Biological Control of Weeds in Rangelands in Northern California-Research at USDA-ARS

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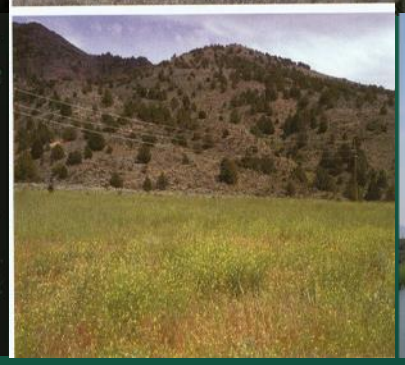
Why consider biological control of weeds?

- **For weeds invading ecosystems where other methods can't keep up-natural areas-rangelands, forests, riparian zones, wetlands and aquatic habitats.**
- For effective agents, benefit : cost ratios range from 8:1 to 300:1.
- Worldwide, 70% of agents released since 1991 have established populations.
- In the U.S., about 45 weeds targeted since 1940s; significant impacts in 33% of cases.
- In California, success rate is 42%; over 50% across Australia, New Zealand, and South Africa.



Trade-offs of biological control

Advantages

- Biological controls are host plant specific-no collateral damage to native plants.
- Biocontrol agents are self-dispersing.
- Once established, biocontrols provide lasting control at little or no cost.
- Do not interfere with other control methods.

Disadvantages

- Up-front cost and research investment.
- May take several years to establish.
- May take several more years to see impact.
- May not produce the desired level of control.
- Risk of non-target damage and indirect ecological effects (low risk).

Research Facilities at the USDA-Agricultural Research Service
Invasive Species and Pollinator Health Research Unit, Albany and Davis, CA

Aquatic Weed Research Lab (AWRL), Davis, CA

Arthropod Quarantine Laboratory:

- 150 m^2 of lab space
- 300 m^2 of greenhouse space
- 10 reach-in growth chambers

Supporting Facilities:

- 700 m^2 -non-quarantine greenhouses
- Aquatic tanks in one greenhouse
- Three non-quarantine lab suites

- 2 greenhouses with over 60 tanks.
- Outdoor arrays with over 50 tanks.

Host range, biological life cycle and impact testing of candidate biocontrol agents
Studies done overseas, and in quarantine at the USDA-ARS in Albany, CA

Arthropod Quarantine Laboratory
USDA-ARS, Albany, CA

Biological evaluations of insect/mite life cycle:

Host range testing in laboratories and greenhouses:

Efficacy evaluations-laboratory overseas and at USDA; field overseas

- **Laboratory/greenhouse:** Plant damage (% of leaves); plant size, biomass; reproduction (one generation).

- **Field (overseas-native range of agent):** Farm/garden plots in a climatically similar area; insecticide exclusion; assess insect damage; assess weed cover, biomass, flower count, seed weight.

Historical overview of biological control of weeds in California and examples of recently completed projects

Biological Weed Control in California: An Overview-as of 2023

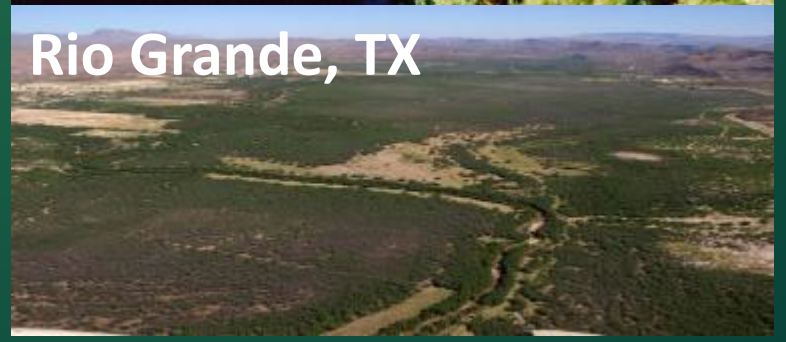
Pitcairn MJ. 2018. Weed biological control in California, USA: review of the past and prospects for the future. BioControl 63: 349-359

- **First release of non-native agent for biocontrol in CONUS occurred in 1944-47 in California-flea beetle (*Chrysolina hyperici*) for Klamath weed.**
- **Total of 40 weeds targeted with released agents in California.**
- **Total of 80 biological control agents released. 82% are established.**
- **42% of the projects so far have led to successful control-moderate to major impact on weed.**
- **Twelve weeds-too early to evaluate success.**

Saltcedar-*Tamarix* spp. (Tamaricaceae) invades riparian habitats across the western U.S

Tamarix spp.-*T. parviflora* in coastal mountain drainages of CA;

T. ramosissima/T. chinensis in inland desert washes.



Life Stages of *Diorhabda* spp. Leaf Beetles (Coleoptera: Chrysomlelidae)-4 species released in U.S.

Diorhabda carinulata, Diorhabda carinata, Diorhabda elongata, Diorhabda sublineata

