

Biological control of *Arundo donax*; an invasive weed of the Rio Grande Basin

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Research Team

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- **Beto Perez de Leon, Felix Guerrero**, USDA-ARS, Kerrville, TX, ant impacts, decomposition of dead biomass
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- **Alan Kirk, Marie Claude, Javid Kashefi** - USDA-ARS, EBCL, Montpellier, France, Foreign exploration for biological control agents in Europe, ID of leafminer endophytes
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- **John Gaskin**, USDA-ARS, Sidney, MT Genetic characterization of biological control agents
- **Matt Ciomperlik, Aaron Carlson**, USDA-APHIS, Edinburg, TX, Aerial release of agents, implementation program
- **Alex Racelis**, UT-RGV, Edinburg, TX, Water use of Arundo
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- **Mike Grusak**, USDA-ARS, Houston, TX plant nutrient effects on agents
- **Ron Lacewell**, – Texas A&M Agrilife, College Station, Economic impact of *Arundo donax* in the Rio Grande Basin
- **Jim Manhart, Alan Pepper, Daniel Tarin** - Texas A&M, College Station, Molecular genetics of Arundo and biological control agents
- **Chenghai Yang** - USDA-ARS, College Station, TX, Remote sensing

Research Funding

- Dept. of Homeland Security, Customs and Border Protection
- U.S. Dept. of Agriculture

Arundo donax L.



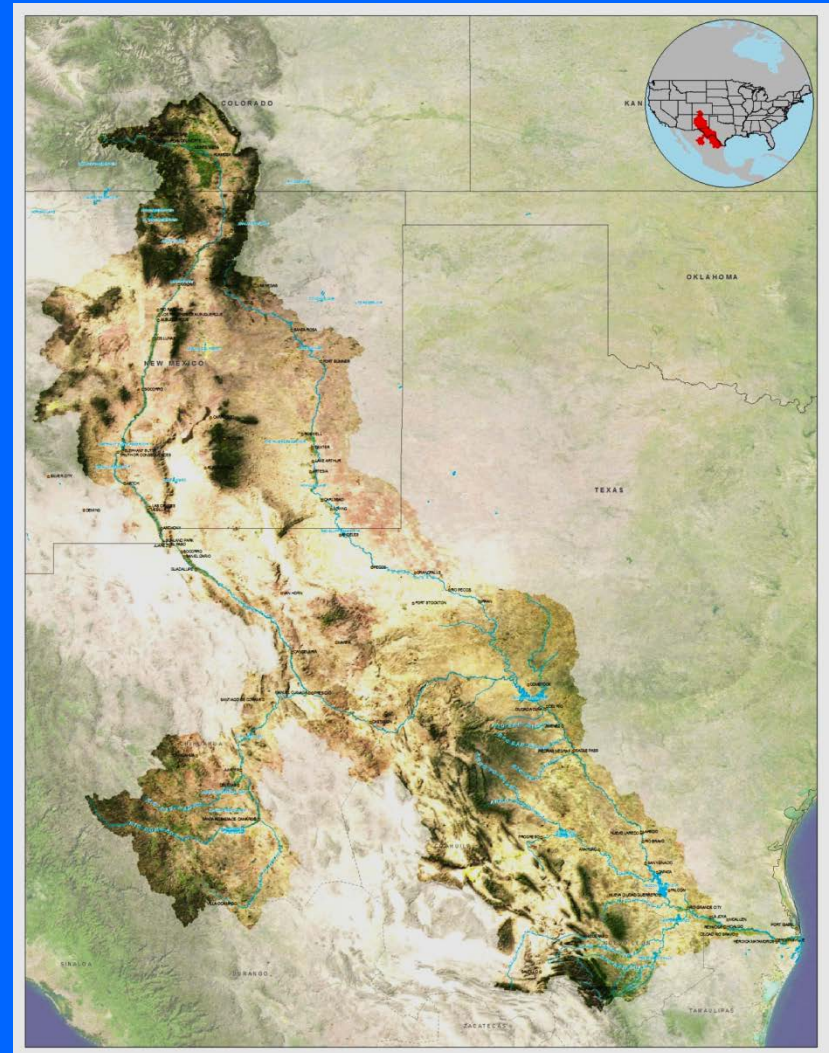
- ▶ **Common names: giant reed, carrizo cane**
- ▶ **An invasive weed in riparian habitats**
- ▶ **Clonal – spreads by movement of rhizomes**
- ▶ **Declared noxious weed – 45 States, listed by Cal EPPC, SE EPPC**
- ▶ **Also invasive in Mexico, Argentina, Australia & South Africa**

Presentation

- Impacts of Arundo in Rio Grande Basin
- Comparison to native range in Europe
- Biological control program in TX & Mexico
- Immediate Results: **New Mechanical Topping + Biological Program** to achieve immediate visibility of river
- Summary of accomplishments

Impacts of Arundo in the RGB

- Water Availability
- Environmental
- National Security
- Livestock Health



Rio Grande Basin

A satellite-style map of the Rio Grande Basin, showing the river's path from the top left towards the bottom right. The terrain is a mix of brown, tan, and green, indicating varying vegetation and soil types. A blue banner with yellow text is overlaid on the map.

Water is the limiting resource



How do we conserve water in Rio Grande Basin

- Reduce urban landscape water use
- Industrial water recycling
- Reduce irrigation losses – line canals
- **Control invasive water-using weeds**

