Chapter 2. Principles of Ecologically Based Adaptive Management

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INTRODUCTION

We promote an ecologically based adaptive management approach because it continually builds on knowledge obtained at the target site, thus tailoring management to that site. Use of the adaptive management approach helps develop and prioritize strategies by considering land management objectives, ecological principles and processes, and contemporary assessment techniques. We recognize that prevention of new species introductions should also be a concept incorporated into a management plan, but we will primarily emphasize management of species found in the management area.

The first step in devising and adopting any weed management plan is defining the bigger picture land management goals for the area of interest. For example, if you are managing a golf course one of the overall management goals will be to have a consistent vegetation surface which allows free and unhindered movement of a golf ball. If weeds occur on your course and they occur in areas and at levels that significantly hinder the movement of golf balls, then you may determine a need to manage the weeds. Your weed management objectives, in order to achieve the management goals, could be to remove dandelions from the fairway and moss from the green. You would then need to determine how best to achieve your weed management objectives.

If you were managing a forest service district you may have a number of land management goals for different areas, including increasing forage for grazing, maintaining wilderness areas, etc. In this more complicated scenario your weed management objectives may be to increase non-native grasses such as smooth brome *(Bromus inermis*) and timothy (*Phleum pratense*) or at least not worry about decreasing them; whereas in your wilderness area your objectives would be to prevent introduction of those species or at least contain them. Thus, in this example different land management objectives would become priority for different areas of the forest to achieve the different management goals, and subsequent weed management goals could be opposing one another on different sides of a fence or boundary.

However, in order to define weed management objectives one needs to know which species are present and where in the area of interest. This is achieved by performing an inventory or survey. A survey is a sampling of a representative portion of a management area, whereas an inventory is a catalogue of the entire management area. The distinction between a survey and an inventory is analogous to the difference between a poll and a census. A census is intended to account for all people within an entire targeted population. In a poll, a sub-group of the total population is sampled with the hope of obtaining information representative of the whole.

Once information on the presence and location of different species has been collected a selection of populations (again a sub-sample representative of the whole area) needs to be monitored for change over time. We define two types of monitoring:

Monitoring for Invasiveness.

A population could be considered invasive if it consistently increases in density or spatial extent, or is the source of new populations.

Monitoring for Impact:

(1) Impact and effect of non-indigenous species on the surrounding vegetation and ecosystem relevant to the land management goals.

(2) Impact and effect of weed management practices on the target populations.

(3) Impact and effect of weed management practices on non-target species and ecosystems.

There are numerous inventory/survey (Rew and Pokorny 2006) and monitoring methods (Elzinga et al. 2001). Methods should be chosen with consideration of the overall land management goals.

Management of biological systems is inherently difficult because prediction of ecosystem behavior is highly imprecise. That is due partly to land management history, and differences in biotic and abiotic variables, which means taking successful practices from one area to another has limitations. Or at least the management practice may not work exactly as anticipated.

Ecologically based adaptive management is conducted with the understanding that prediction of management outcomes in ecosystems is imprecise. Therefore, the focus is on gathering information and adjusting management over time and space for the particular area of interest, and adjusting management practices according to assessment of new information.

Essentially, every management practice should be considered and set up as an experiment to compare with other practices. For example, if one is setting out to control weeds with a particular practice, then it may be best to choose a number of different environments to test the practice and leave some areas of each treated populations with no management. This approach may seem like a science experiment. It is. When you think about it, whenever you manage you are predicting a certain outcome. If the outcome is relevant to the management objectives; i.e., it is not to just see dead weeds, but to see a sustained change in the plant community, then one must compare the management outcome to an unmanaged community.

The effectiveness of the practice on the different populations and environments should then be evaluated to determine if it is working better or worse in some environments, or if the practice was equally good or equally variable across sites. The no-management (control) data would be used as a baseline to determine if the practice was any better, more reliable or had more impact than doing nothing. It would be better again to add at least one or two alternative practices for additional comparison. The information from the comparisons of the practices and no-management option should be taken into account for future management actions. It may be that one practice works better than the another but in certain environments—possibly those least conducive to the growth of that particular species—that doing nothing works just as well. Thus, the adaptive approach is the most efficient way to deal with the high degree of uncertainty in ecosystem response to management and incorporates site-specific knowledge about responses to management.

