Monitoring Protocols for the Ossipee and Waterboro Pine Barrens

Presented to the New Hampshire and Maine chapters of The Nature Conservancy
5/5/2011
Prepared by Taylor Bushell
Field Naturalist Program
University of Vermont

Acknowledgements

I wish to thank you the many people that have supported me through completion of this project. Walt Poleman, Jen Pontius and Jeff Hughes served as my advising committee helped to steer my work in a meaningful direction. The Nature Conservancy acted as a superb partnering organization. Nancy Sferra and Parker Schuerman were my guides in the Waterboro Barrens. Jeff Lougee endured countless hours of my questioning and provided on the ground support during my summer in New Hampshire. Samuel McCabe assisted me with a weekend of data collection at the Ossipee Pine Barrens. Rose Graves shared roughly one thousand cups of coffee with me, over which she provided sound feedback and her critical opinion to my work. Lastly, the Paine cabin on Whitton Pond served as my summer retreat. From there I launched a season of solo explorations over land and water.

Table of Contents

List of Figures and Tables

Executive Summary

Fire suppression during the last 50-100 years has changed the composition and structure of northeastern pine barrens, a globally rare and fire-dependent natural community that provides habitat for numerous rare and declining Lepidopteran, plant and early successional/shrubland bird species. These changes have resulted in a number of deleterious effects to the natural community, including an increase in canopy cover and organic soils and the proliferation of tree species less tolerant of fire (such as red maple, white pine, red oak, aspen, and American beech). In some areas these species have invaded pine barrens to the exclusion of pitch pine and other constituent species. Additionally, in the absence of fire, fuel loads have in many areas reached a level that threatens nearby human development and could result in a catastrophic wildfire with an ecologically damaging intensity. As northeastern pine barrens shift away from their historic character the continued increase in hazardous fuels will be unabated and the composition of rare Lepidoptera and birds will shift, leaving some species more imperiled. In these scenarios, biodiversity—both in terms of natural communities and species—will be lost.

In response to these negative ecological changes the New Hampshire and Maine chapters of The Nature Conservancy (TNC) have set out to restore and/or maintain the northern pitch pine-scrub oak barrens (pine barrens) historically found at the Ossipee Pine Barrens (NH) and Waterboro Barrens (ME), as well as several other smaller sites. While managing the *entire* pine barrens system will include supporting viable wildlife populations and increasing herbaceous plant diversity, TNC is currently focusing on increasing the variability of the pine barrens seral stages to create a *woody plant composition* and *community structure* that is reminiscent of a pine barrens system historically influenced by fire. It is thought that promoting this structure and composition will support the constituent species dependant on it. After a pine barrens community structure and composition is present TNC will place emphasis on wildlife and herbaceous plant diversity objectives.

To manage the pine barrens and reduce fuel loads TNC has implemented a variety of 'treatments': timber harvest targeting fire-intolerant tree species, mowing of dense or senescent thickets of scrub oak, and prescribed burning. The ecological effects of these treatments are sometimes obvious but more often they are difficult to interpret. Because of this, TNC needs a systematic way to measure their progress towards meeting their ecological objectives (pg. 13). The purpose of this document is to assist TNC in carrying out the most cost and labor efficient approach to field-based data collection and data analysis.

I developed a set of monitoring protocols that yield quantitative information about five ecological attributes on treated lands, including:

1) The percent cover of exposed mineral soil,
2) The average height of scrub oak,
3) The percent cover of scrub oak,
4) The relative abundance of pitch pine saplings vs. fire-intolerant saplings, and
5) The condition of fire-intolerant tree species.

This quantitative information can be used to directly assess the progress land managers have made in their efforts to restore and/or manage the pine barrens as laid out in the TNC's ecological objectives (pg. 13). These ecological objectives relate directly to the structure and composition of the pine barrens and

are a subset of the broader ecological objectives designed for the Ossipee Pine Barrens and the Waterboro Barrens, which include safeguarding populations of rare or declining wildlife (moth and bird species) and rare herbaceous plants.

Maintaining the pine barrens will rely on reoccurring fire, of which the frequency is unknown. The protocols described herein may produce ecological insight that helps The Nature Conservancy better understand the appropriate frequency of prescribed fire in their pine barrens.

In sections 7 of this document I outline a variety of analytical pathways and a sampling design alternative that, while using a common set of data collection methods, can be used to generate additional information about pine barrens ecology, including:

1) Tracking how ecological attributes (e.g., percent cover of mineral soil) change over time,
2) Measuring an ecological attribute in different structural types (e.g., relative abundance of pitch pine saplings in areas of high and low canopy cover)
3) Analyzing the relationship of ecological attributes on one another (e.g., percent cover of scrub oak vs. pitch pine relative abundance), and
4) Reporting the variation of an ecological attribute within a given area as 'percent of sampling locations that meet the ecological objective'.

The data collection protocols are accompanied by sections about sampling design, sample size, data storage and data analysis. The document is intended to inform the reader about the current ecosystem management at Ossipee and Waterboro and guide TNC through their monitoring program. These protocols were specifically designed with Ossipee and Waterboro in mind, but they may be applicable to other northeastern pine barrens.

I. Introduction

Pine barrens form on nutrient poor sandy soils of glacial outwash or ice-contact sediments, and in the eastern United States are found both near the coast (NJ, Long Island, Cape Cod, Martha's Vineyard, NH, ME), and at a few inland sites (NY, VT). The term *pine barrens* has long been used to describe dry, pine dominated forests and woodlands, but is now often replaced with more ecologically meaningful names like 'pine-oak-heath sandplain community' (Thompson, 2000) and 'pitch pine-scrub oak barrens' (Ediger, 2002). The Ossipee Pine Barrens (NH) and the Waterboro Barrens (ME) (Fig. 1) are described as 'northern pitch pine-scrub oak barrens' which emphasizes the presence of two common plants—pitch pine (*Pinus rigida*) and scrub oak (*Quercus ilicifolia*) (NatureServe, 2010). Those pine barrens found outside of New Hampshire and Maine are referred to as a 'southern variant' and differ from the 'northern variant' by including an additional species of oak (*Quercus prinoides*) and experiencing a higher frequency of fire. Because of their sparse distribution across the landscape and history of human use (Motzkin, 1996) pine barrens are globally rare (G2G3), and as such, are now the focus of conservation. Currently, TNC and its partners are engaged in a strategic effort to restore and/or maintain a functioning and sustainable pitch pine –scrub oak barrens at the Ossipee Pine Barrens and the Waterboro Barrens, as well as several smaller sites across the Northeast.

TNC is currently at an important stage in their ecosystem management—it is time measure their progress toward meeting their ecological goals. This document serves TNC as a tool to accomplish this importance task. During pine barrens restoration and maintenance, it is sometimes difficult to assess progress. For instance, in large management units it is difficult to determine how much mineral soil was exposed as a result of a fire. Currently at Ossipee and Waterboro TNC primarily measure the effects of treatments by site visits, wherein conditions are assessed visually in a non-systematic way. While these qualitative techniques are essential for TNC to understand the 'big picture', the systematic approach to field-based data collection described in this document will generate more consistently meaningful quantitative information. This quantitative information will be compared to the thresholds in the ecological objectives (pg. 13) in order to measure TNC's management progress. In addition to the monitoring protocols themselves (data collection methods, data analysis and interpretation) are sections that document TNC's current state of ecosystem management at Ossipee and Waterboro. This entire document will act as a record of TNC's management activity and a resource to other TNC chapters and partnering organizations.

Although this document consistently refers to TNC's work at 'Ossipee and Waterboro' TNC's management practices at Ossipee and Waterboro differ slightly. At Ossipee, TNC is involved in *ecological restoration* that includes reducing the presence of invading fire-intolerant trees— red maple (*Acer rubrum*), white pine (*Pinus strobus*), red oak (*Quercus rubra*), American beech (*Fagus grandifolia*), and aspen (*Populus* spp.). Without the burden of fire-intolerant tree invasion at Waterboro, TNC's management practices are directed toward *maintaining* the pine barrens, not their *ecological restoration*.

Differences in natural community classification exist between Ossipee and Waterboro as well. The New Hampshire Division of Forest and Lands refers to the Ossipee Pine Barrens as the 'Ossipee variant' of the 'pitch pine- scrub oak woodland' natural community which consists of thicket, woodland and forest structural types (Lands). The Waterboro Barrens consist of three distinct natural communities—'pitch pine-scrub oak woodland', 'pitch pine-scrub oak heath' and the pitch pine-scrub oak barrens

(Conservation, 2010)—each which resemble parts of the Ossipee Pine Barrens. Beyond these differences in management and terminology, the Ossipee Pine Barrens and Waterboro Barrens are ecologically similar and for convenience in this document both will be referred to as 'pine barrens'.

Ecology of pitch pine-scrub oak woodlands

Pine barrens differ from the forests that surround them. The differences in ecology, vegetation structure, disturbance regime, and wildlife are due to the underlying substrate—well drained, sandy soil which allows groundwater to easily percolate. This dryness results in a relatively higher rate of fire disturbance which influences vegetation composition.

Pine barrens flora is characterized by low-diversity and consists of plants that exhibit some degree of fire adaptation. For example, pitch pine's thick bark is an extremely effective insulator, helping the species to survive fire events. Also, scrub oak roots survive and quickly sprout new stems after a fire. Natural exposure to fire allows characteristic plants, such as pitch pine, scrub oak, blueberries (*Vaccinium* spp.), black huckleberry (*Gaylussacia baccata*), and bracken fern (*Pteridium aquilinum*) to thrive to the exclusion of less fire-tolerant species**.**

Pine barrens abound in structural diversity; dense thickets, patches of sand, closed canopy forest and open canopy woodlands come together to form the landscape of this natural community. These structures create habitat for over a dozen (17 at Osspiee, 14 at Waterboro) state rare Lepidopteran species and 5 rare early successional/shrubland birds: the eastern towhee (*Pipilo erythrophthalmus*), prairie warbler (*Dendroica discolor*), brown thrasher (*Toxostoma rufum*), common nighthawk (*Chordeiles minor*) and whip-poor-will (*Caprimulgus vociferous*). Wagner (2003) said that the uncommon shrubland habitat formed by scrub oak (abundant at Ossipee and Waterboro) is among the most important structural type for the Lepidoptera in the Northeast.

Because of the stark difference in substrate, plant composition and wildlife, it is appropriate to think of pine barrens as dry 'islands' in a sea of mesic forests. In the absence of fire pine barrens fail to ecologically resist colonization by less fire-tolerant plants from the surrounding forests. As invasion continues, the pine barrens as a functional natural community might be removed from the landscape. Therefore, conserving pine barrens is an act in defense of biodiversity.

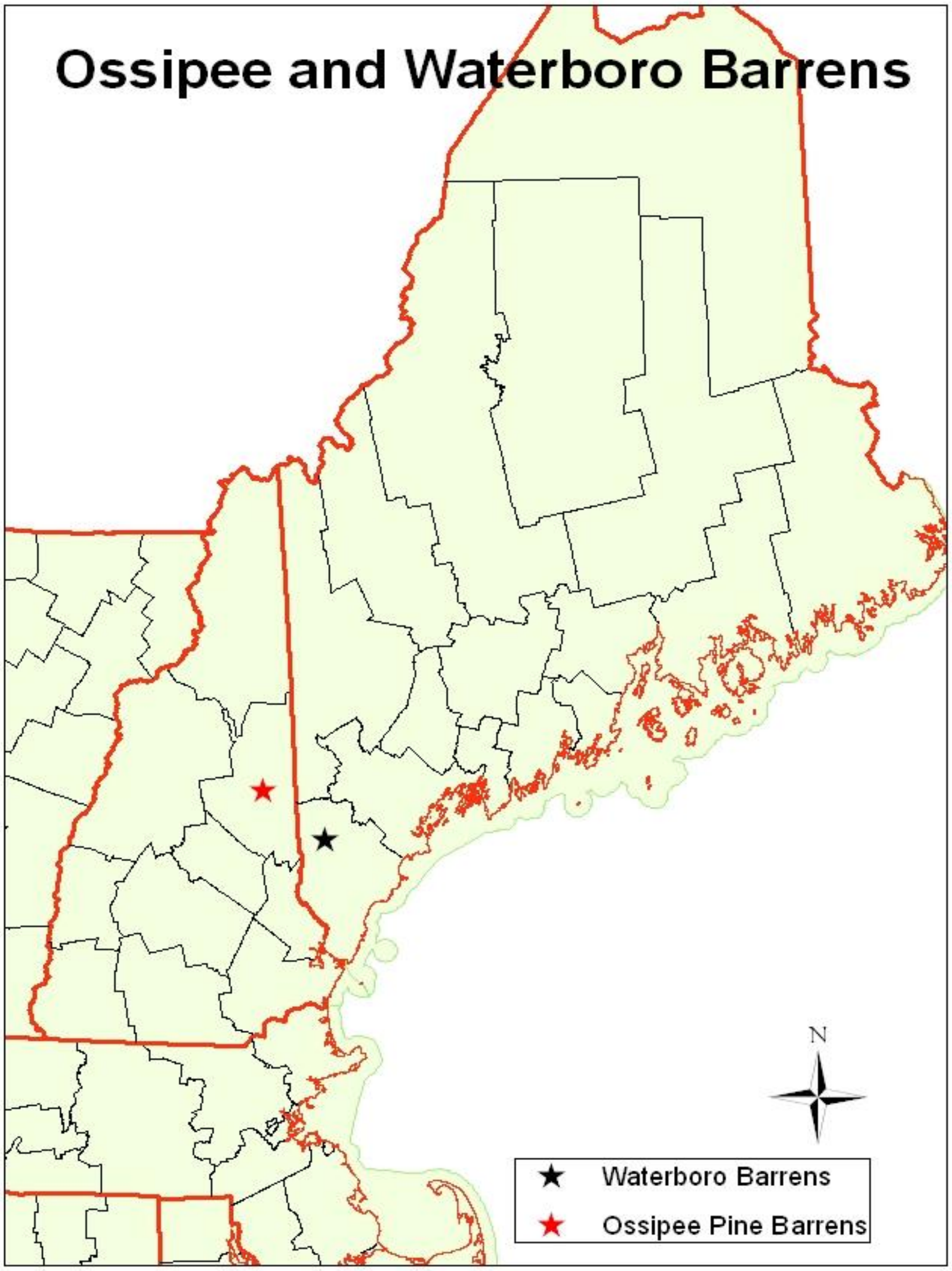

Figure 1. The locations of Ossipee (NH) and Waterboro (ME) Pine Barrens.

II. Current management at Ossipee and Waterboro

A. Introduction

The pine barrens at Ossipee and Waterboro are primarily being managed for biodiversity—restoration and maintenance of the globally rare northern pitch pine-scrub oak barrens—by active treatments. Because of the potential for catastrophic wildfires, the fuel loads of Ossipee and Waterboro are also managed and routinely reduced. Additionally, the public is permitted to use the trail system for 'low impact' activities (hiking, birding, and snowmobiling), while camping and campfires are prohibited.

TNC has used scientific research and reports to reconstruct past ecological features such as fire history and woody plant composition to create reference conditions for Ossipee and Waterboro (Dacey, 2003; Finton, 1998; Patterson, 1994). The pine barrens experienced a natural range of variability and it is likely that landscape elements that are undesirable today, such as mesic forests and tall scrub oak thickets, were periodically incorporated into the fabric of their landscape. To promote the community assemblage that is reminiscent of a historical pine barrens, TNC is restoring the natural processes (namely, fire) that shaped its overall ecology.

Reoccurring fire creates physical conditions which influence the regeneration of pitch pine. The roots of germinating pitch pine seeds cannot penetrate deep organic soils, making them reliant on areas of reduced duff and exposed mineral soil; moreover pitch pine seedlings do not fare well in shade. Periodic fire burns off deep organic soils and produces a high-light environment optimal for pitch pine seedlings (Burns and Honkala 1990). In absence of fire, organic soils build up and pitch pines lose their ideal germination niche.

