Monitoring Balance in Working Landscapes: a forest health monitoring protocol for Little Traverse Conservancy's Working Forest Reserve program

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Introduction and Background

Purpose and Scope

The Little Traverse Conservancy's overarching mission aims at protecting the natural diversity and beauty of northern Michigan by preserving significant land and scenic areas, while fostering appreciation and understanding of the environment. For that purpose, understanding the ecological conditions of their land is fundamental and especially critical for their Working Forest Reserve Program, which seeks to balance the management of an active timber harvest between three primary objectives: sustainable commercial timber production, improving forest health, and increasing wildlife habitat. In support of this mission and objectives, the following document contains a forest condition monitoring protocol crafted for the Little Traverse Conservancy (LTC) by the University of Michigan School for Environment and Sustainability graduate capstone project. It focuses on the practical and implementable aspects of LTC's citizen science-based monitoring program as it applies to their Working Forest Reserve Program. While using citizen science as a primary strategy this document details:
1) monitoring protocols for the ecological and biological metrics of protected properties pre- and post- timber harvest;
2) instructions for LTC staff to train volunteers (presentation and step-by-step instructions of how to run the training workshop);
3) volunteers' field instructions guide and data collection form;
4) assessment and evaluation of management activities; and
5) adapting management recommendations.

Monitoring with Citizen Science

The following protocol is designed to be implemented primarily by the Little Traverse Conservancy's volunteer base. The reliance on volunteers who likely have little to no professional scientific training necessitates creating a protocol that is repeatable, understandable, efficient, and adaptable in terms of time and ecological value, and that balances organizational and volunteer capacity with accurate protocol implementation. LTC staff and contractors will establish the monitoring objectives and protocols while the role of citizen scientists within this protocol is primarily confined to data gathering activities with potential for some analysis and interpretation of results. This section of the document will consider several of the guiding aspects of citizen science programs including the importance and benefits, challenges and limitations, and commonalities of success.

Here we define **citizen science**, synonymous with volunteer monitoring, as a research arrangement in which members of the public participate in scientific research or monitoring (Chase & Levine 2016). Citizen science has developed as a concept in response to the increased need for high quality and quantity of ecological data across space and time to enhance land management objectives and activities and the corresponding lack of organizational capacity to meet this increasing demand.

It is of particular note that research indicates Rapid Forest Assessment (RFA) approaches, which collect similar vegetative data to our protocol, have been effective when used by citizen science groups (Davis et al., 2016). Due to the success seen in the RFA model, we have integrated aspects of this model into our own protocol detailed herein. RFA field protocols emphasize efficiency and require minimal training, although care is taken during training to thoroughly explain monitoring needs, expectations, and methods (Davis et al., 2016). Data collection prioritizes simplified methods that could be taught relatively quickly, primarily consisting of broad categorization and/or tallying (Davis et al., 2016).

<u>Importance and Benefits</u>

Specific benefits of a citizen science program for LTC:

a) **Supports organizational mission**: This program will bolster LTC's mission to foster appreciation and understanding of the environment through the cultivation of various types of learning and skill-building. The act itself of involving volunteers educates the public on LTC's goals and work while growing their understanding and appreciation of their local environment.

b) **Supports programmatic mission**: Utilizing citizen science will assist the mission of the Working Forest Reserve Program by providing data which may not otherwise be collected, allowing for informed management actions toward seeking a balance between sustainable commercial timber production, improving forest health, and increasing wildlife habitat.

c) **Leverages existing resources**: This program allows LTC to utilize and strengthen existing community connections. Doing so allows more fieldwork to be undertaken over larger areas and during non-office hours.

d) **Increases community trust**: This program will increase trust between LTC and the local community. Citizen science programs increase transparency in the natural resource decision-making process. This transparency, along with the opportunity for collaboration, builds social capital by increasing trust, harmony, and cooperation between peers, stakeholders, and the public (Conrad & Hilchey, 2011; Davis et al., 2016).

e) **Strengthens conservation community**: Citizen science participants are shown to be increasingly engaged in community development, local issues, and be more influential in regard to policy-makers--all of which are crucial in growing more sustainable communities (Conrad & Hilchey, 2011). The ripple effects of these types of enhanced community participation are numerous and can be leveraged toward more systemic goals in line with LTC's mission.

f) **Promotes strategic partnerships**: Engaged participants and, in turn, a more engaged community lays the groundwork for strategic partnerships with other institutions and organizations with similarly aligned missions and goals which can also bolster more systemic changes (Conrad & Hilchey, 2011). These partnered organizations can work together to build support for longer-term policy solutions at multiple levels from local to state to federal, through funding and outreach campaigns. Conservation-oriented policies then can feed back into providing invaluable support for larger-scale ecosystem management objectives such as watershed and habitat protection.

Specific benefits of a citizen science program for volunteers:

a) **Presents opportunities for outdoor appreciation**: Providing opportunities to interface with our natural world while gathering data allows program participants to spend time getting to enjoy, appreciate, and become more familiar with the intricacies and subtleties of their local environment.

b) **Promotes environmental awareness**: Training and participation in data collection and assessment increases scientific and ecological literacy by augmenting understanding of scientific processes and anthropogenic impacts on natural systems (Conrad & Hilchey, 2011).

c) **Provides valuable learning opportunities**: Learning benefits for the public include leadership skill-building, collaborative problem solving, and project management (Conrad & Hilchey, 2011). This type of learning over time has been shown to contribute to the growth of a contingent of ecological stewards by cultivating an ethic of stewardship lasting into the future (Conrad & Hilchey, 2011).

d) **Encourages health and well-being**: Actively participating in stewardship practices fosters well-being by reducing stress and improving health as well as cultivating a feeling of connection to community and a sense of greater purpose (Krasny & Tidball, 2015).

<u>Challenges and Limitations</u>

Citizen science is not without challenges and limitations, which are critical to consider when altering monitoring protocol as part of adaptive management. This section will address common issues, while potential solutions will be mentioned, characteristics of a successful program will be addressed more specifically in the following section.

a) **Volunteer recruitment and retention**: Volunteers can be difficult to get and to keep. This can be addressed by effectively articulating organizational and project goals and successes (Peters et al, 2017). Volunteer retention can be addressed by institutionalizing positive reinforcement practices (e.g., volunteer recognition, informing volunteers of beneficial impacts), appropriately matching monitoring protocols to the interests and skills of individual volunteers, and ensuring volunteers build skills in line with their personal goals by continually ensuring adequate training (Conrad & Hilchey, 2011). In this regard, establishing a group of core volunteers who are invested in organizational and monitoring program success will be vital so organizational investment in volunteers is not lost (Peters et al, 2017).

b) **Organizational capacity**: As much as volunteers are a valuable asset to LTC, dedication of staff time to training and managing volunteers is substantial and can put strain on an already hefty workload. Established core volunteers can mitigate this issue.

c) **Data quality control and assurance**: Common data collection issues include data inaccuracy and lack of participant objectivity though can be adequately addressed through wise program and process design (e.g., proper experimental design) (Conrad & Hilchey, 2011). Along with overall design, training is the most important way to ensure reliable data. Volunteers must understand the goals and objectives of the monitoring program to understand the importance of their contribution and what it is saying about the ecosystem (Cohn, 2008). Data collection protocol, as is laid out herein, must be simple enough to mitigate potential errors and may need to be further simplified depending on early results. Although error is unavoidable, proper guidance and consistency over time with large amounts of data, citizen scientists collect data with over 80% accuracy, which is an acceptable level of accuracy even among published ecological studies (Cohn, 2008). It is also worthwhile to record metadata on training and collection methods to mitigate credibility and completeness concerns (Conrad & Hilchey, 2011).

d) **Integration of data into adaptive management**: A chronic data collection issue across citizen science programs is translating data collected into implemented management actions. To mitigate this issue, it is imperative to establish adaptive management protocol, a standardized procedure for integrating data into management actions. Embedded herein should be a process for reporting back results to volunteers to properly underscore the value of their efforts.

<u>Commonalities in Success</u>

By nature, all citizen science programs are unique to their respective locale and goals but there are commonalities running through all successful and enduring programs. All mentioned commonalities are necessary to achieve long-term success.

a) **SMART objectives**: (SMART = Specific, Measurable, Achievable, Realistic, Timely); The educational and stewardship goals and priorities initially set will most strongly guide how monitoring protocol are designed, implemented, and evaluated, as relative importance of each resource and metric is assessed within the framework (Chase & Levine, 2016).

b) **Adaptive management**: To best utilize data yielded from the program, it is critical to link collected and assessed data to outcomes through adaptive management activities. Communicating these actions will help to convey the importance of monitoring efforts to the public and volunteers, encouraging buy-in to sustain program.

c) **Effective communication strategy**: Communicating goals and successes to volunteers and the general public will help to increase and sustain volunteer engagement. Ultimately, funding should also be bolstered through this same strategy.

d) **Cultivating champions**: Cultivating and identifying strong champions of particular initiatives will assist in overall program efficacy and longevity. These types of individuals can help to lead other volunteers, raise funds, and make partnership connections, thus creating and bolstering organizational resources.

e) **Proper training and meaningful experience**: Training and experience are two of the most important factors for success in citizen science programs, as well as the most implementable and controllable strategies for success (Freitag et al. 2016). It is through these factors that sampling design errors can be addressed since properly, thoroughly trained and more experienced volunteers will be more adept at mitigating their own biases through correctly following protocol (Freitag et al. 2016; Latimore & Steen 2014).

f) **Diverse partnerships and stakeholder engagement**: Diverse partnerships significantly assist in securing more reliable, diversified funding streams as well as other nonmonetary resources, including logistical support and access to larger participant pools (Chase & Levine, 2016). Involving partners and stakeholders can also strengthen community networks as well as ease information sharing by pooling data across a wider region which allows for landscape-level analysis, a critical consideration as climate change alters ecosystem structure, function, and biodiversity (Peters et al., 2017; Conrad & Hilchey, 2011).

Forest Health Monitoring

Ecological Context

<u>What is Forest Health?</u>

LTC currently defines forest health as:

> "When Little Traverse Conservancy aims to improve and maintain forest health, the aim is a sustainable and resilient forest that contains age class and species diversity, healthy individual trees, uninhibited forest functions and services, and habitat that supports native biodiversity."

Sustainable forests will be those that are carefully managed in a way that they are able to naturally regenerate via successional processes, i.e. as mature trees are harvested or naturally die, seedlings are able to recruit and mature into new, adult trees (Rainforest Alliance, 2016).

Resilience allows ecosystems to recover from disturbances they experience and/or withstand ongoing external pressures, i.e. ongoing environmental change (Yan et. al, 2011). As the climate is changing and shifting and is likely to continue to do so, the majority of ecosystems on the planet will be subjected to novel conditions that they have not experienced in the past or at the very least not in recent history (Cote and Darling, 2010).

Biodiversity, whether it be species diversity or structural diversity within a forest, is a factor that drives ecosystem resilience (Mori et. al, 2013). Higher diversity in species and/or functional groups is often correlated with increased productivity (Mittlebach et. al, 2001) and ecosystem resilience (Hooper et. al, 2005). Specific aggregations of species often indicate an ecosystem's health or functionality, regulating the movement of physical and chemical components of the ecosystem between biota and the physical environment (Mori et. al, 2013).

<u>Challenges to Forest Health</u>

Incidences of tree pests and diseases and invasive species are increasingly common factors affecting forest ecosystems. Broader, long-term, larger scale challenges such as climate change, landscape fragmentation, and pollution can put stresses on forest health that may be further exacerbated by disturbance from selective logging (Thiollay, 2002). All these threads have the potential to affect the system's ability to recover from other disturbances (Ennos, 2015). Additionally, measures of coarse woody debris have the ability to inform ecosystem processes such as decomposition and nutrient cycling, as well as provide vital habitat for native biodiversity (Yuan et.al, 2017).

Indicator Context

The general guidelines we have used in this protocol to identify "good indicators" (Schueller et al., 2006) are:

- Relevant and useful to decision-making
  - When choosing indicators to measure in any monitoring protocol, it is important to choose indicators that provide information that will actually help LTC to test management effects and make strategic choices for adaptive management.
- Easy to interpret
  - Good indicators have a clear and understood link to particular attributes or stressors within the system, so specific results can be interpreted.
- Sensitive to change
  - It is vital that indicators chosen are sensitive enough to change to be measured against any background variation and change on timescales meaningful to LTC (aka months, years, decades, not centuries) so as to allow adaptive management decisions.

- Feasible and cost-effective to obtain
    - It is important that indicators chosen to measure are feasible in terms of equipment, time, and expertise in regard to both the collection and analysis of data. It is also important that the indicators could be repeated easily.
- Easily communicated to target audience

It is critical that the indicators chosen and methods of analysis are not overly complicated and can be easily understood by scientists, board members, policy makers, and the general public.

