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Documenting Macrophytes and Thier Habitat Preferences in Southeastern South Dakota

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DOCUMENTING MACROPHYTES AND THEIR HABITAT PREFERENCES IN SOUTHEASTERN SOUTH DAKOTA

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ABSTRACT

One of the most pressing environmental problems that waterbodies currently face is eutrophication. When eutrophication occurs in lakes, phytoplankton dominance increases and macrophyte (aquatic plant) populations decrease. Macrophyte population fluctuation can be used to detect eutrophication and indicate lake health. Despite this novel use of macrophytes, the state of South Dakota has few, if any, baseline public records of its macrophyte species. In an effort to establish a record and work towards the use of macrophytes as potential eutrophication indicators in South Dakota, this study seeks to provide a better understanding of the macrophytes that occur in the southeastern portion of the state and their relationships with lake habitats. The objectives of this study were to 1) survey the macrophytes of a small sample of lakes in southeastern South Dakota, 2) evaluate the relationships between existing macrophytes and the physical characteristics of their lakes, and 3) determine if there are any predictable habitat preferences. The survey was conducted at a total of 78 sample sites among two lakes during mid-summer 2020. Macrophyte samples were taken using a weighted sampling rake and substrates were visually estimated. Overall, ten different macrophytes types, including emergent, submerged, and free-floating species and genera, were recorded among sample sites. West 81 Lake had the highest species richness, with nine species present and a significantly higher ($P < 0.05$) average species richness than Island Lake. Additionally, West 81 Lake showed a significantly higher ($P < 0.05$) presence frequency of silt/muck substrates than Island Lake and a significant positive ($P < 0.05$) relationship between percent silt/muck and species richness. Both lakes demonstrated a significant negative ($P < 0.05$) relationship between percent clay and species richness. As the results suggest, both percent silt/muck and percent clay play important roles in determining the types of macrophytes in southeastern South Dakota lakes, and silt/muck dominated habitat systems appear to be preferred by a diverse array of macrophytes.

Keywords

Macrophyte, eutrophication, lake, substrate, silt, muck, clay, species richness

INTRODUCTION

Since the Industrial Revolution, increases in human populations and activity have dramatically altered the structure and function of environments across the globe (Smith et al. 1999; Gilbert et al. 2005). Humans are changing the composition of many naturally occurring biological communities by way of common practices such as urbanization, deforestation, agriculture, and hydrological cycle alterations (Smith et al. 1999). Specifically in lakes, anthropogenic activities can lead to unnaturally accelerated eutrophication rates (Bhagowati and Ahamad 2019), and in today's world, eutrophication is one of the most pressing environmental problems that waterbodies face (Gilbert et al. 2005; Bhagowati and Ahamad 2019).

In simple terms, eutrophication is a process by which bodies of water become increasingly enriched with nutrients like nitrogen (N) and phosphorus (P) (Bhagowati and Ahamad 2019). Through increased land use and fertilizer application, humans catalyze eutrophication and raise aquatic primary production rates (Bhagowati and Ahamad 2019). Once eutrophication begins, algal blooms, health risks, pH levels, and probabilities of fish kills increase; while water clarity, dissolved oxygen (DO), and aquatic plant population levels decrease (Smith et al. 1999; Gilbert et al. 2005; Phillips et al. 2016). Observing noticeable degradations in these characteristics, however, can serve as indicators of eutrophication events, especially in regard to changes in macrophyte species composition. Currently, there is a lack of information about South Dakota macrophytes, but developing knowledge and records of these species could provide lake managers with a useful tool for monitoring and detecting eutrophication in local lakes.

Macrophytes, also known as submersed aquatic vegetation or simply aquatic plants, are organisms that specialize their growth in and around bodies of water or wet habitats (Freedman and Lacoul 2006; Wersal et al. 2006; O'Hare et al. 2018*b*; Li et al. 2020). However, the exact definition of these terms can be vague, as some authors refer only to hydrophytes in descriptions, and others include amphibious, marshland, or even wet meadow species in definitions (Francová et al. 2019). For simplification in this paper, the term macrophyte was used to describe species of filamentous algae and other species that fit the description provided by Freedman and Lacoul (2006) that places aquatic plants into four functional groups: emergent species, floating-leaved hydrophytes, submerged hydrophytes, and free-floating hydrophytes.

In shallow, freshwater ecosystems, macrophytes are important because they have a large influence on the abiotic and biotic characteristics that surround them (Zimmer et al. 2003), playing key roles in the structure and function of their environments (Larson 1993; Bakker et al. 2013). A standing crop of any macrophyte species can impact nutrient cycling, habitat creation, predator-prey relationships, species assemblages, and the chemical and physical characteristics of a waterbody (Zimmer et al. 2003; Madsen et al. 2006). Macrophytes are primary producers and create complex aquatic food webs by providing food to many other organisms, including migratory waterfowl, aquatic invertebrates, and even large mammals like moose (Zimmer et al. 2003; Madsen et al. 2006; Bakker et al.

