

The Present and Future Contributions of Biological Control to Integrated Adaptive Management of Water Hyacinth and Other Invasive Aquatic Macrophytes in the Delta

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United States Department of Agriculture

Agricultural Research Service

Outline

- **Rationale and practice of biological control of weeds.**
- **Why biological control is needed for successful management of invasive aquatic weeds in the Delta.**
- **Current status of biological control tools for aquatic weeds in the Delta.**
- **Integration of biological control into an adaptive management framework for aquatic weeds in the Delta.**

What is Biological Control?

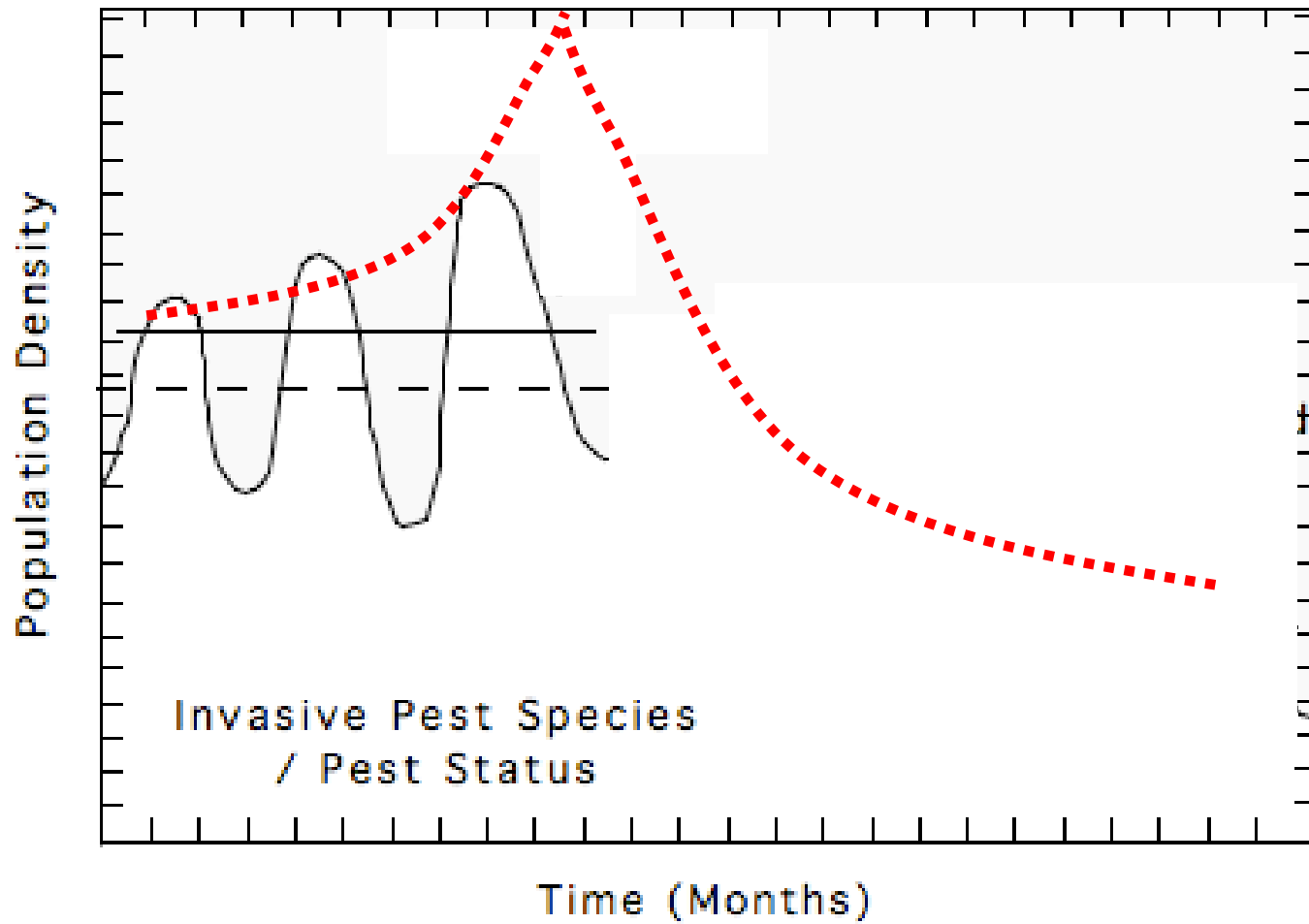
Natural phenomena: “The action of parasites, predators, or pathogens in maintaining an organism’s population level at a level lower than would occur in their absence” - DeBach, *Biological Control of Insect Pests and Weeds*, 1964

Approach for invasive weeds/pests: ‘The introduction of self-sustaining populations of pathogens, parasites, and predators to reduce densities (and thus impacts) of a pest organism’ - Huffacker and Dahlsten, *Handbook of Biological Control*, 1999



