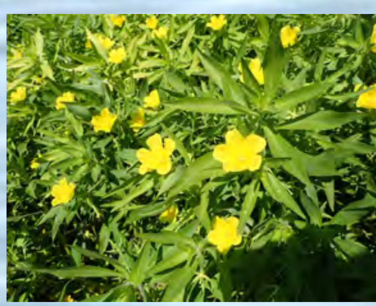
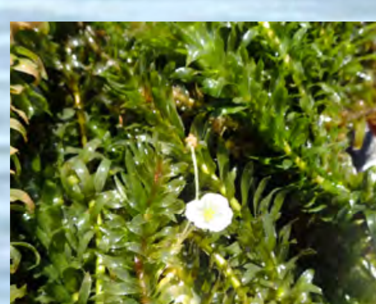
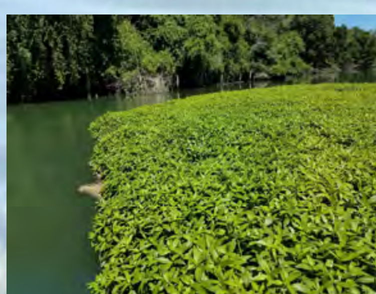
Aquatic Invasive Plant Control Program

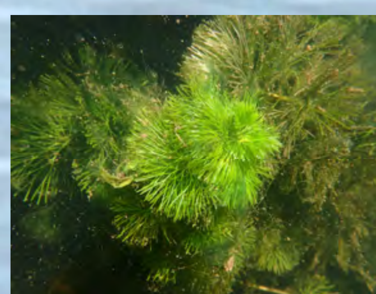
2021

Annual Monitoring Report









California Department of Parks and Recreation

Division of Boating and Waterways

April 2021

Aquatic Invasive Plant Control Program
2021 Annual Monitoring Report

Submitted Pursuant to:

- **State Water Resources Control Board (SWRCB)**
  - Statewide General National Pollutant Discharge Elimination System (NPDES) Permit (CAG990005)
- **United States Fish and Wildlife Service (USFWS) Biological Opinion**
  - Service File No. 08FBDT00-2018-F-0029, effective April 3, 2019
- **USFWS Reinitiation of Consultation**
  - Service File No. 08FBDT00-2018-F-0029-1, effective July 22, 2020
- **National Marine Fisheries Service (NMFS) Biological Opinion**
  - WCR-2017-8268, effective May 15, 2018

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate information submitted. Based on my inquiry of the persons who manage the program, Edward Hard*, Environmental Program Manager*, Jeffrey Caudill (Senior Environmental Scientist, Supervisory), Patricia Gilbert (Senior Environmental Scientist, Specialist), Michael Cane (Senior Environmental Scientist, Specialist), Michael Kwong (Environmental Scientist), Jose Martinez (Environmental Scientist), and Lydia Kenison (Environmental Scientist), the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

DocuSigned by:
Ramona Fernandez

8/21/2023

Ramona Fernandez, Acting Deputy Director
California Department of Parks and Recreation
Division of Boating and Waterways

Date

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ACRONYMS AND ABBREVIATIONS

2,4-D	2,4-dichlorophenoxyacetic acid
AB	Assembly Bill
AIPCP	Aquatic Invasive Plant Control Program
AIS	Aquatic Invasive Species
APAP	Aquatic Pesticide Application Plan
BAMS	BioBase Aquatic Map System
BDCW	Python scrips titled Biovolume Data Correction Workflow
BMP	Best Management Practice
BiOp	Biological Opinion
CDFA	Department of Food and Agriculture
CDFW	California Department of Fish and Wildlife
CDW	Change Detection Workflow
CEQA	California Environmental Quality Act
CNDDB	California Natural Diversity Database
csv	comma separated value
CVP	Central Valley Project
CVRWQCB	Central Valley Regional Water Quality Control Board
DBW	Division of Boating and Waterways
Delta	Sacramento-San Joaquin Delta, Suisun Marsh, and southern tributaries– the Tuolumne River and Merced River
DIZ	Demonstration Investigation Zone
DO	Dissolved Oxygen (measured in mg/l or ppm)
DPR	Department of Pesticide Regulation
DPS	Distinct Population Segment
DRAAWP	Delta Regional Area Wide Aquatic Weed Project
DSRS	Delta Smelt Resiliency Strategy
DWR	Department of Water Resources
EAV	Emergent Aquatic Vegetation
EDCP	*Egeria densa* Control Program
EPA	United States Environmental Protection Agency
ESA	Endangered Species Act
FAV	Floating Aquatic Vegetation
FRP	Fish Restoration Program
GC-MS-SPE	gas chromatography-mass spectrometry
GGS	Giant Garter Snake
GIS	Geographic Information System
GPS	Global Positioning System
HPLC	High Performance Liquid Chromatography
IEP	Interagency Ecology Program
MMRP	Mitigation Monitoring Reporting Program
MUN	Municipal and Domestic Supply
NASA	National Aeronautics and Space Administration
ND	No Detection/Non-detect
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NPDES	National Pollution Discharge Elimination System
NTU	Nephelometric Turbidity Units
OEHHA	Office of Environmental Health Hazard Assessment
OMP	Operations Management Plan
PCR	Pest Control Recommendation

ppb	Parts per Billion (µg/l)
QAC	Qualified Applicator Certificate
QAPP	Quality Assurance Project Plan
RMA	Routine Maintenance Agreement
SAV	Submersed Aquatic Vegetation
SB	Senate Bill
SCP	Spongeplant Control Program
SWP	State Water Project
SWRCB	State Water Resources Control Board
UC	University of California
USDA-ARS	United States Department of Agriculture – Agricultural Research Service
USFWS	United States Fish and Wildlife Service
UTM	Universal Transverse Mercator
VELB	Valley Elderberry Longhorn Beetle
WHCP	Water Hyacinth Control Program
WSID	West Side Irrigation District
WSID	

EXECUTIVE SUMMARY

Report Highlights: This annual report provides an overview of the activities conducted by the Aquatic Invasive Plant Control Program (AIPCP) under the Aquatic Invasive Species (AIS) Branch of the California Department of Parks and Recreation's Division of Boating and Waterways (DBW) during the 2021 calendar year in the Sacramento-San Joaquin Delta, and southern tributaries– the San Joaquin River, Tuolumne River and Merced River (hereinafter referred to as the "Delta").

Importance of Controlling Invasive Aquatic Plants: DBW is the authorized lead agency responsible for identifying, detecting, controlling and administering programs to manage aquatic invasive plants in the Delta. It is crucial to control aquatic invasive plants in the Delta for public health, the economy, and the environment. Aquatic invasive plants can rapidly displace native species, clog water conveyance systems, form dense mats that restrict water movement, trap sediment, provide habitat for mosquitos, and cause fluctuations in water quality. Additionally, dense growth may interfere with recreational uses of a waterbody and with navigation.

This program operates under the National Pollutant Discharge Elimination System (NPDES) Statewide General Permit (CAG990005), issued by the State Water Resources Control Board; the United States Fish and Wildlife Service (USFWS) Biological Opinion (08FBDT00-2018-F-0029-1); the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS) Biological Opinion (WCR-2017-8268); and the California Department of Fish and Wildlife (CDFW) Streambed Alteration Agreement (1600-2015-0132-R3). Federal consultations were conducted with the U.S. Department of Agriculture – Agricultural Research Service (USDA-ARS) as DBW's federal nexus. The program also complies with the California Environmental Quality Act (CEQA) Environmental Impact Report (DBW January 24, 2018, Addendum April 2, 2018) and Mitigation Monitoring and Reporting Program (MMRP).

Target Species: The AIPCP is currently authorized to treat the species listed in Table ES-1.

Table ES-1: Target Species

Common Name	Scientific Name
Alligatorweed	*Alternanthera philoxeroides*
Brazilian waterweed or Egeria	*Egeria densa*
Coontail	*Ceratophyllum demersum*
Curlyleaf pondweed	*Potamogeton crispus*
Eurasian watermilfoil	*Myriophyllum spicatum*
Fanwort	*Cabomba caroliniana*
South American spongeplant	*Limnobium laevigatum*
Uruguay water primrose	*Ludwigia hexapetala*
Water hyacinth	*Eichhornia crassipes*

Monitoring: All compliance parameters set forth in both the USFWS and NMFS biological opinions were met during the 2021 treatment season. All monitoring for herbicide residue concentrations at receiving water locations were either not detected or were below receiving water limits as specified in the NPDES

Permit. Any occurrences where dissolved oxygen levels, turbidity and pH exceeded limits in the Water Quality Control Plan for the Sacramento and San Joaquin River Basins, established by the Central Valley Regional Water Quality Control Board (CVRWQCB), were expected to be temporary given the tidal nature of the Delta, varying hydrodynamics, and periodic mixing of the water column. No incidental take of threatened or endangered species occurred during the 2021 season.

2021 season program treatment metrics:

- Treatment dates: March 19, 2021 to November 30, 2021
    - 4,132 acres were treated of the 15,000 acres authorized per permits and Biological Opinions.
    - 2,500.28 acres were treated for Floating Aquatic Vegetation (FAV).
    - 1,632 acres were treated for Submerged Aquatic Vegetation (SAV).
    - 0 acres of FAV were mechanically harvested.
- Treatments occurred in 131 sites for FAV and 79 sites for SAV throughout the Delta.
- 1,010 water samples were collected for analysis to determine concentrations of herbicides in the water column.
- Conducted hydroacoustic mapping for all 79 SAV treatment sites.
- Conducted point sampling to identify the SAV species in all treatment sites.
- Conducted point-intercept sampling to identify the FAV species in 16 treatment sites.
- Conducted photo-point monitoring to monitor FAV growth at 31 locations throughout the Delta.
- The following quantities of herbicide were applied:
    - 567.25 gallons of 2,4-D
    - 2,324.71 gallons of glyphosate
    - 649.16 gallons of imazamox
    - 3,324.2 gallons of diquat
    - 85,957 pounds of fluridone

1 INTRODUCTION

The objective of the AIPCP is to control the growth and spread of aquatic invasive plants in the Delta in support of the environment, economy, and public health. Due to the long-term presence and the persistence of aquatic invasive plants in the Delta, the AIPCP legislative mandates are for control, rather than eradication of aquatic invasive plants. The AIPCP DBW AIS program. The mission of the Program is to manage aquatic invasive plants and to help prevent the introduction and establishment of Dreissenid mussels in uninfested lakes, rivers and/or reservoirs in the State of California in partnership with other state, local, and federal agencies. This document describes the program to control aquatic invasive plants in the Delta.

The AIPCP provides a comprehensive approach to aquatic invasive plant control in the Delta by incorporating all Delta plant control programs conducted by the Division of Boating and Waterways into a single Program. Previously, the control efforts were divided into the Water Hyacinth Control Program (WHCP), Spongeplant Control Program (SCP) and *Egeria densa* Control Program (EDCP). New aquatic invasive plants can be incorporated into the AIPCP through the process defined by Assembly Bill (AB) 763. The AIPCP is supported by the *Collaboration Guidelines for Delta Aquatic Invasive Plant Control* (Guidelines) (Delta Stewardship Council 2018). These Guidelines identify actions, goals, and metrics to support a comprehensive, adaptive, collaborative, flexible, practical, efficient, effective and sustainable approach to managing AIS in the Delta. The AIPCP adheres to an adaptive management strategy with annual evaluation. This adaptive strategy allows the program to respond to changing conditions in the Delta and facilitates adaptability to changes in other elements, such as regulatory environment, public health, and the economy.

The AIPCP's adaptive management approach to aquatic invasive plant control reflects the changing nature of the Delta ecosystem and the authorization granted by AB 763. It is based on the use of a comprehensive set of treatment tools and approaches to optimize efficacy and environmental protection and is defined by increased use of monitoring, performance metrics, and treatment triggers to guide program actions and reduce risks. The AIPCP uses a comprehensive, diverse and integrated set of tools to effectively target treatments, with the aim of controlling infestations before they spread.

The AIPCP aims for efficacious management actions to control aquatic invasive plants while at the same time strives to minimize non-target species impacts and to prevent environmental degradation in the Delta.

DBW is the authorized lead agency for controlling nine aquatic invasive plant species. According to the California Department of Fish and Wildlife (CDFW), invasive species are organisms (plants, animals, or microbes) that are not native to an environment, and once introduced, they establish, quickly reproduce and spread, and cause harm to the environment, economy, or human health (CDFW 2020). The federal definition of "invasive species" is an alien species (any species that is not native to that ecosystem) whose introduction does or is likely to cause economic or environmental harm or harm to human health (Exec. Order No. 13112, 3 C.F.R. 1999). The nine invasive floating aquatic vegetation (FAV) and submersed aquatic vegetation (SAV) species listed in **Table 1-1** are targeted for control by DBW.

Table 1-1 – Targeted Invasive Plant Species

Common Name	Scientific Name	Floating or Submerse Aquatic Vegetation
Alligatorweed	*Alternanthera philoxeroides*	FAV
Brazilian waterweed or Egeria	*Egeria densa*	SAV
Coontail	*Ceratophyllum demersum*	SAV
Curlyleaf pondweed	*Potamogeton crispus*	SAV
Eurasian watermilfoil	*Myriophyllum spicatum*	SAV
Fanwort	*Cabomba caroliniana*	SAV
South American spongeplant	*Limnobium laevigatum*	FAV
Uruguay water primrose	*Ludwigia hexapetala*	FAV
Water hyacinth	*Eichhornia crassipes*	FAV

Plants that grow under the water surface (some submersed plants may have floating leaves) are known as SAV. They grow in wetlands, marshes, shallow water bodies, slow moving waterways, lakes, reservoirs, and rivers. Some SAV are invasive, and if they are left unchecked, they can be a problem for boaters, agriculture and public safety.

Plants that grow on top of the water surface (some with emergent characteristics) are known as FAV. They grow in wetlands, marshes, shallow water bodies, slow moving waterways, lakes, reservoirs, and rivers. FAV can be a problem for boating, agriculture, public safety, and can negatively impact the environment, industry and local economies.

Extent of Infestation

The Delta contains an estimated 101,000 water surface acres, all of which may provide habitat for FAV and SAV. Aquatic invasive plants are fast growing and have a significant impact on the shallow water habitat in the Delta ecosystem. Since these aquatic invasive plants were introduced to the region, many areas have become infested. Aquatic invasive species influence biological diversity, water conveyance, navigation, recreation and agriculture of the Delta. Aquatic invasive plants can crowd out native vegetation, provide habitat for mosquitoes, reduce water flows, entrap sediments, de-stabilize dissolved oxygen cycles, obstruct waterways and navigational channels, impede anadromous fish migration, shade out crucial shallow-water fish habitat, and clog agricultural and municipal water intakes.

Water hyacinth coverage estimates in the Delta since 1981 have ranged from less than 500 acres up to approximately 2,500 acres (DBW 2012). This wide range of annual water hyacinth acreage in the Delta is dependent upon many factors including acreage treated, timing of treatments, seasonal air and water temperatures, water flows, water levels, and rainfall. During years with higher than average rainfall, high flows can flush water hyacinth out of the Delta and towards marine waters.

Determining the annual extent of infestation of invasive FAV and SAV in the Delta and its tributaries can be difficult because both individual plants and large mats can move with river currents, diurnal tidal movement, and winds. Historically, pre- and post-season infestations have been assessed through visual estimates conducted by DBW field staff. Additionally, hydroacoustic mapping, point-intercept survey, photo point monitoring, and multispectral satellite imagery analyses have assisted with tracking FAV and SAV distributions.

Setting

The AIPCP includes portions of eleven counties that encompass the Delta, including Alameda, Contra Costa, Fresno, Madera, Merced, Sacramento, San Joaquin, Solano, Stanislaus, Tuolumne, and Yolo. General boundaries for the treatment area in the Delta are as follows:

- West up to and including Sherman Island, at the confluence of the Sacramento and San Joaquin Rivers
- West up to the Sacramento Northern Railroad to include water bodies north of the southern confluence of the Sacramento River and Sacramento River Deep Water Ship Channel
- North to the northern confluence of the Sacramento River and Sacramento River Deep Water Ship Channel, plus waters within Lake Natoma
- South from Clifton Court along Old River to Mossdale, and continuing along the San Joaquin River to Mendota, just east of Fresno
- East along the San Joaquin River to the City of Stockton, continuing east along the San Joaquin River to Friant Dam on Millerton Lake
- East along the Tuolumne River to La Grange Reservoir below Don Pedro Reservoir
- East along the Merced River to Merced Falls, below Lake McClure

Within the AIPCP's project area, there are 418 possible treatment sites. These sites vary in size between five and 1,700 acres and may be between one and three miles in length. See **Figures A-1, A-2, and A-3** in **FAV Appendix A** and **SAV Appendix A** for maps of the AIPCP's project area and monitoring sites sampled in 2021.

2 ENABLING LEGISLATION

Both the USDA-ARS and DBW will implement the AIPCP. The AIPCP is an aquatic weed program designed to control the growth and spread of aquatic invasive plants in the Delta. The USDA-ARS is the federal nexus, providing research and scientific expertise for the AIPCP. Additionally, the USDA-ARS in conjunction with the AIPCP, manages, implements, and monitors the use of biological control methods. DBW is the lead agency for managing and implementing herbicide and physical control methods.

The AIPCP replaces the prior WHCP, SCP, and EDCP actions with one comprehensive aquatic invasive plant control program for the Delta. The Harbors and Navigation Code, Section 64, authorizes DBW AIS control programs. The legislature has provided authority through the following:

- Senate Bill (SB) 1344 (Garamendi, Chapter 263, Statutes of 1982) designated the then Department of Boating Waterways as the lead agency for controlling water hyacinth (*Eichhornia crassipes*) in the Delta, its tributaries, and Suisun Marsh.
- AB 2193 (Rainey, Chapter 728, Statutes of 1996) authorized DBW to develop a control program for *Egeria densa* (Brazilian waterweed) in the Delta, its tributaries, and Suisun Marsh.
- AB 1540 (Buchanan, Chapter 188, Statutes of 2012) authorized DBW to control *Limnobium laevigatum* (South American spongeplant) in the Delta, its tributaries, and Suisun Marsh.
- AB 763 (Buchanan, Chapter 330, Statutes of 2013) created a new process within Section 64.5 of the Harbors and Navigation Code for authorizing new AIS control programs in the Delta, its tributaries, and Suisun Marsh. The bill authorizes DBW, in consultation with appropriate state, local, and federal agencies, and upon concurrence from the California Department of Fish and Wildlife (CDFW), following the completion of a specified assessment described in the bill, to take such action it determines is necessary to implement control and, when feasible, eradication measures for invasive aquatic plants.

AB 763 requires DBW to consult regularly with the USDA-ARS, USFWS, NMFS, the University of California, members of the scientific and research communities, and other state agencies with authority over the control of invasive aquatic plants to determine which invasive plant species should be given the highest priority for management and to determine the best control, and, when feasible, eradication measures. To date, five species have been added to the AIPCP through AB 763 risk assessments (water primrose, curlyleaf pondweed, Eurasian watermilfoil, Carolina fanwort, and coontail).

AB 763 also requires DBW to notify CDFW of potential threats from aquatic plants that may be invasive and need to be controlled or eradicated. AB 763 requires CDFW, after receipt of that notice, in consultation with other appropriate local, state, and federal agencies, to conduct a risk assessment of that aquatic plant species to determine whether the plant presents a threat to the environment, economy, or human health, as determined after consideration of specified factors. AB 763 requires the risk assessment to specify whether the aquatic plant under consideration has been determined to be invasive. It requires CDFW, within 60 days after completing that assessment, to report its findings to DBW so that DBW may take any necessary action to control and, when feasible, eradicate the invasive aquatic plant.

Rather than being guided by the historical species-by-species approach, the AIPCP is a single, comprehensive program that incorporates all current and potential future aquatic invasive plant control activities. This shifts the focus from separate treatment regimens for one target plant species to a holistic and integrated multispecies treatment approach by employing the most current, appropriate, and feasible available methods.

2.1 Section 64 of the Harbors and Navigation Code

Section 64 of the Harbors and Navigation Code is amended to read as follows:

"(a) The Legislature hereby finds and declares that the growth of water hyacinth (*Eichhornia crassipes*), Brazilian elodea (*Egeria densa*), and South American spongeplant (*Limnobium laevigatum*) in the Sacramento-San Joaquin Delta, its tributaries, and the Suisun Marsh has occurred at an unprecedented level and that the resulting accumulations of water hyacinth, *Egeria densa*, and South American spongeplant obstruct navigation, impair other recreational uses of waterways, have the potential for damaging manmade facilities, and may threaten the health and stability of fisheries and other ecosystems within the Delta and marsh. Accordingly, it is necessary that the state, in cooperation with agencies of the United States, undertake an aggressive program for the effective control of water hyacinth, *Egeria densa*, and South American spongeplant in the Delta, its tributaries, and the marsh."

"(b) The Division is designated as the lead agency of the state for the purpose of cooperating with agencies of the United States and other public agencies in controlling water hyacinth, *Egeria densa*, and South American spongeplant in the Delta, its tributaries, and the marsh."

SB 1344 (Garamendi and Nielsen, Ch. 263, Statutes of 1982) amended Section 64 of the Harbors and Navigation Code to read as follows:

"(a) The Legislature hereby finds and declares that the growth of water hyacinth (*Eichhornia crassipes*), Brazilian elodea (*Egeria densa*), and South American spongeplant (*Limnobium laevigatum*) in the Sacramento-San Joaquin Delta, its tributaries, and the Suisun Marsh has occurred at an unprecedented level and that the resulting accumulations of water hyacinth, *Egeria densa*, and South American spongeplant obstruct navigation, impair other recreational uses of waterways, have the potential for damaging manmade facilities, and may threaten the health and stability of fisheries and other ecosystems within the delta and marsh. Accordingly, it is necessary that the state, in cooperation with agencies of the United States, undertake an aggressive program for the effective control of water hyacinth, Egeria densa, and South American spongeplant in the delta, its tributaries, and the marsh."

