Cultural and ecological characterization at Net River Impoundment and Vermillac Lake

Manoomin and its associated habitat at the Net River Impoundment and Vermillac Lake were characterized over two time periods. This characterization begins after the Net River was impounded as a wetland mitigation bank in 1990.

1990 to 2013: Before Manoomin seeding

Based on the combined ranking of cultural and ecological metrics, conditions at the Net River Impoundment and Vermillac Lake were characterized as “not very good” during this period. This ranking reflects the absence of Manoomin from the Net River Impoundment and Vermillac Lake before 2013. Although Manoomin was absent, these areas were culturally and ecological important. Community members used these sites for gathering, fishing, and hunting activities; during these activities, families passed down knowledge to their children or grandchildren about traditional practices and resources. Given the intrinsic cultural and ecological value of these places, some metrics – including spirit relationships, food sovereignty, knowledge generation and sharing, and water level and quality – ranked higher in cultural and ecological characterization.

2014 to 2019: After Manoomin seeding

Once KBIC began seeding the Net River Impoundment and Vermillac Lake, Manoomin grew at these places. Currently, Manoomin supports wildlife and other ecosystem functions. These places have the potential for Manoomin harvesting in the future, although they cannot yet support it. The presence of Manoomin significantly improved the ranking of most of the cultural and ecological metrics. During this period, conditions at the Net River Impoundment and Vermillac Lake ranked as “pretty good” based on cultural and ecological metrics. Although Manoomin provides many cultural and ecological functionality, additional management of water levels at the Net River Impoundment could continue to improve the abundance of Manoomin and the long-term sustainability of healthy Manoomin beds.

Cultural and ecological functionality provided by Manoomin and its associated habitat at the Net River Impoundment and Vermillac Lake have increased over time, both in aggregate and for the individual metrics (Exhibit 5.11).

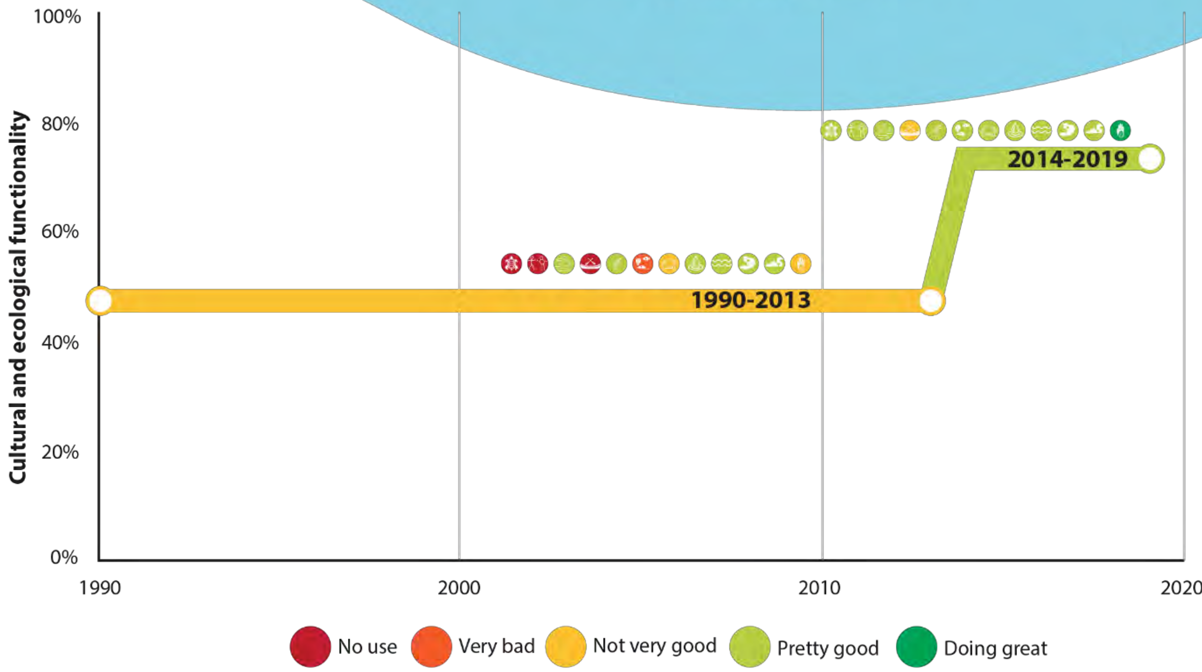

Exhibit 5.11. Characterization of cultural and ecological functionality provided by Manoomin and its associated habitat at Net River Impoundment and Vermillac Lake

Additional restoration needed

Based on the characterization of the degree of cultural and ecological function over the four time periods, the HEA calculations demonstrate the additional equivalent units of restoration needed to counter-balance the severity and timespan of degradation. With seeding, resource managers successfully established Manoomin across the Net River Impoundment and Vermillac Lake. However, given that the period of degradation is much larger (over 20 years) than the period of restoration (around 5 years), an additional 1,129 acres of similar Manoomin restoration is needed to counter-balance the lost habitat functionality that has occurred over time. In other words, nearly 12 equivalent restoration efforts at the Net River Impoundment and Vermillac Lake (from 2014 to 2019) are needed to counter-balance the lost cultural and ecological habitat functionality (from 1990 to 2013).

Case study acknowledgments

The Project Team would like to acknowledge Evelyn Ravindran, Karena Schmidt, and Erin Johnston (KBIC) for their valuable input and feedback in the development of this case study; and for participating in the cultural and ecological characterization of KBIC's Net River Impoundment and Vermillac Lake.

Hiles Millpond

Hiles Millpond is an approximately 300-acre lake located in Forest County, Wisconsin, an 1842 Ceded Territory (Exhibit 5.12).

The millpond provides excellent wildlife habitat, especially for waterfowl, furbearers, eagles, and other wetland-dependent species. The lake also supports a northern pike and panfish fishery.

Threats to Manoomin at Hiles Millpond

Water ponded at Hiles Millpond in the late 1880s, when the Hiles Lumber Company built a dam for logging purposes. Although there is no record of the presence of Manoomin at Hiles Millpond, it may have been there at some point prior to dam construction, since Manoomin is in nearby waters. If Manoomin was present at Hiles Millpond historically, it could have been negatively affected by changes in water levels associated with construction of the dam.

Exhibit 5.12. Map of Hiles Millpond

The area and waters around the Town of Hiles were traditionally used by the Lac du Flambeau Band of Lake Superior Chippewa Indians (LDF Band), the Sokaogon Chippewa Community, and other Ojibwe Bands and their ancestors. However, use of the area by Bands for hunting, gathering, fishing, and trapping was limited during much of the last century up until the 1980s. Use of this area increased after this time when relations with the local community in the Town of Hiles improved.

Actions taken to improve the abundance of Manoomin at Hiles Millpond

In 1992, safety inspections found several problems with the dam structure at Hiles Millpond. To meet contemporary safety standards, the Town of Hiles needed to replace the dam structure. Since the town lacked adequate funds, federal, state, tribal, and nongovernmental organizations entered into a cooperative effort. A Memorandum of Understanding included a provision for the town to cooperate with the Forest Service to manage the millpond for productive wildlife and fish habitats, including possible manipulation of water levels, following completion of the project. The dam and water control structure were rebuilt in fall 1993.

Shortly after, biologists realized that the ecological benefits of Hiles Millpond could be significantly enhanced by establishing Manoomin on the millpond. Establishing Manoomin could also help to make up for the loss of Manoomin on other waters in the region, many of which were difficult or impossible to recover due to excessive development, conflicting uses, or other threats to Manoomin (Peter David, GLIFWC, personal communication, November 27, 2019).

In 1998, GLIFWC and the Forest Service cooperatively seeded the Hiles Millpond flowage with a relatively modest amount of Manoomin (329 pounds). Small patches of Manoomin then expanded modestly over the next several years. In 2011, Manoomin expanded significantly under natural drought conditions, which led biologists to believe that Manoomin might increase if the typical summer water level was lowered slightly.-

Although the Town of Hiles was initially concerned that lower water levels might negatively affect the northern pike fishery, it ultimately agreed to manage the water level for Manoomin. Once lowered, Manoomin showed an immediate response. Manoomin abundance increased significantly from 2013, before water levels were lowered, to 2014, following a lowering of water levels (Exhibit 5.13). In recent years, over 125 acres of Manoomin can be found across much of the lake and surrounding wetlands (Peter David, GLIFWC, personal communication, November 27, 2019).

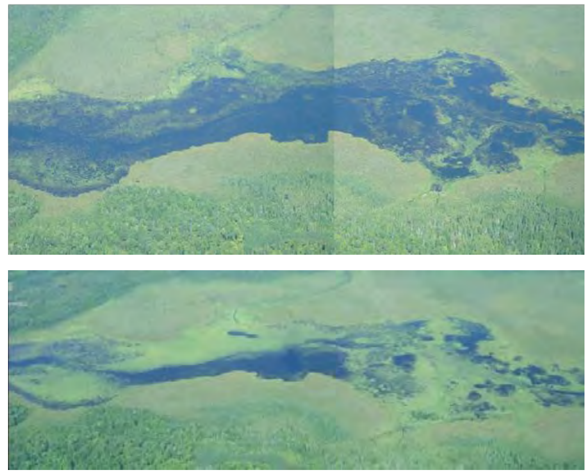

Exhibit 5.13. Manoomin abundance on a portion of the Hiles Millpond in 2013 (above), and in 2014 (below) following a lowering of water levels

Credit: Peter David, GLIFWC.

Cultural and ecological characterization at Hiles Millpond

Manoomin and its associated habitat at Hiles Millpond were characterized over three time periods. The characterization starts in 1980 because prior to that time community members were less likely to travel to Hiles Millpond to harvest Manoomin, and undertake other traditional hunting and gathering practices.

1980 to 1997: Before Manoomin seeding

Based on the combined ranking of cultural and ecological metrics, Hiles Millpond was characterized as “very bad” during this period. Because of the absence of Manoomin in the millpond, most of the metrics – particularly cultural metrics – ranked low on the score range.

