1. Contact Information: "Area-Wide Management of Aquatic Weeds in the Sacramento-San Joaquin Delta for Protection of Critical Water Resources in Farming Area, Wildlife Habitats, Recreational and Commercial Navigation Areas, and Water Conveyance Systems Important for California Agriculture and Human Health". Lead PI: Dr. Patrick J. Moran, Research Entomologist, USDA-ARS ISPHRU, 800 Buchanan St., Albany, CA 94710. Patrick.Moran@ars.usda.gov

2. Narrative Report of Progress (since 12/1/2018 with cumulative considerations). The Delta Region Areawide Aquatic Weed Project (DRAAWP) is near the conclusion of Phase III, and received no new funding in FY19. Cooperative agreements dating to FY14 or FY15 expired in FY19, including with the main operational partner, the Division of Boating and Waterways-California Department of Parks and Recreation (DBW). Three agreements expired at the University of California-Davis (Department of Entomology and Nematology (UC-Ent); Department of Agricultural and Natural Resource Economics-Agric. Issues Center; (UC-AIC) and Department of Land, Air and Water Resources (UCD-LAWR)). Other expiring agreements included the Contra Costa Mosquito Vector Control District (CCMVCD) and San Joaquin County Mosquito Vector Control District (SJMVCD). Agreements continue into FY20 at the UC-Davis Department of Plant Sciences (UCD-PS) and Sacramento-San Joaquin Delta Conservancy (a CA State Agency) (SSJDC). Interagency Agreements with NASA-Ames Research Center (NASA-Ames) expired each year from FY14 through FY18. Progress was made in FY19 in Implementation of products from the Assessment and Research components of the project.

Operational Component: So far for 2019, DBW has treated 2,038 acres for control of floating aquatic vegetation (FAV), including water hyacinth, water primrose, spongeplant and alligatorweed (Obj. 4), of which 12% was treated with a new operational tool, imazamox, that was previously tested in the field under DRAAWP (Obj. 3). In 2019, DBW has treated 2,429 acres of submersed aquatic vegetation (SAV), including Brazilian waterweed, curlyleaf pondweed, Eurasian wartermilfoil, Carolina fanwort, and coontail (Obj 4). For the first time, DBW used a new operational tool, endothall (7% of acres) which had been tested in the field under DRAAWP (Obj. 3). Endothall is cheaper than the main current tool, fluridone. Diquat was used (7% of acres) to control SAV in strategic locations based on dialogue with ARS scientists. In biocontrol (Obj. 4), surveys in December 2018 indicated water hyacinth planthoppers at 16 of 19 release sites at low densities (Fig. 2). By May 2019, planthoppers had established at only two sites near Stockton. Selection of 2019 release sites was based on maximum site stability. Approximately 30,000 planthoppers were re-released at six 2018 sites and at two new sites (Fig. 2). To assist with efforts to determine causes of establishment failure, UCD-LAWR scientists provided ARS with a report based on California Department of Pesticide Regulation (DPR) Pesticide Use Data to determine if the most frequently-used insecticides are those that have activity against hemipterous crop pests. Progress was also made in arundo biocontrol (Fig. 3). In operational modeling (Obj. 1) NASA and ARS scientists worked with UC-Davis AIC to continue to develop a bioeconomic model of aquatic weed management. NASA and ARS provided a plant growth component. UCD-AIC incorporated information on cost of herbicides, fuel, and labor. The model indicates that treating all FAV sites early in the season reduces costs by up to 50% (Table 1) (Obj 1, 4). About 10% of FAV and SAV herbicide acres contributed to external projects for restoration of listed fish habitat (Obj. 4).

Assessment Component: In 2019, NASA-Ames completed a transition in remote sensing technology transferred to DBW from Landsat to Sentinel (Obj. 2), offering 3-fold improved resolution (10 m instead of 30 m), 2x more frequent data (every 5 days instead of 2 weeks) and five additional spectral bands than Landsat. The transition, however, led to false positives for FAV detection (Fig. 1). NASA continues to fine-tune the new tool to allow assessment, to see if the 30% decline in peak annual FAV acreage from 2014-2017/2018 continued for 2019. DBW is working on new photomonitoring for FAV and biovolume assessments for SAV. Prior predictions of decreased annual acreage necessary for FAV and SAV treatment due to improved strategic targeting were realized for FAV in 2018 (30% decrease) but total 2019 FAV acreage is already close to final total 2018 levels, so the 2019 FAV total by the end of the herbicide season (11/30/19) is likely to be about 10% higher. SAV treatment acreage will likely be about 30% less than 2018. Cost estimates from UCD-AIC for non-DBW stakeholders such as marinas have not yet been completed for 2018, but are expected to show a continuation of prior 33%-100% decline in costs.