1 200 mm rainfall

1 200 mm rainfall

1 200 mm rainfall

Control of invasive weeds – increased water conservation

10%

Dense infestation

Run-off in river: 123 mm

25%

Medium infestation

Run-off in river: 303 mm

40%

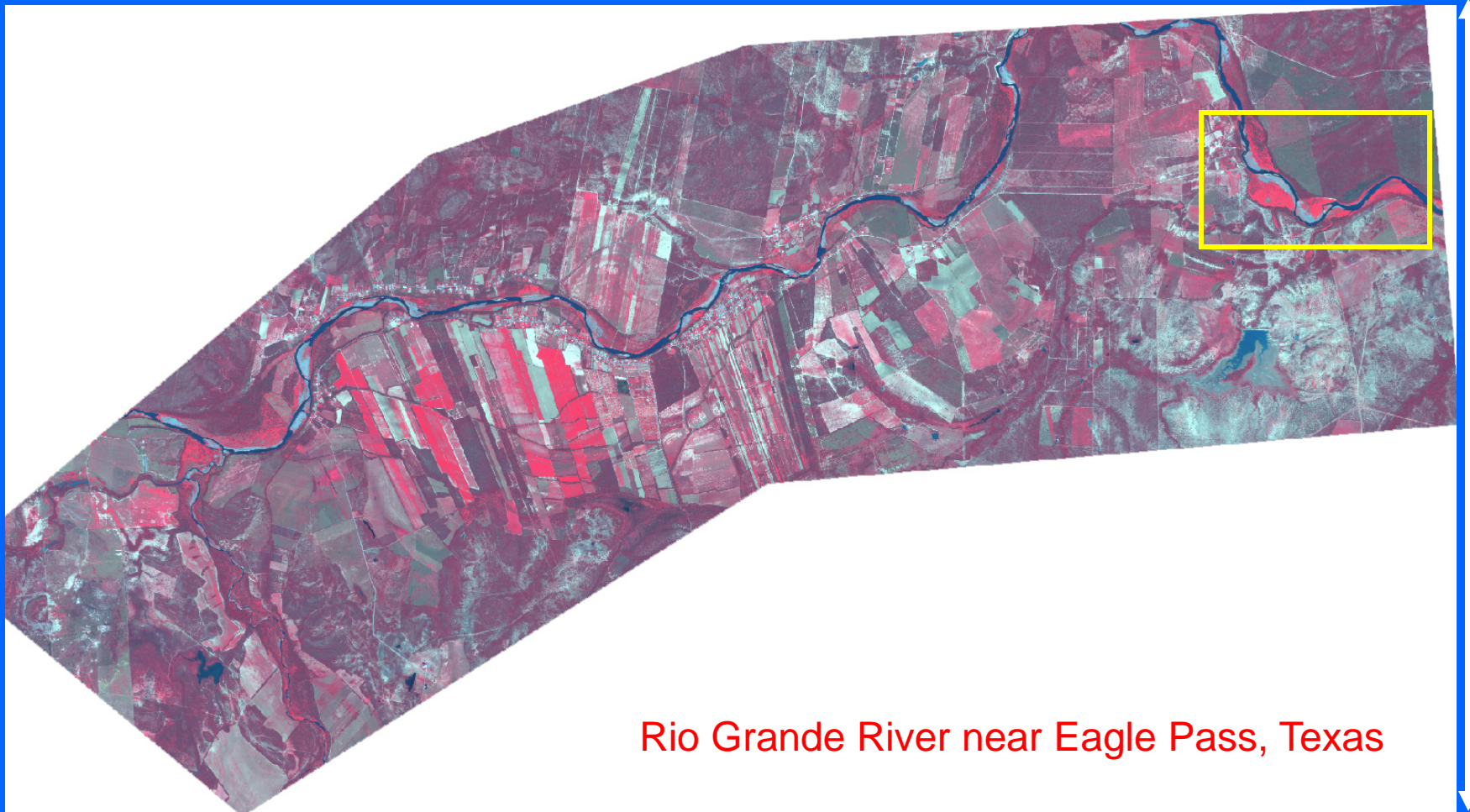
Light infestation

Run-off in river: 472 mm



Size of *Arundo* infestation in RGB

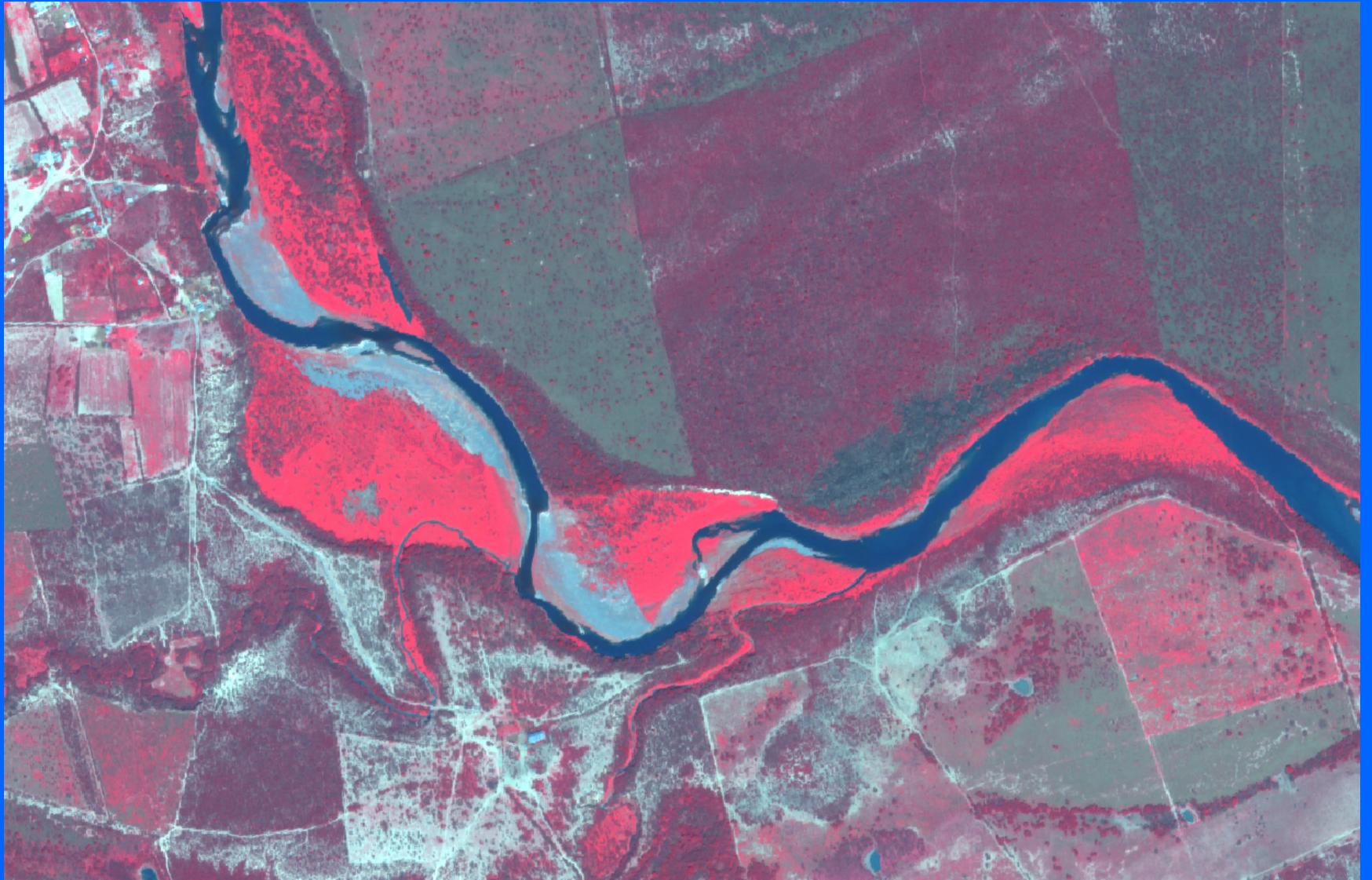
Satellite Image of *Arundo donax*



Rio Grande River near Eagle Pass, Texas

17 km (10.6 mi)

Tasked February 2007
Subset1



Estimated Area of Arundo in RGB

- 70,000 – 100,000 acres in the Rio Grande Basin
- This is along the main rivers and tributaries
- Does not include infestations along creeks, ditches, canals
 - Could be as much as 100,000 additional acres

Expected Benefit-Cost Implications and Economic Cost of Water Saved for the *Arundo donax* Biological Control Program between San Ignacio and Del Rio, on the Rio Grande River.^a

Result Item	Social Benefits of Biological Control (Using Normalized Prices)		Costs
	Low Value of Water ^b	High Value of Water ^c	
Net Present Value	\$72,400,000	\$145,700,000	\$16,700,000
Annualized Benefits	\$4,700,000	\$9,400,000	---
Benefit to Cost Ratio	4.35 : 1	\$8.74 : 1	---
Annuity Equivalent-- Economic Cost of Water Saved (\$/acre-foot)		\$44.42	

^a Source: Seawright, Emily. Masters of Science Thesis, Department of Agricultural Economics, Texas A&M University

^b Low Value of Water refers to the low marginal returns for water calculated using the composite acre for low value crops (i.e., corn, cotton, sorghum), a value of \$139.22 per acre-foot. The values calculated with the low value of water represent the lower bound of the social benefits to be realized over the 50-year planning horizon.

^c High Value of Water refers to the high marginal returns for water calculated using the composite acre for high value crops (i.e., fruits, vegetables, sugar cane, corn, cotton, sorghum), a value of \$279.99 per acre-foot. The values calculated with the high value of water represent the upper bound of the social benefits to be realized over the 50-year planning horizon.