2013; Tischler et al. 2019; Li et al. 2020). The strength of these relationships between macrophytes and their environments, however, can fluctuate with changes in species abundance and community composition (Zimmer et al. 2003).

Despite the significance of aquatic macrophytes to the structures, functions, and services of freshwater ecosystems, researchers have only recently recognized their benefits (O'Hare et al. 2018*b*). A century ago, limnologists and other researchers largely regarded aquatic plants as unimportant to the ecosystems they resided in, some even arguing that the removal of larger aquatic plants and the subsequent substitution of similarly shaped glass structures would not affect food relations (O'Hare et al. 2018*b*). However, over the past one hundred years and especially into the beginnings of the 21st century, the study of macrophytes has expanded immensely, as nowadays there is an increased recognition of the importance in fully comprehending and supporting basic aquatic ecosystem functions (O'Hare et al. 2018*b*).

Regarding the effects of eutrophication on lake macrophytes, researchers have clearly linked nutrient enrichment with aquatic plant loss (Phillips et al. 2016), noting that nutrient oversaturation can cause increased phytoplankton dominance and algal blooms (Smith et al. 1999). With increased levels of N and P, all aquatic plants increase their growth (Smith et al. 1999), prompting intraspecific competition between macrophytes and interspecific competition between different categories of aquatic vegetation for light (O'Hare et al. 2018*a*). Eventually, algae will outcompete larger macrophytes for light and dominate ecosystems (O'Hare et al. 2018*a*). This eutrophication fueled competition causes only temporary plant species loss; however, continued eutrophication events can lower the overall global macrophyte population (Phillips et al. 2016).

Despite the negative consequences of eutrophication, biologists have learned that long-term differences in macrophyte abundance and composition can act as observable signals of water quality and nutrient alterations, therefore making macrophytes potentially useful in future detection of eutrophication, organic pollution, and hydrological changes in waterbodies (Phillips et al. 2016; O'Hare et al. 2018b). As Melzer (1999) explains, macrophytes react slowly and steadily to nutrient fluctuations in a waterbody. With slow changes, macrophytes are then able to display the health status of lakes over time, which is an indicator that can be of great significance when working to maintain clear waters (Li et al. 2020). Before macrophytes can be used to detect eutrophication events, however, researchers need to establish records of the abundance and distribution of the different plants of their regions and understand the factors that naturally drive those metrics.

Historically, research into macrophyte habitat requirements focused on light, as the growth and survival of macrophytes often depends on underwater light availability (Shields and Moore 2016; Gillard et al. 2020). However, as past research has collectively proven, there is no single environmental factor that influences the abundance of underwater plants (Madsen and Adams 1989). Rather, patterns of aquatic plant accumulation and distribution in certain areas are complex and regulated by multiple abiotic factors, including light penetration, water chemistry, water depth, water flow velocity, salinity, turbidity, disturbance by wave action, sediment abrasion, substrate type, substrate redox potentials, and nutrient availability (Madsen and Adams 1989; Madsen et al. 2006; Wersal et al. 2006; Engloner et al. 2013; Shields and Moore 2016; Gillard et al. 2020).

Looking into the preferences of various forms of macrophytes, researchers have discovered differences in habitat between free-floating and rooted macrophytes, noting that rooted vegetation is often influenced by characteristics of the substrate that surrounds it (Madsen and Adams 1989). Free-floating macrophytes depend on nutrient availability only in the water column, but rooted macrophytes may be limited by nutrients available in the surrounding sediment (Madsen and Adams 1989). Overall, substrate type can influence rooted species through organic content, redox potentials, and water flow velocity (Engloner et al. 2013), as well as through impacts on their rates of nutrient uptake (Shields and Moore 2016).

When it comes to substrate preferences, researchers often hypothesize that sand is least preferred by macrophytes. In a 1989 study, Madsen and Adams explored the importance of substrate characteristics in riverine systems, theorizing that sand sediments in eutrophic streams are too unstable for proper rooting and claiming that areas without sand provide macrophytes with a better grip. At the study's conclusion, Madsen and Adams (1989) found that lotic macrophytes can become depressed in areas that contain purely sand sediments. In lakes, wave action works to wash away fine substrates, leaving behind rough and less fertile substrates like sand and gravel (Madsen et al. 2006). Once the fine substrates are gone, continued wave action threatens sand-growing macrophytes with abrasion or uprooting (Madsen and Adams 1989).

