Biological Control BMPs

Lincoln Smith[1], Michael J. Pitcairn[2], Patrick J. Moran[1]

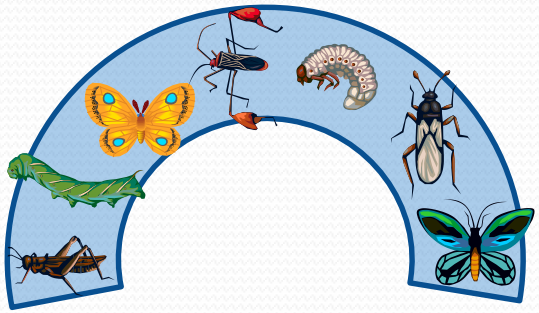
[1] USDA-Agricultural Research Service,
Invasive Species and Pollinator Health Research Unit, Albany, CA

[2] California Dept. of Food and Agriculture, Pest Detection and Exclusion and Biological Control Program, Sacramento, CA

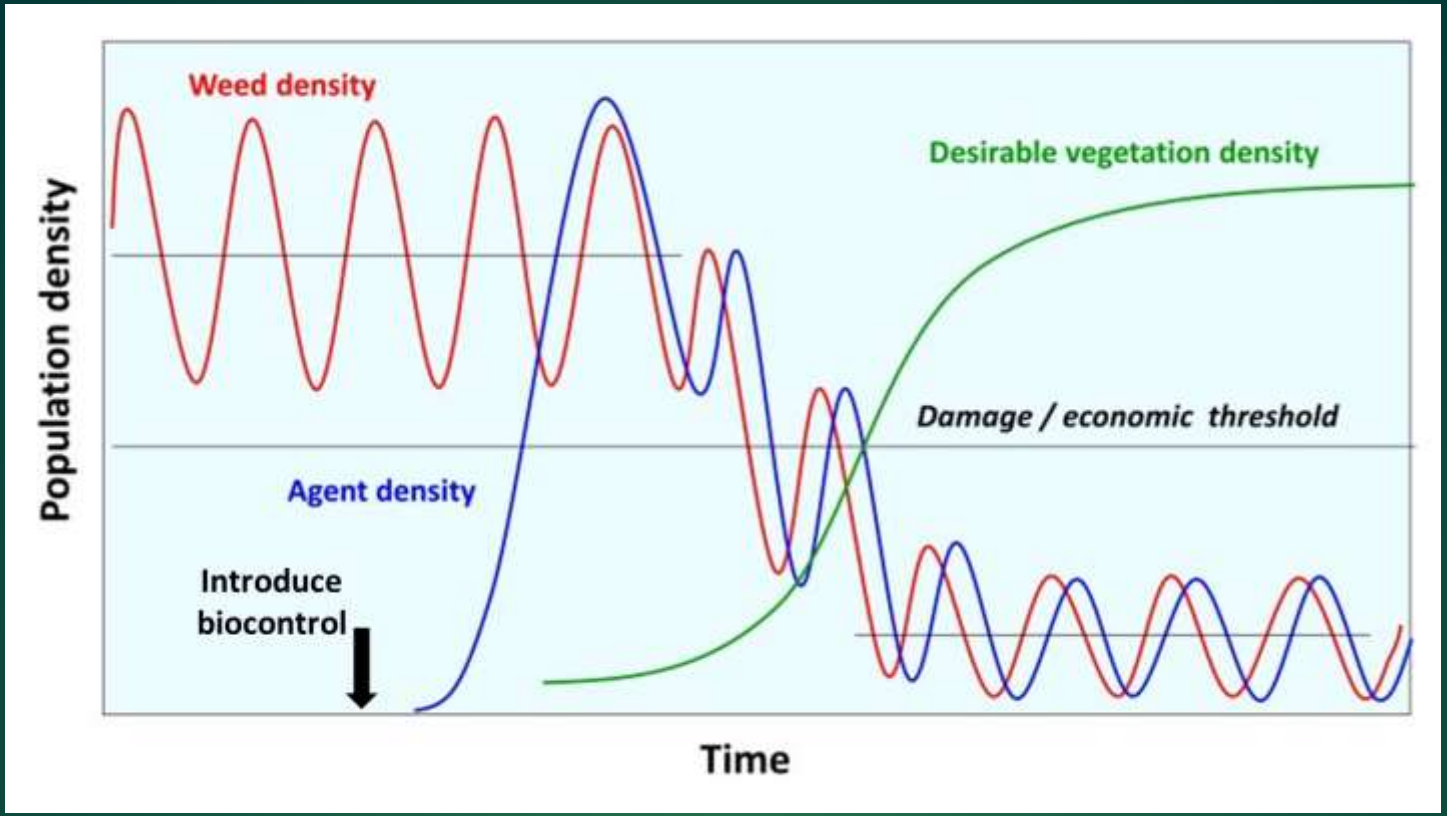
Thanks to Jutta Burger, California Invasive Plant Council (Cal-IPC), for coordination of this effort!