<u>Selected Metrics</u>

Keeping in mind LTC's definition of forest health as previously defined, we have chosen six different metrics to track the health of the forest ecosystems their management:

a) forest inventory measures,
b) coarse woody debris (CWD),
c) wildlife surveys,
d) floristic quality assessment,
e) occurrence of of tree diseases,
f) presence of invasive species

These are all metrics that qualify as good indicators of changes in forest health (Schueller et al. 2006), as they are relevant and useful for decision making, easy to interpret, sensitive to change, feasible and cost effective to obtain, and easily communicated to target audience. The rationale for each specific metric chosen and how it fits into LTC's overarching vision and pre-defined goals of forest health is addressed below:

a) Forest Inventory Measures:

- Tree Size Classes
- Species Composition
- Canopy Cover

Forest inventory measures, such as tree size/age classes, species composition, and canopy cover are simple but foundational measures that are vital to understanding the basic structure and function of a forest. Vegetation, particularly trees, are the dominant source of biomass in the ecosystem. Understanding and monitoring the structure and species composition of the trees will not only tell us a great deal about the sustainability and resilience of the forest itself but also the greater community that the forest supports (Scherer-Lorenzen et. al., 2005). A variety of age classes are necessary for forest sustainability. Older trees provide important wildlife resources, propagate new generations of trees, and eventually become coarse woody debris (Connell & Slatyer, 1977). Younger trees occupy additional niches of wildlife resources while ensuring the region continues to be forested into the future (Frelich & Reich, 1999). Tree species data, especially when coupled with age class, helps provide an understanding of diversity and stand age and structure. Canopy cover affects the moisture and heat that enters and stays in the forest, as well as the light available to understory plants (Jennings et. al, 1999).

There are limitations to the use of forest inventories as metrics, though. Decreases in canopy cover and size/age class may just be the result of natural disturbance, an important factor in maintaining the successional cycles of many temperate ecosystems. Variations in ecotones, soil type, hydrology, and other factors can also make comparisons between sites difficult. For this reason, we recommend, along with LTC's specific goals, that changes in these metrics be tracked over time at the reserve level, and not for the purpose of comparing sites to one another.

b) Coarse Woody Debris (CWD):

Coarse Woody Debris (CWD) is dead and dying woody plant material. CWD acts as a food source and habitat for a wide variety of forest organisms. Birds, bats, and other arboreal mammals often nest in snags, while woodpeckers use snags to forage for insects. Downed wood shelters rodents, mustelids, other small mammals, snakes, lizards, and the vast majority of forest-dwelling amphibians (Harmon et al. 1986). Smaller organisms like gastropods, arthropods, and fungi use CWD for both shelter and food (Wu et al. 2005). CWD is also an important source of soil nutrients; depending on the decomposition rate, CWD can act as a source of nutrients for many years (Wu et al. 2005). It is vital to track this metric over time because CWD biomass has been found to be substantially lower in managed vs. unmanaged forests, and LTC has explicitly identified maintaining or increasing CWD as a target in their forest management prescriptions (Duvall and Grigal, 1999). Increased tree mortality as a result of disease may complicate CWD measures, as it could cause an increase in CWD while simultaneously worsening forest health and biodiversity.

c) Wildlife Surveys:

Wildlife has long been documented to be sensitive to ongoing disturbances in their habitat, and are useful indicators of mature forest ecosystem health (MacNeil and Williams, 2014). Salamanders, many bird species, and other wildlife species are often monitored to detect shifts in habitat quality and ecosystem functions (MacNeil and Williams, 2014; Campbell et. al, 2007).

- Bird Surveys
    - Birds are ideal indicators for forest condition, as their habitat is heavily influenced by factors like tree size, tree species, and presence of snags. Some bird species are associated with specific types of disturbance, like logging. A change in the bird community is one sign that the successional state of the ecosystem has changed. Table 1 lists several bird species that respond to logging. The presence or absence of these species is an indicator of the strength of impact that logging operations have on a northern hardwood forest. Additionally, Costello et al. (2000) found that red-eyed vireos decrease in abundance in logged stands

relative to mature forest, whereas chestnut-sided warblers preferred clearcut areas to selective logging. Northern parulas and brown creepers were found only in mature stands, while tree swallows, indigo buntings, and alder flycatchers were exclusively observed in clearcut areas.

- Camera Traps
  - Predators serve an important role in the ecosystem, as they affect herbivore behavior and can protect preferred plant species from overbrowsing. However, apex predators are often difficult to observe due to large territories and varied activity patterns. Camera traps allow locations to be observed 24/7 without disturbing the site or wasting volunteers' time. Studies show that camera traps can be an effective mode of monitoring populations of large mammals (Carbone 2001).
- Sign/Habitat Analysis
  - Because some of the more direct observations of wildlife habitation can be time intensive and proved mostly uninformative in our baseline data collection, we are recommending using more indirect methods to assess wildlife presence. This can include looking for physical signs of wildlife such as dens, tracks, scat, herbivory, and scrapes on trees. This can also include calculating a quantitative measure, habitat suitability index (HSI), for species of concern to LTC to assess if certain aspects of suitable habitat are present in the reserves to encourage the presence of wildlife. These are not metrics that we will create specific protocols to follow in every plot created, but there will be a section in the data collection forms to document anything of note.

There are caveats to the use of wildlife as forest health indicators, though. Animals, especially birds, are highly mobile relative to plants; observations may just be of animals passing through, rather than indicators of high quality habitat. The mobility of wildlife also makes them more difficult to locate, so it is more difficult to regularly observe wildlife than to monitor plants.

d) Floristic Quality Assessment (FQA):

A species list is the most immediate measure of forest integrity and can be used in generating additional forest health indicators. Species lists are simply recorded observations of all of the species in a given area. Although species lists provide useful data, they measure only the total number of species or species richness. The FQA improves upon a basic species list by adding information about how rare or common the species are. The FQA is created by identifying plant species occurring on a given site and looking up the Conservatism Coefficient (CC) of each species (Herman et al. 2001). FQA is a useful metric of forest health as it is a good estimate of the rarity of plant species found in a local site. Rare species are often some of the first to disappear after a disturbance event, replaced by "weedier" competitor species (Sheley et. al, 1999). If LTC's planned commercial timber operations were affecting the viability of native biodiversity that they wished to protect as per their stated mission, then FQA would be a good measure to indicate this effect.

The accuracy of FQA as a metric is limited by a volunteer's ability to identify plants and the comprehensiveness of the survey, as some herbaceous plants could certainly be left out of the nested plots in this monitoring protocol.

e) Disease:*

In many forests, disease is a major source of mortality for trees. Exotic pathogens are one of the most lethal problems in forestry today, as native trees have had no chance to build immunity to them. Michigan trees such as ash, elm, beech, and chestnut have all been greatly affected by the spread of introduced parasites. One tree pest that might be of particular interest to LTC, due to the presence of hemlock in certain parcels, is the hemlock woolly adelgid, an insect that kills hemlocks by feeding on their sap. The woolly adelgid can be identified by the white sacs it creates at the base of the needles of an infected hemlock (McClure, 2001). Heterobasidion root disease and oak wilt are other increasingly widespread pathogens that should be searched for in areas with vulnerable species, as they can cause significant deterioration in forest health.

Additionally, the effects global warming will likely increase and exacerbate the spread of new pathogens and tree diseases as cold temperature may not keep them from spreading anymore. Whether it be a warmer and wetter scenario or a warmer and drier scenario, the anticipated changes in climatic conditions may impact the prevalence and severity of these diseases (Frankel et. al, 2012). Changing climatic conditions may dramatically affect the outcome of pathogen-host-insect interactions in forest environments, with warmer temperatures leading to increased geographic ranges for pests and and altered moisture levels leading to decreased stress tolerance for trees (Frankel et. al, 2012). This combination of multiple changes and future stressors will influence a forest's ability to sustain goods and services at existing levels (Bentz et. al, 2010). Careful monitoring of tree diseases is critical because early detection can increase the potential for successful disease management (Frankel et. al, 2012).

f) Invasive Species:*

Invasive species are one of the foremost threats to global biodiversity, and that is no different for Michigan forests. Invasive species are often found in disturbed areas, which makes them of special interest in LTC's timber harvesting plans (Sheley et. al, 1999). Not only will removing trees open up additional space and light for invading plants, but logging equipment may disturb soil and allow invasive plant seeds to spread (Sheley et. al, 1999). An extensive list of invasive species that may be potentially found in WFR sites can be found at https://www.misin.msu.edu/ or http://www.michigan.gov/invasives/0,5664,7-324-68002---,00.html. Also, while it is often a main focus in restoration efforts, a lack of invasive species in an area does not necessarily mean that the ecosystem is in pristine condition.

***Note:** These two metrics are not necessary or informative on a plot by plot level, but more of an entire reserve level. They should be used sparingly and at LTC's discretion to track diseases and invasive species of concern to LTC.

Additional consideration: Many of the metrics selected and discussed are sensitive to **timing** of data collection. Herbaceous plants will be easier to identify when flowering, and breeding birds are not present in the area year-round. Previous floristic quality studies in Michigan have taken place in July (Bourdaghs, 2006), and most breeding birds are usually in the region at that point (eBird data), so we recommend that this protocol be conducted in early July. At the very least, if some metrics are collected at different times than others, the timing in data collection should be consistent from year to year for each metric. Due to the small size of plots and patchwork distribution of reserves across the landscape, we consider it unrealistic to expect LTC to be able to account for landscape-scale factors, which is the scale at which many wildlife patterns occur.

Metric	Frequency	Timing	Experience Required
Forest Inventory Measures			
Tree Size/Age Classes	Once per year	All year	None
Species Survey	Twice a year	Spring, early summer	At least one year
Canopy Cover	Once a year	Summer	None
Coarse Woody Debris	At least once a year	All year	None
Wildlife Surveys			
Small Mammal Trapping	No more than once a month	All year	At least six months
Bird Survey	Once in April, June, and December	Spring, early summer, winter	At least one year
Camera Traps	Once a month	All year	None
Sign/Habitat Analysis	Whenever in field	All year	At least six months
Floristic Quality Assessment	Once a month from April-July	Spring, early summer	At least one year
Tree Disease	Once a year	All year	None
Invasive Species	Twice per growing season	Spring, summer	None

Table 1. Frequency, timing, and experience required for each of the metrics selected for the long-term monitoring program.

Trainer Instructions

Purpose

To guide trainers of citizen scientists involved in Little Traverse Conservancy (LTC) Working Forest Reserve (WFR) ecological monitoring in training volunteers to successfully implement ecological monitoring protocol.

Preparation

- Familiarize yourself with the Volunteer Training Protocol, given to volunteers as part of initial training as well as an ongoing reference to ensure proper ecological monitoring data collection.
- Practice presenting (provided as NAME OF FILE) the WFR ecological monitoring training presentation.
- Practice performing the protocol to become familiar. Consider what volunteers may have difficulty with or need extra time practicing.
- If desired, more background information on LTC's WFR ecological monitoring program is available in the comprehensive Monitoring Protocol Guide. This will provide additional reasoning for questions volunteers may ask.

Training

1. Deliver the training presentation provided with this document.
2. Using the Volunteer Guide provided, instruct and practice with volunteers how to identify common plant species as well as set up and collect data in nested plots. Go over additional methods when initially giving training, although emphasis should be placed on plant identification and nested plots due to the foundational nature of these methods.
3. Go outside to practice laying out and collecting data in a nested plot. Two to three sample plots are ideal. Everyone should feel confident in the basics of nested plot data collection. Teach volunteers how to use equipment (compass, dbh tape, densiometer, etc...)
4. If volunteers are immediately going out into the field to gather data, assist them in gathering equipment and background information (e.g., location of reserve, location or existence of permanent plots).
5. Teach volunteers how to enter data

Volunteer Guide

Role of Volunteer Monitoring

Being part of something bigger

Maintaining a current understanding of ecological conditions is fundamental to the Little Traverse Conservancy (LTC) in meeting its overarching mission—to protect the natural diversity and beauty of northern Michigan by preserving significant land and scenic areas, while fostering appreciation and understanding of the environment. This is especially critical for their Working Forest Reserve (WFR) program which seeks to balance the management of an active timber harvest between three primary objectives: sustainable commercial timber production, improving forest health, and increasing wildlife habitat. It is in support of these missions, LTC is grateful to have the support of volunteers to aid in data collection as part of a monitoring program for LTC's Working Forest Reserve program.

Volunteers make the difference

Volunteers like you are vital to ensuring LTC is stewarding healthy forests by helping to provide necessary data to scientists and resource managers. Volunteers are able to provide extra boots on the ground to collect data out in the field that may not otherwise happen due to resource constraints. In return, volunteers are rewarded with valuable training in foundational data collection skills, the knowledge that they are contributing to positive ecological outcomes in their own backyard, and spending time outdoors in beautiful northern Michigan. Thank you for being part of our hard working team!

