was inundated for 129 days, 177 days, and 169 days during the 2020, 2021, and 2022 growing seasons, respectively. The maximum water level maintained for at least 14 days during the growing season was 5 ft in 2020, 4.6 ft in 2021, and 5.1 ft in 2022.

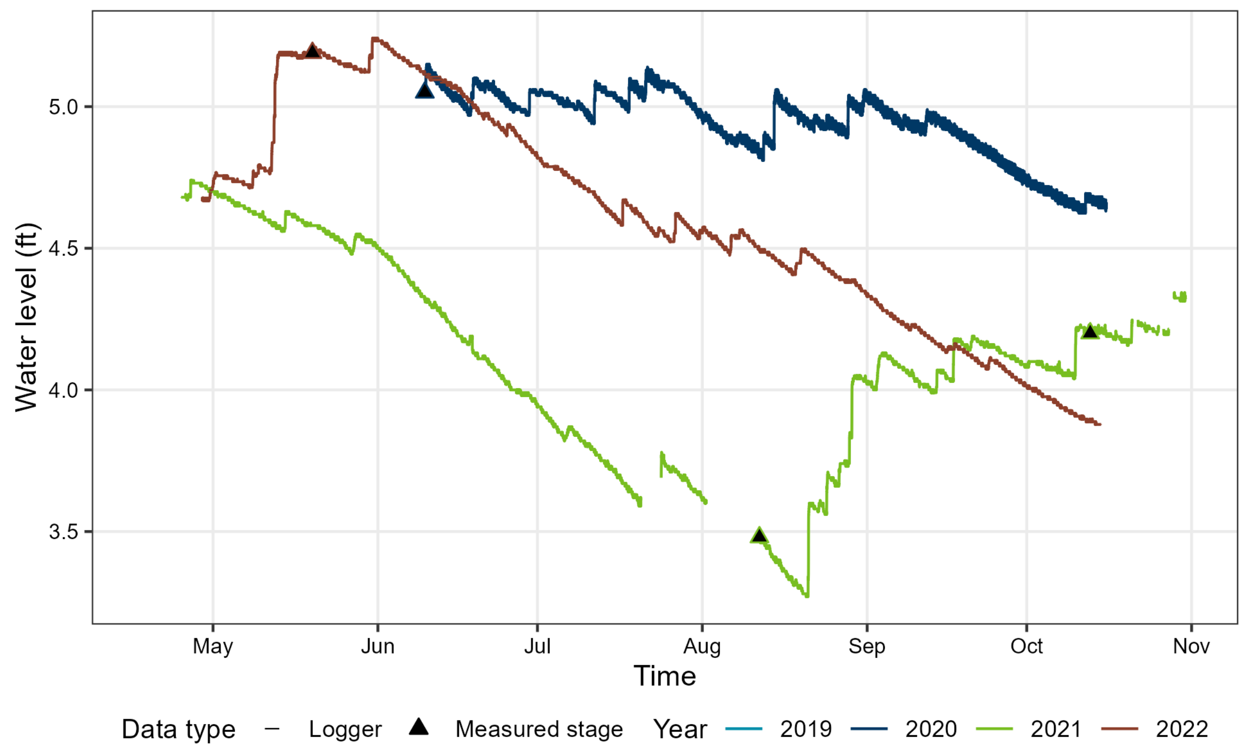

Figure A59: Hydrograph from Little Jo WMA 1.

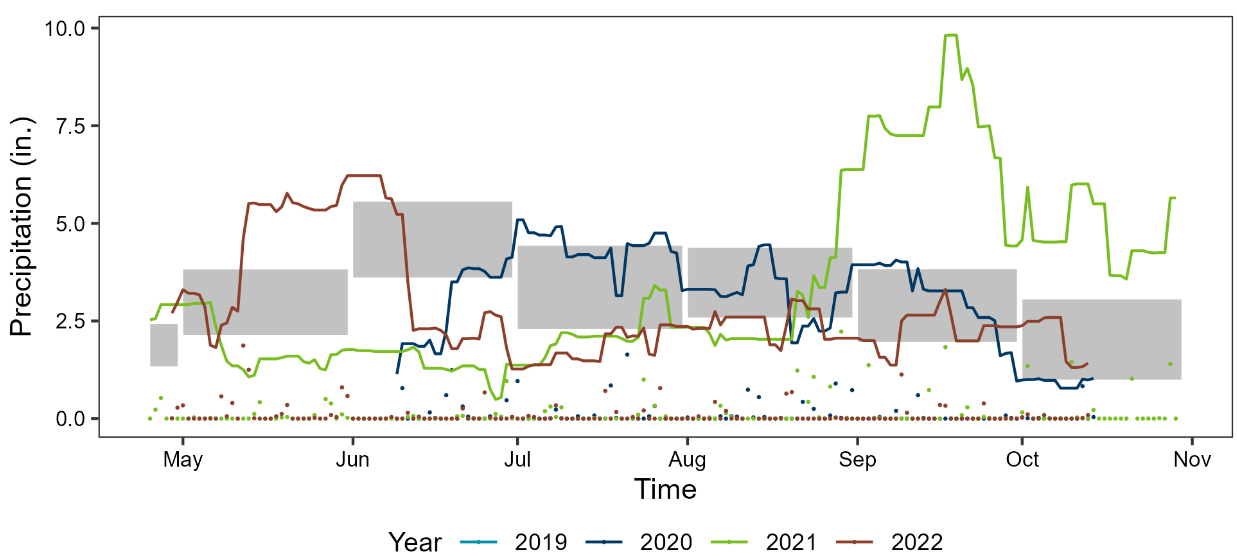

Figure A60: Precipitation at Little Jo WMA 1. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Murphy Hanrehan Park Reserve 1

Methods

We monitored a deep marsh/shallow open water in Murphy Hanrehan Park Reserve (Scott County), which is in the Eastern Broadleaf Forest province (Fig. A61A). The monitored wetland is located on the eastern side of the park (Fig. A62). The outlet is a culvert on the southeastern end of the wetland. We installed bubbler equipment (Fig. 3) and began collecting hydrological data on July 22, 2020 (Fig. A61B). We replaced the bubbler with OTT equipment (Fig. 2) on April 27, 2022 (Fig. A61C). We conducted a vegetation survey on August 20, 2020. We collected bathymetry data for the wetland on April 28, 2021 (Fig. A61D).

Figure A61: (A) View of Murphy Hanrehan Park Reserve 1 on November 12, 2020. (B) Fence posts supporting bubbler transducer, taken on October 6, 2021. (C) PVC pipe housing OTT transducer, taken on July 14, 2022. (D) Conducting a bathymetric survey on April 28, 2021.

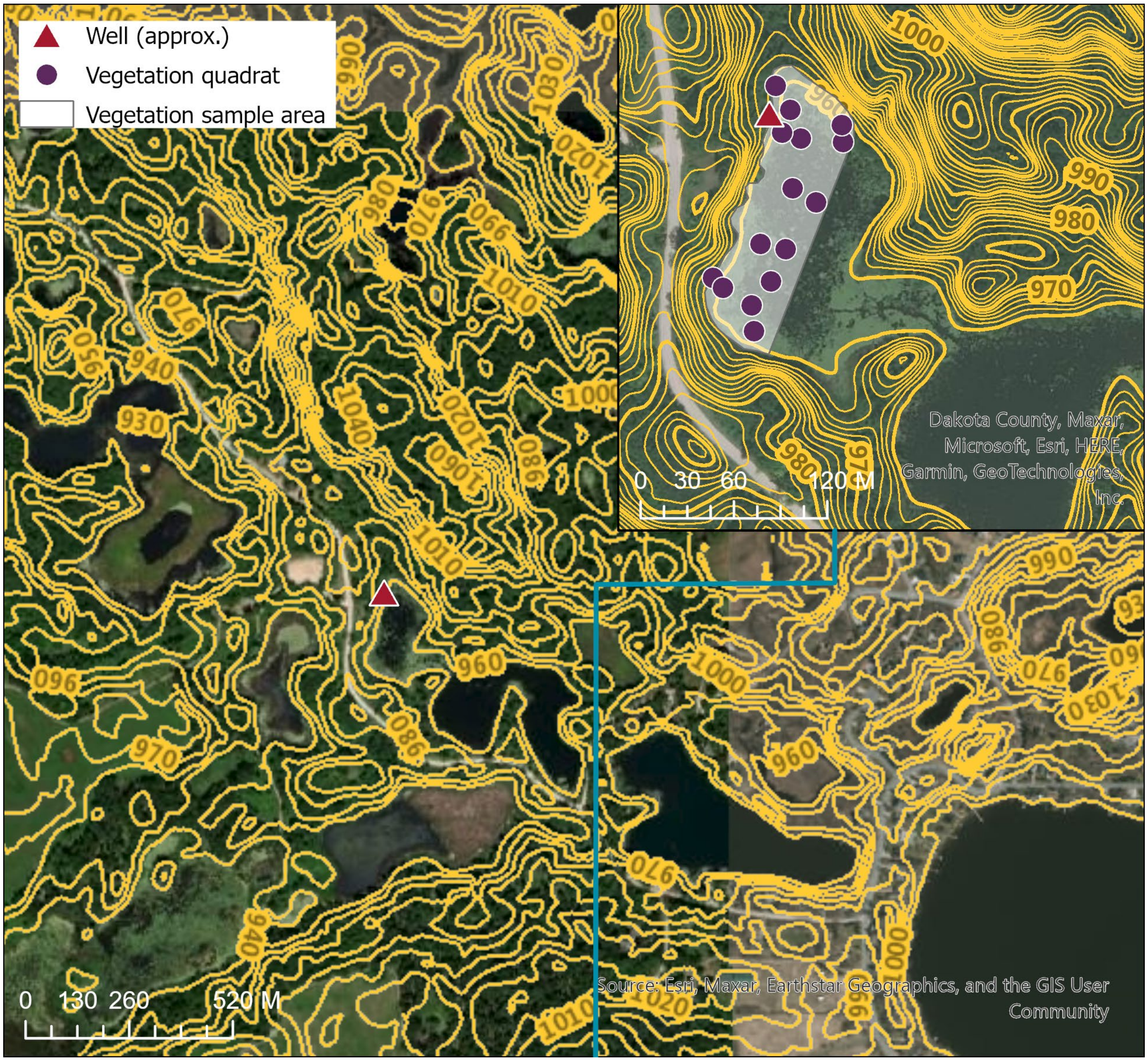

Figure A62: Map of Murphy Hanrehan Park Reserve 1 data collection sites. The blue line shows the boundaries for Murphy Hanrehan Park Reserve and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data.

Results

We identified 16 plant taxa at the deep marsh/shallow open water in Murphy Hanrehan Park Reserve, with a diversity of 2.3 and evenness of 0.84. The deep marsh/shallow open water is dominated (present in > 75% of the quadrats) by common coontail (*Ceratophyllum demersum*), American white waterlily (*Nymphaea odorata*) (Fig. A63).

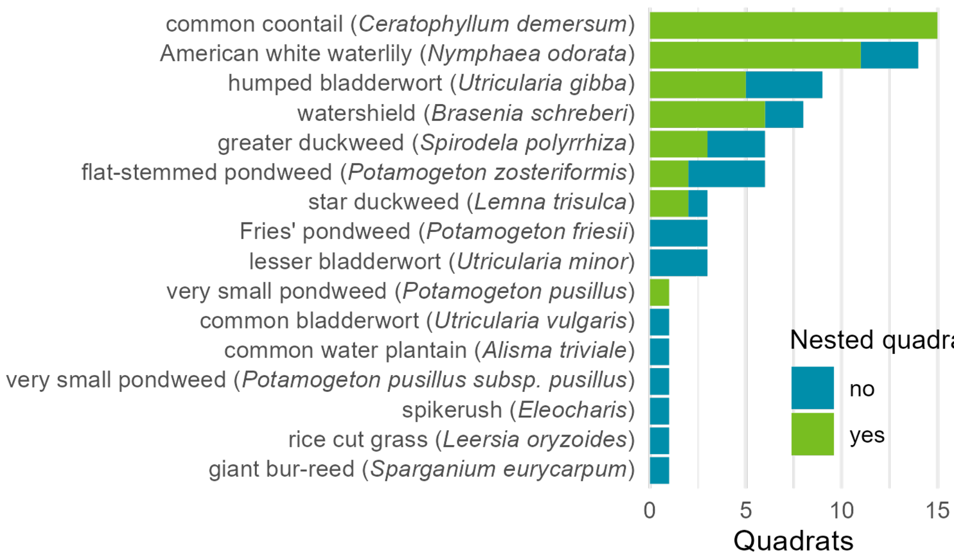

Figure A63: Plant community of Murphy Hanrehan Park Reserve 1.

The median water level in the deep marsh/shallow open water in Murphy Hanrehan Park Reserve was 3.5 ft in 2020, 2.5 ft in 2021, and 1.7 ft in 2022 (Fig. A64). The wetland was saturated within 1 ft of the ground surface for 88 days, 215 days, and 177 days during the 2020, 2021, and 2022 growing seasons, respectively. It was inundated for 88 days, 215 days, and 177 days during the 2020, 2021, and 2022 growing seasons, respectively. The maximum water level maintained for at least 14 days during the growing season was 3.7 ft in 2020, 3.3 ft in 2021, and 2.4 ft in 2022.

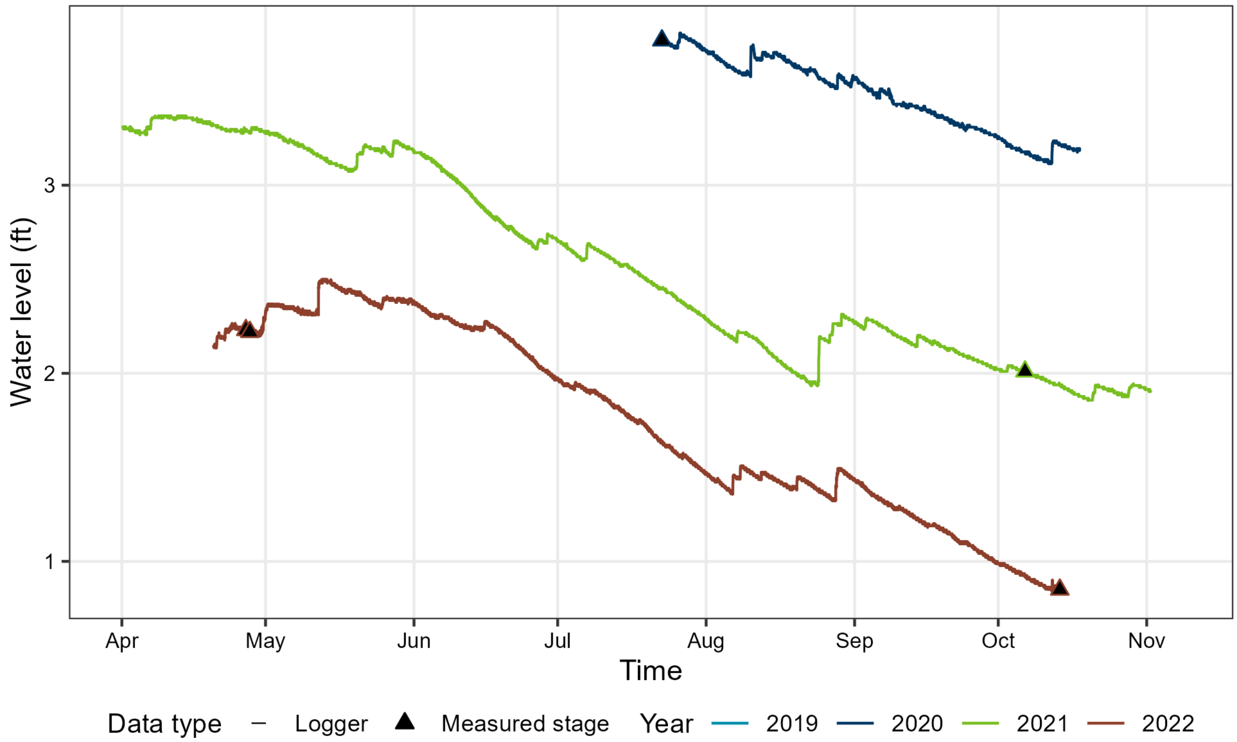

Figure A64: Hydrograph from Murphy Hanrehan Park Reserve 1.