Adaptive management assumes that the managers will fine tune general management options. The more biologically based the management option, the more general the principles to manage upon and the more local experimentation will be required to identify the options that work.

For example, if you plan to manage a weed species by manipulating the native vegetation through seed additions to a plant community, you will be relying upon a complex set of interactions among ecological processes in order to get the desired outcome. Thus, it will be difficult for any plot experiment in any one place to provide prescriptive information about the outcome of such a management option and one should plan on adaptive management. On the other end of the spectrum, if you spray with a herbicide to remove a species it can be relatively predictive and extrapolation from small plot experiments is more successful. Thus, prescription for application of the practice is much more possible at this end of the spectrum. However, off-target impacts of herbicides can be highly variable by environment and therefore adaptive management in the form of incorporating experimentation is still critical even if testing herbicides.

These examples also demonstrate that monitoring is a key component of the ecologically based adaptive management approach. Monitoring is fundamental, as stated above, to determining if populations are invasive, if they are having an impact, and if management practices are having an impact on target and/or non-target species. These are crucial pieces of information that must be obtained in order to begin successful adaptive management. Monitoring is also critical for successful and effective conventional management but it is less frequently performed.

One critical point that emerges when using adaptive management is that management must be justified based on data, and that data should be obtained from the management area in order to increase certainty of local management outcomes. Many believe that collecting data to prove that species or populations are invasive or have impact is ludicrous—because everyone knows that certain species are highly invasive. However, there are data showing that even the most invasive species are not at all invasive in some environments. They somehow got lucky and became established, but are not increasing and are not a source of new populations. So maybe such populations are not worth managing from the ecological or economical point of view; monitoring a number of populations will allow that to be determined. It will also increase our understanding of what conditions are required for populations to move into an invasive mode.

Therefore, we propose that the time taken by managers to conduct monitoring to determine the range of invasiveness of non-indigenous species populations, and range of effectiveness of management practices, across the different conditions within a management area, will pay for itself by reducing unneeded and potentially environmentally damaging management.

DEFINITIONS

Listed below are definitions of terms specific to non-indigenous plant species which we use in this chapter.

Plant Population A group of individual plants of the same species in an area usually specified to make measurements of density or other characteristics (often 1 m^2). Often, we will assume that a single patch of a species is a population.

Plant Metapopulation A set of patches of the same species in the same habitat that are close enough to permit interbreeding.

Plant Community A mixture of plant populations (more than one species) that share a habitat.

Non-Indigenous Plant Species (NIS) A non-native plant species introduced to an area by people, either on purpose or accidentally. There are NIS plant species that are not generally regarded as weeds (e.g., Kentucky bluegrass, *Poa pratensis).*

Invasive Plant Species An NIS that has populations or metapopulations that are increasing in density and/or spatial extent. There is considerable debate over whether "impact" should be included in the invasive definition. See Chapter 7 for a reading list of relevant articles.

Weed A subset of plant species, not necessarily NIS, that are placed on a list (often designated by law; e.g., state or federal noxious weed list) based on professional consensus that the species represents some problem for people.