Stewarding healthy forests

A healthy forest is one that is sustainable and resilient, containing a variety of tree age classes, high species diversity, healthy individual trees, and habitat for native wildlife. LTC uses ecological indicators which are assessed to tell us how healthy the forest is. Ecological indicators, such as tree basal area, coarse woody debris, and a Floristic Quality Index, are assessed to see if the forest is falling within a healthy range for each indicator. The assessed ecological indicators give LTC an overall snapshot of how the forest is doing. An indicator in a less healthy range gives managers a starting place for related management actions to improve forest health.

Getting Started

Since some of these reserves are in remote areas and there is little to no cell service, it is important to be well-prepared before heading into the field. Before each trip into the field to gather data, you will need to know:

1. Location

    a. Access point to reserve
    b. Coordinates of permanent plot (if already exists) or instructions for where to set up new permanent plot
2. Data to be collected

You should check with your contact at LTC before heading into the field, so you know exactly what data need collecting that day. Table 1 (below) outlines the basics of frequency, timing, and experience requirements, but for your benefit, let's go into a little more detail first.

If the reserves you are working in have permanent plots set up with flags, PVC pipes, etc. marking the corners of plots and nested plots within each plot, you may not need the equipment necessary for setting up new plots. If unsure, always check with LTC or take the equipment along anyway.

Take note: most of the metrics will require further specific equipment, which will be noted in the protocol/sampling instructions below.

Field Methods

There are several types of information you may be gathering depending on the season and needs of LTC, but there are two methods most critical for our purposes of ecological monitoring in these forests: **plant identification** and **nested plots**. You will be given the opportunity to practice these methods before collecting data in the field.

Plant identification

Plant species identification, for both common native and invasive species, is an important part of our data collection methods. Volunteer monitoring allows us to make sure native species are not being taken over by invasives which would threaten native biodiversity and the health of our forests. It is important for volunteers to have a foundational understanding for identification in order to be effective at collecting data within plots. Identifying plants can be tricky, even for professionals. Take photos of what you can't identify. Place a pencil or other item of known size next to the plant for reference.

For smaller, herbaceous species, it is often helpful to have pictures of leaf shape, any fruiting bodies or seeds, any flowers, and leaf arrangement on stems. For larger, woody plants (including trees), pictures of bark and leaves, if possible, are often helpful in ID-ing, as well as any fruiting bodies, seeds, or flowers.

Please utilize Common Species Identification Guide provided for a quick, easy reference you can take into the field. LTC also has a library of identification book which can be brought out and used to practice identification during training sessions. Online reference guides include:

- Midwest Invasive Species Information Network: http://www.misin.msu.edu/species-training/ MISIN collects information about invasive species occurring throughout the midwest. Online training modules are available for learning to identify a wide variety of invasive organisms. MISIN has a free phone app for reporting occurrences of invasives that includes species ID information.
- iNaturalist: https://www.inaturalist.org/ iNaturalist is a citizen science network for mapping observations of organisms. Photos uploaded to iNaturalist can receive ID suggestions from other users, as well as automatic suggestions based on similarities with other photos. iNaturalist provides a free phone app in addition to their website.

Full Equipment List:

GPS (w/ reserve boundaries built in)	Transect Tape
Maps of preserves (w/ habitat types)	Metric DBH tape
Wire Stake Flags (34)	Data Collection Forms
Compass	Camera
Pencils/Pens	Densiometer (canopy cover)
Measuring Tape	Plant ID Books

Step-by-Step Protocol

1. **Plot Set-Up**

Equipment Necessary: Map of the reserve (electronic or paper), GPS, Wire Stake Flags, Compass, Transect Tape

a. Before you go to the assigned LTC reserve consult with LTC staff about the overall locations of your samping units. The goal is to sample all vegetation types occurring at the reserver and to have 2-3 replicated plots per vegetation type.

b. Once a rough area has been chosen for a plot, have one person hold a flag, close their eyes, and spin in a circle roughly 10 times. This person should then throw the flag behind them. Wherever this first flag lands is the southwest corner of the plot (corner 1).

c. Using the compass and the transect tape, walk 20m on a north bearing (0°) and place the second corner flag. Repeat this step on an east bearing (90°) and a south bearing (180°) for the third and fourth corner flags.

d. Use the transect tape to check that each of the sides of your square plot is ~20 m long, and adjust as needed.

2. Creating the Nested Plots

Equipment Necessary: Transect Tape, Compass, Wire Stake Flags

Nested plots are an effective, efficient sampling method commonly used in assessing forest health. A variety of data will be collected within these plots as a way to better understand the forest's condition while judiciously utilizing resources and without having to sample the entire forest. Plots are either 20 x 20 m or 10 x 10 m depending on the size and variability of the forest--this will be determined by LTC and communicated to volunteers before field data collection (Figure 1).

a. All of the corners of the plots will have smaller, nested plots (1 x 1 m and 2 x 2 m) within them (see Figure 1), and two of the corners (corners 2 & 4) will have 5 x 5 m nested plots.

b. Using the transect tape and compass, start in corner 1 and measure out a distance of 1 m, 2 m, and 5 m (when necessary) in both a north (0°) and east (90°) bearing and mark these increments with flags.

c. Make sure to measure a distance of 1 m, 2 m, and 5 m (when necessary) into the plot and mark with flags as well, so that you have distinct, marked **square** plots of appropriate sizes.

d. Repeat steps c & d for each of the four corners so that your finished plot setup looks like Figure 1 (or with 5 x 5 m plots nested in opposite corners). You should have a flag in each corner of the nested squares.

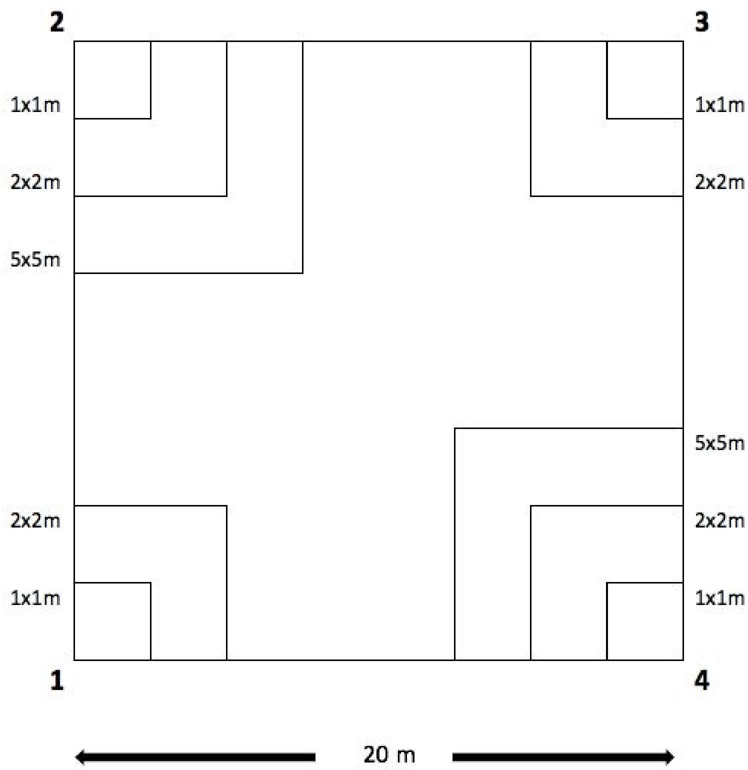


Figure 1. Nested plot design of 20x20 meter plots.

3. Photo Points

Purpose: To visually track changes in sites over time

Equipment Necessary: Camera

a. Use the GPS to find the approximate center of the plot.

b. Take four pictures, one in each cardinal direction, starting in the north direction (0°), with the camera facing straight out at eye height.

4. Herbaceous Ground Cover & Seedlings

Purpose: To assess potential for new trees to grow and assess overall forest structure, and assess quality of plants growing here

Equipment Necessary: Plant ID books, Measuring Tape

a. This is measured in every 1 x 1 m subplot.

b. Note all herbaceous plants, small shrubs, and seedlings within the subplot on data sheet. Only take note of plants under ~50 cm in height (knee height).

c. Identify every unique species (you do not need note how many individuals of a given species are present). Tree seedlings, as well as recently germinated (sprouted) herbaceous plants, can often be very difficult to identify because there are few identifying characteristics available on so small a specimen, many young plants look highly similar, and the leaves often look very different on young vs. mature trees. If you are unsure of species, even with plant ID books, either take a picture to submit on iNaturalist later or take a small sample in newspaper to later identify off site. Write "Unknown" and a unique number for each unknown species in "Species Name" column of data sheet (i.e. "Unknown 1"), so you can keep track of how many total unique species there were. Whether collecting with newspaper or taking a photo, be sure to write the unique species number ("Unknown 1") on both the data sheet and the sample (newspaper/photo) so the entries can be matched later upon identification.

Forest Inventory Data:

Herbaceous Plants, Seedlings, and Shrubs

Plot #	Corner #	Quadrat Size (1x1, 2x2)	Species Name	Count

5. **Saplings and Shrubs**

Purpose: To assess whether seedlings are able to mature and grow, and to assess overall forest structure

Equipment Necessary: Measuring Tape, dbh Tape, Plant ID Books

a. This is measured in the four 2 x 2 m subplots, and the two 5x5m subplots.

b. Take note of all plants in the 2 x 2 m subplots that are woody and > 50 cm in height, but < 2cm in diameter at breast height (dbh; 4.5'). Take note of each unique species and record the number of saplings or large shrubs of each unique species.

c. Take note of all plants in the 5 x 5 m subplots that are woody with a diameter (dbh) between 2-10 cm. Take note of each unique species and record the number of saplings of each unique species.

Forest Inventory Data:

Herbaceous Plants, Seedlings, and Shrubs

Plot #	Corner #	Quadrat Size (1x1, 2x2)	Species Name	Count

Saplings and Overstory Trees:

Plot #	Quadrat Size (5x5, 20x20)	Species Name	dbh

7. **Overstory Trees**

Equipment Necessary: Measuring Tape, dbh Tape, Plant ID Books

Purpose: To track which species are present and how their populations are progressing (biodiversity), and to assess overall forest structure

Equipment Necessary: Plant ID Books, dbh Tape

a. This is measured in the entirety of every (20 x 20 m or 10 x 10 m) plot.

b. Record the species and diameter (dbh) of each adult (>10 cm dbh) tree in the plot.

Saplings and Overstory Trees:

Plot #	Quadrat Size (5x5, 20x20)	Species Name	dbh

8. **Snags**

Purpose: To assess potential wildlife habitat

Equipment Necessary: Measuring Tape, dbh Tape, Plant ID Books

a. This is also measured across the entirety of the (20 x 20 m or 10 x 10 m) plot.
b. Record the dbh of all snags (standing dead trees). To be counted, snags must be at least at diameter breast height (aka, cannot be stumps) and have a dbh >10 cm. Take note of the total number of snags measured in each plot.

Snags:

Plot #	dbh	Plot #	dbh	Plot #	dbh

9. **Coarse Woody Debris (CWD)**

Purpose: To assess potential wildlife habitat and return of nutrients back into soil

Equipment Necessary: Measuring Tape, dbh Tape

a. This is measured over the perimeter of the largest (20 x 20 m or 10 x 10 m) plot. Start in corner 1 and walk the perimeter in a clockwise direction.

b. Only measure the coarse woody debris (fallen dead wood) that intersects the boundary line of the plot and is at least 10 cm in diameter.

c. Measure the diameter of the CWD with the dbh tape and the length of the CWD with regular measuring tape.

Coarse Woody Debris:

Plot #	dbh	Length	Plot #	dbh	Length

10. Canopy Cover

Purpose: To see how much light is reaching ground level, important for plant growth

Equipment Necessary: Densiometer, Transect Tape

a. This is measured on the perimeter of the entire (20 x 20 m or 10 x 10 m) plot with the densiometer.

b. In a 20 x 20 plot, stop and measure every 5 meters while walking along the boundary line of the plot, including the corners of the plot (16 points total). In a 10 x 10 plot, stop and measure at the corners, 2 meters from the corners, and 5 meters from the corners (16 points total).

c. Look through the densiometer and adjust its position so that each spirit level's bubble is in the center of the level.

d. Look at the crosshairs of the lens; if this point is intersected by leaves, the area is considered to have canopy coverage. If this point is open sky, the area does not have canopy coverage (Figure 2).

e. Record whether the area has canopy coverage. If it does, record the species providing coverage.