Impacts of *Arundo donax*

- Water Availability
- Environmental
- National Security
- Animal Health



Environmental

Rio Nadadores, Coahuila, México
Extinction of endemic fish species

U.S. National Security



Livestock Health

River willows

Infested cattle

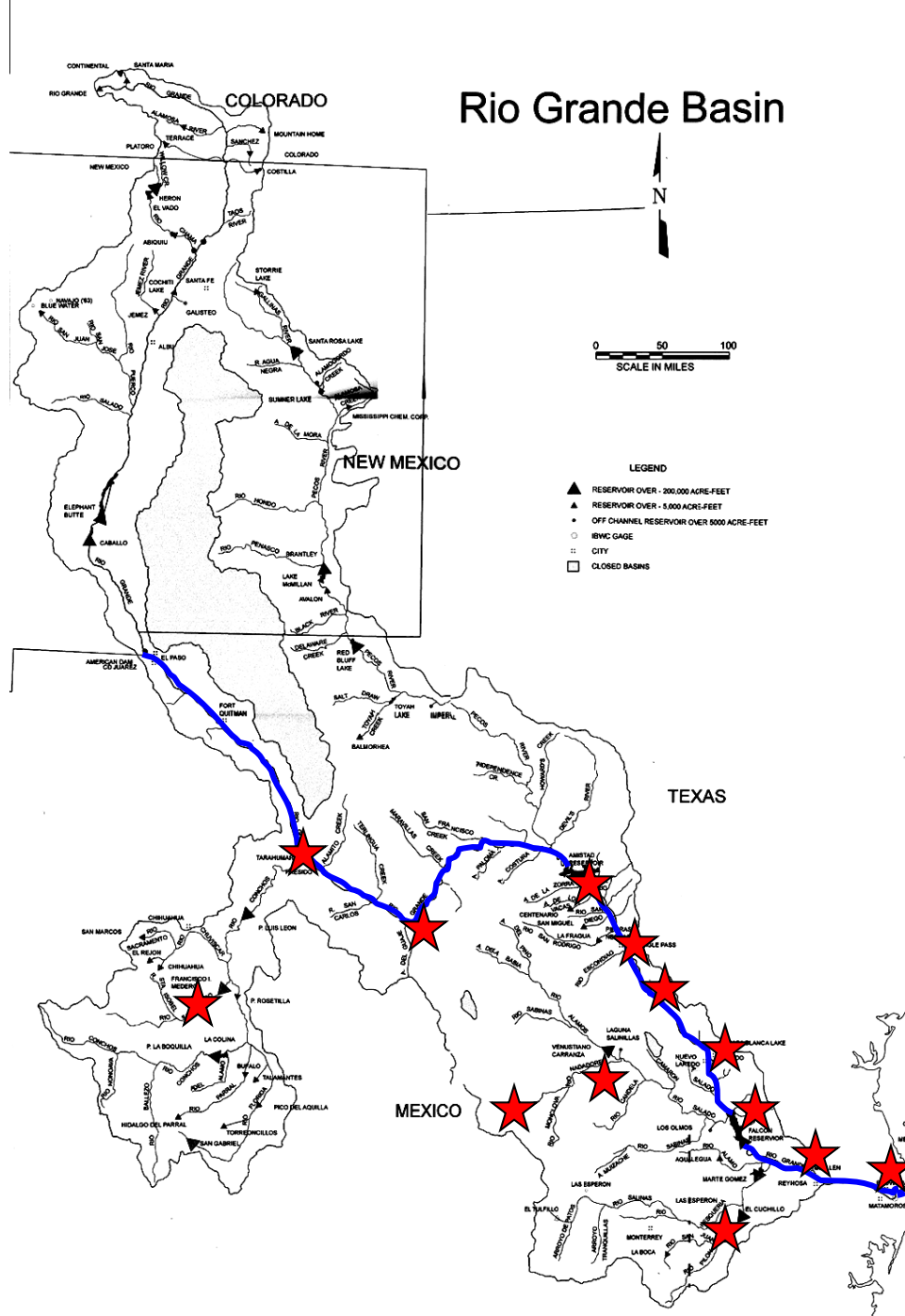
Cattle fever tick



Infested deer

1. *Arundo* enhances survival of tick
2. Transition back to native vegetation--better biological barrier to ticks

Racelis, A.E., R. B. Davey, J. A. Goolsby, A. A. Pérez de León, K. Varner, and R. Duhaime. 2012. Facilitative ecological interactions between invasive species: *Arundo donax* (Poaceae) stands as a favorable habitat for cattle ticks (Acari: Ixodidae) along the US-Mexico border. *Journal of Medical Entomology* 49: 410-417.



Rio Grande Basin

- LEGEND**
- ▲ RESERVOIR OVER - 200,000 ACRE-FEET
 - ▲ RESERVOIR OVER - 5,000 ACRE-FEET
 - OFF CHANNEL RESERVOIR OVER 5000 ACRE-FEET
 - BEWC GAGE
 - CITY
 - CLOSED BASINS

★ High Infestation Areas

Invasive Monoculture



Down river from Big Bend

Invasive Monoculture



Rio Conchos, Chihuahua, Mexico

Invasive Monoculture



Amistad Dam, Del Rio, Texas

Invasive Monoculture



South of Del Rio

Invasive Monoculture

South of Eagle Pass, Texas

A landscape view from a vehicle, showing a river winding through a field of tall, dry grasses. The sky is overcast and grey. The foreground shows the dark, curved roof of the vehicle. The river flows from the bottom left towards the center, then curves to the right. The surrounding area is dominated by tall, dry grasses, with some green trees visible in the distance on the left side.

Invasive Monoculture

A photograph of a riverbank in Laredo, Texas. The foreground and middle ground are dominated by a dense, tall monoculture of grasses, likely Phragmites, which are leaning over the water. The background consists of a thick, green forest of trees. The water in the river is a murky, greenish-brown color.

Laredo, Texas

Invasive Monoculture



Irrigation canal, Weslaco

Comparison of *Arundo donax* in
its native range in
Mediterranean Europe

Native Biodiverse Ecosystem

Rio Guadiana, Portugal





**Native Biodiverse
Ecosystem**

Mediterranean coast of Spain near Malaga

Native Biodiverse Ecosystem

El Saler (Valencia), Spain

A photograph of a riverbank in Tortosa, Spain. The foreground is dominated by tall, dense reeds with green and brown stalks. Behind the reeds, a river flows, and the far bank is lined with several bare, leafless trees. In the background, a multi-story building is visible. The sky is overcast and grey. The text "Native Biodiver" and "Ecosystem" is overlaid in the top right corner, and "Ebro River, Tortosa, Spain" is overlaid in the bottom center.

Native Biodiver
Ecosystem

Ebro River, Tortosa, Spain

Native Biodiverse Ecosystem



Rivesaltes, France

Origin of RGB *Arundo donax*

There are over 230 types of *A. donax* in Spain. Through our research we found that only 1 type from Mediterranean Spain was brought over to Mexico in the 16th century and spread across the Americas.

This was fortuitous as we could concentrate our research on the single set of type-specific biological agents for controlling the dominant type in the Rio Grande Basin.