Although sediment preference research exists for many different locations, the relationships between environmental variables and macrophyte abundance is poorly understood in the prairie pothole region (Zimmer et al. 2003). Occupying the center of the North American continent and parts of both Canada and the United States, the prairie pothole region includes the wetlands of southeastern South Dakota and is one of the most productive freshwater regions in the world (Madsen et al. 2006; Millett et al. 2009). Here, common native vascular macrophytes were recorded in 1993 to include submergent types (*Potamogeton* spp. , *Elodea* spp., *Myriophyllum* spp., and *Ruppia maritima*), emergent types (*Typha* spp., *Scirpus* spp., *Sagittaria* spp., and *Phragmites australis*), free-floating types (*Lemna* spp., *Utricularia vulgaris*, and *Ceratophyllum demersum*), and amphibious species (*Ranunculus flabellaris, R. gmelinii*, *Polygonum amphibium*, and *Marsilea vestita*) (Larson 1993). However, there seems to be few, if any, current public records that document the exact macrophyte species of southeastern South Dakota or any population changes that have occurred over the past two decades.

To provide a better understanding of macrophytes and their potential use as indicator species in southeastern South Dakota, we sought to 1) survey the lake macrophytes of a small sample of lakes in this region, 2) evaluate the relationships between existing macrophytes and the physical characteristics of their lakes, and 3) determine if existing macrophytes have any predictable habitat preferences. Based on existing literature and field observations, we hypothesized that the lakes in southeastern South Dakota contain some of the common macrophyte species and genera listed above and that sand has the highest negative correlation with macrophyte species richness.

METHODS

Study Area—This study focused on two lakes in the southeastern portion of the state, West 81 and Island. These lakes, east of the Missouri River, exist in an area of high corn, soybean, wheat, and livestock production (Paul et al. 2017). Annual mean precipitation is around 550 mm, 76% of which falls from April to September, and mean daily temperature fluctuates from a minimum of -13°C in January to a maximum of 29°C in July (Paul et al. 2017). The two lakes are about 56.5 kilometers apart (Figure 1).

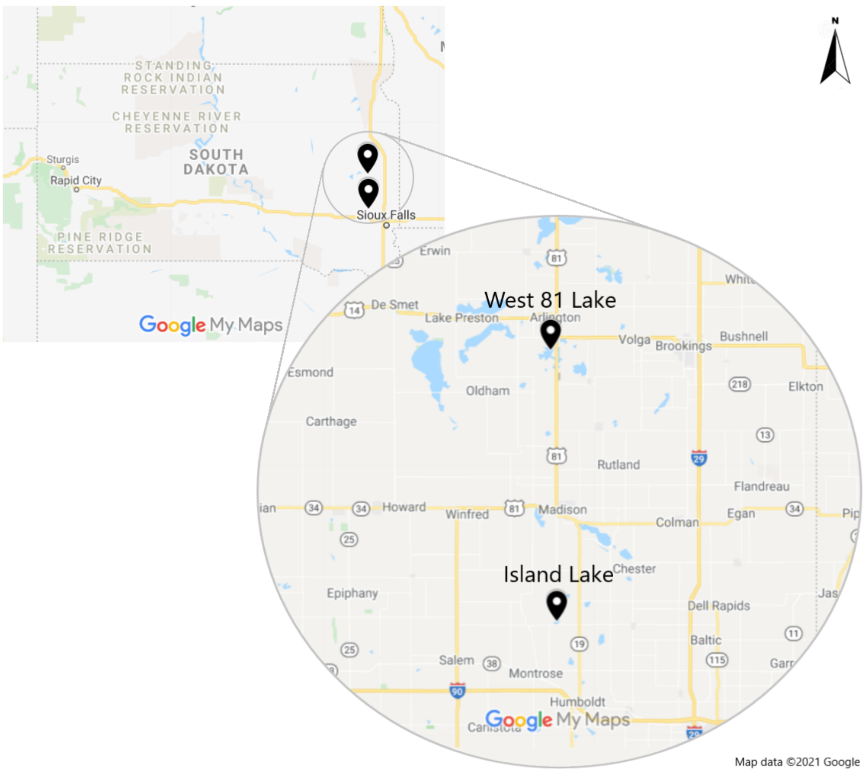

Figure 1. Geographic location of the two sampled lakes in southeastern South Dakota.

Site Descriptions—Island Lake (43.79416°N, -97.1292°W) has an area of roughly 151 ha, a maximum depth of 5.2 meters, and is located in northern Minnehaha county (Squillace et al. 2019). Only the northern portion of the lake was used for this study, bordered on the south side by 248th street and surrounded by a mosaic of agricultural land that includes pasturelands, croplands, game production area grasslands, and federal waterfowl production areas (South Dakota Game Fish and Parks Department 2021). Categorized as a true prairie pothole and a lake that is capable of changing size over time, Island Lake has complex surface and groundwater interactions and can often overflow into and mix with nearby Buffalo Lake and Creek when flooded (Squillace et al. 2019).

