Restoring Lakeshore Habitat on Little St. Germain Lake, Vilas County

Developing Best Management Practices and Evaluating the Ecological and Water Quality Benefits.

A Final Report Prepared by:

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Executive Summary

Little St. Germain Lake (LSG) located in Vilas County, Wisconsin, is one of 21 impoundments operated by Wisconsin Valley Improvement Company, originally to float cut timber downstream to mills, now mostly to provide seasonal water storage for downstream power, industry, and recreational use. The level of Little St. Germain, which was dammed in 1882, has been maintained about 5 feet above its natural level since 1929, and is annually drawn down about 1.5 feet from December – March.

A healthy lake ecosystem is a function of good water quality and intact lakeshore and aquatic habitat and food webs. Human alteration of lakeshore and aquatic habitat can result in changes to lake water quality (due to increased nutrient loading), decreases in native plant and animal species diversity, an increase in exotic invasive species, and changes in the populations of individual fish and wildlife species.

Water quality has recently declined across all basins of Little St. Germain – water clarity has decreased and algae blooms occur annually. Seasonal trends in water quality show that degradation occurs during the summer when phosphorus contributions from inflows are lower but internal phosphorus loading is elevated. The degraded water quality has negative impacts on aesthetics, fish populations, and aquatic plants, leading to lower enjoyment of the lake by residents and others who use the lake for these purposes. Long-term negative impacts on property values are also possible. While no solutions have been identified to rectify this problem, research conducted on northern Wisconsin lakes shows nutrient yield and overland runoff is lower along wooded shorelines as opposed to shorelines where natural vegetation has been replaced by managed lawns. Lakeshore habitat restoration has been proposed as a management practice to improve lake health by 1) increasing native plant abundance and diversity, 2) improving lakeshore habitat quality, 3) producing positive changes in wildlife abundance and diversity, 4) decreasing the presence of invasive species, and 5) reducing overland and nutrient runoff.

With grant support from the Little St. Germain Lake Protection and Rehabilitation District (WDNR Lake Protection grant LPT-344-1) WDNR Science Services, Michigan Technological University School of Forest Resources and Environmental Science, and regional environmental consultants implemented lakeshore habitat restorations at 6 private properties on LSG and is conducting long-term monitoring to quantify the ecological benefits of the restoration. Surveys were initiated to quantify the ecological benefits of lakeshore

habitat restoration for native plant communities and wildlife populations. Consultants developed methods with which to assess the impact of lakeshore habitat restoration on overland and nutrient runoff. Finally, experiments were conducted to develop Best Management Practices for lakeshore habitat restoration on LSG with applications regionally.

Measuring the Ecological Benefits of Lakeshore Habitat Restoration on Little St. Germain Lake 2010-2013

We developed site-specific management recommendations for LSG property owners who participated in the lakeshore habitat restoration program, completing restoration projects at six properties 2011-2012. Lakeshore habitat restoration occurred at over 1700' of developed lakeshore. Restoration activities included conservation and restoration of native vegetation, placement of physical structure such as downed trees and down woody material for fish and wildlife habitat, bank and toe erosion control with biodegradable materials, and other management techniques designed to reduce overland erosion and nutrient runoff. Habitat and wildlife surveys were conducted prior to commencement of restoration efforts, including baseline measures of relative abundance and diversity of native vegetation, pollinators (bees), birds, and small mammals. Physical characteristics of habitat such as vegetation structure and canopy closure were also measured. These measures will be repeated during the next 10 years to document changes as the projects mature. Results collected at the LSG restorations are compiled with data from completed projects at Moon, Found, Crystal, and Lost Lakes, Vilas County to assess whether lakeshore habitat restoration results in positive benefits to lake health in the Northern Highlands Ecological Landscape.

<u>Landowner Participation</u> - We recruited LSG property owners interested in participating in the Wisconsin Shoreland Restoration Project by conducting educational workshops and mailing educational materials/flyers in 2009 and 2010. We found interest in the project low among the 425 lake district property owners, despite the no-cost/no-labor investment on their behalf. Four property owners enrolled a total of 6 lakeshore parcels in the project, allowing us to meet our restoration objectives. The low level of enrollment may have been a consequence of required temporary (3-year) deer-proof fencing around restoration projects, follow-up visits by researchers for maintenance and periodic wildlife and vegetation surveys, and a restrictive covenant on the property deed protecting the restoration going forward. Also, landowners may have been deterred from participation due to the involvement of WDNR in the project (see Comments from Participants, Page 13). Finding local, trusted on-lake champions of

lakeshore rehabilitation work such as lake association officers, private sector business owners, or master gardeners can make for effective peer-to-peer learning and project buy-in. An effort initiated from the “grassroots” may yield greater participation than one initiated and sponsored by WDNR.

Restoration Activities - In the spring and summer months of 2011,187 trees, 1014 shrubs, two vines, 65 ferns, 4000 forbs and grasses and sedges were planted within the 35′ buffer zone along approximately 500′ of linear lakeshore on two privately owned LSG properties. In the spring and summer months of 2012, 542 trees, 1510 shrubs, eight vines, 93 ferns, 6000 forbs, grasses and sedges were planted within the 35′ buffer zone along approximately 1200′ of linear lakeshore on four privately owned properties. Geotextile bag walls and erosion control blankets were installed to reduce bank erosion and coconut coir biologs were used to reduce toe erosion. Rain gardens were installed to reduce runoff from impervious surfaces and tree drops were created to enhance fish habitat and reduce bank undercutting from wave action.

Measuring Ecological Benefits - Experimental Design - A habitat and wildlife sampling design was implemented to compare habitat and wildlife endpoints measured along 250 m of the “Treated” (developed/to be restored) lakeshore with those measured at 250 m of the “Control” (developed/unrestored) lakeshore on LSG Lake, as well as an additional 250 meters of lakeshore on Star Lake which is in state ownership (undeveloped “Reference” lakeshore). Star Lake was paired with LSG Lake on the basis of similar lake characteristics (surface area, substrate, and lake type) as well as aspect, fetch, and slope, but having low levels of housing development.

Vegetation and Habitat Surveys Prior to Restorations - We found a greater number of trees within vegetation plots on the reference transect (Star Lake, Vilas County) as compared to the LSG treated (developed/to be restored) and LSG control (developed/no restoration) vegetation plots prior to restoration activities. Sapling numbers were also higher on the Star Lake reference transect, the majority being conifers. There were no shrubs detected on either the control or treated transects on LSG prior to restoration, while there were two species of shrub detected on the reference site on Star Lake; 9 sweet fern (Comptonia peregrina) and 23 tag alders (Alnus rugosa) for a total of 32 shrubs. Habitat measures show the canopy was more open at the LSG control and treated transects prior to restoration compared to the Star Lake reference transect, and the understory (shrubs and saplings) is less dense at LSG control and treated transects than at the Star Lake reference shore transect. We will measure vegetation and habitat parameters again in the same vegetation plots in 2014, 2 years after LSG restoration planting has been completed.

Preliminary data from Wildlife Surveys 2010-2013 - Breeding bird and small mammal surveys were initiated on the LSG treated and control transects and the Star Lake reference transect in 2011, and will continue as the restoration projects mature on the LSG treated transect. We recorded 19 ground and shrub nesting bird species on the Star reference transect compared to 14 species and 12 species on the LSG control and treated transects respectively during 2011 and 2012 surveys. In addition, we recorded 41 insectivorous bird species on the Reference transect compared to the Treated and Control transects where 35 bird species were recorded on each transect. Overall, the diversity of bird species present was greater on the reference transect in 2011 and 2012; long-term monitoring is required to assess whether this trend continues, and whether diversity increases on the LSG treated transect. The small mammal surveys conducted 2011-2013 show a high amount of variability between years, with the total number of small mammals captured at all sites much higher in 2011 (86 captured) than in 2012 (24 captured) and 2013 (56 captured). Factors such as weather, predators, and population cycles can contribute to variability in small mammal abundance thus long-term measures will be required to discern whether restoration activities impact small mammal populations. A total of 8 species of small mammals were recorded. The early results do show a greater number of eastern chipmunks were captured on developed LSG lakeshore and a greater number of southern red-backed voles were captured on Star Lake reference transects. Finally, a pilot study was conducted on LSG treated and control transects in 2013 to develop methods with which to compare native bee (pollinator) populations post-restoration on LSG. "Bee-bowl" traps were deployed along these transects during 3 sampling intervals – one in May and two in June. During each sampling period a greater number of native bees (of 5 taxa) were collected at the treated transect, and diversity was higher. This difference may be attributed to habitat differences, however repeat measures at these sites, as well as replication of these methods at other restoration projects, is necessary to draw quantitative inferences.

Local Economic Impact - Materials and services purchased for the project ($103,000) supported jobs in local hardware stores, nurseries, gas stations, and landscaping companies.

In addition, 15 seasonal student internships have been completed since 2011 to assist with wildlife surveys, habitat measurements and restoration activities. Also, environmental consultants were contracted to conduct botanical, wildlife, and water runoff surveys for this project. Furthermore, management activities which project water quality and lake habitat can positively affect lake front property values. Much is a stake on LSG – a recent evaluation of the assessed value of LSG lakeshore properties exceeds $175 million.

Feasibility Assessment – Testing Methods to Evaluate the Effectiveness of Lakeshore Habitat Restoration to Reduce Overland Runoff and Nutrient Loads from Developed Lakes in Northern Wisconsin

As part of the LSG Shoreland Restoration Project 2011-2013, consultants conducted a pilot study to develop and test a overland and nutrient runoff sampling methodology, modified from a USGS study (Graczyk et al., 2003). This method is necessary to determine how effective newly constructed lakeshore habitat buffers are at reducing overland runoff and nutrient loads to nearby water resources. The goal was to develop affordable methods which could be installed at several Vilas County restoration projects to document the effectiveness of lakeshore habitat restoration. A final report titled "Supplemental Report to WDNR: Little St. Germain Lake Protection Grant Restoration of Shoreland Habitat Project Final Report, November 1st, 2013 Re: Surface Water Runoff Volume and Nutrient Loading Surveys" describes the results of a pilot study and is available from the report authors. Excerpts from the report are in italics below:

> *Runoff collector design considerations included the practical needs for site customization and most importantly, to standardize performance so that the design and sample collection methods would produce comparable results across different sites (or treatment plots) within the study area. Additional considerations included a desire to stay within the current project budget and the interest to develop a low-cost prototype collector to measure overland runoff at multiple sites as part of an expanded future study. In practical terms, this omitted the purchase and installation of costly specialized instrumentation typical in large-scale runoff studies designed by the USGS.*
>
> *Three collectors were constructed and designed to represent a closed rainfall basin 50m2 in area approximating a true circle 4 meters in radius. The outer ring consisted of 83 feet of 6-inch plastic landscape edging buried and anchored to a 4-5" depth to enclose all rainfall (and irrigation) for available capture by the collector unit installed at the lowest elevation point of the circular plot. At the lowest end of each collector, a 2-inch PVC tee w/ cleanout*

couplers and sediment screens was installed inline to allow overland flow captured by the slotted pipe to drain to a centralized collecting tube that drained into a clean sampling vessel fabricated from a 3" x 33" Cellular-Core PVC pipe with end caps. The sampling vessel capacity is 3,500 milliliters (3.5 L) – later modified to increase capacity to 17 L.

In spring of 2012 and following the installation of the runoff collectors and edging, two of the experimental plots were "restored" to one of two plant stocking densities (Low- and High-density planting). A third plot received no additional plantings, however naturally occurring trees were present.

Visual observations of all three collectors over a period of 3 years showed no evidence of overland runoff flow over or under the plot edge barrier. From 2011 to fall of 2013, a total of six sampling events were conducted across all three plots (treatments) resulting in: 1) the water quality test results from Wisconsin State Lab of Hygiene analysis of runoff volume samples and 2) measurements of runoff volume per plot per collection period. Results are presented in Chapter 3.

This method offers a lower cost method for collecting overland runoff measures at lake shore sites. However the precision and accuracy of this approach requires evaluation before it can be considered as a method with which to compare overland runoff volume and nutrient loading at developed shorelines with restored lakeshore habitat buffers vs. developed shores without restored buffers. Simply stated, the precision of the collectors needs to be evaluated under controlled conditions. We recommend that overland runoff volume be evaluated under varying precipitation scenarios using controlled irrigation as the source – thereby varying the precipitation amount, duration, and intensity. The precision should also be evaluated using various ground cover substrates. The accuracy of the data also needs to be evaluated. Specifically, do these collectors model "real-world" lakeshore run-off scenarios? The physical forces associated with surface runoff at the landscape scale may or may not be generated within the bounds of the collectors – this should be evaluated. It could be that opening the upper boundary of the collectors will be necessary to intercept the surface water sheet flow generated by precipitation on the slope to be measured. These aspects should be considered in a controlled experimental laboratory environment.

In conclusion, the pilot study has resulted in a low cost method for measuring overland and nutrient runoff following natural or artificial precipitation events. However additional testing under controlled precipitation amounts and intensity, and on differing soil substrates, is required before the method should be considered a viable research tool.

Developing Best Management Practices for Lakeshore Habitat Restoration on Little St. Germain Lake and the Northern Highlands Ecological Landscape

Research continues as we develop Best Management Practices (BMP) for lakeshore habitat restoration on LSG and the NHEL. Here we present our preliminary BMP for LSG, including recommended steps for implementing a restoration. As additional research data is gathered, we will expand and finalize these recommendations, and extend them to the Northern Highlands Ecological Landscape, as many practices which work on LSG will have applicability throughout the region.

Pre-restoration Planning: A detailed restoration plan and map are crucial to a successful restoration project. A restoration map should be generated from careful notes taken in the field and through discussion with property owners. In addition, several photos should be taken on-site at various places in the restoration area, usually at the corners facing the restoration area, with multiple angles. These photos will be valuable when planning a restoration and for comparing before and after restoration activities. Once all information is collected this can be transferred to a detailed map of the area. Gridded map paper can be used to produce a product approximately to scale. Then restoration plants and erosion control techniques can be added to the final map. Several map copies should be made, with one being sent to landowner, and one to interested government agencies (state or county if permitting is required), as well as to the restoration practitioners installing the project. It is critical the landowner, restoration designer (if not the landowner), and practitioners installing the project are in complete understanding as to the map layout. Consultation on bank or shoreline toe erosion problems should be begin by contacting the local county conservation department and/or state agency as permits may be required. The permitting can take several days to months for approval so this should be done as soon as possible. Contact information for Vilas County and Wisconsin DNR shoreland information, regulations and permit requirements can be found here:

• The Vilas County Land and Water Conservation contact number is 715-479-3682, the website is found at http://www.vilasconservation.org/
• The Vilas County Zoning Department contact number is 715-479-3620, the website and Vilas County Shoreland Ordinances are found at http://www.vilascountyzoning.com/ordinances.html

• The Wisconsin Department of Natural Resources Water Regulations and Zoning Specialist for Vilas County can be reached at 715-365-8991, the WDNR Shoreland Zoning website can be found at http://dnr.wi.gov/topic/ShorelandZoning/.

Planting Decisions: Plant densities used at the five Northern Highland Ecological Landscape (NHEL) lakeshore habitat restoration projects, including LSG, are based on the Wisconsin Biology Technical Note 1: Shoreland Habitat (NRCS 2002). The planting density includes 25 ground cover plants (forbs and grasses), three shrubs, and one tree per 100 ft^2 –the low end of densities prescribed by the technical note. The species of trees and shrubs to be planted at LSG restorations can be guided by examining the NHEL lakeshores which have not been developed for housing. On this basis, we suggest 40-50% of sapling trees planted on future LSG restoration projects be conifers - white pine and balsam fir to be used most frequently as these species are common and somewhat resistant to deer browsing. Deciduous trees that commonly occur on NHEL lakeshores and are available at local and state tree nurseries include red maple, red oak, paper birch, and chokecherry – a mix of which could total 60-70% of all deciduous saplings planted, and are listed in order of their frequency of occurrence. As for shrubs, nearshore we recommend using tag alder, Spirea, sweet gale, and red-osier dogwood (60-80% of those planted), with lesser quantities (<10%) for winterberry, mountain holly, and leatherleaf. For upland shrub species we recommend that 60-70% include a mix of hazel, serviceberry, honeysuckle, and upland dogwood species - other species to consider in small numbers include Salix and Vaccinium species. We have had good success using sweet fern and bearberry on steep, sandy slopes that are highly erodible. These species should be planted at higher densities (six/100 ft^2) as we have found they are adaptable to drier soils and can thrive on degraded and low nutrient soils. Ground cover species (forbs and grasses) chosen will depend on site conditions and nursery availability; we recommend consulting with a local botanist, forestry personnel, and wildlife managers to develop a list.

Addition of Wood to Restorations: Since it may take decades for downed woody material (DWM) to naturally accumulate on lakeshores altered for housing, augmentation of DWM should be considered when planning restoration projects. DWM is critical to ecosystem function, provides habitat to a variety of wildlife, promotes plant health and growth, and provides nutrients to soils. Furthermore, the addition of DWM can reduce fluctuations of soil moisture and temperatures, thus reducing stress to new plantings. DWM should be obtained within 10 miles of the restoration site as so to use site-specific material and to reduce the risk of introducing disease (e.g., emerald ash borers, birch-leaf minor, oak wilt, etc.).

Plant Source: Gravel culture (GC) and spring bare root (BR) trees and shrubs should be considered for restoration projects. They reduce the cost of plant material yet often match grow rates of container (CT) plants. However, logistics need to be considered when using GC and BR. First and foremost, plant roots cannot be allowed to dry out during transport to the site and must be kept moist on site if not immediately planted. This can be accomplished by having a water tank of appropriate size to hold the GC plants, with the entire root ball submerged in water. For spring BR plants, roots can be kept moist by covering with damp wheat or oat straw and storing out of the sun until planting. Both GC and BR should be planted as soon as possible once they have arrived on site. Then once planted irrigation and mulch should be applied for an extended period of time. Of the GC species selection, and based on this study's results, hazel, serviceberry, dogwood, and black chokeberry would be good candidates for restoration activities. Contact study authors for a list of local GC vendors. As for BR species, and based on LSG results, all tree and shrub species from the list are good candidates with an emphasis on hazel, serviceberry, dogwood, black chokeberry, red oak, red maple, and paper birch. Preliminary results indicate GC conifers may be more robust than BR conifers, however continued monitoring of planted conifers is required to reach a definite conclusion.

Lake Bank and Toe Erosion Control: We recommend a geotextile bag system for stabilizing and establishing vegetation on steep, sandy slopes that are highly erodible. The newly installed bags require frequent irrigation to prevent bags and the plants between from drying, and newly planted restorations should be irrigated thoroughly (at least 1" precipitation per week). The logistics of delivering and placing bags can be challenging as each weighs 50 – 80 lbs. Other techniques such as erosion control mats, both coconut coir and straw mats, in combination with geotextile bags can be beneficial in reducing runoff and establishing vegetation on less severe slopes. Straw mats degrade more quickly than coir logs or bags, thus may be more useful for establishing vegetation from seed rather than plug. The netting can persist but becomes buried in the duff over time. Snakes and amphibians have been reported ensnared by the material in other studies, however it was not observed on this study. Erosion control mats with biodegradable netting are available. If property owners chose to install a geotextile bag system we recommend consulting with a local landscaper who has experience with this technique. If erosion blankets are the choice, these can be installed by a capable landowner, but advice as to method of installation should be sought. In regard to toe erosion, the coconut coir log (e.g. biolog) works well in reducing toe erosion and establishing shoreline vegetation. The biolog is designed to degrade within 5-8 years at which time the native vegetation should be sufficiently established to stabilize the lake shore. A combination of earth anchors attached to steel cables and hardwood wooden stakes works well to secure biologs to the shoreline and lake bed. To properly secure biologs to the lakebed requires special tools and experienced personnel. Once biologs are installed, we recommend planting native wetland forbs, grasses, sedges and rushes between the biolog and shoreline, no farther than 30cm (12") apart. In addition, wetland shrubs such as red-osier dogwood, tag alder, spirea, sweet gale, and leather leaf should be planted every third plant. However, biologs have limitations at sites with high water level fluctuations (often due to dam control) - if waves over-top the biolog, the shore can be scoured from behind and beneath and the anchoring system undermined. This impact can also occur at lakes with long fetch distance, thus high wave action – which can be exacerbated by steep shorelines or in areas with much wake action from boating. Implementation and enforcement of no-wake zones can reduce wave damage to vulnerable shorelines. Additionally, biologs are susceptible to ice heaves during spring breakup, which can have a drastic effect on planted vegetation and the biolog itself. If the shoreline is susceptible to ice heave (which can be determined by contacting a private landscapers, county, or state lake management staff), a combination of rip-rap and biologs could be used, but will require a permit application and approval. Because of this requirement, we recommend property owners consult with experienced landscapers for guidance on permit application, selection of proper biolog size and type, as well as for the actual installation. We successfully used tree drops at 4 LSG properties to reduced toe erosion, create fish habitat, and potentially assist in establishment of aquatic macrophyte beds. These techniques have been highly successful and popular to date. Landowners should consider this practice if appropriate for their property, however it is recommended that practitioners contract practitioners experienced in the technique. Also, an approved WDNR waterway permit is required prior to placement of tree drops – application materials can be found at WDNR website *http://dnr.wi.gov/topic/waterways/documents/permitdocs/gps/gp-treedrop.pdf*.

Irrigation: It is essential that newly planted restoration sites receive 1-2" of precipitation (either natural or by irrigation) weekly during the first growing season - even more if extremely hot and dry. The high amount of precipitation can reduce transplant shock which plants can experience. Irrigation should occur early in the early morning or after sunset to reduce evaporation. Restoration projects will benefit from an automatic irrigation system if practical. This will allow practitioners to program watering events. If it is not possible to obtain an automatic irrigation system then a small 110 volt electric or gas powered water pump can be used with the lake as the water source and garden hoses and sprinklers. However, this technique requires practitioners to visit restoration sites at least twice a week to operate pumps or recruit landowners or volunteers to monitor restoration sites and operate pumps. If a drilled well is available, and water use is not limiting, then a household sprinkling system can also be used.

<u>Restoration damage from deer, cottontail rabbits, and snowshoe hare:</u> We recommend using fencing to abate browsing by deer that often occurs on many developed lakes in Vilas County. The fence is a one-time purchase and the cost can be significant (approximately $2.60/foot), depending on the amount of fence needed – the entire area restored should be surrounded on all sides by the fencing for a minimum of 3 years. The fence may require maintenance periodically as trees and tree branches can fall and damage the fence. Developing a monitoring routine is critical – particularly if the property is only seasonally occupied. When used, deer repellent sprays need to be applied frequently as new plant growth emerges. We have observed that deer will become less deterred by repellents over time; therefore, switching repellents throughout the growing season and winter months is necessary. Additionally, we have noted where deer are fed by lake residents (corn, salt/mineral blocks or livestock hay), deer densities are very high, often congregating the local herds within several properties. This concentration of deer can damage or kill a significant proportion of a restored lakeshore habitat, even when first protected by fencing (personal observations). We suggest that when lakeshore property owners initiate a restoration, they stop feeding the deer and suggest their neighbors curtail providing supplemental food for wildlife. Additional work is required to identify tree, shrub, and ground cover species that are less preferred by deer, but provide habitat value. No deer feeding should occur where lakeshore habitat restoration projects are underway – we recommend no deer feeding occur within a minimum of 500 feet of lakeshores to protect native trees, shrubs, saplings, and groundcover which are planted for wildlife habitat and landscaping.

Recommendations to the Little St. Germain Lake Protection and Rehabilitation District

For all measured variables of water quality, the health of Little St. Germain Lake continues to worsen, with all lake basins showing declining trends in water clarity and increasing indices of eutrophication. This change in lake water quality threatens Little St. Germain lakeshore property values and poses a real threat to the health of the lake and its fishery, and to local tourism.

Several studies have evaluated the sources of nutrient enrichment to Little St. Germain Lake. A dam in the outlet of Little St. Germain Lake maintains water levels 5' above the natural shoreline and the lake experiences 1.5' seasonal water level fluctuations, "natural nutrient enrichment" occurs via the lake inlet (Muskellunge Creek), and seasonal remobilization of in-place sediment phosphorus results in extensive algae blooms. While no solutions have been identified to rectify this problem, research conducted on northern Wisconsin lakes (Graczyk et al. 2003) shows nutrient yield and overland run-off is lower along wooded shorelines as opposed to shorelines where natural vegetation has been replaced by managed lawns.

On the basis of these findings, we recommend to the Little St. Germain Lake Protection and Rehabilitation District that they promote lakeshore habitat restoration and conservation as a management practice to all Little St. Germain property owners. This practice alone will not resolve all water quality issues facing Little St. Germain Lake; however it will likely facilitate in reducing nutrient input while at the same time increasing the amount of wildlife and fish habitat.

The following action items are recommended to increase the practice of lakeshore habitat restoration and conservation on Little St. Germain Lake:

1. Onterra LLC produced a Town of St. Germain Lake Management Plan in which they mapped shoreland zone condition on 5 lakes in the town of St. Germain (Found, Lost, Lake Content, Big St. Germain, Fawn – Onterra LLC 2013, pages 31-32). This mapping should be conducted on Little St. Germain to identify portions of the lake most in need of lakeshore habitat restoration. Property owners should be provided with this shoreland condition map and those in the most impacted areas should be provided with restoration incentives and information.

2. The Final Report contains Preliminary Best Management Practices for restoring lakeshore habitat on Little St. Germain Lake (see Chapter 4). These practices should be shared with property owners interested in restoration, as well as a list of vendors with the capabilities of assisting in implementation.
3. White-tailed deer can damage lakeshore plant communities by over browsing. Feeding of deer can result in very high numbers of deer around developed lakes. No deer feeding should occur where shoreland restoration projects are underway – we recommend no deer feeding occur within a minimum of 500 feet of lakeshores to protect lakeshore habitat.
4. Vilas County Land and Water Conservation Department offers a cost-share program which provides partial reimbursement to property owners who conduct approved shoreland restorations (http://www.vilasconservation.org/index.html). Information regarding this program should be made available to property owners.
5. LSGLPRD and project scientists should share the Little St. Germain Lakeshore Habitat Restoration Final Report results through public meetings, factsheets, and various outreach materials made accessible through the LSGPR District website: http://www.littlesaint.org/.
6. An information kiosk should be placed at the public boat landing describing project objectives. An example of kiosk signage can be found as an attached file, supplemental to the Final Report. The placement of small signs at the 6 lakeshore habitat restoration projects on LSG could identify the property/ project as a Demonstration Site – permission from landowners should be sought.
7. Continue lakeshore habitat and wildlife surveys in 2014 and beyond to document vegetation and wildlife response. These findings should be made available to property owners upon completion.
8. Burnett County and UW Extension have produced a 2013 report "Shoreland Habitat Protection Social Marketing Strategies" by John Haack and Brett Shaw. This report describes successful education and outreach methods used to promote shoreland restoration on Des Moines and Long Lakes in Burnett County *http://basineducation.uwex.edu/stcroix/Links/CBSM/campaignFAQ.pdf* . Recommendations from this report should be considered when promoting lakeshore habitat restoration practices on LSG. The report is available from this project's authors.

Comments from Project Participants

My first comment would be how simple the process was. I think if any property owner knew that they could do something so beneficial for their lake, with such little effort, that a lot more would be inclined to sign up. However, people that did consider it were often spooked by the thought of "government involvement" in their personal property. That notion kept a lot of folks on the sidelines. Downplaying that fact in future projects would get a lot more land-owners on-board.

Getting that public education out there is still a challenge however. Everyone wonders what the fences are for, but there is very little in the way of accessible information about the project. We included an explanation about it, and the lake benefits thereof, in each of our rental units. But having similar information at the boat landings, other resorts, the chamber, or even posted at the sites themselves so people can read about it when they see it (often from their boats) would have gone a long way in spreading the word.

The tree drops in particular are a huge hit on our lake as they constantly get fished during the open water season. I can only see two of them from my house, but it is unusual not to have a boat anchored off one of them and fishing, every day when I come home from work. Not only are they fisherman attractors, but they actually hold fish. Schools of pan-fish use the branches all summer long, and many people catch the occasional bass off them yet besides.

The renters are a bit indifferent to the yard use thus far because our fences are still up. I think once those fences come down, and people can walk through and see how the plantings are controlling erosion, providing habitat, etc., there will be a lot more positive feedback.

I've had people tell me, that pontoon ride our lake once in a while, that it looks run-down and un-kept, primarily because of the tree-drops and shoreline cover. There is a mind-set out there that thinks a beautiful lake lot is one that is totally cleared and professionally landscaped right to the water's edge. For instance, Lake Minocqua is often cited as a prettier lake from that regard. Educating people how harmful those practices are to a lake, and teaching them that natural cover is the true beauty, is the essence of this project.

Since being involved with this project it has opened my own eyes to the shoreline abuse that it running rampant out there. Being a vacation home contractor I'm on lake-front properties every single day, and I can't begin to tell you how much filling, dredging, shoreline cover removal, and other harmful activities that I see. I went through a phase of reporting such activities for a while, but there's virtually no enforcement of these policies, so the vast majority of violations continue unchecked. As a point of reference, I bet I could cite 50 recent examples on our little lake alone. So, all we can do is set a good example, and hope that someday it will start to at least slow this current trend.

Brad Waldmann, Waldmann Construction, St. Germain, WI.

While we always noticed the habits of the wildlife on and around our property and shoreline, we have taken a greater interest since we were included in the restoration project. We also make it a point to watch the progress in most of the other areas of the lake included in the restoration project. Just hearing about the restoration project at a lake association meeting got Paula interested in planting a wildflower garden in an area where it was difficult to grow grass. So when our property was included in the restoration project, she was into her second or third year of working to get her plot established.

The first year of the restoration project we were most concerned about getting the planted area watered sufficiently so the plants had a chance to get a good footing in spite of the lack of rain. After the first winter we were pleasantly surprised to see how almost everything in the planting came back and how healthy everything looked.

This second year we looked forward to getting up to see whether everything was still doing well. One thing in which we were particularly interested was to see if the Canada yew plantings were successful. While most every yew appeared to survive the first winter, we had expected to notice more new growth. I'm sure this will be one part of the planting that we will follow very closely going forward.

To date we haven't noticed any new birds visiting the feeders and we will be watching to see if there is any additional wildlife that visits the planting once the fencing comes down in the future. There was no evidence yet of a nest in one of the wood duck houses I checked this fall so I continue to hope this project will help attract wood ducks.

The last 18 months have been an interesting and rewarding experience and it is nice to be a small part of a much larger effort to improve the lake. We appreciate being included in the restoration project and look forward to working with the team in the future.

Paula and Frank Skweres, St. Germain,WI.

Comments from Project Contractors

Our business, Hanson's Garden Village, LLC, Rhinelander, WI, is significantly impacted by our involvement with lakeshore restoration projects. We got into the business of lakeshore restorations early and with as much emphasis as we felt was appropriate for the amount of potential demand. Ten years ago most of the demand was for "lawns and retaining walls", which was an activity we avoided (and was sometimes not legal anyway). Slowly the demand for projects that were more lake and habitat friendly came along. Projects like those on Little Saint Germain have provided us important business revenue in the short term, but just as importantly will hopefully create more business in the future as people see and appreciate what can be done with native plants and appropriate erosion control practices. We will need that to happen to justify the very large investment in time and inputs to become a valid source of native northern Wisconsin plants.

Purchases made by the Little Saint Germain Lake Protection and Rehabilitation District provided approximately 3% of our firms' total gross income over the period covered by the grant monies. During that period, sales of native plants and materials for restoration purposes approximated 12% of our gross income and supported about two full time equivalent job positions here. Those positions, however, do not exist in a vacuum. The infrastructure, greenhouses, delivery capability and other inputs for growing or providing these products would not, at present, be financially supported on their own. This means that this kind of business is quite valuable to our company as a part of the mix of business that we do, but would not at present adequately support an independent business only involved with restoration products. But we are happy with the business that exists now as part of our operations, and we are hopeful about future gains through more widespread recognition of our offerings and/or because of more interest from the general public in these kinds of plants and products. I am also in agreement with those who state that the economy of Northern Wisconsin is heavily dependent upon the lakes, and that healthy lakes will be the most capable of contributing to the local economy in the long run. So, to some extent, we are merely trying *to do our part to provide for a good economic future by being able to supply some of what is needed to help keep our lakes healthy.*

Brent Hanson, Owner, Horticulturist, and Landscape Designer, Hanson Garden Village, Rhinelander, WI.