Canopy Cover:

Plot #	Cardinal Direction	Coverage (Yes/No)	Species

11. Invasive Species

Purpose: To make sure invasive species are not taking over and threatening native biodiversity

Equipment Necessary: Common Species ID Guide, Transect Tape, GPS, Plant ID Books

a. Walk one quarter-mile transect along one boundary of preserve. Stay 3 yards inside the boundary to better observe the interior of the reserve and to be sure that you are not going off of LTC property. Make observations on either side of transect. Repeat once on opposite boundary and once down the middle of the preserve.

b. When an invasive species is observed, mark the area with a GPS point. If the patch of invasives is larger than 5x5 ft, make a GPS point at the center of the patch. Record the species, approximate size (squared ft) and whether the area has already been treated by LTC. The Common Species ID guide provided has native as well as invasive species commonly found, so this can be a useful tool in helping you ID invasive species you encounter if you are unsure.

c. Estimate the density of the invasive patch. If less than 25% of the patch is covered, it is sparse. If 25-40% is covered, it is patchy. If more than 40% is covered, it is dense.

Parcel	GPS Point #	Species	New or Treated	Density (Dense, Patchy, Sparse)
				D P S
				D P S
				D P S

12. Tree Disease

Purpose: To track spread and mortality caused by tree diseases

Equipment Necessary: GPS

a. Survey any location with species of concern present.

b. Mark infection locations with GPS.

c. Record extent of infection. In a stand, number of trees infected and physical area infected. For individual trees, whether trees are still healthy, sickly, or dead.

Parcel	GPS Point #	Disease/Host Species	Number Infected	Tree Health (Healthy, Sick, Dead)

13. Bird Survey

Purpose: To track species present in reserves because birds are good indicators of healthy forests

Equipment Necessary: GPS

Note: must be properly trained in auditory bird species identification

a. Conduct point survey at least once in each forestry management unit.

b. Stand at this point for 5 minutes. Record all visual and auditory bird species observations.

Parcel	Survey Point	Species

Qualitative Data Collection:

All of the data so far has been quantitative, meaning that it involves numbers that can be used directly in analysis of forest health. However, there are other important things worth noting that involve descriptions and notes, instead of numbers. Soil compaction is one negative consequence of logging equipment that is not explicitly included in the monitoring protocol; however, you should record any area in a parcel with ruts or paths that have been permanently compacted by machinery. Heavily compacted soil can make it difficult not only for roots to move in the soil and for seeds to germinate, but reduces infiltration of water into the soil. Therefore, it would also be prudent to note soils that are waterlogged and have water trapped at the ground horizon. Any observations of animals, as well as their nests or dens, could prove helpful in understanding a parcel's ecological community and in finding areas to utilize camera traps. Other factors that could be noted qualitatively include soil erosion, animal tracks or waste, trash piles, and any other aspects of the site that you feel is worth noting. LTC has expressed a desire to be aware of these types of qualitative issues, so they can address them if they deem to them to become too prevalent. There is a section at the end of your data sheets to make notes of this kind of data.

Additional Training:

<u>Explanations of Area Estimate and Density of Invasive Species</u>

Area Estimate: estimate the overall area of the infestation at the GPS point in which you are at
- 0 - if none found where there was previously some sound
- 1 - individual stems scattered
- 2 - up to 1,000 square feet (approx. half of a tennis court)
- 3 - 1,001 square feet up to half an acre
- 4 - half an acre up to 1 acre (1 acre is approx. the size of a football field)
- 5 - one acre and greater (should GPS a polygon with a point in the center in this case)

Density: estimate the density based on three coverage classes
- **D**ense - over 40% of area under consideration (one or several obvious, dense layers)
- **P**atchy - a mix of dense and sparse areas

- **S**parse - scattered individuals stems or very small patches

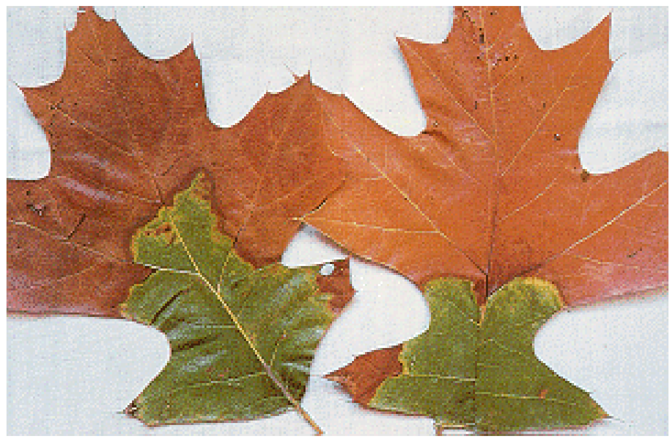
<u>Common Tree Diseases:</u>

Hemlock Woolly Adelgid:
- Affects Hemlock
- Creates white sacs at the base of needles


Heterobasidion Root Disease:
- Affects many conifer species in northern parts of the world
  - Specifically plantation grown pines, red and white pines
- Obvious signs: fungus growing from stumps of trees
  - Other symptoms are thin foliage, reduced height, crown dieback, reduced shoot growth


Oak Wilt:
- Affects all species of oaks, red oak species particularly vulnerable

- Infection symptoms more prevalent in the spring
    - Leaves appear wilted and yellow or brown in color, accompanied by heavy defoliation (leaf loss)
    - Produce fungus mats on white oak species

Emerald Ash Borer:
- Affects ash species all across North America
- Pest is a disease caused by an emerald beetle imported from Asia
- Bores D-shaped holes in trees to lay larvae, which disrupt bark, sapwood, and transport of water and nutrients in tree


Beech Bark Disease:

- Affects beech species
- Caused by insect feeding on sap within trees
- Tiny insects appear to be white scales on trunk of tree, and weaken trees and often introduce further pathogens (esp. *Nectria* fungus) into the now open wounds of affected trees
- Trees often eventually snap in half in weakened state


Densiometer Display (Canopy Cover)

Figure 2. Densiometer display.

This is an example of the display that you will see when viewing canopy cover using the densiometer. Since measurement of canopy cover is either “yes” or “no” according to the center if the display, it should be an easy metric to collect data on. This is simply to familiarize yourself with the display you will be seeing when measuring this metric.

Data Management

Data will be recorded by volunteers on provided data form sheets, on handheld GPS devices (waypoints), and phone/cameras (photo points and photos of unknown vegetation). Volunteer-collected data will then be recorded electronically by appropriate LTC staff to the appropriate long-term database for assessment. Assessed data will be used to inform future management actions taken by LTC.

Assessment

Assessment is an essential component of all monitoring programs. The collection of data, no matter how large a quantity, is essentially useless without some tools with which to assess the data. The baseline data collected by our team in August of 2017 serves to illustrate the current conditions of the reserves, and a survey of the scientific literature is serving as reference conditions that LTC should be striving to attain, or not stray from if the reserves are already at or near the reference conditions.

Most of the assessment tools discussed here, which will be located in additional Excel worksheets provided to LTC by the team, will primarily be simple graphs that will plot the variables and metrics of interest as a function of time. The reference condition for that specific metric will be clearly marked, with range bars delineating a “safe” distance from the recommended reference condition. In this way, LTC and/or their volunteers, if they choose to allow the volunteers to assist in assessment of the data, can enter their data into the spreadsheets over the long term and track the progress of each of the reserves for the different variables of concern.

For most metrics, data for all of the plots in each reserve will be averaged together for a representative value that will be assigned to each plot and used for assessment purposes, i.e. all the diameters of all adult trees from all plots in a reserve will be added together for assessment of total basal area in a reserve.

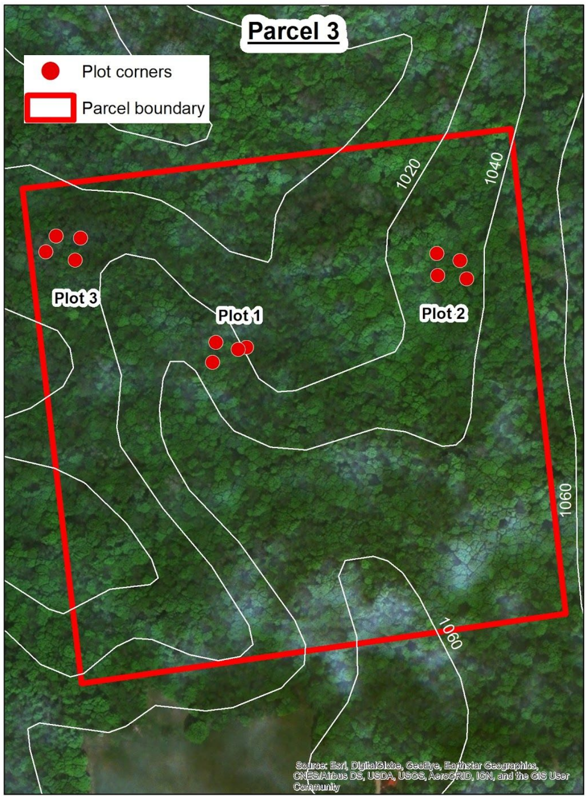
Baseline Data

To illustrate the assessment protocols we collected baseline data from August 22-27, 2017 in reserves 3, 6, and 8 as recommended by LTC because they were scheduled for selective timber harvest soonest afterwards.

For specific, step-by-step methodology for each metric, see the LTC Volunteer Guide.

<u>Emmet #3 Preserve</u>

Emmet County parcel 3 is located immediately southeast of the Elmer Johnston Nature Preserve. The parcel is comprised of northern hardwood forest mostly dominated by sugar maple. Striped maple is common in the understory. The western border is more diverse, with stands of aspen as well as scattered yellow birch, paper birch, and ironwood. In the spring, the forest floor is carpeted with trout lily, Dutchman’s breeches, and spring beauties. Blue cohosh, leeks, and sarsaparilla can be found through most of the site. A few patches of invasive garlic mustard can be found scattered around the eastern half of the preserve; this weed likely used a nearby abandoned logging road as an avenue of invasion. The parcel is hilly throughout, and there is a ravine that is found along the southern and western edges of the property. According to National Wetlands Inventory data, there is a creek in the southwest corner. However, it has either dried up or is highly ephemeral, as it did not exist when we looked at the site in May 2017.



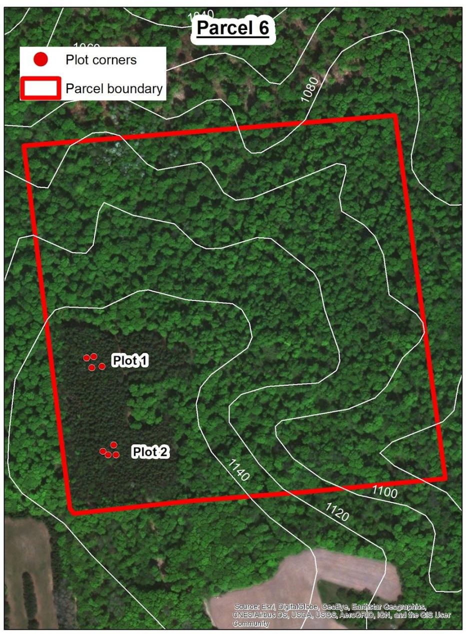
E3 Plot 1 description:
The canopy is dominated by sugar maple, with some ash and beech mixed in. Leeks could be found on the forest floor throughout the plot. The land slopes downward on the eastern side of the plot.

E3 Plot 2 description:
The forest is comprised of beech and sugar maple, while most of the ground is densely covered by sarsaparilla. Some patches of garlic mustard are located south of this plot.

E3 Plot 3 description:
It has the most diverse collection of trees of the E3 plots; ash, sugar maple, and paper birch are all found here, with some ironwood and yellow birch nearby. Red oak leaf litter indicate that there are some red oaks in close proximity, but none are visible from the plot. The plot is located on a small hill near the edge of a valley.

Emmet #6 Preserve

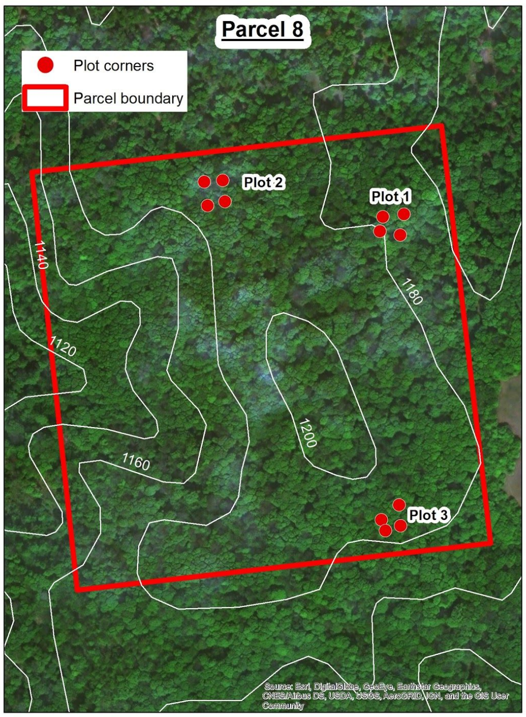
Emmet County Parcel 6 is located on Webb Road via West Stutsman Road. This parcel is comprised of two distinct forest stands: a white spruce plantation surrounded by natural northern hardwoods in the rest of the parcel. The white spruce plantation is overstocked and very crowded, though most of the trees are currently healthy with only sparse mortality. LTC tentatively plans on thinning some of these trees post-2018. The northern hardwood forest making up the rest of the parcel is dominated by sugar maple, with some ash scattered throughout. The ash is infected with emerald ash borer, which LTC predicts will kill the trees in the near future, and lead to them being snags and eventually coarse woody debris. LTC views this stand, particularly the northern hardwoods stand, as good wildlife habitat.