Research Component: DRAAWP research has been completed, but the project leveraged other studies. These included herbicide and growth trials for spongeplant and Eurasian watermilfoil, and host range testing of new biocontrol agents targeting water primrose.

Tech Transfer and Education Component: For the fifth time, ARS DRAAWP scientists planned and carried out an invited symposium, this time at the 59th Annual Meeting of the Aquatic Plant Management Society in San Diego, CA (July 14-17, 2019). There were eight oral presentations, and a total of 15 posters and presentations from DRAAWP at the meeting. Dr. J. Madsen chaired the symposium and is also serving as Guest Editor for a special issue of the Journal of Aquatic Plant Mgmt. focused entirely on DRAAWP (12 manuscripts, currently in review). DRAAWP scientists from NASA and ARS, and DBW presented for key stakeholders, including a Remote Sensing Workshop, and a One Day Symposium hosted by the Delta Stewardship Council (DSC). The DRAAWP website hosted blog posts once per month in 2019.

Key Partnerships: DRAAWP continued to attend and present at meetings of the Interagency Ecology Program-Invasive Plant Work Team, the DSC, and established new contacts with the State Water Contractors for possible leveraged funding.

Areas for Improvement: DRAAWP has not produced one or more videos to explain the project and its continuations through other funding channels. A glossy publication is also still planned but not complete.

Corrections: Ensure that Sentinel platform takes the place of Landsat as an operational and assessment tool. Produce outreach products. Complete Final Project Report by October 2020.

3. Anticipated Benefits: **Operational:** Two new herbicide tools (imazamox and endothall) operationalized fully in 2019. Additional tools including tank mixes are expected. Leveraged development of new biocontrol tools for three FAVs. **Ecological**. Benefits for restoration of fish habitat and native wetland plant communities. DBW led publication of peer-reviewed paper documenting benefits of pre-DRAAWP SAV control in central Delta (Caudill et al. 2019). **Economic**: Continued reduced control costs (33%-110% reduction) and reduced damage for stakeholders such as the Bureau of Reclamation, marina owners and the Port of Stockton.

4. Additional Funds Leveraged: DBW continued to receive 2.82M in new CA state funding in FY19 (started in 2016). CA Water Resources (CADWR) awarded $900K to DBW in FY19 as part of a two-year program to control SAV in the most important habitat of Delta smelt, and CA Fish and Wildlife (CDFW) awarded $6.5M annually beginning in FY18, for five years total. Total leveraging in FY19: $10.2M.

Table 1. Results of bioeconomic cost modeling by K. Jetter, UC-Davis, Agricultural Issues Center. The cost model takes into account weed growth rate as informed by NASA, USDA-ARS and UC-Davis studies; cost of herbicides and labor as informed by DBW data; and a factor for cost to other agencies. The results show that if all sites could be treated as early as March, costs would be reduced by 50%, compared to the current regulatory constraint of many sites being permitted for treatment only after June 1st. Results have implications for improving both control efficacy and economic efficiency through strategic FAV control site targeting.

Scenario	When treatments start	Herbicide Efficacy	Estimated Costs
1	March and June	90%	$5,443,907
2	All March	90%	$2,684,959
3	March and June	95%	$5,404,211
4	All March	95%	$2,628,954