We started doing shoreline restorations in 2005. It was a key player on helping us make it through the collapse in 2007. We are noticing that our clients are asking us to educate them on natural shoreline restorations. I would say approx. 35% of our calls are for Shoreline restoration and out of that about 23% continue through with the install. We have seen an increase in interest in shoreline restorations in the last five years and foresee it to continue to grow.

Jason Bach, Owner, Horticulturist, and Landscape Designer, Wild Wood Custom Landscape & Design, Eagle River, WI

If I add up all the restoration work we've did in the past couple seasons, it probably was 4 or 5 percent of our total volume, some with the DNR and the cost share program, and some with homeowners on their own. The program seemed popular and brought good awareness to the need of shoreline restoration. We had clients that didn't want to wait on the cost share program, and paid for the work themselves. Some had friends and neighbors in the program, and saw the process/results. That awareness and impact is above and beyond any tax money spent on the program.

Mike Krueger, Owner, Horticulturist, and Landscape Designer, MK Landscape Company LLC, Eagle River, WI

Chapter 1. Introduction

In 2007, the Wisconsin Department of Natural Resources (WDNR) Bureau of Science Services initiated a new research effort, the Wisconsin Shoreland Restoration Project (WSRP). Project partners include Michigan Technological University (MTU) and the Vilas County Land and Water Conservation Department (VCLWCD) with participation from local private landscapers, nurseries, and environmental consultants. To date, extensive lakeshore habitat restoration projects have been completed at Little St. Germain, Found, Lost, Crystal, and Moon lakes in Vilas County. Long-term maintenance and monitoring continue at the sites to evaluate the success and benefits of the restoration practice. In this Wisconsin Lake Protection Grant Final Report, we describe the restoration efforts on Little St. Germain Lake, preliminary monitoring results from all 5 restoration sites, and recommendations for continued restoration efforts.

Project Concept

A healthy lake ecosystem is a function of good water quality and intact lakeshore and aquatic habitat and food webs. Human alteration of lakeshore and aquatic habitat can result in changes to lake water quality (due to increased nutrient loading), decreases in native plant and animal species diversity, an increase in exotic invasive species, and changes in the populations of individual fish and wildlife species. Lakeshore habitat restoration is currently being promoted as a management action which can improve ecosystem health at sites where lakeshore habitat has been substantially altered. Lakeshore habitat restoration is defined as a lake management practice that uses native trees, shrubs, and groundcover, along with natural and biodegradable materials (biologs, geotextile soil bags, sediment logs, soil lifts, woody material), to reduce lakeshore erosion and improve aquatic and upland wildlife habitat quality. Lakeshore habitat restoration will be considered a successful management practice if it 1) increases native plant abundance and diversity, 2) improves lakeshore habitat quality, 3) results in positive changes in wildlife abundance and diversity characteristic of the Northern Highlands Ecological Landscape (NHEL), 4) decreases the presence of invasive species, and 5) reduces overland and nutrient run-off. Documentation of these changes will enhance public support and implementation of these management activities. Further, development of Best Management Practices for lakeshore habitat restoration is required to provide property owners, restoration practitioners, and lake associations with the tools necessary to maximize the benefits of this practice.

With technical support from WDNR Science Services and Michigan Technological University School of Forest Resources and Environmental Science and regional environmental consultants, the Little St. Germain (LSG) Lake Protection and Rehabilitation District implemented shoreland habitat restorations at 6 private properties and is conducting long-term monitoring to quantify the ecological benefits of the restoration. In this project, we 1) initiate surveys to quantify the ecological benefits of lake buffer restoration for wildlife populations 2) assess the feasibility of using the LSG restoration project to conduct experiments to quantify the benefits of re-establishment of riparian buffers to reduce overland surface-water and nutrient run-off, and 3) conduct experiments to develop Best Management Practices for shoreland restoration on LSG.

Project Location and Regional Description

Little St. Germain Lake (Figure 1) is located in the township of St. Germain in Vilas County, Wisconsin, USA.

Figure 1 Little Saint Germain Lake, Vilas County, WI, USA

The lake occurs in an ecological landscape known as the Northern Highlands – see Appendix 1-A for information related to the Northern Highland Ecological Landscape (NHEL) as found at the WDNR website (*http://dnr.wi.gov/topic/landscapes/index.asp?mode=detail &landscape=5),* along with a history of European settlement on LSG (Appendix 1-B).

Little St. Germain Lake Characteristics

Little St. Germain is one of 21 impoundments operated by Wisconsin Valley Improvement Company (WVIC), originally to float cut timber downstream to mills, now mostly to provide seasonal water storage for downstream power, industry, and recreational use. The level of Little St. Germain, which was dammed in 1882, has been maintained about 5 feet above its natural level since 1929, and is annually drawn down about 1.5 feet from December – March, potentially resulting in seasonal destabilization of the lake bank. Little St. Germain is a multi-basin lake (upper East Bay, East Bay, No Fish Bay, West Bay, and South Bay) with a total of 977 surface water acres. Maximum depth ranges from 10-16 feet in East Bay, No Fish Bay, and South Bay to 53 feet in West Bay.

We used data from the Wisconsin Citizen Lake Monitoring Network to assess recent water quality characteristics of Little St. Germain Lake (*http://dnr.wi.gov/lakes/clmn/Stations.aspx ?location=64*)at 4 monitoring sites, as well as to evaluate long-term trends at one site, West Bay. A map of the monitoring stations can be found below (Figure 2), and the data for the monitoring stations can be found at these links:

http://dnr.wi.gov/lakes/CLMN/Station.aspx?id=643170
http://dnr.wi.gov/lakes/CLMN/Station.aspx?id=643171
http://dnr.wi.gov/lakes/CLMN/Station.aspx?id=643172
http://dnr.wi.gov/lakes/CLMN/Station.aspx?id=643557

Figure 2 Location of Little St. Germain lake monitoring sites

Table 1 Average July/August Secchi and water quality parameters for 4 collection stations on Little St. Germain Lake (WBIC 1596300) 2011-2013.

Collection Station (ID)	*Secchi*	*Chlorophyll a (ug/L)*	*Total Phosphorus (ug/L)*	*Chlorophyll TSI*
West Bay (643171)	8.7	9.4	18.1	50.5
South Bay (643172)	4.1	23.0	35.9	57.4
Upper East Bay (643557)	2.2	58.6	73.4	65.3
North East Bay (643170)	2.2	63.3	83.6	66.0

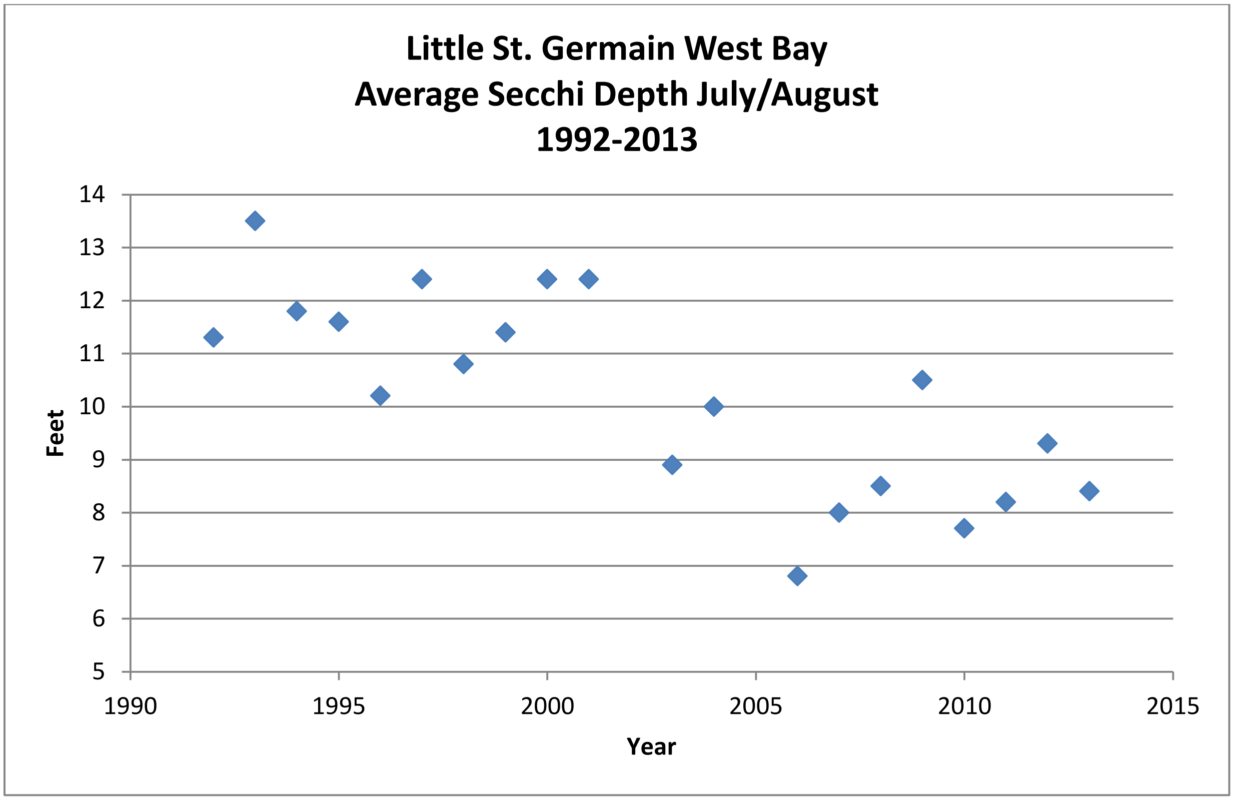


Figure 3 Trends in West Bay average July/August Secchi depth (feet) 1992-2013.

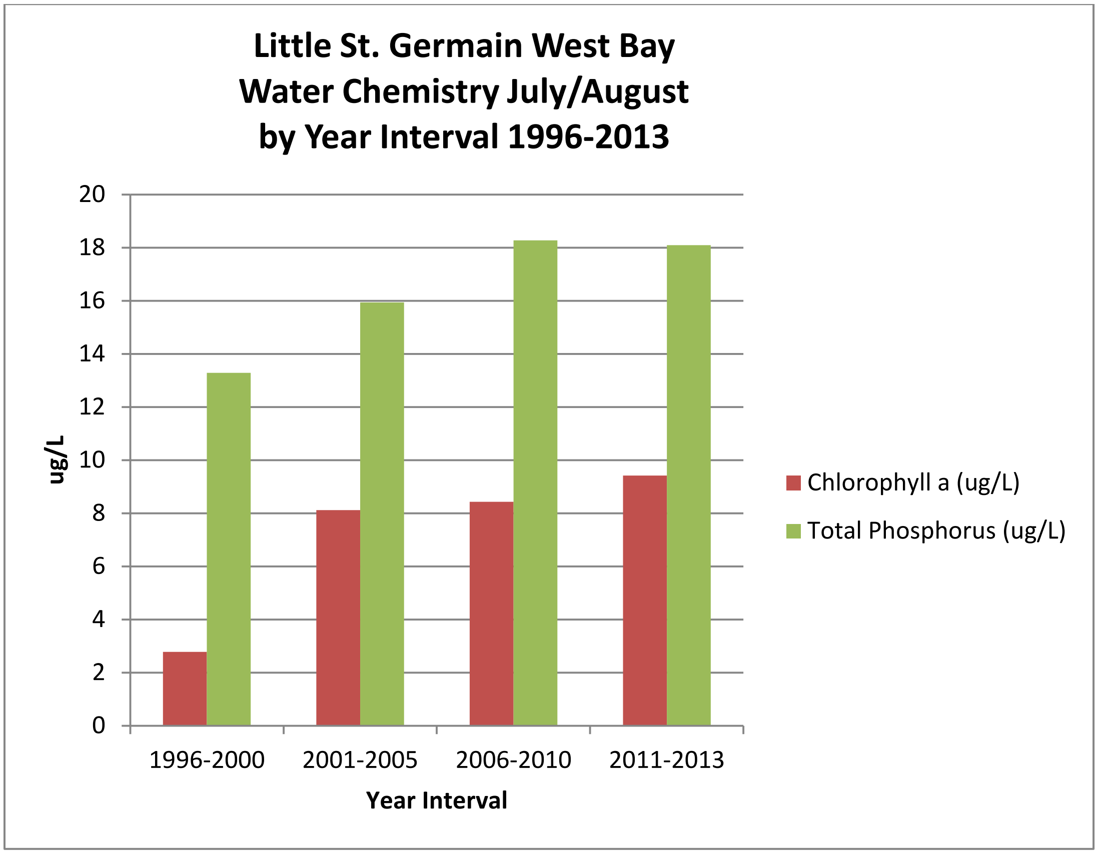


Figure 4 Trends in West Bay average July/August chlorophyll a (ug/L) and total phosphorus (ug/L) 1996-2013.

Water quality has recently declined across all basins of Little St. Germain Lake (Robertson and Rose 2000). The West Bay has consistently scored the best in water quality in terms of trophic status (as indexed by Chlorophyll TSI, see Table 1). The South Bay has intermediate, and East Bay the worst water quality (Table 1). While LSG water quality was relatively stable 1991-2000, it has since worsened. The West Bay has changed in trophic status from oligotrophic to mesotrophic, and recently to eutrophic (Figures 3-4). The South Bay changed from a mesotrophic status to eutrophic, and the East Bay from eutrophic to occasionally hypereutrophic (Robertson *et al*. 2005). Seasonal trends in water quality show that degradation occurs during the summer when phosphorus contributions from inflows are lower but internal phosphorus loading is elevated. The degraded water quality has negative impacts on aesthetics and fish populations, leading to lower enjoyment of the lake by residents and others who use the lake for these purposes (Robertson *et al.* 2005). The soils in the watershed consist of mainly well-drained sand and sandy loam types. These soils are thought to be naturally high in phosphorus content.

Appendix 1-A

The Northern Highland Ecological Landscape

Figure A-1. The Northern Highlands Ecological Landscape (from WDNR website *http://dnr.wi.gov/topic/landscapes/index.asp?mode=detail&landscape=5)*

"Size - 2,081 square miles (1,331,970 acres), representing 3.7% of the total land area of the State of Wisconsin.
Climate - is typical of northern Wisconsin, with a mean growing season of 122 days. The mean annual temperature is 39.5 deg. F, the lowest of any Ecological Landscape in the state and almost 2 degrees lower than other northern ecological landscapes. The mean annual precipitation is 31.6 inches, similar to other northern ecological landscapes. The mean annual snowfall is 68.1 inches, the second largest amount of snowfall in the state. Only the Superior Coastal Plain receives more snowfall (87.4 inches). Snowfall varies dramatically within the Northern Highland, with the northern part of the Ecological Landscape being within the outer edge of the lake effect "snowbelt" of Upper Michigan and northwestern Wisconsin. The cool temperatures, short growing season, and sandy soils are not adequate to support agricultural row crops, such as corn. Only about one percent of the Northern Highland is used for agricultural purposes. The climate is favorable for forests, which cover more than 76% of the Ecological Landscape.
Bedrock – The bedrock is predominantly igneous and metamorphic rock, generally covered by deposits of glacial drift from 5 to over 100 feet in depth.
Geology & Landforms - Most of the Ecological Landscape is an undulating, gently rolling glacial outwash plain with many kettle lakes, wetlands, and bogs. Remnant moraines and drumlins occur often, with their lower slopes covered with outwash sands.

Soils - Most soils are sands and gravels, some with a loamy mantle. Soil productivity is low compared to glacial till but relatively high for outwash sands. Wetlands are numerous; most have organic soils of peat or muck.

Hydrology - There is a globally significant concentration of glacial lakes in the Northern Highland: 4,291 lakes; 1,543 miles of streams, including the headwaters of the Wisconsin and Manitowish-Flambeau-Chippewa river systems. Many lakes are connected by small streams. Rare aquatic species and extensive wetlands occur here.

Current Landcover - 48% upland forest, 34% wetlands (both forested and non-forested), 13% open water, 5% grassland and open land, and 1% urban.

Socioeconomic Conditions (based on data from Iron, Oneida and Vilas counties)

Population - 65,660, 1.2% of the state total Population Density - 23 persons/ sq. mile

Per Capita Income - $26,853

Important Economic Sectors - Retail trade (16%); accommodation and food services (11%), construction (10%) and real estate, rental, and leasing (5%) sectors led in 2002, reflecting high recreation and rural development. Forestry, residential development, and recreation have the largest impacts on the Ecological Landscape's natural resources.

Public Ownership - 30% of the land area and 43% of the forestland in the Ecological Landscape is in public ownership. Some of the larger properties are the Chequamegon-Nicolet National Forest, Northern Highland-American Legion State Forest, Turtle-Flambeau Flowage, Willow Flowage, and the Iron, Vilas, and Oneida County Forests.

Other Notable Ownerships - Tribal ownership is significant, as the large reservation of the Lac du Flambeau band of the Ojibwa Nation is here. The University of Wisconsin maintains research-oriented Field Stations at Trout Lake and Kemp Station, and also has stewardship responsibilities for several ecologically significant tracts.

Considerations for Planning & Management - There has been a steady increase in both seasonal and permanent residents, creating a pattern of dispersed urbanization. This has been especially evident along shorelines, where habitat loss has occurred in the littoral zone and on lands adjacent to the shore. Residential development is also increasing in the forests which surround many lakes. Population growth and associated development appear likely to limit some management options in the future, such as the ability to manage at large scales, maintaining ecosystem connectivity, protecting important spawning, nesting, and foraging habitats. Restoration of shoreline habitats and the processes that maintain them will become more difficult over time. Several large industrial forest holdings have changed ownership in recent years. In some cases these properties have been sold to public agencies, but they may also be sold to other industrial owners, real estate developers, or other private entities".

http://dnr.wi.gov/topic/landscapes/index.asp?mode=detail&landscape=5

Appendix 1-B

History of Settlement on Little St. Germain Lake

Following the historic harvest of NHEL old growth forests (>3 billion board feet of primarily white- and red pine) in the late1880s – early 1900s, many logging and lumber companies divested themselves of their landholdings, with vast expanses of the region left abandoned and cut-over by the early 1900s. The original forests that existed pre-European settlement, that had surrounded Little St. Germain Lake were logged primarily during the 20 year period 1890–1910. Following the cut-over, the region was marketed as an agricultural frontier, with land developers and speculators purchasing extensive tracts of stump fields which were then marketed as future farmsteads to interested parties from southern Wisconsin to Eastern Europe. From the period 1900-1930, the current St. Germain Township was named Farmington. In addition, abandoned cut-over lands were offered for homestead claims. Such was the case of the F. Carly claim of 20 acres on the West Bay of Little St. Germain Lake in 1899 (Jackson, 2013). Initially farmed, the property became the first settlement to become a resort destination on LSG in 1901 - the Lakeside Farm Resort. With land purchases 1913-14, Sisson's Resort opened on West Bay as did Greenwood Ranch Resort at the outlet of L. St. Germain Lake in South Bay (Jackson, 2013). During the early 20th century, travel to Vilas County resorts was by train, and resort staff would meet travelers at train stations, then transported by wagon and later automobile to their destinations. Resorts of this era catered mostly to the affluent, offering cabins and guest services which became known as the "American Plan" with all meals prepared for guests, and a resort store providing all the necessities as Eagle River (incorporated 1882) was a several hour round-trip on an unpaved road. Guided sport fishing was the most popular past-time. As the highway system developed and automobile travel became more common, travel to the "Northwood's" was opened to a broader segment of the downstate population. Additional resorts, many catering to the automobile traveler, opened on Little St. Germain during the 1920s, and despite losses during the Great Depression, the number of resorts on the lake increased to 23 by 1941 (Jackson, 2013). The resort industry increased again after World War II, and reached its highpoint during the 1960s. It was during this period that working families from Wisconsin, Indiana, Illinois, and Iowa made Little St. Germain a premiere resort destination – an industry dominated by "housekeeping cabins" where families were provided with fully furnished cabins with kitchens, at a price point accessible to blue-collar workers and their families from downstate. Families often stayed for 1–2 weeks and some families returned to the same resort for several generations. Over the most recent 40 years, a multitude of social and economic factors has once again transformed property patterns along the Little St. Germain shoreline. Many resorts have been subdivided into individual parcels, or cabins were "condominium-ized" (example – Sissons, then Perks, then West Bay Resort), many new year-round homes were built, and a few resorts expanded and modernized so that today, as one resort destination describes it- "*guest cottages, suites, luxury lodge homes and private log homes are sure to provide each guest with a memorable Northwoods experience*" (*http://www.blackbearlodge.com*). F. Carly's resort, established in 1901 as Lakeside Farm Resort, remains in business today as Jackson's Lakeside Cabins - a "housekeeping resort", new modern cabins have been recently added to the property (*http://www.jacksonslake side.com/*). Perhaps most important from the perspective of lakeshore habitat impact is the increase in housing density and property parcelization along Little St. Germain Lake's shores during the past 40 years – clearing of native vegetation for building, lake access, viewing, and recreation has resulted in the loss of habitat for fish and lake-dependent wildlife, while opening up additional avenues for nutrient loading to the lake, which already has exhibited decreasing water quality. Currently, there are 356 parcel polygons and 596 tax records (more than the polygons because of condos) for parcels on Little St. Germain Lake *(A. Grassl, Vilas County GIS Analyst, personal communication, 11/18/13).*

Chapter 2. Measuring the Ecological Benefits of Lakeshore Habitat Restoration on Little St. Germain Lake

Background

The water quality of Little St. Germain Lake, as indexed by Secchi disk depth, has notably worsened over the past 5 years (Figure 3). Lake District residents are interested in implementing management strategies to improve water quality and reduce shoreland (overland) nutrient run-off, and to improve lakeshore habitat quality. Recent studies conducted by WDNR Science Services and the UW Trout Lake Research Station have documented dramatic alteration of lakeshore habitat (terrestrial and littoral zone) on many lakes in northern Wisconsin. The alteration is primarily due to shoreland housing development associated with negative changes in native plant communities, simplification of habitat structure, and changes in fish, amphibian, and bird populations. Many of the findings have been published in peer-reviewed scientific journals (Elias & Meyer 2003, Lindsay *et al*. 2002, Woodford & Meyer 2002; Sass; Haskell et al. 2013). Another study in the regions demonstrated nutrient run-off was less at wooded lake lots compared to those with managed lawns (Graczyk et al. 2003).

We developed site-specific management recommendations for LSG property owners who participated in the lakeshore habitat restoration program, completing restoration projects at the properties 2011-2012. Restoration activities included conservation and restoration of native vegetation, removal of exotic and invasive species, placement of physical structure such as downed trees and down woody material for fish and wildlife habitat, bank and toe erosion control with biodegradable materials, and other management techniques designed to enhance native plant and animal communities and to reduce overland erosion and nutrient run-off.

Terrestrial vegetation and wildlife surveys were conducted prior to commencement of restoration effort, including baseline measures of relative abundance and diversity of native vegetation, pollinators (bees), birds, and small mammals. Physical characteristics of habitat such as vegetation structure and canopy closure were also measured. Surveys will be repeated annually as restoration projects mature– methods follow those described in detail in Haskell (2009).

The project focused restoration efforts on 500 meters of LSG lakeshore where habitat impacts are significant and private landowners agreed to participate in the restoration efforts.

Incentives (free materials and labor) were offered to recruit participation. The study design also included a control shoreline on LSG, 500 meters of shoreline with significant habitat alteration that did not receive restoration efforts. Biotic survey results are compared between the LSG control and restoration shore sites, and to a "reference" shoreline (Star Lake, Plum Lake Township) where LSG results are compared to benchmark values established through identical surveys at an undisturbed shoreline.

Results of the LSG restoration are compiled with data from completed projects at Moon, Found, Crystal, and Lost Lakes, Vilas County. The long-term goal of this restoration project is to assess whether wildlife habitat structure, native plant and wildlife diversity and abundance changes differently over time on "treated" (developed lakeshore with habitat restored) shorelines as compared to "control" (developed with no habitat restoration) shorelines, and to assess whether the habitat structure, native vegetation, and wildlife populations on the "treated" shoreline trends towards those measured at pre-selected "reference" (no housing development) lake shores.

Objectives

1. Solicit private landowner project participation through Little St. Germain Lake Protection and Rehabilitation District newsletters and annual meetings. Hold public meetings to present the project and to solicit participation. Follow up with interested property owners with letters, phone calls, and personal visits.

2. Develop site specific shoreland restoration management plans for each property owner enrolled in the project. Landowners and project scientists will produce a site specific restoration plan that provides the maximum ecological value while integrating property owner land-use preferences.

3. Implement the restoration plan by planting and conserving native vegetation within the shoreland riparian buffer [defined as the area from the ordinary high water mark (OHWM) to 35' inland] and littoral zone of properties participating in the project. Remove all invasive plant species encountered. Directly involve members of lake associations, landowners, and citizen groups in the restoration projects.

4. Repair shoreland bank erosion and shoreline toe erosion using biologically degradable materials such as biologs, geotextile soil bags, straw blankets, sediment logs, as well as

development of impervious surface run-off management plans for rain gardens and retention ponds when appropriate.

5. Remove/replace impervious surface (asphalt, concrete), retaining walls and rip-rap within the 35′ buffer when feasible, replacing with bio-degradable materials and improved run-off engineering. Install tree-drops to enhance fish habitat structure and reduce wave and boat wake impact within the littoral zone.

6. Quantify the benefits of restoration by conducting periodic measures of habitat structure and native plant and wildlife abundance and diversity at reference, control, and treatment lake shorelands before restoration occurs and in subsequent years as the shoreland restoration continues to mature.

Methods

Landowner Enrollment

We recruited LSG property owners interested in participating in the Wisconsin Shoreland Restoration Project by conducting educational workshops and mailing educational materials/flyers in 2009 and 2010. Project scientists met with the Little St. Germain Lake Protection and Rehabilitation District (LSGPRD) Board of Directors on March 30, 2009 to present project goals, to offer to assist in grant proposal development, and pending funding, to implement the project, conduct data analysis, and prepare the final report. The LSGPRD held an open hearing on April 9, 2009 and the Board of Directors unanimously approved a motion to submit a WDNR Lake Protection Grant proposal for Shoreland Restoration on Little St. Germain Lake. The grant proposal was prepared and submitted to WDNR in May 2009 and approved for funding in September 2009. Following award of the grant, the Little St. Germain Lake District and project scientists held a public hearing for all Lake District property owners at the St. Germain Community Center on October 3, 2009, at which time a description of the project was made and a request for participants was offered. The meeting was announced by public notice, the Lake District newsletter and website, and by direct mail of a brochure to all 425 property owners within the Lake District. See below for an example of the Public Meeting Announcement. Finally, the Little St. Germain Lake Protection and Rehabilitation Spring 2010 Newsletter focused on the Shoreland Restoration Grant, and provided another description of project goals and the benefits to be received by property owners who participate. The newsletter was sent to 425 District property owners. Following these meetings, expressions of interest were received and were followed up with contacts by project scientists. Enrollment was low (2 property owners) so an additional mailing was distributed in August 2010.

Informational Meeting for Residents of the Little St. Germain Lake Protection and Rehabilitation District

Date/Time: October 3, 2009 10AM
Location: St. Germain Community Center

The Little St. Germain Lake Protection and Rehabilitation District has been awarded a Wisconsin Shoreland Restoration Grant to assist lakeshore property owners repair erosion problems and restore native vegetation to the shorelands. The district has been awarded a grant that will cover up to $100,000 of project costs. Enrolled property owners typically receive $3000 - $5000 of grant support per 100 feet of property restored, at no direct cost to them. The shoreline and wildlife habitat restoration research project will restore up to 1,500 feet of eroding or improperly developed shoreline. Project leaders are now working to identify Little St. Germain Lake property owners interested in participating. To that end, a public informational meeting will be conducted at 10AM, Saturday, October 3, at the St. Germain Community Center.

The meeting will be hosted by Dr. Mike Meyer, Wildlife and Forestry Research Scientist for WDNR Science Services Rhinelander office. Dr. Meyer has been conducting shoreline restoration/wildlife habitat research work on several lakes in St. Germain over the past several years. Shoreline restoration projects on Found, Lost and Moon Lakes are either completed or are underway. The grant funds are used to purchase native trees, shrubs, wildflowers, and erosion control materials including rain gardens, Biologs and Enviroloc retaining walls.

A slide presentation of the Found Lake and Moon Lake projects will start the meeting, followed by an open question and answer session to discuss the project's objectives and participating landowner benefits and requirements. All lakeshore property owners with an interest in participating in this project are encouraged to attend and learn more about the benefits this project can bring to their property. Interested parties can also sign up to tour restorations projects on Moon and Found Lakes

It's a great project with property owners, lakes, fish, and wildlife being the winners! Work on the project is scheduled to begin in the spring and summer of 2010.

Found Lake 2007-2008

Experimental Design

A habitat and wildlife sampling design was implemented to compare habitat and wildlife endpoints measured along 250 m of the "Treated" (developed/restored) lakeshore with those measured at 250 m of the "Control" (developed/unrestored) lakeshore on LSG Lake and an additional 250 meters of lakeshore on Star Lake which has most shoreland in public ownership ("Reference" lakeshore). Star Lake was paired with LSG Lake on the basis of similar lake characteristics (surface area, substrate, and lake type) as well as aspect, fetch, and slope, but having low levels of housing development.

Habitat and Wildlife

Habitat measurements were recorded prior to restoration on five 10 m x 10 m plots along the "Treated" shoreline. Within these plots trees ≥5 cm DBH, tall saplings & shrubs (≥30cm height) were identified to species and tallied, forest canopy and understory structure was also recorded. A Control transect was established on South Bay and the same habitat measurements were recorded. In addition, both avian and small mammal surveys were conducted in June and July on both transects. Concurrently, the same data was collected on Star Lake (Reference transect) using the same protocols; transects on both lakes will be compared to determine if restoration efforts meet or exceed the reference lake's habitat and biotic characteristics.

Vegetation Sampling

Each restoration, control, and reference lakeshores were divided into 50 m segments using GIS (Geographic Information System) software and segments labeled with consecutive numbers (1, 2, 3, etc.). Each 50 m segment was divided into 10 m sub-segments and coded as follows: 1a, 1b, 1c, 1d, 1e, 2a, 2b, 2c, 2d, 2e, etc. (1a through 1e represents the first 50 m segment and 2a through 2e the second segment). The intention was to survey one 10 m × 10 m (100 m^2) vegetation plot for each of the 50 m segments of the 250 m transect.

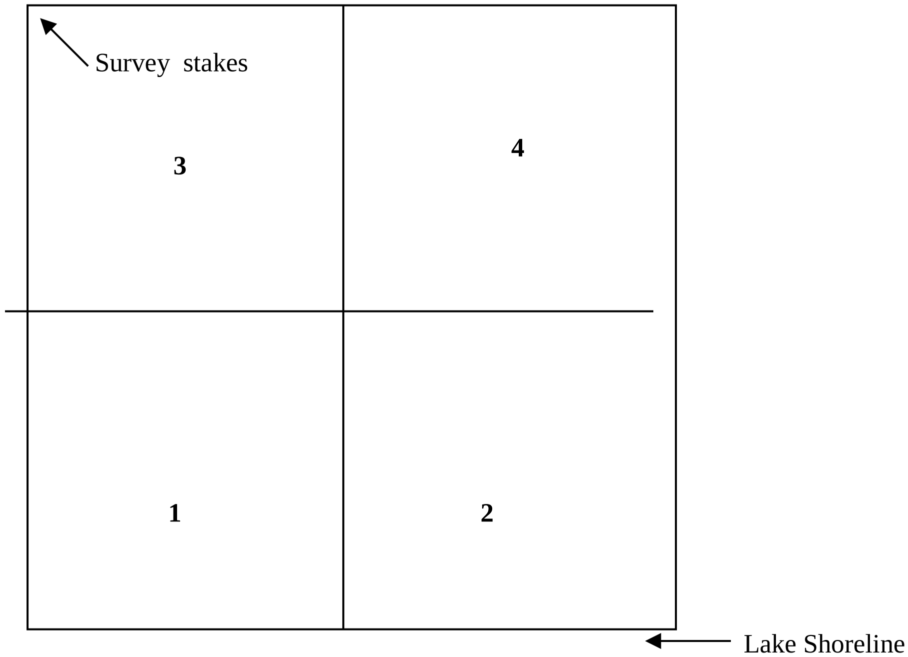


Figure 5 Example of 10 m × 10 m vegetation sampling plot with four 5 m × 5 m subplots LSG and Star Lakes in 2011. All live trees ≥ 5 cm DBH were recorded in plot and live saplings and shrubs were recorded in two subplots. All plot corner locations were marked by a survey stake sunken into the ground at corner of the plot.

