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INVASIVE SPECIES ADVISORY COMMITTEE

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Enhancing the Effectiveness of Biological Control Programs of Invasive Species by Utilizing an Integrated Pest Management Approach

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PREFACE

Invasive species threaten agriculture and natural ecosystems. Methods for control and management have evolved over time, and often rely on combinations of techniques and long-term planning. This white paper discusses the benefits and increased potential for long-term success of invasive species biological control programs when utilizing an Integrated Pest Management (IPM) approach.

Integrated control was first defined by Stern et al. (1959) as applied insect pest control, which combines and integrates biological control and chemical control to maintain a pest population below an economic injury level. Integrated control has evolved over time to include all taxa, as well as prevention, other control, and ecological, health, and economic aspects. IPM emphasizes long-term prevention of damage through the utilization of various techniques such as chemical control, biological control, physical control, habitat manipulation, modification of cultural practices, and resistant varieties using combinations that are compatible and produce the desired outcome. An IPM approach can be implemented in agricultural, residential, and natural areas.[1]

Biological control is an integral component of IPM programs and has far greater potential for success when used in an IPM system. Land managers rely on information provided by researchers during the time period leading up to the release of the biological control agent (generally an insect or pathogen), to help guide them on the best procedures, approaches and use of the agent. As the number of biological control programs increase, information from successful and unsuccessful programs can be used to increase the chances for the successful establishment of biological control agents in the future. Post-release monitoring can inform land managers on how to achieve their management goals by guiding them in the most effective use of adaptive Best Management Practices (BMP). Post-release information is also critical for assessing the economic costs and benefits of an IPM approach. Implementing such efforts may increase the success of biological control efforts and the confidence of private and public land managers when making decisions about integrated invasive species management programs.

This white paper will discuss:

- benefits for biological control efforts through inclusion in an IPM approach;
- partnership programs to facilitate the incorporation of biological control in IPM programs of invasive species;
- incorporation of long-term stewardship in biological control programs;
- model program for integrated biological control of an invasive species;
- ecological approaches to maximize success of biological control;
- genetic advances in biological control.

BENEFITS OF BIOLOGICAL CONTROL EFFORTS THROUGH INCLUSION IN AN IPM APPROACH

Biological control agents are intended to reduce an invasive species population through a typical predator-prey or pathogen-host response. The incorporation of other control methods, such as chemical, mechanical, and cultural, may also help to maintain a balanced population of both predator and prey or pathogen and host. This balance minimizes the chance of dramatic swings in invasive species populations, and therefore, failure of the program. At the beginning of a biological control program, when an invasive species population is large, the number of agents that can be released to achieve a noticeable population decline may not be possible. In such cases, the use of other control methods may reduce the invasive species population to a level that is more responsive to the success of the biological control agent. An example is the use of chemical and biological control on diffuse knapweed, *Centaurea diffusa*. Wilson et al. (2004) showed that a low

1 University of California Statewide IPM Program, http://www2.ipm.ucanr.edu/WhatIsIPM

rate of the herbicide picloram or clopyralid applied to diffuse knapweed in early summer increased the percentage of plants infested by the root-boring beetle, *Sphenoptera jugoslavica*, and improved diffuse knapweed control compared with using the weevil alone.

In addition to combining multiple control methods, IPM approaches require a thorough understanding of the interactions between invasive species and beneficial species, as well as the dynamics of these organisms under varying environmental conditions and factors, all within an economic framework for assessment of costs and benefits. For example, Pacific Northwestern orchard systems have several key diseases and arthropod pests that detrimentally affect their production (Jones et al. 2009). Control of these pest species involves the integration of selective pesticides and numerous species of key natural enemies. In such complex systems, frequent monitoring is needed to assess the population levels and seasonal phenology of target pests and natural enemy species and to identify periods of high vulnerability to disruption of natural enemies in orchards. This information is used to better understand the relative ecological benefits of different IPM programs. A web-based decision aid system (DAS) in Washington State was developed for pest management of apple, cherry, pear, peach and nectarine orchards (Jones et al. 2009). The website has ten insect models and three disease models and integrates weather data, model predictions, and pesticide recommendations (including known natural enemy and non-target pest effects) to provide management recommendations. This IPM system has been widely adopted by growers and pest control advisors in many orchards in the Pacific Northwest.