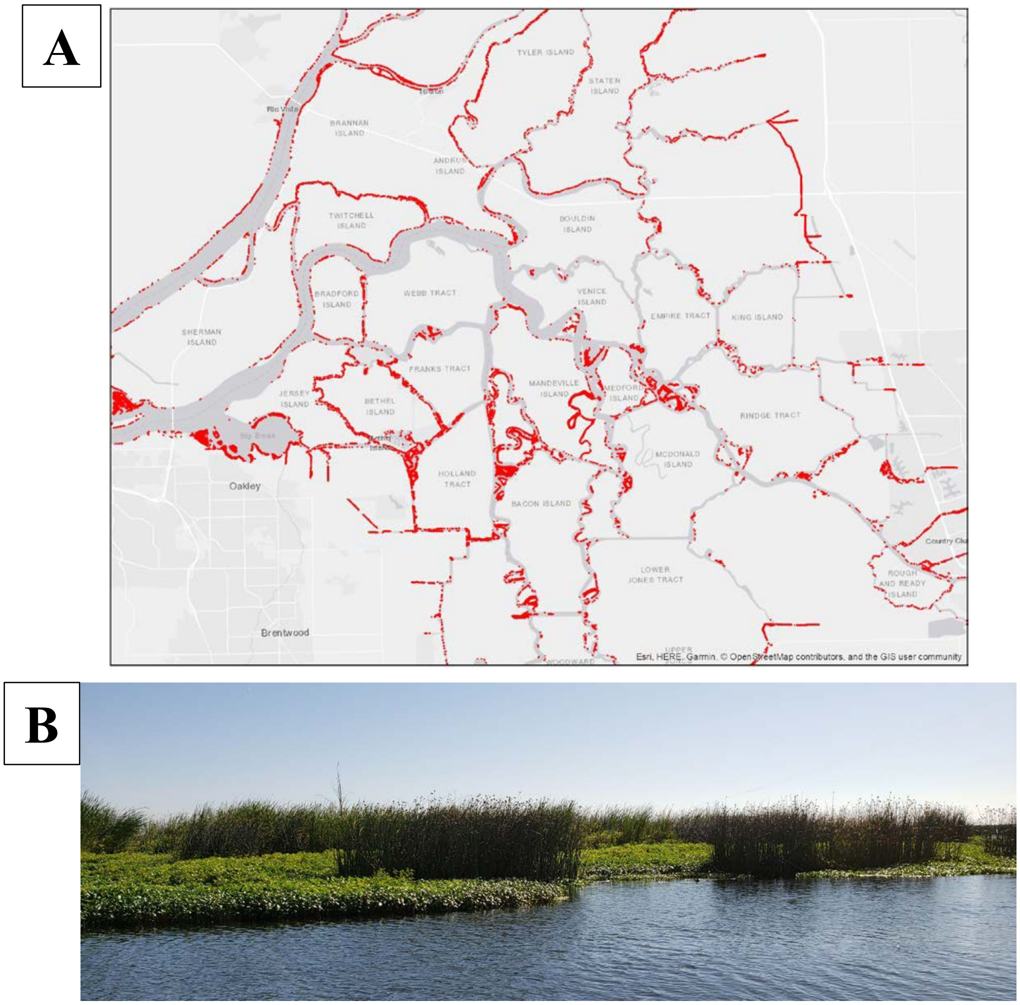


Figure 1. Use of Sentinel satellite-based remote sensing system to map FAV in the Delta. **A.** Image from July 2019. Apparent "FAV" shown in red. **B.** Water-level truthing of specific area in southeastern Delta shows FAV intermixed with tule reeds and other native vegetation. With its 3-fold greater resolution than Landsat, Sentinel tends to overestimate FAV cover due to this intermixing. NASA is developing algorithms to remove this 'background noise'.

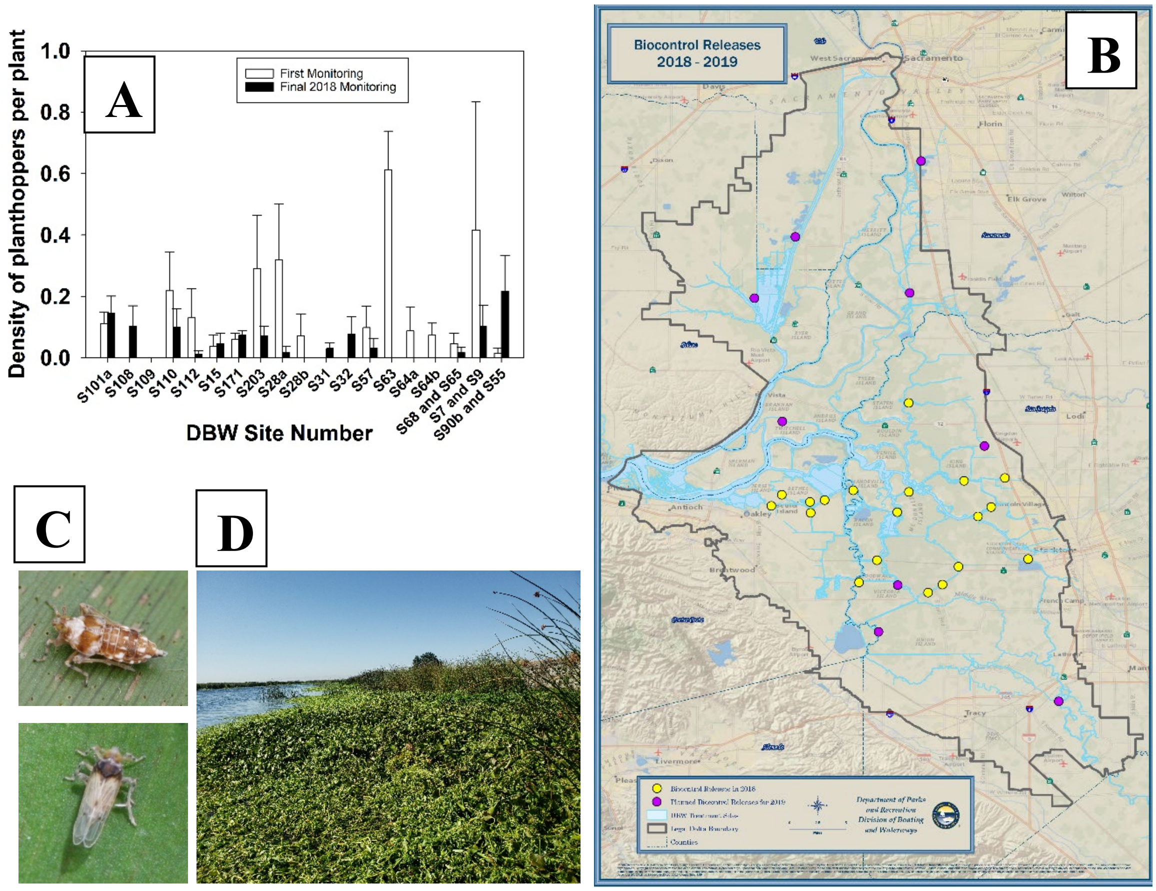
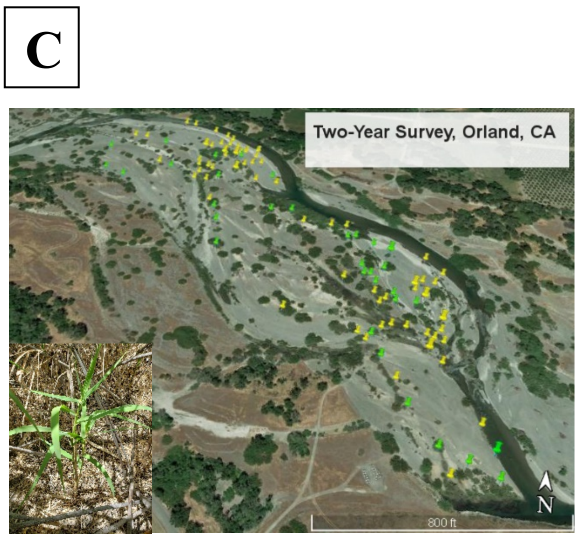