Eggs

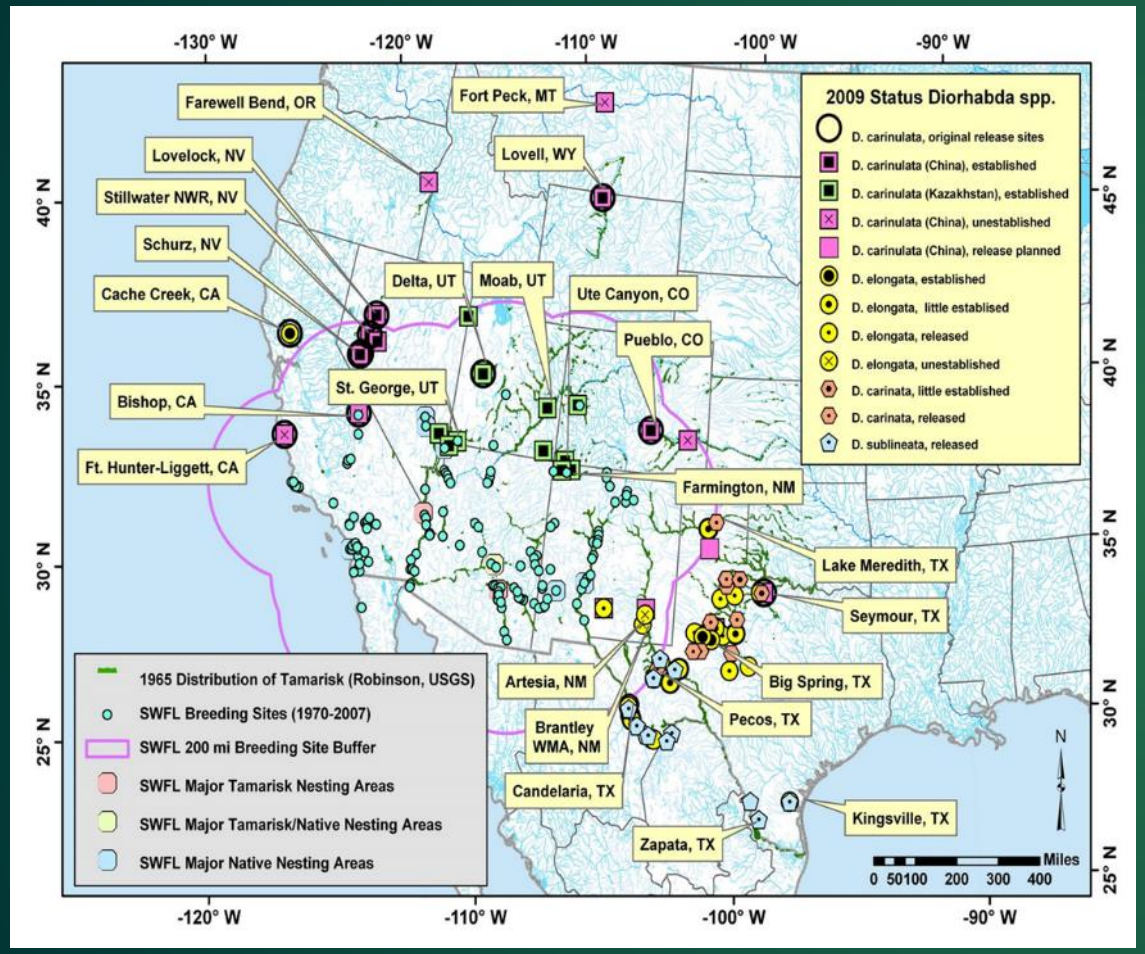
Young larvae

Mature larva

Adult

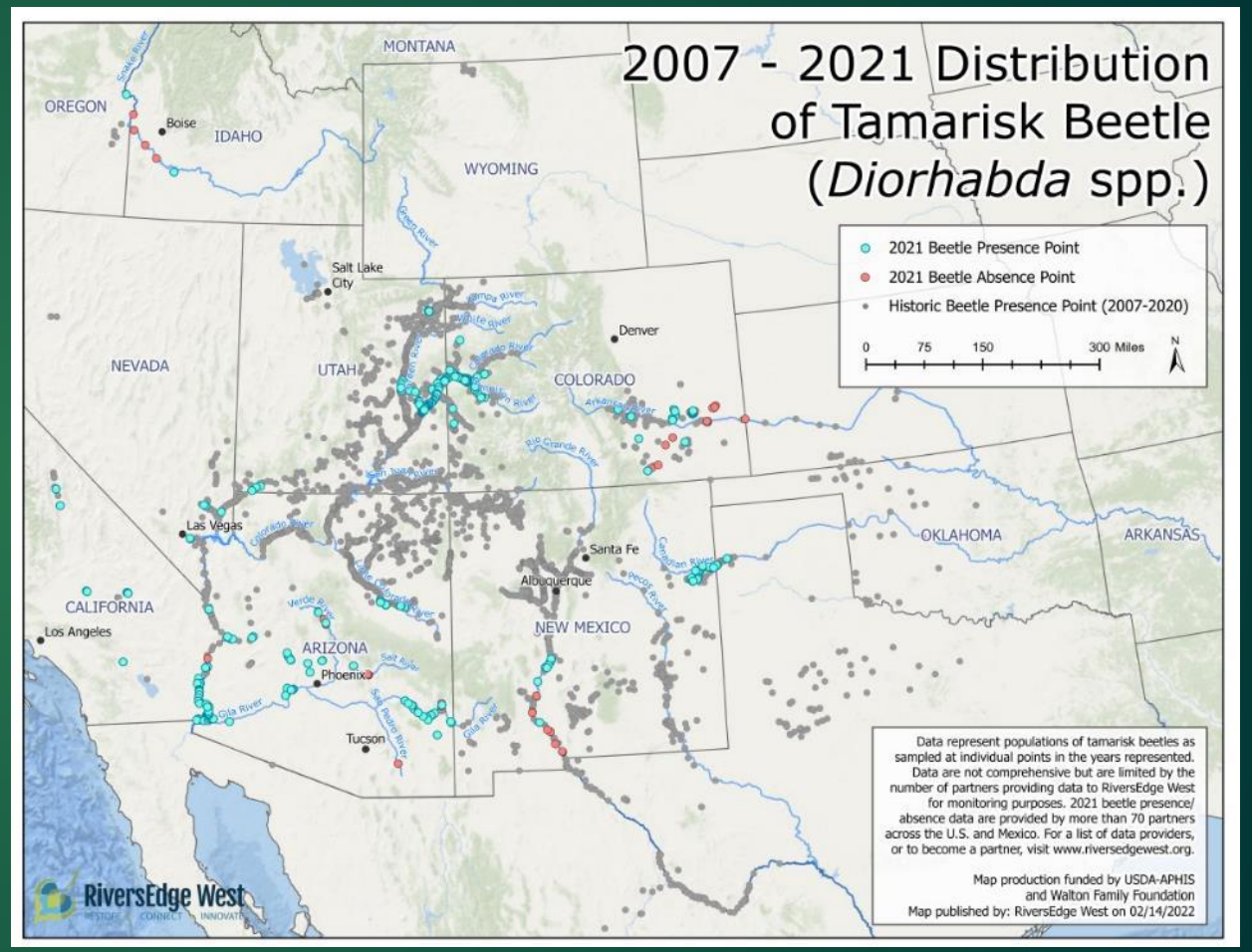
Showed reduced feeding and survival *on Tamarix parviflora* in lab/cage tests

Biological Control of Saltcedar with Diorhabda spp. Beetles: A Program Covering Many Western U.S. Watersheds



Map of release sites 2000-2010

made by USDA-ARS

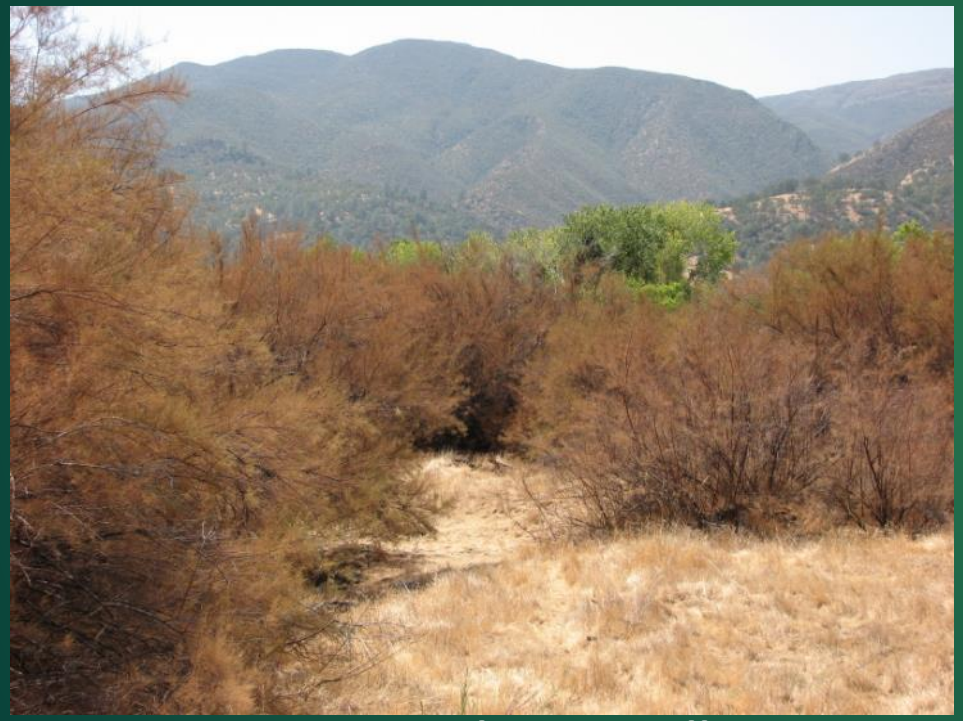


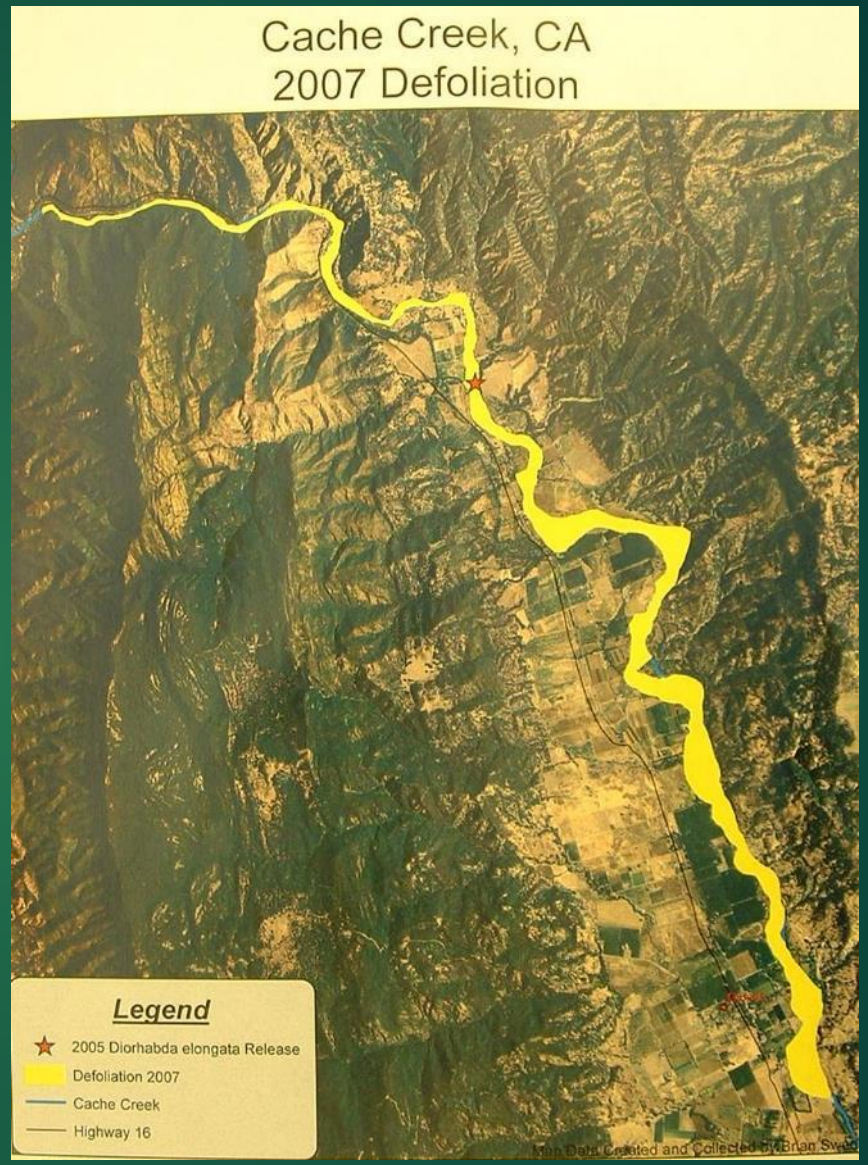
2021 saltcedar beetle monitoring map

made by Rivers Edge West (former Tamarisk Coalition)

<u>Does not show Cache Creek or Bishop, CA-beetles are present</u>

Released in 2005. By September 2007, *Diorhabda* beetles had defoliated saltcedar growing along 20 miles of Cache Creek in the upper Capay Valley.