PARTNERSHIP PROGRAMS TO FACILITATE THE INCORPORATION OF BIOLOGICAL CONTROL IN IPM

To further enhance the potential effectiveness of biological control programs, federal land management agencies that oversee and conduct control operations utilizing biological control agents would greatly benefit by partnering with federal, state, and local scientists and agencies. These should include partnerships and collaborations from a variety of relevant pest management disciplines (Carruthers 2011). Such partnerships should develop strategies to monitor, evaluate/measure and communicate meaningful project results. This would facilitate more effective IPM and adaptive management approaches. In particular, increased emphasis on post-release monitoring data could be instrumental in the decision-making process to enhance the success and economic performance of biological control programs. To accomplish this, project funding must be established that takes into consideration the full duration of the project, as well as the broader framework of the IPM approach. While specific funding for post-release monitoring has been requested from many agencies over the past several years, such support has not been viewed as a funding priority.

As an example of the increased effectiveness of biological control through collaboration, the success of tropical soda apple, *Solanum viarum*, control with the beetle, *Gratiana boliviana,* in Florida (Diaz et al. 2012) was the direct result of the cooperative effort of many individuals and organizations including U. S. Department of Agriculture-Agriculture Research Service (USDA-ARS), Animal and Plant Health Inspection Service (APHIS) and Natural Resources Conservation Service (formerly U. S. Soil Conservation Service), University of Florida Cooperative Extension, Florida Department of Agriculture and Consumer Service, South and Southwest Florida Water Management Districts, and the St. Johns River Water Management District. APHIS supported the rearing, distribution and release of the biological control agents, followed by the involvement of many other agencies in the monitoring, implementation, and adaptive management efforts. In addition, private landowners, primarily ranchers, also greatly assisted with the program by allowing access to their property for the collection and redistribution of beetles. The success of these partnerships led to the biological control program receiving the Florida Entomological Society's Achievement Award for Research Teams in 2010.

Another example of a successful partnership is the rearing, release and establishment of the parasitoids of the emerald ash borer, *Agrilus planipennis*. In this case, a Michigan lab developed the production technique that provided natural in-field emergence of adult parasitoids, particularly the larval parasitoid, *Tetrastichus planipennisi,* and the egg parasitoid, *Oobius agrili*. The lab produced over 500,000 parasites that were distributed in 17 states. USDA APHIS and ARS, working together, developed life table analyses for evaluation of the impact of the biocontrol agents, including establishment rates, spread and parasitism levels. Adults were released into each of six forest sites where their population numbers increased rapidly. Recent information indicates that 21.2% of emerald ash borers were parasitized by the fall of 2015. In addition, APHIS, again partnering with ARS, provided data and submitted a petition for release of another parasitoid species.

INCORPORATION OF LONG-TERM STEWARDSHIP IN BIOLOGICAL CONTROL PROGRAMS

Federal agencies should include long-term stewardship and the sustainability of desired ecosystem functions as the ultimate goal of any biological control program. To this end, part of a successful integrated pest management program may include rehabilitation of the ecosystem to a healthier condition. Such a functional state may not be possible with biological control alone. Rehabilitation practices should be developed to facilitate resilience to the ecosystem and help prevent re-invasion or replacement of one invasive species with another. This will require coordination among many federal agencies and partners, including those responsible for developing the biological control programs and those in charge of managing the resources.

For example, tamarisk or saltcedar, *Tamarix* spp. biological control in some riparian areas with the northern tamarisk beetle, *Diorhabda carinulata*, is being used in combination with chemical and mechanical control methods. The IPM approach has a holistic goal of increasing the ecosystem health through restoration of native riparian vegetation to mitigate excessive water loss and reinvasion, while also providing important nesting habitat for the threatened southwestern willow flycatchers, *Empidonax traillii extimus* (Dudley and Bean 2012).