Biological control

- Reunite a foreign species with one or more *host-specific, damaging* natural enemies from the species native range.



The enemy of my enemy is my friend!



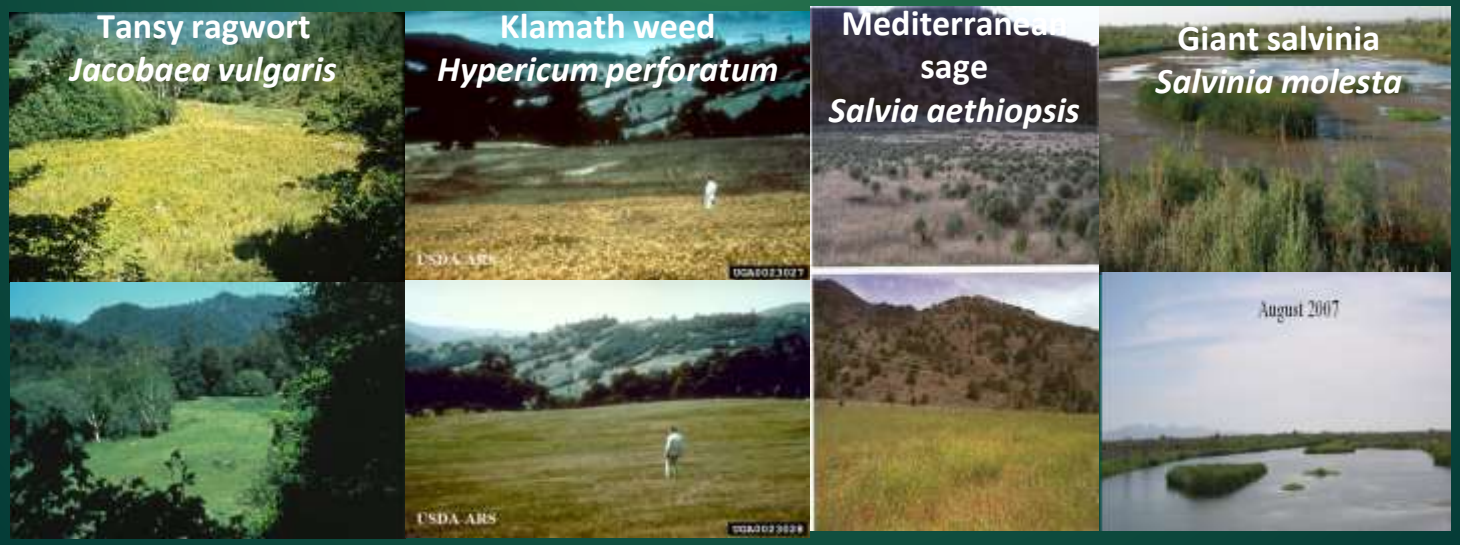
Introducing biological control agents re-establishes natural enemy relationships and may halt rapid population growth.

Notes: Introduced weed species can increase exponentially and reach undesirable densities that exceed economic thresholds and cause damage to the environment. The introduction of biological control agents may reduce weed densities to new equilibrium densities below levels of economic concern. Biological control is not an eradication tool, and is therefore not a tool for use in Early Detection and Rapid Response (EDRR) strategies to control new invasive weeds. Biological control should always be considered as a control technique for invasive weeds that have dispersed over large geographic areas, are dominating and damaging both natural and human-altered ecosystems, and cannot be controlled in an economically or environmentally sustainable manner using other control methods such as herbicide application.

