# Optimal Monitoring of Rare Plant Populations: Report for the USDA Forest Service

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**Preface**

The Chicago Botanic Garden was contracted by the USDA Forest Service to develop a decision tree and report on optimal monitoring methods for rare plants. The Forest Service currently does not have consistent guidance for monitoring rare plant populations, and monitoring methods often vary across Forest Service units. The resulting flow charts, table and report will help guide botanists to the most appropriate monitoring protocols based on the questions being asked and the species being monitored, while also taking into account limitations in financial and human resources that many Forest Service units face. Development of monitoring protocol guidelines will better position Forest Service botanists to implement conservation and recovery of rare species that is more fiscally sound and scientifically credible.

Our first step in working on this project was to review the current body of literature on plant population monitoring. One of the most comprehensive references available is the BLM publication *Measuring and Monitoring Plant Populations* (Elzinga *et al.* 1998). While this publication contains a great deal of information on designing and implementing a monitoring program, we find it is not as useful for deciding which techniques to use and lacked helpful examples. Therefore, part of our approach is to create a document that will be able to lead a botanist to the appropriate, detailed how-to information on sampling and monitoring techniques in this resource. In addition, we want to provide information on any additional current monitoring techniques that are being used with success that are not found in the Elzinga *et al.* (1998) publication.

After collecting information on the strengths and limitations of frequently used monitoring techniques, we then organized them in a way that would be both informative and user friendly. Monitoring techniques were grouped based on what type or level of monitoring they represented according to Palmer (1987; Inventory, Survey, or Demographic) or Menges and Gordon (1996; Levels 1, 2 and 3). Using this organized list of techniques, we then wanted to create a decision tree or flow chart that the botanists could use to lead them to the most appropriate techniques for their needs. The detailed table of technique strengths and limitations could then be used to double check that the technique indicated by the flow chart was indeed the most appropriate. We also included text to help and guide users through the flow chart and to help explain each step.

To help ensure that our flow chart and report would be useful for our intended audience, two different surveys were sent out to USDA Forest Service botanists who are responsible for rare plant monitoring. The first survey was sent out to a small number of higher-ranking botanists. In this first survey we learned that the botanists were monitoring a wide variety of species for a long list of objectives. We also learned that a large majority of those botanists were doing some sort of demographic monitoring. This was interesting to us, because demographic monitoring is very time and resource expensive, but may not always be necessary to answer many monitoring questions. The other major theme we collected from the first survey was that limited time and funding cause most monitoring programs to be carried out on an intermittent and irregular basis.

With the second survey, we hoped to capture the goals behind monitoring program designs in more detail and how data are processed after they are collected. This survey was sent out to a large group of Forest Service employees responsible for plant monitoring. This second survey revealed a number of informative trends. First, surveys to identify presence/absence or distribution of a population are more commonly conducted than more detailed demographic monitoring. We also learned that the majority of employees create their own monitoring protocols based on a monitoring objective, but that over half of them are only somewhat confident that their current protocols are appropriate. Over 80% of the respondents said they approach their monitoring program with a clear question or goal, with 40% telling us that their goal comes from a management plan. Additionally, only 65% of respondents answered that the data they collect help answer their monitoring questions or goals. This is a number we aim to improve with the use of our flow chart in designing a monitoring program. A full summary of the data collected and figures from both surveys is available in Appendix A.

In order to incorporate feedback from several plant monitoring experts, we held a workshop in St. Louis on October 25th, 2009. From this workshop we received feedback reinforcing the direction of the project, as well as additional information that the group felt would strengthen our final product. The group agreed that the focus should be placed on designing a monitoring program based on a clear and descriptive monitoring goal and objective. Based on this, we have created a decision tree to help guide botanists through the process of identifying a strong monitoring objective or question before choosing a technique or method. Concern was raised that using a minimum viable population number was unnecessarily driving a lot of monitoring. Except in certain situations where a population viability assessment (PVA) is mandated by a recovery plan, a strict number for a minimum viable population is not often useful. In this report, we define a viable population in more applicable terms that gets to the spirit of monitoring goals without providing a simple number of individuals. There was also agreement that the effects of limited or unreliable funding should be considered when recommending a monitoring technique or strategy. Additionally, an enhanced count technique including counts of individuals along with recording their age/stage class was discussed. The group felt that this technique can give more statistically significant data than a simple population count, but is not as time or resource consuming as a detailed demographic study. For these reasons we hope to highlight this technique as a recommended alternative where applicable.

## Executive Summary

A well designed plant monitoring program with a clear question and goal is a very valuable tool in successful management. Monitoring programs come in varying levels of intensity, and each level will provide you with different information about your population or species. Demographic monitoring will provide you with a great deal of data and give you predictive power, but it is the most time and resource intensive level of monitoring. If time and resources are scarce, as they often are, you may not be able to conduct a demographic study regularly or for a long enough time period to provide you with useful data. In these cases it is often more informative to conduct a less intensive monitoring program (population counts, etc.) consistently over a longer time period. If you hope to achieve some predictive ability, but do not have the time or resources for a full demographic study, taking enhanced (life history stage) count data can be a great compromise. This technique involves taking count data as well as noting the number of plants in each age or stage class. With only slightly more effort than a traditional population count, you can collect data that can be used in a count based population viability assessment (PVA) to give you some predictive ability. Most importantly, monitoring programs should be based on the management and monitoring questions you hope to answer. Whatever technique you choose should be based on that question as well as the particular species you are interested in to ensure you are collecting useful data. In this report we have provided a set of flow

charts and a strengths and limitations table along with accompanying explanatory text to help you design a monitoring program that will fit your needs. We have also provided a case study, based on work done with the rare plant *Lespedeza leptostachya* to provide you with examples of all of the components of a working monitoring program.

## General Introduction

What is monitoring?

The monitoring of plant populations is a common practice on many federally-held lands. Monitoring is defined by Elzinga *et al.* (1998) as, "the collection and analysis of repeated observations of measurements to evaluate changes in condition and progress toward meeting a management objective". While monitoring a species or population is not an end in itself, it is a very valuable tool that can be used to answer a wide range of management questions. Data gained from a well-designed monitoring program can be extremely valuable in aiding managers in making well informed decisions when it comes to taking management actions. Monitoring can be undertaken with various levels of intensity, ranging from a simple determination of a population's presence or absence to a full demographic study of individuals in a population. Common targets of monitoring efforts tend to be rare plants and invasive species, but monitoring can be used in a wide variety of applications.

In order for a monitoring program to be effective in answering the management questions and fulfilling management objectives, it must be carefully planned and focused. As defined by Nichols and Williams (2008), targeted monitoring occurs when a monitoring program is based on *a priori* hypotheses and models of system responses. Carrying out a poorly designed monitoring program can often be more damaging and expensive (time, resources) than simply not having a monitoring program at all. The key feature in a successful monitoring program is to have clear, well-defined goals and/or questions before the program begins. This not only helps to assure that you will have statistically reliable data (when needed) to answer your questions; it also helps to avoid wasting time and resources on collecting superfluous data and limits potential damage to sensitive habitats. This document is designed to help you articulate your management questions and goals, and give you guidance on designing a monitoring program that will help to answer those questions.

Management Objectives

Elzinga *et al.* (1998) define management objectives as "clearly articulated descriptions of a measurable standard, desired state, threshold value, amount of change, or trend that you are striving to achieve for a particular plant population or habitat characteristic." The more clear and detailed your monitoring objectives are, the more successful your monitoring program can be. The way you structure your monitoring program (which monitoring/sampling techniques to use, how intensively or often to monitor, etc.) will depend greatly on the management objectives and questions you hope to answer with your data. Management and monitoring objectives fall into a number of categories, including but not limited to capturing baseline data prior to management activities, assessing the presence or absence of a species or population at a given site, evaluating management activities, tracking long term trends, assessing for legal requirements.

When designing your own monitoring program, the objectives should be clear and specific to your situation, and should include information on a number of site or species-specific details. The first component that a management objective should contain is the basic details of what needs to be monitored (species, population, subset of population, etc.) and where those plants are located. Secondly, your monitoring objective should include the attribute(s) of the population(s) you need to measure (density, cover, frequency, vigor, demography, population size, presence/absence data, etc.) and the type of change you are looking for (increase, decrease, no change). You also need to specify if you are interested in a numeric change in numbers of plants, populations, etc. or if you are interested in a spatial change in extent or ranges of populations, etc. The time-frame required and the degrees of change you want to see are the final components of defining a complete management objective.

In addition to the basic structure advocated above, Vesley *et al.* (2006) outline additional considerations. They recommend defining the desired level of precision you need from your data in order to answer your management question and that will allow you to provide managers with useful information following monitoring. Additionally, the level of change (in population trend, etc.) that will trigger a modification in management practices should be determined. Again, spatial and temporal scales of your monitoring will be the most helpful when they are clearly defined before the program begins.

Monitoring programs can provide a wide range of data that will answer a number of different questions, so a well-defined question is critical in determining the techniques to use and data to collect. If your goal is to detect population trends over time, the design of your monitoring program should also include considerations of statistical power to detect trends, contrasts between treatments, and statistical issues with sampling in order to collect data that will give you a reliable answer once analyzed (Lindemeyer and Likens 2009). If you have inherited a long term-data set and it is important to continue collecting data, you must be careful to make sure any changes in monitoring protocols are compatible with the historic dataset.

<u>How can monitoring help answer these objectives?</u>

Because funding for plant conservation activities is generally limited, undertaking a monitoring program that collects too much unnecessary data will pull valuable time and resources from other programs. Once you have clearly stated your management objectives, you can begin to design a monitoring program that will fulfill your goals. In order to get the most information for the least cost, you should aim to make your monitoring program only as intense as it needs to be to achieve your monitoring goals. In this report we categorize monitoring techniques into three different groups based on monitoring intensity. These levels follow groupings described by Menges and Gordon (1996) and Palmer (1987). Level 1 monitoring is the least intense level and consists of general counts or estimations of population number or spatial extent. This level is most useful in situations where you are looking to obtain baseline data on a species or population. Level 2 monitoring is more time and resource intensive than Level 1, and involves taking quantitative measures of the abundance or condition of a population. These data are then used to measure trends in a population or species over time. Finally, Level 3 is the most intensive level of monitoring, and consists of demographic monitoring, or marking and following individuals over time.

The types of data you collect will be based on your reasons for monitoring. While at times you may have a great deal of discretion in deciding what attributes of the species or population are the most important to measure, when monitoring for legal (National Environmental Policy Act (NEPA), Endangered Species Ace (ESA), etc.) requirements, you may have very specific data you need to record. Some recovery plans will specify details like minimum viable populations or trends that can help to guide you in designing your monitoring programs. However, if the recovery plan you are working with does not give specific targets to reach, or if you are monitoring for a reason other than legal requirements, you may have to determine on your own a suitable definition for a minimum viable population. A generally recognized definition of a minimum viable population is a population with >95% probability of persistence over 100 years. Often techniques such as a population viability analysis (PVA) can be used to calculate the population size that should be conserved. These numbers, however, are only guidelines, and may be altered depending on species life history, environmental variables, etc. This report is not meant as a detailed guide to completing a PVA, but more detailed information can be found in the primary literature, including Akcakaya and Burgman (1995), Menges (2001), and Coulson *et al.* (2001).

Once you have collected your monitoring data, it is important to not just set it aside or file it away. Analyzing and creating a report from your data will not only help to answer your monitoring questions, but will also help to illuminate any problems with your current methods. This will allow your monitoring programs to be adaptive, and to evolve iteratively as information emerges and questions change (Lindemeyer and Likens 2009). Most monitoring programs will include some sort of sample-based monitoring, and in these situations, statistical analysis is important in order to draw larger conclusions from smaller samples. The statistical power of the data you collect during a monitoring program should be thought about before the program begins, in order to assure that you can make quality analyses once the data are collected. A detailed explanation of many statistical analyses and where they can be useful can be found in Chapter 11 of *Measuring and Monitoring Plant Populations* (Elzinga *et al.* 1998). A number of software programs are available for free download from websites including http://www.freestatistics.info/stat.php and http://statpages.org/javasta2.html.

Finally, collecting data from monitoring programs will not help to answer your management questions or objectives unless the information is made available to those who need it. A monitoring program is not considered successful unless the information from the program is applied, resulting in changes or validations of current management strategies (Elzinga *et al.* 1998). Creating a report on your monitoring program will not only make the information you collected more readily available to interested parties, it also gives you a chance to reflect on the program and protocols. The first and most important question a report can help you to answer is whether or not your stated goals and objectives for the program are being met. Reviewing your monitoring program and protocols can also help you see if there are any data you are missing, or any extraneous data you are collecting that could be changed for the next year or monitoring cycle. In addition, reporting your results in a technical paper or symposium proceedings could be interesting and useful to others. Sharing your information has a number of benefits, including increasing your audience and possibly helping other monitoring programs, increasing your professional credibility, and contributing to your professional growth (Elzinga *et al.* 1998).

**How to use this document**

This report contains three separate pieces that are designed to stand alone or work together to help guide users through the steps of designing a monitoring protocol. We have also included a case study to illustrate a complete monitoring program including protocols, forms, data sheets, and a sample monitoring report. This text is the first piece of our report, and is intended to provide background on monitoring programs and to guide the user through the process of designing a monitoring program using the other two pieces of the report. The second piece of this report is a set of flow charts designed to guide you through the process of choosing a monitoring technique and sampling method. The **Primary Flow Chart** leads you to a monitoring level or intensity by guiding you through a set of steps designed to help clarify the question(s) you are hoping to answer with your monitoring program. Once you have chosen an intensity level to monitor, the corresponding flow charts for that level (**Level 1, Level 2, Level 3/Sampling**) will help to guide you to the most appropriate technique or sampling strategy to use in order to obtain the data you need to answer your monitoring questions. Each of these techniques and sampling strategies are then listed in the **Strengths and Limitations Table** as the third part of this report. Each technique and strategy is color coded and numbered to correspond to its matching box from the set of flow charts. In the table, you can then read more about the strengths and limitations of each of these choices, as well as see a list of references where you can read even more about a specific technique, in order to decide if it is the most appropriate choice for your particular situation. Additionally, if you are already using a certain monitoring technique, the strengths and limitations table can be a quick reference to check whether it is appropriate for your situation, or if a different technique may be more beneficial.

Once you have finalized your management objectives, one of the first decisions you can make is the level of intensity of program you need in order to answer your questions. In any monitoring program, tradeoffs between the amount and type of data you can collect and the time and resources available must be made (Palmer 1987). The level of intensity of a monitoring program increases as you move from Inventory Monitoring (Level 1), to Survey Monitoring (Level 2), to Demographic Monitoring (Level 3). Each level of monitoring intensity can help you to answer a different set of questions. **Level 1** is most appropriate when you are monitoring to acquire some type of baseline data on a species or population. With a small increase in time and effort, Level 1 monitoring can be enhanced to include the collection of stage class data. The inclusion of this extra data provides increased information on the population and can be used in a count-based PVA to provide you with some predictive power. An enhanced Level 1 monitoring program can also be easily converted to a demographic study if more detailed monitoring data is needed. **Level 2** is the most appropriate level to use when you are monitoring to observe trends in a population. These trends could be changes in numbers, changes in spatial extent or density, or response to a management action or treatment. When using Level 2 monitoring to observe changes in spatial extent, it is also necessary to make sure you collect spatial data, or a polygon. **Level 3** monitoring is the most appropriate method when you intend to predict trends over time. While the key term here is a prediction, Level 3 monitoring can be used to predict trends in population numbers or to predict a response to a management action or treatment. Level 3 monitoring is also the only level of monitoring that can help you to answer questions about particular life history stages or age classes of a population. More detailed information on advantages, disadvantages, and execution of the following techniques can be found in the cited literature. Any cited page numbers refer to pages in *Measuring and Monitoring Plant Populations* (Elzinga et al. 1998 available at: http://www.blm.gov/nstc/library/techref.htm).

Depending on your specific situation and monitoring goals there are a number of different techniques that can be used within each level of monitoring intensity. **Level 1** monitoring is the least intensive level, but it can still provide you with important data on your population or species. After you have decided that you plan to monitor for baseline data, the first question to ask is whether you are monitoring to make sure the population or species is still there, or if you want to obtain a measure of how much of it is there. If you are only interested in whether a species or population is still present in a site, a simple presence/absence measure[1*] will be sufficient (Elzinga et al.. 1998, pp. 159). If your monitoring question requires a measure of abundance[2], you will need to decide between a complete count of a population[2b] (pp. 168) and an estimation of population size[2a] (pp.159). Complete counts are best for small populations (<500), while estimations are more appropriate for large populations (>500) or when you are dealing with a sensitive habitat where trampling needs to be avoided. When performing a complete count, the technique of a patterned search[2b1] should be used; while a meander search[2a1] (Lancaster 2000) is a better technique for making an estimation of population size. **In both cases, the searches can be combined with identification of individual stage classes[3] as enhanced count data in order to gain more information and some predictive ability on your population or species (pp.171).**

**Level 2** monitoring is appropriate to use when you are looking for trends in a population or species. If the trends you are hoping to observe are changes in numbers, then monitoring frequency[5] is the most appropriate option (pp.175). Once you have decided on using a measure of frequency, the technique you use should be based on the rarity of your species, and then density of surrounding vegetation. If the species you are monitoring is common, the most appropriate technique to use is the point-intercept method[5b], which works especially well when measuring/monitoring adult trees. If your species is rare, the method you choose will be based on the density of surrounding vegetation. If the vegetation surrounding your focal species is dense, the nested frequency method[5a] is best, while the line-intercept method[5c] should be used where there is sparse vegetation. When using Level 2 monitoring techniques, you can also look to observe a trend in density or spatial extent of a species or population. When monitoring to see this change in individuals, density[4] (pp. 168) is the measure you should record, while when monitoring for changes in relative abundances, cover[6] is a more appropriate method (pp. 178). When measuring density, the line-intercept method[4a] is most appropriate when your population is large, randomly distributed, and/or along an obvious gradient. If you have large, scattered individuals, you may also be interested in measuring nearest neighbor distances[9a] (pp. 173). On the other hand, when you have a small population with a clumped distribution, the quadrat method[4b] is a more appropriate way to measure density (pp. 170). When using cover as a measure it is important to consider the fact that it can be very subjective. One of the most important factors to consider in choosing your technique to measure cover is the number of investigators that will be doing the data collection in order to minimize observer bias. Cover quadrats[6c] should only be used if a single investigator will be making all of the cover estimates (pp.111). Photoplots and photopoints[8a] can also be very useful when a program

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***Numbered/Lettered superscripts correspond to the techniques and sampling strategies in both the flow charts and strengths and limitations table.**

has limited time and investigators, but the species is very easily identified within photographs (pp.161). When you have multiple investigators, the technique used should be based on plant height. For tall plants (>1m) the point-intercept method[6a] is more appropriate (pp.182), and for shorter plants (<1m) the Daubenmire method[6b] of 6 defined cover classes is the most useful (Daubenmire 1959).

