*Egeria densa* Control Program

# Biological Assessment

December 31, 2012

*A program for effective control of* Egeria densa *in the Sacramento-San Joaquin Delta and its tributaries.*

*Egeria densa* Control Program

*A program for effective control of* Egeria densa *in the Sacramento-San Joaquin Delta and its tributaries.*

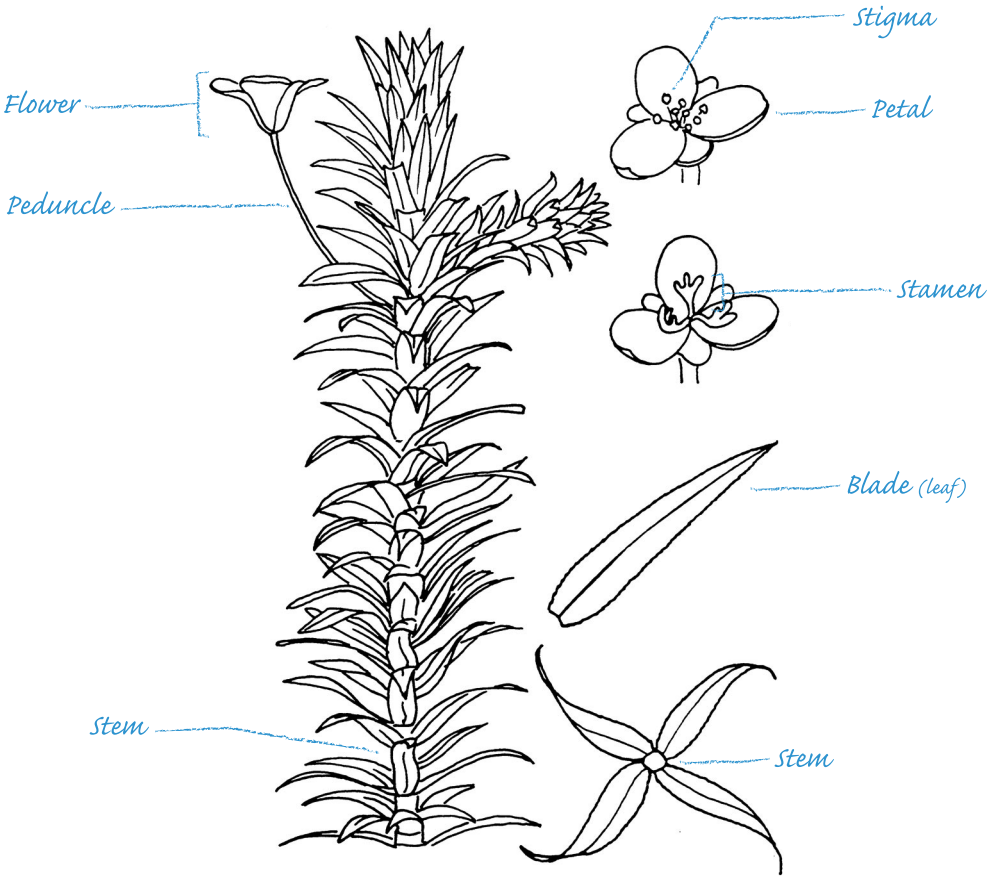
# Biological Assessment

## December 31, 2012

**United States Department of Agriculture**
Agricultural Research Service
Exotic & Invasive Weeds Research
800 Buchanan Street
Albany, California 94710
(510) 559-6127

**California Department of Boating and Waterways**
Aquatic Weed Control Program
2000 Evergreen Street
Suite 100
Sacramento, California 95815
(916) 263-1331

# Egeria densa



# Table of Contents

# Table of Contents


Section — Page

**Acronyms and Abbreviations** ..... **AA-1**

**1. Introduction** ..... **1-1**

A. Threatened, Endangered, Proposed Threatened, or Proposed Endangered Species ..... 1-1

B. Candidate Species, Sensitive Species, and Species of Concern ..... 1-2

C. Critical Habitat ..... 1-2

**2. Consultation to Date** ..... **2-1**

A. United States Fish and Wildlife Service (USFWS) Consultations to Date ..... 2-1

B. National Oceanic and Atmospheric Administration – National Marine Fisheries Service (NMFS) Consultations to Date ..... 2-2

**3. Description of the Proposed Action** ..... **3-1**

A. Action Agency and Authority for EDCP ..... 3-1

B. Overview and Purpose of EDCP ..... 3-2

1. Biology and Invasion of *Egeria densa* ..... 3-2
2. Summary of Prior EDCP Activities ..... 3-4
3. Purpose and Overview of Proposed EDCP ..... 3-8

C. Action Area for EDCP ..... 3-10

1. Project Area Specified in Enabling Legislation ..... 3-10
2. Prioritization of Treatment Sites and Methods ..... 3-14
3. Avoidance Areas within Project Action Area ..... 3-15

D. Timing of Activities of EDCP ..... 3-18

E. Control Methods for EDCP ..... 3-22

1. General Program Activities ..... 3-24
2. Herbicide Treatments ..... 3-25
3. Diver-Assisted Handpicking and Diver-Operated Suction Harvesting ..... 3-46
4. Benthic Barriers ..... 3-48
5. Biological Controls ..... 3-49

F. Monitoring Protocols for EDCP ..... 3-50

G. Mitigation Measures for EDCP ..... 3-52

Section Page

**4. Status of Species and Critical Habitat in the Action Area** ..... **4-1**
A. USFWS Listed Species and Critical Habitats ..... 4-2
1. Threatened delta smelt *(Hypomesus transpacificus)* ..... 4-2
2. Threatened giant garter snake *(Thamnophis gigas)* ..... 4-21
3. Threatened valley elderberry longhorn beetle *(Desmocerus californicus dimporphus)* ..... 4-24
4. Candidate Threatened San Francisco Bay-Delta Distinct Population Segment (DPS) of longfin smelt *(Spirinchus thaleichthys)* ..... 4-25
B. NMFS Listed Species and Critical Habitats ..... 4-31
1. Endangered Sacramento River winter-run Chinook salmon *(Oncorhynchus tshawytsha)* .. 4-31
2. Threatened Central Valley spring-run Chinook salmon *(Oncorhynchus tshawytsha)* ..... 4-42
3. Threatened Central Valley steelhead *(Oncorhynchus mykiss)* ..... 4-51
4. Threatened Southern Distinct Population Segment (DPS) of North American green sturgeon *(Acipenser medirostris)* ..... 4-56

**5. Environmental Baseline and Cumulative Effects** ..... **5-1**
A. Environmental Baseline ..... 5-1
1. Water Hyacinth Control Program (WHCP) ..... 5-3
2. Delta Invasive Species ..... 5-6
3. Delta Agriculture ..... 5-7
4. Delta Water Quality ..... 5-10
B. Cumulative Effects ..... 5-16
1. Spongeplant Control Program ..... 5-17
2. Climate Change ..... 5-18
3. Increased Urbanization ..... 5-19

**6. Effects of the Action** ..... **6-1**
A. Listed Species in the Action Area ..... 6-1
B. Overview of EDCP Stressors ..... 6-7
C. Direct Effects of EDCP ..... 6-7
1. Toxicity of Herbicides to Listed Species ..... 6-7
2. Bioaccumulation of EDCP Herbicides ..... 6-24
3. Disturbance from Treatment and Monitoring Boats ..... 6-26
D. Indirect Effects of EDCP ..... 6-26
1. Loss of Native Plant Species ..... 6-26
2. Food Web Effects ..... 6-30
3. Dissolved Oxygen Effects ..... 6-43

Section Page

**6. Effects of the Action** *(continued)*

E. Direct and Indirect Effects of Interrelated or Interdependent Actions ..... 6-46

F. Effects Considering Environmental Baseline and Cumulative Effects ..... 6-46

G. Subsidies of EDCP ..... 6-47

H. Alternative Actions ..... 6-51

**7. Other Relevant Information** ..... **7-1**

A. Studies to Evaluate Treatment Alternatives, Efficacy, and to Identify New Treatment Options ..... 7-1

B. Herbicide Labels ..... 7-2

C. EDCP Site List ..... 7-2

D. EDCP Treatment Map ..... 7-4

**8. Conclusions** ..... **8-1**

A. Conclusions Regarding USFWS Listed Species and Critical Habitats ..... 8-1

1. Threatened delta smelt and Threatened delta smelt Critical Habitat ..... 8-1
2. Threatened giant garter snake ..... 8-3
3. Threatened valley elderberry longhorn beetle ..... 8-4
4. Candidate Threatened San Francisco Bay-Delta DPS of longfin smelt ..... 8-4

B. Conclusions Regarding NMFS Listed Species and Critical Habitats ..... 8-5

1. Endangered Sacramento River winter-run Chinook salmon and Endangered Sacramento River winter-run Chinook salmon Critical Habitat ..... 8-5
2. Threatened Central Valley spring-run Chinook salmon and Threatened Central Valley spring-run Chinook salmon Critical Habitat ..... 8-8
3. Threatened Central Valley steelhead and Threatened Central Valley steelhead Critical Habitat ..... 8-10
4. Threatened Southern DPS of North American green sturgeon and Threatened Southern DPS of North American green sturgeon Critical Habitat ..... 8-12

**9. List of Documents** ..... **9-1**

A. Materials Provided in the Supplemental Materials Binder ..... 9-1

B. Materials Provided on CD-ROM ..... 9-1

**10. Literature Cited** ..... **10-1**

**11. List of Contacts/Contributors/Preparers** ..... **11-1**

**12. Supplemental Materials Binder Table of Contents** ..... **12-1**

[This page intentionally left blank.]

# Acronyms and Abbreviations

# Acronyms and Abbreviations

1. **2,4-D** – 2,4-dichlorophenoxyacetic acid
2. **a.i.** – Active Ingredient
3. **AGR** – Agricultural Supply (Basin Plan beneficial use)
4. **ALS** – Acetolactate Synthase
5. **AMPA** – Aminomethylphosphonic Acid
6. **APMP** – Aquatic Pesticide Monitoring Program
7. **Bay-Delta Estuary** – San Francisco Bay and Sacramento-San Joaquin Delta
8. **BA** – Biological Assessment
9. **BCF** – Bioconcentration Factor
10. **BDCP** – Bay Delta Conservation Plan
11. **BMP** – Best Management Practices
12. **BO or BiOp** – Biological Opinion
13. **BSMT** – Bay Study Midwater Trawl
14. **BSOT** – Bay Study Otter Trawl
15. **C** – Centigrade/Celsius
16. **c.e.** – cation equivalence
17. **CAC** – County Agricultural Commissioner
18. **CALFED** – California-Federal Bay Delta Program
19. **CCF** – Clifton Court Forebay
20. **CCWD** – Contra Costa Water District
21. **CDFA** – California Department of Food and Agriculture
22. **CDFG** – California Department of Fish and Game
23. **CE** – California Endangered
24. **CEC** – Contaminants of Emerging Concern
25. **CEQA** – California Environmental Quality Act
26. **CET** – Concentration and Exposure Time
27. **CESA** – California Endangered Species Act
28. **cfs** – Cubic Feet Per Second
29. **CI** – Confidence Interval
30. **COA** – Coordinated Operations Agreement
31. **COMM** – Commercial Sport Fishing (Basin Plan beneficial use)
32. **COLD** – Cold Freshwater Habitat (Basin Plan beneficial use)
33. **CNDDB** – California Natural Diversity Database
34. **CNPS** – California Native Plant Society

## Acronyms and Abbreviations *(continued)*

35. **CRR** – Cohort Replacement Rate
36. **CSC** – California Species of Special Concern
37. **CT** – California Threatened
38. **CVP** – Central Valley Project
39. **CVRWQB** – Central Valley Regional Water Quality Control Board
40. **CVTRT** – Central Valley Technical Review Team
41. **CWA** – Clean Water Act
42. **CWT** – Coded-Wire Tag
43. **dBA** – Decibels
44. **DBW** – California Department of Boating and Waterways
45. **DCC** – Delta Cross Channel
46. **Delta** – Sacramento-San Joaquin Delta
47. **DMA** – Dimethylamine Salt
48. **DO** – Dissolved Oxygen (measured in mg/l or ppm)
49. **DOC** – California Department of Conservation
50. **DPR** – California Department of Pesticide Regulation
51. **DPS** – Distinct Population Segment
52. **DRERIP** – Delta Regional Ecosystem Restoration Implementation Plan
53. **DWSP** – Delta Water Supply Project
54. **DWR** – California Department of Water Resources
55. **E:I** – Export to Import
56. **EA** – Environmental Assessment
57. **EC** – Effective Concentration
58. **EC50** – Effective Concentration for 50 Percent of Target
59. **EDCP** – *Egeria densa* Control Program
60. **EEC** – Expected Environmental Concentration
61. **EFH** – Essential Fish Habitat
62. **EIR** – Environmental Impact Report
63. **EIS** – Environmental Impact Statement
64. **ELISA** – Enzyme-Linked Immunoassay
65. **ERL** – Effects Range-Low
66. **ERM** – Effects Range-Medium
67. **ERP** – Ecosystem Restoration Program
68. **ESA** – Endangered Species Act (federal)
69. **EST** – Estuarine habitat (Basin Plan beneficial use)
70. **ESU** – Evolutionary Significant Unit

## Acronyms and Abbreviations *(continued)*

71. **EWA** – Environmental Water Account
72. **F** – Fahrenheit
73. **FasTEST** – a liquid chromatography monitoring method
74. **FC** – Federal Candidate (for consideration of endangered or threatened status)
75. **FCH** – Federal Critical Habitat
76. **FCHP** – Federal Critical Habitat for this Species Proposed
77. **FE** – Federal Endangered
78. **FETAX** – Frog Embryo Teratogenesis Assay – *Xenopus*
79. **FIFRA** – Federal Insecticide, Fungicide, and Rodenticide Act
80. **FMWT** – Fall Midwater Trawl
81. **FONSI** – Finding of No Significant Impact
82. **FRH** – Feather River Hatchery
83. **FT** – Federal Threatened
84. **GCID** – Glenn Colusa Irrigation District
85. **GGS** – Giant Garter Snake
86. **GWR** – Groundwater Recharge (Basin Plan beneficial use)
87. **HAPC** – Habitat Areas of Particular Concern
88. **HCP** – Habitat Conservation Plan
89. **HPLC** – High Performance Liquid Chromotagraphy
90. **HQ** – Hazard Quotient
91. **IEP** – Interagency Ecology Program
92. **IND** – Industrial Service Supply (Basin Plan beneficial use)
93. **IPM** – Integrated Pest Management
94. **JPE** – Juvenile Production Estimate
95. **JPI** – Juvenile Production Index
96. $\mathbf{K_{oc}}$ – Soil Adsorption Coefficient (normalized by organic matter)
97. $\mathbf{K_{ow}}$ – Octanol/Water Coefficient
98. **LC5** – Lethal Concentration for 5 Percent of Subjects
99. **LC10** – Lethal Concentration for 10 Percent of Subjects
100. **LC50** – Lethal Concentration for 50 Percent of Subjects
101. **LD50** – Lethal Dose or Lethal Dietary Dose for 50 Percent of Subjects
102. **LOC** – Level of Concern
103. **LOD** – Limit of Detection
104. **LOAEC** – Lowest Observable Adverse Effect Concentration
105. **LOEC** – Lowest Observable Effect Concentration
106. **LOEL** – Lowest Observable Effect Level

## Acronyms and Abbreviations *(continued)*

107. **LSNFH** – Livingston Stone National Fish Hatchery
108. **LSZ** – Low Salinity Zone
109. **MAF** – Million Acre Feet
110. **MATC** – Maximum Acceptable Toxicant Concentration
111. **MCL** – Maximum Contaminant Level
112. **MCP** – Maintenance Control Practices
113. **MCPA** – 4-chloro-2-methylphenoxyacetic acid
114. **MIGR** – Migration of Aquatic Organisms (Basin Plan beneficial use)
115. **mM** – Millimolar (a concentration of one thousandth of a mole per liter)
116. **MOE** – Margin of Error or Margin of Safety
117. **MOU** – Memorandum of Understanding
118. **MRDL** – Maximum Residual Disinfectant Level
119. **MSA** – Magnuson-Stevens Fishery Conservation and Management Act
120. **MSDS** – Material Safety Data Sheet
121. **MUN** – Municipal and Domestic Supply
122. **NAV** – Navigation (Basin Plan beneficial use)
123. **NBA** – North Bay Aqueduct
124. **NCCP** – Natural Community Conservation Plan
125. **ND** – Non-detectable
126. **NIH** – National Institute of Health
127. **NMF** – N-methyl formamide
128. **NMFS** – National Marine Fisheries Service
129. **NOAA-Fisheries** – National Oceanic and Atmospheric Administration-Fisheries (also previously referred to as NMFS, National Marine Fisheries Service)
130. **NOAEC** – Non-observable Adverse Effect Concentration
131. **NOEC** – Non-observable Effect Concentration
132. **NOEL** – Non-observable Effect Level
133. **NOI** – Notice of Intent
134. **NOP** – Notice of Preparation
135. **NPDES** – National Pollution Discharge Elimination System
136. **NPE** – Nonylphenol Ethoxylates
137. **NRDC** – Natural Resources Defense Council
138. **NTU** – Nephelometric Turbidity Units
139. **OCAP** – Operations Criteria and Plan
140. **OMP** – Operations Management Plan
141. **OMR** – Old and Middle River

## Acronyms and Abbreviations *(continued)*

142. **PAHs** – Poly aromatic Hydrocarbons
143. **PCA** – Pest Control Advisor
144. **PCE** – Primary Constituent Elements (of critical habitat)
145. **PEIR** – Program Environmental Impact Report
146. **PFMC** – Pacific Fisheries Management Council
147. **POD** – Pelagic Organism Decline
148. **POEA** – Polyethoxylated tallowamine
149. **ppb** – Parts per Billion (μg/l)
150. **ppm** – Parts per Million (mg/l or mg/kg)
151. **ppt** – Parts per Thousand (g/l)
152. **PPE** – Personal Protective Equipment
153. **PRO** – Industrial Process Supply (Basin Plan beneficial use)
154. **PUR** – Pesticide Use Recommendations
155. **PVA** – Population Viability Analysis
156. **QAC** – Qualified Applicator Certificate
157. **QAPP** – Quality Assurance Project Plan
158. **RARE** – Rare, Threatened, or Endangered Species (Basin Plan beneficial use)
159. **RBDD** – Red Bluff Diversion Dam
160. **RCRA** – Resource Conservation and Recovery Act
161. **REC-1** – Water Contact Recreation (Basin Plan beneficial use)
162. **REC-2** – Non-water Contact Recreation (Basin Plan beneficial use)
163. **RfD** – Reference Dose
164. **RM** – River Mile
165. **ROD** – Record of Decision
166. **RPA** – Reasonable and Prudent Alternative
167. **RQ** – Risk Quotient
168. **RR** – Risk Ratio
169. **RTS** – Rotary Screw Traps
170. **RUP** – Restricted Use Permit
171. **SAV** – Submersed Aquatic Vegetation
172. **SDIP** – South Delta Improvement Program
173. **SF** – San Francisco
174. **SFA** – Seasonally Flooded Agricultural
175. **SFEI** – San Francisco Estuary Institute
176. **SHELL** – Shellfish harvesting (Basin Plan beneficial use)
177. **SJ** – San Joaquin

## Acronyms and Abbreviations *(continued)*

178. **SJRRP** – San Joaquin River Restoration Program
179. **SL** – Standard Length
180. **SMR** – Standard Mortality Ratio
181. **SPM** – Suspended Particulate Matter
182. **SPWN** – Spawning, Reproduction, and/or Early Development (Basin Plan beneficial use)
183. **SVWMA** – Sacramento Valley Water Management Agreement
184. **SWB** – State Water Board (Water Resources Control Board)
185. **SWP** – State Water Project
186. **SWRCB** – State Water Resources Control Board
187. **TDF** – Through-Delta Facility
188. **TFE** – Tidal Freshwater Emergent
189. **THM** – Trihalomethane
190. **TL** – Total Body Length
191. **TNS** – Townet Survey
192. **TRCD** – Tahoe Resource Conservation District
193. **UNR** – University of Nevada, Reno
194. **USBR** – United States Bureau of Reclamation
195. **USDA-ARS** – United States Department of Agriculture – Agricultural Research Service
196. **USFS** – United States Forest Service
197. **USFWS** – United States Fish and Wildlife Service
198. **VAMP** – Vernalis Adaptive Management Plan
199. **WARM** – Warm Freshwater Habitat (Basin Plan beneficial use)
200. **WHCP** – Water Hyacinth Control Program
201. **WILD** – Wildlife Habitat (Basin Plan beneficial use)
202. **WOE** – Weight-of-evidence
203. **WY** – Water Year
204. **X2** – The Line at which 2ppt (parts per thousand) Saline Occurs
205. **YOY** – Young of the Year.

Section 1

# Introduction

# 1. Introduction

The purpose of this initiation package is to review the proposed *Egeria densa* Control Program (EDCP) to determine if this proposed action may affect any of the threatened, endangered, proposed, or sensitive species; and designated or proposed critical habitats listed herein. In addition, the following information is provided to comply with statutory requirements to use the best scientific and commercial information available when assessing risks posed to listed and/or proposed species; and designated and/or proposed critical habitat by proposed federal actions. This initiation package is prepared in accordance with legal requirements set forth under regulations implementing Section 7, of the Endangered Species Act (50 CFR 402; 16 U.S.C. 1536 (c)).

The EDCP was established in 2001 to control *Egeria densa*, an invasive aquatic weed, in the Sacramento-San Joaquin Delta (Delta) and its major tributaries. The EDCP is managed by the California Department of Boating and Waterways (DBW) with their federal partner, United States Department of Agriculture, Agricultural Research Service (USDA-ARS).

## A. Threatened, Endangered, Proposed Threatened, or Proposed Endangered Species

USDA-ARS obtained a list of federal endangered and threatened species that occur in, or may be affected by projects in, the Sacramento/San Joaquin Delta on June 11, 2012, from the USFWS web page (http://www.fws.gov/sacramento). The list was current as of September 18, 2011.[1] The original list included 22 animal species, 13 plant species, and 19 critical habitats. USDA-ARS reviewed the list and identified those species that utilize waterways, channels, and immediate channel banks of the EDCP area. These 7 species are identified below. Species that do not occur in, or utilize waterways, channels, and channel banks of the Delta or its tributaries, are not considered in this biological assessment. These non-impacted species are identified in **Exhibit 1-1,** on page 1-3.

The following three listed and proposed species regulated by the United States Fish and Wildlife Service (USFWS) may be affected by the proposed action:

[1] As of November 6, 2012, the species identified on this June 11, 2012, list are current.

**USFWS**

1. Delta smelt *(Hypomesus transpacificus)*, **T**[2] [3]
2. Giant garter snake *(Thamnophis gigas)*, **T**
3. Valley elderberry longhorn beetle *(Desmocerus californicus dimporphus)*, **T.**

The following four listed and proposed species regulated by the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) may be affected by the proposed action:

**NMFS**

4. Sacramento River winter-run Chinook salmon *(Oncorhynchus tshawytscha)*, **E**
5. Central Valley spring-run Chinook salmon *(Oncorhynchus tshawytscha)*, **T**
6. Central Valley steelhead *(Oncorhynchus mykiss)*, **T**
7. Southern Distinct Population Segment (DPS) of North American green sturgeon *(Acipenser medirostris)*, **T.**

## B. Candidate Species, Sensitive Species, and Species of Concern

There is currently one (1) candidate species, sensitive species, and species of concern that may be affected by the proposed EDCP action:

**USFWS**

1. Longfin smelt *(Spirinchus thaleichthys)*[4]

## C. Critical Habitat

The EDCP action addressed within this document falls within the Critical Habitat for one (1) species regulated by USFWS, and four (4) species regulated by NMFS, as follows:

**USFWS**

1. Delta smelt *(Hypomesus transpacificus)*

**NMFS**

2. Sacramento River winter-run Chinook salmon *(Oncorhynchus tshawytscha)*
3. Central Valley spring-run Chinook salmon *(Oncorhynchus tshawytscha)*
4. Central Valley steelhead *(Oncorhynchus mykiss)*
5. Southern Distinct Population Segment (DPS) of North American green sturgeon *(Acipenser medirostris).*

[2] T = threatened species, E = endangered species

[3] On April 7, 2010, USFWS announced a 12-month finding that the reclassification of the delta smelt from threatened to endangered was warranted, but precluded by other higher-priority listing actions. USFWS will develop a proposed rule to reclassify delta smelt as their priorities allow (Federal Register, Volume 75, No. 66, April 7, 2010, page 17667).

[4] On April 2, 2012, USFWS released the results of a 12-month finding on the San Francisco Bay-Delta Distinct Population Segment (DPS) of longfin smelt. The finding was that this longfin smelt DPS warrants protection under the Endangered Species Act (ESA), but that USFWS is precluded at this time from drafting a formal listing rule by the need to address other higher priority species.

**Exhibit 1-1**

**Listed Species and Critical Habitats that Occur in, or May Be Affected by Projects in, the Sacramento-San Joaquin Delta and Not Considered in This Biological Assessment**

| | |
|---|---|
| **Invertebrates** | *Apodemia mormo langei* – Lange's metalmark butterfly (E)<br>*Branchinecta conservatio* – Conservancy fairy shrimp (E)<br>*Branchinecta longiantenna* – longhorn fairy shrimp (E)<br>*Branchinecta lynchi* – vernal pool fairy shrimp (T)<br>*Elaphrus viridis* – delta green ground beetle (T)<br>*Lepidurus packardi* – vernal pool tadpole shrimp (E) |
| **Amphibians** | *Ambystoma californiense* – California tiger salamander, central population (T)<br>*Rana draytonii* – California red-legged frog (T) |
| **Reptiles** | *Masticophis lateralis euryxanthus* – Alameda whipsnake [=striped racer] (T) |
| **Birds** | *Rallus longirostris obsoletus* – California clapper rail (E)<br>*Sternula antillarum (=Sterna, =albifrons) browni* – California least tern (E) |
| **Mammals** | *Neotoma fuscipes riparia* – riparian (San Joaquin Valley) woodrat (E)<br>*Reithrodontomys raviventris* – salt marsh harvest mouse (E)<br>*Sylvilagus bachmani riparius* – riparian brush rabbit (E)<br>*Vulpes macrotis mutica* – San Joaquin kit fox (E) |
| **Plants** | *Amsinckia grandiflora* – large-flowered fiddleneck (E)<br>*Castilleja campestris ssp. succulenta* – succulent (=fleshy) owl's-clover (T)<br>*Cirsium hydrophilum var. hydrophilum* – Suisun thistle (E)<br>*Cordylanthus mollis ssp. mollis* – soft bird's-beak (E)<br>*Cordylanthus palmatus* – palmate-bracted bird's-beak (E)<br>*Erysimum capitatum ssp. angustatum* – Contra Costa wallflower (E)<br>*Lasthenia conjugens* – Contra Costa goldfields (E)<br>*Neostapfia colusana* – Colusa grass (T)<br>*Oenothera deltoides ssp. howellii* – Antioch Dunes evening-primrose (E)<br>*Orcuttia tenuis* – slender Orcutt grass (T)<br>*Orcuttia viscida* – Sacramento Orcutt grass (E)<br>*Sidalcea keckii* – Keck's checker-mallow (=checkerbloom) (E)<br>*Tuctoria mucronata* – Solano grass (=Crampton's tuctoria) (E) |
| **Critical Habitats For:** | Alameda whipsnake<br>Antioch Dunes evening-primrose<br>California tiger salamander, central population<br>California red-legged frog (No critical habitat within the Delta)<br>Colusa grass<br>Conservancy fairy shrimp<br>Contra Costa goldfields<br>Contra Costa wallflower<br>large-flowered fiddleneck<br>longhorn fairy shrimp<br>soft bird's-beak (proposed)<br>Solano grass (=Crampton's tuctoria)<br>Suisun thistle (proposed)<br>vernal pool fairy shrimp<br>vernal pool tadpole shrimp |

[This page intentionally left blank.]

Section 2

# Consultation to Date

# 2. Consultation to Date

This current consultation process for the EDCP with USFWS and NMFS follows several prior formal and informal consultations and biological opinions (BOs). The EDCP has operated under BOs from USFWS and NMFS for over ten (10) years since 2001. Below, for each service, we describe the prior and current consultation history.

## A. United States Fish and Wildlife Service (USFWS) Consultations to Date

In November 2000, USDA-ARS initiated consultation with USFWS, submitting a Biological Assessment (BA) of EDCP. On June 1, 2001, USFWS issued a biological opinion (BO) for EDCP (1-1-00-F-0234). This BO was subsequently amended three (3) times (1-1-02-F-0158, 1-1-03-F-0061, and 1-1-04-F-0125).

In February 2004, USDA-ARS submitted a request to USFWS to reinitiate consultation after toxicological studies required in the June 1, 2001 BO had been completed. USDA-ARS requested that a new BO reflect this study information on the toxicity of the herbicides and adjuvants used in EDCP. The USFWS issued a new BO for EDCP in May 2004, that reduced the toxicological testing requirements of the program (1-1-04-F-0148). The EDCP operated under this 2004 BO through the 2012 treatment season. This 2004 BO is provided in the EDCP Biological Assessment Supplemental Materials Binder.

On January 18, 2012, USDA-ARS, USFWS, NMFS, and DBW met to discuss consultations for 2012, and later treatment seasons. The two services determined that USDA-ARS and DBW should divide the consultation process into two packages, one for the 2012 treatment season, and a separate package for 2013 and beyond.

On March 5, 2012, USDA-ARS requested initiation of consultation for the 2012 treatment season with submission to USFWS of a package of information on the program. USFWS determined that EDCP could continue in 2012 without a consultation process. In April 2012, USDA-ARS submitted a letter to USFWS withdrawing the consultation request for the 2012 EDCP treatment season.

## B. National Oceanic and Atmospheric Administration – National Marine Fisheries Service (NMFS) Consultations to Date

In November 2000, USDA-ARS initiated consultation with NMFS, submitting a Biological Assessment (BA) for EDCP. NMFS issued a BO for EDCP on July 23, 2001, with two amendments dated July 3, 2002, and August 11, 2003. These biological opinions respectively concluded that EDCP was not likely to jeopardize the continued existence of Sacramento River winter-run Chinook salmon *(Oncorhynchus tshawytscha)*, Central Valley spring-run Chinook salmon *(O. tshawytscha)*, and Central Valley steelhead *(O. mykiss)*, or adversely modify designated critical habitat for the 2001, 2002, and 2003 through 2005 application. NMFS issued the one-year extension for the 2006 treatment season on April 18, 2006.

In August 2006, USDA-ARS submitted a request to initiate formal consultation for the 2007 through 2011 treatment seasons. Between September 2006 and December 2006, NMFS, USDA-ARS, and DBW met several times to discuss the consultation process. USDA-ARS and DBW submitted to NMFS a BA and other supporting documents during this time period. On June 19, 2007, NMFS issued a biological opinion for EDCP for the five-years 2007 through 2011.

On January 18, 2012, USDA-ARS, USFWS, NMFS, and DBW met to discuss consultations for 2012 and later treatment seasons. The agencies determined that USDA-ARS and DBW should divide the consultation process into two packages, one for the 2012 treatment season, and a separate package for 2013 and beyond. On March 2, 2012, USDA-ARS requested initiation of consultation for the 2012 treatment season with submission to NMFS of a package of information on the program. On March 23, 2012, NMFS responded to the USDA, requesting that USDA-ARS provide additional information. USDA-ARS submitted a letter to NMFS on March 29, 2012, addressing issues listed in the March 23, 2011 letter.

USDA-ARS, DBW, USFWS, and NMFS met to discuss USDA-ARS's March 29, 2012 submission on March 30, 2012. At that time, NMFS clarified additional information that USDA-ARS should submit. USDA-ARS submitted this information to NMFS, in the form of a biological evaluation, on April 19, 2012. The biological evaluation concluded that the EDCP may affect, but is not likely to adversely affect threatened and endangered species. USDA-ARS requested a concurrence letter from NMFS, which they received on July 2, 2012, after providing additional clarifying information to NMFS. The letter of concurrence is provided in the Supplemental Materials Binder.

This BA is concerned with USFWS and NMFS consultation for 2013 and beyond.

Section 3

# Description of the Proposed Action

# 3. Description of the Proposed Action

The goal of EDCP is to keep waterways safe and navigable by controlling the growth and spread of *Egeria densa* in the Delta and its surrounding tributaries. Because of the continued survivability and persistence of *Egeria densa* in the Delta, EDCP legislative mandate is for control, rather than eradication of *Egeria densa*.

The EDCP seeks to minimize negative impacts of the invasive plant on navigation, public safety, recreation, agricultural activities, and ecosystem services in Delta waterways. The EDCP balances potential impacts of *Egeria densa* management by working to minimize non-target species impacts and prevent environmental degradation in Delta waterways and tributaries.

This section of the Biological Assessment provides a detailed description of EDCP. The section is organized as follows:

*A. Action Agency and Authority for EDCP*
*B. Overview and Purpose of EDCP*
*C. Action Area for EDCP*
*D. Timing of Activities of EDCP*
*E. Control Methods for EDCP*
*F. Monitoring Protocols for EDCP*
*G. Mitigation Measures for EDCP.*

## A. Action Agency and Authority for EDCP

USDA-ARS and DBW implement EDCP. The EDCP is an aquatic weed program designed to control the growth and spread of *Egeria densa* in the Delta and its tributaries. The USDA-ARS has served as the federal nexus for EDCP for the last eleven (11) years, providing research, and scientific expertise. The USDA-ARS has provided technical and programmatic advice to EDCP since the program's inception, and has been instrumental in program design.

The EDCP is a well-established program, which has been operating in the Delta for over 10 years. In 1996, in response to growing concerns about the spread of an aquatic invasive weed, *Egeria densa*, the California Legislature passed Assembly Bill (AB) 2193 (Rainey, Statutes of 1996, Chapter 728), authorizing the DBW to develop a control program for this invasive species. The DBW began treating *Egeria densa* in the Delta in 2001, in collaboration with USDA-ARS, after completing an Environmental Impact Report (EIR) and obtaining

the required NPDES permit and NMFS and USFWS biological opinions.

The EDCP operates under three key environmental documents: (1) 2001 EDCP Environmental Impact Report, (2) 2003 First Addendum to EDCP EIR, and (3) 2006 Second Addendum to EDCP EIR (with five year program review and future program operations plan). The Second Addendum, and the regulatory agency documents have guided the EDCP over the last six years (2007 through 2012).

Prior to 2006, the EDCP operated under the original, and somewhat more restrictive, NPDES permit and Biological Opinions. The more recent documents reflect the lower level of environmental impact demonstrated during the first five years of the EDCP.

The regulatory documents guiding EDCP in 2012 included:

- NPDES Statewide General Permit (CAG990005) (still current, but will be replaced in February 2013)
- USFWS Biological Opinion (1-1-04-F-148) (extended through 2012)
- NOAA-NMFS Letter of Concurrence (2012/01688) (for 2012)[1].

USDA-ARS and DBW are now seeking five-year biological opinions or letters of concurrence for the 2013 through 2017 treatment seasons.

There are no interrelated or independent actions associated with EDCP.

[1] On July 2, 2012, the USDA-ARS and the DBW received a letter of concurrence from NMFS agreeing with the USDA-ARS and the DBW's determination that the proposed use of fluridone-based herbicide products for the 2012 treatment season is not likely to adversely affect federally listed salmonids, green sturgeon, or critical habitat.

*Photo:* Egeria densa *infestation.*

## B. Overview and Purpose of EDCP

In order to provide context to proposed EDCP activities described in detail in this Biological Assessment, this subsection begins by summarizing *Egeria densa's* biology, invasion, and spread in California, as well as summarizing EDCP activities over the last several years. Finally, this subsection describes the purpose of EDCP and provides an overview of proposed EDCP activities.

### 1. Biology and Invasion of *Egeria densa*

*Egeria densa* Planchon (Brazilian Elodea) is a submersed, non-native aquatic plant (submersed aquatic vegetation or SAV), introduced into the Delta approximately sixty years ago. *Egeria densa* is a member of the Hydrocharitaceae family. This fast growing weed obstructs waterways, crowds out native plants, impedes anadromous fish migration and boat navigation, slows water flows, entraps sediments, and clogs agricultural and municipal water intakes. *Egeria densa* negatively impacts delta smelt by reducing turbidity and overwhelming littoral (near shore) habitats (USFWS 2008). *Egeria densa* infests

almost twenty percent of the Delta's 61,619 surface acres, and is spreading at approximately 100 acres per year.

*Egeria densa* is native to Southeast Brazil and Uruguay. *Egeria densa* has few natural predators because it was introduced from Brazil disease and insect-free. Spread of *Egeria densa* outside its native range has been attributed to the fact that it was once considered an important "oxygenator" for ponds and aquaria, and thus became widely available as an aquarium plant (Cook and Urmi-Konig 1984). The impacts of *Egeria densa* on dissolved oxygen are complex. During daylight hours, DO levels in *Egeria densa* mats are similar to uninfested water due to the oxygen produced from photosynthesis. However, overnight, when plants are only respiring, DO levels within *Egeria densa* mats drop to low levels (Anderson 2012). In addition, Mazzeo et al. (2003) and Champion (2000) found that surface DO was not significantly different between *Egeria densa* mats and open water in the daytime, but noted anoxic conditions in the benthic zone under *Egeria densa* mats once the weeds had grown enough to reach the surface.

Stems of *Egeria densa* are usually one to two feet long, but can be much shorter or longer, growing to over 9 feet long (Yarrow et al. 2009). *Egeria densa's* leaves are small and strap-shaped, typically about one-inch long and one-quarter inch wide. The leaf margins have very fine saw teeth that require a magnifying lens to see. *Egeria densa* has dense whorls of three to six bright green leaves arranged around the stem. The stems are irregularly branched, with buds and branches developing between zero to fifteen internodes (Cook and Urmi-Konig 1984). Double nodes occur every ten to twelve internodes and are important for carbohydrate storage and vegetative reproduction (Center for Lakes and Reservoirs 2012). Rapidly growing *Egeria densa* tips produce more double nodes, increasing both plant biomass and potential for expansion as stem fragments break above the double nodes (Pennington 2007). Flowers are on short stalks about one inch above the water. Flowers have white petals and are about ¾ inch across. Most of *Egeria' densa's* biomass is produced near the water surface.

*Egeria densa* reproduces asexually or vegetatively, through fragmentation. In this process, severed plant fragments regenerate into new plants capable of establishing themselves at new locations. Pennington (2007) found that in the Delta, *Egeria densa* plants fragmented in late-winter/early spring, as day-length increased and water temperature was approximately 10°C (50°F). Part of the widespread success of the plant is due to its ability to reproduce in this manner. Only male plants are found in the United States, thus all reproduction is vegetative, resulting in an extremely homogenous genotype (Center for Lakes and Reservoirs 2012).

*Photo:* Egeria densa.

Literature shows that *Egeria densa* is very adaptable to local conditions (Yarrow et al. 2009). Factors that support *Egeria densa's* invasiveness include: a relatively fast growth rate, acclimatization to different light regimes (particularly its ability to grow in low-light environments), flexible nutrient uptake from water column and sediments, high productivity in low to medium nutrient environments, high phenotypic plasticity, high dispersal via fragmentation, and high potential to colonize disturbed areas (Yarrow et al. 2009). *Egeria densa* thrives in shallow waters (< 10 feet deep), such as those found in much of the Delta. In addition, *Egeria densa* in the Delta does not senesce in the fall, as do most native plant species. As a result, *Egeria densa* continues producing biomass, some of which persists through the winter. For example, *Egeria densa* in Disappointment Slough, in the Delta, had growth rates of approximately 0.2 cm/day at sampling dates in November, December, and August, and higher rates of over 0.6 cm/day in April (Pennington 2007).

The overwintering biomass can respond quickly to rising temperatures and increased day length in the following spring, providing a competitive advantage over both native and non-native species (Santos et al. 2010). Typically, *Egeria densa* starts growing rapidly when Delta water temperatures reach 12°C to 14°C (Anderson 2012), with the ideal temperature range for *Egeria densa* between 14°C to 25°C (Pennington 2007). In the fall, *Egeria densa* has a second growth spurt that generally coincides with water temperatures dropping back into the middle of the ideal range (close to 20°C) (Shuler 2012). This second growth spurt usually begins in mid- September and peaks in mid-October. The Delta provides ideal weather and hydrological conditions for *Egeria densa*.

## 2. Summary of Prior EDCP Activities

Since the program's inception in 2001, EDCP has sought to balance the need to control *Egeria densa* with the need to minimize resulting environmental impacts to Delta waterways. The selected program alternative has consisted of an integrated and adaptive approach, emphasizing chemical treatment.

The EDCP has historically been permitted to utilize two aquatic herbicides, (1) fluridone (as Sonar® products) and (2) diquat (as the product Reward®) for control of *Egeria densa*. Over the last five years, the DBW has not utilized diquat, but has utilized up to three formulations of fluridone: (1) Sonar® PR Granular, (2) Sonar® Q Pellets, and (3) Sonar* AS Aqueous. These three Sonar formulations contain the same active ingredient, but allow for differing release times. Treatment crews used injection hoses to apply aqueous herbicide into treatment areas, and a broadcast method to apply pellets or granules.

**Figure 3-1,** on the next page, provides a summary of EDCP historical characteristics. The EDCP has been a relatively small aquatic weed control program concerned with managing the invasive, and non-native, *Egeria densa* in a large and complex Delta water environment.

**Figure 3-1**
**Summary of EDCP**

- Program Initiated: **2001**
- Annual Budget: **$5.3 to $6.0 million** (for WHCP and EDCP) (2010 to 2012)
- Total Staffing: **19** (for WHCP and EDCP, includes DBW and USDA-ARS) (2012)
- Monitoring Crews/Boats: **one to two 2-person crews** (for WHCP and EDCP) (2012)
- Average* Annual EDCP Sites Treated: **7** (range = 3 to 18)
- Average* Annual EDCP Acres Treated: **1,978** (range = 228 to 3,195)
- Average* Annual EDCP Treatments: **114** (range = 43 to 207)

* 2007 to 2012 averages and ranges per EDCP daily logs.

*Photo:* Egeria densa *infestation.*

*Photo:* Egeria densa *treatment, pellet application.*

The EDCP has evolved since its inception in 2001. For the first five (5) years of EDCP (2001 to 2005), the DBW treated 19 different sites within the Delta, covering between 268 and 622 acres per year. A study of the first five-years of operation found that EDCP was likely restraining *Egeria densa* from spreading even more than it already had, but that EDCP was "not keeping up" with the Delta-wide *Egeria densa* infestation. Following this initial five-year program evaluation in 2006, the DBW implemented a new, more focused, approach.

In 2007, renewal of the NMFS and the USFWS Biological Opinions allowed an early April 1st start date and a new treatment regime. In 2007 and 2008, DBW focused all EDCP treatments within three treatment sites in Franks Tract, a known *Egeria densa* nursery area. This focused treatment approach was highly effective, and after two years of treatment, boats could again navigate within Franks Tract.

Due to success of the Franks Tract treatment regime, DBW continued the focused treatment approach, expanding to new areas in 2009, 2010, 2011, and 2012. **Table 3-1,** on the next page, identifies EDCP treatment areas, net acreage treated, and pounds of active ingredient (fluridone) for the last six years of operation, the period covered by the most recent Biological Opinions, plus 2012. These historical treatment data provide an indication of potential chemical treatment levels in future years.

The EDCP implemented a treatment protocol designed to maintain a low concentration of herbicide active ingredient (fluridone) over an eight to twelve week period. Prior to the start of the treatment season,

**Table 3-1**
**EDCP Areas Treated, Net Acres, and Pounds Herbicide Active Ingredient (Fluridone)**

| Site Name | Site Number(s) | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|
| 1. Franks Tract | 173, 174, 175 | ✓ | ✓ | | ✓ | ✓ | ✓ |
| 2. White Slough | 36, 37, 39 | | | ✓ | ✓ | | ✓ |
| 3. Disappointment Slough | 32 | | | ✓ | ✓ | | ✓ |
| 4. Bishop Cut | 34 | | | ✓ | | | ✓ |
| 5. Honker Cut | 38 | | | | | | ✓ |
| 6. Fourteen Mile Slough | 26 | | | ✓ | | | ✓ |
| 7. Whiskey Slough | 62 | | | | | | ✓ |
| 8. Old River | 79 | | | | | | ✓ |
| 5. Pipers Slough (Bethel Island) | 107 | | | | | ✓ | ✓ |
| 6. Taylor Slough (Bethel Island) | 110 | | | | | ✓ | ✓ |
| 7. Sandmound Slough (Bethel Island) | 108, 109, 111, 112 | | | | | ✓ | ✓ |
| 8. Discovery Bay | 93 | | | | | ✓ | ✓ |
| 9. Sycamore Slough | 203 | | | | | | ✓ |
| 10. Snug Harbor | 252 | | | | | | ✓ |
| Net Acres | **Average: 1,978** | 2,571 | 2,571 | 228 | 641 | 3,195 | 2,663 |
| Pounds Active Ingredient | **Average: 5,077** | 7,479 | 4,977 | 562 | 1,974 | 8,113 | 7,357 |

USDA-ARS, DBW, and herbicide experts developed a weekly application protocol for each site. Once treatments were initiated, DBW environmental scientists conducted regular FasTEST (immunoassay) monitoring to measure fluridone concentrations and adjust weekly applications to maintain the appropriate fluridone concentration, if necessary.

During the last six years of EDCP operation, there was no known take or harassment of federally endangered or threatened species. To minimize the occurrence of take the DBW checked Interagency Ecological Program (IEP) surveys and California Department of Fish and Game trawls prior to and during the treatment season to monitor the presence of Chinook salmon, steelhead, and delta smelt during early treatment season months when these species may be present in treatment areas. Treatment crews also conducted surveys to evaluate the presence of valley elderberry longhorn beetle and giant garter snake habitats throughout each treatment season.

Based on NPDES permit requirements, DBW followed an Annual Monitoring Protocol. This protocol fulfilled monitoring requirements of the Regional Water Quality Control Board, NMFS, and USFWS.

At the completion of each treatment season, DBW and USDA-ARS reported program results to USFWS, NMFS, and CVRWQB. The DBW conducted toxicity

testing in the first several years of operation, but the regulatory agencies eliminated this requirement when test results showed no significant impacts. The Supplemental Materials Binder provides a discussion of efficacy of EDCP control methods over the last six years of the program.

There is a long history of research and program development associated with EDCP. Since 1998, USDA-ARS and DBW have conducted or sponsored a number of additional studies to evaluate treatment alternatives, efficacy, and identify new treatment options. Many of these additional studies were requested as part of previous USFWS or NMFS consultations. These studies, provided with this consultation submission in the Supplemental Materials Binder, include the following thirteen reports:

- *Fluridone (4AS) Dissipation During Typical Application of Sonar (4AS),* Lars W.J. Anderson, Ph.D., USDA-ARS Exotic and Invasive Weed Research (2005)
- Residue of Fluridone and Diquat Dibromide in Sediment from the Sacramento-San Joaquin Delta, California, 2002-2005, Robert C. Hosea, California Department of Fish and Game (2005)
- *Residue of Fluridone in Chinook Salmon Smolts from the Sacramento-San Joaquin Delta, California, 2005,* Robert C. Hosea, California Department of Fish and Game (2005)
- *An Evaluation of Potential Effects of Fluridone on Pacific Salmon in the California Delta,* Clifford Habig, Ph.D., SePRO (2004)
- *Experimental Studies of the Effects of Temperature, Salinity and Light Intensity of Growth of Egeria densa,* Steven Obrebski and Robin Rooth, Romberg Tiburon Center, San Francisco State University (2003)
- *Acute Oral and Dermal Toxicity of Aquatic Herbicides and a Surfactant to Garter Snakes,* Robert C. Hosea, California Department of Fish and Game (2004)
- *Chronic Toxicities of Herbicides Used to Control Water Hyacinth and Brazilian Elodea on Neonate Cladoceran and Larval Fathead Minnow,* Frank Riley and Sandra Finlayson, California Department of Fish and Game (2004)
- *Acute Toxicities of Herbicides Used to Control Water Hyacinth and Brazilian Elodea on Larval Delta Smelt and Sacramento Splittail,* Frank Riley and Sandra Finlayson, California Department of Fish and Game (2004)
- *Ceriodaphnia dubia (water flea) Static Definitive Chronic Toxicity Test Data (7-day) for Exposure to Various Aquatic Herbicides,* California Department of Fish and Game, Aquatic Toxicology Laboratory (2003)
- *Pogonichthys macrolepitdotus (Sacramento Splittail) Static Definitive Acute Toxicity Test Data (96-hour) for Exposure to Various Aquatic Herbicides,* California Department of Fish and Game, Aquatic Toxicology Laboratory (2003)
- *Mapping Invasive Plant Species in the Sacramento-San Joaquin Delta Region Using Hyperspectral Imagery,* Susan L. Ustin, Ph.D., et al, Center for Spatial Technologies and Remote Sensing (CSTARS), California Space Institute Center of Excellence (CalSpace), UC Davis (2004)
- Dissipation and Movement of Sonar, and Komeen Following Typical

Applications for Control of Egeria densa in the Sacramento/San Joaquin Delta and Production Viability of E. Densa Fragments Following Mechanical Harvesting, Lars W.J. Anderson, USDA-ARS, Aquatic Weed Control Research Laboratory, Invasive Weed Research Unit, U.D. Davis (1998)

- *Effects of Control Methods on the Egeria densa Community*, Steve Obrebski, Terry Irwin, and Jennifer Pearson, Romberg Tiburon Center, San Francisco State University (1998).

## 3. Purpose and Overview of Proposed EDCP

The EDCP will continue to be an adaptive and integrated pest management (IPM) program. The EDCP will utilize treatment protocols that balance the need to control *Egeria densa* with the need to minimize resulting environmental impacts to Delta waterways. The proposed program consists of an integrated and adaptive approach, emphasizing chemical treatment supported by limited handpicking and suction harvesting (by SCUBA divers), benthic barriers, and continued assessment of biological controls. Use of biological controls for *Egeria densa* is currently in the experimental phase, and discussed for information purposes, not as part of this consultation. The EDCP will continue to evolve over time as treatment methods, technology, and environmental factors change.

