Wild Rice Lakes in Comparison to Mapped Surficial Sands in Minnesota

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ABSTRACT

Several recent studies have considered the distribution of wild rice (Zizania palustris) compared to a variety of physical and watershed parameters. However, the distribution of wild rice has not been systematically compared to the surficial geology. In this study, a relatively comprehensive list of identified wild rice lakes in Minnesota was compared to the mapped areas of surficial sands. Wild rice is significantly more likely to occur on basins which are within or adjacent to mapped surficial sands. Statewide, an odds ratio of 2.1. indicates that a given lake within the mapped surficial sands has more than twice the odds of wild rice occurrence than a lake outside of the mapped surficial sands. The correlation observed here between mapped surficial sands and wild rice presence suggests that a groundwater-surface water interaction may have more widespread importance for sustaining wild rice populations than previously considered.

INTRODUCTION

Wild rice (Zizania palustris) is an emergent, annual aquatic plant (Figure 1), which occurs in shallow lakes and rivers in central North America, particularly around the Great Lakes Region. Minnesota has the largest area of natural wild rice (Zizania palustris) of any state (MN DNR 2008). Wild rice is culturally, spiritually, and economically important to Minnesota (MN DNR 2008). Wild rice is especially significant to the first nation's peoples of Minnesota (Katanski 2017). This species is also highly valuable for wildlife food and habitat (MN DNR 2008).

Figure 1. A dense stand of wild rice in early September when it occurs as a fully grown emergent plant. Photo taken from a shallow lake entirely surrounded by mapped surficial sands (Anoka County, MN).

The highest concentration of wild rice lakes occurs in north-central Minnesota. The quaternary geology of north-central Minnesota has been shaped by a series of glacial advances and retreats. This has left a surficial geology that is a patchwork of higher permeability glacial outwash sands/gravels and lower permeability end-moraine and stagnation moraine glacial tills (Lusardi et al. 2019). The far northeastern portion of the state has a distinctly different surficial geology from the rest of the state, with extensive areas of thin, rocky, locally derived soils or exposed Precambrian bedrock, particularly in the Boundary Waters Formation (Lusardi et al. 2019).

Several studies have considered the range and distribution of wild rice in Minnesota (Moyle 1944; MN DNR 2008; Myrbo et al. 2017; LaRoe 2020). Recent work has focused on wild rice occurrence in comparison to physical and chemical parameters (Carson 2002; Pillsbury 2009; Mybro et al. 2017) as well as watershed characteristics (LaRoe 2020). However, the relationship between wild rice occurrence and surficial geology has not been systematically assessed. A comparison between mapped surficial geology and known wild rice lakes in Minnesota and Wisconsin suggests that wild rice tends to occur in lake basins near or surrounded by surficial sand deposits.

In this work, a relatively comprehensive list of identified wild rice lakes in Minnesota was compared to the mapped areas of surficial sands. The hypothesis was that a higher proportion of the lakes within the mapped surficial sands areas contain wild rice than outside of the mapped surficial sands both statewide and for each given county.

METHODS

Existing Data on Wild Rice

Four datasets were used to identify lakes where wild rice is present or has been present in the recent past:

- Wild rice lakes identified/inventoried by the Minnesota Department of Natural Resources (MN DNR) Section of Wildlife (MN DNR 2008)
- The MN DNR Shallow Lakes Program point intercept surveys (obtained by request from the MN DNR Shallow Lakes Program; at the time that the data were acquired, the database contained surveys which occurred between June 2002 and August 2020).
- The Minnesota Biological Survey lake surveys (downloaded from Minnesota Geospatial Commons, https://gisdata.mn.gov/; at the time that the data were acquired, the database contained surveys which occurred between June 1995 and August 2016).
- Aquatic plant management (APM) permits issued by the MN DNR (These included the wild rice inventory compiled by Drewes and Silbernagel (2012). (Note: In Minnesota, removal of wild rice along shorelines requires an APM permit, which includes a staff site visit to observe the vegetation. At the time the dataset was acquired, wild rice was identified by

APM permits on 184 public waters basins, which were issued between March 2000 and May 2022.)