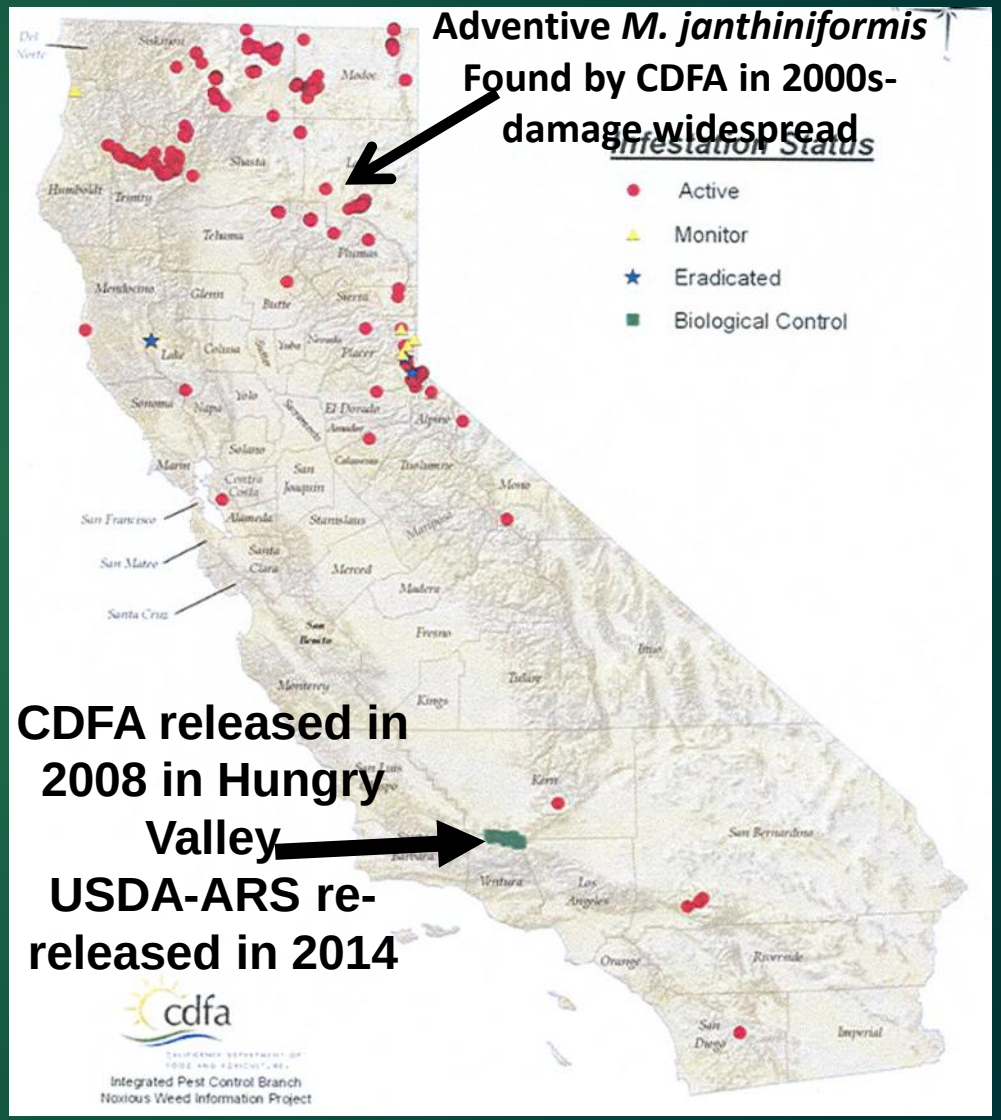
- **More recent surveys: Beetles are still present in Cache Creek (Solano County), and near Bishop, CA (Inyo County), but have not spread.**

Pratt PD, Herr JC, Carruthers RI, Pitcairn MJ, Villegas B, Kelley MB. 2019. Release, establishment and realised geographic distribution of *Diorhabda carinulata* and *D. elongata* (Coleoptera: Chrysomelidae) in California, U.S.A. Biocontrol Sci. Technol. 29:7, 686-705

Dalmatian Toadflax (*Linaria dalmatica subsp. genistifolia* (Scrophulariaceae))
USDA-ARS and CDFA project