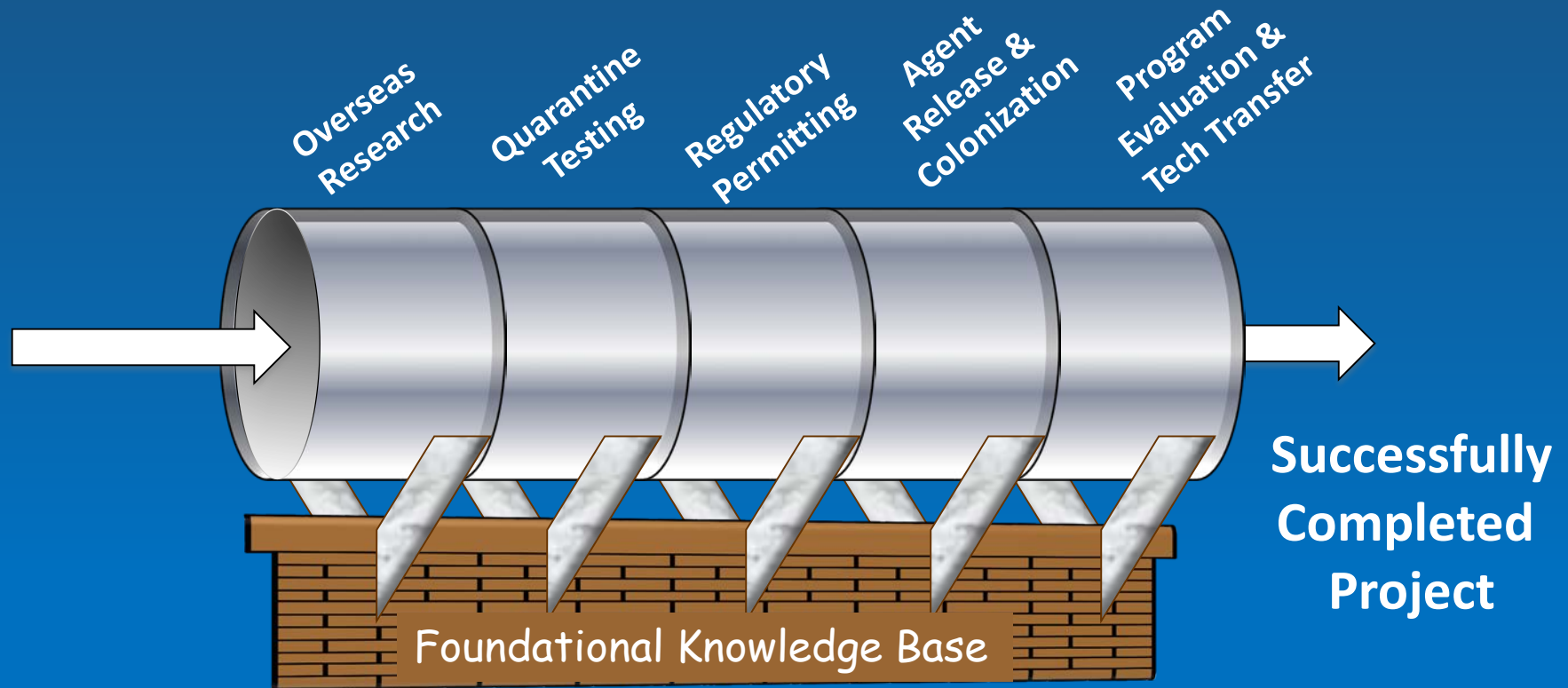
Basic Concepts Guiding Biological Control of Aquatic Weeds

- Aquatic weeds that are *non-native* are the only ones suitable for biological control.
- Biological control should always be considered for non-native, invasive aquatic weeds for other control methods are insufficient to achieve *sustainable control*.
 - Economic sustainability
 - Environmental sustainability
- Biological control seeks to restore balance between non-native, invasive aquatic weeds and their *host-specific natural enemies*.
- Biological control does not constitute an eradication tool.
- Biological control of aquatic weeds must be integrated with other methods in an *adaptive management* framework.



Introducing biological control agents re-establishes natural enemy relationships and may halt rapid population growth and spread of invasive pest species. Sometimes it only takes one agent, and other times, several agents.

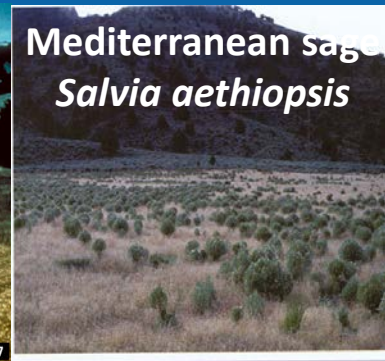
The Biological Weed Control “Pipeline” for Development of New Biocontrol Weed Tools (*Agents*)



Taxonomy, Biogeography, Genomics, Ecology, Entomology,
Plant Pathology, Population biology, Vegetation analysis,
Phytochemistry, Insect-Plant Interactions

Benefits of Biological Control

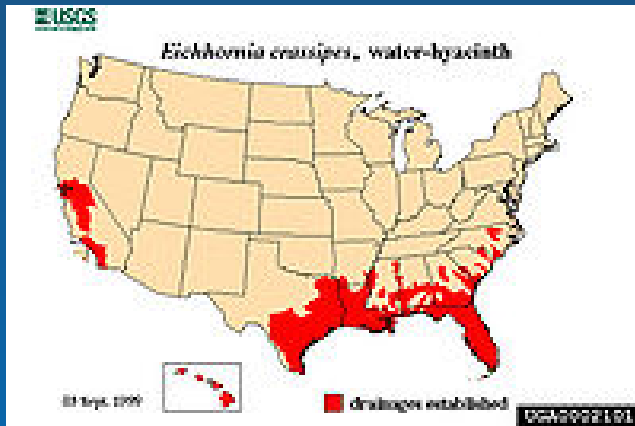
- For efficacious agents, benefit:cost ratios range from 8:1 to 300:1.
- 70% of agents released since 1991 have established populations.
- In the U.S., about 45 weeds targeted since 1940s; significant impacts in at least 33% of cases. Includes three aquatics.
- In Australia, New Zealand, South Africa-success rates over 50%