1998 to 2013: After Manoomin seeding

Once seeding activities began in 1998, Manoomin began to grow at the millpond. The presence of Manoomin improved the rankings for most cultural and ecological metrics. In particular, the presence of Manoomin at Hiles Millpond allowed for some harvesting, preparation, and sharing of Manoomin by the community. It also improved the Anishinaabe’s connections and balance with spirit beings and relatives, and it supported diverse biological communities. During this period, Hiles Millpond ranked as “not very good” based on the combined ranking of cultural and ecological metrics.

2014 to 2019: With water level management

After resource managers adjusted water levels for Manoomin in 2014, its coverage continued to expand. More Manoomin allowed for harvesting, preparation, and sharing of Manoomin in ways practiced by ancestors. It also allowed for knowledge generation and sharing of Anishinaabe practices, values, beliefs, and language. Although Manoomin provides many cultural and ecological functionality, additional management of water levels could continue to improve Manoomin and its associated habitat at Hiles Millpond. During this period, Hiles Millpond ranked as “pretty good” based on the combined ranking of cultural and ecological metrics.

Cultural and ecological functionality provided by Manoomin and its associated habitat at Hiles Millpond have increased over time, both in aggregate and for individual metrics (Exhibit 5.14).

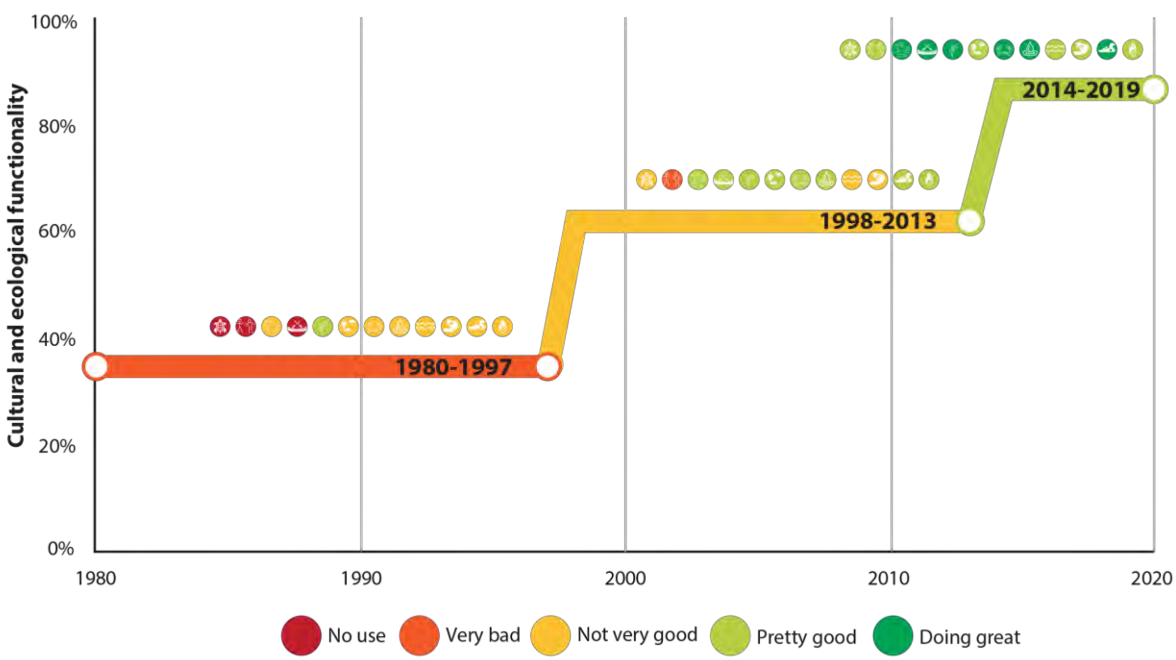

Exhibit 5.14. Characterization of cultural and ecological functionality provided by Manoomin and its associated habitat at Hiles Millpond

Additional restoration needed

Based on the characterization of the degree of cultural and ecological function over the four time periods, the HEA calculations demonstrate the additional equivalent units of restoration needed to counter-balance the severity and timespan of degradation. With modest seeding and slight modifications in water-level management, resource managers successfully established Manoomin across the Hiles Millpond. The analysis indicates that an additional 864 acres of similar Manoomin restoration is needed to counter-balance the lost habitat functionality that has occurred over time. In other words, nearly three equivalent restoration efforts at Hiles Millpond (from 1998 to 2019) are needed to counter-balance the lost cultural and ecological habitat functionality (from 1980 to 1997).

Case study acknowledgments

The Project Team would like to acknowledge Peter David (GLIFWC), Eric Chapman and Joe Graveen (LDF Band), and Peter McGeshick (Sokaogon Chippewa Community) for their valuable input and feedback in the development of this case study, and for participating in the cultural and ecological characterization of the Hiles Millpond. In addition, we would like to acknowledge that Peter David provided background information used in this case study.

Big Rice Lake

Big Rice Lake, located in St. Louis County in northeastern Minnesota, is approximately 1,870 acres (Exhibit 5.15). The area was traditionally used for ricing, sugar bush and hunting activities; and archeological evidence indicates human use on sites surrounding the lake for hundreds – perhaps thousands – of years.

The lake is an important feeding and resting area for migrating waterfowl. In years of good Manoomin production, mallards, goldeneyes, wood ducks, blue winged teal, and ring-necked ducks use the lake. In 1992, Big Rice Lake became a Designated Wildlife Lake because of its "outstanding value to wildlife." Currently, the lake supports a bald eagle nesting territory, as well as muskrats, minks, beaver, otter, great blue herons, and trumpeter swans.

Exhibit 5.15. Map of Big Rice Lake

Threats to Manoomin at Big Rice Lake

Hydrologic changes, impacts from competing vegetation, and perhaps climate change have threatened Manoomin at Big Rice Lake. Manoomin is very sensitive to changes in water levels. At Big Rice Lake, artificial (human-controlled) changes in water levels have caused problems for Manoomin. Flooding and deep water prevent seed germination, whereas low or stable water conditions encourage the proliferation of other vegetation, such as ginoozhegoons, which can outcompete Manoomin for space and resources. In addition to the artificial controls on water levels, climate change could change precipitation patterns, which may increase both the likelihood of drought and the frequency of heavy rain events that can cause flooding in Big Rice Lake.

Actions taken to improve Manoomin at Big Rice Lake

Natural resource managers have taken several actions with the goal of increasing Manoomin at Big Rice Lake. In 1995, federal and state agencies built a rock weir at the outlet of the lake to increase the water flow out of the lake and reduce rapid water-level changes that can negatively impact Manoomin growth

(MN DNR, 2013). Since its installation in 1995, the weir's height has been adjusted several times. Natural resource managers lowered the weir in 2005 and reestablished it in 2007 to create unfavorable conditions for ginoozhegoons and other vegetation that competes with Manoomin. Initially, the installation of the rock weir seemed to improve Manoomin coverage at Big Rice Lake; however, despite adjustments to the weir, the more stable water level appears to have favored ginoozhegoons over Manoomin (Exhibit 5.16).

Since 2006, a cooperative effort of several federal, state, and tribal partners have taken additional management activities to further support Manoomin (Vogt, 2020a). The Fond du Lac Band of Lake Superior Chippewa provided equipment and staff to cut ginoozhegoons. The Band used an airboat with chains to disturb the substrate of Big Rice Lake to encourage the germination of Manoomin seed in several test plots (Vogt, 2020a). These efforts control about 100 acres of ginoozhegoons each year, but Manoomin regrowth in cut areas has been minimal (Vogt, 2020a). Over the years, partners have also trapped beavers and removed beaver dams to control water levels.

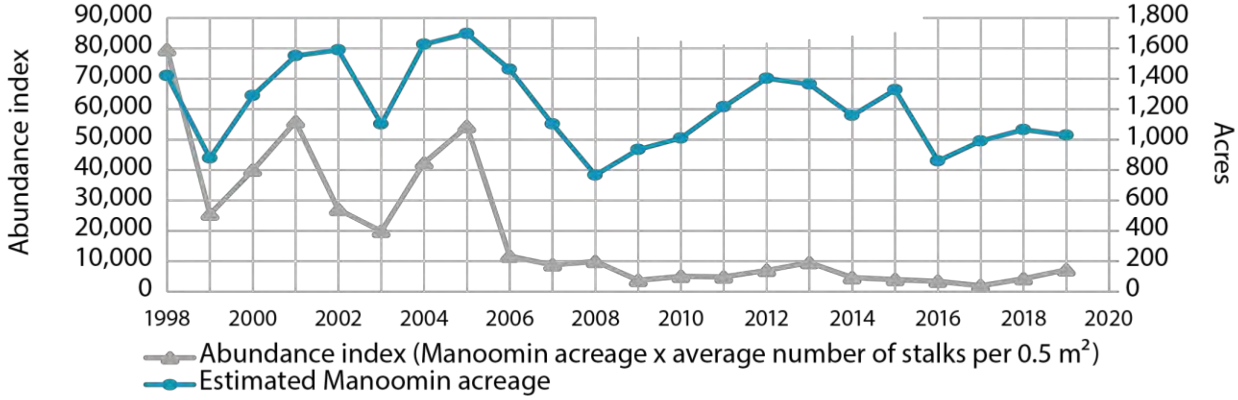

Exhibit 5.16. Manoomin abundance index and acres on Big Rice Lake

Source: Vogt, 2020a.

Cultural and ecological characterization at Big Rice Lake

Big Rice Lake's Manoomin and its associated habitat were characterized over three time periods.

1900 to 1994: Before rock weir construction

Based on the combined ranking of the cultural and ecological metrics, Big Rice Lake was characterized as "pretty good." During this period, Big Rice Lake was dominated by Manoomin with variable production across years, which provided high-quality waterfowl and wildlife habitats, and the opportunity for harvesting. The lake was culturally and historically important to Ojibwe Bands who used the lake during this period and exercised their treaty rights.