Complete restoration and maintenance of the pine barrens means securing habitat for viable populations of rare plants and animals. While this is a long term goal for TNC, current resources are being focused on restoring and/or maintaining the pine barrens composition and structure, which will support the habitat needs of target species. In the future, after structural restoration is complete, more energy will be spent to address the needs of specific wildlife and plant populations.

B. Management units

To facilitate their management treatments TNC has compartmentalized the landscapes of Ossipee and Waterboro into 'management units', ranging in size from 6-40+ acres (Fig. 2). Management units have borders determined by natural barriers (streams, lakes, distinct vegetation changes) or human engineered barriers (roads, fire breaks, power lines) and serve as discrete areas for ecological management planning and implementation. Both Ossipee and Waterboro have a unique management plan that reflects their ecological needs.

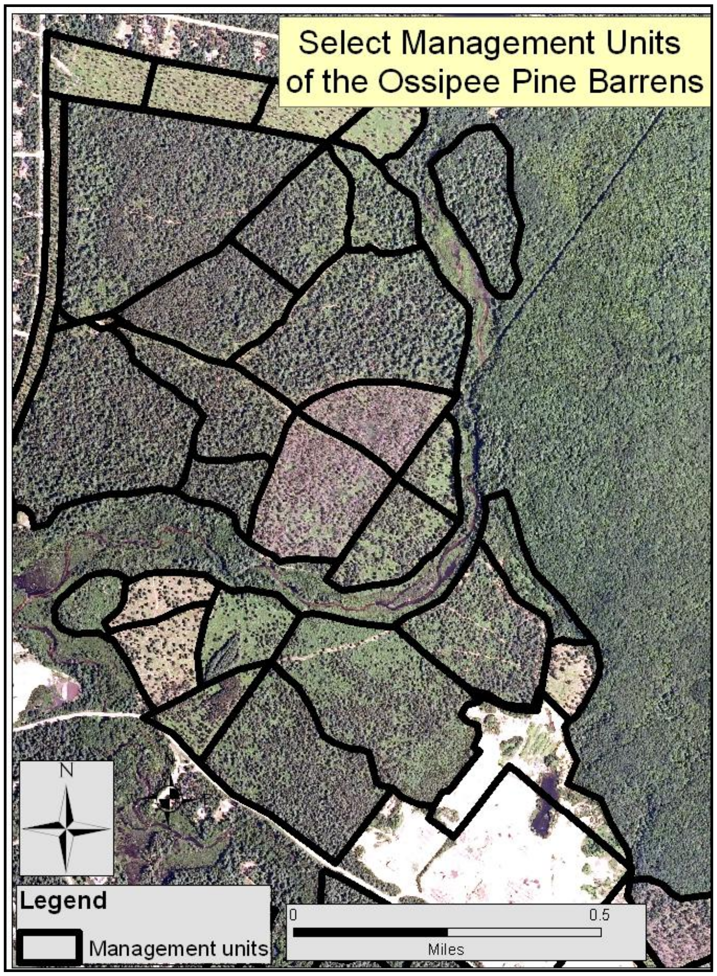

Figure 2. Map of select management units in the Ossipee Pine Barrens.

C. The ecological objectives for Ossipee and Waterboro

The Nature Conservancy has developed ecological goals and objectives to guide their management (Table 1.). The objectives are based on ecological attributes essential to the persistence of the pine barrens (exposed mineral soil, pitch pine regeneration) and fuel reduction (scrub oak percent cover and height). The current ecological objectives were adapted from a set originally documented in the Ecological Management Plan for the Ossipee Pine Barrens (Batcher, 2006) that consisted of an additional 11 objectives addressing target wildlife species and their habitat resources, the seral stages of the pine barrens, and areas of very dense pitch pine. The following table outlines the ecological objectives pertinent to the current structural restoration of the pine barrens and summarizes the attributes and data collection methods needed to monitor each.

Table 1. The Nature Conservancy's ecological objectives for the Ossipee and Waterboro pine barrens.

Ecological attribute	Ecological objective	Issue
Exposed mineral soil percent cover	Management units treated between 2010 and 2020 result in at least 20% mineral soil exposure.	Litter and duff layers have accumulated substantially in the absence of fire over the past 50-100 years resulting in very little exposed mineral soil. Areas of exposed mineral soil are important for pitch pine recruitment and regeneration, and also provide a habitat for other early successional plant species whose historical presence were likely more abundant.
Scrub oak height and cover	Management units treated between 2010 and 2020 result in an average scrub oak height of <6ft .	Scrub oak has become dominant in areas where the canopy is open (< 60% cover) and there has been limited disturbance (fire, mechanical, frost) in the past 20 years. While dense and tall stands of scrub oak can provide habitat for early successional and shrub nesting birds, the dominance of scrub oak also results in: 1) a loss of plant diversity, 2) reduced habitat for Lepidopteran species requiring host plants outcompeted by scrub oak, and 3) areas of hazardous fuel that present a safety concern and management challenge.
Scrub oak percent cover	Management units treated between 2010 and 2020 result in an average scrub oak cover of <50%.	Same as above.
Pitch pine saplings, relative abundance	Pitch pine represent at least 80% of saplings in management units treated with fire between 2010 and 2020 (saplings= stems between 0.5 and 6 ft tall or stems > 6 ft tall *and* ≤ 1 inch dbh).	Due to the lack of disturbance over the past 50-100 years, pitch pine recruitment is limited across the site. Pitch pine is seen as a key component of the ecosystem, therefore its presence is needed. Fire-intolerant tree species have gained a strong foothold in some areas of the pine barrens and is outcompeting pine barrens species.
Additional Ecological Attributes of Interest to The Nature Conservancy		
Fire-intolerant trees, fire-induced mortality rate	No ecological objective has yet been stated for this ecological attribute	Mature fire- intolerant trees are currently abundant in some parts of the Ossipee Pine Barrens. Mechanical thinning is used to remove select trees while prescribed fire is used to kill those remaining. It is desirable to understand how effective fire is in killing fire-intolerant trees.
Pitch pine sapling density	No ecological objective has yet been stated for this ecological attribute	Current pitch pine sapling densities are unknown in the pine barrens. It is desirable to measure sapling densities and understand how much pitch pine regeneration is needed to sustain different structural types.

D. Restoration

The Nature Conservancy is actively engaged in restoring their pitch pine-scrub oak barrens at Ossipee. Restoration entails removing fire-intolerant tree species such as red maple, white pine, red oak, American beech and aspen and creating opportunities (a high-light environment and exposed mineral soil) for characteristic species to thrive. They are currently progressing toward their ecological objectives by employing four 'treatments': mowing dense or senescent thickets of scrub oak, timber harvest targeting fire-intolerant tree species, thinning of the canopy within the Wildland Urban Interface, and prescribed burning.

The intentional fire suppression of the twentieth century has had a negative effect on the composition of the pine barrens at Ossipee. In her work at Ossipee, Dacey (2003) showed that without fire the pine barrens was succumbing to invasion by red maple and white pine. Dacey's succession model suggested that over time, the pine barrens at Ossipee would be dominated by white pine and hardwoods. Similarly, Patterson (1994) predicted similar canopy changes at Waterboro but to date there is evidence of only minimal invasion by fire-intolerant species. There is a consensus among scientists and land managers that in order to reverse these ecological trends and conserve pine barrens, active restoration is needed (Dickman and Rollinger 1998; Motzkin, Patterson et al. 1999).

E. Maintenance

TNC is currently in a maintenance phase of their ecosystem management at Waterboro. With maintenance regime in place, mowing and thinning is minimized, leaving prescribed fire as the primary management technique. As land managers at Ossipee continue to work from a restoration phase to a maintenance phase they will have to answer some important questions including:

- What is the structure and composition of a fully restored pine barrens?
- Once restored, how often should a pine barrens burn?
- Do the ecological objectives for pine barrens maintenance differ from those of pine barrens restoration?
- If so, what will be central to those maintenance objectives/ how do we learn what is most important for the persistence of the pine barrens?

These protocols are not intended to directly answer these questions, but are likely to generate ecological insight which can guide TNC from restoration a to a maintenance phase. For example, knowing the density of pitch pine saplings in a management unit will help TNC understand if more fires are needed to prepare a seedbed for pitch pine germination.

F. Treatment packages

To meet their ecological objectives TNC is implementing a variety of treatments at Ossipee and Waterboro. Some management units receive only one treatment. More commonly, management units receive multiple treatments or, a 'treatment package', which reflect the most safe, affordable, logistical or ecologically necessary course of management action. For instance, at Ossipee fire-intolerant trees have been harvested from management units before a prescribed fire was set. Likewise, in dense scrub oak thickets the fuel load, which is potentially hazardous, is reduced by mowing before fire is set. In general, as the ecological communities at Ossipee and Waterboro move further from the historical fire-influenced pine barrens, more fire-intolerant tree harvest will be needed to restore and/ or maintain them. The following describes each type of treatment.

- **Mowing** usually takes place in areas of dense scrub oak. Otherwise nearly impenetrable, these thickets are mowed in order to reduce fuel height, and thus, potential for a canopy fire. Mowing also creates fire breaks which border or bisect management units. These areas of low fuel allow fire crews to move among the management unit and control the fire during a burn.

- **Thinning**, or mechanically harvesting mature fire-intolerant trees, is done at Ossipee. White pine, red maple, red oak and aspen are among the most commonly removed trees. Thinning quickly alters the composition and structure of a management unit and is a way to generate income and offset management costs, especially when there is significant quantity of white pine in the management unit.

- **Prescribed fire** is used to kill fire-intolerant trees, reduce fuel loads, decrease organic soils and litter, and expose mineral soil. Fire-treated management units are bounded by fire breaks (bodies of water, roads, engineered paths, quarries, etc.), and fires are controlled by a trained crew. Fires, more than other treatment methods, restore the natural character of the pine barrens and create opportunities for its persistence.

- **Canopy thinning within the Wildlife Urban Interface** is done at Ossipee and Waterboro to create fire breaks near private residences. This interface is managed for low fuel and low canopy to inhibit unwanted movement of fire toward public and private structures.

The cost of these treatment methods varies and is dependent upon numerous factors. Figure 3 below shows the effects of a treatment package on a management unit. Here, the area on the right side of the photograph was thinned and mowed while the area on the left was untouched. Eventually a prescribed fire will be set in this management unit and the area of low fuel on the right will act as a fire break.

Figure 3. A pictorial example of a treatment package on a management unit at the Ossipee Pine Barrens.

G. Past and current monitoring at Ossipee and Waterboro

These are not the first monitoring protocols to be used at Ossipee and Waterboro. As part of their ongoing Lepidoptera monitoring at Ossipee, TNC New Hampshire verified the presence of rare species. Also, point counts were used at Ossipee to confirm song bird presence and approximate relative abundance. Since 2004, New Hampshire Audubon has collected data on whippoorwills and nighthawks at Ossipee. TNC uses Maine Ecological Reserve monitoring protocol at Waterboro

Barrens to document forest structure, composition and health. Through long term monitoring of permanent plots this program, which is also used by the State of Maine to monitor their ecological reserves, will allow for the detection of long-term changes in a broad spectrum of ecological attributes—from canopy cover to the herbaceous layer. In 2006, a round of data was collected at Ossipee using an earlier set of monitoring protocols (Batcher, 2006). These protocols returned information about many ecological attributes, including scrub oak height and cover, leaf litter, duff, saplings, seedlings, and trees. Due to the resources required by these extensive protocols, a more streamlined set of protocols was desired.

III. The role of ecological monitoring in current management

The role of ecological monitoring in the adaptive management process. Monitoring is a step in the adaptive management process (Fig. 4). These protocols will generate information characterizing ecological attributes within a given management unit. For example, data analysis might indicate that 5% of West Branch 8 at Ossipee is covered in exposed mineral soil—this would be measured as a management failure when compared to the ecological objective ('the fire treated management units have at-least 20% mineral soil exposure'). If the objective has not been met TNC is likely to alter their restoration treatments or the conditions under which the treatments are applied (such as weather conditions during a prescribed fire). On the other hand, if data analysis indicates that an ecological objective has been met, TNC is likely to continue using those effective treatments.

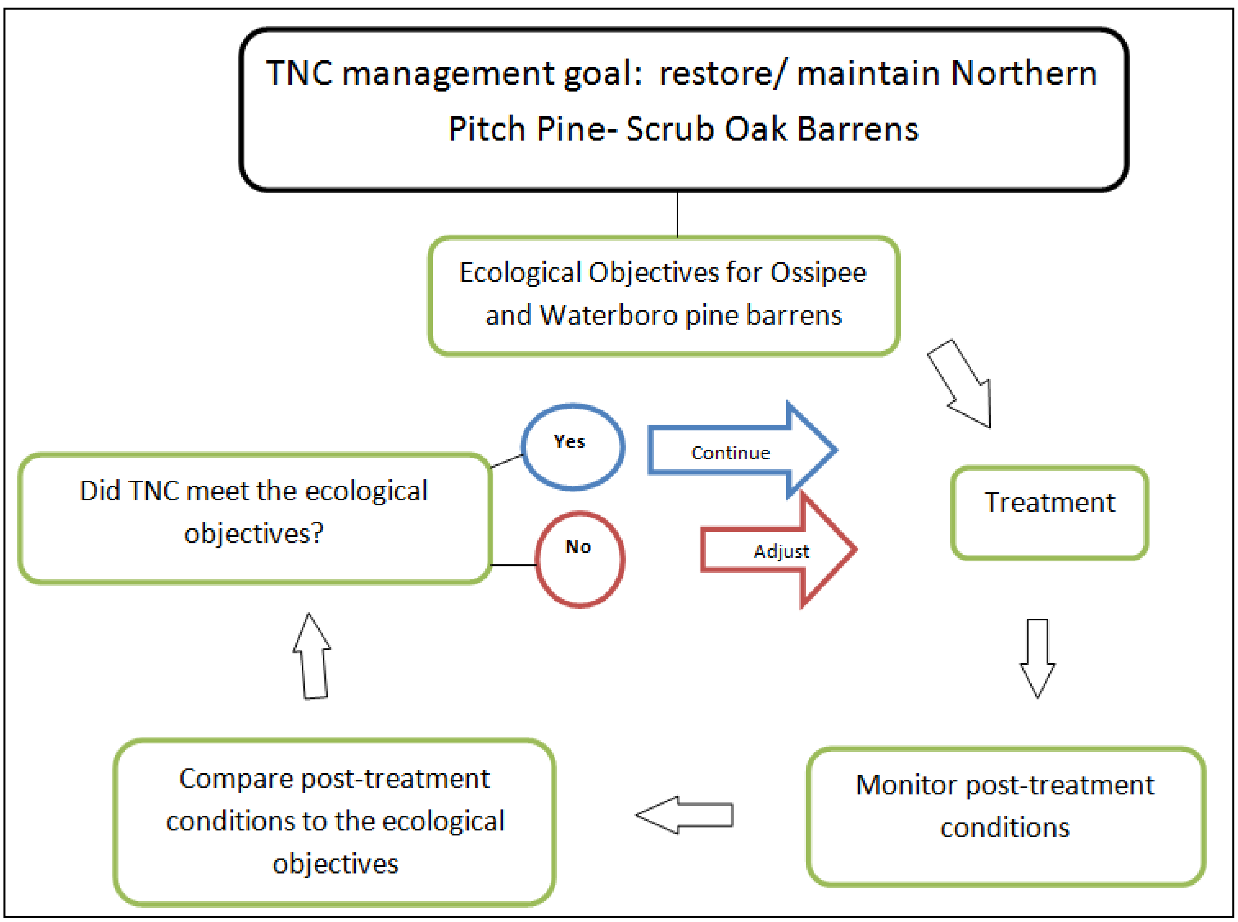

Figure 4. A diagram showing the role of monitoring in TNC's adaptive management process at Ossipee and Waterboro.