An attempt was made to survey every point that fell on the letter "a" (i.e. 1a, 2a, 3a). Each survey plot always began to the right of the point (start of 10 m × 10 m plot at point, end of plot to the right when facing shore from the lake). However, if a point fell on a usage area or access area to the lake (e.g. designated for no restoration) then an alternate sub-segment was randomly picked, using a random number table, until the vegetation plot did not fall on a usage or access area. For example, if plot 3a fell on a usage area then another point was randomly picked such as 3b, 3c, 3d or 3e. A metal rebar (1.25 cm ×15 cm) with a 1.25 cm flat washer welded to one end was used for a permanent survey stake and driven flush with the ground at an inland corner of the vegetation plot. The metal stakes can be relocated in subsequent years with a metal detector to reconfigure and resample the plots. Each plot was divided into four 5 m × 5 m subplots (Figure 5).

All living tree and shrub species growing in the plots that were ≥ 5 cm diameter breast height (DBH; 1.37 m) within treated, control and reference lakeshores were identified to species and their DBH recorded. Two subplots were randomly chosen per plot and all live deciduous and coniferous saplings and shrubs that were ≥ 30 cm in height but having < 5 cm DBH were identified to species and tallied.

Habitat Structure

In order to measure canopy cover, gap fraction was calculated using WinSCANOPY™ 2005 software to analyze digital hemispherical photographs (Nikon Cool Pix 5000 and FC-E8 fisheye converter) taken at 50 cm above the ground and centered in each plot. Gap fraction is defined as a fraction of pixels classified as open sky in a region in the image [*Gap fraction* = number of pixels classified as sky in a region/total number of pixels in a region].

A density board (or checker board) 0.5m in width and 3.0m height with a 10cm × 10cm grid of black-and-white contrasting squares was used to measure understory foliage density and to estimate the percent cover at four different heights above ground (0-0.3 m, 0.3-1 m, 1-2 m, 2-3 m). Squares at least 50% obstructed by vegetation were counted and converted to a relative index of percent cover. The density board was placed at 1 m, 5 m, and 9 m inland from the shoreline at the edge of each plot. This gave a height and density profile within each plot at three different distances from the shoreline. Each measurement was taken at a distance of 10m while observer and the density board moved perpendicular away from the shoreline.

Downed Woody Material

Downed Woody Material (DWM) was also measured in each plot. DWM includes logs ≥ 10 cm in diameter and ≥ 150 cm in length and touching the ground at two or more points. Logs were identified to species where possible and grouped as conifer, hardwood, and unknown. The diameter at the base and log length from base to longest branch tip was recorded, as was branchiness (0-3) and decay class (0-5) (see definitions below). Logs that extend over the water were measured from the base to the shoreline and listed in notes as “measured to water.” Standing dead trees or snags ≥ 10 cm at DBH were also counted, identified to species (where possible), and branchiness (0-3) recorded. Tree and shrub stumps ≥ 10 cm diameter at the base of stump and cut or broken off below 1.37 m (DBH), and above root mass, were recorded, including the following characteristics: species (conifer, hardwood, unknown), and type of break (natural, un-natural, beaver). Branchiness for all stumps was assumed to be 0.

<u>Decay Class Definitions</u>

0 – Live tree touching the ground at two or more points

1 – Recent down wood (e.g. lacking litter or moss cover)

2 – Down wood with litter/humus or moss cover; bark sound

3 – Bark sloughing from wood; wood still sound

4 – Down wood mostly bark-less; stubs loosening; wood beginning to decay; logs becoming oval and in contact with the ground along most of their length

5 – Decay advanced; pieces of wood blocky and softened; logs becoming elliptically compressed

NOTE: paper birch retains its bark long after the wood has rotted; we scored logs of this species by the softness of the wood, not the presence/absence of bark.

Branchiness Definitions

0 – no branches

1 – few branches

2 – moderate number of branches

3 – many branches (full crown)

Avian Surveys

A dependent, double-observer 250 m line transect (LT) method was used to characterize bird communities along targeted lakeshores. Transects were placed in three lakeshore treatments: 1) Control, 2) Treated, and 3) Reference. Members of the North Lakeland Discovery Center Bird Club conducted the bird surveys concurrently on LSG and Star lakes in two separate visits in June 2011-2012. Transects followed the shoreline, and all birds seen and heard on the terrestrial side of each transect were recorded and tallied. Bird surveys were conducted between 0600 and 1000 hrs. Surveys were not conducted during rain or high winds (>20 km/hr), or when wave noise influenced detectability. Bird species diversity, richness and abundance were calculated for each treatment.

Small Mammal Surveys

No previous work has been conducted in northern Wisconsin to evaluate the effects of lakeshore housing development on small mammal abundance and distribution. Small mammal surveys were conducted late June to late July 2011-2013, and included two sampling events per transect. Sherman traps were placed parallel with each other and with the shoreline and within 10 m of the shoreline along a 250 m transect. One line of traps was placed within 1 m of the shoreline and the second line was approximately 10 m from the shoreline. Traps were placed at 10 m intervals along both trap lines for a total of 52 traps per transect. Each trap was baited with a mixture of rolled oats and peanut butter, and a handful of polyethylene fiber was added for bedding. Traps were covered with a ½-gallon cardboard milk container that provided captured animals with additional protection from inclement weather. Traps were opened for three nights at each transect, checked every morning and closed, then reopened in the late evening hours. All small mammals, other than *Peromyscus spp*. were identified to species. Observations on gender, reproductive status, overall condition, and weight were recorded for each captured animal. In addition, all small mammals captured were ear-tagged with a metal tag labeled with a unique number to document recaptures. Each individual received an ear-tissue biopsy for subsequent analysis for the prevalence of Lyme's Disease antigen (and sent to Marshfield Clinic Research Foundation for evaluation of tick-borne infectious diseases), and fur systematically searched to quantify total #'s of ticks. *Peromyscus* sp. captured were sampled using a buccal swab to collect salivary enzymes used in DNA analysis, conducted by Marshfield Clinic, in order to distinguish between the species of *Peromyscus leucopus* and *P. maniculatus*. All animals were released at the place of capture once the general condition of the animal was assessed and determined fit for release.

Pollinator Surveys

A goal of the Wisconsin Shoreland Restoration Project is to enhance shoreland buffer zones by supplementing existing vegetation with additional native trees, shrubs and ground-cover plants, replacing ecologically valuable coarse woody material and conducting erosion-control practices in order to mitigate development-induced overland and shoreline bank erosion. Several wildlife surveys (birds, amphibians, small mammals, and furbearer) are ongoing at selected shoreland restoration and control sites in Vilas County to determine whether there are benefits to wildlife by restoring lakeshore habitat at properties owned or managed as individual parcels. To our knowledge, no prior experimental research has been conducted in Vilas County to understand if lakeshore habitat restoration practices result in improved habitat for insect pollinators, specifically bees. A pilot study was conducted on Little St. Germain in 2013 to develop methods with which to test the impact of restoration on pollinator abundance. The full report of the Pollinator Pilot Study can be obtained upon request from the authors as "Supplemental Material." Excerpts from the report "**2013 Vilas County Pollinator Response Surveys; Final draft submitted: November, 25, 2013"** can be found below, in italics, and again in the Results section.

METHODS

Native bee relative abundance and species diversity were assessed at the restored and control sites twice during the period May 24th through June 28th using methods and protocols modified from Grundel et al. (2011) and Roulston et al. (2007). Modifications were made to incorporate logistical considerations as described by Sam Droege, USGS and published online at: http://online.sfsu.edu/beeplot/pdfs/bee%20bowl%20%20tip %20sheet1.pdf. Statistical evaluation of field data was analyzed with reference to Lebuhn et al. (2012) recommendation on considerations for establishing likelihood probabilities to detect a demonstrable difference in pollinator use between treatment types (restored vs. control) as described in Haskell et al. (2009) and representing the shoreland restoration practices applied by the WSRP.

Study Design

Native bee populations were compared between restored and unrestored (control) shoreland transects following an "impact-control" study design modified from the "before-after-control-impact" (BACI) design, used by the WSRP umbrella study (and described by Morrison et al., 2003), in order to account for the absence of "before" treatment measurements. The goal of this pilot study was to develop the methods, standard operating procedures, and to provide estimates on capture-rate variation in order to design and replicate an improved and scaled-up experiment to be conducted on the remaining study sites of the WSRP – pending available funding. Shoreland transects are represented by a series of five 10m x 10m vegetation plots arranged linearly (similar to Roulston et al. 2007) and parallel to the lake shoreline ordinary high water mark. See Figure 6 for illustration of the plot layout design. The area represented by each vegetation plot is considered a subsample contributing to a composite sample that represents the combined 5 plots (or transect) as shown in Figure 7. Results from all 5 plots are pooled to estimate bee relative abundance and species richness at the site or transect level to represent the experimental unit of study. Survey results were analyzed to develop total numbers, mean, standard deviation and coefficient of variation (CV) of bees captured per transect to describe and test for differences in relative abundance *(pooled and by species), species richness (and other diversity measures described in Magurran, 1988), and dominant species based on highest capture rates.*

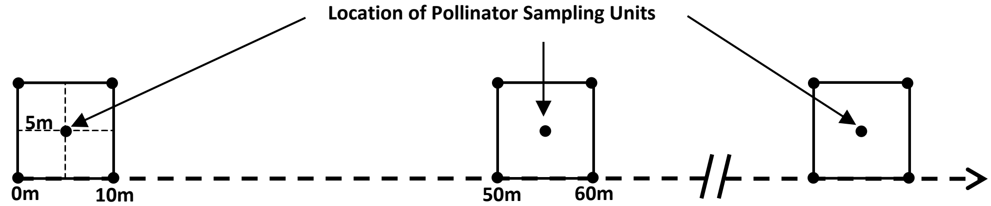


Figure 6 Hypothetical configuration of a survey transect with systematically placed 10m x 10mvegetation plots laid out parallel to the lake shoreline.

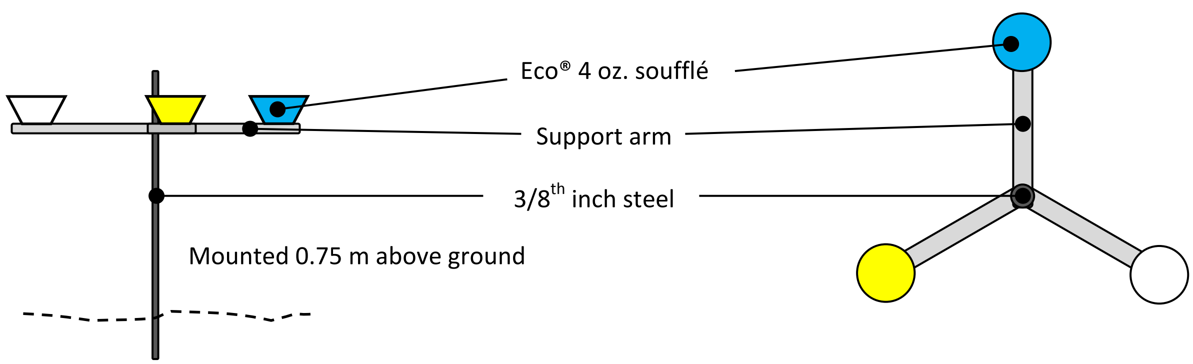
A) Restoration Transect (plots 1-5) *B) Control Transect (plot 1-5)*

Figure 7 Plot transect layout along the shoreland zone of the restored (photo A) and control (photo B) transects

Sampling Unit

A set of bee bowls is defined as three 4 oz. soufflé cups each painted one of three colors: fluorescent yellow, fluorescent blue and a standard opaque white color (S. Droege, USGS, in "Tips on How to Use Bee Bowls to Collect Bees). Each set constituted a sampling unit and was deployed as a unit in the shape of a triangle or 3-way cross elevated 0.75 meters above the ground on an anchored 40-inch length of 3/8th inch black steel rebar (modified from Droege (USGS); and described in: http://www.slideshare.net/sdroege/height-adjustable-bee-bowltraps). Elevating the bowl traps is considered an effective method to minimize disturbance by ground dwelling animals, and to ensure that all bowl traps are exposed at heights similar to standing vegetation. The set of painted bee bowls were inserted into unpainted soufflé cups (that served as seats to insert bowl traps) that were *secured by wood screws at the outside ends of a fabricated 3-way cross (made up by 1"x2"x30" hardwood stakes). Once seated, bee bowls were spaced equidistant (approximately 36 inches apart) on each sampling unit by adjusting the position of each wood arm. A sampling unit is considered deployed when it is installed at site, and when all 3 bee bowls are filled 3/4th volume with a nontoxic, soapy-water solution (with no nitrogen, phosphorous or potassium), and placed inside the attached base. See Figure 8 for a schematic diagram illustrating the design of deployed bee bowl traps elevated above vegetation. Bee bowls may be technically considered a bait trap since it is well document that bees are attracted to specific colors. However, the traps provide no food or reward and capture insects passively when they land on the surface of the soapy water solution that has little surface-tension trapping and killing the insect once it lands.*

Each of the 5 sampling units (per transect or site) was installed at a trap station representing the center of each of the five 10m x 10m vegetation plots that were previously established at approximately 50 meter distances along the lake shoreline with one edge of each plot starting 1 meter above, and parallel to, the ordinary high water mark (OHWM).



Side- and Top-view of the Pollinator sampling unit

Figure 8 Schematic illustration of a bee sampling unit consisting of 3 bee bowls mounted on separated arms approximately 0.75m above ground.

Sampling Duration

Northern Wisconsin's temperate climate and seasonal weather fluctuations impose a narrow duration of time suitable for adequate sampling of active local bee populations. This study focused on sampling effort during the early "flight" season of local bees with interest of detecting bee species associated with early spring emergence. Surveys were required to be completed by June 30th. As result, a total of 3 paired sampling (or trapping) events were conducted simultaneously across the restored and control sites. The first event was over 2 days May 23-24th with the remaining two surveys (June 12-14th and June 26-28th) extended by 1 day each due to limited captures during the May survey effort. Since each trap station (or sampling unit) included a total 3 bee bowls, each site consisted of 5 trap stations (plots) and was considered to represent a total of 15 trap-days per site (5 traps each) per day (0900-1700 hours). In total, the May survey produced 30 trap-days per site (5 traps stations x 3 bee bowls x 2 days), and the June surveys each produced a total of 45 trap-days per site or sampling event. The season's combined trap effort per site was a total of 120 trap-days each. Sampling events were initiated during mid-week to minimize sampling disturbance due to home/cottage owner and pet use of property typical of summer weekends along shorelands of Wisconsin's lake country.

Bee-Bowl (trap) Deployment and Monitoring

Bee bowls (traps) were prepared by filling 4.0 oz. soufflé cups to 3/4th volume solution of 1:100 concentration of non-nitrogen, phosphorous and potassium, dishwasher detergent (brand examples: Ecos®, Seventh Generation ®) to tap water and inserted into each base attached to the elevated platform. Bee bowls were distributed in sets of three to represent each color (fluorescent yellow, fluorescent blue and white) considered necessary to attract species with differing color preferences. Bee traps were deployed by 0900 hours each morning and removed by 1700 hours each day for 3 consecutive days (trap event). Trap deployment and inspection followed a sequential order to ensure uniform trap effort across each transect and treatment site.

Sample Unit Inspection and Specimen Handling

Monitoring and sample collection efforts began with the same plot ID number (plot 1 at the restoration transect and plot 5 at the control transect) at each transect, and once established became the rule for subsequent monitoring to ensure consistent trapping effort across both treatments. This approach was performed consistently for each transect and site for all trap event periods. Sample unit inspection and monitoring was completed within 30 minutes for each transect. Drive and setup time between the restoration and control transects was approximately 15-30 minutes depending upon landowner or restoration crew interactions.

A) Control Transect (plot 1)

B) Control Transect (plot 5)

C) Restoration Transect (plot 1)

D) Restoration Transect (plot 5)

Figure 9 Photos A-D represent photos of bee sample stations installed at opposite ends of the 210-meter long control transect and 200-meter long restoration transect (see Figure 3). A single bee station was installed in the center of each of the five 10m x 10m plots per transect. Plot centers were located approximately 5 meters from the lake's ordinary high water mark.

Specimens captured in each trap of each sampling unit were transferred to a locking plastic storage bag with an alcohol-proof label containing the following information written with pencil: date, time, site name, and plot ID. Once all specimens from each bee bowl were transferred to the same bag, approximately 5 ml of ≥ 80% ethyl alcohol was added prior to sealing bag. Trapped target species were pooled from all 3 traps per sampling unit. In other words, there was no effort to document species collected per trap color. Immediately following the inspection of all sampling units for each transect, all samples were placed in a cold portable cooler for transportation of specimens to a controlled environment for later processing (sorting, washing, drying, pinning), group identification and counting. Specimen processing will follow methods described by Droege (USGS) in: "The Very Handy Manual: How to Catch and Identify Bees and Manage a Collection" available on-line at http://bees.tennessee.edu/publications/ HandyBeeManual.pdf. Bee species identification and voucher specimen archival will be facilitated by the University of Wisconsin-Madison, Department of Entomology.

Results

Landowner Participation and Restoration Effort

Landowners are essential to any restoration strategy; without willing lakeshore property owners, opportunities for rehabilitating lakeshore habitat are minimal. At LSG, we found interest in project participation low among the 425 lake district property owners, despite the no-cost/no-labor investment on their behalf. Our public meeting was attended by 24 property owners, and we did receive expressions of interest and followed up with 12 parties. Of those 12, only 2 property owners remained interested when all requirements and goals were described. We did require temporary (3-year) construction of deer-proof fencing around our restoration projects, follow-up visits by researchers for maintenance and periodic wildlife and vegetation surveys for 10 years, and a restrictive covenant on the property deed protecting the restoration going forward. These requirements may have influenced some folks to decline participation, however, some did not see the need for restoration, and/or did not agree with the goals of the project. Also, landowners may have been deterred from participation due to the involvement of WDNR in the project (see Comments from Participants). During the Fall/Winter of 2010, one recreational rental property owner offered 3 sites for restoration, and one property owner with >750' of frontage signed up, allowing the project to move forward. Finding local, trusted on-lake champions of lakeshore rehabilitation work such as lake association officers, private sector business owners, or master gardeners can make for effective peer-to-peer learning and project buy-in. An effort initiated from the "grassroots" may yield greater participation than one initiated and sponsored by WDNR. As for this project, participating landowners are listed below.

Brad & Judy Waldmann (BJW) provided three rental properties for restoration:

- Sunset Pines (SP) property is located in East Bay and approximately 150' of lakeshore received restoration plantings in June 2011. One 1,200 ft^2 rain garden was installed to collect runoff from rental cabins, concrete patio and sidewalk, and driveway. Two tree drops were deployed perpendicular to shoreline to damper wave action and for fish habitat enhancement. Biologs were installed along 120' of shoreline using twelve 16" diameter x 10' length coconut coir biologs to reduce the under-toe erosion caused by high wave action – the space between biologs and the bank were planted with native wetland species. In June of 2011, 58 trees of 18 species, 440 shrubs of 24 species, and 1482 forbs and grasses of 85 species were planted on this property.

- Point House (PH) property is located at the east end of West Bay, on a peninsula with a rental house, and 165' of shoreline which was restored in May 2012. Four trees were dropped perpendicular to shoreline to mitigate wave action from boat traffic and wind and to provide fish habitat enhancement. In May 2012, 71 trees of 10 species, 160 shrub of 13 species, and 1188 forbs and grasses of 42 species were planted on this property.

- South Point House (SH) is located at the north end of South Bay on a peninsula with a rental house and 500' of shoreline which was restored in May 2012. Five tree-drops were secured perpendicular to shoreline for wave mitigation and fish habitat enhancement. In May 2012, 152 trees of 16 species, 280 shrubs of 20 species, and

1510 forbs and grasses of 53 species were planted on this property. A temporary, automatic irrigation system was installed to maintain plants during early growth.

Lou and Donna Mirek (LDM) provided 750’ of lakeshore for restoration in No Fish Bay. In July-August 2011, 450’ (Phase I) of lakeshore was restored. In phase I we installed 500 geotextile bags that were carefully placed at steep, highly erodible areas. All bags were planted with various native shrubs, forbs and grasses. Five tree-drops were also deployed perpendicular to the shoreline for shoreline protection and fish habitat enhancement. In May-June 2012, another 300’ (Phase II) was restored and a 1,000 ft^2 rain garden was installed to collect runoff from human dwellings roof via down-spouts. In both Phase I & II 195 trees of 14 species, 572 shrubs of 17 species, and 4226 grasses and forbs of 40 species were planted on this property. In addition, a temporary, automatic irrigation system was installed.

Frank and Paula Skweres (FPS) provided 100’ of lakeshore in No Fish Bay. In June 2012, 49 trees of 14 species, 122 shrubs of 20 species, and 1182 forbs and grasses of 51 species were planted on this property. An automatic irrigation system was installed.

Keith and Cheryl Generotzke (KCG) on the north shore of No Fish Bay had small but significant bank erosion occurring on their property in an area approximately 6’ wide by 35’ long. We installed erosion control matting then planted the matting with eight trees of four species, 14 shrubs of 2 species, and 388 grasses and forbs of 12 species on this property in June 2012.

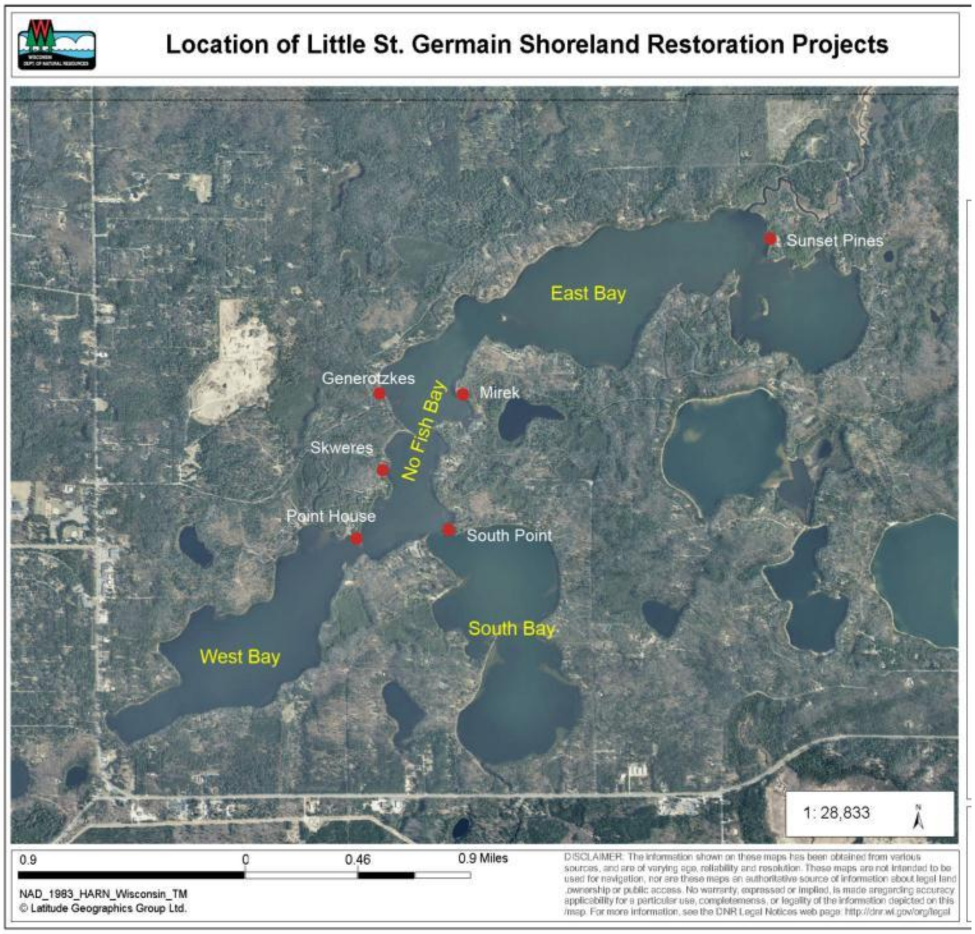


Figure 10 Location of Little St. Germain Restoration Projects

Vegetation Surveys

We found a greater number of trees within vegetation plots on the reference lakeshore (Star Lake, Vilas County) as compared to the LSG treated (developed/to be restored) and LSG control (developed/no restoration) vegetation plots. These finding are similar to other studies in the area (Christensen *et al.* 1996, Elias and Meyer 2003, Haskell 2009). For example Christensen *et al* (1996) found a negative correlation of tree basal area with human dwelling density. Elias and Meyer 2003 documented reduced tree and shrub coverage on survey transects along developed lakeshores in Vilas and Oneida counties, WI. Additionally, Racey and Euler (1982) reported a decrease in trees with development in central Ontario, Canada.

In this study, 91% of trees on reference vegetation plots were conifers as compared to 57% on the control, and 81% on the treated shoreline (Table 2). Also, 26% of the trees detected on reference plots were eastern hemlock (*Tsuga canadensis*); no eastern hemlock was detected on the treated or control plots. Eastern hemlock is considered a valuable resource to white-tailed deer providing winter browse and thermal cover (Anderson and Loucks 1979). The high density of deer associated with developed lakes in our study (Haskell *et al*. 2013), may be one cause for the lack of eastern hemlock occurrence on LSG.

Sapling numbers were also higher on the Star Lake reference transect, the majority being conifers (Table 3). Eastern hemlock saplings were again only detected on reference plots, perhaps a consequence of the high density of deer on LSG (Alverson *et al.* 1988). It is well known that eastern hemlock seedlings and saplings are browsed heavily by white tail deer especially in winter months (Beals *et al.* 1960, Anderson and Loucks 1979, Alverson and Waller 1997, Witt and Webster 2010). In addition to the lack of eastern hemlock, spruce species were also not present on LSG vegetation plots. The lack of a diverse conifer component of trees and saplings on LSG Lake compared to Star Lake may be a consequence of deer herbivory, or differences in soil and/or microclimate characteristics.

Table 2 Number of trees and species > 5cm DBH within vegetation plots, by transect, on LSG and Star Lakes

	Transect Type		
Common Name	**Control**	**Reference**	**Treated**
Balsam Fir	0	4	1
Black Spruce	0	8	0
Eastern Hemlock	0	30	0
Eastern White Pine	10	11	7
Northern Red Oak	0	0	3
Paper Birch	14	9	5
Red Maple	8	0	1
Red Pine	43	50	32
White Spruce	0	2	0
Grand Total	**75**	**115**	**49**

Table 3 Total saplings and species on LSG and Star Lakes.

	Transect Type		
Common Name	**Control**	**Reference**	**Treated**
Balsam Fir	0	9	5
Black Spruce	0	2	0
Eastern Hemlock	0	14	0
Eastern White Pine	36	45	21
Red Maple	0	8	0
Red Pine	18	14	22
White Spruce	0	4	0
Grand Total	54	96	48

There were no shrubs detected on either the control or treated transects on LSG, while there were two species of shrub detected on the reference site on Star Lake; 9 sweet fern (*Comptonia peregrina*) and 23 tag alders (*Alnus rugosa)* for a total of 32 shrubs.

Habitat Structure

Habitat structural characteristics of vegetation differed between the reference plots and the control and treated plots (Table 4). WinSCANOPY results (vertical structure) show the gap fraction smaller (indicating a more closed canopy) at the Star Lake Reference vegetation plots as compared to the LSG treated and control plots. The greatest difference in horizontal habitat density was the understory density (0.1m – 3.0m height) at the Star Lake reference vs. LSG control and treated plots. These findings are similar to Elias and Meyer (2003) who reported a reduction of sub-canopy and shrub layer coverage on high-development lakes compared to low-development lakes. In addition, Robertson and Flood (1980) reported a reduction of structural diversity at developed sites at all height categories. Additionally, Clark *et al.* (1984) found tree density, canopy volume, and shrub coverage negatively correlated with housing development.

Variable	Shoreline (Treatment)	*N*	Mean	Std. Deviation	Variance
Gap Fraction	Reference	5	19.0	2.5	**6.5**
	Control	5	23.6	1.8	**3.3**
	Treated	5	28.4	6.3	**4.0**
Density Board					
Understory Foliage Density (%)					
0-0.3 m	Reference	5	68	26	**7**
	Control	5	48	18	**3**
	Treated	5	56	32	**10**
. 0.3-1 m	Reference	5	68	25	**6**
	Control	5	25	22	**5**
	Treated	5	39	19	**4**
1-2 m	Reference	5	70	25	**6**
	Control	5	25	23	**5**
	Treated	5	40	20	**4**
2-3 m	Reference	5	73	23	**5**
	Control	5	30	30	**9**
	Treated	5	43	33	**11**

Table 4 Gap Fraction and Understory Foliage Density for LSG and Star Lakes in Vilas County, Wisconsin. Gap fraction was estimated by WINScanopy™ analysis of digital hemispherical photographs.

We found the number of pieces of DWM was higher on the LSG treated vegetation plots as compared to the Star reference vegetation plots (Table 5) which is not consistent with other studies (Marburg *et al.* 2006, Elias and Meyer 2003, Christensen *et al.* 1996). These previous studies reported a negative correlation between human development and DWM along lakeshores and near shore. However, in this study stumps were more numerous on both the control (90%) and treated (39%) plots; all stumps were the result of tree harvest on Treated plots and 78% of stumps resulted from tree harvest on the Control plots. In 2007 a forest fire ran through a portion of the Treated plots killing several trees (personal conversation Lou Mirek), which may explain the number of snags and logs present.

Table 5 Total number DWM pieces (snags, logs, stumps) on Star and Little Saint Germain Lakes in Vilas County, Wisconsin. This data was collected in 2011.

	Transect Type		
DWM Type	Reference	Control	Treated
Snag	12	1	7
Log	2	0	7
Stump	2	9	9
Total	**16**	**10**	**23**

Avian Surveys

Riparian areas offer diverse habitat features and niches for many bird species (Naiman *et al.* 1993), and development along riparian areas can have a detrimental effect on bird communities (Lindsay *et al*. 2002). We recorded 19 ground and shrub nesting bird species on the reference transect compared to 14 species and 12 species on the LSG control and treated transects respectively. In addition, we recorded 41 insectivorous bird species on the Reference transect compared to the Treated and Control transects where 35 bird species were recorded on each transect. These results are similar to Lindsey *et al.* (2002) who also found only small differences in species diversity associated with shoreland development (Tables 6-9). Their results did show several species and certain resource–selection guilds responded either negatively or positively to lake development. For example, ground nesting and insectivorous birds were more common on low-development lakes. Unmeasured in our surveys is habitat-specific avian reproductive success and productivity along developed vs. undeveloped shoreline. Previous studies suggest that an increase of raccoon (*Procyon lotor*) and feral cats (*Felis catus*) predation rates on bird nests are associated with human development (Schmidt and Whelan 1998).

Table 6 Summary of bird species richness (S), total bird abundance (N), Shannon's index of diversity (H'), and evenness (E) separated by lake, treatment and year for LSG and Star Lakes in Vilas County, Wisconsin. Data has not been analyzed for 2013.

Lake	Treatment	2011				2012			
		S	N	*H'*	E	S	N	*H'*	E
LSG	Control	16	16	2.77	1.00	17	41	2.54	0.90
	Restoration	18	18	2.89	1.00	16	31	2.56	0.92
Star	Reference	22	30	3.03	0.98	16	31	2.64	0.95

Table 7 Summary of bird foraging guild richness (G) total bird abundance within guides (N) Shannon's index of diversity (H') treatment and year for LSG and Star Lakes in Wisconsin. Vilas County

Lake	Treatment	2011				2012			
		G	N	*H'*	E	G	N	*H'*	E
LSG	Control	6	26	1.50	0.84	7	39	1.58	0.81
	Restoration	7	35	1.64	0.76	7	27	1.61	0.82
Star	Reference	8	50	1.60	0.85	6	27	1.55	0.86

Table 8 Summary of bird nesting guild richness (G), total bird abundance within guild (N), Shannon's index of diversity (H'), and evenness (E) separated by lake, treatment and year for LSG and Star Lakes in Vilas County, Wisconsin.