Plot Description:
Because we focused on the white spruce plantation that will be harvested first, both plots were similar in terms of species composition. The dominant tree species was white spruce, with some cherry, ash, and maple. Red oak was also found in the understory, but not in our plots. Once again, the nearby logging roads provided a route of invasion for weeds like garlic mustard and bull thistle.

Emmet #8 Preserve

Emmet County Parcel 8 was the most difficult of the sites to access, as the private property between the site and the intersection of Beacon Hill and Wressel Road was gated off. Although neither road is well-maintained, driving down Beacon Hill is recommended over Wressel Road because Beacon Hill is quicker, less rocky, and less hilly. Walking to the site from the road takes 15-20 minutes. Sugar maple is the most common tree here, followed by beech and ash. The western side of the property also contains a significant population of yellow birch, while paper birch is scattered throughout the preserve. The forest becomes younger moving north to south, and the southern boundary is dominated by dense stands of young, thin maples and beeches.



E8 Plot 1 Description:
The plot is on top of a small hill. The canopy is comprised of sugar maple and beech, with striped maple and beech common in the understory. The shallow valleys nearby have significant amounts of coarse woody debris.

E8 Plot 2 Description:
The plot is on a small incline, with the northern edge sloping slightly downwards toward the south. The trees in this plot are older and larger than in most of the rest of the preserve. Sugar maple, beech, and ash are all present on the site. To the west of this plot, there are some steeper ravines where yellow birch grow.

E8 Plot 3 Description:

This area is relatively flat, with a slight decline down towards the south. The forest in and around the plot is very dense, packed with young, thin-stemmed beech, sugar maple, and striped maple. The stands in this general area are the youngest in the parcel.

Assessment Methods

Most of the assessment tools discussed here, which will be located in additional Excel worksheets provided to LTC by the team, will primarily be simple graphs that will plot the variables and metrics of interest as a function of time. The reference condition for that specific metric will be clearly marked, with range bars delineating a “safe” distance from the recommended reference condition. In this way, LTC and/or their volunteers, if they choose to allow the volunteers to assist in assessment of the data, can enter their data into the spreadsheets over the long term and track the progress of each of the reserves for the different variables of concern.

Forest Structure and Basal Area:

The data collected on all plant class sizes, from seedling to adult, and for all vegetation types, herbaceous and woody, will be important in assessing forest structure. As mentioned before, a healthy and well-functioning forest will have both herbaceous and woody plants, and a wide variety of vertical structure from the forest floor to the understory to the canopy. This variety in forest structure is vital in maintaining not only basic forest functions, but the successional processes that sustain a forest into the future (Tiscar and Lucas-Borja, 2016). Diverse forest structure also plays a large role in providing vital habitat for many wildlife species; therefore, it is essential that this is assessed on a regular basis and managed for in LTC’s Working Forest Reserves.

A commonly used tool for assessing **forest structure** is graphing the diameters of all trees for which dbh was measured and graphing them in a bar graph to get a distribution of the age/size classes present in the forest. Heavily managed and natural forests have very different distributions and would be fairly easy to determine where LTC’s reserves fall. Heavily managed forests often have very narrow ranges of tree diameters, either in the middle size/age category if the stand hasn’t been logged for some time or narrowly concentrated in the small size classes if the stand has been recently logged and most trees have recently recruited (Tiscar and Lucas-Borja, 2016). Natural stands, on the other hand, have a much wider range of tree diameters, specifically with a small number of very large trees, often referred to as legacy trees (Tiscar and Lucas-Borja, 2016). The figure (Figure 3) below (Tiscar and Lucas-Borja, 2016) illustrates the typical differences between old growth (natural) and managed stands:

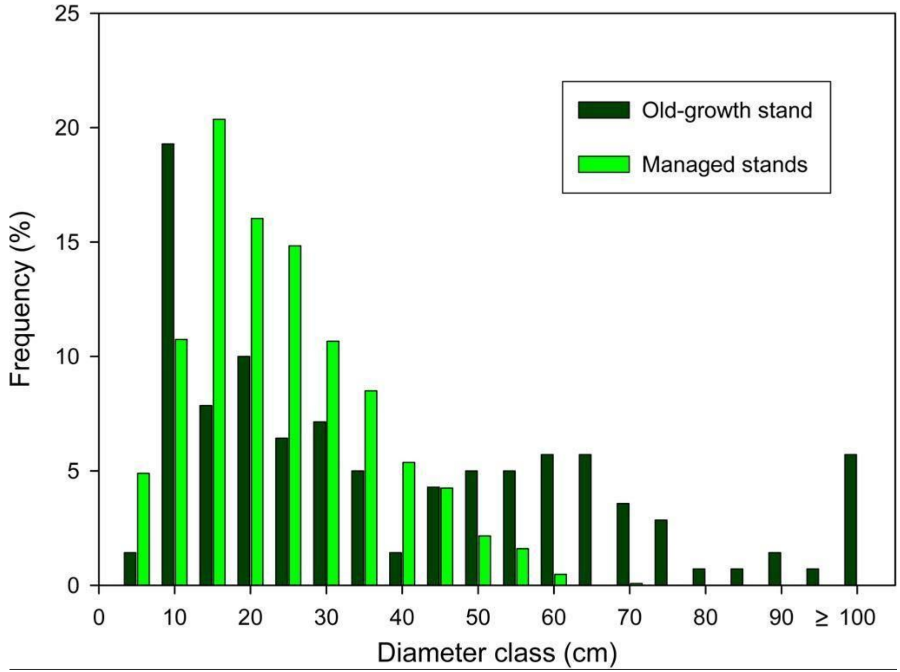


Figure 3. Forest structure: The diameter distributions for old-growth and managed stands, showing wide vs. narrow ranges of diameters

One caveat, though, is that approximately 13% of total stand area should be sampled to get an accurate representation of diameter distributions and stand structure, so it may take extensive sampling (many plots) to capture the variability accurately (Janowiak et. al, 2008). Since the management treatments would be occurring at the reserve level and not specifically at the stand level, diameters of all adult trees measured in all plots across a single reserve should be grouped together and evaluated at the reserve level.

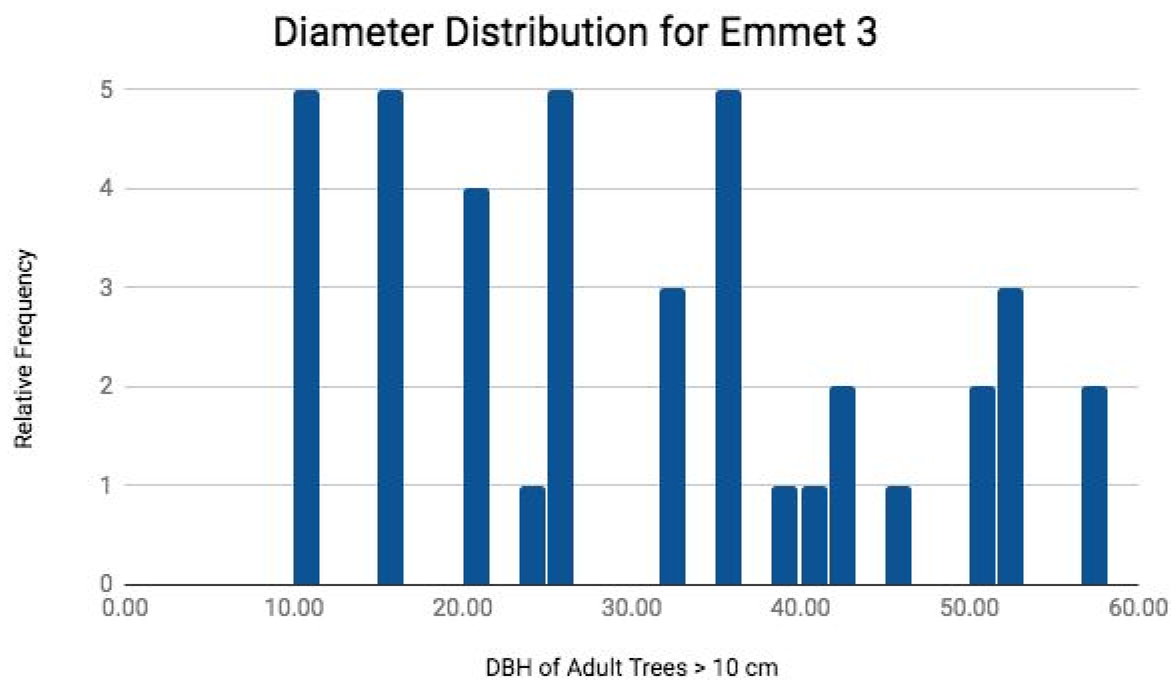


Figure 4. Diameter distribution of all trees > 10cm dbh in Emmet 3.

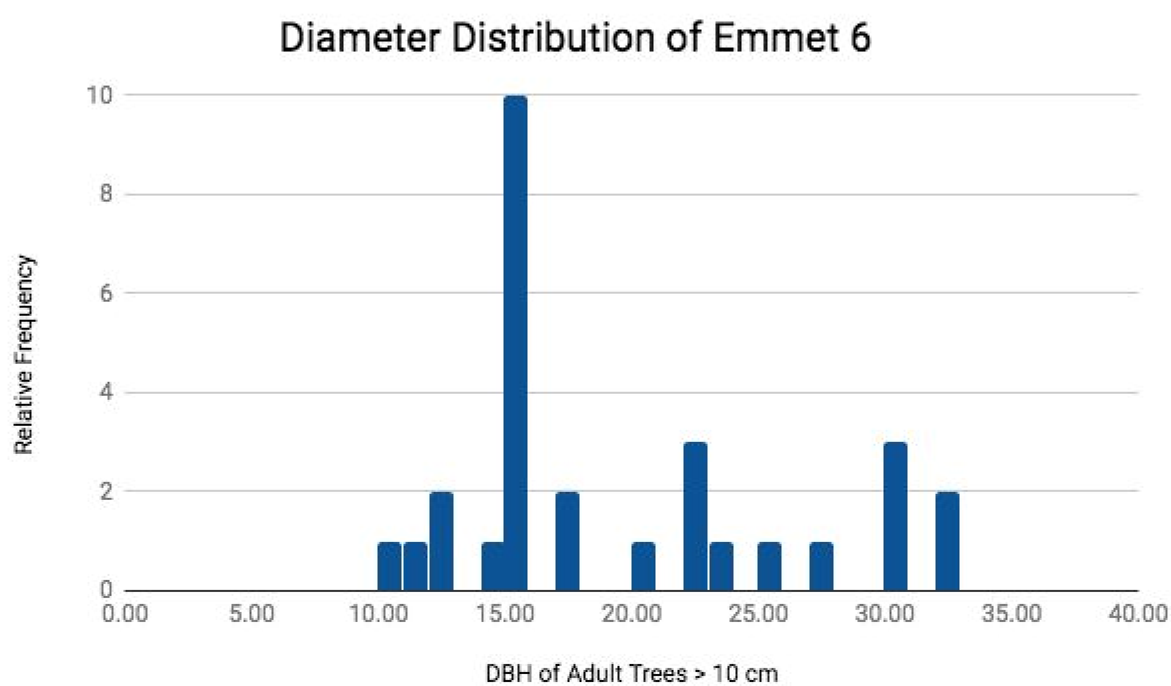


Figure 5. Diameter distribution of all trees > 10cm dbh in Emmet 6.

