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Integrated Weed Management: Strategies, Tactics, Decision Criteria, and the Importance of Partnerships

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Introduction

According to Sheley et al. (2011), "integrated pest management (IPM) is a long-standing, science-based, decision-making process that identifies and reduces risks from pests by using pest management strategies and tactics." Practitioners have commonly used IPM in intensive agricultural settings to develop strategic and tactical management technologies designed to prevent significant pest damage, while posing minimal risk to people, property, resources, and the environment.

Management of invasive plants on rangelands and wildlands incorporates many of the same principles found in IPM. Because rangeland and wildland weeds are technically plant pests, invasive plant management is commonly referred to as Integrated Weed Management (IWM). IWM attempts to address the ultimate causes of weed infestations rather than simply focusing on controlling weeds (Lane et al., 2010). Accordingly, IWM practices are planned to maintain or restore desirable plant communities to provide: 1) sustainable ecosystem functions, 2) resistance to reinvasion, and 3) sustainable long-term control of invasive plants (Sheley et al. 2011).

The first part of this paper explains fundamental principles for implementing IWM strategies, tactics, and decision criteria based on key points found in Lane et al. (2010); Sheley et al. (2011); and Zimmerman et al. (2011). The second part of the paper discusses four active partnerships in southeastern Arizona that have used IWM principles to battle various noxious weed species. The goal of this paper is to provide a strategic and tactical framework for collaborative partnerships to consider when dealing with invasive plant problems across multiple land ownerships.

IWM Strategies

Implementing IWM practices on rangelands or wildlands usually begins by considering four overarching strategies: 1) prevention and early detection, 2) eradication, 3) containment, and 4) suppression and restoration. The primary strategies implemented within a management area will depend on the number and size of infestation(s), the potential for forming collaborative partnerships among landowners, and available resources (e.g., time, money, personnel, equipment, supplies).

Prevention and early detection (P&ED) strategies are based on the premise that "the easiest and most economical weed to control is the one you don't have yet." If you or your neighbor has a small noxious weed problem, it can pay huge dividends for you to work together to ensure that the problem is addressed quickly. Rapidly responding to problems while they are still small (and seemingly inconsequential) is the most powerful thing people can do to prevent a small problem from becoming insurmountable (Photo 1). When noxious weed problems are detected early, and in a small area, eradication may be possible.

Eradication strategies fit hand-in-glove with P&ED as a complimentary approach. Eradication is practical only for small-scale infestations that have been detected early enough so that fast and complete control can be achieved.

Photo 1. Manually removing a small infestation of onionweed the day after it was detected. Photo credit, Kim McReynolds.

The goal of eradication is to eliminate all individuals, root remnants, and seed banks of an unwanted plant. For an eradication project to be successful, all possible cause(s) of the invasion must be addressed, and all potential seed sources and reproductive vegetal parts from invasive plants must be removed. Eradicating a small weed problem can save you from having to implement containment or suppression and restoration strategies (discussed next) which require more time, more money, and have a lower return on investment (discussed later) than either P&ED or eradication strategies.

Containment strategies attempt to control established infestations which are unlikely to be eradicated due to their size and/or level of establishment. Containment projects treat smaller "satellite" or "spot" infestations that may be advancing from the perimeter of a larger "core" infestation. This approach is analogous to the way fire fighters deal with unwanted wildfires by putting out small "spot fires" ahead of conflagrations so that small fires are prevented from merging and ultimately growing into larger fires.

Suppression and restoration (S&R) strategies attempt to reduce invasive plant infestation size, abundance, and/or reproductive output (e.g., density, cover, seed production, vegetative roots) below a defined threshold needed to maintain desirable species and healthy ecological processes. Restoration projects may use a combination of tactical tools (e.g., herbicides, grazing, mechanical control) to target and suppress unwanted plants while encouraging remnants of desirable plants that are still viable within the plant community. If little or no remnants of desirable plants remain it may be necessary to follow suppression treatments with seeding desirable species that can become competitors for resources against undesirable weeds. The time frame of S&R projects depends on the invasive capacity of the undesirable weed(s), the extent of the infestation to be restored, the ecological potential of a site for recovery, and the goals and objectives for a plant community. S&R projects are usually the most expensive of the three IWM strategies and should be undertaken only if clear conservation outcomes can be attained within a reasonable amount of time with the resources at hand. In reality, large infestations may require some level of "forever" control because seed banks and vegetative reproductive plant parts can be huge.