Monitoring to refine ecological objectives. The information generated by these protocols can be used to refine TNC's ecological objectives. While the objectives are well founded in science, the specific numbers which mark success or failure (thresholds) are TNC's best guess at what is ecologically important. As monitoring data is collected and analyzed, those thresholds may change. For instance, it might come to be known that 20% exposed mineral soil does not yield the desired recruitment level of pitch pine. It might then be appropriate to change the amount of exposed mineral soil specified in the objective. Similarly, it might be found that TNC did not meet its ecological objective but still produced desired outcomes or that certain ecological objectives cannot be safely met through prescribed fires currently permissible.

Monitoring to gain ecological insight. Restoring/maintaining the pine barrens will require understanding how they react to treatments and change over time. Within these protocols are options for monitoring ecological changes over time (see *Section 4)* which will inform 're-entry'—re-applying fire to a management unit, or some other treatment package. Maintenance of the pine barrens is dependent on an ecologically appropriate fire-return interval. In deciding this interval TNC must consider: pitch pine recruitment rates, threshold age/size which new pitch pine recruits must pass in order to survive a fire, how wildlife populations respond/ rebound after fire, and fuel accumulation rates. While these protocols aren't intended to directly monitor wildlife or fuels, they will generate information useful when determining fire-return interval. For instance, information about average scrub oak height and percent cover will help judge potentially hazardous fuel loads. By knowing the pitch pine sapling density TNC can decide whether or not enough regeneration has taken place and whether re-entry is appropriate. Also, as the data set grows the relationship between different attributes can be explored (see Section 7). For instance, correlating sapling abundance to percent cover of exposed mineral soil might reveal how substrate specifically affects pitch pine regeneration.

IV. Preparing for data collection

Figure 5 (below) illustrates the five steps to be taken before data collection. Following the diagram are sections describing each step. At the completion of these five steps TNC will know *where* to carry out data collection— at 'sampling locations'. Sampling locations should be randomly determined in each management unit to allow TNC to make inferences about the sampled population through statistical analysis. Section 5, *Protocols for data collection,* will describe *how* to carry out data collection.

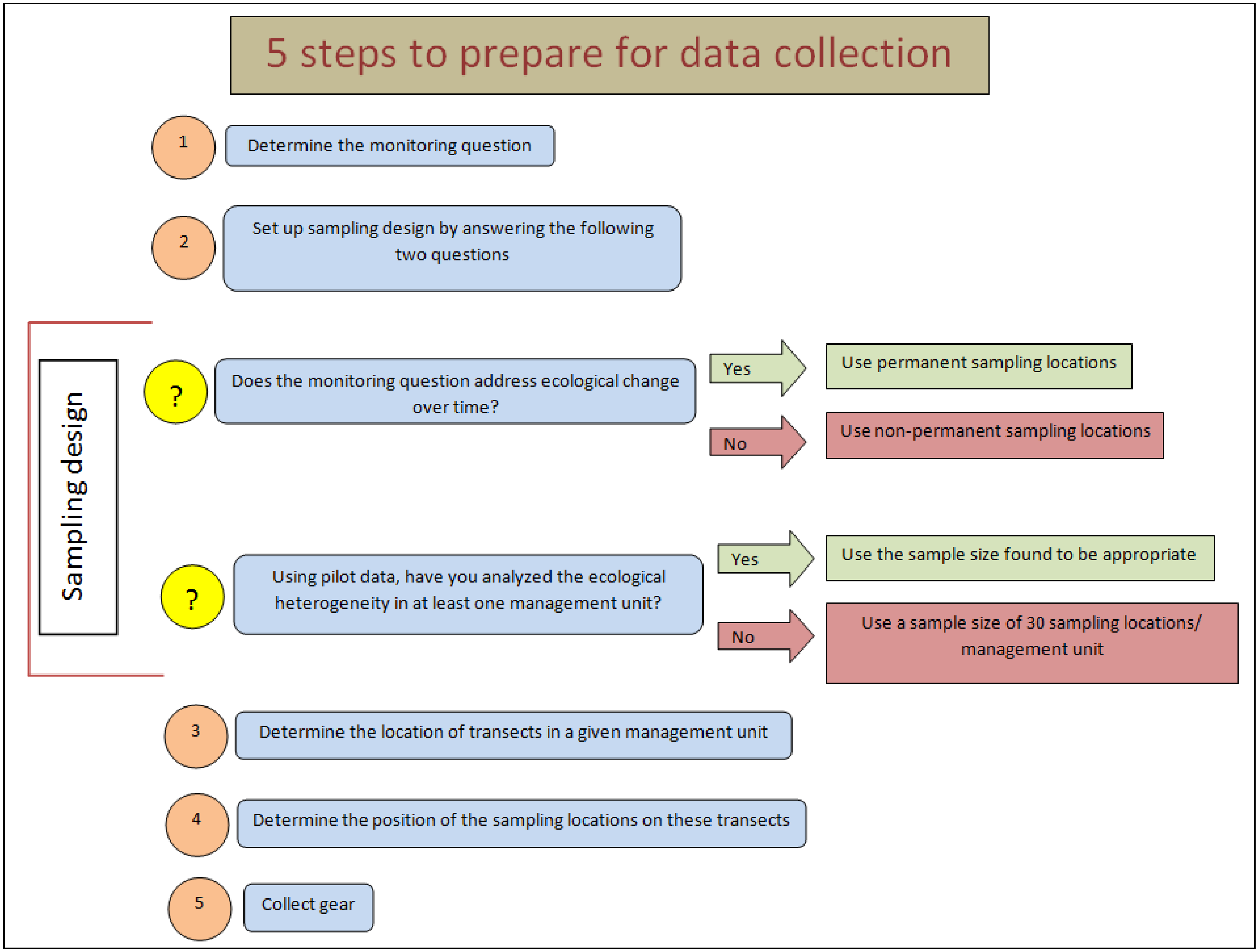

Figure 5. Diagram showing the 5 steps to prepare for data collection

Step #1-Determine the monitoring question

TNC should start the monitoring process by pinpointing the exact question(s) they intend to answer with monitoring. The specific monitoring question will dictate the sampling design and data analysis. For example the questions, 'what is the percent cover of scrub oak in *East Shore Drive 3* directly after treatment?', 'what is the percent cover of scrub oak in *East Shore Drive 3* under low tree canopy cover?', and 'how does the percent cover of scrub oak in *East Shore Drive 3* differ under low and high tree canopy covers?' are three unique questions that can be answered by using three slightly different sampling designs. One 'default' sampling design can be used for nearly all of TNC's monitoring questions but a variation on this sampling design (referred to as a 'stratified sampling design' in this document) will allow for additional analysis. The following are questions that can be answered by following these protocols. All 'values' are described as mean with standard deviation unless otherwise noted. An expanded explanation of each question appears in *Section 7, Data analysis*.

- What is the value of a particular ecological attribute (e.g., percent cover of exposed mineral soil, scrub oak height) in a given management unit?
- Has the value of a particular ecological attribute in a given management unit changed over a known amount of time? If so, how has the value changed?
- Does the value of a particular ecological attribute vary in different strata? If so, how?
- Is the value of a particular ecological attribute influenced by the value of a different ecological attribute?
- Is the value of a particular ecological attribute predictable based on a value of a different ecological attribute?
- What percent of sampling locations meet a particular ecological objective?
- What is the density of pitch pine or fire-intolerant saplings in a given management unit after treatment?
- Do the mortality rates of fire-intolerant trees vary with different prescribed fires?
- Does fire affect fire-intolerant tree species differently? If so, how?

Step #2 -Set up a sampling design by answering the following two questions.

Question #1. Does the monitoring question address ecological change over time?

Ecological change over time can be measure using permanent and non-permanent sampling locations. **If TNC wishes to measure ecological change over time, it is recommended that permanent sampling locations be used.** Permanent sampling locations must be marked in the field for future data collection while non-permanent sampling locations are usually not marked and only visited once. Non-permanent sampling locations can be useful if TNC wishes to quantify ecological change over time but did not establish permanent plots at the initial time of data collection. The same information (e.g., mean, with standard deviation) will be generated by both permanent and non-permanent sampling locations. Likewise, sampling locations for both permanent and non-permanent sampling design will be determined randomly.

Question #2. Using pilot data, have you analyzed ecological heterogeneity in at least one management unit?

It is recommended that TNC initially use a sample size of 30 sampling locations in each management unit. An appropriate sample size cannot be known until data is collected and analyzed. Using a sample size of thirty is commonly recommended when no preexisting data is available for analysis because it is usually large enough to capture the variability within the population.

To find the smallest sample size that still meaningfully represents the conditions inside a management unit TNC can analyze a dataset that has already been collected. The sample size will depend on how much variability there is in the ecological attribute you are measuring. By isolating subsets of a dataset and calculating their mean you can see how the variation within the subsets changes as a function of sample size. The following steps outline the sample size analysis.

- Start by collecting data with a sample size of 30 sampling locations.
- Convert raw data to into meaningful information (a value for each sampling location and a management unit mean). The values for each sampling location equal the management unit's *dataset*.
- Randomly generate subsets of the dataset with different sample sizes (e.g., sample sizes of 15, 20, 25, 30, 33) and determine the mean of each. **Generate ten subsets for each sample size.**
- Plot mean for each subset on a scatter plot, where 'Sample Size' is on the X-axis and 'Mean' is on the Y-axis (Fig. 6).
- Each group of subsets will contain sum variability. Derive the standard deviation for each group of subsets and plot the standard deviation on a scatter plot, where 'Sample size' is on the X-axis and 'Standard deviation' is on the Y-Axis (Fig. 7).

Interpretation of analysis: The variability within each set of means is what you are trying to understand by making a scatter plot. Important to this analysis are the subset's standard deviation and range of means. From Figure 6 below, with a sample size of 20 it would be possible to derive a mean that fell between 5 and 45 (standard deviation= +/-16). This represents quite a large amount of variability that would not be suitable for comparing to the threshold in the ecological objective. With a sample size of 30, it would be possible to derive a mean that fell between 15 and 22 (standard deviation= +/-2.5). With a sample size of 33, it would be possible to derive a mean that fell between 19 and 22 (standard deviation= +/- 1.0).

The landscape heterogeneity will differ for each ecological attribute therefore a different sample size might be suitable for each. It is recommended that a sample size analysis be done for each ecological attribute. Additionally, a sample size that suits one management unit may not suit another. It is recommended then that a sample size analysis be done for multiple management units in order to capture the variability between them. By completing a few of these analyses, land managers will be able to make an educated decision about future sample size needs. Essentially, the sample size can be modified to meet the need of TNC; graphing the variation (Fig. 6, Fig. 7) will allow TNC to choose the level of precision they desire. It is important to note that variability is not necessarily dependent on area therefore larger management units do not need a larger sample size.

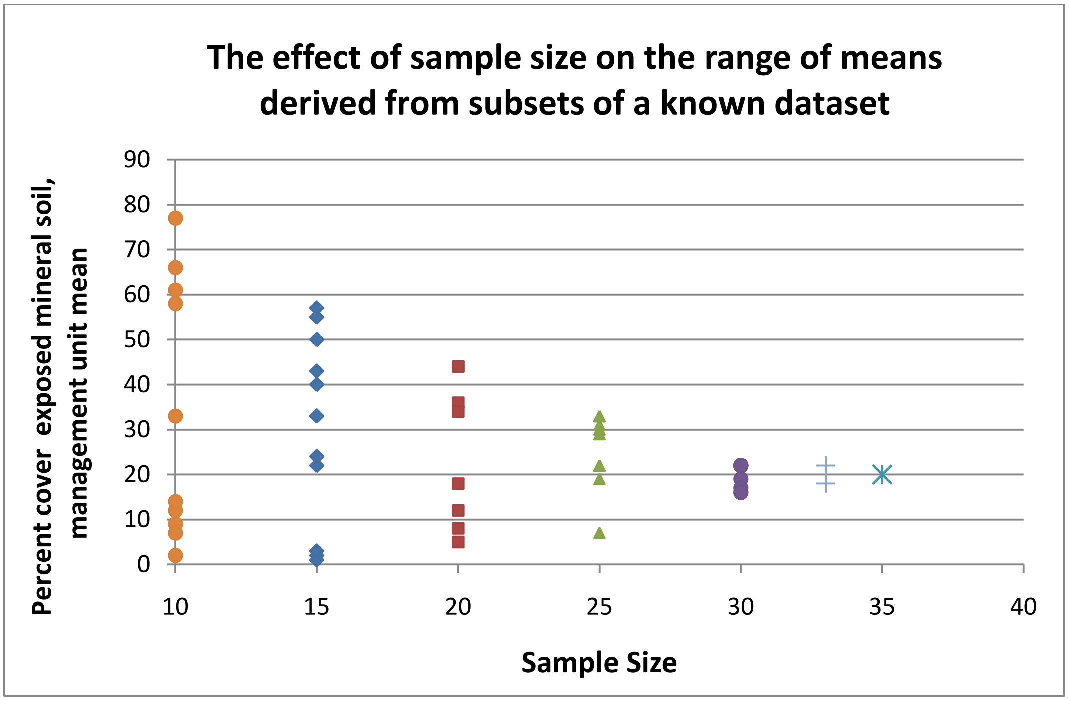

Figure 6. A sample graph showing the effects of sample size on the possible range of means that can be produced from subsets of a known dataset.

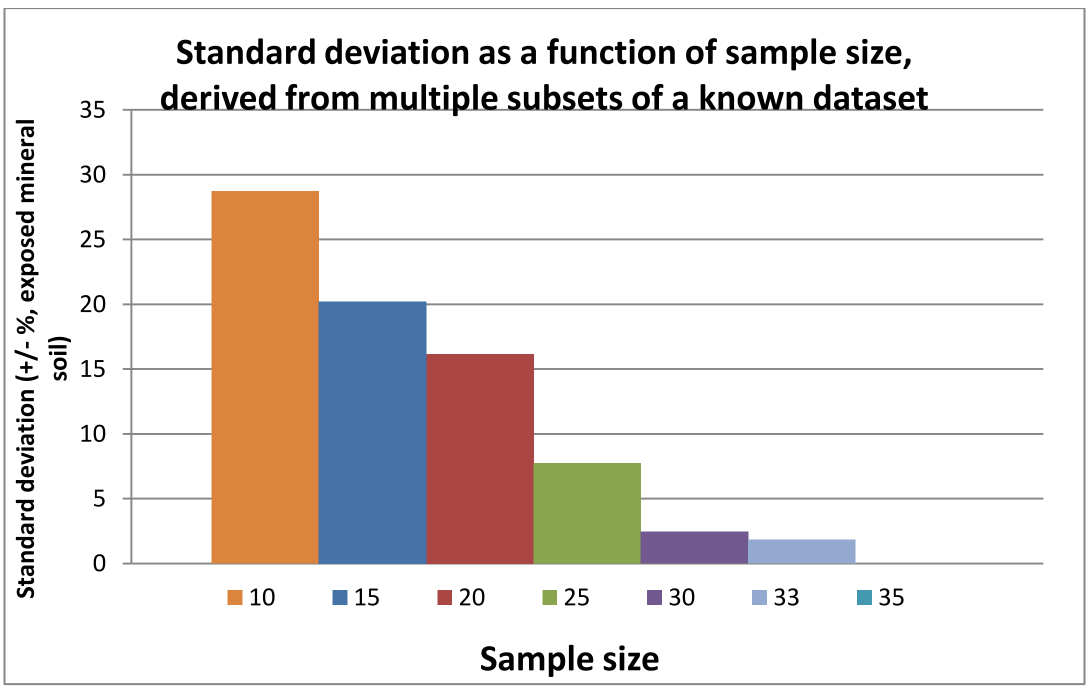

Figure 7. A sample graph showing the relationship between standard deviation and sample size produced from subsets of a known dataset .

Step #3-Determine the locations of transects in the management unit

Sampling locations will be positioned on one of two transects in each management unit. In some rare cases (stratified sampling) TNC will want to use more than two transects. To minimize bias when determining the location of transects, background imagery (e.g., natural community maps, NAIP imagery) should not be used. The ArcGIS tool 'Create Random Points' can be used to establish transects (Fig. 8): the 'Constraining Feature Class' is the area in/on which the random points are placed. The number of random points is entered in the 'Number of Points' field and the minimum distance between points is entered in the 'Minimum Allowed Distance' field.