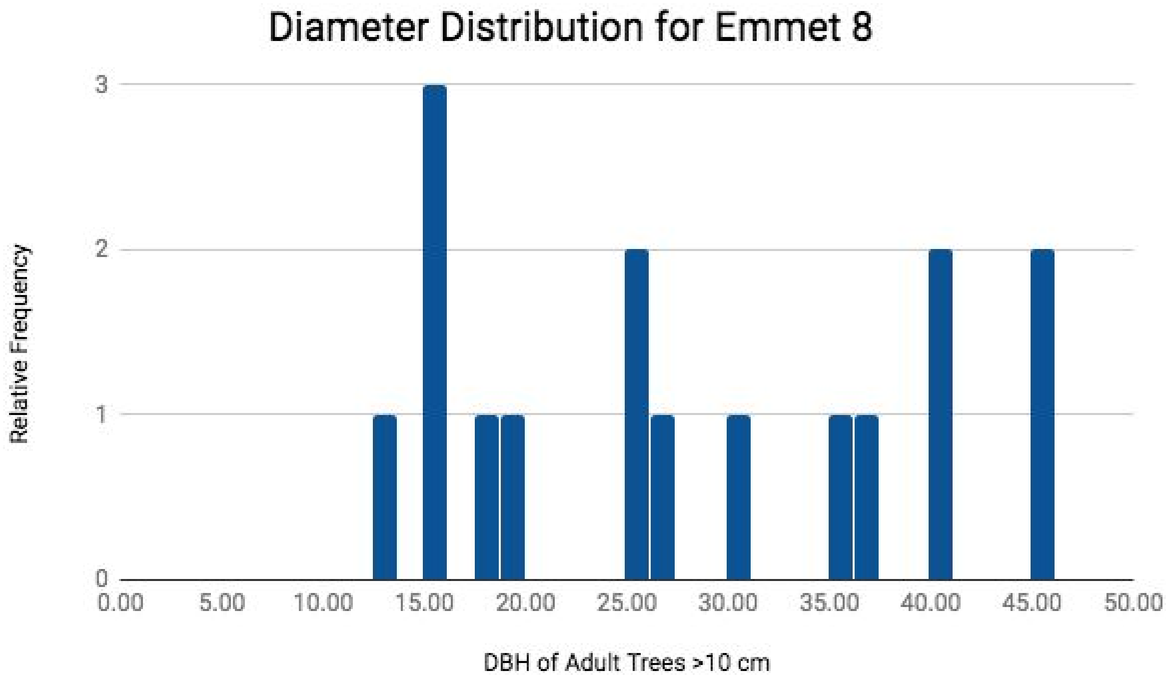


Figure 6. Diameter distribution of all trees > 10cm dbh in Emmet 8.

Basal area is the area of a predetermined section of land that is occupied by the cross-sectional area of trees at their base (Bohn and Huth, 2017). Basal area increases with forest age and it can be used as a proxy for forest productivity and biomass accumulation. It is a very commonly used calculation by forest ecologists and managers to assess the productivity and growth of a forest (Bohn and Huth, 2017). The diameter measurements (dbh) of all adult trees in each plot will serve as the input for the calculation of basal area (i.e., tree trunk circumference). To calculate the basal area of an individual tree, the dbh (cm) is divided by 2 to obtain the radius and then squared and multiplied by pi :

$$\text{Basal Area (BA)} = 3.14\text{x } (\text{dbh}/2)^2$$

To calculate basal area of the entire forest stand, the basal areas of all adult tree in each plot will be added together and divided by the area of land in which the trees were measured, BA is usually expressed in units of cm^2/m^2, m^2/ha, $feet^2/acre$. A study by Crow et al. (2001) in Ottawa National Forest in upper Michigan found that old growth forest had an average BA (mean±SD) of 34.0 ± 3.6 m^2/ha, unmanaged second-growth forest had an average BA of 31.0 ± 3.0 m^2/ha, managed uneven-aged forests had an average BA of 23.4 ± 1.2 m^2/ha, and managed even-aged forests had an average BA of 24.3 ± 0.6 m^2/ha. Since these studies use m^2/ha as their units, we have set up the assessment tool spreadsheets to convert to this unit.

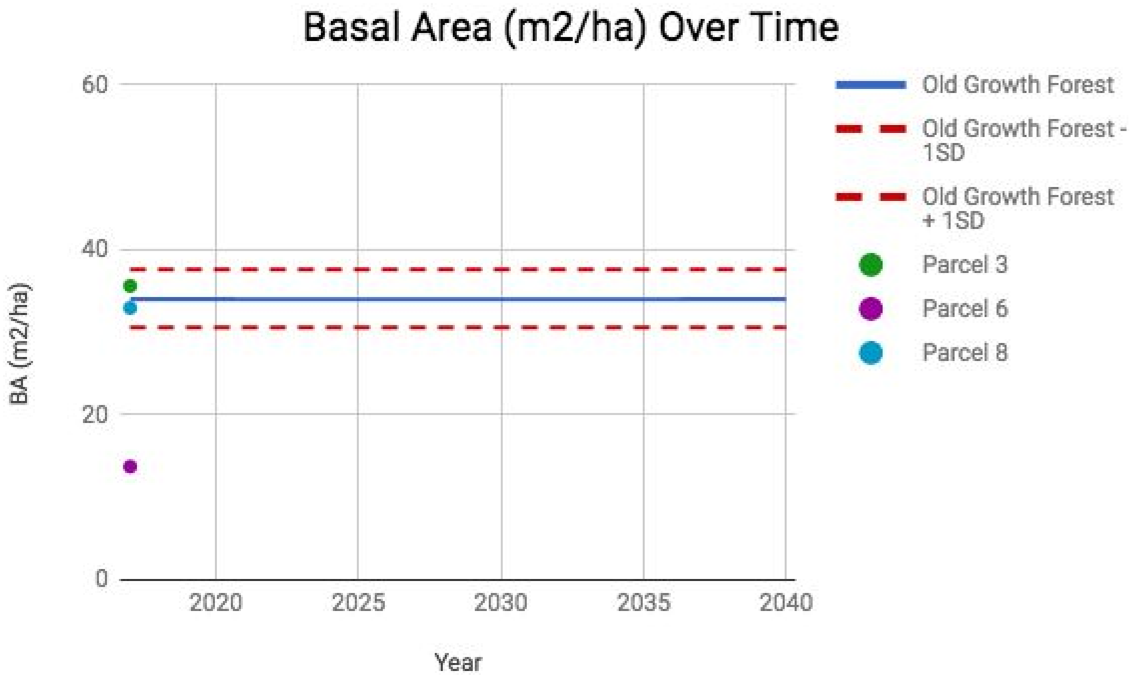


Figure 7. Basal area: Graph showing optimum levels of basal area in "old-growth" forests with baseline data collected from LTC parcels.

Parcel 3 and Parcel 8 had very similar amounts of basal area, 35.63 m^2/ha and 32.95 m^2/ha, respectively (Figure 7). Both of these parcels fall within the optimum level of expected basal area for old-growth forests conditions (lines in graph; Crow et. al, 2001). As selective timber harvest begins, the progression of BA back to this original level, post-disturbance, would be desirable. Parcel 6 had a much lower average basal area of 13.73 m^2/ha, typical of a younger and planted forest (Figure 3). Ideally, after timber harvest of some areas of this parcel, the remaining trees will be allowed to grow larger and into more optimum, mature forest conditions.

Coarse Woody Debris (CWD):

Coarse woody debris levels can be assessed with multiple different measures. Snags and fallen logs can be counted individually to estimate their density on the landscape, and the total volume of fallen coarse woody debris over an area is another common metric.

Snags: Goodburn and Lorimer (1998) measured snags in northern hardwood forests in Wisconsin and northern Michigan. In old growth forests, there was a mean of 39 snags per hectare (11.2% of all stems). Monfils et al. (2009) found a mean of 29.3 snags/ha in managed stands and 31.7 snags/ha in unmanaged stands. For data collected by LTC volunteers, the data is collected in plots smaller than a hectare, so the data must be converted. To obtain the number of individual snags per hectare, multiply by 10,000 and divide by the size of the plot in meters (a 20x20 plot is 400 square meters and a 10x10 plot is 100 square meters). The size of the plots should be added together when calculating density for an entire parcel (three 20x20 plots means 1200 square meters).

Snag density (snags/ha) = 10,000 (number of snags/size of plots in meters squared)

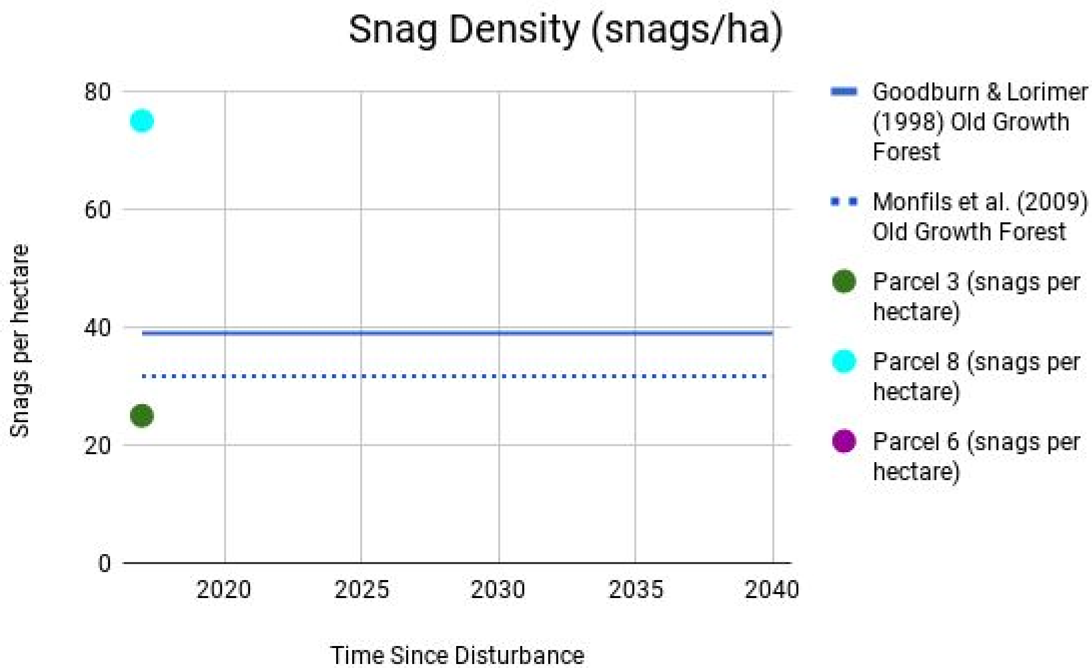


Figure 8. Snags: Graph showing optimum levels of snag density in "old-growth" forests with baseline data collected from LTC parcels.

Fallen logs: In northern Michigan forests, Monfils et al. (2009) found an average of 169.4 fallen logs per hectare in unmanaged northern hardwood stands, while there were only 111.7 logs/ha in managed stands. It is important to note that this study obtained these numbers by using a slightly more complicated formula, different from the simpler CWD over area equation that is used by the Forest Service and in this protocol. Forest Service data from old growth northern hardwood stands located in the northeastern U.S. found a range of 99 to 481 logs/ha (USFS 1998).

Fallen CWD density (logs/ha) = (10,000) (number of logs/size of plots in m squared)

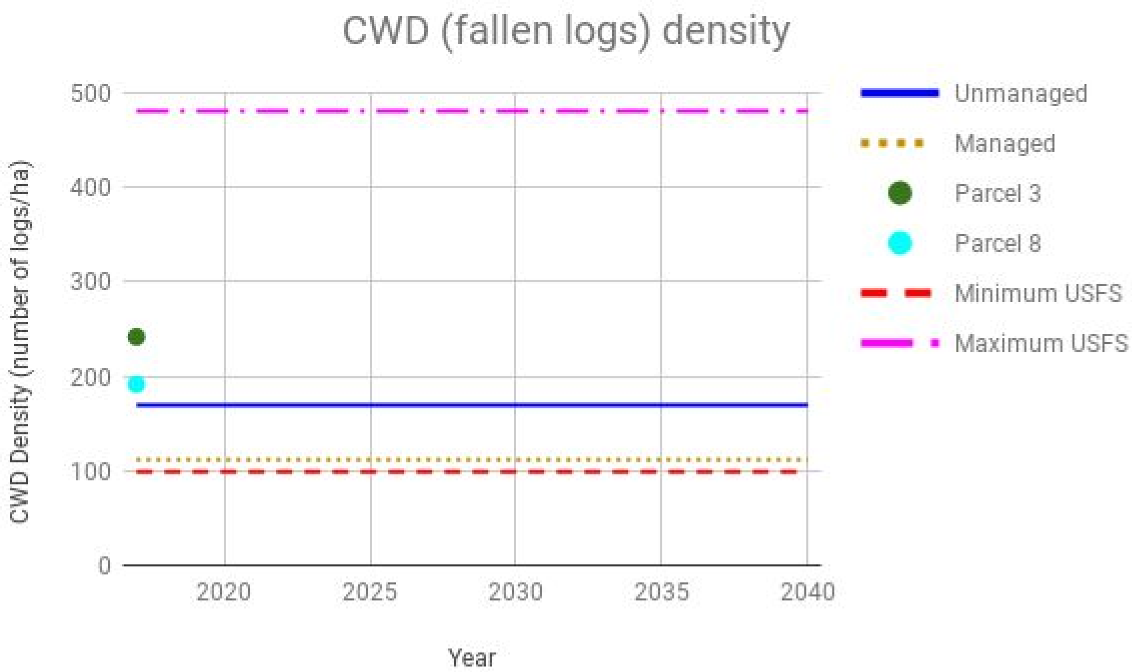


Figure 9. Fallen trees density: Graph showing optimum levels of coarse woody debris (logs/ha) in "old-growth" forests with baseline data collected from LTC parcels.

