Invasive Species Advisory Committee

Control and Management Subcommittee Proposed White Paper

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

Integrated control was first defined by Stern et al. (1959) as applied pest control, which combines and integrates biological control and chemical control in an ecological comparable manner to maintain a pest population below an economic injury level. Integrated control has evolved over time into integrated pest management (IPM). 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 in a compatible manner. An IPM approach can be implemented in agricultural, residential, and natural areas (www.ipm.ucdavis.edu/GENERAL/ipmdefinition.html).

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, to help guide them on the best procedures, approaches and use of the agent. As the number of biological control programs increase, there is the opportunity to gain additional information from successful and unsuccessful programs that can then be used to increase the chances for the successful establishment of biological control agents in the future. The increased information obtained from 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 would increase the success achieved with biological control and increase the confidence of private and public land managers when making decisions on integrated invasive species management programs. This white paper will discuss: 1) benefits for biological control efforts through inclusion in an IPM approach, 2) partnership programs to facilitate the incorporation of biological control in IPM programs of invasive species, 3 incorporation of long-term stewardship in biological control programs, 4) model program for integrated biological control of an invasive species, 5) ecological advances in biological control and 6) genetic advances in biological control.

<u>Benefits for Biological Control Efforts through Inclusion in an IPM Approach</u>

Biological control agents reduce an invasive species population through a typical predator-prey or pathogen-host rresponse. The incorporation of other control methods may also help to maintain a more balanced population of both predator and prey or pathogen and host. This minimizes the chance of dramatic swings in invasive species populations or 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 obtain a noticeable population decline may be unachievable. In such cases, the use of other control methods may reduce the invasive species population to a level that is more amenable to the success of the biological control agent. An example is diffuse knapweed, *Centaurea diffusa*. Wilson et al. (2004) showed that a low 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 more 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 (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 support system in Washington State (DAS, https://das.wsu.edu) was developed for pest management in 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.

<u>Partnership Programs to Facilitate the Incorporation of Biological Control in IPM Programs of Invasive Species</u>

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 would provide feedback that 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 USDA-ARS, 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. These two parasites are becoming widely established and their population numbers are increasing. In addition, APHIS, again partnering with ARS, provided data and submitted a petition for release of another parasitoid species.

<u>Incorporation of Long-term Stewardship in Biological Control Programs</u>

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 provide 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, 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 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 flycatcher (Dudley and Bean 2012).

<u>Model Program for Integrated Biological Control of an Invasive Species</u>

TEAM Leafy Spurge (The Ecological Area-Wide Management of Leafy Spurge; www.team.ars.usda.gov/index2.html) 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 (www.team.ars.usda.gov/v2/publications/brochures/brochures.html). 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 the APHIS, BLM, Forest Service, National Park Service, Bureau of Indian Affairs, Bureau of Reclamation, USGS, 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 population, 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 long lasting invasive weed control program.

<u>Ecological Advances in Biological Control</u>

Because the historical success rate of classical biological control programs is quite variable with 12 to 83% of the projects resulting 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. 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 US 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). Gene transfer 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.

Conclusions

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 long-term success in suppression of established invasive species.

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