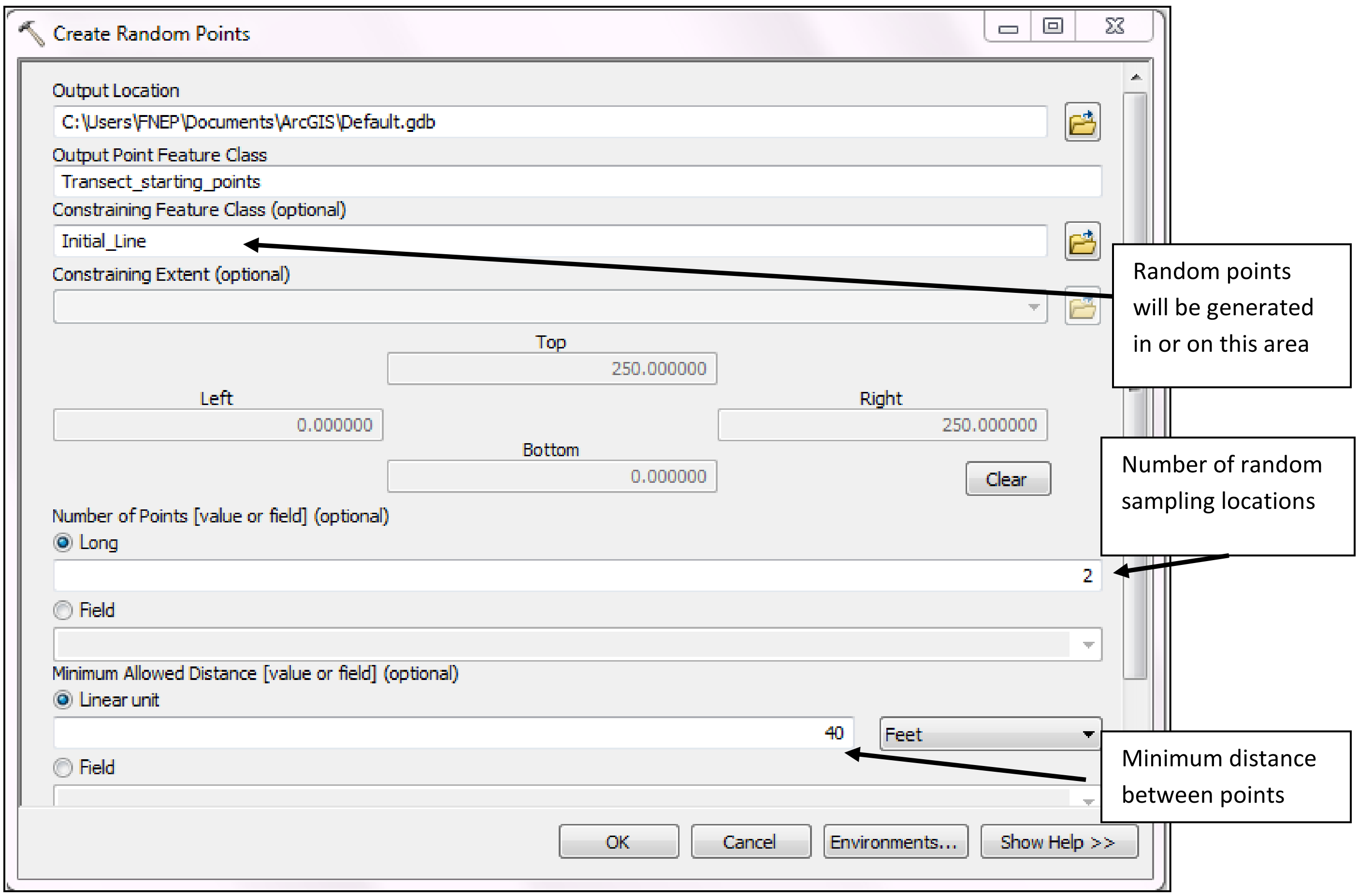

Figure 8. Screen capture of ArcGIS 'Create Random Points' user interface.

To determine the placement of two transects and sampling locations:

1) Draw a polyline along half of the management unit boundary (Fig. 9). It is acceptable to draw the polyline to avoid unnatural obstruction (e.g., fire break, log landing) adjacent to the management unit boundary. This line will be used as your 'constraining feature class' in the 'Create Random Points' tool with ArcGIS.
2) Create two random points along this line (40 feet minimum distance between points). These points will act as starting points for the transects.
3) From each of the two starting points, create a transect (polyline) that extends to the furthest part of the management unit. Figure 10 illustrates two possible ways of creating transects—one way is desirable while the other is not. The goal is to place the transects so that their combined lengths equal the greatest possible number. Transects should not cross each other.

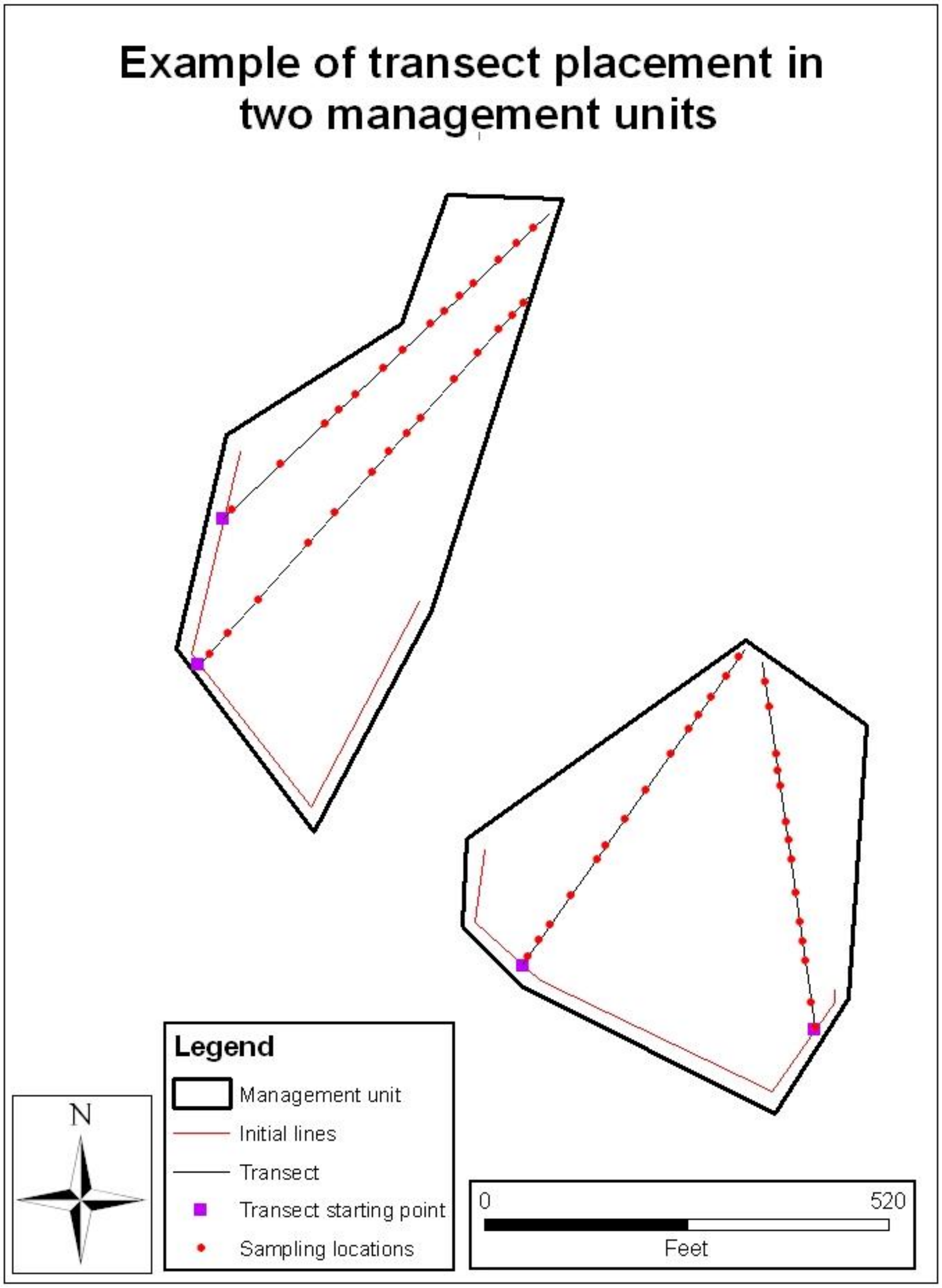

Figure 9. Example of generating 2 transects and 30 sampling locations in two management units

In this example the transcect on the left represents the longest possible transect in the management unit (2234 feet), but the sum of transect lengths is only 3234 feet.

In this example neither transect represents the longest possible transect, but the sum of transect lengths is the greatest (3460 feet).

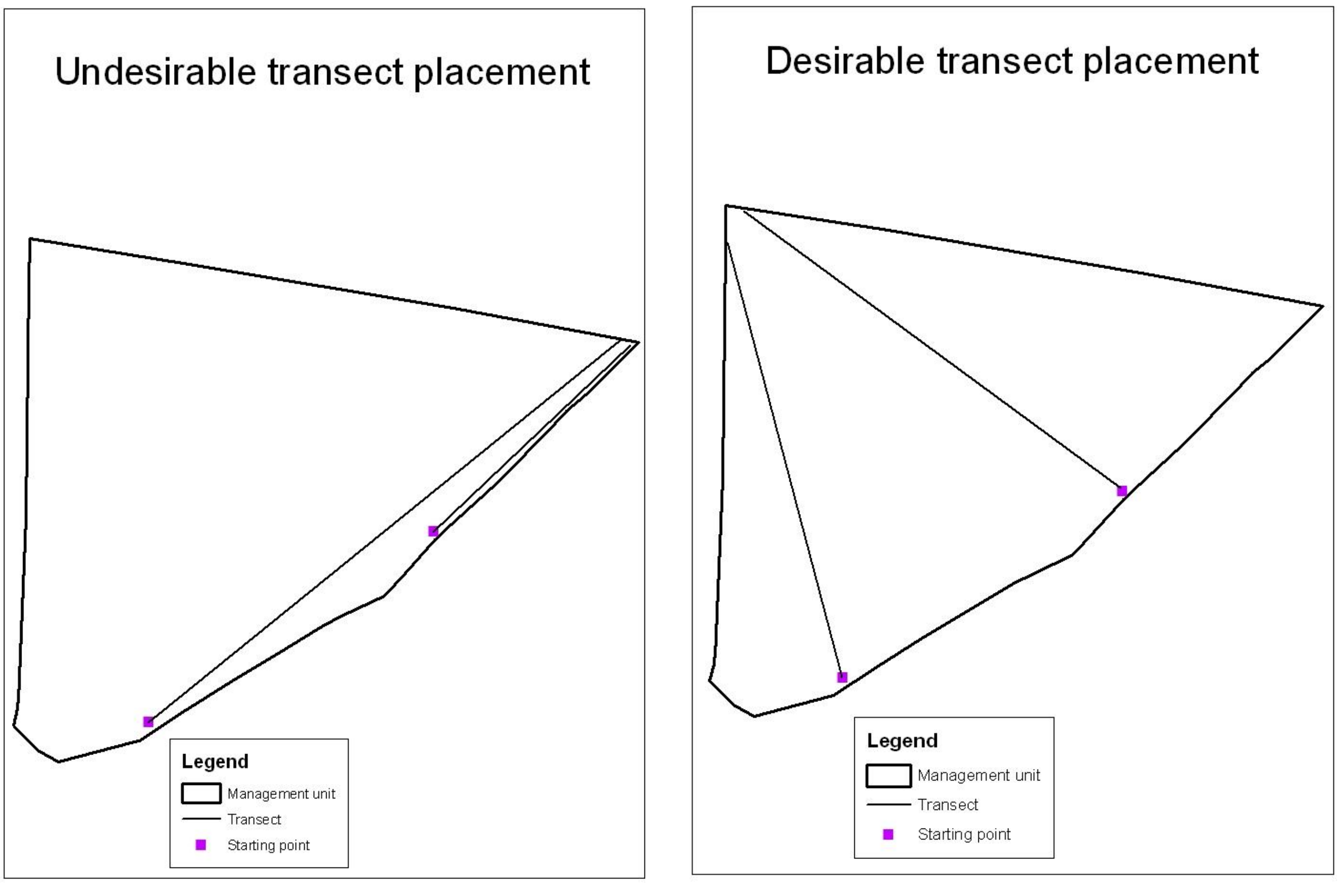

Figure 10. Example of desirable and undesirable transect placement in a management unit

Step #4-Determine the positions of the sampling locations on the transects

On each transect, generate 15 random points using the 'Create Random Points' tool in ArcGIS (Fig. 9). These points will act as the sampling locations. To ensure that sampling locations do not overlap it is recommended that a distance of 30 feet be used to separate the points.

Step #5-Collect Gear

The following is a list of gear needed for data collection (Table 2.). This list is not exhaustive, but highlights the identity and use of uncommon tools used in these protocols. Excluded are things such as first aid kit, water, food, writing materials and maps which should always be carried during data collection. Technicians should think about what is needed to carry out a safe and effective day of field work and plan accordingly.

Table 2. List of tools for data collection and their use.

Item	Quantity	Use
Rigid 6 foot ruler, clearly marked at 6 inch increments	1	For measuring percent cover of exposed mineral soil this ruler should be laid horizontally on the ground. For measuring percent cover of scrub oak this ruler should be extended horizontally (either on the ground or in the air) to mark each two foot interval where point intercept will take place. For measuring scrub oak height this ruler should be held vertically.
Pliable 6 foot measuring tape	1	For measuring percent cover of exposed mineral soil this ruler should be laid horizontally on the ground. For measuring percent cover of scrub oak this ruler should be extended horizontally (either on the ground or in the air) to mark each two foot interval where point intercept will take place. For measuring scrub oak height this ruler should be hung vertically.
Rigid 6 foot rod ('bike flag', Fig. 11)	1	For measuring percent cover of scrub oak this rod should be vertically driven into the ground to detect scrub oak presence or absence. For measuring relative abundance of saplings this rod should be extended horizontally from the waist of the carrier. A rod with a colorful flag will be easiest to see in the pine barrens.
GPS unit, equipped with management unit boundaries, transect location and the position of each sampling location	1	To aid navigation during data collection.
Compass	1	To set line intercepts along a known bearing.
Data sheets	As needed	For recording data
DBH tape	1	For measuring DBH of fire-intolerant trees

Figure 11. Example of 6 foot rod topped with a flag.

V. Protocols for data collection

A. Introduction

The data collection methods presented below can be used to measure ecological attributes in pine barrens communities. The 'nested' design encourages data collection of multiple ecological attributes at the same time by using a common set of sampling locations. Figure 12 displays the data collection methods at a sampling location. Figure 13 displays data collection at multiple sampling locations along a portion of a transect. For data collection both a rigid ruler and cloth tape (six feet long, clearly marked at six inch increments) should be carried. In some structural environments (e.g., a thicket) a rigid ruler will be useful to slide through the scrub oak, while in open areas a pliable measuring tape will be easier. The rigid six-foot ruler can be used to measure scrub oak height. To measure scrub oak over 6 feet tall use a body part with a known length (e.g., waist to ground= 3 feet). Color-coding the ruler's increments (two feet, one foot, 6 inches) will help identification in the field.