Canopy Cover

According to U.S. Forest Service classification standards (Pugh et al. 2009), every plot has a high level of canopy coverage except for plot 1 in Parcel 6 at 50% (which is considered average as it is between 31% and 55%). Parcel 8 has the highest canopy coverage (84.4%), followed by Parcel 3 (65.6%), and Parcel 6 has the lowest (59%). Timber harvest will affect the amount of canopy cover, which can affect the composition of species that germinate on the ground. Monitoring of canopy cover percentages decreasing below average levels should be watched for.

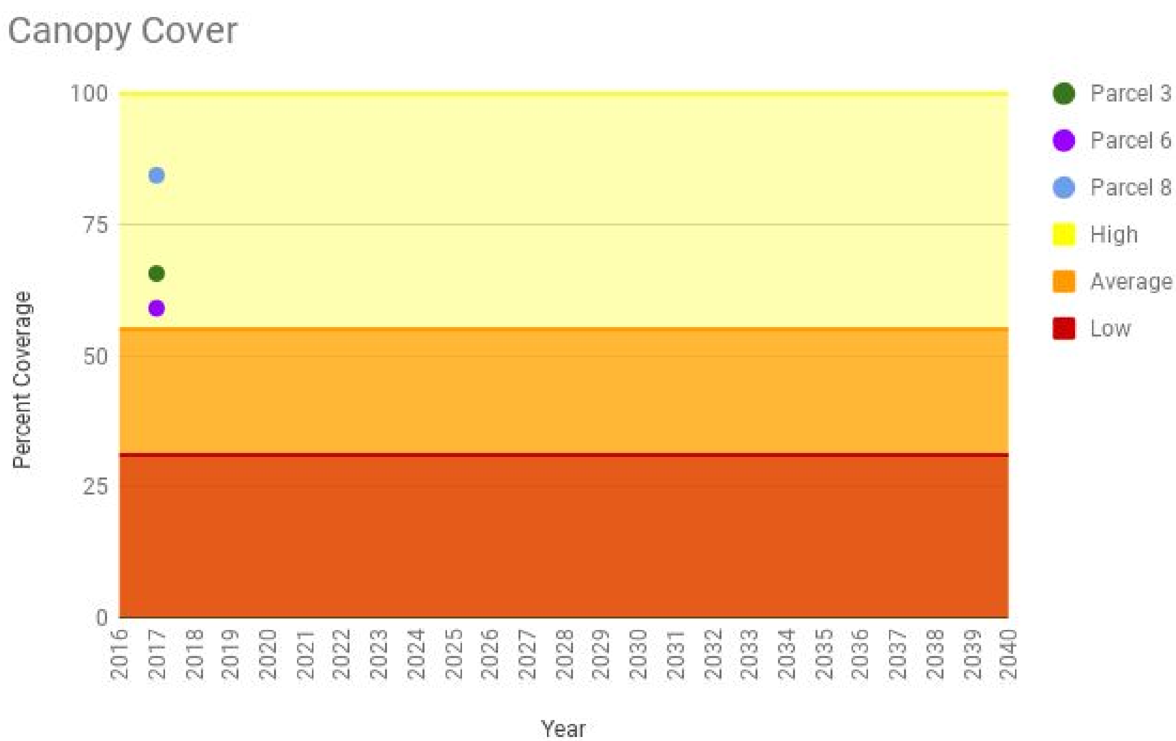


Figure 9. Graph showing USFS classifications of canopy coverage with baseline data collected from LTC parcels.

Floristic Quality Index (FQI):

Floristic Quality Assessments (also often called FQI scores) can be difficult to compare between sites for a variety of reasons: there is no widely-accepted index for determining high and low quality overall values, significant variation will exist between any two sites, and (specific to this protocol) not all plant species will be identifiable by interns or volunteers. Instead of having a specific value to aim for, the FQA will be used to track botanical changes over time in the preserves. Floristic Quality Assessment are often used in other instances to guide management decisions. In existing protected natural areas, such as the parcels owned by LTC, values that are holding steady or increasing suggest sound management decisions (Freyman et. al, 2016). Decreasing FQA values over time can be interpreted as a signal that logging is negatively affecting forest quality and biodiversity, and adaptive management decisions should be considered.

The simplest way to determine FQA values for a plot, or for a parcel as a whole, is to use an online tool called Universal FQA Calculator, located at the website: http://universalfqa.org. This is an official and accepted tool, and the methodology has been published in *Methods in Ecology and Evolution* (Freyman et. al, 2016).

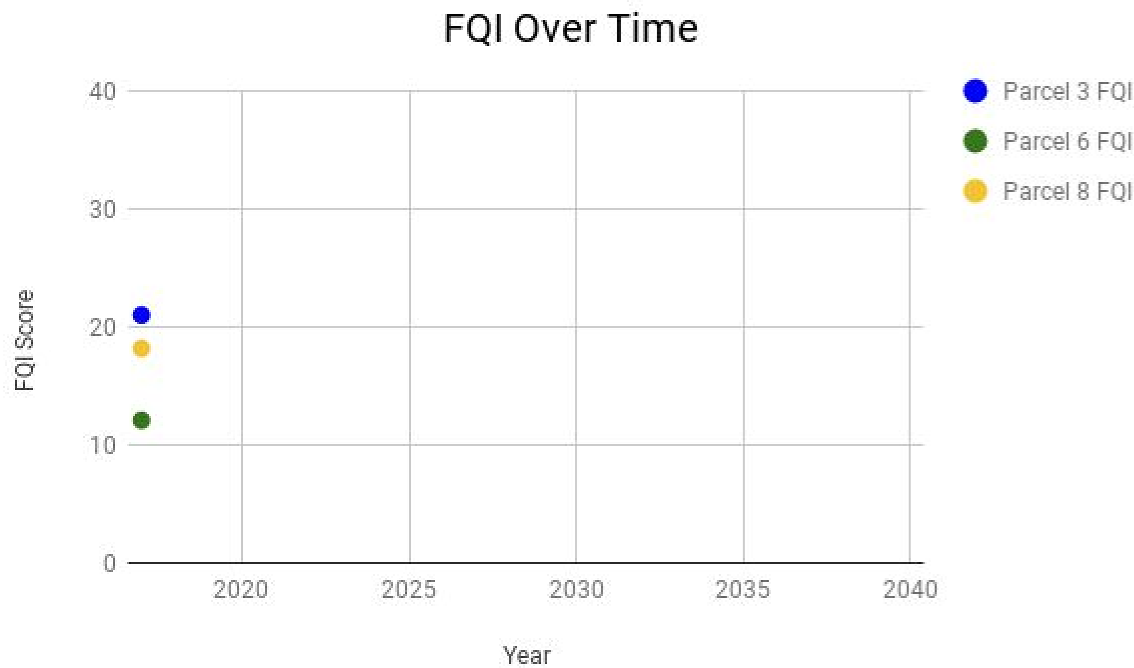


Figure 10. Floristic Quality Index: Graph showing FQI scores for each of the parcels sampled to be tracked over time.

Invasive Species

During our data collection, we discovered both garlic mustard and bull thistle growing in the parcels. Parcel 3 had multiple patches of mature garlic mustard. Parcel 6 had a few scattered individuals of garlic mustard and thistle near the old logging roads. Overall, though, the level of invasive species at each site appeared to be very low. There were no woody invasive species recorded at any site. As selective timber harvest proceeds in the future, the potential for invasive species to move in to the parcels due to increases in disturbance and accidental transport. Close monitoring of the parcels should be enacted.

Wildlife

Small Mammal Trapping

We did not capture any mammals in the traps after setting them. If proceeding with this methods increase the area, period of time, and traps to be used.

Camera traps

The cameras did not capture any images of animals. This is likely due to the very short amount of time that the cameras were in operation (less than a week). We expect that longer-term use of camera traps will produce more interesting results.

Bird survey

The bird survey will also be more effective when conducted at another time of year. At the end of August, most breeding birds had already begun to migrate. We therefore recommend future surveys be conducted in mid-July. We found the highest level of species richness at site 6, likely due to the habitat heterogeneity (forest edge, northern hardwoods, and white spruce plantation) as well as observing the site earliest in the morning.

Parcel	**Bird species observed**
3	Peewee, Blue Jay, Chickadee, Robin
6	Red-breasted nuthatch, white-breasted nuthatch, blue jay, chickadee, raven, peewee, rose-breasted grosbeak, yellow-rumped warbler, robin, tufted titmouse
8	Peewee, Blue Jay, Chickadee, Song Sparrow, Canada Goose, Raven, Downy Woodpecker

Adaptive Management

The monitoring protocol in this document is meant to inform future management activities through a process called adaptive management. Adaptive management is "an approach to environmental management based on learning-by-doing, where complexity, uncertainty, and incomplete knowledge are acknowledged and management actions are treated as experiments" (West et al., 2016) with the goal to create an effective process for ongoing integration of lessons learned into planning and management activities (Conrad & Daoust, 2008). There are many benefits to performing appropriate adaptive management including effectively leveraging limited resources, better understanding how the project operates within a complex system (e.g., ecologically as well as politically, socially, etc), improving human elements of management (e.g., group dynamics and processes), building systemic support at multiple scales, and better preparing for uncertainty and change (Schueller et al., 2006). While adaptive management is an increasingly popular theory, the concept remains challenging to effectively enact. This relates to the substantial challenges of citizen science programs in using data to inform management activities.

Evaluation

A 2015 study by Aceves-Bueno et al. found that citizen science could be used to address two of the most common shortcomings of adaptive management: low stakeholder buy-in and insufficient monitoring. The study found that citizen scientists can contribute to effective adaptive management by contributing to the gathering of data that is cost-effective, quality-controlled, management-focused, and appropriately-scaled. To achieve these positive outcomes, it is critical to properly utilize evaluation as a tool to appropriately adapt management, otherwise data collection becomes a wasted effort (Schueller et al., 2006). Proper evaluation will assist in tracking and measuring progress toward organizational goals at multiple levels, allowing LTC to clarify and communicate what LTC is aspiring to achieve (Schueller et al., 2006). The information these efforts provide support to better document and communicate successes, bolster buy-in, and make more efficient and effective decisions (Schueller et al., 2006).

In tandem with the protocol guide, we highly recommend LTC utilize the Ecosystem Management Initiative's (EMI) *Evaluation Sourcebook* along with *Measuring Progress: An Evaluation Guide for Ecosystem and Community-Based Projects* to support proper evaluation of adaptive management activities. As adaptive management is an on-going and iterative process, we cannot be exhaustive here. See Appendix A for figure of the EMI Evaluation Cycle. See Appendix B for some key points and illustrative examples.

If the *forest health metrics* listed above *decline* over time, one of the most evident adjustments would be to decrease the frequency of logging operations at the site. Consulting with the forester may be helpful in determining the properties of the site or the logging operations that could be causing logging to be so detrimental in this location. However, simply discontinuing the logging may not be enough to solve the problems resulting from it.

Invasive species control is one of the most common forms of ecological restoration, and one that LTC is likely already familiar with. Upon discovering an invasive in a parcel, control efforts should take place as soon as possible to minimize the chance of the invasive establishing a permanent seed bank or spreading. Annuals and biennials must be removed before seeding to reduce the chance of spread, and, if herbicide is used, invasives should be treated during seasons when nutrients are flowing to the roots (late summer to winter). We have already noted the existence of small populations of garlic mustard and bull thistle at the parcels we surveyed.

Tree parasitism is another major concern for ecosystem health. There are several potential parasites and pathogens that can reduce forest health, and appropriate treatments will vary greatly among species of diseases and hosts. Organizations that can help deal with tree disease include the Midwest Invasive Species Information Network and the Michigan Department of Natural Resources.

The *decrease in canopy cover* could be seen as an opportunity rather than a detriment. Basswood, which produces a large portion of the nectar available for insects in northern hardwood forests, requires more light than other trees in this ecosystem type; saplings grow best in larger canopy openings (Crow 1990). Basswood populations have been in decline as a result of habitat fragmentation, but canopy openings that result from logging can be used as an opportunity for planting this ecologically important species. Native species plantings could also take place in areas where erosion is a concern, as plant roots could hold soil in place. Fallen branches from logging could also be fashioned into coir logs to help prevent erosion in areas where this is an issue. Native plants could also be used as a cover crop of sorts in newly-open areas where nearby invasive plants are a concern; herbaceous plantings might include sarsaparilla or blue cohosh, as well as live stake or bare root plantings of shrubs like alternate-leaved dogwood or maple-leaf viburnum.