**Table 3-2,** on the next page, identifies ten specific objectives for EDCP. Table 3-2 also identifies performance measures (i.e. expected outcomes) that the USDA-ARS and DBW use to evaluate success of EDCP in meeting these project objectives.

Selected primary program aquatic herbicides will be (1) fluridone (known as Sonar products), (2) penoxsulam (known as Galleon), (3) imazamox (known as Clearcast), and (4) diquat (known as Reward). Fluridone, in the form of several different Sonar® products, will be utilized for the majority of treatments. The EDCP may introduce the two new herbicides (penoxsulam and imazamox) starting in 2013. As these herbicides have not yet been used for treating *Egeria densa* in the complex, tidal, Delta environment, EDCP will begin evaluating their efficacy and impacts at selected sites, and may increase use over time, depending on initial results. Diquat may be used in limited situations when more rapid efficacy would benefit the overall treatment approach. The DBW will utilize different formulations of fluridone including: (1) Sonar PR Granular, (2) Sonar Q Pellets, (3) Sonar AS Aqueous, Sonar* SRP, and (4) SonarOne®. These products contain the same herbicide active ingredient, but allow for differing release times. Treatment crews will use injection hoses to apply aqueous herbicide into treatment areas, and a broadcast method to apply pellets or granules. Pellets and granules will be applied on the water surface, but sink rapidly to the sediment.

In addition to herbicide treatments, EDCP proposes, in selected situations, to utilize handpicking and suction harvesting (by SCUBA divers), and benthic barrier. Evaluation of biological control methods is currently experimental. Handpicking and suction harvesting by SCUBA divers will primarily be utilized to reduce plant biomass in sensitive sites where chemical treatments cannot be utilized. Use of benthic barriers will be evaluated in select approved sites.

**Table 3-2**
**EDCP Objectives and Performance Measures**

| Objectives | Performance Measures |
|---|---|
| 1. Limit future growth and spread of *Egeria densa* in the Delta<br>2. Improve boat and vessel navigation in the Delta<br>3. Utilize the most efficacious treatment methods available with the least environmental impacts<br>4. Prioritize sites so that EDCP activities are focused on sites with a high degree of infestation, as well as navigational, public safety, agricultural, environmental, public access, or recreational significance<br>5. Employ a combination of control methods to allow maximum program flexibility<br>6. Enhance EDCP as more information is available on advances in control methods for the Delta<br>7. Monitor results of EDCP to fully understand its impacts on the environment<br>8. Improve shallow-water habitat for native species by controlling *Egeria densa*<br>9. Decrease EDCP control efforts, if sufficient efficacy of *Egeria densa* treatment is realized<br>10. Minimize use of control methods that could cause adverse environmental impacts. | ■ Reduce total acres infested with *Egeria densa*<br>■ Reduce *Egeria densa* biomass at high priority navigation sites currently infested with *Egeria densa*<br>■ Reduce *Egeria densa* biomass at nursery sites<br>■ Prevent *Egeria densa* infestation of new sites<br>■ Produce fewer incidents of boat navigation, public safety, public access, agricultural, and recreation incidents related to *Egeria densa*<br>■ Prepare reports for regulatory agencies and the public summarizing EDCP monitoring results<br>■ Minimize EDCP environmental impacts, as measured by compliance with program permits<br>■ Increase efficacy of EDCP, and of each control method over time<br>■ Increase the number of shallow-water sites suitable for native species<br>■ Limit the number of, and significance of, environmental impacts resulting from EDCP<br>■ Limit the number of EDCP acres treated with methods that have the potential for adverse environmental impacts<br>■ Reduce the quantity (pounds a.i.) of herbicides applied into the Delta over time. |

The EDCP will utilize trained teams to conduct treatments in the Delta between approximately March and November. The number of crews may be increased or decreased, depending on available resources and program needs. USDA-ARS and DBW propose a growth-based start-date approach that will minimize potential impacts on fisheries and maximize treatment efficacy. This approach will be dependent on fish survey data, Delta water temperatures, and field surveys for *Egeria densa*, within calendar-date windows, as described in Subsection D, below. Chemical treatments in selected sites will likely begin in March, with the majority of treatments beginning by April 1st. Treatments will continue for up to sixteen weeks, depending on the particular herbicide protocol. EDCP may conduct additional treatments in the fall during the late-season growth spurt characteristic of *Egeria densa*. These fall treatments will be completed by November 30th. The amount of herbicide applied in the project area to treat *Egeria densa* can be minimized by treating plants early in the growing season. Early treatment will also minimize the negative ecosystem impacts of this invasive species.

The legally defined EDCP region is divided into approximately 350 treatment sites that average between one and two miles in length. In any given year, EDCP will typically treat between three and twenty-five different sites,[2]

[2] This is slightly more than the maximum number of sites treated historically, at 18.

although this number may increase depending on the extent of *Egeria* invasion and available resources. In the early season, these sites may be treated as often as weekly for up to sixteen weeks during a treatment season in order to maintain an effective herbicide level. Some sites may be treated again in the fall during *Egeria densa's* second growth phase. Treatment sites will be prioritized so that nursery areas and areas where *Egeria densa* causes negative public safety, navigational, agricultural, environmental, or industrial impacts are treated first. Treatments sites in any given year will also be based on treatments in the prior year, as EDCP experience has shown that focused treatment in a given site for two to three years results in more effective control.

The EDCP will follow an Operations Management Plan that specifies a pre-application planning protocol, an Application/Monitoring Coordination Protocol, "Best Maintenance Practices" for Handling Herbicides, Equipment Maintenance and Calibration, and an Herbicide Spill Contingency Plan. The Operations Management Plan includes specification requirements related to avoiding threatened or endangered species, conducing habitat evaluation, dissolved oxygen measurement, and other program monitoring requirements. The DBW is currently updating the Operations Management Plan, and will provide a copy to NMFS and USFWS when the plan is finalized.

Based on NPDES permit requirements DBW will follow an Annual Monitoring Protocol. This protocol will fulfill monitoring requirements of the Central Valley Regional Water Quality Control Board (CVRWQB), NMFS, and USFWS. The State Water Resources Control Board (SWRCB) is updating the NPDES General Permit, with a draft for public comment released on June 27, 2012 and a final version for Board approval expected on February 19, 2013. DBW will revise their monitoring protocol to reflect the new conditions in the final General Permit.

The EDCP will conduct additional monitoring to ensure that herbicide levels are maintained, and to ensure that herbicide residues do not exceed manufacturer's acceptable levels for crops being grown in nearby fields. For these tests, EDCP will utilize FasTEST, an immunoassay test that can rapidly determine fluridone and penoxsulam concentrations.

## C. Action Area for EDCP

The EDCP action area can be defined at several different levels. First, the overall project area is defined in statute. Within the legislatively-defined project area, EDCP is divided into approximately 350 treatment sites. Only waterways within any given treatment site are actually part of the action area, and in any given treatment season EDCP treats only a small fraction of the 350 total treatment sites. The EDCP proposes specified avoidance protocols that may also limit treatments within a given treatment site.

### 1. Project Area Specified in Enabling Legislation

The project area for EDCP is specified in statute, as follows: "the delta[i], its tributaries, and the marsh" (Harbors and Navigation Code Section 64). The State of California legal definition of the Sacramento-San Joaquin

Delta (Delta) includes just six counties (San Joaquin, Yolo, Sacramento, Solano, Contra Costa, and Alameda). While statute authorizes EDCP treatments in Suisun Marsh, *Egeria densa* has not grown in Suisun Marsh due to higher salinity levels. In addition, to-date, EDCP treatments have not occurred in the southern tributaries. Treatments in these southern sites could be necessary if *Egeria* becomes established in these areas. The general boundaries for the treatment area include the legal Delta and its tributaries are as follows:

- West up to, and including, Sherman Island, at the confluence of the Sacramento and San Joaquin Rivers;
- North to the northern confluence of the Sacramento River and Sacramento River Deep Water Ship Channel;
- 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 LaGrange Reservoir below Don Pedro Reservoir; and
- East along the Merced River to Merced Falls, below Lake McClure.

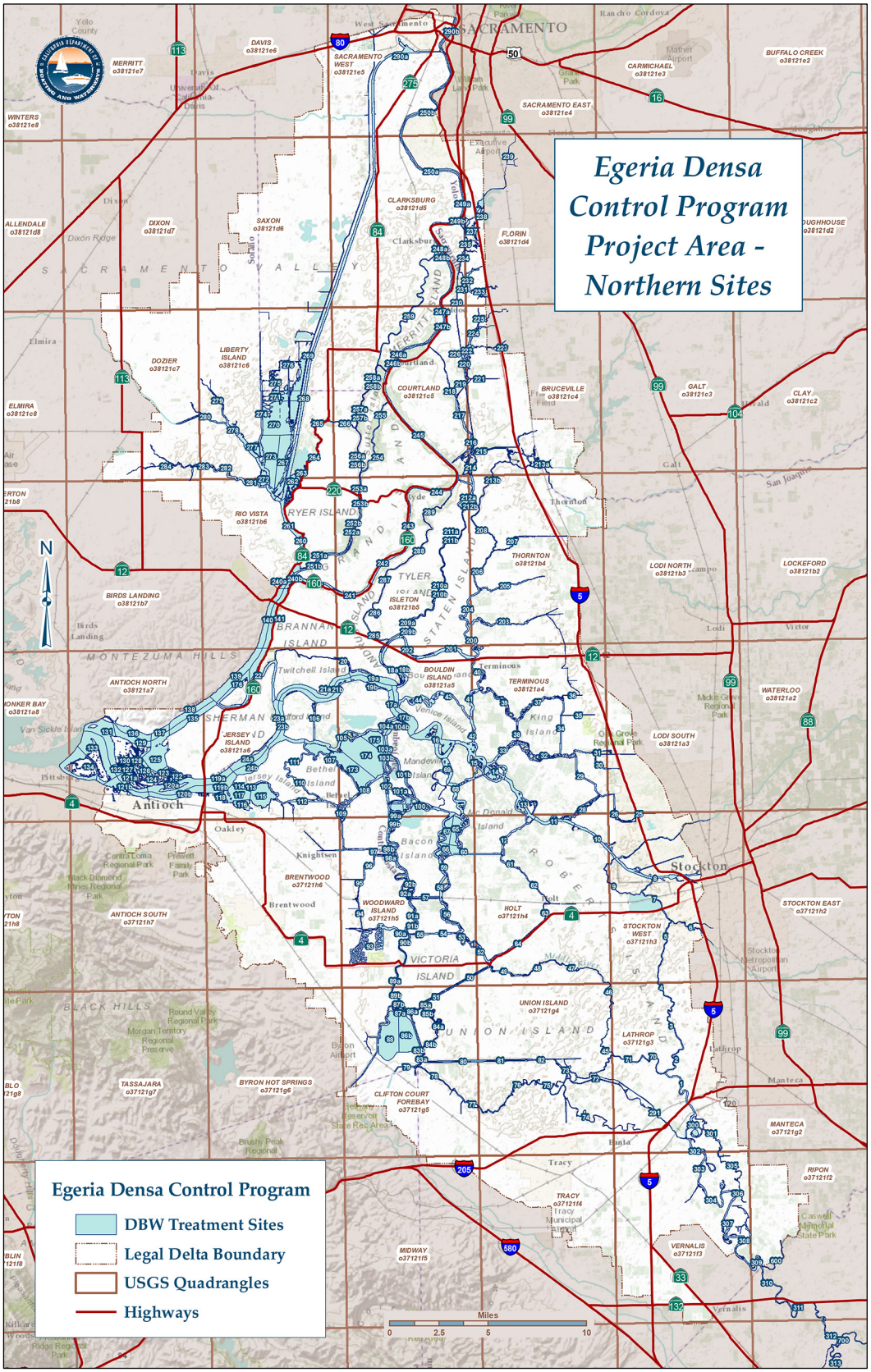
The project area is contained within the following fifty-one (51) United States Geological Service (USGS) quadrants: (1) Antioch North, (2) Rio Vista, (3) Jersey Island, (4) Isleton, (5) Bouldin Island, (6) Clifton Court Forebay, (7) Thornton, (8) Terminous, (9) Holt, (10) Union Island, (11) Lodi North, (12) Lodi South, (13) Stockton West, (14) Lathrop, (15) Woodward Island, (16) Courtland, (17) Gravelly Ford, (18) Mendota Dam, (19) Folsom, (20) Yosemite Lake, (21) Gustine, (22) Stevinson, (23) San Luis Ranch, (24) Turner Ranch, (25) Santa Rita Bridge, (26) Poso Farm, (27) Friant, (28) Lanes Bridge, (29) Vernalis, (30) Ripon, (31) Riverbank, (32) Waterford, (33) Paulsell, (34) Cooperstown, (35) La Grange, (36) Westley, (37) Brush Lake, (38) Ceres, (39) Denair, (40) Turlock Lake, (41) Snelling, (42) Merced Falls, (43) Crows Landing, (44) Hatch, (45) Turlock, (46) Cressey, (47) Winton, (48) Biola, (49) Herndon, (50) Firebaugh, and (51) Fresno North.

Within EDCP project area, there are approximately 350 possible treatment sites that average between one and two miles in length. The total number of treatment sites may be further defined and refined by EDCP to reflect jurisdictional and operational factors. The primary purpose of these defined treatment sites is to facilitate planning and reporting of EDCP activities. **Exhibit 3-1,** beginning on the next page, provides a map of the total potential EDCP treatment area and numbered treatment sites. **Section 7** provides a spreadsheet identifying each treatment site, county, acres, and previous treatment history.

*Photo:* Egeria densa *infestation.*

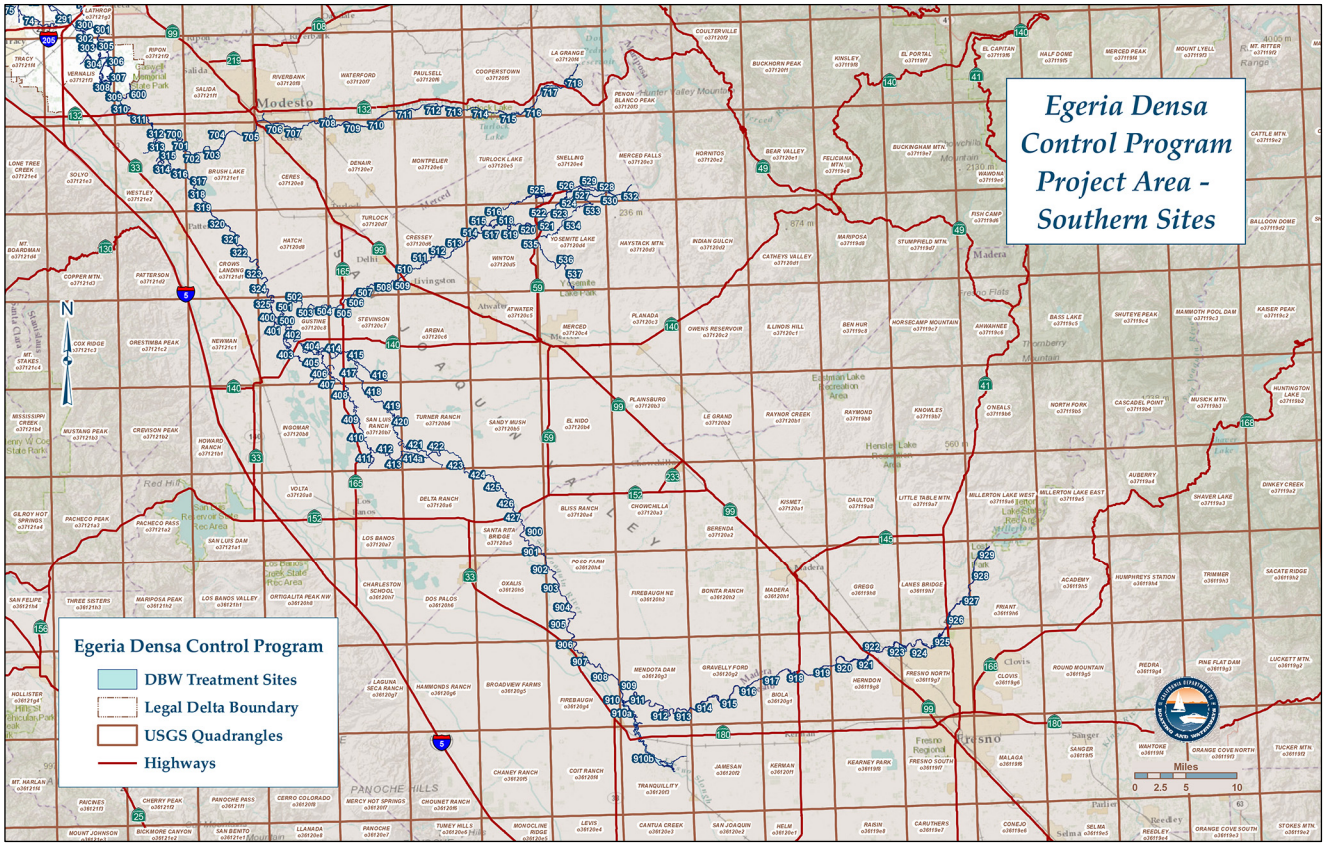
## Exhibit 3-1
### Northern Sites Map

*Page 1 of 2*



## Exhibit 3-1
### Southern Sites Map






NOTE: Large-scale versions of the map Exhibits in this Biological Assessment are provided in the Supplemental Binder.

In any given year, EDCP will treat a selected number of treatment sites, typically ranging from three to twenty-five different treatment sites.[3] The number of treatment sites in a given year may increase and will depend on the extent of *Egeria densa* invasion and available resources. Within a given treatment site, EDCP will treat only a carefully defined treatment polygon. The treatment polygon represents the area of the *Egeria densa* infestation and is often a small proportion of the overall treatment site.

Following the prioritization and site selection criteria described below, USDA-ARS and DBW will identify likely treatment sites and acres prior to each treatment season and provide a list of these sites and acres to USFWS and NMFS. In addition, USDA-ARS and DBW will provide the services with copies of the Notice of Intent (NOIs) before each treatment week. The NOIs identify likely treatment sites for each treatment crew for the following week.

Because *Egeria densa* treatments are most effective when a relatively small area is treated over an extended period of time, most treatment sites will be identified prior to the start of the treatment season. In no case will the program treat *Egeria densa* beyond the defined treatment sites within the project area described above and specified in statute.

## 2. Prioritization of Treatment Sites and Methods

Prior to the start of each treatment season, DBW and USDA-ARS will prioritize treatment sites and methods. The prioritization process will be based on results of pre-season field surveys combined with the experience and knowledge of the program environmental scientists, herbicide management experts, field supervisor, and program managers.

During the pre-season, EDCP staff and management will conduct one or more field surveys. During these surveys, teams will visit potential treatment sites, conduct rake surveys, and evaluate the extent of *Egeria densa* infestation and site conditions at each location. The team will also evaluate the extent of *Egeria densa* coverage at sites treated in previous years to determine whether these sites need to be re-treated.

During the rake surveys, the team will make "throws" of the rake into the *Egeria densa* mat, pull out the plants, evaluate the health of the plants, photograph the sample, and record the results. Rake samples are taken at a depth such that they collect plants near the sediment. The sampled plants are placed in the boat and disposed of away from the water and sensitive habitats.

After completing the field inspection, EDCP will create a list of potential treatment sites. EDCP management will further evaluate the sites and make the final treatment decisions, removing sites from the potential treatment list for factors such as presence of irrigation intakes and fast moving water flows. Sites that are nursery areas (generally high boat traffic sites and/or sites with dense stands of *Egeria densa*), and sites with numerous complaints, may receive higher priority. The management team will also evaluate quantitative survey data on bio-volume and bio-cover when available. Following this evaluation of the field surveys and additional data, USDA-ARS, DBW management, EDCP staff, and herbicide management specialists will jointly evaluate the

[3] This is slightly more than the maximum number of sites treated historically, at 18.

sites and prepare a treatment site list for the season. DBW will submit this list to NMFS and USFWS prior to the start of each treatment season. This list will include an estimate of the actual acreage to be treated (i.e. the treatment polygons) for each site.

This initial ranking will indicate the general priority for site treatment. DBW and USDA-ARS will identify priority treatment sites and develop a treatment plan for each site based on water acres, required herbicide concentrations, and length of treatment. USDA-ARS will provide USFWS and NMFS with a map of proposed EDCP treatment sites prior to the start of each treatment season. Under EDCP's focused approach developed between 2007 and 2012, DBW has generally conducted comprehensive treatments within a given site for at least two consecutive years, with some follow-up in later years. This approach has resulted in control within a given site, allowing EDCP to focus on different sites in the third year. EDCP may need to return to areas with persistent *Egeria densa* infestations, such as Franks Tract, every few years.

## 3. Avoidance Areas within Project Action Area

Within EDCP action area, and in addition to the prioritization process described above, EDCP provides an additional layer of site selection based on presence of listed species. The intent of these avoidance actions is to minimize the opportunity for treatments to occur when a listed species is present in, or near, a particular site.

The DBW will provide treatment crews with a field guide (Species Identification Deck) for easy identification of special-status species on-site. Prior to treating a site, crews will conduct a visual survey to determine whether special status plants, animals, or sensitive habitats are present. Crews will complete an Environmental Observation Survey for each site to document presence or absence of special status species. If special status species or sensitive habitats are present at the site, field crews will not perform any treatment. Historically, once or twice within a treatment season, crews identify a potential listed species (for example, a snake that could be a giant garter snake). A copy of the Environmental Observation Survey is provided in the Supplemental Materials Binder.

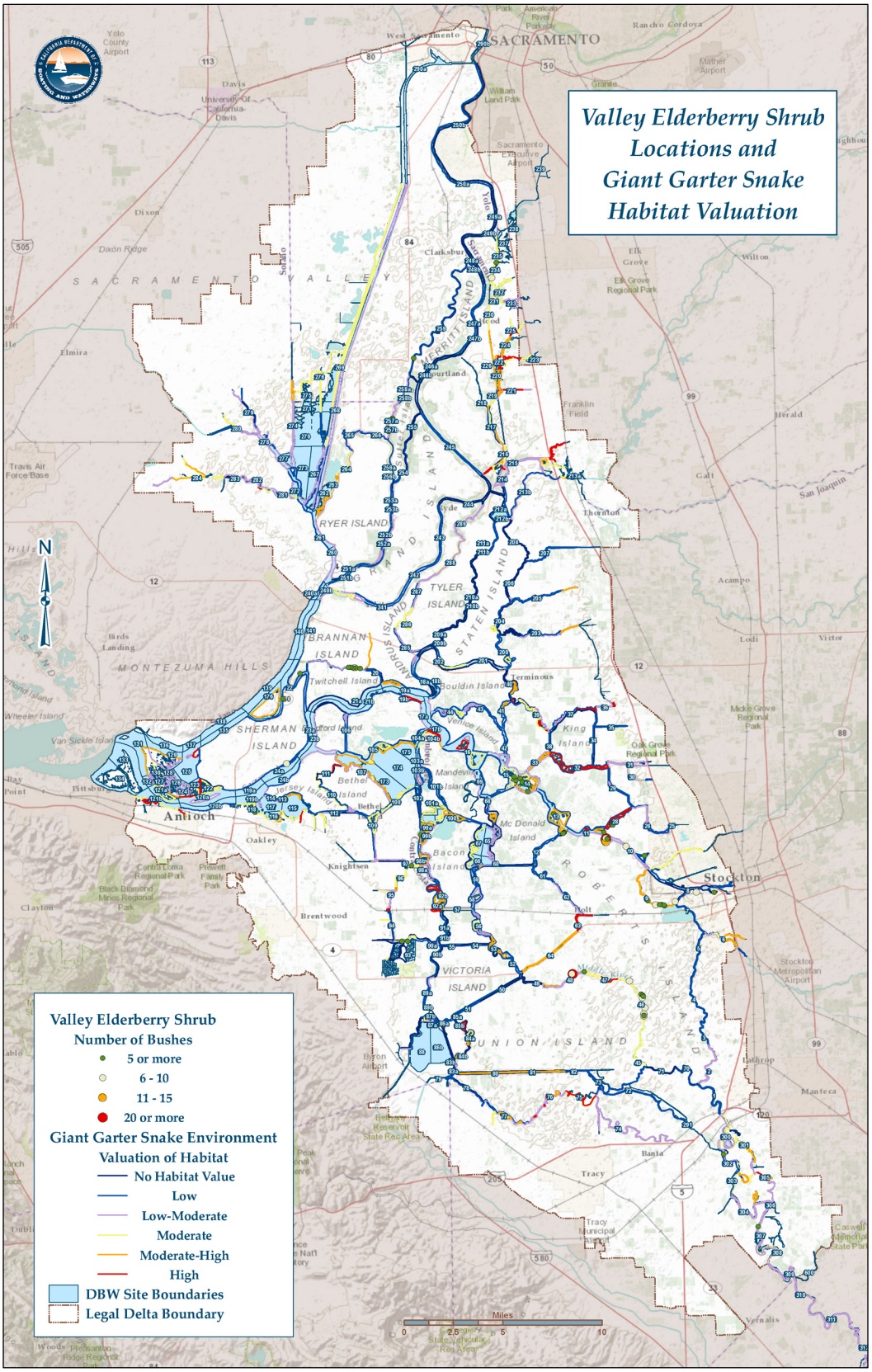
The EDCP implements additional measures to avoid the potential for impacts on listed species. The EDCP bases treatment dates, in part, on Interagency Ecology Program (IEP) monitoring showing that the salmon pulse has migrated through the system.

To avoid potential impacts to the valley elderberry longhorn beetle, the DBW conducts a survey of treatment sites to prepare a map that identifies locations of *Sambucus ssp*. (elderberry shrub), and provides this map to field crews. **Exhibit 3-2,** starting on the next page, provides the most recent version of a map showing valley elderberry shrub locations and giant garter snake habitat valuations. DBW crews will maintain a 50 foot buffer between treatment sites and shoreline elderberry shrubs. As Exhibit 3-2 illustrates, elderberry shrubs are common along some Delta waterways. To date, the sites known to have large numbers of elderberry have not been treated within EDCP.

## Exhibit 3-2

**Valley Elderberry Shrub Locations and Giant Garter Snake Habitat Valuation – Northern Sites**

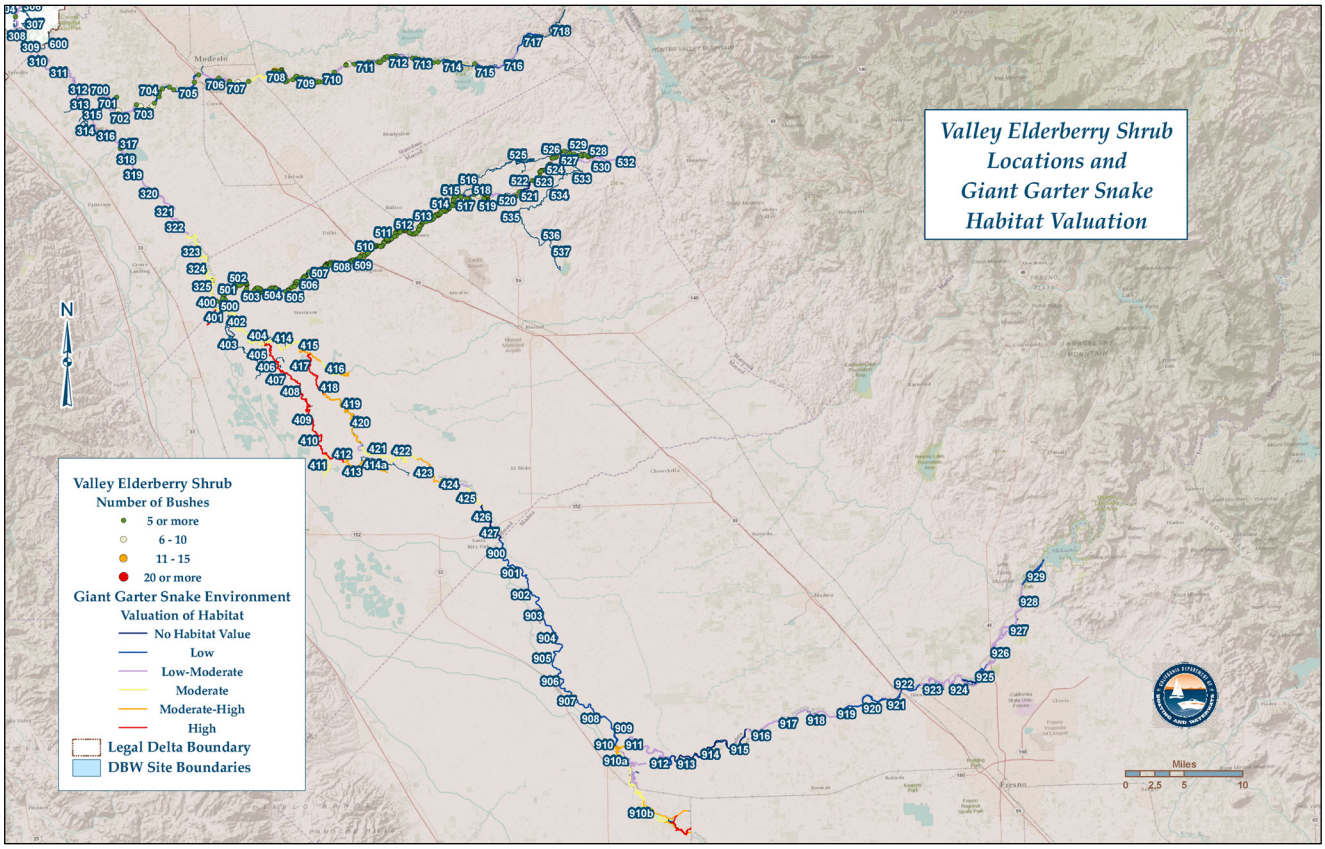
*Page 1 of 2*



## Exhibit 3-2

**Valley Elderberry Shrub Locations and Giant Garter Snake Habitat Valuation – Southern Sites** *(continued)*

*Page 2 of 2*




NOTE: Large-scale versions of the map Exhibits in this Biological Assessment are provided in Tab 20 of the Supplemental Materials Binder.

**Figure 3-2**
**Proposed Calendar of Treatment Activities for EDCP**

| Activity | 2012 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | JAN | FEB | MAR[a] | APR | MAY | JUNE | JULY | AUG | SEP | OCT | NOV | DEC |
| Environmental Surveys | | | | | | | | | | | | |
| Surveyor Training | | | | | | | | | | | | |
| Coverage Surveys | | | | | | | | | | | | |
| Fluridone Treatment | | | | | | | | | | | | |
| Penoxsulam Treatment[b] | | | | | | | | | | | | |
| Imazamox Treatment[c] | | | | | | | | | | | | |
| Diquat Treatment[d] | | | | | | | | | | | | |
| Herbicide Monitoring | | | | | | | | | | | | |
| Diver Handpicking and Suction Harvesting | | | | | | | | | | | | |
| Benthic Barriers | | | | | | | | | | | | |
| Reporting | | | | | | | | | | | | |

[a] The March start date for herbicide treatment would be dependent on temperature and fish surveys.

[b] Penoxsulam (Galleon)was approved by CDPR for aquatic use in 2009, but has not been utilized in EDCP as of 2012.

[c] Imazamox (Clearcast) was approved by CDPR for aquatic use on August 7, 2012, but has not been utilized in EDCP as of 2012.

[d] Diquat was utilized in EDCP between 2001 and 2005; diquat will be utilized in limited applications to support treatments with the other EDCP herbicides.

At the same time that DBW conducts its survey of valley elderberry within treatment sites, DBW environmental scientists conduct a survey to evaluate the value of habitat within treatment sites for giant garter snake. Habitat valuations include six habitat value levels: (1) no, (2) low, (3) low-moderate, (4) moderate, (5) moderate-high, and (6) high. DBW creates a map that identifies the habitat valuations (see Exhibit 3-2), as well as identifies locations of giant garter snake sitings. Treatment sites with high quality giant garter snake habitat include: 16, 17, 19, 28, 32, 47, 63, 75, 76, 115, 121, 122, 125, 215, 221, and 223. Sites where giant garter snakes have been seen in the past include: 15, 36, 119, 225, 237, 246, 275, and 410. Of these 24 sites, only sites 32 and 36 were treated for *Egeria densa* between 2007 and 2012.

## D. Timing of Activities of EDCP

**Figure 3-2,** above, provides a schedule of EDCP treatment activities. Timing of various treatment components, particularly chemical treatments, have historically been limited by the USFWS and NMFS biological opinions in order to avoid potential exposure of listed species, particularly juveniles, to herbicides.

This seasonal pattern of plant growth stage (its phenology) is why DBW will apply herbicides in the early part of the season, with some follow-up at the end of the season. Thus the phenology of *Egeria densa* and the mode of action of EDCP herbicides together drive the treatment strategies: timing, locations and QA/QC to ensure that proper concentrations and contact time are achieved

**Figure 3-3**
**Date and High Water Temperature (F) Ranges Supporting *Egeria densa* Growth at Bethel Island Station**

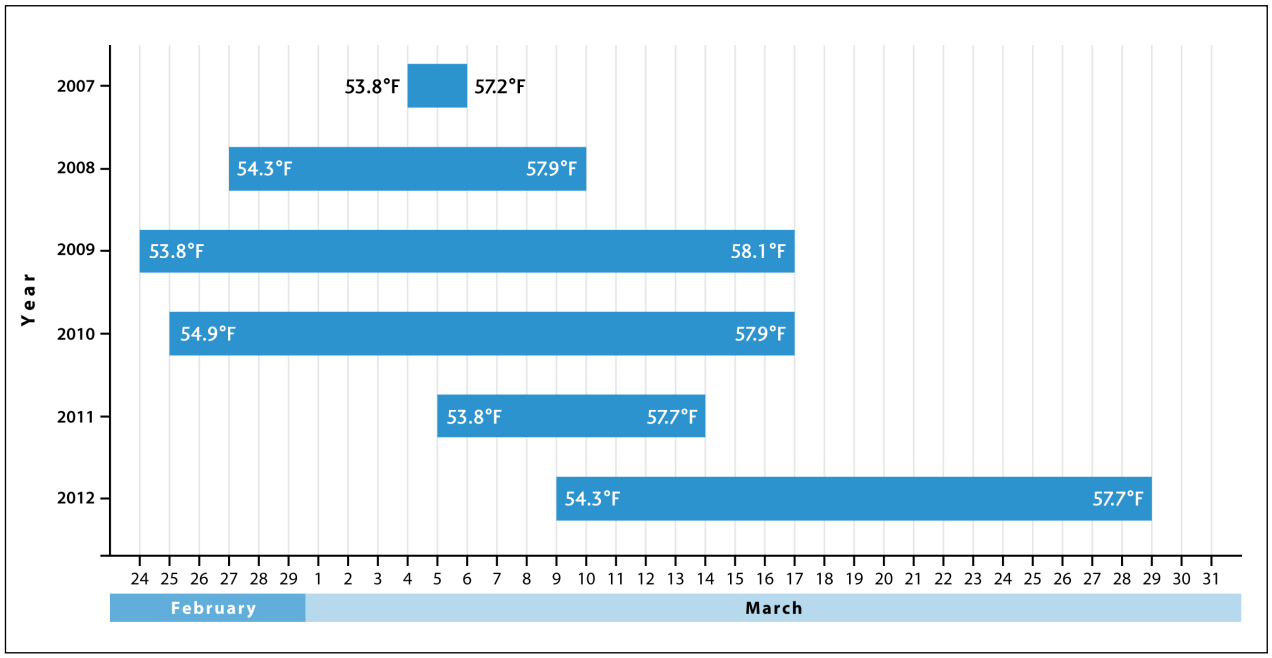


*Photo:* Egeria densa *infestation.*

to produce maximum efficiency while reducing the potential for impacts to special status species.

For 2013 and beyond, EDCP proposes a start-date approach that utilizes a combination of calendar-dates, field surveys of *Egeria densa*, Delta water temperatures, and IEP and CDFG surveys to determine presence of special status fish species. The objective of this approach is to improve EDCP chemical treatment efficacy without negatively impacting special status fish species. Seasonal temperature fluctuations in the Delta impact both *Egeria densa* growth and migratory fish activity. These weather fluctuations can become relatively extreme.

**Figure 3-3,** above, provides an illustration of the range of water temperatures and dates suited to *Egeria densa* starting spring growth at the Bethel Island DWR monitoring station, near Franks Tract, a major *Egeria* infestation site. For each year (2007 through 2012), Figure 3-3 shows the time period during which high water temperatures reached the optimal growth daily high water temperature of 12°C to 14°C (53.6°F to 57.2°F). Based on established *Egeria densa* growth patterns, we can assume from the start of the shaded period for each year, *Egeria densa* was beginning its spring growth spurt. For example, in 2008,

Egeria densa would have started its spring growth spurt on approximately February 27th, and continued growing through the summer and fall. As Figure 3-3 illustrates, there is a range of dates that growth could start, for example in late February in some years or mid-March in other years.

A further indication for early *Egeria densa* treatments in the Delta is the finding that *Egeria densa* self-fragments at approximately 10°C (50°F)(Pennington 2007). This naturally generated fragmentation, occurring at the plant's nodes, is the method of vegetative reproduction. Released fragments move in Delta waters and can reestablish at new locations. Thus, beginning *Egeria densa* treatments early, prior to the fragmentation, can reduce the potential for viable fragments to release and establish new plants (Pennington 2007). Analysis of water temperatures at the same Bethel Island DWR monitoring station shows water temperatures in most years in the 49°F to 51°F range between late January and early February. This might be earlier than would be reasonable to treat in most Delta locations, because *Egeria densa* will not have started actively growing (Shuler 2012). However, EDCP may want to evaluate the impact of even earlier treatments on fragmentation and spread of infestations at some locations.

While *Egeria densa* grows to some extent year-round in the Delta, it experiences a fall growth spurt, typically when water temperatures fall back to around 20°C (68°F), and day-length is shortening (Shuler 2012). At the Bethel Island DWR monitoring station, water temperatures returned to around 68°F between September 15th (2008) and October 3rd (2011). Ideally, fall treatments should start at this time, and continue for up to eight weeks, depending on the herbicide used.

Treatment start dates linked to historical calendar dates may not necessarily reflect presence or absence of migratory special status fish species. These species migrate through the Delta under conditions of cooler water temperatures. The EDCP regularly consults several state and federal fish surveys to monitor presence of listed fish species. DBW environmental scientists compare results from fish surveys with scheduled treatment sites to determine likely presence of listed fish species. If these surveys indicate that threatened or endangered fish are likely to be present in the treatment site, EDCP will delay treatment. These surveys include the following:

- USFWS "DatCall" data (juvenile fish monitoring program through the Interagency Ecology Program (IEP)). This survey includes three trawls and various beach seines at locations throughout the Delta. Reports are sent on a weekly basis to report data from the previous week (http://www.fws.gov/stockton/jfmp)
- CDFG surveys and studies (also through IEP). These surveys include the 20mm Survey, Smelt Larva Survey, and Spring Kodiak Survey in the Delta, Suisun Bay, and San Francisco Bay. Results are posted on the CDFG website within 72 hours of data collection on interactive maps (http://www.dfg.ca.gov/delta/data/)
- DWR and USBR (through CDFG) fish salvage data. These daily and weekly reports provide salvage data collected at the state and federal fish salvage facilities (http://www.dfg.ca.gov/delta/apps/salvage/Default.aspx and

http://www.water.ca.gov/swp/operationscontrol/calfed/calfedmonitoring.cfm)

- FishBio San Joaquin Basin Update reports on surveys in the San Joaquin Basin, including Calaveras River, Stanislaus River, Tuolumne River and Mokelumne River. Report frequencies vary, and will be used to supplement the regular surveys listed above. DBW subscribes to the FISHBIO newsletter (http://fishbio.com/fisheries/industry-news/regional-fisheries-news)
- CDFG Knights Landing Rotary Screw Trap (RST) data provides weekly reports (via email newsletter) of fish presence on the Sacramento River at Knights Landing. This location is outside of EDCP program area, but migration of fish at Knights Landing can indicate movement toward the Delta.

*Egeria densa* growth increases as water temperatures rise. As water temperatures rise during a given season (and more particularly at a given site), migratory fish are more likely to move through the Delta earlier. Early fish movement through the Delta will also coincide with earlier rapid growth of *Egeria densa*, when chemical treatments are most effective. Thus, when fish have migrated through the Delta earlier, beginning *Egeria densa* treatments early can help to maximize effectiveness of chemical treatments. These early treatments can reduce the total amount of herbicide necessary during the treatment season.

The EDCP start-dates will be determined as follows:

1. EDCP will monitor daily Delta water temperatures at several key DWR monitoring stations near EDCP treatment sites, such as Bethel Island, Steamboat Slough, and Middle River @ Tracy Road Bridge. In addition, EDCP crews and environmental scientists will monitor *Egeria densa* infestations during the winter period to determine the extent of growth and health of the weed
2. When water temperatures at these sites consistently reach 10°C (50°F), and/or there are signs of plant fragmentation, EDCP will evaluate the need for early season treatments, report these locations to USFWS and NMFS, and consult with IEP/CDFG databases to determine whether listed fish species are present. If listed fish species are not present, and USFWS and NMFS concur, treatments will start in these specific sites, potentially as early as late-February, but likely by early March
3. EDCP will continue to monitor water temperatures and conduct field surveys in other sites with *Egeria* infestations between mid-February and March 31st. As water temperatures reach the 12°C to 14°C range (53.6°F to 57.2°F), EDCP will report these locations to USFWS and NMFS, and consult with IEP to determine whether listed fish species are present. If listed fish species are not present, and USFWS and NMFS concur, treatments will start in these specific sites

*Photo:* Egeria densa *rate sampling.*

**Figure 3-4**
**Summary of Proposed EDCP Chemical Treatment Start Dates**

| Proposed EDCP Treatment Dates (2013-2017) | | Comments |
|---|---|---|
| Beginning between late February to April 1st, for up to 12 weeks | Specific approved high priority nursery sites, and warm-water sites, TBD | Length of treatment period depends on herbicide |
| Beginning April 1st to May 15th, for up to 12 weeks | Other EDCP treatment sites where listed fish are not present | Length of treatment period depends on herbicide |
| Beginning mid-September for up to 8 weeks, and ending by November 30th | Selected fall EDCP treatment sites where listed fish are not present | Length of treatment period depends on herbicide |

4. The EDCP will maintain the historical April 1st start dates in any remaining *Egeria densa* treatment sites where treatments did not begin earlier based on water temperatures and surveys
5. Following completion of the first treatment phase, which will last up to sixteen weeks from treatment start date depending on the herbicide used, EDCP will monitor treatment effectiveness and survey for new infestations. EDCP will identify potential sites for fall treatments, depending on the extent of *Egeria* infestations, efficacy of spring treatments, and amount of herbicide used (so as to not exceed any applicable seasonal application rates). EDCP will inform USFWS and NMFS of proposed fall treatment sites. Fall treatments will typically start in mid-September, or when water temperature drops to approximately 20°C, and will last approximately 8 weeks, to be completed by November 30th.

**Figure 3-4,** left, summarizes proposed EDCP start and end dates. This adaptive approach to treatment dates has strong potential to improve EDCP efficacy and reduce chemicals in the Delta. Both of these factors will provide long-term benefits to listed species in the Delta.

EDCP treatment methods such as diver-assisted handpicking and diver-operated suction harvesting, and benthic barriers will typically occur early in the treatment season, but could be employed at any time during the treatment season to address new infestations or infestations in high-use areas. The EDCP will not employ these methods in areas or at times when sensitive species are likely to be present.

On any given treatment day, actual start of treatments depends on the distance from DBW's boat dock to the treatment site. Field crews typically begin their work day at 6:30 am, thus treatment activities generally occur in mid-morning and again in early-afternoon.

## E. Control Methods for EDCP

The EDCP applies Integrated Pest Management (IPM) and Maintenance Control Practices (MCP). IPM denotes the coordinated use of available control methods for a particular pest. The State of California defines IPM as: a pest management strategy that focuses on long-term prevention or suppression of pest problems through a combination of techniques such as monitoring for pest presence and establishing treatment threshold levels, using non-chemical practices to make the habitat less conducive to pest development, improving sanitation, and employing mechanical and physical controls. Herbicides that pose the least possible hazard and are effective in a manner that minimizes

risks to people, property, and the environment, are used only after careful monitoring indicates they are needed according to pre-established guidelines and treatment thresholds.

MCP refers to practices that minimize plant biomass through regular, low-level, control treatments applied at times during a plant's life cycle when treatments are most effective. Ideally under a maintenance control program, the acres of *Egeria densa* required to be treated are reduced each year until they reach a minimal level.

The EDCP has historically been following IPM and MCP and will continue to do so. The EDCP balances IPM and MCP approaches in order to simultaneously reduce impacts and increase effectiveness. For example, in order to avoid impacts to migrating special status fish, treatments may occur as early in the growing season as possible but later in a plant's lifecycle than would be ideal.

The EDCP follows an adaptive management approach in which DBW seeks to improve efficacy and reduce environmental impacts over time as new and better information is available about the program. Within the adaptive management approach, EDCP will:

- Evaluate the need for control measures on a site-by-site basis
- Utilize most effective herbicide application protocols and reduce use of potentially riskier herbicides
- Follow NPDES general permit pre- and post-treatment monitoring protocols and evaluate data to determine environmental impacts
- Support ongoing research to explore the impacts of EDCP and alternative control methodologies, including biological controls and herbicides with reduced environmental impacts
- Report findings from monitoring evaluations and research to regulatory agencies and stakeholders.

To minimize potential environmental impacts, EDCP selects the most appropriate control methods for a given site in the Delta based on the season (spring or fall) and that site's conditions. The USDA-ARS and DBW will also monitor results of EDCP and base future control methods on these results. The selected treatment alternative and protocol will be selected to provide the greatest reduction in *Egeria densa* biomass and bio-volume while avoiding or minimizing environmental impacts. The EDCP will continue to adjust program actions, as necessary, in response to recommendations and evaluations by regulatory agencies and stakeholders.

The EDCP will emphasize chemical treatment, with limited application of diver assisted handpicking and diver-operated suction harvesting, benthic barriers, along with continued assessment of biological controls. Selected herbicides are fluridone, penoxsulam, imazamox, and diquat, with fluridone to be used for the majority of treatments. Diquat use will be minimized.

The EDCP will include diver assisted handpicking and diver-operated suction harvesting in limited situations when there are isolated infestations in high-use or sensitive areas, particularly when chemical treatments are not allowed. The EDCP will include limited use of benthic barriers in selected locations where there are isolated infestations in high-use or high-water flow areas where chemical applications will be less effective.

*Photo:* Egeria densa *liquid injection treatment*

The DBW and USDA-ARS are also evaluating viable biological control methods for *Egeria densa*. These research efforts currently focus on a study of a larval fly from Argentina. Biological controls are briefly described in this document for background, but are not part of this consultation.

For each particular season and treatment site, EDCP will evaluate characteristics of the site and select the most appropriate treatment option(s). Prior to the start of each treatment season, EDCP will provide USFWS and NMFS with a treatment plan that outlines and prioritizes treatment sites and treatment methods.

## 1. General Program Activities

There are a number of management activities within EDCP that support the program. USDA-ARS staffing for the WHCP and EDCP will include a managing supervisor, administrative support, and scientific staff. Within DBW, employees that work directly on the EDCP will include a manager, a senior environmental scientist, field environmental scientists, a field supervisor, a GIS mapping specialist, and field crew members. DBW may add or reduce staff to support program needs over time. The EDCP also receives management and administrative support from the executive office within DBW.

Prior to the start of each treatment season, DBW will conduct environmental awareness training for all field crew members. The training will include: species identification and impact avoidance guidelines, protocol for identification and protection of elderberry shrubs, protocol for identification and protection of delta smelt, Chinook salmon, steelhead, green sturgeon, and associated protected habitats, and protocol for take of protected species. In addition, field crew members will be trained on use and calibration of equipment and EDCP Operations Management Plan.

The EDCP will implement pre- and post-season surveys to identify locations and coverage of *Egeria densa*, and will supplement these formal surveys with mid-season evaluations of *Egeria densa* coverage. Beginning in mid-February, and again in the fall, field crews will conduct visual surveys of all treatment sites. For each site, crews will record the extent of *Egeria densa* coverage (acres and percent coverage) and status of *Egeria* at the site. In the early season survey, field crews will identify problem areas such as those with the greatest impact on navigation, public safety, nursery areas, and sites close to pumps or other structures. This survey information will be used to help prioritize treatment locations at the start of the treatment season, and to help measure efficacy of *Egeria densa* treatments at the end of the season. During the treatment season, as crews are working throughout the Delta, they will continue to monitor and record *Egeria densa* coverage by site.

DBW environmental scientists will conduct additional *Egeria densa* monitoring throughout the year at selected locations, including rake surveys and quantitative measures of bio-volume and bio-cover. These surveys will provide detailed quantitative metrics of the change in bio-volume (percent of volume of *Egeria densa* in a given site) and bio-cover (percent of coverage of *Egeria densa* in a given site) in treated sites, as compared to control sites, during and after a treatment season. In prior years, EDCP has conducted hydroacoustic (sonar) monitoring surveys, and will continue these surveys in 2013 and beyond.

In addition to survey reports, each year USDA-ARS and DBW will prepare an EDCP annual report. This annual report will summarize infestation levels, treatment acreage and types, compliance with biological opinions and/or letters of concurrence and the NPDES permit, materials and methods, monitoring results, and daily treatment logs. The annual report will fulfill the reporting requirements of the federal agencies and NPDES permit.