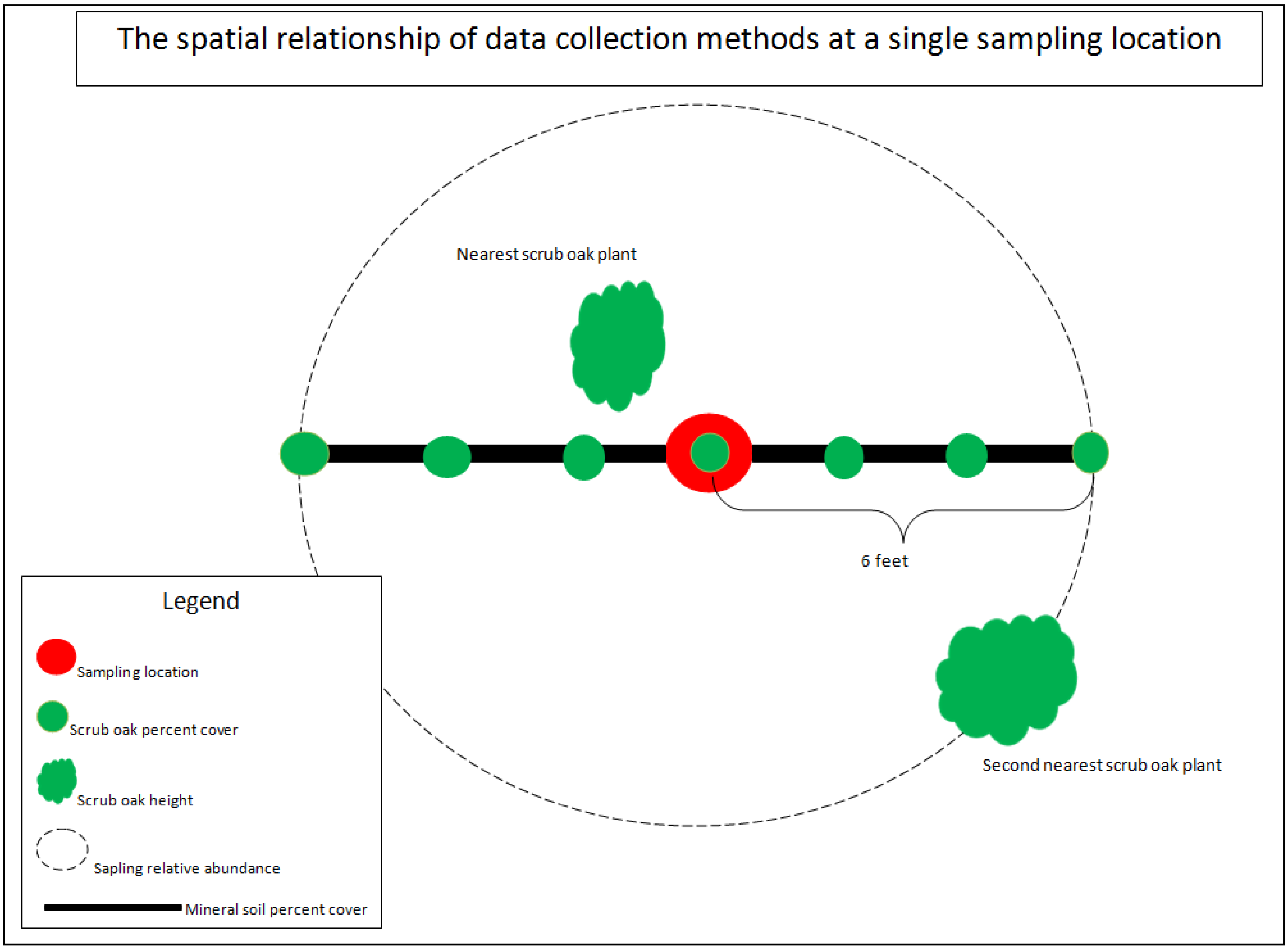

Figure 12. A diagram showing the spatial arrangement of data collection methods surrounding one sampling location.

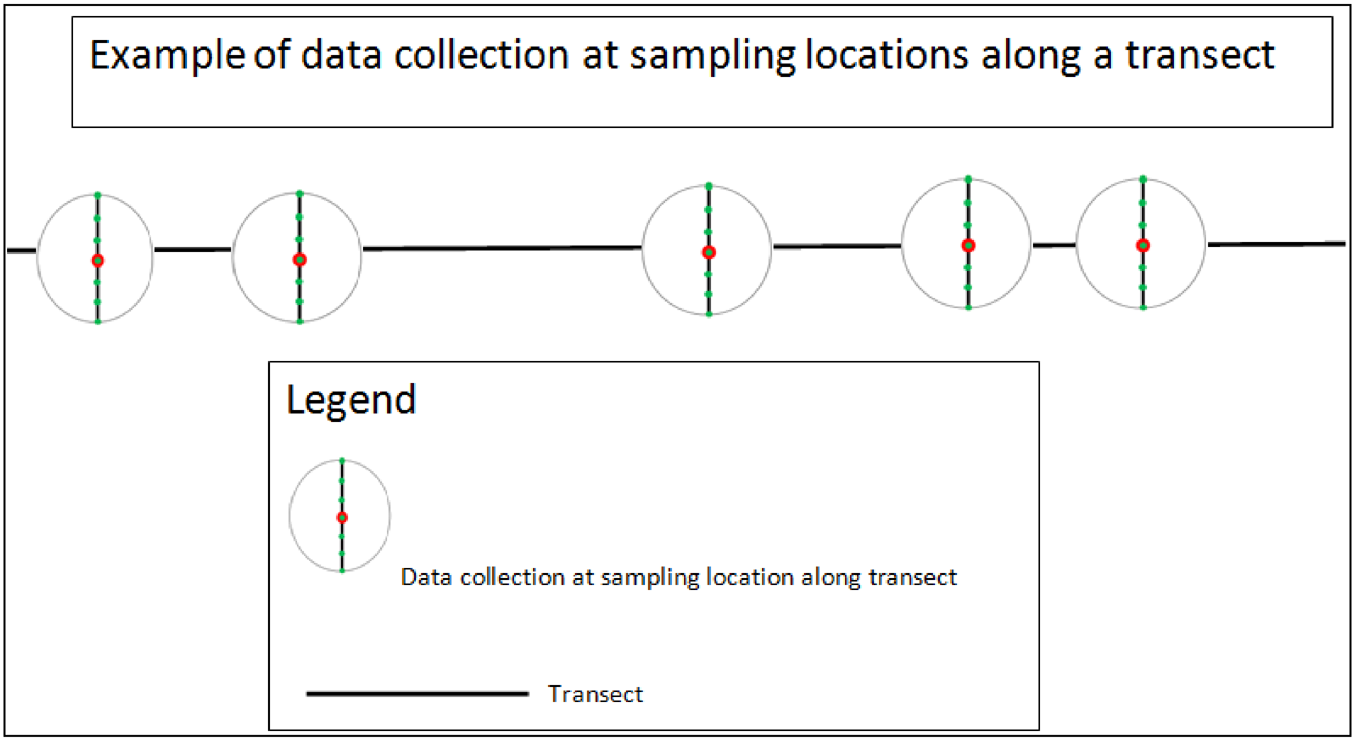

Figure 13. A diagram showing an example of data collection at mutliple sampling locations along a portion of transect.

B. Making sampling locations permanent.

To make a sampling location permanent record the precise location (with GPS coordinates) and mark it with a length of PVC or rebar driven into the ground. Sampling location should be marked at three places— at the center of the sampling location and at either end of the mineral soil/scrub oak percent cover lines (Fig. 14). To facilitate relocating the three markers should each be painted a different color—for example, knowing that 'the pink one' is always east of the sampling location will help technicians locate the other two markers to the west. Additionally, it may be desirable to permanently mark the scrub oak plants used in the height analysis so they can be measured in the future. To facilitate relocation, tag stems with a uniquely numbered metal tag. During the second round of data collection technicians should find these permanent markers and use them as guiding points for future data collection**. The goal of using permanent sampling locations is to measure the same place**.

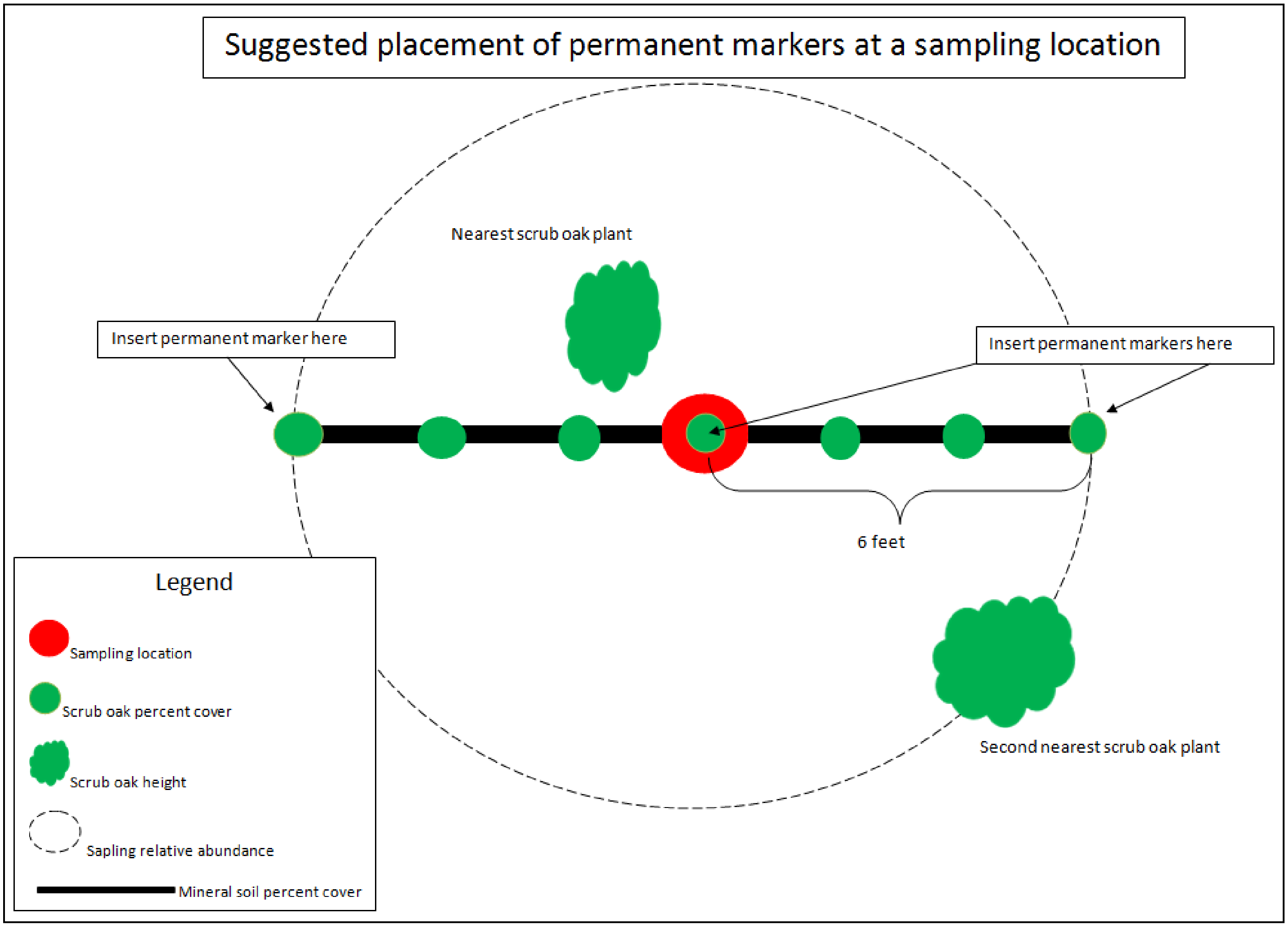

Figure 14. A diagram showing the suggested placement of permanent plot markers at a sampling location.

C. When to collect data?

Suggestions on when to collect data are displayed in the following table (Table 3).

Table 3. Table of appropriate times to collect data.

Ecological Attribute	Preferred season for measurement	Rationale	When to collect data	Rationale
Exposed mineral soil, percent cover	Any time other than winter	In winter, snow and ice will make measurement very difficult.	Within one year of treatment	Mineral soil is impacted instantaneously during treatment. A punctual collection will yield the most authentic assessment of treatment's impact.
Scrub oak percent cover and height	When leaves are on plant	Cover measurements will differ from leaf on to leaf off. The shade produced by scrub oak leaves is of ecological importance and therefore should be considered during measurement.	One year post-treatment	Scrub oak is impacted instantaneously during treatment. A punctual collection will yield the most authentic assessment of treatment’s impact.
Fire-intolerant mortality	When leaves are on trees/ in winter. Easily coupled with other collection methods	Use leaves as a health indicator/ white pine are easily visible when contrasted against snow.	1-2 years after fire	Trees inured by fire might take two years to die.
Pitch pine and fire-intolerant saplings, relative abundances	When leaves are on fire intolerant trees	Leaves make identification of fire intolerant trees easy.	5 years after treatment	Seedlings could experience very high rates of mortality. Measuring surviving saplings after 5 years will provide a more useful look at future trees.

D. Data collection methods

Attribute(s): Exposed mineral soil

Overview: *Use the line-intercept method. At randomly determined sampling locations, place a six-foot ruler on the ground and measure lengths (in inches) of exposed mineral soil lying beneath the ruler. Turn 180° and repeat procedure. Time for data collection of mineral soil along twelve feet of ruler: 3 minutes.*

Method:

- Using a hand held GPS unit, navigate to the first sampling location
- At the sampling location, center a six foot measuring device along the ground following a 90° bearing.
- Look at the substrate underneath the ruler and identify patches of exposed mineral soil.
- Measure the patches of exposed mineral soil that are crossed by the ruler to the nearest inch. For each foot of the ruler, enter the amount of inches of exposed mineral soil (Fig. 15). Disregard patches of exposed mineral soil less than one inch in length.
- Place the measuring device along the ground following a 270° bearing and repeat procedure.
- Navigate to the next sampling location and repeat procedure. Continue until all sampling locations have been visited.

	Record inches of exposed mineral soil for each foot											
	Foot #											
Location #	1	2	3	4	5	6	1	2	3	4	5	6
1	3	0	0	1	4	7	1	3	0	0	3	0
2	0	0	0	11	9	2	1	6	2	0	0	1

Figure 15. Excerpt from 'Exposed mineral soil data sheet'.

Identifying exposed mineral soil: It is often difficult to determine what type of soil you are examining. **Only soil with sand or rocks is considered mineral soil.** <u>Mineral soil is dry, gritty and loose. Organic soil is moist, full of plant material, held together by a network of roots, and squishy</u>. It may be necessary to brush away the top-most layer of leaves to see mineral soil- this is acceptable.

Attribute: Scrub oak height

Overview: *At randomly determined sampling locations measure height of two scrub oak plants. Time for data collection: 1 minute.*

Method:

- Using a handheld GPS unit, navigate to the first sampling location.
- Using a six foot ruler, measure the two closest scrub oak plants to the nearest quarter foot and enter data on sheet (Fig. 16). Enter height as 8+ if the scrub oak is over 8 feet.
- Navigate to the next sampling location and repeat procedure. Continue until all sampling locations have been visited.

Measuring the height of a scrub oak plant: It is often difficult to determine where one scrub oak plant ends and another begins. To isolate one plant for measuring, trace the plant's branches and stem to the ground. A scrub oak individual might be heavily branched and interwoven to its neighbor, but it will have a unique stem. This is a consistent way of differentiating between neighboring individuals.

Date:	Technicians:								
Location #	Scrub oak present (Y/N)							Height 1 (ft)	Height 2 (ft)
1	Y	Y	N	Y	N	N	N	2	2.5
2	N	N	N	Y	Y	N	N	0.5	1

Figure 16. Excerpt from 'Scrub oak percent cover and height data sheet'.