1995 to 2005: After rock weir construction

Immediately after the installation of the rock weir in 1995, Manoomin coverage at Big Rice Lake seemed to improve in some years. However, over time the more stable water level favored ginoozhegoons over Manoomin, and Manoomin began to decline, although it remained at the "pretty good" ranking score based on the combined ranking of cultural and ecological metrics.

2006 to 2019: With active management of Manoomin

By 2006, Big Rice Lake ranked as "very bad" based on the combined ranking of cultural and ecological metrics. Hydrologic changes, competition from ginoozhegoons, and perhaps other unknown factors led to the dramatic decline of Manoomin. From 2006 to 2019, natural resource managers took active management steps to recover Manoomin at Big Rice Lake; however, it remained sparse in coverage, with only a few small, moderate-to-good density stands found on the lake. As a result, community members were unable to harvest, prepare, and share Manoomin in ways practiced by their ancestors. This also limited sharing, transmittal, and generation of Anishinaabe practices. The decline in Manoomin has also negatively affected migratory waterfowl that use the lake.

Cultural and ecological functionality provided by Manoomin and its associated habitat at Big Rice Lake decreased over time, both in total and for individual metrics (Exhibit 5.17).

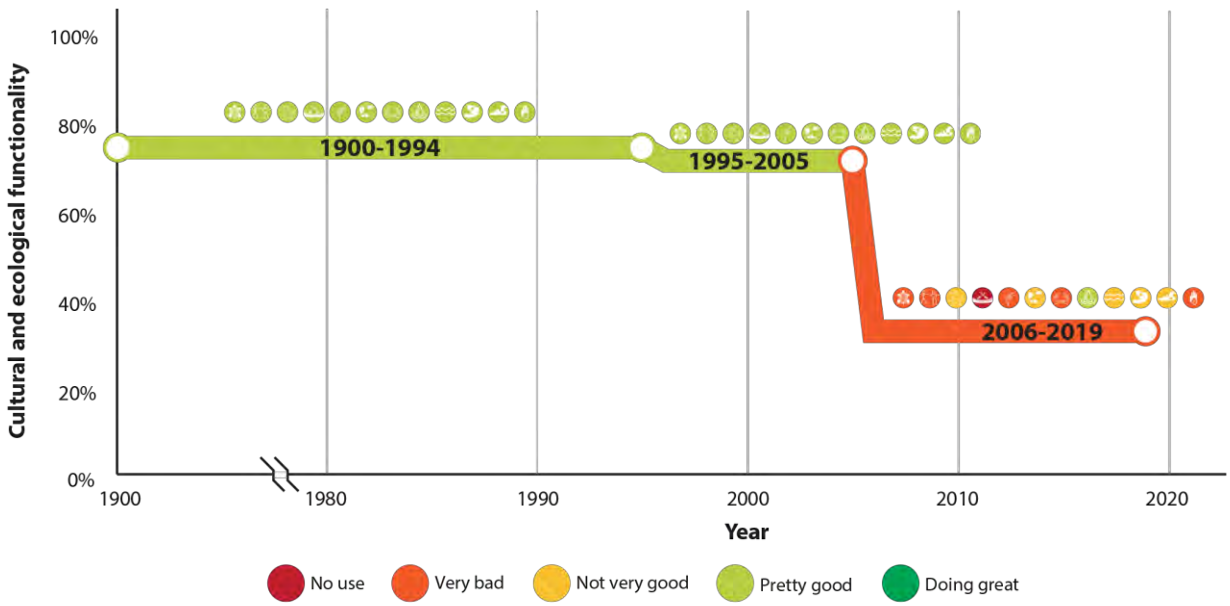

Exhibit 5.17. Characterization of cultural and ecological functionality provided by Manoomin and its associated habitat at Big Rice Lake

Additional restoration needed

Since the 1990s, natural resource managers have tried to improve the conditions of Manoomin and its associated habitat at Big Rice Lake; however, recent actions have not been successful and conditions continue to be diminished.

Restoration funds have recently been awarded to undertake further actions at the lake (Helmberger, 2019). If these actions were to improve functionality, we could use an HEA to demonstrate the additional equivalent units of restoration that would be needed to counter-balance the severity and timespan of degradation. For example, if actions were implemented over the next 20 years (2020 to 2040) to improve habitat functionality by 2.5%, we would need over 400,000 acres of similar Manoomin restoration to counter-balance the lost habitat functionality that has occurred over time (from 1995 to 2019). This is equivalent in size to over 200 Big Rice Lakes. The table below provides the HEA results, assuming several hypothetical scenarios of improvements in habitat functionality (Exhibit 5.18); it is important to note that we do not know what actions are needed to create these percent improvements or if they are achievable. The main purpose of these scenarios is to highlight that if only minimal restoration is achieved at Big Rice Lake (which may be anticipated, given the long history of attempting restoration, with minimal response), then significant equivalent amounts of this restoration would be needed to balance the prolonged period of degradation at this lake.

Exhibit 5.18. HEA results, assuming several hypothetical scenarios of improvements in habitat functionality

Hypothetical percentage of improvement in habitat functionality	Acres needed to counter-balance historical losses given hypothetical improvement[a]	Number of Big Rice Lake needed to counter-balance historical losses given hypothetical improvement
2.5%	411,900	220
5.0%	205,900	110
10.0%	103,000	55
20.0%	51,500	28

a. Acres rounded to the nearest hundred.

This case study demonstrates how difficult it is to restore degraded Manoomin and its associated habitat, and how important it is to protect existing Manoomin habitat, as actions taken at Big Rice Lake have not improved its ability to support the various functions of Manoomin. A future characterization of Big Rice Lake could consider the effects of new restoration funding aimed at returning the natural functionality of the lake (Helmberger, 2019). This would refine and improve the current estimate of additional amount of restoration needed. Future restoration actions will include increased efforts to remove ginoozhegoons and return the outlet of the lake to natural rock rapids by removing the rock weir and accumulated sediment (Helmberger, 2019).

Case study acknowledgments

The Project Team would like to acknowledge Darren Vogt (1854 Treaty Authority) and Nancy Schuldt (Fond du Lac Band of Lake Superior Chippewa) for their valuable input and feedback in the development of this case study. In addition, the Project Team would like to thank Thomas Howes (Fond du Lac Band of Lake Superior Chippewa), Tara Geshick (Bois Forte Band of Lake Superior Chippewa), Daniel Ryan (U.S. Forest Service), and Melissa Thompson and Tom Rusch (Minnesota Department of Natural Resources) for participating in the cultural and ecological characterization of Big Rice Lake.

Twin Lakes

The Twin Lakes are located in St. Louis County in northeastern Minnesota. Sandy Lake is approximately 120 acres and Little Sandy Lake is approximately 90 acres (Exhibit 5.19). The Twin Lakes are located immediately downstream of the tailings basin for U.S. Steel's Minntac iron ore operation. Prior to mining operations, the Twin Lakes produced good stands of Manoomin and were important ricing sites for Ojibwe Bands and vital habitat for a range of wildlife species.

Exhibit 5.19. Map of Twin Lakes

Threats to Manoomin at the Twin Lakes

U.S. Steel's Minntac iron ore operation facility includes two mining areas, several processing plants, a heating and utility plant, a water reservoir, and a tailings basin (MWH, 2004). Construction of the tailings basin began in 1966 (MWH, 2004). Part of the seepage from the tailings basin discharges to the east into the Sand River, flows into the Twin Lakes, and into the Sand River watershed. Discharge from the tailings basin has changed the chemical composition and hydrologic condition of the Twin Lakes by increasing sulfate levels and, to a lesser extent, increasing the volume of water in the lakes.

Ongoing sulfate loading renders restoration ineffective at the Twin Lakes

The Twin Lakes are severely degraded by sulfate-laden mine waste from U.S. Steel's tailings basin. Because sulfate concentrations are high, any attempts to restore Manoomin stands that do not address this fundamental issue have proven largely ineffective. For example, multiple attempts by natural resource managers to adjust water levels through beaver management (in the 1970s to 1990s and 2015 to 2018) have not improved Manoomin stands in a measurable way. Modest reseeding efforts (in 1991 and 1992) have also not been effective. Restoration efforts are not successful because sulfate levels at the Twin Lakes are at least 10 times higher than the Manoomin sulfate standard; the current sulfate standard is 10 mg/L (Exhibit 5.20; Tribal Wild Rice Task Force, 2018).

In 2010, U.S. Steel was required to construct a seepage collection system to collect some of the mine wastewater discharging at the base of the tailings basin. While this reduced the total volume of water discharging from the mine site, it did not fully stop it. As a result, mine waste high in sulfate continued to contaminate the Twin Lakes after the collection system was installed. The 1854 Treaty Authority monitored lake conditions before the installation of the seepage collection system (2010) and after (2011 to 2019). Data collected included information on water quality (sulfate and other water quality indicators) and water-depth recordings; as well as data from inlet and outlet field surveys, vegetation surveys, and aerial surveys (Vogt, 2020b). Results showed that sulfate levels remained elevated well above the standard over the nine years of monitoring after the installation of the seepage system, and remained substantially unchanged from conditions prior to the installation (Exhibit 5.20).

During the monitoring study, very limited Manoomin stalks were also observed across the Twin Lakes over the same time period. In 2015, U.S. Steel planted test plots to determine if Manoomin had the potential to grow in the Twin Lakes. In this small-scale test plot, U.S. Steel reseeded with 40 pounds of Manoomin. After seeding, Manoomin success has varied but has been limited across years (Vogt, 2020b). Full-scale reseeding was not attempted.