## 2. Herbicide Treatments

The EDCP proposes to utilize four different herbicide active ingredients: fluridone, penoxsulam, imazamox, and diquat. Fluridone has been, and will continue to be, the primary herbicide utilized. Penoxsulam and imazamox will be new to the program. These two herbicides have received United States Environmental Protection Agency (USEPA) approval for use on *Egeria densa*. The California Department of Pesticide Regulation (CDPR) has also recently approved the use of these two new aquatic herbicides for treating *Egeria densa*. Penoxsulam and imazamox are included in this program description and biological impact assessment. These two new herbicides are intended to have low toxicity profiles, and would reduce the potential for negative impacts. The fourth herbicide active ingredient, diquat, has been utilized by the EDCP in limited quantities, although not since 2005. Due to its rapid mode of action, spot applications of diquat at selected times and sites may reduce the overall amount of herbicide needed to control *Egeria densa*.

There are several reasons why EDCP is adding two new herbicides to the program. First, new lower-toxicity profile herbicides have the potential to reduce the environmental impact of EDCP. Second, new herbicides may reduce the amount of chemical applied to Delta waterways to treat *Egeria densa*. Third, utilizing herbicides with varying modes of action reduces the potential for target species to develop resistance.

While there are no indications of *Egeria densa* resistance to date, there are reports of aquatic weed resistance to herbicides. A 2006 study by Koschnick et al. reported a 50-fold resistance to diquat for duckweed in a canal in Florida (Richardson 2008). A 2004 study by Michel et al. identified two- to sixfold fluridone resistance of hydrilla in at least twenty water bodies in Florida, with three different hydrilla biotypes having distinct somatic mutations (Michel et al. 2004). The fluridone-hydrilla example, in particular, emphasizes that reliance on a single herbicide for aquatic invasive weed management is not wise (Richardson 2008).

Resistance is an important consideration in use of any herbicide over a long period of time. Some species of terrestrial weeds have developed resistance to glyphosate (Powles

2008) or acetolactate synthase (ALS) inhibitors (Wisconsin Department of Natural Resources 2012). Terrestrial resistance to ALS inhibitors has occurred after many (over ten) years of use. Resistance is not necessarily the same across terrestrial and aquatic plants, and generally is species specific. Recommended methods to minimize potential for resistance include rotating herbicides with different modes of action or using tank mixtures of two or more herbicides with different modes of action (Hutchinson et al. 2007).

Because EDCP is a long-term control program, it will be prudent to increase the portfolio of herbicide active ingredients and of non-herbicide treatment options in order to reduce the potential for resistance. Rotating treatments in a given site after several years and using herbicides with different modes of action reduces the potential for a plant to develop resistance. USDA-ARS, EDCP environmental scientists and Pest Control Advisors (PCAs) will evaluate *Egeria densa* response to program herbicides over time to identify potential resistance problems.

The two new EDCP herbicides (penoxsulam and imazamox) are part of the USEPA's Office of Pesticide Program's Conventional Reduced Risk Program. This program expedites the review and regulatory decision-making process of conventional pesticides that pose less risk to human health and the environment than existing conventional alternatives (Washington DOE 2012). Pesticides are typically included in the reduced risk program because they have advantages over existing pesticides such as low impact on human health, lower toxicity to non-target organisms, low potential for groundwater contamination, lower use rates, low pest resistance potential, and/or compatibility with integrated pest management practices.

Herbicide applications will typically be conducted once or twice per week over a two to sixteen week treatment period. The EDCP will develop specific herbicide treatment protocols for each site prior to the start of the treatment season. Treatment crews use injection hoses to apply aqueous herbicide into treatment areas, and a broadcast method to apply pellets. Both methods are applied from airboats or outboard motor workboats. Prior to the start of the treatment season, EDCP will design a treatment protocol for each selected site that is designed to maintain a pre-determined concentration of herbicide in the water column during the treatment period. Treatment crews follow specific requirements to account for wind, dissolved oxygen, pH, drinking water intakes, agricultural intakes, and total acres treated. Treatment crews follow all label requirements.

The amount of herbicide used and number of acres treated in a given year can reflect the magnitude of infestation. However, there are several other factors that affect the amount of treatment that EDCP conducts (regulatory limits, local water conditions, weather, staff levels, etc.).

*Photo:* Egeria densa *treatments.*

The ideal herbicide treatment time for *Egeria densa* is when the plant is in the early growth phases, typically starting in March in the Delta. Treating *Egeria densa* during the early growth phase will increase herbicide efficacy and reduce the total amount of herbicide required. When appropriate, EDCP will also conduct a second series of treatments starting in September, during *Egeria densa's* second growth phase. The need for these second treatments will be determined on a site and season basis, depending on the response of *Egeria* to the first treatment.

Herbicide applications to treat submersed aquatic vegetation (SAV) such as *Egeria densa* requires an herbicide rate calculation on the basis of the volume of water to be treated (Richardson 2008). Water flow, such as that resulting from the diurnal tides in the Delta, is a concern because it will reduce both herbicide concentrations and contact time with the target concentration. EDCP herbicide treatment protocols will be developed assuming static water conditions due to the difficulty in predicting the impact of tidal flows in each site, thus, actual herbicide concentrations in a site will be lower than application rates. This is exemplified in fluridone monitoring data, as described below.

Once EDCP has determined the treatment sites for the season, the management team will develop a treatment protocol for each site and treatment polygon. The treatment polygon refers to a specifically defined area within the treatment site, infested with *Egeria densa*, in which herbicides will be applied. The treatment protocol will identify the herbicide active ingredient(s) and formulation(s) that will be utilized, number of treatment weeks, application concentrations, and total application concentrations. The number of treatment weeks and application concentrations will depend on the herbicide, formulation, status of *Egeria densa* at the site, and water flow characteristics.

The treatment polygon will typically represent a fraction of the water acres of the treatment site. **Table 3-3,** on the next page, provides a summary comparison of the treated water acres and site water acres for EDCP between 2007 and 2012. Table 3-3 also provides a percent of Delta waters treated, for comparison purposes. As Table 3-3 illustrates, EDCP treats, on average, just over 50 percent of the waters within treatment sites, and just over three percent of Delta waters.

Depending on FasTEST results, crews will typically treat each site once a week for the duration of the treatment protocol for that site. For fluridone, DBW has found that in most Delta locations a twelve-week treatment protocol is effective. The EDCP will evaluate treatment protocols for penoxsulam and imazamox to determine the most effective treatment period in the Delta environment. Based on herbicide characteristics, it is likely that penoxsulam will require an 8 to 12 week treatment period, and imazamox will require a shorter, 2 to 4 week treatment period. As EDCP begins utilizing these new herbicides DBW will closely monitor results to determine ideal treatment periods, which could vary from these preliminary estimates. Diquat will be used in limited instances to supplement the other herbicide treatments, and/or when public safety or other factors require that the weed be killed more rapidly.

The remainder of this subsection describes the mode of action, chemical characteristics, environmental fate, application rates and

frequency, label requirements, and concentrations in water for each of proposed four EDCP herbicides. **Exhibit 3-3,** on the next page, provides a comparison of the four potential EDCP herbicides.

The EDCP does not have access to compounds of the inert ingredients in herbicides, as explained by USEPA (http://www.epa.gov/opprd001/inerts/inertsdisclosure.html):

> "USEPA does not currently identify inert ingredients on pesticide labels. Pesticide manufacturers often claim as confidential the identities of inert ingredients in their products. Federal confidentiality regulations (40 CRF part 2, subpart B) require USEPA to protect information claimed as confidential by companies. Once exception is when USEPA provides inert ingredient information to medical professionals treating persons in connection with exposure to a pesticide (FIFRA § 12(a)(2)(D)).
>
> USEPA requires registrants to identify to the Agency all ingredients in their pesticide products. A challenge for inerts disclosure by registrants is that their pesticides may include proprietary products whose contents are held confidential by the manufacturer. EPA knows the composition of those products, but does not disclose it to registrants."

California Department of Pesticide Regulation (CDPR) follows a similar policy regarding inert ingredients. However, any toxic ingredients in a pesticide formulation must be identified on Material Safety Data Sheets (MSDS) for the product; none of EDCP herbicides identify toxic inert ingredients. Inert ingredients in the fluridone pellet formulations consist primarily of different clays that result in varying release times for the active ingredient. MSDSs for each of the EDCP herbicides are provided in the supplemental binder with this consultation package. The EDCP does not use any adjuvants or surfactants at this time for EDCP.

### Fluridone

Fluridone was approved by the USEPA in 1986 and by the CDPR for use in California as an aquatic herbicide in 1996. There are a variety of different formulations of the herbicide, including liquid and pellets. The EDCP will utilize fluridone formulations such as: Sonar* AS (liquid), Sonar® PR (granular) and two pellet formulations, SonarOne®, Sonar® Q. The pellet and granular formulations provide different release profiles due to the characteristics of the inert clay ingredients. All formulations have the same mode of action and concentration limitations. SePRO developed the release profile for SonarOne based on the characteristics of the Delta. The chemical structure of fluridone is provided in **Figure 3-5,** on page 3-30.

**Table 3-3**
**Comparison of EDCP Treatment Acres with Site Water Acres and Delta Water Acres, by Year (2007 to 2012)**

| Year | Number of Sites | Site Treated Acres | Site Water Acres | Percent of Site Area Treated | Percent of Delta Treated |
|---|---|---|---|---|---|
| 2007 | 3 | 2,571 | 3,466 | 74% | 4.2% |
| 2008 | 3 | 2,571 | 3,466 | 74% | 4.2% |
| 2009 | 5 | 228 | 836 | 27% | 0.4% |
| 2010 | 3 | 641 | 1,768 | 36% | 1.0% |
| 2011 | 9 | 3,195 | 4,976 | 64% | 5.2% |
| 2012 | 18 | 2,663 | 6,773 | 39% | 4.3% |
| **Average** | **7** | **1,978** | **3,548** | **53%** | **3.2%** |

**Exhibit 3-3**

**Summary Comparison of Current and New EDCP Treatment Herbicides**

| | Fluridone | Penoxsulam | Imazamox | Diquat |
|---|---|---|---|---|
| **Status** | DPR approved<br>Used in EDCP | DPR approved<br>New to EDCP | DPR approved<br>New to EDCP | DPR approved<br>Used in EDCP |
| **Application Rate** | 5 to 30 ppb per application | Maximum 150 ppb/ growing season<br>10 to 50 ppb per application (est.) | Maximum 500 ppb/ growing season<br>100 to 250 ppb per application (est.) | 0.37 ppm/ application with 14 to 21 days between applications |
| **Estimated Concentration after Application** | 1 to 10 ppb | 5 to 25 ppb | 50 to 125 ppb | 0.01 to 0.37 ppm |
| **NPDES Maximum Limitation in Receiving Waters** | 560 ppb | 10.1 ppm | To Be Determined | 20 ppb |
| **USEPA Fish Toxicity Classification (Section 6)** | Slightly toxic | Practically non-toxic | Practically non-toxic | Slightly toxic |
| **USEPA Macroinvertebrate Toxicity Classification (Section 6)** | Moderately toxic to slightly toxic | Slightly toxic | Practically non-toxic | Very highly toxic to highly toxic |
| **Concentrations Utilized for RQ Calculations (Section 6)** | 30 ppb acute<br>3 ppb chronic | 50 ppb acute<br>10 ppb chronic | 250 ppb acute<br>100 ppb chronic | 0.37 ppm acute<br>15.9 ppb chronic |
| **Pros** | Proven effective method in Delta; low concentrations; many formulations available | Lower toxicity; requires lower concentration than imazamox | Lower toxicity; shorter exposure time; more selective than penoxsulam | Fast acting contact herbicide, supplements slower acting herbicide treatments in areas with acute *Egeria densa* problems |
| **Cons** | Used as a single treatment method for many years, no resistance to date, but good to vary; requires 12 weeks for best results | Likely needs 8 to12 week exposure; need to experiment with application plans in Delta waters; 1 ppb irrigation water restriction | Need to experiment with application plans in Delta waters | Toxicity to macroinvertebrates; not all plant exposed to herbicide, resulting in more rapid re-growth, need to retreat |

**Figure 3-5**
**Fluridone Chemical Structure**

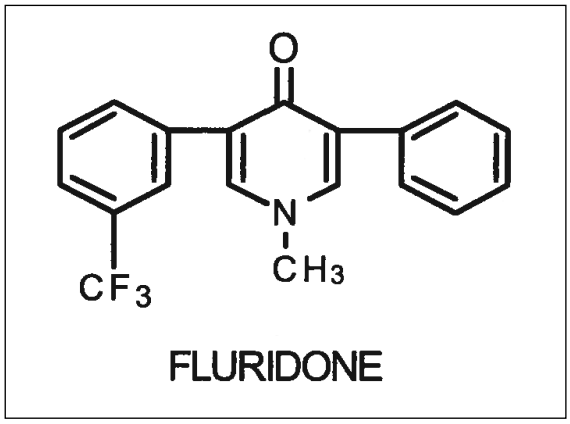


*Photo:* Egeria densa *trapping motor.*

Fluridone (1-methyl-3-phenyl-f-[3-(trifluoromethyl)phenyl]-4(1H)-pyridinone) is a slow-acting selective systemic aquatic herbicide used to control primarily broad-leaved, submersed aquatic macrophyte species. Fluridone moves from exposed shoots to rhizomes and roots. Fluridone inhibits formation of carotenoid pigments (including carotene) through inhibition of the enzyme, phytoene desaturase. Carotenoids protect chlorophyll from photooxidation and therefore lack of carotenoids results in the degradation of chlorophyll when exposed to sunlight. Because carotene and chlorophyll are formed primarily during new growth, fluridone is most effective when the plant is growing rapidly (i.e. in spring, and sometimes in fall during a final growth phase). White (chlorotic) or pink growing points appear on the target weed seven to ten days following initial treatment. Weed control is achieved after thirty to ninety days of treatment under optimal conditions. Langeland et al. (2009) rate fluridone as having good efficacy against *Egeria densa* in Florida.

Photolysis is one of the major degradation pathways of fluridone, breaking down the herbicide into naturally occurring elements. The primary metabolite of fluridone degradation in fish was identified as 1-methyl-3-(4-hydroxyphenol)-5-[3-trifluoromethyl) phenyl]-4[1H]-pyridone. Other metabolites include benzaldehyde, 3-(trifluoromethyl)-benzaldehyde, benzoic acid and 3-(trifluoromethyl)-benzoic acid, and N-ethylformamide (NMF) (McLaren/Hart, 1995). The half-life of fluridone in water of small artificial ponds range from one to seven days. Fluridone is stable to oxidation and hydrolysis and volatization of fluridone is not expected to be significant. The organic carbon sorption coefficient ($K_{oc}$) for fluridone is approximately 350 to 2,460 ml/g (USEPA, 2004).

A study summarizing field dissipation data for fluridone formulations found an average half-life of 20 days in pond water (ranging from 5 days to 60 days) and 3 months in pond hydrosoil (West et al., 1983). Fluridone half-life in lakes is shorter due to dispersal of fluridone, with an average half-life of less than one week. Lake applications are more similar in characteristic to those in the Delta, as compared to pond applications. In tidal

situations such as the Delta, movement of herbicide will likely be the greatest factor affecting half-life. This is important because herbicide movement out of a treatment area before target plants are adequately exposed can results in poor control (Nawrocki 2011). Nawrocki (2011) evaluated the half-life of fluridone based on bulk water exchange characteristics in Lake Gaston (North Carolina and Virginia) by utilizing rhodamine dye water tracing. Average half-lives in two different areas of the lake were 19 hours and 23 hours. Half-lives were shorter at the surface (8 and 13 hours) than in the middle of the water column (27 and 23 hours).

$^{14}C$ aqueous studies demonstrate that the only major residue in fluridone treated water is the parent compound, i.e. fluridone (West et al. 1983). When fluridone undergoes photolysis, the photoproducts rapidly dissipate from water by volatization, thus not accumulating in water. Fluridone establishes an equilibrium concentration between water and hydrosoil, and removal of fluridone from water results in desorption of fluridone from hydrosoil to maintain equilibrium (West et al. 1983).

One of the photodegradation products, N-methylformamide (NMF) was monitored in a field application to determine if NMF, which is toxic, would be produced in a lake application of commercial fluridone formulations. None of the water samples collected up to 49 days after application had any detectable quantities of NMF at a minimum detection limit of 5 ppb (Pfeuffer 1990). Pfeuffer concluded that NMF does not appear to be a concern when fluridone is utilized in a lake application according to label rates. A limited number of other studies have been conducted under field conditions and these studies suggest that NMF is undetectable in water bodies treated with fluridone at the maximum application rate (EPA 2004, Smith et al. 1991). The tidal influences in the Delta will further reduce any potential impacts of NMF.

Other fate processes for fluridone include plant uptake and adsorption to soil and suspended colloids (Joyce and Ramey 1986). Some microbial degradation of fluridone has been reported as well (Mossler et al. 1991). Also, exposure to sunlight breaks fluridone down into naturally occurring elements in the environment.

The effectiveness of fluridone depends on the degree to which the herbicide maintains contact with the target plant. Fluridone treatment programs will typically last from 8 to 16 (or12) weeks based upon site conditions (weed growth, flow patterns and agriculture irrigation intake considerations). In some instances, the treatment program may last less than 8 weeks. Some sites might require an extended treatment protocol to meet specific site conditions. No treatments will be conducted outside of the treatment season window set by the Agency. Use of multiple lower concentration applications are recommended in situations such as EDCP when the objective is to use the minimum effective dose, maintaining the low dose for a sufficient time to ensure efficacy and enhance selectivity. Fluridone formulations will be applied at rates of five (5) to thirty (30) ppb per application, lower than the 10 to 40 ppb or 16 to 75 ppb listed on Sonar labels. The intent will be to maintain a fluridone concentration in the water column of the treatment site of between one (1) and ten (10) ppb, most often in the one (1) to three (3) ppb range. This is more than two orders of

magnitude below the NPDES receiving water limit of 560 ppb. As specified on the herbicide label, there is no seasonal application maximum for fluridone applied in a flowing water system, such as the Delta (which is classified as a riverine system). For waters such as the Delta, the label specifies that the application technique should maintain a concentration of 10 ppb to 40 ppb in the applied area for a minimum of 45 days. As noted, EDCP protocols typically apply lower concentrations for longer time periods.

Prior to the start of each treatment season, USDA-ARS, DBW, and SePRO Aquatic Specialists will develop a treatment protocol for each selected treatment site. The protocol will specify weekly fluridone applications at a specific 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 of High-Performance Liquid Chromatography (HPLC) FasTEST. EDCP will conduct regular FasTEST sampling at each treatment site and send the collected samples, overnight, to a SePRO laboratory. SePRO can provide EDCP with test results within 48 hours of sampling. After they receive FasTEST results, EDCP will adjust the treatment protocol, if necessary, to maintain a desired fluridone concentration.

The concept of concentration and exposure time (CET) is important for treating submersed aquatic vegetation (SAV) such as *Egeria densa*. Incorporating current CET information with site specific water exchange data can result in selective control of invasive aquatic weeds with little to no damage to beneficial native vegetation (Nawrocki 2011, Getsinger et al. 2011). The EDCP has continued to improve and adapt the program based on CET experience. Continued development of the fluridone use pattern in the Delta over the last six years has proven that lower rate applications repeated over an 8 to16 week period meet the control objectives of EDCP while efficiently utilizing the lowest amount of herbicide possible. Due to the dilution caused by the treatment of partial areas of the Delta and the diurnal tidal flux, lower rates and more frequent applications of Sonar allow the program to maintain herbicide concentrations that will control *Egeria densa* while avoiding impacts on listed species as well as allowing for irrigation uses of Delta water. EDCP will utilize site-specific adaptive management based upon plant community response, potential dilution, irrigation use, FasTEST analysis of herbicide concentrations and regular calls with, USDA-ARS, DBW and/or SePRO to review results and discuss potential treatment adjustments. The use of several fluridone formulations with differing release profiles, combined with weekly FasTEST monitoring, will allow the EDCP to balance efficacy with reduced environmental impact.

Liquid fluridone will be applied below the water surface and the pellets or granules will be applied with broadcast spreaders that are attached to the boat. There is little concern regarding air drifting because liquid fluridone will be applied below the water surface via weighted hoses (not over the surface), and the pelleted/granular formulations are heavy enough that the wind speeds in which DBW will be treating will not cause them to drift. Once

on the water surface, the pellets or granules sink to the bottom rapidly (within seconds).

Per the Sonar labels, there are no restrictions on the use of fluridone treated water for fishing, swimming, drinking by humans, livestock, or other domestic animals. The label recommends that fluridone be applied prior to initiation of growth or when plants begin active growth. Mature plants may require more herbicide and take longer to control. According to the herbicide label, for best results, Sonar formulations should be applied on a minimum of five acres. Fluridone is not to be applied at a rate of greater than 20 ppb within ¼ mile of active potable water intake. However, the labels specify that Sonar PR, Sonar Q, and SonarOne may be applied at between 8 to 20 ppb where functioning water intakes are present. Sonar AS may be applied at between 6 to 20 ppb where functioning water intakes are present. The EDCP will follow the maximum 20 ppb requirement in those sites with functioning potable water intakes.

The herbicide labels specify waiting periods of between 7 to 14 days before using fluridone treated water for irrigation. However, crops may be treated after FasTEST results show fluridone levels of less than 10 ppb. More susceptible plants such as Solanaceae Family (tobacco, tomatoes, peppers), and newly seeded crops or newly seeded grasses, should not be irrigated with fluridone treated water until FasTEST results are below 5 ppb. The herbicide labels specify that for nurseries and greenhouse irrigation the applicator should consult with SePRO Corporation for site-specific recommendations. Without such recommendations, fluridone treated water should not be used for greenhouse or nursery irrigation unless a FasTEST has been run and confirmed that fluridone concentrations are below 1 ppb fluridone.

There is an important distinction between the nominal concentration of fluridone and the measured concentration of fluridone in the water (SERA 2008). The nominal concentration, or application rate, refers to the calculated amount of fluridone in the water given the size of the water body to be treated. The herbicide label provides specific algorithms for calculating the nominal concentration. Measured concentration refers to the actual monitored concentration of fluridone in the water. A further distinction is the target concentration, which is the desired concentration to be maintained in the water to demonstrate efficacy on the target species. For EDCP, this target concentration will range from one to ten ppb, and depends on factors such as infestation level, water flow, and presence of irrigation intakes.

Several studies have demonstrated that the actual measured concentration is typically one-half or less of the application concentration, as measured seven days after treatment (Bultemeier et al. 2009). Reasons for this difference include the gradual release of fluridone from the pellet and granular formulations, and dilution due to water movement. For example, Bultemeier et al. evaluated the characteristics of two different liquid fluridone formulations (including Sonar AS), and found that the measured concentrations in a static pond seven days after treatment at an application rate of 50 ppb were 19 ppb and 26 ppb (Bultemeier et al. 2009). Because EDCP treatment sites are not static, measured concentrations will be even lower than Bultemeier's results.

**Figure 3-6**
**Example EDCP Fluridone Application and Actual Concentrations in Delta Waters (2009)**

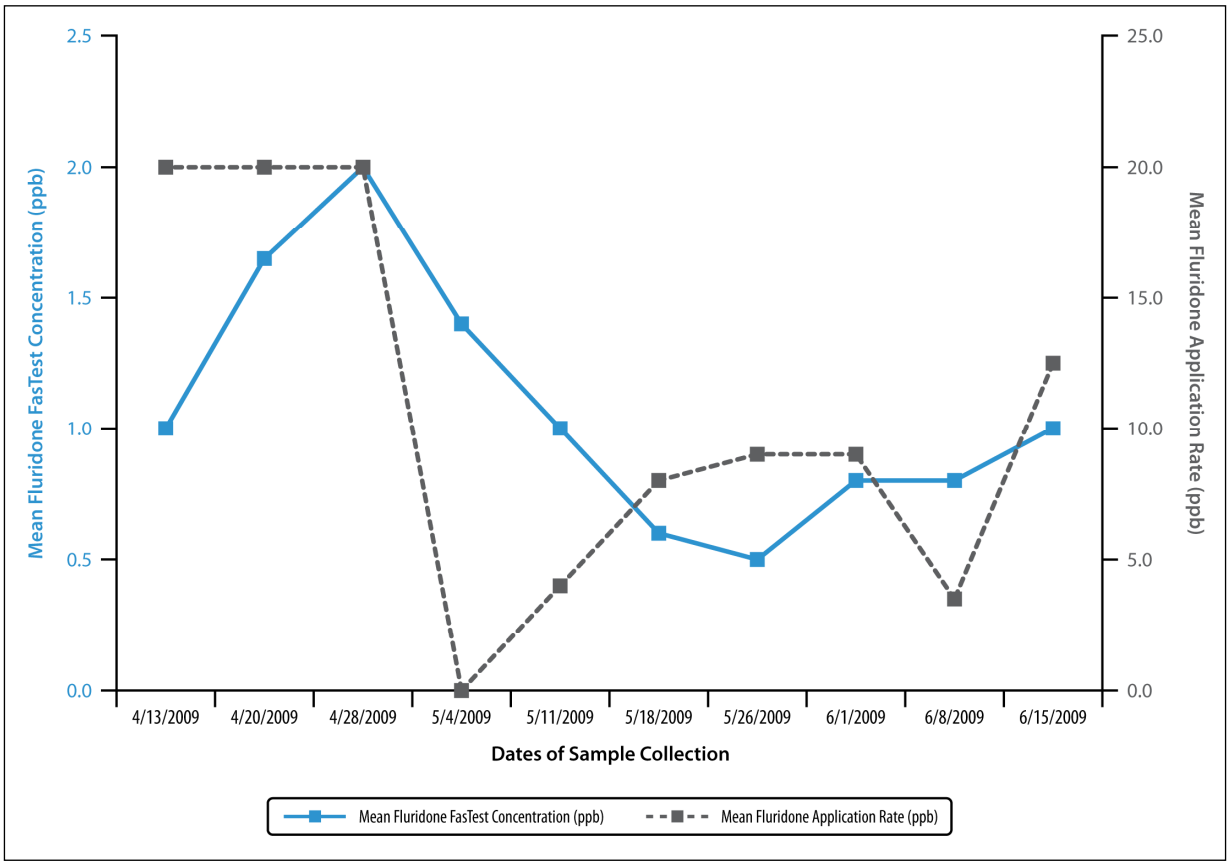



**Figure 3-6,** above, demonstrates the substantial difference between application rates and target concentrations at an EDCP treatment site during a 10 week treatment period in 2009. For the first three treatment weeks, the Sonar application rate was 20 ppb (dotted gray line). The resulting fluridone concentration (blue line) was only 1 ppb the first week, increasing to a maximum of 2 ppb by the third week. Once EDCP achieved the 2 ppb, no fluridone was applied in the fourth week. As fluridone levels dropped, fluridone was again applied, but at lower rates than the first three weeks. The resulting fluridone levels remained below 2 ppb during the entire treatment period, even though the cumulative fluridone application was approximately 100 ppb. Figure 3-7 provides an example of actual data. Each EDCP site is unique, and may have somewhat different application rates and resulting fluridone concentrations. However, this example is typical of EDCP fluridone applications.

Likely fluridone concentrations following EDCP treatments can be estimated from historical NPDES and FasTEST monitoring data. Since 2007, there have been over 2,500 samples taken for EDCP, most for FasTEST monitoring. **Table 3-4** and **Figure 3-7,** on the next page, summarize the EDCP monitoring conducted for NPDES permit compliance. These data illustrate that of over

**Figure 3-7**
**Number of Samples at Non-Detect (ND) and 1 to 5 ppb Fluridone for EDCP Monitoring (2007 to 2011)**

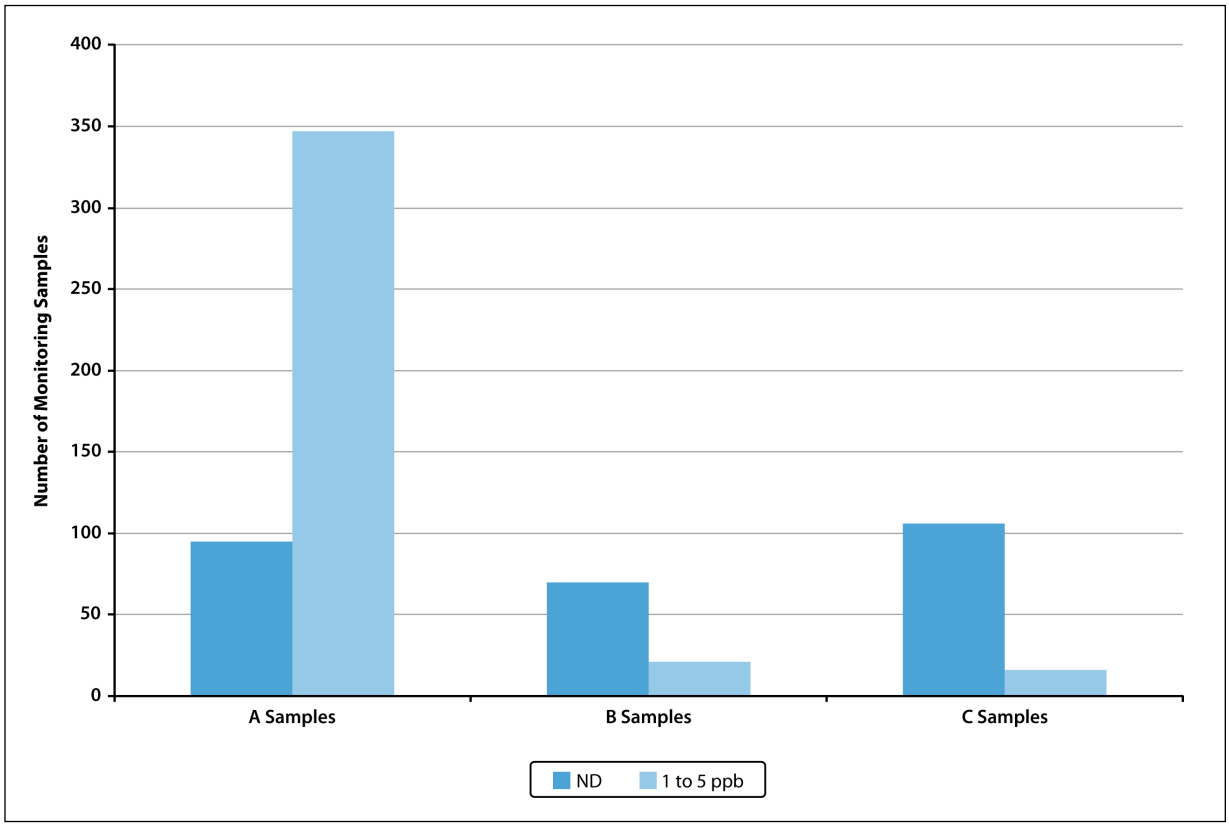



**Table 3-4**
**Summary of EDCP Environmental Scientist Fluridone Monitoring (2007 to 2011)**

| | | Sample Location | | |
|---|---|---|---|---|
| | | A | B | C |
| 2007 | ND | 5 | 9 | 7 |
| | 1 to 5 ppb | 10 | 6 | 8 |
| 2008 | ND | 14 | 16 | 16 |
| | 1 to 5 ppb | 2 | – | – |
| 2009 | ND | 16 | 15 | 19 |
| | 1 to 5 ppb | 4 | 4 | – |
| 2010 | ND | 12 | 10 | 10 |
| | 1 to 5 ppb | – | 2 | 2 |
| 2011 | ND | 48 | 20 | 54 |
| | 1 to 5 ppb | 331 | 9 | 6 |
| 2007 to 2011 | **ND** | **95** | **70** | **106** |
| | **1 to 5 ppb** | **347** | **21** | **16** |

600 samples taken within a treatment site (A), downstream (B), or outside (C), none were over 5 ppb fluridone. Over 40 percent of these NPDES samples had non-detectable (ND) fluridone levels. FasTEST monitoring, summarized in **Table 3-5** and **Figure 3-8,** on the next page, occurs more frequently, and always within treatment sites. In addition to fluridone ppb levels, Table 3-5 summarizes the total number of FasTEST samples, maximum fluridone concentration, number of sample days, and number of sample locations, for each year (2007 to 2011). More than one-half of the samples were taken in 2011 to monitor Discovery Bay treatments, which are close to agricultural intakes. The highest maximum

**Figure 3-8**
**Number of FasTEST Fluridone Samples, by ppb ranges (2007 to 2011)**

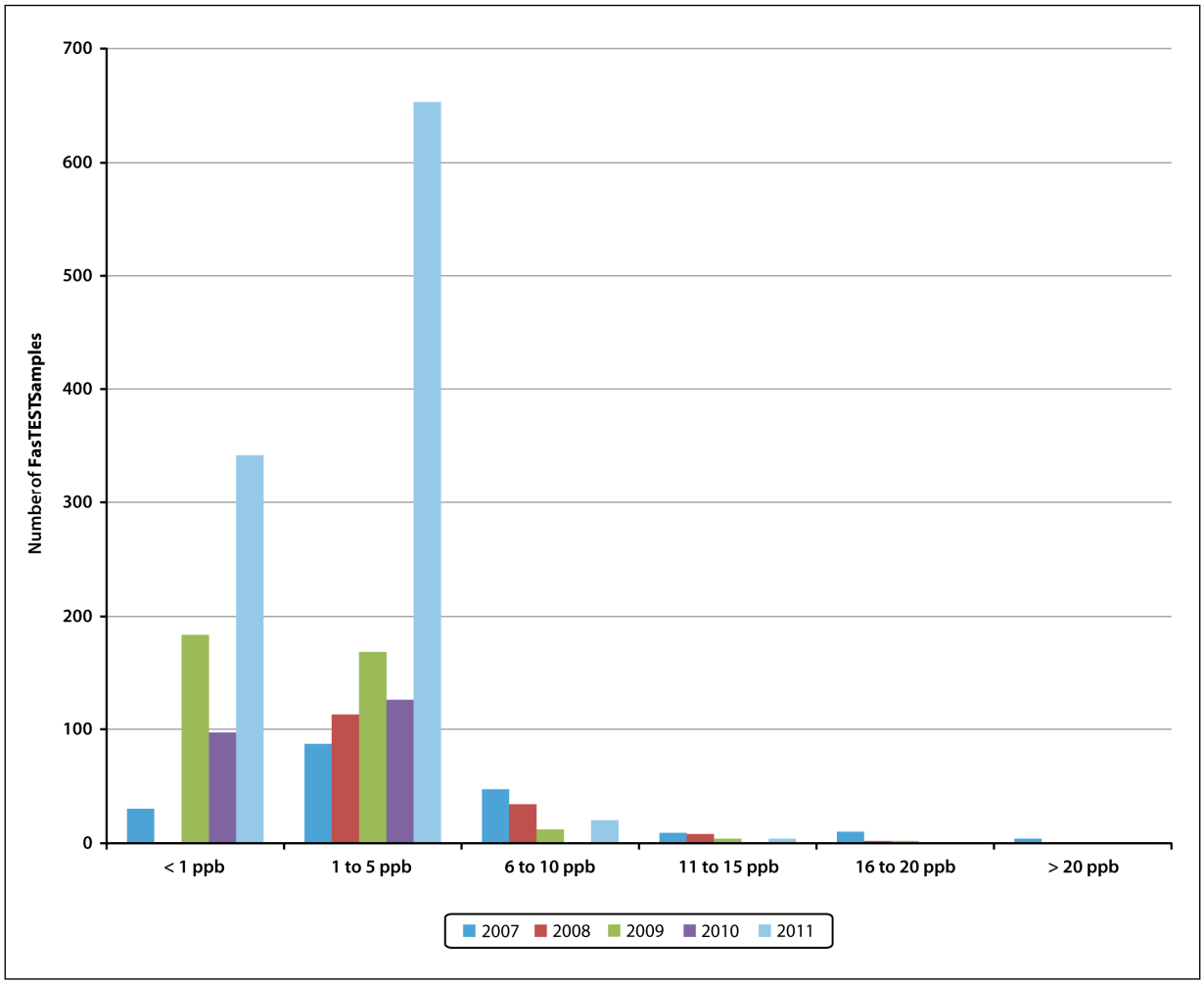



**Table 3-5**
**Summary of EDCP FasTEST Fluridone Monitoring (2007 to 2011)**

| Year | <1 ppb | 1 to 5 ppb | 6 to 10 ppb | 11 to 15 ppb | 16 to 20 ppb | >20 ppb | Total Samples | Maximum ppb | Sample Days | Sample Locations |
|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | 30 | 87 | 47 | 9 | 10 | 4 | 187 | 42.6 | 15 | 32 |
| 2008 | 1 | 113 | 34 | 8 | 2 | 0 | 158 | 17.5 | 11 | 21 |
| 2009 | 184 | 168 | 12 | 4 | 2 | 0 | 370 | 16.5 | 10 | 55 |
| 2010 | 97 | 126 | 0 | 0 | 0 | 0 | 223 | 4.0 | 10 | 28 |
| 2011 | 342 | 653 | 20 | 4 | 0 | 1 | 1,020 | 32.6 | 46 | 63 |
| Total | 654 | 1,147 | 113 | 25 | 14 | 5 | 1,958 | Avg. 22.6 | 92 | 199 |
| **Percent** | **33%** | **59%** | **6%** | **1%** | **1%** | **0.3%** | **100%** | | | |

concentration found in any one year was 42.6 ppb; however the maximum concentration in 2010 was only 4 ppb. The average maximum concentration over the five years was 22.6 ppb. Figure 3-8 summarizes the FasTEST sampling results, and again illustrates that the vast majority of all samples taken are between 1 to 5 ppb or less than one ppb.

Estimates of fluridone concentrations in one and two meters deep water will depend on the application rate, water depth, and tidal influence. For purposes of calculating risk quotient (RQ) values to determine impacts on listed fish species, EDCP will utilize the maximum weekly application level of 30 ppb. This level is extremely conservative, as described above. Dissipation data show that herbicide levels will ultimately be similar in one and two meters depth.

Anderson (2004b) evaluated the dilution of Sonar AS in two Delta locations and found that maximum concentration levels were maintained for only one to 1.5 hours. Maximum levels began decreasing by 2 hours, and at 24 hours were minimal. Anderson also found lower fluridone concentrations in deeper waters as compared to the top few feet of water. Hosea (2005) found that fluridone did remain in Delta sediment following treatment, but not at levels of concern.

EDCP monitoring results are consistent with studies in the scientific literature. Nawrocki (2011) evaluated fluridone concentrations at the surface, middle, and benthic layer at two locations in Lake Gaston (North Carolina and Virginia) after application of granular fluridone to the benthic layer to treat hydrilla.[4] Fluridone was applied at a total application rate of 75 ppb in the Lyons Creek site and 55 ppb at the Hubquarter Creek site, including two "bump" applications at 25 and 55 days after initial treatment. Individual applications were between 15 ppb and 30 ppb. Fluridone samples were taken on five dates, including six days after the initial treatment, three weeks after the first bump treatment, and three weeks after the second bump treatments.

Fluridone levels were higher in the benthic and middle samples as compared to the surface samples at both sites. However, it is important to note that fluridone levels were well below the maximum application rate of 30 ppb in all samples. The maximum fluridone level measured at Lyons Creek was 3.9 ppb. **Tables 3-6** and **Table 3-7,** on the next page, (Table 5 and Table 7 from Nawrocki 2011) provide the sample means and standard errors for the surface, middle, and benthic layers at both locations. Treatments dates are illustrated in both tables.

### Penoxsulam

The herbicide active ingredient penoxsulam received USEPA approval through the reduced risk program for use on aquatic weeds from the USEPA in 2007 and from the CDPR in 2009. Penoxsulam was initially approved for use on rice crops by USEPA in 2004. The chemical structure of penoxsulam is illustrated in **Figure 3-9,** on the next page. The EDCP currently plans to utilize the penoxsulam product Galleon* SC in a liquid formulation, and may eventually add other formulations, such as a granular formulation, Galleon 2.7G, which is currently in the USEPA registration process.

[4] For comparison, EDCP applies granular and pellet fluridone at the surface and allows the herbicide to sink to the bottom.

**Table 3-6**
**Sample Means and Standard Errors for Fluridone Residues in Lyons Creek (in µg/L) (Total application of 75 µg/L (ppb))**

| Date | Surface | Middle | Benthic |
|---|---|---|---|
| 6/12/2008 | 15 to 30 µg/L application | | |
| 6/18/2008 | 0 | 0 | 1.24 ± 0.33 |
| 6/23/2008 | 0.7 ± 0.29 | 1.44 ± 0.29 | 2.12 ± 0.49 |
| 7/6/2008 | 0 | 0 | 1.18 ± 0.32 |
| 7/7/2008 | 15 to 30 µg/L application | | |
| 7/28/2008 | 0.2 ± 0.2 | 0.7 ± 0.29 | 1.36 ± 0.42 |
| 8/5/2008 | 15 to 30 µg/L application | | |
| 8/26/2008 | 0 | 0.22 ± 0.22 | 1.08 ± 0.36 |

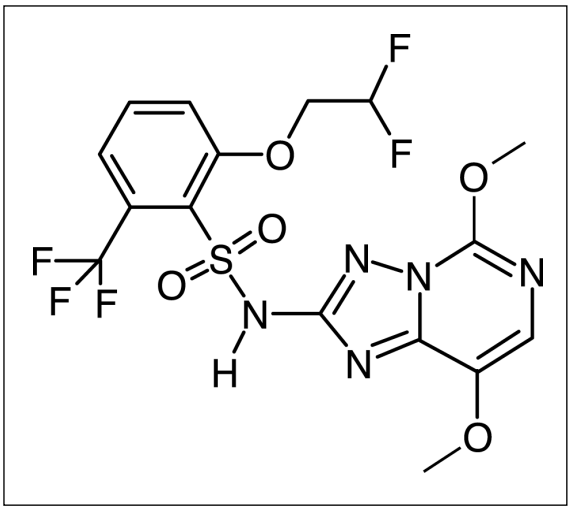
Source: Adapted from Nawrocki, 2011, page 74.

**Table 3-7**
**Sample Means and Standard Errors for Fluridone Residues in Hubquarter Creek (in µg/L) (Total application of 55 µg/L (ppb))**

| Date | Surface | Middle | Benthic |
|---|---|---|---|
| 6/12/2008 | 15 to 30 µg/L application | | |
| 6/18/2008 | 0.25 ± 0.25 | 0.98 ± 0.4 | 2.2 ± 0.72 |
| 6/23/2008 | 0.76 ± 0.33 | 1.74 ± 0.15 | 2.14 ± 0.19 |
| 7/6/2008 | 0.2 ± 0.2 | 0 | 0.5 ± 0.3 |
| 7/7/2008 | 15 to 30 µg/L application | | |
| 7/28/2008 | 0.4 ± 0.25 | 0.44 ± 0.44 | 0.88 ± 0.39 |
| 8/4/2008 | 15 to 30 µg/L application | | |
| 8/26/2008 | 0 | 0.2 ± 0.2 | 0.72 ± 0.51 |

Source: Adapted from Nawrocki, 2011, page 75.

**Figure 3-9**
**Penoxsulam Chemical Structure**




Penoxsulam (2-(2,2-difluoroethoxy)-N-(5,8-dimethoxyl[1,2,4] triazolo[1,5-c]pyrimidin-2-yl)-6-trifluoromethyl)benzenesulfonamide), is a broad spectrum systemic herbicide in the triazolopyrimidine sulfonamide family. This herbicide inhibits the enzyme acetolactate synthase (ALS), which regulates the production of three essential amino acids: valine, leucine, and isoleucine (Washington DOE 2012). ALS inhibitors such as penoxsulam slowly starve plants of these amino acids, eventually killing the plants by halting DNA synthesis. These biochemical pathways are not present in animals.

Plants absorb penoxsulam through leaves, shoots, and roots. The herbicide affects new growth more rapidly than older plant tissue. Symptoms following treatment with penoxsulam include immediate growth inhibition, a chlorotic growing point with reddening, and slow plant death over a period of 60 to 120 days (Washington DOE 2012). Langeland et. al. (2009) identified penoxsulam as providing good control for *Egeria densa* in Florida.

Penoxsulam has low to moderate water solubility (Dow Agro Sciences 2008), and is very mobile in soil. The organic carbon sorption coefficient, $K_{oc}$, of penoxsulam is between 13 and 305 in soil (indicating weak adsorption), with higher adsorption in sediment, $K_{oc}$ = 1,130 (USEPA 2007).

Penoxsulam follows two complex degradation pathways, and degrades into

**Table 3-8**
**Major and Minor Transformation Products of Penoxsulam**

| Abbreviation | Chemical Name |
|---|---|
| 1. BSTCA | 3-[[[2-(2,2-difluroethoxy)-6-(trifluromethyl)phenyl]-sulfonyl]amino]-1H-1,2,4-triazole-5-carboxylic acid |
| 2. TPSA | 5,8-dimethoxyl[1,2-4]triazolo-[1,5-c]pyrimidin-2-yl-sulfamic acid |
| 3. 2-Amino TP | 5,8-dimethoxyl[1,2-4]triazolo-[1,5-c]pyrimidin-2-amine |
| 4. BSA | 2-(2,2-difluoroethoxy(-5-(trifluoromethyl) benzenesulphonic acid |
| 5. 2-Amino TCA | 2-amino-1,2-4-triazole carboxylic acid |
| 6. 5-OH, 2-Amino TP | 2-amino-8-methoxy-[1,2,4]triazolo[1,5-c]pyrimidin-5-(6H)-one |
| 7. BSTCA methyl | methyl 5-[[[2-(2,2-difluoroethoxy)-6-(trifluoromethyl) phenyl]sulphony]amino]-1H-1,2,4-triazole-5carboxylate |
| 8. BST | 2-(2,2-difluoroethyoxy)-N-1H-1,2-4-triazol-3-yl-6-(trifluoromethyl)benzenesulphonamide |
| 9. Di-FESA | 3-(2,2-difluoroethoxy)-2-hydroxybenzoic acid |
| 10. 5-OH-penoxsulam | 2-(2,2-difluoroethoxy)-N-(5,6-dihydro-8-methoxy-5-oxo[1,2,4]triazolo[1,5-c]pyrimidin-2-yl)-6-(trifluoromethyl)benzenesulfonamide |
| 11. Sulfonyl-formamidine | 2-(2,2-difluoroethoxy)-N-(iminomethyl-6-(trifluoromethyl)-benzenesulfonamide |
| 1. Sulfonamide | 2-(2,2-difluoroethoxy)-6-(trifluoromethyl)-benzenesulfonamide |
| 2. 5-OH XDE638 | 2-(2,2-difluoroethoxy)-6-trifluoromethyl-N-(5,8-dihyroxy-[1,2,4]triazolo[1,5-c]pyrimidin-2-yl) benzenesulfonamide |

eleven major and two minor degradates, listed in **Table 3-8,** above (USEPA 2007). None of these metabolites or degradates have been identified as having a higher toxicity potential than penoxsulam (Washington DOE 2012).

There was some concern in the first review of penoxsulam (USEPA 2004) that some of the major degradates of penoxsulam might pose phytoxicity concerns; however, additional testing found no observable injury by the eleven metabolites to pre-emergent seeds, and that only two caused injury to seedlings at high-levels (USEPA 2007).

In water, penoxsulam breaks down primarily by photolysis, with some microbial degradation. Water depth, water clarity, plant density, and season of application can influence photolytic degradation. Penoxsulam breaks down faster in higher water clarity and lower plant density. The water solubility of penoxsulam increases in more alkaline conditions. The half-life of penoxsulam in water ranges from 1.5 to 14 days (USEPA 2007). The total system half-life of penoxsulam is 16 to 38 days (Washington DOE 2012). In sediment, penoxsulam is expected to degrade rapidly through anaerobic degradation (USEPA 2007). Penoxsulam is adsorbed by soil and has low to moderate leaching potential in most soil types, where it is broken down by microbial degradation (Dow Agro Sciences 2008). However, CDPR has identified penoxsulam as having the potential to pollute ground water. Penoxsulam has low vapor pressure, and will not dissipate by volatization.

Because of the Delta's unique characteristics, EDCP will evaluate penoxsulam application protocols to determine the most effective treatment approach and treatment period for *Egeria densa*. Based on herbicide characteristics, it is likely that *Egeria densa* treatment will require an eight to twelve week treatment protocol, similar to the approach for treating *Egeria densa* with fluridone. EDCP also expects that the concentration of penoxsulam in the water column following treatment will be similar to that of fluridone, with actual water concentrations following treatment likely to be less than one-half of the application rate.

For split or multiple in-water applications to a treatment zone, the Galleon label specifies that penoxsulam should be applied at the minimum effective dose of 10 to 30 ppb, and through the use of water analysis (FasTEST), add additional penoxsulam to maintain a concentration to achieve plant management objectives. As specified on the label, water should be retreated to maintain penoxsulam concentrations for a minimum of sixty days, or until satisfactory weed control is achieved. The label notes that higher (than 10 to 30 ppb) concentrations and longer exposure times may be necessary. The concentration of any single application or sum of all applications per annual growing cycle may not exceed 150 ppb.

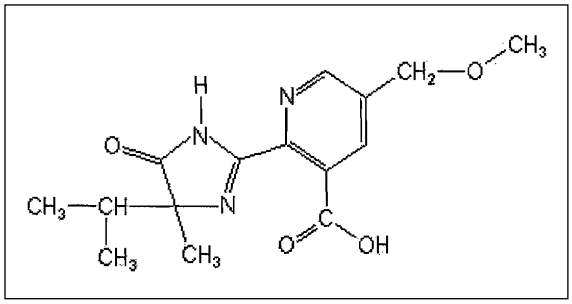
In order to identify effective penoxsulam treatment protocols for *Egeria densa* in the Delta, USDA-ARS, DBW, and herbicide managers will select one or more treatment sites for penoxsulam treatment each season and employ different treatment protocols. Each protocol will follow label requirements, and will include sampling and monitoring (using FasTEST) to determine herbicide concentrations. For example, one treatment protocol might be to start with a 50 ppb application, followed by weekly 10 ppb applications, for a maximum of ten additional weeks. Another treatment protocol might be to start with a 30 ppb application, followed by weekly 15 ppb or less applications, until the maximum 150 ppb application and/or efficacy is achieved. Prior to the start of each treatment season, EDCP will provide USFWS and NMFS with the penoxsulam treatment plan.