Attribute: Scrub oak percent cover

***Overview:** At randomly determined sampling location use the point-intercept method. Detect presence and absence of scrub oak at 7 points along a twelve-foot line. Time for data collection at 7 points: 2 minutes.*

Methods:

- Using a handheld GPS unit, navigate to the first sampling location.
- Once at the sampling location and without looking down, drive a rod *vertically* into the ground. If the rod intersects the crown of a scrub oak plant, scrub oak is present. If the rod does not intersect the crown of a scrub oak plant, it is absent (Fig. 17). Enter data on sheet (Fig. 16). **The rod does not have to intersect any physical piece of scrub oak to be counted as 'present'. Scrub oak is counted as 'present' if the rod intersects any part of the 'aerial cover'** (Fig. 18).
- From the center of the sampling location, extend a six-foot ruler along a 90° bearing. At each two foot interval detect presence or absence of scrub oak like above.
- Turn 180°and repeat procedure along a 270° bearing.
- Navigate to the next sampling location and repeat procedure. Continue until all sampling locations have been visited.

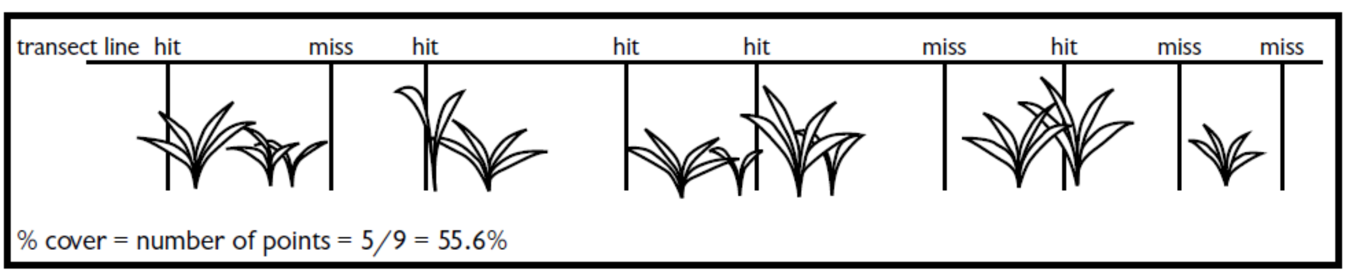

Figure 17. An illustrated example of the point intercept method (Elzinga, Salzer et al. 1998).

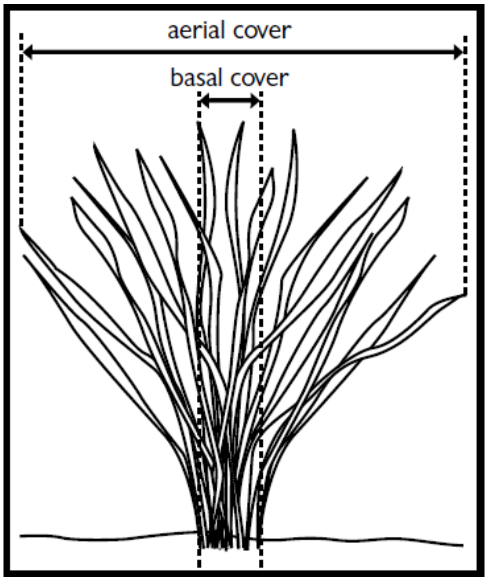

Figure 18. A illustrated example of 'aerial cover' (Elzinga, Salzer et al. 1998).

Attribute: Fire-intolerant tree mortality

Overview: *Starting from randomly determined sampling locations, locate the closest fire-intolerant tree and record its condition. Time for data collection at one tree: two minutes.*
Fire-intolerant trees: red maple, white pine, red oak, American beech and aspen.

Method:

- Using a handheld GPS unit, navigate to the first sampling location.
- Locate the closest fire-intolerant tree.
- Record appropriate information on data sheet.
- Navigate to the next sampling location and repeat procedure. Continue until all sampling locations have been visited.

Assessing tree condition: Technicians should quantify the *percent of foliage absent or destroyed* to assess the condition of the tree (Table 4). This percent represents the absence of a tree's leaves or needles that are expected to be present and/or appearing healthy on a healthy tree condition. Snags and older dead branches are not included. Twigs and branches that are dead because of normal shading are not included in this assessment. This procedure was modified from the 'Crown Indicator Methods' portion of the Forest Inventory and Analysis Program data collection methods (Service 2005).

Table 4. Codes for assessing the condition of fire-intolerant tree species.

Code	Percent of foliage absent or destroyed
1	0-25
2	25-50
3	50-75
4	75-100

Attribute: Sapling abundance

Overview: *In fixed-radius plots at randomly determined sampling locations, count living saplings. Data collection will be expedited when done with at least two people. While one person wields the rod, another can count saplings within the plot. Time to count saplings in plot: two minutes.*

- Using a handheld GPS unit navigate to the first sampling location.
- Once at sampling location, your body will act as 'plot center'. While standing securely at plot center hold a rod (6 foot) out horizontally with one end against your waist.
- Pivot around plot center to make one complete rotation. This will create a fixed radius plot (area= 1/300th acre).
- As the rod passes over live saplings, record their abundance and species on the data sheet (Fig. 19). Saplings= stems between 1.5 and 6 ft tall *or* stems > 6 ft tall *and* ≤ 1 inch dbh. Saplings species of interest are pitch pine, white pine, red maple, red oak, American beech, and aspen.
- Navigate to the next sampling location and repeat procedure. Continue until all sampling locations have been visited.

PP=Pitch Pine		RM= Red Maple		WP=White Pine		AB=American Beech		RO=Red Oak	AS=Aspen
Plot #	**PP**	**RM**	**WP**	**RO**	**AB**	**AS**	**Notes**		
1	4	1	1	0	0	0			
2	0	0	4	0	2	0			

Figure 19. Excerpt from 'Sapling abundance data sheet'.

E. *After* data collection

Data Storage. After collection, data will be stored in two places. 1) Data should be entered into the pre-existing electronic database, and 2) paper hard-copies should be stored in a binder.

Technicians should generate a brief report about the ecological conditions found in each management unit that gives context to the numerical information generated by the protocols (Fig. 20). This report should be a summary of the conditions within a management unit and could include, but is not limited to: average depth of organic material, patterns in an ecological attribute, a reoccurring treatment effect, difficulties in data collection do to some ecological characteristic, etc. Reports should be stored electronically in a folder alongside the rest of the data. The following is a sample report.

SJR_2 8/05/2010. This unit has considerable natural and fire effects variation. The edges of the unit are dominated by a mesic forest, while the center is more typical barrens vegetation. Within the typical pine barrens, there is much variability in structure: In some areas there are patches of dense and tall scrub oak, while other areas are open and covered in grasses. Contrasting the seemingly untouched scrub oak and surviving fire intolerant trees is a reduced layer of duff. I found high amounts of mineral soil, most of it appearing as small, hidden patches-not large openings. Near the southern part of the unit, I found some pitch pine regeneration at the bases of mature pitch pine. Some areas resemble untreated units, marked by the presence of fire intolerants (red oak, American beech, aspen, white pine, red maple) and dense, tall scrub oak.

Figure 20. An example of an after-collection report.

Data manipulation. Once in a database, raw data will need to be manipulated into meaningful information (e.g., average scrub oak height, percent cover of exposed mineral soil). Additionally, it is recommended that standard deviation be generated for each data set (see Section 7, Data Analysis). Such calculations can easily be carried out in Microsoft Excel or Microsoft Access. The following table outlines steps in the data manipulation process (Table 5).

Table 5. Data manipulation table showing how raw data becomes ecological information.

Ecological Attribute	Data collection method	Form of raw data	Data manipulation (step 1)	Data manipulation (step 2)	Output information
Percent cover, exposed mineral soil	Line intercept method	Lengths (in inches) of exposed mineral soil under measuring tape at each sampling location	At each sampling location, sum (in inches) of exposed mineral soil patches/ total number of inches on measuring tape (36), *100= % cover at sampling location	Sum of percent cover values (from sampling locations)/# of sampling locations	Percent cover of exposed mineral soil in management unit. Find standard deviation within dataset
Percent cover, scrub oak	Point intercept	9 'absent/present' data points for each sampling location	At each sampling location, the number of 'present' tallies/ total number of places sampled *100= % cover of scrub oak at each sampling location	Sum of percent cover values (from sampling locations)/ # of sampling locations	Percent cover of scrub oak in management unit. Find standard deviation within dataset
Average scrub oak height	Measurement of individual scrub oak plants	A scrub oak height measurement at each sampling location	Average all measurements from population	N/A	Average scrub oak height in management unit. Find standard deviation within dataset
Relative abundance of pitch pine saplings	Counting of all saplings in plots	Number of saplings of different species in each plot	Sum of pitch pine saplings/ total number of saplings * 100= relative abundance of pitch pine saplings at each plot (%)	Average all measurements from population	Relative abundance (%) of pitch pine saplings in management unit. Find standard deviation within dataset
Relative abundance of fire-intolerant saplings	Counting of all saplings in plots	Number of saplings of different species in each plot	Sum of fire-intolerant saplings/ total number of saplings * 100= relative abundance of fire-intolerant saplings at each plot (%)	Average all measurements from population	Relative abundance (%) of fire-intolerant saplings in management unit. Find standard deviation within dataset

VI. Technical considerations for field-based data collection

A. Multiple technicians

A team of three or technicians is ideal for data collection. One technician can be responsible for collecting fire-intolerant tree and scrub oak height data while two others remain at the sampling location and collect data for scrub oak percent cover and exposed mineral soil percent cover.

B. Collecting data in areas of dense scrub oak

Dense scrub oak will sometimes pose a challenge for data collection. When collecting sapling abundance data scrub oak plants might be an obstacle, inhibiting a full rotation of the ruler. In these cases it will be necessary for a technician to 'stick' the ruler through the scrub oak plant while remaining at the center of the sampling location. Another technician can help by locating the end of the ruler and counting any saplings that have been covered by its arc.

If a sampling location falls in/on an area of dense scrub oak it is important to proceed with marking the sampling location with as little bias as possible. A continued biased placement of sampling locations in the field may distort the representation of the management unit.

VII. Data analysis

Variability within a dataset. Datasets are commonly described by their central tendency (mean, median or mode) but the variability (standard deviation or standard error) is often more revealing. Standard deviation quantifies the average distance a dataset's values are from its mean. The following table illustrates the role of variability in data analysis. Scrub oak height data from two management units are presented (Table 6); the means are identical but the standard deviations describe very different structural diversity in the two management units. Scrub oak height in Thicket 4 is much more variable than in West Branch 9. Understanding the variability of an ecological attribute is fundamental in understanding its condition in a management unit.

Table 6. Two tables showing sample data from two different management units. Mean scrub oak height is equal while standard deviations vary.

Management unit: West Branch 9	
Sampling location	Scrub oak height (ft)
1	4
2	4.5
3	3.5
4	4
5	4
6	3
7	5
8	4
9	4
10	4
11	4
12	4
13	4
14	4
15	4
16	4
17	4
18	5
19	4
20	3
Mean	**4**
Standard deviation	**+/-0.5**

Management unit: Thicket 4	
Sampling location	Scrub oak height (ft)
1	0.5
2	13
3	1
4	6
5	5
6	0.5
7	6
8	0.5
9	7.5
10	7
11	3
12	9
13	1
14	0.5
15	2
16	5.5
17	1
18	6
19	1
20	2
Mean	**4**
Standard deviation	**+/-3.5**

Basic data analysis. The most basic data analysis summarizes the ecological conditions within a management unit by producing an average value (e.g., average scrub oak height) that can be compared directly to the stated objectives. These management unit means can be used in a comparison against a mean from a different management unit (Fig. 21), or a mean from another time in the same management unit (Fig. 22) (error bars in the following graphs represent standard deviation).

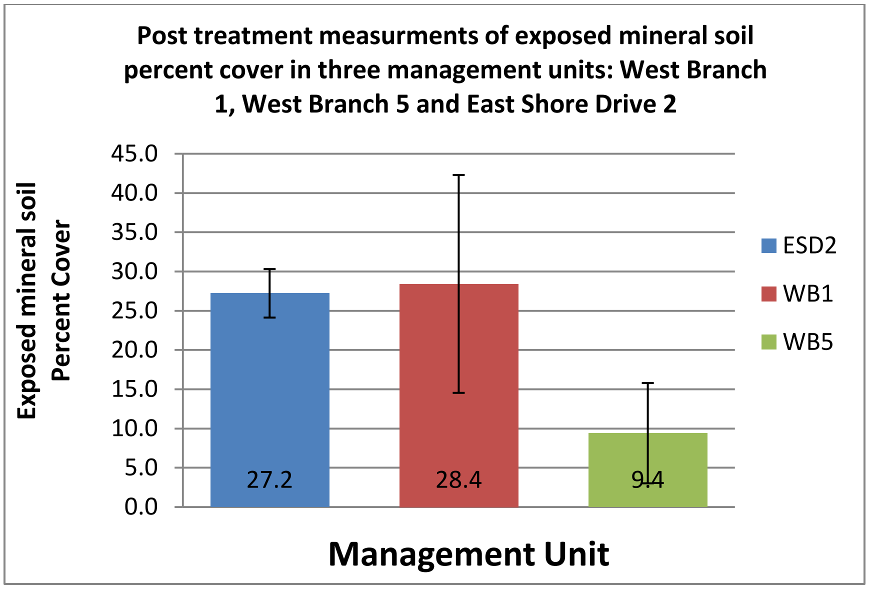

Figure 21. A sample graph showing percent cover of exposed mineral soil in three post-treatment management units.

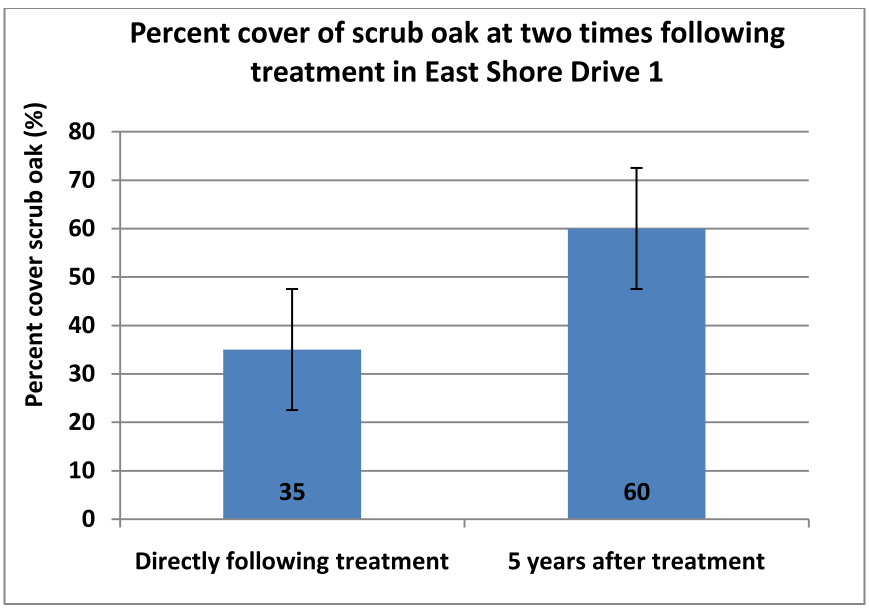

Figure 22. A sample graph showing the use of permanent plots.

Additional data analysis. In addition to an attribute's mean and standard deviation, other analyses can answer a variety of ecological questions. Examples of further data analysis are described below.

<u>*Comparing an ecological attribute in two different environments (stratified sampling).*</u> TNC may wish to characterize ecological attributes in different environments within the pine barrens. For example, it may interest TNC to know how the rate of scrub oak growth (in height or percent cover) varies between scrub oak growing under a low vs. high percent tree canopy cover. Likewise, it may interest TNC to know how pitch pine

relative abundance varies between areas of low and high percent cover of exposed mineral soil. For these comparisons 'stratified random sampling' is used, explained below:

Different strata of interest (e.g., low vs. high canopy cover, low vs. high percent cover of exposed mineral soil) can sometimes be found in uniform clumps in a management unit. These can be spatially delineated and independently sampled (Fig. 23).