Fig 2. Implementation of releases of the water hyacinth planthopper *Megamelus scutellaris* in 2018-2019 for biocontrol of WH. **A:** Densities at initial (white bars) and final (black bars) (December 2018) monitoring of 19 release sites in the Sacramento-San Joaquin Delta in 2018. Densities were low at that time-1 planthopper every 5 to 10 leaves. **B.** Map of 19 2018 release sites (yellow dots) and planned 2019 release sites (purple dots). Establishment was found in May 2019 at only two 2018 sites, S63 and S64. 2019 site selection prioritized stability of water hyacinth patches and relatively little overtopping by water primrose. Re-releases were performed in July-Aug 2019 at the following 2018 sites: S101a, S28a, S31, S32, S68/S65, and S90b/55. Two new sites were added: S84 (Salisbury Island) in the southern Delta and S37 (White Slough) in the eastern Delta. Releases at other new sites could not be performed due to chemical control or access issues. Final 2019 surveys for all 2019 sites will be conducted in December. **C:** Planthopper short-winged (top) and long-winged (bottom) adults. **D:** Site S68/S65, August 2019, showing integration of chemical control on left and untreated part of patch targeted for biocontrol on right.



D

Region	Site	% of Rhizomes with Females	Average Females per Rhizome	Total Crawler Production	Production per Female
Sacramento River watershed	Northern Sacramento Valley (2 sites)	33%	11.3	1516	2.7
Delta	Andrus Island	33%	50	799	5
Delta	Three new sites	TBD	TBD	TBD	TBD
San Joaquin River watershed	Southern SJ River watershed (3 sites)	37%	12	831	7

Fig 3. Implementation of releases of the shoot tip-galling arundo wasp *Tetramesa romana* and the rhizome-feeding arundo armored scale *Rhizaspidiotus* donacis for biocontrol of arundo. **A:** Satellite images of release regions (3 sites per region) in northern California, including both the Delta (upper right) and upper Sacramento and San Joaquin watersheds. **B.** Arundo wasp (top) and armored scale. **C.** Two-year postrelease survey of a site in the upper Sacramento River watershed, near Orland, CA. Yellow marks represent survey points at which the wasp was present. 55% of points showed wasp damage, up to 200 m from release plots. Inset shows young arundo shoot with large gall. **D.** Table of one-year postrelease sampling of arundo rhizomes for the armored scale. Between two and five of nine plots per site had adult females on rhizomes, and many produced crawlers, indicative of establishment of a reproducing population. The arundo wasp has not yet established at sites in the Delta. Assessment of three Delta sites for the armored scale is pending.