Liquid penoxsulam will be applied below the water surface and when available, granular forms will be applied with broadcast spreaders that are attached to the boat. There is little concern regarding air drifting because liquid penoxsulam will be applied below the water surface via weighted hoses (not over the surface), and the granular formulations will be heavy enough that the wind speeds in which DBW will be treating will not cause them to drift. Once on the water surface, granules sink to the bottom rapidly (within seconds).

There are no label restrictions for penoxsulam regarding dissolved oxygen, as the slow-acting nature of this herbicide should have minimal impact on dissolved oxygen levels (Washington DOE 2012).

Waters treated with penoxsulam are not to be used for food crop irrigation until concentrations are determined to be equal to, or less than, 1 ppb. Water samples must be collected using Enzyme-Linked Immunoassay (ELISA) or other approved analytical methods. There are no restrictions on consumption of treated water for potable use or by livestock, pets, or other animals, and no restrictions on the use of treated water for recreational use, including swimming and fishing.

**Figure 3-10**
**Imazamox Chemical Structure**




As penoxsulam will be a new EDCP herbicide, there are no prior program data regarding actual herbicide concentrations following *Egeria densa* treatment. The EDCP will conduct monitoring at the initial penoxsulam treatment sites to develop a baseline for expected herbicide concentrations in treatment sites and receiving waters following treatment. For purposes of RQ calculations in Section 6, we assume a conservative figure of 50 ppb, which would likely be the maximum application rate. We should note that the actual concentration of penoxsulam in the water column will be lower, given tidal movement and dissipation.

### Imazamox

Imazamox is a relatively new aquatic herbicide active ingredient. The aquatic formulation of imazamox, Clearcast®, received USEPA approval through the reduced risk program in 2008 (SERA 2010). The chemical structure of imazamox is illustrated in **Figure 3-10,** above.

CDPR approved Clearcast in liquid form for aquatic uses in California on August 7, 2012. The USEPA has also approved a fast release granular imazamox formulation for aquatic use, Clearcast® 2.7G. The EDCP will incorporate this imazamox formulation once it is approved in California. The manufacturer may also develop a slow-release imazamox formulation that would be particularly appropriate for Delta water conditions. The EDCP will utilize available formulations of this active ingredient. Imazamox was approved for terrestrial use by the USEPA in 1997, and by the CDPR, in 2002. Imazamox liquid form consists of 12.1 percent solution of the ammonium salt of imazamox (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-(methyoxymethyl)-3-pyridinecarboxylic acid). The granular formulation of imazamox consists of a 2.7 percent granule, equivalent to 0.135 pounds of active ingredient per five pounds of product.

Imazamox is in the imidazolinone herbicide family. The mode of action is inhibition of the acetolactate synthase (ALS) enzyme, blocking the synthesis of three essential amino acids, leucine, isoleucine, and valine (Washington DOE 2012).

Imazamox is a relatively fast-acting systemic herbicide. It is rapidly absorbed into the foliage and translocated throughout the plant by phloem and xylem tissues (Washington DOE 2012). Imazamox inhibits plant growth within the first 24 hours, with visual symptoms appearing about one week after treatment. Symptoms include yellowing leaves and general discoloration.

Imazamox is highly soluble in water, and is mobile to highly mobile in soil (Washington DOE 2012; USEPA 2008). The organic carbon sorption coefficient, $K_{oc}$, of imazamox is between 5 and 143 (indicating weak adsorption). Volatization of imazamox is not significant (USEPA 1997). Imazamox has a low potential for bioaccumulation (Washington DOE 2012).

*Photo:* Egeria densa *mat.*

The primary method of degradation of imazamox in surface water is photolytic (Washington DOE 2012). Photolytic degradation is influenced by water depth, water clarity, and season, and continues via microbial action to carbon dioxide. The half-life in water ranges from five to fifteen days (Washington DOE 2012). CDPR identified imazamox as having the potential to pollute groundwater due to its high water solubility; however, in well-lit waters imazamox breaks down quickly (Washington DOE 2012). USEPA concluded that even if imazamox persists in dark or turbid waters it is unlikely to present a risk to fish, invertebrates, birds, or mammals (Washington DOE 2012).

Imazamox is moderately persistent in soil, degrading aerobically to a non-herbicidal metabolite which is immobile or moderately mobile in soil (USEPA 1997). The primary metabolite is a demethylated parent chemical with intact ring structures and two carboxylic acid groups. A secondary metabolite is a demethylated, decarboxylated parent with intact rings and one carboxylic acid group (USEPA 2008). Leaching of imazamox in field studies was very limited, and microbial breakdown products under aerobic soil conditions are not herbicidal. The range of half-lives in terrestrial field dissipation studies was fifteen to 130 days, with typical half-lives ranging from 35 to 50 days (USEPA 1997; USEPA 2008). Imazamox is unlikely to accumulate in sediments.

Because of the Delta's unique characteristics, EDCP will evaluate imazamox application protocols to determine the most effective treatment approach and treatment period for *Egeria densa*. Based on herbicide characteristics, it is likely that *Egeria densa* treatment will require two to four week treatment protocol, much shorter than the current approach for treating *Egeria densa* with fluridone. EDCP also expects that the concentration of imazamox in the water column following treatment will be similar to that of fluridone, with actual water concentrations following treatment likely to be less than one-half of the application rate. The concentration of any single application or sum of all applications per annual growing cycle may not exceed 500 ppb.

In order to identify effective imazamox treatment protocols for *Egeria densa* in the Delta, USDA-ARS, DBW, and herbicide managers will select one or more treatment sites for imazamox treatment each season, and employ different treatment protocols. Each protocol will follow label requirements, and will include sampling and monitoring (using FasTEST) to determine herbicide concentrations. For example, one treatment protocol might be to start with a 200 ppb application, followed by three weekly 100 ppb applications, for a maximum of 500 ppb over four weeks. Another treatment protocol might be to start with a 250 ppb application,

followed by a second treatment one week later of another 250 ppb. Prior to the start of each treatment season, EDCP will provide USFWS and NMFS with the imazamox treatment plan. Because imazamox requires a shorter treatment window, EDCP may evaluate several different treatment approaches in the first season that the herbicide is used to determine the most effective approach for following years.

Liquid imazamox will be applied below the water surface and the granular formulations, when available, will be applied with broadcast spreaders that are attached to the boat. There is little concern regarding air drifting because liquid fluridone will be applied below the water surface via weighted hoses (not over the surface), and the granular formulations will be heavy enough that the wind speeds in which DBW will be treating will not cause them to drift. Once on the water surface, the granules sink to the bottom rapidly (within seconds).

There are no label restrictions regarding dissolved oxygen; however, DBW will follow the same application approaches as for other herbicides to minimize potential for low DO levels to impact endangered species. Waters treated with imazamox will not be used for irrigation until concentrations are less than 50 ppb. The label requires a 24 hours period after treatment to irrigate from still and quiescent waters. There are no wait restrictions for irrigation when liquid imazamox is applied to flowing waters at a rate of less than or equal to 2 quarts (32 ounces) per acre to waters with an average depth of at least four feet, or when concentrations are less than 50 ppb following granular imazamox applications. There are no restrictions on livestock watering, swimming, fishing, domestic use, or use of treated water for agricultural sprays (SePRO 2010). The label specifies that imazamox may be applied to potable water sources at concentrations up to 500 ppb within ¼ mile of an active potable water intake. Inside ¼ mile, imazamox concentrations must be maintained at less than 50 ppb.

As imazamox will be a new EDCP herbicide, there are no prior test data regarding actual herbicide concentrations following *Egeria densa* treatment. The EDCP will conduct monitoring at the initial imazamox treatment sites to develop a baseline for expected herbicide concentrations in treatment sites and receiving waters following treatment. For purposes of RQ calculations in Section 6, we assume a conservative figure of 250 ppb, which would likely be the maximum application rate. We should note that the actual concentration of imazamox in the water column will be lower, given tidal movement and dissipation.

### Diquat

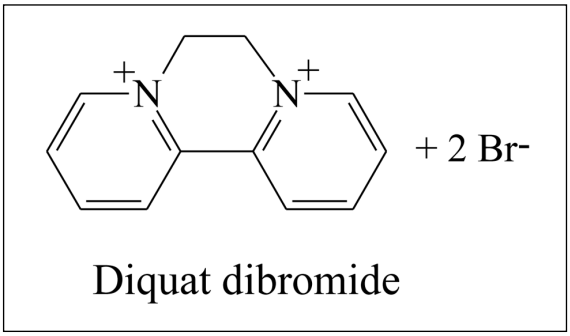
The herbicide active ingredient diquat dibromide was first approved by the USEPA for aquatic use in 1962, and again in 2000 (Washington DOE 2012). CDPR approved the use of diquat for aquatic uses in California in 2002. Diquat has been part of the EDCP since 2002, but has not been utilized by DBW since 2005. There are several different diquat products, with a liquid formulation, Reward®, used most recently by EDCP. The chemical structure of diquat dibromide is illustrated in **Figure 3-11,** on the next page.

Diquat dibromide (6,7-dihydrodipyrido(1,2-a:2',1'-c) pyrazinediium dibromide) is a post-emergent, non-selective, fast-acting, contact herbicide. Diquat is a photosynthetic electron

flow diverter. Diquat is rapidly absorbed by green plant tissues and results in rapid disruption of cell membranes and rapid kill (Washington DOE 2002), with effects visible within a few days. The bipyridyliums penetrate into the cytoplasm, causing the formation of peroxides and free electrons upon exposure to light, destroying the cell membranes. Because the herbicide is so fast-acting, diquat is not translocated to other portions of the plant, acting only on the portions that the herbicide contacted. Langeland et. al. (2009) identified diquat as providing excellent control for *Egeria densa* in Florida.

Diquat is water soluble, non-volatile, and binds strongly to soil and sediment. Diquat dibromide rapidly disassociates to the diquat cation, and herbicide concentrations are typically measured in cation equivalence (c.e.). When diquat comes in contact with soil, it is strongly adsorbed to clay particles or organic matter for a long period of time (several years) (EXTOXNET 1993). Diquat is biologically inactive in this bound state, and is often unavailable for further degradation (EXTOXNET 1993, Washington DOE 2002). The $K_{oc}$ of diquat is 100,000 g/ml. Because of the high affinity to soil, there is little possibility that diquat will leach or result in groundwater contamination. Adsorbed diquat is subject to microbial degradation, where the herbicide is broken down into carbon dioxide (EXTOXNET 1993). In pure culture, isolates of bacteria are capable of degrading diquat; three separate metabolites have been isolated, but not identified (Washington DOE 2002). Hosea (2005) found diquat in Delta sediments following EDCP treatments in 2002 through 2005, but not at levels of concern.

**Figure 3-11**
**Diquat dibromide Chemical Structure**




Because diquat binds strongly to soils, it is not persistent in water, and dissipates rapidly to low levels. Several studies have demonstrated that diquat dissipated to levels lower than 0.01 ppm in four to twelve days, depending on the sediment type (Washington DOE 2002). Applications at the maximum diquat use rate of 0.37 ppm to a lake in New York dropped to 0.08 ppm c.e. after one day and 0.024 ppm after four days (Washington DOE 2002). Many other studies have found similar declines in diquat cation concentrations. The half-life of diquat in water is less than 48 hours (EXTOXNET 1993) due to its ability to bind to sediment in water; a factor that also limits the herbicide's efficacy in turbid waters. If it does not adsorb to sediment, diquat will photodegrade in surface layers of water in one to three weeks (EXTOXNET 1993). Diquat has a low octanol/water coefficient ($K_{ow}$ = 0.000025), indicating little or no likelihood of bioaccumulation (Washington DOE 2002).

There are no known impurities in the manufacture of diquat, and none of the inert ingredients in diquat have been classified as having toxicological concerns (Washington DOE 2002). The primary inert ingredient in Reward is water (Washington DOE 2002).

If diquat is used, it will be applied below the water surface using weighted hoses. There is little concern regarding air drift because liquid diquat is applied below the surface. The herbicide label recommends applying diquat in water at a rate of 0.5 to 2.0 gallons per surface acre per four foot water depth (Syngenta 2005). The higher level is recommended for severe weed infestations. For deeper treatment sites, this is equivalent to an additional 0.25 to 0.50 gallons per acre-foot. This is equivalent to a concentration of 0.37 c.e. ppm at immediate application. For best results, the label recommends re-treating, as necessary, on 14 to 21 day intervals.

The EDCP will utilize diquat only in certain cases where more rapid efficacy is required, and when listed fish species are not likely to be present. Diquat will augment fluridone treatment protocols, providing a different and faster mode of action. Longer-acting herbicides such as fluridone, penoxsulam and imazamox will be the primary control methods.

Because diquat is fast-acting, there is potential for reductions in dissolved oxygen levels following treatment. To avoid low DO impact the label recommends treating only 1/3 to ½ of the water body area at one time, and to wait fourteen days between diquat treatments. The tidal flow in the Delta and limited diquat utilization will reduce potential for low DO. The herbicide label specifies wait periods following treatment before treated water can be utilized for various purposes. After treatment at the rate of two gallons per surface acre (in four feet of water), drinking is allowed after three days, fishing and swimming after zero days, livestock/ domestic animal consumption after one day, and spray tank applications for irrigation after three to five days. Any of these uses is allowed if diquat c.e. levels are below the maximum contaminant level goal (MATC) of 0.02 ppm. The EDCP will follow all label requirements when using diquat.

The maximum diquat application rate will result in an instantaneous concentration of 0.37 ppm diquat c.e. in the water column. This concentration will rapidly dissipate due to water flow and binding to sediment. Most assessments of diquat persistence have focused on lentic (i.e. standing) water systems, such as ponds or lakes. In such systems, an instantaneous concentration of 0.37 ppm can fall to approximately 0.10 ppm after 24 hours and 0.01 ppm after four days (DBW 2001). Field trials have shown that dissipation and dilution of diquat (as Reward) in flowing, tidally influenced and highly turbid waters such as the Delta are much more rapid. In 1988, a study in conducted at three one-acre plots in the Delta (White Slough, Owl Harbor, and Sandmound Slough) examined the persistence of diquat under different environmental and tidal conditions (DBW 2001). Persistence at these sites varied, depending on conditions. Where there was less water movement, diquat concentrations in the sites remained at 30 to 75 percent of initial levels after three hours. At faster moving sites, diquat dissipated within one hour of application. Overall, in four of the five test applications, an instantaneous concentration of 0.50 ppm decreased to 0.01 ppm within twelve to twenty-four hours, indicating that the persistence of diquat in a tidal environment is shorter than that observed for closed ponds (DBW 2001).

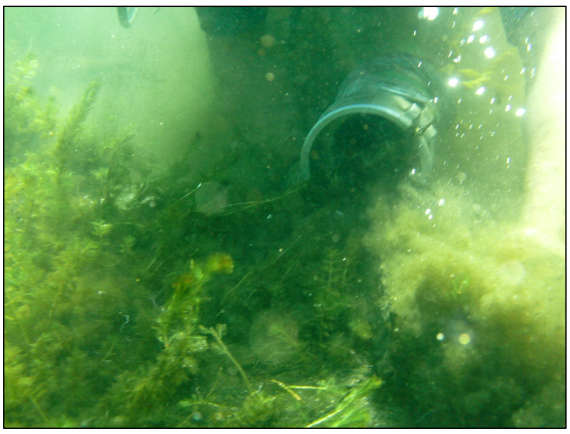


*Photo: Diver-assisted suction harvesting at Emerald Bay, courtesy of TRCD.*

Anderson (2004a) investigated diquat mixing characteristics in Delta sites and found that herbicide mixing began between 7.5 and 30 minutes after application. Initially, most of the diquat was found in the upper one foot of water. Maximum diquat concentrations lasted less than 60 minutes due to mixing, turbulence, and turbidity.

EDCP monitoring conducted between 2001 and 2005 found a range of diquat levels within treatment sites and downstream of treatment sites (DBW 2006). Out of a total of 107 diquat samples taken immediately following and up to two weeks following treatment diquat was detected in just under 50 percent of the samples. The mean residue concentration among all 107 samples was 15.9 ppb. Among samples taken on the same day as treatment, the detection percentage was higher, at 66.7 percent, or 38 of 57 samples. The minimum detected residue immediately following treatment was 0.75 ppb, and the maximum detected level was 922 ppb. This high sample, from within the treatment site, was considered an outlier (DBW 2006). Of the 41 samples taken one to two weeks following treatment, only four had detectable diquat levels, ranging from 0.80 to 10 ppb. For purposes of the RQ calculations in Section 6, we will utilize a conservative 0.37 ppm for acute exposure and the mean residue concentration of 15.9 ppb for chronic exposure.

## 3. Diver Assisted Handpicking and Diver-Operated Suction Harvesting

The EDCP will incorporate diver assisted handpicking and diver-operated suction harvesting in isolated instances. These methods, which are well-established in states such as Washington, Idaho, and New York, will be new to EDCP operations. Below, we briefly describe these methods and their potential use in the Delta.

### Diver Assisted Handpicking

This method involves handpicking *Egeria densa*, with the use of a small rake or hand-tool when needed, to ensure that the plant is completely removed. It will be necessary to utilize contracted SCUBA divers for this work because *Egeria densa* is rooted in the sediment, typically in an average of five to ten feet water depth. Divers will place the harvested *Egeria densa* in net bags, making sure to collect all plant fragments. Because *Egeria densa* reproduces vegetatively, plant fragments can be a source of new infestations if not removed from the water. Collected plants will be disposed of in approved locations away from the water's edge and sensitive habitats, typically on nearby farm fields.

Key issues related to handpicking include removal of the entire root crown and fragments (Greenfield et al. 2004), disposal of plants away from the shore (New York State Department of Environmental Conservation (DEC) 2005), and need for certified SCUBA divers. For EDCP, handpicking is likely to be most effective when used to remove small, localized infestations, and/or in conjunction with benthic barriers, described below.

### Diver-Operated Suction Harvesting

This method is essentially equivalent to vacuuming the plants, which are then removed to a basket on a boat, barge, or nearby dock. SCUBA divers hold a 3 to 5 inch-wide hose attached to a high pressure water pump located on the boat, barge, or dock. The hose extends about 50 feet from the pump (USACE 2005). The pump creates a venturi effect, creating suction to pull the plant through the hose and into the collection basket. Water and any sediment is drained back into the waterbody, and the plant mass is disposed of at an approved site away from the shore. Divers may use small rakes or tools to ensure that the plant is removed at the root, and then guide the plant into the hose. This method can be highly selective, as trained divers can literally pick and choose which plants to remove.

Diver-operated suction harvesting was first developed by the British Columbia Ministry of the Environment in the 1970s, and has been used in states such as Washington, Idaho, and New York, primarily for removal of Eurasian watermilfoil (Washington DOE 2012, New York State DEC 2005). The Tahoe Resource Conservation District (TRCD) is currently utilizing this method at several locations in Lake Tahoe (Jeff Brockett October 2012), primarily in conjunction with benthic barriers.

Similar to handpicking, it will be important to ensure that the complete root crown and all plant fragments are collected in order to prevent reinfestation. This method can cause a temporary disruption in sediment, with the extent of disruption dependent on the substrate and depth of plant roots. If sediment disruption significantly increases turbidity, EDCP could utilize silt curtains to localize the temporary increase in turbidity. Suction harvesting is most effective in fast-moving water, small high-use areas, isolated and early infestations, and as a follow-up to herbicide treatment in small areas (Madsen 2000, Greenfield et al. 2004).

The method can be expensive, and is limited by underwater visibility and diver safety concerns (USACE 2012). Another concern is that if sediments in an area that is harvested contains heavy metals or other toxic materials, suction harvesting can release these materials into the water (New York DEC 2005). We evaluate the potential effects of incorporating this method into EDCP in Section 6 of this Biological Assessment. The amount of biomass removed through suction harvesting can be substantial; for example, one diver in Lake Tahoe (Emerald Bay) removed seven 35 gallon trash cans full of Eurasian watermilfoil in one hour (Jim Brockett October 2012). However, the method is comparatively slow, with one diver able to harvest approximately 100 square meters per day (Madsen 2000). Diver-operated suction

harvesting may require an United States Army Corps of Engineers (USACE) permit and additional permitting from the CVRWQB. The EDCP will obtain all necessary additional permits prior to implementing this method.

## 4. Benthic Barriers

The EDCP will incorporate benthic barriers in isolated instances. This method, which is well-established, will be new to EDCP operations. Below, we briefly describe benthic barriers and their potential use in the Delta.

Benthic barriers consist of a physical cover over aquatic weeds, preventing sunlight from reaching the plants. Without the ability to photosynthesize, plants typically die back within approximately four to eight weeks (New York DEC 2005, Madsen 2000). The EDCP will utilize benthic barriers in selected locations where they are likely to be most effective, including relatively small areas (2 acres or less), and high-intensity use areas such as docks, boat launch areas, and swimming areas. Benthic barriers can be an important tool in removing new infestations in these areas (Madsen 2000), and may be especially effective in high-water flow areas of the Delta where herbicide treatments will not be effective.

Benthic barriers are non-selective, killing all plants underneath the barrier. Depending on the material, benthic barriers may also kill macroinvertebrates that are under the mat, although some newer materials do not result in effects to macroinvertebrates (Lake Bottom Barriers 2012). Benthic barriers can be made from a variety of different materials, including textiles (burlap, jute), plastic, woven synthetics, or screens (Washington DOE 2012). According to Washington DOE, an ideal benthic barrier should be durable, heavier than water, reduce or block light, prevent plants from growing into and under the fabric, be easy to install and maintain, and should readily allow gases produced by rotting weeds to escape without buoying the fabric upwards. To avoid potential issues with gas production under the mats, Gunnison and Barko (1992) recommend deploying barriers early in the year when the standing crop is low, and under cooler temperature conditions when microbial decomposition rates are low.

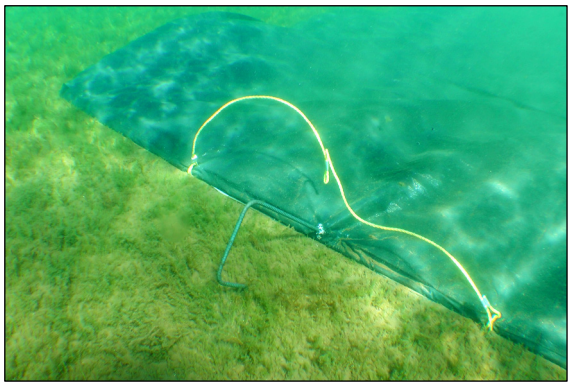


*Photo: Benthic barrier fastened with rebar, Emerald Bay, courtesy of TRCD.*

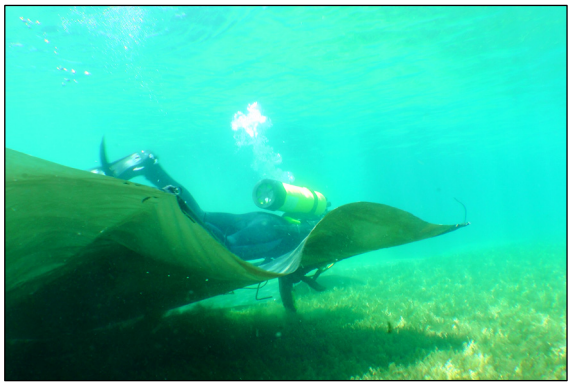


*Photo: Benthic barrier installation, Emerald Bay, courtesy of TRCD.*

The experience gained by the Tahoe Resource Conservation District can inform EDCP's future use of benthic barriers. The TRCD found benthic barriers to be very effective in controlling Eurasian watermilfoil in areas where there are isolated infestations such as Emerald Bay, Lakeside Beach and Marina, and near Ski Run Marina (Jim Brockett October 2012). EDCP will utilize a similar method and approach to TRCD. TRCD utilizes 10 foot by 40 foot sheets of a synthetic material that allows gas to escape and is not detrimental to benthic macroinvertebrates. There is a sleeve on the edges of the barriers in order to insert 3/8 inch rebar, which holds down the material. The material is also pinned down into the substrate with rebar to hold it in place. Contract divers install the barriers. In Emerald Bay, TRCD placed over 200 barriers, covering a total of 2 acres. For watermilfoil and pondweed, TRCD maintains the barriers in place for at least six to eight weeks. The length of time that the barriers are to remain in place depends on the biology of the plants being controlled. The barriers are reusable.

TRCD has addressed a number of operational issues in their barrier program. Factors that must be addressed include: topology (bathymetry) of the substrate, water movement, substrate material, and water traffic considerations. In addition, TRCD found that benthic barriers are best utilized when the weeds are no more than one-foot high. This involves placing the barriers early in the growing season, or using diver-operated suction harvesting to cut the weeds down to one foot before placing the barriers. TRCD has also found that it is important to re-evaluate and potentially retreat with barriers for a second year. Barriers are most effective when the plant population is not too dense, and when the barriers can be placed over the entire plant mat. It is possible to handpick or suction harvest a small amount of weeds adjacent to the mats, but not practical to use the mats when there are larger patches nearby of untreated weeds.

Benthic barriers may require USACE and DFG permits and additional permitting from the CVRWQCB. The EDCP will obtain all necessary additional permits prior to implementing this method.

## 5. Biological Controls

Biological control is the use of biological agents, typically insects or pathogens, to control undesirable plants. The EDCP to date has had minimal experimentation with biological controls. Activities related to biological control of *Egeria densa* are described here for information purposes, but are not part of this consultation. Currently, USDA-ARS is working to incorporate biological controls into EDCP activities. USDA-ARS is working with the Argentinian government to import new biological agents. Within two years, USDA-ARS hopes to import, quarantine, and test a small leafminer fly, *Hydriella* sp. 1. The larval stage of *Hydriella* sp. 1 eats *Egeria den*sa leaves. The first level of safety testing of this fly has been completed overseas, and the insect appears to be fairly specific to *Egeria densa*.

*Hydriella* sp. 1 is currently the only known specialist herbivore of *Egeria densa* (Walsh et al. 2012). In a comprehensive study of the biology of *Hydriella*, Walsh et all. (2012) found that *Hydriella* inflicts widespread and consistent damage to *Egeria densa* in Argentina, feeding mostly on the terminal 15

to 25 cm of the plant. *Hydriella* is adaptable to adverse climatic and physical constraints, but may not be able to establish where *Egeria densa* remains prostrate for long periods of time (Walsh et al. 2012).

USDA-ARS will be evaluating whether the fly also attacks Elodea, a related species, as well as climate matching and potential field impact studies. Depending on the results of these studies, EDCP will work to incorporate *Hydriella* and/or other biological control agents that are specific to *Egeria densa*. When effective, use of biological controls can reduce the amount of herbicides or other control measures required to manage *Egeria densa*. USDA-ARS is working with the Argentinian government to collect and export other natural *Egeria densa* biological control agents. Implementation of biological control agents is likely several years away in the Delta, and will be a supplemental treatment method in the future.

## F. Monitoring Protocols for EDCP

The EDCP will conduct extensive monitoring for the program. The EDCP is responsible for collecting water quality monitoring data, as well as collecting water samples for chemical residue testing.

Based on NPDES permit requirements, EDCP will follow a monitoring protocol. This protocol has historically fulfilled requirements of the Regional Water Quality Control Board, NMFS, and USFWS. At each monitoring site, EDCP's environmental scientists will take the initial samples within 24 hours of the treatment start (upstream and adjacent to the *Egeria densa* mat). Post-application monitoring (downstream of the treatment area) will begin after the treatment period is over, and continue until all sampling locations show non-detectable herbicide levels. At each sampling event, environmental scientists take samples from the following six locations, illustrated in **Figure 3-12,** on the next page:

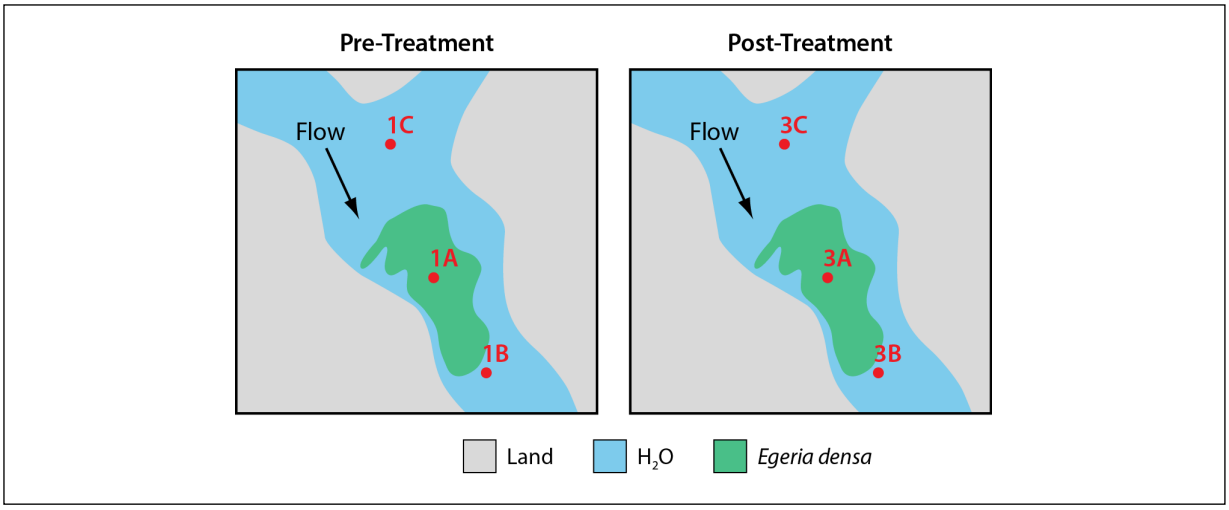
- 1A – Pre-treatment, in site
- 1B – Pre-treatment, downstream
- 1C – Pre-treatment, control
- 3A – Post-treatment, in site
- 3B – Post-treatment, downstream
- 3C – Post-treatment, control.

The EDCP will select monitoring sites for all herbicides used, and different habitat types. The EDCP will revise the monitoring approach to comply with the new NPDES General Permit, as described below.

At each monitoring site, EDCP environmental scientists will monitor dissolved oxygen, turbidity, pH, and several other water quality measures. EDCP environmental scientists will collect water in bottles and submit them to a Certified Analytical Laboratory to measure chemical residue levels.

*Photo: Water quality monitoring.*

**Figure 3-12**
**EDCP Monitor Sites**




Coordination between treatment crews and monitoring crews will be structured. Treatment and monitoring plans will be established in advance. Pre-treatment monitoring will take place within 24 hours of the start of the treatment protocol. For FasTEST monitoring, treatment crews will contact the monitoring crew when treatment is complete, so that the monitoring crew can obtain samples, as needed. Post-treatment monitoring will begin only after the treatment period within a given site is completed, thus there will be no overlap with treatment crews. Treatment and monitoring crews will be in separate vessels. Monitoring vessels will not carry herbicide to minimize any contamination that might occur.

EDCP treatment crews also conduct monitoring, in addition to monitoring conducted by EDCP environmental scientists. Treatment crews will monitor and report pre- and post-treatment dissolved oxygen, wind speed, temperature, acres treated, quantity of herbicide and adjuvant, presence of elderberry shrubs or other species of concern, and coordinates of treatment location. **Table 3-9,** on the next page, lists monitoring requirements for EDCP environmental scientists and EDCP treatment crews.

In addition to the regular monitoring described above, EDCP will conduct additional herbicide monitoring at EDCP treatment sites. Environmental scientists will obtain water samples at approximately 3 feet depth and submit these samples, overnight, to a laboratory. The laboratory will determine herbicide concentrations by an Enzyme-Linked Immunoassay (ELISA) test, known as FasTEST, typically providing results within 48 hours of the time the sample was taken. This quick and regular herbicide monitoring will allow EDCP to ensure that herbicide concentrations are maintained at efficacious levels, and that water quality standards are not exceeded, particularly for irrigation. Depending on the FasTEST results, treatment crews may adjust future herbicide applications to achieve an appropriate herbicide concentration.

The State Water Quality Control Board is updating the NPDES General Permit, with a

**Table 3-9**
**EDCP Environmental Monitoring Requirements**

| Treatment Crews (for each site treated) | Environmental Scientists (for each sample event) |
|---|---|
| 1. Water temperature (°C)<br>2. Dissolved oxygen (DO, mg/L or parts per million (ppm))<br>3. Wind speed (mph)<br>4. Coordinates of treatment location<br>5. Presence of elderberry shrubs<br>6. Presence of species of concern<br>7. Acres treated<br>8. Quantity of herbicide | 1. Water temperature (°C)<br>2. Dissolved oxygen (DO, mg/L or ppm)<br>3. Turbidity (NTU)<br>4. pH<br>5. Salinity (ppt)<br>6. Specific conductance (mS/cm)<br>7. Water depth (feet)<br>8. Tide cycle<br>9. Water samples (pre-treatment, post-treatment, control; submitted to a Certified Analytical Laboratory) |

draft for public comment released on June 27, 2012, and a final version for Board approval expected on February 19, 2013. The June 27, 2012 preliminary version of the General Permit maintains a similar monitoring protocol as described in Figure 3-12. However, the new General Permit requires a sampling frequency of six application events per year for each environmental setting (flowing water and non-flowing water), per herbicide. Once a discharger has provided the SWRCB with results from six consecutive application events showing concentrations that are less than the receiving water limitation/ trigger for an active ingredient in a specific environmental setting, sampling shall be reduced to one application event per year for that active ingredient in that environmental setting. **Table 3-10,** right, provides the receiving water limits and monitoring triggers for the three potential EDCP herbicides. These maximum limitations are above the calculated instantaneous concentrations for fluridone and penoxsulam, but below the calculated instantaneous concentration of diquat cation. The SWRCB will add imazamox to the General Permit now that it is approved for use in California. The EDCP will revise their monitoring protocols, as appropriate, to comply with the new NPDES General Permit.

## G. Mitigation Measures for EDCP

The EDCP implements a number of mitigation measures to minimize or reduce potential impacts of the program. These mitigation measures have been developed over time, working with USFWS, NMFS, the State Water Resources Control Board, and local Agricultural Commissioners. **Exhibit 3-4,** starting on the next page, describes seventeen (17) EDCP mitigation measures that EDCP regularly implements to reduce or eliminate potential impacts of the EDCP.

**Table 3-10**
**General Permit Receiving Water Limits or Monitoring Triggers for EDCP Herbicides**

| Herbicide Active Ingredient | Maximum Limitation |
|---|---|
| Fluridone | 560 ppb |
| Penoxsulam | 10.1 ppm |
| Imazamox | TBD |
| Diquat | 20 ppb |

## Exhibit 3-4
### EDCP Mitigation Measures Summary



| Mitigation Measures Summary | Mitigation Measures Description |
|---|---|
| 1. Avoid herbicide application, diver-assisted removal, and use of benthic barriers near special status species, and sensitive riparian and wetland habitat; and other biologically important resources | Each year, prior to the start of the treatment season, EDCP will conduct field crew environmental awareness training. Under this training, crews will be informed about the presence and life histories of special status species; habitats associated with species; sensitive habitats and wetlands; the terms and conditions of the program's biological opinions; incidental take procedures; and that unlawful take of an animal or destruction of its habitat is a violation of the Endangered Species Act.<br><br>EDCP also will provide crews with a field guide (Species Identification Deck) for easy identification of special status species on-site. Prior to treating a site, crews will conduct a visual survey to determine whether special status plants, animals, or sensitive habitats are present. Crews will complete an Environmental Observations Checklist for each site to document the presence or absence of special status species. If any special status species or sensitive habits are present at the site, the field crew will not perform any treatment. |
| 2. Provide a 50 foot buffer between treatment sites and shoreline elderberry shrubs (*Sambucus* ssp.), host plant for the valley elderberry longhorn beetle *(Desmocerus californicus dimorphus)* | EDCP will conduct a survey of treatment sites to prepare a map that identifies locations of elderberry shrubs, and provide this map to field crews. EDCP crews will maintain the 50 buffer zone for herbicide treatments when elderberry shrubs are present. Crews will also conduct treatments downwind of elderberry shrubs.<br><br>In addition, EDCP environmental scientists will survey a sample of elderberry shrubs which could be potentially impacted by application activities at the beginning of the treatment season, and at the end of the treatment season. The 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 treated sites show signs of adverse effects from treatment, EDCP will develop additional mitigation measures to protect elderberry shrubs (for example, increasing the size of the buffer zone). |
| 3. Operate program vessels in a manner that causes the least amount of disturbance to the habitat | Operational procedures for EDCP vessels will minimize boat wakes and propeller wash. These procedures will be particularly important in shallow water, or other sensitive habitats. |
| 4. Implement temporal and spatial limitations and restrictions on herbicide treatments and other removal methods to minimize treatments during times, and at locations, where larval and/or migratory fish are likely to be present | The specific locations and times followed in the EDCP have been guided by the prior biological opinions. In the future, EDCP will implement a survey-based approach to conducting treatments that allows for early season treatments in areas with *Egeria densa* infestations when listed fish species are not likely to be present. In addition, EDCP will follow calendar year treatment dates when listed fish species may be present (although treatments will not be conducted in sites where IEP data shows listed fish are present). These treatment time restrictions minimize potential exposure of migratory salmonids and sensitive juvenile fish to EDCP herbicides. Figure 3-4 summarizes treatment timing. |
| 5. Monitor herbicide levels to ensure that EDCP does not result in potentially toxic concentrations of chemicals in Delta waters | EDCP will conduct comprehensive monitoring. This monitoring is in compliance with the general NPDES permit, and prior NOAA-Fisheries and USFWS Biological Opinions. EDCP will collect a pre-treatment sample no more than 24 hours prior the start of treatment, and collect post-treatment samples, continuing until the sampling location shows non-detectable herbicide levels. EDCP will conduct water quality monitoring as required by the NPDES General Permit for each pesticide, and water body type. Water samples will be submitted to a certified analytical laboratory to measure fluridone, penoxsulam, imazamox, and diquat, as appropriate. Should these levels exceed allowable limits, EDCP will take immediate measures to reduce chemical levels at future treatment sites. EDCP will conduct additional FasTEST monitoring for fluridone and penoxsulam applications to more closely track herbicide levels. |

**Exhibit 3-4**

**EDCP Mitigation Measures Summary** *(continued)*



| Mitigation Measures Summary | Mitigation Measures Description |
|---|---|
| 6. Implement an adaptive management approach to minimize the use of herbicides | Under an adaptive management approach, EDCP will seek to improve efficacy and reduce environmental impacts over time as new and better information is available. Specifically, EDCP will evaluate the need for control measures on a site by site, month-to-month, basis; select appropriate indicators for pre-treatment monitoring; monitor indicators following treatment and evaluate data to determine program efficacy and environmental impacts; support ongoing research to explore impacts of the EDCP and alternative control methodologies; report findings to regulatory agencies; and adjust program actions, as necessary, in response to recommendations and evaluations by USDA-ARS, DBW staff, regulatory agencies and stakeholders.<br><br>In addition to this adaptive management approach, EDCP will follow maintenance control practices that from a program standpoint seek to reduce the number of acres of *Egeria densa* to be treated each year, until treatment acreage reaches a minimal level. This will reduce the volume of herbicide utilized by the EDCP. |
| 7. Provide treatment crews with electronic mapping that identifies previously surveyed areas for giant garter snake habitat | EDCP application crews will use this map as a tool for performing pre-application visual inspections for the presence of giant garter snakes. If giant garter snakes are present, treatment crews will not treat at that location. |
| 8. Monitor dissolved oxygen levels pre- and post-treatment for all EDCP treatments, and at selected locations in the Delta over time | Based on the pre-treatment DO levels, the EDCP application crew will determine whether to conduct treatment at that site. No treatment will be performed when dissolved oxygen levels are between 3 ppm (the level below which DO is considered to be detrimental to fish species) and the basin plan limits established by the Central Valley Regional Water Quality Control Board (CVRWQB). The basin plan limits depend on location and time of year, and range from 5 ppm to 8 ppm. DBW will maintain written and map summaries of specific DO numeric limits. When pre-treatment levels are below 3 ppm, fish species are not likely to be present due to the extremely low oxygen levels. When pre-treatment levels are above the basin plan limit, EDCP treatments, following label guidelines and mitigation measures, are not expected to adversely affect special status fish, resident native or migratory fish, or sensitive riparian or wetland habitats. |
| 9. Collect plant fragments during and immediately following treatment | To maximize containment of plant fragments, EDCP crews will collect *Egeria densa* fragments. Crews will also be trained on the importance of minimizing fragment escape. |
| 10. Identify and utilize disposal areas for diver-harvested *Egeria densa* that have no and/or low habitat value for the federal and State listed giant garter snake *(Thamnophis gigas)* | EDCP will provide crews electronic mapping that identifies previously surveyed areas for giant garter snake habitat. Crews also will conduct surveys to ensure that there are no other special status plant or animal species located within 50 feet of disposal sites. Harvested *Egeria densa* will be disposed of only in pre-approved disposal sites. |
| 11. Identify and utilize disposal areas for diver-harvested *Egeria densa* that are at least 50 feet away from elderberry shrubs (*Sambucus* ssp.) and 50 feet away from aquatic giant garter snake habitat | EDCP disposal will not occur near elderberry shrubs, which are potential habitat for the federally threatened valley elderberry longhorn beetle (*Desmocerus californicus dimorphusb*). EDCP disposal will not occur near aquatic giant garter snake habitat. Diver-harvested *Egeria densa* will be disposed of only in pre-approved disposal sites. |

**Exhibit 3-4**

**EDCP Mitigation Measures Summary** *(continued)*



| Mitigation Measures Summary | Mitigation Measures Description |
|---|---|
| 12. Minimize public exposure to herbicide treated water | Prior to treatments, EDCP will release a public notice announcing the program. EDCP treatments generally take place in heavily infested waterways, which are usually unsuitable for water recreation. If recreationists are present when treatment occurs, treatments crews will inform recreationists about the treatment, asking them to move to a different location, or crews will move treatments to a different location. |
| 13. Require treatment crews to participate in training on herbicide and heat hazards | EDCP will provide training to ensure that treatment crews have the knowledge and tools necessary to conduct the program in a safe manner. Training will include reading, understanding, and following herbicide label requirements; purpose and proper use of Personal Protective Equipment; symptoms of herbicide poisoning and minimization of exposure; avoidance, symptoms, and treatment of heat exposure; and emergency medical procedures. |
| 14. Follow best management practices to minimize the risk of spill and to minimize the impact of a spill, should one occur | The EDCP best management practices include several provisions to reduce the potential for spill, such as: fastening herbicide containers securely in boats in original, watertight containers; carrying a marker buoy and anchor line to mark any spills in water; reporting spills immediately to appropriate State and local agencies; immediately stopping movement of land spills using absorbing materials; marking and monitoring spills in water for herbicide residues and environmental impacts, if appropriate. Treatment crews will include at least one person with a Qualified Applicators Certificate (QAC), and all crew members will participate in annual training on herbicide handling procedures. |
| 15. Implement safety precautions on hot days to prevent heat illness | In addition to annual training on heat illness prevention, and compliance with CalOSHA's California Heat Illness Prevention Standard, EDCP field supervisors will conduct special training sessions on days when weather is expected to be hot. This training will cover the symptoms of heat illness, and immediate actions to take should any symptoms occur. Field supervisors will cancel treatments if the weather is exceptionally hot. EDCP will also provide bimini tops (shade covers) for EDCP treatment boats. |
| 16. Follow the Memorandum of Understanding (MOU) protocol for herbicide applications within one (1) mile of Contra Costa Water District (CCWD) drinking water intake facilities | The MOU is an agreement between CCWD and DBW. No applications shall occur within Rock Slough, or within one mile of the confluence of Rock Slough and Old River, or within one mile of CCWD's Old River or Mallard Slough intake pumps without consensual agreement between CCWD and DBW. Herbicide applications within one mile of CCWD's water intakes may only occur with prior consent of CCWD. In order to treat within one mile of an intake, EDCP must notify CCWD at least two weeks in advance, and make every reasonable attempt to schedule applications during periods when CCWD's intakes are shut down for environmental or maintenance reasons, allowing at least two complete tidal cycles between application and restart. This measure is primarily aimed at reducing the potential for drinking water contamination from the EDCP. |
| 17. Notify County Agricultural Commissioners about EDCP activities | Before an application may occur, EDCP shall file Pesticide Use Recommendations (PUR) and a Notice of Intent (NOI) with the appropriate County Agricultural Commissioner (CAC) office, when required for restricted material or as requested by each county. Each NOI will include the site number, spray dates, locations, and herbicides and adjuvants to be used. NOIs will be submitted before the upcoming treatment week. Based on information in the NOIs, CAC's could inform land owners of particular periods of time during which irrigation should not occur. If necessary, EDCP shall also obtain a Restricted Use Permit (RUP) from all appropriate CACs. |

[i] The legal definition of the Sacramento-San Joaquin Delta is as follows. These boundaries are reflected in Exhibit 1-2. 12220. The Sacramento-San Joaquin Delta shall include all the lands within the area bounded as follows, and as shown on the attached map prepared by the Department of Water Resources titled "Sacramento-San Joaquin Delta," dated May 26, 1959:

Beginning at the Sacramento River at the I Street bridge proceeding westerly along the Southern Pacific Railroad to its intersection with the west levee of the Yolo By-Pass; southerly along the west levee to an intersection with Putah Creek, then westerly along the left bank of Putah Creek to an intersection with the north-south section line dividing sections 29 and 28, T8N, R6E; south along this section line to the northeast corner of section 5, T7N, R3E; west to the northwest corner of said section; south along west boundary of said section to intersection of Reclamation District No. 2068 boundary at northeast corner of SE 1/4 of section 7, T7N, R3E; southwesterly along Reclamation District No. 2068 boundary to southeast corner of SW 1/4 of section 8, T6N, R2E; west to intersection of Maine Prairie Water Association boundary at southeast corner of SW 1/4 of section 7, T6N, R2E; along the Maine Prairie Water Association boundary around the northern and western sides to an intersection with the southeast corner of section 6, T5N, R2E; west to the southwest corner of the SE 1/4 of said section; south to the southwest corner of the NE 1/4 of section 7, T5N, R2E; east to the southeast corner of the NE 1/4 of said section; south to the southeast corner of said section; west to the northeast corner of section 13, T5N, R1E; south to the southeast corner of said section; west to the northwest corner of the NE 1/4 of section 23, T5N, R1E; south to the southwest corner of the NE 1/4 of said section; west to the northwest corner of the SW 1/4 of said section; south to the southwest corner of the NW 1/4 of section 26, T5N, R1E; east to the northeast corner of the SE 1/4 of section 25, T5N, R1E; south to the southeast corner of said section; east to the northeast corner of section 31, T5N, R2E; south to the southeast corner of the NE 1/4 of said section; east to the northeast corner of the SE 1/4 of section 32, T5N, R2E; south to the northwest corner of section 4, T4N, R2E; east to the northeast corner of said section; south to the southwest corner of the NW 1/4 of section 3, T4N, R2E; east to the northeast corner of the SE1/4 of said section; south to the southwest corner of the NW 1/4 of the NW 1/4 of section 11, T4N, R2E; east to the southeast corner of the NE 1/4 of the NE 1/4 of said section; south along the east line of section 11, T4N, R2E to a road intersection approximately 1000 feet south of the southeast corner of said section; southeasterly along an unnamed road to its intersection with the right bank of the Sacramento River about 0.7 mile upstream from the Rio Vista bridge; southwesterly along the right bank of the Sacramento River to the northern boundary of section 28, T3N, R2E; westerly along the northern boundary of sections 28, 29, and 30, T3N, R2E and sections 25 and extended 26, T3N, R1E to the northwest corner of extended section 26, T3N, R1E; northerly along the west boundary of section 23, T3N, R1E to the northwest corner of said section; westerly along the northern boundary of sections 22 and 21, T3N, R1E to the Sacramento Northern Railroad; southerly along the Sacramento Northern Railroad; southerly along the Sacramento Northern Railroad to the ferry slip on Chipps Island; across the Sacramento River to the Mallard Slough pumping plant intake channel of the California Water Service Company; southward along the west bank of the intake channel and along an unnamed creek flowing from Lawler Ravine to the southern boundary of the Contra Costa County Water District; easterly along the southern boundary of the Contra Costa County Water District to the East Contra Costa Irrigation District boundary; southeasterly along the southwestern boundaries of the East Contra Costa Irrigation District, Byron-Bethany Irrigation District, West Side Irrigation District and Banta-Carbona Irrigation District to the northeast corner of the NW 1/4 of section 9, T3S, R6E; east along Linne Road to Kasson Road; southeasterly along Kasson Road to Durham Ferry Road; easterly along Durham Ferry Road to its intersection with the right bank of the San Joaquin River at Reclamation District No. 2064; southeasterly along Reclamation District No. 2064 boundary, around its eastern side to Reclamation District No. 2075 and along the eastern and northern sides of Reclamation District No. 2075 to its intersection with the Durham Ferry Road; north along the Durham Ferry Road to its intersection with Reclamation District No. 17; along the eastern side of Reclamation District No. 17 to French Camp Slough; northerly along French Camp Turnpike to Center Street; north along Center Street to Weber Avenue; east along Weber Avenue to El Dorado Street; north along El Dorado Street to Harding Way; west along Harding Way to Pacific Avenue; north along Pacific Avenue to the Calaveras River; easterly along the left bank of the Calaveras River to a point approximately 1,600 feet west of the intersection of the Western Pacific Railroad and the left bank of said river; across the Calaveras River and then north 18* 26' 36 west a distance of approximately 2,870 feet; south 72* 50' west a distance of approximately 4,500 feet to Pacific Avenue (Thornton Road); north along Pacific Avenue continuing onto Thornton Road to its intersection with the boundary line dividing Woodbridge Irrigation District and Reclamation District No. 348; east along this boundary line to its intersection with the Mokelumne River; continuing easterly along the right bank of the Mokelumne River to an intersection with the range line dividing R5E and R6E; north along this range line to the Sacramento-San Joaquin County line; west along the county line to an intersection with Reclamation District No. 1609; northerly along the eastern boundary of Reclamation District No. 1609 to the Cosumnes River, upstream along the right bank of the Cosumnes River to an intersection with the eastern boundary of extended section 23, T5N, R5E; north along the eastern boundary of said extended section to the southeast corner of the NE 1/4 of the NE 1/4 of said extended section; west to the southeast corner of the NE 1/4 of the NW 1/4 of extended section 14, T5N, R5E; west to an intersection with Desmond Road; north along Desmond Road to Wilder-Ferguson Road; west along Wilder-Ferguson Road to the Western Pacific Railroad; north along the Western Pacific Railroad to the boundary of the Elk Grove Irrigation District on the southerly boundary of the N 1/2 of section 4, T5N, R5E; northerly along the western boundary of the Elk Grove Irrigation District to Florin Road; west on Florin Road to the eastern boundary of Reclamation District No. 673; northerly around Reclamation District No. 673 to an intersection with the Sacramento River and then north along the left bank of the Sacramento River to I Street bridge. Section, range, and township locations are referenced to the Mount Diablo Base Line and Meridian. Road names and locations are as shown on the following United States Geological Survey Quadrangles, 7.5 minute series: Rio Vista, 1953; Clayton, 1953; Vernalis, 1952; Ripon, 1952; Bruceville, 1953; Florin, 1953; and Stockton West, 1952.