Biological Control of *Arundo donax*

- Long-term, sustainable
- Low cost
- Environmentally friendly
- Bi-national agreement



Seville, Spain

Biological Control Agents

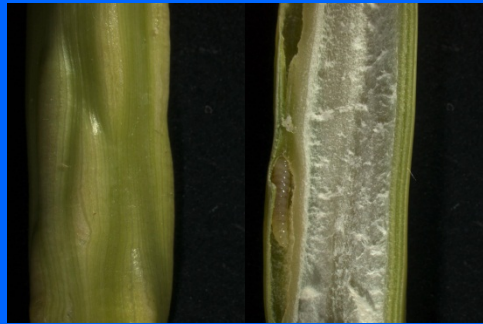
Arundo wasp



Arundo scale



Arundo leafminer Arundo fly



Tetramesa romana
Arundo wasp
Hymenoptera: Eurytomidae
larvae feed on stems & side shoots (adult stingless)

Released
April 29, 2009

Rhizaspidiotus donacis
Arundo scale
Homoptera: Diaspididae
scale insects feed on roots and side shoots

Released
Dec 17, 2010

Lasioptera donacis
Arundo leafminer
Diptera: Cecidomyiidae
Larvae are leaf sheath miners causing defoliation

Released
Dec. 2016

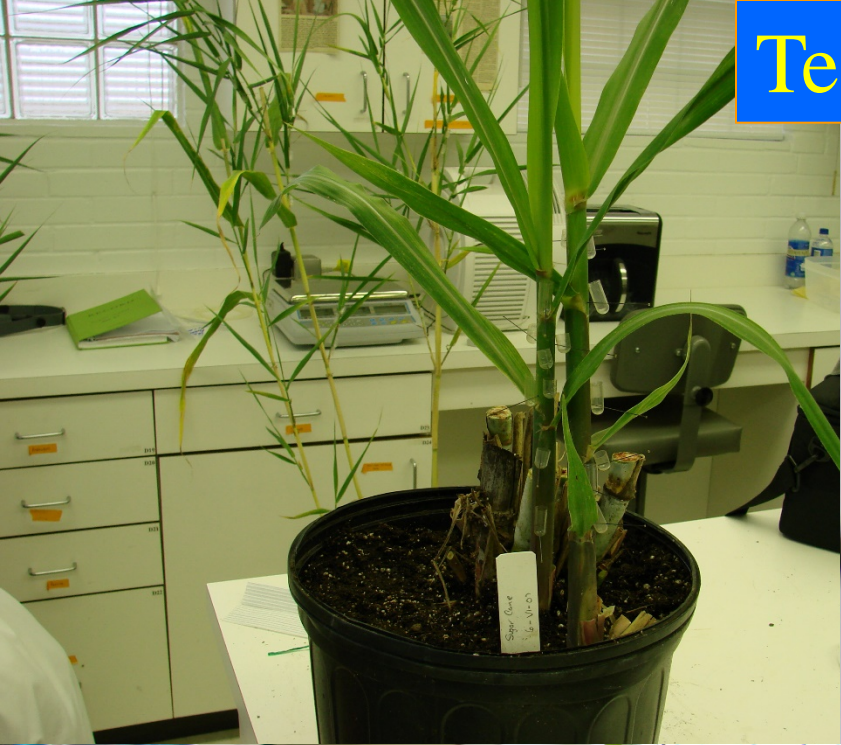
Cryptonevra spp.
Arundo fly
Diptera: Chloropidae
fly larvae feed on new stem shoots

Testing in
Europe

Biocontrol agents transferred to Mexico U.S.-Mexico binational program



Testing of Biocontrol Agents



Tetramesa romana (Hymenoptera: Eurytomidae)



- Adult females live 4-5 days and reproduce via parthenogenesis-
- One female produces an avg. of 26 new adults; max of 66.
- Larvae develop inside cane (endophagy) in 30-35 days.
- Almost all (90%) of egg-laying and feeding occur at shoot tip.
- Growth of plant stunted by gall.
- Host specific to *Arundo donax*.

Goolsby J. A. and Moran, P. J. Host range of *Tetramesa romana* Walker (Hymenoptera: Eurytomidae), a potential biological control of giant reed, *Arundo donax* L. in North America. *Biological Control* 49:160-168. 2009.

Moran, P. J., and Goolsby, J. A. Biology of the galling wasp *Tetramesa romana*, a biological control agent of giant reed. *Biological Control* 49:169-179. 2009.

Wasp Impacts on Growth



Side shoot galls, ideal for arundo scale



Mass-rearing of *T. romana*



Arundo wasp damage LRGV

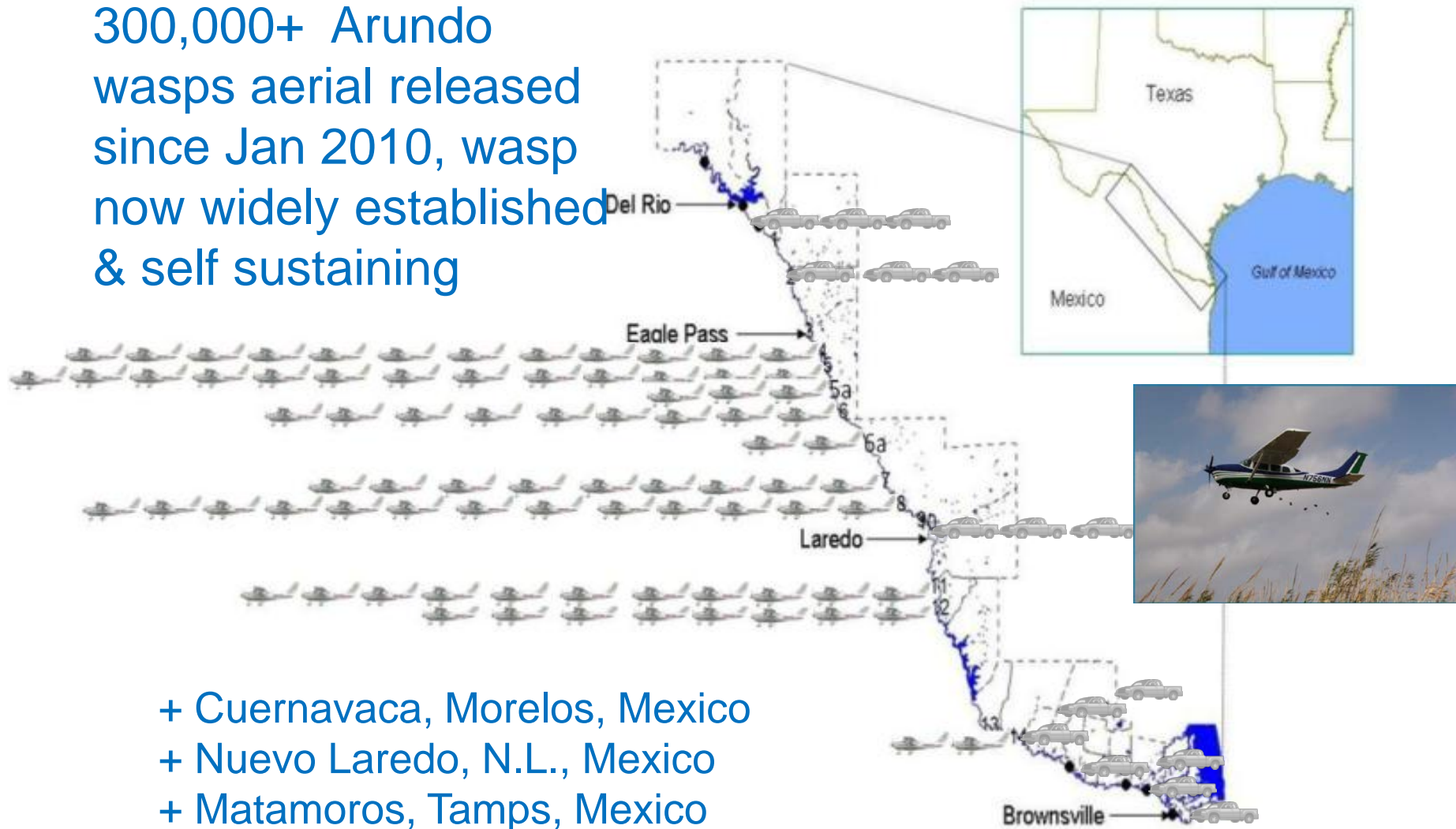


Aerial release of arundo wasps



Racelis, A.E., Goolsby, J.A., Penk, R., Jones, W.K., and Roland, T.J. 2010. The inundative, aerial release technique for the arundo wasp, a biological control agent for *Arundo donax*. *Southwestern Entomologist*. 35: 495-501.

