MODELING WILD RICE BED HEALTH: A DUAL METRIC APPROACH FOR BED STRENGTH AND INVASIVE IMPACT

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Abstract—Wild rice (mannoomin; *Zizania palustris*) is an aquatic grain that grows in slow-moving rivers and shallow bays throughout northern Minnesota. In Headquarters Bay on Leech Lake, wild rice has served as a cultural staple for Indigenous communities for centuries. However, its population has declined in recent years due to multiple environmental issues. One potential contributor is Eurasian watermilfoil (*Myriophyllum spicatum*; EWM), an invasive species that forms dense mats capable of outcompeting native aquatic vegetation, including wild rice. EWM was first recorded on the southern shoreline of Leech Lake in 2005 and has since become widespread. This study aimed to determine whether wild rice has declined and identify the factors influencing its persistence. Vegetation surveys were conducted at 293 sites, of which 93 supported wild rice in 2005. At each site, aquatic plants were sampled using a rake, identified, and related to lake depth. Logistic regression analyses revealed that wild rice survival is significantly influenced by proximity to EWM ($P < 0.01$), historical bed strength ($P = 0.03$), and distance from the main channel ($P < 0.01$). These results provide evidence to suggest wild rice decline is not sustainable and is affected by these factors. Future management should prioritize their efforts on invasive species management and habitat preservation. Continued monitoring and collaboration with the Leech Lake DRM will be essential for protecting wild rice beds, not only as ecological assets but also to protect the Indigenous cultural heritage of the land and water.

I. INTRODUCTION

Wild rice (*mannoomin; Zizania palustris; ZIP*) is an aquatic grain that grows in slow moving rivers and shallow bays of many lakes in northern Minnesota. Wild rice holds sediment in place on shorelines and riverbanks protects those areas from erosion (Drewes 2020). For fish, rice fields provide habitat, nutrients, and organic material necessary for seasonal spawning and feeding (Freed et al. 2020). On a nutritional basis, this native plant has many health benefits in comparison to other grains. As a complete protein, wild rice replaced bread for the early indigenous people for centuries. Many tribes of the Dakota, Menominee, and Ojibwe people use manoomin in their everyday diets, and as a useful medicine. Wild rice is crucial to native culture and many native peoples' incomes. Anishinaabe believe whatever happens to the mannoomin happens to them. As a result, many tribes of the north would fight each other over control of wild rice rivers (Vennum 1988). These tribes to this day try their best to protect ricing beds from all the threats that occur in lakes and rivers.

Eurasian watermilfoil (*Myriophyllum spicatum*; EWM) is an invasive species that comes from Asia. The EWM invasion of North America is hypothesized to have originated along the U.S. Eastern Seaboard. The earliest North American herbarium collections of EWM are from Washington, D.C., in 1942 (Moody et al. 2016). EWM was first found in Leech Lake in 2005 on the south shoreline. This plant reproduces very rapidly by vegetative propagules such as stolons and fragments. Stolons, or runners, reproduce by branching off the main plant. Once a runner touches the ground, roots can develop and grow into an identical copy of the plant prior (Madsen et al. 1998). EWM can also fragment, meaning when a piece of the plant breaks off, it can begin to grow into a new plant. This invasive is especially harmful because it can out-compete many of the native plants by creating dense mats that can seal off the competing plants from sunlight, resulting in an environment that is less biodiverse. As a result of the dense mats at the end of the growing season, a high biomass decomposition leaves high concentrations of nitrogen and phosphorus in the water collum (Grace and Wetzel 1978).

Lakes in Minnesota and many other states are dealing with affected fisheries because of many invasive species. Leech Lake, located in northern Minnesota, is one of the most revered muskellunge and walleye fishing lakes in the world, even being crowned the muskellunge capital in 1955. EWM affects these fish communities by changing the macrophyte community of a waterbody, leading to a cascade of abiotic and biotic alterations that can change fish species diversity and reduce fish abundance (Kusnierz et al. 2024). EWM does this by obstructing swimming space of pelagic fishes while sheltering juvenile fishes and disrupting foraging movements of piscivores. With EWM outcompeting native plants that support a diverse array of invertebrates and macrophytes, food shortages for fish may occur due to reduced sunlight penetration and limited water movement (Engel 1995). The objective of this study is to assess the factors contributing to the decline of wild rice since 2005, using vegetation survey data collected by the Leech Lake Department of Resource Management and the Minnesota Department of Natural Resources.