Section 4

# Status of Species and Critical Habitat in the Action Area

# 4. Status of Species and Critical Habitat in the Action Area

This section of the biological assessment summarizes relevant information on the biological requirements of the species, population trends, abundance, viability, distribution, and condition of critical habitat. This section draws heavily on USFWS and NMFS documents, as well as the WHCP PEIR, and other relevant resources.

This section addresses four species and one critical habitat under the jurisdiction of USFWS, and four species and four critical habitats under the jurisdiction of NMFS. This section is organized as follows:

*A. USFWS Listed Species (4) and Critical Habitats (1)*

1. *Threatened delta smelt*
   - *Threatened delta smelt Critical Habitat*
2. *Threatened giant garter snake*
3. *Threatened valley elderberry longhorn beetle*
4. *Candidate Threatened San Francisco Bay-Delta Distinct Population Segment (DPS) of longfin smelt*

*B. NMFS Listed Species (4) and Critical Habitats (4)*

1. *Endangered Sacramento River winter-run Chinook salmon*
   - *Endangered Sacramento River winter-run Chinook salmon Critical Habitat*
2. *Threatened Central Valley spring-run Chinook salmon*
   - *Threatened Central Valley spring-run Chinook salmon and Threatened Central Valley steelhead Critical Habitats*
3. *Threatened Central Valley steelhead*
4. *Threatened Southern Distinct Population Segment (DPS) of North American green sturgeon*
   - *Threatened Southern Distinct Population Segment (DPS) of North American green sturgeon Critical Habitat*

*Source:* www.fws.gov.

*Photo:* Delta smelt.

## A. USFWS Listed Species and Critical Habitats

### 1. Threatened delta smelt *(Hypomesus transpacificus)*

The delta smelt *(Hypomesus transpacificus)* is State listed as endangered, and federally listed as threatened. USFWS will be reclassifying delta smelt from threatened to endangered. Delta smelt was first listed as threatened in 1993, with critical habitat designated in 1994.

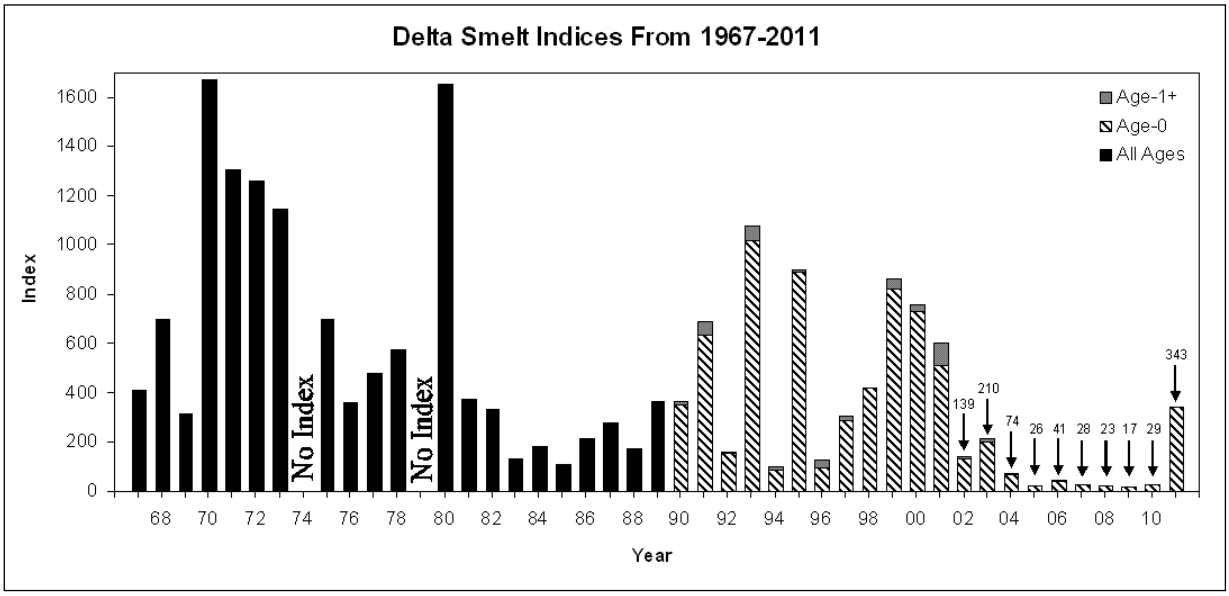
Delta smelt was one of eight fish species addressed in a 1996 *Recovery Plan for the Sacramento-San Joaquin Delta Native Fishes*. The federal threatened status was maintained following the 5-Year Review (USFWS March 2004). USFWS developed a Spotlight Species 5-Year Action Plan for delta smelt in 2009 (USFWS September 13, 2010). On April 7, 2010, USFWS issued a 12-month finding to reclassify delta smelt from threatened to endangered. USFWS completed a 5-Year Review of delta smelt on September 13, 2010, that confirmed the reclassification from threatened to endangered. While the reclassification is documented, it is precluded by other higher priority listing actions. The future reclassification will not impact EDCP activities that already seek to avoid impacts to delta smelt.

Delta smelt are threatened by factors such as: alterations to salinity and turbidity, entrainment, modified river flows, invasive species, and water export facility operations. Delta smelt abundance indices declined significantly in the early 2000s, as part of the broader Pelagic Organism Decline (POD). In 2011, following a high water year, delta smelt indices increased to their highest level since 2001. However, the indicators are still far below historical levels. **Figure 4-1,** on the next page, provides a summary of Fall Midwater Trawl (FMWT) surveys for delta smelt, from 1967 to 2011.

Critical habitat for delta smelt includes Suisun Bay (including contiguous Grizzly and Honker Bays); the length of Goodyear, Suisun, Cutoff, First Mallard, and Montezuma sloughs; and existing continuous waters within the Sacramento-San Joaquin Delta. Delta smelt are native to the Sacramento-San Joaquin estuary. They are found primarily in the lower Sacramento and San Joaquin Rivers, in the Delta above their confluence, in Suisun Marsh water channels, and in Suisun Bay. Delta smelt are endemic to low-salinity and freshwater habitats of the Delta (Bennett 2005).

Delta smelt spawning occurs within the Delta, potentially overlapping with some EDCP treatment site locations, primarily during April through mid-May. Some juvenile rearing occurs within the Delta into early July (USFWS 2008); however, juveniles and adult delta smelt spend time in the low salinity zone (LSZ), at salinity levels that are not conducive to water hyacinth growth.

**Figure 4-1**
**Delta smelt Fall Midwater Trawl Indices (1967-2011)**




Source: California Department of Fish and Game (http://www.dfg.ca.gov/delta/data/fmwt/Indices/sld002.asp)

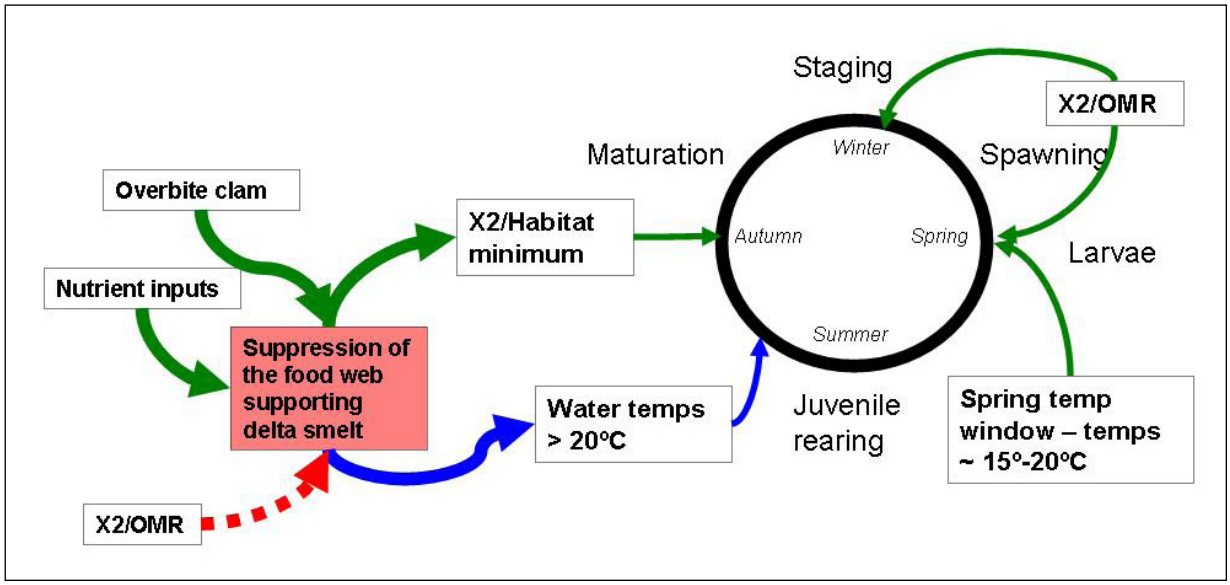
The description below of delta smelt biology, abundance, and habitat requirements is drawn from the USFWS OCAP Biological Opinion of December 15, 2008.

Delta smelt are a member of the Osmeridae family (northern smelts) (Moyle 2002) and is one of six species currently recognized in the *Hypomesus* genus (Bennett 2005). Delta smelt are endemic to the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta) in California, and are restricted to the area from San Pablo Bay, upstream through the Delta in Contra Costa, Sacramento, San Joaquin, Solano, and Yolo counties (Moyle 2002). Their range extends from San Pablo Bay upstream to Verona on the Sacramento River; and Mossdale on the San Joaquin River. Delta smelt were formerly considered to be one of the most common pelagic fish in the upper Sacramento-San Joaquin estuary.

Delta smelt are a slender-bodied fish, generally about 60 to 70 millimeters (mm) long, although they can reach lengths of up to 120 mm (Moyle 2002). Delta smelt are nearly translucent and have a steely blue sheen to their sides. Delta smelt usually aggregate but do not appear to be a strongly schooling species.

Genetic analyses have confirmed that *H. transpacificus* presently exists as a single intermixing population (Stanley et al. 1995; Trenham et al. 1998). The most closely related species is the Surf smelt (*H. pretiosis*), a marine species common along the western coast of North America. Despite its morphological similarity, delta smelt are less-closely related to wakasagi (*H. nipponensis*), an anadromous western Pacific species introduced into California Central Valley reservoirs in 1959 and now distributed in the historic range of delta smelt (Trenham et al. 1998). Genetic introgression among *H. transpacificus* and *H. nipponensis* is low.

**Figure 4-2**
**Lifecycle Conceptual Model For delta smelt**
*(The Larger the Arrow Size, the Stronger the Influence on the Process Box)*




(Source: USFWS December 15, 2008)

The delta smelt life cycle is completed within the freshwater and brackish low salinity zone (LSZ) of the Bay-Delta. **Figure 4-2,** above, portrays the conceptual model used for delta smelt. Delta smelt are moderately euryhaline (Moyle 2002). However, salinity requirements vary by life stage. Delta smelt are a pelagic species, inhabiting open waters away from the bottom and shore-associated structural features (Nobriga and Herbold, 2008). Although delta smelt spawning has never been observed in the wild, clues from the spawning behavior of related osmerids suggests delta smelt use bottom substrate and nearshore features during spawning. However, apart from spawning and egg-embryo development, the distribution and movements of all life stages are influenced by transport processes associated with water flows in the estuary, which also affect the quality and location of suitable openwater habitat (Dege and Brown 2004; Feyrer et al. 2007; Nobriga et al. 2008).

Delta smelt are weakly anadromous and undergo a spawning migration from brackish water to freshwater annually (Moyle 2002). In early winter, mature delta smelt migrate from brackish, downstream rearing areas, in and around Suisun Bay and the confluence of the Sacramento and San Joaquin rivers, upstream to freshwater spawning areas in the Delta. Delta smelt historically have also spawned in the freshwater reaches of Suisun Marsh. In winters featuring high Delta outflow, the spawning range of delta smelt shifts west to include the Napa River (Hobbs et al. 2007).

The upstream migration of delta smelt, which ends with their dispersal into river channels and sloughs in the Delta (Radtke 1966; Moyle 1976, 2002; Wang 1991), seems to be triggered or cued by abrupt

changes in flow and turbidity associated with the first flush of winter precipitation (Grimaldo et al. 2009) but can also occur after very high flood flows have receded. Grimaldo et al. (2009) noted salvage often occurred when total inflows exceeded over 25,000 cfs, or when turbidity elevated above 12 Nephelometric Turbidity Units (NTU) (at Clifton Court Forebay (CCF) station).

Delta smelt spawning may occur from mid-winter through spring; most spawning occurs when water temperatures range from about 12°C to 18°C (Moyle 2002). Most adult delta smelt die after spawning (Moyle 2002). However, some fraction of the population may hold over as two-year-old fish and spawn in the subsequent year.

During and after a variable period of larval development, the young fish migrate downstream until they reach the LSZ (indexed as X2) where they reside until the following winter (Moyle 2002). The location of the delta smelt population follows changes in the location of the LSZ, which depends primarily on Delta outflow.

### *Spawning*

Adult delta smelt spawn during the late winter and spring months, with most spawning occurring during April through mid-May (Moyle 2002). Spawning occurs primarily in sloughs and shallow edge areas in the Delta. Delta smelt spawning has also been recorded in Suisun Marsh and the Napa River (Moyle 2002). Most spawning occurs at temperatures between 12°C to 18°C. Although spawning may occur at temperatures up to 22°C, hatching success of the larvae is very low (Bennett 2005).

Fecundity of females ranges from about 1,200 to 2,600 eggs, and is correlated with female size (Moyle 2002). Moyle et al. (1992) considered delta smelt fecundity to be "relatively low." However, based on Winemiller and Rose (1992), delta smelt fecundity is fairly high for a fish its size. In captivity, females survive after spawning and develop a second clutch of eggs (Mager et al. 2004); field collections of ovaries containing eggs of different size and stage indicate that this also occurs in the wild (Adib-samii 2008).

Captive delta smelt can spawn up to four to five times. While most adults do not survive to spawn a second season, a few (less than five percent) do (Moyle 2002; Bennett 2005). Those that do survive are typically larger (90 to 110 mm standard length (SL)) females that may contribute disproportionately to the population's egg supply (Moyle 2002 and references therein)). Two-year-old females may have three to six times as many ova as first year spawners.

Most of what is known about delta smelt spawning habitat in the wild is inferred from the location of spent females and young larvae captured in the Spring Kodiak Trawl (SKT) and 20-mm survey, respectively. In the laboratory, delta smelt spawned at night (Baskerville-Bridges et al. 2000; Mager et al. 2004). Other smelts, including marine beach spawning species and estuarine populations and the landlocked Lake Washington longfin smelt, are secretive spawners, entering spawning areas during the night and leaving before dawn. If this behavior is exhibited by delta smelt, then delta smelt distribution based on the SKT, which is conducted during daylight hours in offshore habitats, may reflect general regions of spawning activity, but not actual spawning sites.

Delta smelt spawning has only been directly observed in the laboratory and eggs have not been found in the wild. Consequently, what is known about the mechanics of delta smelt spawning is derived from laboratory observations and observations of related smelt species. Delta smelt eggs are 1 mm diameter and are adhesive and negatively buoyant (Moyle 1976, 2002; Mager et al. 2004; Wang 1986, 2007). Laboratory observations indicate that delta smelt are broadcast spawners, discharging eggs and milt close to the bottom over substrates of sand and/or pebble in current (DWR and Reclamation 1994; Brown and Kimmerer 2002; Lindberg et al. 2003; Wang 2007).

Presence of newly hatched larvae likely indicates regions where spawning has occurred. The 20-mm trawl has captured small (~5 mm Standard Length [SL]) larvae in Cache Slough, the lower Sacramento River, San Joaquin River, and at the confluence of these two rivers (e.g., 20-mm trawl survey 1 in 2005). Larger larvae and juveniles (size > 23 mm SL), which are more efficiently sampled by the 20-mm trawl gear, have been captured in Cache Slough (Sacramento River) and the Sacramento Deep Water Channel in July (e.g. 20-mm trawl survey 9 in 2008).

Because they are small fish inhabiting pelagic habitats with strong tidal and river currents, delta smelt larval distribution depends on both the spawning area from which they originate and the effect of transport processes caused by flows. Larval distribution is further affected by water salinity and temperature. Hydrodynamic simulations reveal that tidal action and other factors may cause substantial mixing of water with variable salinity and temperature among regions of the Delta (Monson et al 2007). This could result in rapid dispersion of larvae away from spawning sites.

Sampling of larval delta smelt in the Bay-Delta in 1989 and 1990 suggested that spawning occurred in the Sacramento River; in Georgiana, Prospect, Beaver, Hog, and Sycamore sloughs; in the San Joaquin River adjacent to Bradford Island and Fisherman's Cut; and possibly other areas (Wang 1991). However, in recent years, the densest concentrations of both spawners and larvae have been recorded in the Cache Slough/Sacramento Deepwater Ship Channel complex in the North Delta. Some delta smelt spawning occurs in Napa River, Suisun Bay and Suisun Marsh during wetter years (Sweetnam 1999; Wang 1991; Hobbs et al. 2007). Early stage larval delta smelt have also been recorded in Montezuma Slough near Suisun Bay (Wang 1986).

***Larval Development***

Mager et al. (2004) reported that embryonic development to hatching takes 11 to13 days, at 14°C to 16°C for delta smelt, and Baskerville-Bridges et al. (2000) reported hatching of delta smelt eggs after 8 to 10 days at temperatures between 15°C to 17°C. Lindberg et al. (2003) reported high hatching rates of delta smelt eggs in the laboratory at 15°C, and Wang (2007) reported high hatching rates at temperatures between 14°C to 17°C. Bennett (2005) showed hatching success peaks near 15°C. Swim bladder inflation occurs at 60 to 70 days, post-hatch, at 16°to 17°C (Mager et al. 2004). At hatching and during the succeeding three

days, larvae are buoyant, swim actively near the water surface, and do not react to bright, direct light (Mager et al. 2004).

As development continues, newly hatched delta smelt become semi-buoyant and sink in stagnant water. However, larvae are unlikely to encounter stagnant water in the wild. In the laboratory, a turbid environment (>25 NTU) was necessary to elicit a first feeding response (Baskerville-Bridges et al. 2000; Baskerville-Bridges 2004). Successful feeding seems to depend on a high density of food organisms and turbidity, and increases with stronger light conditions (Baskerville-Bridges *et al.* 2000; Mager et al. 2004; Baskerville-Bridges *et al.* 2004).

Growth rates of wild-caught delta smelt larvae are faster than laboratory-cultured individuals. Mager et al. (2004) reported growth rates of captive-raised delta smelt reared at near-optimum temperatures (16°C to 17°C). Their fish were about 12 mm long after 40 days, and about 20 mm long after 70 days. In contrast, analyses of otoliths indicated that wild delta smelt larvae were 15 to 25 mm, or nearly twice as long at 40 days of age (Bennett 2005). By 70 days, most wild fish were 30 to 40 mm long, and beyond the larval stage. This suggests there is strong selective pressure for rapid larval growth in nature, a situation that is typical for fish in general (Houde 1987).

Laboratory-cultured delta smelt larvae have generally been fed rotifers at first-feeding (Baskerville-Bridges et al. 2004; Mager et al. 2004). However, rotifers rarely occur in the guts of wild delta smelt larvae (Nobriga 2002). The most common first prey of wild delta smelt larvae is the larval stages of several copepod species. These copepod 'nauplii' are larger, and have more calories, than rotifers. This difference in diet may enable the faster growth rates observed in wild-caught larvae.

The food available to larval fishes is constrained by mouth gape and status of fin development. Larval delta smelt cannot capture as many kinds of prey as larger individuals, but all life stages have small gapes that limit their range of potential prey. Prey availability is also constrained by habitat use, which affects what types of prey are encountered. Larval delta smelt are visual feeders. They find and select individual prey organisms and their ability to see prey in the water is enhanced by turbidity (Baskerville- Bridges et al. 2004). Thus, delta smelt diets are largely comprised of small crustacea that inhabit the estuary's turbid, low-salinity, open-water habitats (i.e., zooplankton). Larval delta smelt have particularly restricted diets (Nobriga 2002). They do not feed on the full array of zooplankton with which they co-occur; they mainly consume three copepods, *Eurytemora affinis*, *Pseudodiaptomus forbesi*, and freshwater species of the family Cyclopidae. Further, the diets of first-feeding delta smelt larvae are largely restricted to the larval stages of these copepods; older, larger life stages of the copepods are increasingly targeted as the delta smelt larvae grow, their gape increases, and they become stronger swimmers.

The triggers for and duration of delta smelt larval movement from spawning areas to rearing areas are not known. Hay (2007) noted that eulachon larvae are probably flushed into estuaries from upstream spawning areas within the first day after hatching, but downstream movement of

delta smelt larvae occurs much later. Most larvae gradually move downstream toward the two parts per thousand (ppt) isohaline (X2). X2 is scaled as the distance in kilometers from the Golden Gate Bridge (Jassby et al. 1995). It is a physical attribute of the Bay-Delta that is used as a habitat indicator and as a regulatory standard.

At all life stages, delta smelt are found in greatest abundance in the water column and usually not in close association with the shoreline. They inhabit open, surface waters of the Delta and Suisun Bay, where they presumably aggregate in loose schools where conditions are favorable (Moyle 2002). In years of moderate to high Delta outflow (above normal to wet water years (WYs)), delta smelt larvae are abundant in the Napa River, Suisun Bay, and Montezuma Slough, but the degree to which these larvae are produced by locally spawning fish or the degree to which they originate upstream and are transported by tidal currents to the bay and marsh is uncertain.

***Juveniles***

Young-of-the-year delta smelt rear in the LSZ from late spring through fall and early winter. Once in the rearing area growth is rapid, and juvenile fish are 40 to 50 mm SL long by early August (Erkkila *et al.* 1950; Ganssle 1966; Radtke 1966). They reach adult size (55 to 70 mm SL) by early fall (Moyle 2002). Delta smelt growth during the fall months slows considerably (only 3 to 9 mm total), presumably because most of the energy ingested is being directed towards gonadal development (Erkkila *et al.* 1950; Radtke 1966).

Nobriga et al. (2008) found that delta smelt capture probabilities in the Townet Survey (TNS) are highest at specific conductance levels of 1,000 to 5,000 µS cm-1 (approximately 0.6 to 3.0 practical salinity unit [psu]). Water hyacinth grows at salinity levels of 2 psu or less. Similarly, Feyrer et al. (2007) found a decreasing relationship between abundance of delta smelt in the Fall Midwater Trawl (FMWT) and specific conductance during September through December. The location of the LSZ and changes in delta smelt habitat quality in the San Francisco Estuary can be indexed by changes in X2. The LSZ historically had the highest primary productivity and is where zooplankton populations (on which delta smelt feed) were historically most dense (Knutson and Orsi 1983; Orsi and Mecum 1986). However, this has not always been true since the invasion of the overbite clam (Kimmerer and Orsi 1996). The abundance of many local aquatic species has tended to increase in years when winter-spring outflow was high and X2 was pushed seaward (Jassby et al. 1995), implying that the quantity and quality (overall suitability) of estuarine habitat increases in years when outflows are high. However, delta smelt is not one of the species whose abundance has statistically covaried with winter-spring freshwater flows (Stevens and Miller 1983; Moyle et al. 1992; Kimmerer 2002; Bennett 2005). There is evidence that X2 in the fall influences delta smelt population dynamics.

Delta smelt seem to prefer water with high turbidity, based on a negative correlation between the frequency of delta smelt occurrence in survey trawls during summer, fall, and early winter; and water clarity. For

example, the likelihood of delta smelt occurrence in trawls at a given sampling station decreases with increasing Secchi depth at the stations (Feyrer et al. 2007, Nobriga et al. 2008). This is very consistent with behavioral observations of captive delta smelt (Nobriga and Herbold 2008). Few daylight trawls catch delta smelt at Secchi depths over one half meter and capture probabilities for delta smelt are highest at 0.40 m depth or less. The delta smelt's preference for turbid water may be related to increased foraging efficiency (Baskerville-Bridges et al. 2004) and reduced risk of predation.

Temperature also affects delta smelt distribution. Swanson and Cech (1995) and Swanson et al. (2000) indicate delta smelt tolerate temperatures (<8°C to >25°C), however warmer water temperatures >25°C restrict their distribution more than colder water temperatures (Nobriga and Herbold 2008). Delta smelt of all sizes are found in the main channels of the Delta and Suisun Marsh and the open waters of Suisun Bay where the waters are well oxygenated and temperatures are usually less than 25°C in summer (Nobriga et al. 2008).

### *Foraging Ecology*

Delta smelt feed primarily on small planktonic crustaceans, and occasionally on insect larvae (Moyle 2002). Juvenile-stage delta smelt prey upon copepods, cladocerans, amphipods, and insect larvae (Moyle 2002). Historically, the main prey of delta smelt was the euryhaline copepod *Eurytemora affinis* and the euryhaline mysid *Neomysis mercedis*. The slightly larger *Pseudodiaptomus forbesi* has replaced *E. affinis* as a major prey source of delta smelt since its introduction into the Bay-Delta, especially in summer, when it replaces *E. affinis* in the plankton community (Moyle 2002). Another smaller copepod, *Limnoithona tetraspina*, which was introduced into the Bay-Delta in the mid-1990s, is now one of the most abundant copepods in the LSZ, but not abundant in delta smelt diets. *Acartiella sinensis*, a calanoid copepod species that invaded the Delta at the same time as *L. tetraspina*, also occurs at high densities in Suisun Bay and in the western Delta over the last decade. Delta smelt eat these newer copepods, but *Pseudodiaptomus* remains a dominant prey (Baxter et al. 2008).

River flows influence estuarine salinity gradients and water residence times and thereby affect both habitat suitability for benthos and the transport of pelagic plankton upon which delta smelt feed. High tributary flow leads to lower residence time of water in the Delta, which generally results in lower plankton biomass (Kimmerer 2004). In contrast, higher residence times, which result from low tributary flows, can result in higher plankton biomass but water diversions, overbite clam grazing (Jassby et al. 2002), and possibly contaminants (Baxter et al. 2008) remove a lot of plankton biomass when residence times are high. These factors all affect food availability for planktivorous fishes that utilize the zooplankton in Delta channels. Delta smelt cannot occupy much of the Delta anymore during the summer (Nobriga et al. 2008). Thus, there is the potential for mismatches between regions of high zooplankton abundance in the Delta and delta smelt distribution now that the overbite clam has decimated LSZ zooplankton densities.

The delta smelt compete with and are prey for several native and introduced fish species in the Delta. The introduced inland silverside may prey on delta smelt eggs and/or larvae and compete for copepod prey (Bennett and Moyle 1996; Bennett 2005). Young striped bass also use the LSZ for rearing and may compete for copepod prey and eat delta smelt. Centrarchid fishes and coded wire tagged Chinook salmon smolts released in the Delta for survival experiments since the early 1980s may potentially also prey on larval delta smelt (Brandes and McLain 2001; Nobriga and Chotkowski 2000). Studies during the early 1960s found delta smelt were only an occasional prey fish for striped bass, black crappie and white catfish (Turner and Kelley 1966). However, delta smelt were a comparatively rare fish even then, so it is not surprising they were a rare prey. Striped bass appear to have switched to piscivorous feeding habits at smaller sizes than they historically did, following severe declines in the abundance of mysid shrimp (Feyrer et al. 2003). Nobriga and Feyrer (2008) showed that inland silverside, which is similar in size to delta smelt, was only eaten by subadult striped bass less than 400 mm fork length. While largemouth bass are not pelagic, they have been shown to consume some pelagic fishes (Nobriga and Feyrer 2007).

### *Habitat*

The existing physical appearance and hydrodynamics of the Delta have changed substantially from the environment in which native fish species like delta smelt evolved. The Delta once consisted of tidal marshes with networks of diffuse dendritic channels connected to floodplains of wetlands and upland areas (Moyle 2002). The in-Delta channels were further connected to drainages of larger and smaller rivers and creeks entering the Delta from the upland areas. In the absence of upstream reservoirs, freshwater inflow from smaller rivers and creeks and the Sacramento and San Joaquin Rivers were highly seasonal and more strongly and reliably affected by precipitation patterns than they are today. Consequently, variation in hydrology, salinity, turbidity, and other characteristics of the Delta aquatic ecosystem was greater in the past than it is today (Kimmerer 2002b). For instance, in the early 1900s, the location of maximum salinity intrusion into the Delta during dry periods varied from Chipps Island, in the lower Delta, to Stockton, along the San Joaquin River, and Merritt Island in the Sacramento River. Operations of upstream reservoirs have reduced spring flows while releases of water for Delta water export and increased flood control storage have increased late summer and fall inflows (Knowles 2002), though Delta outflows have been tightly constrained during late summer-fall for several decades.

Channelization, conversion of Delta islands to agriculture, and water operations have substantially changed the physical appearance, water salinity, water clarity, and hydrology of the Delta. As a consequence of these changes, most life stages of the delta smelt are now distributed across a smaller area than historically (Arthur et al. 1996, Feyrer et al. 2007). Wang (1991) noted in a 1989 and 1990 study of delta smelt larval distribution that, in general, the San Joaquin River was used more intensively for spawning than the Sacramento River. Though not restricting spawning *per se*, based on particle tracking modeling, export of water by the

Central Valley Project (CVP) and State Water Project (SWP) would usually restrict reproductive success of spawners in the San Joaquin River by entraining most larvae during downstream transport from spawning sites to rearing areas (Kimmerer and Nobriga 2008). There is one, non-wet year exception to this generalization: in 2008, delta smelt entrainment was managed under a unique system of restrictions imposed by the Court in Natural Resources Defense Council (NRDC) v Kempthorne. In 2008, CVP/SWP operations were constrained in accordance with recommendations formulated by the Service expressly to limit entrainment of delta smelt from the Central Delta.

Persistent confinement of the spawning population of delta smelt to the Sacramento River increases the likelihood that a substantial portion of the spawners will be affected by a catastrophic event or localized chronic threat. For instance, large volumes of highly concentrated ammonia released into the Sacramento River from the Sacramento Regional County Sanitation District may affect embryo survival or inhibit prey production. Further, agricultural fields in the Yolo Bypass and surrounding areas are regularly sprayed by pesticides, and water samples taken from Cache Slough sometimes exhibited toxicity to Hyalella azteca (Werner et al. 2008). The thresholds of toxicity for delta smelt for most of the known contaminants have not been determined, but the exposure to a combination of different compounds increases the likelihood of adverse effects. The extent to which delta smelt larvae are exposed to contaminants varies with flow entering the Delta. Flow pulses during spawning increase exposure to many pesticides (Kuivila and Moon 2004) but decrease ammonia concentrations entering the Delta from wastewater treatment plants.

The distribution of juvenile delta smelt has also changed over the last several decades. During the years 1970 through 1978, delta smelt catches in the TNS survey declined rapidly to zero in the Central and South Delta and have remained near zero since. A similar shift in FMWT catches occurred after 1981 (Arthur et al. 1996). This portion of the Delta has also had a long-term trend increase in water clarity during July through December (Arthur et al. 1996; Feyrer et al. 2007; Nobriga et al. 2008).

The position of the LSZ where delta smelt rear has also changed over the years. Summer and fall environmental quality has decreased overall in the Delta because outflows are lower and water transparency is higher. These changes may be due to increased upstream water diversions for flooding rice fields (Kawakami et. al. 2008). The confluence of the Sacramento and San Joaquin rivers has, as a result, become increasingly important as a rearing location for delta smelt, with physical environmental conditions constricting the species range to a relatively narrow area (Feyrer et al. 2007; Nobriga et al. 2008). This condition has increased the likelihood that most of the juvenile population is exposed to chronic and cyclic environmental stressors, or catastrophic events. For instance, all seven delta smelt collected during the September 2007 FMWT survey were captured at statistically significantly higher salinities than what would be expected based upon historical distribution data generated by Feyrer et al. (2007). During the same year, the annual bloom of toxic cyanobacteria (*Microcystis*

*aeruginosa*) spread far downstream to the west Delta and beyond during the summer (Peggy Lehman, pers comm). This has been suggested as an explanation for the anomaly in the distribution of delta smelt relative to water salinity levels (Reclamation 2008).

#### Delta Smelt Population Dynamics and Abundance Trends

The FMWT provides the best available long-term index of the relative abundance of delta smelt (Moyle et al. 1992; Sweetnam 1999). The indices derived from these surveys closely mirror trends in catch per unit effort (Kimmerer and Nobriga 2005), but do not at present support statistically reliable population abundance estimates, though substantial progress has recently been made (Newman 2008). FMWT derived data are generally accepted as providing a reasonable basis for detecting and roughly scaling interannual trends in delta smelt abundance.

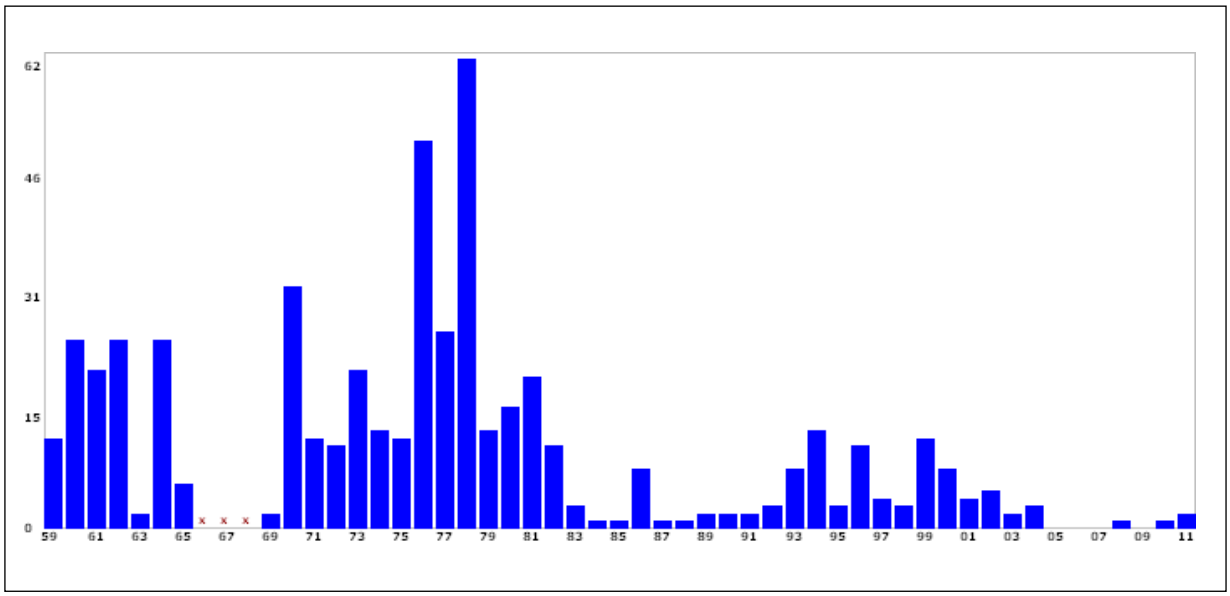
The FMWT derived indices have ranged from a low of 17 in 2009, to 1,653 in 1970 (Figure 4-1). For comparison, TNS indices, shown in **Figure 4-3,** on the next page, have ranged from a low of 0.3 in 2005 and 2009, to a high of 62.5 in 1978. From 1969 to 1981, the mean delta smelt TNS and FMWT indices were 22.5 and 894, respectively. Both the FMWT and TNS indices suggest the delta smelt population declined abruptly in the early 1980s (Moyle et al. 1992). From 1982 to 1992, the mean delta smelt TNS and FMWT indices dropped to 3.2 and 272 respectively. The population rebounded somewhat in the mid-1990s (Sweetnam 1999); the mean TNS and FMWT indices were 7.1 and 529, respectively, during the 1993 to 2002 period. However, delta smelt numbers have trended precipitously downward since about 2000, with a slight increase in 2011.

Even with the 2011 increase, the delta smelt population indices are two orders of magnitude smaller than historical highs and recent population abundance estimates are up to three orders of magnitude below historical highs (Newman 2008). After 1999 both the FMWT and the TNS population indices showed declines, and from 2000 through 2007 the median FMWT index was 106.5. The lowest FMWT abundance indices ever obtained were recorded during 2004 to 2007 (74, 27, 41, and 28, respectively).

The median TNS index during the period from 2000 through 2008, fell similarly to 1.6, and has also dropped to its lowest levels during the last four years with indexes of 0.3, 0.4, 0.4, and 0.6 during 2005 through 2008, respectively. It is highly unlikely that the indices from 2004 to 2007 can be considered statistically different from one another (see Sommer et al. 2007), but they are very likely lower than at any time prior in the period of record.

Since about 2002, delta smelt is one of four pelagic fish species subject to what has been termed the Pelagic Organism Decline or POD (Sommer et al. 2007). The POD denotes the sudden, overlapping declines of San Francisco Estuary pelagic fishes first recognized in data collected from 2002 to 2004. The POD species include delta smelt, longfin smelt, Threadfin shad (*Dorosoma petenense*), and (age-0) Striped bass (*Morone saxatillis*), which together account for the bulk of resident pelagic fish biomass in the tidal water upstream of X2.

**Figure 4-3**
**Townet Survey delta smelt Indices (1959-2011)**




Source: California Department of Fish and Game (http://www.dfg.ca.gov/delta/data/townet/indices.asp?species=3)

The year 2002 is often recognized as the start of the POD because of the striking declines of three of the four POD species between 2001 and 2002; however, statistical review of the data (e.g., Manly and Chotkowski 2006) has revealed that for at least delta smelt, the POD downtrend really began earlier (around 1999). Post-2001 abundance indices for the POD species have included record lows for all but Threadfin shad. The causes of the POD and earlier declines are not fully understood, but appear to be layered and multifactorial (Baxter et al. 2008). Several analyses have concluded that the shift in pelagic fish species abundance in the early 1980s was caused by a decrease in habitat carrying capacity or production potential (Moyle et al. 1992, Bennett 2005; Feyrer et al. 2007).

There is some evidence that the recruitment of delta smelt may have sometimes responded to springtime flow variation (Herbold et al. 1992; Kimmerer 2002). However, the weight of evidence suggests that delta smelt abundance does not (statistically) respond to springtime flow like the abundance of the species mentioned above (Stevens and Miller 1983; Jassby et al. 1995; Bennett 2005). The number of days of suitable spawning temperature during spring is correlated with subsequent abundance indices in the autumn (Bennett 2005). This is evidence that cool springs, which allow for multiple larval cohorts, can contribute to population resilience. However, these relationships do not explain a large proportion of variance in autumn abundance. Depending on which abundance index is used, the $r^2$ are 0.24 to 0.29.

The relationship between numbers of spawning fish and the numbers of young subsequently recruiting to the adult population is known as a stock-recruit relationship. Analysis of stock-recruit relationships using delta smelt survey data indicate that a weak density dependent effect has occurred during late summer/fall (Bennett 2005, Reclamation 2008), suggesting that delta smelt year-class strength has often been set during late summer and fall. This finding is supported by studies suggesting that the delta smelt is food limited (Bennett 2005; IEP 2005) and evidence for density dependent mortality has been presented by Brown and Kimmerer (2001). However, the number of days during the spring that water temperature remained between 15°C and 20°C, with a density-dependence term to correct for the saturating TNS-FMWT relationship, predicts FMWT indices fairly well ($r^2 \approx 0.70$; $p < 0.05$; Bennett, unpublished presentation at the 2003 CALFED Science Conference). This result shows that the quantity of young delta smelt produced also contributes to future spawner abundance.

Bennett (2005) analyzed the relationship between delta smelt spawner population and spawner recruits using data before, and after, the 1980s decline. He concluded that density dependence pre-1982 may have occurred at FMWT values of 600 to 800 and at FMWT values of 400 to 500 for the period 1982 through 2002. Bennett (2005) also conducted extensive stock-recruit analyses using the TNS and FMWT indices. He provided statistical evidence that survival from summer to fall is nonlinear (= density-dependent). He also noted that carrying capacity had declined. Bennett (2005) surmised that density-dependence and lower carrying capacity during the summer and fall could happen in a small population if habitat space was smaller than it was historically. This hypothesis was recently demonstrated to be true (Feyrer et al. 2007). Reduced Delta outflow during autumn has led to higher salinity in Suisun Bay and the Western Delta while the proliferation of submerged vegetation has reduced turbidity in the South Delta. Together, these mechanisms have led to a long-term decline in habitat suitability for delta smelt. High summer water temperatures also limit delta smelt distribution (Nobriga et al. 2008) and impair health (Bennett et al. 2008).

A minimum amount of suitable habitat during summer-autumn may interact with a suppressed pelagic food web to create a bottleneck for delta smelt (Bennett 2005; Feyrer et al. 2007; Bennett et al. 2008). Prior to the overbite clam invasion, the relative abundance of maturing adults collected during autumn was unrelated to the relative abundance of juveniles recruiting the following summer (i.e., the stock-recruit relationship was density-vague). Since the overbite clam became established, autumn relative abundance explains 40 percent of the variability in subsequent juvenile abundance (Feyrer et al. 2007). When autumn salinity is factored in, 60 percent of the variance in subsequent juvenile abundance is accounted for statistically.

Since 2000, the stock-recruit relationship for delta smelt has been stronger still ($r^2 = 0.88$ without autumn habitat metrics factored in; Baxter et al. 2008). This has led to speculation about Allee effects. Allee effects occur when reproductive output per fish declines at low

population levels (Allee 1931, Berec et al. 2006). Below a certain threshold the individuals in a population can no longer reproduce rapidly enough to replace themselves and the population spirals to extinction. For delta smelt, possible mechanisms for Allee effects include mechanisms directly related to reproduction and genetic fitness such as difficulty finding enough males to maximize egg fertilization during spawning (e.g., Purchase et al. 2007). Genetic problems arising from small population sizes like inbreeding and genetic drift also can contribute to Allee effects, but genetic bottlenecks occur after demographic problems like the example of finding enough mates (Lande 1988). Other mechanisms related to survival such as increased vulnerability to predation are also possible based on studies of other species.

These data provide evidence that factors affecting juvenile delta smelt during summer and autumn are also impairing delta smelt reproductive success. Thus, the interaction of warm summer water temperatures, suppression of the food web supporting delta smelt, and spatially restricted suitable habitat during autumn affect delta smelt health and ultimately survival and realized fecundity.

Another possible contributing driver of reduced delta smelt survival, health, fecundity, and resilience that occurs during winter is the "Big Mama Hypothesis" (Bill Bennett, UC Davis, pers. comm. and various oral presentations). As a result of his synthesis of a variety of studies, Bennett proposed that the largest delta smelt (whether the fastest growing age-1 fish or fish that manage to spawn at age-2) could have a large influence on population trends. Delta smelt larvae spawned in the South Delta have high risk of entrainment under most hydrologic conditions (Kimmerer 2008), but water temperatures often warm earlier in the South Delta than the Sacramento River (Nobriga and Herbold 2008). Thus, delta smelt spawning often starts and ends earlier in the Central and South Delta than elsewhere. This differential warming may contribute to the "Big Mama Hypothesis" by causing the earliest ripening females to spawn disproportionately in the South Delta, putting their offspring at high risk of entrainment. Although water diversion strategies have been changed to better protect the 'average' larva, the resilience historically provided by variable spawn timing may be reduced by water diversions and other factors that covary with Delta inflows and outflows.

Substantial increases in winter salvage at Banks and Jones that occurred contemporaneously with recent declines in delta smelt and other POD species (Kimmerer 2008, Grimaldo et al. 2009) support the interpretation that entrainment played a role in the POD-era depression of delta smelt numbers. Increased winter entrainment of delta smelt represents a loss of pre-spawning adults and all their potential progeny (Sommer et al. 2007). Note that winter salvage levels subsequently decreased to very low levels for all POD species during the winters of 2005 to 2006 and 2006 to 2007, possibly due to the very low population sizes during those periods. Reduced pumping for protection of delta smelt also substantially reduced Old and Middle River (OMR) flow towards the pumps and subsequently reduced number of delta smelt entrained during the winters of 2006 to 2007 and 2007 to 2008.

The hydrologic and statistical analyses of relationships between OMR flows and salvage suggest a reasonable mechanism by which winter entrainment increased with increased exports during the POD years; however, entrainment is not a substantial source of mortality every year. Manly and Chotkowski (2006; IEP 2005) found that monthly or semi-monthly measures of exports or Old and Middle rivers flow had a reliable, statistically significant effect on delta smelt abundance; however, individually they explained a small portion (no more than a few percent) of the variability in the fall abundance index of delta smelt across the entire survey area and time period. Kimmerer (2008) addressed delta smelt entrainment by means of particle tracking, and estimated historical entrainment rates for larvae and juvenile delta smelt to be as high as 40 percent; however, he concluded that non-entrainment mortality in the summer had effects on FMWT delta smelt numbers. Hence, there are other factors that often mask the effect of entrainment loss on delta smelt fall abundance in these analyses. Among them, availability and quality of summer and fall habitat are clearly affected by CVP/SWP operations.

We conclude that entrainment and habitat availability/quality jointly contribute to downward pressure on spawner recruitment and one or both of these general mechanisms is operating throughout the year. The intensity of constraints of the other threats affecting the delta smelt carrying capacity varies between years, and the importance of contributing stressors changes as outflow, export operations, weather, and the abundances of other ecosystem elements vary. For instance, Bennett (2005) noted that seasonally low outflow and warmer water temperatures may concentrate delta smelt and other planktivorous fishes into relatively small patches of habitat during late summer. This would increase competition and limit food availability during low outflow. Higher outflow that expands and moves delta smelt habitat downstream of the Delta is expected to improve conditions for delta smelt (Feyrer et al. 2007). The high proportion of the delta smelt population that has been entrained during some years (Kimmerer 2008) would be expected to reduce the ability of delta smelt to respond to the improved conditions, thereby limiting the potential for increased spawner recruitment. Further, the smaller sizes of maturing adults during fall may have affected delta smelt fecundity (Bennett, 2005). This would further reduce the species' ability to respond to years with improved conditions.

#### Seasonal Life History of delta smelt

The following discussion, also from USFWS (December 15, 2008), describes the life stage and location of delta smelt by season. This is relevant to EDCP activities, which occur within the Delta during limited time periods. **Table 4-1,** on page 4-18, summarizes the life cycle of delta smelt. Spawning and some juvenile rearing occurs within potential EDCP treatment locations.

***Winter (December to February)***

Adult delta smelt are generally distributed in low salinity habitats of the greater Suisun Bay region and the Sacramento and San Joaquin River confluence during fall. Variation in outflow appears to initiate their

migration from Suisun Bay upstream to freshwater habitats for spawning. This is because initial catches upstream normally occur in close association with increased turbidity associated with the first strong flow pulse of the winter (Grimaldo et al. 2009). As a result, entrainment of adult delta smelt at Banks and Jones is also closely associated with factors controlled by outflow or X2 (Grimaldo et al. 2009). Specifically, salvage of adult delta smelt is significantly negatively associated with flows in OMR, and when the flows are highly negative the starting location of the fish indexed by X2 the month prior to entrainment also has an effect (Grimaldo et al. 2009).

Outflow during winter also affects the entrainment of early-spawned larvae when their distribution is within the hydrodynamic zone affected by pumping operations (Kimmerer 2008). Winter outflow also affects the distribution of spawning fish in major regions. For example, the Napa River is used for spawning only in years when outflow is sufficient to connect the Napa River with low salinity habitat in the estuary (Hobbs et al. 2007).

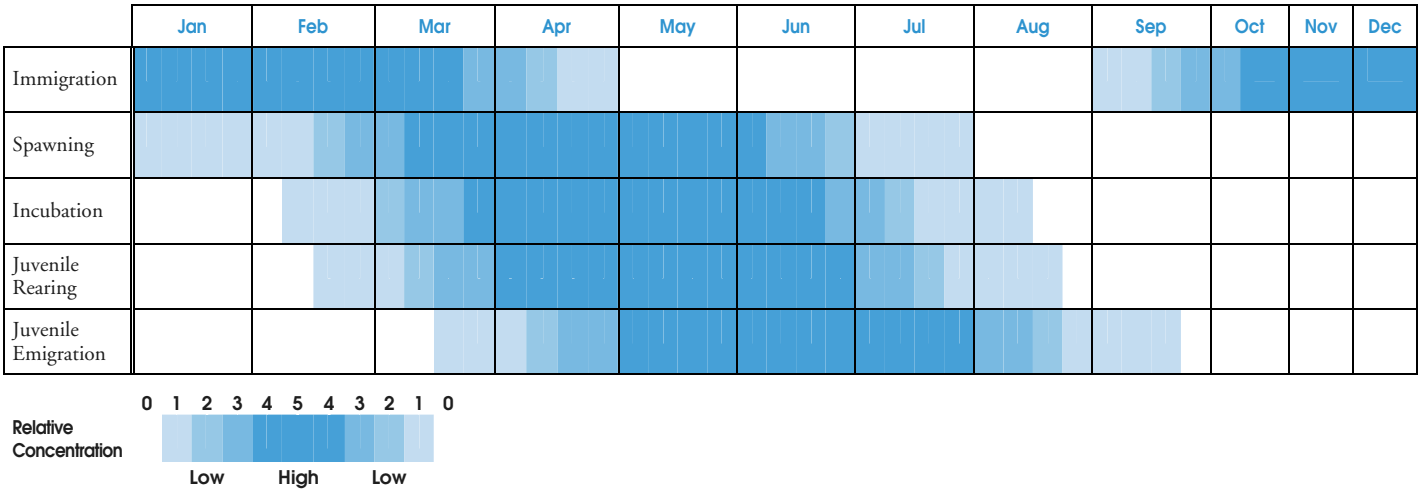
### *Spring (March to May)*

During spring, young of the year (YOY) delta smelt generally move from upstream spawning locations downstream into low salinity rearing habitats. There is some evidence that recruitment variability of delta smelt may have sometimes responded to springtime flow variation (Herbold et al. 1992; Kimmerer 2002). For example, the number of days X2 is in Suisun Bay during spring is weakly positively correlated with abundance as measured by the FMWT index. However, the weight of evidence suggests that delta smelt abundance does not statistically respond to springtime flow in a similar manner to other species for which the spring X2 requirements were developed (Stevens and Miller 1983; Jassby et al. 1995; Bennett 2005).