"(b) The Division is designated as the lead agency of the state for the purpose of cooperating with agencies of the United States and other public agencies in controlling water hyacinth, *Egeria densa*, and South American spongeplant in the delta, its tributaries, and the marsh."

Egeria densa was first introduced in Assembly Bill 2193 (Rainey, Ch. 728, Statutes of 1996), then Assembly Bill 763 expanded jurisdiction to DBW in 2013.

"This bill would additionally designate the Division as the lead agency of the state for the purpose of cooperating with other state, local, and federal agencies in identifying, detecting, controlling, and administering programs to manage invasive aquatic plants, as defined, in the Sacramento-San Joaquin Delta, its tributaries, and the Suisun Marsh."

In 2012, Assembly Bill 1540 (Buchanan, Ch. 188, Statutes of 2012) was passed to add spongeplant control to DBW's jurisdiction.

AB 763 (Buchanan, Ch. 330, Statutes of 2013) amended Section 64 of the Harbors and Navigation Code as follows:

"This bill would additionally designate the Division as the lead agency of the state for the purpose of cooperating with other state, local, and federal agencies in identifying, detecting, controlling, and administering programs to manage invasive aquatic plants, as defined, in the Sacramento-San Joaquin Delta, its tributaries, and the Suisun Marsh."

2.2 Section 64.5 of the Harbors and Navigation Code

Section 64.5 of the Harbors and Navigation Code is amended to read as follows:

"(a) The Division is designated as the lead agency of the state for the purpose of cooperating with other state, local, and federal agencies in identifying, detecting, controlling, and administering programs to manage invasive aquatic plants in the Sacramento-San Joaquin Delta, its tributaries, and the Suisun Marsh. The Division, in consultation with appropriate state, local, and federal agencies, may take such action it determines is necessary, upon concurrence from the Department of Fish and Wildlife following the completion of the risk assessment described in subdivision (c), to implement control and, when feasible, eradication measures for invasive aquatic plants. Any actions taken to control invasive aquatic plants shall be in compliance with all applicable laws and regulations and conducted in an environmentally sound manner."

"(b) The Division shall regularly consult with the United States Department of Agriculture, the United States Fish and Wildlife Service, the National Oceanic and Atmospheric Administration, the University of California, and other members of the scientific and research communities, as well as other state agencies with authority over the control of invasive aquatic plants to determine which species of those plants should be given the highest priority for management and determine the best control and, when feasible, eradication measures."

"(c) (1) After consulting with the various entities as required in subdivision (b), if the Division identifies a species of aquatic plant that may be invasive and need to be controlled or eradicated, the division shall notify the Department of Fish and Wildlife of the potential threat from that aquatic plant species. After receipt of that notice, the Department of Fish and Wildlife, in consultation with other appropriate local, state, and federal agencies, including, but not limited to, the Department of Food and Agriculture, the Department of Water Resources, the State Water Resources Control Board, the Department of Pesticide Regulation, and the Office of Environmental Health Hazard Assessment, shall conduct a risk assessment of the aquatic plant species identified by the Division to determine whether the plant species is invasive and presents a threat to the environment, economy, or human health. In making that determination, the Department of Fish and Wildlife shall take prompt action to minimize detrimental impacts and costs of management, and shall consider all of the following:

(A) Whether the aquatic plant species may obstruct navigation and recreational uses of waterways.

(B) Whether the aquatic plant species may cause environmental damage, including threats to the health and stability of fisheries, impairment to birds' access to waterways and nesting, roosting, and foraging areas, deterioration of water quality resulting from plant decay, and harm to native plants.

(C) Whether the aquatic plant species may cause harm to the state's economy, infrastructure, or manmade facilities such as state water storage facilities and pumping operations, by increasing flood risk, threatening water supplies by blocking pumps, canals, and dams necessitating early control efforts.

(2) Based on factors specified in subparagraphs (A), (B), and (C) of paragraph (1) and any other environmental, economic, or human health impacts, the risk assessment shall specify whether the plant species under consideration has been determined to be an invasive aquatic plant. Findings from the risk assessment shall be documented in a way that clearly describes the severity and types of impacts caused by a plant species determined to be an invasive aquatic plant.

(3) Within 60 days after completing the risk assessment required by paragraph (1), the Department of Fish and Wildlife shall report its findings to the division so that the division may take any necessary action to control and, when feasible, eradicate an invasive aquatic plant, as authorized under subdivision (a).

(d) For purposes of this section, "invasive aquatic plant" means an aquatic plant or algae species, including its seeds, fragments, and other biological materials capable of propagating that species, whose proliferation or dominant colonization of an area causes or is likely to cause economic or environmental harm or harm to human health.

(e) Aquatic plants shall be determined to be invasive through the risk assessment required to be completed by the Department of Fish and Wildlife in consultation with the division and other state, local, and federal agencies pursuant to subdivision (c)."

2.3 Risk Assessment Status

CDFW administers the risk assessment process to determine whether a species can be considered an invasive species in California. CDFW uses the U.S. Aquatic Weed Risk Assessment tool to evaluate aspects of a species' ecology, reproductive potential, dispersal mechanisms, competitive ability, actual and potential impacts (including impacts to navigation and recreation, the environment, economy, and human health as specified in Harbors and Navigation Code 64.5), and resistance to management. Based on this evaluation, CDFW, in consultation with the California Department of Water Resources (DWR), State Water Resources Control Board (SWRCB), Department of Food and Agriculture (CDFA), Department of Pesticide Regulation (DPR), and Office of Environmental Health Hazard Assessment (OEHHA), and in concurrence with DWR will make a determination whether the species is an invasive aquatic plant that causes, or is likely to cause, economic or environmental harm, or harm to human health in California. The scoring system is broken into three categories, non-invaders score less than 31, scores between 31 and 39 require further evaluation, and any species with a score greater than 39 is considered a major invader. **Table 2-1** shows the risk assessment determination for each species.

Table 2-1 – Risk Assessment Scores

Common Name	Scientific Name	Score	Date of Determination
Brazilian waterweed	*Egeria densa*	*	Not Available
Water hyacinth	*Eichhornia crassipes*	*	Not Available
South American spongeplant	*Limnobium laevigatum*	*	Not Available
Curlyleaf pondweed	*Potamogeton crispus*	66	June 12, 2015
Eurasian watermilfoil	*Myriophyllum spicatum*	76	June 28, 2016
Uruguay water primrose	*Ludwigia hexapetala*	76	July 22, 2016
Coontail	*Ceratophyllum demersum*	58	October 14, 2016
Fanwort	*Cabomba caroliniana*	75	January 25, 2018
Alligatorweed	*Alternanthera philoxeroides*	74	March 1, 2018

**Brazilian waterweed, water hyacinth, and South American spongeplant were determined to be invasive, prior to the use of this scoring tool.*

3 ENVIRONMENTAL COMPLIANCE

3.1 Summary of Regulatory Compliance Requirements

The following constitutes a summary of the environmental regulatory documents required to implement the AIPCP. These documents have requirements designed to ensure avoidance or minimization of significant impacts to beneficial uses of waters of the U.S., waters of the State, species protected by the federal Endangered Species Act (ESA) and to prevent the spread of invasive plants.

A National Pollutant Discharge Elimination System (NPDES) permit is required by SWRCB. Coverage under this permit was obtained in December 2013 and expired in 2018. The permit is referenced as the Statewide General NPDES Permit for the Discharge of Aquatic Pesticides for Aquatic Weed Control in Waters of the United States (Permit No. CAG990005, Water Quality Order 2013-0002-DWQ).

A 5-year Routine Maintenance Agreement (RMA; October 23, 2015-December 31, 2020) under the Lake or Streambed Alteration Agreement Program was entered into between DBW and CDFW for mechanical removal and harvesting efforts of FAV (Notification No. 1600-2015-0132-R3). A 5-year extension was granted on November 10, 2020.

DBW partners with the USDA-ARS for the AIPCP and the USDA-ARS acts as a federal nexus to obtain Biological Opinions (BiOp) from the USFWS and NMFS to operate the AIPCP. The following BiOps were obtained from the USFWS and NMFS to operate the AIPCP pursuant to Section 7 of the ESA:

- USFWS Biological Opinion (08FBDT00-2018-F-0029-1), effective July 22, 2020
- NMFS Biological Opinion (WCR-2017-8268), effective May 15, 2018

In addition, two permits to Move and Use Live Plant Pests or Insects or Noxious Weeds under the Plant Health and Pest Prevention Services program were approved by CDFA for outreach purposes and to collect small, free-floating plants, or fragments encountered in the field to prevent further growth and establishment.

- CDFA State Plant Pest Permit (#3451), issued on December 6, 2018, allows for the collection of water hyacinth (*Eichhornia crassipes*), Brazilian waterweed (*Egeria densa*), fanwort (*Cabomba caroliniana*), Eurasian watermilfoil (*Myriophyllum spicatum*), curlyleaf pondweed (*Potamogeton crispus*), and coontail (*Ceratophyllum demersum*).
- CDFA State Plant Pest Permit (#3681) issued on October 27, 2020 allows for the collection of alligatorweed (*Alternanthera philoxeroides*).

3.2 Reporting Requirements

3.2.1 NPDES Statewide General Permit

The NPDES Statewide General Permit for Aquatic Pesticide Use requires DBW to submit an annual report on March 1, following the AIPCP application season. Reporting per NPDES guidelines must include the following:

1) An executive summary discussing compliance or violation of this General Permit and the effectiveness of the Aquatic Pesticide Application Plan (APAP) to reduce or prevent the discharge of pollutants associated with algaecide and aquatic herbicide applications.

2) A summary of monitoring data, including the identification of water quality improvements or degradation as a result of the algaecide or aquatic pesticide application, if appropriate, and recommendations for improvements to the APAP [including proposed best management practices (BMPs)] and monitoring program based on the monitoring results. All receiving water monitoring data shall be compared to receiving water limitations and receiving water monitoring triggers.

3) Identification of BMPs currently in use and a discussion of their effectiveness in meeting the requirements in this General Permit.

4) A discussion of BMP modifications addressing violations of this General permit.

5) A map showing the location of each treatment area (explanation of Treatment Site Selection and Prioritization on page 23).

6) Types and amounts of algaecides and aquatic herbicides used at each application event.

7) Information on surface area and/or volume of treatment areas and any other information used to calculate dosage, concentration, and quantity of each algaecide and aquatic herbicide used.

8) Sampling results shall indicate the name of the sampling agency or organization, detailed sampling location information (including latitude and longitude or township/range/section if available), detailed map or description of each sampling area (address, cross roads, etc.), collection date, name of constituent/parameter and its concentration detected, minimum levels, method detection limits for each constituent analysis, name or description of water body sampled, and a comparison with applicable water quality standards, description of analytical quality assurance/quality control plan. Sampling results shall be tabulated so that they are readily discernible.

9) Summary of algaecide and aquatic herbicide application log.

3.2.2 CDFW Lake and Streambed Alteration Agreement

The CDFW Lake and Streambed Alteration Agreement outlines all reporting requirements for DBW's mechanical harvesting efforts. DBW must routinely submit quarterly reports (i.e. February, May, August, and November); an annual report, due within 45 days of December 31; a 7-day pre-removal notification to CDFW, prior to scheduled mechanical harvesting at a given project site; documentation pursuant to CDFW approval of project-certified Designated Biologists; and Biological Pre-Construction Survey reports to CDFW within 5 business days of each survey and prior to the commencement of mechanical harvesting at a given project site.

Further reporting is necessary when a spill into the waters of the State occurs, or a special status species, chiefly giant garter snake, is observed in pre-construction surveys or project monitoring. In the event of a spill, DBW must immediately notify the California Emergency Management Agency and initiate cleanup activities. Observations of special status species must be submitted to the California Natural Diversity Database (CNDDB) within 15 working days of the sighting, and CDFW must be provided copies of the CNDDB forms and associated survey maps.

3.2.3 USFWS and NMFS Biological Opinions

The USFWS and NMFS BiOp's require an Operations Management Plan to be submitted annually before the herbicide application season, an annual report to be submitted by January 31, following the application season and a Project Completion Report to be submitted within 45 days of project completion. This report fulfills the annual reporting requirements and summarizes compliance with the terms and conditions of the BiOp's.

Additional reporting requirements are on a case-by-case basis in the event of incidental take of federally listed species. Take is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (ESA; 16 U.S.C. 1532 et. Seq.). Reporting of take begins with immediate notification to the federal biologist (based on jurisdiction) in charge of administering the BiOp and requires documentation of information, such as location of take, number of species, water quality conditions, chain of custody, and prescriptive action for preventing future occurrences.

3.2.4 CDFA State Plant Pest Permits

The CDFA State Plant Pest Permits include specific conditions associated with the collection of approved plant pest species and work conducted under the permits, in general. These conditions include notifications to the CDFA Permits and Regulations Program regarding the following:

1) The arrival of each shipment of the regulated organism to the DBW office identified on the permits. Notification must be provided to the Sacramento County Agricultural Commissioner or the CDFA Permits and Regulations Program. If the county elects to waive the notification, DBW must notify the CDFA Permits Office.

2) Other plant pests found or identified that are not known to occur in California and/or are a quarantine plant pest, regardless of origin, not authorized under a valid permit.

3) The escape of a regulated organism not permitted for release.

4) Any violations and resolutions of permit conditions.

4 PERSONNEL, MATERIALS AND METHODS

4.1 AIPCP Personnel and Certifications

4.1.1 Application Crews

During 2021, DBW had five to ten full-time crews, each crew consisting of an Aquatic Pest Control Specialist and an Aquatic Pest Control Technician. DBW also had an interagency contract with the California Conservation Corps for additional personnel to assist the application crews. Each crew contains a minimum of one member possessing a Category F (Aquatics) Qualified Applicators Certificate (QAC), administered by the California Department of Pesticide Regulation. Under contract with DBW, Merced County and Fresno County Departments of Agriculture also had staff assigned to conduct surveys, and herbicide treatments or manual removal of FAV in the southern tributaries as needed.

APPLICATION EQUIPMENT

Crews uses a 19- or 21-foot aluminum boat powered by an outboard motor or an air drive. For pellet formulations, each crew uses either an Earthway Commercial spreader (30-foot spread), Hopper (50-foot to 60-foot spread), or Vortex (15-foot spread) unit with handheld blower tube to disperse herbicide to the target site. For liquid injection applications, each crew uses a spray rig connected to tubing with installed orifice plates to control herbicide flow. The spray units are equipped for direct metering of herbicide, adjuvant, and water into the pump system of each unit. At the start of each treatment, the application crew takes dissolved oxygen and temperature measurements using a HACH® HQ-30 Dissolved Oxygen Meter within the treatment site. These readings must be within the parameters outlined in the NPDES Permit and the USFWS BiOp before an application can be made. The crews use GETAC A140 tablets equipped with a Global Positioning System (GPS) unit to record the beginning and ending spray lines, coordinates of the spray area, time of treatment, treatment data and environmental data.

Spray equipment is calibrated routinely, after changing injection pumps, or whenever problems with the equipment occurred. Injection systems are cleaned daily and hoses cleaned as needed. Pump oil is changed every 50 hours. Boat maintenance is also conducted on a regular schedule.

All boats are washed regularly to remove herbicide residues and all application pumps, hoses, and nozzles are inspected and, if found defective, are replaced on an as-needed basis.

APPLICATION PERSONNEL EDUCATION AND TRAINING

Qualified Applicator Certificate

All Aquatic Pest control specialists are required to have a Qualified Applicator Certificate (QAC). Application crews receive continuing education credits in pesticide training to keep their QAC's current. Continuing education covers pesticide laws and regulations which may include topics such as federal and state pesticide regulations, pesticide and worker safety, surface and ground water protection, pesticide labeling and label interpretation, and pesticide effects on the environment. Category F QAC's are renewed every two years upon completion of the continued education credit requirements.

Environmental Awareness Training

Environmental awareness training was conducted on February 24, 2021 and on subsequent days for new employees. This training included the following items:

- Identification of commonly observed invasive aquatic plants in the Delta
- Species identification and impact avoidance guidelines on all threatened and endangered species associated with the AIPCP.
- Identification and protection of elderberry shrubs and protocol for monitoring species during an application season.
- Identification and protection of the giant garter snake including life history, importance of irrigation canals, marshes, wetlands, and seasonally flooded areas as habitat.
- Identification and protection of Delta smelt, longfin smelt, Chinook salmon, steelhead, green sturgeon, and associated protected habitats, fishery closure dates, and other regulatory agency requirements.
- Terms and conditions of the USFWS and NMFS BOs for the FAV Program for protection, avoidance and minimization of adverse effects to protected species under the ESA.
- Avoidance and minimization measures for species of concern that are outlined in the Routine Maintenance Agreement for mechanical removal/harvesting of FAV.
- Protocol for “take,” including reviewing the “Incidental Take Statement,” collection and handling of dead species, completion of chains of custody, and notification to USFWS.

Equipment Training

Refresher training on the use and calibration of the dissolved oxygen meters and use of Getac Tablets, Survey 123, and Collector applications take place routinely.

4.1.2 Monitoring Personnel

Environmental monitoring activities are overseen by a Senior Environmental Scientist and conducted by qualified personnel, which may include a Senior Environmental Scientist, Environmental Scientist, Associate Toxicologist, Fish and Wildlife Scientific Aids and/or Student Assistants. All water sampling events are carried out in accordance with the Quality Assurance Project Plan (QAPP) and the FAV Environmental Monitoring Protocol as approved by the SWRCB, NMFS, and USFWS.

Environmental Scientists are responsible for understanding and adhering to the regulatory permits and BiOp’s terms and conditions. They are also responsible for training other monitoring crew members on monitoring protocols, water sampling techniques, and the calibration and use of field equipment necessary to collect accurate data. Environmental scientists conducted training for all monitoring personnel on environmental monitoring and field equipment protocols.

Scientist's schedule and plan all field sampling events. Pictures are used to document any unusual conditions of the sampling locations, vegetation, or surrounding areas. Additional responsibilities include quality control field monitoring, laboratory analysis and reporting of findings in this annual report.

MONITORING EQUIPMENT

A 21-foot outboard motorboat was used for monitoring activities. Water samples for FAV water quality testing were collected using the MasterFlex® E/S® Portable Sampler fitted with 7 to 10 feet of tubing. Water samples for SAV water quality testing were collected using a sampling pole. Water quality parameters were measured with a YSI ProDSS Multiparameter Water Quality Meter with a 4-port cable assembly. Water quality parameters included water temperature, dissolved oxygen, electrical conductivity, salinity, pH, and turbidity. Parameters measured by the YSI ProDSS were geographically referenced with GPS coordinates with a GETAC A140 Tablet and ArcGIS Survey123. In the event of equipment malfunction, a Hach® HQ-30 Dissolved Oxygen Meter was used as a backup to measure temperature and dissolved oxygen within monitoring sites. In addition, all data was handwritten on datasheets as a backup copy. These datasheets were subsequently used for data quality control purposes. A digital camera was used to provide visual records of sampling locations and other notable factors that may affect water quality, species of concern, or the condition of the surrounding environment.

To avoid water sample contamination, boats used for environmental monitoring were never used for herbicide applications. For Diquat treatments some treatment boats were used, but contamination is not an issue when collecting from treatment boats. Monitoring boats are periodically washed. To ensure that water quality data is reliable, the YSI ProDSS and Hach® DO meters were calibrated on a regular basis based on the manufacturer’s requirements.

4.2 Materials and Methods

4.2.1 Herbicide Application

AIPCP OPERATIONS MANAGEMENT PLAN

The AIPCP Operations Management Plan (OMP) details general requirements, the scope of program activities, a pre-application planning protocol, application/monitoring coordination protocol, herbicide application protocol, Best Management Practices (BMP) for herbicide handling, spray equipment maintenance and calibration, spill avoidance and contingency plan, listed species avoidance and habitat evaluation, dissolved oxygen/temperature measurement, fish passage protocol, and agricultural and water intake coordination.

HERBICIDES

The herbicide products used for AIPCP treatment include the following:

- 2,4-D (Nufarm Weedar® 64), EPA Reg. No. 71368-1-ZB
- Diquat (Reward Landscape and Aquatic Herbicide), EPA Reg. No. 100-1091
- Fluridone (Sonar Q®) - EPA Reg. No. 67690-3 (Pellets)
- Fluridone (Sonar One®) - EPA Reg. No. 67690-45 (Pellets)
- Fluridone (Sonar PR®) - EPA Reg. No. 67690-12 (Pellets)
- Fluridone (Sonar H4C ®) - EPA Reg. No. 67690-61 (Pellets)
- Glyphosate (Monsanto Round-up Custom™), EPA Reg. No. 524-343-ZG

- Imazamox (Clearcast herbicide), EPA Reg. No. 241-437-67690

Prior to the start of each fluridone treatment season, USDA-ARS and DBW (with consultative support from SePRO Corporation Aquatic Specialists) will develop a treatment protocol for each selected treatment site. The protocol will specify weekly fluridone applications at a specific parts per billion (ppb) level, by quantity and formulation, based on the size and depth of the treatment area, infestation level, presence of nearby irrigation or potable water intakes, and the extent of tidal influence at the site. This protocol will provide a baseline treatment plan that will be adjusted on a weekly basis, if necessary, based on results from water samples taken at treatment sites throughout the treatment season. The AIPCP will conduct regular water sampling per the fluridone annual monitoring protocol. Information on the AIPCP treatment sites by Delta smelt habitat level are found in **Table 4.1**.