**Level 3** demographic monitoring is the most resource and time intensive level, however it is the only level of monitoring able to provide you with predictive power. In order to justify the use of demographic monitoring, you need to have a very well-defined and specific question (i.e., is this management treatment better than this one? Is this environment type better than another one? Is factor A a bigger threat to the species than factor B?). If done correctly, demographic monitoring will allow you to assess the impact of management on population growth rates intensively over 3-5 years at a few sites. This type of monitoring strategy works well to answer questions involving how a particular management action or treatment affects particular life history stages. Demographic monitoring also requires knowledge of, or access to, math and statistics expertise in order to analyze the data collected and produce informative results. A comprehensive discussion of demography and associated techniques can be found in Chapter 12 of Elzinga et al. (1998).

Demographic methods[10] are defined by measuring individuals and their success or fate over time. In general, the main advantage of demographic monitoring over other types is the ability to use the data collected to make predictions. To use demographic data for predictive purposes, you must first assign each plant to a stage/age class, and then you can determine the frequency within each stage/age class. To do this you should use a frequency table or matrix, which can be done with R (R Project, www.r-project.org; codes for this can be found in Morris and Doak 2002). Before you can start to collect data, you will need to decide which plants you want to include (choose a sampling method) and the best way to track those individuals over time. When deciding on a sampling method, you want to keep in mind the scale on which you are working. The scale of a sampling scheme is going to be dependent upon the organism in question, particularly the size and spatial distribution of the organism. For example, you wouldn't want to sample a hectare$^2$ plot to sample a pincushion moss, but neither would you want to sample a meter$^2$ plot to sample oak trees. You want to design the scale of your sampling scheme to provide the most useful results for your question.

Unless the population you are monitoring is small enough (<500 plants), you will likely need to mark and follow only a subset of plants, rather than every individual. Sampling strategies can be divided into three main categories; random sampling[A], cluster sampling[C], and systematic sampling[B]. Random sampling is best when you are dealing with a small population that has a regular or random distribution. If your population is dense, a simple random[A1] sampling method is best, while a stratified random[A2] sample is more appropriate when your plants are distributed along an obvious environmental gradient (soil moisture, aspect, major vegetation type, etc.) or slope. Cluster sampling methods work best for sampling small populations with clumped distributions. If your plants are fairly common, the two-stage sampling method[C2] may be best, while adaptive cluster sampling[C1] (Philippi 2005) may be more beneficial if the plants you are monitoring are rare. Finally, systematic sampling methods are the most efficient way to sample very large populations. If you have a large population that is spread out over a relatively smaller spatial scale, a grid-based survey[B1] (Young et al. 2008) may be the most appropriate sampling method to use. On the other hand, if your population is spread out over a very large area, a dot-grid[B2] sampling method (Hamilton and Megown 2005) may be best, as it employs the use of areal photography and can cover very large areas. Finally, if your population is spread out along an environmental gradient and/or your population is spread out over long distances and has sparse distributions, transects[B3] (Barker 2001) may be the most appropriate method of sampling.

Having a clear sampling methodology will help to avoid a sampling bias (such as sampling only the biggest plants) and to achieve a sample that is well representative of the population at large. In all cases, once you have sampled your population, you will need a way to track individuals over time. The two most common methods are tagging individual plants or mapping plants within a plot (a type of mark/recapture method). The method you choose should be based on the species you are monitoring as well as the sampling strategy used. More information on the above sampling strategies can be found in Chapter 7 of Elzinga et al. (1998) and the other cited works.

Once you have decided how to sample your population, you must also decide what attributes you plan to measure, and how you plan to measure them. There are a number of variables you should consider when carrying out a demographic monitoring program, including plant size, reproductive state, and fecundity (flower number, fruit number, fruit: flower, seed: ovule, germination). These data can then be used to calculate mortality, survivorship, and recruitment in your population in order to determine population growth or to make predictions for the future of your population. When taking plant measurements (plant height, basal area, leaf length, leaf area, etc.) it is extremely important to make sure your measurements are consistent. Having a detailed protocol for taking these measures will help to decrease variation in measurements especially when there are multiple data collectors.

**Conclusion**

The planning that goes into designing a monitoring program is important, as a poorly-designed monitoring program can often harm a species or population by wasting time and resources and damaging sensitive habitats. Protocols in a successful monitoring program should be based on the management and monitoring questions you hope to answer along with the species that is of concern. Different levels if monitoring intensity will provide you with different types of data, so it is important to choose the level that will provide you with the answers to your questions while staying within your time and resource budget. If you have enough time and funding to complete a full demographic study, it will provide you with the most detailed data set and give you predictive power. However, funding and manpower are generally limited in most monitoring programs, and for this reason we have highlighted a technique of collecting enhanced count data as a compromise. This technique takes little more time and effort than recording simple count data, but gives you with the ability to use the data in a count-based PVA to provide some predictive power. Data gained from a well-designed monitoring program can be extremely valuable in aiding managers in making well informed decisions when it comes to taking management actions.

**Optimal Monitoring Case Study – *Lespedeza leptostachya*, a federally threatened gravel-hill prairie plant**

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## Introduction

The following case study illustrates the creation and execution of a monitoring program for the federally endangered prairie plant, *Lespedeza leptostachya* (Prairie Bush Clover), growing in Nachusa Grasslands in Illinois. The biology of the species, as well as the specific management goals and objectives of Nachusa Grasslands were taken into consideration when selecting a monitoring level and technique. Monitoring at all three levels of intensity was undertaken in response to specific management objectives, and as part of an adaptive management strategy. A description of the study plant and site are provided as background information on the study. Explanations of protocols used for each monitoring level and examples data collection forms used in the monitoring program are also provided.

Overview of species and study site

The genus *Lespedeza* (Fabaceae) is comprised of about 160 species, 11 of which are native to the United States (Clewell 1964). One of these species, *Lespedeza leptostachya*, commonly known as prairie bush clover, is a Federally Threatened herbaceous perennial legume, and is endemic in only four states: Minnesota (55 populations), Iowa (29 populations), Illinois (16 populations), and Wisconsin (27 populations). Most populations contain less than 100 individuals. It grows predominately on north-facing slopes in mesic tallgrass prairies in several soil types, most commonly underlain by limestone (USFWS, 1998). It is also State listed as endangered in Illinois and Wisconsin and threatened in Iowa and Minnesota (USFWS 1998). The highest density populations occur in southern Minnesota and northern Iowa near the Des Moines River Valley (USFWS 1988, Sather, Minnesota Department of Natural Resources, personal communication). Only 40 % of the occurrences are on public land and therefore afforded protection under the Endangered Species Act (Kurz and Bowles, 1981).

Nachusa Grasslands supports the largest population of *Lespedeza leptostachya* in Illinois. Over 600 native species can be found at the Grassland including other rare plant species, grassland birds, and arthropods (Taft et al. 2006). Owned by the Illinois Nature Conservancy, Nachusa Grasslands comprise 2500 acres of prairie, savanna, woodlands, and wetlands, located at the border of Lee and Ogle County in Northwestern Illinois (41°53'N latitude and 89°20'50 longitude). 81 of these acres are remnants of naturally occurring community, while the remainder were once developed for agriculture and are now being restored by docents and stewards of the Grassland to a more natural state (Taft et al. 2006).

Where the sandstone substrate is buried more deeply, silt loam or sandy loam soils characterize the site (Taft et al. 2006).

*L. leptostachya* life history

*Lespedeza leptostachya* occurs in remnant gravel hill prairie at Nachusa Grassland and, like other species in the genus, it reproduces *via* seed produced by both cleistogamous and chasmogamous flowers; however vegetative reproduction is not unknown. Plants reach maturity after six to nine years and may live up to ten years (Sather 1989). A single plant can flower up to four years with low mortality rates (USFWS 1988). The species typically begins germination in May. Reproductive adults flower in mid July and begin seed production in early September. Adults may produce up to 560 pods per plant but average about 235 pods.

Seeds are borne singly in pods and reach maturity in October. Not all pods contain seeds and seeds are produced primarily from cleistogamous flowers. A study conducted in Minnesota revealed that cleistogamous pods formed seeds with a 75% frequency while chasmogamous pods formed seeds with a 17% frequency (US Fish and Wildlife Service). A greenhouse study, conducted at the University of Kentucky, revealed that most *L. leptostachya* seeds germinated in the first growing season and the *L. leptostachya* seed bank longevity lasted only 3 years (Baskin and Baskin 1998). Seed bank and germination studies are underway at Nachusa Grasslands (Vitt personal communication)

Due to *L. leptostachya* primary reproduction via cleistogamous seed output, *L. leptostachya* is hypothesized to have low genetic diversity. Cole and Biesboer (1992) conducted an allozyme study of *L. leptostachya* and *Lespedeza capitata* comparing their genetic diversity from samples collected at 40 locations throughout Minnesota, Wisconsin, and Iowa. They found that *L. leptostachya* was entirely monomorphic. (†$F_{st} = 0$), indicating that under stressful conditions, such as hybridization, *L. leptostachya* populations could be subject to increasing chances of extinction. However, Cole and Biesboer (1992) did not include Illinois populations of *L. leptostachya* in their studies. Illinois' populations of *L. leptostachya* have dramatically less chasmogamous flowers than Minnesota, Iowa, and Wisconsin populations indicating that their might be a genetic distinction among populations (Pati Vitt personal observation). A preliminary study of five *L. leptostachya* populations occurring in Illinois using ISSR (Inter Simple Sequence Repeat) methods conducted by the Chicago Botanic Garden (2001 unpublished data) found that they significantly differed (Fst = 0.42, 0.25, 0.25). Neutral genetic markers therefore indicate that *L. leptostachya* is more genetically diverse than shown by the allozyme study of Cole and Biesboer (1992).

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† **Fixation index ($F_{ST}$)** is a measure of population differentiation, or genetic distance, based on genetic polymorphism data, such as ISSR's. $F_{ST}$ may be thought of as a measure of the amount of allele frequency variance in a sample relative to the maximum possible. It is often expressed as the proportion of genetic diversity due to allele frequency differences among populations, thus comparing levels of genetic variability within and between populations with values ranging from 0 to 1.

Threats to *L leptostachya*

*Lespedeza leptostachya* faces both anthropogenic and biological threats including: development, mining, competition, granivory, as well as climate change and loss of species distinction as a result of hybridization with the common congener *Lespedeza capitata*. Development threats include both agricultural expansion and rural development. Agricultural expansion poses three major threats: direct conversion of land to row crops, grazing, and broad leaf herbicide treatment. Rural development directly decreases *L. leptostachya* habitat by highway and pipeline expansion. Biological threats add another cause of concern for *L. leptostachya* viability. Competitors such as *Schizachyrium scoparium* (Little Blue Stem), and woody species: *Ceanothus* species (Buckthorn species), *Crataegus* species (Hawthorn species), *Juniperus virginiana* (Eastern Red Cedar), *Populus tremuloides* (Quaking Aspen), *Prunus* species (Cherry species), *Quercus macrocarpa* (Burr Oak), *Quercus velutina* (Black Oak), *Rhus glabra* (Smooth Sumak), *Rhus typhina* (Staghorn Sumak), *Symphoricarpos occidentalis* (Western Snowberry), and *Vitis riparia* (Riverbank Grape), can intrude on *L. leptostachya* habitat. A study conducted at River Falls North in Wisconsin, a location where *L. leptostachya* was once found is now shaded by *Quercus velutina* and *Populus tremuloides*. The *L. leptostachya* plants are now most abundant on an open roadside. Only 32 individuals remain in the shaded area *versus* 118 individuals growing along the roadside.

In addition, granivory and herbivory pose both short and long term threats. In particular, late season herbivory on plants reduces their average height and seed production in the following growing season. Seed predation by small mammals and rabbits has been documented, as well as by *Cuculionoid* or *Brucid* beetle larvae, which have been found inside seed pods. Biological threats such as threshold population size, loss of pollinators, disease, responses to grazing and fire, and low seedling recruitment all may affect the viability of *L. leptostachya* populations (USFWS 1988).

Most *Lespedeza* species naturally hybridize, yet hybrids are rare and comprise only 0.1-10% of populations. Hybrids are often less fit than parents and genetic introgression is common (Clewell 1966). *L. leptostachya* frequently co-occurs with its common congener *Lespedeza capitata* and both field studies of morphological measurements, and molecular genetic studies were conducted to determine if hybridization does occur between these taxa. The presence of hybrids, and potential for backcrossing or selfing, was confirmed by genetic markers. Individuals that were morphologically identified as hybrids had cpDNA phentotypes identical to *L. leptostachya* and nDNA phenotypes of both parents, providing support that hybridization and potentially backcrossing or selfing is occurring in these populations of *L. leptostachya,* with *L. capitata* serving as the pollen donor and *L. leptostachya* as the maternal plant (Fant et al, in press).

Adaptive management of existing populations, coupled with monitoring of the responses to that management, is a critical tool to assess the viability of the species. Monitoring occurs at all known sites in Illinois, as well as three sites in Wisconsin, seven sites in Iowa, and three sites in Minnesota, though the method at each site varies. Demographic studies are underway at sites in Minnesota, Iowa, and Illinois. Removal of woody species that co-occur with *Lespedeza leptostachya*, which might over-shade the population, is occurring at Westport Drumlin Prairie State Natural Area in Wisconsin, Prairie Bush Clover Scientific and Natural Areas, Kilen Woods State Park in Minnesota (USFWS 1988). Preliminary studies conducted by Smith (1991) on the effects of fire and competition on *L. leptostachya* population growth indicated that fire reduced competition and increased the abundance of *L. leptostachya.* Additional studies by Bockenstedt (2002), Bitner and Kleinman. (1999) and

Menges and Quintana-Ascencio (1998) did not find any conclusive evidence on the benefits of fire and grazing. Finally, controlled burns and grass specific herbicide treatment is being conducted at Nachusa Grasslands (Chicago Botanic Garden 2007).

## Adaptive Management and Monitoring at Nachusa Grasslands

### Count-Based Monitoring/Level 1

*Lespedeza leptostachya* was discovered in Dixon, Illinois in 1981. At that time, there were two subpopulations with a total of 125 plants. In 1986 The Nature Conservancy acquired the first parcel of land that was to become the Nachusa Grasslands Preserve. They eliminated grazing on the preserve in 1986, a standard practice throughout the range of *L. leptostachya,* when a parcel was brought into protection. After grazing was suspended, the population exploded to a total of 585 plants across 7 subpopulations. Since then, however, the population has been declining. This pattern has been found on sites throughout the range when grazing has been totally suspended (Nancy Sather, pers. comm.).

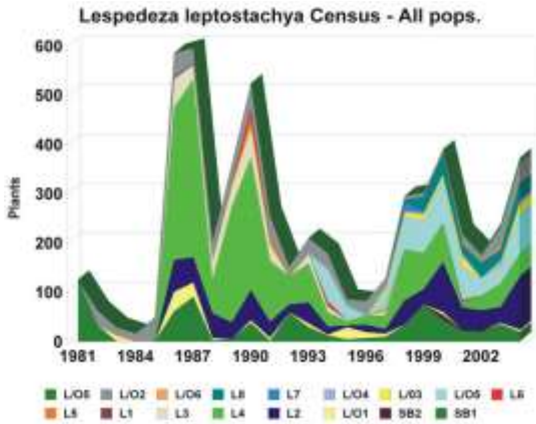

Figure 1. Population census of all *L. leptostachya* populations, 1981-2003.

In order to collect baseline data on the populations after grazing was suspended, a complete population count was undertaken using a patterned search. The count was performed along a transect of a known sub-population. Groups of 7-10 people walked the length of the site about 1 meter apart, and all plants encountered were recorded and categorized as either sterile, subadult, or adult. This additional enhanced count data on stage classes was taken in order for us to have the ability to perform a count-based PVA. Very small plants and juveniles are not encountered with this method, and as a result, the true populations could be at least twice as large as the census populations in well managed sites.

Given the apparent decline of *Lespedeza leptostachya* in Illinois over the past 20 years, one of the best opportunities to maintain a viable population outside its core range of northern Iowa and adjacent southwestern Minnesota is at Nachusa Grasslands. Based on the most recent site visits, Nachusa Grasslands has the largest existing population in Illinois, and it will be important for restoration efforts involving reintroduction and transplantation of prairie bush-clover into suitable habitats.

### Count-based PVA of Nachusa Grasslands Populations:

To determine the likelihood of extinction at the site, an analysis of the census counts over a 20-year period was conducted. Figure 2 displays annual transect survey data from 1982-2004 for the Nachusa Lee/Ogle site. Visually assessing the trend in this sub-population leads to two conclusions: 1) the sub-population appears to be increasing over time; and 2) the sub-population appears to experience both bonanzas and catastrophes. Although we might expect to see a pattern of "boom and bust" cycles in an annual species, this is not generally true for long-lived perennials. The apparent pattern may simply be an artifact of sampling error. However, it may also indicate a population that is unstable, which may therefore be more susceptible to stochastic environmental events.