West 81 Lake (44.30216°N, -97.14536°W) has an area of about 500 ha, a maximum depth of 5.5 meters, and is located in Kingsbury County (Squillace et al. 2019). Belonging to an area that is comprised of flooded farmlands (Squillace et al. 2019), this lake is surrounded by farmsteads, croplands, and pasturelands; however, two waterfowl production areas border its east side (South Dakota Game Fish and Parks Department 2021). Like Island Lake, West 81 is a true prairie pothole, and during floods, it can overflow into and mix with Lake Sinai (Squillace et al. 2019). In 2015, West 81 had at least three different macrophyte species: Coontail (*Ceratophyllum demersum*), Sago Pondweed (*Stuckenia pectinata*), and Clasping Leaf Pondweed (*Potamogeton perfoliatus*) (Blackwell et al. 2015).

Data Collection—In accordance with differences in area, Island Lake had 30 random sample points and West 81 Lake had 48 random sample points (Figure 2). All random sample points were located on main shores or the shores of each lake's islands. Island Lake was surveyed on August 10th, 2020, and West 81 Lake was surveyed on August 11th and August 12th. At each site, information was gathered on macrophyte types, substrate types, and the physical characteristics of the water.

Macrophyte Survey—The presence and identity of macrophyte species or genera was determined by conducting point intercept surveys at each sampling site (Madsen et al. 2006). At each point, three samples were taken by throwing a weighted garden rake attached to a long rope. The rake was thrown at three different angles off the back of a boat and dragged in along the lake bottom, species were identified and recorded with each throw. Macrophytes that were overly time consuming or difficult to identify to a species level (i.e., filamentous algae, bulrushes, and cattails) were classified by genus and placed into one category.

Macrophyte Habitat Survey—Macrophyte habitat preferences were determined through ocular estimates of substrate percentages at each sample point on both lakes. Substrate types were classified using a simpler version of the Wentworth (1922) scale, and categories included boulders, cobble, gravel, sand, silt/muck, and clay.

Data Analysis—The diversity and commonness of macrophytes was described by species richness and species frequency for each lake. Species richness was determined by counting the different species and genera that occurred at each sample site. Species frequency was calculated using the number of sample points with the target species category present divided by the total number of points