Table 4-1. SAV Treatment Sites, Herbicides and Timing

Delta Smelt Habitat Level	USFWS Area	Legal Delta Boundary Area	Treatment Site Numbers[f]	Fish Survey Reporting Required[b,c]	Fluridone	Diquat
Primary Habitat	1	Legal Delta North of Hwy 12	200-290	March 1 to June 30	March 1 to Nov. 30	August 1 to Nov. 30
		Legal Delta South of Hwy 12	16-24b, 39-44, 69, 98a-176	March 1 to June 30	March 1 to Nov. 30	August 1 to Nov. 30
Secondary Habitat	2	Legal Delta South of Hwy 12	11-15, 33, 49-68, 78, 79, 83a-97	March 1 to June 30	March 1 to Nov. 30	August 1 to Nov. 30
Tertiary Habitat	3	Legal Delta South of Hwy 12	1-10, 25-38, 45-48, 70-77, 80-82, 291	March 1 to June 30	March 1 to Nov. 30	August 1 to Nov. 30
Non- Habitat	4	Legal Delta South of Hwy 12	300-309	March 1 to June 30	March 1 to Nov. 30	August 1 to Nov. 30
		Non-Legal Delta	370 and above	March 1 to June 30	March 1 to Nov. 30	August 1 to Nov. 30

[a] *DBW may not treat in any site if DO is between 3 ppm and Basin Plan limits (5 ppm to 8 ppm, by location).*

[b] *DBW will implement a survey-based approach to conducting treatments that allows for treatments starting as early as March 1, in areas with re-growing Egeria densa when listed fish species are not present and water temperatures are rising, as reported to NMFS and USFWS*

[c] *DBW environmental scientists will continue to monitor fish surveys and avoid treating in sites where listed fish species are present; however, formal weekly reporting to NMFS and USFWS is not required after July 1.*

[d] *DBW will monitor the efficacy of the new herbicides penoxsulam and imazamox (time to symptoms, plant death, and regrowth).*

Table 4-2: DBW acquired restricted materials permits from the County Agricultural Commissioners for utilizing 2,4-D within the authorized time frame from June 15 to September 15.

Delta Smelt Habitat Level (USFWS Area)	Legal Delta Boundary Area	Treatment Site Numbers	Fish Survey Reporting Required[b,c]	Glyphosate	2,4-D[d]	Penoxsulam[e]	Imazamox[e]	Agridex	Competitor
Primary Habitat (Area 1)	Legal Delta North of Hwy 12	200-290	June 1 to June 30	June 1 to Nov. 30	No	No	No	June 1 to Nov. 30	No
	Legal Delta South of Hwy 12	16-24b, 39-44, 69, 98a-176	June 1 to June 30	June 1 to Nov. 30	June 15 to Sept. 15	No	No	June 1 to Nov. 30	No
Secondary Habitat (Area 2)	Legal Delta South of Hwy 12	11-15, 33, 49-68, 78, 79, 83a-97	March 1 to June 30	Mar. 1 to Nov. 30	June 15 to Sept. 15	No	No	Mar. 1 to Nov. 30	No
Tertiary Habitat (Area 3)	Legal Delta South of Hwy 12	1-10, 25-38, 45-48, 70-77, 80-82, 21	March 1 to June 30	Mar. 1 to Nov. 30	June 15 to Sept. 15	Mar. 1 to Nov. 30	Mar. 1 to Nov. 30	Mar. 1 to Nov. 30	Mar. 1 to Nov. 30
Non-Habitat (Area 4)	Legal Delta South of Hwy 12	300-309	March 1 to June 30	Mar. 1 to Nov. 30	June 15 to Sept. 15	Mar. 1 to Nov. 30	Mar. 1 to Nov. 30	Mar. 1 to Nov. 30	Mar. 1 to Nov. 30
	Non-Legal Delta	310 and above	March 1 to June 30	Mar. 1 to Nov. 30	July 15 to Aug 15	Mar. 1 to Nov. 30	Mar. 1 to Nov. 30	Mar. 1 to Nov. 30	Mar. 1 to Nov. 30

[a] DBW may not treat in any site if DO is between 3 ppm and Basin Plan limits (5 ppm to 8 ppm, by location). DBW may not treat if winds are >10 mph (or >7 mph in Contra Costa County).

[b] DBW will implement a survey-based approach to conducting treatments that allows for treatments from March through June in areas with re-growing water hyacinth when listed fish species are not present, as reported to NMFS and USFWS.

[c] DBW environmental scientists will continue to monitor fish surveys and avoid treating in sites where listed fish species are present; however, formal weekly reporting to NMFS and USFWS is not required after July 1.

[d] The 2,4-D time and location restrictions are specified in the NMFS BiOp for the Environmental Protection Agency registration of pesticides in order to protect listed salmonid species.

Best Management Practices

The DBW developed a series of BMP's that outline methods or techniques that have been found to be the most effective and a practical means of achieving a particular objective and/or to comply with AIPCP requirements.

- Herbicide Handling Requirements – all personnel will be trained in herbicide handling in accordance with Food and Agriculture Code and Title 3 of California Code of Regulations pertaining to Pesticides and Pest Control Operations.
- Spray Equipment Calibration – herbicide application equipment used for the AIPCP is to be calibrated on at least a monthly basis during the treatment season.
- Spill Avoidance and Contingency Plan – all herbicide spills are treated as emergencies and need to be remediated immediately. DBW applies preventative measures to reduce the potential for a serious spill.
- Annual Environmental Awareness Training – all program personnel involved in herbicidal treatments receive required Annual Environmental Awareness training
- Endangered Species Avoidance Measures – implement avoidance measures to reduce or eliminate potential impacts of the programs on endangered species.
- Agricultural and Water Intake Coordination – specific measures are implemented to ensure herbicide treatments do not negatively impact water intakes. All herbicide label requirements are followed as they related to use of treated water for irrigation or drinking purposes. DBW also coordinates with county, water districts, State Water Project (SWP) or Central Valley Project (CVP) regarding water quality impacts.

Treatment Site Selection and Prioritization

Prior to the start of the treatment season, field crews visually surveyed all sites in their application region and estimated the acres infested with invasive aquatic plants. Site prioritization was determined to be the same as the 2021, therefore the same prioritization evaluation was used for 2022.

Herbicide applications were prioritized such that nursery areas with a high amount of growth and areas that are critical to public, agricultural, municipal, industrial, recreational, or navigational use were treated first. DBW prioritized treatment sites based on results of these pre-season field surveys, combined with the staff experience and knowledge of AIS growth patterns and distribution. Each site was ranked on several factors including: 1) whether the site was a nursery area, 2) current infestation levels, 3) potential for infestation, and 4) whether the site is important for navigation, public safety, recreation, and/or commercial use, and Fish Restoration Program (FRP) sites. A score was given to each of the previous factors from 0 to 4. Zero having no weed infestation, one having a low infestation, two having a medium infestation, three having a high infestation, and 4 having a very high infestation. The environmental scientists collected their sheets and input all of their scores intro a spreadsheet. The FAV prioritization spreadsheet relies not only on the scores/input provided by the field crews, but also on a historical score given by the database. This historical score gathers a decade of data collected and the level of frequency a site is being treated. Basically, the sites with the highest historical score have a high chance of being a nursery site or a site with a high level of infestation. The site selection process also considered information and concerns received from the public.

Initial plans indicated the general priority for site treatment, and treatment plans were modified during the season due to weather conditions, growth and movement of floating aquatic vegetation, and environmental considerations.

There are other logistical factors involved in daily site selections for treatment, including the number of application crews available, travel-time to sites, herbicide label restrictions, environmental mitigations measures, and daily tidal conditions.

Hydroacoustic mapping was conducted in the areas considered by the crews to have a high infestation of submersed aquatic plants and that fell into one of DBW's high priority categories.

The herbicide application season began on March 19, 2021 throughout the Delta where protected fish species were not likely to be present, and away from spawning and rearing habitat sites for Delta smelt. At the start of the season, initial site prioritization focused FAV treatments in sections of the San Joaquin River such as Finnegan Cut, West Stanislaus Main Canal, Burns Cutoff, and Turner cut. Given efficacy requirements and the low herbicide concentrations for several SAV treatments, there were cases were SAV treatments took place in sites where listed fish may have been present.

The USDA-ARS and partner agency DBW sent a letter on April 8, 2020 requesting reinitiation of the April 3, 2019 section 7 consultation on the 2018-2022 AIPCP (Service file number (08FBDT00-2018-F-0029). DBW requested an amendment to the April 3, 2019 biological opinion to include (1) selected north and west Delta treatments when Delta smelt may be spawning or rearing and (2) selected additional use of diquat dibromide treatment locations. The USFWS on July 22, 2020 issued a new biological opinion that supersedes the 2019 biological opinion and revised the *Description of the Proposed Action* and subsequent sections to reflect change in timing of herbicide application within the Delta and the increased use of diquat. As a result, treatments take place in areas where treatment was not previously allowed and increased the use of diquat. Diquat treatment sites and polygons are listed in **SAV Appendix C**.

DBW reviewed fish survey data through the entire treatment season and avoided specific areas where special status fish species were present.

4.2.2 Environmental Monitoring

The AIPCP is responsible for collecting water quality monitoring data for the NPDES permit, as well as collecting water samples for herbicide residue testing.

AIPCP NPDES Annual Monitoring Protocol

All water quality monitoring follows the NPDES Annual Monitoring Protocol as outlined in the AIPCP APAP, which was approved in January 2014 by the SWRCB. Quality control and quality analysis measures are outlined in the Quality Assurance Project Plan. Monitoring activities include recording FAV and SAV impacts on beneficial waters of the United States, federally listed threatened and endangered species, and associated threatened or endangered species habitats. DBW is required to document herbicide residues in receiving waters and monitor water quality parameters such as water temperature, electrical conductivity, salinity, dissolved oxygen, pH, and turbidity. DBW also conducts physical inspections of the treated and surrounding areas to identify changes in water color and odor along with changes in vegetative health of the species within and around the treatment area.

NPDES MONITORING SITE SELECTION

Environmental monitoring sites were selected based on requirements listed under the NPDES permit and BiOp's. The SWRCB Statewide General NPDES Permit requires that dischargers monitor a certain proportion of sites based on the total number of treated sites. Since DBW does not conduct herbicide applications in non-flowing water and tidal and riverine water body types are considered flowing water, all monitoring took place only in the "flowing water" environmental setting category.

In 2021, Delta Coves and a portion of Sand Mound Slough was designated as a NPDES monitoring site for the SAV fluridone program. Long Island Slough and Marina Bay were chosen for NPDES monitoring for Diquat treatments. For each herbicide, one flow through site and one dead end site were chosen to represent different hydrology found at sites within the Delta.

Table 4-3. 2021 SAV Monitoring Sites

Site Number	Site Name	Herbicide	Water Body Type
108	Sandmound Slough	Fluridone	Flow Through
171	Delta Coves	Fluridone	Dead End
93.M	Marina Bay	Diquat	Dead End
241.L	Long Island Slough	Diquat	Flow Through

Three sites within the Delta were designated as monitoring sites for the FAV Program (**Table 4-4**). Representative monitoring for the FAV Program occurred in sites with varying degrees of habitat for the following species: giant garter snake, Delta smelt, and Valley elderberry longhorn beetle. Giant garter snake habitat has been rated as No Habitat, Low, Low-Moderate, Moderate, Moderate-High, and High, while VELB and Delta smelt habitat are classified as being absent or present based on the known distribution of delta smelt and the known locations of elderberry shrubs in the project area (**Table 4-5**). Laboratory results data can be found in **FAV Appendix E** and **SAV Appendix B.**

Table 4-4. 2021 FAV Monitoring Sites

Site #	Location	Water Body Type	Herbicide
28	Fourteen Mile Slough	Tidal	Imazamox
39	White Slough	Tidal	Glyphosate
100	Connection Slough	Tidal	2,4-D

Table 4-5. 2021 FAV Monitoring Sites and Habitat Quality

Site #	Location	GGS Habitat Quality	Delta Smelt Habitat	VELB Habitat
28	Fourteen Mile Slough	Low to High	Present	Present
39	White Slough	No Habitat to High	Present	Absent
100	Connection Slough	Low to Moderate-High	Absent (Jan-Jun)	Present

NPDES Residue Sampling

For liquid herbicides, water sampling occurs on the same day immediately prior to the respective herbicide application, in addition to follow-up sampling at the same locations within a week after treatment. All sampling stations at representative locations are identified as “A”, “B”, and “C”. Sampling station “A” represents the treatment area where the respective FAV or SAV species were treated. Sampling station “B” represents receiving water that is downstream from the treatment area. Sampling station “C” represents a control site that is sampled before herbicide treatment, typically upstream of the treatment area. Sampling times are identified as “1”, “2”, and “3”. Sampling time “1” indicates pre-treatment. Sampling time “2” indicates immediately post-treatment. Sampling time “3” indicates within seven days after treatment. Thus, sample 1A is taken before a treatment, within the treatment area. Likewise, sample 3C is taken within one week after treatment, upstream of the treatment area (i.e., control site).

For Sonar pellet applications, the NPDES sampling protocol differs. For each application event, DBW takes a pre-sample and as many weekly post samples as necessary until a non-detection of fluridone is obtained. These samples are identified as A, B, and C. Sample location A is inside of the application area approximately 1/4 to 1/3 the distance from the downstream edge of the application polygon. Sample location B is located on the downstream edge of the application polygon, and sample site C is in an adjacent non-impacted area with similar hydrological conditions as the application or receiving waters. For fluridone, A, B, and C are taken prior to treatment. After the last fluridone application is made in that site, A, B, and C samples are taken weekly until fluridone concentration reaches 0. Diquat treatment sites follow a slightly different protocol with the A sample being taken immediately before treatment, B sample being taken immediately after treatment, and C sample being taken one week after treatment.

All water quality monitoring followed the NDPES Annual Monitoring Protocol as outlined in the APAPs.

FLURIDONE ANNUAL MONITORING PROTOCOL

DBW will also take water samples at approximately three feet depth and submit these samples to Dr. Pramod K. Pandey's Laboratory at the Department of Population and Health, School of Veterinary Medicine, UC Davis. The lab will determine herbicide concentrations by High Performance Liquid Chromatography (HPLC). Results will be provided within 24 hours of the time the sample was taken. This quick and regular herbicide monitoring will allow AIPCP staff to ensure that herbicide concentrations are maintained at efficacious levels, and that water quality standards are not exceeded, particularly for irrigation. Depending on the results, the treatment protocol may be adjusted to achieve an appropriate herbicide concentration.

FLURIDONE MONITORING SITE SELECTION

Each treatment polygon has at least one water sample site selected that best represents the treatment site. These sample points are generally selected at the middle and end points for sloughs and equally spaced around larger polygon areas such as Franks Tract. Each site is sampled every week. Most of the sites are established at the beginning of the treatment season and remain throughout. Four fluridone sites were treated starting at the beginning of the season for two sets of nine weeks with a ten week break in between and are referred to as split sites. This was an experimental treatment regime aimed at addressing the bimodal growth pattern of Egeria densa. These sites included Cruiser Haven, Delta Marina Yacht Club – Rio Vista, Stockton Sailing Club, and Korth's Pirates Lair. Maps of each treatment site with water sample point locations are listed in **SAV Appendix C**.

DIQUAT MONITORING SITE SELECTION

Diquat quickly binds to sediment and suspended solids in the water column causing it to become chemically inactive in a short amount of time. Therefore, weekly residue sampling of diquat treatments sites is unnecessary, as it does not provide information that will affect the rate of the next treatment.

FLURIDONE RESIDUE SAMPLING

The results of the water samples were used to monitor and adjust the herbicide rate of application to ensure that the residues in the water column are conducive to attain the maximum aquatic invasive plant treatment efficacy, preferably 1.5 to 3.5 ppb. DBW collected 933 fluridone water samples during the 2021 treatment season.

Contract Laboratory Standard Operating Procedures

The analytical methods used by contract laboratories are published in the EPA Test Methods for Evaluating Solid Waste Physical/Chemical SW 846 or EPA Method for Chemical Analysis of Water and Waste. Analysis of water samples was conducted by Dr. Pramod K. Pandey's Laboratory at the Department of Population and Health, School of Veterinary Medicine, UC Davis. The method used to analyze fluridone and diquat in surface water is HPLC (High Performance Liquid Chromatography). The method used to analyze glyphosate in surface water is HPLC with a post column reactor. The method used to analyze imazamox in surface waters is LC-MSMS (Liquid Chromatograph Triple Quadrupole Mass Spectrometer). The method used to analyze 2,4-D in surface waters is HPLC-SPE-UV (High Performance Liquid Chromatography-Solid Phase Extraction-Ultra Violet).

Analytical Testing Validation

DBW used several methods to validate results found by contracting laboratories. These methods include collecting split water samples, field blanks, and equipment blanks; and preparing spiked samples. An equipment blank sample (de-ionized water) was collected at every sampling event to detect potential contamination from sampling equipment.

4.2.3 Hydroacoustic Monitoring

Measuring efficacy is an important part of any treatment program. Monitoring methods need to be non-intrusive, repeatable, and show consistent and reliable results over time.

Hydroacoustic monitoring has been employed in a robust and systematic fashion. These surveys provided detailed, quantitative metrics of the change in bio-volume and percent cover in treated sites.

Hydroacoustics and BioBase

The sonar system used by DBW is a combination of Lowrance™ HighDefinition System (HDS®) consumer echosounders (www.lowrance.com) and a cloud-based algorithm called Biobase (www.cibiobase.com). Biobase is a geo-spatial web platform designed to process Lowrance sonar logs for mapping SAV. The software is retailed by Navico on an annual subscription basis. Biobase generates data on water depth, SAV presence/absence, SAV height, bottom hardness (composition), and biovolume. The Lowrance / Biobase combination has a distinct advantage over other sonar systems for mapping aquatic vegetation by having lower hardware and analysis costs as well as faster processing times (Radomski and Holbrook 2015). In addition, Biobase outputs are automatically adjusted to Mean Lower Low Tide for consistency across all measurements; an important feature when mapping tidal-influenced systems such as the Delta. The service provided by Biobase offers vegetation point data, interpolated vegetation grids, default maps and tabular data that can be viewed online or downloaded to the subscription holder.

Acoustic and global positioning system (GPS) data are obtained using echosounders connected to 200-Khz 20 degree, single-beam transducers mounted on the research vessels' sterns. When conducting hydroacoustic surveys, the transducer transmits sound pulses through the water column, termed pings, and the return acoustic signals are recorded by the unit. Settings for the echosounders follow those recommended by Biobase. The units are set to collect fifteen acoustic pings per second and GPS coordinates every one millisecond. The internal GPS units are differentially corrected using a wide-area augmented system (WAAS). The acoustic and GPS signals are logged to secure digital cards in sl2 and slg format.

Upon completion of a survey, the sonar data is uploaded to Biobase. The algorithm evaluates each ping to determine SAV presence/absence and calculates water depth and a plant height for valid features. These values are concatenated into biovolume, the proportion of plant height occupying the water column. The vegetation data points from the survey are interpolated into a raster grid format and map products are produced from this data. The original vegetation point data and the raster grids are available for download as text files in Comma Separated Values (csv) format.

PYTHON CODES, TOOLS, AND MAP PRODUCTS

Data Processing

Hydroacoustic data collected by DBW staff uses the BioBase Aquatic Map System (BAMS) to analyze data which is then converted into aquatic maps using a series of Python scrips titled Biovolume Data Correction Workflow (BDCW). The first step of the process is shown in **Figure 1**.

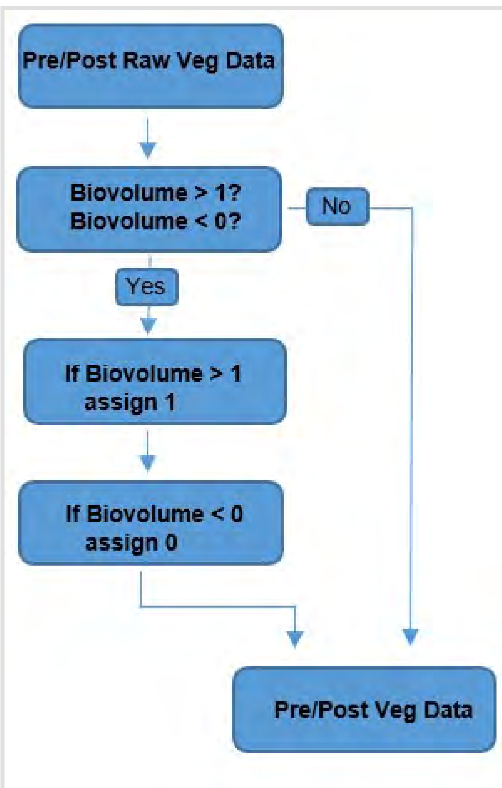


Figure 1. Biovolume Data Correction Workflow

Pre and Post grid data are analyzed through a series of steps that are designed to remove negative numbers and values greater than one that do not satisfy the criteria for the aquatic vegetation analysis.

The next step of the process involves the Change Detection Workflow (CDW) which uses a set of geoprocessing operations, including Spline Interpolation, to generate raster surfaces and vegetation percent coverages that are then used to obtain aquatic vegetation change detection and percent cover maps respectively. The logical process is shown in **Figure 2**.