Lake	Treatment	2011				2012			
		G	N	*H'*	E	G	N	*H'*	E
LSG	Control	5	27	1.38	0.86	6	38	1.24	0.78
	Restoration	7	36	1.58	0.81	4	27	1.22	0.87
Star	Reference	5	48	1.42	0.88	6	23	1.24	0.69

Table 9 Summary of bird diet guild richness (G) total bird abundance within guild (N) Shannon's index of diversity (H') and evenness (E) separated by lake treatment and year for LSG and Star Lakes in Vilas County Wisconsin.

Lake	Treatment	2011				2012			
		G	N	*H'*	E	G	N	*H'*	E
LSG	Control	4	23	0.66	0.47	4	33	0.92	0.67
	Restoration	4	35	0.96	0.69	4	27	0.77	0.56
Star	Reference	4	50	0.79	0.57	4	23	0.80	0.58

Small Mammal Surveys

In 2011 (prior to restoration activities), a total of 21 small mammals were captured on the LSG control site, 31 on the LSG treated site, and 30 on the Reference site. In 2012 (following restoration activities), a total of 18 small mammals were captured on the control site, eight on the treated site, and seven on the reference site (Table 10). In our study, higher numbers of eastern chipmunks (*Tamias striatus*) occurred on LSG control and treated transects as compared to the Star reference transect, suggesting eastern chipmunks may be associated with development in our study area. Bird feeders and human garbage may be important to eastern chipmunks as a source for supplemental food. Haskell (2009) found a similar association on other developed lakes in Vilas County as did Racey and Euler (1982) in central Ontario.

Haskell (2009) reported that the deer mouse (*Peromyscus maniculatus*) was the most frequently captured species on reference lakeshores. Racey and Euler (1982) reported that deer mice abundance was negatively correlated with human development in central Ontario, Canada. The inverse relationship between deer mouse abundance and lake development suggests the same maybe true in northern Wisconsin. The presence of white-footed mice (*Peromyscus leucopus*) in northern Wisconsin also raises additional questions (Haskell 2009). Historically, white-footed mice were found in the southern three quarters of the state with a preference for deciduous forests (Jackson 1961). Currently, their range may be moving northward concurrent with habitat fragmentation due to the increase of development, climate change, and/or forest management practices (see Myer *et al 2009*). However, because morphological characteristics are similar between *P. maniculatus* and *P. leucopus*, field identification was difficult and unreliable so all *Peromyscus* species captured were recorded to genus only until species can be confirmed by DNA analysis (Table 10).

Table 10 Summary of small mammal captures on LSG and Star Lakes in 2011-2013.

Common Name	Scientific Name	Year	Reference	Control	Treated
Unk. Mouse	*Peromyscus sp.*	2011	7	4	10
		2012	1	0	0
		2013	0	0	3
White-footed Mouse	*P. leucopus*	2011	7	3	7
		2012	0	0	0
		2013	0	0	2
Red Squirrel	*Tamiasciurus hudsonicus*	2011	1	0	0
		2012	0	0	0
		2013	2	0	0
Eastern Chipmunk	*Tamias striatus*	2011	7	6	14
		2012	0	9	1
		2013	0	8	4
M. Jumping Mouse	*Zapus hudsonius*	2011	0	0	2
		2012	0	0	0
		2013	0	0	1
S. Red-backed Vole	*Clethrionomys gapperi*	2011	7	0	0
		2012	0	0	0
		2013	11	0	0
Meadow Vole	*Microtus pennsylvanicus*	2011	0	8	0
		2012	0	7	0
		2013	0	14	0
Unk. Shrew	*Sorex sp*	2011	0	0	0
		2012	2	2	3
		2013	1	0	0

Pollinator Surveys

Excerpts from the Results and Discussion from the report "**2013 Vilas County Pollinator Response Surveys; Final draft submitted: November, 25, 2013"** can be found *in italics* below. The full report of the Pollinator Pilot Study can be obtained upon request from the authors as "Supplemental Material". The full report also contains recommendations for future pollinator surveys if conducted in association with shoreland restoration projects and should be consulted prior to implementation.

Summary of total trap nights and effort

Bee surveys were conducted simultaneously along transects located at both the restoration (treatment) site and the non-restoration (control) site on May 23-24th, June 12-14th, and June 26-28th for a total of 3 sampling events per transect spanning a 34-day survey window during the early growing season. The 2-day, May sampling event consisted of a total of 30 trap-days per site, and both June surveys each represented a 3-day trapping period to produce a total of 45 trap-days per site. The effective hours of trap availability were considered to be from 9:00 AM to 5:00 PM. In total, the season's effort produced 120 trap-days when combining all sampling events. From this effort, a variety of bee- and non-bee (non-target species) taxa were captured in the bee bowl traps. Bee capture rates per individual trap station were unexpectedly low, and as result captures for all stations were pooled into a single sample. Including all bee bowl traps (including those w/no captures), bee capture rates were 0.23 and 0.05 bees per bowl for the restoration and control sites, respectively; much lower than the average 0.66 bees/bowl per day as reported by Grundel et al. (2001) in a study evaluating bee capture rates for bee-bowls. However, in light of the fact that zero bees were captured at either site during the May survey may suggest weather was inappropriate. If we exclude the May sampling effort, then bee capture rates for June were 0.31 and 0.07 for the restoration and control site, respectively; a marginal improvement for comparison to Grundel et al.'s findings. In Grundel et al.'s study, they also estimated that 70% of the bowls did not capture any bees.

Sites differed considerably in total number of bees captured with greatest captures recorded at the restoration site (28 bees representing 5 taxonomic groups), and the lowest at the control site with only 6 bees total representing a single taxonomic group. No bees were captured at either site during the May survey which was associated with the coldest min-max (mean) daily *temperatures with a minimum temperature of 36 degrees F, maximum daytime temperature of 66° F and mean temperature of 45° F. Temperatures for the remaining 2 sampling events are reported in Table 1. Non-bee taxa represented in the captures included primarily fly species (syrphids, deer fly, black fly, and other unidentified 2-winged insects), as well a single unidentified small butterfly, springtails, ants, and spiders. All non-target species captures were low (<5) in total numbers per trap station. Actual numbers of bees captured per date and site and their taxonomic classification are reported in Table 11.*

Table 11 Bee taxa detected per site and date during spring and early summer bee surveys.

	CONTROL			RESTORATION		
GROUP†	14 JUNE	28 JUNE	TOTAL	14 JUNE	28 JUNE	TOTAL
Daily Temperature min-max (mean) °F	40-75(58)	58-70(63)		-	-	
Andrenidae (mining bee)	0	0	0	1	0	1
Bombus (bumble Bee)	0	0	0	0	2	2
Halictus (sweat bee)	0	0	0	1	1	2
Lasioglossum (sweat bee)	5	1	6	8	11	19
Nomada (cuckoo bee)	0	0	0	0	4	4
TOTAL INDIVIDUALS COUNTED	5	1	6	10	18	28
TOTAL NUMBER OF GROUPS	1	1	1	3	4	5
Sample Standard Deviation (total captures per date)			2.828			5.657
Coefficient of Variation (total captures per date)			0.942			0.404
Simpson's Diversity Index (within site α diversity):			1.00			2.11
Sorenson's Quantitative Index* (a measure of community similarity - β diversity): 0.353						
*Scale of 0 to 1, where 0 represents no similarity and 1 represents high similarity						

Bee surveys were conducted during 3 separate survey events: May 23-24 (no captures at either transect), June 12-14, and June 26-28, 2013. †Group classification at *Family* or *Genus* level. Species level identification and specimen voucher archival are to be facilitated by the University of Wisconsin - Madison.

Summary of species relative abundance per treatment type (transect):

Survey results (Table 11) suggest there may be a substantial difference in habitat use by bees between the treatment (28 bees of 5 taxa) and control (6 bees of 1 taxon) sites. Reasons for the seemingly disparate capture rates (Figure 11) at the early stages of restoration are likely a result of combinations of various environmental factors as well as the physical factors unique to each site. Though visually distinct (compare photos A and B with C and D in Figure 9), both sites are comparable in many ways at the plot level as indicated in Table 12, in that they both exhibit *similar percent canopy cover (shade), similar tree basal area, and similar amounts of bare ground (as measured in 2011).*

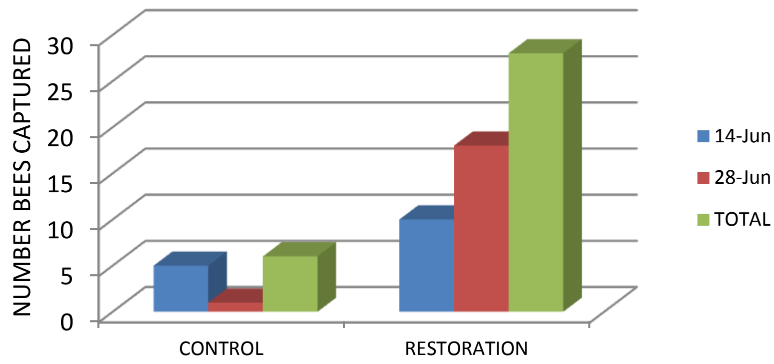


Figure 11 Relative abundance of total bees captured per date and treatment type

The notable habitat differences between the restoration and control sites are the greater amounts of coarse down woody material (logs, snags, and stumps) and fine woody material (small twigs and small plant stems) measured at the restoration site. The control site is different also in that it reflects a slight increase (from 0 to 1-5% cover) in managed lawn landscape and less overall slope relative to the restoration site. However, regardless of the measured and likely un-measured differences between both sites, the results from this study can at this time only serve in a descriptive sense for potential changes expected as the two sites diverge in similarity as the plantings associated with the restoration site continue to mature. In Cane (2001), he suggests caution with interpreting patterns of bee abundance when they are based on surveys of short duration emphasizing that high temporal variation in bee species diversity is well documented and problematic.

Table 12 Summary of plot measurements conducted in 2011 describing site characteristics.

2011 Transect Survey Measurements (Haskell et al., unpub. Data)	*Treatment***	*Control*
Ground Cover Species Total (per 1-m^2)	*14*	*17*
Ground Cover Species Diversity (per 1-m^2)*	*2.46*	*2.76*
Tree Density (Average # trees per 100 m^2)	*9.8*	*15.0*
Tree Basal Area (m^2) (Averaged per 100 m^2)	*0.59*	*0.57*

Canopy Openness (Average per 100 m^2)	*29%*	*24%*
Coarse Woody Material (Average count per 100 m^2)	*4.6*	*1.8*
Managed or Mowed Grass/Lawn (per 1-m^2)	*0%*	*1-5%*
Fine Woody Material/Litter (per 1-m^2)	*50-75%*	*25-50%*
Bare Ground Average Cover Class (% cover per 1-m^2)	*1-5%*	*1-5%*
Shoreland Buffer Mean Slope (% slope)	*29%*	*15%*
Shoreland Buffer Mean Aspect (240^o- 250^o faces WSW)	*242^o*	*247^o*

***Plant species diversity per 1-m^2 was calculated based on percent cover and the Shannon Weiner diversity index. ** Data for treatment represent minimum estimates for plant species total and diversity, tree density, and canopy openness; 2011 survey results represents treatment site measurements 1-yr prior to planting of additional trees and groundcover.**

Vegetation measurements summarized in this report reflect shoreland conditions during 2011, one year prior to the beginning of any restoration work. Actual restoration efforts for the "restoration" site began in the summer of 2012, supplementing existing shoreland vegetation with an additional 25 forbs (grasses, wildflowers, sedges and ferns), 3 shrubs, and 1 tree for every 100 square feet of available restoration area. In some areas within the restoration buffer zone, more or less numbers were planted based on existing vegetation, soil type, slope, and landowner use of the area which do not translate specifically to each 10m x 10m survey plot. No vegetation surveys were conducted during 2012, or 2013 which was the last year of effort to complete the restoration work. Re-measurements of vegetation are scheduled to take place at both the restoration site and the control site during summer of 2014 which will provide a more accurate description of the vegetation and plant community as related to bee use at either site.

Comparison of bee communities between the restoration and control sites:

Both individual sample station and combined capture totals of bees were lower than expected across both sites. Visual observations of foraging bees during trap monitoring also were not common during any of the 3 sampling periods lending credence to the points made by Crane (2001) cautioning pre-mature interpretation of single season survey results to accurately describe bee relative abundance patterns. Reasons for an apparent low activity of bees along the shoreland zone of each study site are unclear but may be due to a variety of weather- and floral ecology related factors. It's important to point out that the restoration site reflects conditions *early in recovery, and multi-year bee monitoring efforts will be necessary at both sites to better characterize potential differences in bee-use based on changing habitat variables as result of restoration practices. However, despite the low overall capture rates, a difference in capture rates was observed (refer to Table 1) between the control and restoration transects during this first year's survey effort.*

In Table 11, a total of 5 bee taxa are listed, where four of the taxa (groups): Halictus, Lasioglossum, Andrenidae and Bombus are represented by primarily ground-nesting species, including many species considered ubiquitous and commonly represented in bee surveys across a variety of habitats. The last group, Nomada, is a group known for species that specialize as nest parasites of ground cavity nesting bee species. Within each group there are species with life histories that depend upon stable exposed soils on slopes or well-drained soil types. Many also rely upon mud, plant stems and other woody material for construction of nests and/or as resources for wood fiber to line brood cells (The Xerces Society, 2011; http://www.xerces.org/bees/). Other than Nomada, all groups contain oligolectic species that have evolved to specialize in the foraging (pollination) of only one or a few species of flowering plants. The two most abundant groups represented in the survey results are bee species typically dependent upon available bare ground or exposed stable soils either on slopes and/or well drained soils, and fiber material to line brood cells during nest construction. Fiber material may come from many sources of plant tissue from live green leaves, to stem bark and other woody structure associated with persistent dead shrub and plant stems. The absence of the larger bee species may be an indication of trap bias. Cane (2001) concluded from other research efforts that pan traps seem to "preferentially catch small-bodied bees, especially sweat bees, and miss many bee taxa altogether". With this in mind, future surveys would do well to supplement bee-bowl (pan traps) traps with other techniques suitable to detect larger species.

As noted previously, there are two main differences in habitat characteristics between both sites that can be supported by the 2011 plot survey data. These include slope (topographic relief) and the abundance of available coarse and fine woody material (logs, snags, stumps, and small twigs, stems and branches), both of which have been measured in greater abundance at the site receiving the treatment (restoration). These differences are visually discernible in the photo comparisons between the two sites (Figure 9) as well as graphically in Figure 1 showing the relative abundance of down woody material. With that said, it must be clearly stated that characteristics for slope and abundance of available dead woody structure were not appreciably *amended at the restoration site during restoration efforts 2012-2013. Regardless of woody material origin, its value is well documented as an important nesting substrate for many bee species and other organisms (small mammals, epigeal arthropods, amphibians and other ground-dwelling animals), as well as its functional role in moderating soil moisture, soil temperature, and organic matter contribution. It's plausible to consider that the increased abundance of woody material associated with well drained soils on a westerly facing slope provides more nest resources for the bee species detected relative to the control site that overall is a more managed landscape.*

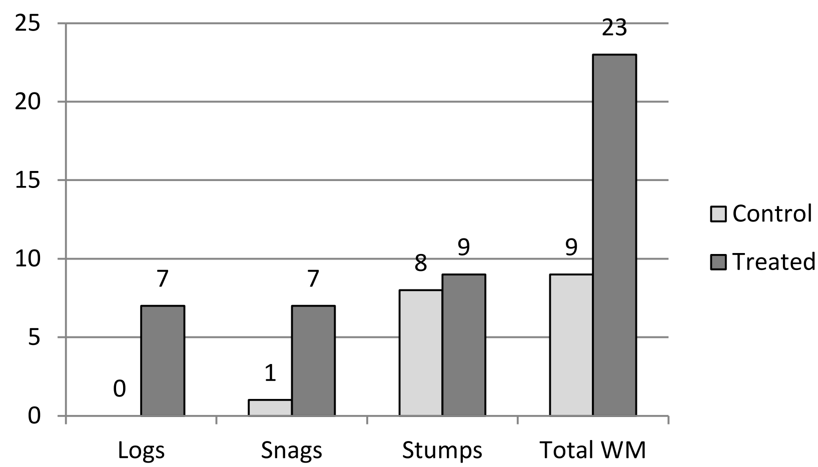


Figure 12 Relative abundance of available dead, woody material (WM) totals and by type as measured at the control and treated (restoration) sites during 2011.

A quantitative comparison (Table 1) of the capture rates and taxa representation between the restoration and control site support a preliminary assessment that bee-use or activity by bees at each site is distinct. Alpha-level diversity, species richness within a sample or study site, differ by a factor of 2 with the restoration site showing greater diversity (Simpson's DI: 2.1) relative to the control (Simpson's DI: 1.0). Beta-level diversity, a measure of the shared diversity across samples or different sites, was calculated using the Sorenson's Quantitative Index (a measure of community similarity/dissimilarity). A Sorenson's QI of 0.353 implies that the bee communities, as represented by the survey results, are measurably dissimilar. Caution is advised when interpreting results from a single survey effort and where sample variance is nearly double for one (control) of the two study sites as indicated by coefficient of variation values of 0.942 and 0.404, respectively, for the control and restoration sites. Future survey efforts will require increased sample effort to reduce sample variance in order to provide greater confidence in *actual measured differences. In addition, incorporating replication into the survey design by conducting similar surveys at additional WSRP Vilas County restoration sites (Crystal Lake, Lost Lake, Found Lake, and Moon Lake) will increase quantitative rigor in the experimental results.*

Local Economic Impact

This project helps support jobs in the local economy. All plants and erosion materials were purchased from local nurseries, four local landscapers and contractors provided logistical support in tree-drops, excavating the rain garden, installing biologs, and installing automatic irrigation system. In addition, hardware goods and materials were purchased at local hardware stores. Furthermore, Michigan Technological University personnel were housed in the local area which they purchased food and consumer goods from local small businesses.

Materials and services purchased for the project supported jobs in the local nurseries and landscaping companies. In addition, 15 seasonal MTU student internships have been completed since 2011 to assist with wildlife surveys, habitat measurements and restoration activities. Students recruited to fill the internships came from across the country (Pennsylvania, Wisconsin, Iowa, Michigan, Minnesota, and Illinois) and gained valuable experience in the natural resource field, by working with private landowners, government agencies, and gaining applied field skills. In addition, private environmental consultants were contracted to conduct botanical, wildlife, and water runoff surveys for this project.

Furthermore, management activities which project water quality and lake habitat can affect lake front property values – it has been shown that declines in water clarity can negatively affect property values (Michael *et al.* 1996). The University of Wisconsin Extension Lakes Partnership program has developed a website which covers many aspects of the economics of lake management – information related to the topic can be found at *http://www4.uwsp.edu/cnr/uwexlakes/economicsOfWater/*. Much is a stake on LSG – a recent evaluation of the assessed value of LSG lakeshore properties exceeds $175 million.

For 2012, the totals for Little St. Germain Lake, as extracted from our tax roll, are as follows:

- *Fair Market Value: $168,834,184*
- *Land Value: $109,113,000*
- *Improvements Value: $65,088,600*
- *Total Value: $176,470,600*

(Adam Grassl - GIS Analyst, Vilas County Mapping Department, pers. comm 11/18/13.)

Comments from local business:

"We started doing shoreline restorations in 2005. It was a key player on helping us make it through the collapse in 2007. We are noticing that our clients are asking us to educate them on natural shoreline restorations. I would say approx. 35% of our calls are for Shoreline restoration and out of that about 23% continue through with the install. We have seen an increase in interest in shoreline restorations in the last five years and foresee it to continue to grow." Jason Bach, Owner, Horticulturist, and Landscape Designer, Wild Wood Custom Landscape & Design, Eagle River, WI

"If I add up all the restoration work we've did in the past couple seasons, it probably was 4 or 5 percent of our total volume, some with the DNR and the cost share program, and some with homeowners on their own. The program seemed popular and brought good awareness to the need of shoreline restoration. We had clients that didn't want to wait on the cost share program, and paid for the work themselves. Some had friends and neighbors in the program, and saw the process/results. That awareness and impact is above and beyond any tax money spent on the program." Mike Krueger, Owner, Horticulturist, and Landscape Designer, MK Landscape Company LLC, Eagle River, WI

"Our business, Hanson's Garden Village, LLC, Rhinelander, WI, is significantly impacted by our involvement with lakeshore restoration projects. We got into the business of lakeshore restorations early and with as much emphasis as we felt was appropriate for the amount of potential demand. Ten years ago most of the demand was for "lawns and retaining walls", which was an activity we avoided (and was sometimes not legal anyway). Slowly the demand for projects that were more lake and habitat friendly came along. Projects like those on Little Saint Germain have provided us important business revenue in the short term, but just as importantly will hopefully create more business in the future as people see and appreciate what can be done with native plants and appropriate erosion control practices. We will need that to happen to justify the very large investment in time and inputs to become a valid source of native northern Wisconsin plants. Purchases made by the Little Saint Germain Lake Protection and Rehabilitation District provided approximately 3% of our firms' total gross income over the period covered by the grant monies. During that period, sales of native plants and materials for restoration purposes approximated 12% of our gross income and supported about two full time equivalent job positions here. Those positions, however, do not exist in a vacuum. The infrastructure, greenhouses, delivery capability and

other inputs for growing or providing these products would not, at present, be financially supported on their own. This means that this kind of business is quite valuable to our company as a part of the mix of business that we do, but would not at present adequately support an independent business only involved with restoration products. But we are happy with the business that exists now as part of our operations, and we are hopeful about future gains through more widespread recognition of our offerings and/or because of more interest from the general public in these kinds of plants and products. I am also in agreement with those who state that the economy of Northern Wisconsin is heavily dependent upon the lakes, and that healthy lakes will be the most capable of contributing to the local economy in the long run. So, to some extent, we are merely trying to do our part to provide for a good economic future by being able to supply some of what is needed to help keep our lakes healthy". Brent Hanson, Owner, Horticulturist, and Landscape Designer, Hanson Garden Village, Rhinelander, WI

Appendix 2-A

Little St. Germain Lake Protection and Restoration District Lake Protection Grant

Avian Survey Data 2011-12

2011 Survey # 1			LSG	Star	LSG
Date	**Common Name**	**Scientific Name**	**Control**	**Reference**	**Treated**
6/6/2011	American Crow	*Corvus brachyrhynchos*	3	3	2
	American Goldfinch	*Carduelis tristis*	1		3
	American Robin*	*Turdus migratorius*	4	1	5
	Bald Eagle	*Haliaeetus leucocephalus*	1		4
	Baltimore Oriole	*Icterus galbula*			2
	Black-capped Chickadee	*Parus atricapillus*	1		3
	Blue Jay	*Cyanocitta cristata*	1	1	1
	Chip Sparrow*	*Spizella passerine*	3	1	1
	Common Loon	*Gavia immer*		1	1
	Chestnut-sided Warbler*	*Dendrocia pennsylvanica*	1	1	
	Eastern Phoebe	*Sayornis phoebe*			1
	Great-crested Flycatcher*	*Myiarchus crinitus*		1	
	Hairy Woodpecker	*Picoides villosus*		1	1
	Myrtle Warbler*	*Dendroica coronate*	1		
	Nashville Warbler*	*Vermivora ruficapilla*		1	
	Pine Warbler*	*Dendroica pinus*	1	1	
	Pileated Woodpecker	*Dryocopus pileatus*			1
	Red-breasted Nuthatch*	*Sitta Canadensis*	1		1
	Red-eyed Vireo*	*Vireo olivaceus*	4	3	4
	Song Sparrow*	*Melospiza melodia*			4
	Yellow-bellied Sapsucker	*Sphyrapicus varius*		1	1
Total			**22**	**16**	**35**
2011 Survey # 2			**LSG**	**Star**	**LSG**
Date	**Common Name**	**Scientific Name**	**Control**	**Reference**	**Treated**
6/20/2011	American Crow	*Corvus brachyrhynchos*	2	7	
	American Goldfinch	*Carduelis tristis*			2
	American Robin*	*Turdus migratorius*	3	4	1
	Baltimore Oriole	*Icterus galbula*		1	
	Black and White Warbler	*Mniotilta varia*	1		
	Black-capped Chickadee	*Parus atricapillus*	3		1
	Belted Kingfisher	*Cerlye alcyon*		2	
	Blue Jay	*Cyanocitta cristata*	2	3	1
	Chip Sparrow*	*Spizella passerine*	1		

	Common Loon	*Gavia immer*		4	
	Chestnut-sided Warbler*	*Dendrocia pennsylvanica*		1	
	Eastern Phoebe	*Sayornis phoebe*		1	
	Great-crested Flycatcher*	*Myiarchus crinitus*	1		
	Gray Catbird	*Dumetella carolinensis*		1	
	Hermit Thrush*	*Catharus guttatus*		1	
	Mallard	*Anas platyrhynchos*		3	
	Mourning Dove	*Zenaida marcroura*	1		
	Myrtle Warbler*	*Dendroica coronate*	2		1
	Northern Flicker	*Colaptes auratus*		1	
	Northern Parula*	*Parula americana*		1	
	Pine Warbler*	*Dendroica pinus*	2	4	1
	Rose-breasted Grosbeak*	*Pheuctius ludovicianus*		3	
	Red-breasted Nuthatch*	*Sitta canadensis*	1	4	2
	Red-eyed Vireo*	*Vireo olivaceus*	1	9	2
	Red-winged Blackbird	*Agelaius phoeniceus*	2		1
	Song Sparrow*	*Melospiza melodia*			1
	Yellow-bellied Sapsucker	*Sphyrapicus varius*			2
Total			**22**	**50**	**15**

2012 Survey # 1			**LSG**	**Star**	**LSG**
Date	**Common Name**	**Scientific Name**	**Control**	**Reference**	**Treated**
6/4/2012	American Crow	*Corvus brachyrhynchos*	1		1
	American Goldfinch	*Carduelis tristis*	5		
	American Robin*	*Turdus migratorius*	5		3
	Bald Eagle	*Haliaeetus leucocephalus*			1
	Black and White Warbler	*Mniotilta varia*	1		
	Black-capped Chickadee	*Parus atricapillus*	2	1	1
	Brown-headed Cowbird	*Molothrus ater*			1
	Blue Jay	*Cyanocitta cristata*		4	2
	Chip Sparrow*	*Spizella passerine*	1		
	Common Loon	*Gavia immer*	1		
	Chestnut-sided Warbler*	*Dendrocia pennsylvanica*		2	1
	Hermit Thrush*	*Catharus guttatus*		1	
	Indigo Bunting	*Passerina cyanea*		1	
	Mallard	*Anas platyrhynchos*	1		
	Mourning Dove	*Zenaida marcroura*	1		
	Myrtle Warbler*	*Dendroica coronate*		3	
	Nashville Warbler*	*Vermivora ruficapilla*		2	
	Northern Flicker	*Colaptes auratus*	1		
	Pine Warbler*	*Dendroica pinus*	3	3	4
	Pileated Woodpecker	*Dryocopus pileatus*	1		
	Rose-breasted Grosbeak*	*Pheuctius ludovicianus*		2	

	Red-breasted Nuthatch*	*Sitta canadensis*	1		
	Red-eyed Vireo*	*Vireo olivaceus*	2	2	1
	Song Sparrow*	*Melospiza melodia*			4
	White-breasted Nuthatch	*Sitta carolinensis*	2		
	Yellow-bellied Sapsucker	*Sphyrapicus varius*		1	
Total			**28**	**22**	**19**
2012 Survey #2			**LSG**	**Star**	**LSG**
Date	**Common Name**	**Scientific Name**	**Control**	**Reference**	**Treated**
6/14/2012	American Crow	*Corvus brachyrhynchos*	2		
	American Goldfinch	*Carduelis tristis*	7		3
	American Robin*	*Turdus migratorius*	4		3
	Black and White Warbler	*Mniotilta varia*		2	
	Black-capped Chickadee	*Parus atricapillus*	7		2
	Belted Kingfisher	*Cerlye alcyon*	1		
	Blue Jay	*Cyanocitta cristata*	1		1
	Chip Sparrow*	*Spizella passerine*	1		
	Common Grackle	*Quiscalus quiscula*			1
	Common Loon	*Gavia immer*		1	
	Eastern Phoebe	*Sayornis phoebe*			1
	Great-crested Flycatcher*	*Myiarchus crinitus*			1
	Hairy Woodpecker	*Picoides villosus*		2	
	Mallard	*Anas platyrhynchos*			1
	Myrtle Warbler*	*Dendroica coronate*		2	1
	Northern Flicker	*Colaptes auratus*		1	
	Pine Warbler*	*Dendroica pinus*	3	1	3
	Red-breasted Nuthatch*	*Sitta canadensis*	2	1	
	Red-eyed Vireo*	*Vireo olivaceus*	4	4	2
	Song Sparrow*	*Melospiza melodia*			6
	White-breasted Nuthatch	*Sitta carolinensis*	1		
Total			**33**	**14**	**25**

*= Indicator Species

Article I.

Appendix 2-B

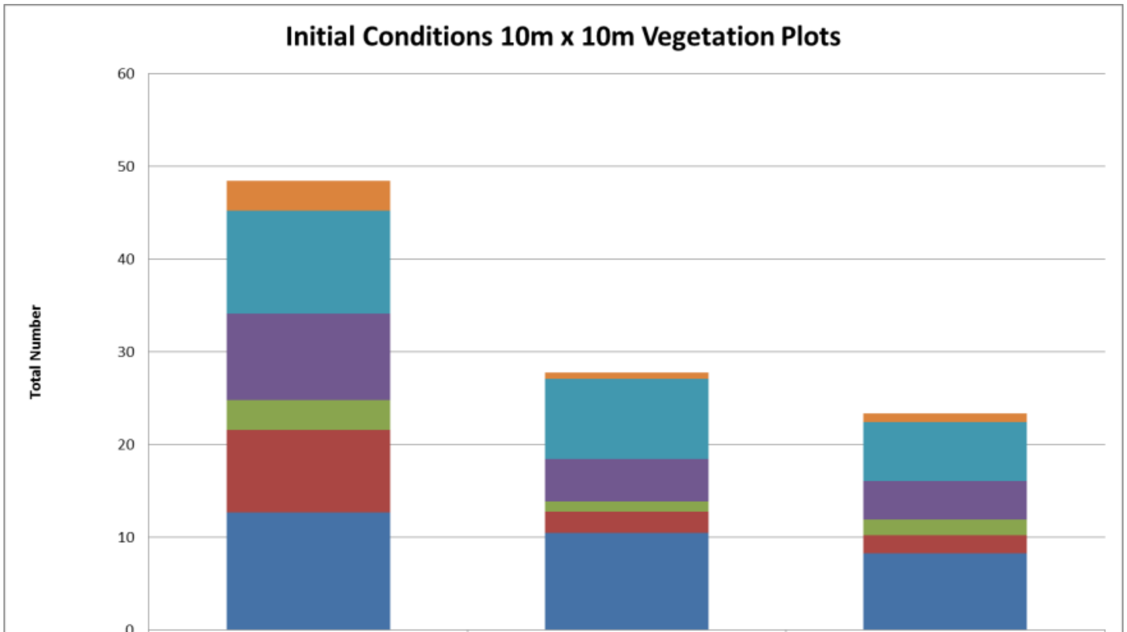
Preliminary Findings 2007-2012 – Wisconsin Shoreland Restoration Project

Carnivore distribution on high-developed vs. low-developed lakes

Earlier studies comparing low- and high-development lakes in Vilas County documented declines in the flora and fauna on the high-developed lakeshores (Elias and Meyer 2003; Lindsay *et al*. 2003; Woodford and Meyer 2003). However, very little was known about the effect of residential development on the mammalian carnivore community in this region, especially along lakeshores. We paired ten low-development lakes (< 10 houses/km, mean = 2.10 ± SE 0.64) with ten high-development lakes (≥ 10 houses/km, mean = 23.45 ± SE 2.69) and conducted winter track surveys between January – February 2008. Track surveys were conducted along the lakeshore 48 hours after snow fall. We recorded all fresh carnivore tracks encountered 10m on each side of the survey transect. In addition, we tallied encounters with white-tailed deer (*Odocoileus virginianus*). We calculated Shannon's index of species diversity for each lake. We documented 83 encounters of tracks of nine carnivore species across all lakes sampled. Five of the nine species were detected exclusively on low-development lakes. Coyotes (*Canis latrans*) were the most encountered species (n = 34) across all lakes. Red foxes (*Vulpes vulpes*) and raccoons (*Procyon lotor*) had the highest encounters on high-development lakes. Shannon's index of species diversity was significantly higher (t = 3.547, df = 9, P = 0.006) on low-development (mean = 1.974 ± 0.438 SE) than on high-development lakes (mean = 0.277 ± 0.113 SE). Overall, there were twice as many carnivore species on low-development lakes (n = 8) than on high-development lakes (n = 4). For non-carnivore species, white-tailed deer were abundant on all high-development lakes, but were detected on only 50 percent of low-development lakes. Our results suggest that high-development lakes are having a negative effect on the carnivore community in this region. The absence of apex carnivores in an ecosystem can have a significant effect on the relative abundance of herbivores and small carnivores. This trend can lead to further reductions in biodiversity because of overgrazed native vegetation and reduced nesting bird abundance (Haskell *et al.* 2013).