MODEL PROGRAM FOR INTEGRATED BIOLOGICAL CONTROL OF AN INVASIVE SPECIES

TEAM Leafy Spurge (The Ecological Area-Wide Management of Leafy Spurge)[2] is an example of how biological control can be successful when incorporated into a broad regional approach that includes integrated strategies, as well as strong partnerships, outreach and education components, and a stewardship program.[3] By the mid-1990s, leafy spurge, *Euphorbia esula*, caused over $130 million in losses each year in the northern states. TEAM Leafy Spurge was established in 1997 as a six-year IPM research and demonstration project to effectively manage leafy spurge. TEAM Leafy Spurge was funded and led by the USDA-ARS in partnership with APHIS, Bureau of Land Management, Forest Service, National Park Service, Bureau of Indian Affairs, Bureau of Reclamation, U.S. Geological Survey, USDA Cooperative Extension Services, land grant universities, state agencies, county weed managers, and landowners. The IPM approach combined different management tools, including a mix of multi-species grazing programs, herbicides, reseeding, tillage, burning and/or clipping, in combination with insect biological controls to more effectively, affordably, and sustainably manage leafy spurge over a large area. The combined integrated approach with multiple tools not only maximized the overall control of the invasive populations, but also provided more flexibility for land managers and more site-specific options. The results of the program additionally refined the BMP protocol for insect release location, timing, number, appropriate species per site and optimal spurge densities and site habitat types for natural enemy release. The partnership also included a stewardship program by tracking successes and failures, costs and benefits, and subsequently analyzing the results to improve the efficacy and success of the biological control agents.

By 2011, the five-year research and demonstration program helped reduce the total size of the leafy spurge infestation by 75% of its projected range without intervention. Controlling the invasive weed also led to the recovery of some endangered species, such as the western prairie fringed orchid, *Platanthera praeclara*. Multiple agencies working together to provide research and extension coordination met the goal of implementing a long-lasting invasive weed control program.

2 http://www.team.ars.usda.gov/index2.html

3 http://www.team.ars.usda.gov/v2/publications/brochures/brochures.html

ECOLOGICAL APPROACH TO ACHIEVE MAXIMUM SUCCESS IN BIOLOGICAL CONTROL

Because the historical success rate of classical biological control programs is quite variable with 12 to 83% of the projects resulting in establishment of the biological control agent and suppression of the invasive species (Clarke and Walter 1995, McFadyen 1998), increased emphasis should be placed on supporting research funding for cost-benefit analysis of biological control programs to assist prioritization. To reduce the risk of failure, a more ecological approach is also needed to achieve maximum successful selection of effective natural enemies, as well as to better understand the biology of the target pest and biological control species, and ecology associated with regional establishment. While there are multiple factors that can influence the effectiveness of biological control agents, increased attention should be paid to: 1) characterizing natural enemy candidates and target host using morphological taxonomy or genetic markers at the onset of a program, 2) utilizing climatic matching models to accurately determine the most likely areas of successful establishment of candidate agents, 3) understanding biological control agent host-finding behavior and attack rates, and 4) elucidating the most relevant habitat characteristics of biological control agents in their place of origin to better predict rates of colonization and spread in the invaded range (Hoelmer and Kirk 2005, Nowierski et al. 2002).

As an example of the latter factor, Nowierski et al. (2002) examined the habitat associations of four species of *Euphorbia* and seven species of their associated flea beetle species, *Aphthona* spp. Their goal was to identify important habitat factors that might be conducive to flea beetle establishment and impact on leafy spurge in North America. Through ordination models of both *Euphorbia* and *Aphthona* species in their native range in Europe, they identified the preferred soil, nutrient, and plant productivity conditions for the different *Aphthona* species. From this work, they provided a diagnostic framework for the identification of appropriate biological control habitats and key site requisites that might be conducive to the establishment and impact of the biological control agents on U.S. populations of leafy spurge.

GENETIC ADVANCES IN BIOLOGICAL CONTROL

Among the approaches for using natural enemies of target invasive species, classical biological control is the most common strategy. However, advances in genetics now allow for greater precision and predictive power in our understanding and development of biological control for invasive species, particularly insects, and such tools greatly increase the opportunities for managing invasive species (Roderick and Navajas 2003). Genetic engineering or traditional breeding techniques can enhance biological control organisms before their release. The goal of these approaches is to improve host specificity. Despite the potential for using genetic manipulations in biological control development programs, these new technologies still pose a number of challenges that must be addressed by regulators.