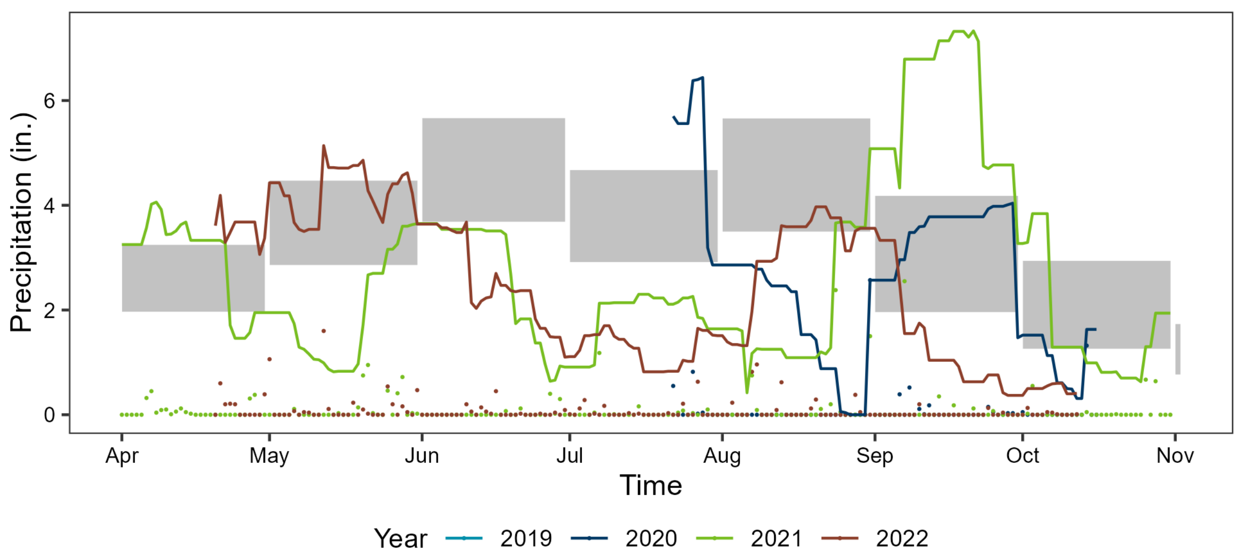

Figure A65: Precipitation at Murphy Hanrehan Park Reserve 1. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Murphy Hanrehan Park Reserve 2

Methods

We monitored a fen in Murphy Hanrehan Park Reserve (Scott County), which is in the Eastern Broadleaf Forest province (Fig. A66A). The monitored wetland is on the eastern side of the park (Fig. A67). It has vegetation on a floating mat in the center with a moat along the edge (Fig. A66B). We installed bubbler equipment (Fig. 3) in the moat and began collecting data on July 22, 2020 (Fig. A66B). We added an OTT (Fig. 2) to the vegetation mat on October 21, 2021 (Fig. A66C-D). The two sets of equipment have measured equal water elevations. We present data from the bubbler until the OTT was installed, and then the data comes from the OTT. The OTT is in a shallower portion of the wetland and has sparser vegetaion than the dominant fen community. We measured water elevations at the equipment and in the interior of the fen community and found that they were equal. We therefore translated the hydrograph to represent water levels in the interior of the wetland. We conducted a vegetation survey on August 20, 2020.

Figure A66: (A) View of Murphy Hanrehan Park Reserve 2 on July 14, 2022. (B) Fence posts supporting bubbler equipment in moat, taken on April 27, 2022. (C) Surveying at the location of the OTT equipment on October 21, 2021. (D) Conduit entering PVC well housing OTT transducer, taken on October 21, 2021.

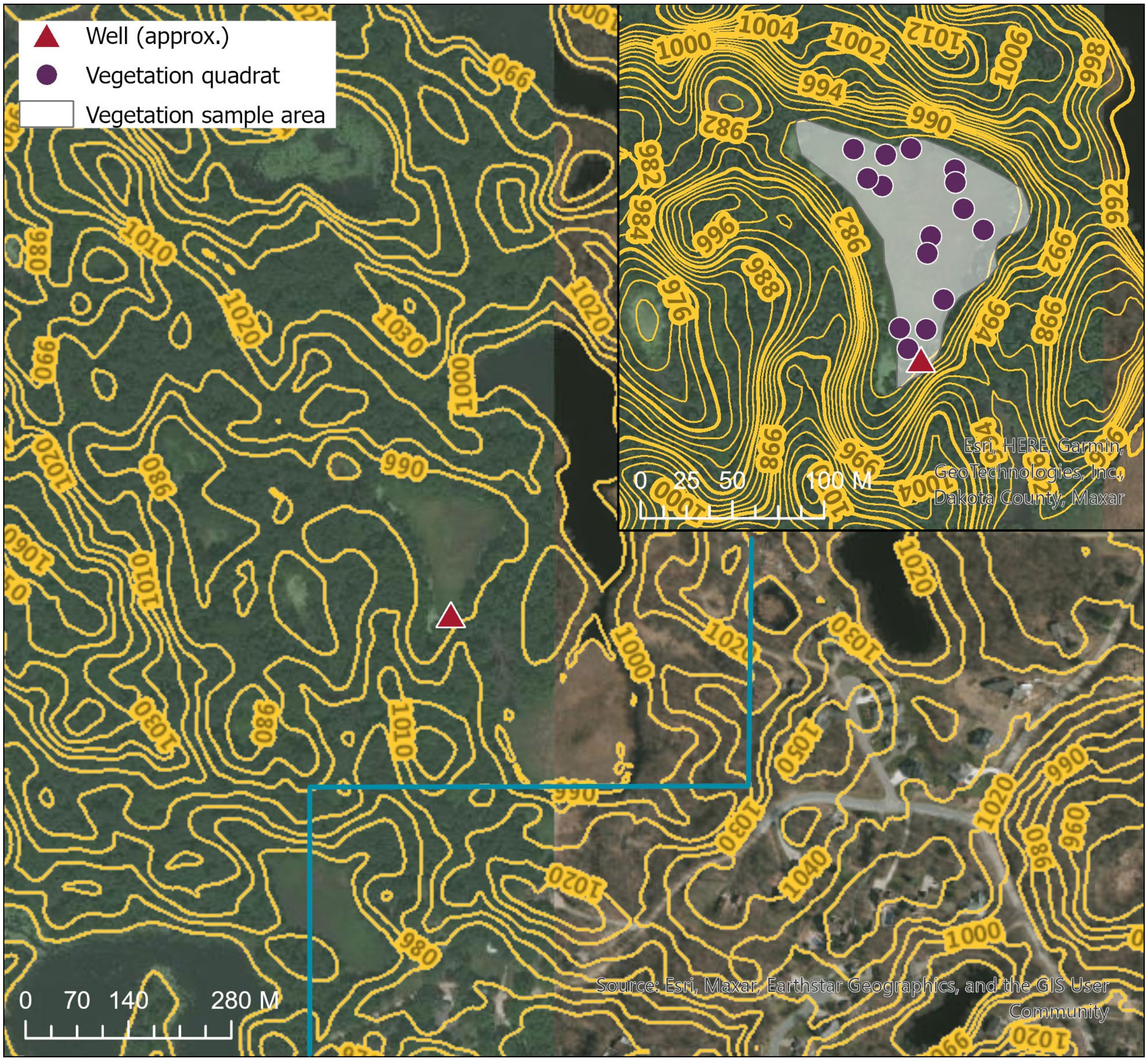

Figure A67: Map of Murphy Hanrehan Park Reserve 2 data collection sites. The blue line shows the boundaries for Murphy Hanrehan Park Reserve and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data.

Results

We identified 35 plant taxa at the fen in Murphy Hanrehan Park Reserve, with a diversity of 3.2 and evenness of 0.9. The fen is dominated (present in > 75% of the quadrats) by fen wiregrass sedge (*Carex lasiocarpa subsp. americana*), northern bugleweed (*Lycopus uniflorus*), northern marsh fern (*Thelypteris palustris var. pubescens*), marsh cinquefoil (*Comarum palustre*), three-way sedge (*Dulichium arundinaceum var. arundinaceum*), broad-leaved arrowhead (*Sagittaria latifolia*), marsh St. John's wort (*Triadenum fraseri*) (Fig. A68).

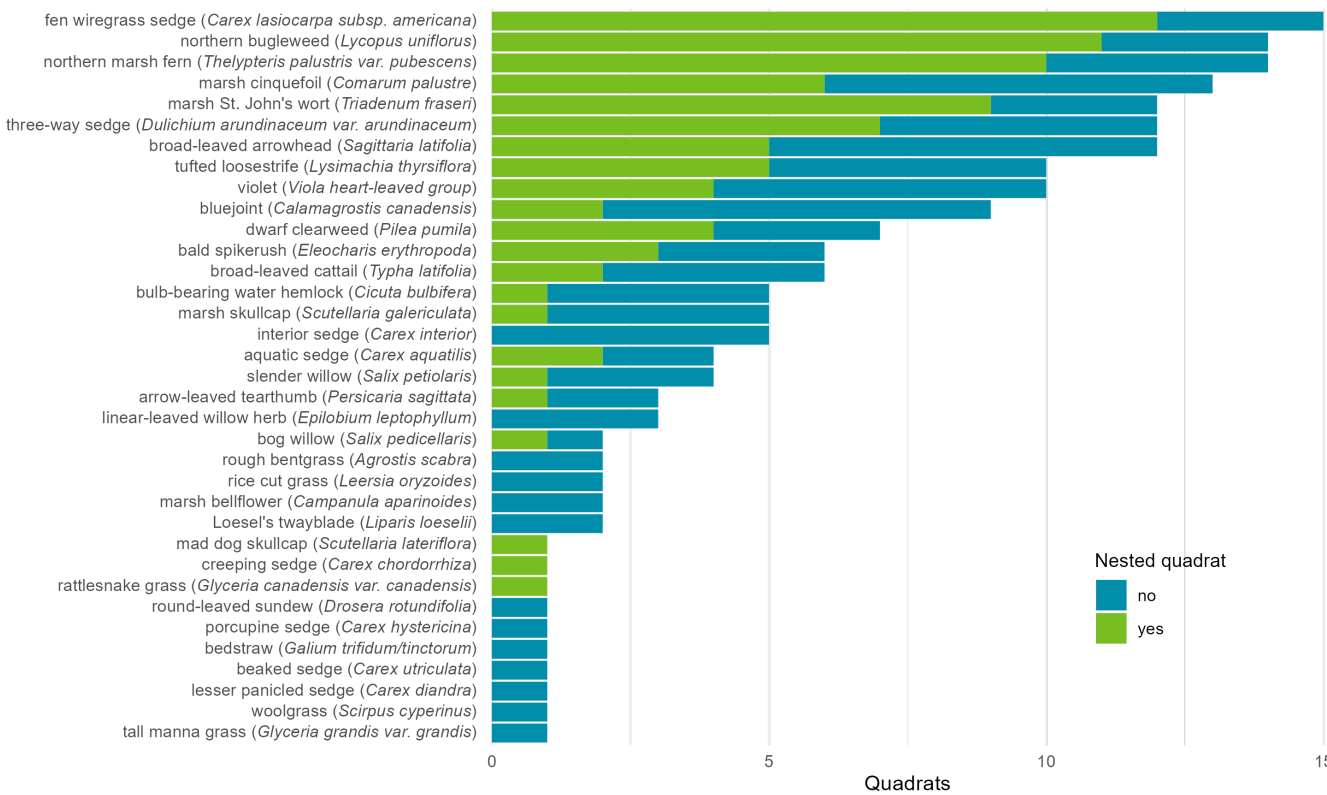

Figure A68: Plant community of Murphy Hanrehan Park Reserve 2.

The median water level in the fen in Murphy Hanrehan Park Reserve was 4.4 ft in 2020, 3.4 ft in 2021, and 2.6 ft in 2022 (Fig. A69). The wetland was saturated within 1 ft of the ground surface for 87 days, 192 days, and 177 days during the 2020, 2021, and 2022 growing seasons, respectively. It was inundated for 87 days, 192 days, and 177 days during the 2020, 2021, and 2022 growing seasons, respectively. The maximum water level maintained for at least 14 days during the growing season was 4.7 ft in 2020, 4.2 ft in 2021, and 3.2 ft in 2022.

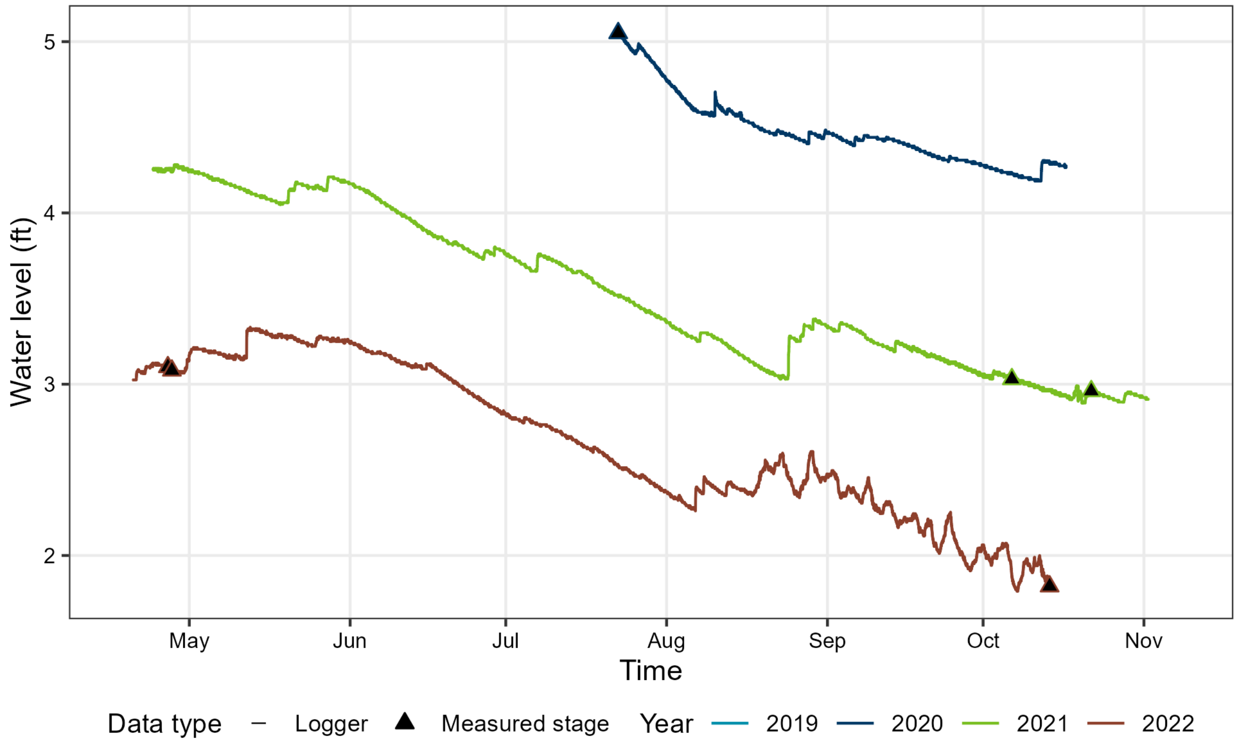

Figure A69: Hydrograph from Murphy Hanrehan Park Reserve 2.