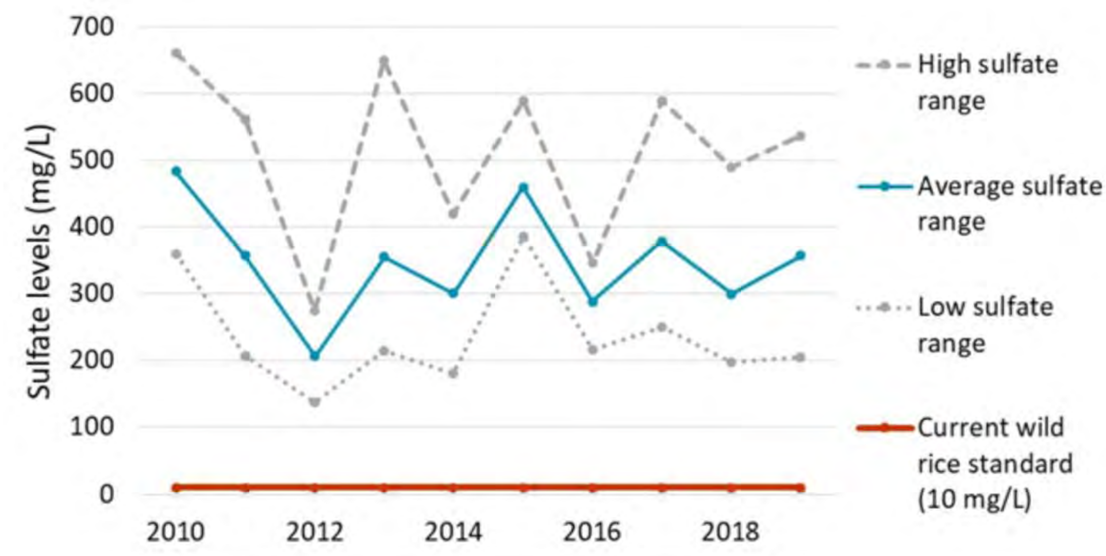

Exhibit 5.20. Sulfate concentrations at the inlet to the Twin Lakes compared to current standard sulfate levels (10 mg/L) for Manoomin, 2010 to 2019

Source: Vogt, 2020b.

Cultural and ecological characterization at the Twin Lakes

The Twin Lakes' Manoomin and its associated habitat were characterized over four time periods.

1950 to 1965: Before construction of the tailings basin

Based on the combined ranking of cultural and ecological metrics, conditions at the Twin Lakes were characterized as "pretty good" during this period. Prior to the discharge of mine waste into the Twin Lakes, both lakes had moderately dense to dense stands of Manoomin. The Bois Forte Band of Chippewa, Grand Portage, and other community members historically harvested Manoomin in these lakes. In addition, Manoomin supported waterfowl (e.g., mallard, black ducks, green winged teal, wood ducks), fish such as northern pike, and other wildlife during this period (Michigan Division of Game and Fish, 1966a, 1966b).

1966 to 1989: After construction of the tailings basin

After the discharge of mine waste started, Manoomin coverage in the Twin lakes steadily declined. Compared to a 1966 vegetation survey of the Twin Lakes (Michigan Division of Game and Fish, 1966a, 1966b), a 1987 survey found that Manoomin was essentially absent from both lakes, while water levels were considerably higher and water clarity increased dramatically (State of Minnesota, 1987). By 1989, the Twin Lakes ranked as “no use” based on the combined ranking of cultural and ecological metrics.

1990 to 2009: With limited restoration actions

During this period, some actions were undertaken to recover Manoomin, including beaver management and small-scale reseeding efforts. However, these actions did not address the fundamental issue of high levels of sulfate and were largely ineffective at restoring the abundance of Manoomin and its associated habitat at the Twin Lakes. Given the absence of Manoomin on the lakes, community members were unable to harvest, prepare, and share Manoomin in ways practiced by their ancestors. The lost use of the Twin Lakes also limits sharing, transmittal, and generation of Anishinaabe practices at these lakes. During this period, the ranking of the Twin Lakes remained near “no use” based on the combined ranking of cultural and ecological metrics.

2010 to 2019: After construction of the seepage collection system

After U.S. Steel constructed the seepage system, Manoomin remained essentially absent from the Twin Lakes. With the lakes unable to support Manoomin, community members remained unable to harvest, prepare, and share Manoomin in ways practiced by their ancestors. During this period, the ranking of the Twin Lakes remained near “no use” based on the combined ranking of cultural and ecological metrics.

Cultural and ecological functionality provided by Manoomin and its associated habitat at the Twin Lakes declined over time, both in aggregate and for the individual metrics (Exhibit 5.21).

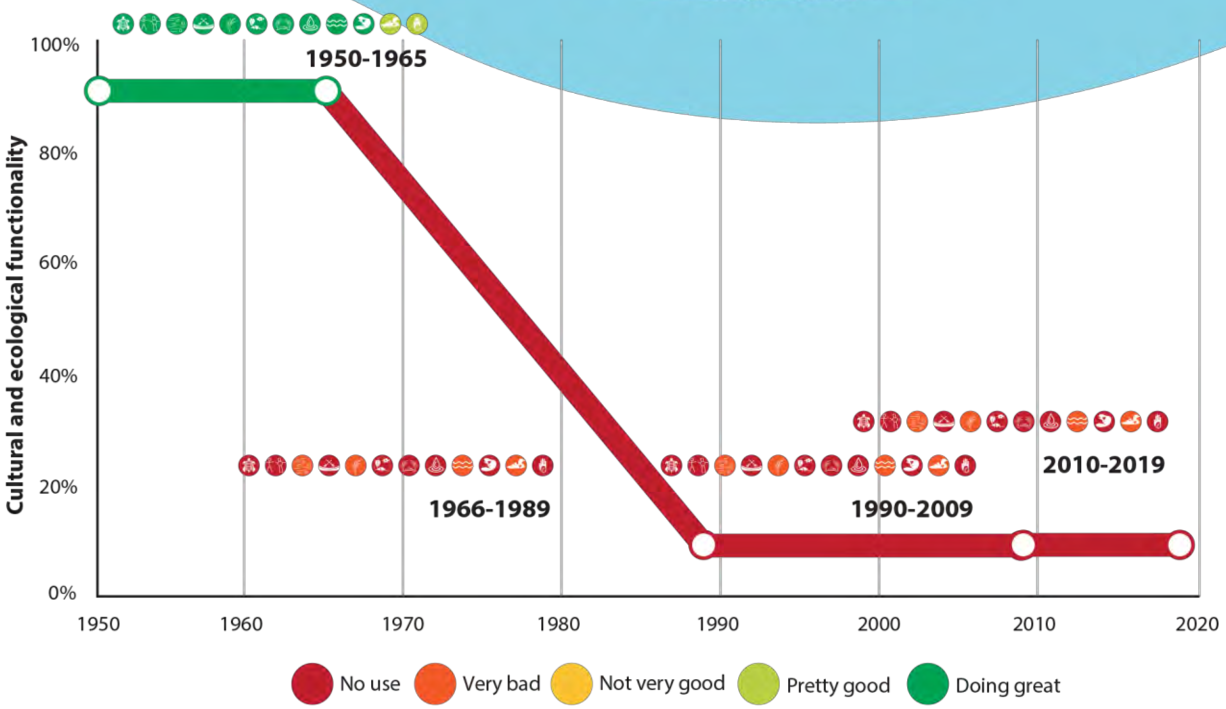

Exhibit 5.21. Characterization of cultural and ecological functionality provided by Manoomin and its associated habitat at the Twin Lakes

Additional restoration needed

Since the installation of a tailings basin for the U.S. Steel's Minntac facility in the mid-1960s, the abundance of Manoomin at the Twin Lakes has steadily declined. Actions taken at the Twin Lakes to improve Manoomin and its associated habitat have been limited and have not addressed the fundamental problem of sulfate loading from the mine. If actions were taken to improve conditions in the future, we could use an HEA to demonstrate the additional equivalent units of restoration needed to counter-balance the severity and timespan of degradation. For example, if actions were implemented over the next 20 years (2020 to 2040) to improve habitat functionality by 2.5%, over 100,000 acres of similar Manoomin restoration would be needed to counter-balance the lost habitat functionality that has occurred over time (from 1966 to 2019). This is equivalent in size to over 550 Twin Lakes.
Exhibit 5.22 provides the HEA results, assuming several hypothetical scenarios of improvements in habitat functionality; it is important to note that we do not know what actions are needed to create these percent improvements, but they would likely require addressing the fundamental problem of sulfate loading from the mine. The main purpose of these scenarios is to highlight that if only minimal restoration is achieved at Big Rice Lake (which may be anticipated, given the long history of attempting restoration, with minimal response), then significant equivalent amounts of this restoration would be needed to balance the prolonged period of degradation at this lake.

Exhibit 5.22. HEA results, assuming several hypothetical scenarios of improvements in habitat functionality

Hypothetical percentage of improvement in habitat functionality from 2020 to 2040	Acres needed to counter-balance historical losses given hypothetical improvement[a]	Number of Twin Lakes needed to counter-balance historical losses given hypothetical improvement
2.5%	116,700	556
5.0%	58,400	278
10.0%	29,200	139
20.0%	14,600	69

a. Acres rounded to the nearest hundred.

This case study demonstrates the difficulty in restoring Manoomin and its associated habitat when the root cause of the degradation – in this case, sulfate discharge – is not addressed. Given the difficulty of restoring degraded habitat, it is important to protect and preserve existing Manoomin habitat to ensure a future with Manoomin.

Case study acknowledgments

The Project Team would like to acknowledge Darren Vogt (1854 Treaty Authority) and Nancy Schuldt (Fond du Lac Band of Lake Superior Chippewa) for their valuable input and feedback in the development of this case study. The Project Team would also like to thank Wayne Dupuis (Fond du Lac Band of Lake Superior Chippewa), Tara Geshick (Bois Forte), John Coleman and Esteban Chiriboga (Great Lakes Indian Fish & Wildlife Commission), and Amy Myrbo for participating in the cultural and ecological characterization of the Twin Lakes.