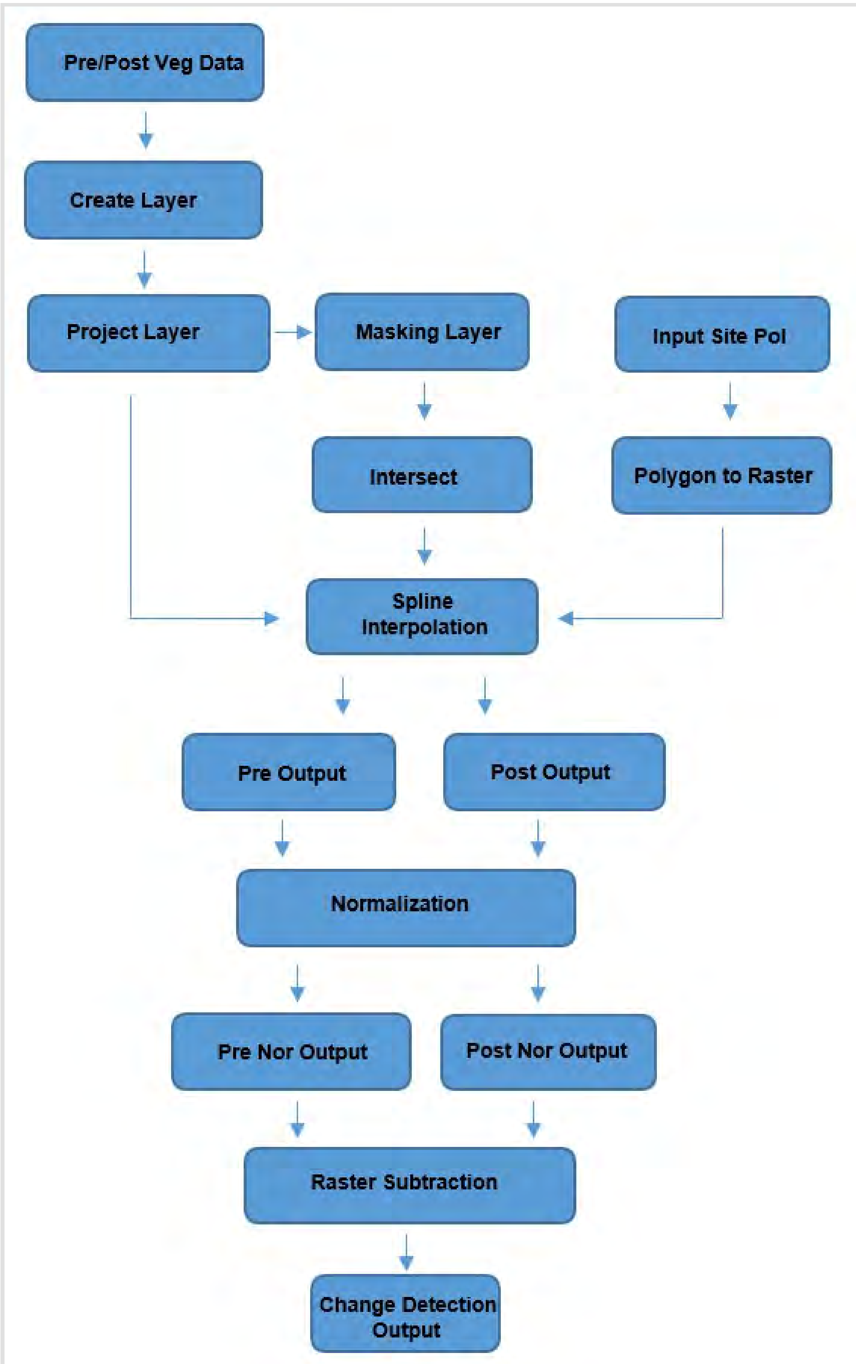


Figure 2. Change Detection Workflow

Biovolume value is the relation between the actual height of the aquatic plant divided by the height of the water column and is ranged from zero to one. Vegetation cover is any sort of aquatic plants present in a water body which has a biovolume greater than 0.05 percent. A percent cover of this vegetation is calculated as vegetation cover divided by the total area surveyed. This parameter is used to compare both the pre- and post- treatment.

MAP PRODUCT

The final biovolume maps show SAV with color gradients: blue indicates areas with no aquatic plants, to red where aquatic plants fill the entire water column, with intermediate gradients of green to yellow to orange. A histogram accompanies each map to show the frequency of biovolume data.

The two values used are Biovolume data and vegetation cover. Biovolume value is the relation between aquatic plant height divided by the height of the water column, ranging from zero to one.

Vegetation cover is any sort of aquatic plants present in a water body which has a biovolume value greater than 0.05. A percent cover of this vegetation is calculated as vegetation cover divided by the total area surveyed. This parameter is used to compare both the pre and post treatment.

SURVEY METHODS

Hydroacoustic surveys were conducted in the legal Delta. Seventy-nine sites totaling 1,632 surface acres were selected for treatment and mapped based on confirmation of visual and hydroacoustic surveys for high densities of Brazilian waterweed and other invasive SAV. Pre- and post-treatment hydroacoustic surveys were instituted to accomplish two efficacy-orientated goals. First, the pre- treatment surveys establish a measure of SAV abundance/density at these sites and the level of treatment needed. Second, the post-treatment surveys provide a current assessment of treatment efficacy and will be used to assess the program's overall efficacy on an annual basis. Two sites, River's End and Hammer Island, were not mapped post-treatment due to navigational blockage of FAV. Surveys were completed by various DBW staff using unit research vessels. Since the Delta is comprised of sloughs, riverine areas, and large shallow waterbodies, mapping was divided into two strategic methods. Large bodies of water, such as Frank's Tract, were gridded to approximately 30-meter intervals for survey transects. In smaller slough and marina areas, transects followed the contours of the shoreline and internal structure (e.g., boat docks, tule islands) and ranged between 10 and 30 meters in width. Transects were performed in water depths ranging from 1 to 15 feet as SAV are shallow-water plants not typically found deeper than 15 feet. SAV Point Sample Monitoring

Hydroacoustic mapping is a tool used to measure the abundance of submersed aquatic vegetation in an area but does not identify the plants scanned. Therefore, a new metric was added in the 2017 treatment season – point sampling. Point sample data is gathered by using double-sided rakes that are tossed from the boat and dragged along the bottom substrate bringing the submersed aquatic plants back to the boat. Density and health data of submersed aquatic vegetation were evaluated and rated onto Survey 123. A summary of rake pull data results is in **Table 5-3.**

Submersed Vegetation Density Scale

Rating	Range	Description
1	1-25%	A fragment to a few strands of species on rake – nothing visible other than a few plants
2	26-50%	Rake has good abundance of a species up to 50% of rake and/or visible plant coverage of approximately 25% of the area
3	51-75%	Rake has good abundance of a species up to 75% of rake and/or visible plant coverage of approximately 50% of the area
4	76-100%	Topped out dense plants – abundant rake mass and/or visible plant coverage of 75% of the area or greater

The above health scale was developed for *Egeria densa* and is slightly modified for other submersed aquatic plants evaluated, such as curly leaf pondweed and fanwort. Sites with 1 to 9 acres had 5 rake pulls; 10 to 100 acres had 10 rake pulls; and sites over 100 acres had 15 rake pulls.

4.2.4 FAV Elderberry Surveys

The FAV program conducts treatments in up to 418 defined sites throughout the Delta and tributaries. Many of these sites are surrounded by riparian habitat containing *Sambucus ssp.* (elderberry shrub) the host plant for VELB, a species listed as threatened (Federal Register 45: 52803-52807), under the Endangered Species Act of 1973 and completely dependent on the elderberry shrub for its reproductive life cycle.

- On April 3, 2019, DBW was issued a BiOp from the USFWS. In accordance with this BiOp the DBW-AIPCP follows specific guidelines to minimize potential impacts to the VELB resulting from treatment activities. DBW will conduct a survey of treatment sites to prepare a map that identifies locations of *Sambucus ssp.* and provide this map to field crews.
- In most locations, AIPCP crews will maintain a 100-foot buffer zone for herbicide treatments when elderberry shrubs are present and conduct treatments downwind of elderberry shrubs.
- For selected treatment sites where Priority 1 and Priority 2 treatment occurs adjacent to elderberry shrubs, DBW crews will utilize backpack style spray wands to target herbicide directly onto FAV species.
- Service-approved AIPCP environmental scientists will compare the health of elderberry shrubs at control sites (i.e. not adjacent to treatments) with elderberry shrubs located adjacent to treated sites. If elderberry shrubs located near treatment sites show signs of adverse effects from treatment AIPCP will develop additional conservation measures to protect elderberry shrubs.

This report describes the methodology used for assessing elderberry shrub presence and health. It also includes survey results from select sites to identify any adverse effects resulting from FAV herbicide treatments near elderberry shrubs during the 2021 calendar year. AIPCP scientists conducted surveys beginning on March 24 and ending on August 24, 2021. Where shrubs were accessible on land, surveys were completed by foot, and when this was not possible surveys were completed by boat using binoculars.

DBW'S SITES SURVEYED IN 2021 (FAV APPENDIX A, FIGURE A-10)
SITES COMPLETED IN 2021: 12, 20, 30, 31, 32, 33, 34, 36, 37, 38, 39, 40, 41, 42, 50, 51, 52, 53, 56, 57, 58, 59, 60, 61, 62, 65, 66, 67, 68, 76, 77, 78, 79, 92A, 92B, 98A, 99A, 100, 101A, 101B, 102, 200, 203, 204, 205, 206, 207, 262

SITES PARTIALLY SURVEYED IN 2021: 10, 46, 75, 252 AND 257

The objectives are the following:

- Survey sites as outlined in the April 3, 2019, USFWS BiOp
- Conduct surveys of locations with *Sambucus spp.* across the whole Delta and update the GIS layer to inform Aquatic Specialists about elderberry shrub locations before they treat FAV.
- Report results of shrub health both before and after treatment at selected site(s) outlined in the BiOp or site(s) in the Delta with a high density of elderberry shrubs
- Prioritize areas for surveying and to have a complete GIS layer of the entire DBW service area

SURVEY METHODS

Site selection:

Sites selected for survey in 2021 included some previously surveyed by Aquatic Specialists and Environmental Scientists in the early 2000s. During those early efforts, only basic information was collected, not all sites were completely surveyed, and some plants may have misidentified as other species. For these reasons, we revisited these sites to conduct a comprehensive qualitative and quantitative assessment of the elderberry shrubs and to verify the accuracy of this data. The USFWS BiOp requires us to survey the entire service area. In order to do this, DBW will survey as many sites as feasible each year until the site surveys have been completed.

Project wide Surveys:

Surveys were conducted by boat or on foot. Shrubs found within 100 feet of waterways were defined as the 'treatment area' group and were documented, while those more than 100 feet from the waterline are far enough to be protected from the effects of potential herbicide drift.

Stems occurring within 6 feet of each other are likely to share below ground root networks. Each cluster of stems was therefore counted as an individual plant with multiple stems. Two clusters of stems more than 6 feet apart were counted as separate individuals.

Once shrub clusters were identified, scientists marked their location, estimated the shrub radius, estimated percentage of the shrub that was dead, and estimated the percentage that was choked out by a competing species. Comments were also collected and could include qualitative data aimed at assessing the extent to which each shrub is a suitable habitat for the valley elderberry longhorn beetle.

Fig. 3. Table listing the qualitative variables measured during elderberry shrub surveys. The left column lists the variable, and the right column describes how that variable was measured or characterized.

Habitat type	**Describes the habitat type in which the shrub is growing (see below for habitat descriptions).** **Riparian includes areas where the waterway is nearby, historically riparian, or if riparian plants are present.** **Forest includes woody vegetation such as trees or shrubs** **Herbaceous includes low growing, non-woody vegetation** **Rip-rap refers to land with broken concrete, river rocks, or other rock-type landscapes**
Adjacent land use	**Describes how nearby land has been modified by humans.** Wildlife Areas, Undisturbed, Herbaceous, Rip-rap
Plant vigor	**An estimate of overall shrub vigor considering factors such as disease, herbivory, infestation, leaf color, leaf size, abnormal internode length, density of foliage.** **(3) Good** = less than 25% of aboveground growth displaying one or more of the factors listed above **(2) Fair** = between 25% and 75% of aboveground growth displaying one or more of the above factors **(1) Poor** = more than 75% of aboveground growth displaying one or more of the above factors **(0) Dead** = specimen that is no longer viable and capable of growth
Dead limbs percent	Estimated percentage of dead limbs.
Choked limbs percent	Estimated percentage of the aboveground growth being choked or covered by other plant species (especially vines, trees, bushes).
Height	Height of plant from the base of the plant to its tallest point.
Radius	Radius of the aboveground portion of the plant (ft)
Stem count	**Number of stems occurring within 6 feet of each other. Separated into three size classes:** 1-3 inches 3-5 inches 5 inches and above Stems smaller than 1 inch in diameter were excluded.
Max diameter	The measured diameter of the largest stem in a cluster (inches).
Beetle Exit holes	**Number of exit holes occurring on shrub. Separated into three classes based on stem size:** 1-3 inches 3-5 inches 5 inches and above

Post-treatment elderberry surveys were completed using the same criteria outlined above, however, due to the survey taking place near the end of the year, many plants had browning leaves, fermenting fruits and naked stems due to annual senescence. Because of this, estimating the amount of dead material on each shrub was accomplished by examining the health of elderberry stems and branches specifically. Dead branches often feel dry and hollow, appear grayish in color, and break easily when bent. In contrast, live branches are turgid, slightly heavy, and are highly flexible when bent. Using these factors, we were able to estimate the amount of dead material. This was important for determining whether elderberry shrubs were dying, or simply undergoing seasonal changes.

4.2.5 FAV Point-Intercept Sampling

The point-intercept method is commonly used in terrestrial vegetation sampling but is continuing to become standard for measuring aquatic plant communities. The application of this method in aquatic plant management is important as it provides an approach for collecting objective, quantitative data in aquatic ecosystems; rigorous statistical analysis of plant community trends, both spatial and temporal; and assessing and adapting management techniques (Madsen 1999). Additionally, compared to standard biomass sampling for aquatic plants, point-intercept sampling is less time-intensive, less costly, less sensitive to seasonal changes, more readily adaptable to larger sampling areas, and more sensitive to species diversity (Ibid).

Point-intercept sampling for FAV was implemented into the control program in 2018 to determine change in FAV species composition over time throughout select sites in the Delta, including numerous high-priority FAV sites. The primary sampling effort occurs on an annual basis in September (late summer to early fall). A small subset of sites is additionally sampled on a seasonal basis in March (late winter), May (spring), July (summer), and November (mid-late fall).

Sampling was conducted by boat. Data was acquired using a pole with graduated lines (gradations of 0.10 meters with subdivisions of 0.05 meters, up to 1.50 meters) placed on the water surface at 30 sampling points within selected sites. Point-intercept measurements can be taken at regular intervals or predefined locations (Madsen 1999). DBW predefined its sampling points using a random point generator in GIS software, per guidance by the USDA-ARS, to ensure that the sampling points are not biased through subjective selection in the field. Additionally, the points are confined to 20 feet or less of site boundaries to ensure that measurements are only taken in FAV habitat (i.e., close to bank and island margins), especially in larger and/or deeper waterways. Data on presence and absence (1 or 0, respectively), plant species (Table 4-6), plant height (meters), water depth (meters), and plant species within vicinity (i.e., within 3 meters) was collected onto electronic datasheets. All plant species documented in vicinity represent rare, sensitive, or invasive species (Table 4-6).

Table 4-6. 2021 Survey Species List for FAV Point-Intercept Sampling

Common Name	Scientific Name	USDA PLANTS Symbol/Code
alligatorweed*	*Alternanthera philoxeroides**	ALPH
arrowhead spp.	*Sagittaria* spp.	SAGIT

arundo or giant reed	*Arundo donax*	ARDO4
bulrush spp.*	*Schoenoplectus* spp.*	SCHOE6
bur marigold*	*Bidens laevis**	BILA
calla lily	*Zantedeschia aethiopica*	ZAAE
cattail spp.*	*Typha* spp.*	TYPHA
elderberry	*Sambucus nigra* ssp. *caerulea*	SANIC5
pampas grass	*Cortaderia selloana*	CORTA
pennywort spp.*	*Hydrocotyle* spp.*	HYDRO2
phragmites or common reed	*Phragmites australis*	PHAU7
purple loosestrife	*Lythrum salicaria*	LYSA2
red sesbania	*Sesbania punicea*	SEPU7
salt cedar or tamarisk spp.	*Tamarix* spp.	TAMAR2
seep monkeyflower*	*Erythranthe guttata**	MIGU
smartweed spp.*	*Persicaria* spp.*	POLYG4
speedwell spp.*	*Veronica* spp.*	VERON
spongeplant*	*Limnobium laevigatum**	LILA7
water hyacinth*	*Eichhornia crassipes**	EICR
water primrose spp.*	*Ludwigia* spp.*	LUDWI
wild taro	*Colocasia esculenta*	COES
woolly rose-mallow	*Hibiscus lasiocarpos* var. *occidentalis*	HILAO
yellowflag iris	*Iris pseudacorus*	IRPS

**Primary sampling species for point-intercept measurements. Species without an asterisk are only documented when scanning for plants in vicinity of the sampling point.*

After each sampling effort and in between sampling months, the data was reviewed for quality control. This included addressing any missing or potentially incorrect data. The data was then analyzed and summarized by number of intercepts where the respective species was present, frequency per species, percent difference or change, and chi-square analysis.

Photo Point Monitoring

Photo point monitoring is a relatively inexpensive way to monitor vegetation changes in a pre-selected geographic area over a period of time. Photo point monitoring has been used by agencies like the US Forest Service in areas where weed control has occurred to determine if the weed management objectives are being met, and to show progression of native vegetation growth at restoration sites. Although, photo point monitoring has been used primarily in terrestrial settings, there isn't research available to determine whether the use of photo point monitoring has been used in aquatic settings such as rivers, sloughs and/or canals. AIPCP started a pilot project in 2018 to investigate whether this monitoring strategy could help the program understand FAV growth patterns, best times to treat FAV, and to show herbicide efficacy. Obtaining these types of visual and qualitative data could serve as a performance metric measure to allow the program to make better treatment management decisions. Over the years, the program has narrowed down the objectives with the utmost importance. The objectives for the FAV photo point monitoring are as follows: (1) monitor FAV growth and/or infestation levels at various sites in the Delta, (2) obtain FAV presence and/or absence data, (3) establish a baseline for treating invasive FAV, (3) show before and after photos of herbicide and/or mechanical control, (4) correlate water temperatures with FAV growth based on current data, (5) understand how much variation there is in dissolved oxygen depletion with high FAV growth areas, and (6) monitor new FAV invasions.

Survey Methods

Design

Selecting and Establishing Photo Point Locations to Monitor

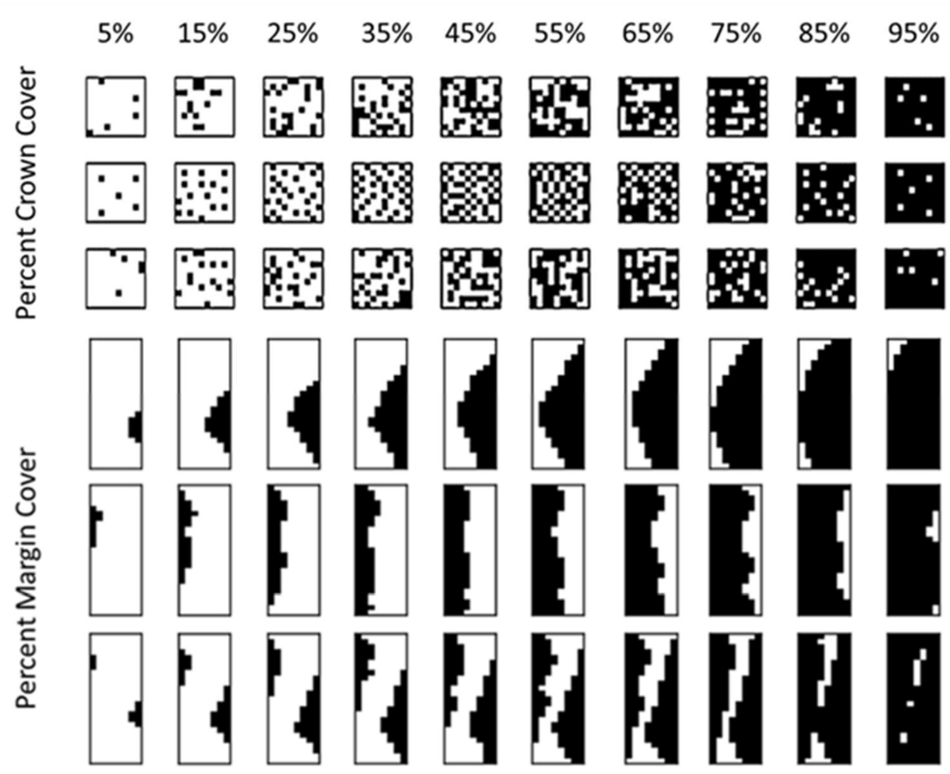
Photo points were selected to include water bodies that have a recreational, economic and/or a restoration component in the Sacramento-San Joaquin Delta. These points included marinas, ports, water intakes, navigable waterways, wildlife/restoration areas, and historical nurseries (problematic areas infested with FAV). The environmental scientists drove by land and by water to the aforementioned areas and identified the photo point locations based on site accessibility and view of the waterways. For each site(s), a representative location was chosen with a clear line of vision in each direction and with landscape structure heterogeneity for contrast and for easy reference. Enough points were included to encompass North, Central and South areas of the Delta with various conditions such as fast-moving waters, slow-moving water such as sloughs or canals, and areas with rip-rap and/or high rich riparian habitat. Southern tributaries such as the Merced, Stanislaus, and Fresno were not included since the protocol was designed to include sites in the Delta proper, and to save time and/or resource allocation.

Site locators were created to organize the photo point monitoring locations using Google Earth Pro and then transferred to ArcGIS where a map was created (**FAV Appendix G**). Landmarks or object were used to take photos from the same angle. The US Forest Service calls these 'witness points' (USDA Forest Service). Flash cards were created using a Microsoft publisher to assign identification site numbers, to include the date and the orientation. At each site(s), a photo was taken, and a cardinal direction was chosen based on the visibility and landmarks of the waterway. The weather forecast was checked before heading out to collect the photos during sunny days to obtain clear and crisp photos. In addition, the photos were taken between the hours of 8:00 AM and 16:00 PM.