Sampling within delineated strata will yield a mean for each strata type BUT WILL NOT YIELD A MEAN FOR AN ENTIRE MANAGEMENT UNIT. To yield a management unit mean while sampling within delineated strata it will be necessary to place additional transects outside of either delineated strata—this will result in sampling three distinct sections of the management unit (Fig. 24). To derive a management unit mean, the relative weight of each strata's mean value should correspond to its area. For instance if the area of 'low cover' was 25% of the management unit, its mean would carry a weight 25% when being averaged with the other two strata.

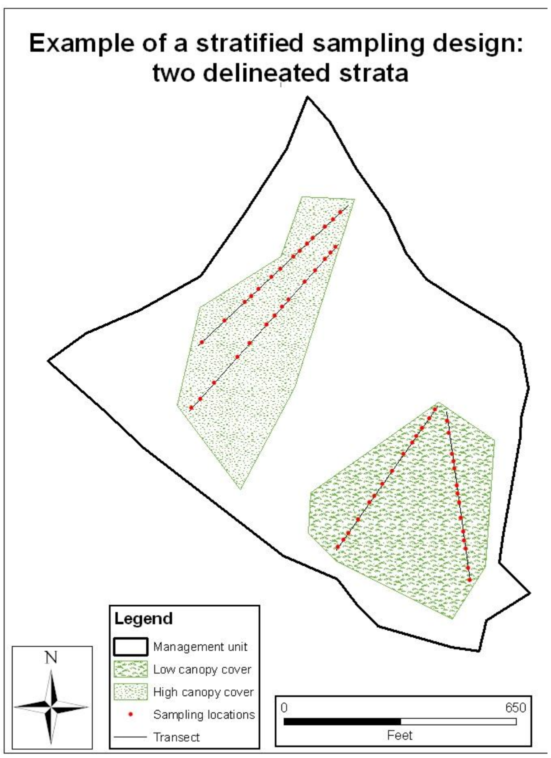

Figure 23. An example of a stratified sampling design with two strata spatially delineated.

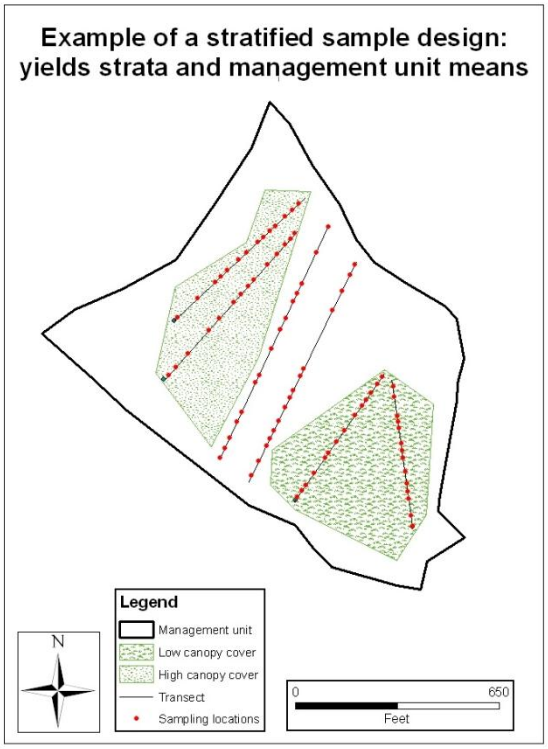

Figure 24. Example of a stratified design that yields a management unit mean as well as a mean for each spatially delineated strata.

It's common for strata may be natural scattered within a management unit, making them difficult to spatially delineate (Fig. 25). Adding columns to a datasheet will allow TNC to collect information about strata alongside the other ecological attributes (e.g., exposed mineral soil) (Fig. 26). Two comparable sub-populations will emerge after the original dataset is reorganized. For instance, the dataset from *West Branch 5* can be reorganized into two sub populations that correspond with high (>60) and low (<30) percent cover of scrub oak. This sampling design will yield a mean from each strata type along with a management unit mean. In this sample design it is important to maintain adequate sample sizes for each strata, therefore it might be necessary to start with a sample size of greater than 30 per management unit.

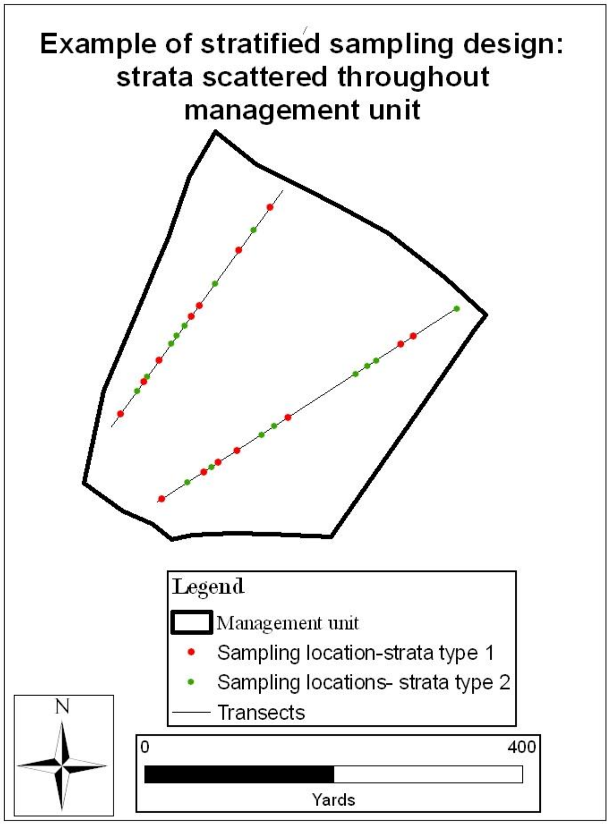

Figure 25. Example of a stratified sampling design with two strata types scattered throughout the management unit.

Additional columns allow dataset to be reorganized into strata sub-populations.

Date:	Technicians:						Management unit:														
	Record inches of exposed mineral soil for each foot												Record scrub oak						Record scrub oak		Canopy cover
	Foot #												presence (Y/N)						height (ft)		at sampling lcoation
Location #	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	(high/low)

Figure 26. Excerpt from data sheet illustrating the use of extra strata in data collection.

Either method of stratification will yield a mean and standard deviation for each strata. To determine if there is a statistically significant difference between attributes from different strata, consult '*statistical analyses*', pg. 47. The following example graphs (Fig. 27, Fig. 28) illustrate how data collected from a stratified data collection might be presented (errors bars represent standard deviation).

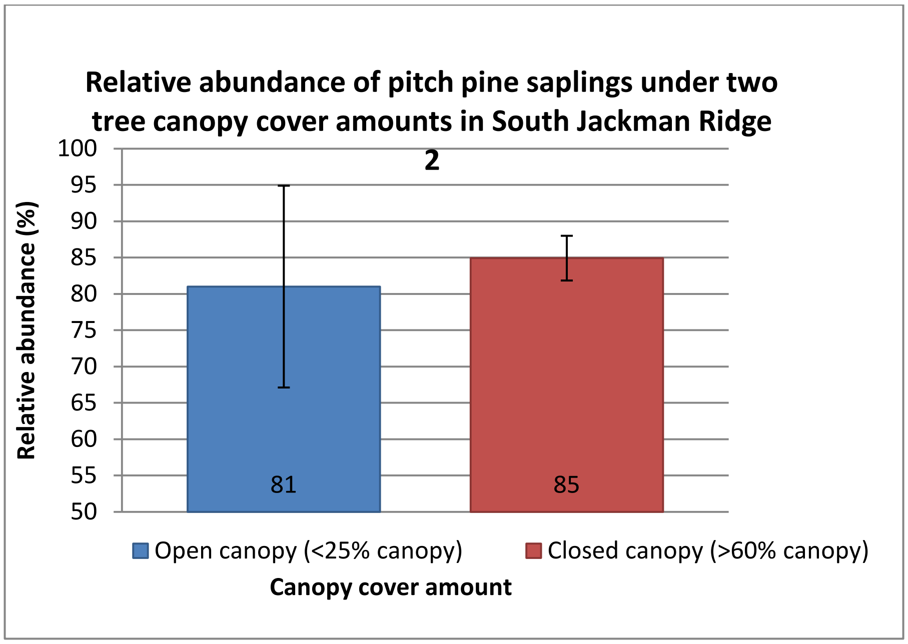

Figure 27. A sample graph showing the results from a stratified data collection where relative abundance of pitch pine was measured under two canopy amounts.

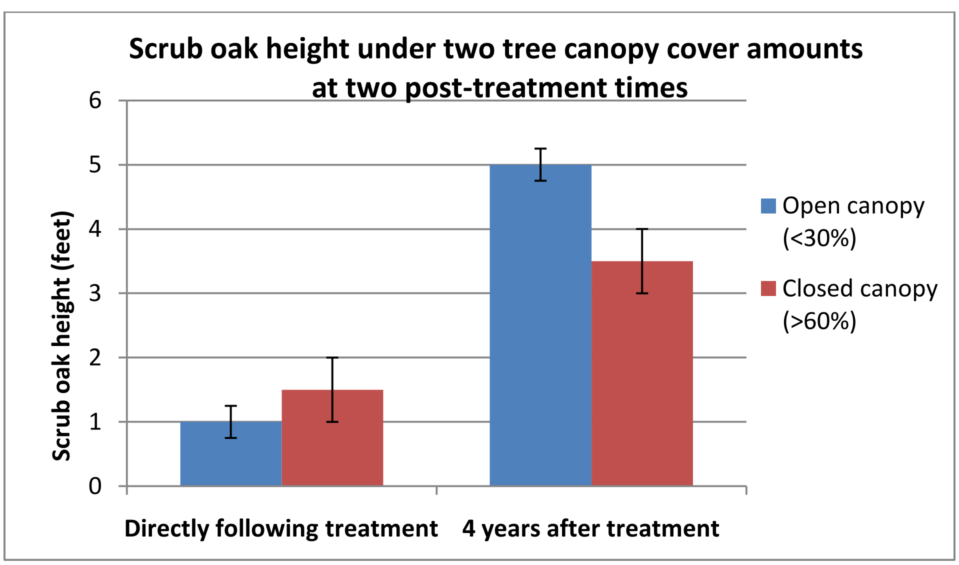

Figure 28. A sample graph showing the use of permanent plots in a stratified sample design.

<u>How do the ecological attributes influence one another</u>? Linear regression can be used to uncover relationships between different ecological attributes. With this analysis you can see how the amount of one ecological attribute changes in relationship to the changing amount of another ecological attribute. For instance, TNC may wish to know how the percent cover of exposed mineral soil relates to the relative abundance of pitch pine saplings. To test whether or not there is a statistically significant relationship between two ecological attributes a regression analysis must be done using a statistical software package. If there is not a statistically significant relationship between the ecological attributes, no more analysis can be done. If there is a statistically significant relationship between the attributes it will be important to interpret the line of best fit and the R^2 value. The slope of the line indicates the magnitude of change that the dependent variable (on y-axis) experiences per unit of independent variable (on x-axis). The R^2 value ranges from 0-1 and describes how close the points are to the line. The higher the R^2 value, the more that the dependent variable is explained by the independent variable. An R^2 value of 1 indicates that the dependent variable is completely described by the independent variable. Likewise, an R^2 of 0 indicates that there is no relationship between the variables. The line of best fit allows land managers to make predictions about ecological attributes based on known relationships. The analysis is can be done in two ways:

1) **Across multiple management units:** Ecological attribute information (e.g., management unit means) from *multiple* management units can be plotted; each management unit is represented by a single point on the scatter plot (Fig. 29).

2) **Within one management unit:** It is also possible to analyze a relationship between attributes *within one management unit*. To do this the sampling locations for each attribute in the analysis **must** be the same. This is shown in Figure 30, where each sampling location is represented by a point on the scatter plot.

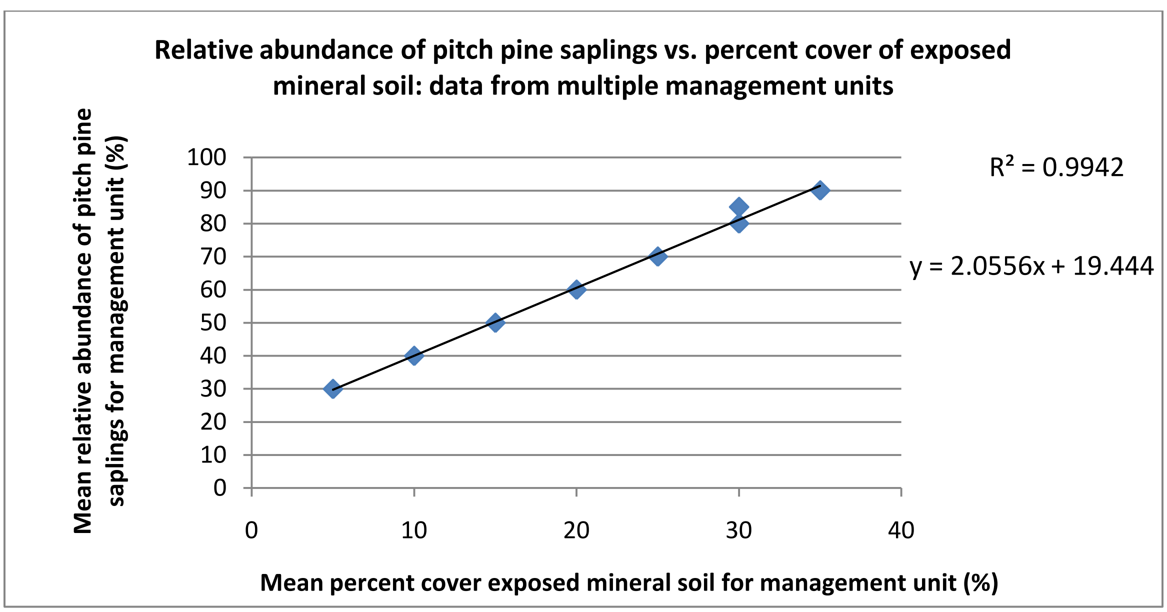

Figure 29. A sample graph showing the relationship between percent cover of exposed mineral soil and relative abundance of pitch pine saplings—data from multiple management units.

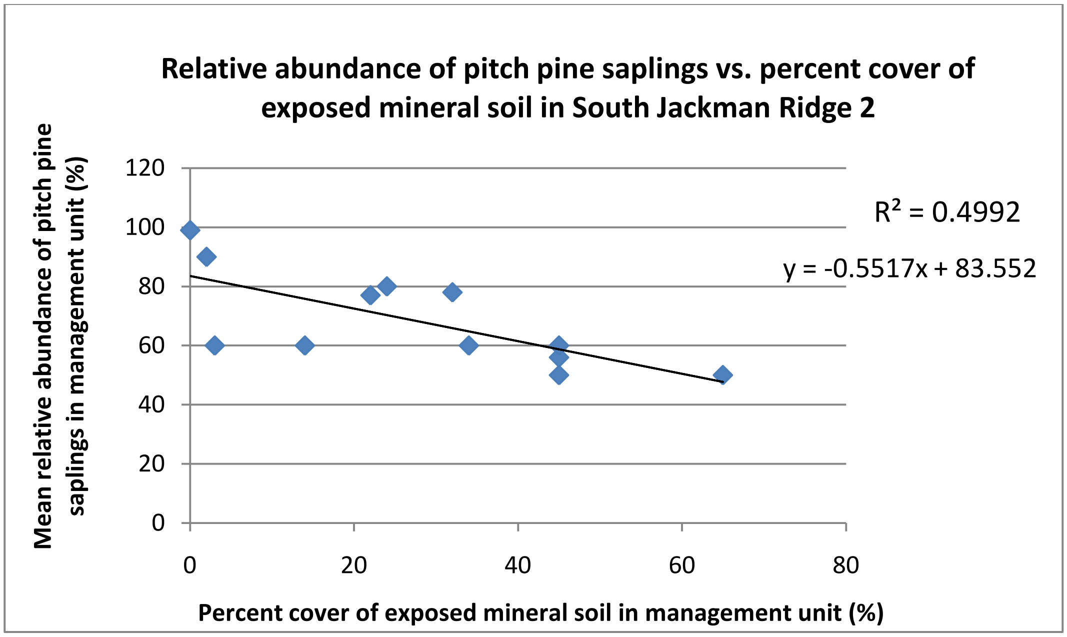

Figure 30. A sample graph showing the relationship between percent cover of exposed mineral soil and relative abundance of pitch pine saplings in a single management unit.