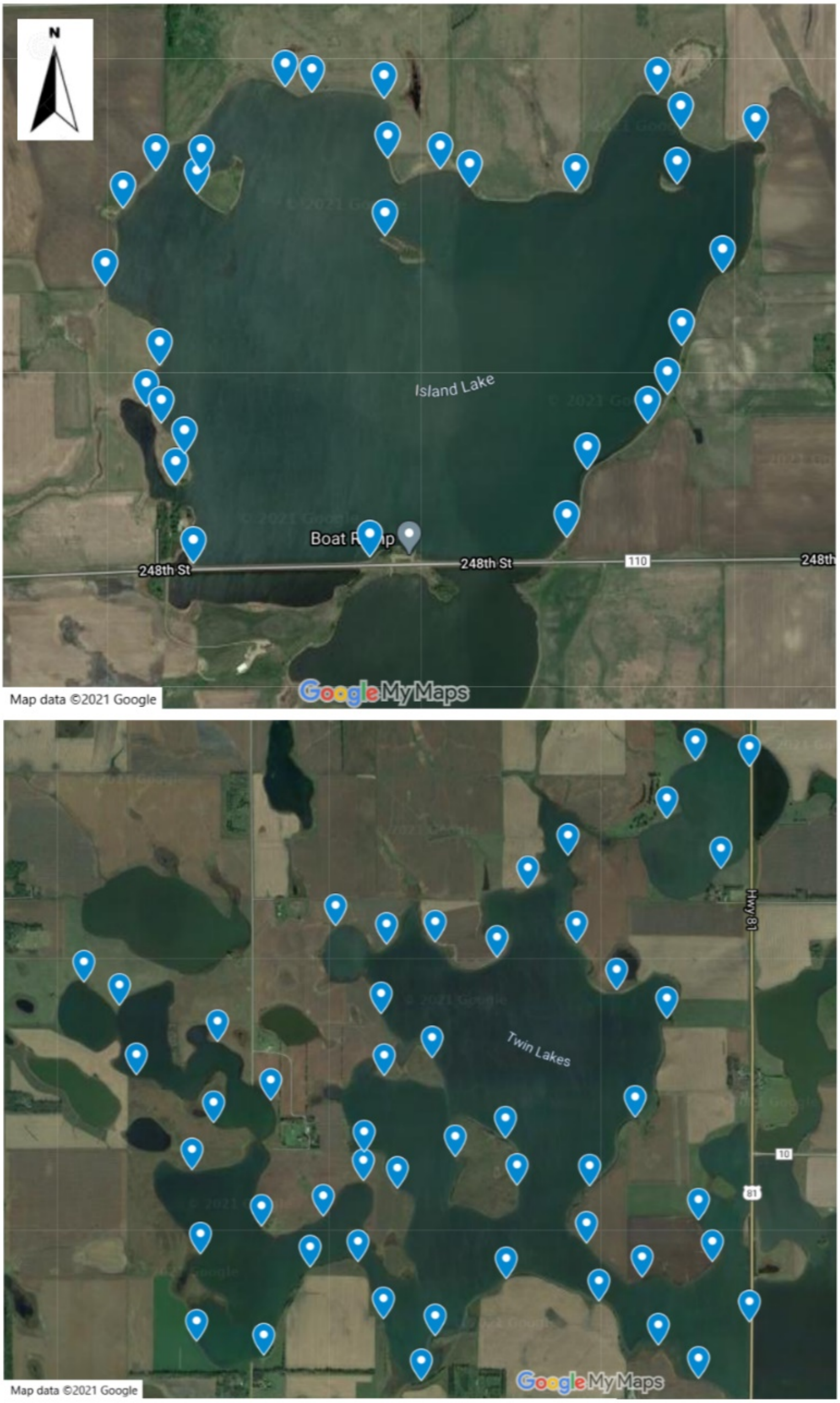

Figure 2. Sampling points on Island Lake (top) and West 81 Lake (bottom).

surveyed. Substrate frequency was calculated with the same formula to quantify variation in substrate type. A simple linear regression was used to identify potential habitat preferences and provide Pearson correlation coefficients between species richness and six other variables: percent boulder, percent cobble, percent gravel, percent sand, percent silk/muck, and percent clay. Simple linear regressions were conducted using RStudio (version 1.3.1093) and Microsoft Excel. The differences of species richness and substrate frequency between the two lakes were tested through a Chi-square analysis, and species richness between the two lakes was analyzed using ANOVA. All significant difference levels were set at $\alpha = 0.05$.

RESULTS

Macrophytes of Island and West 81 Lakes—Combining the two lakes yielded a total of 10 macrophyte categories. West 81 had the highest species richness with nine different categories of macrophytes present, including clasping leaf pondweed (*Potamogeton perfoliatus*), sago pondweed (*Stuckenia pectinata*), coontail (*Ceratophyllum demersum*), northern (shortspike) watermilfoil (*Myriophyllum sibiricum*), filamentous algae (*Cladophora* spp., *Spirogyra* spp., *Anabaena* spp., *Oscillatoria* spp., *Lyngbya* spp., and *Pithophora* spp.), duckweed (*Lemna* spp.), flatstem pondweed (*Potamogeton zosteriformis*), horned pondweed (*Zannichellia palustris*), and cattails (*Typha* spp.).

By contrast, Island Lake had a species richness of three macrophyte categories, with two of the three macrophytes also occurring in West 81 Lake. The shared genera between the lakes were cattails (*Typha* spp.) and filamentous algae (*Cladophora* spp., *Spirogyra* spp., *Anabaena* spp., *Oscillatoria* spp., *Lyngbya* spp., and *Pithophora* spp.), while bulrushes (*Bolboschoenus* spp., *Schoenoplectus* spp., and *Scirpus* spp.) were only present in Island Lake.

As shown in Figure 3, the presence frequency of clasping leaf pondweed (*Poamogeton perfoliatus*), sago pondweed (*Stuckenia pectinata*), coontail (*Ceratophyllum demersum*), filamentous algae (Filamentous algae), duckweed (*Lemna spp.*), and flatstem pondweed (*Potamogeton zosteriformis*), was significantly higher ($P < 0.05$) in West 81 Lake than in Island Lake. The presence frequency of bulrush species was significantly higher ($P < 0.05$) in Island Lake than in West 81 lake; however, there were no bulrush species found in West 81 Lake. The average species richness for each sample point in West 81 Lake was 3.2 ± 0.18 macrophyte categories, which was significantly higher ($P < 0.05$) than the 0.87 ± 0.23 (se) average species richness for each sample point in Island Lake (Figure 4).

Patterns in Habitat Preferences of Southeastern South Dakota Macrophytes—As shown in Figure 5, there were no significant differences ($P > 0.05$) in the frequencies of the boulder, cobble, sand, and clay categories between the lakes. However, the frequency of silt/muck was significantly higher ($P < 0.05$) in West 81 Lake than in Island Lake, and the frequency of gravel was significantly higher ($P < 0.05$) in Island Lake than in West 81 Lake.

In opposition to the literature reviewed above, there was a significant ($P < 0.05$) negative relationship between species richness and percent clay for Island ($r =$