Why Use Biological Control?

- It's for invasive weeds that have attained large distributions and cannot be controlled adequately using other methods.
- When effective biological control agents are used, benefit-to-cost ratios range from 8:1 to 300:1.

- In the U.S., about 45 weeds targeted; significant impacts in at least 33% of cases.
- In Australia, New Zealand, South Africa-success rates over 50%.



Notes: There have been many studies in recent years of the benefits of "classical" biological weed control-the use of non-native plant-feeding insects intentionally imported from the native range of the weed and released in the introduced range. There is an up-front investment to discover these biocontrol agents and evaluate them to verify that they are host-specific-able to feed and develop only on the target weed-and efficacious-their damage reduces weed growth, survival, and/or reproduction. Not all agents released are effective-some fail to establish, and some establish but do not have major impacts on the target weed. But historical studies show that the benefits of effective agents are massive, due to the reduced need/cost/risk associated with other control methods, and the improved availability of natural resources resulting from effective weed control. Visually, the results can be quite dramatic, as in these 'before' and after' images. All of these weeds were targeted for biocontrol in California as far back as the 1950s.

Clewley, G.D., Eschen, R., Shaw, R.H., Wright, D.J., 2012. The effectiveness of classical biological control of invasive plants. J. Appl. Ecol. 49: 1287-1295.

Culliney, T.W., 2005. Benefits of classical biological control for managing invasive plants. Crit. Rev. Plant Sci. 24, 131-150.

Hinz, H.L., Schwarzlander, M., Gassmann, A., and Bourchier, R.S. 2014. 2014. Successes we may not have had: A retrosdpective analysis of selected weeed biological control agents in the United States. Inv. Plant Sci. Mgmt. 7: 565-579.

Suckling, DM. 2013. Benefits from biological control of weeds in New Zealand range from negligible to massive: a retrospective analysis. Biol. Cont. 66:27-32

Van Driesche, R.G., 2012. The role of biological control in wildlands. BioControl 57,131-137.

Van Driesche, R.G., Carruthers, R.I., Center, T., Hoddle, M.S., Hough-Goldstein, J., Morin, L., Smith, L.M, Wagner, D.L., et al. 2010. Classical biological control for the protection of natural ecosystems. Biol. Cont. 54 Suppl. 1, S2-S33.

van Wilgen, B. W., De Lange, W.J., 2011. The costs and benefits of biological control of invasive alien plants in South Africa. African Entomol. 19, 504-511.

Advantages and disadvantages in biological control

Advantages

- The only sustainable solution for invasive weeds that have attained large, damaging populations.
- Biological controls are host plant specific-no collateral damage to native plants.
- Biocontrol agents are self-dispersing.
- Once established, efficacious biocontrols provide lasting control at little or no cost.
- Do not interfere with other control methods, and can contribute to IWM.

Disadvantages

- Finding agents to release .
- May take several years to establish.
- May take several more years to see impact.
- Agents cross land ownership/jurisdictional boundaries and need to be monitored.
- May not produce the desired level of control.

Notes: Here are some of the advantages and disadvantages of biological weed control. This comparison assumes that a host-specific and effective plant-feeding weed biocontrol insect is released.

BMPs prepared for 19 Weed Targets = 24 spp.

Common Name	Scientific Name
bull thistle	*Cirsium vulgare*
Canada thistle	*Cirsium arvense*
Cape ivy	*Delairea odorata*
Toadflax	*Linaria dalmatica* *L. vulgaris*
giant reed	*Arundo donax*
gorse	*Ulex europaeus*
knapweeds	*Centaurea diffusa, Ce. jacea, Ce. stoebe, Ce. virgata var. squarrosa*
Mediterranean sage	*Salvia aethiopis*
musk, Italian, milk thistles	*Carduus nutans, Ca. pycnocephalus, Silybum marianum*

Common Name	Scientific Name
puncture vine	*Tribulus terrestris*
purple loosestrife	*Lythrum salicaria*
Russian knapweed	*Rhaponticum repens (Acroptilon repens)*
saltcedar	*Tamarix parviflora*
Scotch broom	*Cytisus scoparius*
skeleton weed	*Chondrilla juncea*
St. Johnswort	*Hypericum perforatum*
tansy ragwort	*Jacobaea vulgaris (Senecio jacobaea)*
yellow starthistle	*Centaurea solstitialis*

Notes: We have included only weeds for which there are agents that have some level of impact. 20 chapters, which cover 27 species of invasive alien weeds. Those species attacked by the same agents are grouped together.