However, studies have demonstrated that outflow has a strong effect on the distribution of YOY delta smelt (Dege and Brown 2004) and that it therefore also ultimately influences entrainment at Jones and Banks pumping facilities (Kimmerer 2008). Dege and Brown (2004) found that X2 had a strong influence on the geographic distribution of delta smelt, but distribution with respect to X2 was not affected, indicating that distribution is closely associated with habitat conditions proximal to X2. YOY delta smelt are consistently located just upstream of X2 in freshwater until they become juveniles and enter the low salinity habitats of Suisun Bay later in the year.

Outflow affects the entrainment of YOY delta smelt at the Jones and Banks facilities in several ways. First, because outflow affects adult spawning migration and juvenile distribution, it affects their position relative to the hydrodynamic influence of the diversions (Kimmerer 2008). Second, Old and Middle River (OMR) is the best predictor of salvage and entrainment for adult delta smelt and it is also relevant to larval and juvenile entrainment when considered in the context of X2. In general, the more water that is exported relative to that which is dedicated to outflow enhances negative flows in OMR flow towards the diversions, which in turn increases salvage (Baxter et al. 2008; Kimmerer 2008; Grimaldo et al. 2009).

**Table 4-1**
**Life-cycle of the delta smelt *(Hypomesus transpacificus)***




Source: Hoogeweg et al. 2011 p.147

### *Summer (June to August)*

Summer represents a primary growing season for delta smelt while they are distributed in low salinity habitats of the estuary. X2 affects delta smelt distribution during summer (Sweetnam 1999). Food supply and habitat suitability are currently believed to be important factors for delta smelt during summer (Bennett 2005; Baxter et al. 2008; Nobriga and Herbold 2008). The CVP/SWP affect summer habitat suitability and might affect summer prey co-occurrence through their effect on Delta hydrodynamics.

### *Fall (September to November)*

During fall, delta smelt are typically fully distributed in low salinity rearing habitats located around the confluence of the Sacramento and San Joaquin Rivers. Suitable abiotic habitat for delta smelt during fall has been defined as relatively turbid water (Secchi depths < 1.0 m) with a salinity of approximately 0.6 to 3.0 psu (Feyrer et al. 2007). The amount of suitable abiotic habitat available for delta smelt, measured as hectares of surface area, is negatively related to X2. The average X2 during fall has exhibited a long-term increasing trend (movement further upstream), which has resulted in a corresponding reduction in the amount and location of suitable abiotic habitat (Feyrer et al. 2007, 2008).

The available data provide evidence to suggest that the amount of suitable abiotic habitat available for delta smelt during fall affects the population in a measurable way. There is a statistically significant stock-recruit relationship for delta smelt in which pre-adult abundance measured by the FMWT positively affects the abundance of juveniles the following year in the TNS (Bennett 2005; Feyrer et al. 2007). Incorporating suitable abiotic habitat into the stock-recruit model as a covariate improves the model by increasing the amount of variability explained by 43

percent, r-squared values improved from 46 percent to 66 percent (Feyrer et al. 2007).

It is likely that changes in X2 and the corresponding amount of suitable abiotic habitat are important to the long-term decline of delta smelt but may have been of lesser importance in the more recent POD. Over the long-term, the amount of suitable abiotic habitat for delta smelt during fall has decreased anywhere from 28 percent to 78 percent, depending on the specific habitat definitions that are considered (Feyrer et al. 2008). The majority of this habitat loss has occurred along the periphery, limiting the distribution of delta smelt mainly to a core region in the vicinity of the confluence of the Sacramento and San Joaquin Rivers (Feyrer et al. 2007). Concurrently, delta smelt abundance as measured by the FMWT decreased by 63 percent. This correspondence and the significant stock-recruit relationship with the habitat covariate strongly suggest that delta smelt have been negatively affected by long-term changes in X2 and habitat. However, at the onset of the POD, delta smelt abundance and suitable abiotic habitat had already declined to a point where it was unlikely that Feyrer's two variable definition of habitat was the primary limiting factor constraining the population.

Nevertheless, X2 and inflow-corrected X2 during fall in the years following the POD (2000 to 2005) was several km upstream compared to that for the pre-pod years (1995 to 1999). This suggests that operations in the Delta have exported more water relative to inflow, which has had a negative effect on X2 by moving it upstream. This is confirmed by a long-term positive trend in the export to inflow (E:I) ratio for all months from June through December. In fact, long-term trends in X2, inflow-corrected X2, and the E:I ratio indicate this pattern has been in effect for many years and likely one of the factors responsible for the long-term decline in habitat suitability for delta smelt.

## Threatened delta smelt Critical Habitat

USFWS designated critical habitat for the delta smelt on December 19, 1994 (59 FR 65256). The geographic area encompassed by the designation includes all water and all submerged lands below ordinary high water and the entire water column bounded by and contained in Suisun Bay (including the contiguous Grizzly and Honker Bays); the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma sloughs; and the existing contiguous waters contained within the legal Delta (as defined in section 12220 of the California Water Code) (USFWS 1994).

### *Description of the Primary Constituent Elements (PCEs)*

In designating critical habitat for the delta smelt, USFWS identified the following primary constituent elements essential to the conservation of the species:

1. "Physical habitat" is defined as the structural components of habitat. Because delta smelt is a pelagic fish, spawning substrate is the only known important structural component of habitat. It is possible that depth variation is an important structural characteristic of pelagic habitat that helps fish maintain position within the estuary's LSZ (Bennett et al. 2002).

2. "Water" is defined as water of suitable quality to support various delta smelt life stages with the abiotic elements that allow for survival and reproduction. Delta smelt inhabit open waters of the Delta and Suisun Bay. Certain conditions of temperature, turbidity, and food availability characterize suitable pelagic habitat for delta smelt. Factors such as high entrainment risk and contaminant exposure can degrade this PCE even when the basic water quality is consistent with suitable habitat.
3. "River flow" is defined as transport flow to facilitate spawning migrations and transport of offspring to LSZ rearing habitats. River flow includes both inflow to and outflow from the Delta, both of which influence the movement of migrating adult, larval, and juvenile delta smelt. Inflow, outflow, and OMR influence the vulnerability of delta smelt larvae, juveniles, and adults to entrainment at Banks and Jones pumping facilities. River flow interacts with the fourth primary constituent element, salinity, by influencing the extent and location of the highly productive LSZ where delta smelt rear.
4. "Salinity" is defined as the LSZ nursery habitat. The LSZ is where freshwater transitions into brackish water; the LSZ is defined as 0.5 to 6.0 psu (parts per thousand salinity; Kimmerer 2004). The 2 psu isohaline is a specific point within the LSZ where the average daily salinity at the bottom of the water is 2 psu (Jassby et al. 1995). By local convention the location of the LSZ is described in terms of the distance from the 2 psu isohaline to the Golden Gate Bridge (X2); X2 is an indicator of habitat suitability for many San Francisco Estuary organisms and is associated with variance in abundance of diverse components of the ecosystem (Jassby et al. 1995; Kimmerer 2002). The LSZ expands and moves downstream when river flows into the estuary are high. Similarly, it contracts and moves upstream when river flows are low.

During the past 40 years, monthly average X2 has varied from as far downstream as San Pablo Bay (45 km) to as far upstream as Rio Vista on the Sacramento River (95 km). At all times of year, the location of X2 influences both the area and quality of habitat available for delta smelt to successfully complete their life cycle. In general, delta smelt habitat quality and surface area are greater when X2 is located in Suisun Bay. Both habitat quality and quantity diminish the more frequently and further the LSZ moves upstream, toward the confluence.

***Conservation Role of delta smelt Critical Habitat***

USFWS's primary objective in designating critical habitat is to identify the key components of delta smelt habitat that support successful spawning, larval and juvenile transport, rearing, and adult migration. Delta smelt are endemic to the Bay-Delta and the vast majority only live one year. Thus, regardless of annual hydrology, the Delta must provide suitable habitat all year, every year. Different regions of the Delta provide different habitat conditions for different life stages, but those habitat conditions must be present when needed, and have sufficient connectivity to provide migratory pathways and the flow of energy, materials and organisms among the habitat components. The entire Delta and Suisun Bay

are designated as critical habitat; over the course of a year, the entire habitat is occupied.

Delta smelt live their entire lives in the tidally-influenced fresh- and brackish waters of the San Francisco Estuary (Moyle 2002). Delta smelt are an open-water, or pelagic, species. They do not associate strongly with structure. They may use nearshore habitats for spawning (PCE #1), but free-swimming life stages mainly occupy offshore waters (PCE #2). Thus, the distribution of the population is strongly influenced by river flows through the estuary (PCE #3) because the quantity of fresh water flowing through the estuary changes the amount and location of suitable low-salinity, open-water habitat (PCE #4). This is true for all life stages. During periods of high river flow into the estuary, delta smelt distribution can transiently extend as far west as the Napa River and San Pablo Bay. Delta smelt distribution is highly constricted near the Sacramento-San Joaquin river confluence during periods of low river flow into the estuary (Feyrer et al. 2007).

In the 1994 designation of critical habitat, the best available science held that the delta smelt population was responding to variation in spring X2. In the intervening years, the scientific understanding of delta smelt habitat has improved. The current understanding is that X2 and OMR both must be considered to manage entrainment and that X2 indexes important habitat characteristics throughout the year.

*Source:* www.californiaherps.com.

*Photo:* giant garter snake.

## 2. Threatened giant garter snake *(Thamnophis gigas)*

The giant garter snake *(Thamnophis gigas)* is listed as State and federal threatened. Giant garter snakes are the largest garter snake in North America and are endemic to the valley floor wetlands in the Sacramento and San Joaquin Valleys. They inhabit sloughs, ponds, small lakes, and other low-gradient waterways, including irrigation canals where water is present throughout the summer. Giant garter snakes are rarely found away from water, forage in the water for food, and will retreat to water to escape predators and disturbance (USFWS May 2004). These snakes typically avoid larger waterways with predatory fish, and woodland streams with excessive cover.

The description below of giant garter snake range, habitat, biology, and status is drawn from USFWS Biological Opinion for WHCP, 81410-2011-F-0035 (USFWS August 2012).

Giant garter snake (GGS) reach a total length of approximately 160 cm. Females tend to be slightly longer and proportionately heavier than males. Generally, GGS has a dark dorsal background color with pale dorsal and lateral stripes, although coloration and pattern

prominence are geographically and individually variable (Hansen 1980). The weight of adult female GGS is typically 500 to 700 grams. Dorsal background coloration varies from brownish to olive with a checkered pattern of black spots, separated by a yellow dorsal stripe and two light colored lateral stripes. Background coloration and prominence of black checkered pattern and the three yellow stripes are geographically and individually variable (Hansen 1980). The ventral surface is cream to olive or brown and sometimes infused with orange, especially in northern populations.

The historical range of the snake is thought to have extended from the vicinity of Chico in Butte County, southward to Buena Vista Lake, near Bakersfield, in Kern County (Fitch 1940, Fox 1948, Hansen and Brode 1980). Early collecting localities of the GGS coincide with the distribution of large flood basins, particularly riparian marsh or slough habitats and associated tributary streams (Hansen and Brode 1980).

The known range of GGS has changed little since the time of listing. In 2005 and 2006, GGS have been seen northward in Chico, and southward at the Mendota Wildlife Area in Fresno County. Habitat has been lost to urban development in the Natomas Basin in Sacramento and Sutter Counties. Two known population clusters south of Stockton are small, fragmented, and unstable.

Endemic to wetlands in the Sacramento and San Joaquin valleys, GGS inhabit marshes, sloughs, ponds, small lakes, low gradient streams, and other waterways and agricultural wetlands, such as irrigation and drainage canals, rice fields, and adjacent uplands (USFWS 1999). Essential habitat consists of: (1) wetlands with adequate water during the GGS's active season (early-spring through mid-fall) to provide food and cover; (2) emergent, herbaceous wetland vegetation, such as cattails and bulrushes, for escape cover and foraging habitat during the active season; (3) upland habitat with grassy banks and openings in waterside vegetation for basking; and (4) higher elevation uplands for over-wintering habitat with escape cover (vegetation, burrows) and underground refugia (crevices and small mammal burrows) (Hansen 1988). GGS are typically absent from larger rivers and other bodies of water that support introduced populations of large, predatory fish, and from wetlands with sand, gravel, or rock substrates (Hansen 1988, Hansen and Brode 1980). Riparian woodlands do not provide suitable habitat because of excessive shade, lack of basking sites, and absence of prey populations (Hansen 1988).

GGS are extremely aquatic, are rarely found away from water, forage in the water for food, and will retreat to water to escape predators and disturbance. GGS are active foragers, feeding primarily on aquatic prey such as fish and amphibians. Historically, prey likely consisted of Sacramento blackfish *(Orthodon microlepidotus)*, thick-tailed chub *(Gila crassicauda)*, and red-legged frog *(Rana draytonii)*. Because these species are no longer available (chub extinct, red-legged frog extirpated from the Central Valley, blackfish declining/in low numbers), the predominant food items are now introduced species such as carp *(Cyprinus carpio)*, mosquito-fish *(Gambusia affinis)*, bullfrogs *(Rana catesbiana)*, and Pacific chorus frog

*(Pseudacris regilla)* (Fitch 1941, Rossman et al. 1996).

Rice fields have become important habitat for GGS. In particular, the associated canals and their banks are important for both spring and summer active behavior and winter hibernation (Hansen 2004, Wylie 1998). While within the rice fields, GGS forage in the shallow water for prey, utilizing rice plants and vegetated berms dividing rice checks for shelter and basking sites (Hansen and Brode 1993).

The breeding season for GGS extends through March and April, and females give birth to live young from late July through early September (Hansen and Hansen 1990). Brood size is variable, ranging from 10 to 46 young, with a mean of 23 (Hansen and Hansen 1990). At birth young average about 20.6 cm snout to vent length and three to five grams. Young immediately scatter into dense cover and absorb their yolk sacs, after which they begin to feed on their own. Although growth rates are variable, young typically more than double in size by one year of age (USFWS 1999a). Sexual maturity averages three years in males and five years for females (USFWS 1999a).

The GGS typically inhabits small mammal burrows and other soil crevices throughout its winter dormancy period (November to mid-March). Although these areas are generally thought to be above prevailing flood elevations, snakes may not always utilize high ground during their winter dormancy period. The Biological Resources Division of the United States Geological Survey has documented GGS at the Colusa National Wildlife Refuge overwintering in areas with few high ground retreat sites (Wylie et al. 1997). GGS in another study population in Gilsizer Slough overwintered at a low elevation wetland area, even though higher ground was present nearby. Both of these populations survived flooding and were not displaced from the area. GGS also use burrows as refuge from extreme heat during their active period. Wylie et al. (1997) documented GGS using burrows in the summer as much as 165 feet away from the marsh edge. Overwintering GGS have been documented using burrows as far as 820 feet from the edge of marsh habitat (Wylie et al. 1997).

During radio-telemetry studies, GGS typically moved little from day to day. However, total activity varied widely between individuals. Snakes have been documented moving up to 5 miles (8 kilometers) over the period of a few days (Wylie et al. 1997). In agricultural areas, GGS were documented using rice fields in 19 to 20 percent of the observations, marsh habitat in 20 to 23 percent of observations, and canal and agricultural waterway habitats in 50 to 56 percent of the observations (Wylie et al. 1997).

At the time of the listing, GGS was known from 13 populations. Populations 4 through 13 included the San Joaquin Valley, portions of the eastern fringe of the Delta, and the southern Sacramento Valley; an area encompassing about 75 percent of the species' known geographical range (USFWS 1993). Several of these populations are within the EDCP project action area.

Habitat loss is a primary threat to this species (USFWS 1999). Prior to Bureau of Reclamation activities beginning in the mid- to late-1800s, about 60 percent of the Sacramento Valley was subject to seasonal

overflow flooding providing expansive areas of GGS habitat (Hinds 1952). Now, less than 10 percent, or approximately 319,000 acres, of the historic 4.5 million acres of Central Valley wetlands remain (US Department of Interior 1994), of which very little provides habitat suitable for the GGS. Loss of habitat due to agricultural activities and flood control have extirpated the GGS from the southern one-third of its range in former wetlands associated with the historic Buena Vista, Tulare, and Kern lakebeds (Hansen 1980, Hansen and Brode 1980).

Other threats include ongoing maintenance of aquatic habitats for flood control and agricultural purposes, which can fragment and isolate available habitat, prevent dispersal of snakes among habitat units, and adversely affect the snake's availability of food items (Hansen 1988, Brode and Hansen 1992). Other threats include application of herbicides to control aquatic vegetation (Wylie et al. 1995), rodent control activities within upland aestivation (warm weather dormancy) habitat for the GGS (Wylie et al. 1995 and Wylie et al. 1997), and livestock grazing along the edges of water sources which may degrade water quality (Hansen 1988).

Currently, GGS is only known from a small number of populations. The status of these populations and the threats to these snakes and their habitats are detailed in the final rule that listed the GGS as threatened (USFWS 1993). A number of land use practices and other human activities currently threaten the survival of the GGS throughout the remainder of its range.

*Source:* www.fws.gov.

*Photo:* valley elderberry longhorn beetle.

### 3. Threatened valley elderberry longhorn beetle *(Desmocerus californicus dimporphus)*

Valley elderberry longhorn beetle is classified as federally threatened. The most recent 5-year review of valley elderberry longhorn beetle, completed in September 2006, recommended delisting the beetle, primarily due to the fact that conservation actions have resulted in protection of 50,000 acres of riparian habitat and the restoration of 1,500 acres of beetle habitat. In addition, the number of occurrences increased from 10 locations in 1980, to 190 known locations in 2006 (USFWS 2009).

On September 10, 2010, USFWS received a petition from the Pacific Legal Foundation requesting that USFWS delist the valley elderberry longhorn beetle. USFWS initiated a 12-month status review on August 19, 2011, to determine if delisting is warranted (Federal Register, August 19, 2012). USFWS's Spotlight Species 5-Year Action Plan (2010 to 2014) for the valley elderberry longhorn beetle recommends post-delisting monitoring of status, patch occupancy, and local turnover, should the species be delisted (USFWS 2009).

Valley elderberry longhorn beetle is a dimorphic species strictly tied to its host plant, the elderberry *(Sambucus* ssp.) during its entire

life cycle. Adults emerge from pupation inside the wood of the elderberry in the spring as the trees begin to flower. The exit holes made by the emerging adults are distinctive small oval openings. Often these holes are the only clue that beetles occur in an area. Adults eat elderberry foliage until approximately June when they mate. Females lay eggs in crevices on the bark. Upon hatching, larvae begin to tunnel into the shrub, where they will spend one to two years eating interior wood, which is their sole food source.

Valley elderberry longhorn beetle historically occurred throughout the Sacramento and San Joaquin valleys and into the foothills of the Coast Ranges and the Sierra Nevada to 2,200-foot in elevation. Elderberry shrub is a common component of riparian forests and savannah areas (USFWS 2004). Recent surveys have found beetles in only scattered localities along the Sacramento, American, San Joaquin, Kings, Kaweah, and Tuolumne rivers and their tributaries. Valley elderberry shrubs with evidence of beetles have been spotted in EDCP treatment sites along the Sacramento and Cosumnes Rivers (CNDDB 2006).

Over the last 150 years, agricultural and urban development has destroyed 90 percent of Central Valley riparian vegetation, which included the elderberry host plant, resulting in extreme fragmentation of the beetle's habitat.

The valley elderberry longhorn beetle is threatened by habitat loss and fragmentation, invasion by Argentine ants, agricultural conversion, levee construction, removal of riparian vegetation, riprapping of shoreline, and possibly other factors such as pesticide drift, exotic plant invasion, and grazing (USFWS 2004).

*Source:* swr.nmfs.noaa.gov.

*Photo:* Longfin Smelt.

## 4. Candidate Threatened San Francisco Bay-Delta Distinct Population Segment (DPS) of longfin smelt *(Spirinchus thaleichthys)*

The San Francisco Bay-Delta DPS of longfin smelt was classified by USFWS as threatened on April 2, 2012. However, listing of the species is currently precluded by other higher-priority actions, thus longfin smelt is a candidate species. USFWS will list the San Francisco Bay-Delta DPS of longfin smelt as priorities allow, and will review its status annually. The 2012 finding supersedes a 2009 finding that the species did not warrant listing under the ESA because the Bay-Delta population did not meet discreteness criteria. However, in the most recent 12-month finding, USFWS evaluated new information and determined that the Bay-Delta population is distinct from other longfin smelt populations on the West Coast (Federal Register April 2, 2012). Longfin smelt is listed as a threatened species by the State of California. Threats to longfin smelt in the Bay-Delta include reduced freshwater outflow, a food web altered by the invasive overbite clam, and ammonium contamination (USFWS March 29, 2012). The following description of longfin smelt status and abundance is extracted from the April 2, 2012 12-month finding published in the Federal Register.

Longfin smelt measure 9 to 11 centimeters (cm) standard length, although third-year females may grow up to 15 cm. The sides and lining of the gut cavity appear translucent silver, the back has an olive to iridescent pinkish hue, and mature males are usually darker in color than females. Longfin smelt can be distinguished from other smelts by their long pectoral fins, weak or absent striations on their opercular (covering the gills) bones, incomplete lateral line, low numbers of scales in the lateral series (54 to 65), long maxillary bones (in adults, these bones extend past mideye, just short of the posterior margin of the eye), and lower jaw extending anterior of the upper jaw (Mcallister 1963, p. 10; Miller and Lea 1972, pp. 158–160; Moyle 2002, pp. 234–236).

The longfin smelt belongs to the true smelt family Osmeridae and is one of three species in the *Spirinchus* genus; the night smelt (*Spirinchus starksi*) also occurs in California, and the shishamo (*Spirinchus lanceolatus*) occurs in northern Japan (McAllister 1963, pp. 10, 15). Because of its distinctive physical characteristics, the Bay-Delta population of longfin smelt was once described as a species separate from more northern populations (Moyle 2002, p. 235). McAllister (1963, p. 12) merged the two species *S. thaleichthys* and *S. dilates* because the difference in morphological characters represented a gradual change along the north-south distribution rather than a discrete set. Stanley *et al.* (1995, p. 395) found that individuals from the Bay-Delta population and Lake Washington (Washington State) population differed significantly in allele (proteins used as genetic markers) frequencies at several loci (gene locations), although the authors also stated that the overall genetic dissimilarity was within the range of other conspecific fish species. They concluded that longfin smelt from Lake Washington and the Bay-Delta are conspecific (of the same species) despite the large geographic separation.

Delta smelt and longfin smelt hybrids have been observed in the Bay-Delta estuary, although these offspring are not thought to be fertile because delta smelt and longfin smelt are not closely related taxonomically or genetically (California Department of Fish and Game (CDFG) 2001, p. 473).

### *Biology*

Nearly all information available on longfin smelt biology comes from either the Bay-Delta population or the Lake Washington population. Longfin smelt generally spawn in freshwater and then move downstream to brackish water to rear. The life cycle of most longfin smelt generally requires estuarine conditions (CDFG 2009, p. 1).

Longfin smelt are considered pelagic and anadromous (Moyle 2002, p. 236), although anadromy in longfin smelt is poorly understood, and certain populations are not anadromous and complete their entire life cycle in freshwater lakes and streams. Within the Bay-Delta, the term pelagic refers to organisms that occur in open water away from the bottom of the water column and away from the shore.

Juvenile and adult longfin smelt have been found throughout the year in salinities ranging from pure freshwater to pure seawater, although once past the juvenile stage, they are typically collected in waters with salinities ranging from 14 to 28 parts

per thousand (ppt) (Baxter 1999, pp. 189–192). Longfin smelt are thought to be restricted by high water temperatures, generally greater than 22 degrees C (71 degrees F) (Baxter *et. al.* 2010, p. 68), and will move down the estuary (seaward) and into deeper water during the summer months, when water temperatures in the Bay-Delta are higher. Within the Bay-Delta, adult longfin smelt occupy water at temperatures from 16 to 20 C (61 to 68 F), with spawning occurring in water with temperatures from 5.6 to 14.5 C (41 to 58 F) (Wang 1986, pp. 6–9).

Longfin smelt usually live for 2 years, spawn, and then die, although some individuals may spawn as 1- or 3-year old fish before dying (Moyle 2002, p. 36). In the Bay-Delta, longfin smelt are believed to spawn primarily in freshwater in the lower reaches of the Sacramento River and San Joaquin River. Longfin smelt congregate in deep waters in the vicinity of the LSZ near X2 during the spawning period, and it is thought that they make short runs upstream, possibly at night, to spawn from these locations (CDFG 2009, p. 12; Rosenfield 2010, p. 8).

Salinity in psu is determined by electrical conductivity of a solution, whereas salinity in parts per thousand (ppt) is determined as the weight of salts in a solution. For use in this document, the two measurements are essentially equivalent. X2 is defined as the distance in kilometers up the axis of the estuary (to the east) from the Golden Gate Bridge to the location where the daily average near-bottom salinity is 2 psu (Jassby *et al.* 1995, p. 274; Dege and Brown 2004, p. 51).

Longfin smelt in the Bay-Delta may spawn as early as November and as late as June, although spawning typically occurs from January to April (CDFG 2009, p. 10; Moyle 2002, p. 36). Longfin smelt have been observed in their winter and spring spawning period as far upstream as Isleton in the Sacramento River, Santa Clara shoal in the San Joaquin system, Hog Slough off the South-Fork Mokelumne River, and in Old River south of Indian Slough (CDFG 2009a, p. 7; Radtke 1966, pp. 115–119). As **Table 4-2,** on the next page, illustrates, longfin smelt are most likely to be found in the Delta between November and March.

Exact spawning locations in the Delta are unknown and may vary from year to year in location, depending on environmental conditions. However, it seems likely that spawning locations consist of the overlap of appropriate conditions of flow, temperature, and salinity with appropriate substrate (Rosenfield 2010, p. 8). Longfin smelt are known to spawn over sandy substrates in Lake Washington and likely prefer similar substrates for spawning in the Delta (Baxter *et. al.* 2010, p. 62; Sibley and Brocksmith 1995, pp. 32–74). Baxter found that female longfin smelt produced between 1,900 and 18,000 eggs, with fecundity greater in fish with greater lengths (CDFG 2009, p. 11). At 7 C (44.6 F), embryos hatch in 40 days (Dryfoos 1965, p. 42); however, incubation time decreases with increased water temperature. At 8 to 9.5 C (46.4 to 49.1 F), embryos hatch at 29 days (Sibley and Brocksmith 1995, pp. 32–74).

**Table 4-2**
**Summary of Longfin Smelt Life History Within the Bay-Delta, and Generalized Coastal Ocean Circulation**

| Month | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| First Year | | Peak Hatching – freshwater, upstream | | | | | | | | | | |
| First Year | | | Larval Rearing – San Pablo and San Francisco Bays – salinities < 8 psu | | | | | | | | | |
| First Year | Juveniles Rearing | | | | Juvenile Rearing – Primarily San Pablo, San Francisco Bays | | | | | | | |
| Second Year | | | Juvenile Rearing | | | | | | | | | |
| Second Year | | | | | Juvenile Rearing – Movement to the coastal ocean begins in the summer, mass movement to coastal ocean begins in July and August | | | | | | | |
| Second Year | Spawning Migration | | | | | | | | | | | Spawning Migration |
| Second Year | Peak Spawning – freshwater, Delta | | | | | | | | | | | |
| Coastal Current | Storm Season (Northward Flow | | | | Upwelling Season (Predominate Southward and Offshore Flow) | | | | Relaxation Season (Weak Northward Flow) | | | |

Source: Federal Register, April 2, 2012, p.19779. Shaded areas indicate peak periods within the Delta.

Larval longfin smelt less than 12 millimeters (mm) in length are buoyant because they have not yet developed an air bladder; as a result, they occupy the upper one-third of the water column. After hatching, they quickly make their way to the LSZ via river currents (CDFG 2009, p. 8; Baxter 2011a, pers comm.). Longfin smelt develop an air bladder at approximately 12 to 15 mm (0.5 to 0.6 in.) in length and are able to migrate vertically in the water column. At this time, they shift habitat and begin living in the bottom two thirds of the water column (CDFG 2009, p. 8; Baxter 2008, p. 1).

Longfin smelt larvae can tolerate salinities of 2 to 6 psu within days of hatching, and can tolerate salinities up to 8 psu within weeks of hatching. Very few larvae (individuals less than 20 mm in length) are found in salinities greater than 8 psu, and it takes almost 3 months for longfin smelt to reach juvenile stage. A fraction of juvenile longfin smelt individuals are believed to tolerate full marine salinities (greater than 8 psu) (Baxter 2011a, pers. comm.).

Longfin smelt are dispersed broadly in the Bay-Delta by high flows and currents, which facilitate transport of larvae and juveniles long distances. Longfin smelt larvae are dispersed farther downstream during high freshwater flows (Dege and Brown 2004, p. 59). They spend approximately 21 months of their 24-month life cycle in brackish or marine waters (Baxter 1999, pp. 2–14; Dege and Brown 2004, pp. 58–60).

In the Bay-Delta, most longfin smelt spend their first year in Suisun Bay and Marsh, although surveys conducted by the City of San Francisco collected some first-year longfin in coastal waters (Baxter 2011c, pers. comm.; City of San Francisco 1995, no pagination). The remainder of their life is

spent in the San Francisco Bay or the Gulf of Farallones (Moyle 2008, p. 366; City of San Francisco 1995, no pagination). Rosenfield and Baxter (2007, pp. 1587, 1590) inferred based on monthly survey results that the majority of longfin smelt from the Bay-Delta were migrating out of the estuary after the first winter of their life cycle and returning during late fall to winter of their second year. They noted that migration out of the estuary into nearby coastal waters is consistent with captures of longfin smelt in the coastal waters of the Gulf of Farallones.

It is possible that some longfin smelt may stay in the ocean and not re-enter freshwater to spawn until the end of their third year of life (Baxter 2011d, pers. comm.). Moyle (2010, p. 8) states that longfin smelt that migrate out of and back into the Bay-Delta estuary may primarily be feeding on the rich planktonic food supply in the Gulf of Farallones. Rosenfield and Baxter (2007, p. 1290) hypothesize that the movement of longfin smelt into the ocean or deeper water habitat in summer months is at least partly a behavioral response to warm water temperatures found during summer and early fall in the shallows of south San Francisco Bay and San Pablo Bay (Rosenfield and Baxter 2007, p. 1590).

In the Bay-Delta, calanoid copepods such as *Pseudodiatomus forbesi* and *Eurytemora sp.,* as well as the cyclopoid copepod *Acanthocyclops vernali* (no common names), are the primary prey of longfin smelt during the first few months of their lives (approximately January through May) (Slater 2009b, slide 45). Copepods are a type of zooplankton (organisms drifting in the water column of oceans, seas, and bodies of fresh water). The longfin smelt's diet shifts to include mysids such as opossum shrimp (*Neomysis mercedis*) and other small crustaceans (*Acanthomysis* sp.) as soon as they are large enough (20 to 30 mm (0.78 to 1.18 in)) to consume these larger prey items, sometime during the summer months of the first year of their lives (CDFG 2009, p. 12). Upstream of San Pablo Bay, mysids and amphipods form 80 to 95 percent or more of the juvenile longfin smelt diet by weight from July through September (Slater 2009, unpublished data). Longfin smelt occurrence is likely associated with the occurrence of their prey, and both of these invertebrate groups occur near the bottom of the water column during the day under clear water marine conditions.

### *Abundance*

In most locations throughout their range, longfin smelt populations have not been monitored. Within the Bay- Delta, longfin smelt are consistently collected in the monitoring surveys that have been conducted by CDFG as far back as the late 1960s. USFWS knows of no similar monitoring data for other longfin smelt populations. CDFG did report catches of longfin smelt in Humboldt Bay from surveys conducted between 2003 and 2009; small numbers of longfin were collected each of the years except 2004 (CDFG 2010, unpublished data). Moyle (2002, p. 237; 2010, p. 4) noted that the longfin smelt population in Humboldt Bay appeared to have declined between the 1970s and 2002, but survey data are not available from that time.

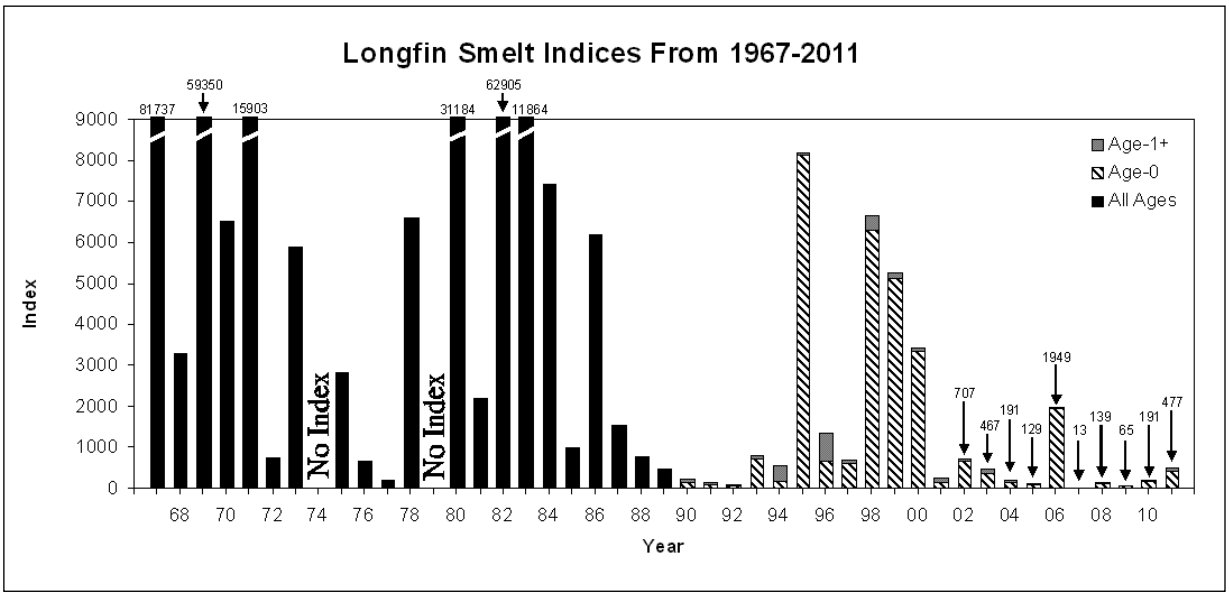
Longfin smelt numbers in the Bay-Delta have declined significantly since the 1980s (Moyle 2002, p. 237; Rosenfield and Baxter 2007, p. 1590; Baxter *et. al.* 2010, pp. 61–64). Rosenfield and Baxter (2007, pp. 1577–1592) examined abundance trends in longfin smelt using three long-term data sets (1980 to 2004) and detected a significant decline in the Bay-Delta longfin smelt population. They confirmed the positive correlation between longfin smelt abundance and freshwater flow that had been previously documented by others (Stevens and Miller 1983, p. 432; Baxter *et al.* 1999, p. 185; Kimmerer 2002b, p. 47), noting that abundances of both adults and juveniles were significantly lower during the 1987 to 1994 drought than during either the pre- or postdrought periods (Rosenfield and Baxter 2007, pp. 1583–1584).

Despite the correlation between drought and low population in the 1980s and 90s, the declines in the first decade of this century appear to be caused in part by additional factors. Abundance of longfin smelt has remained very low since 2000, even though freshwater flows increased during several of these years (Baxter *et al.* 2010, p. 62). Abundance indices derived

from the Fall Midwater Trawl (FMWT), Bay Study Midwater Trawl (BSMT), and Bay Study Otter Trawl (BSOT) all show marked declines in Bay-Delta longfin smelt populations from 2002 to 2009 (Messineo *et al.* 2010, p. 57). Longfin smelt abundance over the last decade is the lowest recorded in the 40-year history of CDFG's FMWT monitoring surveys. Scientists became concerned over the simultaneous population declines since the early 2000s of longfin smelt and three other Bay-Delta pelagic fish species—delta smelt (*Hypomesus transpacificus*), striped bass (*Morone saxatilis*), and threadfin shad (*Dorosoma petenense*) (Sommer *et al.* 2007, p. 273). The declines of longfin smelt and these other pelagic fish species in the Bay-Delta since the early 2000s has come to be known as the Pelagic Organism Decline, and considerable research efforts have been initiated since 2005, to better understand causal mechanisms underlying the declines (Sommer *et al.* 2007, pp. 270–277; MacNally *et al.* 2010, pp. 1417–1430; Thomson *et al.* 2010, pp. 1431–1448). The population did increase in the 2011 FMWT index to 477 (Contreras 2011, p. 2), probably a response to an exceptionally wet year.

The FMWT index of abundance in the Bay-Delta shows great annual variation in abundance but a severe decline over the past 40 years (**Figure 4-4,** on the next page). The establishment of the overbite clam (*Corbula amurensis*) in the Bay-Delta in 1987 is believed to have contributed to the population decline of longfin smelt, as well as to the declining abundance of other pelagic fish species in the Bay-Delta (Sommer *et al.* 2007, p. 274). Figure 4-4 shows low values of the abundance index for longfin smelt during drought years (1976–1977 and 1986–1992) and low values overall since the time that the overbite clam became established in the estuary.

**Figure 4-4**
**Longfin Smelt Fall Midwater Trawl Indices (1967-2011)**




Source: CDFG (http://www.dfg.ca.gov/delta/data/fmwt/Indices/sld003.asp)

Using data from 1975 to 2004 from the FMWT survey, Rosenfield and Baxter 2007 (p. 1589) found that longfin smelt exhibit a significant stock-recruitment relationship—abundance of juvenile (age-0) fish is directly related to the abundance of adult (age-1) fish from the previous year. They found that the abundance of juvenile fish declined by 90 percent during the time period analyzed. Rosenfield and Baxter (2007, p. 1589) also found a decline in age-1 individuals that was significant even after accounting for the decline in the age-0 population. If unfavorable environmental conditions persist for one or more years, recruitment into the population could be suppressed, affecting the species' ability to recover to their previous abundance. The current low abundance of adult longfin smelt within the Bay-Delta could reduce the ability of the species to persist in the presence of various threats.

## B. NMFS Listed Species and Critical Habitats

*Source:* U.S. Geological Survey.

*Photo:* Chinook Salmon.

### 1. Endangered Sacramento River winter-run Chinook salmon *(Oncorhynchus tshawytsha)*

In 1989, the Sacramento River winter-run Chinook salmon was listed as threatened under the federal ESA by NMFS (54 FR 32085). NMFS reclassified the winter-run as endangered in 1994 (59 FR 440), and

reaffirmed this classification in 2005 (NMFS 2005). Winter-run Chinook salmon were classified by the State as endangered in 1989. In 1993, NMFS designated critical habitat for the winter-run Chinook from Keswick Dam (Sacramento river mile 302) to the Golden Gate Bridge (58 FR 33212) (Federal Register 2004). NMFS developed a draft recovery plan in 1997 that was never finalized. In the 2005 5-Year Review, NMFS determined that the endangered classification for winter-run Chinook salmon was still warranted. NMFS completed another 5-Year Review of Sacramento River winter-run Chinook salmon in August 2011, and again recommended maintaining the endangered classification (NMFS August 2011a). The 2011 review also recommended increasing the recovery priority number from 3 to 1 (based on a scale of 1 to 12 with 1 the highest priority).

Adult Sacramento River winter-run Chinook salmon migrate through the Delta from November through June. Juveniles spend approximately 40 days migrating through the Delta, and are primarily present from November through early May (NMFS March 2012). The major concerns related to the status of winter-run Chinook are that there is only one remaining extant population, and it is spawning outside of its historical range (below Keswick Dam and above the Red Bluff Diversion Dam (RBDD)) in artificially maintained habitat (cold water releases from Shasta Dam)that is vulnerable to drought and catastrophe (NMFS August 2011a).

The text below describing Sacramento River winter-run Chinook salmon in more detail is drawn from the March 8, 2012 Biological Opinion of the South Delta Temporary Barriers Program (NMFS March 2012). The initial discussion of general life history also relates to the Central Valley spring-run Chinook salmon.

#### General Chinook salmon Life History

Chinook salmon exhibit two generalized freshwater life history types (Healey 1991). “Streamtype” Chinook salmon, enter freshwater months before spawning and reside in freshwater for a year or more following emergence, whereas “ocean-type” Chinook salmon spawn soon after entering freshwater and migrate to the ocean as fry or parr within their first year. Spring-run Chinook salmon can exhibit a stream-type life history. Adults enter freshwater in the spring, hold over summer, spawn in the fall, and some of the juveniles may spend a year or more in freshwater before emigrating.

The remaining fraction of the juvenile spring-run population may also emigrate to the ocean as young-of-the-year in spring. Winter-run Chinook salmon are somewhat anomalous in that they have characteristics of both stream- and ocean-type races (Healey 1991). Adults enter freshwater in winter or early spring, and delay spawning until spring or early summer (stream-type). However, juvenile winter-run Chinook salmon migrate to sea after only 4 to 7 months of river life (ocean-type). Adequate instream flows and cool water temperatures are more critical for the survival of Chinook salmon exhibiting a stream-type life history due to over summering by adults and/or juveniles.

Chinook salmon typically mature between 2 and 6 years of age (Myers *et al.* 1998). Freshwater entry and spawning timing generally are thought to be related to local

water temperature and flow regimes. Runs are designated on the basis of adult migration timing; however, distinct runs also differ in the degree of maturation at the time of river entry, thermal regime and flow characteristics of their spawning site, and the actual time of spawning (Myers *et al.* 1998). Both spring-run and winter-run Chinook salmon tend to enter freshwater as immature fish, migrate far upriver, and delay spawning for weeks or months. For comparison, fall-run Chinook salmon enter freshwater at an advanced stage of maturity, move rapidly to their spawning areas on the main stem or lower tributaries of the rivers, and spawn within a few days or weeks of freshwater entry (Healey 1991).

During their upstream migration, adult Chinook salmon require stream flows sufficient to provide olfactory and other orientation cues used to locate their natal streams. Adequate stream flows are necessary to allow adult passage to upstream holding habitat. The preferred temperature range for upstream migration is 38 F to 56 F (Bell 1991, CDFG 1998). Boles (1988) recommends water temperatures below 65 F for adult Chinook salmon migration, and Lindley *et al.* (2004) report that adult migration is blocked when temperatures reach 70 F, and that fish can become stressed as temperatures approach 70 F. Reclamation reports that spring-run Chinook salmon holding in upper watershed locations prefer water temperatures below 60 F; although salmon can tolerate temperatures up to 65 F before they experience an increased susceptibility to disease (Williams 2006).

Information on the migration rates of Chinook salmon in freshwater is scant and primarily comes from the Columbia River basin where information regarding migration behavior is needed to assess the effects of dams on travel times and passage (Matter *et al.* 2003). Keefer *et al.* (2004) found migration rates of Chinook salmon ranging from approximately 10 kilometers (km) per day to greater than 35 km per day and to be primarily correlated with date, and secondarily with discharge, year, and reach, in the Columbia River basin. Matter *et al.* (2003) documented migration rates of adult Chinook salmon ranging from 29 to 32 km per day in the Snake River.

Adult Chinook salmon inserted with sonic tags and tracked throughout the Delta and lower Sacramento and San Joaquin rivers were observed exhibiting substantial upstream and downstream movement in a random fashion while migrating upstream over the course of several days at a time (CALFED 2001). Adult salmonids migrating upstream are assumed to make greater use of pool and mid-channel habitat than channel margins (Stillwater Sciences 2004), particularly larger salmon such as Chinook salmon, as described by Hughes (2004). Adults are thought to exhibit crepuscular behavior during their upstream migrations; meaning that they primarily are active during twilight hours. Recent hydroacoustic monitoring showed peak upstream movement of adult Central Valley spring-run Chinook salmon in lower Mill Creek, a tributary to the Sacramento River, occurring in the 4-hour period before sunrise and again after sunset.

Spawning Chinook salmon require clean, loose gravel in swift, relatively shallow riffles or along the margins of deeper runs, and suitable water temperatures, depths, and velocities for red construction and adequate

oxygenation of incubating eggs. Chinook salmon spawning typically occurs in gravel beds that are located at the tails of holding pools (USFWS 1995a). The range of water depths and velocities in spawning beds that Chinook salmon find acceptable is very broad.

The upper preferred water temperature for spawning Chinook salmon is 55 F to 57 F (Chambers 1956, Smith 1973, Bjornn and Reiser 1991, and Snider 2001).Incubating eggs are vulnerable to adverse effects from floods, siltation, desiccation, disease, predation, poor gravel percolation, and poor water quality. Studies of Chinook salmon egg survival to hatching conducted by Shelton (1995) indicated 87 percent of fry emerged successfully from large gravel with adequate subgravel flow. The optimal water temperature for egg incubation ranges from 41 F to 56 F (44 F to 54 F [Rich 1997], 46 F to 56 F [NMFS 1997 Winter-run Chinook salmon Recovery Plan], and 41 F to 55.4 F [Moyle 2002]). A significant reduction in egg viability occurs at water temperatures above 57.5 F and total embryo mortality can occur at temperatures above 62 F (NMFS 1997). Alderdice and Velsen (1978) found that the upper and lower temperatures resulting in 50 percent pre-hatch mortality were 61 F and 37 F, respectively, when the incubation temperature was held constant. As water temperatures increase, the rate of embryo malformations also increases, as well as the susceptibility to fungus and bacterial infestations. The length of development for Chinook salmon embryos is dependent on the ambient water temperature surrounding the egg pocket in the redd. Colder water necessitates longer development times as metabolic processes are slowed. Within the appropriate water temperature range for embryo incubation, embryos hatch in 40 to 60 days, and the alevins (yolk-sac fry) remain in the gravel for an additional 4 to 6 weeks before emerging from the gravel.

During the 4 to 6 week period when alevins remain in the gravel, they utilize their yolk-sac to nourish their bodies. As their yolk-sac is depleted, fry begin to emerge from the gravel to begin exogenous feeding in their natal stream. The post-emergent fry disperse to the margins of their natal stream, seeking out shallow waters with slower currents, finer sediments, and bank cover such as overhanging and submerged vegetation, root wads, and fallen woody debris, and begin feeding on zooplankton, small insects, and small invertebrates. As they switch from endogenous nourishment to exogenous feeding, the fry's yolk-sac is reabsorbed, and the belly suture closes over the former location of the yolk-sac (button-up fry). Fry typically range from 25 mm to 40 mm during this stage. Some fry may take up residence in their natal stream for several weeks to a year or more, while others are displaced downstream by the stream's current. Once started downstream, fry may continue downstream to the estuary and rear, or may take up residence in river reaches farther downstream for a period of time ranging from weeks to a year (Healey 1991).

Fry then seek nearshore habitats containing beneficial aspects such as riparian vegetation and associated substrates important for providing aquatic and terrestrial invertebrates, predator avoidance, and slower velocities for resting (NMFS 1996a). The benefits of shallow water habitats for salmonid rearing also have recently been realized as shallow water habitat

has been found to be more productive than the main river channels, supporting higher growth rates, partially due to higher prey consumption rates, as well as favorable environmental temperatures (Sommer *et al.* 2001).

When juvenile Chinook salmon reach a length of 50 mm to 57 mm, they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures. In the mainstems of larger rivers, juveniles tend to migrate along the margins and avoid the elevated water velocities found in the thalweg of the channel. When the channel of the river is greater than 9 feet to 10 feet in depth, juvenile salmon tend to inhabit the surface waters (Healey 1982). Migrational cues, such as increasing turbidity from runoff, increased flows, changes in day length, or intraspecific competition from other fish in their natal streams may spur outmigration of juveniles when they have reached the appropriate stage of maturation (Kjelson *et al.* 1982, Brandes and McLain 2001).

As fish begin their emigration, they are displaced by the river's current downstream of their natal reaches. Similar to adult movement, juvenile salmonid downstream movement is crepuscular. Documents and data provided to NMFS in support of ESA section 10 research permit applications depicts that the daily migration of juveniles passing RBDD is highest in the four hour period prior to sunrise (Martin *et al.* 2001). Juvenile Chinook salmon migration rates vary considerably presumably depending on the physiological stage of the juvenile and hydrologic conditions. Kjelson *et al*. (1982) found fry Chinook salmon to travel as fast as 30 km per day in the Sacramento River and Sommer *et al.* (2001) found rates ranging from approximately 0.5 miles up to more than 6 miles per day in the Yolo Bypass. As Chinook salmon begin the smoltification stage, they prefer to rear further downstream where ambient salinity is up to 1.5 to 2.5 parts per thousand (Healey 1980, Levy and Northcote 1981).

Fry and parr may rear within riverine or estuarine habitats of the Sacramento River, the Delta, and their tributaries. In addition, Central Valley spring-run Chinook salmon juveniles have been observed rearing in the lower reaches of non-natal tributaries and intermittent streams in the Sacramento Valley during the winter months (Maslin *et al.* 1997, Snider 2001). Within the Delta, juvenile Chinook salmon forage in shallow areas with protective cover, such as intertidal and subtidal mudflats, marshes, channels, and sloughs (McDonald 1960, Dunford 1975). Cladocerans, copepods, amphipods, and larvae of diptera, as well as small arachnids and ants are common prey items (Kjelson *et al.* 1982, Sommer *et al.* 2001, MacFarlane and Norton 2002).