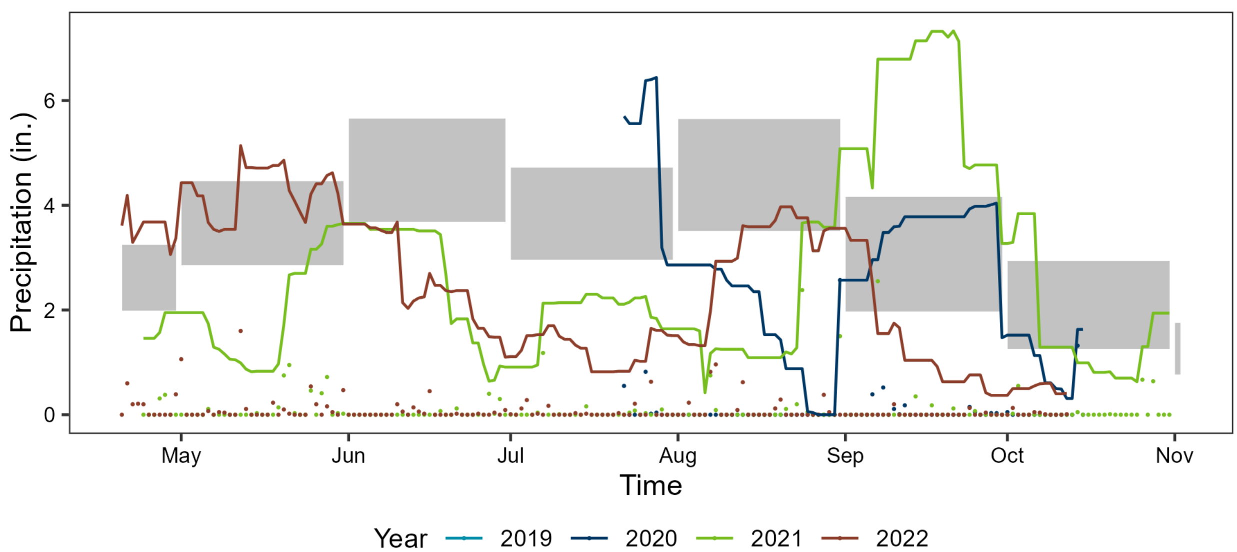

Figure A70: Precipitation at Murphy Hanrehan Park Reserve 2. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Prairie Marshes WMA 1

Methods

We monitored a deep marsh/shallow open water in Prairie Marshes WMA (Lyon County), which is in the Prairie Parkland province (Fig. A71A). Prairie Marshes WMA 1 is located in the southwest portion of the WMA (Fig. A72). Water drains from the west side of the wetland to a dam on the boundary of the WMA (Fig. A71B, Fig. A72). We installed bubbler equipment (Fig. 3) and began collecting data on July 24, 2019 (Fig. A71C). We temporarily removed the bubbler equipment during the winter of 2019-2020 to prevent freeze damage. We placed the bubbler orifice line inside of a slotted PVC in October 2021 in order to measure water levels below the surface. We replaced the bubbler equipment with OTT equipment (Fig. 2) on May 5, 2022 (Fig. A71D). The OTT transducer was placed approximately 1 ft below the ground surface within the PVC well. We measured the ground elevation in the deepest portion of the wetland and use this to translate the hydrograph to the water levels in that area. We conducted a vegetation survey on August 6, 2020.

Figure A71: (A) View of Prairie Marshes WMA 1 facing north on May 5, 2022. (B) Water draining from west of wetland, taken on May 5, 2022. (C) Fence posts supporting bubbler equipment, taken on December 2, 2021. (D) PVC well housing OTT equipment, taken on May 5, 2022.

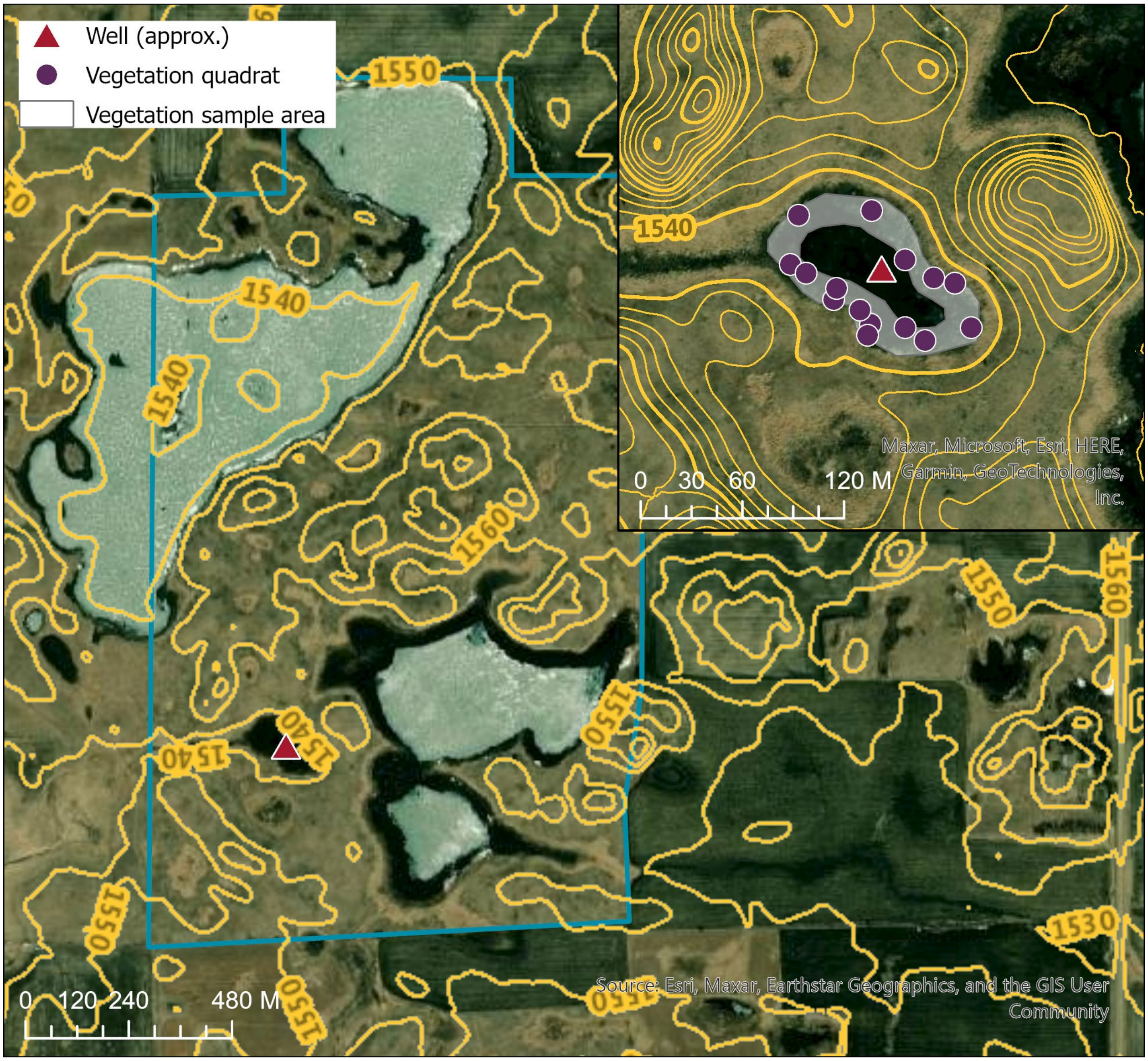

Figure A72: Map of Prairie Marshes WMA 1 data collection sites. The blue line shows the boundaries for Prairie Marshes WMA and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data.

Results

We identified 18 plant taxa at the deep marsh/shallow open water in Prairie Marshes WMA, with a diversity of 2.4 and evenness of 0.82. The deep marsh/shallow open water is dominated (present in > 75% of the quadrats) by turion duckweed (*Lemna turionifera*), star duckweed (*Lemna trisulca*) (Fig. A73).

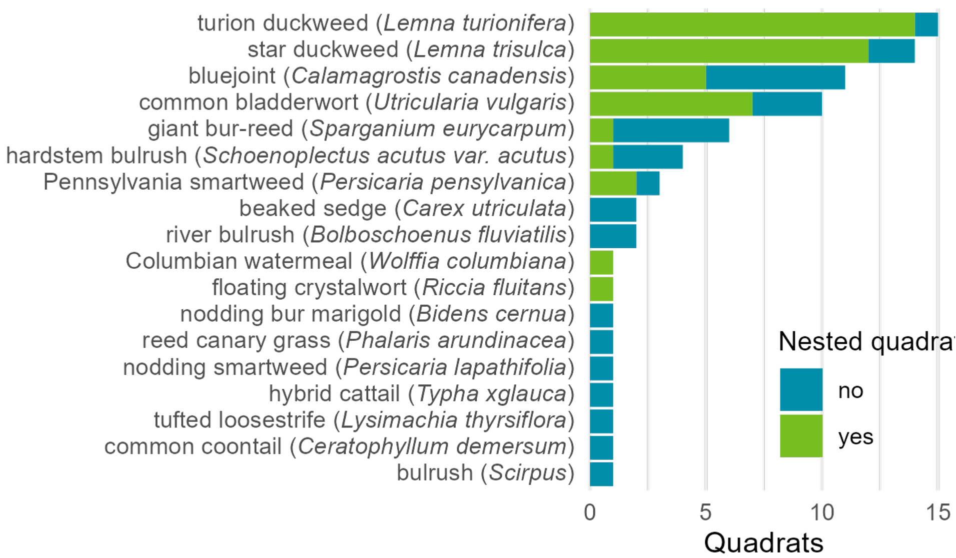

Figure A73: Plant community of Prairie Marshes WMA 1.

The median water level in the deep marsh/shallow open water in Prairie Marshes WMA was 2.4 ft in 2020, 1.6 ft in 2021, and 2.2 ft in 2022 (Fig. A74). The wetland was saturated within 1 ft of the ground surface for 69 days, 138 days, and 132 days during the 2020, 2021, and 2022 growing seasons, respectively. It was inundated for 69 days, 138 days, and 132 days during the 2020, 2021, and 2022 growing seasons, respectively. The maximum water level maintained for at least 14 days during the growing season was 2.5 ft in 2020, 2.5 ft in 2021, and 2.9 ft in 2022.

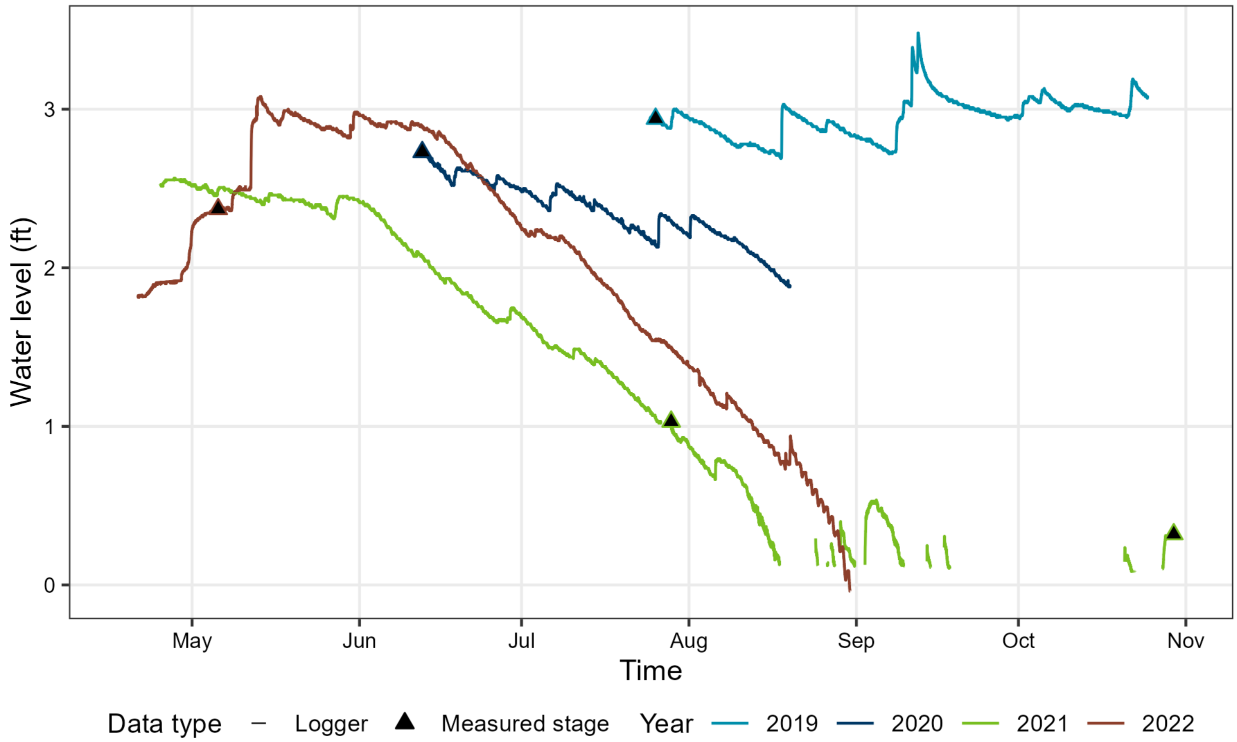

Figure A74: Hydrograph from Prairie Marshes WMA 1.

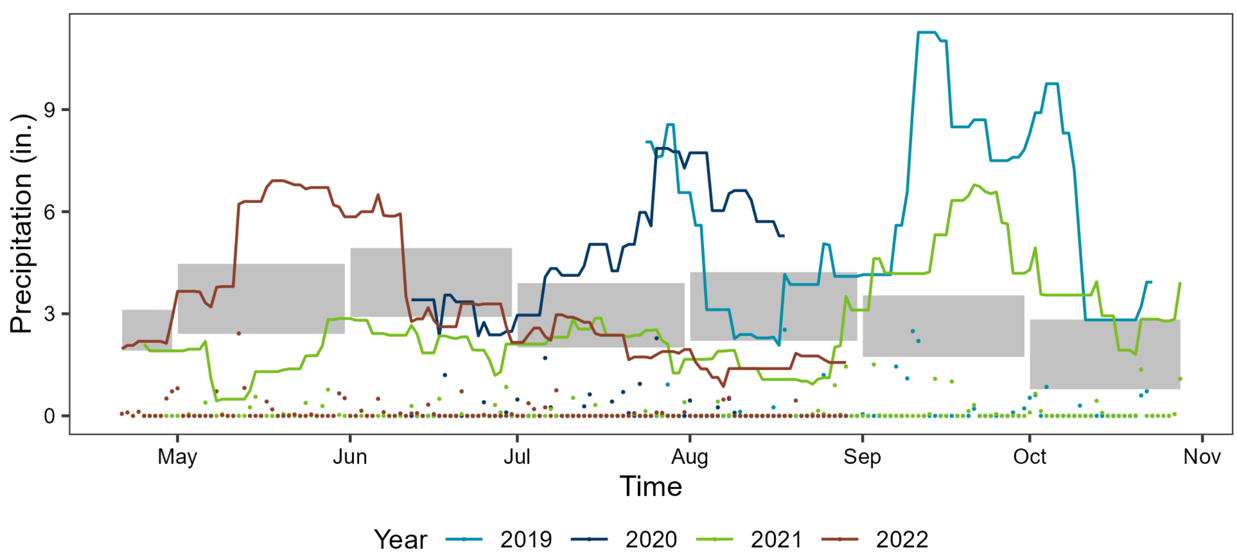

Figure A75: Precipitation at Prairie Marshes WMA 1. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Prairie WMA 1

Methods

We monitored a fresh meadow in Prairie WMA (Big Stone County), which is in the Prairie Parkland province (Fig. A76A). Prairie WMA 1 is in the center of the WMA and just east of Prairie WMA 2 (Fig. A77). We installed bubbler equipment (Fig. 3) on October 3, 2019 and began collecting data on June 9, 2020 (Fig. A76B). On August 18, 2021, we placed the bubbler orifice line 0.7 ft belowground within a slotted PVC well (Fig. A76C). We replaced the bubbler equipment with OTT equipment (Fig. 2) on May 10, 2022 (Fig. A76D). The OTT transducer is approximately 0.6 ft below the ground. We conducted a vegetation survey on August 5, 2020. This WMA is grazed by cattle, which may influence the vegetation.