Agents with impact are readily* available for 10 targets:

***readily = permitted agents that are likely already present at your site or nearby; read BMPs, check for presence of agents, talk to your neighbors, and follow BMPs**

Common Name	Scientific Name
bull thistle	*Cirsium vulgare*
Canada thistle	*Cirsium arvense*
Cape ivy	*Delairea odorata*
Dalmatian toadflax	*Linaria dalmatica*
giant reed	*Arundo donax*
gorse	*Ulex europaeus*
knapweeds	*Centaurea diffusa, C. jacea, C. stoebe, C. virgata var. squarrosa*
Mediterranean sage	*Salvia aethiopis*
musk, Italian, milk thistles	*Carduus nutans, Ca pycnocephalus, Silybum marianum*

Common Name	Scientific Name
puncture vine	*Tribulus terrestris*
purple loosestrife	*Lythrum salicaria*
Russian knapweed	*Rhaponticum repens (Acroptilon repens)*
saltcedar	*Tamarix parviflora*
Scotch broom	*Cytisus scoparius*
skeleton weed	*Chondrilla juncea*
St. Johnswort	*Hypericum perforatum*
tansy ragwort	*Jacobaea vulgaris (Senecio jacobaea)*
yellow starthistle	*Centaurea solstitialis*

Topics covered

- Overview
- Biological control agents
- How the technique is employed
- Special Tips
- Caveats
- Where Can I Get These?
- Contributing Authors
- Photographs
- References

Approved vs. Adventive Insects

- **Approved agents** have been issued permits by USDA-APHIS and CDFA.
  - APHIS regulates interstate movement.
  - CDFA regulates within state movement.

  These agents have been tested for safety.
- **Adventive insects** do not have permits.

  They arrived on their own; accidental introductions.
  Some may affect the target weed,
  but they are not necessarily specific.
  It may be useful to know that they are present,
  but you cannot redistribute them

Yellow Starthistle
Centaurea solstitialis

Overview

- Six species of insects and one rust fungus that attack yellow starthistle have become established in California.
- All the insects attack the flower heads, which reduces seed production. The hairy weevil (*Eustenopus villosus*) and the false peacock fly (*Chaetorellia succinea*) have achieved high densities over large areas in California.
- The latter species was unintentionally introduced, and is not permitted for release; however, it is very specific to yellow starthistle (Balciunas and Villegas 2007).
- Yellow starthistle populations have decreased in some areas, especially in ungrazed grasslands that have a dense cover of grasses.

Notes: A general summary about biological control of this weed and specific information about each agent. This is a very brief treatment.

Yellow Starthistle *Centaurea solstitialis*
Biological Control Agents

Species

peacock fly

Chaetorellia australis-uncommon

false peacock fly

Chaetorellia succinea-adventive, not permitted, but abundant and host-specific

bud weevil

Bangasternus orientalis-widespread, low impact

flower weevil

Larinus curtus-widespread, low impact

hairy weevil

Eustenopus villosus-widespread and damaging

rosette weevil

Ceratapion basicorne-new agent-first root and rosette specialist

gall fly

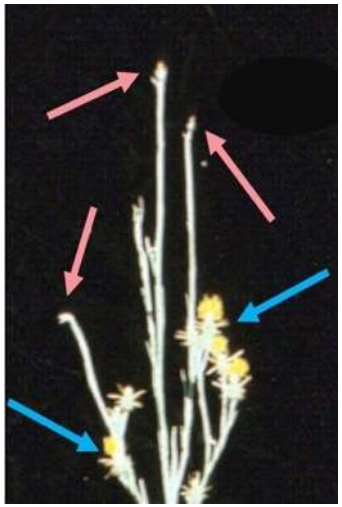
Urophora sirunaseva-common is some areas, low impact