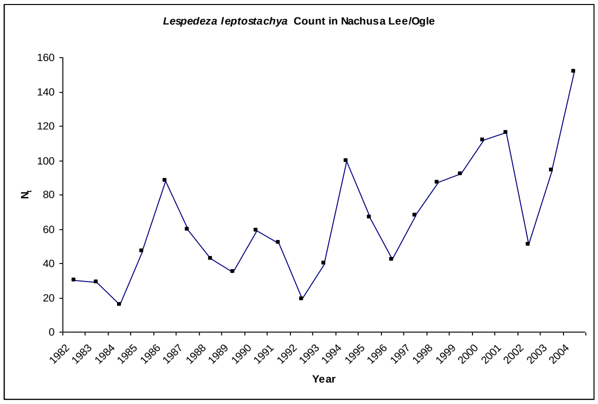


Figure 2. Data from annual transect surveys of *L. leptostachya* at the Nachusa Lee/Ogle site, 1982-2004

To assess if the population has an increased risk of extinction, a "count-based" method of population viability analysis was undertaken to determine the extinction probability of this species at this site, given a particular extinction threshold. Collecting information on stage classes as part of our enhanced count method allowed us to complete this type of predictive analysis. We chose a threshold of 15 individuals of *L. leptostachya*. That is, <u>if</u> the population ever declines to 15 plants the population is considered to be "demographically extinct." Two different count-based models were undertaken, one assumes all individual *Lespedeza leptostachya* compete equally (scramble competition) for the resources provided at the Nachusa Lee/Ogle site, where a Ricker model may be used to estimate extinction risk. The other model assumes there is a competitive hierarchy where some individuals out-compete others, and a Beverton-Holt model must be used to estimate population viability in this case.

In the short-term, the Ricker model showed that with a quasi extinction threshold of 15, there is 100% confidence that there is less than a 20% chance of extinction in 10 years. In comparison, the second model's 10-year risk gives us 100% confidence that there is no more than a 10% chance of extinction (Klaus et al, unpublished data). Looking at extinction probability over 100 years, however, there is an approximate 50% risk of extinction with the Ricker model. This is a high enough probability of extinction to warrant better management. This is shown in Figure 3a. Furthermore, if the quasi extinction threshold was set higher, the extinction probability would also increase over the 100 years. The extinction probability for the Beverton-Holt model over 100 years was minute, indicating a highly viable population (Figure 3b). However, sampling error may have contributed to biased estimates of extinction risk. As discussed earlier, the exclusion of juvenile individuals in sampling could have led to an underestimate of population size, which in turn may have caused an overestimate of extinction risk in the models.

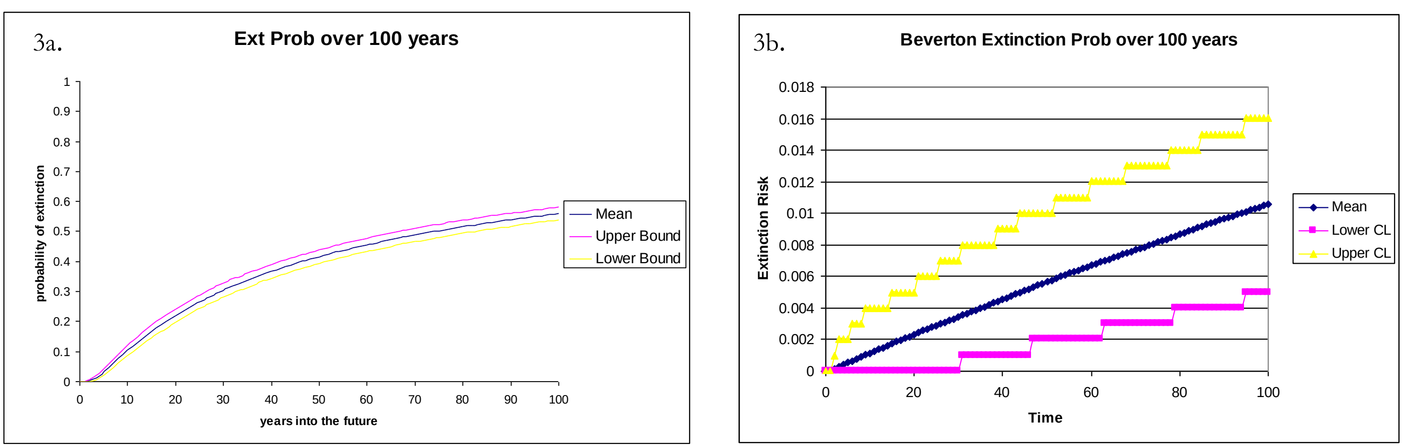


Figure 3. Extinction probabilities for *L. leptostachya* over 100 years using the Ricker model (3a) and the Beverton-Holt model (3b).

We conclude from these results that while the population at Nachusa Grasslands is viable over the long-term, adaptive management of the population might decrease the risk of extinction. Given a correlation with local population decline and the cessation of grazing, periodic grazing might be used to increase growth rates and lower the probability of extinction of prairie bush-clover, given its susceptibility to competition. Current burning regimes should also be modified to include grazing, as only burning tends to increase competition. Literature also indicates the species is threatened by lack of genetic diversity within and among populations. A plan for interbreeding would, then, allow for more genetic exchange. Additionally, even if this population did go extinct in 100 years, it could possibly be re-introduced from another site. Finally, further development of sampling techniques to include juvenile individuals would also be useful in making more accurate estimates of population size and probability of extinction.

**Adaptive Management of *Lespedeza leptostachya* – Grazing and Level 2 Monitoring**

Although conventional wisdom suggests that suspension of grazing should ensure population viability, populations of *Lespedeza leptostachya* began to decline when grazing was been completely eliminated as a management goal. *L. leptostachya* most likely evolved within a competitive regime that included bison, which may have significantly decreased levels of direct competition with many grass species, particularly *Schizachyrium scoparium*, little bluestem. As a result of the declining numbers, a grazing experiment with Level 2 monitoring was undertaken to assess the efficacy of grazing as a management tool at Nachusa Grasslands in Dixon, IL. The experiment was carried out to determine if grazing would decrease the cover of both forbs and grasses potentially decreasing competition, resulting in increased juvenile recruitment, and leading therefore to an increase in the population size.


Figure 4. Juvenile *Lespedeza leptostachya*, located as a result of close "hands and knees" search of each meter square Level 2/3 plot. Numbered tags are always placed 2 cm directly north of the plant being demarcated.

Thirty meter square permanent plots were created in August 2000 (Year 1), each centered on a randomly selected single adult plant of prairie bush clover. In Year 2, 15 randomly selected plots were grazed, while the remaining 15 plots were left ungrazed. Normal management practices, including burning, were conducted throughout the course of the study. Variables collected over the course of the study included percent cover, as well as height, of all species in the plots in each year during the latter part of August. All plants were counted and categorized as 1) Juveniles (<20cm in height, with no reproductive structures); 2) Sub-Adults (< 20cm in height at flowering); 3) Sterile Adults (non-flowering individuals > 20); and 4) Adults (> 20cm at flowering). A thorough search for juvenile plants of prairie bush clover in all plots was also conducted.

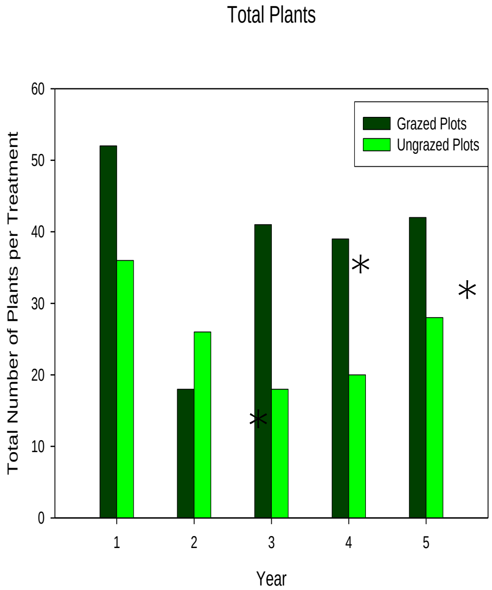


Figure 5. Numbers of *L. Leptostachya* plants in each grazing treatment over 5 years after treatment. Asterisks indicate statistically significant differences.

There is a significant difference in the total number of plants of prairie bush clover in the grazed versus ungrazed plots in the year (Year 3 in Figure 5) after treatment (T=1.758; P=0.05; d.f.=14). Overall, there was a 33% decline in the number of target plants during the course of the study, however the grazed plots experienced only a 25% loss while the ungrazed plots experienced a 45% decline. The pattern of decline shows that the grazed plots rebounded in the year after treatment through an increase in the number of juveniles, leading to a significantly greater number of individuals overall in the grazed plots relative to the control. Because we only tracked the number of plants, identified by stage, without marking and following individuals, however, we cannot estimate the effects of grazing on survivorship.

**Adaptive Management of *Lespedeza leptostachya* – Grass-Specific Herbicide and Level 3 Monitoring**

Investigation into the effects of grazing on recruitment, especially of plants deemed to be juvenile, revealed that grazing positively affects the number of juveniles located in grazed plots relative to ungrazed plots (Bittner and Vitt, unpub. data). While grazing had the desired effect, the logistics on site proved to be difficult, particularly as an ongoing management tool. Therefore, concluding that the response was likely due to reduced grass competition, it was determined that the application of a grass-specific herbicide may be a viable management tool for this species.

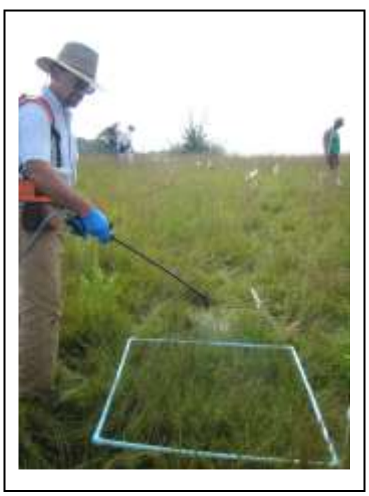

Figure 6. Bill Kleiman, Director of Nachusa Grasslands, spraying Poast herbicide on one of *Lespedeza leptostachya* plots in August of 2007.

In order to assess the efficacy of this management approach, an herbicide-treatment experiment was begun in August 2007. It was determined that the most accurate assessment of the experimental treatment could only be undertaken in the context of a demographic Population Viability Analysis (PVA), requiring Level 3 monitoring. In addition, the sample size, including both the number of plots and the number of plants, was increased to improve statistical power. An additional 20 meter-square plots were created using the same selection criterion as in 2000. All individual plants found in each plot were permanently marked with a unique numbered tag, and Poast, a grass-specific herbicide, was applied to 20 randomly selected plots in both 2007 and 2008 while the remaining 31 plots served as the control. Variables collected in this study include: average height of the little bluestem in each plot to assess response to herbicide, as well as height and cover class of all species found in the plots to determine if community composition changes over time in response to differing competitive regimes. The height and age class of each permanently marked *Lespedeza leptostachya* is also recorded, as well as the presence and height of additional seedlings or juveniles. Branch number and length have also been recorded, as well as a count of seed pods, which are primarily cleistogamous.

The annual life cycle graph of *Lespedeza leptostachya* will explicitly incorporate the mixed-mating system found in this species (cleistogamous and chasmogamous seed types). Each circle represents a stage class, and arrows represent vital rates (fecundity, stage transitions) from one year to the next. The PVA will be conducted after the close of the 2010 field season. However, preliminary results indicate that Poast effectively reduces the grass cover in the treated plots, and there appears to be a greater number of seedlings and juveniles in the treated versus the untreated plots. The effects on the overall viability of this population are yet to be determined.

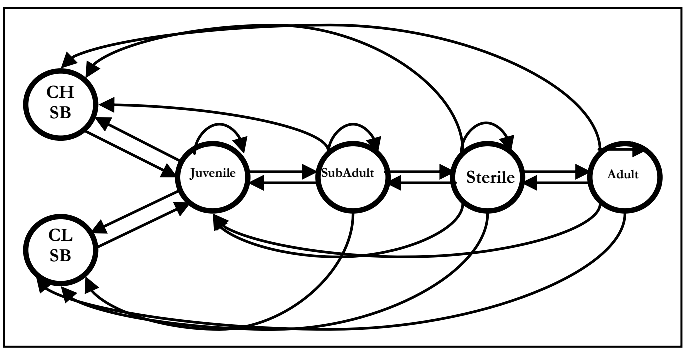


Figure 7. Annual life cycle model of *Lespedeza leptostachya*. CH/SB = Chasmagamous seed production and soil seed bank arising from chasmogamous seeds. CL/SB = Cleistogamous seed production and soil seed bank arising from cleistogamous seeds.

**Preliminary Conclusions** - A total of 415 marked individuals in 90 meter$^2$-plots centered on focal reproductive adults (45 control plots and 45 plots treated with Poast grass-specific herbicide) have been monitored to determine the efficacy of management. **Significantly more new seedlings have been found in the plots treated with Poast than those left untreated, indicating that grass competition inhibits seedling recruitment, particularly when fire intervals are great enough to increase the cover of dead organic material**. Treatments and monitoring of these plots will continue, for a minimum of once yearly for the foreseeable future. We are finalizing analysis on the data and will be modeling the demographic impacts of increased seedling recruitment to determine the effects of using Poast on population growth rates. We expect the results to show that this management activity, especially when combined with fire, is an effective tool in the recovery of this species.

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**Sample Data Sheets**

Level 2 data collection form: *L. leptostachya* grazing study, Nachusa Grasslands

Plot # 97

**NACHUSA GRASSLANDS LESPEDEZA LEPTOSTACHYA GRAZING STUDY**

**Date:** 8/30/05 **Investigators:** Bittner, Wiese

**Management Unit:** GR 1 GR 2 GR 3 UNGR 1 UNGR 2 (UNGR 3)
**Plot:** 1 2 3 (4) 5 **Burned Last Year:** (Y) / N

| *Lespedeza leptostachya* | Juvenile | Sub-adult | Sterile Adult | Adult |
|---|---|---|---|---|
| # of plants w/ 1 stem | | | | III |
| # of plants w/ 2 stems | | | | II |
| # of plants w/ 3 stems | | | | |
| # of plants w/ ___ stems | | | | |
| **TOTALS** | 0 | 0 | 0 | 5 |

Cover Class: **1** (0-1%); **2** (1-5%); **3** (5-25%); **4** (25-50%); **5** (50-75%); **6** (75-95%); **7** (95-100%)
Height Class: **1** (1-10cm); **2** (10-20cm); **3** (20-50cm); **4** (50-100cm); **5** (100+cm)

| Plant ID # | Height (cm) | Flower shoots | Stems | East Coord. | South Coord. |
|---|---|---|---|---|---|
| 26 | 57.5 | 13 | 1 | | |
| 27 | 63.3 | 17 | 1 | | |
| 28 | 39.2 | 9 | 2 | | |
| 29 | 20.5 | 4 | 2 | | |
| 101 | 22.5 | 1 | 1 | 19 | 72 |
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Level 3 data collection form: *L. leptostachya* plant competition study, Nachusa Grasslands

## NACHUSA GRASSLANDS LESPEDEZA LEPTOSTACHYA PLANT COMPETITION STUDY

**Date:** 8/30/07 **Investigators:** Vitt + Bittner

**Management Unit:** H 1 C 1 H 2 (C 2) H 3 C 3 **TAGGED PLOT #** 2982

**Burned Last Year:** (Y) N

| *Lespedeza leptostachya* | Juvenile (< 20cm, not flowering) | Sub-adult (< 20cm, flowering) | Sterile Adult (> 20cm, not flowering) | Adult (> 20cm, flowering) |
|---|---|---|---|---|
| # of plants w/ 1 stem | | | 11 | 11 |
| # of plants w/ 2 stems | | | | |
| # of plants w/ 3 stems | | | | |
| # of plants w/ ___ stems | | | | |
| **TOTALS** | | | 2 | 2 |

Cover Class: **1** (0-1%); **2** (1-5%); **3** (5-25%); **4** (25-50%); **5** (50-75%); **6** (75-95%); **7** (95-100%)
Height Class: **1** (1-10cm); **2** (10-20cm); **3** (20-50cm); **4** (50-100cm); **5** (100+cm)

| Plant ID # | Height (cm) | Flower shoots | Stems | East Coord. | South Coord. |
|---|---|---|---|---|---|
| 1975 | 1.5 | 0 | 1 | | |
| 1909 | ∅ | | | | |
| 1940 | 57.0 | 9 | 1 | | |
| 1905 | 19.0 | 6 | 1 | | |
| 1915 | 6.0 | 0 | 1 | | |
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Jay + Cindi

| ASSOCIATE PLANT SPECIES | Cover Class | Height Class |
|---|---|---|
| ~~Andropogon~~ Little Blue | 5-10% | 14.5 25.5 |
| Andropogon-dead | 0% | 22.5 23.0 26.0 |
| Rosa carolina | 5 | 4 |
| Rubus alleganianthus | 2 | 3 |
| Viola sagitata | 3 | 2 |
| Dicanthenium Villossissum | 3 | 2 |
| Uthamia gymnospermoides | 3 | 3 |
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| | | |
| | | |
| | | |
| CG | 1 | |
| open ground | 1 | |

Note disturbance & % area:

Level 3 data collection form: Demographic study

*Lespedeza leptostachya* Demography Study at Nachusa Grasslands, IL

Site:
Plot:
GPS:
Picture #:
Picture taken by:

Date:
Investigators' Names:

Management Unit: H1 H2 H3 C1 C2 C3
Burned Last Year: Y / N

*Lespedeza leptostachya*

| Plant ID | # Stems | Stem # | Plant Height | # Branches | Branch Length 1 | Branch Length 2 | Branch Length 3 | Branch Length 4 | Branch Length 5 | CL Flowers/Fruit | # Flowering Stems | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
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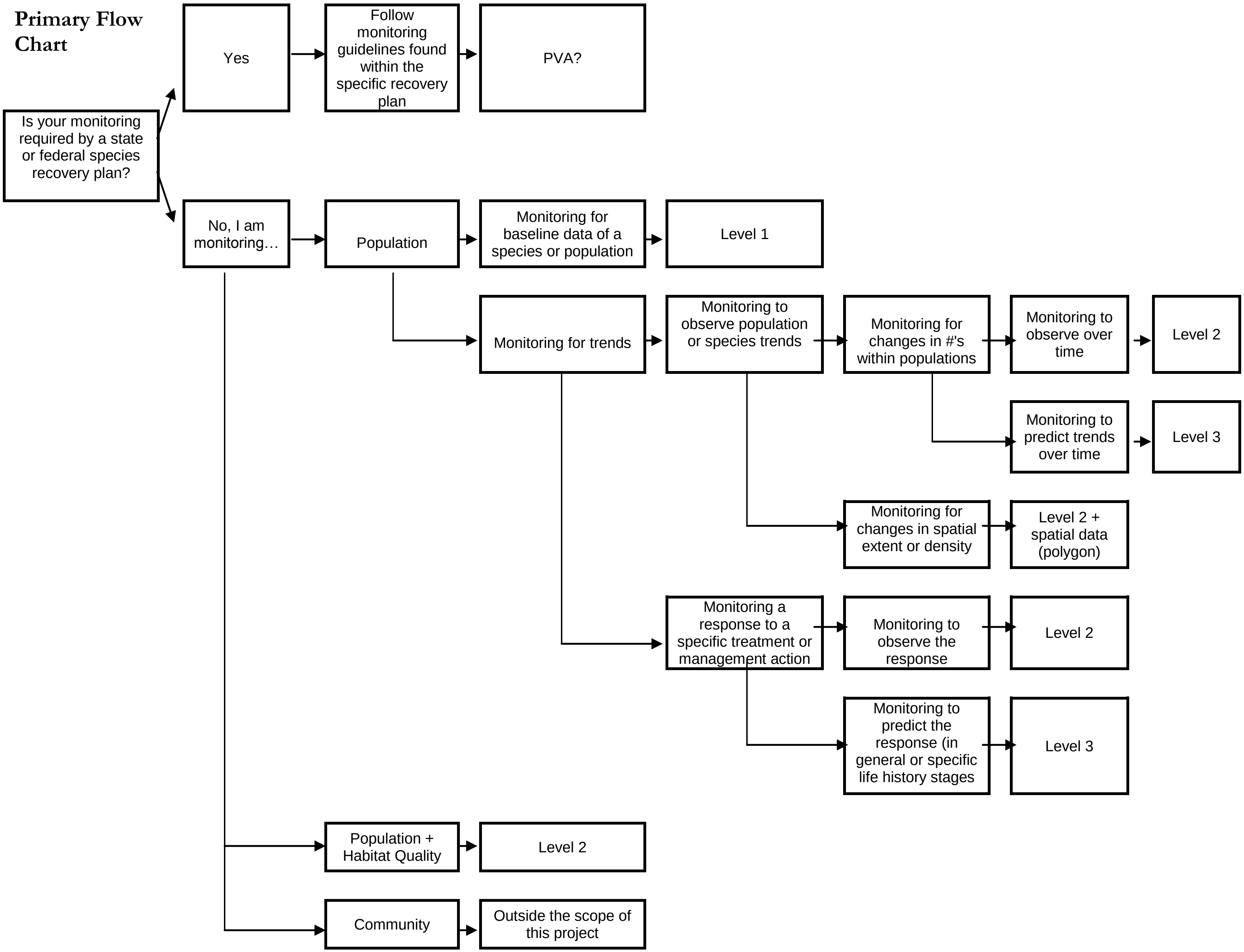
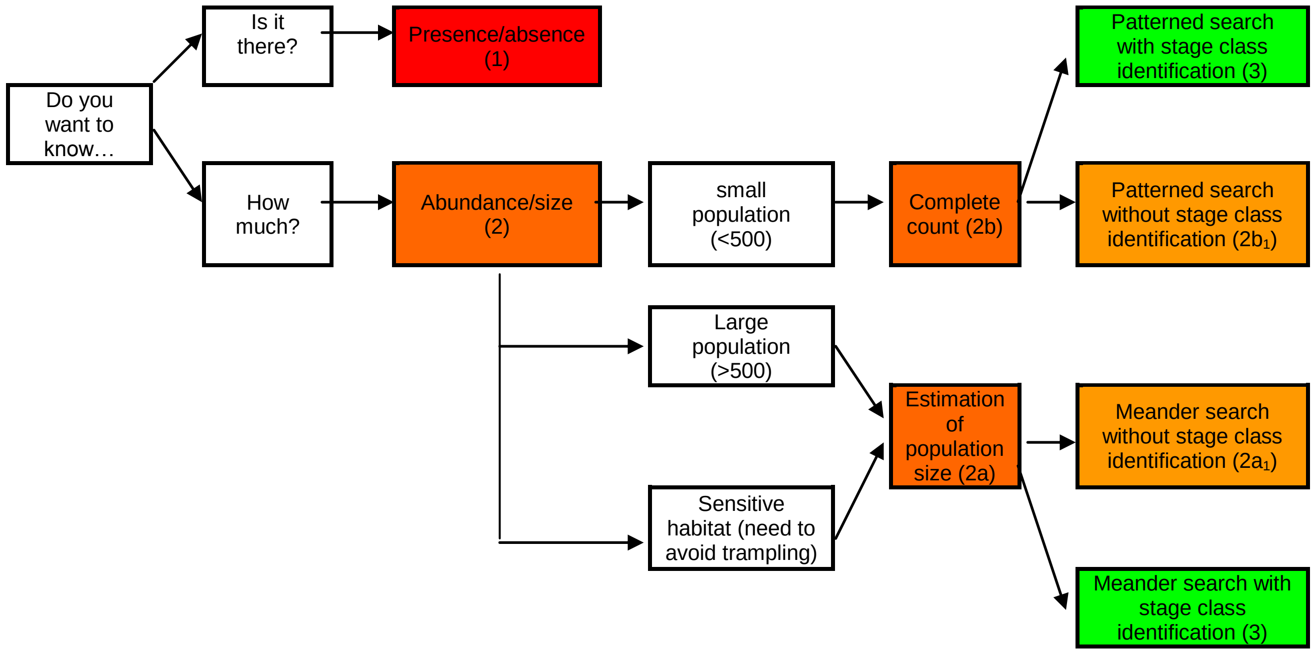
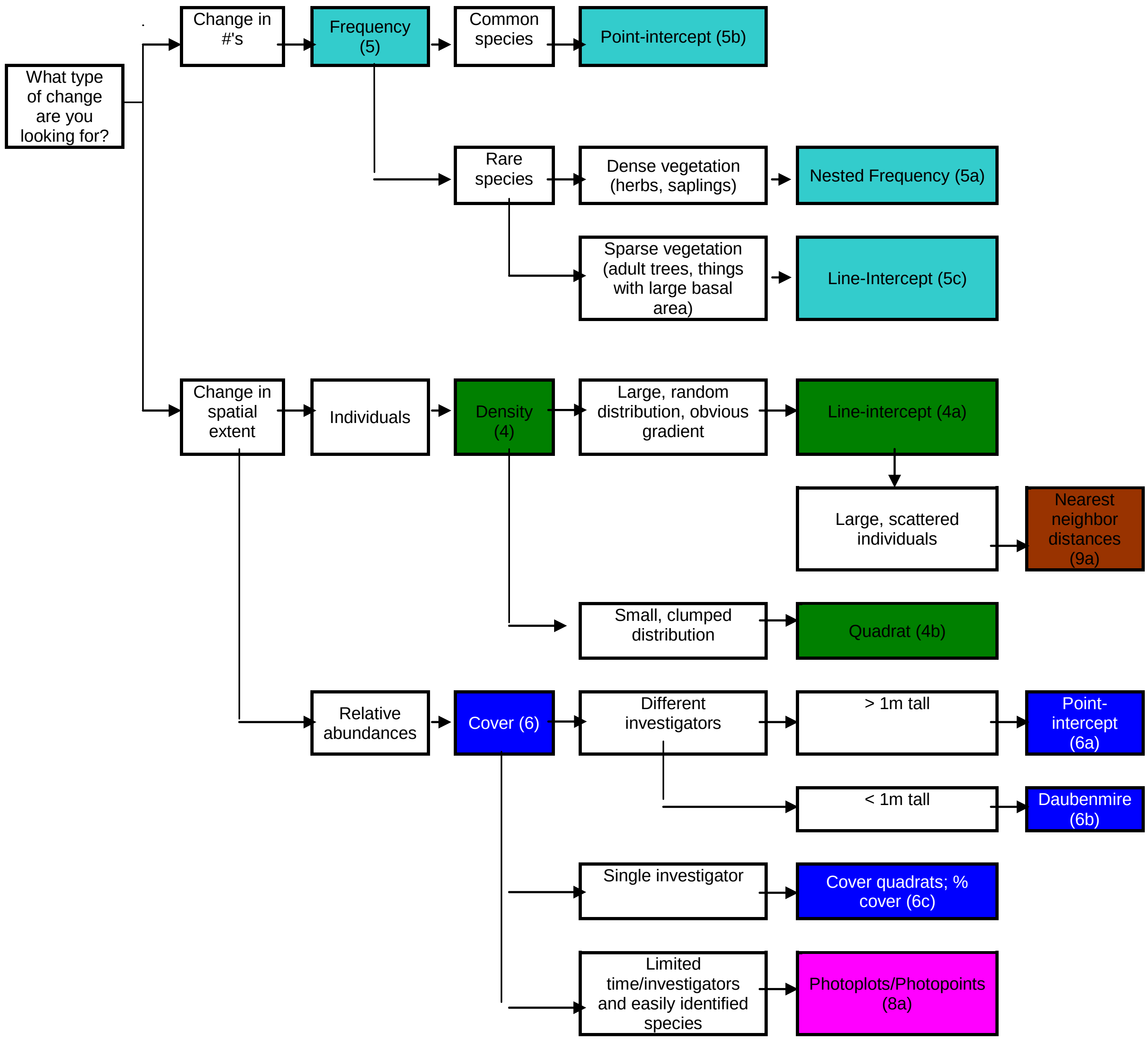
**Flow Charts**


Primary Flow Chart
Is your monitoring required by a state or federal species recovery plan?
Yes
Follow monitoring guidelines found within the specific recovery plan
PVA?
No, I am monitoring…
Population
Monitoring for baseline data of a species or population
Level 1
Monitoring for trends
Monitoring to observe population or species trends
Monitoring for changes in #'s within populations
Monitoring to observe over time
Level 2
Monitoring to predict trends over time
Level 3
Monitoring for changes in spatial extent or density
Level 2 + spatial data (polygon)
Monitoring a response to a specific treatment or management action
Monitoring to observe the response
Level 2
Monitoring to predict the response (in general or specific life history stages
Level 3
Population + Habitat Quality
Level 2
Community
Outside the scope of this project

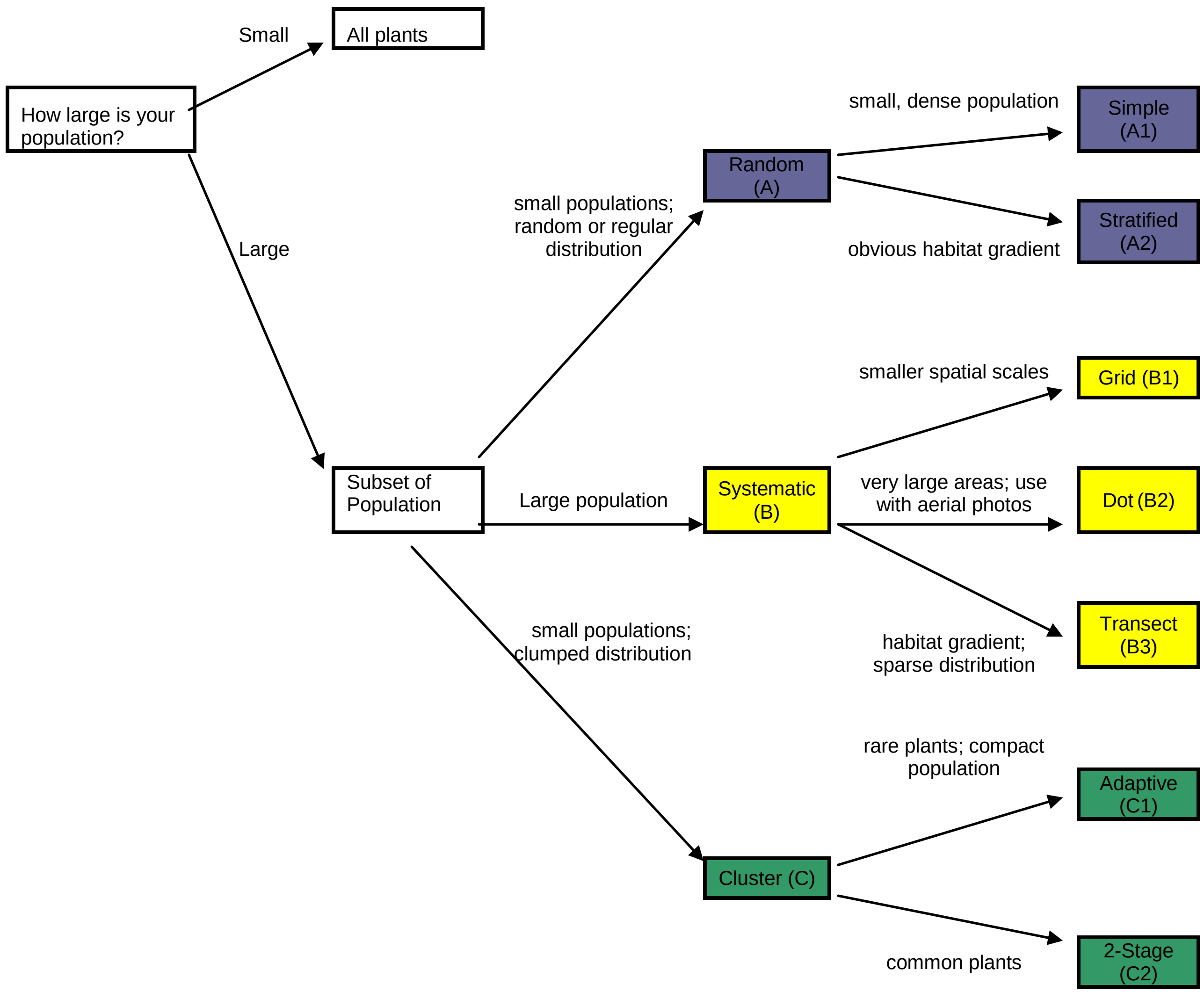
**Level 1 Chart**



**Level 2 Chart**



## Level 3 / Sampling Chart




Ways to track individuals:
- --Mark with tags
- --Mark/recapture (map them within a plot)

*Double or 2-Phase sampling can be used when the trait you really want is difficult to measure on all individuals.

**Many computer programs are available to aid in calculating sample sizes. Examples can be seen on page 153 of Elzinga et al (1998).

## Strengths and Limitations Table

| Category | Level | Technique/ attribute | Definition | Strengths | Limitations | References |
|---|---|---|---|---|---|---|
| Inventory Methods (Palmer 1987) / Level 1 Monitoring (Menges and Gordon 1996) | 1 | Presence/ absence measures | Note whether the species still occurs at a site. | ~no special skills required<br>~requires little time<br>~useful for large, showy plants<br>~better than abundance measures for small, cryptic plants when working with a small budget<br>~good for species with many small populations | ~gives you no information on population trends | Elzinga et al. 1998; Joseph et al. 2006; |
| | 2 | Abundance measures | Measurement of how much of a plant occurs at a site. | ~works well for higher density species<br>~most useful for species with high observability | ~better results obtained when larger budget is available | Joseph et al. 2006; |
| | 2a | Estimations of population size | Estimation of the number of individuals in a population. | ~only slightly more time consuming than simple presence/absence data<br>~gives a gross index of trends<br>~can be consistent if you choose which individuals to use based on species ecology | ~only large changes can be seen due to observer variation<br>~small/cryptic plants lead to increased variation | Elzinga et al. 1998; |
| | 2a1 | Meander searches | Involves walking randomly through a site and noting each new individual or species. | ~useful in difficult terrain or irregularly shaped areas | ~may be biased to some areas that are easier walking<br>~not repeatable from year to year | Lancaster 2000 |
| | 2b | Complete population counts | A complete count or census of all plants in a population. | ~no statistics required to analyze data<br>~no sampling error | ~difficult with large population are or numbers, dense vegetation, with similar species in the area or cryptic stage classes<br>~can be poor due to missed individuals<br>~need a consistent counting unit | Elzinga et al. 1998; |
| | 2b1 | Patterned searches | Involves walking a series of roughly parallel "transects" in a search unit and noting each new individual or species. | ~maximizes coverage and minimizes overlap<br>~reduces a tendency to avoid difficult terrain<br>~can be repeated on a regular basis | ~access may be difficult at times, and unique habitats may be missed | Lancaster 2000 |
| | 3 | Counts plus stage classes (enhanced count data) | Count or census of all plants in a population plus the number of plants in each age or stage class. | ~gives more robust data for statistical analysis than simple counts alone<br>~takes only a small amount of extra time than simple counts to collect the data<br>~can help to pinpoint which life stage of a species may need intervention<br>~can be used to create a count-based PVA which provides some predictive value. | ~Does not produce the same detailed information on individuals as a full blown demographic study | Elzinga et al. 1998 (pg. 171) |