Figure A76: (A) View of Prairie WMA 1 on November 3, 2020. (B) View of the wetland on June 9, 2020, when bubbler equipment began collecting data. (C) PVC well housing bubbler transducer, taken on August 18, 2021. (D) View of the wet meadow on May 10, 2022, when OTT equipment was installed.

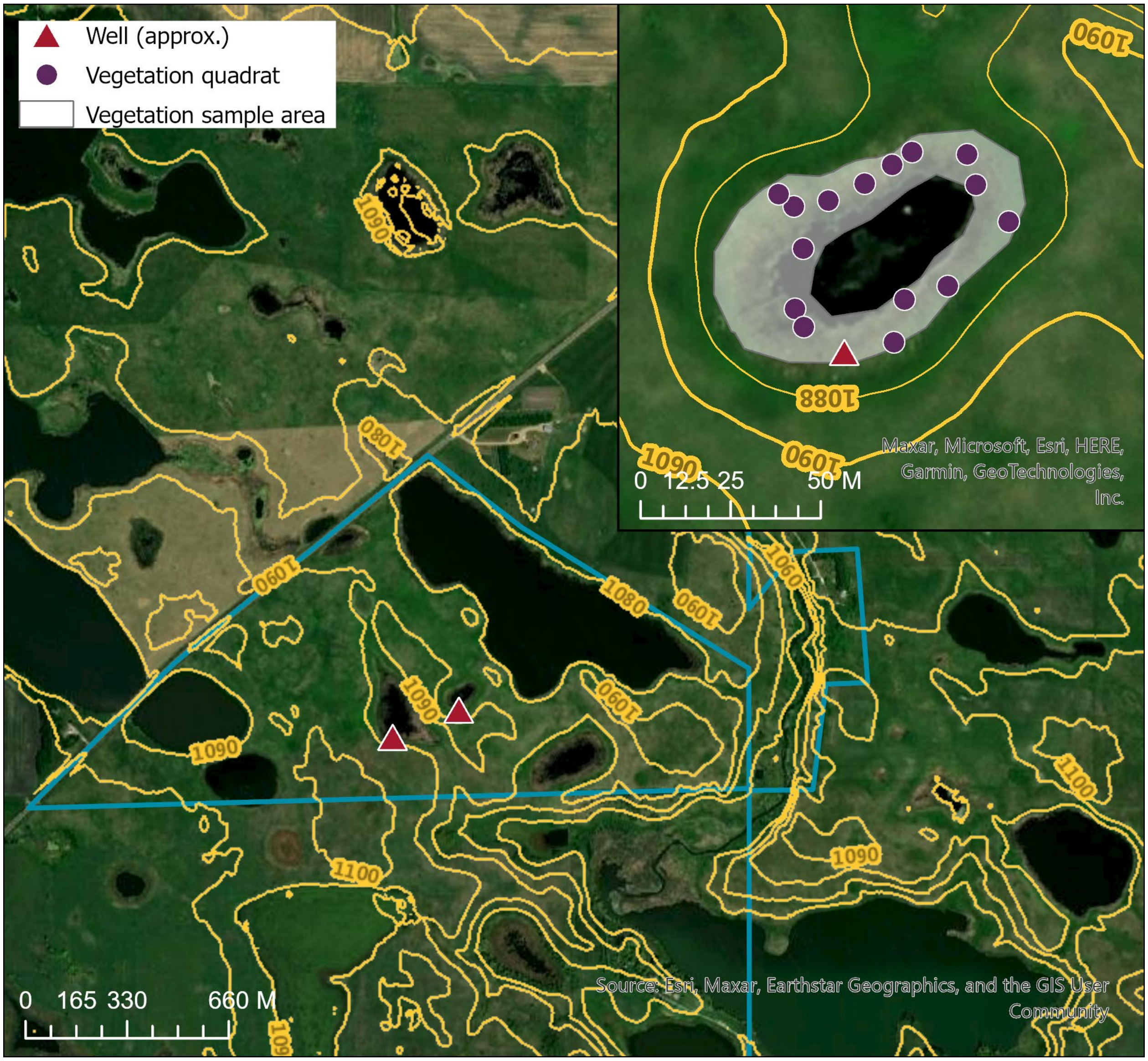

Figure A77: Map of Prairie WMA 1 data collection sites. The blue line shows the boundaries for Prairie WMA and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data. In the larger scale map, Prairie WMA 1 is east of Prairie WMA 2.

Results

We identified 14 plant taxa at the fresh meadow in Prairie WMA, with a diversity of 2.3 and evenness of 0.86. The fresh meadow is dominated (present in > 75% of the quadrats) by Pennsylvania smartweed (*Persicaria pensylvanica*) (Fig. A78).

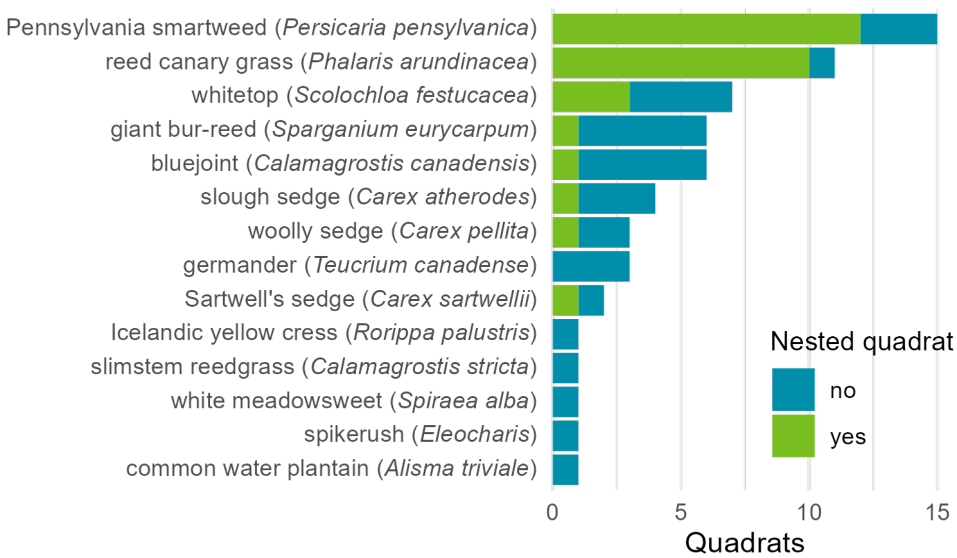

Figure A78: Plant community of Prairie WMA 1.

The median water level in the fresh meadow in Prairie WMA was 1.3 ft in 2020, 0.8 ft in 2021, and 1.8 ft in 2022 (Fig. A79). The wetland was saturated within 1 ft of the ground surface for 39 days, 116 days, and 150 days during the 2020, 2021, and 2022 growing seasons, respectively. It was inundated for 39 days, 60 days, and 144 days during the 2020, 2021, and 2022 growing seasons, respectively. The maximum water level maintained for at least 14 days during the growing season was 1.5 ft in 2020, 1.4 ft in 2021, and 2.8 ft in 2022.

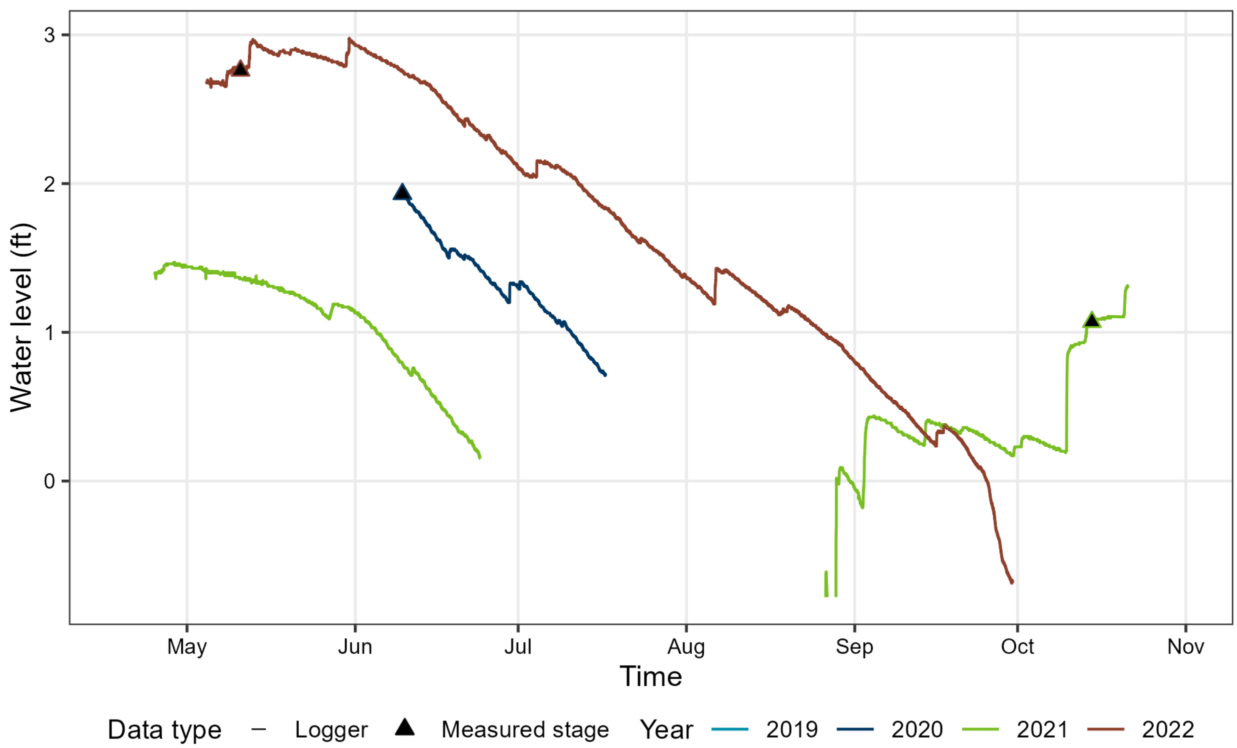

Figure A79: Hydrograph from Prairie WMA 1.

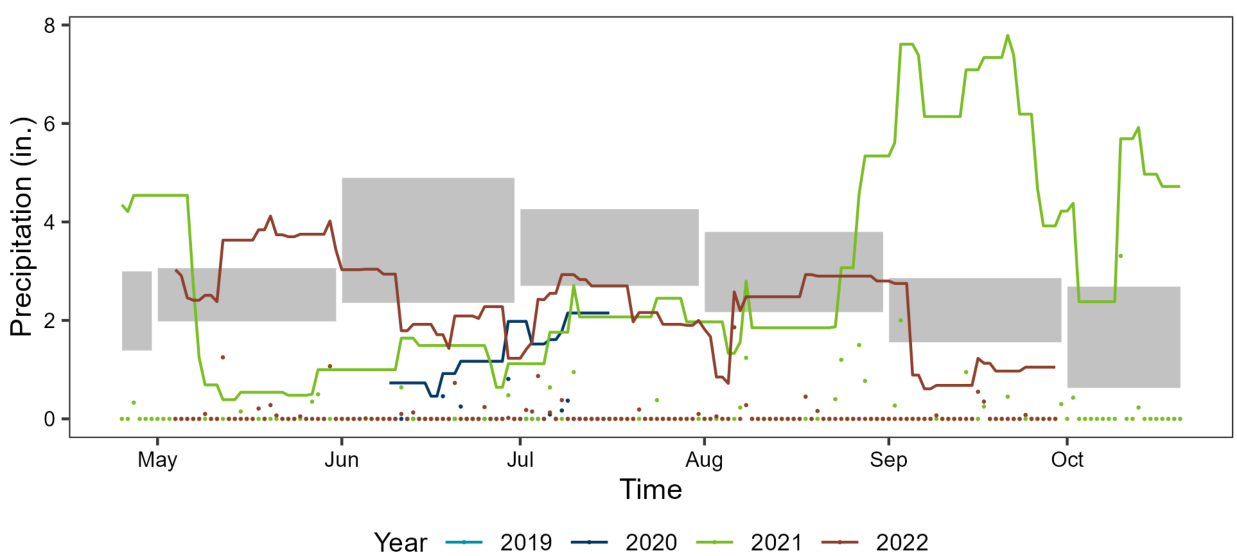

Figure A80: Precipitation at Prairie WMA 1. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Prairie WMA 2

Methods

We monitored a shallow marsh in Prairie WMA (Big Stone County), which is in the Prairie Parkland province (Fig. A81A). Prairie WMA 2 in the center of the WMA, and just west of Prairie WMA 1 (Fig. A82). We installed bubbler equipment (Fig. 3) on October 3, 2019, and began collecting data on June 9, 2020 (Fig. A81B-C). On August 18, 2021, we put the bubbler orifice line inside of a PVC well (Fig. A81C), which allowed us to collect data on water level belowground. We replaced the bubbler equipment with OTT equipment (Fig. 2) on May 10, 2022 (Fig. A81D), mounting the PVC well to the fence post that previously supported the bubbler orifice line. The OTT transducer was placed approximately 0.9 ft belowground within the PVC well. We conducted a vegetation survey on August 5, 2020. This WMA is grazed by cattle, which may influence the vegetation.

Figure A81: (A) View of Prairie WMA 2 on June 9, 2020. (B) Fence post supporting bubbler equipment and no water above ground on Augst 18, 2021. (C) Fence posts supporting bubbler equipment (including PVC well) with inundation on October 14, 2021. (D) Installation of OTT equipment on May 10, 2022.