YST rust Puccinia jacea var. solstitialis-uncommon

Yellow Starthistle *Centaurea solstitialis*

How the Technique is Employed

- **The hairy weevil, *Eustenopus villosus***, is the most effective permitted biological control agent for yellow starthistle.
- The hairy weevil can be collected and released by property owners
- Look for signs of insects. Before flowers bloom, the hairy weevil feeds on small flower buds, causing them to 'flag'. This damage also changes the plant's architecture, as secondary buds develop into flowers.
- The weevil chews a small hole in the side of flower buds, where it lays an egg and covers it with black frass (waste pellet).
- One larva develops inside the flower head and consumes most of the developing seed.
- Best time to collect flying adults: June-July



Notes: Here is an example of information on one biological control agent.

Yellow Starthistle *Centaurea solstitialis*

Special Tips

Mowing Leave central area un-mowed to allow insects to develop and overwinter in dead seedheads and in ground litter.

Caveats

Mowing yellow starthistle in the spring will delay flowering, which may reduce the effectiveness of the insects-they may die before flowers are available for egg-laying.

Herbicides that kill yellow starthistle before it produces mature flower heads will deprive the insects of the ability to reproduce. However, the insects will search for the remaining plants that have not been killed.

Fall grazing of flower heads by goats would kill most of the flies, but not affect the weevils.

Notes: Provides additional advice on how to use this approach and integrate it with other management strategies.

Yellow Starthistle *Centaurea solstitialis*

Where Can I Get These?

- You can collect adult insects in the field by **sweep net**. Place in paper cups, protect from heat in transport, and release at new site.
- Some insects may be available from your County Agricultural Commissioner.
- The Association of Natural Biocontrol Producers (ANBP) lists some vendors of biological control agents, but we do not know of any that sell yellow starthistle agents.
- More information and images: https://www.cal-ipc.org/docs/ip/management/pdf/YSTBiocontrol.pdf

Notes: In fact, it is not easy to obtain most insects, but most of them are already widespread.

Yellow Starthistle *Centaurea solstitialis*

Contributing Authors:

Lincoln Smith[1], Michael J. Pitcairn[2]

[1] USDA-Agricultural Research Service,
Invasive Species and Pollinator Health Research Unit, Albany, CA
Link.Smith@usda.gov

[2] California Dept. of Food and Agriculture, Pest Detection and Exclusion and Biological Control Program, Sacramento, CA
Mike.Pitcairn@cdfa.ca.gov

Yellow Starthistle *Centaurea solstitialis*

References

Balciunas, J. K. and B. Villegas. 2007. Laboratory and Realized Host Ranges of *Chaetorellia succinea* (Diptera: Tephritidae), an Unintentionally Introduced Natural Enemy of Yellow Starthistle. Environ. Entomol. 36(4): 849-857.

DiTomaso, J., G. B. Kyser and M. J. Pitcairn. 2006. Yellow Starthistle Management Guide. Cal-IPC Publication 2006-03. California Invasive Plant Council, Berkeley, California. 74 p. http://www.cal-ipc.org/ip/management/yst.php

Maddox, D.M., D.B. Joley, A. Mayfield and B.E. Mackey. 1991. Impact of *Bangasternus orientalis* (Coleoptera:Curculionidae) on achene production of *Centaurea solstitialis* (Asterales: Asteraceae) at a low and high elevation site in California. Environ. Entomol. 20(1):335-337.

Pitcairn, M. J., B. Villegas, D. M. Woods, R. Yacoub, and D. B. Joley. 2008. Evaluating implementation success for seven seed head insects on *Centaurea solstitialis* in California, U.S.A. In: Julien, M.H., Sforza, R., Bon, M.C., Evans, H.C., Hatcher, P.E., Hinz, H.L. & Rector, B.G. (eds.), Proceedings of the XII International Symposium on Biological Control of Weeds. CAB International Wallingford, UK. April 22-27, 2007, La Grande Motte (Montpellier), France. pp. 607-613.