Floating Aquatic Vegetation Percent Cover Measurements and Water Quality Collection Methods

Photos were taken during the spring (April), summer (June/July) and frall (Sept/Oct).

After photos were taken, the field of view was visually broken into grids to break down the floating aquatic vegetation density in the waterway, and a density scale laminated sheet was used to make sure the conditions in the waterway matched the visual observations. The new density scale sheet mimics the Kleinn's percent crown cover density scale and was modified to be used for visual observations of FAV covering the waterway. In prior years, the "Daubenmire method" was used, a tool for using vegetation sampling to estimate the percent, cover, frequency, and composition of vegetation in a grassland or fob community. This time the program decided to try the "Kleinn's percent crown cover density scale" to visually account for the amount of FAV covering the waterway. The percent crown cover density scale was changed to better simulate the ways various species of FAV cluster water bodies. See chart below. The chart includes the original percent crown cover (Kleinn, C. 2000), and below it includes the simulated percent margin cover that was created using Microsoft Excel to mimic some of the floating aquatic vegetation overall distribution.



The FAV percent cover was broken down into the following density class categories:

DENSITY CLASS	Percent Cover
1 - VERY SPARSE	0-10%
2 - SPARSE	10-40%
3 - MODERATE	40-70%
4 - DENSE	70-100%

When collecting the data, a density class category was selected to estimate the percent cover in the waterway. After assigning a density class category, the overall percent cover in that category was broken down into percentages of the individual species of FAV and estimates of how much of each of the floating aquatic plants were covering the waterway were recorded. Zeiss 8x42 Conquest HD Binoculars were used to identify, scan the areas, and obtain proper presence and/or absence of species being recorded.

In addition to recording FAV percent cover totals, the following water quality parameters were collected at each site: dissolved oxygen (mg/L) and temperature (◦C). These water quality parameters were collected using a HQ30D Portable Dissolved Oxygen Meter with Field Luminescent DO Sensor. The meter was lowered into the waterway at about mid water column from bridges. In some instances when the cable did not reach the water, the reading was taken close to shore. Data was recorded into ArcGIS Survey 123, and on a paper sheet as a back-up.

The equipment used was the following: HQ30D Portable Dissolved Oxygen Meter with Field Luminescent DO Sensor, ArcPad tablet, iPhone XR, Olympus TG-3 Waterproof 16 MP digital camera, Zeiss 8x42 Conquest HD Binoculars, flash cards, reflective vests, hard hats, and traffic cones.

5 MONITORING RESULTS AND DISCUSSION

5.1 Threatened and Endangered Species

The USFWS established incidental take for federally listed species and outlined terms and conditions necessary to minimize the impact of incidental take on listed species. No incidental take of federally listed species occurred in the 2021 season. Since NMFS concurs with USDA and DBW's determination that the proposed AIPCP is not likely to adversely affect federally listed salmonids or green sturgeon, or their habitat, there is no incidental take provided by NMFS in implementing the AIPCP.

5.2 Infestation and Herbicide Application

In 2021, the DBW treated a total of 1,632 acres at 79 sites of the project area for SAV, and 2500 acres at 125 sites of the project area for FAV. The treated sites encompassed most of the Delta; maps can be found in **FAV Appendix A, Figures A-4 through A-7, FAV Appendix D;** and **SAV Appendix A**.

5.2.1 Summary of Herbicide Use

Each crew completed a daily treatment log to record herbicide treatment activities. The 2021 daily treatment log information can be found in **FAV Appendices B and C** and **SAV Appendix D, Tables I-1 to I-7**. Number of crews available, travel time to sites, herbicide label restrictions, and environmental mitigation measures were important factors used when scheduling which sites to treat each day. No applications were made if DO concentrations were between 3.0 mg/L and the Basin Plan limits (5 mg/L to 7 mg/L, by location) as adopted by the CVRWQCB.

The SAV treatment season was conducted from March 19, 2021 to November 30, 2021. Four fluridone sites, referred to as split sites, were treated starting at the beginning of the season for two sets of nine weeks with a ten week break in between. This was an experimental treatment regime aimed at addressing the bimodal growth pattern of Egeria densa. These sites included Cruiser Haven, Delta Marina Yacht Club – Rio Vista, Stockton Sailing Club, and Korth's Pirates Lair. Results did not show an increase of efficacy and this treatment schedule will not be repeated in the following season. Rake pull results summary for split sites are shown in Table 5-3a. Biomass change detection maps and percent cover maps for split sites are listed in **SAV Appendix H1 and H2.** Total weeks of treatment are noted on site maps in **SAV Appendix C**. In 2021, the AIPCP SAV program used 85,957 lbs. of fluridone, and 3,324.2 gallons of diquat to effectively treat a total of 1,632 acres of SAV in the Delta (**Table 5-1**). Totals of herbicide usage by Sonar product for the SAV program since 2016 are found in **Figure 7**. A breakdown of the SAV acreage treated since 2015 is found in **Figure 8**.

Visible effects of the fluridone herbicide treatment showed bleaching of the tips after two to three weeks, followed closely by breaking of the growing tips, then leaves falling off and gradual degradation of the plants which eventually advanced to small segments of dark husks floating in the water. Even at this late stage, new growth can form at nodes which are still viable. Observations of herbicide symptoms such as bleaching, deleaving and biomass reduction were observed as a result from all treatments.

Visible effects of diquat treatment were dark, necrotic plant tissue, deleaving, and significant biomass reduction within as little as one week post treatment.

The FAV treatment season began on March 19, 2021. The season continued until November 30, 2020. FAV herbicide applications utilized glyphosate, imazamox, 2,4-D, and diquat with the adjuvants, Agridex and Competitor. To minimize potential negative effects to salmon and steelhead, DBW and USDA-ARS included specific timing for 2,4-D applications as a part of the proposed project. The proposed time frame for 2,4-D applications is consistent with the 2011 NMFS BiOp for EPA registration of 2,4-D (for Pacific Salmonids), which limits 2,4-D applications from June 15 through September 15 within the legal Delta, and from July 15 through August 15 in the San Joaquin River (southern sites).

The time to symptom development in FAV treated with glyphosate and imazamox ranged from 1 to 3 weeks. Visible effects were gradual wilting and yellowing of the plants which eventually advanced to complete browning. For FAV treated with 2,4-D and diquat, the time to symptom development was faster, with wilting and chlorosis of the plants being observed as early as two days after treatment. Observations of herbicide symptoms such as wilting, yellowing, and browning were observed from all treatments. However, as temperatures decreased in October and November, herbicide symptoms were slower to appear due to decreased plant growth rates, which caused a decrease in herbicide uptake and translocation rates. In some cases, treated plants remained floating for a significant amount of time, but most decomposing plants eventually sank into the water column.

In 2021, the DBW applied 2,324.71 gallons of glyphosate, 567.25 gallons of 2,4-D, and 649.16 gallons of imazamox for FAV control (**FAV Appendix A, Figures A-8 and A-9**). DBW treated approximately 2,500.28 acres of water hyacinth, spongeplant, water primrose, and/or alligatorweed in the Delta and its tributaries (**Table 5-1 and Figures 3 through 5**). Total herbicide usage and acres treated for the FAV Program varies from year to year (**Figure 6**) due to differing infestation levels, treatment start dates, regulatory restrictions, local water conditions, weather conditions, resources, and other factors.

The BiOp for the AIPCP states, "The proposed limit of the AIPCP is 15,000 acres per year for all SAV, EAV (emergent aquatic vegetation), and FAV during a 5-year (2018-2022) implementation period." DBW prioritizes areas that need the most treatment, and the areas treated last year totaled approximately 2,500.28 acres and fell below the 15,000 acres threshold.

Table 5-1. 2021 AIPCP Herbicide Use by Month

Month	Sonar Q (pounds)	Sonar One (pounds)	Sonar PR (Pounds)	H4C (gallons)	Diquat (gallons)	Glyphosate (gallons)	Imazamox (gallons)	2,4-D (gallons)	Agridex (gallons)	Competitor (gallons)
March						44.75	27.00		13.00	18.50
Apr	0.001708	724	0.00	0.00	0.00	181.89	88.50	0.00	36.79	88.50
May	0.0017848	4,784	0.00	6010.00	98	186.90	77.81	0.00	48.02	78.46
Jun	0.00	27,771	90	2584.00	498	321.97	142.50	10.00	91.48	120.63

Jul	0.00	20,580	0.00	0.00	574	345.00	90.25	161.50	161.00	139.50
Aug	0.0020	7,962	8,107	0.00	232	197.45	35.00	196.50	154.25	57.11
Sept	336	9,542	0.00	0.00	246	478.69	126.35	199.25	194.75	164.50
Oct	0.00	6,827	4,667	0.00	224	327.41	32.50	0.00	148.94	15.50
Nov	0.00	0.00	0.00	0.00	99.0	240.65	29.25	0.00	120.04	2.50
Total	**19,912**	**78,190**	**12,864**	**8594.00**	**1,970.75**	**2,324.71**	**649.16**	**567.25**	**968.27**	**685.20**

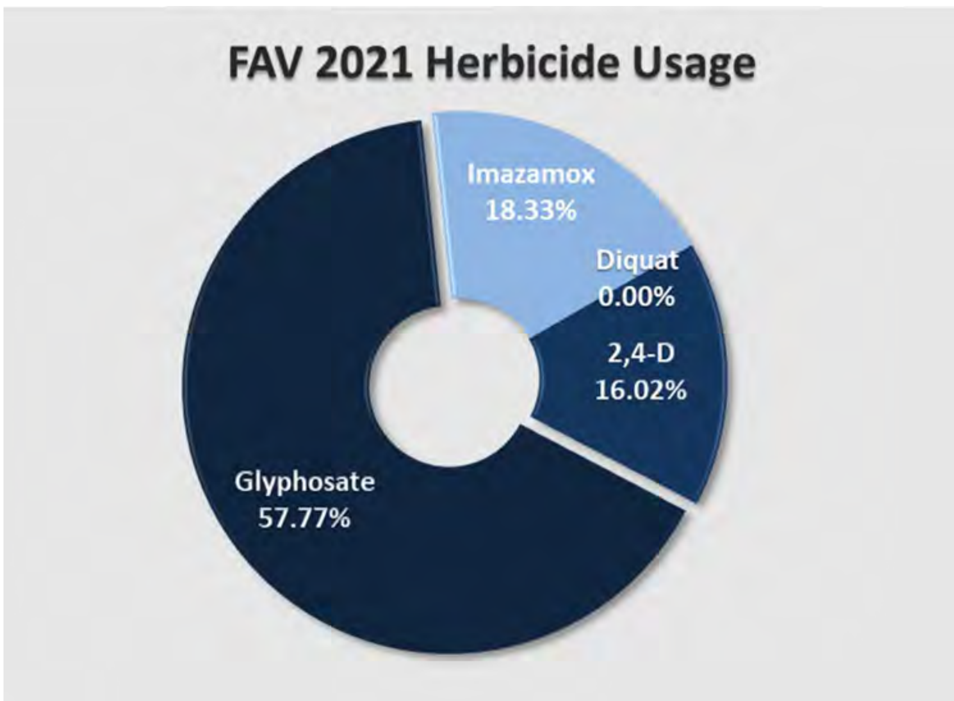
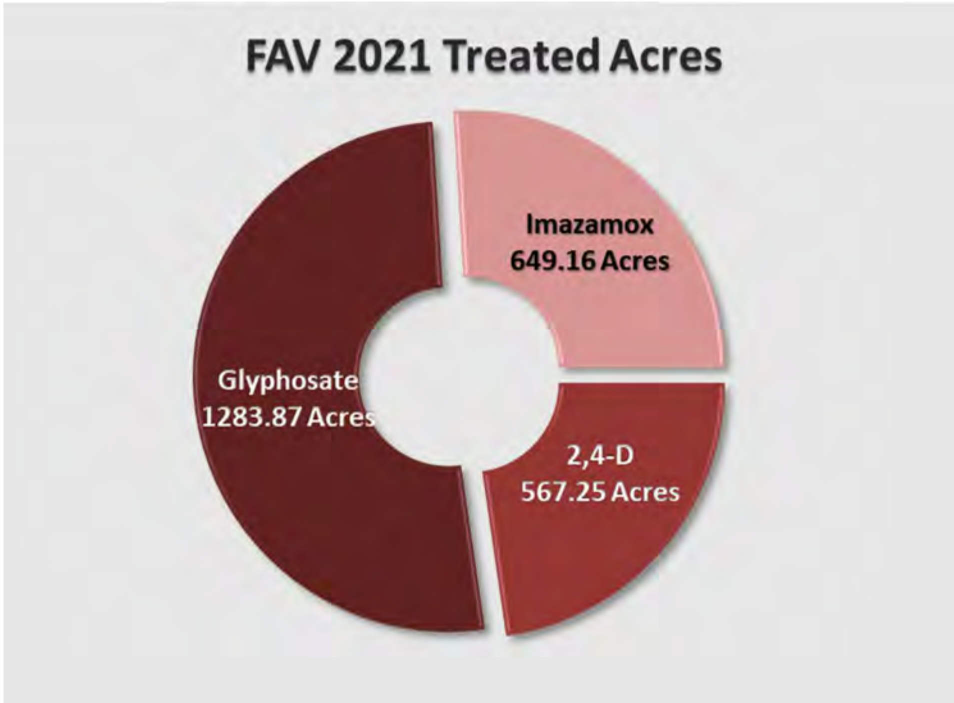


Figure 3. 2021 FAV Herbicide Use



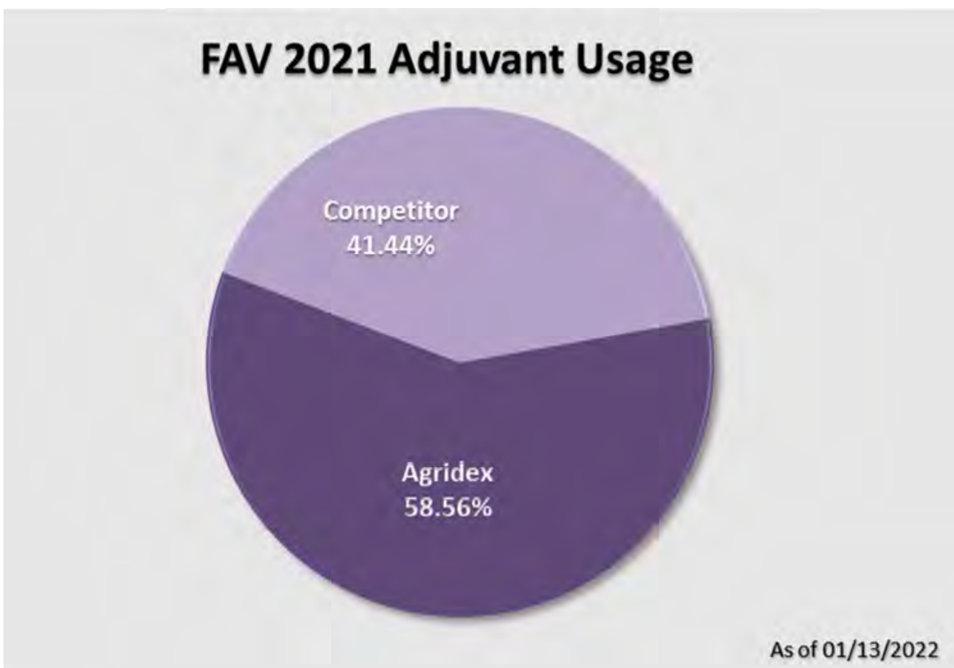


Figure 4. 2021 FAV Acreage Treated Per Herbicide

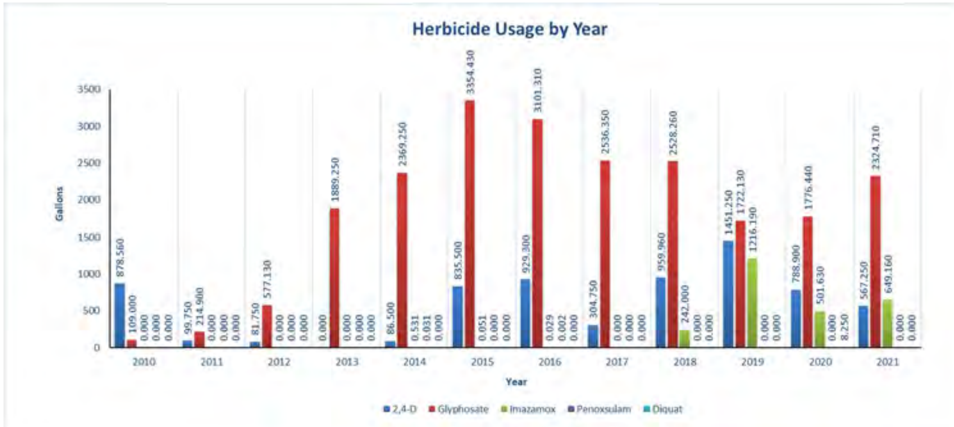


Figure 5. 2,4-D, Glyphosate, Imazamox, Penoxsulam, and Diquat usage by year for 2010 to 2021