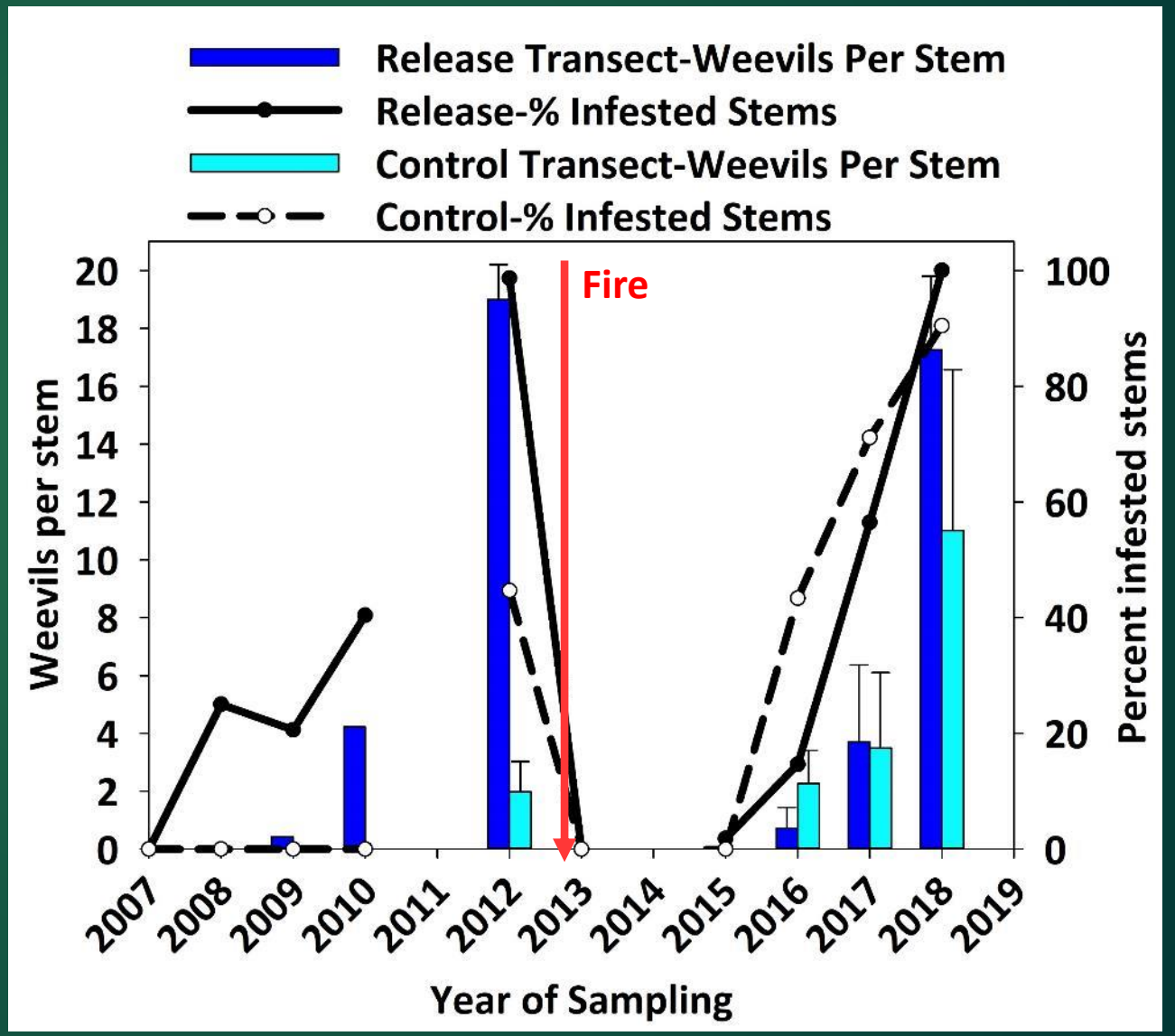
Stem weevil

Mecinus janthiniformis



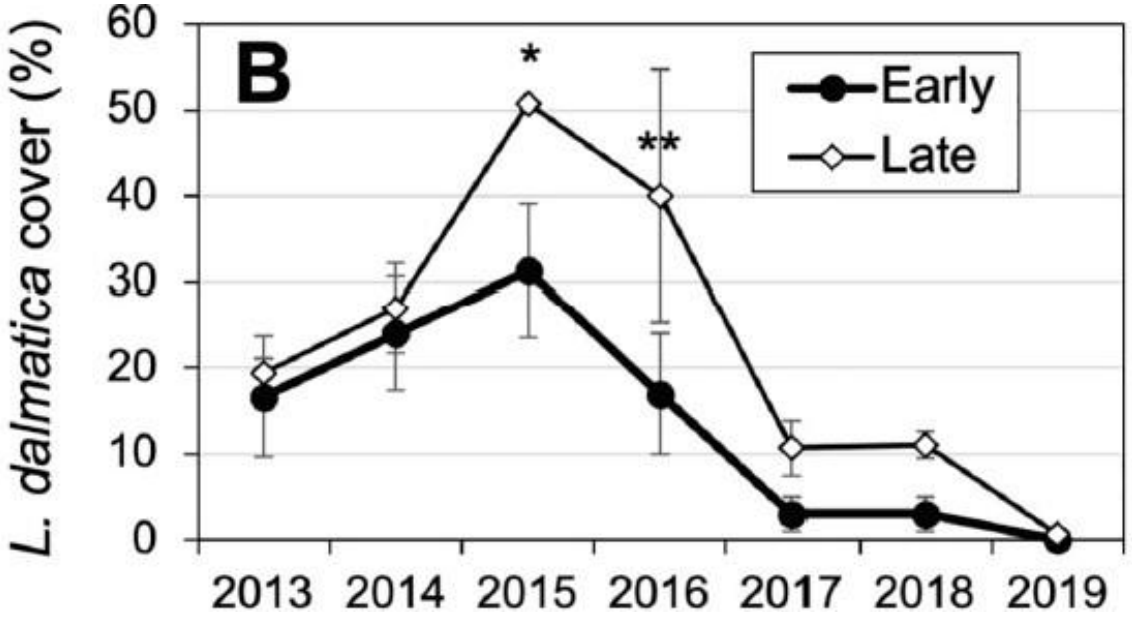
Success of biocontrol of Dalmatian toadflax in southern California with the toadflax weevil-near Gorman, CA Condor Trail, Hungry Valley SVRA

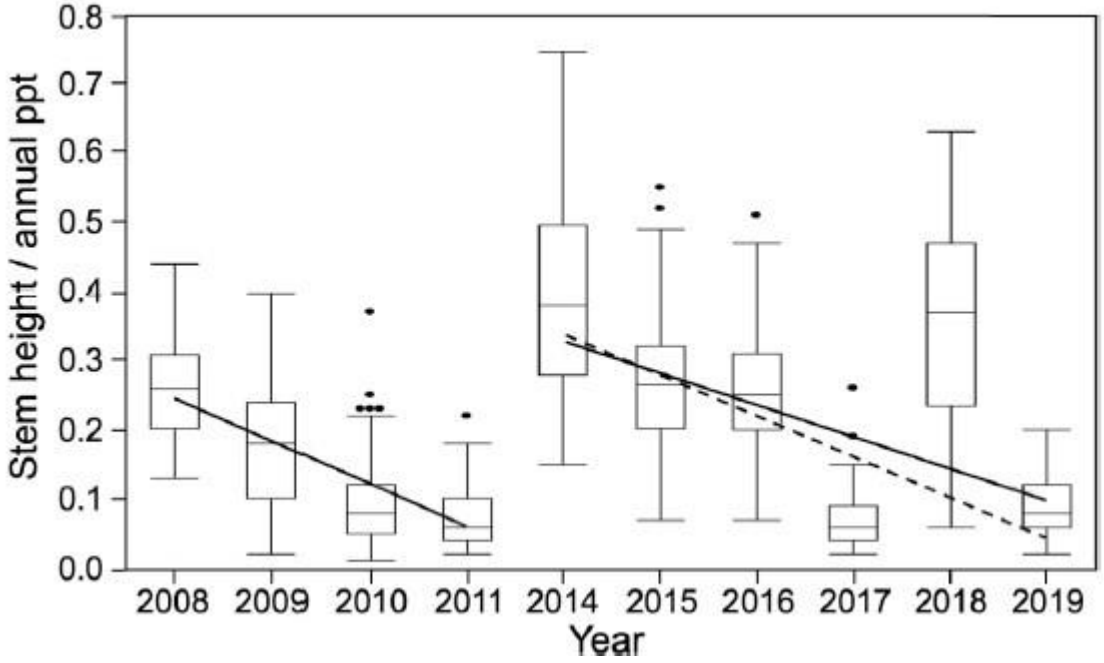
- CDFA released in 2007-2008.
- Exponential increase in weevils by 2012
- Grand Fire in May 2013 destroyed weevil population; plant recovered.
- USDA-ARS re-released weevil in 2014.
- 2015-2017: Clear evidence of increase of weevils in HVSVRA transects.
- Dispersal of weevils to non-release transects on US Forest Service land-2016-2017.
- Weevils reached same abundance in 2018-2019 as in 2012.



Impact of Dalmatian toadflax Biological Control

Hungry Valley SVRA-CA Parks/Los Padres NF-USFS

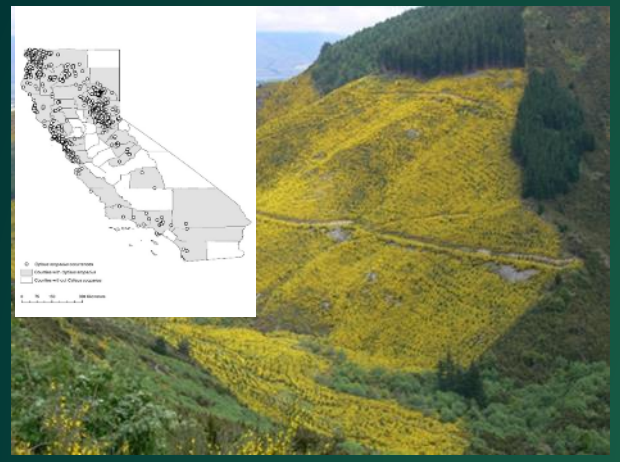




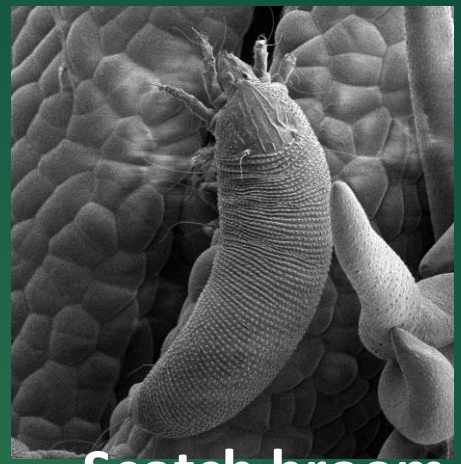
- **Decline in 2015-2017 mirror major increase in *M. janthiniformis* weevil population.**
- **By 2020: 99% reduction in abundance of Dalmatian toadflax; 77% reduction in height of plants.**

Smith L, Woods DM, Wibawa MI, Popescu V, Moran PJ, Villegas B, Pitcairn MJ, Hon C. 2021. Release and establishment of the weevil Mecinus janthiniformis for biological control of Dalmatian toadflax in southern California. Biol. Cont. 161, 104633. doi: 10.1016/j.biocontrol.2021.104633

Scotch broom (*Cytisus scoparius*) (Fabaceae)



Invades pastures, rangelands, forests



Scotch broom mite, *Aceria genista*

Adventive agent, dispersing on its own into CA-big impact?

Scotch broom psyllid
Arytainilla spartiophila

Seed weevil
Bruchidius villosus

Seed pod weevil
Exapion fuscirostre

***Leucoptera spartiofolia*-broom twig miner**

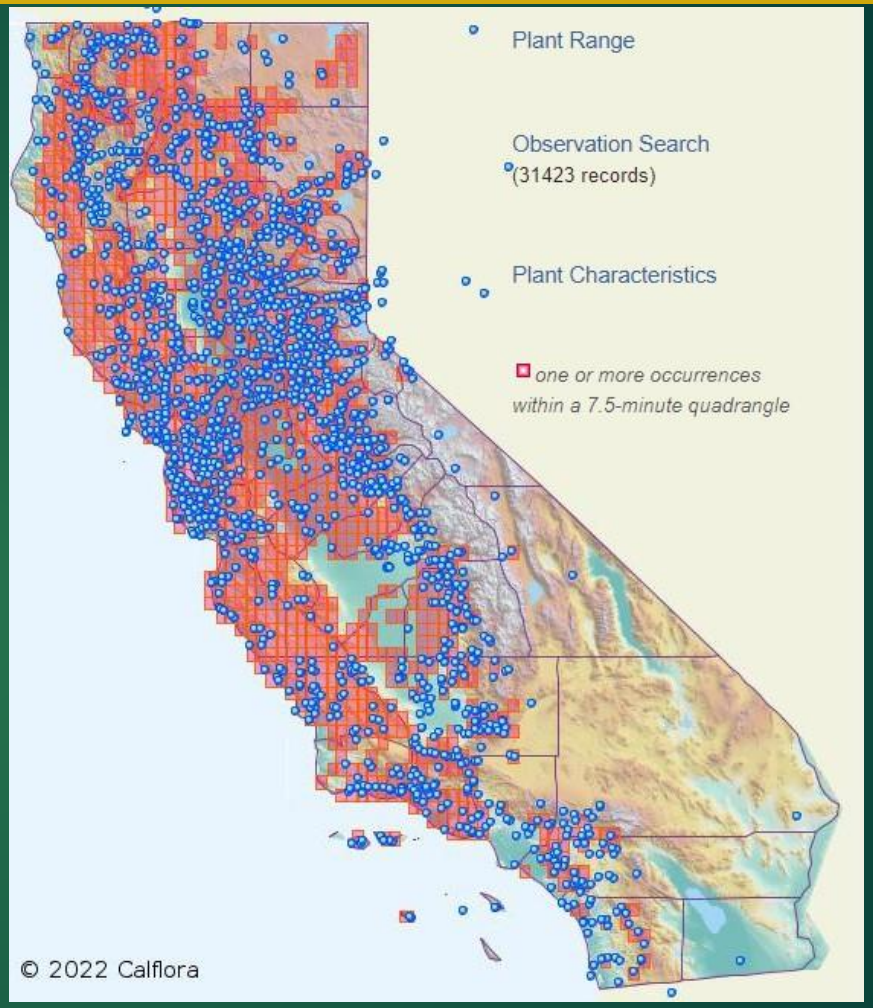
Four old agents-two adventive, two released

Tested mite host range in lab and at field sites-it is safe

Pratt, P.D., M.J. Pitcairn, S. Oneto, M. Brent Kelley, C. J. Sodergren, F. Beaulieu, W. Knee, and J. Andreas. 2019. Biocontrol Science and Technology 29: 494-513.