Woods, D. M., M. J. Pitcairn, D. B. Joley, and C. E. Turner. 2008. Seasonal phenology and impact of *Urophora sirunaseva* on yellow starthistle seed production in California. Biological Control 47: 172-179.

Notes: We list a small number of references to find additional information. We have not listed other websites that have information about these insects.

Giant Reed *Arundo donax*

Overview

- Two insects tested by USDA-ARS, permitted and released
  - **Arundo wasp *Tetramesa romana***
    - Several generations per year (2-3 month generation time).
    - Females reproduce asexually (lay eggs without mating).
    - Egg-laying leads to galls at shoot tip. Larvae feed inside galls.
    - Reduced arundo biomass 20-40% in Texas (first release area).
    - Can disperse across sites within I or 2 years.
    - Adventive in southern California (Ventura Co.).
    - Established at one site each in Glenn, Madera Counties.

  - **Arundo armored scale *Rhizaspidiotus donacis***
    - Two generations per year (5-6 month generation time).
    - Females feed on rhizomes (tuber-like roots) and stem bases.
    - Females produce crawlers that disperse short distance.
    - Reduced biomass by up to 40% beyond wasp damage in Texas (first release).
    - Possibly adventive in Ventura County.
    - Established at six sites (Glenn, Sacramento, Madera Counties)

Giant Reed *Arundo donax*

Biological Control Agents

Not widely established. Check site prior to making releases.

Arundo wasp *Tetramesa romana*, galls and exit holes made by adult wasps as they emerge from galls.

Arundo armored scale *Rhizaspidiotus donacis*, dissected female, plaque of females, and diagnosing in field.

Giant Reed *Arundo donax*

How the Technique is Employed

- **Survey for insects:**
  - Count wasp exit holes for 2 minutes at 10 or more points.
  - Scrape back soil/sand/gravel and look for scale females near soil surface under dead 'root leaves'.
- **When to collect:**
  - Wasp: March-May southern California; April-June northern California; best populations will be near water.
  - Scale: January-February
- **How to collect:**
  - Wasp: Collect galled shoots. Most galls will be on lateral shoots, keep cool
  - Scale: Cut infested rhizomes into pieces, keep cool.
- **How to release:**
  - Wasp: Take galls to new site, place under light mulch near arundo stands. Release April-July.
  - Scale: Place infested rhizome pieces in piles around arundo. Cover with light mulch. Release January-March.

Giant Reed *Arundo donax*

Special Tips

- Pre-cut arundo 3-4 weeks prior to releasing wasps- ground or chest height.
- Creates tender shoots for wasps and new rhizome buds for scales later.

Caveats

- Arundo wasp and armored scale are relatively recent introductions in northern California and are not widely available.
- Mowing may enhance establishment, but do only once per year.
- If mowing or herbicides used, leave refuge plots at least 3 x 3 m untreated.
- Ability to recover from burn treatment not known.
- Insecticide drift from crop fields may limit/prevent establishment.

Giant Reed *Arundo donax*

Where Can I Get These?

- Consult BMP experts
- Check with County Agriculture Commissioners Office prior to release
- Obtain landowner permission to collect galls with wasps and/or rhizomes with scales
- Not available commercially in California

Giant reed, *Arundo donax*

Contributing Authors:

Patrick J. Moran

[1] USDA-Agricultural Research Service,
Invasive Species and Pollinator Health Research Unit, Albany, CA
Patrick.Moran@usda.gov

Giant Reed *Arundo donax*

References

CalWeedMapper. California Invasive Plant Council, Berkeley, CA. https://calweedmapper.cal-ipc.org/maps/

DiTomaso, J.M., Kyser, G.B., Oneto, S.R., Wilson, R.G., Orloff, S.B., Anderson, L.W., Wright, S.D., Roncoroni, J.A., Miller, T.L., & Prather, T.S. 2013. Weed Control in Natural Areas in the Western United States. Weed Research and Information Center, University of California. 544 pp. *Arundo donax*. https://wric.ucdavis.edu/information/crop/natural%20areas/wr_A/Arundo.pdf