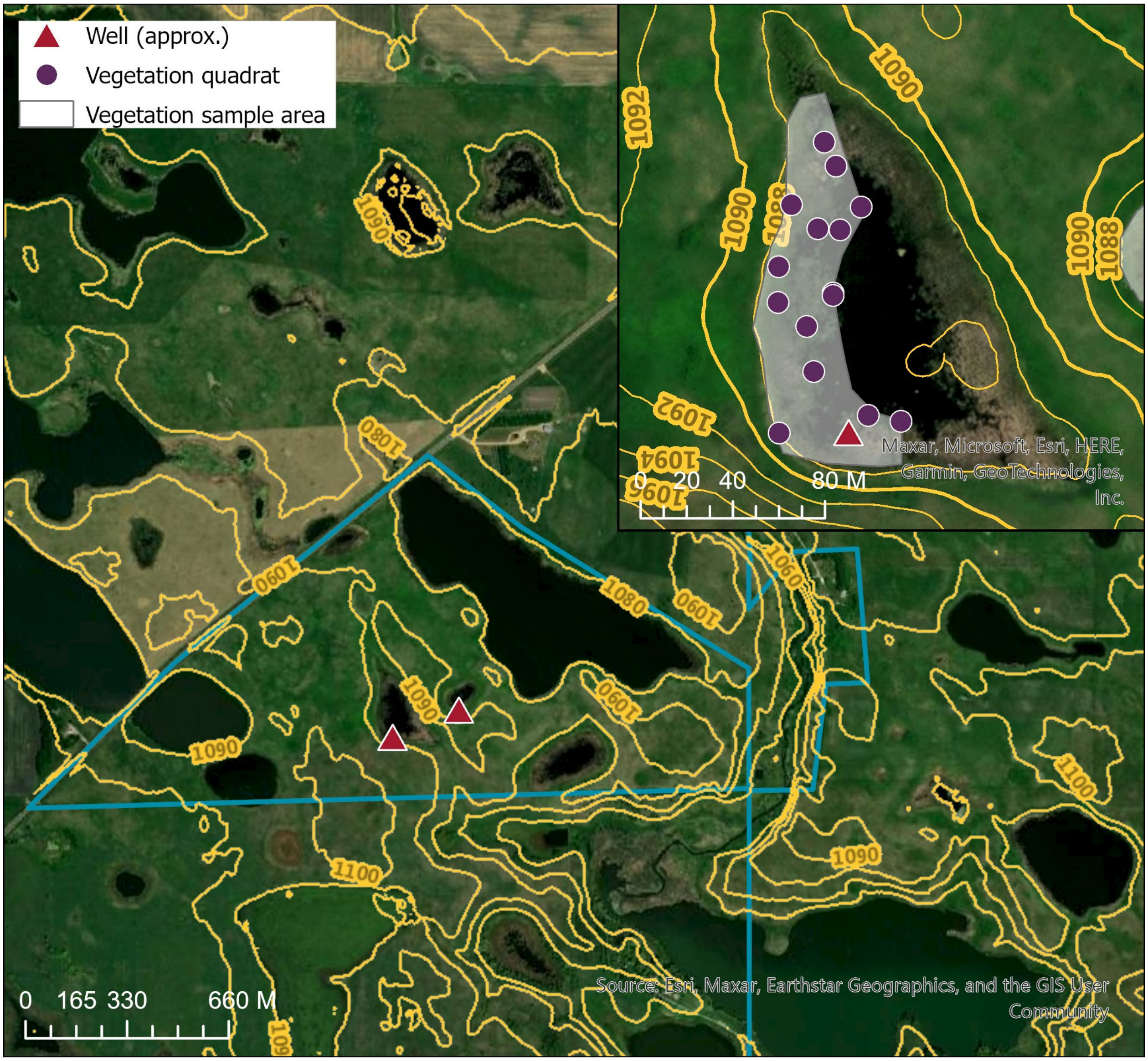

Figure A82: Map of Prairie WMA 2 data collection sites. The blue line shows the boundaries for Prairie WMA and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data. In the larger scale map, Prairie WMA 2 is west of Prairie WMA 1.

Results

We identified 21 plant taxa at the shallow marsh in Prairie WMA, with a diversity of 2.8 and evenness of 0.92. The shallow marsh has no dominant (present in > 75% of the quadrats) taxa (Fig. A83).

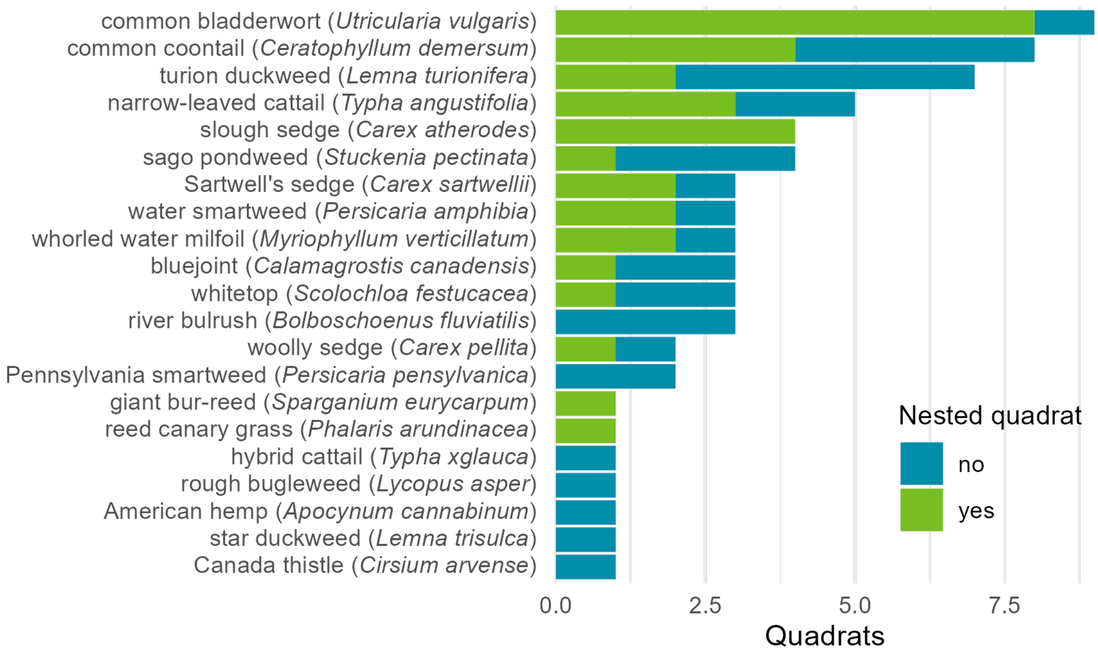

Figure A83: Plant community of Prairie WMA 2.

The median water level in the shallow marsh in Prairie WMA was 1.9 ft in 2020, 1.6 ft in 2021, and 2.7 ft in 2022 (Fig. A84). The wetland was saturated within 1 ft of the ground surface for 120 days, 144 days, and 177 days during the 2020, 2021, and 2022 growing seasons, respectively. It was inundated for 120 days, 144 days, and 177 days during the 2020, 2021, and 2022 growing seasons, respectively. The maximum water level maintained for at least 14 days during the growing season was 2.7 ft in 2020, 2.2 ft in 2021, and 3.7 ft in 2022.

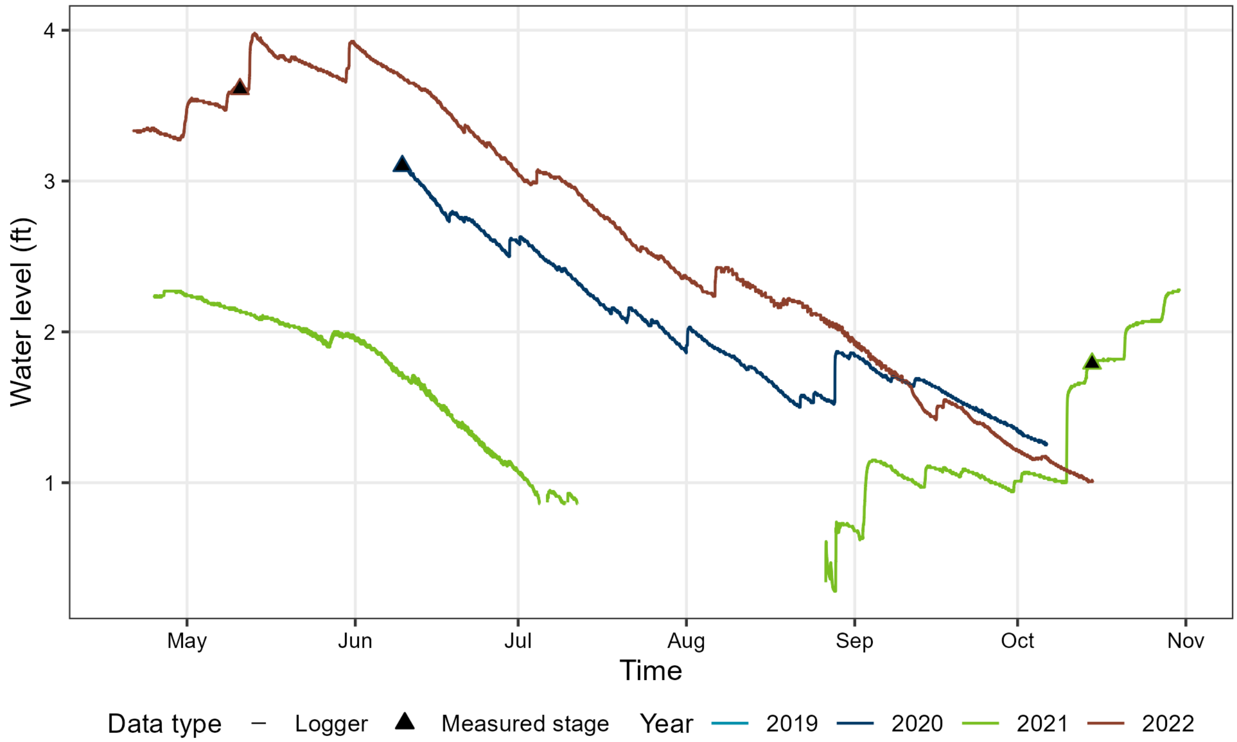

Figure A84: Hydrograph from Prairie WMA 2.

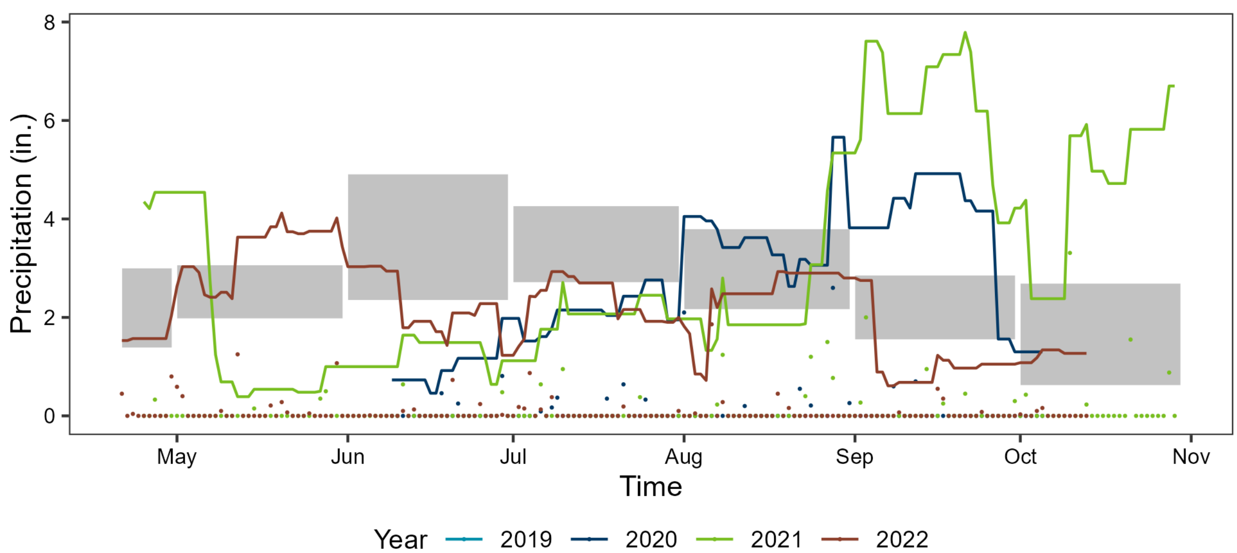

Figure A85: Precipitation at Prairie WMA 2. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Randall WPA 1

Methods

We monitored a sedge mat in Randall WPA (Kandiyohi County), which is in the Prairie Parkland province (Fig. A86A). Randall WPA 1 is in the center of the WPA (Fig. A87). We installed OTT equipment and began monitoring on October 28, 2020. The transducer was initially mounted to a fence post without any covering, but was then covered with landscaping fabric and placed in a slotted PVC well in October 2021 (Fig. A86B). The data logger is housed in a small steel casing, painted black to reduce visibility (Fig. A86C). We conducted a vegetation survey on August 5, 2021. There is current beaver activity within the wetland.

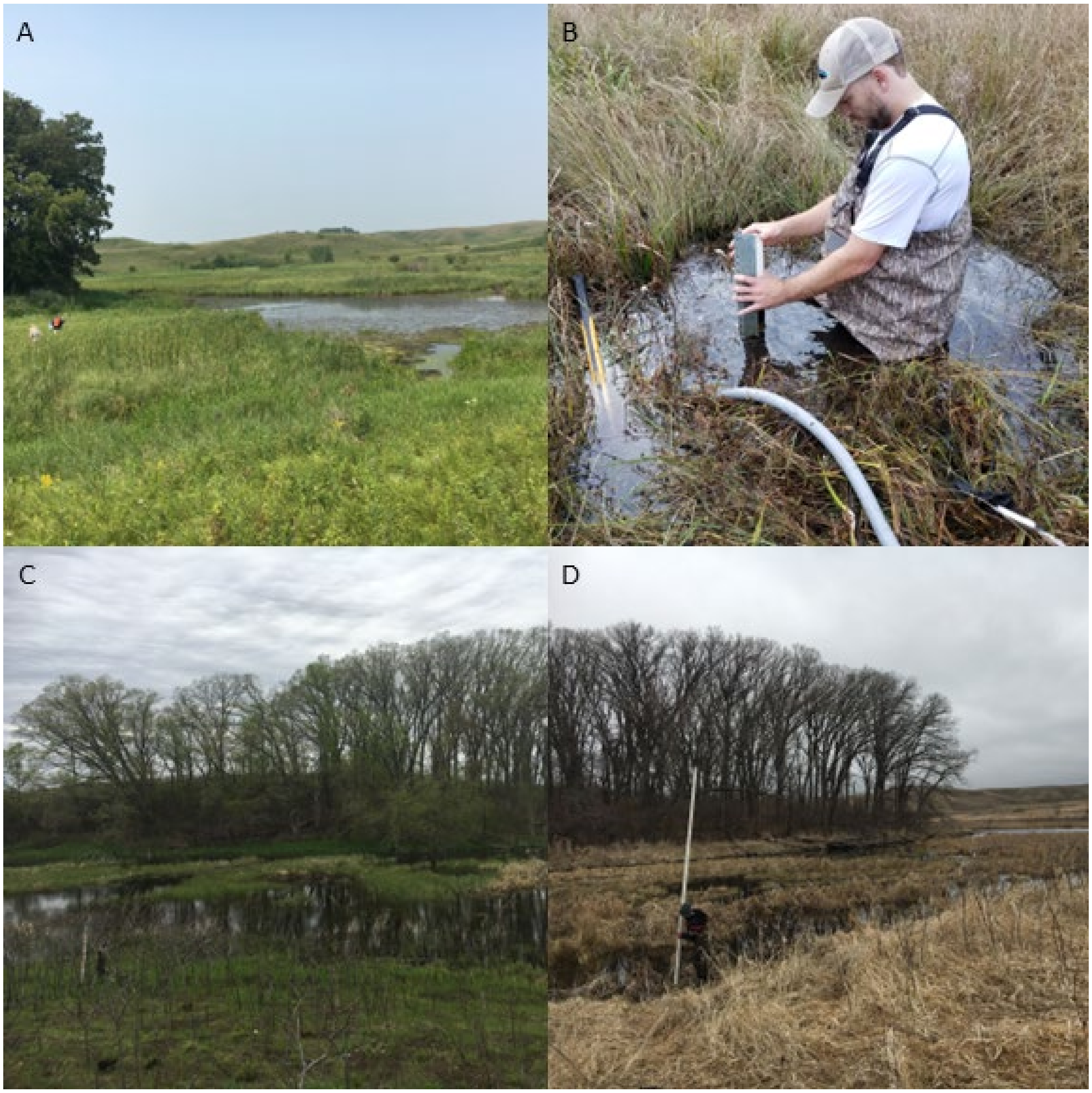

Figure A86: (A) View of Randall WPA 1 on August 3, 2021. Monitoring equipment is installed left of this view. (B) Installing PVC well for OTT transducer on October 12, 2021. (C) The steel casing for the OTT data logger in the bottom left of this photo, next to the surveying rod. Photo taken May 19, 2022. (D) Surveying at the PVC well housing the OTT transducer on April 14, 2021.