Native plant communities prior to lakeshore restoration

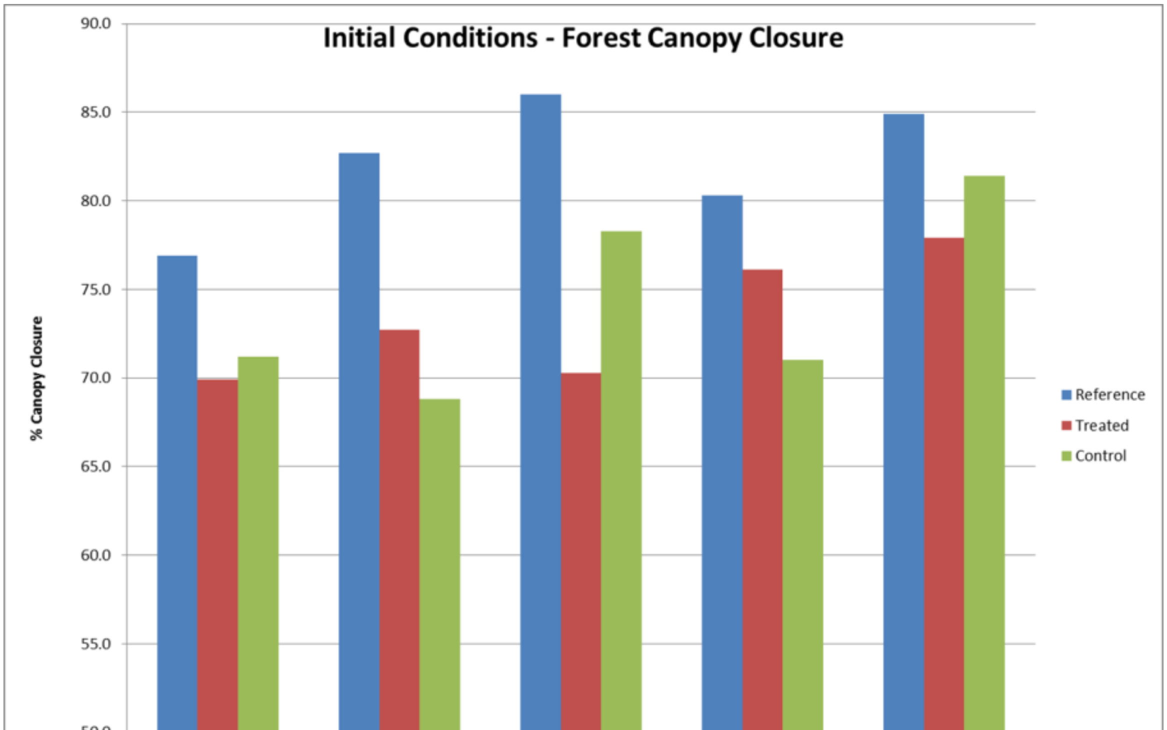
Previous research in the Northern Highlands documented significant effects of housing development on lakeshore habitat, including a reduction in near-shore tree and shrub canopy, floating aquatic macrophytes, tree and sapling canopy in the uplands, and coarse wood in the littoral zone, near-shore zone, and uplands within the terrestrial buffer (Elias and Meyer 2003). In this project, we quantified and compared the abundance and diversity of trees, saplings, and shrubs measured at fifty 10m X 10m vegetation plots on Reference Lakes (Jag, White Sand, Starrett, Star, and Escanaba Lakes) to that measured at forty-nine vegetation plots on Developed Lakes (Moon, Lost, Crystal, Little St. Germain, and Found Lakes-both lake sets are in Vilas County, WI, USA). Vegetation plots on Developed Lakes occurred systematically (one plot every 50m) along lakeshores slated for restoration activities, with measurements made the year prior to restoration activities. Vegetation plots on Reference Lakes also occurred every 50m along a lakeshore selected to provide similar physical characteristics (fetch, slope, and aspect) as the lakeshore to be restored at the paired Developed Lakes. Measurements were made concurrently with those at the Developed Lakes. We also compared canopy openness using digital photography and WinSCANOPY software and counted and measured the amount of coarse wood (logs, snags, stumps) present. Measures made at Reference Lakes were compared to those made at Developed Lakes using nonparametric techniques (Kruskal Wallis nonparametric analysis).



	Reference	Developed/Control	Developed/Treated
Downed Logs	3.15	0.72	0.95
Tall Saplings	11.15	8.63	6.32
Small Saplings	9.29	4.59	4.17
Tall Shrubs	3.27	1.08	1.69
Small Shrubs	8.85	2.29	1.97
Total Trees	12.7	10.5	8.29

Figure A2-1. Initial habitat structure at vegetation plots along reference shorelines on undeveloped lakes (n=5) as compared to vegetation plots at control shorelines on developed lakes (n=5) and treated shorelines (shorelines selected for habitat restoration) on developed lakes (n=5).

We found the total number of trees per plot and the tree species diversity index (SDI) were greater at vegetation plots on Reference lakes, however trees were larger (as indexed by average basal area measured at breast height) on Developed lakes. The total number of small tree saplings (DBH <5cm at 1.37m height) per plot and SDI were significantly lower on Developed lakes, however similar numbers of large tree saplings (DBH > 5cm at 1.37m height) and sapling SDI were measured on Reference vs. Developed lakes. Similarly, the total number of small shrubs (<1.37m) per plot and SDI were greater at Reference vs. Developed sites, however the number and SDI of large shrubs (>1.37m) were similar. There was a greater number and larger diameter of downed woody material (DWM) present at plots on Reference lakes vs. Developed lakes, however there was no difference in the number of snags or stumps present in the two lake categories (Figure A2-1). Analysis of canopy openness indicated canopy openness was greater at Developed vs. Reference lakes (Figure A2-2). These results support the overarching goals for restoration efforts – to increase the density and diversity of small saplings and shrubs, to augment DWM when needed, and to work towards a plant community with greater canopy closure once mature.



	Starrett/Crystal	Escanaba/Found	White Sand/Lost	L St. Germain/Star	Moon/Jag
Reference	76.9	82.7	86.0	80.3	84.9
Treated	69.9	72.7	70.3	76.1	77.9
Control	71.2	68.8	78.3	71.0	81.4

Figure A2-2. Initial forest canopy closure at vegetation plots along reference shorelines on undeveloped lakes (n=5) as compared to canopy closure at vegetation plots at control shorelines on developed lakes (n=5) and treated shorelines (shorelines selected for habitat restoration) on developed lakes (n=5).

Measuring the value of wildlife habitat restoration on lakeshores

Previous research has shown that lakeshore housing development is associated with changes in breeding bird guild structure and green frog (*Rana clamitans*) abundance and habitat suitability on developed Lakes in the Northern Highlands (Lindsay and Meyer 2003; Woodford and Meyer 2003). In this project, wildlife surveys (avian, frog calling, and small mammal) were conducted on targeted lakes since 2007 by staff members from Michigan Technological University, North Lakeland Discovery Center, and Moon Beach United Church of Christ.

Breeding bird surveys

Levels of development on lakeshores in northern Wisconsin appear to affect the composition of avian communities, which is of concern for the health of these forested lacustrine habitats.

Lindsay and Meyer (2002) showed no significant differences between Developed and Undeveloped lakes in bird abundance, richness or species diversity in the Northern Highlands. However, several species and some resource-guilds were commonly associated with one lake-type or the other. A significantly higher diversity of diet guilds was found on Developed lakes, though significant declines in the prevalence of insectivorous and ground-nesting birds were documented on these lakes. In contrast, higher prevalence of seed-eating and deciduous-tree nesting birds was recorded on Developed lakes.

To test whether lakeshore restoration can mitigate these effects, a 250m line transect method was used to characterize bird communities during the breeding season along targeted lakeshores. Transects were placed in our three lakeshore treatments: 1) control, 2) restored, and 3) paired reference. All birds detected by sight or sound were recorded; however, we selected 24 species as indicators that have specific habitat requirements Continued surveys are required to fully understand if the size or area of lakeshore habitat restoration is adequate for response in abundance of breeding birds (Kilgo *et al.* 1998). Furthermore, the development further away from the restoration area may have something to do with this slow response by birds (Andren 1994, Donavon *et al.* 1995, Friesen *et al.* 1995). But we stress that this may require more time to see a significant response to the restoration.

<u>Calling frog surveys</u>

Woodford and Meyer (2003) found lower green frog (*Rana clamitans*) abundance on Developed lakes in the Northern Highlands, an association with habitat suitability, not necessarily housing density. It was found that habitat features associated with green frog presence included adjacent wetlands, shoreline shrubs, and emergent and floating vegetation, which were frequently less on Developed Lakes. In this study, green frog abundance was quantified by conducting nocturnal calling surveys by canoe along 250m transects adjacent to our treatment lakeshores. Calling frog surveys were not conducted on LSG, but in our other 4 lake pair sample, we found no pattern of change in frog abundance at the restored lakeshores. To enhance restoration benefits, we may want to initiate aquatic macrophyte restoration in the near-shore littoral zone along these lakeshores. We created tree-drop zones (downed whole trees, with root mass anchored to shore, branches extending lakeward) to develop quiet-water areas for macrophyte restoration where we can assess green frog response to the practice in the future. Placement of tree drops is currently practiced by WDNR fisheries biologists to augment fish habitat on Developed lakes in the Northern Highlands. Of note, we had a precipitous decline in calling green frogs at one

Reference Lake (Escanaba) 2008-2010, followed by a rebound 2011-present. Ranavirus was diagnosed in a sample of dead frogs found on this lake during that period, when several thousand frogs died. Massive die-offs of amphibians are often caused by ranaviruses. USGS scientists have isolated ranaviruses associated with die-offs in over 25 states involving more than 20 species of turtles and amphibians in mortality events ranging from one to thousands of individuals affected. Some events may involve a single species, others may involve multiple species. Frogs and salamanders in the same pond or lake, for example, may die from ranaviral infections at the same time.

Small mammal surveys

No previous work was conducted in the Northern Highlands to evaluate the effects of lakeshore housing development on small mammal abundance and distribution. To measure possible effects, Sherman live traps were placed along 250m transects on our treatment lakeshores. We captured 2,402 individuals representing 14 species along the small mammal transects (2007-2012). *Peromyscus* spp. and the eastern chipmunk (*Tamias striatus*) were the most common, representing 42 percent and 28 percent of the individuals trapped, respectively.

In 2011 through 2013, we collaborated with the Marshfield Clinic Research Foundation to investigate the effects of lakeshore development in Vilas County on the prevalence of tick-borne infectious diseases (TBIDs), and whether disease risk may be reduced by restoration of native vegetation. Tick-borne diseases (Lyme disease) dramatically increased in Wisconsin over the last decade. Because small mammals are also the primary reservoirs for TBIDs, changes in their communities in response to development and restoration may have important implications for the risks of TBIDs to humans and their pets in these areas. For instance, changes in small mammal communities and specifically the dominance of communities by the white-footed mouse are associated with habitat fragmentation in the eastern United States and are hypothesized to be important ecological drivers of human TBID risks (Ostfeld 2011).

Chapter 3. Feasibility Assessment – Testing Methods to Evaluate the Effectiveness of Lakeshore Habitat Restoration to Reduce Overland Runoff and Nutrient Loads from Developed Lakes in Northern Wisconsin

Background

The U.S. Geological Survey, in cooperation with WDNR, conducted a study which evaluated differences in overland runoff and nutrient yields between grass turf lawns and naturally-occurring woodland buffers at near-shore locations in northern Wisconsin (Graczyk *et al.* 2003). They concluded that while concentrations of nutrients were generally higher in woodland buffers, loads and yields of nutrients delivered to lakes were actually higher from lawns because overland runoff was higher than the wooded buffer. Lake property owners at Moon, Lost, and Found Lakes in northern Wisconsin are currently receiving funding to implement lakeshore improvements that include efforts to reduce overland runoff through the restoration of native lakeshore habitat.

As part of the LSG Shoreland Restoration Project 2011-2013, WDNR worked in cooperation with Lou and Donna Mirek (property owners LDM) and consultants to conduct a pilot study to develop and test lower cost run-off sampling methodology (modified from Graczyk *et al.,* 2003) necessary to determine how effective newly constructed lakeshore habitat buffers are at reducing overland runoff and nutrient loads to nearby water resources. The goal was to develop affordable methods which could be installed at several Vilas County restoration projects to document the effectiveness of lakeshore habitat restoration.

Introduction

A final report titled **"Supplemental Report to WDNR: Little St. Germain Lake Protection Grant Restoration of Shoreland Habitat Project Final Report, November 1st, 2013 Re: Surface Water Runoff Volume and Nutrient Loading Surveys"** describes the results of a pilot study designed to evaluate a method with which to measure the impact of lakeshore habitat restoration on overland run-off and nutrient loading from shorelands into adjacent lake surface waters. Previous work (Graczyk *et al.* 2003) found that nutrient yields from developed shorelands are greater than that from adjacent forested habitat; primarily due to increased levels of overland run-off volume. We developed methods with which to measure whether lakeshore habitat restoration can reduce the amount of run-off to lakes. If deemed feasible, and if additional funding is secured, a comprehensive nutrient run-off experiment could be conducted that will:

- Estimate the quantity of surface-water runoff from developed near shore lawns before and after implementation of constructed lakeshore habitat buffers.
- Determine concentrations, loads, and yields of nutrients and sediment in surface-water runoff from developed near shore lawns before and after implementation of a constructed lakeshore habitat buffers.
- Estimate rainfall/runoff coefficients for developed near shore lawns with and without constructed lakeshore habitat buffers.
- Evaluate differences in the quantity of surface-water runoff between developed near shore lawns and those with constructed lakeshore habitat buffers.

The supplemental report in its entirety can be accessed from this report's authors as "Supplemental Materials". Excerpts from the supplemental report follow and are identified by italics.

This report describes the results of a 2-year pilot study to test methods to quantify localized runoff volume and nutrient loading along shoreland areas in northern Wisconsin. The goal is to recommend methods with which to evaluate the effectiveness of restored shoreland buffers to reduce surface water and nutrient run-off on developed lakes. The pilot effort was conducted in collaboration with WDNR and MTU scientists as part of a larger multi-site restoration lakeshore habitat restoration effort, was conducted at a private residence (7654 Pietz Lane; parcel ID: 24-1253-03) located along the east shore of Little Saint Germain Lake, Saint Germain, Wisconsin. Results include 2011-2013 overland surface water runoff volume measurements and water quality and nutrient concentrations as reported by the Wisconsin State Laboratory of Hygiene (WSLH). The pros-and-cons of the piloted runoff collector design are discussed. Recommendations for collector modifications are provided to improve the efficiency and accuracy of the surface water and nutrient run-off measurements.

In spring of 2011, the WDNR proposed a new study that leverages the results of the USGS study to test whether newly constructed shoreland vegetation buffers are effective at reducing overland runoff and nutrient loads to nearby water resources. We tested the feasibility of implementing this new study at a restoration project located along the east central shoreline of Little St. Germain Lake (Figure 13).

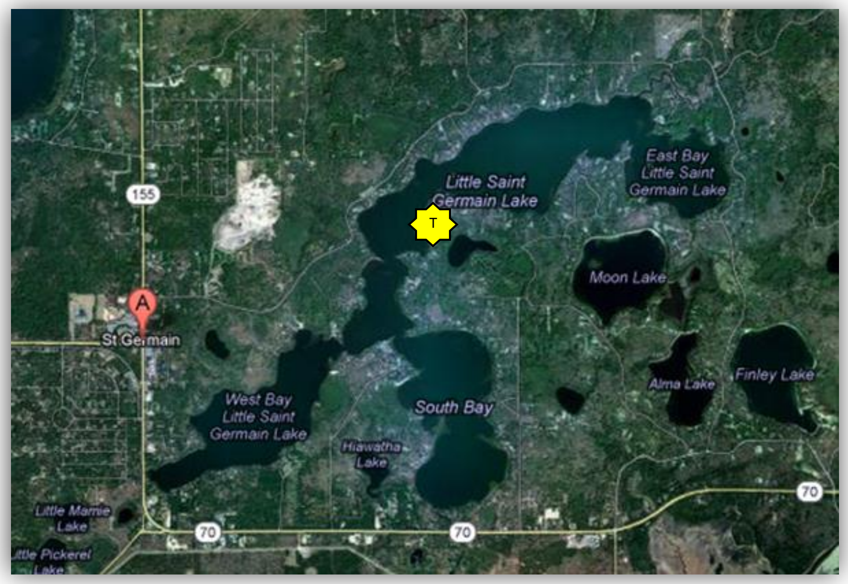


Figure 13 A Google Earth™ image of Little Saint Germain Lake, Saint Germain, Wisconsin showing the location of the restored (T) project site sampled for surface-water and nutrient runoff.

Study Site: The WDNR and MTU collaborated with the Little Saint Germain Lake District to identify private shoreland areas that would benefit from ecological restoration of lakeshore habitat. From this collaboration, a private property located at 7654 Pietz Lane (parcel ID 24-1253-03) and owned by Louis and Donna Mirek, was selected to conduct the pilot project to test concepts and methods to measure surface-water (overland) runoff volume and water quality parameters indicative of nutrient loading potential into the surface-waters of Little Saint Germain Lake (LSGL). The pilot efforts to design, install and collect measures of overland runoff were initiated in 2011 concurrent with shoreland restoration efforts.

Photographs A-D in Figure 14 represents the private shoreland area selected to implement shoreland restoration efforts and overland runoff measurements. The shoreline is characterized by a westerly-facing 20%-35% slope with sandy soils covered by a layer of pine needle duff that varies from 0 to 6 inches in depth. Prior to restoration, the shoreline was sparsely vegetated by native northern forest shrub and tree species considered resistant to deer-browse. The canopy remains dominated by mature red pines (Pinus resinosa) planted several decades earlier, and combined with the few hardwood tree species, creates canopy cover ranging from <5% to near 75% of total sky area.

A) Restoration consultants on site *B) Shoreline prior to restoration*

C) Lawn area above sloping shoreline *D) Transition zone from lawn to shoreline*

Figure 14 Shoreland zone prior to restoration and installation of the runoff collector plots.

The study site is located within the Northern Highlands Ecological Landscape (NHEL) of north-central Wisconsin. The WDNR description (WDNR, 2012) of this EL describes the Northern Highlands as characterized by a deep sandy glacial outwash plateau higher in elevation than most portions of the state, and that contains the State's highest density of lakes created as result of buried glacier ice from the receding Laurentide ice-sheet during the Wisconsin Glaciation. Lakes within this region are generally small in surface area and exhibit shorelines with steep slopes. Regional surface-water hydrology drains via surface and underground flow via a network of seepage and drainage lakes and stream tributaries of the Flambeau, Chippewa and Wisconsin River systems. Climate patterns for this region are typical of northern Wisconsin with a mean growing season of 122 days and mean annual temperature of 39.5^{o} F. Annual snow, sleet, and rainfall precipitation patterns produce a mean annual precipitation of 31.6 inches (including a mean annual 68.1" of snowfall).

Methods

The Project Investigator, Michigan Technological University (MTU), Vilas County and consultant specialists met on-site (Photo A in Figure 14) during fall of 2011 to determine the general location to install three experimental study plots. The sites were selected within context of the overarching shoreland buffer restoration concept. Once the sites were selected, optional design considerations were discussed in reference to the advice from USGS hydrology scientists provided during a previous meeting and reported in Graczyk et al. 2003. Runoff collector design considerations included the practical needs for site customization and most importantly, to standardize performance so that the design and sample collection methods would produce comparable results across different sites (or treatment plots) within the study area. Additional considerations included a desire to stay within the current project budget and the interest to develop a low-cost prototype collector to measure overland runoff at multiple sites as part of an expanded future study. In practical terms, this omitted the purchase and installation of costly specialized instrumentation typical in large-scale runoff studies designed by the USGS.

Collector Design and Installation

Figure 15 presents a schematic illustration of the collector design and concept. Photographs A-F (Figure 16) document the stages of installation of one of three overland runoff collectors. The design required complete fabrication using common building supply materials obtained at a local hardware store. The collector was designed to represent a closed rainfall basin 50m^2 in area approximating a true circle 4 meters in radius. The outer ring consisted of 83 feet of 6-inch plastic landscape edging buried and anchored to a 4-5" depth to enclose all rainfall (and irrigation) for available capture by the collector unit installed at the lowest elevation point of the circular plot. Four 10 foot lengths of 2-inch diameter ABS plastic drainage pipe, each with perpendicular cuts made every 0.5 inches along their length (to produce a slotted pipe) were connected end-to-end (photo E) and anchored partially buried in the down-slope half of the experimental plot. Pipe ends were fitted with leaf screens and clean-out couplers to facilitate maintenance. At the lowest end of the collector, a 2-inch PVC tee w/ cleanout couplers and sediment screens was installed inline to allow overland flow captured by the slotted pipe to drain to a centralized collecting tube that drained into a clean sampling vessel fabricated from a 3" x 33" Cellular-Core PVC pipe with end caps. The sampling vessel capacity is 3,500 milliliters (3.5 L).

At completion of edging, piping, and collector vessel installation, the entire perimeter of each circular plot was smoothed and leaf/needle litter was replaced. Each ABS collector pipe and fittings were sprayed with a non-NPK degreaser, brushed and triple rinsed prior to installation. Precipitation gauges were installed in the center of each plot, including "rain cups" to monitor rainfall during each sampling event. The installation and testing of all three experimental runoff plots was completed by April 2011 and ready for testing and evaluation. At time of collector deployment, all 3 sample containers, and associated hoses and caps were thoroughly cleaned with a non-NPK cleaner solution, double-rinsed by well water, and triple-rinsed by distilled water. A professional grade metric analog All-Weather-Rain Gauge was mounted @1m height on a rigid post approximately 75 meters east of the runoff collector plots near the center of the owner's open lawn. The rain gauge was used to quantify ambient rainfall precipitation in centimeters.

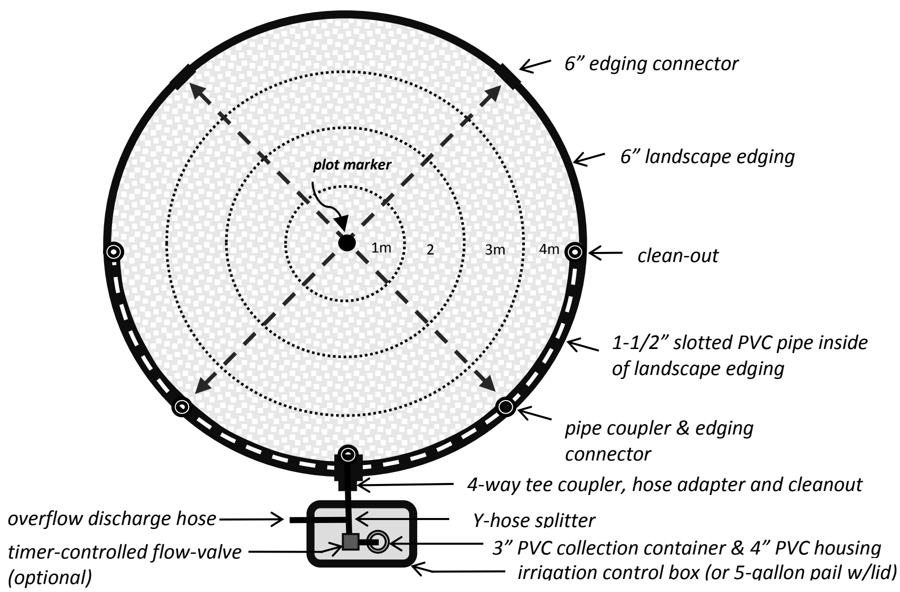


Figure 15 Schematic design of a 50-m2 overland runoff collector and sampling station installed at LSGL study site. A total of 3 collectors were installed where each was planted to a high-density, low-density, or no-planting (control) of native trees and shrubs.

A) 2" ABS pipe connected end-to-end

B) Author installing leaf screen

C) Project assistant on site; facing uphill

D) Runoff collector and sampler housing

E) Completed installation (plot L)

F) 5-gallon pail added to increase capacity

Figure 16 Installation of the concept design for three circular 50m2 overland runoff collectors.

Post-Installation Plot Restoration

In spring of 2012 and following the installation of the runoff collectors and edging, two of the experimental plots were "restored" to one of two plant stocking densities (Low- and High-density planting). A third plot received no additional plantings, however naturally occurring trees were present. See Figure 17 for a graphic representation of the relative proportion of trees and shrubs in each plot that includes potted plants introduced through restoration as well as natural regeneration.

A list of the associated species, form, and count is provided in Table 13. All three plots had similar proportions of dominant trees prior to supplemental planting of potted stock for reasons of applying the treatment prescribed by the restoration. Once the restoration installation was completed, the high-density plot (H) had a total of 46 combining canopy trees, tree saplings and seedlings and shrubs as compared to a combined total of 34 for the low-density (L) plot. Although the low-density plot had similar numbers of dominant trees, the high-density treatment reflected a substantially greater combined density of dominant and sapling trees (total 26) relative to the low-density plot (total 10). The control treatment (plot 3) was void of tree saplings and woody shrubs. Herbaceous, ground-cover plants were not quantified; however they were sparse or non-existent across all three plots reflecting a very high percent plot cover of un-vegetated soil covered by a 0- to 6-inch deep layer of duff consisting primarily of red pine needles.

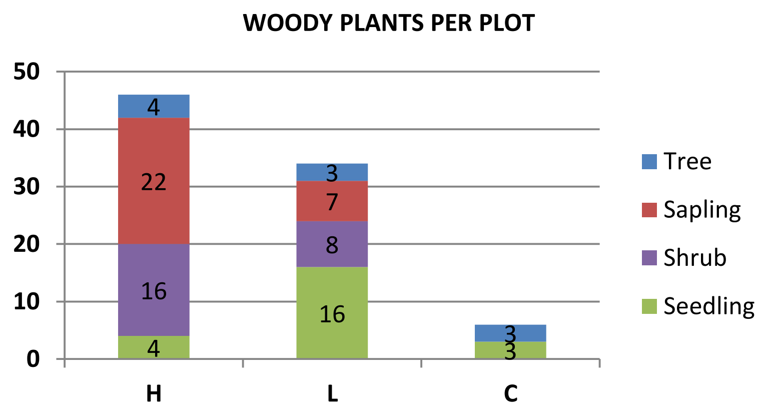


Figure 17 Relative proportions of trees and shrubs by plot treatment type.

Table 13 Species, form, and count of trees and shrubs by plot.

Common Name	*Scientific Name*	*Form*	*High*	*Low*	*Control*
Paper Birch	*Betula papyrifera*	*Tree*	*1*		
Red Pine	*Pinus resinosa*	*Tree*	*3*	*3*	*3*
Balsam Fir	*Abies balsamea*	*Seedling*		*5*	
Red Pine	*Pinus resinosa*	*Seedling*	*4*	*8*	*2*
White Pine	*Pinus strobus*	*Seedling*		*3*	*1*
Balsam Fir	*Abies balsamea*	*Sapling*	*9*		
Red Maple	*Acer rubra*	*Sapling*	*2*	*1*	
Red Oak	*Quercus rubra*	*Sapling*	*2*	*2*	
Red Pine	*Pinus resinosa*	*Sapling*		*1*	
White Pine	*Pinus strobus*	*Sapling*	*9*	*3*	
American Hazel	*Corylus americana*	*Shrub*	*11*	*4*	
Lowbush Blueberry	*Vaccinium angustifolium*	*Shrub*	*5*	*4*	
Total Trees & Shrubs			*46*	*34*	*6*

Collector Testing, Modification and Maintenance

Collector performance was monitored closely during testing in 2011 which included two separate sampling events each associated with heavy rain storms that resulted in over-filling the collector sampling containers despite the small surface area of the artificial watersheds. Graczyk et al. (2003) described similar problems with their collectors which were considerably larger, and which is one of the reasons that we defined a much smaller 50m2 plot area. Despite the reduced plot size, these events suggested it was necessary to increase the total collector runoff storage capacity. To do this, a 5-gallon pail overflow collector was connected to the system via a ¾" diameter hose (connected by a brass coupler mounted 26 cm from bottom of pail) and partly buried to ensure gravity induced flow. The addition of the 5-gallon pail provided an additional 13.7 L capacity (3.6 gallons) for a total plot runoff volume storage capacity of 17.2 Liters (4.5 gallons).

Collector maintenance included regular inspection of the collector perimeter for evidence of overland runoff escaping below or above the edging, removal of leaf debris collected on the gutter screen material to prevent leaves and twigs from entering the collector tubes, and removal of clean-out caps for flushing of built up sediment from inside the collector pipe. Observations on performance during 2011 and 2012 indicated that the total collector system was performing to expectations, with the caveat that a "closed" volume collector design was effective in measuring total runoff volume for only light to moderate (approximately 1-2-inches rain fall per7 day sampling period) precipitation events depending upon intensity or rate of precipitation.

Collector Monitoring and Water Quality Sampling

Overland (surface of ground) runoff from each collection plot (H, L, C) was collected inside 3.5 liter sample containers fabricated from Cellular-Core PVC. Sample container contents were then transferred to an 8-L capacity sample splitter, an EPA approved sample-handling device that homogenizes water samples to produce sample aliquots with equivalent constituent concentrations per unit of volume (e.g., per milliliter). Sample container contents were mildly agitated to re-suspend sediments prior to pouring contents into the sample splitter. Volumetric measurements were quantified visually using a graduated cylinder filled from the sample splitter. Volume measurements were recorded to estimate total runoff sample volume while filling laboratory-sourced plastic sample containers for constituent analysis. Field quality-control duplicate samples were prepared to compare analytical consistency. An additional set of samples were collected from the adjacent lake surface waters approximately 5m from shore by submersing the sample splitter device at an "arm-length" *grab sample below the lake surface. This sample represented the irrigation source as a potential minimum concentrate level per each constituent.*

Excess volume was discarded when it was not needed to produce duplicate samples for quality assurance (QA) measures. Three separate sample containers and preservation methods were used to comply with the methods and procedures of the Wisconsin State Laboratory of Hygiene (WSLH, Table 14). Samples were collected in the following routine sequence to ensure quality sampling: 1) one 500-ml bottle for total suspended solids (TSS), 2) one 250-ml bottle for nutrient analysis preserved with H_2SO_4 ; and 3) one 60-ml bottle for dissolved total phosphorous (TDP) filtered with a 0.45 micron filter and preserved with H_2SO_4. See Table 14 for a list of the specific WQ parameters (also referred to as constituents) and associated lab methods and detection limits. Sample bottles were labeled with site name, plot ID and date then placed in 1-gallon locking plastic bags to group samples prior to placing in a cooler. All samples were shipped in a cooler filled with ice via next day ground transport (SpeeDee, Inc.) to the WSLH facility in Madison, WI. The WSLH provided test results via email and through the WDNR SWIMS (surface water information management system) database. When sample collection was completed, the sample containers were stored until the next deployment date, at which time they went through a complete cleaning and rinsing procedure prior to deployment. A total of 3 sampling events per year (spring, summer, and fall) were made.