Shallow water habitats are more productive than the main river channels, supporting higher growth rates, partially due to higher prey consumption rates, as well as favorable environmental temperatures (Sommer *et al.* 2001). Optimal water temperatures for the growth of juvenile Chinook salmon in the Delta are between 54 F to 57 F (Brett 1952). In Suisun and San Pablo Bays water temperatures can reach 54 F by February in a typical year. Other portions of the Delta (*i.e.*, south Delta and central Delta) can reach 70 F by February in a dry year. However, cooler temperatures are usually the norm until after the spring runoff has ended.

Within the estuarine habitat, juvenile Chinook salmon movements are dictated by the tidal cycles, following the rising tide into shallow water habitats from the deeper main channels, and returning to the main channels when the tide recedes (Levy and Northcote 1982, Levings 1982, Levings *et al.* 1986, Healey 1991). As juvenile Chinook salmon increase in length, they tend to school in the surface waters of the main and secondary channels and sloughs, following the tides into shallow water habitats to feed (Allen and Hassler 1986). In Suisun Marsh, Moyle *et al.* (1989) reported that Chinook salmon fry tend to remain close to the banks and vegetation, near protective cover, and in dead-end tidal channels. Kjelson *et al.* (1982) reported that juvenile Chinook salmon demonstrated a diel migration pattern, orienting themselves to nearshore cover and structure during the day, but moving into more open, offshore waters at night. The fish also distributed themselves vertically in relation to ambient light. During the night, juveniles were distributed randomly in the water column, but would school up during the day into the upper 3 meters of the water column. Available data indicates that juvenile Chinook salmon use Suisun Marsh extensively both as a migratory pathway and rearing area as they move downstream to the Pacific Ocean. Juvenile Chinook salmon were found to spend about 40 days migrating through the Delta to the mouth of San Francisco Bay and grew little in length or weight until they reached the Gulf of the Farallones (MacFarlane and Norton 2002). Based on the mainly oceantype life history observed (*i.e.*, fall-run Chinook salmon) MacFarlane and Norton (2002) concluded that unlike other salmonid populations in the Pacific Northwest, Central Valley Chinook salmon show little estuarine dependence and may benefit from expedited ocean entry.

#### Sacramento River winter-run Chinook salmon

The distribution of winter-run Chinook salmon spawning and rearing historically was limited to the upper Sacramento River and its tributaries, where spring-fed streams provided cold water throughout the summer, allowing for spawning, egg incubation, and rearing during the midsummer period (Slater 1963, Yoshiyama *et al.* 1998). The headwaters of the McCloud, Pit, and Little Sacramento rivers, and Hat and Battle creeks, historically provided clean, loose gravel; cold, well-oxygenated water; and optimal stream flow in riffle habitats for spawning and incubation. These areas also provided the cold, productive waters necessary for egg and fry development and survival, and juvenile rearing over the summer. The construction of Shasta Dam in 1943 blocked access to all of these waters except Battle Creek, which has its own impediments to upstream migration (*i.e.*, the fish weir at the Coleman National Fish Hatchery and other small hydroelectric facilities situated upstream of the weir) (Moyle *et al.* 1989, NMFS 1997, 1998a,b). Approximately 299 miles of tributary spawning habitat in the upper Sacramento River is now inaccessible to winter-run Chinook salmon. Yoshiyama *et al.* (2001) estimated that in 1938, the Upper Sacramento had a "potential spawning capacity" of 14,303 redds. Most components of the winter-run Chinook salmon life history (*e.g.*, spawning, incubation, freshwater rearing) have been compromised by the habitat blockage in the upper Sacramento River.

**Table 4-3**
**The Temporal Occurrence of Adult (a) and Juvenile (b) Sacramento River winter-run Chinook salmon in the Sacramento River**
*(Darker shades indicate months of greatest relative abundance)*

**(a) Adult migration/holding**

| Location | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sac. River basin[a] | | | | | | | | | | | | |
| Sac. River[b] | | | | | | | | | | | | |

**(b) Juvenile migration**

| Location | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sac. River @ Red Bluff[c] | | | | | | | | | | | | |
| Sac. River @ Red Bluff[b] | | | | | | | | | | | | |
| Sac. River @ Knights Landing[d] | | | | | | | | | | | | |
| Lower Sac. River (seine)[e] | | | | | | | | | | | | |
| West Sac. River (trawl)[e] | | | | | | | | | | | | |

Relative Abundance: ■ = High ■ = Medium ■ = Low

Sources: [a]Yoshiyama *et al.* (1998); Moyle (2002); [b]Myers *et al.* (1998); Vogel and Marine (1991); [c]Martin *et all.* (2001); [d]Snider and Titus (2000); [e]USFWS (2001a, 2001b)

Source: NMFS, March 8, 2012, p. 15.

Adult winter-run Chinook salmon enter San Francisco Bay from November through June (Hallock and Fisher 1985) and migrate past the RBDD from mid-December through early August (NMFS 1997). The majority of the run passes RBDD from January through May, with the peak passage occurring in mid-March (Hallock and Fisher 1985). The timing of migration may vary somewhat due to changes in river flows, dam operations, and water year type Yoshiyama *et al.* 1998, Moyle 2002). **Table 4-3,** above, illustrates winter-run Chinook salmon location and timing. Spawning occurs primarily from mid-April to mid-August, with the peak activity occurring in May and June in the Sacramento River reach between Keswick Dam and RBDD (Vogel and Marine 1991). The majority of Sacramento River winter-run Chinook salmon spawners are 3 years old.

Sacramento River winter-run Chinook salmon fry begin to emerge from the gravel in late June to early July and continue through October (Fisher 1994). Emigration of juvenile Sacramento River winter-run Chinook salmon past RBDD may begin as early as mid-July, typically peaks in September, and can continue through March in dry years (Vogel and Marine 1991, NMFS 1997). Juvenile Sacramento River winter-run Chinook salmon occur in the Delta primarily from November through early May based on data collected from trawls in the Sacramento River at West Sacramento (RM 57; USFWS 2001a,b). The timing of migration may vary somewhat due to changes in river flows, dam operations, and water year type. Winter-run Chinook salmon juveniles remain in the Delta until they reach a fork length of approximately 118 millimeters (mm) and are from 5 to 10 months of age, and then

begin emigrating to the ocean as early as November and continue through May (Fisher 1994, Myers *et al.* 1998).

Historical Sacramento River winter-run Chinook salmon population estimates, which included males and females, were as high as near 100,000 fish in the 1960s, but declined to under 200 fish in the 1990s (Good *et al.* 2005). Population estimates in 2003 (8,218), 2004 (7,869), 2005 (15,875) and 2006 (17,304) show a recent increase in the population size (CDFG GrandTab, February 2011) and a 4-year average of 12,316. **Table 4-4,** on the next page, summarizes winter-run Chinook salmon population data from 1986 to 2011. The 2006 run was the highest since the 1994 listing. Abundance measures over the last decade suggest that the abundance was initially increasing (Good *et al*. 2005). However, escapement estimates for 2007, 2008, 2009, and 2010 show a precipitous decline in escapement numbers based on redd counts and carcass counts. Estimates place the adult escapement numbers for 2007 at 2,542 fish, 2,830 fish for 2008, and 4,658 fish for 2009 (CDFG Grand Tab 2010) and 1,596 fish for 2010 (NMFS 2011[JPE letter]).

Two current methods are utilized to estimate the juvenile production of Sacramento River winter-run Chinook salmon: the Juvenile Production Estimate (JPE) method, and the Juvenile Production Index (JPI) method (Gaines and Poytress 2004). Gaines and Poytress (2004) estimated the juvenile population of Sacramento River winter-run Chinook salmon exiting the upper Sacramento River at RBDD to be 3,707,916 juveniles per year using the JPI method between the years 1995 and 2003 (excluding 2000 and 2001). Using the JPE method, they estimated an average of 3,857,036 juveniles exiting the upper Sacramento River at RBDD between the years of 1996 and 2003. Averaging these two estimates yields an estimated population size of 3,782,476.

Based on the RBDD counts, the population has been growing rapidly since the 1990s with positive short-term trends (excluding the 2007-2010 escapement numbers). An age-structured density-independent model of spawning escapement by Botsford and Brittnacker (1998 as referenced in Good *et al*. 2005) assessing the viability of Sacramento River winter-run Chinook salmon found the species was certain to fall below the quasi-extinction threshold of 3 consecutive spawning runs with fewer than 50 females (Good *et al*. 2005). Lindley *et al*. (2003) assessed the viability of the population using a Bayesian model based on spawning escapement that allowed for density dependence and a change in population growth rate in response to conservation measures found a biologically significant expected quasi-extinction probability of 28 percent.

Although the status of the Sacramento River winter-run Chinook salmon population had been improving until as recently as 2006, there is only one population, and it depends on cold-water releases from Shasta Dam, which could be vulnerable to a prolonged drought (Good *et al*. 2005). Recent population trends in the previous 4 years have indicated that the status of the winter-run Chinook salmon population may be changing as reflected in the diminished abundance during this period. The current winter-run Chinook salmon JPE for 2011 is only 165,051 fish entering the Delta, a substantial decline from the previous JPE values seen in the last decade.

## Table 4-4

**Winter-run Chinook salmon Population Estimates from RBDD Counts (1986 to 2001) and Carcass Counts (2001 to 2011), and Corresponding Cohort Replacement Rates for the Years Since 1986 (CDFG Grand Tab February 2011)**

| Year | Population Estimate[a] | 5-Year Moving Average of Population Estimate | Cohort Replacement Rate[b] | 5-Year Moving Average of Cohort Replacement Rate | NMFS-Calculated Juvenile Production Estimate (JPE)[c] |
|---|---|---|---|---|---|
| 1986 | 2,596 | | | | |
| 1987 | 2,185 | | | | |
| 1988 | 2,878 | | | | |
| 1989 | 696 | | 0.27 | | |
| 1990 | 430 | 1,757 | 0.20 | | |
| 1991 | 211 | 1,280 | 0.07 | | 40,100 |
| 1992 | 1,240 | 1,091 | 1.78 | | 273,100 |
| 1993 | 387 | 593 | 0.90 | 0.64 | 90,500 |
| 1994 | 186 | 491 | 0.88 | 0.77 | 74,500 |
| 1995 | 1,297 | 664 | 1.05 | 0.94 | 338,107 |
| 1996 | 1,337 | 889 | 3.45 | 1.61 | 165,069 |
| 1997 | 880 | 817 | 4.73 | 2.20 | 138,316 |
| 1998 | 2,992 | 1,338 | 2.31 | 2.48 | 454,792 |
| 1999 | 3,288 | 1,959 | 2.46 | 2.80 | 289,724 |
| 2000 | 1,352 | 1,970 | 1.54 | 2.90 | 370,221 |
| 2001 | 8,224 | 3,347 | 2.75 | 2.76 | 1,864,802 |
| 2002 | 7,441 | 4,659 | 2.26 | 2.26 | 2,136,747 |
| 2003 | 8,218 | 5,705 | 6.08 | 3.02 | 1,896,649 |
| 2004 | 7,869 | 6,621 | 0.96 | 2.72 | 881,719 |
| 2005 | 15,839 | 9,518 | 2.13 | 2.84 | 3,556,995 |
| 2006 | 17,296 | 11,333 | 2.10 | 2.71 | 3,890,534 |
| 2007 | 2,542 | 10,353 | 0.32 | 2.32 | 1,100,067 |
| 2008 | 2,830 | 9,275 | 0.18 | 1.14 | 1,152,043 |
| 2009 | 4,537 | 8,609 | 0.26 | 1.00 | 1,144,860 |
| 2010 | 1,596 | 5,760 | 0.63 | 0.70 | 332,012 |
| 2011 | 824 | 2,466 | 0.29 | 0.34 | 162,051 |
| **Median** | 2,364 | 2,218 | 1.05 | 2.26 | 370,221 |
| **Mean** | 3,814 | 4,113 | 1.63 | 1.90 | 969,186 |

[a] NMFS included both the escapement numbers from the Feather River Fish Hatchery (FRFH) and the Sacramento River and its tributaries in this table. Sacramento River Basin run size is the sum of the escapement numbers from the FRFH and the tributaries.

[b] Abbreviations: CRR = Cohort Replacement Rate, Trib = tributary

Source: NMFS, March 8, 2012, p. 22.

Recently, Lindley *et al.* (2007) determined that the Sacramento River winter-run Chinook salmon population that spawns below Keswick Dam is at a moderate extinction risk according to population viability analysis (PVA), and at a low risk according to other criteria (*i.e.*, population size, population decline, and the risk of wide ranging catastrophe). However, concerns of genetic introgression with hatchery populations are increasing. Hatchery-origin winter-run Chinook salmon from Livingston Stone National Fish Hatchery (LSNFH) have made up more than 5 percent of the natural spawning run in recent years and in 2005, it exceeded 18 percent of the natural run. If the proportion of hatchery origin fish from the LSNFH exceeded 15 percent in 2006-2007, Lindley *et al*. (2007) recommended reclassifying the winter-run Chinook population extinction risk as moderate, rather than low, based on the impacts of the hatchery fish over multiple generations of spawners. However, since 2005, the percentage of hatchery fish recovered at the LSNFH has been consistently below 15 percent. Furthermore, Lindley's assessment in 2007 did not include the recent declines in adult escapement abundance which may modify the conclusion reached in 2007.

Lindley *et al.* (2007) also states that the winter-run Chinook salmon population fails the "representation and redundancy rule" because it has only one population, and that population spawns outside of the ecoregion in which it evolved. In order to satisfy the "representation and redundancy rule," at least two populations of winter-run Chinook salmon would have to be reestablished in the basalt- and porous-lava region of its origin. An ESU represented by only one spawning population at moderate risk of extinction is at a high risk of extinction over an extended period of time (Lindley *et al*. 2007).

#### Viable Salmonid Population Summary for Sacramento River winter-run Chinook salmon

***Abundance***

During the first part of this decade, redd and carcass surveys as well as fish counts, suggested that the abundance of winter-run Chinook salmon was increasing since its listing. However, the depressed abundance estimates over the past five years are an exception to this trend and may represent a combination of a new cycle of poor ocean productivity (Lindley *et al.* 2009) and recent drought conditions in the Central Valley. Population growth is estimated to be positive in the short-term trend at 0.26; however, the long-term trend is negative, averaging - 0.14. Recent winter-run Chinook salmon abundance represents only 3 percent of the maximum post-1967, 5-year geometric mean, and is not yet well established (Good *et al.* 2005). The current annual and five year averaged cohort replacement rates (CRR) are both below 0.5. The annual CRR has been below 1.0 for the past five years and indicates that the winter-run population is not replacing itself.

***Productivity***

ESU productivity has been positive over the short term, and adult escapement and juvenile production had been increasing annually (Good *et al.* 2005) until recently, with declining escapement estimates for the years 2007 through 2011. However, the long-term trend for the ESU remains negative, as it consists of only one population that is subject to possible impacts from environmental and

artificial conditions. The most recent CRR estimates suggest a reduction in productivity for the three separate cohorts starting in 2007.

### *Spatial Structure*

The greatest risk factor for winter-run Chinook salmon lies with their spatial structure (Good *et al.* 2005). The remnant population cannot access historical winter-run Chinook salmon habitat and must be artificially maintained in the Sacramento River by a regulated, finite cold-water pool behind Shasta Dam. Winter-run Chinook salmon require cold water temperatures in summer that simulate their upper basin habitat, and they are more likely to be exposed to the impacts of drought in a lower basin environment. Battle Creek remains the most feasible opportunity for the ESU to expand its spatial structure, which currently is limited to the upper 25-mile reach of the mainstem Sacramento River below Keswick Dam. Based on Reasonable and Prudent Alternative actions described in the 2009 OCAP Biological Opinion (BiOp), passage of winter-run Chinook salmon above Keswick and Shasta Dams is being considered as one of the actions. This would reintroduce winter-run Chinook salmon into regions they had historically occupied and significantly benefit the spatial structure of the ESU.

### *Diversity*

The second highest risk factor for the Sacramento River winter-run Chinook salmon ESU has been the detrimental effects on its diversity. The present winter-run Chinook salmon population has resulted from the introgression of several stocks that occurred when Shasta Dam blocked access to the upper watershed. A second genetic bottleneck occurred with the construction of Keswick Dam; and there may have been several others within the recent past (Good *et al.* 2005). Concerns of genetic introgression with hatchery populations are also increasing. Hatchery-origin winter-run Chinook salmon from LSNFH have made up more than 5 percent of the natural spawning run in recent years and in 2005, it exceeded 18 percent of the natural run. The average over the last 10 years (approximately 3 generations) has been 8 percent, still below the low-risk threshold for hatchery influence. Since 2005, the percentage of hatchery fish in the river has been consistently below 15 percent.

## Endangered Sacramento River winter-run Chinook salmon Critical Habitat

The designated critical habitat for Sacramento River winter-run Chinook salmon includes the Sacramento River from Keswick Dam (RM 302) to Chipps Island (RM 0) at the westward margin of the Delta; all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge; and all waters of San Francisco Estuary to the Golden Gate Bridge north of the San Francisco/Oakland Bay Bridge. In the Sacramento River, critical habitat includes the river water column, river bottom, and adjacent riparian zone used by fry and juveniles for rearing. The portion of the Sacramento River within the Legal Delta includes potential EDCP treatment sites. In the areas westward of Chipps Island, critical habitat includes the estuarine water column

and essential foraging habitat and food resources used by Sacramento River winter-run Chinook salmon as part of their juvenile emigration or adult spawning migration. Critical habitat primary constituent elements (PCEs) for winter-run Chinook salmon are described below under Central Valley spring-run Chinook salmon.

## 2. Threatened Central Valley spring-run Chinook salmon *(Oncorhynchus tshawytsha)*

Central Valley spring-run salmon was listed as threatened by both the State and federal governments in 1999, and reaffirmed as threatened by the federal government in 2005. Critical habitat for Central Valley spring-run Chinook salmon was designated in September 2005. Critical habitat within the Delta includes portions of three hydrologic units: Sacramento Delta, Valley Putah-Cache, and Valley-American. Unlike winter-run Chinook, which utilize only the Sacramento River, spring-run Chinook utilize primarily the Feather and Yuba Rivers, with smaller populations likely in the Sacramento River and Big Chico Creek (NMFS 2005).

NMFS developed a draft recovery plan in 1997 that was never finalized. In the 2005 5-Year Review, NMFS determined that the threatened classification for spring-run Chinook salmon was still warranted. NMFS completed another 5-Year Review of Central Valley spring-run Chinook salmon in August 2011. At this time, NMFS determined that the status of this ESU has probably deteriorated since 2005, and again recommended maintaining the threatened classification (NMFS August 2011b). The 2011 review placed the Mill and Deer creek populations of spring-run Chinook salmon in the high extinction risk category, and the Butte Creek population in the low risk category (NMFS August 2011b). The 2011 review also recommended no change in the recovery priority number of 7 (based on a scale of 1 to 12 with 1 the highest priority), but that the status be reevaluated in two to three years. Major concerns related to the status of Central Valley spring-run Chinook salmon include: low diversity, poor spatial structure, risk of catastrophic disturbance, and low abundance resulting from loss of historical spawning habitat, degradation of remaining habitat, and genetic threats from the Feather River Hatchery (NMFS August 2011b).

Adult Central Valley spring-run Chinook salmon migrate through the Delta primarily from January through June. Most juveniles emigrate through the Delta from November through early May (NMFS March 2012). The text below describing the status of Central Valley spring-run Chinook salmon is drawn from the March 8, 2012 Biological Opinion of the South Delta Temporary Barriers Program (NMFS March 2012).

Historically the spring-run Chinook salmon were the second most abundant salmon run in the Central Valley (CDFG 1998). These fish occupied the upper and middle reaches (1,000 to 6,000 feet) of the San Joaquin, American, Yuba, Feather, Sacramento, McCloud and Pit rivers, with smaller populations in most tributaries with sufficient habitat for over-summering adults (Stone 1874, Rutter 1904, Clark 1929). The Central Valley Technical Review Team

(CVTRT) estimated that historically there were 18 or 19 independent populations of Central Valley spring-run Chinook salmon, along with a number of dependent populations and four diversity groups (Lindley *et al.* 2004). Of these 18 populations, only three extant populations currently exist (Mill, Deer, and Butte creeks on the upper Sacramento River) and they represent only the northern Sierra Diversity group. All populations in the Basalt and Porous Lava group and the Southern Sierra Nevada Group have been extirpated.

The Central Valley drainage as a whole is estimated to have supported spring-run Chinook salmon runs as large as 600,000 fish between the late 1880s and 1940s (CDFG 1998). Before the construction of Friant Dam, nearly 50,000 adults were counted in the San Joaquin River alone (Fry 1961). Construction of other low elevation dams in the foothills of the Sierras on the American, Mokelumne, Stanislaus, Tuolumne, and Merced rivers extirpated Central Valley spring-run Chinook salmon from these watersheds. Naturally-spawning populations of Central Valley spring-run Chinook salmon currently are restricted to accessible reaches of the upper Sacramento River, Antelope Creek, Battle Creek, Beegum Creek, Big Chico Creek, Butte Creek, Clear Creek, Deer Creek, Feather River, Mill Creek, and Yuba River (CDFG 1998).

Adult Central Valley spring-run Chinook salmon leave the ocean to begin their upstream migration in late January and early February (CDFG 1998) and enter the Sacramento River between March and September, primarily in May and June Yoshiyama *et al.* 1998, Moyle 2002). **Table 4-5,** on the next page, summarizes Central Vallley spring-run location and timing. Lindley *et al.* (2007) indicates adult Central Valley spring-run Chinook salmon enter native tributaries from the Sacramento River primarily between mid-April and mid-June. Typically, spring-run Chinook salmon utilize mid- to high-elevation streams that provide appropriate temperatures and sufficient flow, cover, and pool depth to allow over-summering while conserving energy and allowing their gonadal tissue to mature (Yoshiyama *et al.* 1998). Spring-run Chinook salmon spawning occurs between September and October depending on water temperatures. Between 56 and 87 percent of adult spring-run Chinook salmon that enter the Sacramento River basin to spawn are 3 years old (Calkins *et al.* 1940, Fisher 1994).

Spring-run Chinook salmon fry emerge from the gravel from November to March (Moyle 2002) and the emigration timing is highly variable, as they may migrate downstream as young-of-the-year or as juveniles or yearlings. The modal size of fry migrants at approximately 40 mm between December and April in Mill, Butte, and Deer creeks reflects a prolonged emergence of fry from the gravel (Lindley *et al.* 2007). Studies in Butte Creek (Ward *et al.* 2002, 2003, McReynolds *et al.* 2005) found the majority of Central Valley spring-run Chinook salmon migrants to be fry occurring primarily during December, January, and February; and that these movements appeared to be influenced by flow. Small numbers of Central Valley spring-run Chinook salmon remained in Butte Creek to rear and migrated as yearlings later in the spring.

**Table 4-5**
**The Temporal Occurrence of Adult (a) and Juvenile (b) Central Valley spring-run Chinook salmon in the Sacramento River**
*(Darker shades indicate months of greatest relative abundance)*

**(a) Adult migration**

| Location | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sac. River basin[a,b] | | | | | | | | | | | | |
| Sac. River mainstem[c] | | | | | | | | | | | | |
| Mill Creek[d] | | | | | | | | | | | | |
| Deer Creek[d] | | | | | | | | | | | | |
| Butte Creek[d] | | | | | | | | | | | | |
| **(b) Adult holding** | | | | | | | | | | | | |
| **(c) Adult Spawning** | | | | | | | | | | | | |

**(d) Juvenile migration**

| Location | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sac. River Tribs[e] | | | | | | | | | | | | |
| Upper Butte Creek[f] | | | | | | | | | | | | |
| Mill, Deer, Butte Creeks[d] | | | | | | | | | | | | |
| Sac. River at RBDD[c] | | | | | | | | | | | | |
| Sac. River at Knights Landing | | | | | | | | | | | | |

Relative Abundance: ■ = High ■ = Medium ■ = Low

Note: Yearling spring-run Chinook salmon rear in their natal streams through the first summer following their birth. Downstream emigration generally occurs the following fall and winter. Young of the year spring-run Chinook salmon emigrate during the first spring after they hatch.

Sources: [a]Yoshiyama *et al.* (1998); [b]Moyle (2002); [c]Myers *et al.* (1998); [d]Lindley *et al.* (2007). [e]CDFG (21998); [f]McReynolds *et al.* (2005); Ward *et al.* (2002, 2003); [g]Snider and Titus (2000)

Source: NMFS, March 8, 2012, p. 20.

Juvenile emigration patterns in Mill and Deer creeks are very similar to patterns observed in Butte Creek, with the exception that Mill and Deer creek juveniles typically exhibit a later young-of-the-year migration and an earlier yearling migration (Lindley *et al.* 2007). Once juveniles emerge from the gravel they initially seek areas of shallow water and low velocities while they finish absorbing the yolk sac and transition to exogenous feeding (Moyle 2002). Many also will disperse downstream during high-flow events. As is the case in other salmonids, there is a shift in microhabitat use by juveniles to deeper faster water as they grow larger. Microhabitat use can be influenced by the presence of predators which can force fish to select areas of heavy cover and suppress foraging in open areas (Moyle 2002). The emigration period for spring-run Chinook salmon extends from

November to early May, with up to 69 percent of the young-of-the-year fish outmigrating through the lower Sacramento River and Delta during this period (CDFG 1998). Peak movement of juvenile Central Valley spring-run Chinook salmon in the Sacramento River at Knights Landing occurs in December, and again in March and April. However, juveniles also are observed between November and the end of May (Snider and Titus 2000). Based on the available information, the emigration timing of Central Valley spring-run Chinook salmon appears highly variable (CDFG 1998). Some fish may begin emigrating soon after emergence from the gravel, whereas others over-summer and emigrate as yearlings with the onset of intense fall storms (CDFG 1998).

On the Feather River, significant numbers of spring-run Chinook salmon, as identified by run timing, return to the Feather River Hatchery (FRH). In 2002, the FRH reported 4,189 returning spring-run Chinook salmon, which is 22 percent below the 10-year average of 4,727 fish. However, coded-wire tag (CWT) information from these hatchery returns indicates substantial introgression has occurred between fall-run and spring-run Chinook salmon populations within the Feather River system due to hatchery practices. Because Chinook salmon have not always been temporally separated in the hatchery, spring-run and fall-run Chinook salmon have been spawned together, thus compromising the genetic integrity of the spring-run Chinook salmon stock. The number of naturally spawning spring-run Chinook salmon in the Feather River has been estimated only periodically since the 1960s, with estimates ranging from two fish in 1978 to 2,908 in 1964. However, the genetic integrity of this population is questionable because of the significant temporal and spatial overlap between spawning populations of spring-run and fall-run Chinook salmon (Good *et al.* 2005). For the reasons discussed above, the Feather River spring-run Chinook population numbers are not included in the following discussion of ESU abundance.

The Central Valley spring-run Chinook salmon ESU has displayed broad fluctuations in adult abundance, ranging from 1,404 in 1993 to 24,903 in 1998. **Table 4-6,** on the next page, summarizes Central Valley spring-run Chinook salmon population data from 1986 through 2011. Sacramento River tributary populations in Mill, Deer, and Butte creeks are probably the best trend indicators for the Central Valley spring-run Chinook salmon ESU as a whole because these streams contain the primary independent populations within the ESU. Generally, these streams have shown a positive escapement trend since 1991. Escapement numbers are dominated by Butte Creek returns, which have averaged over 7,000 fish since 1995. During this same period, adult returns on Mill Creek have averaged 778 fish, and 1,463 fish on Deer Creek.

Although trends through the first half of the past decade were generally positive, annual abundance estimates display a high level of fluctuation, and the overall number of Central Valley spring-run Chinook salmon remains well below estimates of historic abundance. The past several years (since 2005) have shown declining abundance numbers in most of the tributaries. Additionally, in 2002 and 2003, mean water temperatures in Butte Creek exceeded 21 C for ten or more days in July (reviewed by Williams 2006). These persistent

**Table 4-6**
**Central Valley Spring-run Chinook salmon Population Estimates from CDFG Grand Tab (February 2011) with Corresponding Cohort Replacement Rates for Years Since 1986**

| Year | Sacramento River Basin Escapement Run Size[a] | FRFH Population | Tributary Populations | 5-Year Moving Average of Tributary Population Estimate | Trib CRR[b] | 5-Year Moving Average of Trib CRR | 5-Year Moving Average of Basin Population Estimate | Basin CRR | 5-Year Moving Average of Basin CRR |
|---|---|---|---|---|---|---|---|---|---|
| 1986 | 25,696 | 1,433 | 24,263 | | | | | | |
| 1987 | 13,888 | 1,213 | 12,675 | | | | | | |
| 1988 | 18,933 | 6,833 | 12,100 | | | | | | |
| 1989 | 12,163 | 5,078 | 7,085 | | 0.29 | | | 0.47 | |
| 1990 | 7,683 | 1,893 | 5,790 | 12,383 | 0.46 | | 15,673 | 0.55 | |
| 1991 | 5,926 | 4,303 | 1,623 | 7,855 | 0.13 | | 11,719 | 0.31 | |
| 1992 | 3,044 | 1,497 | 1,547 | 5,629 | 0.22 | | 9,550 | 0.25 | |
| 1993 | 6,076 | 4,672 | 1,404 | 3,490 | 0.24 | 0.27 | 6,978 | 0.79 | 0.48 |
| 1994 | 6,187 | 3,641 | 2,546 | 2,582 | 1.57 | 0.52 | 5,783 | 1.04 | 0.59 |
| 1995 | 15,238 | 5,414 | 9,824 | 3,389 | 6.35 | 1.70 | 7,294 | 5.01 | 1.48 |
| 1996 | 9,083 | 6,381 | 2,702 | 3,605 | 1.92 | 2.06 | 7,926 | 1.49 | 1.72 |
| 1997 | 5,193 | 3,653 | 1,540 | 3,603 | 0.60 | 2.14 | 8,355 | 0.84 | 1.84 |
| 1998 | 31,649 | 6,746 | 24,903 | 8,303 | 2.53 | 2.60 | 13,470 | 2.08 | 2.09 |
| 1999 | 10,100 | 3,731 | 6,369 | 9,068 | 2.36 | 2.75 | 14,253 | 1.11 | 2.11 |
| 2000 | 9,244 | 3,657 | 5,587 | 8,220 | 3.63 | 2.21 | 13,054 | 1.78 | 1.46 |
| 2001 | 17,598 | 4,135 | 13,463 | 10,372 | 0.54 | 1.93 | 14,757 | 0.56 | 1.27 |
| 2002 | 17,419 | 4,189 | 13,230 | 12,710 | 2.08 | 2.23 | 17,202 | 1.72 | 1.45 |
| 2003 | 17,691 | 8,662 | 9,029 | 9,536 | 1.62 | 2.04 | 14,410 | 1.91 | 1.42 |
| 2004 | 13,982 | 4,212 | 9,770 | 10,216 | 0.73 | 1.72 | 15,187 | 0.79 | 1.35 |
| 2005 | 16,126 | 1,774 | 14,352 | 11,969 | 1.08 | 1.21 | 16,563 | 0.93 | 1.18 |
| 2006 | 10,948 | 2,181 | 8,767 | 11,030 | 0.97 | 1.29 | 15,233 | 0.62 | 1.20 |
| 2007 | 9,974 | 2,674 | 7,300 | 9,844 | 0.75 | 1.03 | 13,744 | 0.71 | 0.99 |
| 2008 | 6,420 | 1,624 | 4,796 | 8,997 | 0.33 | 0.77 | 11,490 | 0.40 | 0.69 |
| 2009 | 3,801 | 989 | 2,812 | 7,605 | 0.32 | 0.69 | 9,454 | 0.35 | 0.60 |
| 2010 | 3,792 | 1,661 | 2,131 | 5,161 | 0.29 | 0.53 | 6,987 | 0.38 | 0.49 |
| 2011 | 4,967 | 1,900 | 3,067 | 4,021 | 0.64 | 0.47 | 5,791 | 0.77 | 0.52 |
| **Median** | 10,037 | 3,655 | 6,727 | 8,262 | 0.73 | 1.70 | 12,386 | 0.79 | 1.27 |
| **Mean** | 11,647 | 3,621 | 8,026 | 7,708 | 1.29 | 1.48 | 11,585 | 1.08 | 1.21 |

[a] NMFS included both the escapement numbers from the Feather River Fish Hatchery (FRFH) and the Sacramento River and its tributaries in this table. Sacramento River Basin run size is the sum of the escapement numbers from the FRFH and the tributaries.

[b] Abbreviations: CRR = Cohort Replacement Rate, Trib = tributary

Source: NMFS, March 8, 2012, p. 22.

high water temperatures, coupled with high fish densities, precipitated an outbreak of Columnaris Disease (*Flexibacter columnaris*) and Ichthyophthiriasis (*Ichthyophthirius multifiis*) in the adult spring-run Chinook salmon over-summering in Butte Creek. In 2002, this contributed to the pre-spawning mortality of approximately 20 to 30 percent of the adults. In 2003, approximately 65 percent of the adults succumbed, resulting in a loss of an estimated 11,231 adult spring-run Chinook salmon in Butte Creek.

Lindley *et al.* (2007) indicated that the spring-run population of Chinook salmon in the Central Valley had a low risk of extinction in Butte and Deer creeks, according to their population viability analysis (PVA) model and the other population viability criteria (*i.e.*, population size, population decline, catastrophic events, and hatchery influence). The Mill Creek population of spring-run Chinook salmon is at moderate extinction risk according to the PVA model, but appears to satisfy the other viability criteria for low-risk status. However, like the winter-run Chinook salmon population, the Central Valley spring-run Chinook salmon population fails to meet the "representation and redundancy rule" since there is only one demonstrably viable population out of the three diversity groups that historically contained them. The spring-run population is only represented by the group that currently occurs in the northern Sierra Nevada.

The spring-run Chinook salmon populations that formerly occurred in the basalt and porous-lava region and southern Sierra Nevada region have been extirpated. The northwestern California region contains a few ephemeral populations (*e.g.*, Clear, Cottonwood, and Thomes creeks) of spring-run Chinook salmon that are likely dependent on the Northern Sierra populations for their continued existence. Over the long term, these remaining populations are considered to be vulnerable to catastrophic events, such as volcanic eruptions from Mount Lassen or large forest fires due to the close proximity of their headwaters to each other. Drought is also considered to pose a significant threat to the viability of the spring-run Chinook salmon populations in these three watersheds due to their close proximity to each other. One large event could eliminate all three populations.

### Viable Salmonid Population Summary for Central Valley spring-run Chinook salmon

#### *Abundance*

Over the first half of the past decade, the Central Valley spring-run Chinook salmon ESU has experienced a trend of increasing abundance in some natural populations, most dramatically in the Butte Creek population (Good *et al.* 2005). There has been more opportunistic utilization of migration-dependent streams overall. The FRH spring-run Chinook salmon stock has been included in the ESU based on its genetic linkage to the natural population and the potential development of a conservation strategy for the hatchery program. In contrast to the first half of the decade, the last 5 years of adult returns indicate that population abundance is declining from the peaks seen in the 5 years prior (2001 to 2005) for the entire Sacramento River basin. The recent declines in abundance place the Mill and

Deer creek populations in the high extinction risk category due to the rate of decline, and in the case of Deer Creek, also the level of escapement. Butte Creek has sufficient abundance to retain its low extinction risk classification, but the rate of population decline in the past several years is nearly sufficient to classify it as a high extinction risk based on this criteria. Some tributaries, such as Clear Creek and Battle Creek have seen population gains, but the overall abundance numbers are still low.

***Productivity***

The 5-year geometric mean for the extant Butte, Deer, and Mill Creek spring-run Chinook salmon populations ranges from 491 to 4,513 fish (Good *et al.* 2005), indicating increasing productivity over the short-term and was projected to likely continue into the future (Good *et al.* 2005). However, as mentioned in the previous paragraph, the last 5 years of adult escapement to these tributaries has seen a cumulative decline in fish numbers and the cohort replacement rate (CRR) has declined in concert with the population declines. The productivity of the Feather River and Yuba River populations and contribution to the Central Valley spring-run ESU currently is unknown.

***Spatial Structure***

Spring-run Chinook salmon presence has been reported more frequently in several upper Central Valley creeks, but the sustainability of these runs is unknown. Butte Creek spring-run Chinook salmon cohorts have recently utilized all currently available habitat in the creek; and it is unknown if individuals have opportunistically migrated to other systems. The spatial structure of the spring-run Chinook salmon ESU has been reduced with the extirpation of all San Joaquin River basin spring-run Chinook salmon populations. In the near future, an experimental population of Central Valley spring-run Chinook salmon will likely be reintroduced into the San Joaquin River below Friant Dam as part of the San Joaquin River Settlement Agreement if NMFS finds that a permit can be issued to do so. Its long term contribution to the Central Valley spring-run Chinook salmon ESU is uncertain. The populations in Clear Creek and Battle Creek may add to the spatial structure of the Central Valley spring-run population if they can persist by colonizing waterways in the Basalt and Porous and Northwestern California Coastal Range diversity group areas.

***Diversity***

The Central Valley spring-run Chinook salmon ESU includes two genetic complexes. Analyses of natural and hatchery spring-run Chinook salmon stocks in the Central Valley indicates that the Northern Sierra Nevada spring-run Chinook salmon population complex (Mill, Deer, and Butte creeks) retains genetic integrity. The genetic integrity of the Northern Sierra Nevada spring-run Chinook salmon population complex in the Feather River has been somewhat compromised. The Feather River spring-run Chinook salmon have introgressed with the fall-run Chinook salmon, and it appears that the Yuba River population may have been impacted by FRH fish straying into the Yuba River. Additionally, the diversity of the

spring-run Chinook salmon ESU has been further reduced with the loss of the San Joaquin River basin spring-run Chinook salmon populations.

### Threatened Central Valley spring-run Chinook Salmon and Threatened Central Valley Steelhead Critical Habitat

Critical habitat was designated for Central Valley spring-run Chinook salmon and California Central Valley steelhead on September 2, 2005, (70 FR 52488). Critical habitat for Central Valley spring-run Chinook salmon includes stream reaches such as those of the Feather and Yuba rivers, Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear creeks, the Sacramento River, as well as portions of the northern Delta. Critical habitat for California Central Valley steelhead includes stream reaches such as those of the Sacramento, Feather, and Yuba Rivers, and Deer, Mill, Battle, and Antelope creeks in the Sacramento River basin; the San Joaquin River, including its tributaries, and the waterways of the Delta. Critical habitat includes the stream channels in the designated stream reaches and the lateral extent as defined by the ordinary high-water line. In areas where the ordinary high-water line has not been defined, the lateral extent will be defined by the bankfull elevation (defined as the level at which water begins to leave the channel and move into the floodplain; it is reached at a discharge that generally has a recurrence interval of 1 to 2 years on the annual flood series) (Bain and Stevenson 1999; 70 FR 52488). Critical habitat for Central Valley spring-run Chinook salmon and steelhead is defined as specific areas that contain the primary constituent elements (PCE) and physical habitat elements essential to the conservation of the species. Following are the inland habitat types used as PCEs for Central Valley spring-run Chinook salmon and California Central Valley steelhead, and as physical habitat elements for Sacramento River winter-run Chinook salmon.

PCEs for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon and California Central Valley steelhead include:

#### *Spawning Habitat*

Freshwater spawning sites are those with water quantity and quality conditions and substrate supporting spawning, incubation, and larval development. Most spawning habitat in the Central Valley for Chinook salmon and steelhead is located in areas directly downstream of dams containing suitable environmental conditions for spawning and incubation. Spawning habitat for Sacramento River winter-run Chinook salmon is restricted to the Sacramento River primarily between RBDD and Keswick Dam. Central Valley spring-run Chinook salmon also spawn on the mainstem Sacramento River between RBDD and Keswick Dam and in tributaries such as Mill, Deer, and Butte creeks (however, little spawning activity has been recorded in recent years on the Sacramento River mainstem for spring-run Chinook salmon). Spawning habitat for California Central Valley steelhead is similar in nature to the requirements of Chinook salmon, primarily occurring in reaches directly below dams (*i.e.*, above RBDD on the Sacramento River) on perennial watersheds throughout the

Central Valley. These reaches can be subjected to variations in flows and temperatures, particularly over the summer months, which can have adverse effects upon salmonids spawning below them. Even in degraded reaches, spawning habitat has a high conservation value as its function directly affects the spawning success and reproductive potential of listed salmonids.

***Freshwater Rearing Habitat***

Freshwater rearing sites are those with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large woody material, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Both spawning areas and migratory corridors comprise rearing habitat for juveniles, which feed and grow before and during their outmigration. Non-natal, intermittent tributaries also may be used for juvenile rearing. Rearing habitat condition is strongly affected by habitat complexity, food supply, and the presence of predators of juvenile salmonids. Some complex, productive habitats with floodplains remain in the system (*e.g.*, the lower Cosumnes River, Sacramento River reaches with setback levees [*i.e.*, primarily located upstream of the City of Colusa]) and flood bypasses (*i.e.*, Yolo and Sutter bypasses). However, the channelized, leveed, and riprapped river reaches and sloughs that are common in the Sacramento-San Joaquin system typically have low habitat complexity, low abundance of food organisms, and offer little protection from either fish or avian predators. Freshwater rearing habitat also has a high conservation value even if the current conditions are significantly degraded from their natural state. Juvenile life stages of salmonids are dependent on the function of this habitat for successful survival and recruitment.

***Freshwater Migration Corridors***

Ideal freshwater migration corridors are free of migratory obstructions, with water quantity and quality conditions that enhance migratory movements. They contain natural cover such as riparian canopy structure, submerged and overhanging large woody objects, aquatic vegetation, large rocks, and boulders, side channels, and undercut banks which augment juvenile and adult mobility, survival, and food supply. Migratory corridors are downstream of the spawning areas and include the lower mainstems of the Sacramento and San Joaquin rivers and the Delta. These corridors allow the upstream passage of adults, and the downstream emigration of outmigrant juveniles. Migratory habitat condition is strongly affected by the presence of barriers, which can include dams (*i.e.*, hydropower, flood control, and irrigation flashboard dams), unscreened or poorly screened diversions, degraded water quality, or behavioral impediments to migration. For successful survival and recruitment of salmonids, freshwater migration corridors must function sufficiently to provide adequate passage. For this reason, freshwater migration corridors are considered to have a high conservation value even if the migration corridors are

significantly degraded compared to their natural state.

***Estuarine Areas***

Estuarine areas free of migratory obstructions with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh and salt water are included as a PCE. Natural cover such as submerged and overhanging large woody material, aquatic vegetation, and side channels, are suitable for juvenile and adult foraging. Estuarine areas are considered to have a high conservation value as they provide factors which function to provide predator avoidance and as a transitional zone to the ocean environment.

*Source:* www.fs.fed.us.

*Photo:* Central Valley steelhead.

## 3. Threatened Central Valley steelhead *(Oncorhynchus mykiss)*

Central Valley steelhead *(Oncorhynchus mykiss),* which are the anadromous form of rainbow trout, were federally listed threatened on March 19, 1998. The DPS consists of steelhead populations in the Sacramento and San Joaquin River basins. Steelhead populations from the Coleman National Fish Hatchery and Feather River Hatchery were included in the DPS in January 2006. The threatened status of Central Valley steelhead was confirmed in 2005 (NMFS 2005), and again in August 2011 (NMFS August 2011c). In August 2011, NMFS noted that the biological status of Central Valley steelhead has worsened since 2005, and recommended that its status be reassessed in two to three years. NMFS noted that the original threats due to loss and degradation of habitat remained, and that hatcheries, drought, poor ocean conditions, and climate change posed additional threats to the species. Critical habitat was designated on September 2, 2005, and is described above. Critical habitat includes potential EDCP treatment sites. NMFS developed a draft recovery plan for Central Valley steelhead in 2009, which has not yet been finalized.

Central Valley steelhead migrate to the ocean as juveniles and return to fresh water to spawn when they are 2 to 4 years old. Spawning migration (through the Delta) can be anytime from August through March. Steelhead usually do not die after spawning. Survivors return to the ocean between April and June, and some make several more spawning migrations. Juvenile steelhead usually remain in fresh water for the first year, then migrate to the ocean between November and May. Steelhead are found in the Delta predominantly during migration.

Steelhead are primarily threatened by loss of the vast majority of historical spawning habitats above impassable dams, and mixing with hatchery fish (NMFS 2005). California began implementing measures to protect steelhead in 1998, including 100 percent marking of all hatchery steelhead, zero bag limits for unmarked

steelhead, gear restrictions, closures, and designation of size limits to protect smolts (NMFS 2007). The text below describing the status of Central Valley steelhead is drawn from the March 8, 2012 Biological Opinion of the South Delta Temporary Barriers Program (NMFS March 2012).

Steelhead can be divided into two life history types, summer-run steelhead and winter-run steelhead, based on their state of sexual maturity at the time of river entry and the duration of their spawning migration, stream-maturing and ocean-maturing. Only winter-run steelhead currently are found in Central Valley rivers and streams (McEwan and Jackson 1996), although there are indications that summer-run steelhead were present in the Sacramento river system prior to the commencement of large-scale dam construction in the 1940s [Interagency Ecological Program (IEP) Steelhead Project Work Team 1999]. At present, summer-run steelhead are found only in North Coast drainages, mostly in tributaries of the Eel, Klamath, and Trinity River systems (McEwan and Jackson 1996).

California Central Valley steelhead generally leave the ocean from August through April (Busby *et al.* 1996), and spawn from December through April with peaks from January through March in small streams and tributaries where cool, well oxygenated water is available year-round (Hallock *et al.* 1961, McEwan and Jackson 1996. **Table 4-7,** on the next page, summarizes Central Valley steelhead location and timing. Timing of upstream migration is correlated with higher flow events, such as freshets or sand bar breaches at river mouths, and associated lower water temperatures. Unlike Pacific salmon, steelhead are iteroparous, or capable of spawning more than once before death (Barnhart *et al.* 1986, Busby *et al.* 1996). However, it is rare for steelhead to spawn more than twice before dying; most that do so are females (Busby *et al.* 1996). Iteroparity is more common among southern steelhead populations than northern populations (Busby *et al.* 1996). Although one-time spawners are the great majority, Shapovalov and Taft (1954) reported that repeat spawners are relatively numerous (17.2 percent) in California streams.

Spawning occurs during winter and spring months. The length of time it takes for eggs to hatch depends mostly on water temperature. Hatching of steelhead eggs in hatcheries takes about 30 days at 51 F. Fry emerge from the gravel usually about 4 to 6 weeks after hatching, but factors such as redd depth, gravel size, siltation, and temperature can speed or retard this time (Shapovalov and Taft 1954). Newly emerged fry move to the shallow, protected areas associated with the stream margin (McEwan and Jackson 1996) and they soon move to other areas of the stream and establish feeding locations, which they defend (Shapovalov and Taft 1954).

Steelhead rearing during the summer takes place primarily in higher velocity areas in pools, although young-of-year also are abundant in glides and riffles. Productive steelhead habitat is characterized by complexity, primarily in the form of large and small woody debris. Cover is an important habitat component for juvenile steelhead both as velocity refugia and as a means of avoiding predation (Meehan and Bjornn 1991).

**Table 4-7**
**The Temporal Occurrence of Adult (a) and Juvenile (b) California Central Valley steelhead in the Central Valley**
*(Darker shades indicate months of greatest relative abundance)*

**(a) Adult migration/holding**

| Location | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [1,3]Sac. River | | | | | | | | | | | | |
| [2,3]Sac R at Red Bluff | | | | | | | | | | | | |
| [4]Mill, Deer Creeks | | | | | | | | | | | | |
| [6]Sac. R. at Fremont Weir | | | | | | | | | | | | |
| [6]Sac. R. at Fremont Weir | | | | | | | | | | | | |
| [7]San Joaquin River | | | | | | | | | | | | |

**(b) Juvenile migration**

| Location | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [1,2]Sacramento River | | | | | | | | | | | | |
| [2,8]Sac. R at Knights Landing | | | | | | | | | | | | |
| [9]Sac. River @ Knights Landing | | | | | | | | | | | | |
| [10]Chipps Island (wild) | | | | | | | | | | | | |
| [8]Mossdale | | | | | | | | | | | | |
| [11]Woodbridge Dam | | | | | | | | | | | | |
| [12]Stan R. at Caswell | | | | | | | | | | | | |
| [13]Sac R. at Hood | | | | | | | | | | | | |

Relative Abundance: ■ = High ■ = Medium □ = Low

Sources: [1]Hallock 1961; [2]McEwan 2001; [3]USFWS unpublished data; [4]CDFG 1995; [5]Hallock *et al.* 1957; [6]Bailey 1954; [7]CDFG Steelhead Report Card Data; [8]CDFG unpublished data; [9]Snider and Titus 2000; [10]Nobriga and Cadrett 2003; [11]Jones & Stokes Associates, Inc., 2002; [12]S.P. Cramer and Associates, Inc. 2000 and 2001; [13]Schaffter 1980, 1997.

Source: NMFS, March 8, 2012, p. 25.

Juvenile steelhead emigrate episodically from natal streams during fall, winter, and spring high flows. Emigrating California Central Valley steelhead use the lower reaches of the Sacramento River and the Delta for rearing and as a migration corridor to the ocean. Juvenile California Central Valley steelhead feed mostly on drifting aquatic organisms and terrestrial insects and will also take active bottom invertebrates (Moyle 2002). Some may utilize tidal marsh areas, non-tidal freshwater marshes, and other shallow water areas in the Delta as rearing areas for short periods prior to their final emigration to the sea. Hallock *et al.* (1961) found that juvenile steelhead in the Sacramento River basin migrate downstream during most months of the year, but the peak period of emigration occurred in the spring, with a much smaller peak in the fall. Nobriga

and Cadrett (2003) also have verified these temporal findings based on analysis of captures at Chipps Island.