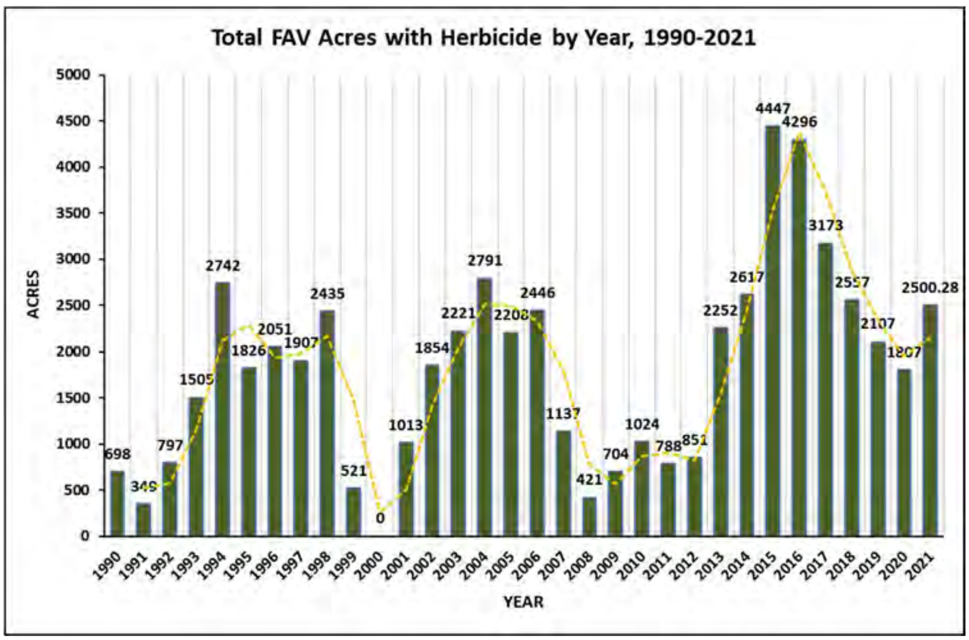


Figure 6. Total FAV Acres Treated with Herbicide by Year, 1990-2021

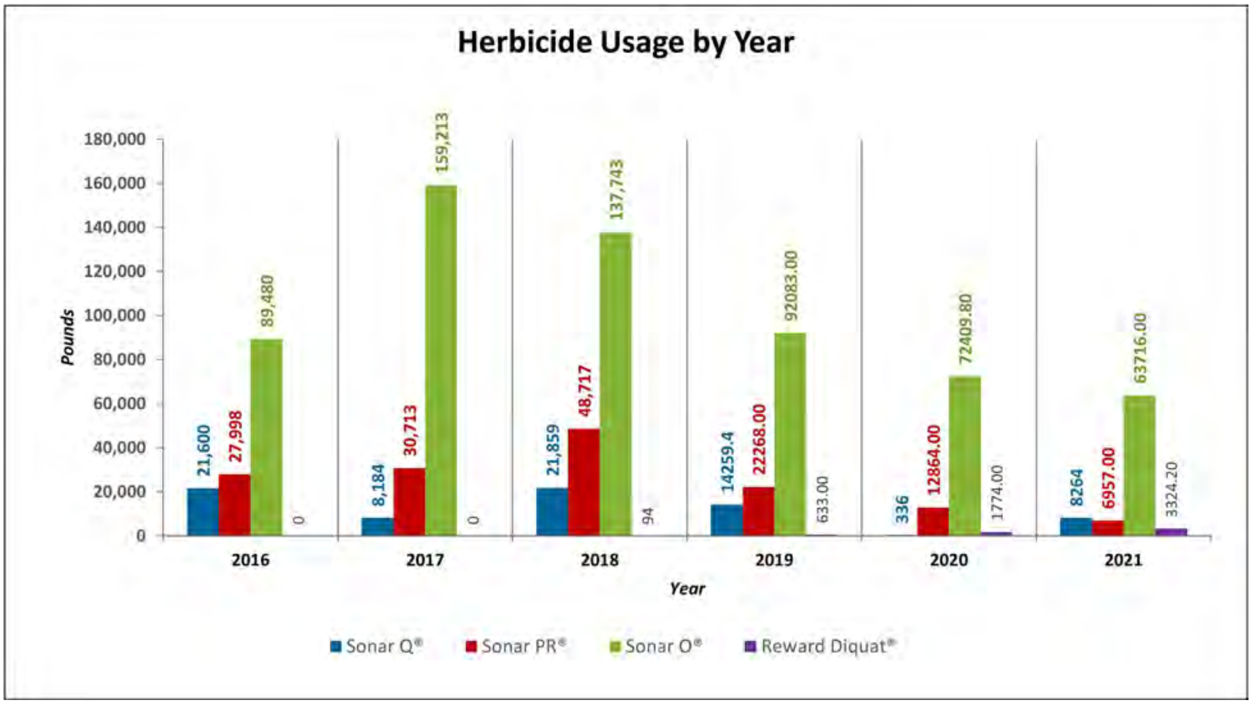


Figure 7. SAV Herbicide usage by year for 2016 to 2021

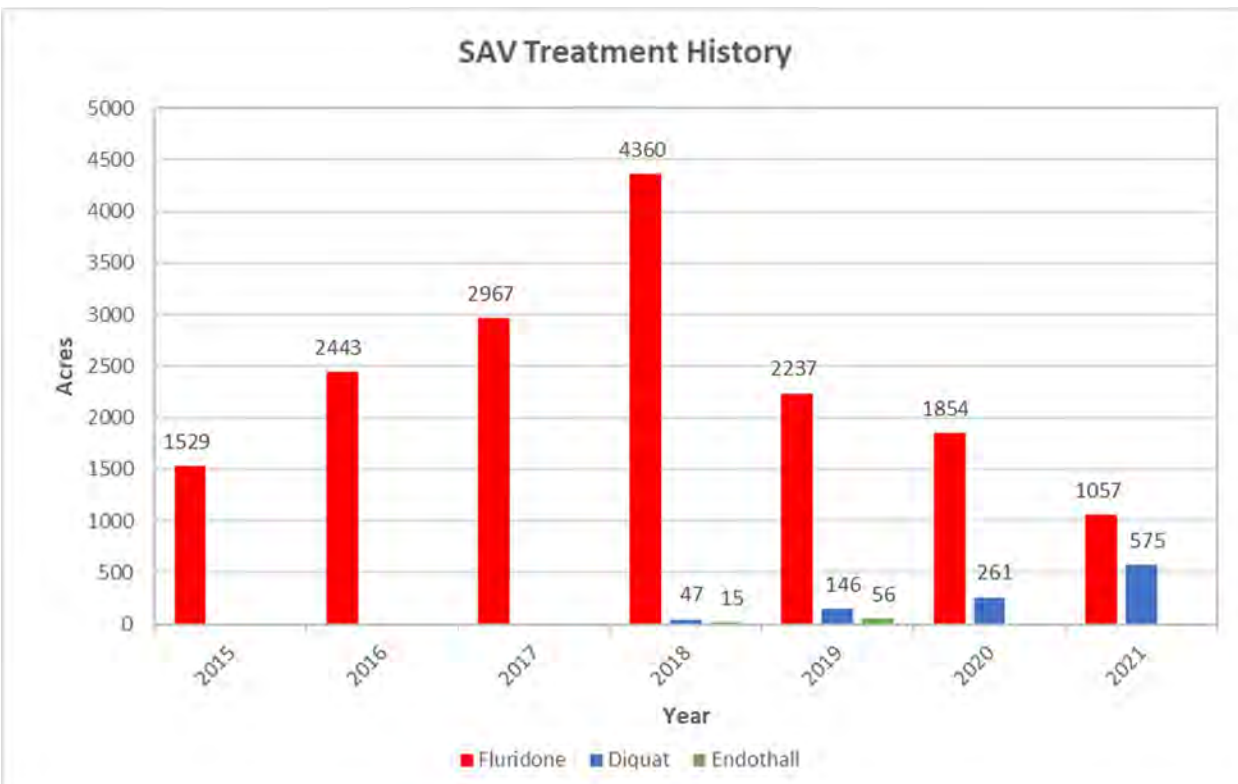


Figure 8. Number of acres of SAV treated from 2015 to 2021

5.3 Monitoring Data and Laboratory Results

5.3.1 NPDES Results

In 2021, a total of seven sites within the legal Delta were selected as monitoring sites for the SAV and FAV Programs. Field monitoring data and lab results collected, in compliance with the NPDES permit and BiOps, are summarized in **FAV Appendix E** and **SAV Appendix B.** The 2021 NPDES sites can be found in **Tables 4-3** (SAV) and **4-4** (FAV). The NPDES permit (General Permit No. CAG990005, Water Quality Order No. 2013-0002-DWQ), effective on December 1, 2013, contains sampling requirements that are materially less than what has been historically measured, in terms of frequency of measurement. To ensure that the AIPCP maintains environmental quality measures and meets federal ESA requirements, and that monitoring provides independent statistical validity, DBW aims to maintain a more thorough monitoring plan as resources will allow.

A total of 87 samples were collected during the 2021 treatment season.

Dissolved Oxygen, Turbidity and pH

The average of the measurements taken at “A” (treatment area) and “C” (control site) locations on the sampling day in question will constitute an average natural against which the receiving water “B” (downstream location) measurements will be compared (refer to maps in **FAV Appendix E** and **SAV Appendix B.**

Dissolved Oxygen

There were no occurrences where DO concentrations were between 3.00 mg/L and the Basin Plan limit (5.00 to 8.00 mg/L, depending on location) during FAV NPDES monitoring. All DO levels measured during FAV NPDES monitoring and sampling efforts in 2021 were between 6.61 mg/L and 19.24 mg/L. The high DO reading (i.e., 19.24 mg/L) was likely a result of widespread, submersed algae and shallow water at the sampling point. There were no occurrences where DO concentrations were below the basin plan limit (5.00 to 8.00 mg/L, depending on location) and above 3.00 mg/L during SAV NPDES monitoring. All fluridone and diquat treatment DO levels measured during SAV NPDES monitoring and sampling efforts in 2020 were between 7.17 mg/L and 11.64 mg/L.

There were no observations of injured or impacted wildlife during follow-up visits.

Turbidity

As per Basin Plan standards for turbidity, waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses. Increases in turbidity attributable to controllable water quality factors shall not exceed the limits.

There were no occurrences where turbidity levels exceeded Basin Plan limits (i.e., increased greater than 20 percent where natural turbidity is between 5 and 10 NTUs, or 1 NTU where natural turbidity is between 0 and 5 NTUs) during FAV NPDES monitoring. All turbidity readings in receiving waters were below the respective average naturals. There were twelve occurrences in SAV NPDES sampling events where the turbidity increased more than 1 NTU.

Monitoring at Sand Mound Slough shows an increase from 1.87 NTU pre-treatment to 7.91 NTU post treatment. Delta Coves shows an increase of more than 1 NTU from the .68 NTU pre-treatment measurement in every post treatment sampling event which occurred once a week for 10 weeks after treatment. Long Island Slough shows an increase from 1.62 NTU pre-treatment to 3.39 NTU post treatment.

Turbidity ranges fluctuate significantly due to activities that take place in the water such as swimming, boating, skiing and anything that may disturb sediment in the waterbody. Treatment sites consist of very shallow waterbodies where boat propellers often stir up sediment just by navigating to the site. Sites also include ski runs and high traffic areas that are often used for recreation. Changes to turbidity in post treatment data may have been caused by natural waterway characteristics or propeller wash from the sampling boat. Pre-treatment sampling for Delta Coves shows turbidity level differences of more than the allowed 1 NTU range, showing a natural variation of greater than 1 NTU without treatment interference. For future data collection, the sampling boat will be shut off so that sediment from propeller wash or boat movement will have time to settle. If the SAV Program was responsible for the turbidity violations, the effects were expected to be temporary due to the tidal nature of the Delta, varying hydrodynamics and periodic mixing of the water column. There were no injured or impacted species of concern observed during post-treatment follow-up monitoring.

PH

The Basin Plan Limit for pH shall not cause the ambient pH in the receiving water to fall below 6.50 or exceed 8.50.

There were no occurrences where pH fell below 6.50 or exceeded 8.50 in receiving waters during FAV NPDES monitoring. The pH levels in receiving waters ranged between 7.66 and 8.23.

One fluridone monitoring site reached pH levels that did not comply with Basin Plan limits during SAV NPDES monitoring. pH levels of fluridone treatments ranged from 6.94-8.85. pH levels for diquat treatments ranged from 7.47-8.43.

In Delta Coves, post treatment pH levels exceeded the maximum 8.50 stated in the Basin Plan Limit for four weeks. pH levels exceeding the Basin Plan Limit ranged from 8.51-8.85. Weekly samples were taken until pH levels fell within Basin Plan Limits. Factors that may affect pH measurements are weather, stratification of the waterbody, wastewater discharge, and runoff from agricultural areas and communities. Delta Coves is located in the middle of a community with extensive landscaping.

There were no injured or impacted species of concern observed during post-treatment follow-up monitoring.

5.3.2 Herbicide Residue Concentrations

Maximum residue limits are based on EPA municipal drinking water standards. Herbicide residue shall not exceed the following concentrations in receiving waters or Municipal and Domestic Supply (MUN) waters (**Table 4**).

Table 5-2. Receiving water limits for herbicides

Herbicide Active Ingredient	Maximum Concentration (MUN)
2,4-D	70 ppb
Diquat	20 ppb
Endothall	100 ppb
Fluridone	560 ppb
Glyphosate	700 ppb
Imazamox	No receiving water limit

** Municipal and Domestic Supply = MUN*

All herbicide residue concentrations at receiving water locations were either not detected or were below receiving water limits as specified in the NPDES permit.

FLURIDONE WATER SAMPLING RESULTS

For best efficacy of the treatment, the intent is to maintain a fluridone concentration in the water column at the treatment site of between 1.5 and 3.5 ppb.

DBW collected 981 fluridone water samples during the 2021 treatment season. In each instance where the residue level exceeded the target of 5 ppb, adjustments were made to the amount of fluridone treated the following week by either skipping a week of treatment or reducing the rate of fluridone used which usually resulted in a reduction in the residue to within range limits.

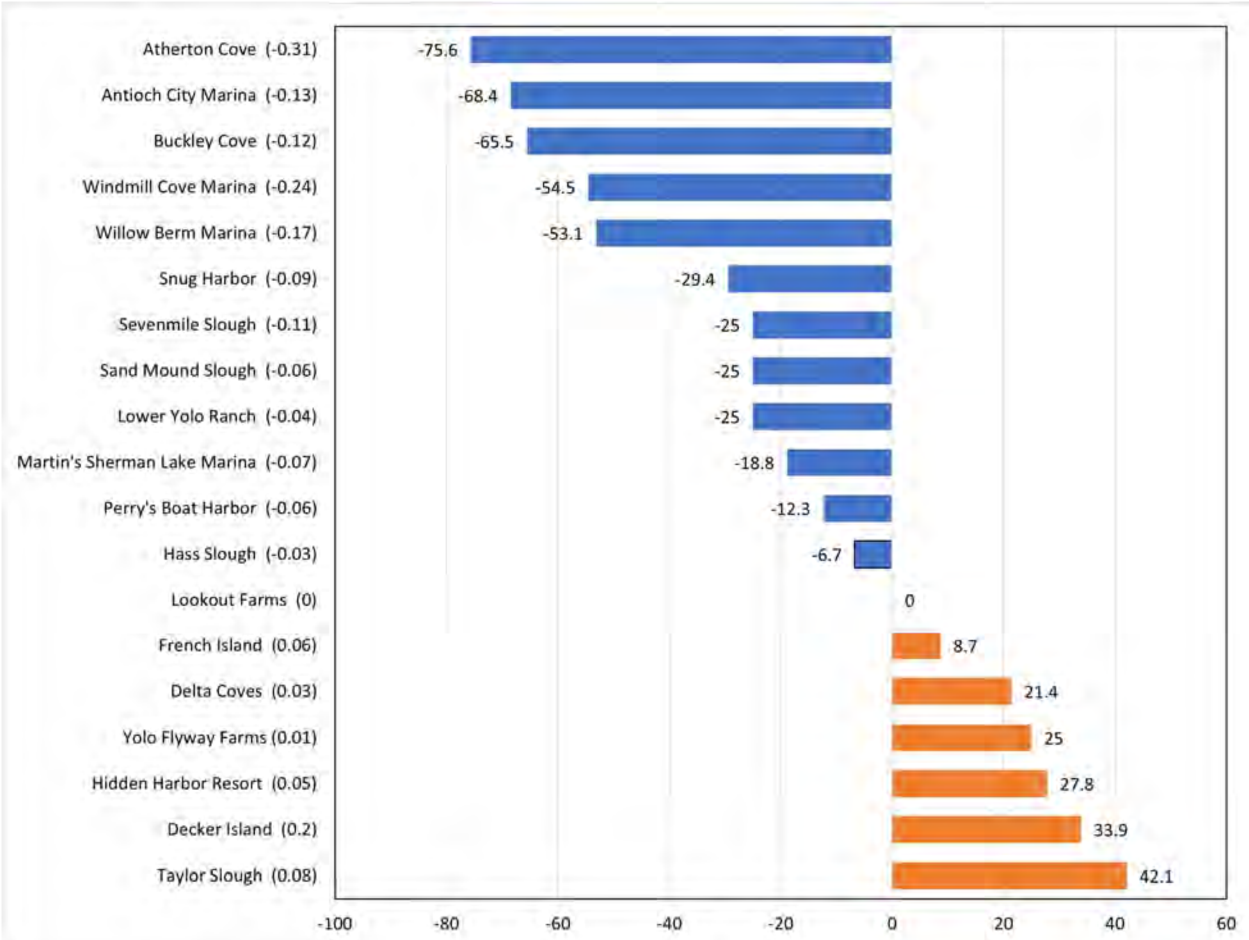


Figure 10a. Graph depicting the mean percent change in biovolume in Fluridone sites between pre- and post-treatment.

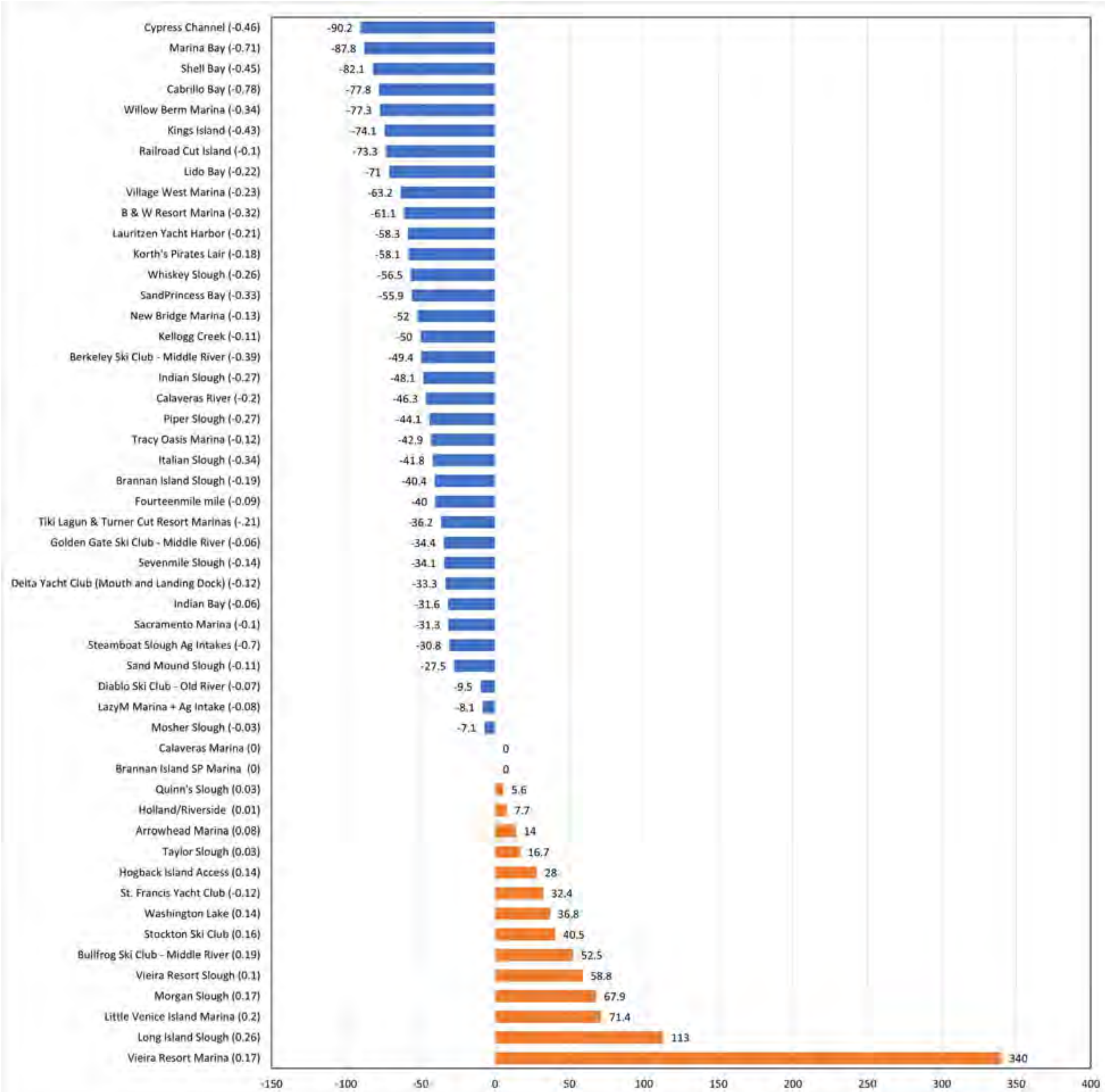


Figure 10b. Graph depicting the mean percent change in biovolume in Diquat sites between pre- and post-treatment.

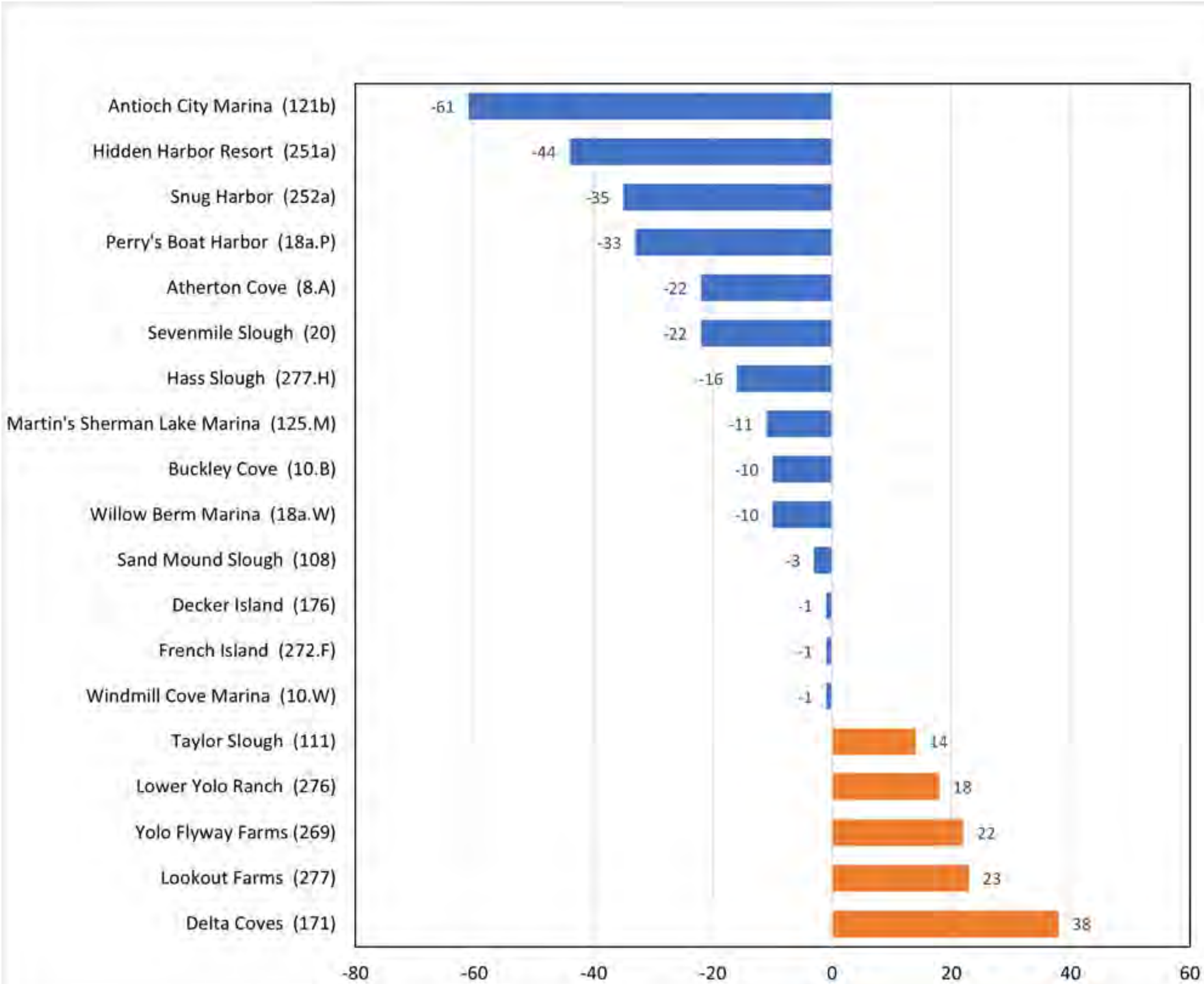


Figure 11a. Graph depicting the mean percent change in SAV cover in Fluridone sites between pre- and post-treatment.