300,000+ Arundo
wasps aerial released
since Jan 2010, wasp
now widely established
& self sustaining



- + Cuernavaca, Morelos, Mexico
- + Nuevo Laredo, N.L., Mexico
- + Matamoros, Tamps, Mexico

Rhizaspidiotus donacis, Arundo scale



- Feeds on roots and stems, host specific to *Arundo*
- Adult female survival (on plant until reproductive maturity): 203 days
- Average crawler production by individual female: 85 to 300, 50-80% of females are reproductive
- Highly significant impact on *A. donax*
- Goolsby, J. A., Moran, P. J., Adamczyk, J. A., Kirk, A. A., Jones, W. A., Marcos, M. A. and Cortés, E. 2009. 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. 19: 899-918
- Moran, P. J., and Goolsby, J. A. 2010. Biology of the armored scale *Rhizaspidiotus donacis* (Hemiptera: Diaspididae), a candidate agent for biological control of giant reed. Annals of the Entomological Society of America 103: 252-263

Arundo scale damage – Del Rio, TX

October 2012



Arundo stand in plot is thinning. 24% of stems dead



Mature rhizomes infested with scale at each node and bud

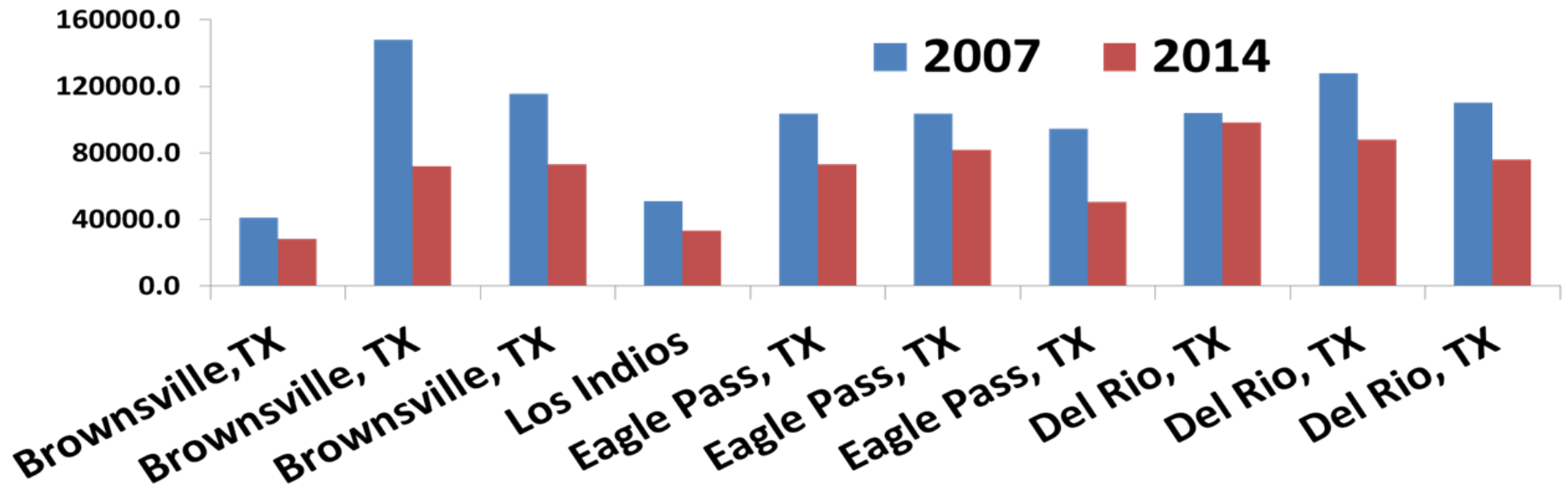


High densities of large, robust, mature F2 females



Many new buds are dead from scale feeding

Impact of the biological control program on *Arundo donax* biomass



- **22 % reduction in *A. donax* biomass between Del Rio and Brownsville**
- **2.5 million tons of *A. donax* removed**
- **6000 acre ft of irrigation water conserved per year**
- **Visibility into stands from 6 to 27 ft.**
- **Ecological transition back to native vegetation beginning**

John A. Goolsby, Patrick J. Moran, Alexis E. Racelis, Kenneth R. Summy, Maricela Martinez Jimenez, Ronald D. Lacewell, Adalberto Perez de Leon, & Alan A. Kirk 2015. **Impact of the biological control agent, *Tetramesa romana* (Hymenoptera: Eurytomidae) on *Arundo donax* (Poaceae: Arundinoideae) along the Rio Grande River in Texas.** *Biocontrol Science & Technology*

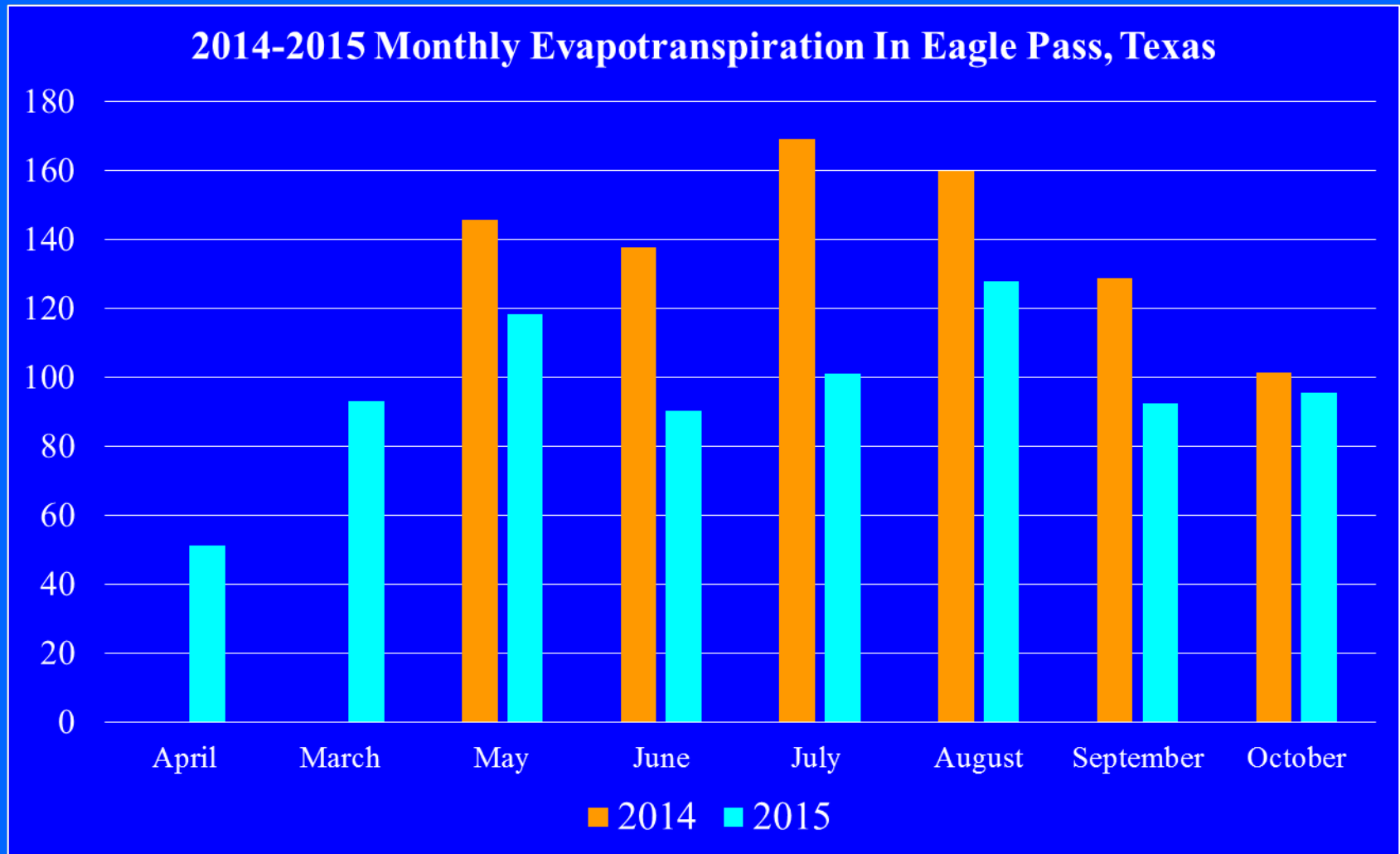
Biocontrol of *Arundo* promotes conservation of water quantity and quality