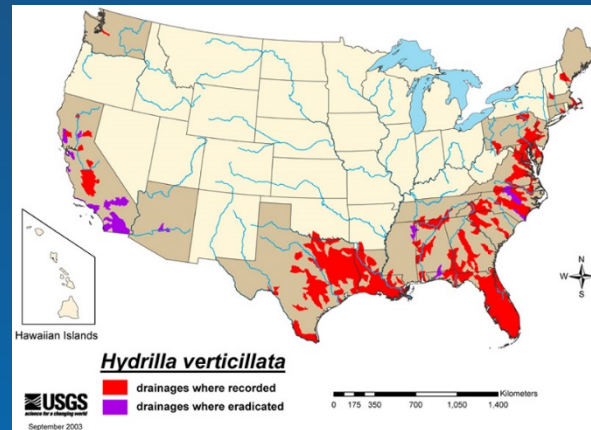
Disadvantages of Biological Control

- Up-front cost and substantial time commitment (typically 5-10 years, \$1-\$5 million) for overseas and quarantine research to select and develop new biological control agents, then release and evaluate impact.
- Once agents are released, irreversible (if established).
- Slow method of control-typically five years or more to see full impact.
- (Like any other method) does not eradicate the weed.
- Risks: Agent does not establish; agent does not have impact.

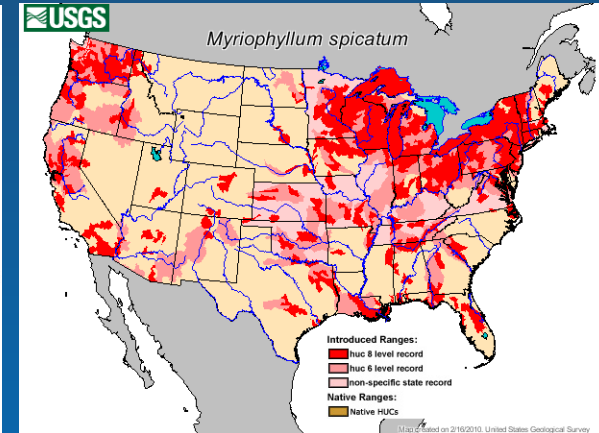
Bottom-up forces acting on aquatic weed invasions



Water hyacinth



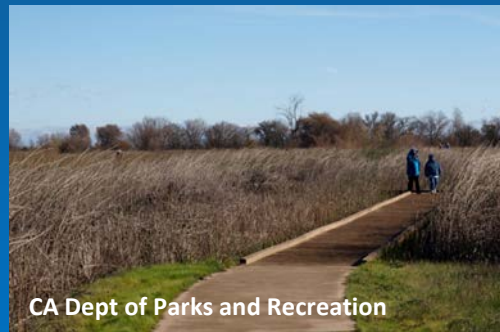
Hydrilla



Eurasian watermilfoil

- Large scale-climatic tolerance range (subtropical to temperate)
 - These forces can also act on biological control agents
- Small/local scale: Water salinity, nutrient levels, turbidity, flow rate
- Human alteration of habitat: River dams, levees, canal systems, dredging
 - Has increased amount of suitable habitat for invasive aquatic weeds

The Sacramento-San Joaquin Delta: A Resource-Critical Aquatic System Vulnerable to Invasion



- Highly modified but still highly diverse habitats and plant/animal communities.
- Over 50 threatened or endangered species.
- Heavy pressure from human use of water and land resources.
- Many invasion vectors-water flow, water and land shipping, agriculture.
- Due to both habitat and jurisdictional/ownership complexity, new invaders likely to go undetected until causing damage.
- Even after detection, complexity likely to hinder effective system-wide control.
- **Biological control can overcome these challenges.**

Non-Native, Invasive Aquatic Weeds- Major Threats to Water Resources, Environmental Health, and Economic Activities In the Sacramento-San Joaquin Delta