II. Methods

The sample site for this project was Headquarters Bay, Leech Lake. The lake itself is primarily shallow water with a mean depth of 18 ft and 50% of the lake is less than 15 ft deep and 80% is less than 25 ft deep. It is characterized as a hard water, mesotrophic lake. Headquarters Bay where the study was conducted is more fertile than the main lake. The bay is entirely shallow, with maximum depths of less than 15 ft. This bay is relatively protected from wind and most boaters. Bottom substrates are sand and muck making it the desired environment for wild rice growth (Perleberg et al. 2010).

Surveys were conducted by boat with two to three surveyors over 293 sites. Surveyors navigated to each site using a handheld Global Positioning (GPS) unit. Surveyors attempted to navigate within 15 feet of the point and precision varied due to wind and boater experience. One side of the boat was pre-selected as the sampling side, and at each sample site surveyors recorded water depth in one-foot increments using an electronic depth finder, or a measured stick in water depths less than eight feet. At each survey site, surveyors approximated a 3 foot squared area and recorded any plant taxa visible from the boat surface. A double-headed long-handled rake with a rope attached to the end of it was lowered vertically to the bottom and dragged over a defined sampled area (Johnson et al. 2011). To survey vegetation not visible from the surface, taxa were identified recorded to the lowest level possible typically to the species level (Perleberg et al. 2010). Wild rice is a protected plant with boating being prohibited within the rice beds. Some of the points unable to be reached/surveyed due to the wild rice being abundant in those sample sites. Those points were then labeled as either “wild rice only present and was not surveyed” or “other emergent plants present.”

Data Analysis

To assess the relationship between the presence of wild rice and EWM and depth, a logistic regression was performed. For this analysis wild rice and EWM were either 1 (presence) or 0 (absence), and depth was a continuous predictor. All data points from both years were used in this analysis.

To evaluate how the strength of rice beds affected wild rice survival, data was collected from the 93 locations that had wild rice present in 2005. Wild rice bed strength was measured at each site in 2005 and assigned a value from 0 to 7, representing the number of neighboring sites with wild rice present in 2005. In 2024, wild rice presence or absence was recorded at each site to assess changes over time. A logistic regression model was applied to examine the effect of bed strength on the probability of wild rice survival.

To examine the relationship between wild rice survival and EWM proximity, data was collected from the 93 locations that had wild rice present in 2005. EWM proximity was calculated by measuring the distance to nearest EWM in 2024 using a GIS map of the points. Wild rice presence or absence was recorded at each site in 2024. A logistic regression model was applied to examine the effect of EWM proximity on the probability of wild rice survival.

To determine if there was a relationship between wild rice survival and proximity to the main channel, data was again used from the 93 locations where wild rice was present in 2005. Proximity to the channel was calculated by measuring the distance to the nearest point in the channel using a GIS map. In 2024, each site was assessed for wild rice presence or absence. A logistic regression model was applied to examine the effect of the main channel on the probability of wild rice survival.

III. Results

Presence or absence of Wild rice and Eurasian watermilfoil was determined at 293 sites in both 2005 and 2024. There was a significant negative relationship between depth and wild rice presence with ($P < 0.01$; Figure 1) indicating wild rice is more likely to occur in shallower waters.

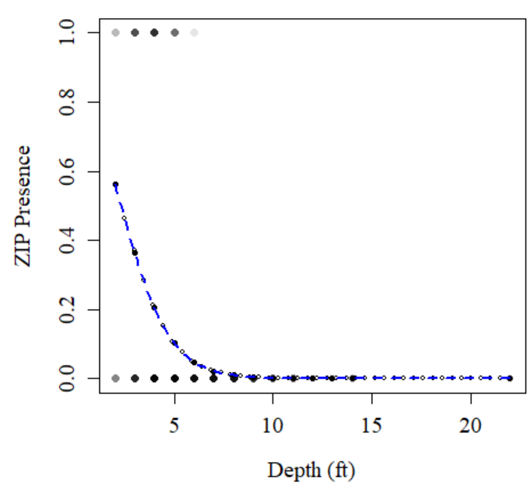

Fig. 1. Probability of wild rice (*mannoomin; Zizania palustris; ZIP)* presence in relation to depth in Headquarters Bay, Leech Lake, MN. Presence absence data was recorded at 293 sites sampled in both 2005 and 2024.

While the fitted model suggests a negative trend. That decreasing probability of EWM presence with depth, the effect is not statistically significant (*P* = 0.61; Figure 2). The large p-value suggests that depth alone does not explain much of the variation in EWM presence.