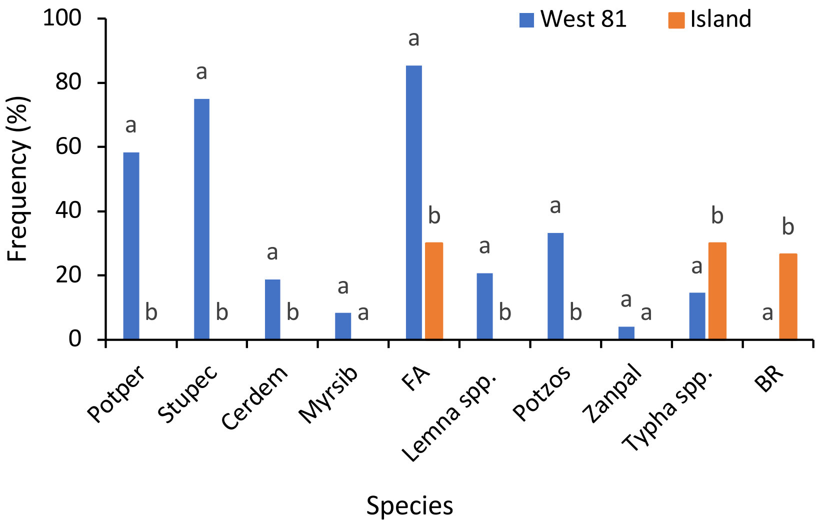

Figure 3. Presence frequencies of ten different types of macrophytes found between West 81 Lake and Island Lake. A different letter within the same macrophyte species or category indicates a significant difference (P < 0.05) between the two lakes based on Chi-sq analysis. Potper = Potamogeton perfoliatus, Stupec = Stuckenia pectinata, Cerdem = Ceratophyllum demersum, Myrsib = Myriophyllum sibiricum, FA = Filamentous algae (genera were grouped together), Lemna spp., Potzos = Potamogeton zosteriformis, Zanpal = Zannichellia palustris, Typha spp., BR = Bulrush (genera were grouped together).

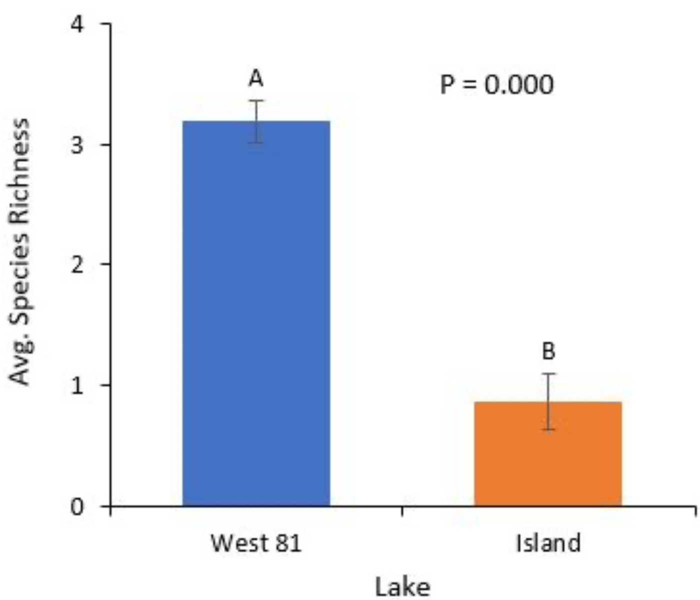

Figure 4. Average species richness for sample sites at West 81 and Island lakes. A different letter indicates a significant difference (P < 0.05) in average species richness between the two lakes. Error bars are standard error of the mean.

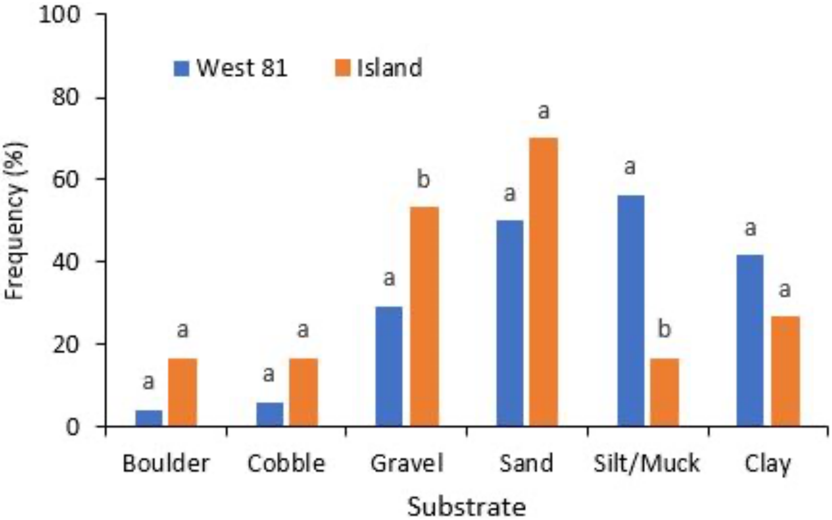

Figure 5. Frequencies of six different substrate types occurring in West 81 Lake and Island Lake. A different letter within the same substrate category indicates a significant difference in frequency (P < 0.05) between the two lakes.

-0.37, $P = 0.0424$) and West 81 lakes ($r = -0.5$, $P = 0.0002$) (Figure 6A). Surprisingly, species richness and percent silt/muck had a positive relationship in Island and West 81 lakes, with correlation coefficients of 0.21 and 0.46, respectively. However, only the correlation at West 81 Lake was found to be significant ($P < 0.05$) (Figure 6B). All other variables had no significant relationships with species richness ($P > 0.05$).