Recent releases of biological control agents of weeds in California

Yellow starthistle (*Centaurea solstitialis*) in California-Distribution and impacts

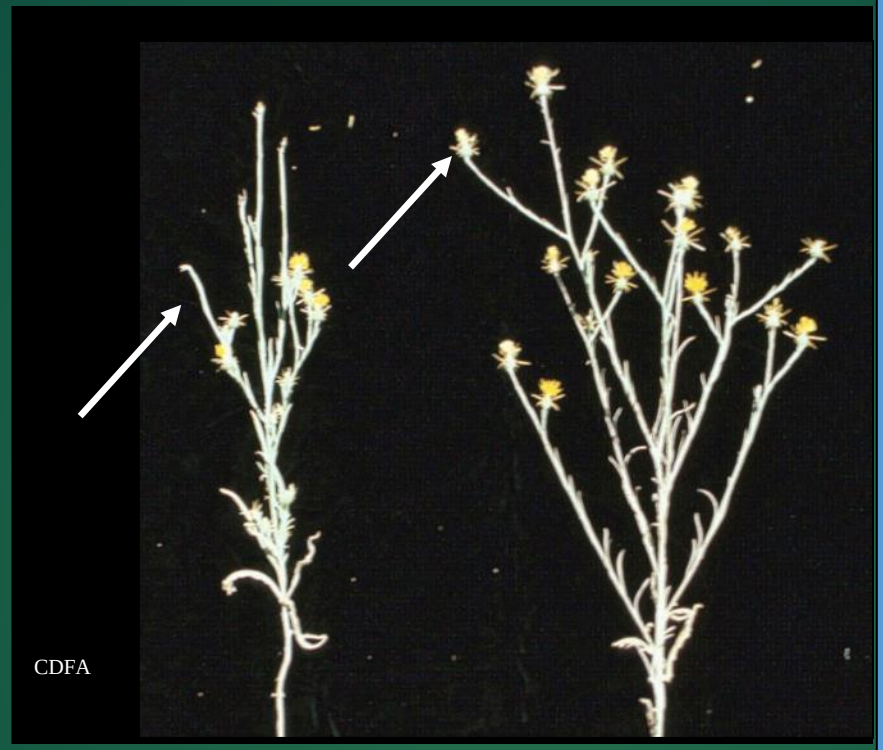


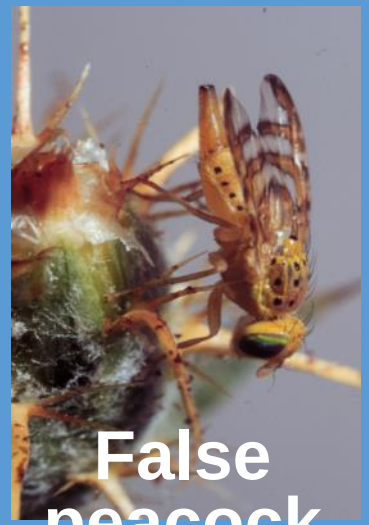
- Outcompetes native and exotic forage grasses
- Increases difficulty for cattle access to forage grasses
- Leaves toxic to cattle
- Deep taproot uses scarce water faster than grasses and native herbs/forbs
- Benefits for successful control (all methods) in CA alone would be $1.4B

Yellow starthistle insect damage

Flower and seedhead-feeding insects released in the 1980s and 1990s

Hairy weevil
Eustenopus villosus





False peacock fly
Chaetorellia succinea

USDA-ARS

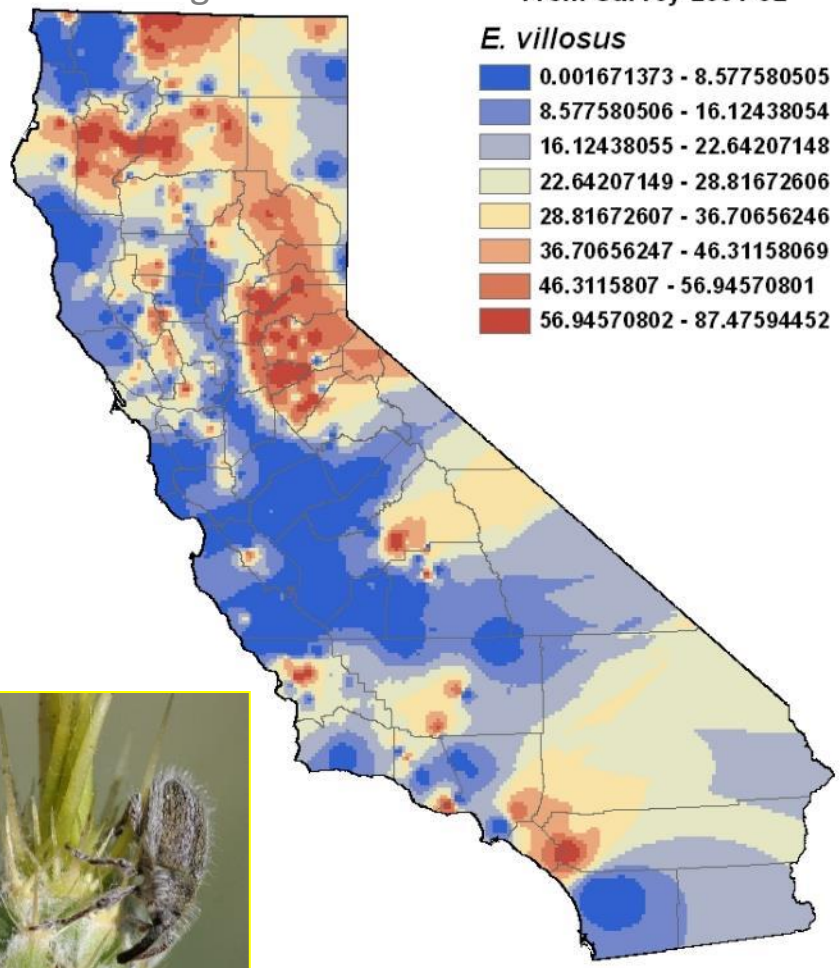
- Studying ability of these three insects to damage yellow starthistle from different regions-field plot and greenhouse.

Candidate agent-seedhead-feeding weevil
Larinus filiformis
Cold-adapted-Sierra foothills