Maverick Irrigation District Facility

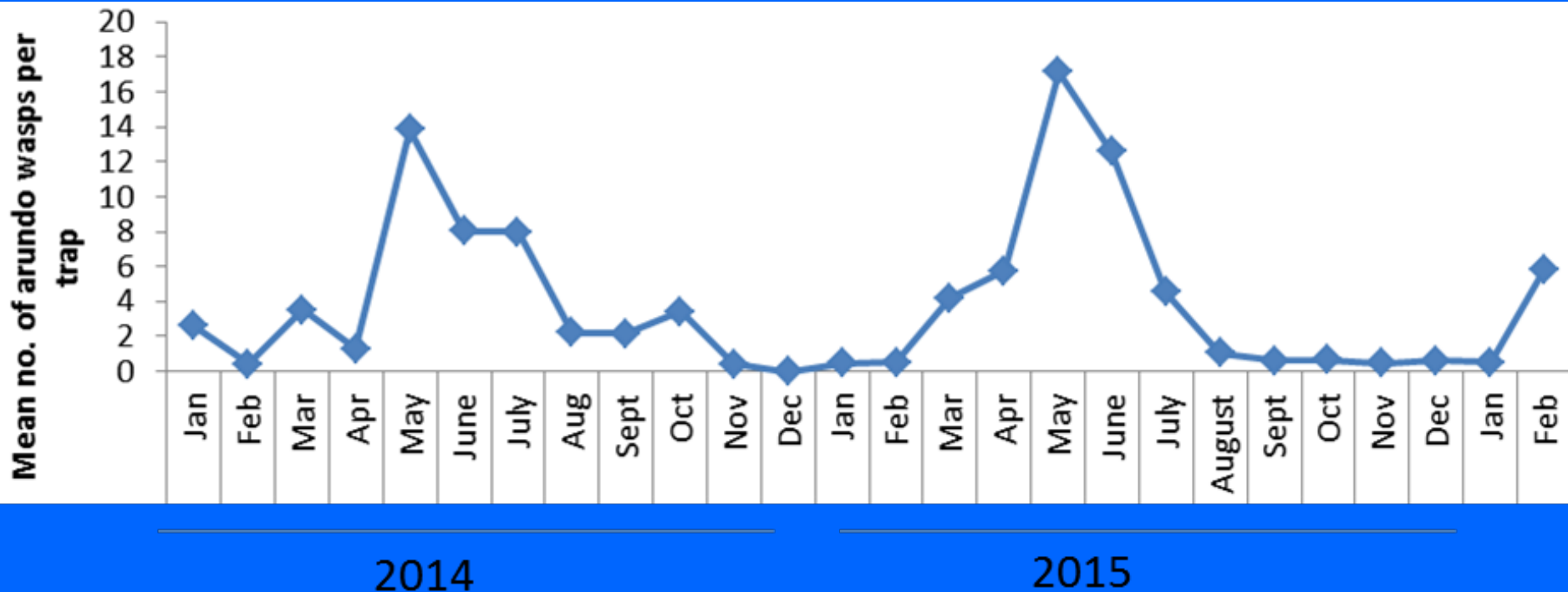


Water use of Arundo reduced in 2015



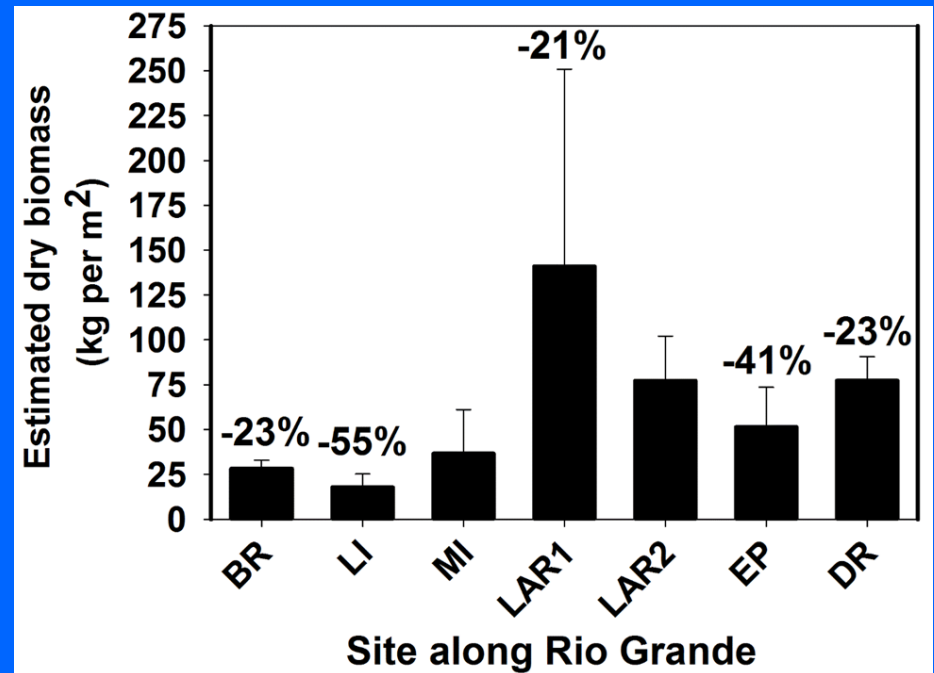
Biocontrol insects reduce water use of Arundo

- 26% decrease in water use during 2015 not due to differences in temperature or precipitation
- ~75% increase of wasps in summer 2015



2016 Recovery of Native Riparian Vegetation on Rio Grande

- Further 28% reduction in biomass
- Biocontrol agent densities correlated with recovery of native plant species
- 44 plant species were encountered in plots, 86% native



Lasioptera donacis, Arundo leafminer



- Leafminer larvae feeds on leafsheath
- Causes rapid leaf death and defoliation
- 1 month life cycle
- Host specific to *A. donax*
- *Newest agent released*

Presentation

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Control of Carrizo Cane

Topping + Biological Control Insects



Tractor with cutter bar for topping cane to 3-4 feet

Cane topper



Mass release of farm reared insects on infested cane along Rio Grande

Carrizo Cane Insects

Advantages:

- Topping provides immediate visibility of river for law enforcement.
- After topping biocontrol insects suppress regrowth of carrizo cane for 1 year.
- No environmental issues.
- Biocontrol process is gradual, which keeps river bank stable and prevents erosion.
- Ready acceptance by landowners
- Mexico supports biocontrol program and is also releasing insects.
- The native trees, shrubs, and grasses re-grow to fill the void, which leads to significant water conservation.
- Biocontrol is permanent, no need for re-release of insects.
- All Federal permits (NEPA) in place for immediate action.