IWM Tactics

IWM tactics typically involve applying one or more weed management tool (e.g., physical/mechanical, biocontrol, livestock, herbicides, fire, seeding, etc.) to support one or more of the four IWM strategies discussed previously. It is common for two or more tactical tools to be applied sequentially as respective "set-up" and "follow-up" treatments. The proper type, sequence, and combination of treatment applications are beyond the scope of this paper because each situation must be evaluated on a case-by-case basis. In other words, there is no cookbook approach to applying IWM tactics or tools because of the multitude of factors that are unique to each setting.

IWM Decision Criteria

Thoughtful discussion of the IWM decision criteria with all partners is key to identifying the most appropriate combination of strategies and tactics to address specific invasive plant challenges. The following is a list of IWM decision criteria modified after Zimmerman et al. (2011).

Goals and Objectives

Successful implementation of IWM strategies and tactics depends on proper framing of goals and objectives for a weed management project. Goals are broad plans related to long-term IWM strategies, whereas objectives break down strategies into achievable, measurable, and time-bound parts that can be achieved via appropriate application of IWM tactics for a given situation. Goals are framed where if a project's objectives are accomplished its goals are naturally met. A project should not be attempted until conservation goals and objectives are well-defined and the project is determined to have a reasonable chance of success with the resources at hand.

Ecological and Economic Impacts and/or Harm to other Values

Managers should evaluate whether the invasive plant(s) in or near the management area exceed legal mandates or are causing (or have the potential to cause) significant ecological or economic impacts, harm to human health, negative impacts to recreational and conservation values or ecosystem services. Some states, land management agencies, and organizations have ranking systems that can help land managers prioritize which invasive plants should receive highest priority for control efforts. Identifying plants that have high potential to cause deleterious ecologic and/or economic impacts can also help partnerships leverage political, cooperative, and monetary support for an IWM project.

Importance of Creating Education and Awareness within the Socio-Political Environment

The social-political environment can determine the success or failure of an invasive plant program which underscores the importance of active partnerships (discussed later). Your 'neighbors' may not be aware of or appreciate the multiple negative impacts that invasive plants can cause. In fact, they may not even recognize they have a harmful weed on their property. Addressing social-political barriers through education and awareness programs can help bridge gaps in commitment towards managing invasive plants across jurisdictional borders (Photo 2).

Photo 2. Community workshops educate citizens about local weeds of concern and IWM practices. Photo credit, Savanna McReynolds.

Mapping and Monitoring

Mapping data are required to document the type, number, size, and density of infestations across a project area's political, jurisdictional, and ecological boundaries. A comprehensive map of a project area's weed infestations provides a critical document for neighboring landowners, agencies, and organizations to plan IWM strategies and tactics while sharing the workload with one another. Monitoring programs should be implemented to document the effectiveness of control efforts. Mapping and monitoring data should be carefully evaluated and updated regularly to prioritize how and where resources will adaptively be used to address goals and objectives as the project evolves from year to year.

Resource Availability

Resource availability (e.g., time, money, personnel, equipment) plays a critical role in determining the feasibility of an invasive plant control project and whether it ultimately is successful. Organizational support (i.e., the power of partnerships, discussed later) for a project must be secured to maintain sufficient long-term funding. Resources are required to monitor outcomes of control treatments, as well as to prevent, detect, and quickly control new occurrences of noxious weeds. Resource requirements should decrease over time if the execution of a project's strategies and tactics proves to be successful. It can be difficult to estimate the total resources needed at the beginning of a complex control project. A starting point might be to develop an initial project budget for a 5-year timeframe using the best available information, followed by periodic adjustments (at least yearly) of budgets, strategies, tactics, goals, and objectives during planning meetings with partners.

Effectiveness of Control Efforts, Building Trust, and Unintended Consequences

Unintended consequences may evaporate trust and spark opposition to future control efforts. A project can fail if the treatments negatively impact both undesirable and desirable plants or other valuable resources. For example, damage to non-target species may occur due to compaction of soils (e.g., mechanical control), herbivory on non-target species (e.g., using classical biocontrol or livestock as tools), or herbicide misapplications. Removal of an invasive plant might result in reinvasion of a site by a plant species that is even more harmful than the initial one being controlled. Continued open communication among all stakeholders and partners will build trust as the project evolves and help to mitigate mistakes or unintended consequences that arise even with the best of intentions.