Survey Methods (Palmer 1987) / Level 2 Monitoring (Menges and Gordon 1996)

| | | | | | |
|---|---|---|---|---|---|
| 4 | Density | A number of counting units per area; for plants a counting unit need not be a genetically unique individual, but needs to be clearly defined (genets, ramet, individual, etc.). | ~good when the change expected is recruitment or loss of individuals<br>~same for all quadrat sizes and shapes (in theory) | ~in reality may vary with quadrat shape due to observer differences and boundary plants<br>~less sensitive to vigor related changes<br>~poor for long lived species<br>~poor for plants that fluctuate greatly from year to year | Elzinga et al. 1998; |
| 4a | Line-intercept for density | A measuring tape is stretched between two stakes and the intercept distance is recorded for any plant that intercepts the line. Accumulated length is divided by transect length to get percent cover. | ~Equally adaptable to small and large areas<br>~works well for basal diameter of grasses<br>~most suitable for sparse vegetation | ~not suitable for dense, intermingled herbaceous species<br>~not appropriate for species with small basal areas | Canfield 1941; Bonham 1989;Tazik et al. 1992; Elzinga et al. 1998 |
| 4b | Density quadrat | A quadrat is identified, and the density of the plant is counted within the boundaries, with each quadrat being a sampling unit. | ~Appropriate for plants with a clumped distribution.<br>~Observer bias is low when the counting units or individuals are few and/or easily recognized | ~Errors can be high when dealing with cryptic individuals or numerous plants.<br>~It can be difficult to make decisions on boundary plants, especially dealing with plants with larger basal areas. | Elzinga et al. 1998 |
| 5 | Frequency | Usually measured in plots, and can be defined as the percentage of possible plots within a sampled area occupied by the target species. | ~good for any species growth form sensitive to changes in spatial arrangement<br>~good for monitoring invasions<br>~no need to define a counting unit, so good for rhizomatous species<br>~minimal training needed<br>~vary fast if species is easy to spot<br>~fairly stable measure throughout the growing season | ~affected by spatial distribution and density<br>~changes can be difficult to interpret<br>~difficult to visually estimate for a site, and hard to express the changes to managers and the public | Elzinga et al. 1998; |
| 5a | Nested Frequency | A small area is designated and all species present are listed. Area is progressively increased and new species encountered are listed. Quadrats are located side by side with smaller quadrats located inside larger ones | ~simple to obtain, rapid and objective<br>~reduces surveyor bias<br>~provides information on the distribution of the species<br>~frequency is dependent on spatial distribution of the species and plant size | ~frequencies of 20%-80% are best to detect changes in a given quadrat | Curtis and McIntosh 1950; Windward and Martinez 1983; Tazik et al. 1992 |
| 5b | Point-intercept for frequency | A rod is lowered at intervals along a transect and contact with the canopy is recorded | ~objective<br>~rapid and easily taught to field workers | ~requires large number of points to meet sample size adequacy<br>~not recommended for cover less than 5% or greater than 35% | Diersing et al. 1992; Tazik et al. 1992; Elzinga et al. 1998 |

| | | | | | |
|---|---|---|---|---|---|
| 5c | Line-intercept for frequency | A measuring tape is stretched between two stakes and the intercept distance is recorded for any plant that intercepts the line. Accumulated length is divided by transect length to get percent cover. | ~Equally adaptable to small and large areas<br>~works well for basal diameter of grasses<br>~most suitable for sparse vegetation | ~not suitable for dense, intermingled herbaceous species<br>~not appropriate for species with small basal areas | Canfield 1941; Bonham 1989;Tazik et al. 1992; Elzinga et al. 1998 |
| 6 | Cover | The vertical projection of vegetation as viewed from above; can either be measured as basal cover (the area where the plant intersects the ground) or aerial cover (the vegetation covering the ground surface above the ground surface | ~works well for matted plants and shrubs ~with a well defined canopy<br>~most directly related to biomass<br>~does not require identification of an individual<br>~easily visualized and intuitive | ~can change dramatically over the course of the growing season<br>~hard to compare results from area to area when sampled weeks or months apart<br>~sensitive to changes in number and vigor; difficult to interpret | Elzinga et al. 1998; |
| 6a | Point-intercept for cover | A rod is lowered at intervals along a transect and contact with the canopy is recorded | ~objective<br>~rapid and easily taught to field workers | ~requires large number of points to meet sample size adequacy<br>~not recommended for cover less than 5% or greater than 35% | Diersing et al. 1992; Tazik et al. 1992; Elzinga et al. 1998 |
| 6b | Daubenmire | Canopy cover is visually estimated into one of six cover classes. | ~cover classes enable repeatable results among surveyors<br>~Best for small shrubs, rhizomatous grasses and bunchgrasses | ~not for plants greater than 1m in height<br>~requires training to standardize observer estimates<br>~data summaries can result in low precision over time | Daubenmire 1959; Tazik et al. 1992 |
| 6c | Cover quadrats | Quadrats are identified and a visual estimate is used to describe the percentage covered by a vertical projection to the ground. | ~cover estimates are relative to quadrat size<br>~desirable when individuals cannot be distinguished | ~requires intensive training and repeated comparisons<br>~difficult to estimate in large quadrats | Bonham 1989; Tazik et al. 1992; Elzinga et al. 1998 |
| 7 | Production / Vigor indicators | Production: the annual output of vegetative biomass, most commonly measured as a harvest of the peak aboveground standing crop. Vigor indicators may include a number of different measures of plant size and reproductive output (height, basal diameter, flower number, etc.) | ~vigor indicators are usually easy to measure with little observer bias | ~production is mostly sampled with destructive measures<br>~not sensitive to many trends that are of interest to rare plants | Elzinga et al. 1998; |
| 8 | Digital Techniques | A mobile system to record demographic and spatial data of plant populations on permanent plots based on digital image processing. | ~can record data from large plots<br>~saves time in the field and data handling | ~need access to the tools and equipment | Roshier et al 1997 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 8a | Photographic Monitoring | Permanent locations described and marked. Identical photos are taken over time. Can be either qualitative (photopoints) or quantitative (photoplots) | ~effective visual tools synthesize site information<br>~inexpensive and repeatable | ~photo plots are more time intensive than photo points<br>~important to conduct during the same season each year<br>~species must be very easily identified from surrounding vegetation | Magill 1989; Tazik et al. 1992; Borman 1995; BLM 1996; Elzinga et al. 1998 |
| | 9 | Distance measures | Include several variations, but all involve the measure of the distance of an individual from a point or from another individual, and using these distances to estimate density. | ~useful with large or scattered individuals for which density quadrats are not practical<br>~a number of techniques have been developed | ~only suitable for plants with random distributions<br>~less efficient than quadrats for most rare plant monitoring situations | Elzinga et al. 1998; |
| | 9a | Point-nearest neighbor distances | Measures of distance between the nearest individual and its nearest neighbors of the same species. | ~unbiased if the population/sample is random | ~biased if the population is uniformly or contiguously distributed | Batcheler 1971 |
| **Demographic Methods (Palmer 1987) / Level 3 Monitoring (Menges and Gordon 1996)** | 10 | Demographic methods | A measure of individuals and some measure of their success or fate over time. | ~very powerful in detecting trends<br>~good for species without seed banks or vegetative reproduction, a moderate lifespan (3-7 yrs), regular reproduction, single stems, low densities, and smaller populations | ~very time and resource consuming<br>~needs to be done on a regular basis to produce any relevant results<br>~does not work well for species with a long-lived seed bank, dense vegetative reproduction, annuals or long-lived perennials, multi-stems, high densities, and large populations with heterogeneous habitats | Elzinga et al. 1998; |

| | Sampling techniques | Definition | Strengths | Limitations | |
|---|---|---|---|---|---|
| A | Random sample of Individual plants | A simple random sample taken of individual plants rather than areas like quadrats. | ~when possible (rarely) the calculations necessary for analysis are simpler than those for either cluster or two-stage sampling | ~usually not practical in most monitoring situations | Elzinga et al. 1998; |
| A1 | Simple random | Must meet the following two criteria: each combination of a specified number of sampling units has the same probability of being selected, and the selection of one unit is in no way tied to the selection of another unit | ~formulas to analyze data the simplest<br>~useful in small areas where habitat is homogeneous | ~Some areas in the target population might be left unsampled due to chance<br>~Not efficient for populations with a clumped distribution | Elzinga et al. 1998; |

| | | | | | |
|---|---|---|---|---|---|
| A2 | Stratified random | Dividing the population into two or more subgroups (strata) and taking simple random samples in each strata. Usually units within a strata are very similar, but unit between strata very different. | ~results in more efficient estimates than simple random when the attribute measured varies with habitat features<br>~good for areas where habitat is heterogeneous with small areas of each different habitat | ~more complex analysis than for simple random<br>~not efficient when the area within a stratum is large or number of sampling units is large<br>~some areas within each stratum may be left unsampled by chance | Elzinga et al. 1998; |
| B | Systematic | The regular placement of quadrats or points along a transect. | ~works when the first sampling unit is selected randomly and the units are far enough apart to be considered independent<br>~better interspersion of sampling units than simple random<br>~data can be gathered very efficiently<br>~can be analyzed with same simple formulas as simple random | ~returns questionable results if the number of possible samples is below 25-30 | Elzinga et al. 1998; |
| B1 | Grid-based survey | An area is permanently divided into grid cells with density estimated in each cell. | ~increase rare plant detection and facilitate repeatable searches<br>~GPS with sub-meter accuracy can remove the need for permanent cell establishments<br>~provides a reasonably precise estimate of population size without complete counts<br>~data are very amenable to spatial analysis and mapping | ~not very applicable at large spatial scales<br>~density class estimates often have significant observer error | Young et al. 2008 |
| B2 | Dot Grid Sampling for invasive cover | Using a dot grid laid over an aerial photograph as sampling units to determine extent of weed coverage. Dots can be laid on photograph using any of the above appropriate sampling techniques. | ~easy, rapid, and repeatable way to assess weed percent cover | ~acquiring large-scale aerial photography on a frequent basis can be very expensive | Hamilton and Megown 2005 |
| B3 | Transects | Data is collected at fixed intervals along a line of from contiguous or discontinuous quadrats. | ~useful to illustrate variation along a gradient<br>~continuous line transects are efficient over long distances when dealing with sparse distributions | ~Data from continuous belt transects may not be independent or suitable for statistical analysis<br>~continuous transects do not work well when individuals are difficult to determine<br>can be very time consuming over long distances if plant cover is dense | Barker 2001 |

| | | | | | |
|---|---|---|---|---|---|
| C | Cluster | Identify groups or clusters of elements and then take a random sample of these clusters. Then measure every element within the selected clusters. | ~useful when random samples are difficult to take<br>~most often used to estimate something about individual plants (e.g. mean height)<br>~often less costly than random sampling<br>~usually more practical than sampling individuals randomly | ~all the elements within a cluster must be measured, difficult if clusters contain a large number of individuals<br>~difficult to determine how many clusters should be sampled versus cluster size<br>~require very complex calculations for analysis | Elzinga et al. 1998; |
| C1 | Adaptive Cluster Sampling (Philippi 2005). | Starts with a simple random sample of units. Units without the plant of concern are scrapped, while units with the plant are measured, along with neighboring units clustering the original unit. The procedure grows until each unit is surrounded by units where no plants are found. | ~works well for rare plants whose distributions are usually clumped<br>~best when the population area is compact enough to intersect several clusters in the initial survey<br>~adaptive methods like ACS may provide the most efficient and unbiased estimates of population sizes of rare plants | ~quadrat size matters and can be difficult to determine for species where little is known<br>~confidence intervals tend to be very large for rare plant applications<br>~temporal and spatial variation can not be separated in adaptive sampling | Philippi 2005 |
| C2 | Two-stage | Groups of elements are identified and randomly sampled as in cluster sampling. Instead of measuring every element within a cluster, a second random sample is taken of the elements within each chosen cluster. | ~more efficient when each group is large<br>~other benefits the same as in cluster sampling | ~very complicated formulas needed to arrive as estimates and standard errors | Elzinga et al. 1998; |
| D | Double / 2 Phase | Involves the estimation of two variables. A more difficult or expensive variable is measured in a small number of sampling units, while an auxiliary variable is measured in a much larger number of sampling units. | ~useful when the variable of interest is difficult to measure, but a correlated variable is easier<br>~only a small amount of more time consuming and destructive sampling may need to be done; can be much more efficient | ~complicated formulas for data analysis and sample size determination are needed | Elzinga et al. 1998; |
| E | Permanent plots | Permanent marking of sampling areas used from year to year in a monitoring program. | ~more powerful than temporary plots in detecting changes in density<br>~fewer plots needed than temp. plots<br>~more advantageous for long-loved perennials<br>~better than temporary plots when dealing with dormancy issues | ~not as beneficial for short-lived perennials or annuals<br>~plot size and shape can affect them<br>~require larger initial expenditure of time to establish | Elzinga et al. 1998; Lesica and Steele 1997 |
| F | Mark-recapture methods | Statistical models that interpret demographic data with regard to detection probabilities, vital rates, and population size. | ~advantageous in detecting trends even with a relatively small number of individual patches and resightings<br>~long term studies can explore recruitment in long-lived species<br>~useful for estimating demographic traits where individuals may be missed or unobservable | ~need a long time series of data<br>~needs a study site with well defined boundaries<br>~can have problems with heterogeneity in capture and age structure effects<br>~quantification of detection probabilities very important for any monitoring program | Shefferson 2001; Alexander 2009 |

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**Appendix A**

**<u>Survey 1 Summary</u>**

We sent out our first survey to 18 FS Botanists to get a better idea of what kinds of monitoring programs they are currently working on and what things are most important to them in regards to a standardized set of protocols. 13 responded and their answers are summarized below. We have also included a set of nine graphs to visually represent the data from each question.

We first asked botanists about how many species they were currently monitoring, the status and life histories of those species, and why they were monitoring that species. Ten of the 13 botanists said they were currently monitoring >10 species, with the numbers ranging as high as >40 species. Of these species, most are rare plants or plants of concern, while fewer were also endangered or threatened (E/T) species, or invasives. Plants with many life histories were covered, but the majority of the species monitored are long-lived perennials. We also learned that the botanists are currently monitoring for a long list of monitoring objectives.

We then asked botanists to describe the monitoring techniques currently being used. A wide range of techniques were indicated, from simple presence absence data to demographic monitoring. We did notice that a majority (9 out of 13) of the botanists who responded were doing some sort of demographic monitoring.

And lastly, we asked botanists to describe the details of their current monitoring programs. In their current programs, none of the botanists are taking advantage of volunteers to collect data. Additionally, most monitoring is not done on a regular basis, rather it is done intermittently, or when funds are available. Most of the botanists listed time and manpower as the major factors that limit their current monitoring programs.

We have included a copy of all of the survey results we have received, along with the answers to the last open-ended question (What would help you to improve your monitoring programs, and what is the most difficult part of designing a program?) for review.

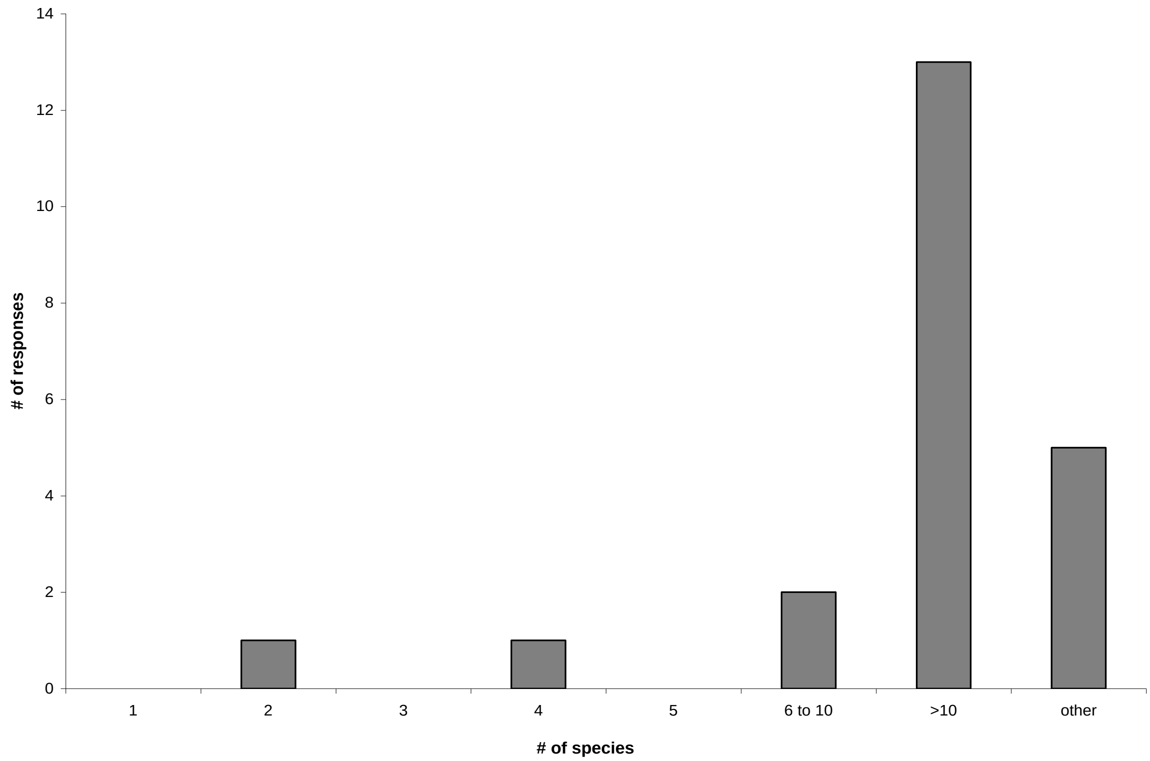


**Figure 1**. How many species are you currently monitoring?

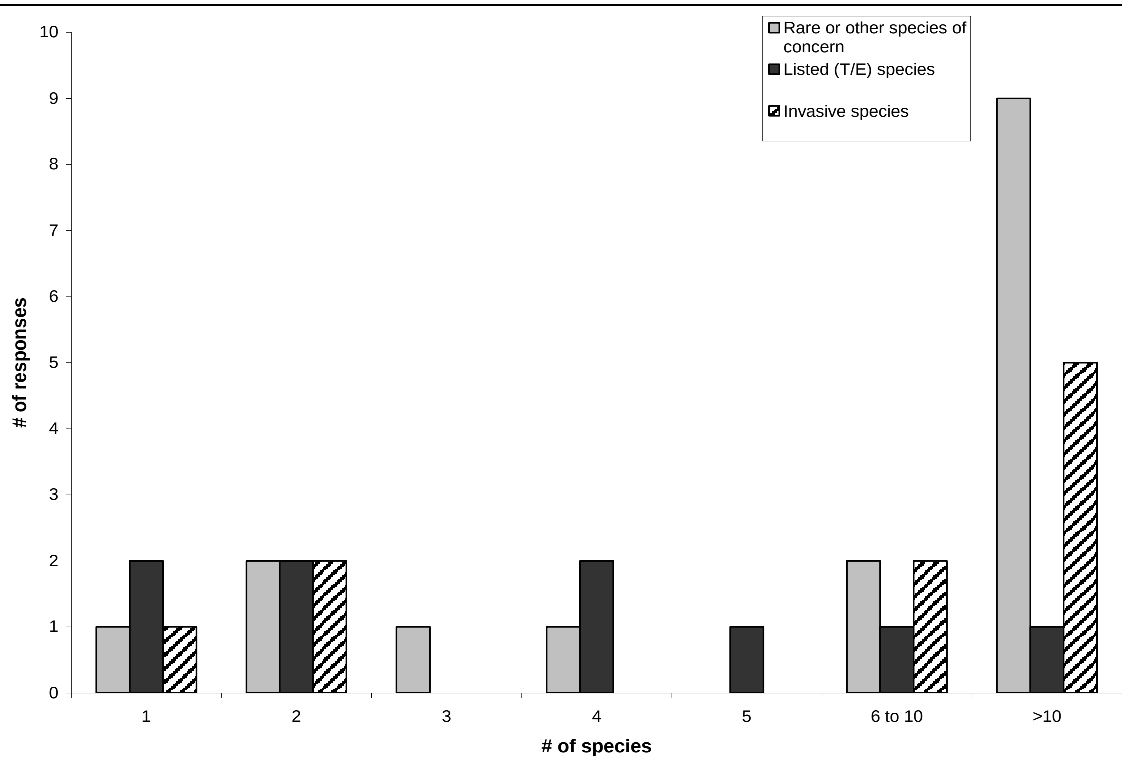


**Figure 2.** Of the species you are monitoring, how many are: Rare or other species of concern, Listed (T/E) Species, Invasive Species?