6 months after topping at 3 ft

6 months after mowing cane to ground



Before and after topping + plus biocontrol insects. Clear view of Rio Grande near Laredo



Arundo wasp feeds above ground on canes



Arundo scale feeds below ground on roots



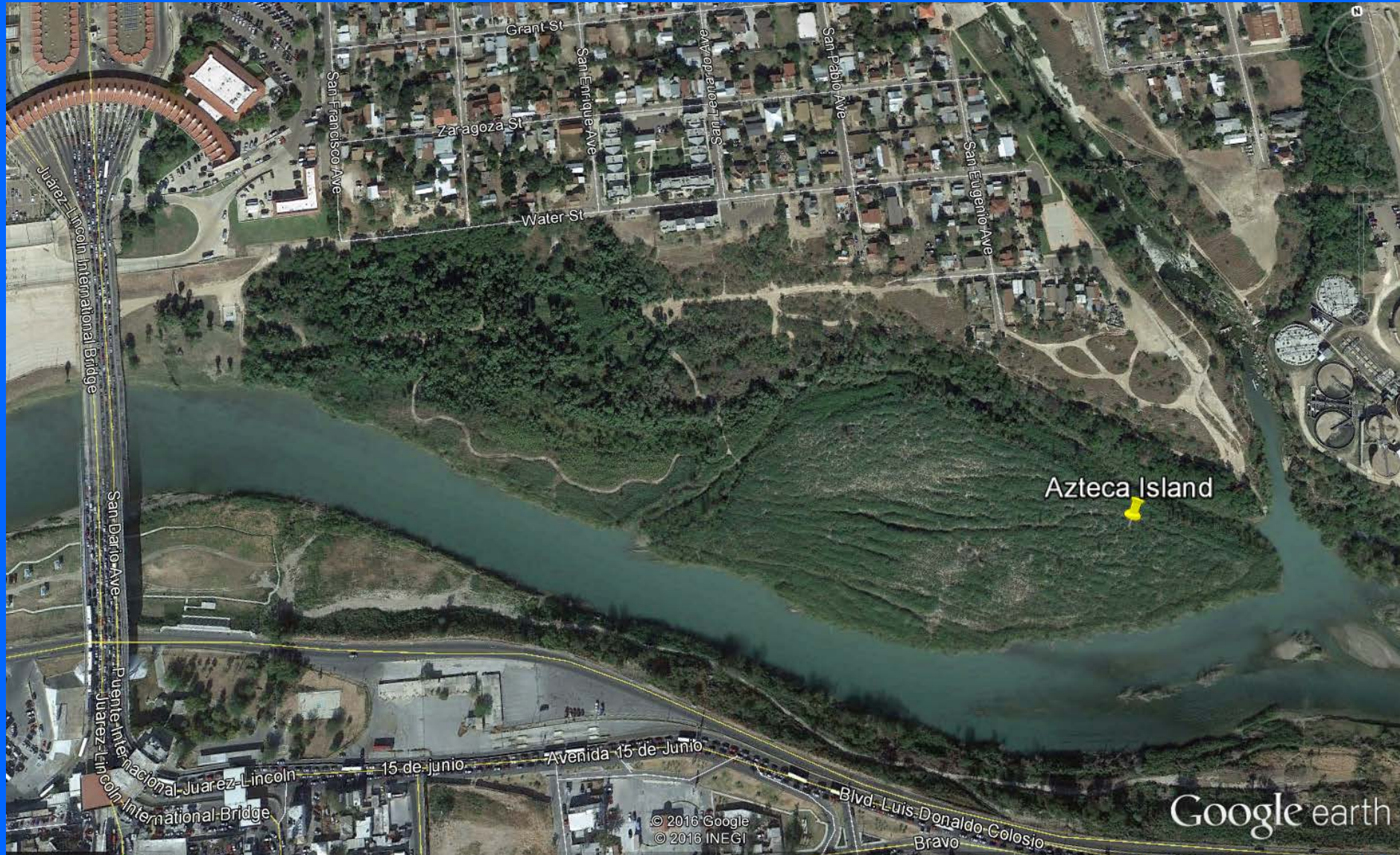
Scale-killed new shoot

Damage to cane from biocontrol insects

Contact: John A. Goolsby, USDA-ARS
 956-373-3223 john.goolsby@ars.usda.gov
 Edinburg, TX (Moore Airbase)

Immediate visibility and long-term control

La Azteca Island, Laredo, TX



La Azteca, Laredo, TX

Before



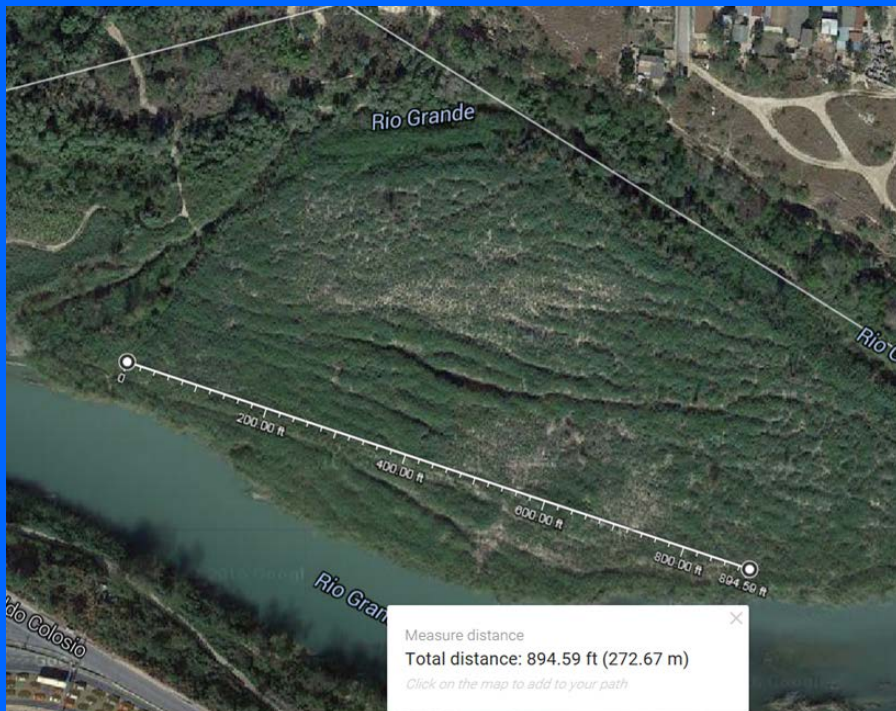
After



Visibility on Day 1 and stays for 1 year, no standing dead cane, no fire hazard

300 Yard Visibility

USDA employee at far end



How long does topping + bio keep carrizo cane stunted?