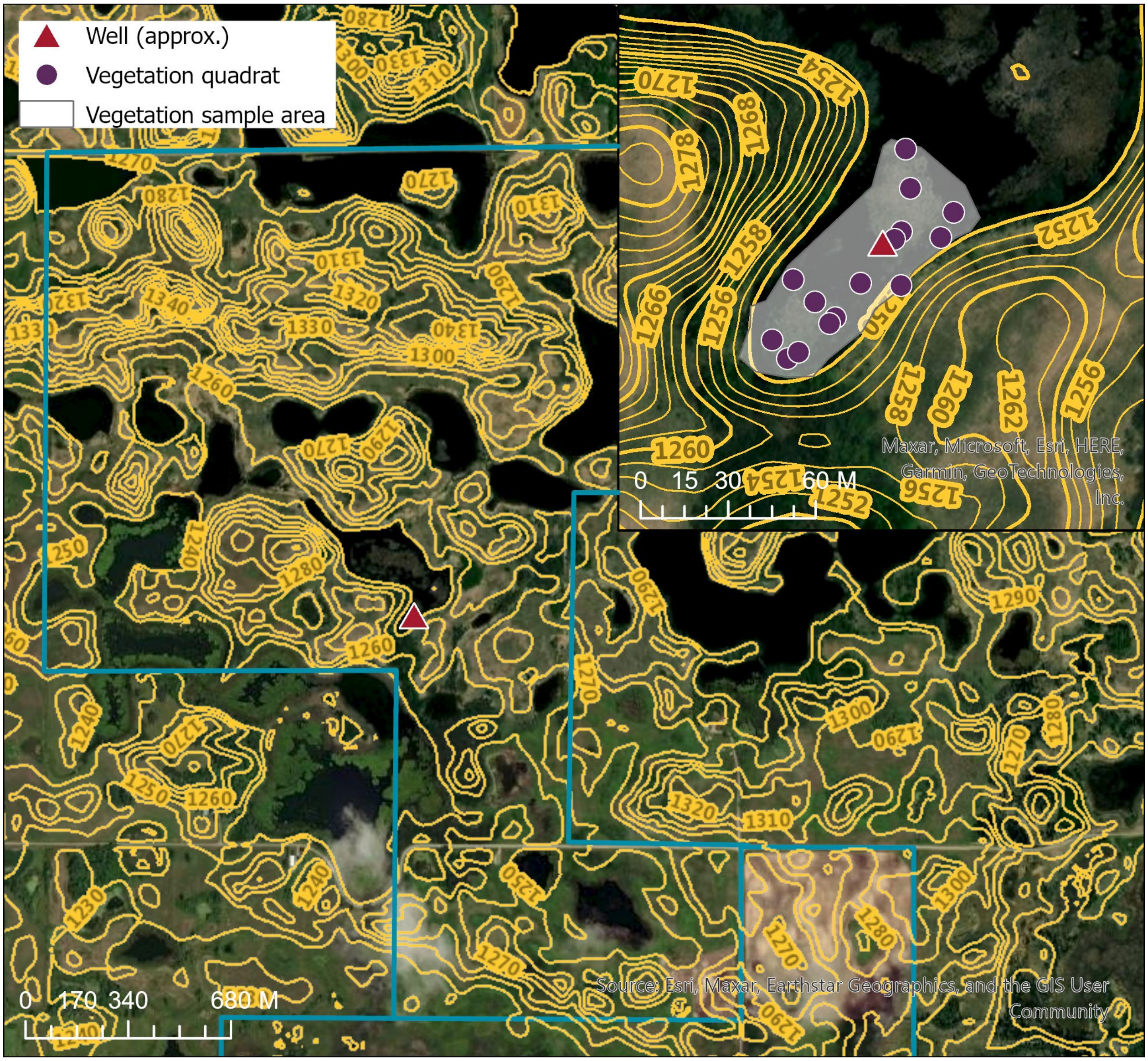

Figure A87: Map of Randall WPA 1 data collection sites. The blue line shows the boundaries for Randall WPA and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data.

Results

We identified 43 plant taxa at the sedge mat in Randall WPA, with a diversity of 3.4 and evenness of 0.91. The sedge mat is dominated (present in > 75% of the quadrats) by lake sedge (*Carex lacustris*), broad-leaved arrowhead (*Sagittaria latifolia*), tufted loosestrife (*Lysimachia thyrsiflora*) (Fig. A88).

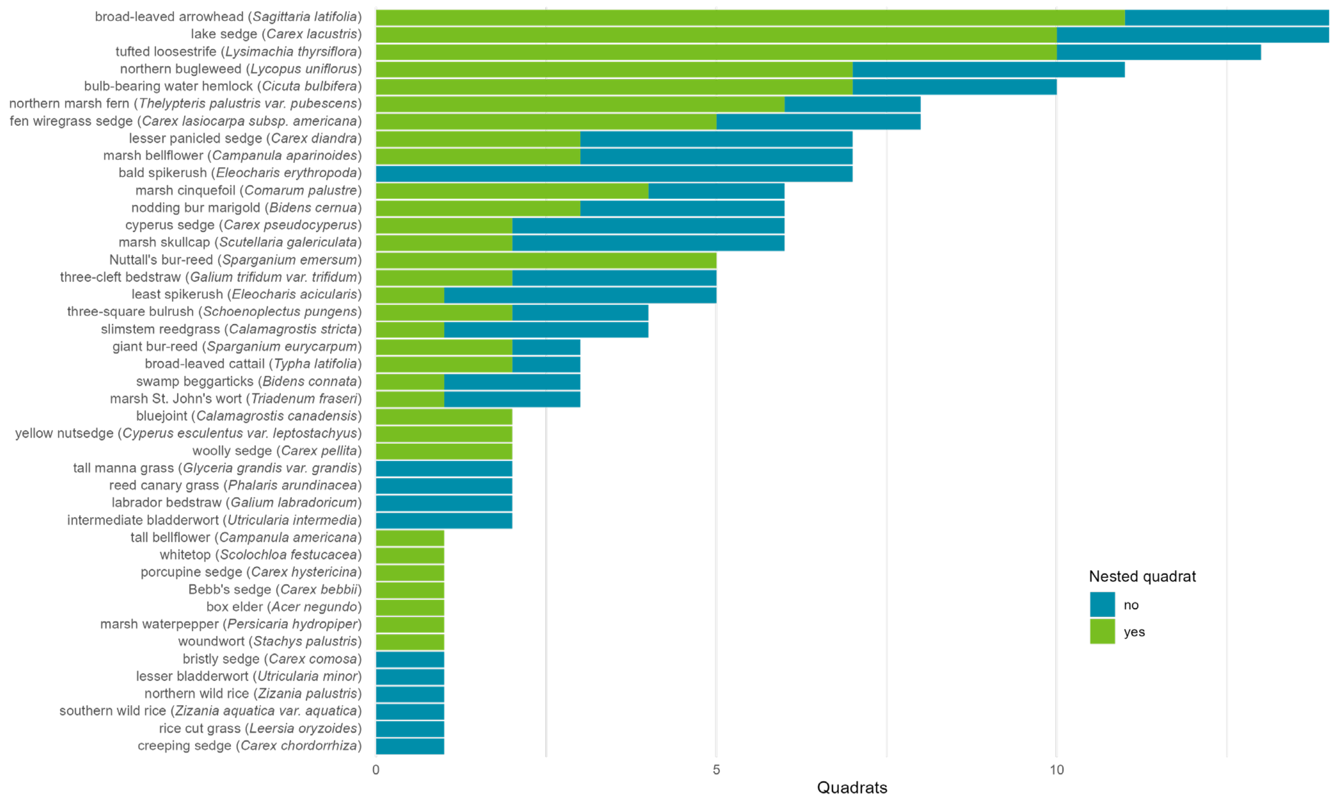

Figure A88: Plant community of Randall WPA 1.

The median water level in the sedge mat in Randall WPA was 2.7 ft in 2021 and 4 ft in 2022 (Fig. A89). The wetland was saturated within 1 ft of the ground surface for 189 days during the 2021 growing season and 169 days during the 2022 growing season. It was inundated for 189 days during the 2021 growing season and 169 days during the 2022 growing season. The maximum water level maintained for at least 14 days during the growing season was 3.6 ft in 2021 and 5 ft in 2022.

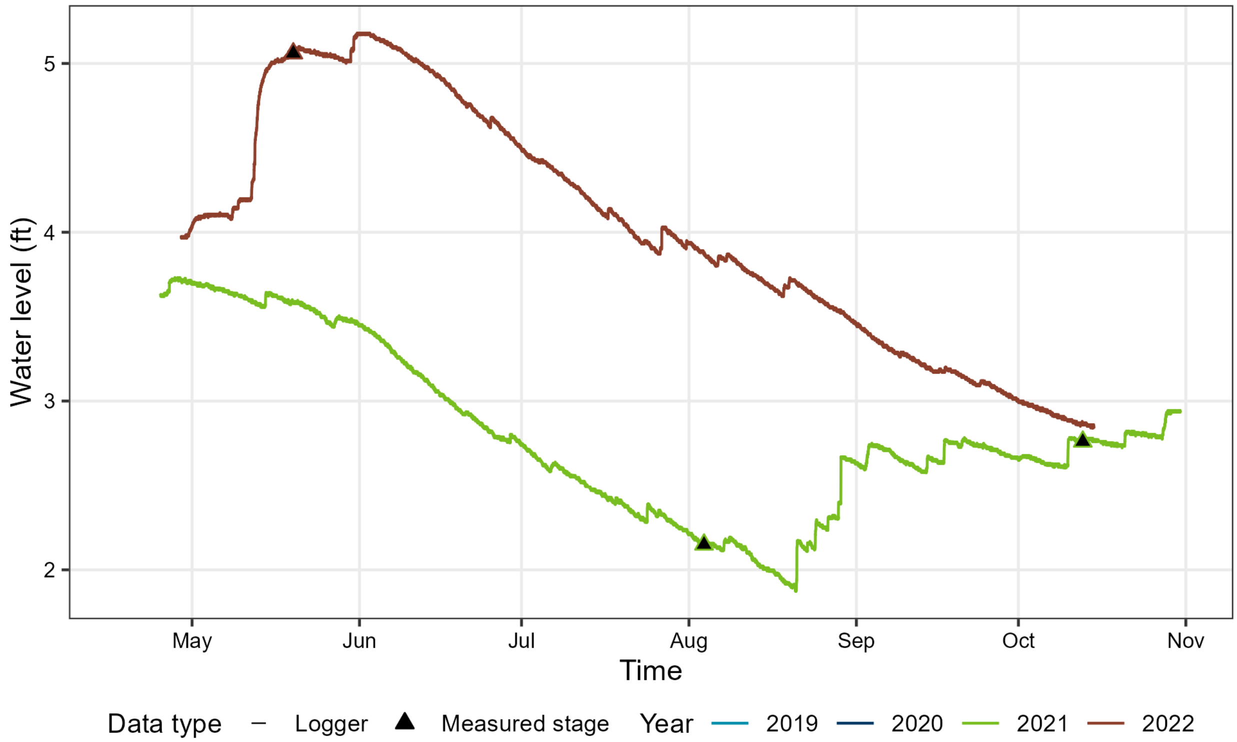

Figure A89: Hydrograph from Randall WPA 1.

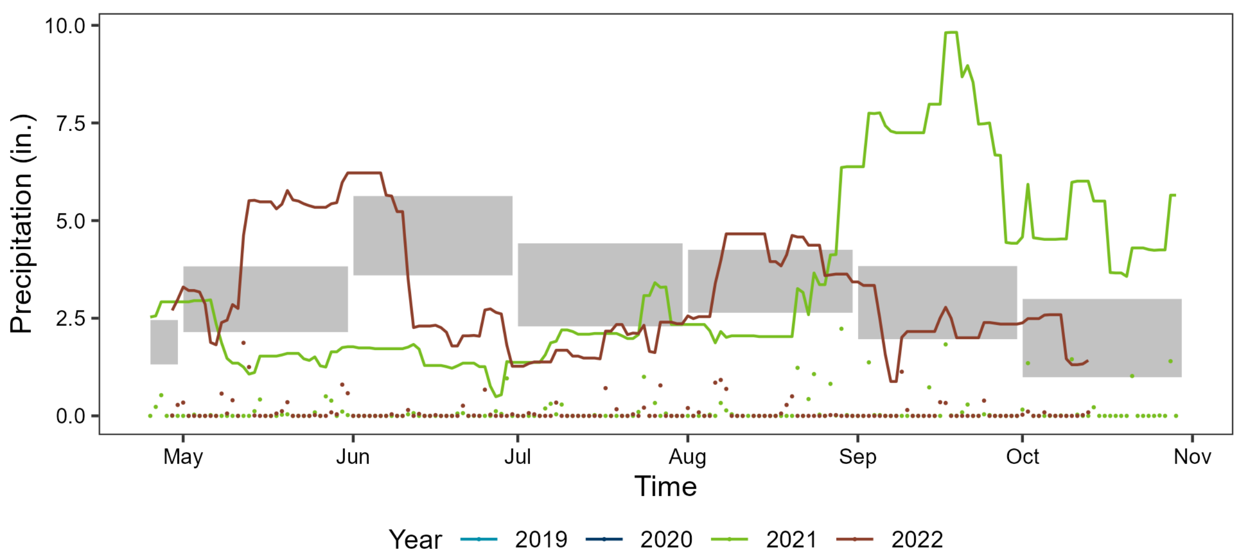

Figure A90: Precipitation at Randall WPA 1. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Sibley State Park 1

Methods

We monitored a shallow marsh in Sibley State Park (Kandiyohi County), which is in the Prairie Parkland province (Fig. A91A). Sibley State Park 1 is in the center of the park, just north of Sibley State Park 3 (Fig. A92). Bubbler equipment was installed on October 15, 2019 and data collection began on June 9, 2020. The bubbler orifice line was extended further into the wetland and placed in a slotted PVC on August 29, 2021. In mid-October, the bubbler cable was found to be chewed (Fig. A91B), which disrupted data collection. Additional OTT equipment was installed at the original orifice line location and began collecting data on October 14, 2021 (Fig. A91C). The OTT transducer is approximately 0.5 ft below ground. Water elevations from the bubbler and the OTT have not been consistently equal, so we continue to monitor both until we can determine the discrepancy. Data are presented from the bubbler equipment until the OTT equipment were installed, and then data are presented from the OTT equipment. There's an outlet approximately 25 ft east of the monitoring equipment, which connects Sibley State Park 1 to a neighboring wetland (Fig. A91D). We conducted a vegetation survey on August 19, 2020.