Giessow, J., Casanova, J., Leclerc, R., MacArthur, R., Fleming, G., & Giessow, J. 2011. *Arundo donax*: *distribution and impact report*. Berkeley: California Invasive Plant Council (Cal-IPC). Available at https://www.cal-ipc.org/solutions/research/arundo-report/

Goolsby, J.A., & Moran, P.J., 2009. Host range of *Tetramesa romana* Walker (Hymenoptera: Eurytomidae), a potential biological control of giant reed, *Arundo donax* L. in North America. Biol. Cont. 49: 160-168. doi:10.1016/j.biocontrol.2009.01.019

Goolsby, J.A., & Moran, P.J. 2019. Field impacts of the arundo scale, *Rhizaspidiotus donacis* (Homoptera: Diaspididae) on *Arundo donax* on the Rio Grande**.** Subtropical Agriculture and Environments 70: 11-16. ttp://www.subplantsci.org/wp-content/uploads/2019/09/SAES-Goolsby-et-al.-2019-3.pdf

Goolsby, J.A., Moran, P.J., Adamczyk, J.A., Kirk, A.A., Jones, W.A., Marcos, M.A., & Cortés, E., 2009a. Host range of the European, rhizome-stem feeding scale *Rhizaspidiotus donacis* (Leonardi) (Hemiptera: Diaspididae), a candidate biological control agent for giant reed, *Arundo donax* L. (Poales: Poaceae) in North America. Biocon. Sci. Technol. 19: 899-918. doi: 10.1080/09583150903189099

Goolsby, J.A., Moran, P. J., Racelis, A. E., Summy, K. R., Jimenez, M. M., Lacewell, R. D., Perez de Leon , A., & Kirk, A. A. 2016. Impact of the biological control agent, *Tetramesa romana* (Hymenoptera: Eurytomidae) on *Arundo donax* (Poaceae: Arundinoideae) along the Rio Grande River in Texas. Biocon. Sci and Technol. 26: 47-60. doi: 10.1080/09583157.2015.1074980.

Goolsby, J.A., Vacek, A.T., Salinas, C., Racelis, A., Moran, P.J., & Kirk, A.A.. 2017. Host range of the European leaf sheath mining midge, Lasioptera donacis Coutin (Diptera: Cecidomyiidae), a biological control of giant reed, *Arundodonax* L., Biocon. Sci. Technol. 27: 781-795. doi: 10.1080/09583157.2017.1342222

Lambert, A.M., Dudley, T.L., & Saltonstall, K., 2010. Ecology and impacts of the large-statured invasive grasses *Arundo donax* and *Phragmites australis* in North America. Inv. Plant Sci. Mgmt. 3: 489-494. doi:10.1614/IPSM-D-10-00031.1

Marshall, M., Goolsby, J.A., Vacek, A.T., Moran, P.J., Kirk, A.A., Cortes Mendoza, E., Cristofaro, M., Bownes, A., Mastoras, A., Kashefi, J., Chaskopoulou, A., Smith, L., Goldsmith, B., Racelis, A.E. 2018. Comparison of *Tetramesa romana* densities across its native range in Mediterranean Europe and introduced ranges in North America and Africa. Biocon. Sci. Technol. 28: 772-785. doi: 10.1080/09583157.2018.1493090

Moran, P.J., & Goolsby, J.A., 2009. Biology of the galling wasp *Tetramesa romana*, a biological control agent of giant reed. Biol. Cont. 49: 169-179. doi:10.1016/j.biocontrol.2009.01.017

Moran, P.J., & Goolsby, J.A., 2010. Biology of the armored scale *Rhizaspidiotus donacis* (Hemiptera: Diaspididae), a candidate agent for biological control of giant reed. Ann. Entomol. Soc. Amer. 103: 252-263. doi: 10.1603/AN09124

Moran, P.J. Vacek, A.T., Racelis, A.E., Pratt, P.D., & Goolsby, J.A. 2017. Impact of the arundo wasp, *Tetramesa romana* (Hymenoptera:Eurytomidae) on biomass of the invasive weed, *Arundo donax* (Poaceae: Arundinoideae) and on revegetation of riparian habitat along the Rio Grande in Texas. Biocon. Sci. Technol. 27:96-114. doi: 10.1080/09583157.2016.1258453