6. Cross-case findings and lessons learned

In this chapter, we detail the cross-case findings and lessons learned developed through this study. The cross-case findings represent the collective wisdom of our project team on these seven unique case studies. While each case study is unique, with distinct attributes, here we focus on some common themes that emerged across the studies.

The Anishinaabe have long history of careful tending to Gitimanidoo gitigan through Manoomin stewardship; however, restoring Manoomin and its associated habitat remains a significant challenge under current conditions.

> The older term for rice beds, *Manito Gitigaan* or the Great Spirit's Garden, "captures (among other concepts) the perspective that while Manoomin is a natural part of the landscape, careful tending to the crop can enhance its health and productivity, in the same way a dedicated gardener benefits her plants."
>
> – David et al., 2019

The Anishinaabe have a long relationship of careful tending to Manoomin to enhance its health and productivity (David et al., 2019). This stewardship is both spiritual and ecological in nature. Wild rice chiefs, for example, conduct ceremonies honoring Manoomin to help protect the crop and ensure its abundance (David et al., 2019). With tribal and other partners, wild rice chiefs also regulate water levels, remove competitive vegetation, and seed new areas. The contemporary restoration undertaken throughout the seven case studies described in this study reflect the stewardship practices.

- *Manoomin seeding* efforts have expanded since the reaffirmation of treaty rights in the Great Lakes region (David et al., 2019). Considerable resources have been expended to increase the abundance of Manoomin through seeding efforts. Most of our case studies include some Manoomin seeding efforts (see Exhibit 5.2). The level of effort varies from modest reseeding efforts in the Twin lakes to more extensive reseeding efforts at Lac Vieux Desert's Rice Bay.
- *Water level management* can help regulate water levels to benefit Manoomin; these management actions can include traditional water level management actions (e.g., removing beaver dams), as well as more complex water level management activities. Most of the restoration efforts in our case studies include water level management of some form (see Exhibit 5.2). Changing the operating regime of a dam on Lac Vieux Desert to lower water levels, for example, combined with Manoomin seeding efforts, helped to reestablish Manoomin on Lac Vieux Desert's Rice Bay.
- *Removal of competitive vegetation* on a rotational schedule can restore Manoomin density. In several case studies, the native plant ginoozhegoons is outcompeting Manoomin (Exhibit 2.1). Fond du Lac Band of Lake Superior Chippewa, for example, is undertaking mechanically removal of ginoozhegoons at *Perch Lake* and Big Rice Lake to restore Manoomin habitat (FDL, 2018).

Success of these restoration actions has been incremental and at times challenging. Restoration actions taken at historically high-producing Manoomin waters – including Big Rice Lake, Twin Lakes, Lac Vieux Desert's Rice Bay, and *Perch Lake* – have not returned Manoomin and its associated habitat to historical cultural and ecological functionality. And, in some cases, restoration actions have been largely ineffective with Manoomin abundance and density continuing to decline. For example, natural resource managers have tried to improve the conditions of Manoomin and its associated habitat at Big Rice Lake since the 1990s; however, actions have had limited success and Manoomin conditions continue to be diminished.

Several case studies also highlight the need to return to the concept of traditional stewardship and carefully tend to Manoomin through sustained, long-term resource management At *Perch Lake,* the Fond du Lac Band of Lake Superior Chippewa developed a management strategy that brings lake levels to flood stage every four years in order to stress perennial species, such as ginoozhegoons that otherwise outcompete Manoomin. This long-term restoration approach provides Manoomin with a competitive advantage in the immediate years following the flood stage (Fond de Lac Band, 2018).

Even in places where Manoomin restoration has shown success, more restoration is often needed given the significant historical losses in Manoomin cultural and ecological functionality.

The combined HEA approach applied in this study accounts for the amount of time that Manoomin habitat has been degraded and the time required for restored Manoomin habitat to recover or reach improved functionality. For several case studies, water level modifications through dams and agricultural diching or mining activities led to a decline in Manoomin habitat over a hundred years ago. For example, Lac Vieux Desert was first dammed around 1870 for logging operations, and by 1907 the WVIC began operating the lake as a storage reservoir. In 1937, WVIC replaced the wooden dam with a reinforced concrete and steel structure. Changes in water levels caused by the dam initiated a decline in Manoomin and, from 1938 to 1952, Manoomin declined steadily and community members stopped harvesting it during this period (Barton, 2018; Labine, 2017). In addition, mine tailings were carried from a copper ore processing plant that operated from 1902 to 1919 around Keweenaw Bay. Connected to Keweenaw Bay, Sand Point Sloughs, a culturally important site for KBIC, and its natural resources have been exposed to high concentrations of heavy metals for many years.

Even with successful restoration, Manoomin habitat at many of our case study sites has had significant cultural and ecological losses over a long period of time, which makes it extremely difficult to counter-balance those lost habitat functionality with additional restoration actions. At Lac Vieux Desert's Rice Bay, the equivalent of 12 restoration efforts (from 1991 to 2019) are needed to counter-balance the lost cultural and ecological habitat functionality (from 1900 to 1990), while at Sand Point Sloughs, 22 equivalent restoration efforts (from 1991 to 2019) are needed to counter-balance lost cultural and ecological habitat functionality (from 1920 to 1990).

At some locations, restoration actions may never fully recover all cultural and ecological functionality given that long time period of loss. At Twin Lakes, for example, actions taken to improve Manoomin and its associated habitat have been limited and have not addressed the fundamental problem of sulfate loading from the mine. Given the significant cultural and ecological losses that have occurred since installation of a tailings basin for the U.S. Steel's Minntac facility in the mid-1960s, it is challenging to foresee a scenario where restoration actions could fully recover all lost functionality. In these cases, protection and/or restoration of Manoomin habitat at additional locations may be one approach to compensate for all the losses that occurred over time.

Seeding to enhance existing Manoomin stands and to introduce it to new locations can be worthwhile and necessary; places with favorable habitat features and conditions seem conducive to growing Manoomin.

Manoomin seeding in waters with favorable physical or hydrologic features can be an effective and inexpensive way to restore Manoomin (David et al., 2019). In addition, seeding at both sites where Manoomin is known to have historically occurred, and sites where there are no records, but hydrologic conditions seem suitable, can be worthwhile and necessary – "worthwhile because of the many ecological and cultural benefits rice provides and because rice abundance in the state remains lower than it was prior to European contact, and necessary because rice seed has a very limited natural ability to disperse" (David et al., 2019, p. 68). Natural resource managers around the Lake Superior region have had some success in identifying good Manoomin habitat, based on physical or hydrologic features, and seeding Manoomin. In two of our seven case studies, natural resource managers selected areas that were not known to have any Manoomin, but were thought to have favorable conditions for Manoomin growth – suitable soils, clean water, and modifications in water level management. These two case studies are showing preliminary success in their seeding efforts. At Hiles Millpond, biologists realized that the ecological benefits of Hiles Millpond could be significantly enhanced by establishing Manoomin. With modest seeding and slight modifications in water-level management, resource managers successfully established Manoomin across the Hiles Millpond. At Net River Impoundment and Vermillac Lake, KBIC worked with the Michigan Department of Natural Resources to identify areas for Manoomin restoration, and the Net River Impoundment and Vermillac Lake were selected as lakes with potential for Manoomin beds. After successful seeded test plots at both lakes, KBIC has expanded seeding efforts and has seen successful establishment of Manoomin across these locations. In addition, cultural teachings and practices related to Manoomin are beginning to occur at the Net River Impoundment.

Although the results of seeding efforts are encouraging, more study is needed to confirm whether seeding can lead to culturally and ecologically high-quality Manoomin habitat. In addition, given that the period of degradation is often longer than the period of restoration, additional Manoomin restoration may be needed to counter-balance the lost habitat functionality that has occurred over time. At Net River Impoundment and Vermillac Lake, for example, nearly 12 equivalent restoration efforts (from 2014 to 2019) are needed to counter-balance the lost cultural and ecological habitat functionality (from 1990 to 2013).

Restoration must be adaptive; what may have worked in the past, may not be successful in the future given additional threats.

Many Tribal, state, and federal agencies have been involved in Manoomin restoration around the Lake Superior region for decades and, in the case of tribal communities, for much longer. However, in some cases, actions taken in the past that have had some success at restoring Manoomin are no longer successful. For example, more frequent heavy rainfall events in the spring and summer have negatively affected Manoomin in Lac Vieux Desert's Rice Bay. These above-average precipitation events have led to "ghost rice" and brown spot disease in Manoomin beds, and are likely driving the decline of Manoomin abundance on Rice Bay. In addition, Sand Point Sloughs is connected to Lake Superior, and affected by changes in the lake's water level and invasive and competitive species. These regional threats to the sloughs may be affecting Manoomin abundance and are largely beyond local control. The decrease in ecological and cultural functionality provided by Manoomin in recent years at several of our case study sites suggests the need for adaptive management of Manoomin habitats. Actions taken that may have been successful in restoring Manoomin in the past may need to be adjusted to respond to additional threats, such as climate change, to be successful in the future.

As conditions change and as we face uncertainty in future environmental conditions, it will be critical to collect monitoring data, evaluate the degree of success of restoration actions based on the interpretation of those data, and then make adaptations, or changes, as needed to future restoration actions to adapt to changing environmental conditions. Adaptive management could include taking initial restoration actions, and then using new information for future decisions. Or it can include exploring a range of options during all phases of restoration to select the best path forward to achieving restoration objectives. Long-term adaptive management of Manoomin and its associated habitat will rely on monitoring and make adjustments in the future based on monitoring results.

Monitoring should be incorporated into all future restoration projects.

Monitoring can help wild rice chiefs and other natural resource managers assess the health of existing Manoomin habitats, evaluate the success of different restoration actions, and make informed resource management decisions. Monitoring can provide information about ecological trends, including Manoomin productivity and biomass, as well as information about other components of Manoomin waters, such as water quality and use of waters by muskrats, beaver, geese, swans, and other beings. It can also provide information about cultural trends, such as harvest levels by tribal members and exercise of treaty-reserved harvesting rights. Monitoring can also evaluate the effectiveness of restoration or inform adaptive management actions. Because of the high variability in the productivity and biomass of Manoomin from year-to-year, monitoring is most useful when undertaken over several years (Kjerland, 2015a). Monitoring should be completed using methods that are both scientifically robust and culturally respectful (Kjerland, 2015a, 2015b).