11 months after topping – Brownsville, TX

Conclusions

- *Arundo donax* is extremely invasive with multiple social, political, agricultural and environmental impacts in the riparian habitats of the Southwestern U.S. watersheds.
- Significant economic benefits from control of *A. donax*
- Biological control best adapted strategy for long-term basin-wide control
- Biological control program has released 3 agents from Spain, gall-forming wasp, armored scale, & leafminer
- Significant benefits to Rio Grande Basin.
- >7000 acre feet of water conserved per year
- Texas Agrilife model – \$5 million in benefits per year

Summary

- *Arundo donax*, carrizo cane is declining along Rio Grande from Del Rio to Brownsville due to attack by biocontrol insects
- New topping techniques synergizes with biocontrol to provide immediate visibility and is a scalable technology for Rio Grande
- 3rd agent the arundo leafminer will further accelerate decline



Biological control of *Arundo donax*; an invasive weed of the Rio Grande Basin

Arundo donax Infestation on Rio Grande

J. Goolsby¹, D. Thomas¹, A. Perez de Leon², A. Kirk³, M.C. Bon³, J. Kashefi³, G. Desurmonti³, L. Smith³, M. Cristofaro⁴, P. Moran⁵, Yang⁶, J. Gaskin⁷, P. Gowda⁸, M. Grusak⁹, M. Ciomperlik¹⁰, T. Roland¹⁰, A. Racelis¹¹, R. Summy¹¹, J. Escamilla¹¹, J. Landivar¹², A. Pepper¹³, R. Lacewell¹⁴, E. Rister¹⁴, M. Martinez Jimenez¹⁵, M. Marcos¹⁶, E. Cortés Mendoza¹⁶, L. Gilbert¹⁷, T. Vaughn¹⁸, A. Rubio¹⁸ ¹United States Dept. of Agriculture, Agricultural Research Service, Cattle Fever Tick Research Laboratory, Mission, TX, john.goolsby@ars.usda.gov; ²USDA-ARS Knipling Bushland U.S. Livestock Insects Research Laboratory, Kerrville, TX; ³USDA-ARS, European Biological Control Laboratory, Montpellier, France; ⁴BBCA Rome, Italy; ⁵USDA-ARS; ⁶Albany, CA; ⁷College Station, TX; ⁸Sidney, MT; ⁹Houston, TX; ¹⁰USDA-APHIS, Moore Airbase, Edinburg, TX; ¹¹Univ. of Texas – Rio Grande Valley, Edinburg, TX; ¹²Texas A&M Univ.; ¹³Dept. of Biology, ¹⁴Dept. of Ag. Economics, College Station, TX; ¹⁵Instituto Mexicano de Tecnología del Agua, Jiutepec, MX; ¹⁶Universidad de Alicante, Spain; ¹⁷Univ. of Texas, Austin, TX; ¹⁸Texas A&M International, Laredo, TX;

Impacts of Arundo Water Use



Rio Nadores in Cuatro Ciénegas, Coahuila, Mexico no longer flows due to severe arundo infestation. A rare fish species has gone extinct due to invasion.

Eddy covariance equipment is being used to measure water use of arundo before and after release of the agents. With more than 30,000 ha. of arundo in the RGB, there is significant potential for water conservation

Arundo donax, known as, giant reed, carrizo cane, and arundo is an exotic and invasive weed of riparian habitats in the southwestern U.S. and northern Mexico. Arundo dominates these habitats, which leads to: loss of biodiversity; stream bank erosion; increased costs for chemical or mechanical control along irrigation canals and transportation corridors; reduction of access and visibility of the international border for law enforcement personnel; increased risk of cattle fever tick incursion; and this weed competes for water resources in an arid region where these resources are critical to the environment, agriculture and urban users. Biological control using insect agents from the native range of *A. donax* in Europe may be the best option for long-term and widespread management. Two biological control agents have been released and established in the U.S. and Mexico. A detailed economic analysis of the biological control program indicates that for each research dollar spent, society benefits between \$4 and \$8 in return.

Research Objectives:

1. Evaluate field impacts and dispersal of established biological agents on *A. donax*, and monitor transition of riparian zone to native vegetation, changes in water use, visibility of border, and interactions with cattle fever ticks.
2. Evaluate of additional biological control agents from the native range that target different life stages of *A. donax*.
3. Develop mass rearing and aerial field release methods for the agents for control of *A. donax* in the remote areas of the Rio Grande.
4. Develop methods to integrate mechanical and biological controls to meet needs for immediate control and visibility.
5. Use aerial remote sensing techniques to measure changes in *A. donax* density and distribution, which can be used in the economic model to quantify benefits of the biological control program.

Biological Control Agents



Tetramesa romana
Arundo wasp
Hymenoptera:
Eurytomidae
larvae produce galls on stems & side shoots
(adult strikes)
Field released April 2009

Rhizaspidiotus donacis
Arundo scale
Hemiptera: Diaspididae
scale insects feed on roots and side shoots
Field released Dec 2010

Lasioptera donacis
Arundo leafminer
Diptera:
Cecidomyiidae
Larvae are leaf sheath miners causing defoliation
Field released Dec 2016

Cryptoneura sp.
Arundo shoot fly
Diptera: Chloropidae
Larvae feed on and kill new cane shoots
In host range testing

Border Security



Law enforcement officials in the U.S. and Mexico have reduced visibility and access to the international border. Biological control has bi-national support as a solution.

Field Results



The arundo wasp reached outbreak levels on the Rio Grande during 2013 which has thinned cane stands. White boards are used to measure changes in within stand visibility caused by the agents.

The arundo scale is established in several locations on the Rio Grande. Scale are causing twisted necrotic growth of side shoots and reducing recruitment of new stems.

Integration with Mechanical Topping



Topping creates immediate river visibility for law enforcement agencies. Topping promotes short bushy side shoots with max plant height = 3-5 feet. Mass release of biocontrol insects further suppresses Arundo canes which stay stunted allowing desirable native vegetation to return.

Impact of Agents on Biomass

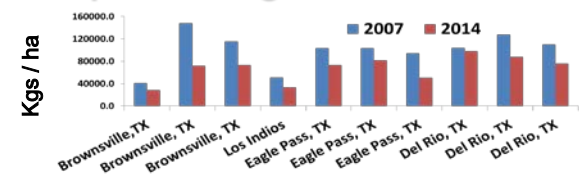


Fig. 1. Arundo biomass on the Rio Grande (558 river miles) has been reduced by 32% from 2007 to 2016 due to widespread arundo wasp damage. This reduction equals 2.5 million tons of cane removed, conserving 6000 acre ft. of water per year valued at \$4.4 million. Additional control expected from the Arundo scale and leafminer.

Cattle Fever Ticks



Arundo along the Rio Grande provides an ideal, cool, shaded habitat for survival of ticks on cattle or wildlife such as nilgai antelope that cross from Mexico. Arundo creates a 'pathogenic landscape' which favors CFT. Biological control of arundo could indirectly control CFT by reducing the risk of tick incursion from Mexico. Direct biocontrol of the CFT has been initiated in its native range in India.

Transition to Native Vegetation



Regrowth of natives

Biological control agents from the native range could greatly reduce the size, density and dominance of *A. donax*, thus allowing native vegetation to return to the banks of the river and streams of the Rio Grande Basin. Long term benefits could be a healthier more resilient ecosystem, which may help the region adapt to potential climate change.



Native riparian