Table 14 WQ parameters and analytical methods performed by WSLH.

WQ Parameter	Method	LOQ	LOD	Units	Preservative/Handling
Ammonia Nitrogen (NH3-N, Diss)	EPA 350.1	0.048	0.015	mg/L	pH < 2 with H_2SO_4
Nitrate + Nitrite (NO3+NO2, Diss)	EPA 353.2	0.061	0.019	mg/L	pH < 2 with H_2SO_4
Total Kjeldahl Nitrogen (TKN)	EPA 351.2	0.040	0.140	mg/L	pH < 2 with H_2SO_4
Total Phosphorus (TP)	EPA 365.1	0.016	0.005	mg/L	pH < 2 with H_2SO_4
Total Phosphorus, Dissolved (TDP)	EPA 365.1	0.016	0.005	mg/L	pH < 2 with H_2SO_4, filtered
Total Suspended Solids (TSS)	SM 2540D	7	2	mg/L	None

LOQ: Level of quantification; LOD: Level of detection. All samples were placed in a cooler filled w/ice following preservative/handling for shipping via next day carrier.

Results and Discussion

In this pilot study, a simple and low-cost design to collect overland runoff without costly instrumentation was tested for function and performance. This section describes the functionality and performance of the design and presents the quantitative results from the monitoring effort.

Recommendations are made for collector (experimental plot) re-design options to enhance function, performance, and accuracy.

Collector Functionality

In a functional sense, the designed collectors operated to expectations capturing overland flow of precipitation runoff into a centralized sampling container to facilitate measurement of total runoff volume and water quality. See Appendix A and B, respectively (in Supplemental Material), for reporting on sample nutrient concentrations and their annual average concentrations. Appendix C (in Supplemental Material) presents measures in runoff volume and estimated constituent yields. The design function of all three collectors was observed to be similar with no apparent signs of runoff overflow over the top of the 6-inch landscape edging or gullying under the edging which was a possibility given the steep (35% slope) shoreline topography, sparse vegetation and sandy soils. Functionally, the only problems with the collector design was its maximum limit (3.5 L) on runoff storage capacity (later increased to 17.2 L) and the need for regular maintenance to flush sand deposits that build up occasionally in segments of the 2-inch ABS pipe serving as the runoff collector. This problem only occurred with one (plot L) of the three collectors, and was a result of establishment of an active ant colony following installation.

A potential third problem relating to function may be the effect of installing the edging on steep slope that may produce change in the rate of slope erosion on the down-slope side outside of the collector creating a curb-like effect (Figure 18). Observations of sprinkler irrigation performance suggest that water from the sprinklers is the primary cause of this erosion problem. It's conceivable that over a longer period of time (5-10 years) this curb-like effect may worsen requiring installation of additional erosion-control infrastructure (e.g., Enviro-lok® bags, rolled E-C fabric, natural or bio-core logs) to mitigate the effect of runoff sampling devices. It's also possible that this effect may occur with any design installed on steep slope with sandy soil that has an active sprinkler irrigation system (typical for new restoration sites). An example of project action to minimize the curbing downside of the collectors can be seen in photo J of Figure 4 where natural birch logs were placed to moderate the slope after installing the 5-gallon pail to increase sample storage capacity. Other control efforts might include strategic placement of sprinkler heads and/or the installation of alternate sprinkler models or sprinkler system deflectors.

Figure 18 Collector in plot L (low-density planting) - post-planting 2013. Note inset highlighting potential "curbing" effect at bottom edge of collector. Visual observations suggest this problem is likely due to water impact from sprinkler irrigation.

Collector Performance

Over the period 2011 to 2013, a total of six precipitation and sampling events occurred that met project quality objectives. Measures of runoff nutrient concentrations (Appendix A, Supplemental Materials) were averaged to provide estimates of annual parameter concentrations and estimates of year-to-year change (Appendix B, Supplemental Materials). The associated overland runoff volume necessary to calculate estimates of nutrient loading potential is provided in Appendix C, Supplemental Materials.

The effectiveness of the collector to capture rainfall within the plot enclosure and to exclude overland runoff originating from outside the enclosure is critical as related to function. As described above, visual observations of all three collectors over a period of 3 years showed no evidence of overland runoff flow over or under the plot edge barrier (buried 6-inch landscape edging). The lack of any sign indicating gullying under the collector tubes (slotted ABS pipe) or landscape edging provides reasonable assurance that all overland runoff flow that developed within each plot was collected and channeled to the plot sample collector pipe used to measure volume and to produce water samples for laboratory analysis of water quality. This conclusion is supported by a general positive correlation between measured total runoff volume and simultaneous measures in precipitation amount using a professional-grade analog rainfall gauge calibrated to cubic centimeters (milliliters). See Table 15 *and Figure 19, respectively, for the actual measurements and graphic relationship between the associated measures in runoff volume by plot type (treatment) and precipitation amounts.*

Table 15 Comparison of measures in runoff volume (ml) by plot type and precipitation amount (ml).

DATE	PRECIPITATION	C	L	H	AVG
NOV-2011	6.0	821	2919	55	1265
AUG-2012	43.8	6030	11505	3445	6993
OCT-2012	29.0	3500	5230	3350	4027
JUN-2013	47.0	8305	2990	470	3922
PEARSON CORRELATION ($R_{PEARSON}$)		0.962	0.452	0.395	0.512*

*AVG: average calculated from total of four independent precipitation periods 2011-2013. Pearson correlation coefficients for total precipitation and runoff volume per plot. R values can range from -1 to + 1, where 0 represents no correlation and 1 a perfect correlation; minus sign (-) if present would indicate an inverse correlation (i.e., when one variable increases the other tends to decrease). *R-value pooling all plots and years.*

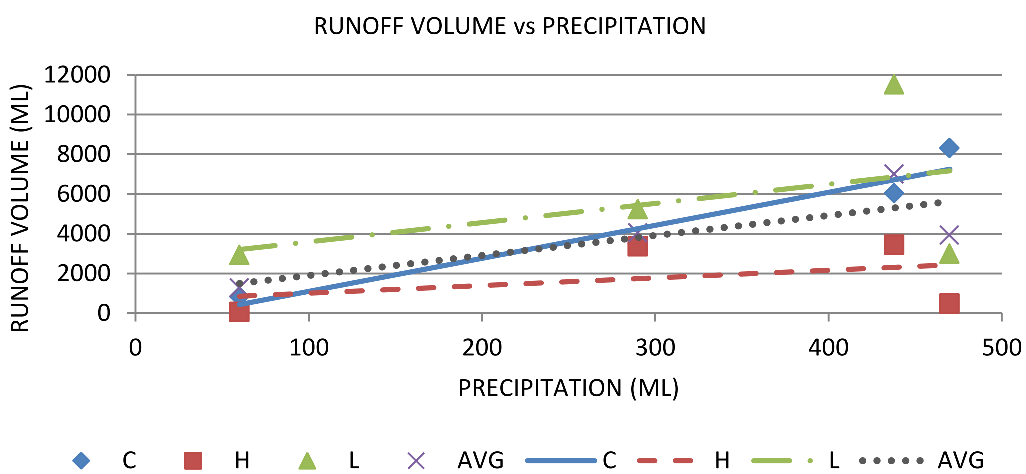


Figure 19 Relationship between amounts in runoff volume and precipitation. AVG: average calculated from total of four independent precipitation periods 2011-2013.

Water Quality of Overland Runoff Samples

From 2011 to fall of 2013, a total of six sampling events were conducted across all three plots (treatments) resulting in: 1)) the water quality test results from WSLH analysis of runoff volume samples (Appendix A) and 2) measurements of runoff volume per plot per collection period (Figure 20). Summaries of this information are presented in Figures 21 and 22 showing annual average water quality constituent concentrations (mg/L) and variation across plot treatments, respectively.

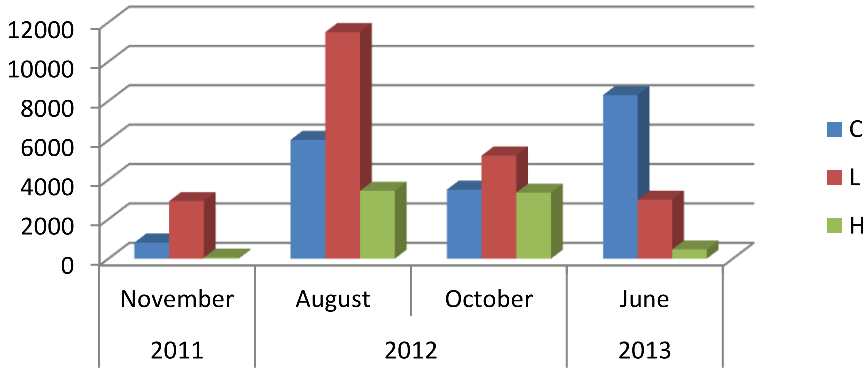


Figure 20 Relative overland runoff volume (ml) per plot.

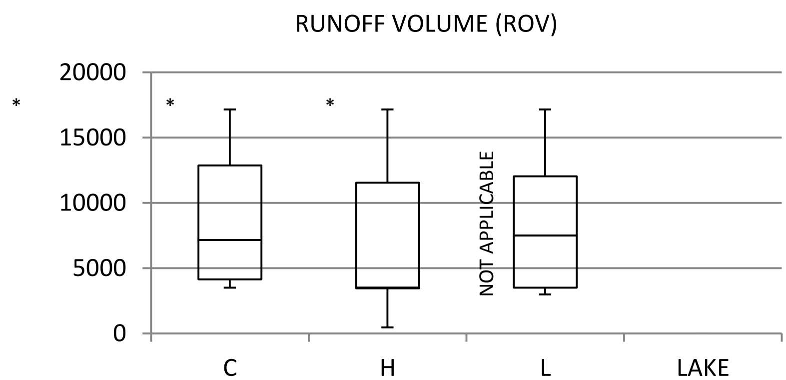


Figure 21 Box and whisker plots presenting the variation in overland runoff volume (ml) by plot type (treatment) over the 3-year period 2011 to 2013; Chart description: Minimum and maximum values (whiskers), the 25th-50th percentile range (lower box), the 50th-75th percentile range (upper box) and median (horizontal line). The narrower the box and shorter the whiskers indicates lower year-to-year variation in sample concentrations. * indicates maximum measurable storage capacity

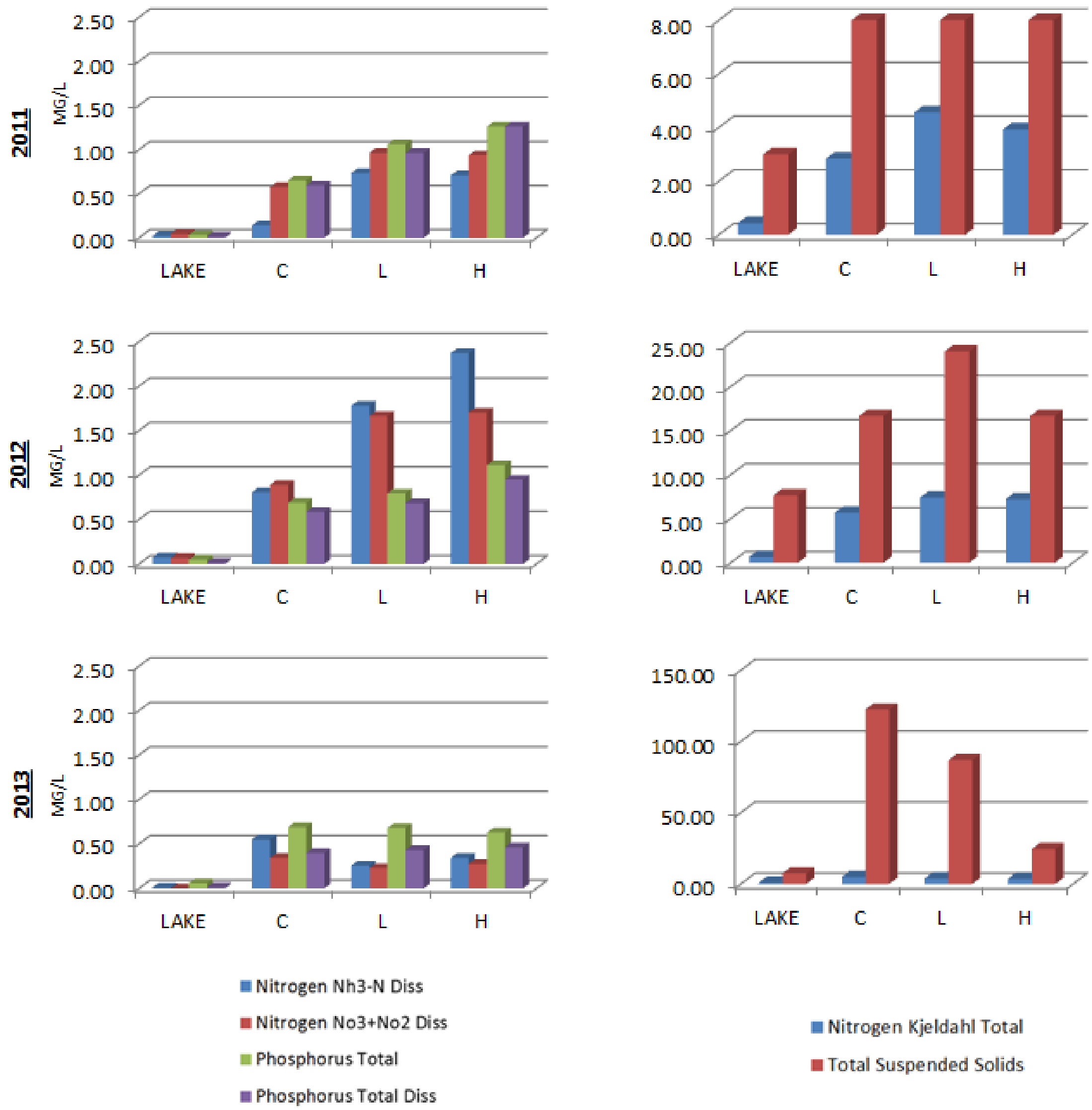


Figure 22 Annual average concentrations (mg/L) for water quality parameters measured 2011 to 2013.

__Nutrient Yield Potential__

Appendix C [in the full supplemental report] lists nutrient loading potential as estimates extrapolated from sample results to represent the total runoff volume measured during each sampling event or period.

__Issues of Precision and Accuracy__

This method does offer a lower cost method for collecting overland run-off measures at lake shore sites. However there is a large amount of variability in run-off volume between treatments during the same collection period, and even within the same treatment plot between collections despite similar precipitation amounts. Therefore the precision and accuracy of this approach requires evaluation before it can be considered as a method with which to compare surface water run-off volume and nutrient loading at developed shorelines with restored lakeshore habitat buffers vs. developed shores without restored buffers. Simply stated, the precision of the collectors needs to be evaluated under controlled conditions. We recommend that overland run-off volume be evaluated under varying precipitation scenarios using controlled irrigation as the source – thereby varying the precipitation amount, duration, and intensity. The precision should also be evaluated using various ground cover substrates. The accuracy of the data also needs to be evaluated. Specifically, do these collectors model "real-world" lakeshore run-off scenarios? The physical forces associated with surface run-off at the landscape scale may or may not be generated within the bounds of the collectors – this should be evaluated. It could be that opening the upper boundary of the collectors will be necessary to intercept the surface water sheet flow generated by precipitation on the slope to be measured. These aspects should be considered in a controlled experimental laboratory environment.

Refer to the full supplemental report (available from Final Report authors) to access the original run-off volume and water quality analysis results produced by this pilot study. **"Supplemental Report to WDNR: Little St. Germain Lake Protection Grant Restoration of Shoreland Habitat Project Final Report, November 1st, 2013 Re: Surface Water Runoff Volume and Nutrient Loading Surveys"**

Chapter 4 Developing Best Management Practices for Lakeshore Habitat Restoration on Little St. Germain Lake and the Northern Highlands Ecological Landscape

Introduction

In the chapter we describe lakeshore habitat restoration practices implemented at select private properties adjacent to Little St. Germain Lake 2010-2013. Described are the steps taken to implement the restorations. We are also comparing variations of some practices (e.g. source of plants, methods of deer deterrence) to identify practices that increase the success of restoration efforts while also minimizing cost. Preliminary findings from these comparisons are presented. The chapter culminates in a description of recommended restoration practices on LSG given our current state of knowledge – the *"Interim Best Management Practices for Lakeshore Habitat Restoration on LSG"*. As our research continues, this BMP will be updated to include results of ongoing experiments and restoration efforts at additional sites in Vilas County, and have applicability throughout the NHEL.

Restoration Methods

Restoration Planning, Planting Density, Species Selection, and Planting Methods

Restoration Planning

Each lakeshore property enrolled in the LSG restoration project received a thorough site assessment to determine the required restoration actions. Native vegetation planting plans were developed for each site following the guidelines and methods described in the Wisconsin Biological Technical Note 1: Shoreland Habitat, with additional recommendations provided by consulting landscape and private nursery owners and VCLWCD staff. Landowner preferences and property-use patterns were taken into consideration in the development of each restoration plan.

The assessment included an evaluation of existing native tree, shrub, and groundcover coverage to determine which plant types were most deficient in the shoreland zone. Soil samples were collected from restoration sites and submitted to the UW Madison Soil and Plant Laboratory to determine soil types and nutrient concentrations – this information guides the selection of native plant species suitable for that soil type. Property areas requiring erosion control were also identified. The amount of down woody material (DWM) present was assessed and decisions made on whether additional DWM should be brought on site. We also assessed the feasibility of installing tree-drops for shoreline protection and to enhance aquatic species habitat. Each restoration plan was recorded on hardcopy and included a map of both the “human infrastructure” and the natural features of the shoreland zone. Human infrastructure included property lines and the locations and dimensions of buildings and other artificial structures such as docks and boats (and their storage locations), outdoor recreation areas (e.g., patios or fire pits), access paths, sidewalks, steps, and driveways. Natural features included the location of the ordinary high water mark (OHWM), topography and shoreland aspect, vegetation, DWM, and priority areas requiring erosion control.

Mapping of most artificial and natural features was accomplished by use of a hand-held recreational grade GPS device (3-5 meter accuracy) and a surveyor’s tape and/or measuring wheel device. Shoreland topography on the LMD property, the location of the OHWM, and prominent landmarks (largest trees, building corners, etc.) were mapped with assistance by Stacy Dehne (engineer, WDATCP, Park Falls) using a surveyor’s grade (sub-meter accuracy) GPS device and base-station reference. We supplemented mapped features with digital photos of the site taken at various locations, usually at each corner and facing different angles, covering most of the proposed restoration project area. These photos provided a valuable reference on site conditions during the planning phase.

Once all features were mapped and information compiled, a restoration ‘base’ map was produced and printed, generally on one or more sheets of 11″ x 14″or 14″ x 17″ paper depending on the size or shape of the restoration project area. Once produced, the scaled ‘base’ map was analyzed to determine planting needs that included compilation of a plant list and expected total numbers needed for each species. Proposed locations for supplemental plantings and augmentation of DWM, any necessary erosion control “green infrastructure” and the perimeter of the herbivore exclosure fence were added to the map documenting the restoration actions required for a particular site. When the restoration plans were finalized, copies were provided to each property owner during a meeting with the owner to explain in detail the concept of the restoration plan. These meetings provided an opportunity for the landowner to request final modifications prior to the implementation of the restoration plan.

Once approved, the timing of delivery of plant orders and other restoration materials were coordinated with local nurseries and/or other local businesses. All regulatory permits required for any erosion control techniques (biologs) and/or tree drops were submitted for approval to the Wisconsin Department of Natural Resources a minimum of three months prior to implementation. The application procedure can be found at this website *http://dnr.wi.gov/topic/waterways/shoreline/shoreline.html*.

Planting Density and Species Selection

Planting density was based on the Wisconsin Biology Technical Note 1: Shoreland Habitat (NRCS 2002) *http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_020187.pdf*. The total square footage of a site was determined and divided by 100, which gave the number of 100ft^2 restoration segments within the restoration area. Supplemental plantings (to meet prescribed density as defined in the Wisconsin Biology Technical Note 1) were then determined for each 100 ft^2 section in consideration of the number of trees, shrubs, and ground cover already present. This procedure was repeated for each 100 ft^2 restoration plot for the entire project site to estimate the total number of trees, shrubs and ground cover required for planting in order to restore native vegetation to the shoreland buffer zone to a minimum standard as recommended in the Wisconsin Biology Technical Note 1.

Tree and shrub species selected for the Little St. Germain projects was based on those occurring at the Star Lake reference transect and other reference transects located on White Sand, Jag, Starrett, and Escanaba Lakes in Vilas County. However, when local nurseries could not provide a selected species, nurseries were allowed to substitute an ecologically appropriate alternative (or horticultural variety) based on seasonal availability. In addition, plant species selection took into consideration soil characteristics and shade tolerance, a species' history of performance on previous restorations and life-history requirements as described in: http://plants.usda.gov/java/, http://wisplants.uwsp.edu/index.html and http://www.botany.wisc.edu/wisflora/. Finally, local botanists and wildlife managers were consulted while planning species lists for restorations.

Handling and Maintenance of Plants prior to Planting

Most plants were delivered from the nursery on the day of planting or one day before - on a few occasions the plants were picked up directly from the nursery. Delivered plants were typically stored inside a fenced area prior to planting to prevent deer browsing when held overnight or longer. When this was not practical, plants were treated with an herbivore repellent (Liquid Fence® or Deer Stopper) and monitored regularly for browse damage. While in storage on site, plants were monitored for adequate soil moisture and shaded to prevent heat stress when temperatures exceeded 60F.

Three tree and shrub planting types were used in LSG restorations – potted or container (CT) trees and shrubs, spring-dormant bare root (BR) trees and shrubs, and bare root trees and shrubs grown in gravel (gravel culture - GC) which allows for bare root plantings trees and shrubs during the growing season. CT trees and shrubs are propagated in potting soil at the nursery, consisting of three parts wood chips, two parts compost, and one part top soil. Prior to delivery, a slow release fertilizer was applied to the top of potting soil. No fertilizer was applied on site or when planted. In addition, CTs are sold in various pot sizes suitable to the size of the plant. BR plants are grown in soil, lifted mechanically while shaking the soil free from the roots prior to sale. These plants come in a dormant state (no leaves present) and are shipped to local nurseries from wholesale nurseries located in the upper Midwest. There is a short period of time when BR can be planted, usually late April through May in northern Wisconsin. However, the BR practice is sensitive to ambient temperatures - if above average temperatures occur in the spring, the window of opportunity to use BR is shorter due to the early leaf out. GC extends the period of time bare root stock can be planted – the practice of growing trees and shrubs in gravel beds after leaf-out allows bare root stock to be planted into the growing season.

Regardless of which form the plants were sold (CT, GC, or BR), all plants were initially propagated in a soil matrix amended with fertilizer. Both forms of bare-root stock (GC and BR) required special care prior to planting. BR plants that were spring dormant were kept under dampened loose straw or placed so that the entire root zone was submersed in water. GC plants were actively growing (buds/leaves forming), therefore each plant's entire root system was submersed in a large water tank supplied by the nursery and/or in lake water adjacent to the project site. All forbs (herbaceous broadleaved plants), ferns and graminoides (grasses and sedges) were sold by nurseries in containers (CT). A component of this study was to evaluate the performance of CT vs. BR vs. GC trees and shrubs.

Planting Methods

Just prior to planting, each plant was evaluated to confirm accuracy of labeling, general condition, and root ball condition. All GC and BR were planted as soon as possible following delivery. Prior to planting, the root systems of GC and BR plants were trimming in to prevent "J-rooting" and to remove root ends that would wrap around the root-collar in later growth. If soil was dry in the area to be planted, water would be applied via irrigation pumps or hand watering. Prior to planting, locations of planting sites were designated with colored wire flags marked with species code and type of plant, for example, a BR red oak would be marked on the flag with "RO, br", the species code capitalized and the type in lower case. In addition, a water based marking paint was used to spray a dot or circle where larger shrubs and saplings were to be planted. Plant holes were dug 50% larger then root masses for all types of plants. CT plant roots were pulled away from root mass prior to planting so roots would spread away from root mass. BR and GC roots were placed in the planting hole and spread evenly while soil was being backfilled. During planting, the soil was amended with compost, approximately, 1-2L placed in the planting hole depending on size of shrub or sapling. Once plants were in the ground, additional water was applied and cedar mulch was applied around the plant stem - extending out 15 cm from base of tree and shrubs, at a depth of five cm. Additional irrigation was applied after planting was completed.

Testing Survival and Growth Rates of "Gravel Culture" and "Spring Bare Root" vs. "Nursery Container" Trees and Shrubs

Haskell (2009) measured the survival and growth rate of six native shrub species that were transplanted in the summer from bare root stock and compared to shrubs planted from nursery containers in 2007 at Found Lake restoration sites. Spring bare root shrubs were established at a local nursery (Hansen's Garden Village, Rhinelander) where they were propagated in a growth medium consisting of 2.5 cm diameter gravel approximately 30 cm deep. GC shrubs can be cost efficient for restoration projects as their use can reduce the restoration costs of shrubs planted in nursery containers by 50-75%, as they can be planted after leaf out. On Found Lake, Haskell (2009) found no difference in growth rates and survival of four species of matched GC and nursery container (CT) shrubs (*Sambucus canadensis, Aronia canadensis, Cornus racmosa, Cornus stolonifera*), but an increase in growth rates of GC snowberry (*Symphoricarpus albus*) and a decrease in growth rates of GC common ninebark (*Physocarpus opulifolius*). Six additional species were added to the experiment in 2008 and evaluated in 2009 on Moon Lake.

We continued the GC vs. CT shrub growth and survival experiments using additional native species on Little St. Germain Lake 2010-2012. These GC and BR plants are lower in cost, depending on the species, 25-50% less than nursery container (CT) trees and shrubs. In summer 2011, we planted three species of GC tree saplings and 12 species of GC shrubs. In spring 2012, we planted five species of BR trees and eight species of BR shrubs (Table 16). All GC and BR species of trees & shrubs were matched with CT species, identified with numbered metal tags, and crown volume measured at the time of planting. These measures are again made in subsequent years to compare survival and growth rates between the three plants sources.

Table 16 Gravel culture and spring bare root tree & shrub species planted at LSG Lake in June 2011. Each plant was matched with a nursery container plant, and both were tagged and measured in late summer of 2011.

Gravel Culture Tree and Shrub Species	# Pairs Planted
Acer rubra- Red Maple	4
Amelanchier canadensis - Canada Serviceberry	6
Amelanchier laevis - Allegheny Serviceberry	7

Aronia melanocarpa - Glossy Black Chokeberry	23
Corylus americana - American Hazelnut	33
Corylus cornuta - Beaked Hazelnut	25
Cornus racemosa - Gray Dogwood	7
Cornus stolonifera - Red Osier Dogwood	10
Dervilla lonicera - Bush Honeysuckle	22
Physocarpus opulifolius - Common Ninebark	10
Betula papyrifera - Paper Birch	5
Symphoricarpos albus - Snowberry	10
Viburnum opulus - High Bush Cranberry	3
Prunus virginiana – Chokecherry	3
Spring Bare Root Tree and Shrub Species	**# Pairs Planted**
Acer rubra - Red Maple	30
Amelanchier canadensis - Canada Serviceberry	16
Aronia melanocarpa - Glossy Black Chokeberry	8
Corylus americana - American Hazelnut	14
Cronus stolonifera - Red Osier Dogwood	16
Dervilla lonicera - Bush Honeysuckle	17
Physocarpus opulifolius - Common Ninebark	15
Betula papyrifera - Paper Birch	20
Prunus virginana - Chokecherry	7
Quercus rubra Red Oak	24
Sorbus decora - Showy Mountain Ash	4
Symphoricarpos albus - Snowberry	9
Viburnum lentago Nannyberry	2

Plant measurements included height (m) and canopy area (m^2) (Bussler et al. 1995). Height was measured from the soil surface to the highest point of the living tissue in its natural state. Plant canopy area was determined by measuring the width of the canopy at its widest point, then a second width perpendicular to the first. The mean of the two widths was used to calculate the canopy radius and circular canopy area ($A = \pi r^2$). The height and canopy area were used to compute the cylindrical volume (m^3) for each plant (Bussler et al. 1995). The percent change in cylindrical volume (m^3) for each plant was calculated based on measurements at two time periods and was used to estimate plant growth ((Bussler et al. 1995, Haskell et al. 2012). Shrub species were measured in late summer of 2011 and again in August 2012 and 2013.

Testing the Benefits of Down Woody Material Augmentation

Haskell *et al.* (2012) investigated the benefits of the addition of DWM at Found Lake lakeshore habitat restoration sites by establishing thirty 10m x10m experimental plots using three treatments of DWM (0, 25, 50% coverage). Daily soil temperature and moisture were measured at a depth of 10 cm, and plots were planted with 2 native shrubs and native understory herbaceous species; change in plant canopy volume was compared between treatments. The mean maximum soil moisture, temperature variation, and change in soil moisture were significantly lower in the 25% and 50% DWM plots. Plant growth volume for snowberry (*Symphoricarpus albus*) and barren strawberry (*Waldenstenia fragaroides*) was significantly greater in the 25% and 50% DWM plots. We replicated these experiments on Little St. Germain, using other native plant restoration species 2011 - 2013.

Six 3m×3m experimental plots were placed within two restoration properties, three on the LDM property and three on the FPS property. Two sets of three experimental plots (0%, 25%, and 50% cover of DWM) were established. Each set of experimental plots was placed in line and parallel with the shoreline and 3 meters inland from the original high water mark. This placed the experimental plots in the middle of the 35-ft state-mandated buffer zone (Wisconsin Shoreland Management Program, chapter NR 115), a consistent distance from the shoreline, and far enough from the shoreline edge to minimized the risk of high wave action. The three plots were placed 0.5 to 1.0 m apart. We defined DWM as branches ≥ 2.5 cm and ≤15 cm in diameter and ≤3 m in length (Haskell et al. 2012).

In each experimental plot four shrubs and 26 forbs and grasses were planted. A total of 24 shrubs (6 common ninebark, 6 pin cherries, and 12 round-leafed dogwoods) and 153 ground cover individuals (see Table 23) were planted and uniquely identified with numbered metal tags. All shrubs and ground cover species were planted in mid-June 2012. Plant survival was recorded in August 2012 and 2013. We define survival as "live plant material present" during data collection. Plants may go into a dormant state, therefore, may not be counted one survey year but are present the following year. Dormancy is a condition in which an herbaceous perennial does not sprout for one or more growing seasons (Lesica and Steele 1994). The cause for dormancy may be transplant shock. This was observed for wild lupine (see table 13). One common ninebark, one pincherry (*Prunus pennsylvanica*), and two round-leafed dogwoods (*Cornus rugosa*) were planted in each experimental plot. For each shrub, one liter of organic compost was incorporated into the soil before shrubs were planted. We planted 2-5 of each of the following forbs and grasses, big bluestem grass (*Andropogon geradii*) (n=30), sky blue aster (*Aster oolentangiensis*) (n=15), woodland sedge (*Carex arcatata*) (n=15), fireweed (*Epilobium angustifolium*) (n=21), wild lupine (*Lupinus perennis*) (n=21), black-eyed Susan (*Rubeckia hirta*) (n=21), and smooth aster (*Symphyotrichum laevis*) (n=30). Plant densities were based on recommendations from the Wisconsin Biology Technical Note 1: Shoreland Habitat (NRCS 2002).

Erosion Control Methods

We consulted with personnel from VCLWCD, WDATCP and local landscapers prior to deciding on the appropriate erosion control methods for each property.