Seed-galling fly
Urophora sinuraseva

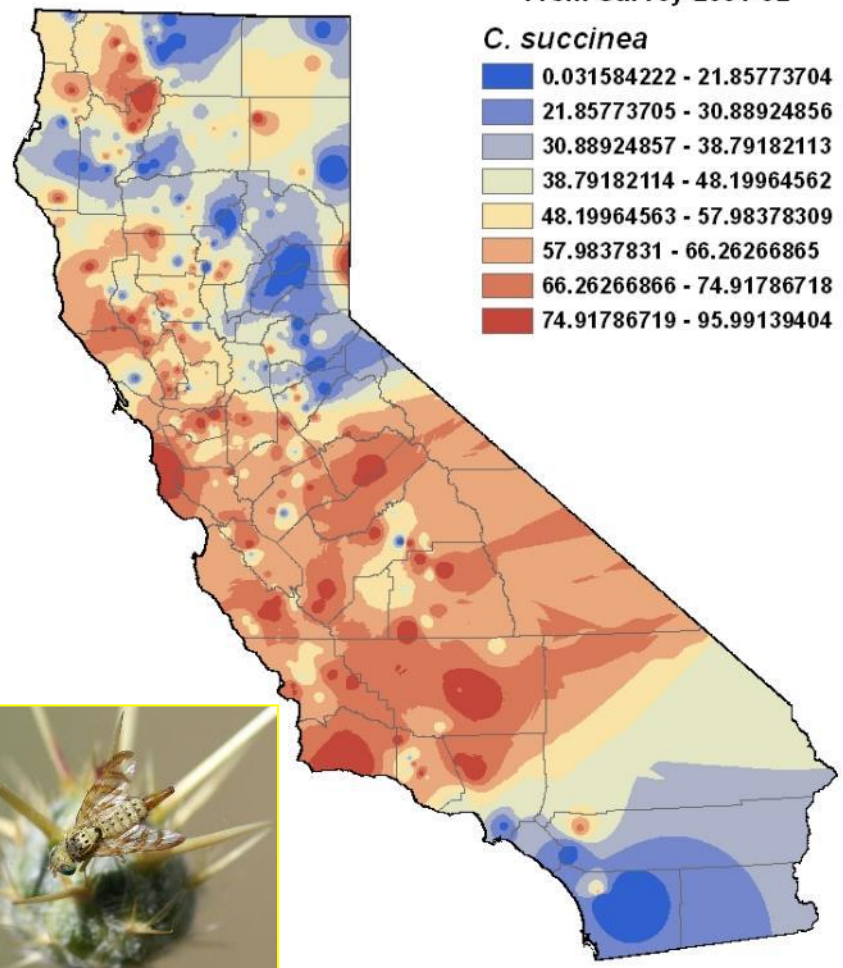
Hairy Weevil

Recovered at 80% of locations
Mean attack rate: 25%
Range: 0 - 93%



False Peacock Fly

Recovered at 99% of locations
Mean attack rate: 53%
Range: 0 - 96%



R. Yacoub & M. Pitcairn (CDFA)

Newly-released biological control agent on yellow starthistle

The rosette weevil *Ceratapion basicorne.*
First new insect agent released against yellow starthistle in 30 years.
First agent that feeds on the root and rosette of immature plants.

- Introduced from yellow starthistle's native range in northern Greece.
- In field, only yellow starthistle damaged.

- Adult female lays eggs on leaves.
- Larvae burrow down leaf, into stem, and eat taproot.

Smith, L. 2007. Physiological host range of *Ceratapion basicorne*, a prospective biological control agent of *Centaurea solstitialis* (Asteraceae). Biol. Control 41: 120-133.
Cristofaro, M., De Biase, A., Smith, L. 2013. Field release of a prospective biological control agent of weeds, Ceratapion basicorne, to evaluate potential risk to a nontarget crop. Biol. Control 64: 305-314.

Innovations in rearing and technology transfer: yellow starthistle root weevil *Ceratapion basicorne*

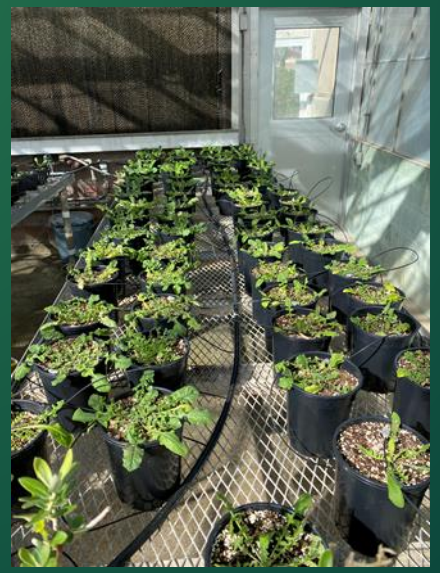
See Lightning Talk by Dr. Ikju Park given on October 26th.

- Insect hormones and cold treatment used to make a *univoltine* insect (one generation per year) *multivoltine*.

Insect naturally lays eggs on leaves.

- Transfer larvae rather than females-more efficient.

-Over 300 weevils reared at USDA-ARS
-100s reared at other facilities

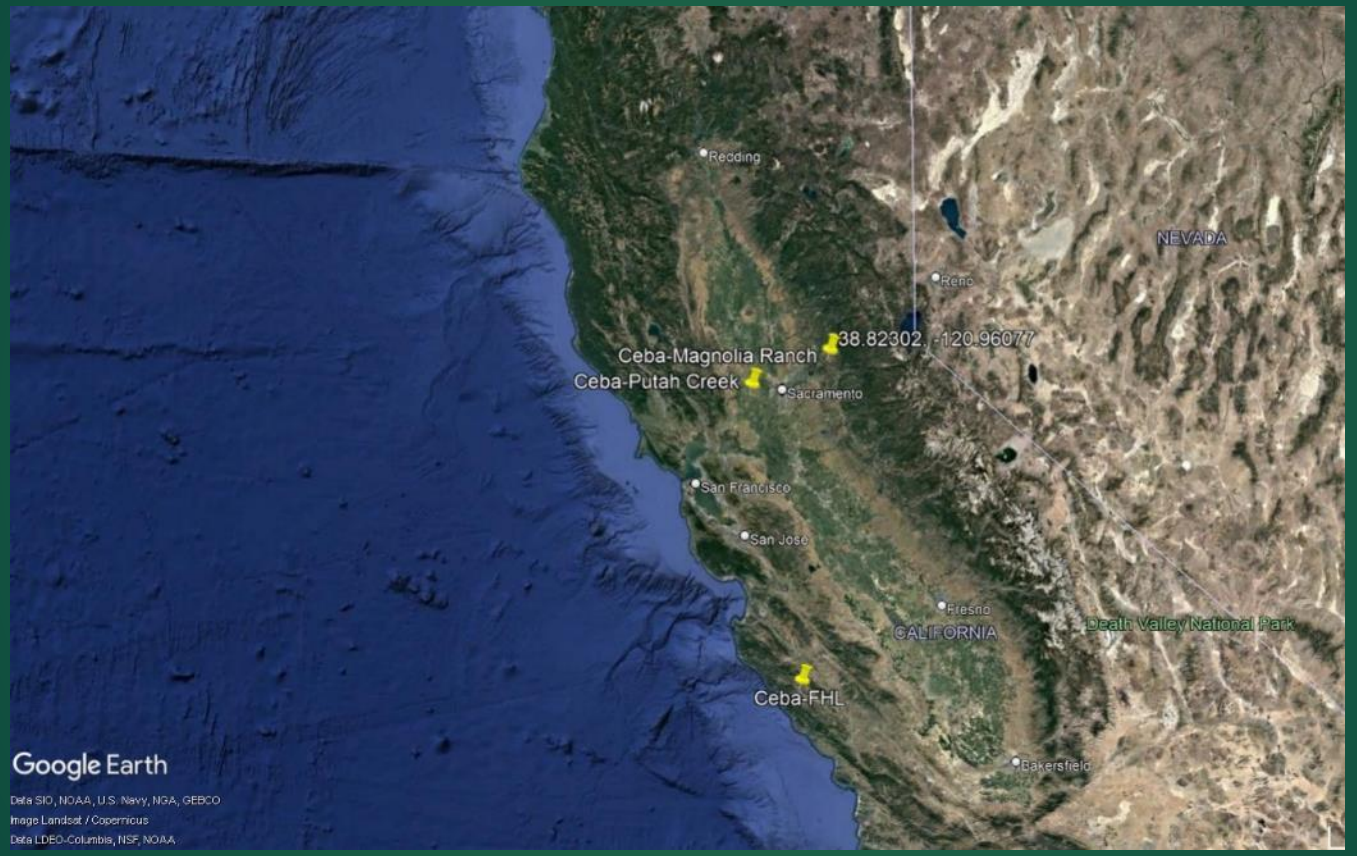


Rearing manual written.

Successful rearing at four cooperating laboratories:

- CDFA, Sacramento
- CO Dept of Agriculture
- Idaho-Nez Perce Tribe
- Idaho-Univ. of Idaho

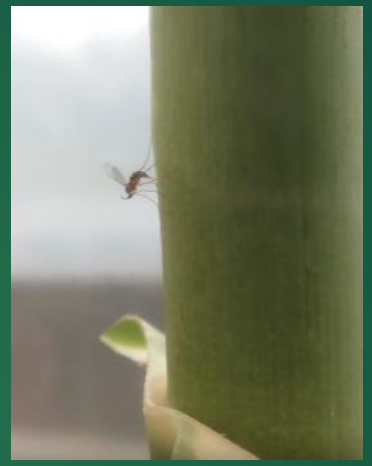
Field release of the rosette/root weevil *Ceratapion basicorne* 2020-2022

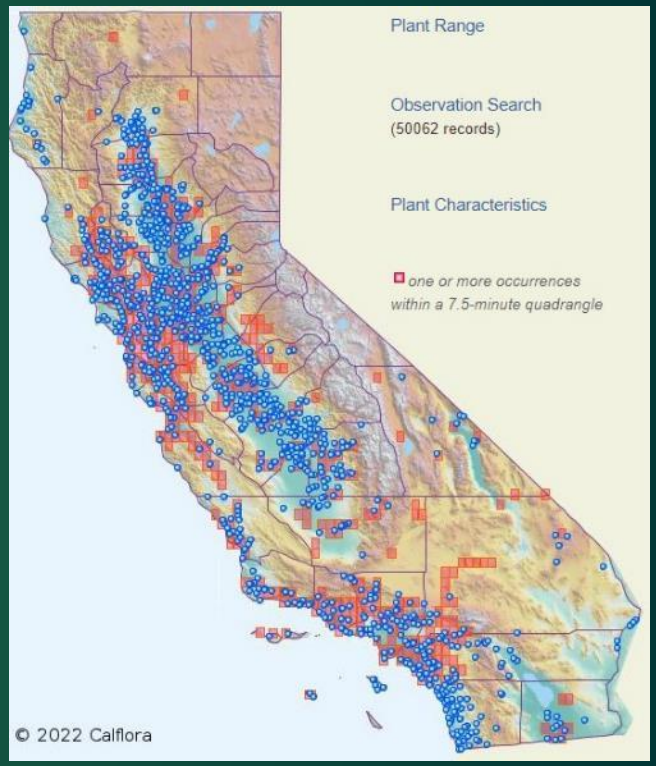


2020-Putah Creek Ecosystem Reserve (UC Davis), Yolo County
2021-Magnolia Ranch/BLM land, El Dorado County
2022-Fort Hunter-Liggett (US Army installation), Monterey County

Arundo (*Arundo donax*)





- **See Lightning Talk given on October 26th.**
- Shoot tip-galling wasp established in northern California-10 sites.
- Rhizome and shoot-feeding armored scale established-10 sites.
- Leafminer-rearing studies ongoing.