This project illustrates the critical importance of monitoring data. The seven case studies in this project would have been possible, if not for existing monitoring data. Around the Lake Superior region, several agencies have undertaken long-term monitoring studies. Since the 1980s, GLIFWC has conducted Manoomin harvest surveys for tribal (off-reservation) and state (statewide) licensed ricers (David et al., 2019). Nearly all of this harvest comes from the ceded territory, and most of the data are from Wisconsin. GLIFWC also uses aerial surveys to approximate rice abundance information for over 200 waterbodies each year (David et al., 2019). NOAA is using hyperspectral imaging to delineate aquatic vegetation, with Manoomin as the primary species. In 1998, the 1854 Treaty Authority initiated a Manoomin monitoring program on lakes and rivers within the 1854 Ceded Territory in northern Michigan (Vogt, 2020a).

This study relies upon the long-term monitoring data from these efforts to understand the cultural and ecological conditions of Manoomin. Where available, case study teams incorporated monitoring data into their cultural and ecological characterization of Manoomin and its associated habitat. For example, the Lac Vieux Desert Band and GLIFWC mapped Manoomin acreage on Lac Vieux Desert's Rice Bay from 2000 to 2019 as part of the 10-year trial Lac Vieux Desert Wild Rice Restoration Plan with Wisconsin Valley Improvement Company (WVIC; Exhibit 6.1). These data provided background on the condition of Manoomin with restoration actions (the 1991 to 2012 time period) and during the decline in Manoomin abundance with above-average precipitation (2013 to 2019 time period). Our study underscores the importance of long-term monitoring. There should be a concerted effort to inventory all Manoomin waters across the Great Lakes.

Traditional ecological knowledge can help understand habitat functionality across the Lake Superior region.

Cultural leaders, community members, wild rice chiefs, Manoomin harvesters, and elders have important knowledge and perspectives that can inform the characterization of cultural and ecological functionality provided by Manoomin over long time periods. Our Project Team was composed of many cultural leaders, community members, harvesters, and wild rice chiefs who shaped the development of our cultural and ecological metrics, and informed the characterization of Manoomin at specific sites. In a few instances, our Project Team relied on their wild rice chiefs and elders to provide cultural and traditional ecological knowledge about a place. For example, the Fond du Lac Band of Lake Superior

Chippewa case study team received input from an elder and wild rice chief to characterize a time period for Perch Lake where the case study team had limited knowledge and limited ecological monitoring data.

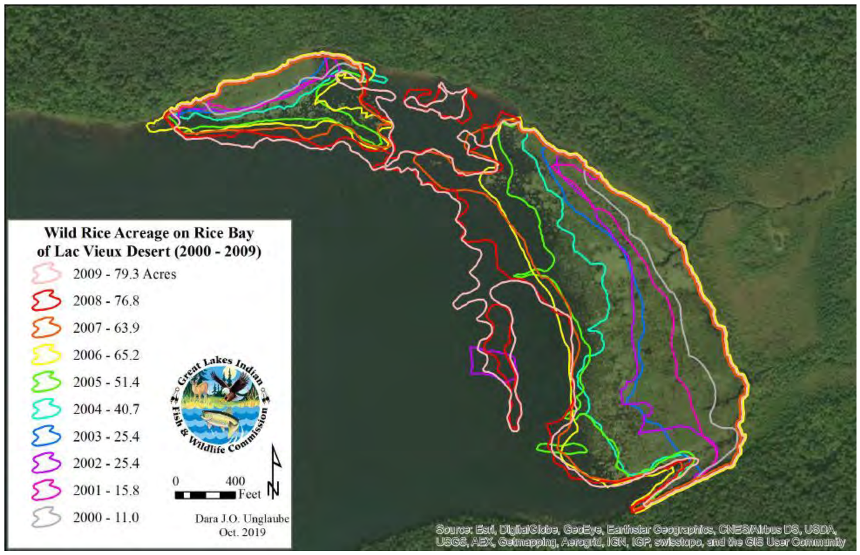

Exhibit 6.1. Manoomin distribution and acreage on Rice Bay on Lac Vieux Desert, 2000–2009

Credit: GLIFWC, 2019.

Educating the tribal and nontribal community members can ensure successful Manoomin restoration.

While Manoomin is one of the most valuable wetlands plants in the Lake Superior region, the benefits and values of Manoomin are often unknown or underappreciated by the general public (David et al., 2019). Education and information about the importance of Manoomin can encourage the stewardship of Manoomin and improve restoration outcomes. On Lac Vieux Desert, for example, lakeshore owners and boaters viewed Manoomin as a nuisance. After taking the time to educate the non-tribal community about the importance of Manoomin and why it is worth protecting, the LVD Band now works closely with them to ensure the existence of Manoomin in Rice Bay and other parts of the lake.

Preserving existing Manoomin habitat is critical to ensuring a future with Manoomin.

Given the significant challenges in restoring Manoomin that has become degraded, a key management strategy for Manoomin is to protect and preserve existing Manoomin stands and the clean water resources and habitats in which it thrives. In many places, dramatic changes to wetland and lake systems – including hydrologic changes from dams and agricultural ditching and mining activities – has had unforeseen consequences. Protecting areas with Manoomin habitat could reduce some stressors to Manoomin, and allow the plant to adapt to climate change and other changing conditions. Manoomin habitats may be protected through a number of different actions, including first ensuring there is a comprehensive characterization (mapping) of the habitat across the Great Lakes Region, such as the use of hyperspectral imaging to delineate Manoomin habitat. Acquisitions and conservation easements may also be part of the strategy to protect Manoomin habitat. In addition, instituting best management practices to protect existing high quality habitat from existing stressors should also be considered. This may include controlling invasive species, limiting activities with adverse consequences in sensitive habitats, such as discharging mine waste, and developing climate monitoring and adaptive management plans. Finally, educational outreach could be an important aspect of preserving Manoomin habitat, including outreach to lakeshore landowners with Manoomin stands about the value of this habitat, and to the general public with respect to the ecological and cultural value of Manoomin.

7. Conclusion and next steps

This report documents and characterizes the importance and functions of Manoomin and its associated habitat to cultural perspectives and identity, community connections, and cultural and spiritual practices of the Anishinaabe people; as well as to biodiversity and ecosystem integrity. Using a set of cultural and ecological metrics and a combined HEA approach, we characterized a range of degraded Manoomin waters where restoration actions have been undertaken, with locations dispersed over the Lake Superior region. We quantified lost cultural and ecological functionality in terms of the additional amount of equivalent restoration that would be need to counter-balance the losses.

We find that restoration is worthwhile, with demonstrable improvements documented in our case studies. However, our case studies also highlight the challenges to return degraded Manoomin stands to full functionality. Many restoration actions have improved cultural and ecological functionality, but have not been successful at fully returning Manoomin to historical conditions. In places where Manoomin restoration has shown some success, we find that additional restoration is often needed, given historical losses in cultural and ecological functionality. The challenges in restoring Manoomin habitat after it is degraded serve to highlight the critical importance of protecting existing Manoomin stands.

To provide a path forward for indigenous communities, tribal and non-tribal governments, organizations, and staff who are working to actively manage and restore Manoomin across the Great Lakes, we would like to offer several possible next steps to further assess the cultural and ecological importance of Manoomin.

Expand the geographic scope of this study

This study focuses on seven case studies around the Lake Superior region. We selected the case studies in places that were of particular importance to our team and had adequate data and information to inform the characterization. As we were only able to delve deep into a limited number of the case studies, it is difficult to generalize our case study findings from these seven places to the Lake Superior region or the Great Lakes basin more broadly.

A cumulative sample of case studies could allow us to aggregate information from places around the Great Lakes – including the full Lake Superior region and across lakes Michigan, Huron, Erie, and Ontario – to allow for greater generalization. With a more representative sample of case studies, we could provide additional insights into threats to Manoomin and different restoration approaches used across the Great Lakes, and better understand the cultural and ecological losses (or gains) in Manoomin and its associated habitat throughout the region. This could help target critical resources to protect the remaining populations of Manoomin and restore Manoomin habitat across the Great Lakes region.

Incorporate cultural and ecological characterizations into annual monitoring efforts

Many of the sites are newly restored, such as Hiles Millpond and the Net River Impoundment, or have recently acquired additional resources to complete more restoration, such as Big Rice Lake and Lac Vieux Desert's Rice Bay. Characterizing future restoration conditions at these places could allow for a continued understanding of how well restoration returns the cultural and ecological functionality of the place and, in some cases, could refine the output from the HEA approach. For example, Big Rice Lake could be characterized after additional restoration efforts are implemented to determine how well those actions return the lake's natural functionality.

Cultural and ecological metrics could also inform annual monitoring efforts. Combined with other annual monitoring metrics such as water quality, water level, and Manoomin biomass and stalk density, cultural and ecological metrics incorporate indigenous knowledge and values into the monitoring process and provide a more holistic understanding of determining if the restoration actions are achieving target goals or returning conditions to historical or baseline conditions. Without the incorporation of indigenous metrics, cultural values, beliefs, and practices are omitted or can become invisible. It is critical to keep in mind that each community is different, and the characterization must be driven and refined by the people in the community. Metrics will need to reflect the unique history of the community or the place, as well as the place-based use of Manoomin or other natural resources.

In the Great Lakes, continuous efforts are needed to protect, restore, and monitor Manoomin and its associated habitat. Understanding the success (or failure) of restoration actions in counterbalancing historical losses in cultural and ecological functionality can help determine how to target future resources toward restoring and protecting Manoomin. We hope that the information and knowledge gained through this study will help indigenous communities, tribal and non-tribal governments, organizations, and staff in the Great Lakes ensure a future with healthy Manoomin waters.