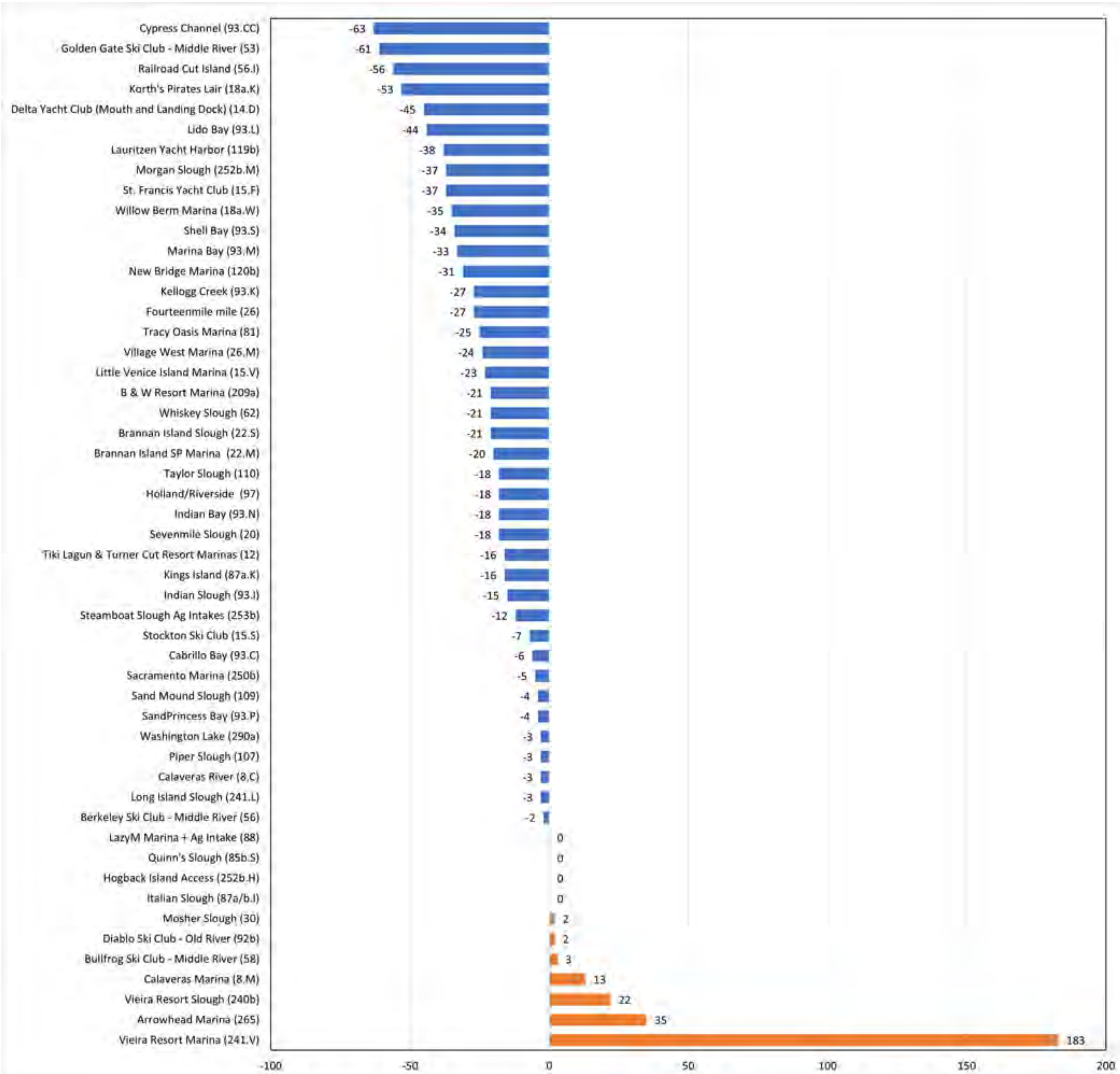


Figure 11b. Graph depicting the mean percent change in SAV cover in Diquat sites between pre- and post-treatment.

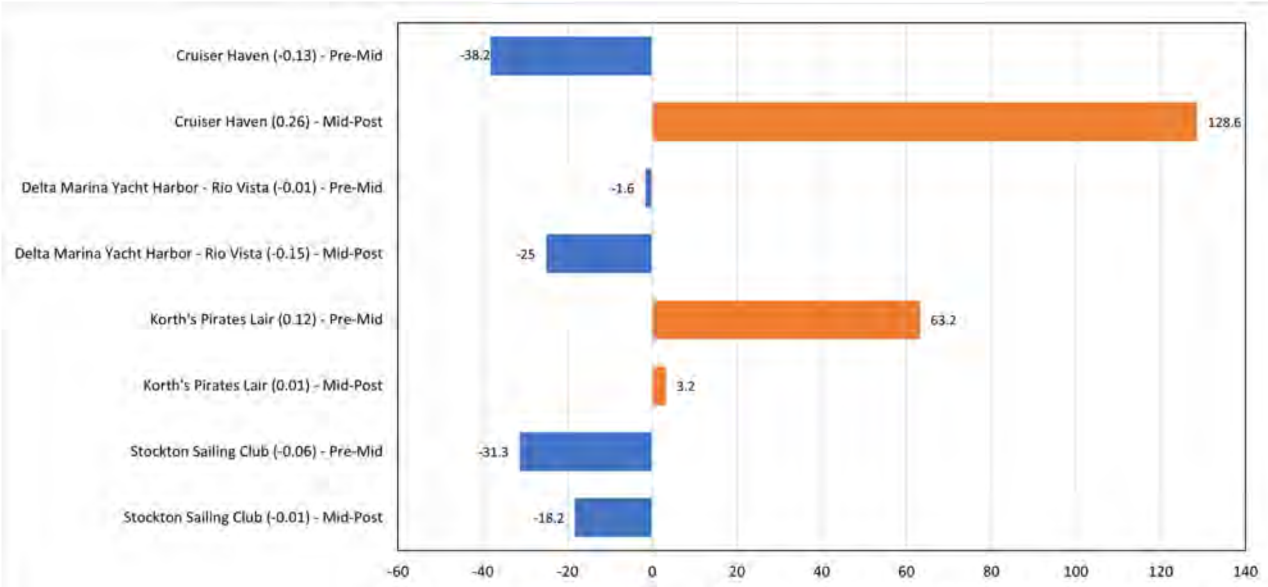


Figure 12a. Graph depicting the mean percent change in biovolume in split sites.

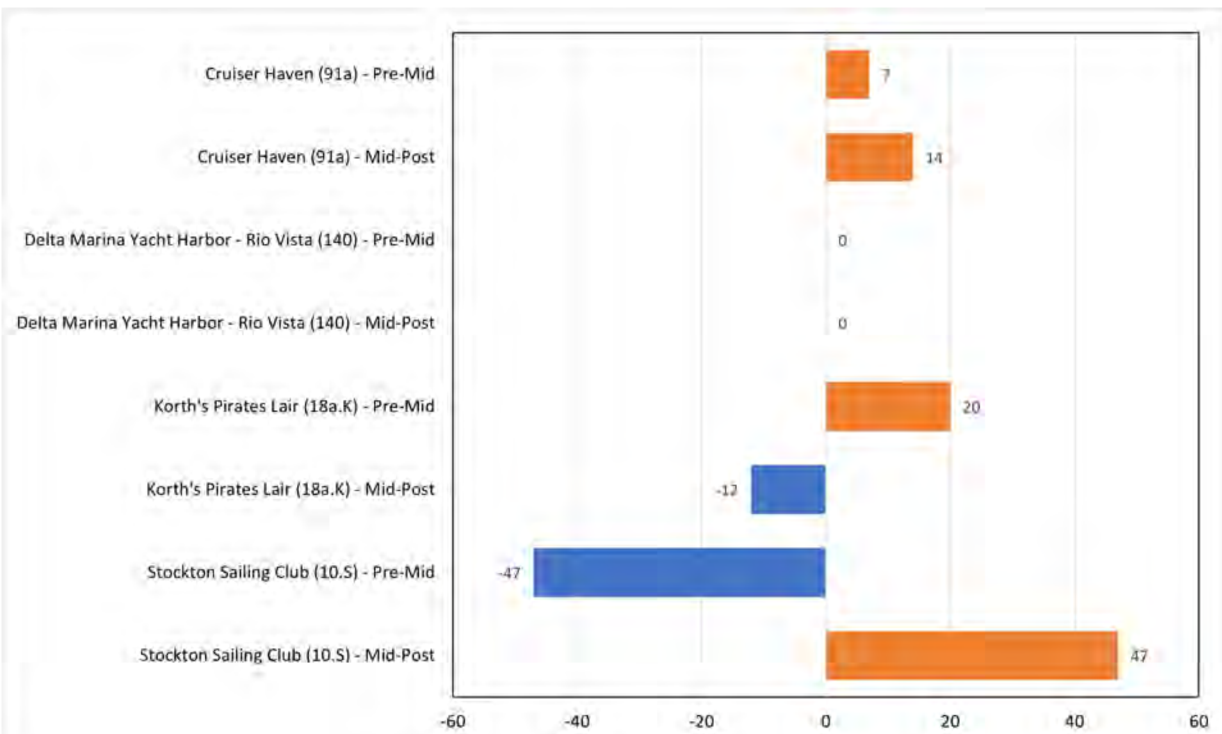


Figure 12b. Graph depicting the mean percent change in SAV cover in split sites.

5.3.3 SAV Point Sample Monitoring

Results and Conclusion

Analysis was only performed for the overall percentages of each of the species collected while rake pulling. Below are the results between the rake pulls conducted pre- and post-treatment.

Table 5-3a. Rake Pull Results Summary for Rake Coverage in Fluridone Sites

	How Much Total?	Coontail	Curlyleaf PW	Egeria	Eurasian watermilfoil	Fanwort
2021 Pre Fluridone	40.57	5.3	0.12	34.79	0.05	0.31
2021 Post Fluridone	53.8	11.42	0.77	40.33	1.16	0.12
% Change	32.61%	115.47%	541.67%	15.92%	2220.00%	-61.29%
Difference in Full Rake Pulls	13.23	6.12	0.65	5.54	1.11	-0.19

Table 5-3a. Rake Pull Results Summary for Rake Coverage in Diquat Sites

	How Much Total?	Coontail	Curlyleaf PW	Egeria	Eurasian watermilfoil	Fanwort
2021 Pre Diquat	115.47	20.4	15.71	72.81	5.18	1.37
2021 Post Diquat	56.37	8.35	0.49	42.87	1.57	3.09
% Change	-51.18%	-59.07%	-96.88%	-41.12%	-69.69%	125.55%
Difference in Full Rake Pulls	-59.1	-12.05	-15.22	-29.94	-3.61	1.72

Table 5-3a. Rake Pull Results Summary For Rake Coverage in Split Treated Sites

	How Much Total?	Coontail	Curlyleaf PW	Egeria	Eurasian watermilfoil	Fanwort
2021 Pre Split	5.89	0.03	0	5.66	0.1	0.1
2021 Post Split	9.27	2.92	0.01	6.34	0	0
% Change	57.39%	9633.33%	100.00%	12.01%	-100.00%	-100.00%
Difference in Full Rake Pulls	3.38	2.89	0.01	0.68	-0.1	-0.1

Table 5-3a. Rake Pull Results Summary For Rake Coverage For All Treated Sites

	How Much Total?	Coontail	Curlyleaf PW	Egeria	Eurasian watermilfoil	Fanwort
2021 Pre All	161.93	25.73	15.83	113.26	5.33	1.78
2021 Post All	119.44	22.69	1.27	89.54	2.73	3.21
% Change	-26.24%	-11.82%	-91.98%	-20.94%	-48.78%	80.34%
Difference in Full Rake Pulls	-42.49	-3.04	-14.56	-23.72	-2.6	1.43

The "% Change" amounts for each AIPCP controlled plant are based on the change in recorded plant observations from the post rake pull surveys in relation to the pre rake pull surveys. The term "full rake pull" is equivalent to one (1) rake pull filled to 100% or 1.00 rake pull. Thus, the "Difference in Full Rake Pulls" numbers are the physical amounts of observed plant differences between post and pre rake pull surveys.

The largest reduction in AIPCP controlled plants across all fluridone, diquat, and split treatment sites occurred in Curlyleaf pondweed with a total decrease of 91.98% (14.56 full rake pulls), followed by Eurasian watermilfoil by 48.78% (2.6 full rake pulls), and Egeria by 20.94% (23.72 full rake pulls). The overall percentage of AIPCP controlled plants observed during rake pulls also decreased by 26.24% (42.49 full rake pulls).

Fluridone treatment sites experienced minimal increases in most AIPCP controlled plants with a total of 32.61% (13.23 full rake pulls). Although individual percentage changes for Eurasian watermilfoil, Curlyleaf pondweed, and Coontail are all in excess of 100%, the actual difference between pre and post amounts recorded are 1.11, 6.12, and 0.65 full rake pulls respectively. Egeria in fluridone treatments sites had a 15.92% (5.54 full rake pulls) increase.

Diquat treatment sites had more significant decreases across AIPCP controlled plants, with an overall decrease of 51.18% (59.10 full rake pulls). Curlyleaf pondweed decreased by 96.88% (15.22 full rake pulls), Eurasian watermilfoil by 69.69% (3.61 full rake pulls), and Coontail by 59.07% (12.05 full rake pulls). Egeria had a decrease of 41.12% and the largest decrease of 29.94 full rake pulls between pre and post recorded amounts.

Split treatment sites also experienced minimal increases for most AIPCP controlled plants, but less than fluridone sites. The largest increase was Coontail by 9633.33% but actually a difference of only 2.89 full rake pulls. Curlyleaf pondweed also had an increase of 100%, but actually only 0.01 of a full rake pull. Eurasian watermilfoil and Fanwort, both had 100% decreases (0.10 full rake pulls each).

5.3.4 FAV Elderberry Survey Results

Results and Conclusion

In DBW's 2021 surveys, a total of 17 elderberry shrubs were identified during the systematic site surveys.

Of the 17 plants surveyed 13 of them were found to be in good condition (<25% exhibiting negative factors), 3 were in fair condition (25 to 75% exhibiting negative factors) and 1 was found to be in poor condition (>75% exhibiting negative factors).

Sites are continuing to be systematically surveyed to provide Aquatic Herbicide Applicators with a comprehensive GIS layer of all elderberry shrubs within the Delta.

5.3.5 FAV Point-Intercept Sampling

Results and Conclusion

In total, 520 point-intercept samples were collected over 17 sites (**Table 5-4 and FAV Appendix F**) during September 2021. Point-intercept sampling points documented 9 unique species and 18 unique species within a 3-meter vicinity of the sampling points (**Table 5-5**). Site 49 (Middle River) was removed as a sampling site, as a partial dataset is only possible due to issues with accessibility. Site 79 (Old River – Tracy), located in the high-profile southern region of the Delta, replaced Site 49 to ensure that the overall sample size did not decrease. Furthermore, Site 176 (Decker Island) was added as a sampling site to 1) represent and assess efforts related to the FRP and 2) collect baseline data for potential future Demonstration Investigation Zone (DIZ) efforts.

Table 5-4. 2021 FAV Point-Intercept Sites Sampled

Site Number	Site Name
6	French Camp Slough
15*	Columbia Cut*
28	Fourteen Mile Slough
32	Disappointment Slough
37	White Slough
65*	Latham Slough*
76†	Old River – Tracy†
92*	Old River – Orwood*
97	Rock Slough
100	Connection Slough
109*	Sandmound Slough*
112	Dutch Slough
176*†	Decker Island*†
203	Sycamore Slough
216	Snodgrass Slough
267	Cache Slough
300	San Joaquin River

**Sites additionally sampled on a seasonal basis*
†Sites added during the 2021 season

Table 5-5. 2021 FAV Point-Intercept Sampling Species Documented in September 2021

Species	Number of Intercepts		Number of Sites Present		In Vicinity
	Count	*Frequency*	*Count*	*Frequency*	
alligatorweed (ALPH)	2	0.38%	5	29.41%	23
bulrush spp. (SCHOE6)	29	5.58%	15	88.24%	213
bur marigold (BILA)	7	1.35%	10	58.82%	38
cattail spp. (TYPHA)	1	0.19%	14	82.35%	68
pennywort spp. (HYDRO2)	3	0.58%	13	76.47%	46
seep monkeyflower (MIGU)	0	0.00%	1	5.88%	1
smartweed spp. (POLYG4)	1	0.19%	11	64.71%	45
speedwell spp. (VERON)	0	0.00%	1	5.88%	1
spongeplant (LILA7)	17	3.27%	12	70.59%	180
water hyacinth (EICR)	104	20.00%	17	100.00%	368
water primrose spp. (LUDWI)	59	11.35%	17	100.00%	244
arrowhead spp. (SAGIT)	0	0.00%	2	11.76%	5
calla lily (ZAAE)	0	0.00%	1	5.88%	1
elderberry (SANIC5)	0	0.00%	0	0.00%	0
giant reed (ARDO4)	0	0.00%	2	11.76%	2
pampas grass (CORTA)	0	0.00%	3	17.65%	5
purple loosestrife (LYSA2)	0	0.00%	0	0.00%	0
red sesbania (SEPU7)	0	0.00%	1	5.88%	1
salt cedar (TAMAR2)	0	0.00%	0	0.00%	0
wild taro (COES)	0	0.00%	0	0.00%	0
woolly rose-mallow (HILAO)	0	0.00%	1	5.88%	2
yellowflag iris (IRPS)	0	0.00%	10	58.82%	17
Open/Inaccessible	297	57.12%	17	100.00%	
Total Intercepts/Samples:	520				

Table 5-6. Direct Comparison of September 2021 Point-Intercept Data to September 2020 Point-Intercept Data

Species	Number of Intercepts		Number of Sites Present		In Vicinity	
	Difference	*% Change*	*Difference*	*% Change*	*Difference*	*% Change*
ALPH	2	N/A	2	66.67%	16	229%
SCHOE6	-3	-9.38%	4	36.36%	31	17%
BILA	4	133.33%	7	233.33%	5	15%
TYPHA	-2	-66.67%	11	366.67%	19	39%
HYDRO2	0	0.00%	10	333.33%	12	35%
MIGU	0	N/A	1	N/A	1	N/A
POLYG4	-3	-75.00%	9	450.00%	-13	-22%
VERON	0	N/A	1	N/A	1	N/A
LILA7	9	112.50%	7	140.00%	33	22%
EICR	11	11.83%	2	13.33%	62	20%
LUDWI	3	5.36%	4	30.77%	28	13%
SAGIT	0	N/A	0	0.00%	-4	-44%
ZAAE	0	N/A	1	N/A	1	N/A
SANIC5	0	N/A	0	N/A	0	N/A
ARDO4	0	N/A	2	N/A	2	N/A
CORTA	0	N/A	1	50.00%	3	150%
LYSA2	0	N/A	0	N/A	0	N/A
SEPU7	0	N/A	1	N/A	1	N/A
TAMAR2	0	N/A	0	N/A	0	N/A
COES	0	N/A	-2	-100.00%	-3	-100%
HILAO	0	N/A	0	0.00%	1	100%
IRPS	0	N/A	3	42.86%	0	0%
Open/Inaccessible	39	15.12%				

Water hyacinth was sampled at the highest frequency during our annual sampling effort in September, occurring at 104 out of 520 sampling points, or 20.00% of all sampling points. Water primrose was sampled at the second highest frequency, occurring at 59 out of 520 sampling points, or 11.35% of all sampling points. These two species also occurred at all sampling sites, considering both intercept samples and species noted in vicinity. FAV species under DBW's jurisdiction were sampled at 182 out of 520 sampling points, or 35.00% of all sampling points. This is a decrease of 11.00% percent compared to 2019; however, this is similar to the 34.00% observed in 2020. A direct comparison of the 2021 and 2020 data can be found in **Table 5-6;** however, it is important to note that the overall sample size increased from 460 in 2020 to 520 to 2021.

The most common species within the 3-meter vicinity of each sampling point were water hyacinth, water primrose, bulrush, and spongeplant. Additional species, including other invasive or rare species, did not occur at any particular sampling point, but were within vicinity of the respective sampling point (**Table 5-5** from arrowhead spp. to yellowflag iris). Maps with information on where each sampling point was located and what species was sampled can be found in **FAV Appendix F**.

To statistically compare the 2021 and 2020 data, 2x2 Chi-square tests were conducted for all primary sampling species (**Tables 5-7** through **5-15** below). There were no significant differences between the 2021 and 2020 datasets ($p > 0.05$). Tables were not included for seep monkeyflower (MIGU) and speedwell (VERON), as they were not directly sampled either year.