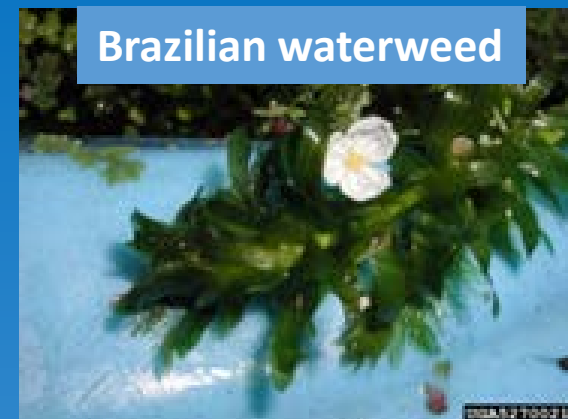
Water hyacinth



Arundo



Brazilian waterweed



Water yellow-primrose



South American
spongeplant



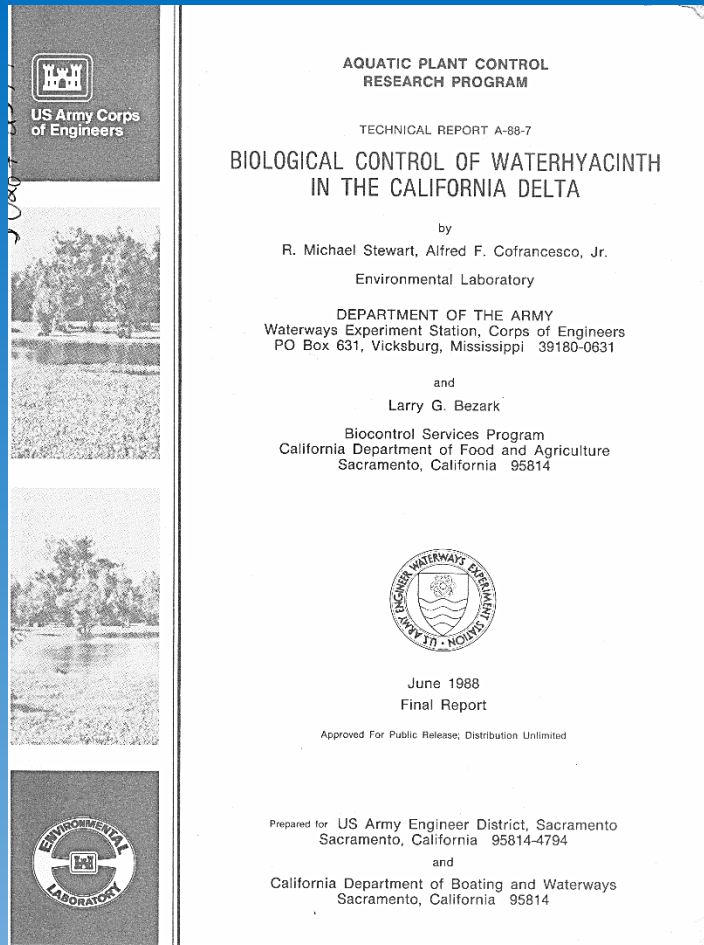
Curly-leafed pondweed



**Biological Control Tools and Prospects
for Non-Native, Invasive Aquatic Weeds
In the Sacramento-San Joaquin Delta**

Waterhyacinth (*Eichhornia crassipes*)

History of Biological Control of Water Hyacinth in the Delta



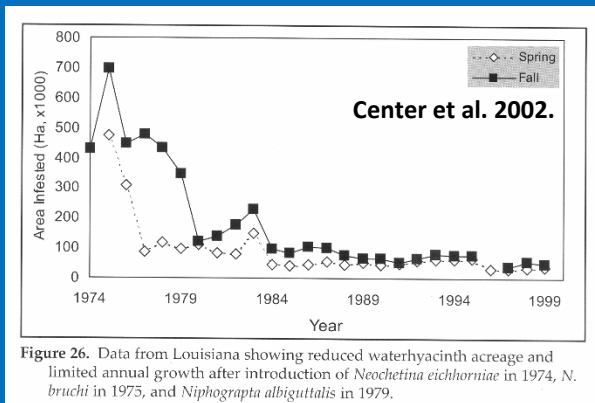
- 1982 (Then) CA Department of Boating and Waterways asked the U.S. Army Corps of Engineers to direct a biological control program.
- 1982-1983: The weevils *Neochetina bruchi* and *Neochetina eichhorniae* released at four Delta sites (Old River; Veale Tract; White Slough; Trapper Slough).
- 1983-1985: The moth *Niphograptia albiguttalis* released, same sites. No establishment.
- By 1985: Weevils established at at least 2 sites.
- Early 2000s (USDA-ARS and CDBW collaboration): Release more weevils, examine water nutrient effects.
- Akers and Pitcairn 2006 (CDFA): Only the weevil *N. bruchi* is established in Delta, impact not substantial.



Akers, R. P. & M. J. Pitcairn. 2006. *Biological Control of Water Hyacinth in the Sacramento-San Joaquin Delta, Year 3-Final Report*. California Department of Food and Agriculture, Sacramento, 12 pp.

Why were the *Neochetina* spp. weevils released?

- Discovered in the native range of water hyacinth and characterized in the 1960s and early 1970s by the USDA-ARS.
- Shown to have rapid life cycle, high fecundity, and high host-specificity to water hyacinth (Deloach 1976, 1982).
- Released first in the U.S. in the 1970s and shown to decrease water hyacinth plant size and asexual reproduction (Center et al 2002).



M. Julien, CSIRO



M. Julien, CSIRO

- Since then, released in over 25 countries, with best results in tropical regions.
- Can be integrated with chemical and mechanical control.

Important New Information on the Water Hyacinth Weevils In the Delta and Associated Tributaries:



See the talk THIS AFTERNOON at 3:35 PM, Room 308

(Species Invasions in the San Francisco Estuary)

By Dr. Julie Hopper:

**Mechanisms for the Effective Biological
Control of the Invasive Water Hyacinth in
the Sacramento-San Joaquin Delta**

New Biological Control Agent for Water Hyacinth: The Water Hyacinth Planthopper *Megamelus scutellaris*

- From South America (Surinam to Argentina)
- Life cycle lasts one to two months
- Two generations reduces plant size and asexual reproduction by 70%



Megamelus scutellaris



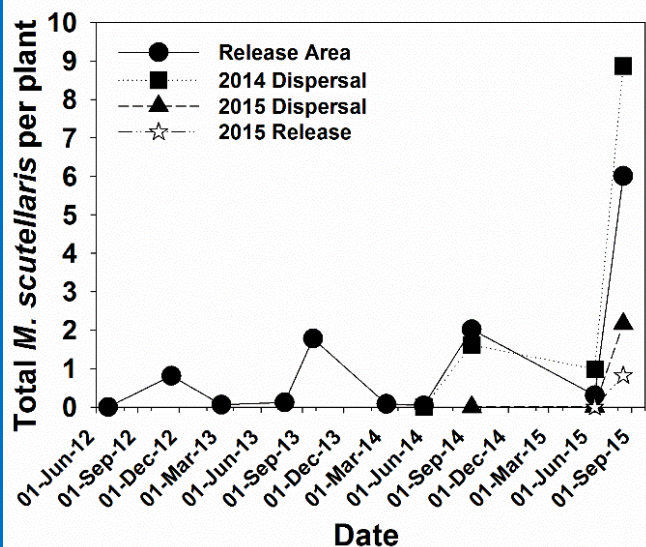
- Released from Florida to Texas 2010-2013.
- Released in 2011-present in CA.
- Specific to waterhyacinth in field.
- Short development time.
- Ability to disperse when crowded or host plant quality declines.