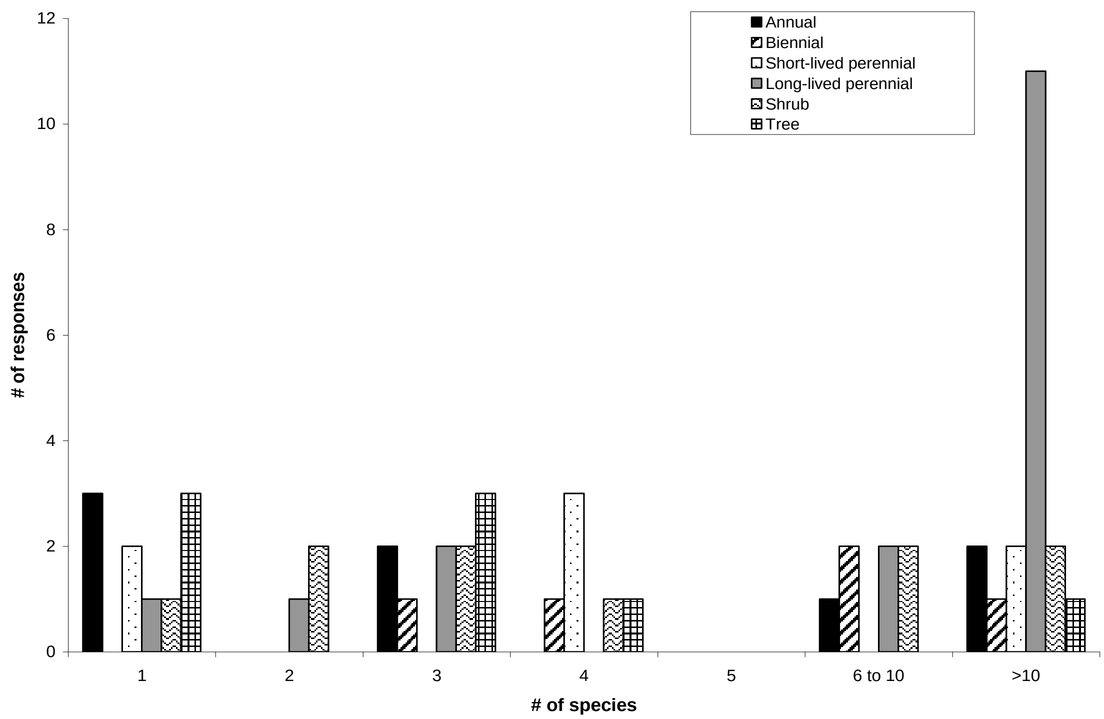


**Figure 3.** Of the species you are monitoring, indicate the life history.

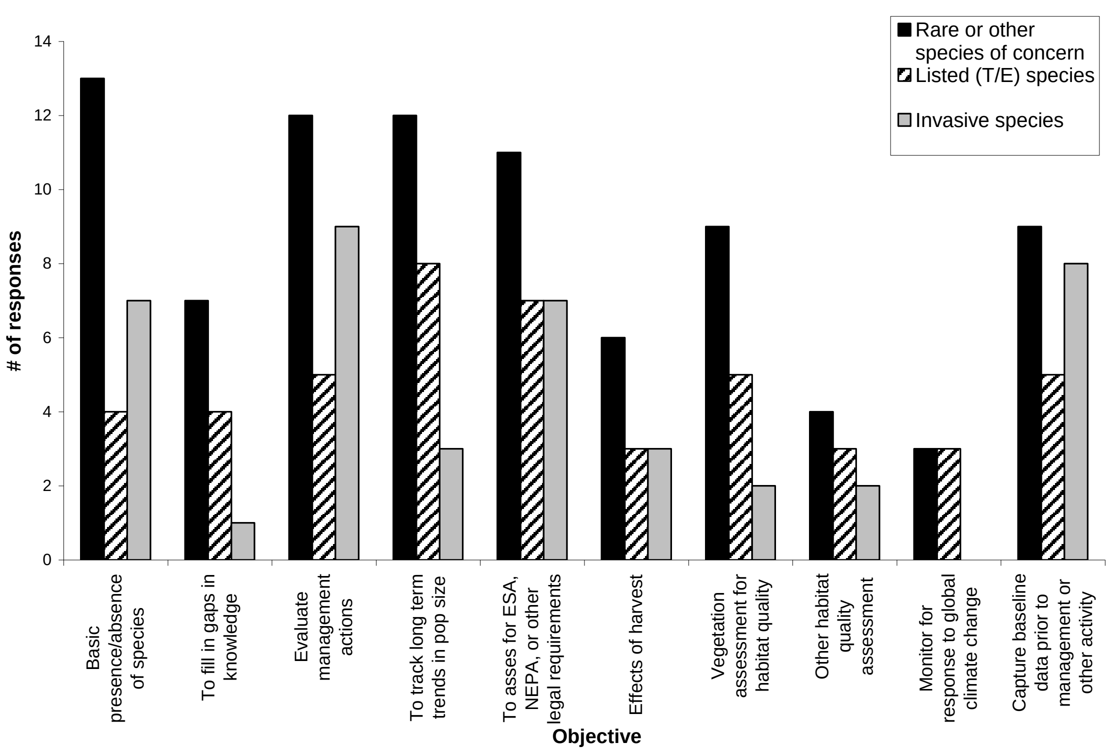


**Figure 4.** Generally, for each type of concern, what are the objectives of your monitoring program?

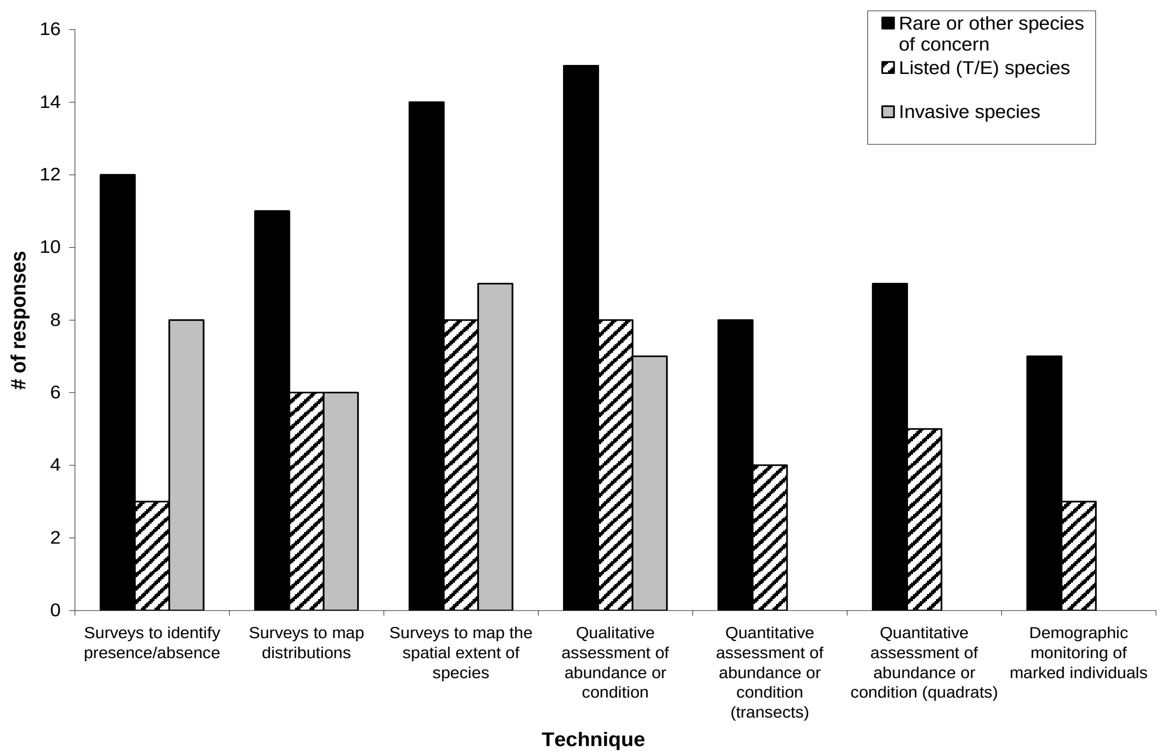


**Figure 5.** What techniques are you currently using to conduct your monitoring program?

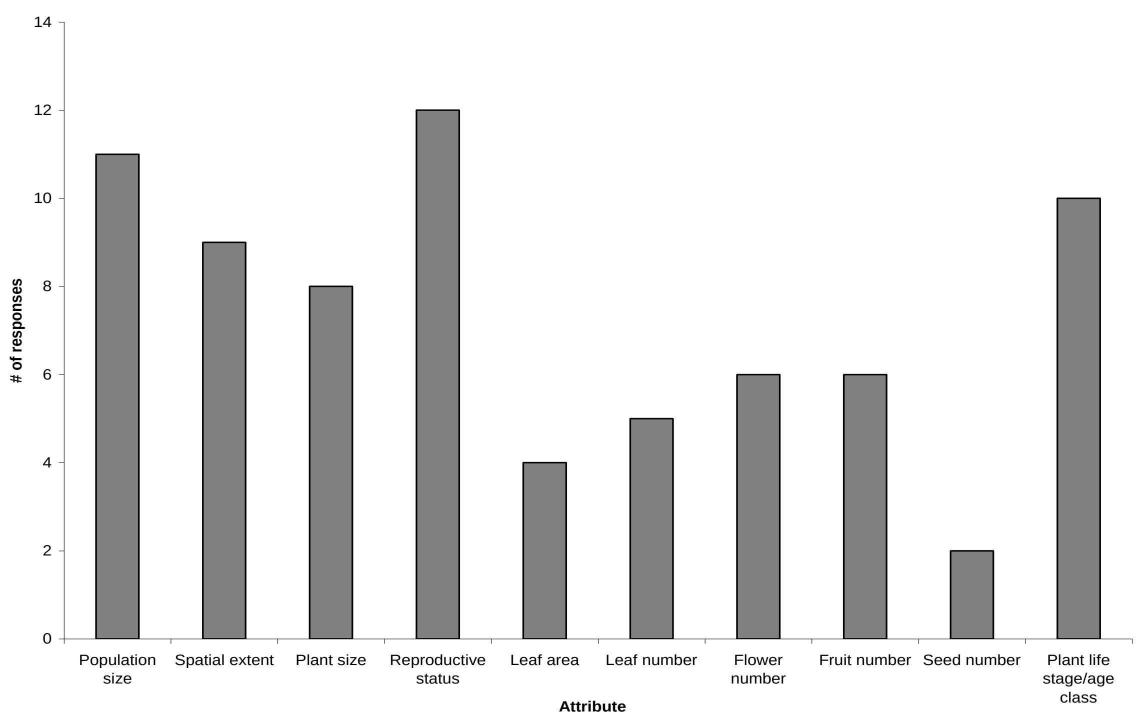


**Figure 6.** If you are doing demographic monitoring, what attributes of the population are you measuring?

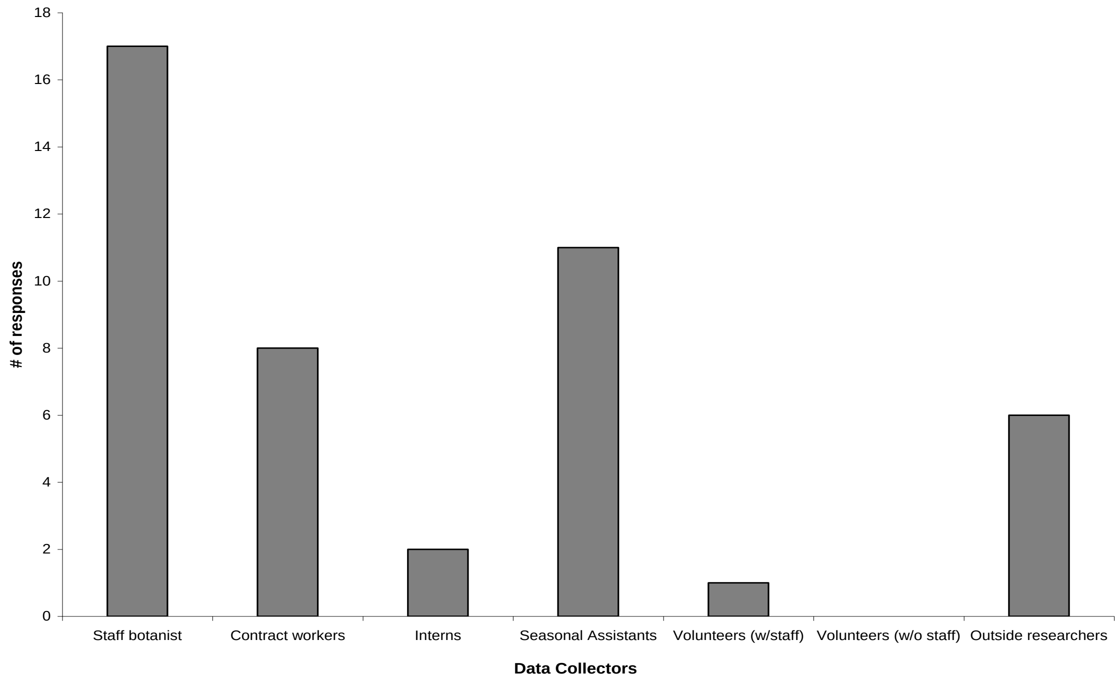


**Figure 7.** Who is responsible for the actual collection of monitoring data?

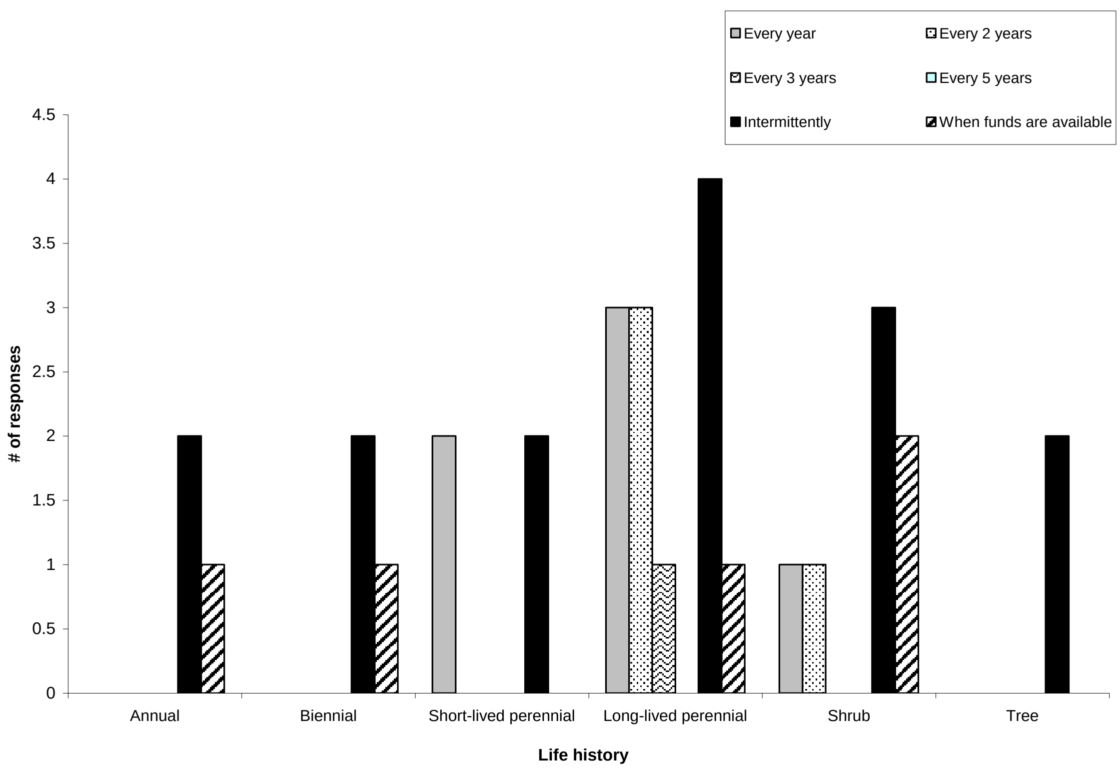


**Figure 8**. On average, how often do you conduct monitoring for each of your listed (T/E) species?

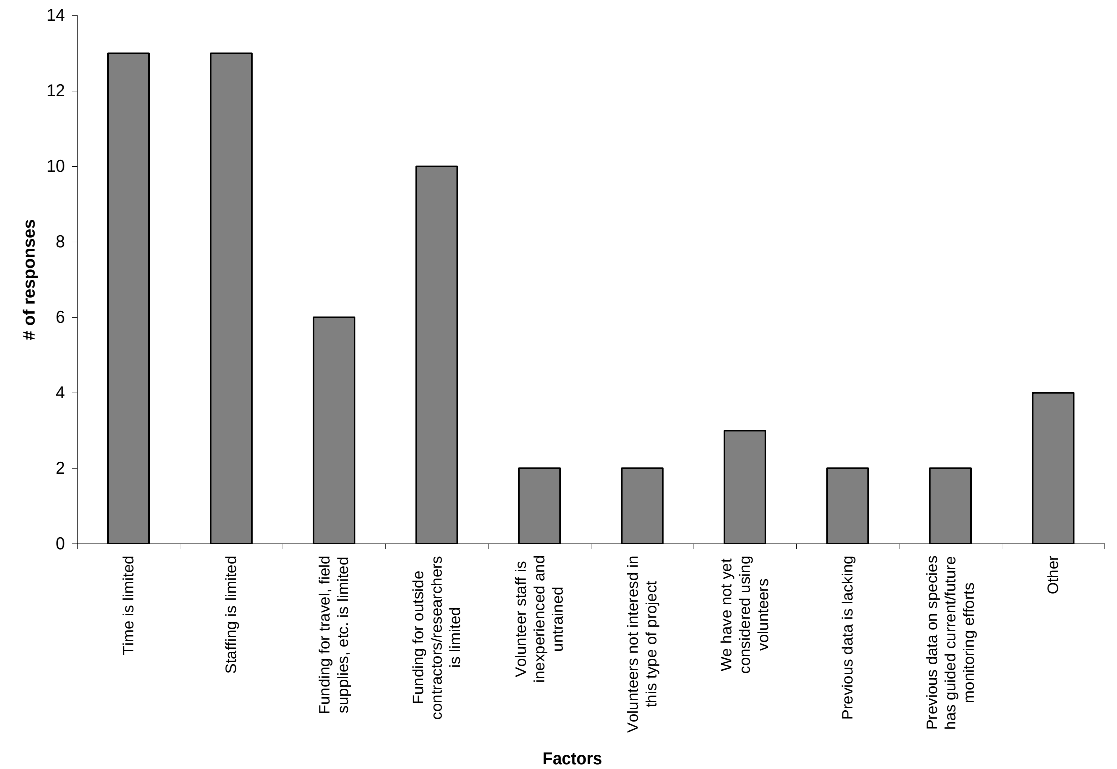


**Figure 9.** What are the factors that limit your current monitoring projects?

**What information would help you to improve your monitoring programs? And, what is the most difficult part in designing a monitoring program?**

1. Information on what constitutes a minimally viable, moderately viable and robust population size by genus or species (for rare species) would be helpful. Then we could do a quick check type monitoring to see which level a population was at, which would be simpler to implement than full status checks or counts, and easier to fit into a very full program where monitoring takes low priority. (We do not have clear targets or mandates to monitor rare plant status.)
Some standardized basic monitoring protocols by type of plant (such as graminoid, orchid, Botrychium, saprophyte) would be useful and easier to get leadership by-in so we could implement them.