Table 5-7. 2 x 2 Comparison of 2020 and 2021 Point-Intercept Data on Alligatorweed Occurrence

Year	ALPH Present		ALPH Absent		Total
	n	%	*n*	%	
2020	0	0.00%	460	100.00%	460
2021	2	0.38%	518	99.62%	520
Total	2		978		980

$\chi^2_{(1)} = 1.77$ p value = 0.18

Table 5-8. 2 x 2 Comparison of 2020 and 2021 Point-Intercept Data on Bulrush spp. Occurrence

Year	SCHOE6 Present		SCHOE6 Absent		Total
	n	%	*n*	%	
2020	32	6.96%	428	93.04%	460
2021	29	5.58%	491	94.42%	520
Total	61		919		980

$\chi^2_{(1)} = 0.80$ p value = 0.37

Table 5-9. 2 x 2 Comparison of 2020 and 2021 Point-Intercept Data on Bur Marigold Occurrence

Year	BILA Present		BILA Absent		Total
	n	%	*n*	%	
2020	3	0.65%	457	99.35%	460
2021	7	1.35%	513	98.65%	520
Total	10		970		980

$\chi^2_{(1)} = 1.16$ p value = 0.28

Table 5-10. 2 x 2 Comparison of 2020 and 2021 Point-Intercept Data on Cattail spp. Occurrence

Year	TYPHA Present		TYPHA Absent		Total
	n	%	*n*	%	
2020	3	0.65%	457	99.35%	460
2021	1	0.19%	519	99.81%	520
Total	4		976		980

$\chi^2_{(1)} = 1.27$ p value = 0.26

Table 5-11. 2 x 2 Comparison of 2020 and 2021 Point-Intercept Data on Pennywort spp. Occurrence

Year	HYDRO2 Present		HYDRO2 Absent		Total
	n	%	*n*	%	
2020	3	0.65%	457	99.35%	460
2021	3	0.58%	517	99.42%	520
Total	6		974		980

$\chi^2_{(1)} = 0.02$ p value = 0.88

Table 5-12. 2 x 2 Comparison of 2020 and 2021 Point-Intercept Data on Smartweed spp. Occurrence

Year	POLYG4 Present		POLYG4 Absent		Total
	n	%	*n*	%	
2020	4	0.87%	456	99.13%	460
2021	1	0.19%	519	99.81%	520
Total	5		975		980

$\chi^2_{(1)} = 2.21$ p value = 0.14

Table 5-13. 2 x 2 Comparison of 2020 and 2021 Point-Intercept Data on Spongeplant Occurrence

Year	LILA7 Present		LILA7 Absent		Total
	n	%	*n*	%	
2020	8	1.74%	452	98.26%	460
2021	17	3.27%	503	96.73%	520
Total	25		955		980

$\chi^2_{(1)} = 2.30$ p value = 0.13

Table 5-14. 2 x 2 Comparison of 2020 and 2021 Point-Intercept Data on Water Hyacinth Occurrence

Year	EICR Present		EICR Absent		Total
	n	%	*n*	%	
2020	93	20.22%	367	79.78%	460
2021	104	20.00%	416	80.00%	520
Total	197		783		980

$\chi^2_{(1)} = 0.01$ p value = 0.93

Table 5-15. 2 x 2 Comparison of 2020 and 2021 Point-Intercept Data on Water Primrose spp. Occurrence

Year	LUDWI Present		LUDWI Absent		Total
	n	%	*n*	%	
2020	56	12.17%	404	87.83%	460
2021	59	11.35%	461	88.65%	520
Total	115		865		980

$\chi^2_{(1)} = 0.16$ p value = 0.69

Additional sampling was conducted on a seasonal basis at select sites (**Table 5-4**). Each seasonal sampling effort consisted of 160 samples. While open water comprised the majority of the samples in all months, there was an overall decrease in open water samples from March to November (114 samples to 67 samples, respectively). Water primrose (LUDWI) samples peaked in May and June, then declined in September and November. Conversely, water hyacinth (EICR) samples decreased from March to May, then increased as the year progressed (**Figure 12**). Other FAV species under DBW's jurisdiction, alligatorweed (ALPH) and spongeplant (LILA7), remained relatively and consistently minimal during the seasonal sampling effort.

Figure 12. 2021 Species Documented at Select Sites During Seasonal FAV Point-Intercept Sampling

Any inaccessible sampling points were documented and may be moved to accessible locations for sampling efforts in 2022, if necessary. In addition, point-intercept sampling efforts in 2022 will include seasonal sampling in January to capture early mid-winter data and inform treatment prioritization. Further summarization and analysis of other collected data (e.g.., plant height, water depth, and species diversity) will occur in the future to identify any trends from year to year, within or between species, and within or between different locations (i.e., sites or water depth ranges).

5.3.6 FAV Photo Point Monitoring

Results and Conclusion

The sites that saw noteworthy increase in FAV from Spring to Fall were the following: Fourteenmile Slough, Honker Cut, Middle River, Trapper Slough, West Side Irrigation District, Snodgrass Slough, Prospect Island, Paradise Cut, Barker Slough, and Walthall Slough.

The sites that saw the highest increase of FAV since 2018 were Barker Slough, and Paradise Cut. Barker Slough doubled in FAV from Spring to Fall. In the other hand, Paradise Cut more than quadrupled in FAV from Spring to Fall. Overall, across the board there was a doubling of FAV in most of the sites.

Sites like Sevenmile Slough, Walthall Slough, Middle River, and West Side Irrigation District remained consistent with the overall patterns of FAV growth over the past few years. It is important to note that Sevenmile Slough historically has been a nursery site for FAV and could be attributed to low flow since site is land locked.

Cruiser Haven Marina in Old River had an increase in FAV of 15% from spring to summer. Herbicide treatments occurred in the late summer, and by fall there was a 15% reduction of FAV.

Other sites with signs of herbicide treatments in the late fall were Fourteenmile Slough, Honker Cut, Middle River, Paradise Cut, Sugar Slough, and Disappointment Slough. See figure 5-16 for the 2021 FAV percent cover. See **FAV Appendix H, Figure H-1** for photo point monitoring photos and charts showing the fav present at each of the locations.

The highest variations in temperature and dissolved oxygen were found in Snodgrass Slough (site 216) and Walthall Slough (site 301) and could be attributed to the increase in FAV at these sites. For example, Walthall Slough was covered in water hyacinth and this plant is known to decrease dissolved oxygen levels. Toe Drain (site 290) shows a dramatic decrease to zero, but that is likely due to the location drying up; therefore, no temperature and dissolved oxygen was collected, and the value was set to zero.

Table 5-16. 2021 Floating Aquatic Vegetation (FAV) Percent Cover Data

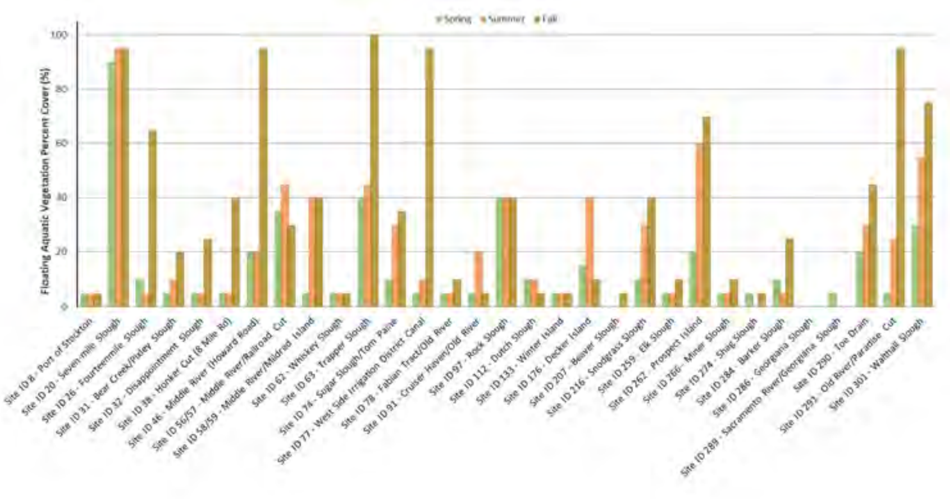


Table 5-17. 2021 Photo Point Monitoring Locations Temperature
For site names see table 5-6.

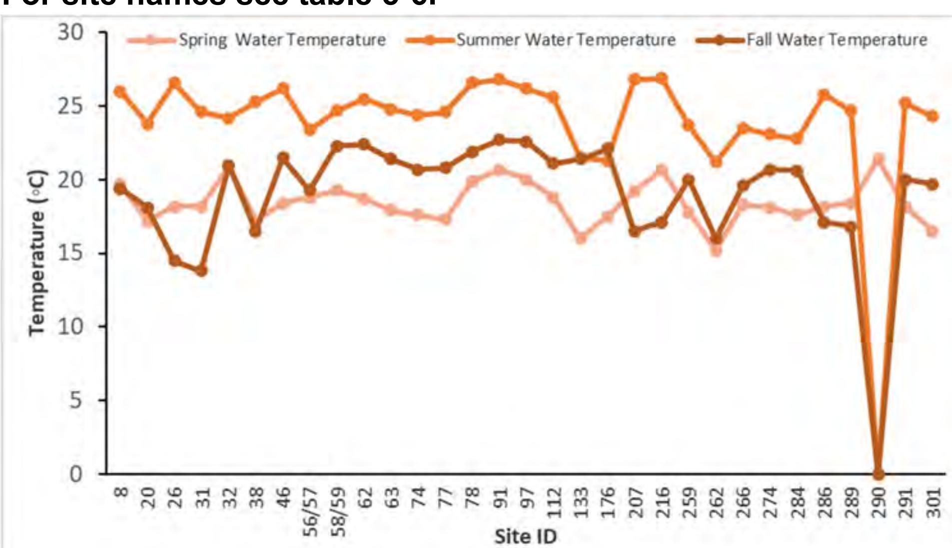


Table 5-18. 2021 Photo Point Monitoring Locations Dissolved Oxygen For site names see table 5-6.

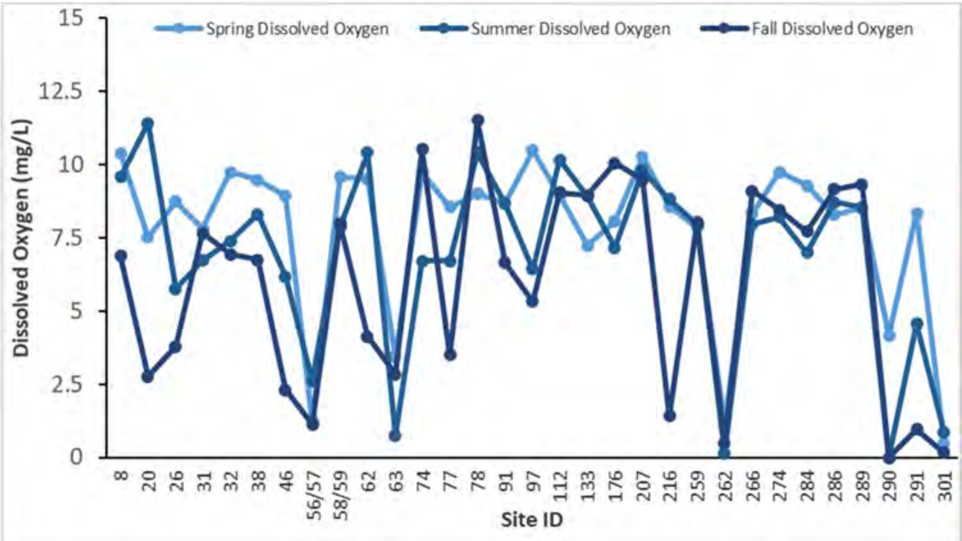


Table 5-19. Floating Aquatic Vegetation Ecology (FAV Appendix H, Figure H-2)

	Water Hyacinth	**S. American spongeplant**	**Uruguay Waterprimrose**	**Alligatorweed**	**Pennywort**
Growth Period	Spring to early Fall	Spring to Fall	Spring to late Fall	Late Spring to Fall	Late Summer
Ideal Temperature	20-35°C	20-30°C	20-30°C	15-30 °C	25°C-35°C

Conducting this type of visual monitoring was an effective way to inform management for when herbicide or mechanical controls were necessary at these sites. Although, there are some challenges that come with this type of monitoring. These challenges include bias in measurement interpretations, FAV hidden between other vegetation and/or other land features, obtaining statistically significant data, and/or size of sites, and/or distance from field of view.

5.3.7 Aquatic Pesticide Application Plan Effectiveness

The APAP describes aquatic pesticides and application methods used for the AIPCP. Herbicide application methods and BMPs were effective in maintaining herbicide residues in receiving water below the maximum concentration limits. In addition, all reporting requirements described in the APAP such as providing a Pest Control Recommendation (PCR), Notice of Intent (NOI) and public notification, were met. NOI were provided to County Agricultural Commissioners at least 24 hours before herbicide applications were made with 2,4-D. The NOI included descriptions, treatment locations, and application rates for restricted use materials in addition to all other herbicides used by the AIPCP. To improve public notifications outreach, DBW used weekly email notifications through the marketing platform called Constant Contact, available to anyone who subscribes to the distribution list from the DBW website.

5.4 Alternative Control Methods and Special Studies

5.4.1 Non-Herbicide Control

MECHANICAL REMOVAL

On October 23, 2015, CDFW and DBW executed a Streambed Alteration Agreement (or Routine Maintenance Agreement (RMA)) Notification No. 1600-2015-0132-R3, pursuant to section 1602 of the Fish and Game Code, for the mechanical removal of water hyacinth. This agreement was extended for five more years through December 31, 2024, and pertains only to the physical and mechanical removal of FAV. There was no mechanical removal of water hyacinth in 2020 and 2021. DBW is in the process of amending the RMA to include mechanical harvesting of all FAV that DBW is authorized to control. Mechanical harvesting is expected to resume in 2022. Several sites that may have mechanical harvesting are: 8, 14, 15, 46, 50, 51, 76, 77, 78, 79, 109, 217, 270, 284, 290 and 291.

The RMA contains avoidance and minimization measures for fish and wildlife species of concern. Examples of these species include giant garter snake, Delta smelt, longfin smelt, Swainson’s hawk, burrowing owl, and western pond turtle. Before any work can commence, Environmental Scientists, approved by CDFW, conduct biological surveys in the project area to make sure there are no species of concern. In addition to biological surveys, a biological monitor must be on site to ensure no species of concern or their habitats are being or will be significantly affected by the FAV removal operation. DBW provides environmental awareness training to application crews.

BIOLOGICAL CONTROL

DBW assists Dr. Patrick Joseph Moran, research entomologist with the U.S. Department of Agriculture - Agricultural Research (USDA-ARS), with releases of the biological control agent, the water hyacinth planthopper (*Megamelus scutellaris*), for the control of water hyacinth in the Delta. This is part of a collaboration with the USDA-ARS to develop a long-term objective to control invasive aquatic plants as part of an Integrated Pest Management approach. In 2018-2019 the USDA received BiOps from USFWS and NMFS that include releases of the water hyacinth planthopper as a means for FAV control. Since 2018, a total of 490,000 planthoppers were released in the Delta.

Table 5-8 - 2020 FAV Water Hyacinth Planthopper Releases Site Locations

DBW Release Site(s)	Site Name Locations
31	Pixley Slough
37	White Slough
63	Trapper-Whiskey Slough Junction
64	Trapper Slough ('Pond')
64	Trapper Slough ('Union Point')
84a	Salisbury Cove/Old River
200	Islemouth Slough/South Mokelumne River

In 2020, a total of 306,450 planthoppers were released, of which 122,077 were adults, in seven distinct DBW sites. Releases were conducted at four navigable sites between July 1, 2020 and August 26, 2020, including Pixley Slough, White Slough, Salisbury Cove/Old River, and Islemouth Slough/South Mokelumne River. A total of 200,110 hoppers, of which 59,485 were adults, were released at the four navigable sites. The releases were approximately equally divided between sites (i.e., approximately 50,027 hoppers, of which 14,871 were adults, per site). Two releases were completed by USDA-ARS at the Trapper-Whiskey Slough site, on April 22, 2020 and October 7, 2020. A total of 58,980 planthoppers were released at this site in 2020, of which 52,336 were adults. At the Trapper Slough – Pond and Trapper Slough – Union Point sites, one release was conducted at each site on September 17, 2020, including 37,304 planthoppers, of which 10,056 of which were adults (i.e., 18,652 per site, of which 5,028 were adults, per site). Each release site contained four separate release plots. All plots were marked with flagging tape and PVC pipe.

Field sampling in October 2020 and dissections of one plant per plot in December 2020 showed presence of planthopper adults and/or nymphs at six out of seven 2020 release sites. During this sampling period, planthoppers were observed in highest densities at Pixley Slough. No planthoppers were observed at White Slough. However, this may have been due to herbicide treatment conducted in the area during July 2020.

There were no additional releases at any new navigable sites in 2021. Excess planthoppers were released from land at the Trapper-Whiskey Slough Junction site between June 29, 2021 and November 23, 2021. An estimated 33,000 planthoppers were released. Sampling and monitoring of the 2020 release sites continued in 2021, with initial sampling occurring between May 20, 2021 and May 21, 2021, and field sampling and dissections occurring in July/August 2021 and October 2021. Six additional release sites from 2018 and/or 2019 were sampled in May 2021.

Initial sampling included the use of a "trashcan sampler" device, or a 33-gallon black plastic trashcan with the bottom removed and replaced with mesh. The sampler was pressed into water hyacinth mats until the plants were submerged, forcing the planthoppers to hop off the plants and onto the plastic. The four navigable sites had additional sampling points 15, 30, 45, and 60 meters (m) from the first plot and from the last plot, totaling 15 maximum possible sampling points per site. No planthoppers were found at 2018 and 2019 release sites. Planthoppers were found in low density at one 2020 release site, Pixley Slough.

Continued monitoring was only conducted for 2020 release sites. Although planthopper densities were low, monitoring indicated that the planthopper potentially established at Pixley Slough, Islemouth Slough/South Mokelumne River, and Trapper Slough – Pond. The planthopper may also be established at Trapper-Whiskey Slough Junction, but monitoring did not occur in October 2021 due to releases that were made in the same timeframe. The observed densities at Pixley Slough, Islemouth Slough/South Mokelumne River, and Trapper Slough – Pond are lower than the densities expected to be needed for impact to water hyacinth (i.e., 50 to 100 planthoppers per plant). The full 2021 Water Hyacinth Biological Control Report with more detailed sampling and monitoring results can be found in **Appendix G**.

No additional releases of the planthopper are planned for the 2022 season. Any further sampling and monitoring efforts in 2022 would focus on the three established planthopper sites. The USDA-ARS is continuing to investigate the potential for a cold-adapted biotype of the water hyacinth weevil (*Neochetina eichhorniae*) and the water hyacinth moth (*Niphograpta albiguttalis*).

5.4.2 Delta Smelt Resiliency Strategy

The Delta Smelt Resiliency Strategy (DSRS) is a science-based document that has been prepared by the State of California to voluntarily address both immediate and near-term needs of Delta Smelt, to promote their resiliency to drought conditions as well as future variations in habitat conditions (California Natural Resource Agency 2016). The primary objective of this strategy is to improve the status of Delta smelt. One of the goals to achieve the strategy objective is to reduce the levels of invasive species, both aquatic weeds and nonnative predators (California Natural Resources Agency 2016). DBW is partnered/involved in the DSRS to help achieve this goal.

5.4.3 Fish Restoration Program

The Fish Restoration Program (FRP) is based on an agreement, signed on October 18, 2010, between CDFW and DWR that addresses regulatory requirements for habitat restoration. The primary objective of the Fish Restoration Program Agreement is to implement specific alternatives and conditions from their associated BOs and Incidental Take Permits in the Delta, Suisun Marsh, and Yolo Bypass to benefit Delta smelt, Chinook salmon, and longfin smelt. Because aquatic invasive plants have the potential to negatively impact these restoration goals, DBW is partnered with DWR to conduct control activities and monitor aquatic invasive plants at specific FRP restoration sites.

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County Sheriffs
County Vector Control Districts
Delta Conservancy
Delta Protection Commission
Delta Stewardship Council
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National Aeronautics and Space Administration
National Oceanic and Atmospheric Administration – National Marine Fisheries Service
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Reclamation District 1601
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7 LITERATURE CITED

BioBase. 2013. User reference guide: ciBioBase vegetation algorithm version 5.2. Contour Innovations, Minneapolis, MN.

California Department of Fish and Wildlife (CDFW). 2020. "About Invasive Species In California." Accessed on March 30, 2020 at https://wildlife.ca.gov/Conservation/Invasives/About.

California Department of Parks and Recreation Division of Boating and Waterways (DBW). 2012. Water Hyacinth Control Program Biological Assessment. California Department of Parks and Recreation, Division of Boating and Waterways, Sacramento, CA.

California Department of Parks and Recreation Division of Boating and Waterways (DBW). 2014. Spongeplant Control Program Biological Assessment. California Department of Parks and Recreation, Division of Boating and Waterways, Sacramento, CA.

California Natural Resources Agency. 2016. Delta Smelt Resiliency Strategy (DSRS). Accessed 1 July 2018. <http://resources.ca.gov/delta-smelt-resiliency-strategy/>

California Regional Water Quality Control Board. 1998. Fourth Edition of the Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins. California Regional Water Quality Control Board, Central Valley Region, Sacramento, CA. ESRI 2011. ArcGIS Desktop: Release 10.4.1 Redlands, CA: Environmental Systems Research Institute.

Daubenmire, R.F. 1959. A canopy--coverage method of vegetational analysis. *Northwest Science* 33: 43-64.

Delta Stewardship Council. 2018. Collaboration Guidelines for Delta AIP Control. Found online at https://coveredactions.deltacouncil.ca.gov/services/download.ashx?u=8df8cc2a-55f0-4f2d-bb3e-c03da0b84a1a

Hansen, Eric C. 2002. Evaluation of Giant Garter Snake (*Thamnophis gigas*) Habitat Within California' Department of Boating and Waterways Aquatic Weed Control Division's Water Hyacinth and Egeria densa Control Program Service Areas.

Kleinn C. 2000. Estimating metrics of forest spatial pattern from large area forest inventory cluster samples. Forest Science 46(4):548-557.

Lowrance high-definition system consumer echosounder, Lowrance, 12000 E. Skelly Dr., Tulsa, OK 74128. Accessed 8 January, 2020 <www.lowrance.com>

Madsen, J. D. 1999. "Point intercept and line intercept methods for aquatic plant management." *ARCRP Technical Notes Collection* (TN APCRP-M1-02). U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/aqua.

Moran, Patrick. *DRAAWP Tech Wrap-Up Meeting: Biological Control.* USDA-ARS Invasive Species and Pollinator Health Research unit. PDF File. 15 October 2020.

Navico BioBase, Navico Inc., 2800 Hamline Ave. N #223, Roseville, MN 55113. Accessed online at www.cibiobase.com

Radomski, Paul & Holbrook, Beth. (2015). A comparison of two hydroacoustic methods for estimating submerged macrophyte distribution and abundance: A cautionary note. Journal of Aquatic Plant Management. 53. 151-159.

USDA Forest Service. "Photo Point Monitoring." *Photo Point Monitoring - Forest Service*, USDA Forest Service Remote Sensing Applications Center, www.fs.fed.us/eng/rsac/invasivespecies/documents/Photopoint_monitoring.pdf.