CONCLUSION

Biological control has been shown on many occasions to be the most cost-effective invasive species management tool available. However, integrating biological control projects with the full breadth of other IPM tools, expanding post-release monitoring to maximize efficacy, adaptive management, and incorporating new and innovative ecological and genetic technologies may provide private and public land managers greater opportunities for long-term success in suppression of established invasive species.

RECOMMENDATIONS

Recognizing that biological control of widespread established invasive species can be the most cost-effective sustainable control mechanism, particularly as part of an integrated pest management (IPM) program, ISAC recommends:

1. Federal land management agencies that oversee and conduct control operations utilizing biological control agents should do so in the context of an adaptive IPM strategy by partnering with federal, state, tribal, and local scientists and agencies of relevant pest-management disciplines to improve the effectiveness of biological control agents.
2. Federal land-management agencies should place increased emphasis on post-release monitoring to provide feedback and input to the decision-making process and enhance the success and
3. economic performance of biological control programs. To accomplish this, project funding must be assured for the full duration of the project, as well as the broader framework of the IPM approach.
4. Federal land management agencies should include long-term stewardship and sustainability of desired ecosystem functions as the ultimate goal of all biological control programs. To this end, IPM programs may include ecological rehabilitation that will provide resilience to the ecosystem and help prevent re-invasion or replacement of one invasive species with another. This will require coordination among many local, state, tribal, and federal agencies, including those responsible for developing the biological control programs and those in charge of resource management.
5. Responsible federal agencies should give increased attention during selection of biological control agents for release to: 1) characterizing natural enemy candidates using morphological taxonomy or genetic markers at the onset of a program, 2) utilizing climatic matching models to accurately determine the most likely areas of successful establishment of candidate agents, 3) understanding biological control agent host-finding behavior and attack rates/efficacy, and 4) recognizing the most relevant habitat characteristics/associations of biological control agents in their place of origin to better predict rates of colonization, spread, and impact in the invaded range.
6. When biological control is used, federal land management agencies should consider utilizing the information made available from the federal regulatory agencies to more effectively implement biological control programs.

REFERENCES

Carruthers RI (2011) Classical biological control of invasive species: fighting fire with fire, Outlooks on Pest Management 22(3):122-128.

Clarke AR, Walter GH (1995) “Strains” and the classical biological control of insect pests. Canadian Journal of Zoology 73:1777-1790.

Diaz R, Medal J, Hibbard K, Roda A, Fox A, Hight S, Stansly P, Sellers B, Cuda J, Overholt WA (2012) Classical biological control of tropical soda apple with *Gratiana boliviana*. University of Florida. IFAS Extension. Publ. ENY-865. 4 p.

Dudley TL, Bean DW (2012) Tamarisk biocontrol, endangered species risk and resolution of conflict through riparian restoration. Biological Control 57:331-347.

Hoelmer KA, Kirk AA (2005) Selecting arthropod biological control agents against arthropod pests: Can the science be improved to decrease the risk of releasing ineffective agents? Biological Control 34:255-264.

Jones VP, Unruh TR, Horton DR, Mills NJ, Brunner JF, Beers EH, Shearer PW (2009) Tree fruit IPM programs in the western United States: the challenge of enhancing biological control through intensive management. Pest Management Sci. 65: 1305-1310.

McFadyen, R (1998) Biological control of weeds. Ann. Rev. Entomol. 43:369-393.

Nowierski RM, Zeng Z, Schroeder D, Gassmann A, FitzGerald BC, Cristofaro M (2002) Habitat associations of Euphorbia and Aphthona species from Europe: Development of predictive models for natural enemy release with ordination analysis. Biological Control 23:1-17.

Roderick GK, Navajas M (2003) Genes in new environments: genetics and evolution in biological control. Nature Reviews Genetics 4:889-899.

Stern VM, Smith RF, van den Bosch R, Hagen KS. 1959. The integrated control concept. Hilgardia 29(2): 81-101.

Wilson R, Beck KG, Westra P (2004) Combined effects of herbicides and *Sphenoptera jugoslavica* on diffuse knapweed (*Centaurea diffusa*) population dynamics. Weed Science 52:418–423.