2. The most difficult part to date is finding time to analyze the data collected. I have been fortunate with the Ivesia aperta canina project in that Dr. Tiffany Knight with Washington University, has volunteered to help me with the data analysis. I spend quite a bit of my non-field season time completing NEPA analysis. Thanks for including me in this survey.

3. Obtaining consistency of monitoring methods across a species range and across ownerships, teasing out the role of environmental factors (ex. prolonged drought) from management factors (ex. woody competition from lack of prescribed fire) affecting population variability.

4. a. Better electronic data about recent field work by outside-agency botanists. More research focus on botanical monitoring. Universities to hire a real systematic botanist who has time to work out taxonomic difficulties.

b. The most difficult part is designing methods that are appropriate for the individual species' habit, phenology, and distribution. These must be highly creative, and will change often as we learn more about the species being monitored. Especially difficult for species with poorly defined habitats (Botrychium) or annuals -- that have a tendency to "pop up" unexpectedly in some odd place.

5. Limited time available, would need clearly identified program target accompanied by funding to make this rise higher in the list of projects.

6. Our monitoring protocol changes almost annually as we find new populations of species, learn more about impacts to these species, and refine the question we wish to answer in our monitoring effort. The most difficult part of designing a monitoring program is the uncertainty in how much funding we will receive as well as the amount of time the crew will have to survey due to weather and an ever shifting growing season (the past two years we have a fairly short monitoring window because of late spring blizzards and early autumn frost).

7. Useful information would be compiling monitoring protocols for the same species across other USFS units and other agencies. Compiling a database of university researchers interested in monitoring rare plant species by subregion could be useful.

One of the most difficult parts in designing a monitoring program is determining the usefulness of a less than ideal monitoring protocol. Frequently time constraints limit the number of plots or subsamples per population. While compromises are always made, is the data that can be collected adequate to provide any meaningful assessment?

A difficulty we have in monitoring is adequately tracking rhizomatous shrubs such as Spiraea virginiana. What is a meaningful metric that is repeatable if stem counts are questionable?

Another difficulty we have is monitoring dense subpopulations of rare species, such as Helonias bullata, where most more intensive monitoring protocols, other a very coarse estimate, would result in significant trampling impacts. The coarse logarithmic scale estimates are questionable for tracking trends.

8. what works for species of similar types; knowing what info is useful to managers for different types of management actions; more long-term (20-30 year) studies

people do too many short-term studies (MS) that really don't take in the vagaries of changes in an area over time due to weather, climate, fire, etc.

Access - road closures resulting in not being able to hike to sites (don't know this at start of monitoring)
changes in plots due to natural/management actions such as fire, floods, downfalls, resulting in loss of end points making relocation of transects difficult, or partial/total loss of transects/quadrats timing of field work around required indoor work, weather, availability of assistants

9. Knowing that funding is available each year for long-term monitoring; rather than having to secure funding each year.

Changing protocols over the years make it difficult to use data collected by many different methods.
Detecting new invasions of invasive exotics.

10. It would be fantastic if there were more time to do proactive monitoring. Much of what we do is reactive monitoring i.e. after the fact, after the sheep, after the road building. There is often not much time to monitor simply to gain more info. also, it is difficult to get funding to support that type of work. Much of the monitoring we do gets done on a volunteer basis or on a rare year when there is some last minute funding.

11. Monitoring seems to work best for us when it is simple and easy to follow the protocol (such as filling out a standard sighting report with qualitative fields and mapping the population with GPS).
Anything that is more complex, time-consuming, or requires quantitative data collection is best done by a contractor or partner, who is not affected by other agency priorities and crises.
Also, I think we lack confidence in our ability to design and execute a 'scientific' monitoring program, so we're more comfortable having a university or professional contractor take that on.

Our Forest is not near a university, so we do not have a pool of interested and botanically trained volunteers.

12. This survey reply refers only to the non-native invasive plant monitoring.

limited funds means limited monitoring..
Funding for weed monitoring from recreation and roads funds would greatly improve the program (since recreation and roads are responsible for over 90% of the weed introduction and spread).

13. The most difficult challenge for us is to design an efficient, easily implemented, yet statistically reliable method to monitor population trends. We typically rely on outside expertise (heritage program, academia, botanical garden, etc.) to design statistically valid monitoring programs. While funding for external parties to initiate monitoring schemes often can be obtained through Forest Service Challenge Cost-Share or USFWS recovery planning programs, funding to continue the monitoring is often difficult to locate. Thus, some of our monitoring efforts have stalled or have not been conducted on a regular basis due to a lack of funding. An efficient, easily implemented design could reduce monitoring costs.
An equally difficult challenge to conduct the monitoring without causing damage to the target plant or its habitat. Two species we monitor grow on steep slopes with coarse soils and low plant cover. These sites are especially vulnerable to trampling and shearing by people. Our annual monitoring clearly damages these sites. Can we monitor these species less frequently - every 5 or 10 years - and still obtain accurate trend data? If this is possible, it would also help address the first concern regarding costs.

14. Knowing in advance, threats to a population that would warrant a prioritization in monitoring
Knowing site conditions that could effect a population; ie worming, NNIS, logging, recreation activities
Knowing future management goals

Prioritizing sites to monitor
Making decisions with incomplete information

## Survey 2 Summary

A second survey was sent out to all members of the US Forest Service with plant monitoring responsibilities. From this survey we were hoping to learn more about the monitoring programs that are currently in place, and what information US Forest Service employees would like to help inform their program designs. We received responses from 38 people, and their answers are summarized below. Figure references refer to the set of figures following this survey summary.

### What is currently being monitored?

When asked to list the 5 species they are most often responsible for monitoring, US Forest Service employees listed species from 101 different genera. 12 of the 38 respondents listed that they were involved in monitoring *Botrychium* species. This was the most common answer, followed by the genera *Cypripedium, Astragalus, and Panax*, with 8, 5, and 5 responses respectively. 31 of the 101 genera listed in the survey were monitored by at least 2 of the respondents. A list of all the genera mentioned is shown in Table 1.

While *Botrychium* species were listed as some of the most commonly monitored, they were also listed as one of the most difficult types of plants for which to design a monitoring program. Thirty percent of respondents also believe that short-lived perennials were difficult, while none of the respondents answered that they had the most trouble designing monitoring programs for long-lived perennials (Figure 1).

The most common responses that are being looked for in a monitoring program are presence/absence of a population and increase/decrease in number of individuals (Figure 2).

### Why is monitoring currently being conducted?

The most commonly used technique for monitoring is a survey to identify presence/absence data, with 27 of 38 respondents ranking it as their most commonly used technique. The least commonly used technique is demography of marked individuals, with only 2 of 38 respondents marking it as their most commonly used technique, and 26 of 38 marking it as the least commonly used. Overall, the respondents from our survey seem to use less intensive methods (surveys) more often than intensive methods (demography) (Figure 3).

A wide range of reasons for monitoring were ranked as very common according to this survey (Figure 4). The most common reasons for monitoring are to capture baseline data prior to management, to identify basic presence or absence of a species or population, to evaluate management actions, and to assess for legal requirements (ESA, NEPA, etc.). Monitoring for response to global climate change is very uncommon, with 29 of 38 respondents ranking it as the least common reason to monitor.

### Designing a monitoring program

According to our survey, grazing, logging, and fire (both wild and prescribed) somewhat impact monitoring programs. We also learned that management for recreation has a very large impact on monitoring programs.

Over half of the respondents in our survey say that their monitoring is impacted by a legal requirement of some kind, with NEPA requirements being much more common than ESA requirements.

With regard to the creation of monitoring protocols, over 60% of respondents say that they are responsible for creating their own monitoring protocols. Additionally, half of those who say they create their own protocols also say that they create them based on a monitoring objective. However, only 29% of respondents are confident that their protocols are appropriate, while 66% are only somewhat confident and 5% are not at all confident that their protocols are appropriate (Figures 5 and 6).

By far the area of greatest expertise among the respondents is in Taxonomy, while very few respondents have experience in experimental design and quantitative skills/statistics.

Monitoring goals

81% of respondents say that they approach their monitoring programs with a clear and distinct question or goal. The most common way to arrive at this goal is either to take the question or goal from a management plan (39%) or to develop the question or goal themselves (24%) (Figure 7).

The majority of respondents say that they have collaborated more than once or twice with botanists outside of their offices on monitoring programs. Most (60%) say they have collaborated with others on a few species, but do not have a great deal of contact.

Data collection and entry

The majority of data collection (~52%) is done in order to answer a monitoring question (Figure 8), and after collection, over ¾ of the data is analyzed in some way, either by the respondents themselves, or by someone else contracted to do the work. According to the survey, however, only about 27% of the analyzed data ends up in a report of some kind, the rest is just filed away (Figure 9). Almost 65% of respondents say that their data helps to answer their monitoring questions.

When it comes to data entry, over 85% of respondents are somewhat or very familiar with working with databases, and only 32% say that they would rather work with a spreadsheet.

Resources and References

When asked about the BLM Publication *Measuring and Monitoring Plant Populations* (Elzinga *et al.*), 78% of respondents were at least somewhat familiar with the publication, however only 35% say that they use this resource often when designing monitoring protocols. Many of the responses indicated that reasons behind not using the publication as a resource included not having the time or skill to produce statistically sound protocols as advised from the book, and already having protocols in place before this resource was published. A list of additional resources that some respondents use is in Table 2.

Tables and Figures

**Table 1.** A list of the most common genera monitored according to our survey respondents, along with the number of respondents who listed the individual genera.

| Genus Name | # of respondents monitoring that genus | Genus Name | # of respondents monitoring that genus |
|---|---|---|---|
| *Botrychium* | 12 | *Huperzia* | 1 |
| *Cypripedium* | 8 | *Ipomopsis* | 1 |
| *Astragalus* | 5 | *Ivesia* | 1 |
| *Panax* | 5 | *Lathyrus* | 1 |
| *Carex* | 4 | *Lindera* | 1 |
| *Penstemon* | 4 | *Listeria* | 1 |
| *Platanthera* | 4 | *Lomantium* | 1 |
| *Salix* | 4 | *Lycopodiella* | 1 |
| *Actea* | 3 | *Lysimachia* | 1 |
| *Allium* | 3 | *Macbridea* | 1 |
| *Draba* | 3 | *Machaeranthera* | 1 |
| *Eriogonum* | 3 | *Minuartia* | 1 |
| *Angelica* | 2 | *Mirabilis* | 1 |
| *Calypso* | 2 | *Moehringia* | 1 |
| *Castilleja* | 2 | *Nolia* | 1 |
| *Cynoglossum* | 2 | *Oryzopsis* | 1 |
| *Dalea* | 2 | *Oxyria* | 1 |
| *Dodecathon* | 2 | *Pachysandra* | 1 |
| *Epipactis* | 2 | *Packera* | 1 |
| *Eutrema* | 2 | *Papaver* | 1 |
| *Geum* | 2 | *Pediocactus* | 1 |
| *Hedeoma* | 2 | *Petasites* | 1 |
| *Hydrastis* | 2 | *Phacelia* | 1 |
| *Isotria* | 2 | *Pityopsis* | 1 |
| *Lycopodium* | 2 | *Polygala* | 1 |
| *Primula* | 2 | *Potentilla* | 1 |
| *Ptilagrostis* | 2 | *Pterospora* | 1 |
| *Purshia* | 2 | *Pyrrocoma* | 1 |
| *Sanguinaria* | 2 | *Ribes* | 1 |
| *Saxifraga* | 2 | *Rudbeckia* | 1 |
| *Viburnum* | 2 | *Salvia* | 1 |
| *Agoseris* | 1 | *Schisandra* | 1 |
| *Antennaria* | 1 | *Schwalbea* | 1 |
| *Aquilegia* | 1 | *Scutellaria* | 1 |
| *Aristida* | 1 | *Silene* | 1 |
| *Asclepias* | 1 | *Solidago* | 1 |
| *Asplenium* | 1 | *Spiraea* | 1 |
| *Bohamia* | 1 | *Tetraneuris* | 1 |
| *Buchnera* | 1 | *Thelysperma* | 1 |
| *Chrysothamnus* | 1 | *Thlaspi* | 1 |
| *Cirsium* | 1 | *Trichomanes* | 1 |
| *Clematis* | 1 | *Trifolium* | 1 |
| *Danthonia* | 1 | *Triphora* | 1 |
| *Dennstaedtia* | 1 | *Vaccinium* | 1 |
| *Disporum* | 1 | *Viola* | 1 |
| *Dryoptens* | 1 | *Waldsteinia* | 1 |
| *Echinacea* | 1 | | |
| *Eriophorum* | 1 | | |
| *Festuca* | 1 | | |
| *Gentian* | 1 | | |
| *Hapiopappus* | 1 | | |
| *Harperocallis* | 1 | | |
| *Helianthus* | 1 | | |
| *Helonias* | 1 | | |
| *Heuchera* | 1 | | |

**Table 2**. A list of additional resources that our survey respondents use to aid in designing their monitoring programs.

| **Additional Resources and References used by survey respondents** |
|---|
| - Local and Regional Floras |
| - Textbooks (Plant Ecology, Statistics, etc.) |
| - Primary Literature / Journal Articles |
| - Collegues / other scientists |
| - Other published protocols for their species or region |
| - Regional Forest Service Handbook |
| - Genetics and Conservation of Rare Plants (Falk and Holsinger 1991) |
| - Principles and Practice of Plant Conservation (Given 1994) |
| - Ground Based Photographic Monitoring (Hall 1998) |
| - Design and Analysis of Ecological Experiments (Scheiner and Gurecitch 2001) |
| - TNC/NatureServe Population Monitoring Handbook |
| - Manual of the Vascular Plants of Northeastern United States and Adjacent Canada (Gleason and Cronquist 1991) |
| - Vegetation Monitoring in a Management Context (course materials from TNC/ Natural Areas training acadamy) |
| - Online training through the BLM |
| - Watershed Conservation Handbook |
| - The Gold Book (BLM) |