ECOLOGICALLY BASED WEED MANAGEMENT PLAN

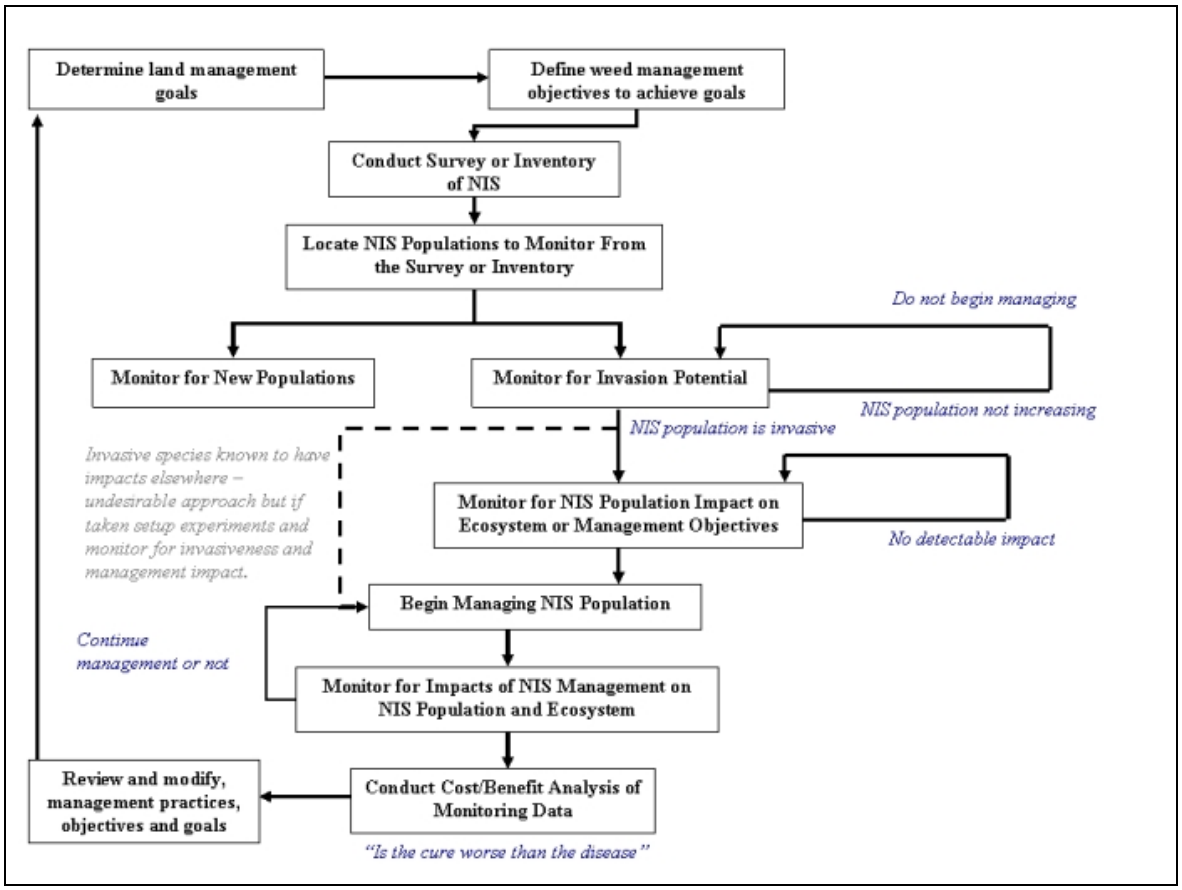
We will adopt an adaptive management approach developed by The Nature Conservancy (see table, page 10) that we have modified to include additional components (see "Steps in Formulating an Ecologically Based Weed Management Plan" and Flow Diagram, below), to create a weed management plan for a target management area. This

approach must be clearly described and evident throughout a plan.
Note that in most cases one does not implement weed control until halfway through the flow chart.

A management area could be a crop field, a ranch, a BLM district, a state fishing access, or a national park, etc. It is often easiest to take portions of a managed area that have similar goals and make them a specific management area.

The cyclic flow is a necessary part of adaptive management, allowing for periodic review of the success of different management practices to determine the best approach but also to evaluate if the management practices are achieving the management goals and weed management objectives. The goals, objectives and management practices should be altered according to the results of the review. This is the essential "adaptive" process required by ecologically based adaptive management (Randall J., et al. 2001, The Nature Conservancy, Weed Management Plan Template Introduction).

Flow Diagram for Ecologically Based Adaptive Weed Management



Steps in Formulating an Ecologically Based Weed Management Plan

1. Describe the management area, including its unique features, history, and who is responsible for management; how adjacent lands are managed and how they may influence or potentially influence the management area.
2. Describe the land management goals for the management area in general and any particular portions of the area that may have different goals.
3. Describe the weed management objectives as they are associated with the general and specific land management goals for the management area.
4. Make a list of the non-indigenous and conservation species that are present in the management area. This should include all non-indigenous plant species (NIS), highlighting potentially invasive species or species labeled as noxious weeds (state lists). Conservation species should include rare, threatened, or endangered native plants, plant communities, and wildlife that could be directly or indirectly impacted by non-indigenous species. Separately list notorious invasive species that you think could invade the management area from adjacent areas in the next 5-10 years. This should be a watch list.
5. Are the locations of the target NIS species known in your management area? If not it will be necessary to perform an inventory or survey to locate them.
6. Forecast which, if any, species or populations threaten or have the potential to threaten your management goals and targets. This forecast is based on, in order of preference, site knowledge, literature review, expert knowledge, and manager's intuition. Much of this information is contained in risk assessments.
7. Identify NIS populations (patches) or metapopulations for monitoring to determine invasiveness and impacts. See Chapter 7 for specific methods for monitoring
8. Identify the practices currently available to manage the NIS. Clearly describe how implementation of the practices will move conditions towards the management goals and abate threats to priority conservation species and conditions. You will need to suggest who (e.g., management agency employees, citizen groups) will do the on-the-ground management activities.
9. Determine how you will set up comparisons of the different management practices (actions) in the field, and how you will compare the results in the office. State how you will incorporate the results into the management plan.
10. Identify a mechanism to revisit and revise the management goals, practices, monitoring, and assessment based on monitoring and evaluation.