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Appendix

In this appendix, we provide the standalone communications materials developed for each case study. In each case study, we provide a brief overview of the place, and describe the threats to Manoomin at the place and the actions taken to improve the abundance of Manoomin at the place. We then describe the case study results, including the metrics used to characterize the cultural and ecological importance of the place, the characterized conditions of Manoomin habitat over time, and the results of the HEA model that calculates the amount of restoration needed to balance the reduced or lost functions. Case studies include:

- Restoration of **Lac Vieux Desert's Rice Bay** increases cultural and ecological functionality: Significant progress made but additional restoration could counter-balance losses
- Restoration of Keweenaw Bay Indian Community's **Sand Point Sloughs** increases cultural and ecological functionality: Significant progress made but additional restoration could counter-balance losses
- Introduction of Manoomin at **Net River Impoundment and Vermillac Lake** provides cultural and ecological functionality: With favorable conditions, restoration can enhance Gichimanidoo gitigan
- Introduction of Manoomin at **Hiles Millpond** provides cultural and ecological functionality: With favorable conditions, restoration can enhance Manoomin habitat
- Efforts to manage **Big Rice Lake** have not improved Manoomin functionality: Manoomin continues to be affected by hydrologic conditions and other threats
- Low ecological and cultural functionality characterized at the **Twin Lakes**: Manoomin is unable to rebound due to ongoing sulfate loading from mine discharges.

Restoration of Lac Vieux Desert's Rice Bay increases cultural and ecological functionality

Significant progress made but additional restoration could counter-balance losses

Recent restoration efforts at Lac Vieux Desert's Rice Bay have improved the cultural and ecological functionality of the bay's Manoomin (wild rice) and its associated habitat. However, given the significant losses, much more restoration is needed. Based on the methods applied in this study, it would take an additional 3,034 acres of similar Manoomin restoration to counter-balance the lost cultural and ecological functionality that has occurred over time. This is equivalent in scale to 12 times the current restoration efforts at Rice Bay. In addition, future restoration actions will need to be adaptive to respond to changing precipitation patterns.

Credit: Todd Marsee, Michigan Sea Grant

Threats to Manoomin at Rice Bay

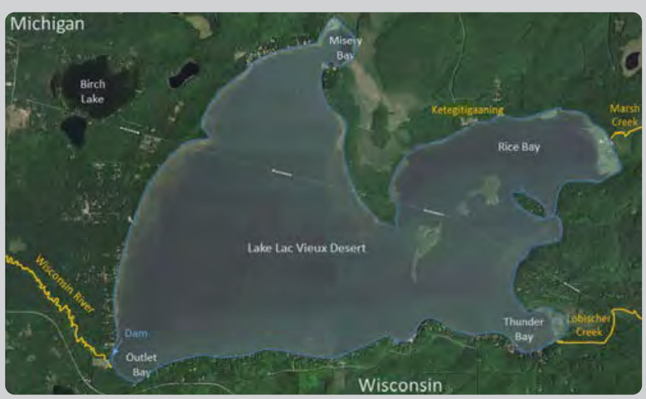
Lac Vieux Desert was dammed around 1870 for logging operations. By 1907 the Wisconsin Valley Improvement Company (WVIC) began operating the lake as a storage reservoir and used the dam to create uniform stream flow down the Wisconsin River to reduce flooding events, facilitate hydroelectric power generation, and regulate effluent discharge downstream. In 1937, WVIC replaced the wooden dam with a reinforced concrete and steel structure. The high water levels caused by the dam initiated a decline in Manoomin (Labine, 2017). From 1938 to 1952, Manoomin declined steadily and community members stopped harvesting it during this period (Barton, 2018). During this period, lakeside property owners became concerned about the erosion caused by rising lake levels.

More recently, heavy rainfall events have negatively affected Manoomin in Lac Vieux Desert [Roger Labine, Lac Vieux Desert Band of Lake Superior Chippewa (LVD Band), personal communication, February 15, 2020]. In the spring, Manoomin is in the floating leaf stage, and can be uprooted by heavy rainfall that raises water levels. In the summer, when Manoomin is in the flowering stage, heavy rainfall can knock Manoomin pollen down from the flower to the water's surface, which prevents pollination and results in "ghost rice" or empty hulls that never fill. In addition, the combination of heavy rainfall events and higher air temperatures may also increase the amount of brown spot – a destructive wild rice fungal disease – in Manoomin beds.

About Lac Vieux Desert's Rice Bay

Lac Vieux Desert, located in Vilas County, Wisconsin, and Gogebic County, Michigan, is over 4,000 acres. Historically, Manoomin covered many parts of Lac Vieux Desert, including Rice Bay, Thunder Bay, Slaughters Bay, Misery Bay, and along the northwestern shore to the Wisconsin River and parts of the south shore.

Rice Bay is a 273-acre bay on the northeastern portion of Lac Vieux Desert, which historically contained a significant stand of Manoomin that was traditionally managed and harvested by the LVD Band. West of Rice Bay is Ketegitigaaning, a ricing village used intermittently in the early 18th century by the LVD Band, followed by continuous habitation by 1900. In 2015, Rice Bay was registered as a Traditional Cultural Property on the National Register of Historic Places.



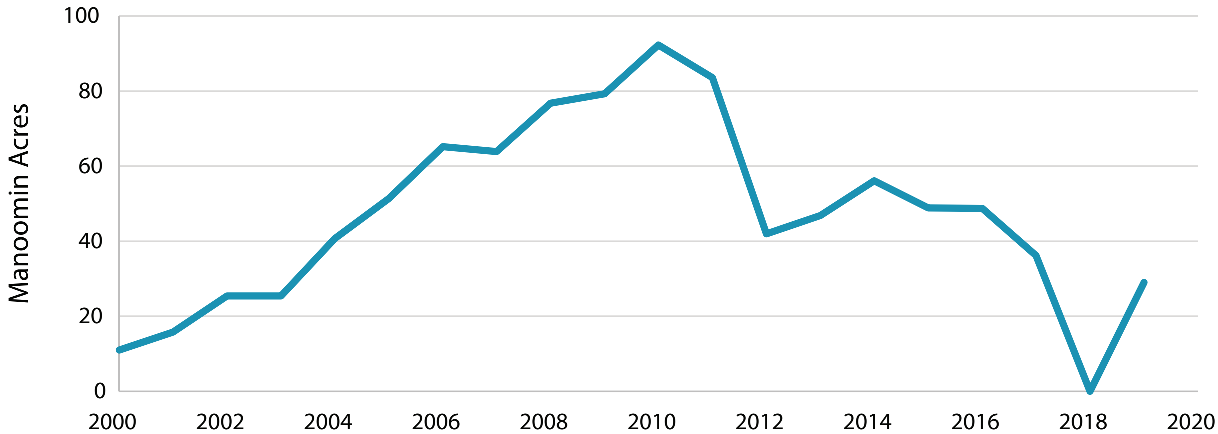
Actions taken to improve the abundance of Manoomin at Rice Bay

In 1991, a coalition of tribal, state, and federal governments and governmental agencies determined the operating regime of the dam on Lac Vieux Desert had been detrimental to Manoomin and its associated habitat (Onterra, 2012). By 2001, following a decade of negotiation and litigation, WVIC lowered the maximum operating level by about nine inches and provided financial contribution toward a Manoomin seeding and monitoring program (Barton, 2018). From 2002 to 2005, Lac Vieux Desert was seeded with 14,000 pounds of Manoomin, most of which occurred in Rice Bay (Labine, 2017). From 2007 through 2012, as Manoomin became reestablished on Rice Bay, the LVD Band held traditional ricing camps and workshops, which included traditional practices and activities (Barton and Labine, 2013).

From 2000 to 2010, the acreage of Manoomin on Rice Bay significantly increased. In 2000, Rice Bay had just 11 acres of Manoomin coverage (or 5% of Rice Bay). After the first year of seeding, Manoomin coverage increased to over 25 acres (or 10% of Rice Bay; top aerial photograph). With below-average rainfall conditions in 2010, the extent of Manoomin increased to over 92 acres (or 38% of Rice Bay; bottom aerial photograph). While the extent of Manoomin on Rice Bay was less than its historical coverage, it was considered an improvement over conditions caused by the operating regime of the concrete dam (Barton, 2018).

Since 2011, the acreage of Manoomin on Rice Bay has been declining, with 34 acres in 2019 (GLIFWC, 2019). Because Manoomin abundance on Rice Bay is generally greatest during low-water years, natural resource managers believe this may be due to above-average precipitation over the past seven years (Peter David, GLIFWC, personal communication, November 12, 2019).

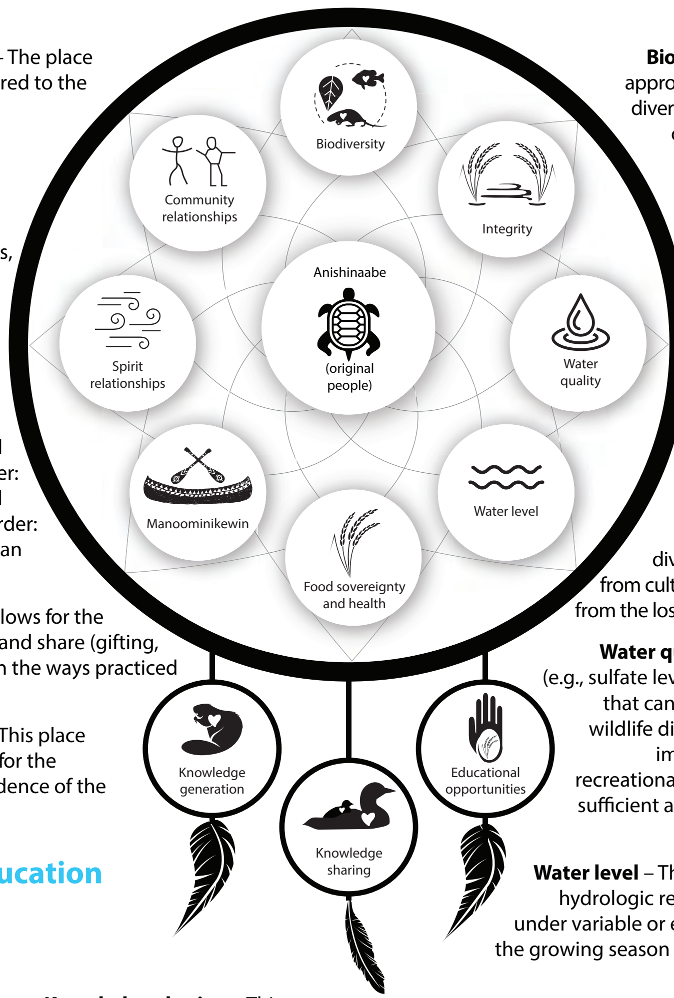
Credit: Peter David,Great Lakes Indian Fish & Wildlife Commission (GLIFWC).