Cape-ivy (*Delairea odorata*)

- **See poster.**
- Shoot-tip galling fly released since 2017.
- Established at 13 sites.

New (since 2017) biological control of weeds agent released in California: the gorse thrips *Seriocothrips staphylinus*

- Agent studied and permit obtained at Oregon State University-135 plant species tested.
- Releases made by USDA-ARS at six sites in 2020 in northern California-coastal mountains.
- In 2022, one thrips recovered at each of two of the six sites.

New (since 2017) biological control of weeds agent released in California: The Japanese knotweed psyllid *Aphalara itadori*

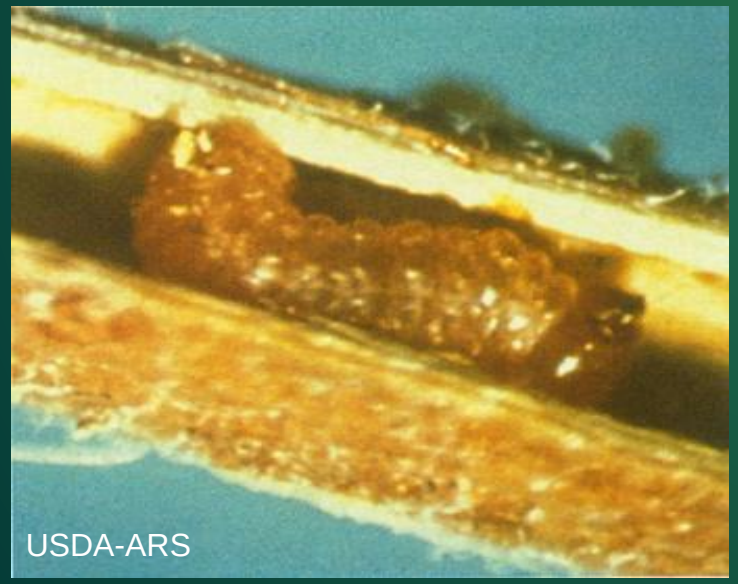
- Reared and released by CDFA in 2022.
- Establishment TBD.

Renewed effort since 2017-Russian knapweed (*Rhaponticum repens*)
Shoot-galling wasp *Aulacidea acroptilinica*
Shoot-galling midge fly *Jaapiella ivannikovi*

Agents released in 2011-2014 by CDFA-in Siskiyou County; 2022-southern CA

Puncturevine-*Tribulus terrestris* (Zygophyllaceae)-CDFA doing survey

Microlarinus lareynii **(Curculionidae)**
Feeds on seeds



- Effective in southern 2/3rds of CA
- Do not establish in areas with cold winters

Microlarinus lypriformis **(Curculionidae)-stem borer**

Examples of weeds for which candidate biological control agents are being studied at the USDA-ARS, Invasive Species and Pollinator Health Research Unit in Albany, CA

French broom (*Genista monspessulana*) (Fabaceae)

Invades pastures and forests in coastal California

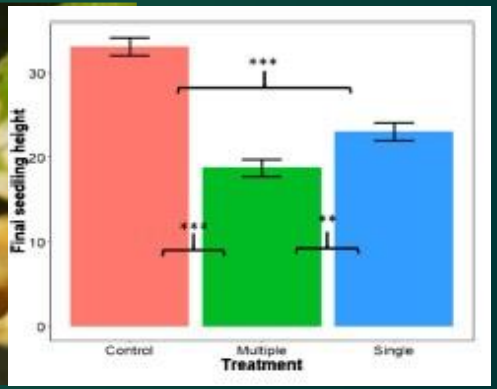
Candidate biological control agents in quarantine

French broom psyllid *Arytinnis hakani*

Accidental release in Australia-big impact there and in our lab tests.
Problem-can feed and develop on some native lupins.

Old agent *Bruchidius villosus*

Accidental release in OR, WA since 1998.



French broom gall weevil *Lepidapion argentatum*

Adults gall shoot tips and feed on seed pods. Reduce plant height by 50%
Host range tests ongoing.

Examples of native lupins in California

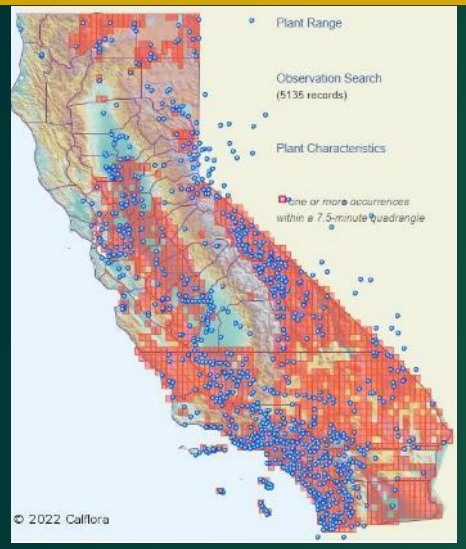
L. chamissonis

L. arboreus

L. albifrons

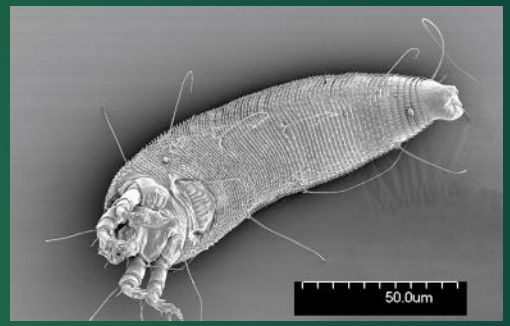
L. longifolius

Russian thistle (*Salsola tragus, S. kali, S. paulsenii, S. australis*) (Chenopodiaceae)



Widespread invader in rangelands, along roadsides

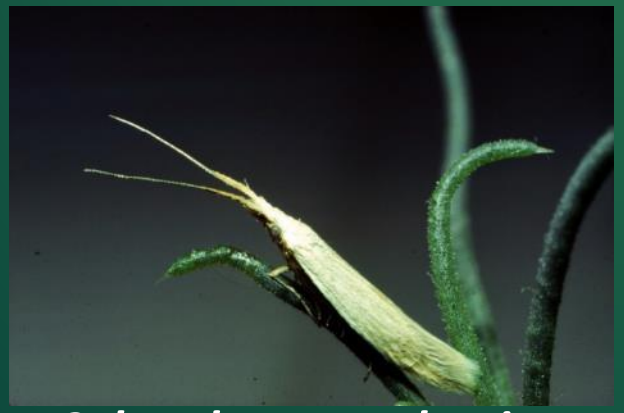
New agents-in quarantine



Stem tip-feeding mite-*Aceria salsolae*

Old agents-both limited by parasitism

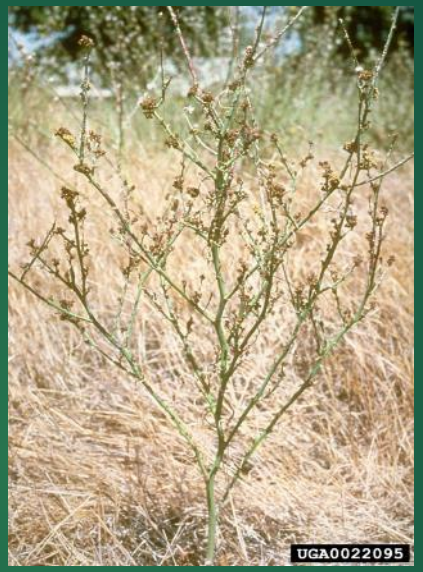
Coleophora klimeschiella



Coleophora parthenica

Shoot-boring moth-*Gymnancyla canella*

Rush skeletonweed (*Chondrilla juncea*) (Asteraceae)
Cooperating with other U.S. researchers and overseas-find and test new agents