Sosa, AJ, Lenicov, MDR, Mariani, R., Cordo, HA. 2005. Annals of the Entomological Society of America 98:66–72.

Tipping, PW, Center, TD, Sosa AJ, Dray, FA. 2011. Biocontrol Science and Technology 21:75–87.

Tipping, PW, Sosa, A, Pokorny, EN, Foley, J, Schmitz, DC, Lane JS, Rodgers, L, McCloud, L, Livingston, P., Cole MS, Nichols, G. 2014. Florida Entomologist 97(2):804–806.

Dispersal and Establishment of the Water Hyacinth Planthopper At the first site of establishment in CA-Folsom, 2012-2015



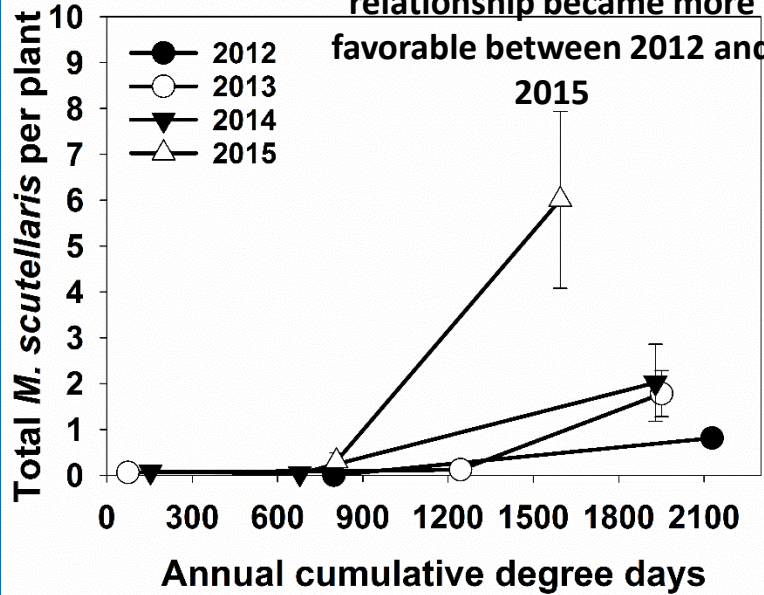
- Planthopper dispersed about 50 m (166 ft) per year
- Planthopper density increased up to 10-fold by 2015
- Long-term impact still uncertain:
 - Reduction of plant density (reproduction)?
 - Reduction of plant survival?

Moran PJ, Pitcairn MJ, Villegas, B. 2016. *Pan-Pacific Entomologist* 91: 32-43.

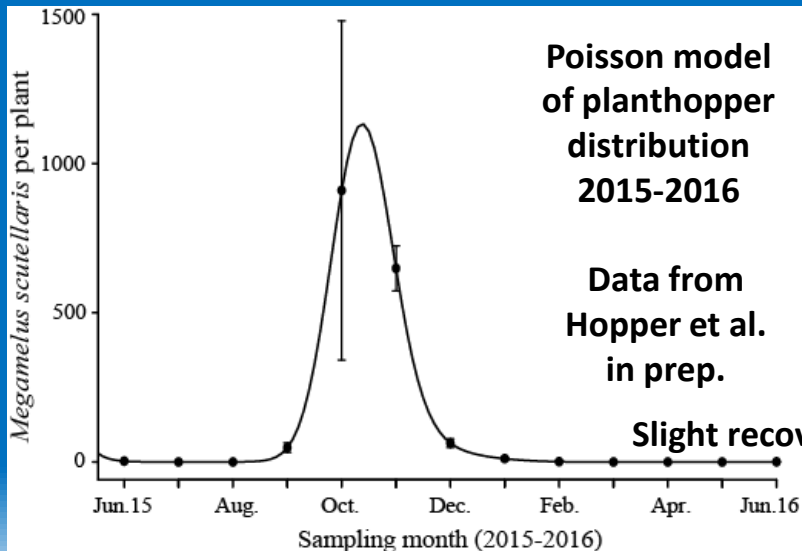
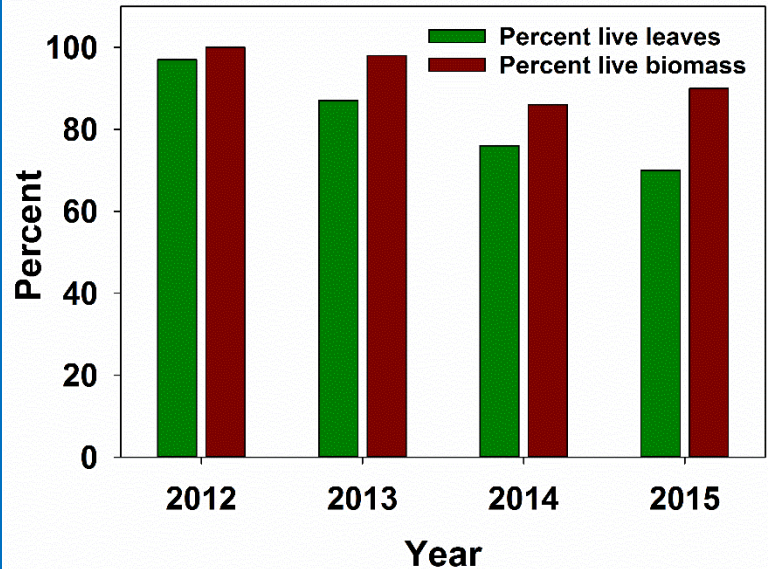
Additional Information-Establishment and impact of the water hyacinth planthopper in Folsom, CA