Geotextile bag walls: Geotextile bags were installed on steep (≥ 25°), sandy slopes that exhibited severe erosion or on slopes which lacked vegetation that could result in future erosion issues. A geotextile bag system is a bio-engineered vegetated retaining wall that is strong, environmentally-friendly, and creates beautiful, pristine, natural landscapes. In addition, the geotextile bag system is an erosion control and slope stabilization system that utilizes ecologically advanced soil bag and interlocking grid technologies. These bags are filled with a ratio of 80% top soil and 20% compost, closed with a UV resistant zip tie, and filled prior to delivery by local vendors. The dimensions of a filled bag are approximately 61 cm (24 inches) long, 30.5 cm (12 inches) wide, and 10 cm (4 inches) thick. The bag material is a polypropylene, staple fiber, needle-punched non-woven geotextile. The fibers are needled to form a stable network that retains dimensional stability relative to each other. The geotextile is resistant to ultraviolet degradation and to biological and chemical environments normally found in soils – an example of a product used in this project can be found at this link (*www.envirolok.com*). Once an area is selected for bag wall installation, a small trench is dug no less than eight cm deep, 40 cm wide and the length of the bag wall. The trenches are leveled using four and two foot carpenter levels or a string level. The bottom of the trench is compacted using a hand tamper and rechecked for levelness. This trench serves as toe stabilization and will protect the bag wall from undermining and collapse. The foundation course begins by placing plastic connection pins in the excavated trench at the desired location of the first row of bags. Filled bags are placed next to each other, horizontally, and run the full length of the trench. Once the first course is laid, the bags are back filled where necessary with top soil and compost, then bags and top soil are compacted using hand tamper, bags soaked with water using a garden hose, and two connection pins are evenly inserted, approximately five cm into bag, on top of each bag . Additional courses of bags are continued until desired height of bag wall is met. Native forbs, grasses and small shrubs are placed between courses as the bag wall is constructed.

Erosion Control Blankets: Two types of erosion control blankets were used on this project - coconut coir and straw blankets. The coconut coir is a long-term, double netted erosion control blanket that is machine-assembled using 100% coconut fibers. The straw blanket is composed of wheat straw and is machine-assembled into rolls on polypropylene netting. These blankets are designed to reduce soil erosion and assist in the growth of vegetation. The blankets are rolled out vertically down-slope or horizontally across a slope in areas with moderate erosion issues. The coconut coir blanket was installed on steeper slopes or in combination with straw blankets. Once the blankets were placed and secured with sod pins, native plants were integrated evenly throughout both blankets.

Rain Gardens: Rain gardens are designed to intercept and retain water following a precipitation event, particularly at sites which have a large proportion of the area as impervious surface (roof tops, paved driveways and pathways, etc.) The retained water then slowly infiltrates into the soil and evaporates rather than running directly into the lake. The storm water runoff can carry pollutants such as oil and other vehicle fluids, lawn fertilizers, and pesticides to the lake. Interception of the runoff in rain gardens can protect the lake from these pollutants, as well as from additional sediments and nutrients. The size of a rain garden will depend on the area available and the amount of water retention required.

Coconut Coir Biologs: Biologs provide initial structural stability for the shoreline by resisting wave action, flow velocity, and an excellent substrate for plant growth. Biologs are constructed of interwoven coconut fibers that are bound together with biodegradable netting. Commercially produced coir logs come in various lengths and diameters, and dimensions chosen are site specific. Steel cables with earth anchors and wooden hardwood stakes are used to secure biologs to shorelines. Native wetlands plants are planted between biologs and the shoreline substrate at approximately 30 cm intervals. We consulted with VCLWCD and WDATCP staff prior to installation and placement of biologs on LSG. All biologs are subjected to permit application and review by WDNR shoreland specialists.

Testing the Effectiveness of Deer Repellents vs. Deer Fencing

We compared the effectiveness of three deer repellents (Liquid Fence®, Deer Stopper, and Deer Fortress) to that of installing an 8-foot tall fence barrier to prevent herbivory of restoration plants. Inspection of several Vilas County restoration projects implemented by Vilas County LWCD prior to the WDNR Shoreland Restoration Project showed moderate to severe damage due to deer, eastern cottontail rabbits (*Sylvilagus floridanus*) and snowshoe hare (*Lepus americanus*) herbivory at those sites. Three deer repellent formulations vs. fencing vs. control (no fence or repellent) were tested in plots containing a combination planting of twelve shrub species. Results from this experiment provide guidance as to how fencing and/or repellents are incorporated into future recommended shoreland restoration best management practices. Both Liquid Fence® and Deer Stopper are liquid concentrates sprayed on plants using a hand held one gallon sprayer and mixed according to manufacturer's recommendations. Liquid Fence active ingredients include putrescent egg solids (25.65%), garlic

(2.96%), sodium lauryl sulfate (0.61%), and potassium sorbate (0.49%). Deer Stopper active ingredients consist of putrescent egg solids (14.40%), rosemary oil (2.06%), and mint oil (1.36%). These repellents are considered to be contact repellents as they are sprayed directly on the plant foliage. One problem with contact repellents is that they only protect the foliage to which they are applied and new growth that emerges after treatment is not protected (Allan et al. 1984). Deer Fortress is a non-toxic, 100% dried blood product in a weather resistant package that produces an odor which triggers fear in deer. As air flows through the repellent station the scent is carried across the area protected, and according to manufacturer's directions, will last the entire growing season.

LSG Restoration Results 2011-2013

Plant Material Installed at Little St. Germain Projects

2011*:* In the spring and summer months of 2011,187 trees, 1014 shrubs, two vines, 65 ferns, 4000 forbs and grasses and sedges were planted within the 35′ buffer zone and along approximately 500′ of linear lakeshore on two privately owned properties.
2012: In the spring and summer months of 2012, 542 trees, 1510 shrubs, eight vines, 93 ferns, 6000 forbs and grasses and sedges were planted within the 35′ buffer zone and along approximately 1500′ of linear lakeshore on five privately owned properties.

Performance of Gravel Culture & Spring Bare Root Trees & Shrubs

Gravel Culture (GC) Plants - Using bare root shrubs is not a new practice in restoration projects. Traditionally, bare root shrubs are used during the period from frost-free soil to bud break in the spring and defoliation to frozen soil in the fall (Starbuck et al. 2005). Bare root nursery stock can be cost efficient and provide handling ease and soil conservation as compared to container nursery stock (Starbuck et al. 2005). However, it has a restrictive time frame for use, a slower establishment time (Johnson et al. 1984), and greater susceptibility to desiccation during transporting and planting (Starbuck et al. 2005). Starbuck et al. (2005) looked at using gravel as a medium to extend the use of bare roots throughout the summer months. They investigated this technique for red oak (*Quercus rubra*) and green ash (*Fraxinus pennsylvanica*) and reported no mortality. We investigated this technique using several native trees and shrub species obtained from a local nursery (Hanson's Garden Village, Rhinelander, Wisconsin) and integrated them into LSG restoration projects as gravel culture nursery stock. In 2012, all CT shrubs/trees survived but 14 GC shrub/tree species individuals died within one year of planting. Of the 14 GC shrub/tree species, American hazelnut had the highest

mortality (n=6) followed by bush honeysuckle (n=3), beaked hazelnut and glossy black chokeberry (n=2), and one paper birch. In 2012, one additional GC bush honeysuckle and one CT Allegheny serviceberry suffered mortality. What is most interesting in these GC results is the growth rate of common ninebark, which was negative for both years for GC and CT plants. This is opposite of that reported by Haskell (2009) on Found Lake, where common ninebark had positive growth rates for both GC and CT. In addition, snowberry CT showed a positive growth rate in contrast to GC which was negative. This also differed from the Found Lake results (Haskell 2009). The average change in canopy volume for CT by 2013 was much higher than GC, which suggests this plant source will result in initial higher growth rates. Further monitoring is needed to determine if this trend persists.
The results of GC vs. CT trees and shrubs are in Tables 17 and 18.

Table 17 Mean crown volume (m^3) of GC & CT for each species planted at LSG Lake in June 2011,measured in August 2011 and re-measured in August 2012.

2012 Results Gravel Culture Species (n= # of pairs)	Mean 2011 GC Vol m^3	Mean 2011 CT Vol m^3	Mean 2012 GC Vol m^3	Mean 2012 CT Vol m^3	Mean GC Change Vol m^3	Mean CT Change Vol m^3
Red Maple (n=2)	1.71	2.19	2.23	2.69	**0.52**	**0.49**
Canada Serviceberry (n=3)	0.01	1.14	0.09	1.10	**0.08**	**-0.04**
Allegheny Serviceberry (n=7)	0.26	0.81	0.37	0.53	**0.11**	**-0.28**
Black Chokeberry (n=23)	0.21	0.49	0.24	0.55	**0.03**	**0.06**
American Hazelnut (n=33)	0.37	0.50	0.39	0.59	**0.02**	**0.09**
Beaked Hazelnut (n=25)	0.04	0.19	0.07	0.30	**0.02**	**0.11**
Gray Dogwood (n=7)	0.02	0.13	0.04	0.27	**0.02**	**0.14**
Red Osier Dogwood (n=10)	0.24	0.32	0.29	0.48	**0.07**	**0.16**
Bush Honeysuckle (n=22)	0.06	0.09	0.05	0.15	**-0.01**	**0.06**
Common Ninebark (n=10)	0.20	0.54	0.20	0.44	**-0.01**	**-0.10**

Paper Birch (n=5)	2.31	2.64	1.81	3.94	**-0.50**	**1.29**
Snowberry (n=10)	0.28	0.25	0.24	0.30	**-0.05**	**0.05**
High bush Cranberry (n=3)	0.01	0.27	0.07	0.77	**0.06**	**0.50**
Chokecherry (n=3)	0.05	0.04	0.08	0.11	**0.03**	**0.07**
Overall Ave (N=163)	**0.41**	**0.69**	**0.44**	**0.87**	**0.03**	**0.19**

Table 18 Mean crown volume (m^3) of GC & CT for each species planted at LSG Lake in June 2011 and measured again in August 2013.

2013 Results Gravel Culture Species	**Mean 2011 GC Vol m^3**	**Mean 2011 CT Vol m^3**	**Mean 2013 GC Vol m^3**	**Mean 2013 CT Vol m^3**	**Mean GC Change Vol m^3**	**Mean CT Change Vol m^3**
Red Maple (n=2)	1.71	2.23	2.46	3.06	**0.76**	**0.87**
Canada Serviceberry (n=3)	0.01	0.09	0.22	1.35	**0.20**	**0.21**
Allegheny Serviceberry (n=7)	0.26	0.37	0.22	0.35	**-0.05**	**-0.46**
Black Chokeberry (n=23)	0.21	0.24	0.31	0.52	**0.10**	**0.03**
American Hazelnut (n=33)	0.37	0.39	1.31	3.74	**0.06**	**0.12**
Beaked Hazelnut (n=25)	0.04	0.07	0.43	0.61	**0.04**	**0.11**
Gray Dogwood (n=7)	0.02	0.04	0.08	0.30	**0.12**	**0.39**
Red Osier Dogwood (n=10)	0.24	0.29	0.14	0.52	**-0.02**	**0.19**
Bush Honeysuckle (n=22)	0.07	0.05	0.20	0.50	**-0.01**	**0.10**
Common Ninebark (n=10)	0.20	0.39	0.05	0.20	**-0.08**	**-0.14**
Paper Birch (n=5)	2.31	1.81	0.12	0.39	**-0.54**	**1.10**
Snowberry (n=10)	0.05	0.24	0.07	0.20	**-0.08**	**0.07**
High Bush Cranberry	0.28	0.07	0.20	0.32	**0.33**	**0.80**

(n=3)						
Chokecherry (n=3)	0.05	0.20	0.34	1.07	**0.02**	**0.16**
Overall Ave (n=163)	**0.26**	**0.28**	**0.28**	**0.58**	**0.06**	**0.25**

Spring Bare Root (BR) Plants - The results of the BR vs. CT revealed no negative growth rates for any species (Table 19). However, there were 17 BR plants that suffered mortality compared to two CT plants. Canada serviceberry experienced the most casualties (n=8) followed by red oak (n=7); red-osier dogwood and low-bush honeysuckle had (one mortality each). Even though the BR red oak had a high mortality rate it still performed well as related to final average canopy volume. Other BR species that show promise are red maple, black chokeberry, and red-osier dogwood which all performed well relative to their matched CT plants. The overall comparison of survival and crown volume revealed that the BR species did better than GC species in 2013. This may be due to the fact that BRs were planted in the cooler temperatures of mid-spring as compared to GC which were planted in the middle of the summer months (July & August). Perhaps GC species are more susceptible to transplant shock than BR.

We tried to match the BR species list with GC species from the previous year, but availability was an issue at the time of planting (May 2012). We recognize that several species of GC and BR had low sample size and may not reflect their potential performance in restoration projects. For example, nannyberry, chokecherry, high-bush cranberry, and elderberry show high growth rates but sample size to date is small – additional study is necessary. We will continue monitoring CT vs. BR vs. GC planting on our Vilas County restoration projects as we believe more monitoring is required before final recommendations are made.

Table 19 Mean crown volume (m^3) of BR & CT for each species planted at LSG Lake in May, measured in August 2012 and re-measured in August 2013.

2012 Results Bare Root Species	Mean 2012 BR Vol m^3	Mean 2012 CT Vol m^3	Mean 2013 BR Vol m^3	Mean 2013 CT Vol m^3	Mean BR Change Vol m^3	Mean CT Change Vol m^3
Red Maple (n=30)	1.12	2.05	11.82	16.68	**10.70**	**14.71**
Canada Serviceberry (n=16)	0.13	0.11	3.48	6.06	**3.35**	**5.95**
Black Chokeberry (n=8)	0.29	0.36	7.93	8.31	**7.64**	**7.95**
American Hazelnut (n=14)	0.18	0.13	6.60	8.18	**6.42**	**8.05**

Red Osier Dogwood (n=16)	0.15	0.20	8.33	10.33	**8.18**	**10.13**
Bush Honeysuckle (n=17)	0.13	0.09	8.47	9.23	**8.34**	**9.14**
Common Ninebark (n=15)	0.43	0.32	9.41	9.43	**8.98**	**9.11**
Paper Birch (n=20)	2.42	2.59	12.16	16.04	**9.86**	**13.45**
Chokecherry (n=3)	0.12	0.12	4.11	5.01	**3.99**	**4.89**
Red Oak (n=24)	0.88	1.54	5.58	13.56	**4.71**	**12.02**
Elderberry (n=2)	0.17	0.12	5.14	5.90	**4.97**	**5.78**
Showy Mt. Ash (n=24)	1.00	0.77	11.40	10.97	**10.39**	**10.21**
Snowberry (n=9)	0.45	0.17	9.61	7.66	**9.16**	**7.49**
Nannyberry (n=2)	0.06	0.05	6.16	4.08	**6.10**	**4.04**
Overall Ave (n=163)	**0.54**	**0.62**	**7.87**	**9.39**	**7.34**	**8.78**

Cost Comparison - A comparison of the cost of using these three plant sources (CT vs. BR vs. GC) follows. For the purpose of comparison, we will use the recommended "low planting density" of one tree and three shrubs per100^2 ft. - the low planting density described in the Wisconsin Biology Technical Note 1: Shoreland Habitat (NRCS 2002) (density ranges 1-3 trees and 3-5 shrub/100^2 ft.). We will use LDM Phase II project, to illustrate the cost of using BR vs. CT vs. GC as plant stock. This site is approximately 6000^2 ft. CT trees obtained from a local nursery in 2011 and 2012 averaged $68.50 each. BR and GC tree prices varied among species, BR Red Maple $40.00 and GC $55.00, BR Paper Birch $35.00 and GC $55.00, Red Oak $50.00, and Showy Mountain Ash $40.00 each. No GC Red Oaks or Showy Mt. Ashes were available at the time of planting. The cost of using all CT plants in seven gallon pots to achieve the low density stock rate on the LDM Phase II project would be $4,110, the cost using GC trees would be $3,300, and the cost of BR trees would be $2,535. On the basis of growth, BR trees out performed both GC and some CT, however overall survival rates were lower. Therefore we feel that planting BR in the spring would be the most cost efficient, and planting BRs at a higher density could offset the higher mortality rate. However, the use of a combination of BR, CT and GC provides flexibility for restoration projects as they extend the period of time during which plantings can occur – BR must be planted in the spring prior to leaf-out. Research should continue to further develop knowledge of these techniques and to increase sample sizes of certain species.

We also compared growth and survival of GC, BR, and CT of several coniferous tree species (Tables 20-22). We planted conifers on three properties (LDM Phase II and BJW-PH and BJW-SH properties) in 2012 and recorded survival and heights of each plant in August 2012 and 2013.

Table 20 Gravel culture and spring Bare Root Conifer type tree species planted at LSG Lake in 2012. Each type was matched with container plant and each individual plant was tagged and measured.

Gravel Culture, Bare Root, Container Conifer Trees	Gravel Culture	Bare Root	Container
Abies balsamea -Balsam Fir	17	17	21
Picea glauca -White Spruce	6	14	14
Pinus resinoa -Red Pine	4	17	17
Pinus strobus -Eastern White Pine	24	28	28
Tsuga occidentalis -Northern White Cedar	5	5	5
Total	**56**	**81**	**85**

Because of availability, GC and BR conifers were not equally matched with CT. The results are quite different than the deciduous plants. The BR conifers suffered the highest mortality, with red pine experiencing the most mortality of all three types (Table 21). White spruce BR had the lowest change in height between years. As this is the first project comparing survival and growth of GC, BR, and CT conifer trees, we recommend additional replication in long-term monitoring before final conclusions and recommendations can be made.

Table 21 Survival results on five GC, BR & CT conifer type tree species planted at LSG Lake planted in 2012 .

Gravel Culture, Bare Root, Container Conifer Trees	Gravel Culture	Bare Root	Container
Abies balsamea -Balsam Fir	71%	76%	95%
Picea glauca -White Spruce	100%	50%	100%
Pinus resinoa -Red Pine	50%	41%	94%
Pinus strobus -Eastern White Pine	96%	50%	100%
Tsuga occidentalis -Northern White Cedar	100%	100%	100%
Overall Average Survival	**85.7%**	**56.8%**	**97.6%**

Table 22 One year average height change in centimeters on five GC, BR & CT conifer type tree species planted at LSG Lake planted in 2012

Gravel Culture, Bare Root, Container Conifer Trees	Gravel Culture	Bare Root	Container
Abies balsamea -Balsam Fir	2.88	2.18	13.43
Picea glauca -White Spruce	2.50	0.43	10.57
Pinus resinoa -Red Pine	5.50	5.50	17.68
Pinus strobus -Eastern White Pine	19.50	11.11	12.32
Thuga occidentalis -Northern White Cedar	4.40	14.20	4.40
Overall Average Height in cm	**10.29**	**5.54**	**12.91**

Performance of Downed Woody Material (DWM) Augmentation

At the time of measurement in August 2012 and 2013, all 24 shrubs had survived, however, round-leafed dogwood on the FPS property exhibited leaf wilting and die-back in 2012. In 2012, wild lupine suffered the most mortality of forbs, with 19% mortality on 0% DWM coverage plot, only one wild lupine suffered mortality on 25% DWM in 2012 (Table 23). This species is not typically found on NHEL shorelands and may not be as suited for the local site conditions as those species which occur on reference shorelands. Overall, in 2013, black-eyed Susans, suffered the highest mortality on all DWM plots with the most on 50% DWM plots. This high rate of mortality is possible due to the fact that black-eyed Susans are considered to be an annual or biennial plant (*http://plants.usda.gov*) and may require a natural disturbance to thrive every year (Howe 1995). We also noticed a decline in woodland sedge (*Carex arcatata*) in the 0% DWM plots during 2013 and this may be due to transplant stress. Woodland sedge is found across the landscape and prefers dry soils and is shade tolerant making it a likely species for restoration projects. All three shrubs species tested in these plots should perform well on sites with sandy dry soils – however slope and aspect can add additional stress, south-facing and steep slopes will always be prone to drier conditions and subject to erosion. We stress that more monitoring of all these species is required in order to come to final recommendations for their use in NHEL restoration projects. However, we do stress that DWM is a beneficial component to ecosystems and should be considered an addition to restoration projects (see Haskell et al. 2012, Harmon et al. 1986).

Table 23 2012-2013 Survival of shrubs, forbs and grasses planted in DWM plots (n=6) on LSG Lake

	DWM Plot 2012 & 2013 Survival					
	0% (n=2)		25% (n=2)		50% (n=2)	
Species	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**
Sky Blue Aster (n-15)	100%	100%	100%	100%	100%	100%
Smooth Aster (n=30)	100%	100%	100%	90%	100%	80%
Big Blue Stem (n=30)	100%	100%	100%	100%	100%	90%
Woodland Sedge (n=15)	80%	60%	100%	100%	100%	100%
Fire Weed (n=21)	100%	100%	100%	100%	100%	100%
Black-eyed Susan (n=21)	100%	43%	100%	29%	100%	14%
Wild Lupine (n=21)	57%	86%	86%	100%	86%	86%
Pin Cherry (n=3)	100%	100%	100%	100%	100%	100%
Common Ninebark (n=3)	100%	100%	100%	100%	100%	100%
Roundleaf Dogwood (n=6)	100%	100%	100%	100%	100%	100%

Performance of Erosion Control Devices

Geotextile Bags: Approximately 400 geotextile bags were installed in July-August of 2011 on the LDM property in areas that were experiencing severe erosion on steep slopes. These bags were integrated into the contour of the slopes and native shrubs, forbs and grasses were planted between the bags (Figure 23). The native plants will develop extensive root systems, growing through the bag and into the soil.

We feel that the geotextile bags bag system did a great job of stabilizing the steep slopes and establishing vegetation at the LDM property. These bags were placed at various locations along 500' shoreline where visual signs of erosion were occurring (personal observation). We feel that this is an effective bioengineering technique to establish vegetation on steep, sandy, and highly erodible slopes. These bags are ideal for steep slopes from 25-40 degrees which require quick vegetation establishment. However, the logistics of getting bags on site can be a challenge, since bags weigh approximately 80lbs each. Avoiding damage to existing vegetation while moving bags to the installation site is difficult and care needs to be taken to avoid new erosion issues. We used a 30′ long 30″ wide plastic road culvert cut in half at its length to slide the bags down the slope to areas where bags were installed. Once bags were placed and planted, irrigation was applied regularly to prevent bags from drying out and risking plant mortality. In 2013, bags were still preforming well in that they were intact, plants were becoming established and no gully erosion was visible. All materials were purchased from local nurseries, and bags were constructed and installed according to manufacturers' specifications.

Figure 23 Photos of geotextile bags installed on Lou Mirek's property during the summer of 2011 and 2012.

Erosion Control Blanket: Approximately 300 square yards of coconut coir and straw-filled erosion control blankets were installed at locations along the restoration lakeshores exhibiting moderate to high erosion. Blankets were secured with 8" sod pins and planted with native trees, shrubs, forbs, and grasses (Figure 24). The coconut coir is a long-term, double netted erosion control blanket that is machine-assembled using 100% coconut fibers. The straw blanket is composed of wheat straw and is machine-assembled into rolls on polypropylene netting. These mats are designed to reduce soil erosion and assist in the growth of vegetation. The blankets were rolled out vertically down-slope or horizontally across a slope in areas that had moderate erosion issues. Both the coconut and straw blankets were installed according to manufacturer's instructions. Following blanket installation, plants were then placed throughout blanket by cutting a slot large enough to get the plant root mass through the blanket and into the soil. This procedure reduces loosened soil from eroding down slope and into the lake. In addition, it provides a work area and walking path when traversing the slope during planting further reducing the impact on the soil and slopes. Both products are biodegradable; however, the coconut longevity will surpass the straw blanket. We feel that a combination of both types of blankets would perform well on highly erodible areas. The coconut coir should be used on steeper slopes (20 degree or greater), due to its longevity.

Figure 24 Installation of erosion control blankets in the summer of 2011 on Mirek's Property, LSG Lake. Two types of blankets were used, coconut coir and straw

Sunset Pine Rain Garden: Water runoff from a large gravel driveway, parking lot, roof, and surrounding wooded upland was channeled into a 1,200 square foot rain garden excavated by a local contractor. This rain garden was constructed at BJW-SP property in East Bay during the spring of 2011 (Figure 25). We planted a variety of wetland plants recommended by a private consultant and native plants were provided by a local nursery. To date the rain garden is functioning properly, retaining water runoff without spill over into lake and no standing water has persisted for more than a few days. One issue - fencing was not constructed around the rain garden therefore deer browsed restoration plants occasionally.

Figure 25 Construction of rain garden on Waldmann's Sunset Pine property in 2011. Rain garden was designed to retain water runoff from hard surfaces surrounding rental cabins. Native wetland plants were integrated throughout the rain garden.

Biologs: One hundred twenty feet of biologs of ten foot length and 16 or 20 inch diameter were installed along the LSG shoreline to prevent toe erosion due to a combination of the artificially elevated and fluctuating water-levels that result from operation of the dam at the lake outlet, high-energy wave action from wind, as well as wakes from recreational boat traffic and jet skis. The biologs were installed on BJW-SP property in 2011 (Figure 26). We used six foot lengths of 1/8" diameter cable with earth anchors (attached to one end of cable) to secure the biologs to the lake bed. Each biolog received four pair of cabled earth anchors. Anchors were pounded into the lakebed and shoreline using a four or eight lb. sledge hammer and six foot long, ½" diameter steel rebar. Each pair of earth anchors were secured with metal cable clamps once they reached the appropriate depth. This technique of placing anchors is very time consuming and can be very physically demanding. We also used an electric hammer drill on the last two biologs in place of the sledge hammer. The electric hammer drill performed with much less exertion and we observed no difference in the securing the biologs compared to the sledge hammer. In addition, the time to complete securing a biolog with electric hammer drill was considerably less. Once biologs were secured, native shrubs, forbs and sedges were planted between the biolog and shoreline. As of summer 2013, vegetation has been established and biologs are still anchored in place along the restoration project shorelines. All biologs were acquired from a local nursery and installation materials were purchased from local hardware stores.

Figure 26 Installation of biologs at BJW-SP property on LSG in June 2011. Biologs were secured to the lake bed using cabled earth anchors and then planted with native wetland plants.

Tree drops: In February and March 2011 six trees were deployed and secured by cable and earth anchors along the LDM shoreline to assist in erosion control, improve fish habitat, and promote aquatic vegetation growth (Figure 27). In the winter of 2012, nine more tree drops were secured on BJW-SH (n=5) and BJW-PH (n=4) properties.

Tree drops were placed at the BJW-SH and BJW-PH rental properties, anticipating the renters would enjoy the fishing opportunity the tree drops provide. All the trees on BJW properties were brought in from an offsite location using construction equipment during the winter of 2012. Trees were placed at least 50 feet apart with root wads intact. Root wads were placed on shore while the crowns reached out into the lake. Once ice was out, a local landscaper was contracted to secure tree drops to the lake bed using cables and earth anchors. The trees used on LDM property were placed by a private consultant and local landscaper in the winter of 2011. The trees selected were stressed red pines growing on the LDM shoreline (the shoreline site is covered with a red pine plantation). These trees were also secured to lake bed using cables and anchors. In 2013, a cable on one tree broke loose causing the top of the tree to be pushed parallel to shore. All other trees are still intact and used extensively by recreational fishers (personal observation).

Figure 27 Tree drops installed at Lou Mirek's Property on LSG Lake during the winter of 2011. Trees were later secured to lake bed using steel cables and earth anchors.

Irrigation

It is recommended that all restoration projects receive at least one inch of precipitation per week during the growing season for the first two years. Irrigation is essential during drought conditions or when there is insufficient rainfall so as to avoid widespread mortality of restoration plantings. Small electric and gas pumps with garden hose and sprinkler system were used to supplement watering at BJW-SP, BJW-PH, FPS, and KCG restoration sites. The pumps, garden houses and sprinklers were purchased at a local hardware store in nearby communities. In addition, an automatic irrigation system that was previously installed for lawn irrigation was enhanced to supply water to the LDM restoration site and BJW-SP property. The automatic irrigation was installed by a small business specializing in irrigation and located within the region. The system was installed above-ground so that it could be removed without significant soil disturbance once the restoration had been in place 3-5 years. FPS purchased their own automatic irrigation system within one month after restoration activities, which they installed for use on their restoration area. No homeowners drew their irrigation water from drilled or sand point wells.

Performance of Herbivory Abatement Techniques

Fence: In 2011, approximately 1500 linear feet of eight foot, nylon mesh, UV-protected fence was constructed along the lakeshore which enclosed the restoration areas on LDM and BJW-SP properties (Figure 28). This fence protected the newly planted trees, shrubs, and forbs/grasses/ferns from the over-abundant deer population in the area. To hold the fence upright, 5.5 foot steel T-posts were pounded into the ground 14-16 feet apart. A five foot long, ¾ inch diameter, steel electrical conduit was attached to each T-post with 16 gauge tie wire to extend the support post length. A 1/8 inch diameter, 7x7 braided steel cable was attached to the top of post assemblies and strung the entire length of fence. The cable was attached to corner posts with a 5/16 inch diameter by six inch long turn-buckle which was attached to a ¼ inch diameter by two inch long eye bolt. The cable then was secured to the turn-buckle by two cable clamps. Wooden braces were installed at each 90 degree corner and at various places along fence and gate entrances which strengthened and provided rigidity to the fence in the event of extreme weather throughout the seasons. These braces were secured to the post assemblies by ¼ inch diameter 2½ - 4 inch long hex bolts, nuts and flat washers. After the posts were assembled, corner braces and the cable was erected, then the nylon mesh fence was strung up to the post assemblies and attached with six and eight inch long, UV protected zip-ties. The nylon mesh fence was also zip-tied to the cable securing the top of the fence and six and eight inch long sod pins secured the bottom of the fence to the ground. Entrance gates were placed in various places along fence. In 2012, an additional 2,500 linear feet of fence was constructed on BJW-SH. FPS, and LDM Phase II restoration areas. The KCG property received three foot tall chicken wire fence to abate the local duck population which climbed the bank each day because of supplemental feeding which KCG agreed to end. We estimate the material cost per linear foot of fence to be approximately $2.60. This includes the nylon, t-post, conduit extension, braces and all the hardware. All the materials and tools to install fence were purchased at local hardware stores.

Falling trees and tree limbs can damage fencing thus inspection is required year-round, particularly after wind and ice events. A breached fence can result in rapid damage to the restoration plants should deer find their way in. Tree falls occurred once at LDM Phase I along the shoreline, three times at BJW-SP property, and once at BJW-SH property. The BJW-SP property was the only fence that deer were able to breach, and caused damage to vegetation. The damage to fences varies dependent on tree or limb size. Large trees can flatten fences, while limbs can stretch, but often not collapse the fence material. The 1/8 inch diameter, 7x7 braided steel cable attached to the top of post assemblies and strung the entire length of fence did not break following tree falls - the cable was pulled loose from its cable clamps or eye bolts. This elasticity is a good thing, because it limits the damage to the fence. Fence maintenance should be scheduled regularly - walking the entire perimeter and inspecting and repairing any damages that are present. The fence maintenance person(s) should carry the following materials in their vehicle: a roll of 16 gauge tie wire, a bag of zip ties, extra post extensions, t-post and extra hardware (eye bolts, cable clamps, turnbuckles, nuts and bolts, 16d and 8d nails, various lengths of deck screws, and the tools needed: slip joint pliers, wire cutters, fence pliers, post pounder, 16-20 oz. claw hammer, a hand bow saw, adjustable end wrenches, cordless or conventional screw drivers [Philips #2], various drill bits, set of end wrenches and hacksaw.

Figure 28 Construction of deer abatement fence on LSG Lake in 2011-2012.

Whited-tailed Deer Repellent Experiment: In addition to constructing fence for deer exclusion, we tested three deer repellents, Liquid Fence®, Deer Stop, and Deer Fortress. Four 5m x 5m experimental plots were establish on the LMD Phase II property in June 2012. Each plot was planted with two of six native shrub species (total 12 per plot) - Canada serviceberry (*Amelanchier canadensis*), low-bush honeysuckle (*Diervilla lonicera*), snowberry (*Symphoricarpos albus*), beaked hazelnut (*Corylus americana*), glossy black chokeberry (*Aronia melanocarpa*), downy arrowwood (*Viburnum rafinesquianum*). Each plot was assigned a deer repellent that was applied according to manufacturer's specifications. One plot did not receive any repellent which represented a control plot. We recorded the percentage of each shrub pair browsed by white-tailed deer one week, then one month after application of repellent. Within one week all shrubs in control and Deer Fortress plots experienced 75% deer browse, in the Liquid Fence plot the snowberries experienced 25% and Canada serviceberry experienced 50% deer browse. No shrubs in the Deer Stop plot experienced any browse. And after one month of application all shrubs in the control and Deer Fortress plots were 85% browsed, Liquid Fence plot all shrubs, except one beaked hazelnut were 75% deer browse, the Deer Stop plot both glossy black chokeberry and low bush honeysuckle experienced 25%, and one snowberry experienced 10% browse. Deer Stop plots continued to show reduced deer browsing through one month post-application (Table 24). This also is indicative of what the high density of deer will do to restoration plants without repellent or fence. We stress that the repellents will need to be applied continuously as new growth appears on plants throughout the growing season. Deer will become less deterred by specific repellents and practitioners should alternate between repellents throughout the year (personal observation).