Below is a table of contents for a weed management plan that follows the Nature Conservancy Weed Management Plan template with a few sections we have added.

Section	Page
1 INTRODUCTION A. Description of the Site and Management Goals including Production and Conservation Targets. There should be no mention of weed management goals or objectives here. These are the site specific goals for the land. For example: sustainable forage production for X number of cattle, conservation of native plants and animals, or conservation and improvement of wildlife habitat to increase elk populations. These goals are best stated so that the outcome is specific and can be quantified so that one knows when the goal is accomplished.	
B. How NIS May Generally Threaten Production and Conservation Targets and Interfere with Management Goals. This is a statement that identifies weed or non-indigenous species (NIS) that may or may not be present in your management area, but there is evidence that the species could be in your area and there is evidence that each of the identified species could have an impact on your overall management goals. There are generally 4 different types of evidence that one may draw upon and weigh according to one's management directives. These are in order of increasing certainty about the accuracy of the information: 1. Local historic knowledge 2. Popular literature, web sites, extension bulletins, etc. 3. Peer reviewed scientific journal articles 4. Local quantitative measurements on the species	
C. Philosophy of Invasive Species Assessment and Subsequent Adaptive Management: Define adaptive management and make it clear how the adaptive management philosophy will be the underlying theme for your management plan.	
2. INVENTORY/SURVEY OF NIS Decide if the area is small enough to do an inventory or should a survey be conducted. If an inventory was already conducted, was it a true inventory? If a survey needs to be conducted how should the area be sampled to best estimate where the suspected invasive species occur? Give the manager a specific protocol for how to proceed with conducting the survey or inventory. Include in this section how often the manager should re-conduct new colony monitoring to determine if new colonies of NIS have occurred. Give them a plan on how to conduct the follow-up sampling or inventory to efficiently identify any new colonies of NIS. Use your knowledge of first principles of weed ecology to design the follow up surveys/inventories. Optional reading: Searching for a needle in a haystack: evaluating survey methods for non-indigenous plant species. Rew et al. (2006).	
3. NIS ASSESSMENT FOR INVASIVENESS (Monitoring) Introduce this section with a paragraph on why NIS assessment for invasiveness is important for the manager. Remember that you are building evidence that increases the certainty about the behavior of the species in your management area and its special response to natural disturbance and management history. Convince the manager that NIS are typically not invasive under all environments within a management area and that assessment for relative invasiveness will help	