**Figure 1**. Life history types that present the most difficulty when trying to design a monitoring program.

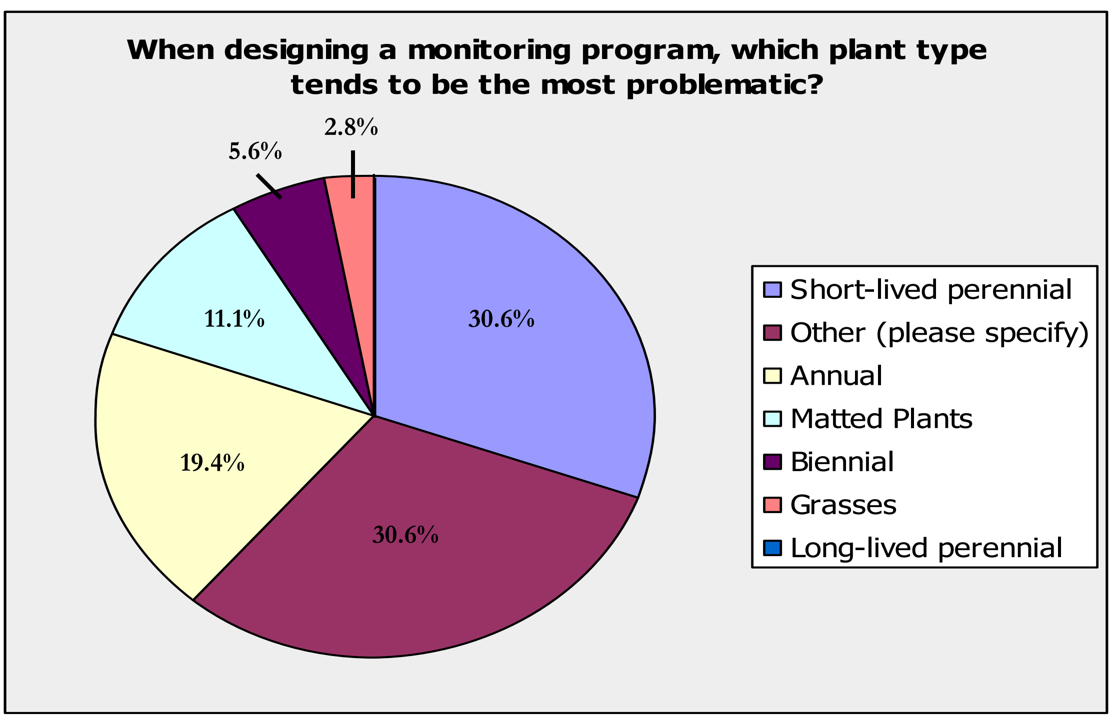

**Figure 2**. Reasons why survey respondents are currently monitoring their species or populations.

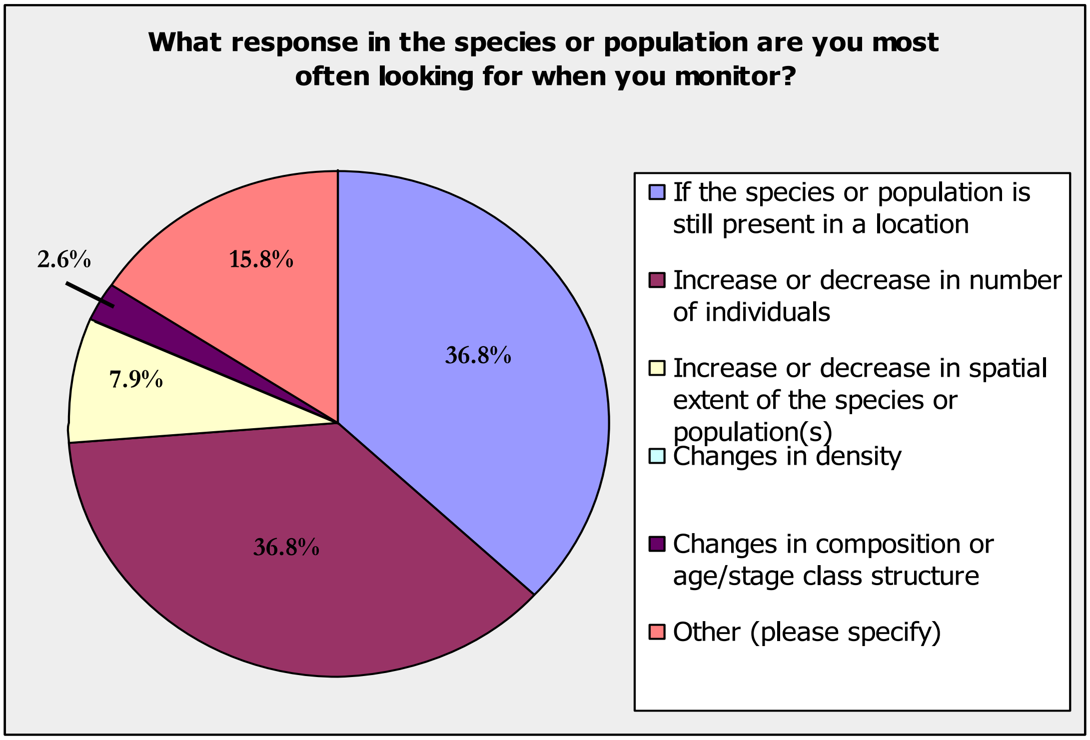


**Figure 3.** This chart shows the ranking of currently used monitoring techniques. A higher rating is equal to a more frequently used technique.

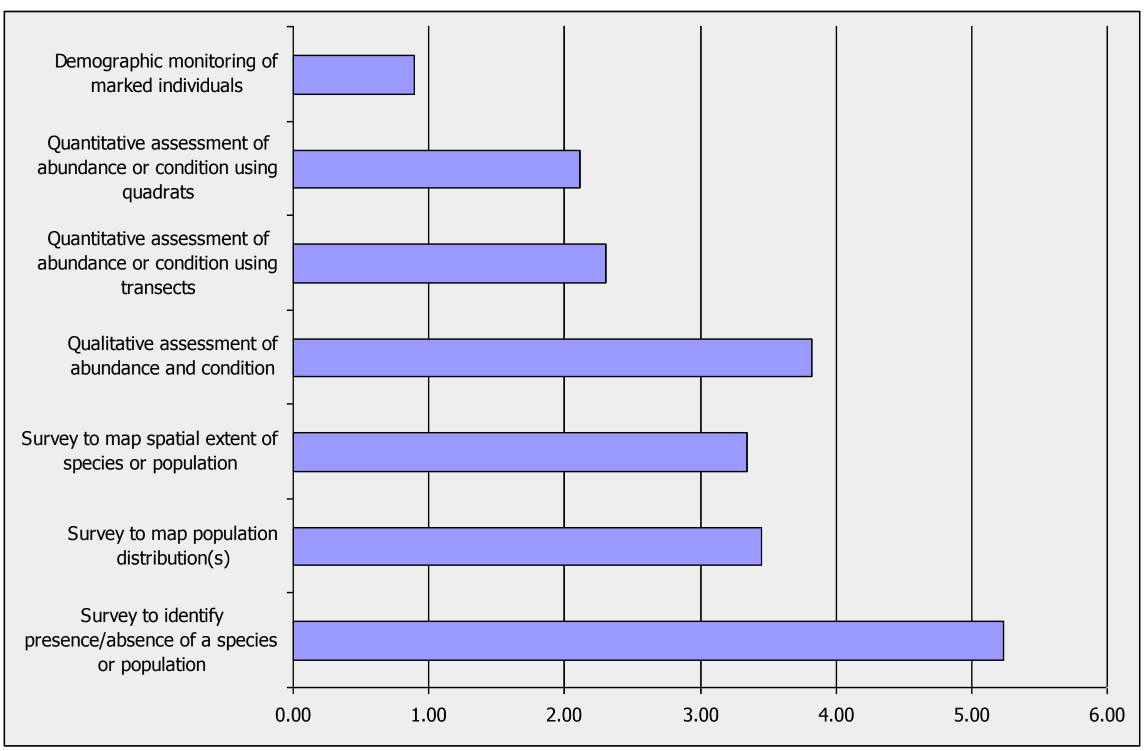

**Figure 4.** This chart shows ranking of current reasons for monitoring. A higher ranking indicates a more frequently stated reason for monitoring.

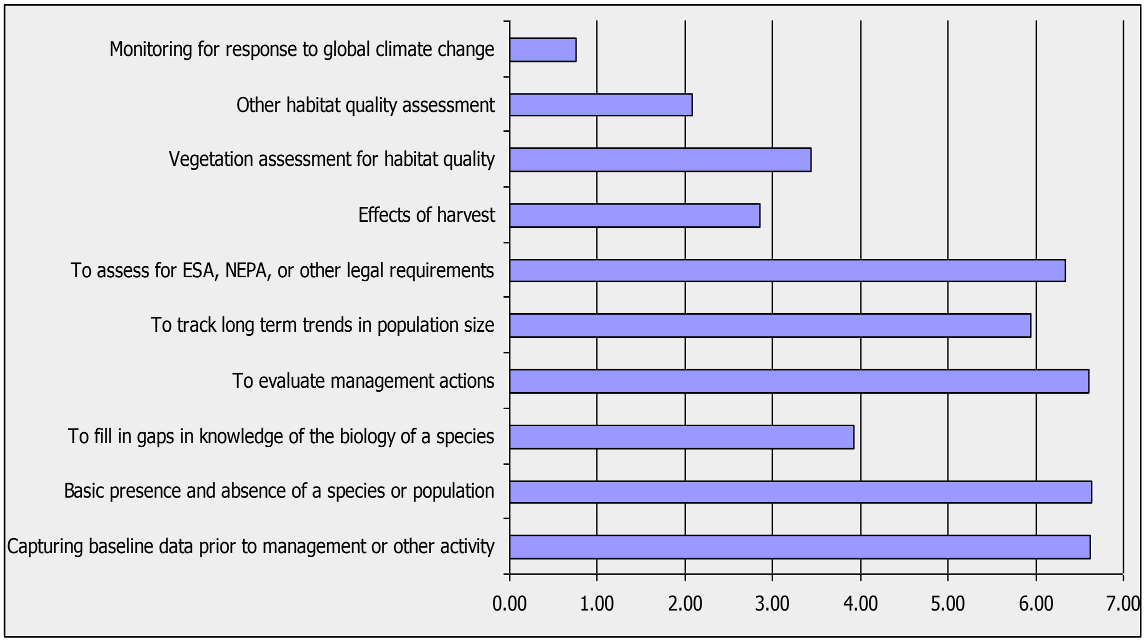


**Figure 5**. Current methods for creating monitoring protocols.

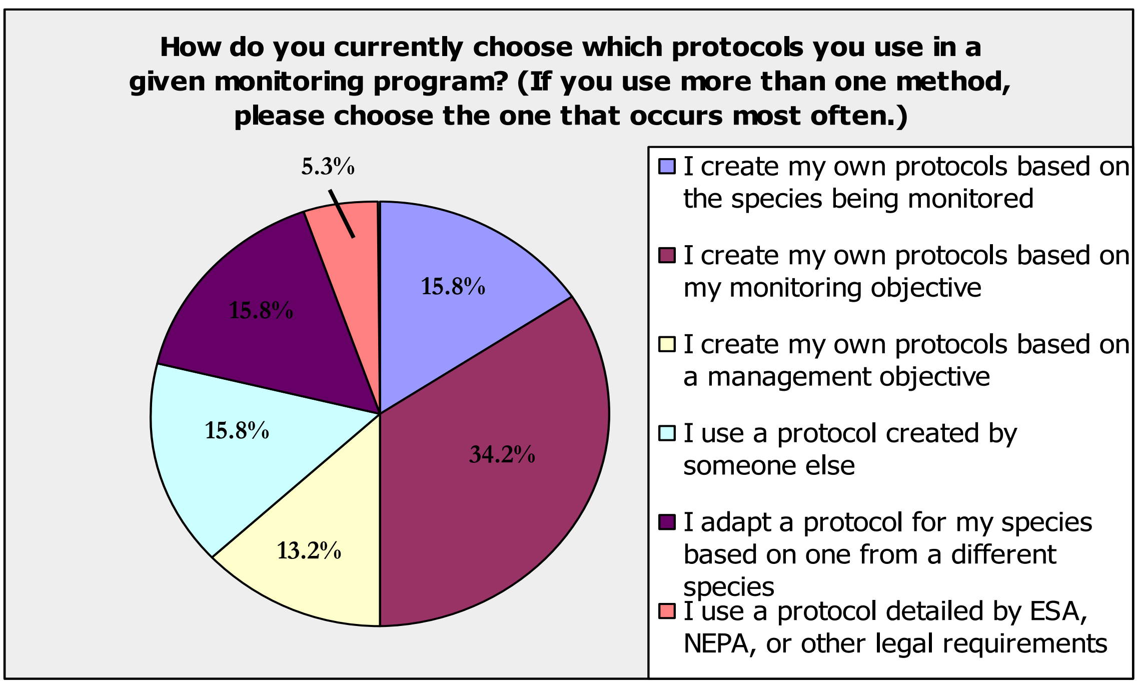

**Figure 6.** Confidence respondents have that their protocols are appropriate.

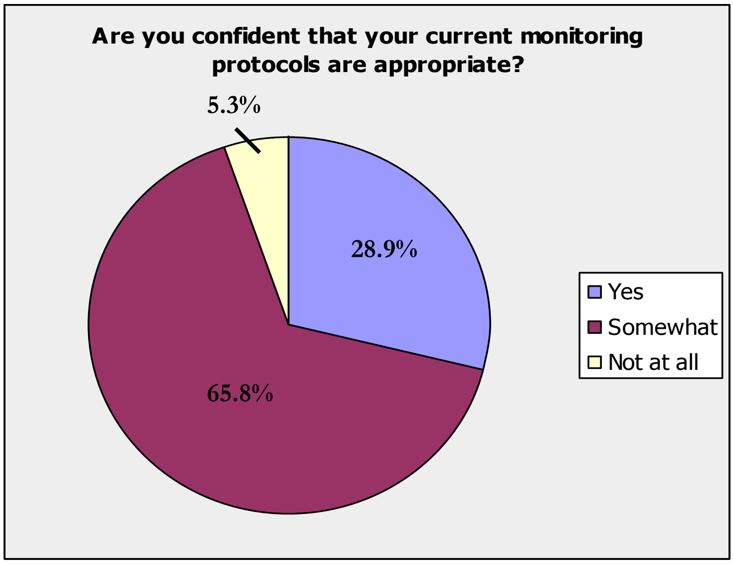


**Figure 7.** Methods used by respondents currently to develop their monitoring protocols.

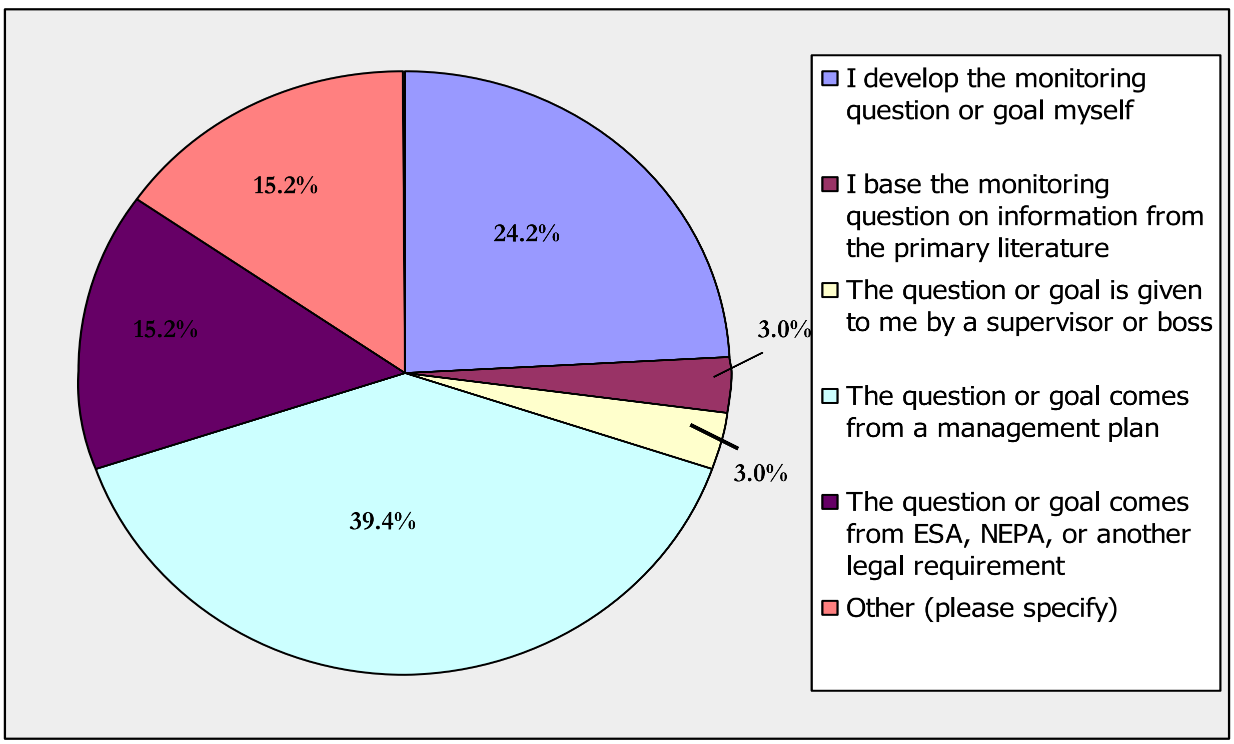

**Figure 8.** Reasons respondents are currently monitoring their species/populations.

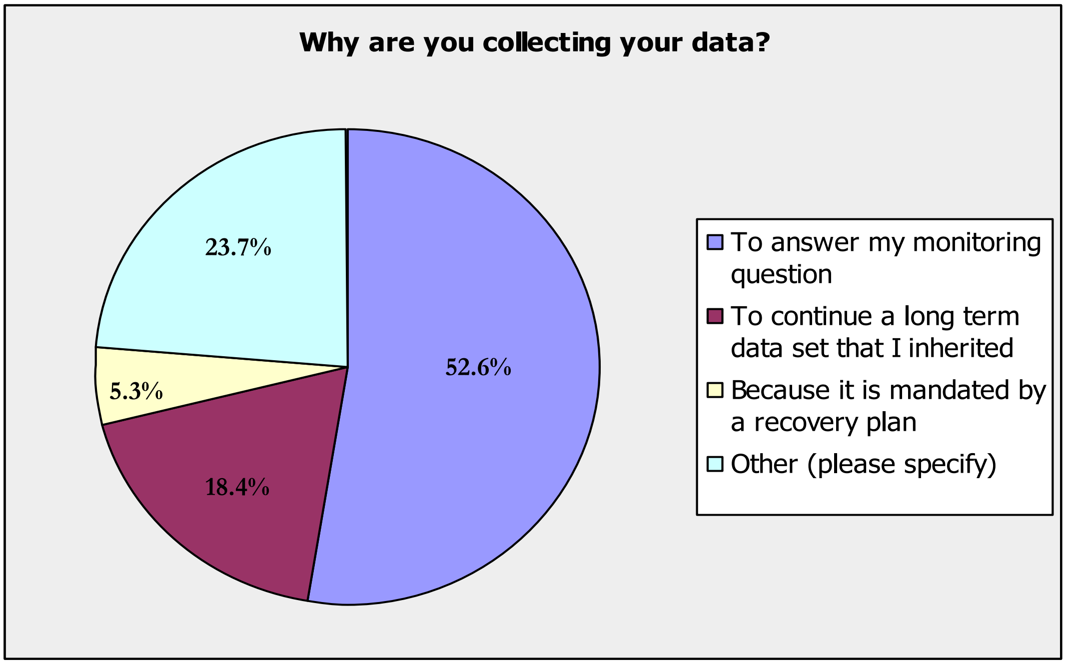


**Figure 9**. What is being done with the data after it is collected.