These four data sets are not mutually exclusive, with some overlap in the wild rice lakes identified. The latter three datasets are not intended to be a systematic inventory of wild rice waters in Minnesota. However, these three datasets can be used to extend the inventory compiled by the MN DNR Section of Wildlife. Combined, these datasets do not produce an exhaustive list of wild rice lakes in Minnesota but do form a relatively comprehensive list of basins where wild rice has been present in recent years. This analysis focused specifically on lakes listed as public water basins by the MN DNR. The wetlands and lakes not identified as public water basins are generally smaller and have not been systematically inventoried throughout Minnesota. Rivers and streams were also excluded from this analysis.

Data on Surficial Sands Geology

The mapped surficial sands in Minnesota was published in 2016 by the MN DNR County Geologic Atlas Program. This dataset is a compilation of previously published surficial geology maps created by the Minnesota Geological Survey from 1996 to 2015. This geospatial dataset was downloaded from the Minnesota Geospatial Commons (https://gisdata.mn.gov/).

Public Water Basins

The entire set of listed public water basins in Minnesota (downloaded from the Minnesota Geospatial Commons) was compared to the surficial sands layer using ESRI ArcMap 10.6.1. Lakes which have some portion within 100 m of the mapped surficial sands were considered within or adjacent to the surficial sands.

The public waters basins within vs. outside of mapped surficial sand areas were then compared to the list of identified wild rice lakes across the state. The comparison was done using the unique basin ID assigned for each public water basin in the state of Minnesota.

Data Analysis

The odds ratio was used to assess if basins within or adjacent to mapped surficial sands are more likely to have wild rice present than basins outside of the mapped surficial sands. The odds ratio and 95% confidence interval were calculated according to Szumalis (2010), using Equation 1 (below). The effect of location within or adjacent to surficial sands on wild rice occurrence was considered statistically significant if the 95% confidence interval of the odds ratio did not include unity.

Eq. 1 Odds Ratio=((number of wild rice lakes wihtin SS)/(numberof non-wild rice lakes wihtin SS))/((number of wild rice lakes outside of SS)/(number of non-wild rice lakes outside of SS))

An initial comparison of available water chemistry data was also completed to assess if the lakes within surficial sands had different water chemistry. Several commonly measured analytes were assessed using the available water quality data collected by the Minnesota Pollution Control Agency (MNPCA) (downloaded from EPA water quality portal online tool (EPA, 2022). The comparison was restricted to public waters basins within the seven counties which have a significant odds ratio and the highest number of wild rice lakes (Aitkin, Becker, Cass, Crow Wing, Itasca, Hubbard, and Ottertail counties). The median value measured for each lake was used for this comparison because of differences in sampling frequency between lakes. It was observed that a few outliers were strongly skewing statistics from lakes which were sampled only 1-time, so the data for each parameter were trimmed to the highest and lowest median value for lakes, which were sampled 3 or more times. A student-t test was then used to compare if each chemical parameter was statistically different for basins within vs. outside of mapped surficial sands.

RESULTS

Statewide Wild Rice Occurrence

A total of 21,990 public waters basins (hereafter referred to simply as basins) are listed in the Minnesota state inventory. Of these basins, 40% (8394) of them are located within or adjacent to mapped surficial sands.

The four sources of wild rice occurrence data collectively identified wild rice on 1,653 basins. The inventory compiled by DNR wildlife identified 1,177 basins with wild rice, so including the other three datasets increased the number of identified wild rice basins substantially. An example of these data is shown for a select portion of north central Minnesota in Figure 2.

The majority of the identified wild rice basins (920 basins) occur within or adjacent to mapped surficial sands. Statewide, the odds ratio was calculated to be 2.1 (95% C.I: 2.0 to 2.4), which is statistically significant. This indicates that the odds of wild rice occurring are more than twice as high on a given basin within or adjacent to the mapped surficial sands than on a basin outside of the mapped surficial sands. If the "Arrowhead Region" of northeast Minnesota (Cook, Lake, and St. Louis counties) is excluded, the odds ratio increases to 2.5, indicating an even higher preference for wild rice lakes to occur in mapped surficial sands areas in the remainder of the state.

The correlation between wild rice occurrence and surficial sands seems to be especially strong in the western half of the primary range where wild rice occurs. For example, Cass, Becker, Hubbard, Clearwater, Otter Tail, Mahnomen, Wadena, Douglas, and Todd counties combined have an odds ratio of 4.2. While Crow Wing and Aitkin counties (further to the east) have an odds ratio, which is less than 2.0, although still statistically greater than unity.

The statewide comparison can also be expressed as a ratio of proportions or "risk ratio" (RR) (Hannu and Atte 2008).