Decreases in diversity as evinced by FQAs or bird surveys are more difficult to deal with immediately. However, a decrease in diversity may mean that logging has decreased the heterogeneity of habitat available in the area. In this case, LTC may want to choose specific sections of the parcel as refugia that are not to be logged at all. Decreases in CWD may mean that logging operations have resulted in a concentration of dead branches in one specific spot. This could be remedied by spreading the branches out throughout a larger area of the parcel.

Communications

Maintaining proactive communication and outreach throughout the monitoring process provides critical transparency to stakeholders, facilitating continued and new buy-in from participants, funders, and the general public. It is useful to consider how monitoring results will be communicated to different audiences when considering what types of data will be collected, as it may influence the form and content of some data collection (Schueller et al., 2006). An effective communication plan involves: (1) identifying information needs; (2) disseminating information (USDA Forest Service, 2003). In the first step, distinct stakeholder groups and their respective needs must be identified. Once identified, a strategy to disseminate information should be crafted for each stakeholder group. Translating and reporting program results will aid in building trust and credibility with LTC's community.

Examples of information dissemination strategies include (USDA Forest Service, 2003):

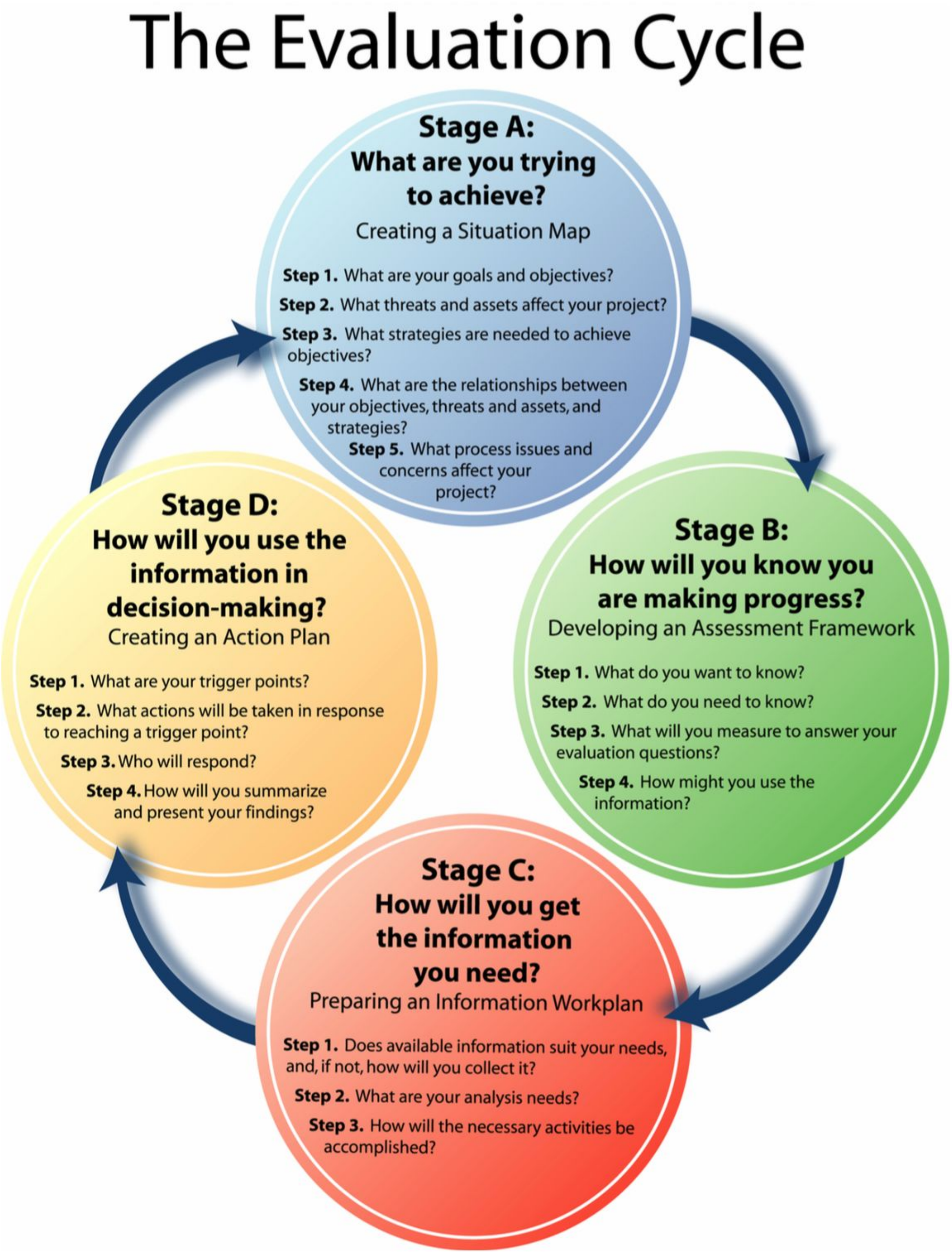
- Give special consideration to diverse and vulnerable populations (e.g., providing information in multiple languages and formats)
- Provide information at training events regarding progress and successes
- Encourage interactive, outdoor learning by providing in-person program updates at respective field sites; invite media to events
- Share lessons learned with the greater community by presenting at open forums and conferences, submitting op-eds to local publications, reaching out to agency officials, utilizing professional networks

- Create and disseminate regular progress reports (e.g., create a webpage dedicated to program updates)

Key Resources

- Citizen Science
  - Developing a Citizen Science Program:
    - <https://cdn1.safmc.net/wp-content/uploads/2016/11/28101104/CS1_Developing20a20Citizen20Science20Program20GUIDE.pdf>
  - Citizen Science Best Practice Guides:
    - <https://www.ceh.ac.uk/citizen-science-best-practice-guide>
  - Citizen Science Toolkit
    - <http://www.birds.cornell.edu/citscitoolkit/toolkit>
  - Motivations for Citizen Scientists
    - <http://www.ukeof.org.uk/resources/citizen-science-resources/MotivationsforCSREPORTFINALMay2016.pdf>
  - Citizen Science Cost Benefit Tools
    - <http://www.ukeof.org.uk/resources/citizen-science-resources>
- Monitoring Protocol
  - Developing a Habitat Monitoring Protocol:
    - <https://ir.library.oregonstate.edu/dspace/bitstream/1957/67/1/Habitat_Monitoring_3-8-05.doc>
  - USFS - Developing a Multiparty Monitoring Plan:
    - <https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev3_021466.pdf>
  - USFS - Multiparty Monitoring and Assessment Guidelines
    - <https://www.fs.usda.gov/wps/portal/fsinternet/cs/detail/!ut/p/z1/04_Sj9CPykssy0xPLMnMz0vMAfIjo8zijQwgwNHCwN_DI8zPyBcqYKAfjlVBmA9cQRQx-g1wAEci9eNREIXf-HD9KH0CHtDHb4KfR35uqn5BbmhohEGWCQCHVD_f/dz/d5/L2dBISEvZ0FBIS9nQSEh/?position=Not%20Yet%20Determined.Html&pname=Region%203-%20Maps&ss=1103&navtype=&pnavid=240000000000000&navid=240110000000000&ttype=detail&cid=fsbdev3_022173>
- Adaptive Management
  - EMI Sourcebook:
    - <http://seas.umich.edu/ecomgt/evaluation/sourcebook.htm>
  - Evaluation resources:
    - <http://seas.umich.edu/ecomgt/evaluation/webLinks.htm>

Appendix A:



(Credit: EMI Measuring Progress)

Appendix B:

Examples of adaptive management questions and indicators to consider for a citizen science program (Schueller et al., 2006):

Community and Volunteer Outreach and Management

- How well have we planned our community education and outreach campaign?
  - Communication goals (attract new members, stimulate behavior change, educate on a specific topic, etc.) are clear and relate to project goals
  - Amount of funds available compared to estimated costs of education activities, materials and evaluation
  - Baseline data on knowledge or attitudes available or plan to collect it
  - Target audience has been identified
- How well have we implemented our outreach campaign?
  - Number of press releases issued /newsletters sent
  - Frequency of web updates
  - Number of new hits to the website
  - Number of people who have received educational material (e.g., mailers, phone campaigns)
  - Number of signs posted to alert visitors to restored sites
  - Feedback from stakeholders about how strategy is being implemented
- What are we doing to increase membership or build our volunteer base?
  - Number of events held to reach out to community
  - Attendance at fundraising or organizational support-building events compared to target audiences
  - Percent of attendees that sign up as members or volunteers
  - Number of skills-building trainings held for volunteers
  - Percent of trained volunteers that are using those skills for the organization
  - Number of volunteer or member recognition/celebration events
  - Percent of volunteers that have not turned over in the last 3 years
  - Percent of community members who are involved in organization or collaborative in some way
- How well are we addressing our space, supplies and equipment needs as they relate to our citizen science program? To what extent are we providing a supportive and productive work environment for our volunteers?
  - Staff/volunteer opinion of whether they have the work space and supplies they need to do their job effectively
  - Identification of donors for needed equipment or supplies
  - Number of informal meetings between coordinator/leader, staff, and volunteers to discuss respective needs
  - Staff and volunteer satisfaction level

Gathering and Managing Information

- How well have we planned our information gathering strategy or monitoring programs?
  - Board retreats or organizational meetings have been held to discuss information needs
  - Priority needs identified (including research, assessments, evaluation questions, key uncertainties, etc.)
  - Goals and use of collected information are clearly identified
  - Roles and responsibilities for collecting, analyzing, reporting on and storing information are clearly identified
  - Required budget and timeline determined
  - Assessment of already available information completed
- How well are we gathering the information we need? Are we efficient in our data collection? Are the data credible?
  - Quantity or quality of data or information compared to desired levels (quality assurance or control standards relative to data quality objectives, such as accuracy, completeness, precision, etc.)
  - Cost of acquiring information vs. expected or realistic cost
  - Percent of acquired information that is used (to make management decisions,inform funders, communicate with public, etc.)
  - Expert review of collection protocols or data quality
  - Number of requests from other organization for our information
  - Consistency of collection protocols across years
  - Consistency of collection protocols between our organizations and other organizations collecting the same type of information
- How effectively are we using potential assets to gather information?
  - Number of volunteer hours spent on information gathering
  - Match between staff expertise and type of information gathered
  - Percent of information needs met by local universities
  - Percent of monitoring programs that involve partner organizations
- How well are we managing or storing the information we have?
  - Number of hours it takes staff/partner/public to find needed information
  - Existence of a data management system
  - Ability of target audience to understand presented information
  - Staff satisfaction level with data management system based on survey
  - Extent to which people within and outside of the organization are familiar with what information the organization is gathering
  - Percent of information that is easily accessible to general public

Ecological Considerations

- How well have we planned our restoration activities?”
  - Estimated cost of activities compared to amount of funds available

    - Quantity and quality of baseline data
    - Peer review of planned restoration activities
    - Use of best available information
    - Existence of clear protocols
    - Existence of project-specific data sheets
- To what extent have we completed restoration activities?
- How well have activities been completed?"
    - Number of acres treated, planted, cleared of invasives, graded, etc. compared to planned timeline or target
    - Number of individual species reintroduced, planted, etc.
    - Number of habitat restoration project work days per month or year
    - Survival rate of reintroduced species

Appendix C: Little Traverse Conservancy Data Collection Sheet

Name ____

Date ________________ Time Volunteered with LTC ___________________________

Previous LTC Volunteer Experience ____

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Reserve Name ____

GPS Points:

Plot1

Latitude ____________________ Longitude _______________________

Plot2

Latitude ____________________ Longitude _______________________

Plot3

Latitude ____________________ Longitude _______________________

Weather ____

Temperature ___________ Start Time ________________ End Time ______________

<u>Forest Inventory Data:</u>

<u>Herbaceous Plants, Seedlings, and Shrubs</u>

Plot #	Corner #	Quadrat Size (1x1, 2x2)	Species Name	Count

Saplings and Overstory Trees:

Plot #	Quadrat Size (5x5, 20x20)	Species Name	dbh

Coarse Woody Debris:

Plot #	dbh	Length	Plot #	dbh	Length

Snags:

Plot #	dbh	Plot #	dbh	Plot #	dbh

Canopy Cover:

Plot #	Cardinal Direction	Coverage (Yes/No)	Species

Invasive Species:

Parcel	GPS Point #	Species	New or Treated	Density (Dense, Patchy, Sparse)
				D P S
				D P S
				D P S
				D P S
				D P S
				D P S
				D P S
				D P S
				D P S
				D P S
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				D P S

Tree Disease:

Parcel	GPS Point #	Disease/Host Species	Number Infected	Tree Health (Healthy, Sick, Dead)

Additional Notes:

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Signature of Collector ____

Signature of LTC ____

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