Return on Investment

As stated previously, assessing the conservation benefit of an IWM project requires that the potential conservation benefits of the project have been well defined. Return on investment (ROI) analysis can be helpful when evaluating costs of an invasive plant control project relative to its conservation benefits. Projects with high costs and low conservation benefits have a low ROI, while projects with a low cost and high conservation benefit have a high ROI. Effective P&ED and eradication strategies will almost always have a higher ROI than containment, suppression, and restoration strategies. This is why it is critical to catch and treat invasive plant problems while they can literally be "nipped in the bud." Larger, more complicated infestations will always require more resources and coordinated efforts to manage. However, if a project has high costs and potentially high benefits, it may still be worth pursuing. In such cases, IWM partners should carefully evaluate anticipated costs, benefits, and resources available to decide if a project has a reasonable chance of success.

Collaborative Partnerships are Critical to the Success of IWM Project

The more widespread noxious weed problems become the more important it is for multiple partners to work together across jurisdictional boundaries. For example, successful IWM partnerships in southeastern Arizona have included county, state, and federal governments, non-profit organizations, universities and community colleges, local K-12 school districts, private industry, and rural and municipal landowners. In the following sections, we highlight four partnerships that have addressed various noxious weed challenges and issues across three counties in southeastern Arizona. A common thread connecting the four efforts has been the use of collaborative partnerships to plan and execute tailored IWM strategies and tactics designed to proactively manage specific invasive weed problem(s).

Sahara Mustard in Graham County

In 2013, The Arizona Department of Transportation (ADOT) completed a lane widening project on state Highway 191 between I-10 and Safford. At the end of the project reclamation of the roadsides and median with seeding was done. The following spring a University of Arizona Cooperative Extension (UACE) agent noticed a 2-mile stretch of Sahara mustard (*Brassica tournefortii*) that had never been seen on Highway 191 before. The agent sent a local weed technician working on a grant-funded project to GPS the plant locations. UACE then notified the Safford ADOT field office about the discovery, provided a map with GPS locations, and literature on how to identify Sahara mustard. The urgency of the matter was emphasized as the cool-season dicot needed to be controlled within the next two weeks before it went to seed[1]. ADOT responded by contracting a Department of Corrections inmate crew to hand-pull the plants within a week. The area was carefully monitored the following spring when several new Sahara mustard plants were found within one mile of the previous year's infestation. ADOT again rapidly responded by contracting another inmate crew to quickly pull the emerging invasive weeds, again, before they produced seed. After two years of hand pulling and continued monitoring, no new Sahara mustard plants have been detected along that stretch of Highway 191.

Key outcomes from this partnership:

1) Limited, collaborative partnerships can work very well for short-term, rapid-response control efforts to quickly control an invasive plant.
2) Early detection and rapid response using manual control, mapping, and follow-up treatments helped to prevent a small problem from becoming bigger.

Bull and Milk Thistle, Malta Starthistle, and Buffelgrass in Cascabel, Cochise County

The community of Cascabel consists of a small, rural group of residents that live about 23 miles north of the town of Benson. The Saguaro-Juniper Group is a collective of cattle owners that operate near Cascabel, grazing their cattle as one herd while sharing privately-owned rangeland pastures and irrigated pastures located near the San Pedro River. The Saguaro-Juniper Group is very committed to raising organic crops, including their livestock operation. The Cascabel Community Center has served as a venue where the Natural Resource Conservation Service (NRCS), the Coronado Resource Conservation and Development (RC&D), and UACE have collaborated to hold numerous noxious weed workshops over the years. These workshops raised awareness in the area about the importance of using an IWM approach to control noxious weeds. However, because of the community's priority towards organic food production, the only available control options were manual digging and prescribed burning. Accordingly, Cascabel community members and the Saguaro-Juniper Group have held "digging days" and have implemented carefully timed controlled burns in some of their privately-owned pastures (Photo 3).

Photo 3. Controlled burning of Malta starthistle in a pasture in Cascabel. Photo credit, Kim McReynolds.

Over the years, community members report that their manual and cultural management practices (i.e., manual digging and prescribed fire) have greatly reduced infestations of bull thistle (*Cirsium vulgare*), milk thistle (*Silybum marianum*), Malta starthistle (*Centaurea melitensis*), and buffelgrass (*Pennisetum ciliare*) while allowing the Saguaro-Juniper Group to pursue its organic mission towards sustainable agriculture.

Key outcomes from this partnership:

1) Persistence, perseverance, and motivation directed towards a common cause can make all the difference in implementing an IWM strategies and tactics even when the tools available to a particular partnership are limited.
2) This collaborative partnership demonstrated the importance of education, early detection, rapid response and follow-up treatments using physical control and prescribed fire to address noxious weed problems while they are still manageable.

Onionweed in Cochise County

Onionweed (*Asphodelus fistulosus*) is a federally listed noxious weed. Two opportunities for partnerships with youth groups arose in Cochise County for control of onionweed in local communities. The first involved

[1] Sahara mustard is a cool season annual forb that reproduces only by seed.