	prioritize populations for management or even identify populations that are not invasive and maybe going locally extinct. By identifying the variation in invasive species behavior you are prioritizing them for management and this is a critical step for those that have limited budgets for management.	
A.	Table 1: Prioritized List of NIS Species To Monitor (TNC-WMPT) See Ranking Approaches: Heffernan, K.E., P.P. Coulling, J.F. Townsend, and C.J. Hutto. 2001. Ranking Invasive Exotic Plant Species in Virginia. Natural Heritage Technical Report 01-13. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, Virginia. 27 pp. plus appendices. APRS Implementation Team. 2000. Alien plants ranking system version 5.1. Jamestown, ND: Northern Prairie Wildlife Research Center Home Page. Based on: Hiebert, R.D. and J. Stubbendieck. 1993. Handbook for Ranking Exotic Plants for Management and Control. U.S. National Park Service Natural Resources Report NPS/NRMWRO/NRR-93/08. This section should begin with a paragraph that describes the theoretical basis for the particular prioritization approach that you are using. There should be citations of publications/web sites that provide this basis. In addition, the Table of prioritization needs to be thoroughly explained with definitions of land cover types, etc. Remember to weigh your decisions about ranking based on the quality of the evidence (information).	
B.	Literature Review to Determine Where, When, Under What Circumstances each NIS Is Invasive. (By species assessment) In this review of the scientific literature you are providing the specific information/evidence that convinced you that the species that you have found in your area are invasive (have high population growth rates). Remember, the more quantitative the information, the more objective it is for making determination of invasiveness. In addition, you are providing the evidence from the literature that allowed prioritization of the species for management with the method above. This section could be somewhat redundant with section 1B, but is a much more in-depth assessment of just the species that you have found with your inventory or survey of your management area. In addition, it merges the information in the literature with your observations of these species in your management area, now that you have conducted the inventory or survey. Include a statement of what portions of your management area may be most vulnerable to invasion or further invasion of each species based on what you can find about the biology of these species. This would be based on habitat availability, distance from source populations and availability of vectors of dispersal.	
C.	Describe methods that will be used to monitor populations of your priority species for invasiveness. Start this section by defining invasiveness (i.e., a population that is consistently increasing in density, spatial extent or a source for new populations). An important aspect of monitoring is drawing on the inventory or survey to select populations across the environments where they are found. This is done because the different environments are likely to be the source of population growth. Selecting measurements to estimate population growth may vary by species. In module 4, you will be introduced to several methods that have been identified as optimized on efficiency and effectiveness. Remember that a manager is going to read this plan and expect instructions on how to go out in the field and accomplish the monitoring objective. Thus, you must be specific on how to make	

measurements and how to interpret the measurements. You may wonder how you will get a manager to do these measurements, but it is your job to provide the plan that best accomplishes a scientifically based approach to monitoring. Most evidence indicates that there is great value in accurate and thorough measurements. For more information on this topic, see Searching for a needle in a haystack: evaluating survey methods for non-indigenous plant species. Rew et al. (2006), at http://www.weedcenter.org/textbook/Rew_haystack.pdf.	
4. NIS ASSESSMENT FOR IMPACT (Monitoring) Impact is a quantification of the effect of something on something else. For example, impact of a NIS on forage production is a quantifiable response of the land management goal of forage production associated with the presence of a NIS population. That is, one could measure the amount of forage before and after an invasion by a NIS to quantify the impact of the NIS. If the management goal is conservation of native plant communities then one would want to measure the degree to which the native plant community is altered following an invasion by a NIS. Change in native species richness may be a standard type of metric for quantitative evaluation of impact under this management goal. Thus, the general point is that NIS "impact" is totally tied to the management goals. Begin this section with a paragraph on why NIS assessment for impact is important for the manager to know. Convince the manager that NIS typically do not have consistent impact under all environments within a management area and that assessment for relative impact will help further prioritize populations for management.	
A. Literature Review to Determine Where, When, Under What Circumstances each NIS Is Likely To Have Impact. By species assessment. Make sure that you use scientific citations for each statement about impact. Emphasize studies that have actually quantified impacts rather than general statements made in introduction sections of papers. Remember to use language that indicates the weakness in drawing general conclusions from single experiments, i.e., reemphasize that just because one experiment found the NIS to have an impact or not have an impact does not mean that the species will have the same impact in your management area.	
B. Describe methods that will be used to monitor for impact. Be specific so the manager can actually go out and make these assessments. Impact must be made specific to the management objective. Thus, if one is interested in growing forage for livestock then the measurements should be focused on forage production. One should make a minimal set of measurements to determine the relationship between amount of a particular NIS species and the amount of forage or better yet, the change in forage production with a change in NIS density through removal or natural increase. Alternatively,if the management objective is conservation, the measurement of impact may be on native species displacement by an invading population of NIS.	
5. OVERVIEW OF WEED MANAGEMENT A. Management Philosophy & Setting Priorities (Using Adaptive Strategies) Here, you should reiterate the adaptive management philosophy as well as the idea that management outcomes can be highly variable. Therefore, test treatments and control plots should be implemented. Remember, every management action should be treated as an experiment.	