Additional controlled experiments are required to further evaluate product repellent performance as this pilot study lacked replication. An additional product which should be included in future testing is Plant Skyd (porcine blood), a liquid deer repellent used by USFS, BCPL, the Nature Conservancy and often by the WDNR. It can be purchased as pellets and mixed prior to application.

Table 24 Results from white-tailed deer repellent experiment conducted on LSG in 2012. Percentages represent the approximate proportion of six native shrubs browsed by white-tailed deer one week and one month after application.

	Repellent							
	Control		**Deer Fortress**		**Liquid Fence**		**Deer Stop**	
Species	One Week	One Month	One Week	One Month	One Week	One Month	One Week	One Month
Canada Serviceberry	75%	85%	75%	85%	50%	75%	0%	0%
Low-bush Honeysuckle	75%	85%	75%	85%	0%	75%	0%	25%
Snowberry	75%	85%	75%	85%	25%	75%	0%	10%
Beaked Hazelnut	75%	85%	75%	85%	0%	50%	0%	0%
Glossy Black Chokeberry	75%	85%	75%	85%	0%	75%	0%	25%
Downy Arrowwood	75%	85%	75%	85%	0%	75%	0%	0%

Preliminary "Best Management Practices" for Lakeshore Habitat Restoration on Little St. Germain Lake

Research continues to develop Best Management Practices (BMP) for lakeshore habitat restoration on LSG and the NHEL. Here we present our preliminary BMP for LSG, including recommended steps for implementing a restoration. As additional research data is gathered, we will expand and finalize these recommendations, and extend them to the Northern Highlands Ecological Landscape, as many practices which work on LSG will have applicability throughout the region.

Pre-restoration Planning: A detailed restoration plan and map are crucial to a successful restoration project. A restoration map should be generated from careful notes taken in the field and through discussion with property owners. The mapping should begin by creating a hand sketch depicting locations of existing vegetation, downed woody material (snags, logs, stumps), storage location of docks and boats, property boundaries, erosion-impacted areas if present, slope and aspect, desired human viewing and use corridors, and all hard surface areas (structures/roof-tops, driveways, sidewalks, patios). In addition, several photos should be taken on-site at various places in the restoration area, usually at the corners facing the restoration area, with multiple angles. These photos will be valuable when planning a restoration and for comparing before and after restoration activities. Once all information is collected this can be transferred to a detailed map of the area. Gridded map paper can be used to produce a product approximately to scale.

Then restoration plants and erosion control techniques can be added to final map. The location of deer exclusion fencing should be mapped out with gates depicted. A scale and legend should also be added to the map. The legend should consist of codes to plant species and symbols of type of plant. For example, the symbol should identify if a plant is conifer or deciduous, tree or shrub, and the desired type for planting (gravel culture, bare root, or container). Several map copies should be made, with one being sent to landowner, and one to interested government agencies (state or county if permitting is required), as well as to the restoration practitioners installing the project. It is critical the landowner, restoration designer (if not the landowner), and vendors installing the project are in complete understanding as to the map layout.

Furthermore, the map can be used in the future for monitoring the plantings or erosion control efforts. Consultation on bank or shoreline toe erosion problems should begin by contacting the local county conservation department and/or state agency as permits may be required. The permitting can take several days to months for approval so this should be done as soon as possible. Contact information for Vilas County and Wisconsin DNR shoreland information, regulations and permit requirements can be found here:

- The Vilas County Land and Water Conservation contact number is 715-479-3682, the website is found at *http://www.vilasconservation.org/*

- The Vilas County Zoning Department contact number is 715-479-3620, the website and Vilas County Shoreland Ordinances are found at *http://www.vilascountyzoning.com/ordinances.html*

- The Wisconsin Department of Natural Resources Water Regulations and Zoning Specialist for Vilas County can be reached at 715-365-8991, the WDNR Shoreland Zoning website can be found at *http://dnr.wi.gov/topic/ShorelandZoning/*.

Planting Decisions: Plant densities used at the five Northern Highland lakeshore habitat restoration projects, including LSG, are based on the Wisconsin Biology Technical Note 1: Shoreland Habitat (NRCS 2002). The planting density includes 25 ground cover plants (forbs and grasses), three shrubs, and one tree per 100^2 ft. – this is the low end of densities prescribed by the technical note. We used the low density on this project to maximize the amount of lakeshore habitat restoration coverage given the budget available - however experience suggests higher densities could be used when the budget allows and conditions are favorable.

The species of trees and shrubs to be planted at LSG restorations can be guided by examining the over- and understory of NHEL shorelines which have not been developed for housing, as well as unaltered shorelines on the lake where restorations are to occur. An examination of undeveloped stretches of LSG shoreline can also be informative. On this basis, we suggest 40-50% of sapling trees planted on future LSG restoration projects be conifers - white pine and balsam fir to be used most frequently as these species are common and somewhat resistant to deer browsing. Eastern hemlock, red pine, white spruce, white cedar, and jack pine can bemixed in at lower numbers, however hemlock and cedar will need long-term protection (individual fencing) from deer and may require unique soil and microclimate conditions. Deciduous trees that commonly occur on NHEL lakeshores and are available at local and state tree nurseries include red maple, red oak , paper birch , and chokecherry – a mix of which could total 60-70% of deciduous saplings planted, and are listed in order of their frequency of occurrence. Other deciduous trees that should be considered in low numbers, but to increase diversity, include quaking and big-tooth aspen, mountain ash, ironwood, American elm, and depending on soil types and conditions, sugar maple and black cherry. As for shrubs, the species selected will depend on location relative to the shoreline and slope. Near shore, we recommend using tag alder species, *Spirea* species, and sweet gale, and red-osier dogwood (60-80% of those planted), with lesser quantities (<10%) for winterberry, mountain holly, and leatherleaf. These species should be planted near shorelines with sun exposure and moist soils. For upland shrub species we recommend that 60-70% include a mix of hazel, serviceberry, honeysuckle, and upland dogwood species - other species to consider in small numbers include *Salix* and *Vaccinium* species. We have had good success using sweet fern and bearberry on steep, sandy slopes that are highly erodible. These species should be planted at higher densities (six/100^{2}ft) as we have found they are adaptable to drier soils and can thrive on degraded and low nutrient soils.

Ground cover species (forbs and grasses) selected will depend on site conditions and nursery availability; we recommend consulting with a local botanist, forestry personnel, and wildlife managers to develop a list. Species that we have used on LSG include big leaf aster, sky-blue aster, smooth aster, heart-leaf aster, flat-top aster, frost aster, barren strawberry, wild strawberry, pearly everlasting, pussytoes, starflower, *Potentilla* species, *Solidago* species, *Galium* species, wild sarsaparilla, yarrow, wood anemone, Pennsylvania sedge, woodland sedge, poverty grass, and rice grass to name a few (see Appendix 4-A for a complete list of species used). For all species, requirements for soil type, amount of sunlight, and moisture should be considered. Websites containing such information include: *http://wisplants.uwsp.edu/index.html*, *http://www.botany.wisc.edu/wisflora/*, and *http://plants.usda.gov/java/*. Native shrub and sapling stock can be obtained from numerous local nursery vendors and spring bare root seedlings can be obtained from Wisconsin DNR state nurseries: http://dnr.wi.gov/topic/treeplanting/contact.html.

Addition of Wood to Restorations: Since it may take decades for downed woody material (DWM) to naturally accumulate on high-development lakes, augmentation of DWM should be considered when planning restoration projects. DWM is critical to ecosystem function, provides habitat to a variety of wildlife, promotes plant health and growth, and provides nutrients to soils. Furthermore, the addition of DWM can reduce extreme fluctuations of soil moisture and temperatures, thus reducing stress to new plantings. The type of DWM selected, whether it be logs or branches, will depend on landowners' property usage. We recommend using any available DWM on site if it exists (such as felling hazard trees/snags or from recent storm damage), if none is present, then acquire DWM from nearby logging area or construction sites with owner permission. If logs are not available on-site, the logistics of delivery can be challenging, and require heavy equipment. However, branches can be brought in on pickup trucks or small utility trailers. Hardwoods such as oaks or maples and pines persist longer than the softer species of birch and aspens, thus will protect the site from soil moisture loss and temperature fluctuations for over 10 years. If you apply softwood DWM, you will gain moisture retention plus addition of organic matter which improves the habitat quality for insects, salamanders, and small mammals. To realize both benefits, you can combine hard and softwoods if available. All DWM material should be obtained within 10 miles of the restoration site to use site specific material and to reduce the risk of introducing diseases (e.g., EAB with ashes, birch-leaf minor, oak wilt, etc.) However, practitioners should consult with the property owner prior to adding DWM to insure it is compatible with usage of the area. We have also used DWM in combination with erosion control techniques on eroding slopes. We placed DWM of various lengths and diameters parallel to the shore on steep, sandy slopes. On very steep slopes (>30 degrees) DWM may need to be staked or a small trench dug into the slope to hold it in place. Soil has been observed accumulating behind DWM installed in this manner, and gullying below has been alleviated. We also recommend planting trees, shrubs, and ground cover amongst DWM as they will benefit from increased soil moisture and reduced temperature fluctuations.

<u>Plant Source</u>: Gravel culture (GC) and spring bare root (BR) trees and shrubs should be considered for restoration projects. They reduce the cost of plant material yet often match grow rates of container (CT) plants. However, logistics need to be considered when using GC and BR. First and foremost, plant roots cannot be allowed to dry out during transport to the site and must be kept moist on site if not immediately planted. This can be accomplished by having a water tank of appropriate size to hold the GC plants, with the entire root ball submerged in water. For spring BR plants, roots can be kept moist by covering with damp wheat or oat straw and storing out of the sun until planting. Both GC and BR should be planted as soon as possible once they have arrived on site. Then once planted irrigation and mulch should be applied for an extended period of time. Of the GC species selection, and based on this study's results, hazel, serviceberry, dogwood, and black chokeberry would be good candidates for restoration activities. Contact study authors for a list of local GC vendors. As for BR species, and based on LSG results, all tree and shrub species from the list are good candidates with an emphasis on hazel, serviceberry, dogwood, black chokeberry, red oak, red maple, and paper birch. Preliminary results indicate GC conifers may be more robust than BR conifers, however continued monitoring of planted conifers is required to reach a definite conclusion.

<u>Lake Bank and Toe Erosion Control</u>: We recommend a geotextile bag system for stabilizing and establishing vegetation on steep, sandy slopes that are highly erodible. The newly installed bags require frequent irrigation to prevent bags and the plants between from drying, but newly planted restorations should be irrigated thoroughly (at least 1" precipitation per week). The logistics of delivering and placing bags can be challenging as each weighs 50 – 80 lbs. Other techniques such as

erosion control mats, both coconut coir and straw mats, in combination with geotextile bags can be beneficial in reducing runoff and establishing vegetation on less severe slopes. Straw mats degrade more quickly than coir logs or bags, thus may be more useful for establishing vegetation from seed rather than plug. The netting can persist but becomes buried in the duff over time. Snakes and amphibians have been reported ensnared by the material in other studies, however it was not observed on this study. However erosion mats with biodegradable netting are available.

If property owners chose to install a geotextile bag system we recommend consulting with a local landscaper who has experience with this technique. If erosion blankets are the choice, these can be installed by the capable landowner, but advice as to method of installation should be sought.

In regard to toe erosion, the coconut coir log (e.g. biolog) works well in reducing toe erosion and establishing shoreline vegetation. The biolog is designed to degrade within 5-8 years at which time the native vegetation should be sufficiently established to stabilize the lake shore. A combination of earth anchors attached to steel cables and hardwood wooden stakes works well to secure biologs to the shoreline and lake bed. To properly secure biologs to the lakebed requires special tools and experienced personnel. Once biologs are installed, we recommend planting native wetland forbs, grasses, sedges and rushes between the biolog and shoreline, no farther than 30cm (12") apart. In addition, wetland shrubs such as red-osier dogwood, tag alder, spirea, sweet gale, and leather leaf should be planted every third plant.

Biologs have limitations at sites with high water level fluctuations (often due to dam control) - if waves over-top the biolog, the shore can be scoured from behind and beneath and the anchoring system undermined. This impact can also occur at lakes with long fetch distance, thus high wave action – which can be exacerbated by steep shorelines or in areas with much wake action from boating. Implementation and enforcement of no-wake zones can reduce wave damage to vulnerable shorelines. Additionally, biologs are susceptible to ice heaves during spring breakup, which can have a drastic effect on planted vegetation and the biolog itself. If the shoreline is susceptible to ice heave (which can be determined by contacting a private landscapers, county, or state lake management staff), a combination of rip-rap and biologs could be used, but will require a permit application and approval. Because of this requirement, we recommend property owners consult with experienced landscapers for guidance on permit application, selection of proper biolog size and type, as well as for the actual installation. Additional information can be obtained from the previously mentioned county and state resources, as well as the Rhinelander Natural Resources Conservation Service (NRCS) office:

USDA NRCS RHINELANDER SERVICE CENTER
2187 NORTH STEVENS STREET, SUITE A

RHINELANDER, WI 54501

(715) 362-5941

The NRCS Conservation Practice Standard 643A also contains prescriptions for shoreland restoration in Wisconsin and should be consulted when restoring shorelands. http://dnr.wi.gov/topic/shorelandzoning/documents/nrcsshorehabstandard.pdf.

We successfully used tree drops at 4 LSG properties to reduced toe erosion, create fish habitat, and potentially assist in establishment of aquatic macrophyte beds. These techniques have been highly successful and popular to date. Landowners should consider this practice if appropriate for their property, however it is recommended that practitioners experienced in the technique be employed. Also, an approved WDNR shoreland permit is required prior to placement of tree drops – application materials can be found at the previously listed WDNR shoreland website.

Irrigation: It is essential that newly planted restoration sites receive 1-2" of precipitation (either natural or by irrigation) weekly during the first growing season - even more if extremely hot and dry. The high amount of precipitation can reduce transplant shock which plants can experience. Irrigation should occur in the early morning or after sunset to reduce evaporation. Restoration projects will benefit from an automatic irrigation system if practical. This will allow practitioners to program watering events. If it is not possible to obtain an automatic irrigation system then a small 110 volt electric or gas powered water pump can be used with the lake as the water source and garden hoses and sprinklers. However, this technique requires practitioners to visit restoration sites at least twice a week to operate pumps or recruit landowners or volunteers to monitor restoration sites and operate pumps. If a drilled well is available, and water use is not limiting, then a household sprinkling system can also be used.

Plant damage from deer, cottontail rabbits, and snowshoe hare: We recommend using fencing (as described previously) to abate browsing by deer that often occurs on many developed lakes in Vilas County. The fence is a one-time purchase and the cost can be significant (approximately $2.60/foot), depending on the amount of fence needed – the entire area restored should be surrounded on all sides by the fencing. The fence may require maintenance periodically as trees and tree branches can fall and damage the fence. Developing a monitoring routine is critical – particularly if the property is only seasonally occupied. When used, deer repellent sprays need to be applied frequently as new plant growth emerges. We have observed that deer will become less deterred by repellents over time; therefore, switching repellents throughout the growing season and winter months is necessary. Additionally, we have noted where deer are fed by lake residents (corn, salt/mineral blocks or livestock hay), deer densities are very high, often congregating the local herds within several properties. This concentration of deer can damage or kill a significant proportion of a restored lakeshore habitat, even when first protected by fencing (personal observations). We suggest that when lakeshore property owners initiate a restoration, they stop feeding the deer and suggest their neighbors curtail providing supplemental food for wildlife. Additional work is required to identify tree, shrub, and ground cover species that are less preferred by deer, but provide habitat value. No deer feeding should occur where shoreland restoration projects are underway – we recommend no deer feeding occur within a minimum of 500 feet of lakeshores to protect native trees, shrubs, saplings, and groundcover which are planted for wildlife habitat and landscaping.

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Appendix 4-A

LSG LAKE SHORELAND RESTORATION SPECIES LIST	
Latin Name	**Common Name**
TREES	
Abies balsamea	Balsam Fir
Acer rubrum	Red Maple
Acer sacchrum	Sugar Maple
Amelanchier laevis	Alleghany Serviceberry
Betula alleghaniensis	Yellow Birch
Betula Papyrifera	White Birch
Ostrya virginiana	Ironwood
Picea glauca	White Spruce
Pinus resinoa	Red Pine
Pinus strobus	Eastern White Pine
Populus tremuloides	Quaking Aspen
Prunus americana	American Plum
Prunus serotina	Black Cherry
Prunus virginiana	Choke cherry
Quercus rubra	Northern Red Oak
Sorbus decora	Showy Mountain Ash
Thuga occidentalis	Northern White Cedar
Tsuga canadensis	Eastern Hemlock
SHRUBS	
Amelanchier canadensis	Juneberry
Arctostaphylos uva-ursi	Bearberry
Aronia meloncarpos	Glossy Black Chokeberry
Cephalanthus	Buttonbush
Chamaedaphne calyculata	Leather Leaf
Comptonia peregrina	Sweet Fern
Cornus canadensis	Bunchberry
Cornus alternifoia	Pagoda Dogwood
Cornus rugosa	Roundleaf Dogwood
Conrus stolonifera	Red Osier Dogwood
Corylus americana	American Hazelnut
Diervilla lonicera	Dwarf Bush Honeysuckle
Ilex verticellata	Winterberry
Lonicera villosa	Mountain Fly Honeysuckle
Physocarpus opulifolius	Common Ninebark

Prunus pennsylvanica	Pin Cherry
Rosa blanda	Wild Rose
Sambucus canadesis	American Elderberry
Spiraea tomentosa	Steeple Bush
Symphoricarpos alba	Snowberry
Viburnum rafinesquianum	Downy Arrowwood
Viburnum angustifolium	Low Bush Blueberry
Viburnum lentago	Nannyberry
Viburnum tribolum	High-bush Cranberry
VINES	
Vitis riparia	Wild Grape
FORBS	
Achillea millifolium	Yarrow
Anaphalis margaritacae	Pearly Everlasting
Anemone quinquefolia	Wood Anemone
Antennaria spp	Pussytoes
Aquilegia canadensis	Columbine
Aralia nudicaulis	Wild Sarsaparilla
Asarum canadense	Native Wild Ginger
Asclepias incarnate	Marsh Milkweed
Aster cordifolius	Heart-Leafed Aster
Aster ericoides	Heath Aster
Aster laevis	Smooth Aster
Aster macrophyllus	Big Leaf Aster
Aster novae-angliae	New England Aster
Aster oolentangiensis	Sky Blue Aster
Aster pilosus	Frost Aster
Aster umbellatus	Flat Top Aster
Symphyotrichum puniceum	Purple-stemmed Aster
Campanula rotundifolia	Harebell
Echinacea pallida	Pale Purple Coneflower
Epilobium angustifolium	Fireweed
Eupatorium macuatum	Joe pye Weed
Fragaria virginiana	Wild Strawberry
Galium boreale	Northern Bedstraw
Geranium maculatum	Wild Geranium
Helianthus strumosus	Woodland Sunflower
Lupinus perennis	Wild Lupine
Lobelia spicata	Pale Spike Lobelia

Linnaea borealis	Twinflower
Maianthemum canadense	Canada Mayflower
Maianthemum racemosum	false Solomon's-seal
Mitchella repens	Partridgeberry
Monarda fistulosa	Wild Bergamont
Potentilla norvegica	Norwegian Cinquefoil
Rubbeckia hirta	Black Eyed Susan
Solidago flexicaulis	Zig Zag Goldenrod
Trientalis borealis	Starflower
Waldstenia fragarioides	Barren Strawberry
Uvularia sessilifolia	Wild Oats
Vernonia fasciculata	Ironweed
Viola pedata	Birds foot Violet
GRASSES/SEDGES	
Andropogon gerardii	Big Blue Stem
Andropogon scoparium	Little Blue Stem
Bouteloua curtipendula	Side Oats Grama
Calamagrostis canadensis	Blue Joint Grass
Carex arctata	Drooping woodland sedge
Carex comosa	Bottlebrush Sedge
Carex crinite	Fringed Sedge
Carex communis	Colonial oak sedge
Carex pennsylvanica	Pennsylvania Sedge
Danthonia spicata	Poverty Oat Grass
Deschampsia cespitosa	Tufted Hair Grass
Hystrix putula	Bottlebrush Grass
Koeleria macrantha	June Grass
Oryzopsis asperfolia	Rough-leaved rice cut-grass
Sorghastrum nutans	Indian Grass
FERNS	
Dryopteris intermedia	Intermediate Wood fern
Athyrium filix-femina	Common Lady Fern
Osmunda cinnamomea	Cinnamon Fern

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Literature Cited

Allan, G. G., D. I. Gustafson, R. A. Mikels, J. M. Miller, and S. Neogi. 1984. Reduction of deer browsing of Douglas-fir *(Pseudotsuga menziesii)* seedlings by quadrivalent selenium. For. Ecol. Manage. 7: 163-181.

Alverson W. S., D.M. Waller, and S.L. Solheim. 1988. Forests too deer: Edge effects in northern Wisconsin. Conservation Biology 2:348-358.

Alverson W. S.,and D.M. Waller, 1997. Deer populations and the widespread failure of hemlock regeneration in northern forests, p. 280–297. In: W. J. McShea, H. B. Underwood, and J. H.

Rappole (eds.). The Science of Overabundance: deer ecology and population management. Smithsonian Institution Press, Washington and London.

Anderson, R. C., and 0. L. Loucks. 1979. White-tail deer (Odocoileus virginianus) influence on the structure and composition of Tsuga canadensis forests. Journal of Applied Ecology 16:855-861.

Andrén, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. Oikos 71:355-366.

Beals, E.W., G. Gottom, and R.J. Vogl. 1960. Influence of deer on vegetation of the Apostle Islands, Wisconsin. Journal of Wildlife Management 24:68–80.

Bormann, F.H., and G.E. Likens. 1979. Pattern and process in a forested ecosystem. Springer-Verlag, New York, NY. 262 pp.

Bussler, B.H., B.D. Maxwell, and K.J. Puettmann. 1995. Using plant volume to quantify interference in corn (*Zea mays*) neighborhoods. Weed Science 43:421-428.

Castro, J., R. Zamora, J.A. Hódar, and J.M. Gómez. 2002. Use of shrubs as nurse plants: A new technique for reforestation in Mediterranean Mountains. Restoration Ecology 10:297-305.

Christensen, D.L., B.R. Herwig, D.E Schindler, and S.R. Carpenter. 1996. Impacts of lakeshore residential development on coarse woody debris in north temperate lakes. Ecological Applications 6:1143-1149.

Clark, K.L., D.L. Euler, and E. Armstrong. 1984. Predicting avian community response to lakeshore cottage development. Journal of Wildlife Management 48:1239-1247.

Dong, S., C.F. Scagel, L. Cheng, L.H. Fuchigami, and P. Rygiewizc. 2001. Soil temperature and plant growth stage influences nitrogen uptake and amino acid concentration of apple during early spring growth. Tree Physiology 21:541-547.

Donovan, T.M, R.H. Lamberson, A. Kimber, F.R. Thompson III, and J. Faaborg. 1995. Modeling the effects of habitat fragmentation on source and sink demography of Neotropical migrant birds. Conservation Biology 9:1396-1407.

Elias, JE and Meyer, MW (2003) Vegetation at undeveloped and developed shorelands, Northern Wisconsin, and recommendations for restoration. Wetlands 23: 800-816.

Friesen, L.E., P.F.J. Eagles, and R.J. Mackay. 1995. Effects of residential development on forest-dwelling Neotropical migrant songbirds. Conservation Biology 9:108-1414.

Gilbert, J.H., J.L. Wright, D.J. Lauten, and J.R. Probst. 1997. Den and rest-site characteristics of American Marten and Fisher in northern Wisconsin. In *Martes:* taxonomy, ecology, techniques, and management, pages 135-145. G. Proulx, H.N. Bryant, and P.M. Woodard, editors. Provincial Museum of Alberta, Edmonton, Alberta, Canada. 484 pp.

Gray, A.H., and T.A. Spies. 1997. Microsite controls on tree seedling establishment in conifer forest canopy gaps. Ecology 78:2458-2473.

Graczyk, D.G., Hunt, R.J., Greb, S.R., Buchwald, C.A. and Krohelski, J.T., 2003, Hydrology, nutrient concentrations, and nutrient yields in nearshore areas of four lakes in northern Wisconsin, 1999-2001: U.S. Geological Survey Water-Resources Investigations Report 03-4144, 64 p.

Hagan, J.M., and S.L. Grove. 1999. Coarse woody debris. Journal of Forestry 97:6-11.

Harmon, M.E., J.F. Franklin, and F.J. Swanson. 1986. Ecology of course woody debris in temperate ecosystems. Advanced Ecological Research 15:133-302.

Haskell, D.E. 2009. Quantifying the Ecological Benefits of Lakeshore Restoration in Northern Wisconsin. MS Thesis, Michigan Technical University.

Haskell, D.E., D. J. Flaspohler, C. Webster, and M.W. Meyer. 2012. Variation in soil temperature, moisture and plant growth with the addition of down woody material on lakeshore restoration sites. Restoration Ecology 20: 113-121.

Haskell, D.E, M.W. Meyer, C. Webster, and D. J. Flaspohler. 2013. The Relationship between Carnivore Distribution and Landscape Features in the Northern Highlands Ecological Landscape of Wisconsin. American Midland Naturalist 169:1-16.

Haskell, D.E, M.W. Meyer, A.Schotthoefer, and P. Goggin. 2013. Wisconsin Lakeshore Restoration Project. Lakeline Spring Edition: 10-16.

Howe, H.F. 1995. Succession and Fire Season in Experimental Prairie Plantings. Ecology 76:1917-1925.

Jackson, H. H. T. 1961. Mammals of Wisconsin. The University of Wisconsin Press, Madison, Wisconsin. 504 p.

Jackson, K. 2013. Vintage St. Germain, Volume 1. Worzalla Publishing Co., Stevens Point, Wisconsin. 223 p.

Jaeger, R.G. 1980. Microhabitats of a terrestrial forest salamander. Copeia, 1980: 265-268.

Johnson, P.S., S.L. Novinger, and W.G. Mares. 1984. Root, shoot, and leaf area growth potentials of northern red oak planting stock. Forest Science 30:1017-1026.

Kilgo, J.C., R.A. Sargent, B.R. Chapman, and K.V. Miller. 1998. Effect of stand width and adjacent habitat on breeding bird communities in bottomland hardwoods. Journal of Wildlife Management 62:72-83.

Krebs, C.J., and J.H. Meyers. 1974. Population cycles in small mammals. Adv. Ecol. Res., 8:267-399.

Lesica, P., and B. M. Steele. 1994. Prolonged dormancy in vascular plants and implications for monitoring studies. Natural Areas Journal 14:209–212.

Lindsay, AR, Gillum, SS, Meyer, MW (2002) Differences in avian assemblages between developed and undeveloped lakeshores in a mixed hardwood forest. Biological Conservation 107: 1-11.

Macbeth, E.J. 1992. Protecting aesthetics and the visual resource of lakes. In Enhancing the states' lake management programs. North American Lake Management Society, Washington, D.C. 112 pp.

Marburg, A.E, M.G. Turner, and T.K Kratz. 2006. Natural and anthropogenic variation in coarse wood among and within lakes. Journal of Ecology 94:558-568.

Maser, C., R. G. Anderson, K. Cromack, Jr., J. T. Williams, and R. E. Martin. 1979. Dead and down woody material. Pages 78–95 in J. W. Thomas, editor. Wildlife habitats in managed forest: the Blue Mountains of Oregon and Washington. Agricultural Handbook No. 553. USDA Forest Service, Washington, D.C..

McComb, B.C. 2008. Wildlife habitat management: concepts and applications in forestry. CRC Press. 319 pp.

Michael, H.J., K.J. Boyle, and R. Bouchard. 1996. Water quality affects property prices: A case study of selected Maine lakes. Maine Agricultural and Forest Experiment Station Miscellaneous Report 398.

Morrison, M.L. 2003. Wildlife Restoration: Techniques for Habitat Analysis and Animal Monitoring. Island Press, Washington.

Myers, P., B.L. Lundrigan, S.M.G. Hoffman, A.P. Haraminac, and S.H. Seto. 2009. Climate-induced changes in the small mammal communities of the Northern Great Lakes Region. Global Change Biology 15:1434–1454.

Naiman, R.J. 1996. Water, Society, and landscape ecology. Landscape Ecology. 11:193-196.
CS 2002.

Onterra LLC 2013. Town of St. Germain Town-wide Lake Management Plan. April 2013,185 pp.

Ostfeld, R. S. 2011. Lyme disease: the ecology of a complex system. Oxford University Press, Inc, New York, NY.

Racey, G.D., and D.L. Euler. 1982. Small mammal and habitat response to shoreline cottage development in central Ontario. Canadian Journal of Zoology 60: 865-880.

Rasmussen, H.N., and D.F. Whigman. 1998. Importance of woody debris in seed germination of *Tipularia discolor* (Orchidaceae). American Journal of Botany 85:829-834.

Reid, K.D., B.P. Wilcox, D.D. Breshears, and L. MacDonald. 1999. Runoff and erosion in a Pinyon-Juniper woodland: influence of vegetation patches. Soil Sci. Soc. Am. J., 63:1869-1879.

Robertson, R.J., and N.J. Flood. 1980. Effects of recreational use of shorelines on breeding bird populations. Canadian Field Naturalist 94:131-138.

Robertson, D.M. and Rose, W.J. 2000. Hydrology, water quality, and phosphorus loading of Little St. Germain Lake, Vilas County, Wisconsin: U.S. Geological Survey Water-Resources Investigations Report 00-4209, 8 pp.

Robertson, D.M., Rose, W.J., and Saad, D. 2005. Water Quality, hydrology, water quality, and phosphorus loading to Little St. Germain, Wisconsin, with special emphasis on the effects of winter aeration and ground water inputs: U.S. Geological Survey Water-Resources Investigations Report 2005-5071, 36 pp.

Russell, E.W. 1973. Soil conditions and plant growth. Longman Group Limited, London, Great Britain. 849 pp.

Sass, Gregory. 2004. Fish Community and Food Web Responses to Whole-Lake Removal of Coarse Woody Habitat. Ph.D. dissertation. University of Wisconsin – Madison. 157pp.

Schmidt, K.A. and C.J. Whelan. 1998. Predator-mediated interactions between and with guilds of nesting songbirds: experimental and observational evidence. The American Naturalist. 152:393-402.

Starbuck, C., D.K. Struve, and H. Mathers. 2005. Bare root and balled-and burlapped red oak and green ash can be summer transplanted using the Missouri gravel bed system. HortTechnology 15: 122-127.

Tallmon, D.A., and L.S. Mills. 1994. Use of logs within home ranges of California Red-backed voles on a remnant forest. Journal of Mammalogy 74:97-101.

Ucitel, D., D.P Christian, and J.M. Graham. 2003. Vole use of course woody debris and implications for habitat and fuel management. Journal of Wildlife Management 67:65-72.

Wisconsin Department of Natural Resources, 2000, Wisconsin Administrative Code, Environmental Protection, Chapter NR115, no. 532.

Wisconsin Biology Technical Note 1: Shoreland Habitat. *http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_020187.pdf*

Witt, J.C., and Webster, C.R. 2010. Regeneration dynamics in remnant *Tsuga canadensis* stands in the northern Lake States: potential direct and indirect effects of herbivory. Forest Ecol. Manag., 269:519-525

Woodford, JE and Meyer, MW. (2002) Impact of lakeshore development on green frog (*Rana mitans*) abundance. Biological Conservation 110(2):277-284.