- Degree-day and density relationship became more favorable between 2012 and 2015



- % live leaves declined 25%
- % live above-water biomass declined 10%



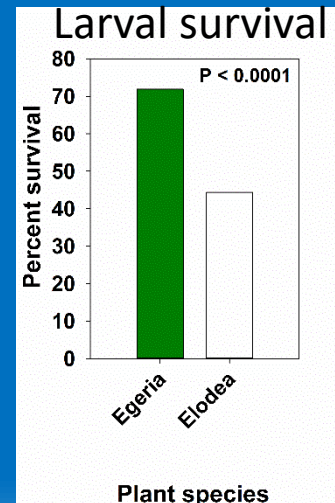
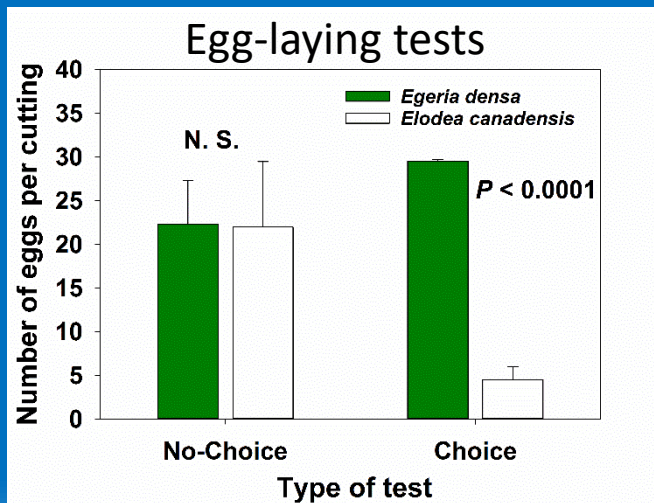
- The planthopper was released at one additional site in August 2016 (near Merced River, Merced County)
- New release sites in the Delta planned

Brazilian waterweed (*Egeria densa*)



- Common canal and slough weed in the Sacramento-San Joaquin Delta and beyond.
- 12,000 acres in Delta.

Candidate Agent for Biocontrol of Brazilian waterweed The Aquatic fly *Hydrellia egeriae* (Diptera: Ephydriidae)



- Egg-laying and survival on and damage to the “nontarget” native submersed plant, *Elodea canadensis*, were unacceptably high.
- Therefore, this fly was rejected as a biocontrol agent by the researchers.

Data provided by Dr. John Herr, USDA-ARS, Albany, CA

Water primrose (*Ludwigia* spp.)



Grewell, BJ, Netherland, MD, Thomason, MJS. 2016. Establishing research and management priorities for invasive water primroses. US Army Engineer Research and Development Center, Publication ERDC/EL TR-16-2, U.S. Army Corps of Engineers, Washington, DC

Ludwigia hexapetala

Ludwigia grandifolia

Ludwigia uruguayensis

copyright 2015 California

Invasive *Ludwigia*: South American Origin

Collaboration with FuDEI lab in Buenos Aires, Argentina.

- investigate biological control options & ecology in native range.
- Determine host range in native range, and include popular ornamentals in U.S. (for example *Clarkia*, *Epilobum*, *Fuchsia*, *Oenothera*).



Systematics

Pathology & Entomology



Plant Ecology



Foreign Exploration

Water primrose



Auleutes sp.



Tyloderma sp.



Lysathia sp.



Fulgoridae



Sphingidae



Pterophoridae



Tortricidae



Pyralidae

South American Spongeplant *Limnobium laevigatum* (or *L. spongia*)



- No biological control project initiated
- Relatively new invader, invasive potential is high-spreading in Delta.



Pre-Release Risk Assessment:

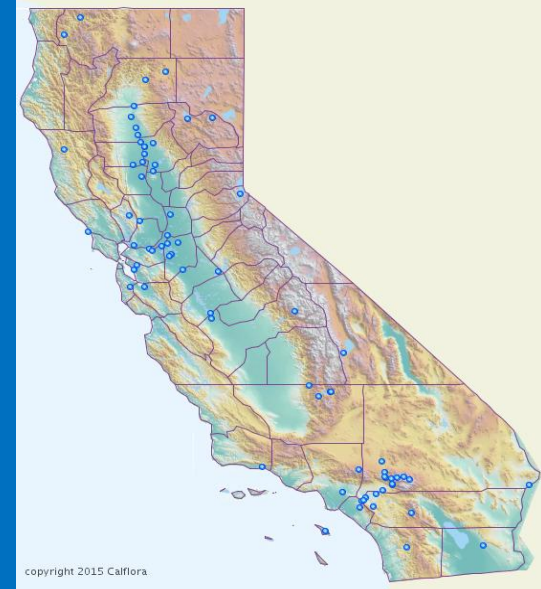
- Non-target list in the plant family Hydrocharitaceae is the same as for *Egeria densa*.
- Leverage contacts in South America for exploration for candidate agents.

Curly-Leafed Pondweed (*Potamogeton crispus*)

- Submersed invasive weed in the Delta.
- Problems caused and current chemical control tools similar to those associated with Brazilian waterweed .
- No biological control project initiated.