6. SPECIFIC WEED CONTROL METHODS (by species) A. Summary of Specific Actions Planned Do this for each weed including the management options for each and any anticipated variation on actions for different populations in the management area. Consider preventative as well as reactive approaches. If you have a restoration situation, then include how you will implement restoration. Determine a schedule for re-conducting the survey or inventory to look for new species. Identify specific prevention approaches that you could apply to species on the watch list. B. Monitoring for Impacts of Management On Target and Non-Target Species Any weed management action that is taken should be evaluated for both its impact on the target NIS population and the non-target ecosystem. Assessing the impact on the target populations could apply the methods discussed for evaluating invasiveness (i.e., population growth rate assessment). Hopefully, populations will be placed on a trend toward local extinction, or lowered below a threshold density, as a result of a management action. Similarly, the measurement of impact on the ecosystem can utilize the measures of impact discussed above and thus are made relevant to the overall management goals. C. Tables (TNC-WMPT) Table 2: Weed Management Plan Implementation Schedule Table 3: Projected Resource Costs Table 4: Itemized Actual Annual Cost and Labor Worksheets	
7. REFERENCES (use scientific format*	
8. APPENDICES	
Appendix 1. Emergency Information/Map to Hospitals	
Appendix 2. Blank Maps/Sample Maps	
Appendix 3. Examples of Forms Used in Collecting Monitoring Data	
If herbicides will be used on the site: Appendix 4. Herbicide Use Protocol	
Appendix 5. Herbicide Use Record Forms	
Appendix 6. Herbicide Labels	
*Examples of citation format: Heck, W. W., C.L. Cambell and G.R. Hess. 1991. Environmental Monitoring and Assessment Program Agroecosystem Monitoring and Research Strategy. EPA/ 600/4-91/013 U.S. Environmental Protection Agency, Washington, D.C. 160 pp. Hoffman, C. A., C. R. Carroll. 1995. Can we sustain the biological basis of agriculture. Annual Review of Ecological Systematics 26, 69-92. Jensen, M. E., W. J. Hann and R. Keane. 1992. Ecosystem Inventory and Analysis Guide, Draft. U.S. Forest Service, Region One, Missoula, MT. 511 pp. Karr, J. R. 1993. Measuring biological integrity: lessons from streams. In: Woodley, S., Kay, J., and Francis, G. (eds) Ecological Integrity and the Management of Ecosystems. pp.83-104. St. Lucia Press, Ottawa. The Food Alliance. 1998. TFA-Approved Farms. [Online]. http://www.foodalliance.org	

THE NATURE CONSERVANCY
Invasive Species Initiative
http://tncweeds.ucdavis.edu.products.html

Links to Adaptive Weed Management

- Using TNC Weed Management Plan http://tncweeds.ucdavis.edu/products/plans/WMPIntro.rtf
- TNC Weed Management Template http://tncweeds.ucdavis.edu/products/plans/WeedTemp.rtf
- TNC Weed Management Tables http://tncweeds.ucdavis.edu/products/plans/WeedTabl.xls

Examples of Weed Management Plans using TNC Template

- South Half of Hebgen Ranger District WMP_erik.pdf
- Emmons Property WMP

Additional Resources

- Management plans by state: http://www.invasivespeciesinfo.gov/toolkit/congeog.shtml
- Creating an Integrated Weed Management Plan. A Handbook for Owners and Managers of Lands with Natural Values. Volume IV in the Caring for the Land series from the Colorado Natural Areas Program. http://parks.state.co.us/NR/rdonlyres/E4FAAC68-00B4-44A8-A4E3-4C88B185BC78/0/IWMhandbooktext.pdf
- Seven Steps to Managing Your Weeds from Weeds BC. http://weedsbc.ca/pdf/7StepsToManagingYourWeeds.pdf

LITERATURE CITED

Elzinga, C.L., D.W. Salzer, J.W. Willoughby and J.P. Gibbs. 2001. Monitoring Plant and Animal Populations. Blackwell Science Inc., Malden, MA. P. 360.

Randall, John, Barry Meyers-Rice, and Mandy Tu, 2001, The Nature Conservancy, Weed Management Plan Template Introduction. http://tncweeds.ucdavis.edu/products/plans/WMPIntro.pdf.

Rew, L.J. and M.L. Pokorny (eds.), 2006. Inventory and Survey Methods for Non-indigenous Plant Species, Montana State University Extension, Bozeman, MT.