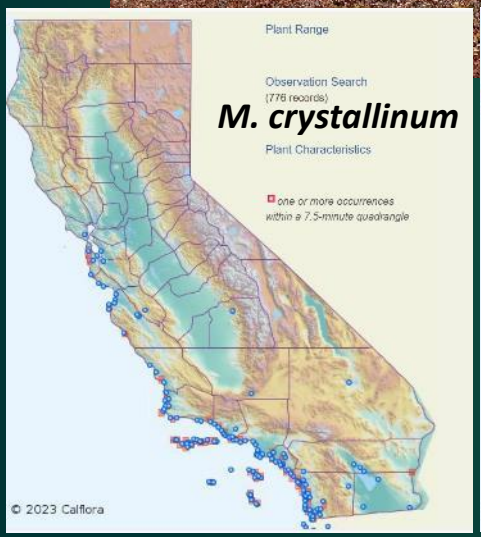


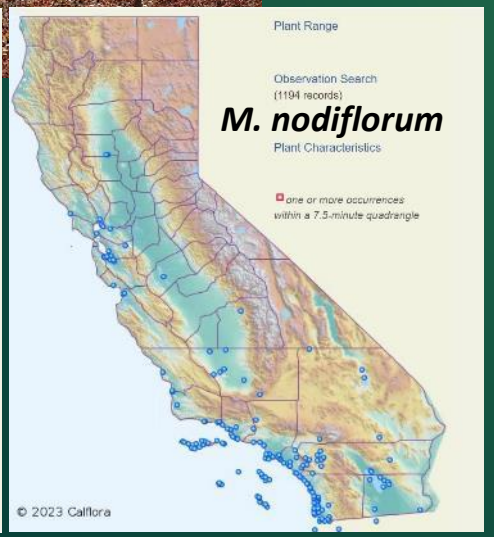
Skeletonweed rust fungus
Puccinia chondrillina

Skeletonweed galling mite
Aceria chondrillae

Skeletonweed Galling midge
Cystiphora schmidti

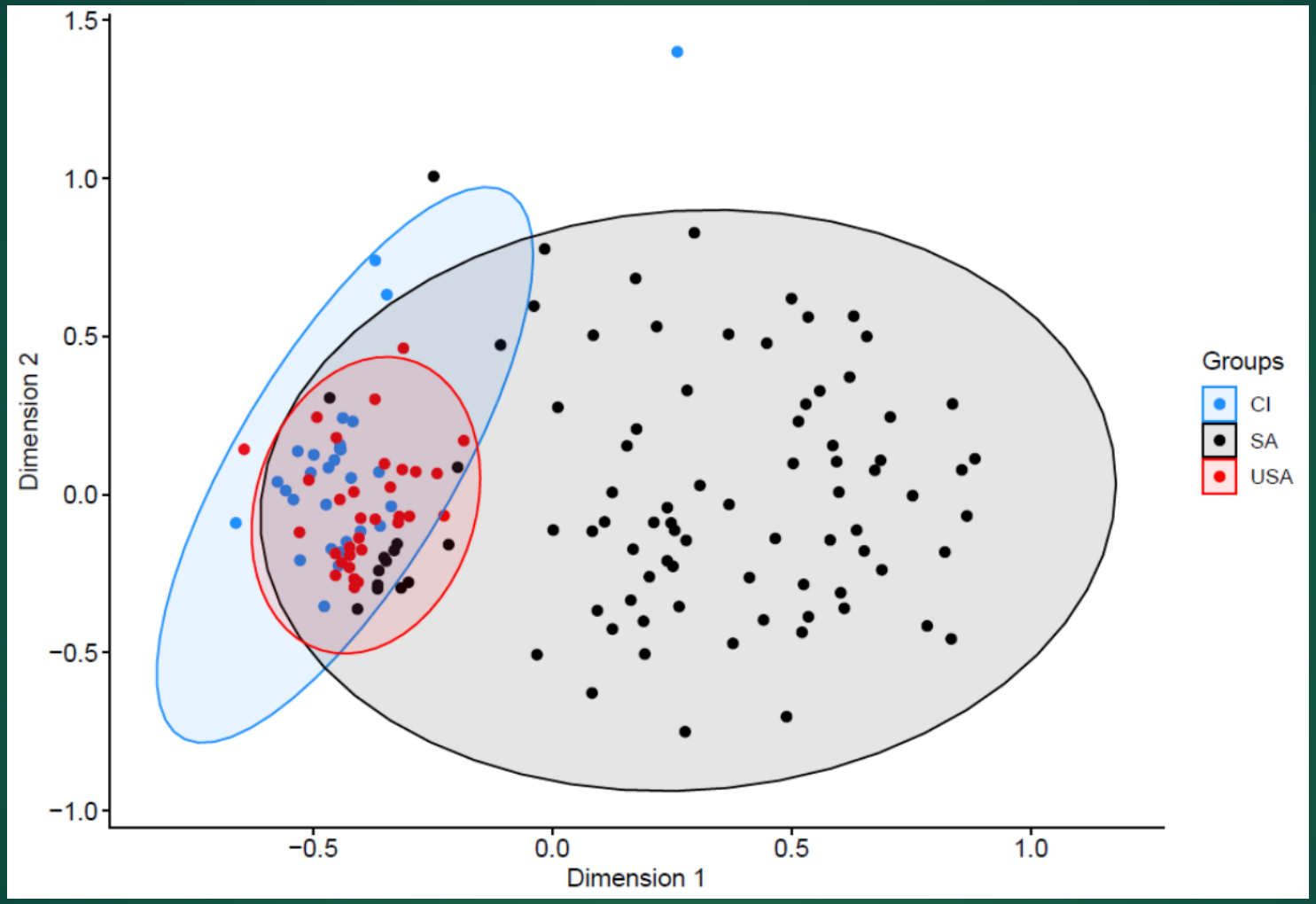
Development of Biological Control of Crystalline / Common Ice Plants (*Mesembryanthemum crystallinum* (MC), also *Mesembryanthemum nodiflorum* (MN))





- Salinizes soil and water in coastal scrublands.
- Displaces native plants and animals that depend on them.
- US Navy has spent $200K+ in planning/control.
- CA Department of Parks and Recreation-about $100K per year.
- US Channel Islands and Mexican islands off Baja-high species endemism. Precludes or limits herbicides.

Ongoing genetic analysis-by South African cooperator (Rhodes University)



Analysis of *M. crystallinum* genetic diversity using ISSR (inter-simple sequence repeat) analysis of DNA 'microsatellites' in non-coding regions:
CI=Canary Islands (Spain)
SA=South Africa
USA=U.S. samples only so far

111 samples in this analysis.

- U.S. samples are contained almost completely within the Canary Islands samples.
- U.S. samples are close to some South African samples-mainly those from Western Cape Province.
- **Suggest U.S. invasion came from Canary Islands, which in turn was invaded by samples from western South Africa.**
- Both Canary Islands and west-coastal Western Cape have Mediterranean climates similar to that of coastal California.
- Either could therefore be good sources of biological control agents.
- **More U.S., Mexican, Mediterranean and South African samples still being analyzed.** Another approach-cpDNA ITS markers-also being evaluated.

The only two CA species and US native genera of the Aizoaceae both in Subfamily Sesuvioideae

Sesuvium verrucosum

4 other *Sesuvium* species native in U.S.
1 additional species native in Mexico
1 non-native species in Georgia

Mainly an Afrotropical genus

Trianthema portulacastrum

No other species native in US
Appears no introduced species in US

This species also found in Mediterranean

Naturalized, ornamental Aizoaceae in California

Aptenia cordifolia

Carpobrotus chilensis/edulis

Major invader

Conicosia pugioniformis

Drosanthemum floribundum

Malephora crocea

Tetragonia tetragonoides

Top Candidate on *Mesembryanthemum/Cryophytum crystallinum*
Shoot-boring weevil *Lixus carinerostris* (Coleoptera: Curculioniadae)

South Africa

Currently awaiting shipment from South Africa for full host range testing.

- First found by South African cooperator in field for this project in 2020.
- Widespread on *Cryophytum crystallinum.*
- Adults feed on leaves and stems and lay eggs in stems. Larvae feed inside stems. Life cycle takes about 8 weeks. Multiple generations per year.
- Host range testing in South Africa indicates narrow range but can feed on closest relatives (plants that do not occur in North America)

Leading Candidate on *Mesembryanthemum nodiflorum*
Root-girdling weevil (possibly *Temnorhinus mixtus* (Coleoptera: Curculionidae))

Canary Islands

Morocco

- Found by Italian cooperator in Canary Islands and Morocco in 2022, confirmed in both places in 2023.
- Molecular identification complete, morphological identification pending.
- Larvae feed on root externally. Pupate in soil in hard cocoon.
- Adult digs its way out of soil, feeds on leaves.
- More information needed on biology.
- No host range testing done yet.
- Is it found in South Africa too?

Resources for More Information

BMPs for Non-Chemical Weed Control-at the Cal-IPC website:
https://www.cal-ipc.org/resources/library/publications/non-chem/

Online Decision Support Tool:
weedcut.ipm.ucanr.edu

Questions? Contact me at Patrick.Moran@usda.gov

THANK YOU FOR YOUR IMPORTANT WORK TO CONTROL INVASIVE WEEDS TO PROTECT SOIL AND WATER RESOURCES AND NATURAL HABITATS!