Pre-Release Risk Assessment:

- Most challenging of the invasive aquatic weeds in the Delta for biocontrol.
- 15 native *Potamogeton* in CA.
- Only other member of family Potamogetonaceae is *Stuckenia* (2 native spp., important ecosystem species in Delta).

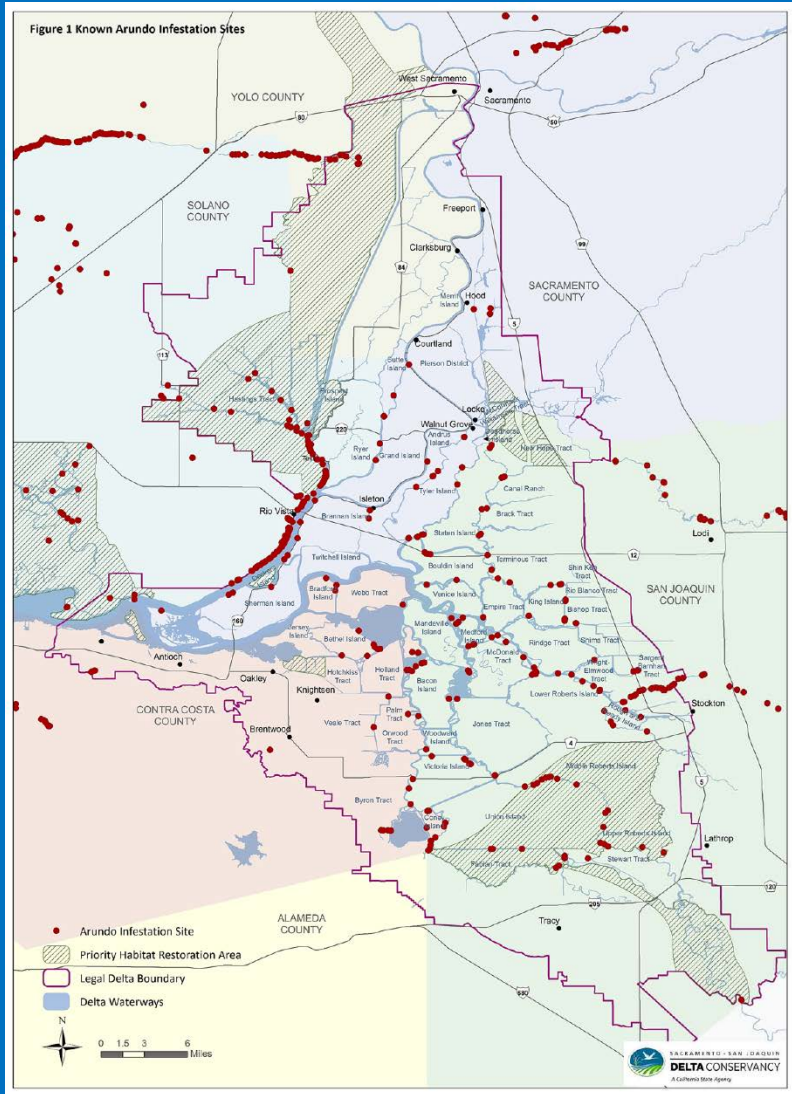


Not Aquatic But..Major Riparian Invader With Importance for Water Resources *Arundo (Arundo donax)*



- Consumes/wastes water.
- Obstructs access to water.
- Obstructs flood control channels.
- Fuels fires.
- Hides illegal activities that damage environment.

Arundo Populations in the Delta



- **Western Delta**
 - Three existing sites (Big Break/Marsh Creek; Andrus Island)
 - Prospective new sites in Brannon-Rio Vista-CDFW, CA DPR, SMUD
 - Lower Sherman Island-CDFW
- **Northwestern Delta**
 - Cache Slough Complex-SSJDC Pilot Project
- **Southern Delta**
 - South Delta WA-Grant Line/Four Corners area-CA DWR, local agencies
 - Central Delta WA-Holt, CA-Whiskey/Trapper Slough
 - Upper Jones Island
- **Central/Eastern Delta**
 - San Joaquin River at Venice Cut/Medford Island/Hog Island areas

Product of the Arundo Mapping Project

Sacramento-San Joaquin Delta Conservancy

Arundo biocontrol agents released recently (since 2014) in the Delta

Arundo wasp *Tetramesa romana*



Arundo armored scale *Rhizaspidotus donacis*



- Lab studies: Each agent reduced plant size/growth/photosynthesis over 50%.
- Native range studies: Armored scale reduced shoot growth and rhizome weight 50%.
- Field studies (Texas): Arundo wasp reduced live biomass 44%, increased native plant diversity 2-3-fold.

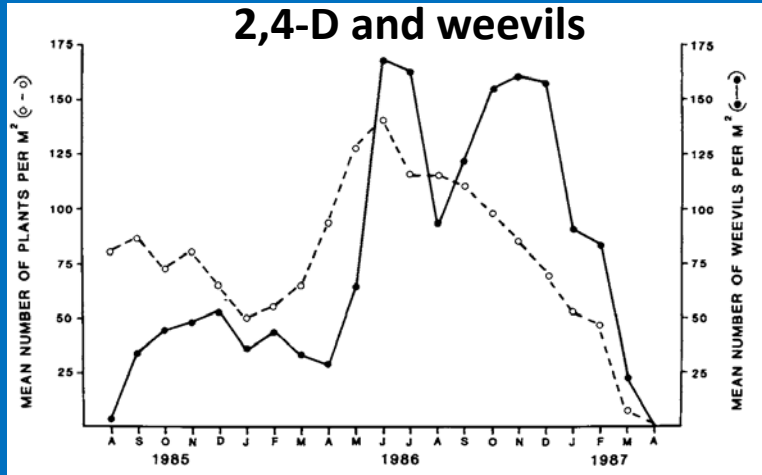
Goolsby, JA, Moran, PJ, Racelis, AE, Summy, KR, Martinez Jimenez, M, Lacewell, RD, Perez de Leon, A, Kirk, AA. 2016. *Biocontrol Sci. Technol.* 26: 47–60

Moran, PJ, Vacek, AT, Racelis, AE, Pratt, PD, Goolsby, JA. 2017. *Biocontrol Sci. Technol*, in press.