DISCUSSION

Macrophytes of Southeastern of South Dakota—Overall, a total of 78 points were sampled in two different southeastern South Dakota waterbodies to determine the types of macrophytes that grow within the lakes of this pothole region. Out of these points, 10 types of macrophytes were found, including some from Larson's (1993) expected submergent genera: clasping leaf pondweed (*Potamogeton perfoliatus*), sago pondweed (*Stuckenia pectinata*), flatstem pondweed (*Potamogeton zosteriformis*) and northern (shortspike) watermilfoil (*Myriophyllum sibiricum*), some from his expected free-floating genera: coontail (*Ceratophyllum demersum*) and duckweed (*Lemna* spp.), and some from his expected emergent genera: cattails (*Typha* spp.) and bulrushes (*Bolboschoenus, Schoenoplectus,* and *Scirpus* spp.). All three species from Blackwell et al. (2015) were re-confirmed in West 81 Lake, and other species or genera found during sampling were horned pondweed (*Zannichellia palustris*) and filamentous algae (*Cladophora* spp., *Spirogyra* spp., *Anabaena* spp., *Oscillatoria* spp., *Lyngbya* spp., and *Pithophora* spp.).

According to the results, West 81 Lake had significantly more macrophyte types at any given shore location than Island Lake, and the macrophyte composi-

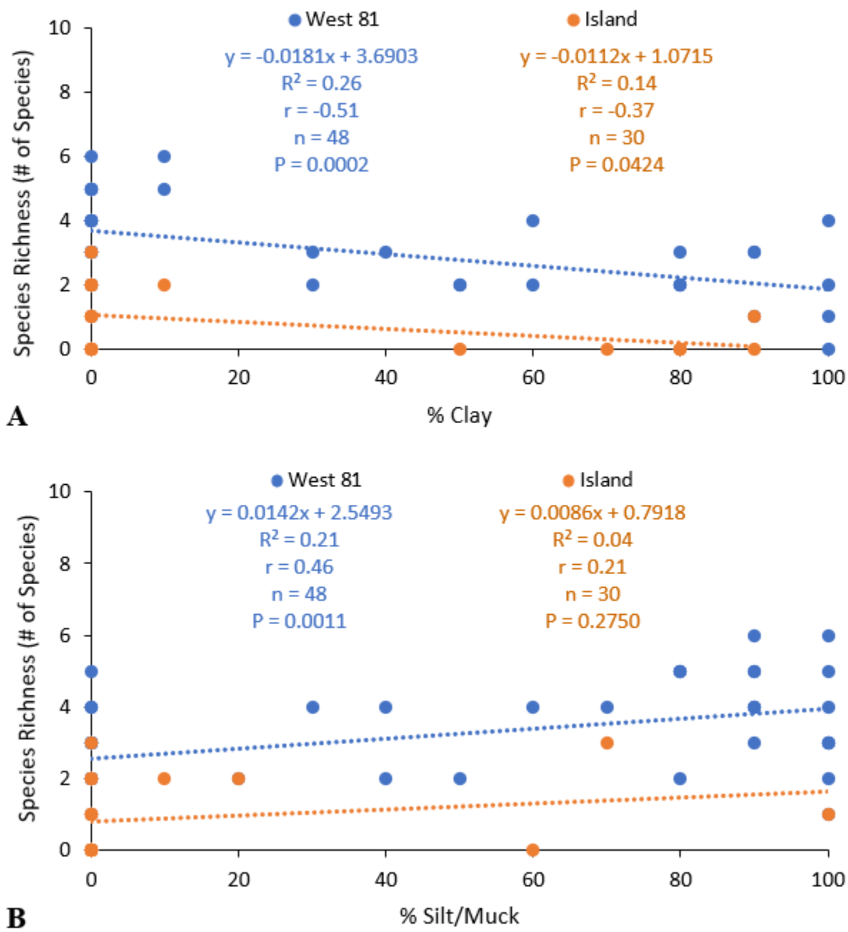

Figure 6. Correlations between percent substrate and species richness for West 81 and Island lakes. A = significant relationships ($P < 0.05$) between percent clay and species richness for both lakes. B = a significant relationship ($P < 0.05$) between percent silt/muck and species richness for West 81 Lake and a non-significant relationship ($P > 0.05$) between percent silt/muck and species richness for Island Lake.

tion of West 81 Lake comprised mostly submerged species types, as defined by Freedman and Lacoul (2006). On the other hand, the macrophyte composition of Island Lake comprised mostly emergent species types. At Island Lake, there was a significantly higher frequency presence of cattails (*Typha* spp.) and bulrushes (*Bolboschoenus* spp., *Schoenoplectus* spp., and *Scirpus* spp.) than at West 81 Lake (Figure 3).