There was a significant negative relationship between bed strength and wild rice survival with a (*P* = 0.03; Figure 3). Wild rice was more likely to persist in areas with lower bed strength and where fewer neighboring wild rice were present, suggesting that both clustering and possible disease can influence survival.

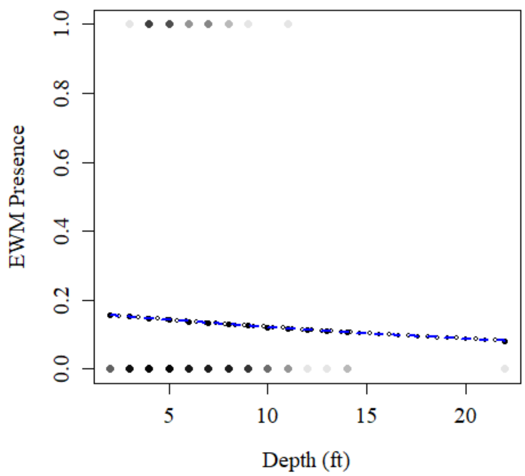

Fig. 2. Probability of Eurasian watermilfoil (*Myriophyllum spicatum*; EWM) presence in relation to depth in Headquarters Bay, Leech Lake, MN. Presence–absence data were recorded at 293 sites sampled in both 2005 and 2024.

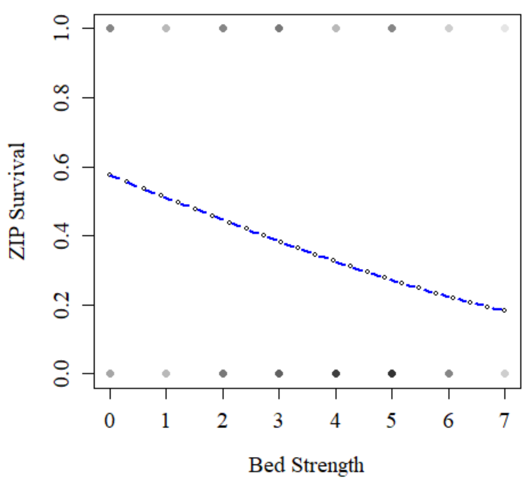

Fig. 3. Probability of wild rice (manoomin; *Zizania palustris*; ZIP) survival in relation to bed strength in Headquarters Bay, Leech Lake, MN. Presence–absence data indicating wild rice survival in 2024 were recorded at 93 sites where wild rice was present in 2005.

There was a significant positive relationship between distance from EWM and wild rice survival (*P* < 0.01; Figure 4). The fitted curve indicates that wild rice is more likely to persist in areas farther from EWM patches, suggesting that proximity to EWM may negatively influence wild rice through competition, habitat alteration, or other ecological factors.

There was a statistically significant positive relationship between distance from the main channel and wild rice survival (*P* < 0.01; Figure 5). The fitted regression curve indicates that wild rice is more likely to persist farther from the main channel, possibly due to reduced boat traffic and less flow disturbance.

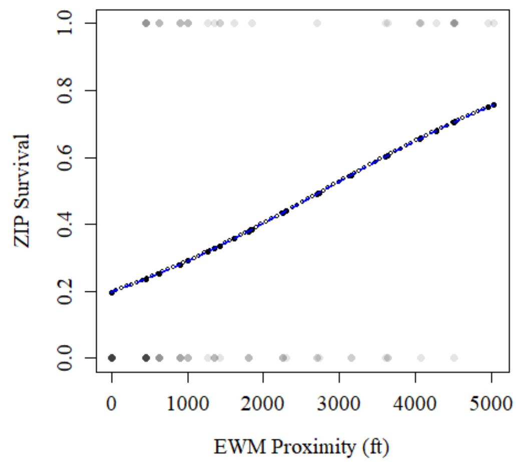

Fig. 4. Probability of wild rice (manoomin; *Zizania palustris*; ZIP) survival in relation to EWM proximity in Headquarters Bay, Leech Lake, MN. Presence–absence data indicating wild rice survival in 2024 were recorded at 93 sites where wild rice was present in 2005.