Delta Arundo Wasp and Armored Scale Release Sites

- Five sites total now in Delta
- New sites planned in 2017

Integrated Chemical-Biological Control of Invasive Aquatic Weeds- Water Hyacinth Examples



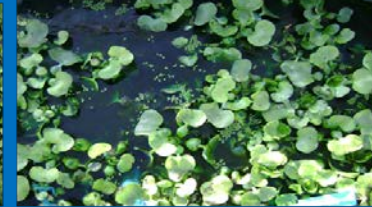
Penoxsulam, triclopyr and glyphosate+ weevils
Impacts on time to death and recolonization

Penoxsulam
2 oz/acre



Penoxsulam
+ biocontrol

Triclopyr
1 pint/acre

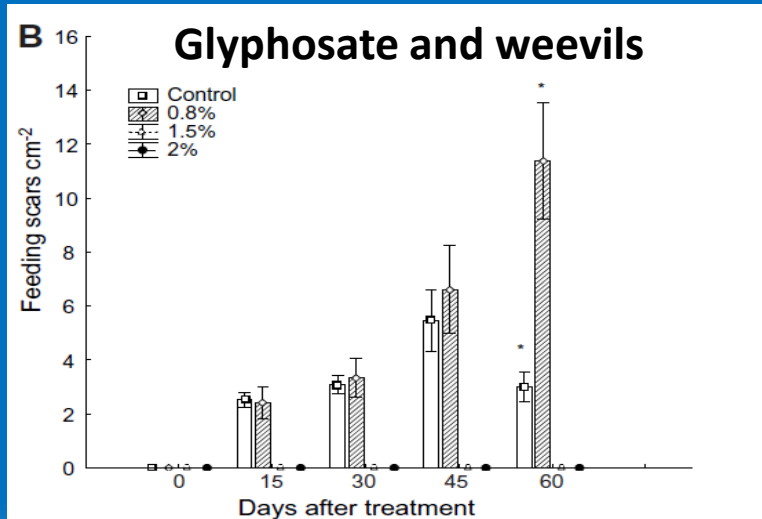


Triclopyr
+ biocontrol

Glyphosate
1 pint/acre

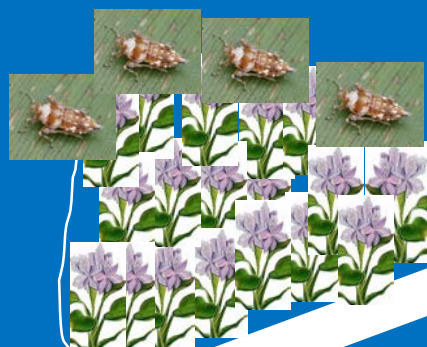


Glyphosate
+ biocontrol

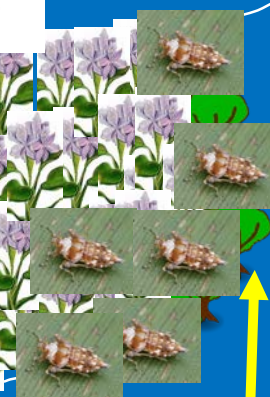
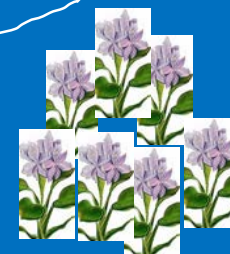


Haag and Habeck 1991. J. Aquat Plant Mgmt. 29:24-28.
Center et al. 1999. Environ. Mgmt. 23: 241-256.
Jadhav et al. 2008. Biol. Cont. 47: 154-158.
Moran 2012. J. Aquat Plant Mgmt. 50: 32-38

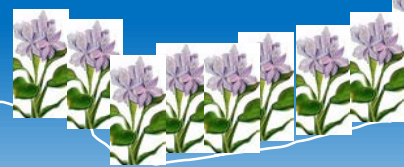
Conceptual Integration of Chemical (or Mechanical) Control and Biological Control of Floating Aquatic Weeds in the Delta



Backwater area
inaccessible
to
treatment



Elderberry=no
treatment within 50 ft



Thanks To...



- **Chris Mehelis, Matthew Perryman, Caroline Nunn, Valle Rogers (USDA-ARS)**
Water hyacinth biocontrol field studies and sample processing.
- **Ed Somera and Tony Delgado (Division of Boating and Waterways-CA Parks)**
Help finding new water hyacinth biocontrol sites.
- **City of Folsom, CA and Pareira Dairy (Hopeton, CA)**
Access to water hyacinth field sites.
- **East Bay Municipal Park District, Gil LaBrie (Rec Dist 556), Dante Nomellini (Central Delta Water Agency)**
Access to arundo field sites.
- **Beckye Stanton (SSJDC)**
Coordination of interagency dialogue for new arundo biocontrol sites.
- **Joel Trumbo (CDFW), Cara Allen (CDPR)**
Development of review process for new arundo biocontrol site.