As past research suggests, fish grazing, phytoplankton shading, highly organic sediments, and increased growth of epiphytes and filamentous algae are all possible contributors to the absence of submerged macrophyte growth forms (Weisner et al. 1997; Short et al. 2016). However, it is unlikely that filamentous algae are the major cause of difference in lake growth form in this study, as West 81

Lake had a higher species richness and a significantly higher presence frequency of filamentous algae than Island Lake. It is possible, though, that the higher presence of filamentous algae at West 81 Lake is due to the leaves of some fine-branched macrophytes acting as habitats and biotic surfaces for algae attachment and growth (Zhang et al. 2020).

Potential Habitat Preferences of Southeastern South Dakota Macrophyte—Sample sites at both lakes displayed very similar substrate conditions with respect to the frequencies of the boulder, cobble, sand, and clay categories. What stood out, however, was the significant differences between the silt/muck and gravel categories of each lake (Figure 6). The percentage of the silt/muck substrate was significantly and positively correlated with the species richness in West 81 Lake, meaning that as silt/muck substrates increased, so did the amount of macrophyte categories for that area. As Figure 5 shows, West 81 lake had a significantly higher frequency of the silt/muck category than Island Lake, and likewise, it also had the highest species richness. It is reasonable to conclude that silt/muck substrates might be a preferred habitat for southeastern South Dakota macrophytes.

As some research suggests, fertile or organic sediments (in this case, the silt/muck category) should have little to no effect on the presence or growth of macrophytes, as macrophytes can utilize both their roots and shoots for nutrient uptake (Madsen and Cedergreen 2002). Conversely, researchers have also found that high availability of nutrients in substrates can increase macrophyte presence or growth (Jiang et al. 2008). In the Lauridsen et al. (1993) study, both nutrients and macrophytes were greater in organic "mud" substrates than in non-organic sand substrates. Likely, the relative importance of macrophyte nutrient absorption from substrates is determined by the ratio of nutrients between substrates and water (Jiang et al. 2008).

In addition to promoting growth directly through nutrient content, organic matter in the substrate changes sediment density, indirectly altering plant growth (Lauridsen et al. 1993). In their study, Lauridsen et al. (1993) found that low density sediments with organic matter, categorized as "mud," promoted more growth than high density sediments without organic matter, like sand. The authors concluded that multiple sediment parameters likely contribute to increased plant growth, including an example of how their "mud," with high silt content and low density, binds phosphate and grows biomass better than sand does. For this study, it is possible that the nutrient content and density of the silt/muck substrates in both lakes support more macrophytes than other substrate types or the water column, but further, more in-depth investigations need to be conducted to support this assumption.

Substrate cohesive strength can also influence macrophyte recruitment and growth (Bornette et al. 2011). If the cohesive strength of a substrate is low, macrophyte seeds can sink down too far into the soft sediment and never germinate due to a lack of light (Bornette et al. 2011). However, if the cohesive strength of a substrate is high, like in the strong clay and peat sediments of healthy lakes (Schutten et al. 2005), it can be hard for some plants to grow roots (Bornette et al. 2011). In the lakes of this study, percent clay had a significant negative relationship with species richness, which does not agree with many studies that found increasing percent sand to be associated with decreases in macrophyte abundance and also studies that claim clay to be rich in nutrients (Madsen and Adams 1989; Madsen et al. 2006; Silveira et al. 2009). Knowing that clay substrates can cause high turbidity (Silveira et al. 2009) and that clay can also have a high cohesive strength, it is likely that the macrophytes of South Dakota do not prefer to grow in substrates with high clay content.

CONCLUSIONS

In an effort to establish a record and work towards the use of macrophytes as potential eutrophication indicators in South Dakota, this study has 1) surveyed the lake macrophytes of a small sample of lakes in this region , 2) evaluated the relationships between existing macrophytes and the physical characteristics of their lakes, and 3) determined if existing macrophytes had any predictable habitat preferences. Overall, this study has demonstrated some of the macrophyte species or genera that are likely to be found in southeastern South Dakota while also depicting the variation that can occur between the region's lakes. Ten species of macrophytes were found during sampling, and although some species were shared between lakes, a majority of the species compositions of each lake occurred in different growth forms. As the results of this study also suggest, both percent silt/muck and percent clay may play important roles in determining the types of macrophytes that occur in this region. Additionally, silt/muck dominated habitat systems appear to be the preference for a diverse array of macrophytes. However, the factors driving macrophyte variation and the differences in substrate preferences are unknown, despite speculation. It is likely that substrate texture, nutrient content, density, cohesive strength, and vulnerability to dislodgement all play a role in the distribution and abundance of macrophyte species, but more research needs to be conducted to document changes in macrophyte populations and pinpoint exact habitat preference mechanisms before these unique plants can be used as indicators for eutrophication in southeastern South Dakota.

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