Figure A91: (A) View of Sibley State Park 1, with researcher at bubbler equipment, taken on June 9, 2020. (B) Damaged bubbler cable, taken on October 12, 2021. (C) Fenceposts supporting bubbler transducer (left side) and OTT transducer housed in PVC well (right side), taken on October 12, 2021. (D) Outlet connecting the monitored wetland to a neighboring wetland, taken on May 19, 2022.

Figure A92: Map of Sibley State Park 1 data collection sites. The blue line shows the boundaries for Sibley State Park and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data. Sibley State Park 1 is north of Sibley State Park 3 in the larger scale map.

Results

We identified 20 plant taxa at the shallow marsh in Sibley State Park, with a diversity of 2.7 and evenness of 0.89. The shallow marsh is dominated (present in > 75% of the quadrats) by (Fig. A93).

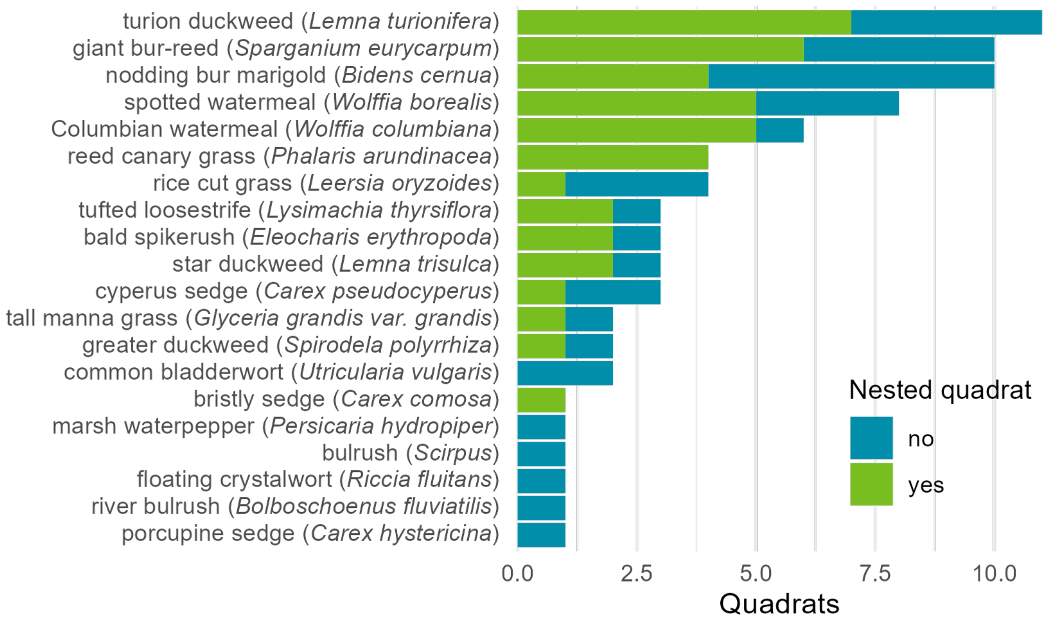

Figure A93: Plant community of Sibley State Park 1.

The median water level in the shallow marsh in Sibley State Park was 2.9 ft in 2020, 2.3 ft in 2021, and 2.8 ft in 2022 (Fig. A94). The wetland was saturated within 1 ft of the ground surface for 129 days, 94 days, and 169 days during the 2020, 2021, and 2022 growing seasons, respectively. It was inundated for 129 days, 94 days, and 169 days during the 2020, 2021, and 2022 growing seasons, respectively. The maximum water level maintained for at least 14 days during the growing season was 3 ft in 2020, 2.8 ft in 2021, and 3.4 ft in 2022.

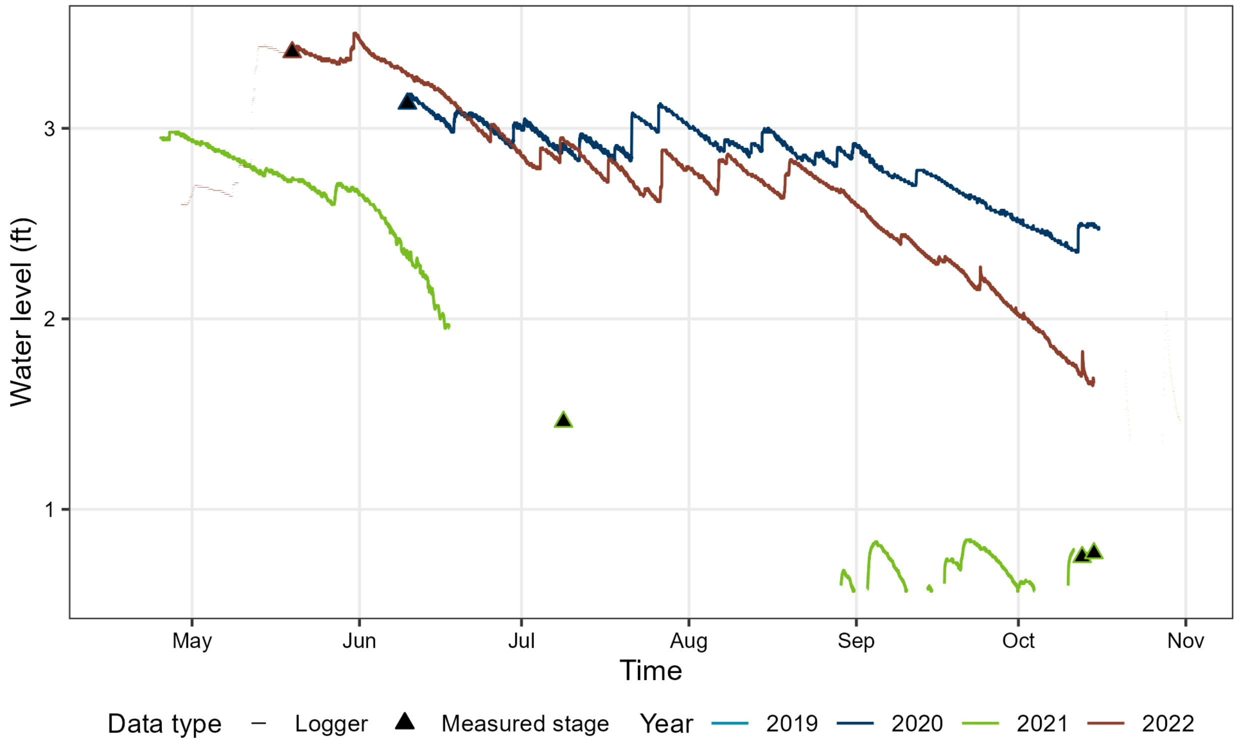

Figure A94: Hydrograph from Sibley State Park 1.

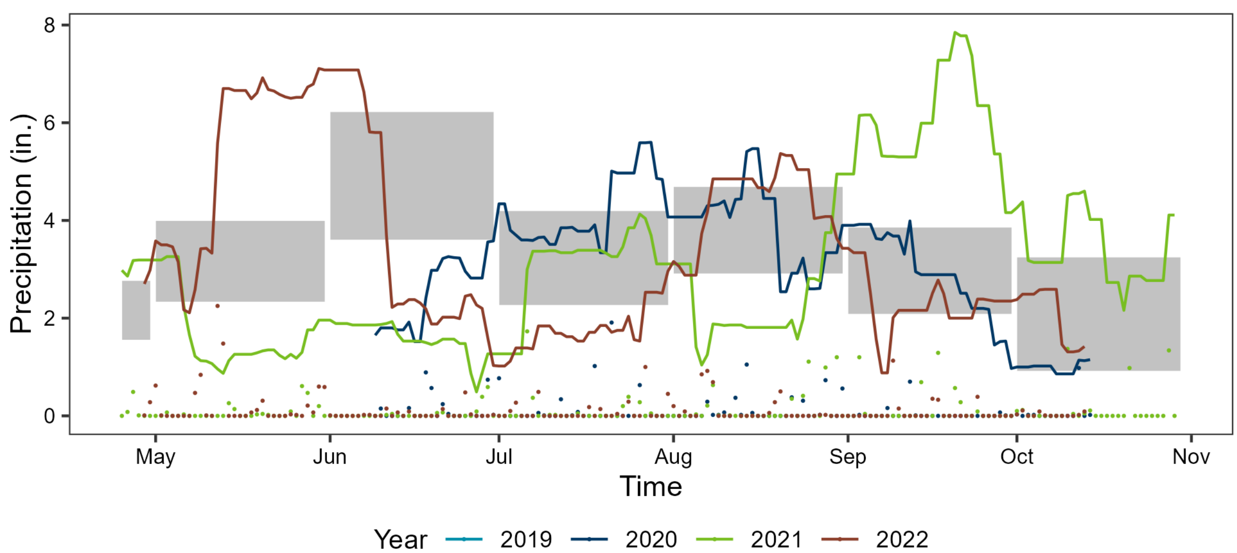

Figure A95: Precipitation at Sibley State Park 1. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.

Sibley State Park 2

Methods

We monitored a deep marsh/shallow open water in Sibley State Park (Kandiyohi County), which is in the Prairie Parkland province (Fig. A96A). Sibley State Park 2 is located in the northeastern part of the park (Fig. A97). Bubbler equipment was installed on October 16, 2019 and data collection began on June 9, 2020 (Fig. A96B). We conducted a vegetation survey on August 18, 2020 (Fig. A96C). We removed the equipment from this wetland and halted monitoring on October 12, 2021 because water leaches out of the wetland to a nearby road (Fig. A96D, Fig. A97), interfering with its hydrology. The wetland also has a lot of beaver activity, which can affect hydrology.

Figure A96: (A) View of Sibley State Park 2 on June 9, 2020. (B) Installation of the steel housing for bubbler logger on October 16, 2019. (C) View of the deep marsh during the vegetation survey on August 18, 2020. (D) Outlet on eastern side of the wetland, taken on August 18, 2020.

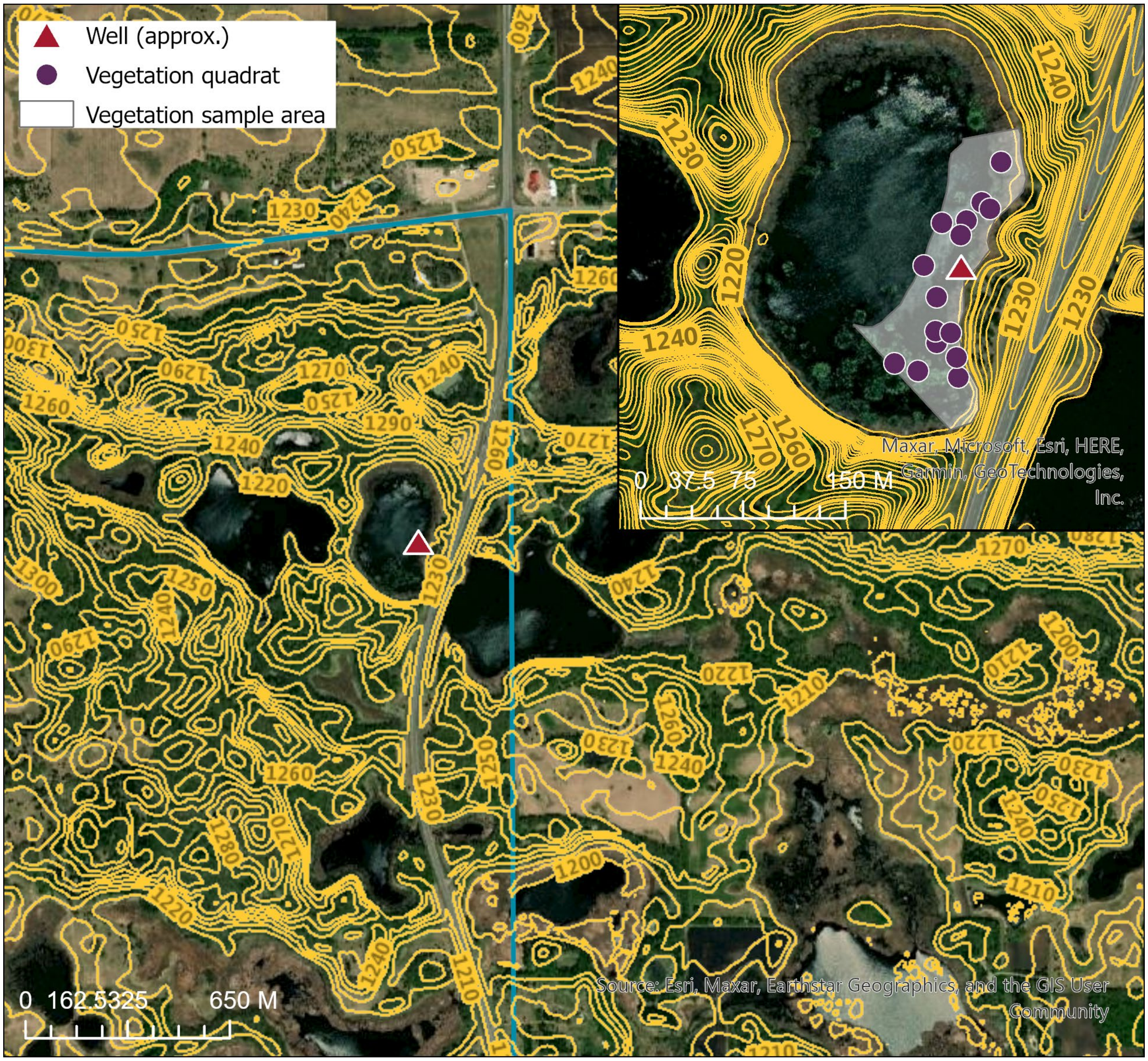

Figure A97: Map of Sibley State Park 2 data collection sites. The blue line shows the boundaries for Sibley State Park and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data.

Results

We identified 12 plant taxa at the deep marsh/shallow open water in Sibley State Park, with a diversity of 2.1 and evenness of 0.85. The deep marsh/shallow open water is dominated (present in > 75% of the quadrats) by northern wild rice (*Zizania palustris*), common coontail (*Ceratophyllum demersum*) (Fig. A98).

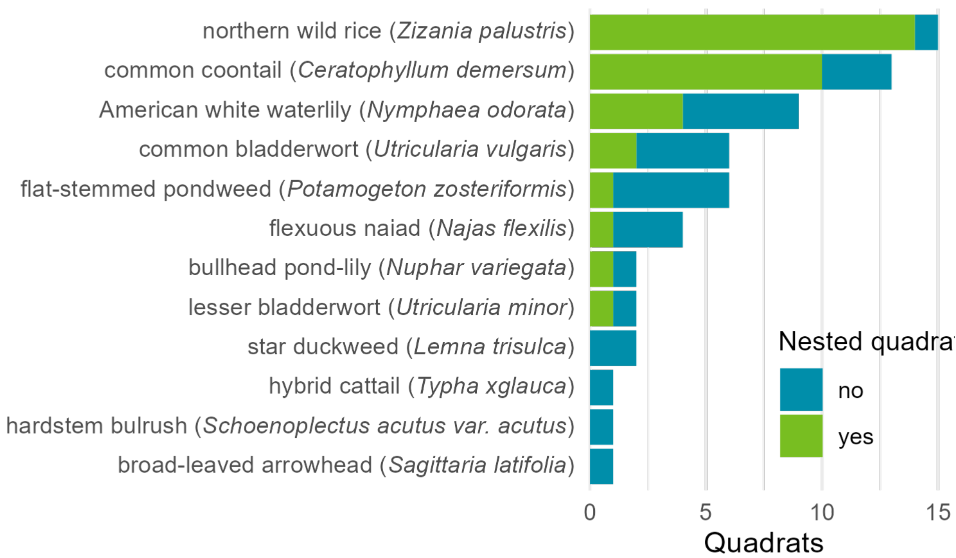

Figure A98: Plant community of Sibley State Park 2.