Photo 4. 4-H youth pose with USDA-APHIS officer following a successful onionweed pull at the Portal Post Office. Photo credit, Kim McReynolds.

Photo 5. Grazing by goats, in combination with other control methods, can be effective in reducing invasive weed infestations. Photo credit, Kim McReynolds

Tombstone High School where an agriculture teacher invited UACE to present lessons on the impacts of onionweed in the classroom. Classroom lessons were followed by the high school students partnering with UACE during a community service day to physically remove onionweed at the Tombstone Volunteer Fire Station. A second opportunity involved a UACE 4-H Community Club whose members decided to make onionweed a part of their Environmental Stewardship Project. Club members (5-16 years old) worked with community members in the town of Portal (a small mountain community in the Chiricahua Mountains), to physically remove 260 pounds of onionweed from an 80-year-old woman's home and at the Portal Post Office (Photo 4).

The following year, the club organized and held a noxious weed workshop for community members at the Portal library. The indoor portion of the workshop was followed by a field demonstration where residents learned how to dig onionweed to extract its roots, and how to double-bag and dispose of the noxious weed in a landfill. The 4-H Community Club won awards for its educational display on onionweed at the Cochise County Fair and at the Arizona State Fair. Their display was later housed for six months at USDA's Animal and Plant Health Inspection Service's (APHIS) State Office in Phoenix. One teen created an onionweed video for Adobe Youth Voices which was featured on the Adobe Software Corporation's website.

Key outcomes from this partnership:

1) Don't limit your ideas for partners. Youth can be incredible emissaries for educating their local communities about the importance of noxious weed awareness and proactive control.
2) In addition to serving as role models in their local communities, students had state-wide and national impacts from their award-winning displays and video on onionweed which reached far beyond their local community.

Gila River Weed Working Group

Partners of the Gila River Working Group (GRWG) include land management agencies, county, state, and federal governments, and private landowners in Greenlee County, AZ and Hidalgo County, NM. A steering committee directs the IWM activities of the GRWG. Previous work by UACE included herbicide field trials that were conducted on local farms on several noxious weed species to determine the most effective herbicide and timing of application. Greenlee County contracts with a local weed technician who oversees the day-to-day workings of the program from January-June each year (i.e., the season when targeted species are actively growing), while assisting landowners with herbicide application and other IWM tools. A check-out system is in place for landowners to use herbicide and spray equipment (after they have received the proper training) for control of several state-listed noxious weeds, including Russian knapweed (*Acroptilon repens*), Malta starthistle, yellow starthistle (*Centaurea solstitialis*), bull thistle, and whitetop (*Lepidium draba*). Landowners have also used goats, sheep, and steers in targeted grazing projects to control some weed species (Photo 5). Yearly educational workshops continue to be held and working group partners have been very successful in receiving numerous grants to support multiple IWM projects over the 2+ decades of active work by GRWG partners.

Key outcomes from this partnership:

1) Partnering with key stakeholders is essential to ensure sustainability in complex weed problems. Agency personnel may move more frequently, whereas private landowners are usually there for the long-term.
2) Once partners buy into the IWM process, decision criteria (discussed earlier) can be used to determine appropriate strategies and tactics in the short-, medium-, and long-term. Success does not come overnight. The GRWG is in its 3rd decade of active collaboration.

3) Having a dedicated steering committee and a local weed technician has facilitated the IWM process of this partnership. Ensuring that partners continue to have proper training on multiple IWM tools (e.g., herbicides, grazing, manual control, etc.) has been a critical factor contributing to the success of the GRWG partnership.

Conclusions

A primary benefit of IWM is maintenance, sustainability, or restoration of healthy ecosystem services (e.g., reduced soil erosion, improved water quality and quantity, enhanced stream flow, increased biological diversity, improved wildlife habitat) which serve to reduce the probability of harmful plant invasions. In this paper we have discussed key principles for implementing IWM strategies, tactics, and decision criteria and provided examples of four active partnerships that have used (and are currently using) IWM principles in southeastern Arizona. These partnerships demonstrated the wide range of strategies and tactics that can be incorporated into an IWM approach.

Some IWM projects will demand rapid responses from a few key partners to quickly respond to small infestations in the short-term. More complicated projects necessitate multiple partners to engage and collaborate over several years. Successful noxious weed partnerships are always about how people come together to patiently, but consistently, build trust over time. Everyone can bring something unique to an IWM program. Figure out what role you can play in an IWM partnership.

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