Manoomin acreage on Rice Bay, 2000 to 2019

Approach to characterizing Manoomin at Rice Bay

Twelve metrics characterize the cultural and ecological functions of Rice Bay's Manoomin and its associated habitat. These metrics describe how Manoomin at Rice Bay contributes to maintaining connections with the Anishinaabe culture, how ecological functionality is supported and resilient to changing conditions, and how continued learning and sharing of Anishinaabe values are promoted.



Cultural Metrics

Anishinaabe (original people) – The place provides Manoomin, which is sacred to the Anishinaabe and central to the foundations of their culture, sovereignty, and treaty rights.

Community relationships – Manoomin at this place contributes to bonding, traditions, and strengthening family and community connections.

Spirit relationships – Manoomin at this place enables the Anishinaabe to maintain connections and balance with spirit beings (or relatives) from all other orders of creation (first order: rock, water, fire and wind; second order: other plant beings; third order: animal beings; fourth order: human beings).

Manoominikewin – This place allows for the Anishinaabe to harvest, prepare, and share (gifting, healing, and eating) Manoomin in the ways practiced by their ancestors for centuries.

Food sovereignty and health – This place provides the capacity to provide for the sustenance, health, and independence of the Anishinaabe.

Ecological Metrics

Biodiversity – Healthy Manoomin and appropriate habitat at this place supports diverse biological communities (e.g., free of invasive species) that indicate the capacity of the place to support abundant associated plant and animal species (e.g., other native aquatic vegetation, fish, waterfowl, muskrat), providing for spiritual and subsistence needs.

Integrity – Physical habitat and hydrology, and water and sediment chemistry support stands of Manoomin that exhibit natural annual variability; viable seed bank ensures that sustainable Manoomin populations will persist even after occasional poor production years. Natural genetic diversity is maintained without impact from cultivated strains, or reduced gene flow from the loss of nearby Manoomin populations.

Water quality – This place has clean water (e.g., sulfate levels below 10 ppm) and sediments that can support robust stand density and wildlife diversity; is free of contamination or impacts from industrial, agricultural, recreational, or residential influence; and is of sufficient areal extent to sustain a Manoomin population.

Water level – This place has a natural or managed hydrologic regime that can maximize resilience under variable or extreme climatic conditions across the growing season (maintaining optimal depth range and flow).

Cultural and Ecological Education Metrics

Knowledge generation – This place allows for continued learning and generation of the Anishinaabe practices, values, beliefs, and language through experience.

Knowledge sharing – This place allows for the continued sharing and transmittal of the Anishinaabe practices, values, beliefs, and language among family members and community.

Educational opportunities – This place provides opportunities for language, land stewardship, and other educational programs, such as educational rice camps.

Cultural and ecological characterization at Rice Bay

Rice Bay's Manoomin and its associated habitat were characterized over four time periods. Each metric was ranked using the following five-point descriptive scale:

No use · Very bad · Not very good · Pretty good · Doing great

1900 to 1936: With a wooden dam

Based on the combined ranking of cultural and ecological metrics, Rice Bay was characterized as "doing great" during this period. In the early 1900s, Ketegitigaaning was inhabited and the community harvested Manoomin in Rice Bay for gifting, healing, and consumption. The area also boasted a rich biodiversity; and hunting, trapping, fishing, and gathering local resources were common.

1937 to 1990: With a concrete and steel dam

After the replacement of the wooden dam with a concrete and steel structure, Manoomin declined steadily until the mid-1950s to the point that it was no longer harvestable by community members. During this time period, community members moved away from the lake and into surrounding towns, and stopped harvesting Manoomin in Rice Bay. The "disappearance of Manoomin started the deterioration of the Lac Vieux Desert community," where bonding, traditions, and community connections ceased (Roger Labine, LVD Band, personal communication, November 12, 2019). There was a steady decline in cultural and ecological functionality provided by Manoomin from 1937 to the mid-1950s, when Rice Bay was characterized as "very bad" based on the combined ranking of cultural and ecological metrics.

1991 to 2012: With restoration actions

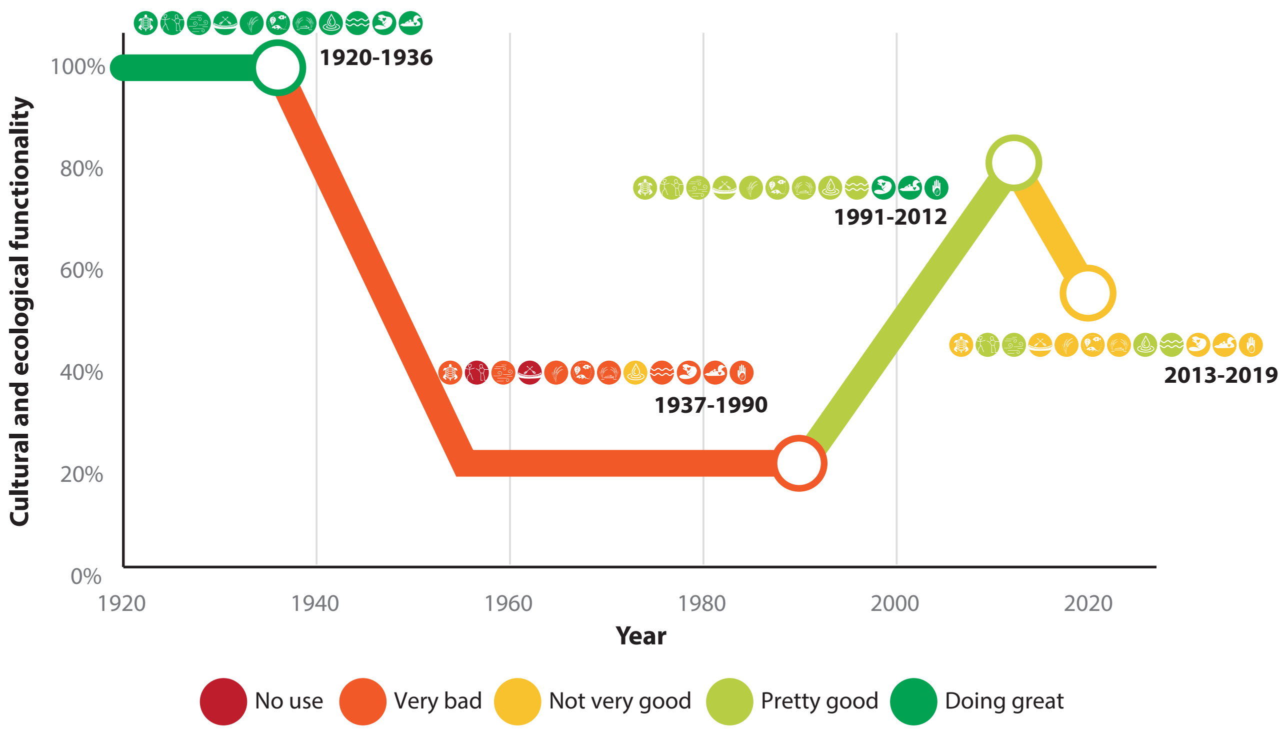
Once restoration actions began in the 1990s, cultural and ecological functionality provided by Manoomin improved. By 2008, the LVD Band opened Rice Bay for Manoomin harvest and began hosting rice camps in the area for the first time since 1940. Although the community began knowledge sharing, knowledge generation, and educational opportunities increased, it remained difficult to get many community members interested in Manoomin because of its absence over the last 50 years. Even so, restoration actions led to an increase in cultural and ecological functionality. By 2012, Rice Bay ranked as "pretty good" based on the combined ranking of cultural and ecological metrics.

2013 to 2019: With restoration actions and above-average precipitation

With heavy rainfall events negatively affecting Manoomin beds during the growing season, cultural and ecological functionality at Rice Bay have declined. Currently, Rice Bay is ranked as "not very good" based on the combined ranking of cultural and ecological metrics. The decrease in ecological and cultural functionality provided by Manoomin in recent years suggests the need for adaptive management of Manoomin. Actions taken that may have been successful in restoring Manoomin in the past may need to be adjusted to respond to additional threats, such as climate change, to be successful in the future.

Cultural and ecological characterization at Rice Bay

Cultural and ecological functionality provided by Manoomin and its associated habitat at Rice Bay have changed over time, both in total and for individual metrics.



Additional Restoration Needed

Based on the characterization of the degree of cultural and ecological function over the four time periods, a Habitat Equivalency Analysis demonstrates the additional equivalent units of restoration needed to counter-balance the severity and timespan of degradation. Given the success of restoration at the 243-acre Rice Bay, 3,034 acres of similar Manoomin restoration is needed to counter-balance the lost habitat functionality that has occurred over time. In other words, 12 equivalent restoration efforts at Rice Bay (from 1991 to 2019) are needed to counter-balance the lost cultural and ecological habitat functionality (from 1900 to 1990).