<u>What percent of sampling locations meet the ecological objectives</u>? As previously stated, a management unit's ecological attributes will be summarized by a mean and standard deviation. The ecological attributes can be expressed another way by summarizing the percent of the sampling locations that have met an attribute's ecological objective. This metric reveals the ecological attribute's distribution in a management unit and can be used to understand ecological conditions within a management unit at smaller scales. As Table 7 displays, in South Jackman Ridge 2 the ecological objective was met ('the fire treated management units have at-least 20% mineral soil exposure') but this condition was measured in only 20% of the sampling locations. Alternatively, in Thicket 4 the ecological objective was not met, but 75% of the sampling locations met the ecological objective. This metric can be used as a means of comparing management units (Fig. 31).

Table 7. Two sample tables showing the percent of sampling locations in a management unit that have met ecological a specific ecological objective.

Management unit: South Jackman Ridge 2	
Sampling location	Percent cover, exposed mineral soil (%)
1	100
2	80
3	80
4	70
5	5
6	5
7	5
8	5
9	5
10	5
11	5
12	5
13	5
14	5
15	5
16	5
17	5
18	5
19	5
20	5
Mean	**20.5**
% of sampling locations that have met ecological objective	**20**

Management unit: Thicket 4	
Sampling Location	Percent cover, exposed mineral soil (%)
1	20
2	20
3	20
4	20
5	20
6	20
7	20
8	20
9	20
10	20
11	20
12	20
13	20
14	20
15	20
16	5
17	5
18	5
19	5
20	5
Mean	**16.25**
% of sampling locations that have met ecological objective	**75**

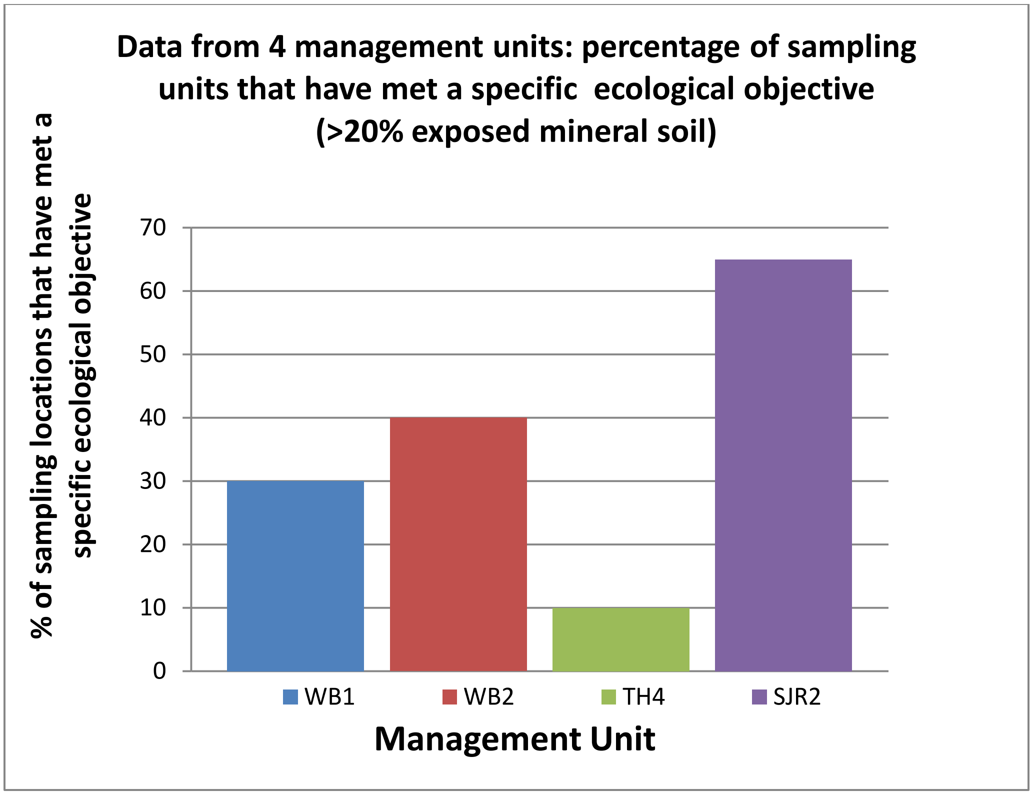

Figure 31. A sample graph showing the percent of sampling locations that have met a specific ecological objective in four management units.

What is the density of pitch pine or fire-intolerant saplings in post treatment management units? Once the relative abundance of pitch pine sapling data is collected, sapling density (saplings/acre) can be calculated to describe how many new pitch pine trees are growing in a management unit. (Hypothetically, it is possible to have plots with 100% pitch pine saplings [no fire-intolerant saplings], but still have management units with very low pitch pine sapling density).

How did fire-intolerant mortality rates vary with different prescribed fires? By using a stratified sampling design the effect of different fires on fire-intolerant mortality rates can be compared. For this analysis, the population will be stratified among different fire types (e.g., crown fire, ground fire) and data from strata will be compared.

How does fire affect different fire-intolerant trees? This is another analysis that relies on a stratified sampling design. In this example, the different strata are different tree species. To answer this question, at least 15 trees of each species in the analysis need to be sampled[1]. To increase the amount of trees sampled it might be

[1] This figure can be modified to meet the specific needs of TNC. The number 15 was used because 1) it is feasible to locate and sample that many trees, and 2) an analysis based on this size is likely to yield meaningful results. As the sample sizes of decrease, the ability for variability to skew the results will increase.

necessary to modify the data collection methods. For example, the condition of *two* fire-intolerant trees can be collected at each sampling location.

Statistical Analyses. Unbiased comparison between datasets is facilitated by statistics. For TNC's purposes, statistics can be used to determine if there is a 'significant' (or meaningful) difference between two or more groups of data. For example, you can determine if the height of a management unit's scrub oak at one time differs significantly from the height of the scrub oak at another time. Likewise, you can determine if the percent cover of exposed mineral soil in one strata differs significantly from the percent cover of exposed mineral soil in another strata. A statistical test considers the variability within datasets while comparing their means. In some cases (where a data set contains little or no variability) a rough, non-statistical comparison might be possible, but as a dataset's variability increases it becomes difficult to make a meaningful comparison without statistics. In Table 8 hypothetical data for two management units illustrates how standard deviation can make a comparison of means difficult. The obvious difference between the two values of mean percent cover of exposed mineral soil (15 and 25) is diluted by the data sets' variability. The use of a T-test would yield a conclusion of 'no significant difference' between these two datasets.   For the purposes of these monitoring protocols use a T-Test when two means are compared. Use an ANOVA (Analysis of Variance) when more than two datasets are being compared. Use a 'paired' T-test when sampling with permanent plots. This will compare the values of each permanent plot at multiple times.

Table 8. Two sample tables showing mean and standard deviation of a dataset.

Management unit: West Branch 7	
Sample location	% cover, mineral soil
1	9
2	6
3	33
4	19
5	15
6	15
7	33
8	3
9	18
10	10
11	9
12	8
13	4
14	39
15	21
16	15
17	9
18	18
19	15
20	5
Mean	**15**
Standard deviation	**10**

Management unit: East Shore Drive 4	
Sample location	% cover, mineral soil
1	20
2	20
3	33
4	30
5	30
6	40
7	40
8	40
9	0
10	6
11	9
12	4
13	6
14	8
15	34
16	31
17	35
18	15
19	37
20	33
Mean	**25**
Standard deviation	**14**

Works Cited

Batcher, M. (2006). *Ecological Management Plan for Ossipee Pine Barrens. Prepared for The Nature Conservancy, New Hampshire Chapter, Concord, NH.*

Batcher, M. (2007). *Field Monitoring Protocols for the Ossipee Pine Barrens. Prepared for The Nature Conservancy, New Hampshire Chapter, Concord, NH.*

Columbia, G. O. (2005, 10 14). *Forest Practices Branch*. Retrieved 12 15, 2010, from Ministry of Forests and Range: http://www.for.gov.bc.ca/hfp/archives/amhome/AMDEFS.HTM

Conservation, M. D. (2010). *Maine Natural Areas Program*. Retrieved May 3, 2011, from Maine Department of Conservation: http://www.maine.gov/doc/nrimc/mnap/features/communities/pitchpineoakbarren.htm

Dacey, C. (2003). *Vegetation of the Ossipe Pine Barrens Preseve: Description, Classification, and Succession Trends. Carroll County, NH.* Burlington, VT: University of Vermont.

Dickman, D. I., & Rollinger, J. L. (1998). Fire for Restoration of Communities and Ecosystems. *Bulletin of the Ecological Society of America* , 157-160.

Edinger, J. G. (2002). *Ecological Communities of New York State, Second Edition. A revised and expanded edition of Carol Reschke's Ecological Communities of New York Sate.* Albany, NY: New York Natural Heritage Program, New York State Department of Environmental Conservation.

Elzinga, C. L., Salzer, D., & Willoughby, J. (1998). *Measuring and Monitoring Plant Populations.* Lincoln: University of Nebraska.

Finton, A. D. (1998). *Succession and Plant Community Development in Pitch Pine-Scrub Oak Barrens of the Glaciated Northeast United States.* Amherst, MA: University of Amherst.

Lands, N. H. (n.d.). *Natural Heritage Bureau*. Retrieved May 3, 2011, from Natural Communities of New Hampshire: http://www.nhdfl.org/about-forests-and-lands/bureaus/natural-heritage-bureau/photo-index/pitch-pine-scrub-oak-woodland.aspx

Motzkin, G. D. (1996). Controlling Site to Evaluate History: Vegetation Patterns of a New England Sand Plain. *Ecological Monographs* , 345-365.

Motzkin, G., Patterson, W., & Foster, D. (1999). A Historical Perspective on Pitch Pine-Scrub Oak Communites in the Connecticut River Valley. *Ecosystems* , 255-273.

NatureServe. (2010, August). *Ecological Associations*. Retrieved May 3, 2011, from NatureServe: Natureserve.org

Patterson, W. A. (1994). *The Waterboro Barrens: fire and vegetation history as a basis for ecological management of Maine's unique scrub oak-pitch pine ecosystem.* Brunswick: Unpublished report, The Nature Conservancy, Maine Chapter.

Thompson, E. E. (2005). *Wetland, Woodland, Wildland: A guide to the Natural Communities of Vermont.* Hanover, CT: The Nature Conservancy and the Vermont Department Fish and Wildlife.

Wagner, L. D. (2003). Early-Successional Forest and Shrubland Habitats in the North Eastern United States: Critical Habitats dependent on Disturbance. *Forest Ecology and Management* , 95-112.

Appendix 1: Printable materials for field data collection

Data collection methods:

- ☐ Navigate to sampling location
- ☐ Once at sampling location, without looking down drive a 6 foot rod *vertically* into the ground. If the rod intersects the crown of a scrub oak plant, scrub oak is present. If the rod does not intersect the crown of a scrub oak plant, it is absent.
- ☐ Enter data on sheet. **The rod does not have to intersect any physical piece of scrub oak to be counted as 'present'. Scrub oak is counted as 'present' if the rod intersects any part of the 'aerial cover'**.
- ☐ **Keep the rod driven into the ground to mark the sampling location.**
- ☐ *Record exposed mineral soil percent cover data-Time for data collection along twelve feet of ruler: 3 minutes.*
- ☐ Starting from the sampling location, place a six foot measuring device along the ground following a 90° bearing.
- ☐ Look at the substrate underneath the ruler and identify patches of exposed mineral soil.
- ☐ Measure the patches of exposed mineral soil that are crossed by the ruler to the nearest inch. For each foot of the ruler, enter the amount of inches of exposed mineral soil. Disregard patches of exposed mineral soil less than one inch in length.
- ☐ Place the measuring device along the ground following a 270° bearing and repeat procedure.
- ☐ *Collect the remaining scrub oak percent cover data- Time for data collection at 6 additional points: 2 minutes.*
- ☐ From the center of the sampling location, extend a six-foot ruler along a 90° bearing. At each two foot interval record presence or absence of scrub oak like above.
- ☐ Turn 180°and repeat procedure along a 270° bearing.
- ☐ *Record scrub oak height-Time for data collection at 2 scrub oak plants: 1 minute.*
- ☐ Using a six foot ruler, measure the two closest scrub oak plants to the nearest quarter foot and enter data on sheet. Enter height as 8+ if the scrub oak is over 8 feet.
- ☐ *Collect fire-intolerant tree data: Time for data collection at one tree: two minutes*
- ☐ Locate the closest fire-intolerant tree.
- ☐ Record appropriate information on data sheet.
- ☐ *Collect relative abundance of sapling data-Time to count saplings in plot: two minutes.*
- ☐ Once at sampling location, your body will act as 'plot center'. While standing securely at plot center hold a rod (6 foot) out horizontally with one end against your waist.
- ☐ Pivot around plot center to make one complete rotation. This will create a fixed radius plot (area= 1/300th acre).
- ☐ As the rod passes over live saplings, record their abundance and species on the data sheet. Saplings= stems between 1.5 and 6 ft tall *or* stems > 6 ft tall *and* ≤ 1 inch dbh. Saplings species of interest are pitch pine, white pine, red maple, red oak, American beech, and aspen.

Identifying exposed mineral soil: It is often difficult to determine what type of soil you are examining. **Only soil with sand or rocks is considered mineral soil.** Mineral soil is dry, gritty and loose. Organic soil is moist, full of plant material, held together by a network of roots, and squishy. It may be necessary to brush away the top-most layer of leaves to see mineral soil- this is acceptable.

Measuring the height of a scrub oak plant: It is often difficult to determine where one scrub oak plant ends and another begins. To isolate one plant for measuring, trace the plant's branches and stem to the ground. A scrub oak individual might be heavily branched and interwoven to its neighbor, but it will have a unique stem. This is a consistent way of differentiating between neighboring individuals.

Assessing tree condition: Technicians should quantify the *percent of foliage absent or destroyed* to assess the condition of the tree (Table 1). This percent represents the absence of a tree's leaves or needles that are expected to be present and/or appearing healthy on a healthy tree condition. Snags and older dead branches are not included. Twigs and branches that are dead because of normal shading are not included in this assessment. This procedure was modified from the 'Crown Indicator Methods' portion of the Forest Inventory and Analysis Program data collection methods (Service 2005).

Table 1. Codes for assessing the condition of fire-intolerant tree species.

Code	Percent of foliage absent or destroyed
1	0-25
2	25-50
3	50-75
4	75-100

Exposed Mineral Soil, Scrub Oak Percent Cover, Scrub Oak Height Datasheet

Date:	Technicians:						Management unit:															
	Record inches of exposed mineral soil for each foot												Record scrub oak presence (Y/N)							Record scrub oak height (ft)		
	Foot #																					
Location #	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	7	1	2	Notes

Relative Abundance of Saplings Data Sheet

	Date:		**Technicians:**				**Management unit:**
PP=Pitch Pine	**RM**= Red Maple		**WP**=White Pine		**AB**=American Beech	**RO**=Red Oak	**AS**=Aspen
Plot #	**PP**	**RM**	**WP**	**RO**	**AB**	**AS**	**Notes**
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							
32							
33							
34							
35							
36							
37							

Fire-Intolerant Tree Condition Data Sheet

Date:	**Technicians:**				**Management unit:**	
Species: **RM**= Red Maple **WP**= White Pine **RO**= Red Oak **AB**= American Beech **AS**= Aspen						
Assess % of foliage absent or destroyed 1=0-25% absent 2= 25-50% absent 3= 50-75% absent 4= 75-100% absent						
Tree #	**Species**	**DBH (in)**	**Condition (1-4)**	**Resprouting (Y/N)**	**Notes**	
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
32						
33						
34						
35						
36						
37						
38						
39						
40						
41						
42						