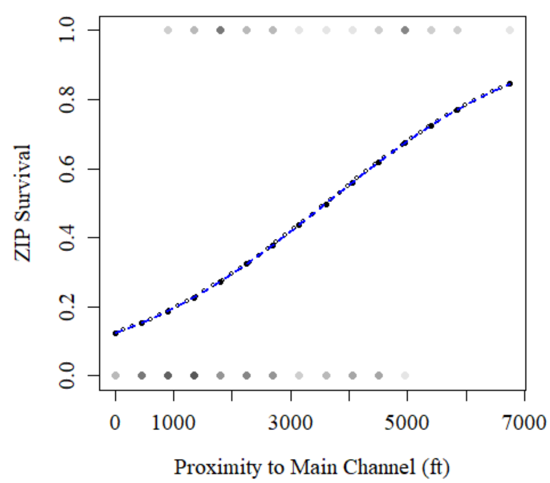

Fig 5. Probability of wild rice (manoomin; *Zizania palustris*; ZIP) survival in relation to proximity to main channel in Headquarters Bay, Leech Lake, MN. Presence–absence data indicating wild rice survival in 2024 were recorded at 93 sites where wild rice was present in 2005.

IV. Discussion

The primary finding of this study is that wild rice has declined significantly since 2005, with 46 sites lost and only 5 new sites established. While 34 sites remained stable, this trend points to an unsustainable rate of loss. This decline appears to be associated with multiple environmental factors, including proximity to the main channel (where boat traffic is highest), proximity to existing EWM populations, and the strength/size of existing wild rice beds. These factors appear to influence whether wild rice sites persist, decline, or are displaced by other species. Sites surrounded by other wild rice locations in 2005 were more likely to be lost by 2024, suggesting that disease might have taken place in this large portion of the wild rice beds. For example, when paddies are flooded in the spring, infested crop debris floats to the surface and conidia of *B. oryzae* and *B. sorokiniana* infect leaves and stems of wild rice as they emerge from the water (Johnson et al. 1992).

Proximity to EWM sites was significantly associated with wild rice decline. Between 2005 and 2024, thirteen wild rice sites were replaced by EWM, suggesting possible competitive displacement. This finding supports the hypothesis that EWM can outcompete wild rice for space, light, and nutrients, altering the native plant communities of Leech Lake over time. These results are consistent with previous research showing that dense EWM growth can significantly reduce the abundance and diversity of native aquatic vegetation (Getsinger et al. 1997).

Proximity to the main channel was significantly associated with wild rice persistence. Sites located closer to the main channel where boat traffic and wave energy are typically higher were less likely to support surviving wild rice populations. This finding points to the negative effects of disturbance on wild rice sustainability. In Jefferson County, Wisconsin macrophyte abundance has declined in areas with high motorboat activity. The decline in macrophytes appears to result mainly from sediment disruption and direct mechanical damage (Asplund et al. 1997).

This study also examined whether wild rice and EWM occupy similar depth ranges, which could indicate competition for habitat. Wild rice is more likely to occur in shallower depths, with occurrence decreasing as depth increases. These results were significant and consistent with other studies showing wild rice requires the presence of shallow, relatively clear water, where water depth is 0.33 to 3.28 ft (Biesboer et al. 2009).

EWM had an equal distribution among different depths and was insignificant. More than likely other factors influenced distribution in depth. In a study conducted on lake Wingra, WI. distribution of Eurasian watermilfoil (*Myriophyllum spicatum L.*) was researched. The linear regression model for predicting milfoil biomass was weak, but optimal ranges of water depth were able to be identified (Nichols 1994).

This study provides clear evidence that wild rice in Headquarters Bay has experienced significant declines since 2005, driven by the factors above. These findings suggest the need for management to prioritize both invasive species control and habitat preservation. Continued monitoring and collaboration with the Leech Lake DRM will be essential for protecting wild rice beds, not only as ecological assets but also to protect the Indigenous cultural heritage of the land and water.

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APPENDIX A. ADDITIONAL FIGURES

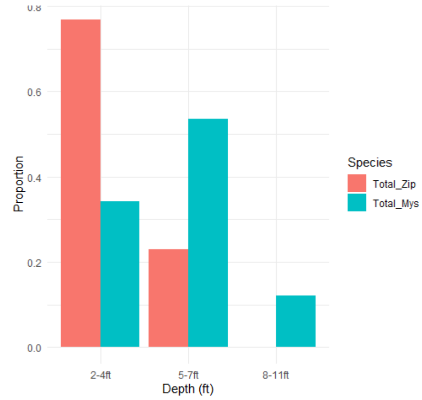

Fig A1. Depth distribution of wild rice (manoomin; *Zizania palustris*; ZIP) and Eurasian Watermilfoil (*Myriophyllum spicatum*; EWM) in Leech Lake MN.