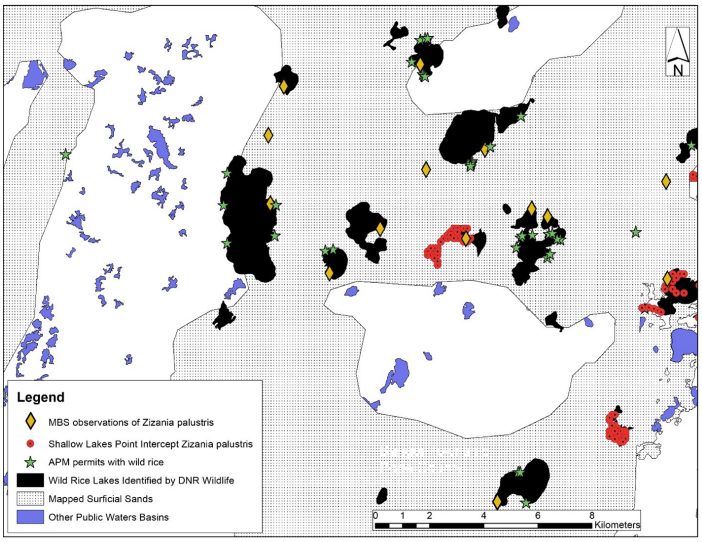

Figure 2. A small area of north-central Minnesota is shown as an example map of identified wild rice lakes, other public water basins, and mapped surficial sands. Although wild rice lakes occur in areas both within and outside of mapped surficial sands, a relatively higher proportion of the lakes contain wild rice within or adjacent to mapped surficial sands than lakes than outside of the mapped surficial sands (area in white). (Note: Minnesota Biological Survey surveys have been conducted on both public-water basins and non-public water basins, which is why some points shown on the map do not correspond to a public water basin [non-public water basins are not shown on this map]. This analysis focused specifically on the [generally larger] public water basins, which have been more systematically inventoried throughout Minnesota.)

In this case, the proportion of basins within the mapped surficial sands which contain wild rice is 0.11 (920/8392) and the proportion of basins which contain wild rice outside of the mapped surficial sands is 0.053 (733/13596), which gives a RR of 2.0. This RR indicates that statewide, wild rice is twice as likely to occur on a given basin within or adjacent to mapped surficial sands compared to a basin outside of the mapped surficial sands. The risk ratio is similar to the OR in this case because a relatively low proportion of lakes contain wild rice statewide.

County Occurrence

Ten counties have 50 or more identified wild rice basins: Cass, St. Louis, Itasca, Crow Wing, Becker, Aitkin, Lake, Hubbard, Otter Tail, and Beltrami. These counties are primarily located in north central Minnesota. With the exception of St. Louis County and Beltrami counties, all of these counties have an odds ratio, which is significantly greater than unity to 95% confidence (Table 1). This means that for these individual counties, wild rice is statistically more likely to occur in basins within or adjacent to the mapped surficial sands. The fact that the county specific data corroborates the statewide trend indicates that the wild rice occurrences are not merely reflecting broad regional distributions but instead are correlated to local variation in the surficial geology.

The "Arrowhead Region" of northeast Minnesota (St. Louis, Lake, and Cook counties) and Beltrami County (also in the northern portion of Minnesota) are an exception to the statewide trend. For these counties, wild rice is not any more likely to occur on basins within mapped surficial sands areas. For example, St. Louis County has an odds ratio of 1.1 (95% C.I: 1.6 to 0.7) and Beltrami County is similar, which means that wild rice lakes have essentially equal odds of occurring on basins within versus outside of the mapped surficial sands. Cook and Lake Counties have limited areas of surficial sands, but both have a fairly large number of wild rice lakes. The odds ratio for Lake Country is significantly greater than unity, but the total number of lakes located within mapped surficial sands is a quite small sample size (n = 14). Other counties in the northern tier of Minnesota (Lake of the Woods, Koochiching, Roseau, Polk, and Marshall) have few wild rice lakes, and cannot be assessed statistically.

DISCUSSION

The reason that wild rice occurrence is so strongly correlated to the mapped surficial sands is not immediately obvious. Wild rice is known to grow on a variety of sediment substrates (MN DNR 2008). Wild rice tends to be most successful on organic sediment, but the underlying substrate can be either clay (Day and Lee 1989) or sand/gravel (Moyle 1944). Also, the presence of a lake within the mapped surficial sands does not necessarily correspond to a particular lake sediment substrate. For example, there are several examples of wild rice populations occurring on lakes with a very mucky organic bottom substrate even though these lakes are surrounded by surficial sands (e.g., Deer Lake, Lake ID 02005900 and Mud Lake, Lake ID 77008700).