We did not analyze the hydrology data from the Sibley State Park 2 wetland because the site was removed from our network.

Sibley State Park 3

Methods

We monitored a fen in Sibley State Park (Kandiyohi County), which is in the Prairie Parkland province (Fig. A99A). Sibley State Park 3 is in the center of the park, just south of Sibley State Park 1 (Fig. A100). We installed OTT equipment, with the transducer mounted on a fencepost, on October 28, 2020 (Fig. A99B). The transducer became clogged with sediment, preventing data collection from late August 2021 to mid-October 2021. On October 12, 2021, we cleaned the transducer, covered it with landscaping fabric, and mounted it within a slotted PVC well (Fig. A99C). We also observed unusually large jumps in water elevation in the data collected during the growing season of 2022, causing us to question the accuracy of the measurements. We conducted a vegetation survey on August 3, 2021.

Figure A99: (A) View of Sibley State Park 3 on May 19, 2022. (B) Steel pipe housing the OTT logger, taken on October 28, 2020. (C) OVC well housing the OTT transducer, taken on October 12, 2021. (D) Vegetation survey on August 3, 2021.

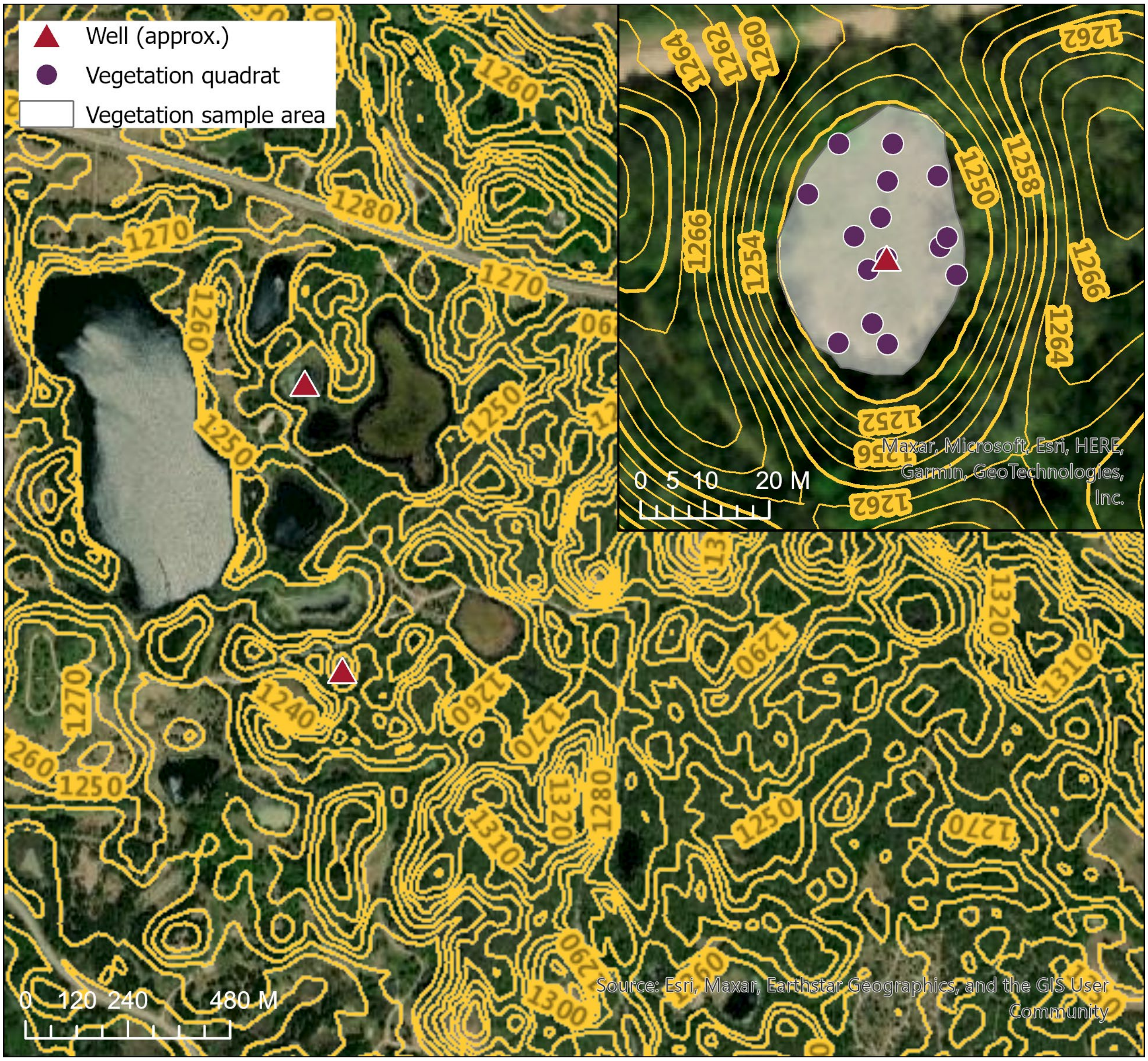

Figure A100: Map of Sibley State Park 3 data collection sites. The blue line shows the boundaries for Sibley State Park and yellow lines show 10 ft (2 ft in inset) contours derived from LiDAR data. The monitored fen is south of the monitored shallow marsh in the larger scale map.

Results

We identified 28 plant taxa at the fen in Sibley State Park, with a diversity of 3 and evenness of 0.91. The fen is dominated (present in > 75% of the quadrats) by northern bugleweed (*Lycopus uniflorus*), northern marsh fern (*Thelypteris palustris var. pubescens*), violet (*Viola heart-leaved group*), beaked sedge (*Carex utriculata*) (Fig. A101).

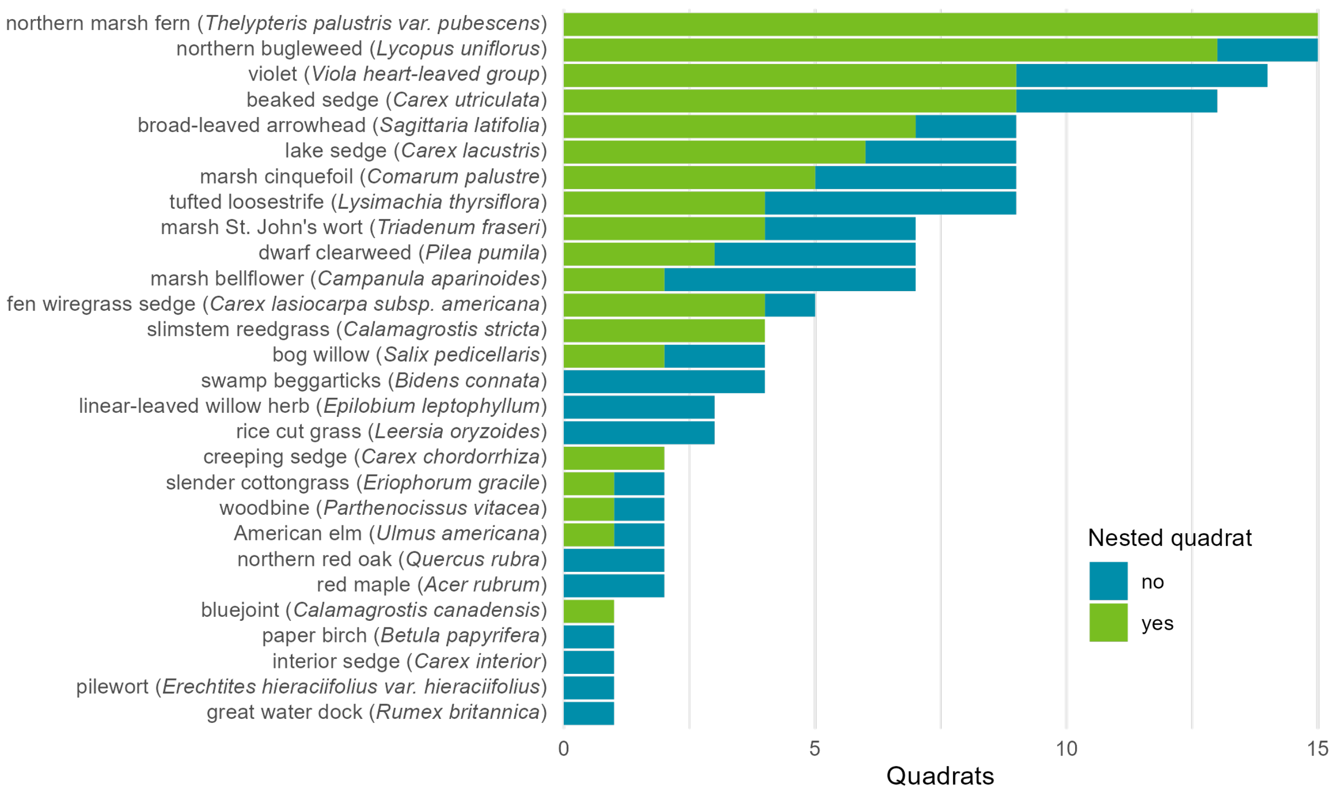

Figure A101: Plant community of Sibley State Park 3.

The median water level in the fen in Sibley State Park was 1.8 ft in 2021 and 2.8 ft in 2022 (Fig. A102). The wetland was saturated within 1 ft of the ground surface for 146 days during the 2021 growing season and 169 days during the 2022 growing season. It was inundated for 146 days during the 2021 growing season and 169 days during the 2022 growing season. The maximum water level maintained for at least 14 days during the growing season was 2.2 ft in 2021 and 3.1 ft in 2022.

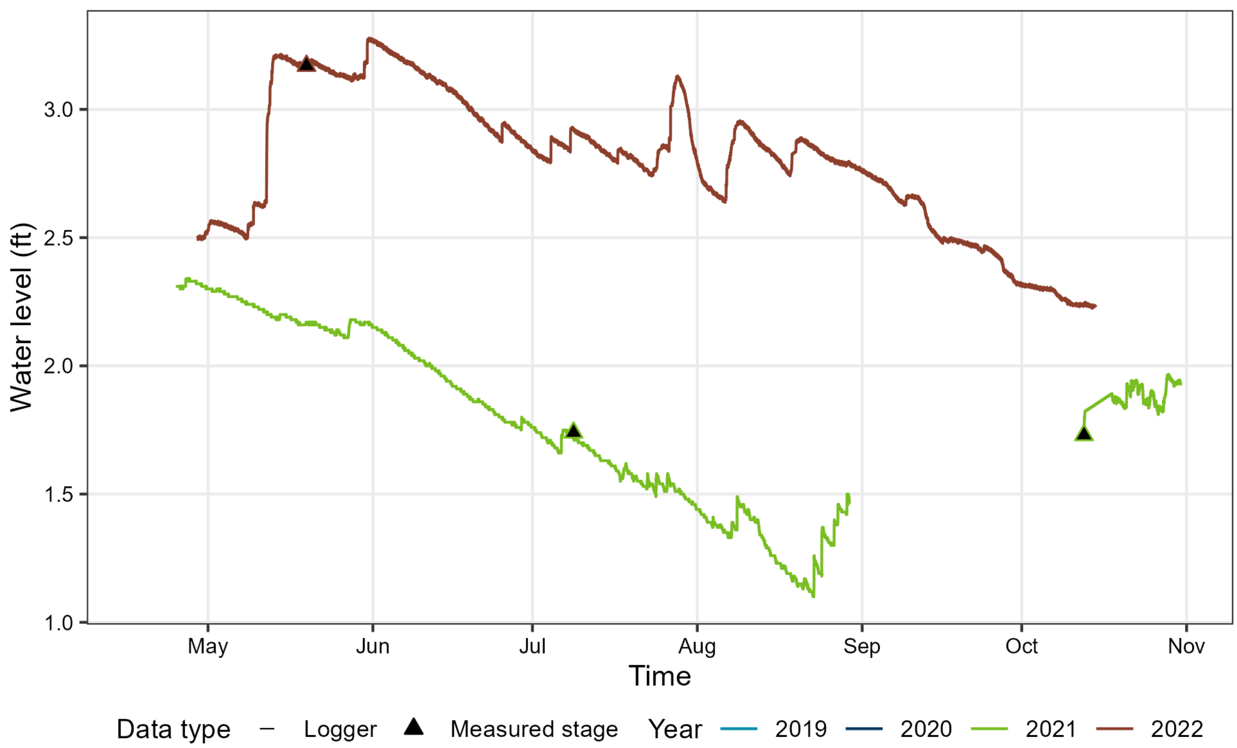

Figure A102: Hydrograph from Sibley State Park 3.

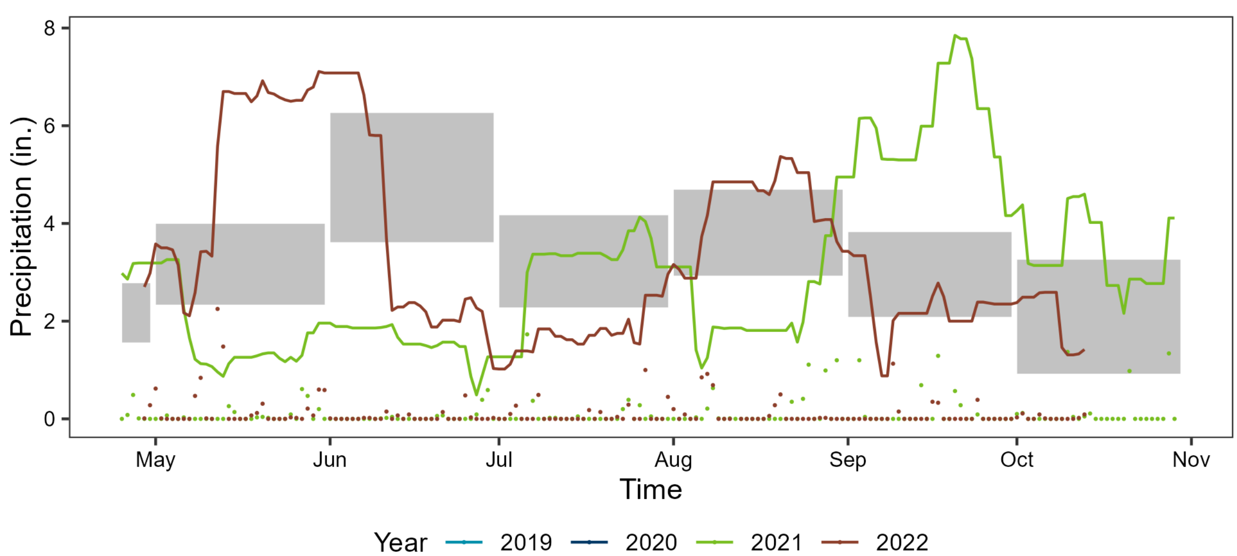

Figure A103: Precipitation at Sibley State Park 3. Points represent daily precipitation, lines represent 30-day cumulative precipitation, and grey boxes represent 30th-70th percentiles of monthly total precipitation from 1976-2015.