Reviewing the surface water quality data collected by the MNPCA, the measured nutrients and other dissolved ions are not statistically different for lakes within verse outside of the mapped surficial sands areas for lakes located in the primary wild rice counties (Table 2). Although this is a fairly coarse level of analysis, it does suggest that the water chemistry is not markedly different in surficial sands lakes in these counties. However, the water clarity does appear to be somewhat higher in lakes which are within or adjacent to surficial sands (Table 2). Since water clarity corresponds to higher probability of wild rice occurrence (Mybro et al. 2017), this difference may partially explain the preference for wild rice to surficial sands lakes.

The correlation of wild rice presence to mapped surficial sands may indicate that groundwater-surface water interactions are an important factor in sustaining wild rice populations. In north-central Minnesota, the mapped surficial sands generally correspond to the presence of a water table aquifer, particularly in proximity of lakes, where the water table would be high (e.g., Petersen 2007, 2010). Thus, the majority of lakes within or adjacent to mapped surficial sands very likely have a strong groundwater connection (Peterson 2010). Ng et al. (2017) demonstrate that

groundwater-surface water interactions strongly influence geochemical cycles in the rooting zone of a wild rice population at one specific site. Waheed (2021) also provides an example of a site with abundant wild rice where the measured groundwater gradient was upward indicating groundwater upwelling into the rice bed. Whereas, at a similar site nearby (where wild rice had declined in recent decades), the measured groundwater gradient was slightly downward. This difference is groundwater flow was identified as one potential factor explaining the difference in the current wild rice abundance between these two sites, and possibly indicates that groundwater upwelling improves wild rice resilience. Another study investigating a formerly abundant wild rice lake in Wisconsin estimated a substantial amount of groundwater discharge into the lake, with groundwater accounting for 22% of the total lake budget (Leaf and Hanseldorf 2020). Although the wild rice population at that particular basin has declined (for reasons not fully understood), this is an example of strong groundwater connection measured at a lake known to have sustained an abundant population of wild rice.

While Ng et al. (2017), Waheed (2021), and Leaf and Hanseldorf (2020) all provide singular examples of the importance of groundwater to a particular wild rice population, the correlation observed here between mapped surficial sands and wild rice presence suggests that a groundwater-surface water interaction may have more widespread importance for sustaining wild rice populations than previously considered. For example, wild rice abundance was positively correlated with sediment total inorganic carbon (TIC) and porewater calcium for study lakes throughout Minnesota (Waheed 2021). These observations point to a potential connection between wild rice abundance and groundwater discharge to the rooting zone, since groundwater is typically higher in both calcium and TIC than surface water in north-central Minnesota (MNPCA 1999). Additionally, groundwater upwelling into a wetland may provide a source of nutrients to enhance wild rice growth (Waheed 2021).

The effect of groundwater-surface water interactions on sediment geochemistry is complex (Ng et al., 2017), and this analysis makes no attempt to fully explain those geochemical complexities. High sulfide in the rooting zone has been found to inhibit wild rice growth and production (Myrbo et al. 2017), and groundwater flux might mitigate sulfide production in the sediment (Ng et al. 2017). The Arrowhead region of northeast Minnesota has a distinct geology and climate from other parts of Minnesota. Since this region generally has both cooler summer temperatures and lower sulfate concentrations in surface waters, these differences in water chemistry and climate may explain why wild rice is not as strongly associated with surficial sands in northeastern Minnesota.

CONCLUSION

The correlation observed here between surficial sands and wild rice presence corroborates some other recent pieces of evidence indicating that groundwater flow is potentially valuable to sustaining wild rice populations. Given this initial finding, the importance of groundwater to wild rice populations certainly warrants further study to understand how to best protect this resource.

Currently, several ongoing efforts to reseed/restore wild rice lakes are occurring within Minnesota (e.g., Vogt 2021) and in other northern states (e.g., Wisconsin Waterfowl Association 2022; McWhirter 2022). Considering the lake location in relationship to the mapped surficial sands (or potentially even groundwater flow system) may help improve the success of these seeding efforts.

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