Historic California Central Valley steelhead run sizes are difficult to estimate given the paucity of data, but may have approached 1 to 2 million adults annually (McEwan 2001). By the early 1960s the steelhead run size had declined to about 40,000 adults (McEwan 2001). Over the past 30 years, the naturally-spawned steelhead populations in the upper Sacramento River have declined substantially. Hallock *et al.* (1961) estimated an average of 20,540 adult steelhead through the 1960s in the Sacramento River, upstream of the Feather River. Steelhead counts at the RBDD declined from an average of 11,187 for the period of 1967 to 1977, to an average of approximately 2,000 through the early 1990s, with an estimated total annual run size for the entire Sacramento-San Joaquin system, based on RBDD counts, to be no more than 10,000 adults (McEwan and Jackson 1996, McEwan 2001). Steelhead escapement surveys at RBDD ended in 1993 due to changes in dam operations. Nobriga and Cadrett (2003) compared CWT and untagged (wild) steelhead smolt catch ratios at Chipps Island trawl from 1998 through 2001 to estimate that about 100,000 to 300,000 steelhead juveniles are produced naturally each year in the Central Valley. In the *Updated Status Review of West Coast Salmon and Steelhead* (Good *et al.* 2005), the Biological Review Team (BRT) made the following conclusion based on the Chipps Island data:

> *"If we make the fairly generous assumptions (in the sense of generating large estimates of spawners) that average fecundity is 5,000 eggs per female, 1 percent of eggs survive to reach Chipps Island, and 181,000 smolts are produced (the 1998-2000 average), about 3,628 female steelhead spawn naturally in the entire Central Valley. This can be compared with McEwan's (2001) estimate of 1 million to 2 million spawners before 1850, and 40,000 spawners in the 1960s".*

Existing wild steelhead stocks in the Central Valley are mostly confined to the upper Sacramento River and its tributaries, including Antelope, Deer, and Mill creeks and the Yuba River. Populations may exist in Big Chico and Butte creeks and a few wild steelhead are produced in the American and Feather rivers (McEwan and Jackson 1996). Recent snorkel surveys (1999 to 2002) indicate that steelhead are present in Clear Creek (J. Newton, USFWS, pers. comm. 2002, as reported in Good *et al*. 2005). Because of the large resident *O. mykiss* population in Clear Creek, steelhead spawner abundance has not been estimated.

Until recently, California Central Valley steelhead were thought to be extirpated from the San Joaquin River system. Recent monitoring has detected small self-sustaining populations of steelhead in the Stanislaus, Mokelumne, and Calaveras rivers, and other streams previously thought to be devoid of steelhead (McEwan 2001). On the Stanislaus River, steelhead smolts have been captured in rotary screw traps at Caswell State Park and Oakdale each year since 1995 (S.P. Cramer and Associates Inc. 2000, 2001). Zimmerman *et al.* (2008) has documented Central Valley steelhead in the Stanislaus, Tuolumne and Merced rivers based on otolith (inner ear) microchemistry.

It is possible that naturally-spawning populations exist in many other streams but are undetected due to lack of monitoring programs (IEP Steelhead Project Work Team 1999). Incidental catches and observations of steelhead juveniles also have occurred on the Tuolumne and Merced Rivers during fall-run Chinook salmon monitoring activities, indicating that steelhead are widespread, throughout accessible streams and rivers in the Central Valley (Good *et al*. 2005). California Department of Fish and Game (CDFG) staff have prepared catch summaries for juvenile migrant California Central Valley steelhead on the San Joaquin River near Mossdale which represents migrants from the Stanislaus, Tuolumne, and Merced rivers. Based on trawl recoveries at Mossdale between 1988 and 2002, as well as rotary screw trap efforts in all three tributaries, CDFG staff stated that it is "clear from this data that rainbow trout do occur in all the tributaries as migrants and that the vast majority of them occur on the Stanislaus River" (Letter from Dean Marston, CDFG, to Michael Aceituno, NMFS, 2004). The documented returns on the order of single fish in these tributaries suggest that existing populations of California Central Valley steelhead on the Tuolumne, Merced, and lower San Joaquin rivers are severely depressed.

Lindley *et al*. (2006) indicated that prior population census estimates completed in the 1990s found the California Central Valley steelhead spawning population above RBDD had a fairly strong negative population growth rate and small population size. Good *et al.* (2005) indicated the decline was continuing as evidenced by new information (Chipps Island trawl data). California Central Valley steelhead populations generally show a continuing decline, an overall low abundance, and fluctuating return rates. The future of California Central Valley steelhead is uncertain due to limited data concerning their status. However, Lindley *et al.* (2007), citing evidence presented by Yoshiyama *et al.* (1996); McEwan (2001); and Lindley *et al.* (2006), concluded that there is sufficient evidence to suggest that the DPS is at moderate to high risk of extinction.

### Viable Salmonid Population Summary for Central Valley steelhead

#### *Abundance*

All indications are that natural California Central Valley steelhead have continued to decrease in abundance and in the proportion of natural fish over the past 25 years (Good *et al.* 2005); the long-term trend remains negative. There has been little steelhead population monitoring, despite 100 percent marking of hatchery steelhead since 1998. Hatchery production and returns are dominant over natural fish and include significant numbers of non-DPS-origin Eel River steelhead stock. Continued decline in the ratio between wild juvenile steelhead to hatchery juvenile steelhead in fish monitoring efforts indicates that the wild population abundance is declining. Hatchery releases (100 percent adipose fin clipped fish since 1998) have remained relatively constant over the past decade, yet the proportion of ad-clipped fish to wild adipose fin bearing fish has steadily increased over the past several years.

### *Productivity*

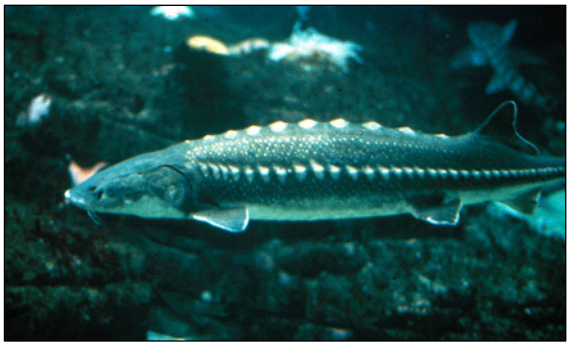
Approximatley 100,000 to 300,000 natural juvenile steelhead are estimated to leave the Central Valley annually, based on rough calculations from sporadic catches in trawl gear (Good *et al.* 2005). Concurrently, one million in-DPS hatchery steelhead smolts and another half million out-of-DPS hatchery steelhead smolts are released annually in the Central Valley. The estimated ratio of nonclipped to clipped steelhead has decreased from 0.3 percent to less than 0.1 percent, with a net decrease to one-third of wild female spawners from 1998 to 2000 (Good *et al.* 2005). Recent data from the Chipps Island fish monitoring trawls indicates that in recent years over 90 percent of captured steelhead smolts have been of hatchery origin. In 2010, the data indicated hatchery fish made up 95 percent of the catch.

### *Spatial Structure*

Steelhead appear to be well-distributed where found throughout the Central Valley (Good *et al.* 2005). Until recently, there was very little documented evidence of steelhead due to the lack of monitoring efforts. Since 2000, steelhead have been confirmed in the Stanislaus and Calaveras rivers. The efforts to provide passage of salmonids over impassable dams may increase the spatial diversity of California Central Valley steelhead populations if the passage programs are implemented for steelhead.

### *Diversity*

Analysis of natural and hatchery steelhead stocks in the Central Valley reveal genetic structure remaining in the DPS (Nielsen *et al.* 2003). There appears to be a great amount of gene flow among upper Sacramento River basin stocks, due to the post-dam, lower basin distribution of steelhead and management of stocks. Recent reductions in natural population sizes have created genetic bottlenecks in several California Central Valley steelhead stocks (Good *et al.* 2005; Nielsen *et al.* 2003). The out-of-basin steelhead stocks of the Nimbus and Mokelumne River hatcheries are not included in the California Central Valley steelhead DPS.



*Source:* www.delta.dfg.ca.gov.

*Photo:* Green Sturgeon.

## 4. Threatened Southern Distinct Population Segment (DPS) of North American green sturgeon *(Acipenser medirostris)*

Green sturgeon *(Acipenser meditrostris)* southern population (south of the Eel River), found in San Francisco Bay and the Delta, and spawning in the Sacramento River, was designated as a federal threatened species by NMFS in July 2006. Critical habitat was designated in October 2009. Take prohibitions were established in June 2010. The Southern DPS is separate from green sturgeon found at the Eel River and north to

British Columbia (NMFS February 2005). The green sturgeon is also listed as a California species of concern by CDFG. Relatively little is known about the biology and population characteristics of green sturgeon. There are many studies currently underway by a number of universities and state and federal agencies to better understand the distribution, migration, spawning habitat utilization, and population genetics of green sturgeon (NMFS 2011).

Green sturgeon appear to inhabit the Delta during their second and third years, although adult sturgeon migrate through the Delta to spawning grounds on the Upper Sacramento River between mid-February and May. Adults spend most of their time in the ocean, and may migrate as far north as British Columbia. Adults spawn every three to five years.

In June 2011, NMFS and DFG biologists rescued over 200 fish that had been trapped in bypass channels of the Sacramento River by high water (NMFS June 2011). There were 25 green sturgeon among the rescued fish, including one with a total length of over seven feet, a girth of 36 inches, and weight of at least 250 pounds. The rescued green sturgeon were implanted with tracking devices to help gain more information on sturgeon movement.

The text below describing the green sturgeon in more detail is drawn from the March 8, 2012 Biological Opinion of the South Delta Temporary Barriers Program (NMFS March 2012).

In North America, spawning populations of green sturgeon are currently found in only three river systems: the Sacramento and Klamath rivers in California and the Rogue River in southern Oregon. Green sturgeon are known to range from Baja California to the Bering Sea along the North American continental shelf. Data from commercial trawl fisheries and tagging studies indicate that the green sturgeon occupy waters within the 110 meter contour (Erickson and Hightower 2007). During the late summer and early fall, subadults and nonspawning adult green sturgeon frequently can be found aggregating in estuaries along the Pacific coast (Emmett *et al.* 1991, Moser and Lindley 2007). Particularly large concentrations of green sturgeon from both the northern and southern populations occur in the Columbia River estuary, Willapa Bay, Grays Harbor and Winchester Bay, with smaller aggregations in Humboldt Bay, Tillamook Bay, Nehalem Bay, and San Francisco and San Pablo Bays (Emmett *et al* 1991, Moyle *et al.* 1992, and Beamesderfer *et al.* 2007). Lindley *et al.* (2008) reported that green sturgeon make seasonal migratory movements along the west coast of North America, overwintering north of Vancouver Island and south of Cape Spencer, Alaska.

Individual fish from the Southern DPS of green sturgeon have been detected in these seasonal aggregations. Information regarding the migration and habitat use of the Southern DPS of green sturgeon has recently emerged. Lindley (2006) presented preliminary results of large-scale green sturgeon migration studies, and verified past population structure delineations based on genetic work and found frequent large-scale migrations of green sturgeon along the Pacific Coast. This work was further expanded by recent tagging studies of green sturgeon conducted by Erickson and

Hightower (2007) and Lindley *et al.* (2008). To date, the data indicates that North American green sturgeon are migrating considerable distances up the Pacific Coast into other estuaries, particularly the Columbia River estuary. This information also agrees with the results of previous green sturgeon tagging studies (CDFG 2002), where CDFG tagged a total of 233 green sturgeon in the San Pablo Bay estuary between 1954 and 2001. A total of 17 tagged fish were recovered: 3 in the Sacramento-San Joaquin Estuary, 2 in the Pacific Ocean off of California, and 12 from commercial fisheries off of the Oregon and Washington coasts. Eight of the 12 recoveries were in the Columbia River estuary (CDFG 2002).

The Southern DPS of green sturgeon includes all green sturgeon populations south of the Eel River, with the only known spawning population being in the Sacramento River. Green sturgeon life history can be broken down into four main stages: eggs and larvae, juveniles, sub-adults, and sexually mature adults. Sexually mature adults are those fish that have fully developed gonads and are capable of spawning. Female green sturgeon are typically 13 to 27 years old when sexually mature and have a total body length (TL) ranging between 145 and 205 cm at sexual maturity (Nakamoto *et al. 1995*, Van Eenennaam *et al.* 2006). Male green sturgeon become sexually mature at a younger age and smaller size than females. Typically, male green sturgeon reach sexual maturity between 8 and 18 years of age and have a TL ranging between 120 cm to 185 cm (Nakamoto *et al. 1995*, Van Eenennaam *et al.* 2006). The variation in the size and age of fish upon reaching sexual maturity is a reflection of their growth and nutritional history, genetics, and the environmental conditions they were exposed to during their early growth years. Adult green sturgeon are believed to feed primarily upon benthic invertebrates such as clams, mysid shrimp, grass shrimp, and amphipods (Radtke 1966). Adult sturgeon caught in Washington state waters were found to have fed on Pacific sand lance (*Ammodytes hexapterus*) and callianassid shrimp (Moyle *et al.* 1992). It is unknown what forage species are consumed by adults in the Sacramento River upstream of the Delta.

Adult green sturgeon are gonochoristic (sex genetically fixed), oviparous (egg laying) and iteroparous (bare repeat offspring). They are believed to spawn every 2 to 5 years (Beamesderfer *et al.* 2007). Upon maturation of their gonadal tissue, but prior to ovulation or spermiation, the sexually mature fish enter freshwater and migrate upriver to their spawning grounds. The remainder of the adult's life is generally spent in the ocean or near-shore environment (bays and estuaries) without venturing upriver into freshwater. Younger females may not spawn the first time they undergo oogenesis and subsequently they reabsorb their gametes without spawning. Adult female green sturgeon produce between 60,000 and 140,000 eggs, depending on body size, with a mean egg diameter of 4.3 mm (Moyle *et al.* 1992, Van Eenennaam *et al.* 2001). They have the largest egg size of any sturgeon, and the volume of yolk ensures an ample supply of energy for the developing embryo. The outside of the eggs are adhesive, and are more dense than those of white sturgeon (Kynard *et al.* 2005, Van Eenennaam *et al.* 2009).

Adults begin their upstream spawning migrations into the Sacramento River in late February with spawning occurring between March and July (CDFG 2002. Heublin 2006, Heublin *et al.* 2009, Vogel 2008). Peak spawning is believed to occur between April and June in deep, turbulent, mainstem channels over large cobble and rocky substrates with crevices and interstices. Females broadcast spawn their eggs over this substrate, while the male releases its milt (sperm) into the water column. Fertilization occurs externally in the water column and the fertilized eggs sink into the interstices of the substrate where they develop further (Kynard *et al.* 2005, Heublin *et al.* 2009). Known historic and current spawning occurs in the Sacramento River (Adams *et al.* 2002, Beamesderfer *et al.* 2004, Adams *et al.* 2007). Currently, Keswick and Shasta dams on the mainstem of the Sacramento River block passage to the upper river. Although no historical accounts exist for identified green sturgeon spawning occuring above the current dam sites, suitable spawning habitat existed and the geographic extent of spawning has been reduced due to the impassable barriers constructed on the river.

Spawning on the Feather River is suspected to have occurred in the past due to the continued presence of adult green sturgeon in the river below Oroville Dam. This continued presence of adults below the dam suggests that fish are trying to migrate to upstream spawning areas now blocked by the dam, which was constructed in 1968. In 2011, fertilized green sturgeon eggs were recovered during monitoring activities by DWR on the Feather River and several adult green sturgeon were recorded on video congregating below Daguerre Dam on the Yuba River. Spawning in the San Joaquin River system has not been recorded historically or observed recently.

Kelly *et al.* (2007) indicated that green sturgeon enter the San Francisco Estuary during the spring and remain until autumn. **Table 4-8,** on the next page, summarizes green sturgeon location and timing. The authors studied the movement of adults in the San Francisco Estuary and found them to make significant long-distance movements with distinct directionality. The movements were not found to be related to salinity, current, or temperature, and Kelly *et al.* (2007) surmised that they are related to resource availability and foraging behavior. Recent acoustical tagging studies on the Rogue River (Erickson *et al.* 2002) have shown that adult green sturgeon will hold for as much as 6 months in deep (> 5m), low gradient reaches or off channel sloughs or coves of the river during summer months when water temperatures were between 15 C and 23 C. When ambient temperatures in the river dropped in autumn and early winter (<10 C) and flows increased, fish moved downstream and into the ocean. Erickson *et al.* (2002) surmised that this holding in deep pools was to conserve energy and utilize abundant food resources. Benson *et al.* (2007) found similar behavior on the Klamath and Trinity River systems with adult sturgeon acoustically tagged during their spawning migrations. Most fish held over the summer in discrete locations characterized by deep, low velocity pools until late fall or early winter when river flows increased with the first storms of the rainy season. Fish then moved rapidly downstream and out of the system.

**Table 4-8**

**The Temporal Occurrence of (a) Adult, (b) Larva, (c) Juvenile, and (d) Subadult Coastal Migrant Southern DPS of green sturgeon.** (Locations emphasize the Central Valley of California)
*(Darker shades indicate months of greatest relative abundance)*

**(a) Adult-sexually mature (≥145 – 205 cm TL for females and ≥ 120 – 185 cm TL old for males**

| Location | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Upper Sac. River[a,b,c,i] | | | | | | | | | | | | |
| SF Bay Estuary[d,h,i] | | | | | | | | | | | | |

**(b) Larval and juvenile (≤ 10 months old)**

| Location | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RBDD, Sac River[c] | | | | | | | | | | | | |
| GCID, Sac River[c] | | | | | | | | | | | | |

**(c) Older Juvenile (> 10 months old and ≤ 3 years old)**

| Location | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| South Delta*[f] | | | | | | | | | | | | |
| Sac-SJ Delta[f] | | | | | | | | | | | | |
| Sac-SJ Delta[e] | | | | | | | | | | | | |
| Suisun Bay[e] | | | | | | | | | | | | |

**(d) Sub-Adult/non-sexually mature (approx. 75 cm to 145 cm for females and 75 to 120 cm for males)**

| Location | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pacific Coast[c,g] | | | | | | | | | | | | |

Relative Abundance: ■ = High ■ = Medium □ = Low

* Fish Facility salvage operations

Sources: [a]USFWS (2002); [b]Moyle *et al.* (1992); [c]Adams *et al.* (2002) and NMFS (2005a); [d]Kelly *et al.* (2007); [e]CDFG (2002); [f]IEP Relational Database, fall midwater trawl green sturgeon captures from 1969 to 2003; [g]Nakamoto *et al.* (1995); [h]Heublein (2006); [i]CDFG Draft Sturgeon Report Card (2007)

Source: NMFS, March 8, 2012, p. 33.

Recent data gathered from acoustically tagged adult green sturgeon revealed comparable behavior by adult fish on the Sacramento River based on the positioning of adult green sturgeon in holding pools on the Sacramento River above the Glenn Colusa Irrigation District (GCID) diversion (river mile (RM) 205). Studies by Heublin (2006, 2009) and Vogel (2008) have documented the presence of adults in the Sacramento River during the spring and through the fall into the early winter months. These fish hold in upstream locations prior to their emigration from the system later in the year. Like the Rogue and Klamath river systems, downstream migration appears to be triggered by increased flows, decreasing water temperatures, and occurs rapidly once initiated. It should also be noted that some adults rapidly leave the system following

their suspected spawning activity and enter the ocean only in early summer (Heublin 2006). This behavior has also been observed on the other spawning rivers (Benson *et al.* 2007*)* but may have been an artifact of the stress of the tagging procedure in that study.

### *Eggs and Larvae*

Currently spawning appears to occur primarily above Red Bluff Diversion Dam (RBDD), based on the recovery of eggs and larvae at the dam in monitoring studies (Gaines and Martin 2002, Brown 2007). Green sturgeon larvae hatch from fertilized eggs after approximately 169 hours at a water temperature of 59 F (Van Eenennaam *et al.* 2001, Deng *et al.* 2002), which is similar to the sympatric white sturgeon development rate (176 hours). Studies conducted at the University of California, Davis by Van Eenennaam *et al.* (2005) indicated that an optimum range of water temperature for egg development ranged between 57.2 F and 62.6 F. Temperatures over 23 C (73.4 F) resulted in 100 percent mortality of fertilized eggs before hatching. Eggs incubated at water temperatures between 63.5 F and 71.6 F resulted in elevated mortalities and an increased occurrence of morphological abnormalities in those eggs that did hatch. At incubation temperatures below 57.2 F, hatching mortality also increased significantly, and morphological abnormalities increased slightly, but not statistically so.

Newly hatched green sturgeon are approximately 12.5mm to 14.5 mm in length and have a large ovoid yolk sac that supplies nutritional energy until exogenous feeding occurs. These yolksac larvae are less developed in their morphology than older juveniles and external morphology resembles a "tadpole" with a continuous fin fold on both the dorsal and ventral sides of the caudal trunk. At 10 days of age, the yolk sac has become greatly reduced in size and the larvae initiates exogenous feeding through a functional mouth. The fin folds have become more developed and formation of fin rays begins to occur in all fin tissues. By 45 days of age, the green sturgeon larvae have completed their metamorphosis, which is characterized by the development of dorsal, lateral, and ventral scutes, elongation of the barbels, rostrum, and caudal peduncle, reabsorption of the caudal and ventral fin folds, and the development of fin rays.

The juvenile fish resembles the adult form, including the dark olive coloring, with a dark mid-ventral stripe (Deng *et al.* 2002) and are approximately 75 mm TL. At this stage of development, the fish are considered juveniles and are no longer larvae. Juvenile fish continue to exhibit nocturnal behavioral beyond the metamorphosis from larvae to juvenile stages. Kynard *et al.*'s (2005) laboratory studies indicated that juvenile fish continued to migrate downstream at night for the first 6 months of life. When ambient water temperatures reached 46.4 F, downstream migrational behavior diminished and holding behavior increased. This data suggests that 9 to 10 month old fish would hold over in their natal rivers during the ensuing winter following hatching, but at a location downstream of their spawning grounds.

Green sturgeon juveniles tested under laboratory conditions had optimal bioenergetics performance (*i.e.* growth, food conversion, swimming ability) between 59 F

and 66.2 F under either full or reduced rations (Mayfield and Cech 2004). This temperature range overlaps the egg incubation temperature range for peak hatching success previously discussed. Ambient water temperature conditions in the Rogue and Klamath River systems range from 39 F to approximately 75.2 F. The Sacramento River has similar temperature profiles, and, like the previous two rivers, is a regulated system with several dams controlling flows on its mainstem (Shasta and Keswick dams), and its tributaries (Whiskeytown, Oroville, Folsom, and Nimbus dams).

Larval and juvenile green sturgeon are subject to predation by both native and introduced fish species. Prickly sculpin (*Cottus asper*) have been shown to be an effective predator on the larvae of sympatric white sturgeon (Gadomski and Parsley 2005). This study also indicated that the lowered turbidity found in tailwater streams and rivers due to dams increased the effectiveness of sculpin predation on sturgeon larvae under laboratory conditions.

Larval and juvenile sturgeons have been caught in traps at two sites in the upper Sacramento River: below the RBDD (RM 243) and from the GCID pumping plant (RM 205) (CDFG 2002). Larvae captured at the RBDD site are typically only a few days to a few weeks old, with lengths ranging from 24 mm to 31 mm. This body length is equivalent to 15 to 28 days post hatch as determined by Deng *et al.* (2002). Recoveries of larvae at the RBDD rotary screw traps (RSTs) occur between late April/early May and late August with the peak of recoveries occurring in June (1995 to 1999 and 2003 to 2008 data). The mean yearly total length of post-larval green sturgeon captured in the GCID rotary screw trap, approximately 30 miles downstream of RBDD, ranged from 33 mm to 44 mm between 1997 and 2005 (CDFG, 2002) indicating they are approximately 3 to 4 weeks old (Van Eenennaam *et al.* 2001, Deng *et al.* 2002). Taken together, the average length of larvae captured at the two monitoring sites indicate that fish were hatched upriver of the monitoring site and drifted downstream over the course of 2 to 4 weeks of growth.

According to the CDFG document commenting on the NMFS proposal to list the southern DPS (CDFG 2002), some green sturgeon rear to larger sizes above RBDD, or move back to this location after spending time downstream. Two sturgeon between 180 mm and 400 mm TL were captured in the rotary-screw trap during 1999 and green sturgeon within this size range have been impinged on diffuser screens associated with a fish ladder at RBDD (K. Brown, USFWS, pers. comm. as cited in CDFG 2002). Juvenile green sturgeon have been salvaged at the Harvey O. Banks Pumping Plant and the John E. Skinner Fish Collection Facility in the south Delta, and captured in trawling studies by CDFG during all months of the year (CDFG 2002). The majority of these fish were between 200 mm and 500 mm, indicating they were from 2 to 3 years of age based on Klamath River age distribution work by Nakamoto *et al.* (1995). The lack of a significant proportion of juveniles smaller than approximately 200 mm in Delta captures indicates that juveniles of the Southern DPS of green sturgeon likely

hold in the mainstem Sacramento River, as suggested by Kynard *et al.* (2005).

Population abundance information concerning the Southern DPS green sturgeon is described in the NMFS status reviews (Adams *et al*. 2002, NMFS 2005a). Limited population abundance information comes from incidental captures of North American green sturgeon from the white sturgeon monitoring program by the CDFG sturgeon tagging program (CDFG 2002). By comparing ratios of white sturgeon to green sturgeon captures, CDFG provides estimates of adult and sub-adult North American green sturgeon abundance. Estimated abundance between 1954 and 2001 ranged from 175 fish to more than 8,000 per year and averaged 1,509 fish per year. Unfortunately, there are many biases and errors associated with these data, and CDFG does not consider these estimates reliable. Fish monitoring efforts at RBDD and GCID on the upper Sacramento River have captured between 0 and 2,068 juvenile North American green sturgeon per year (Adams *et al*. 2002). The only existing information regarding changes in the abundance of the Southern DPS of green sturgeon includes changes in abundance at the John E. Skinner Fish Facility between 1968 and 2001. The average number of North American green sturgeon taken per year at the State Facility prior to 1986 was 732; from 1986 on, the average per year was 47 (70 FR 17386, April 6, 2005). For the Harvey O. Banks Pumping Plant, the average number prior to 1986 was 889; from 1986 to 2001 the average was 32 (70 FR 17386, April 6, 2005). In light of the increased exports, particularly during the previous 10 years, it is clear that the abundance of the Southern DPS green sturgeon is dropping. Additional analysis of North American green and white sturgeon taken at the Fish Facilities indicates that take of both North American green and white sturgeon per acre-foot of water exported has decreased substantially since the 1960s (70 FR 17386, April 6, 2005). No green sturgeon were recovered at either the CVP or SWP in 2010. Catches of subadult and adult North American green sturgeon by the IEP between 1996 and 2004 ranged from 1 to 212 green sturgeon per year (212 occurred in 2001), however, the portion of the Southern DPS of North American green sturgeon is unknown as these captures were primarily located in San Pablo Bay which is known to consist of a mixture of Northern and Southern DPS North American green sturgeon. Recent spawning population estimates using sibling based genetics by Israel (2006b) indicates spawning populations of 32 spawners in 2002, 64 in 2003, 44 in 2004, 92 in 2005, and 124 in 2006 above RBDD (with an average of 71).

As described previously, the majority of spawning by green sturgeon in the Sacramento River system appears to take place above the location of RBDD. This is based on the length and estimated age of larvae captured at RBDD (approximately 2–3 weeks of age) and GCID (downstream, approximately 3–4 weeks of age) indicating that hatching occurred above the sampling location. Note that there are many assumptions with this interpretation (*i.e.*, equal sampling efficiency and distribution of larvae across channels) and this information should be considered cautiously.

Available information on green sturgeon indicates that, as with winter-run Chinook salmon, the mainstem Sacramento River may be the last viable spawning habitat (Good *et al.* 2005) for the Southern DPS of green sturgeon. Lindley *et al.* (2007) pointed out that an ESU represented by a single population at moderate risk is at a high risk of extinction over the long term. Although the extinction risk of the Southern DPS of green sturgeon has not been assessed, NMFS believes that the extinction risk has increased because there is only one known population, that which is spawning within the mainstem Sacramento River.

#### Population Viability Summary for the Southern DPS of North American green sturgeon

The Southern DPS of North American green sturgeon has not been analyzed to characterize the status and viability as has been done in recent efforts for Central Valley salmonid populations (Lindley *et al*. 2006, Good *et al.* 2005). NMFS assumes that the general categories for assessing salmonid population viability will also be useful in assessing the viability of the Southern DPS of green sturgeon. The following summary has been compiled from the best available data and information on North American green sturgeon to provide a general synopsis of the viability parameters for this DPS.

***Abundance***

Currently, there are no reliable data on population sizes, and data on population trends is also lacking. Fishery data collected at Federal and State pumping facilities in the Delta indicate a decreasing trend in abundance between 1968 and 2006 (70 FR 17386). Captures of larval green sturgeon in the RBDD rotary screw traps have shown variable trends in spawning success in the upper river over the past several years and have been complicated by the operations of the RBDD gates during the green sturgeon spawning season in previous years. In 2011, a wet year in the Sacramento River, captures in the rotary screw trap have been substantially higher than in previous years. The last strong year class, based on captures of larval sturgeon, was in 1995. This would suggest that the 2011 year class for green sturgeon will be a strong year class.

***Productivity***

There is insufficient information to evaluate the productivity of green sturgeon. However, as indicated above, there appears to be a declining trend in abundance, which indicates low to negative productivity.

***Spatial Structure***

Current data indicates that the Southern DPS of North American green sturgeon is made up of a single spawning population in the Sacramento River. Although some individuals have been observed in the Feather and Yuba rivers, it is not yet known if these fish represent separate spawning populations or are strays from the mainstem Sacramento River. Therefore, the apparent presence of a single reproducing population puts the DPS at risk, due to the limited spatial structure. As mentioned previously, the confirmed presence of fertilized green sturgeon eggs in the Feather River suggests that spawning can occur in that river, at least during wet years

with sustained high flows. Likewise, observations of several adult green sturgeons congregating below Daguerre Dam on the Yuba River suggests another potential spawning area.

Consistent use of these two different river areas by green sturgeon exhibiting spawning behavior or by the collection of fertilized eggs and/or larval green sturgeon would indicate that a second spawning population of green sturgeon may exist in the Sacramento River basin besides that which has been identified in the upper reaches of the Sacramento River below Keswick Dam.

#### *Diversity*

Green sturgeon genetic analyses shows strong differentiation between northern and southern populations, and therefore, the species was divided into Northern and Southern DPSs. However, the genetic diversity of the Southern DPS is not well understood.

### Threatened Southern Distinct Population Segment (DPS) of North American green sturgeon Critical Habitat

Critical habitat was designated for the Southern DPS of North American green sturgeon on October 9, 2009 (74 FR 52300). Critical habitat for Southern DPS green sturgeon includes the stream channels and waterways in the Sacramento – San Joaquin River Delta to the ordinary high water line except for certain excluded areas. Critical habitat also includes the main stem Sacramento River upstream from the I Street Bridge to Keswick Dam, and the Feather River upstream to the fish barrier dam adjacent to the Feather River Fish Hatchery. Coastal marine areas include waters out to a depth of 60 meters from Monterey Bay, California, to the Juan De Fuca Straits in Washington. Coastal estuaries designated as critical habitat include San Francisco Bay, Suisun Bay, San Pablo Bay, and the lower Columbia River estuary. Certain coastal bays and estuaries in California (Humboldt Bay), Oregon (Coos Bay, Winchester Bay, Yaquina Bay, and Nehalem Bay), and Washington (Willapa Bay and Grays Harbor) are also included as critical habitat for Southern DPS green sturgeon. Only the critical habitat within the Delta fall within the EDCP treatment area.

Critical habitat for the Southern DPS of North American green sturgeon includes the estuarine waters of the Delta, which contain the following elements:

#### *Food Resources*

Abundant food items within estuarine habitats and substrates for juvenile, subadult, and adult life stages are required for the proper functioning of this PCE for green sturgeon. Prey species for juvenile, subadult, and adult green sturgeon within bays and estuaries primarily consist of benthic invertebrates and fish, including crangonid shrimp, callianassid shrimp, burrowing thalassinidean shrimp, amphipods, isopods, clams, annelid worms, crabs, sand lances, and anchovies. These prey species are critical for the rearing, foraging, growth, and development of juvenile, subadult, and adult green sturgeon within the bays and estuaries.

***Water Flow***

Within bays and estuaries adjacent to the Sacramento River (*i.e.*, the Sacramento-San Joaquin Delta and the Suisun, San Pablo, and San Francisco bays), sufficient flow into the bay and estuary to allow adults to successfully orient to the incoming flow and migrate upstream to spawning grounds is required. Sufficient flows are needed to attract adult green sturgeon to the Sacramento River from the bay and to initiate the upstream spawning migration into the upper river.

***Water Quality***

Adequate water quality, including temperature, salinity, oxygen content, and other chemical characteristics, is necessary for normal behavior, growth, and viability of all life stages. Suitable water temperatures for juvenile green sturgeon should be below 24 C (75 F). At temperatures above 24 C, juvenile green sturgeon exhibit decreased swimming performance (Mayfield and Cech 2004) and increased cellular stress (Allen *et al.* 2006). Suitable salinities in the estuary range from brackish water (10 parts per thousand - ppt) to salt water (33 ppt). Juveniles transitioning from brackish to salt water can tolerate prolonged exposure to salt water salinities, but may exhibit decreased growth and activity levels (Allen and Cech 2007), whereas subadults and adults tolerate a wide range of salinities (Kelly *et al.* 2007). Subadult and adult green sturgeon occupy a wide range of dissolved oxygen (DO) levels (Kelly *et al.* 2007, Moser and Lindley 2007). Adequate levels of DO are also required to support oxygen consumption by juveniles (ranging from 61.78 to 76.06 mg O2/hr$^{-1}$ kg$^{-1}$, Allen and Cech 2007). Suitable water quality also includes water free of contaminants (*e.g.*, organochlorine pesticides, poly aromatic hydrocarbons (PAHs), or elevated levels of heavy metals) that may disrupt the normal development of juvenile life stages, or the growth, survival, or reproduction of subadult or adult stages. Green sturgeon have recently been identified by UC Davis researchers as being highly sensitive to selenium levels.

***Migratory Corridor***

Safe and unobstructed migratory pathways are necessary for the safe and timely passage of adult, sub-adult, and juvenile fish within the region's different estuarine habitats and between the upstream riverine habitat and the marine habitats. Within the waterways comprising the Delta, and bays downstream of the Sacramento River, safe and unobstructed passage is needed for juvenile green sturgeon during the rearing phase of their life cycle. Rearing fish need the ability to freely migrate from the river through the estuarine waterways of the delta and bays and eventually out into the ocean. Passage within the bays and the Delta is also critical for adults and subadults for feeding and summer holding, as well as to access the Sacramento River for their upstream spawning migrations and to make their outmigration back into the ocean. Within bays and estuaries outside of the Delta and the areas comprised by Suisun, San Pablo, and San Francisco bays, safe and unobstructed passage is necessary for adult and subadult green sturgeon to access feeding areas, holding areas, and thermal refugia, and to ensure passage back out into the ocean.

### *Water Depth*

A diversity of depths is necessary for shelter, foraging, and migration of juvenile, subadult, and adult life stages. Tagged adults and subadults within the San Francisco Bay estuary primarily occupied waters over shallow depths of less than 10 m, either swimming near the surface or foraging along the bottom (Kelly *et al*. 2007). In a study of juvenile green sturgeon in the Delta, relatively large numbers of juveniles were captured primarily in shallow waters from 3 to 8 feet deep, indicating juveniles may require shallower depths for rearing and foraging (Radtke 1966). Thus, a diversity of depths is important to support different life stages and habitat uses for green sturgeon within estuarine areas.

### *Sediment Quality*

Sediment quality (*i.e.*, chemical characteristics) is necessary for normal behavior, growth, and viability of all life stages. This includes sediments free of contaminants (*e.g.*, elevated levels of selenium, polyaromatic hydrocarbons (PAHs), and organochlorine pesticides) that can cause negative effects on all life stages of green sturgeon.

[This page intentionally left blank.]

Section 5

# Environmental Baseline and Cumulative Effects

# 5. Environmental Baseline and Cumulative Effects

This section of the biological assessment discusses environmental baseline conditions of EDCP treatment area and cumulative effects. The section is organized as follows:

*A. Environmental Baseline*

*B. Cumulative Effects.*

## A. Environmental Baseline

The ESA environmental baseline includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, anticipated impacts of all proposed Federal projects in an action area that have already undergone Formal, or Early Section 7 Consultation, and the impact of State or private actions that are contemporaneous with EDCP (50 CFR §402.02).

This section describes four specific actions that are related to EDCP and potential EDCP impacts on listed species in order to provide a general overview of the Delta project area environmental baseline. The four Delta actions are as follows: (1) Water Hyacinth Control Program (WHCP), (2) Delta invasive species, (3) Delta agriculture, and (4) Delta water quality.

These four impacts should be taken within the context of numerous large and small-scale actions in the Delta related to resource conservation, endangered species, restoration, water conveyance, water quality, and water use that affect listed species in the project area. Many of these larger actions have been in operation for decades, while others are in the early stages of planning, environmental permitting, and/or operation. This section will not attempt to describe in detail these large-scale projects, such as the Central Valley Project (CVP) and State Water Project (SWP), that are extensively documented elsewhere (for example documents related to the water project Operational Criteria and Plan (OCAP): USBR 2008, NMFS 2009, and USFWS 2008). These large scale water projects have known impacts on listed species, particularly fish.

This section provides some background context on the baseline condition of the Delta. The Delta is possibly the most environmentally sensitive region in California today. The Delta also has been described as “heavily modified” (Sommer et al. 2007). Starting in the mid-1800’s, the Delta has been subject to hydraulic gold mining, channelization and wetland reclamation, fish and other

non-native species introductions, dams controlling water inflows, and water exports (Sommer et al. 2007). Long-term monitoring and research into causes of recently identified stressors in the Delta highlight the finding that these stressors result from multiple and interacting changes associated with both anthropogenic and climatic factors (Cloern and Jassby 2011).

Concerns about the Delta environment gained momentum in the early 1990s. In establishing the Delta Protection Commission in 1992, the California legislature recognized that the Delta is "a natural resource of statewide, national, and international significance, containing irreplaceable resources." In the twenty years since the Delta Protection Commission was established, and particularly over the last few years, concerns about water quality, land subsidence, flooding, climate change, salinity, invasive species, risk of catastrophic earthquake, and declining fish populations have increased.

The CALFED Bay-Delta Program was created in 1994 to reduce conflicts between interest groups in the Delta and move toward restoring the Delta ecosystem. CALFED produced a number of planning and environmental documents between 1994 and 2000 (California Department of Fish and Game 2011). The first phase of CALFED efforts were completed in 2007.

There is widespread acknowledgement among California policymakers that the Delta is in crisis. As the Governor's Delta Vision Blue Ribbon Task Force stated, "ecosystems have eroded, levees have deteriorated, fish populations have collapsed, and our system of delivering water has become ever more precarious (Isenberg et al. 2008). There are numerous efforts at the federal, state, and local level, to improve conditions in the Delta.

In 2006, Governor Schwarzenegger established the Delta Vision Blue Ribbon Task Force to identify a sustainable strategy for managing the Delta. The Governor's Executive Order recognized that "failure to act to address identified Delta challenges and threats will result in potentially devastating environmental and economic consequences of statewide and national significance" (Executive Order S-17-06).

The Delta Vision Blue Ribbon Task Force established a strategic plan to meet twelve objectives, the first objective being: "The Delta ecosystem and a reliable water supply for California are the primary co-equal goals of a sustainable Delta" (Delta Vision Blue Ribbon Task Force 2008).

In early 2008, then Governor Schwarzenegger initiated another major collaborative planning effort, the Bay Delta Conservation Plan (BDCP). This initiative is led by the California Department of Water Resources (DWR), California Department of Fish and Game (CDFG), U.S. Bureau of Reclamation (USBR), USFWS, and NMFS. The "purpose of the BDCP is to help recover endangered and sensitive species and their habitats in the Delta in a way that will also provide for sufficient and reliable water supplies" (DWR 2008). The BDCP will examine four water conveyance and physical habitat restoration alternatives for the Delta, including a peripheral aqueduct or tunnel from the Sacramento River to the south Delta. On July 25, 2012, California Governor Edmund G. Brown Jr., Secretary of the Interior Ken

Salazar, and NOAA Assistant Administrator for Fisheries Eric Schwaab outlined revisions to the proposed BDCP that, along with a range of alternatives, will undergo public environmental review. The revised proposal for a peripheral tunnel includes fewer water intake facilities (three versus five), and lower total water capacity (9,000 cfs versus 15,000 cfs) than earlier proposals (California Natural Resources Agency July 2012). The draft BDCP and corresponding EIR/EIS is to be released for public review in Spring 2013.

The Sacramento-San Joaquin Delta Reform Act of 2009 (SBX7 1) enacted by the California legislature in November 2009, established a number of additional Delta-wide initiatives. The Delta Reform Act again established State policy coequal goals of a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The Delta Conservancy was created as a primary state agency to implement ecosystem restoration in the Delta and to support efforts that advance environmental protection and the economic well-being of Delta residents. The Delta Conservancy released a Draft Delta Conservancy Strategic Plan in May 2012.

The Delta Stewardship Council was established to develop and implement a legally enforceable, long-term management plan for the Delta. The Delta Stewardship Council released a draft plan for review in May 2012, with a final plan completed in November 2012.

The CDFG released a draft Conservation Strategy for Restoration of the Sacramento-San Joaquin Delta Ecological Management Zone and the Sacramento and San Joaquin Valley Regions (CDFG 2011) as part of the CALFED process. After passage of the Delta Reform Act, CDFG coordinated their ongoing planning efforts with the Delta Conservancy and Delta Stewardship Council, as well as the BDCP. The challenge of meeting water supply and ecosystem needs in the Delta has also been the subject of three National Academy of Sciences studies since 2010.

The EDCP is a minor element of this complex and dynamic Delta environment. The EDCP seeks to control only one of the hundreds of invasive species in the Delta. The relatively small EDCP operates within the much larger context of an environment that has been managed and materially manipulated since the mid-1800s.

The challenge in today's Delta is to support gradual restoration of natural Delta ecosystems, where possible, while preventing further environmental deterioration. The specific challenge of EDCP to control the growth of *Egeria densa* within this highly modified Delta environment. *Egeria densa*, left to grow unchecked, has significant negative environmental impacts. At the same time, EDCP also must minimize potential negative impacts of *Egeria densa* treatment.

## 1. Water Hyacinth Control Program (WHCP)

The WHCP is an aquatic weed program designed to control the growth and spread of water hyacinth in the Delta and its tributaries. In 1982, in response to concerns about water hyacinth in the Delta, the California Legislature passed Senate Bill 1344 (Garamendi, Chapter 263, Statutes of 1982), designating DBW as the lead agency for

controlling water hyacinth in the Delta, its tributaries, and Suisun Marsh, the same area as EDCP. The USDA-ARS has served as the federal nexus for WHCP for the last fifteen (15) years, providing research and scientific expertise, and has provided technical and programmatic advice to WHCP for 28 years, since the program's inception.

The WHCP has been an adaptive integrated pest management program (IPM). WHCP activities have emphasized chemical treatment, supported by limited handpicking, herding, mechanical removal, and evaluation of biological controls.

**Figure 5-1,** right, provides a summary of WHCP historical characteristics. The WHCP has been (and will continue to be) a relatively small aquatic weed control program concerned with managing the invasive, and non-native, water hyacinth in a large and complex Delta water environment.

Selected primary program herbicides are 2,4-Dichlorophenoxyacetic acid, dimethylamine (DMA) salt, or 2,4-D) and glyphosate, with 2,4-D being used for the majority of treatments. Beginning in 2013, WHCP proposes adding two new herbicides that have recently been approved by the California Department of Pesticide Regulation (CDPR) for water hyacinth treatment in aquatic environments: penoxsulam and imazamox. In addition, WHCP may add a third new herbicide, imazapyr, once it has been approved by CDPR for use on water hyacinth.

DBW applies herbicides with an adjuvant to increase adhesion to water hyacinth leaves. WHCP utilizes the adjuvant Agridex and the vegetable oil-based adjuvant, Competitor.

**Figure 5-1**
**Summary of WHCP Prior Activities**

- Program Initiated: **1983**
- Annual Budget: **$5.3 to $6.0 million** (for WHCP and EDCP) (2010 to 2011)
- Total Staffing: **19** (for WHCP and EDCP, includes DBW and USDA-ARS) (2012)
- Monitoring Crews/Boats: **one to two 2-person crews** (for WHCP and EDCP) (2012)
- Average* Annual WHCP Sites Treated: **167** (range = 104 to 211 sites)
- Average* Annual WHCP Acres Treated: **815** (range = 421 to 1,137 acres)
- Average* Annual WHCP Treatments: **584** (range = 330 to 941 treatments)
- Average* Annual WHCP Acres per Treatment: **1.39** (range = 0.01 to 3.0 acres per single treatment)

* 2007 to 2011 averages and ranges per WHCP daily logs.

Historical treatment data provides an order of magnitude indication of likely chemical treatment levels in future years. **Table 5-1,** on the next page, summarizes the treatment types, number of sites, gallons used, pounds active ingredient, and acres treated from 2007 to 2011. A primary and unpredictable factor influencing treatment acres in any given year is the extent of water hyacinth infestation. In addition, as compared to the 2007 through 2011 data, future chemical use could decrease due to use of the new lower volume herbicides. Future chemical use could also be reduced by treating water hyacinth early in the treatment season. Future treatment acres and chemical use could increase as a result of higher infestation levels and deployment of increased staff resources and/or improved staff utilization.

**Table 5-1**
**Summary Data for WHCP – 2007 to 2011**

| | | | Gallons | | | | Acres | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Number of Sites | Number of Treatments | 2,4-D | Glyphosate | Total Herbicide | Agridex | 2,4-D | Glyphosate | Total Acres |
| 1. 2007 | 211 | 941 | 938 | 149 | 1,087 | 441 | 938 | 199 | 1,137 |
| 2. 2008 | 146 | 439 | 336 | 64 | 400 | 163 | 336 | 85 | 421 |
| 3. 2009 | 177 | 492 | 619 | 64 | 683 | 266 | 619 | 86 | 705 |
| 4. 2010 | 199 | 719 | 879 | 109 | 988 | 372 | 879 | 145 | 1,024 |
| 5. 2011 | 104 | 330 | 449 | 253 | 702 | 286 | 449 | 338 | 787 |
| Total | 837 | 2,921 | 3,221 | 639 | 3,860 | 1,528 | 3,221 | 853 | 4,074 |
| Average | 167 | 584 | 644 | 128 | 772 | 306 | 644 | 171 | 815 |

| | Averages | | | Pounds Active Herbicide Ingredient | | |
|---|---|---|---|---|---|---|
| Year | Average Acres/Treatment | Average Herbicide Gallons/Site | Average Pounds/Site | 2,4-D | Glyphosate | Total |
| 1. 2007 | 1.21 | 5.15 | 19.90 | 3,752 | 447 | 4,199 |
| 2. 2008 | 0.96 | 2.74 | 10.52 | 1,344 | 192 | 1,536 |
| 3. 2009 | 1.43 | 3.86 | 15.07 | 2,476 | 192 | 2,668 |
| 4. 2010 | 1.42 | 4.96 | 19.31 | 3,516 | 327 | 3,843 |
| 5. 2011 | 2.38 | 6.75 | 24.57 | 1,796 | 759 | 2,555 |
| Total | 1.39 | 4.61 | 17.68 | 12,884 | 1,917 | 14,801 |
| Average | | | | 2,577 | 383 | 2,960 |

In addition to herbicide treatments, the WHCP utilizes handpicking, herding, and mechanical removal. These approaches can help reduce the need for herbicides. Handpicking is primarily utilized to reduce plant biomass in nursery areas. Herding is used in order to push water hyacinth mats (1) into main channels where it flows naturally out of the Delta and dies in the more saline water of San Francisco Bay; or (2) toward mechanical removal sites.

The WHCP plans on utilizing two mechanical removal methods: (1) use of specialized mechanical equipment with conveyors to physically remove plants, and (2) use of small excavators sited on concrete boat ramps to scoop plants into trucks/trailers for disposal. In addition, the USDA-ARS, DBW, and their partners will continue to evaluate the use of biological controls to reduce the spread of water hyacinth.

USDA-ARS and DBW recently proposed a growth-based start-date approach for WHCP chemical treatments, similar to that proposed for EDCP. This approach is intended to minimize potential for impacts

on fisheries and maximize treatment efficacy. This approach will be dependent on fish survey data and field surveys for water hyacinth, within calendar-date windows. Chemical treatments will likely begin by mid-March in selected areas. Chemical treatments in some regions of the Delta will continue through the end of November.

Treatment sites will be prioritized so that nursery areas, and areas where water hyacinth causes negative navigational, agricultural, public safety, environmental, or industrial impacts, are treated first. The WHCP will also consider logistical and operational factors such as prevailing winds, travel time, and weather conditions when selecting treatment locations.

The WHCP follows an Operations Management Plan that specifies a pre-application planning protocol; an Application/Monitoring Coordination Protocol; "Best Maintenance Practices" for Handling Herbicides; Spray Equipment Maintenance and Calibration; and an Herbicide Spill Contingency Plan. The Operations Management Plan will include requirements related to avoiding threatened or endangered species, conducing habitat evaluation, dissolved oxygen measurement, a fish passage protocol, and other program monitoring requirements.

Based on NPDES permit requirements, DBW follows an Annual Monitoring Protocol; this protocol is identical to that for EDCP. This protocol fulfills monitoring requirements of the Central Valley Regional Water Quality Control Board, NMFS, and USFWS. The State Water Quality Control Board (SWRCB) is updating the NPDES General Permit, with a draft for public comment released on June 27, 2012, and a final version for Board approval is expected on February 19, 2013. DBW will revise their monitoring protocol to reflect the new conditions in the final General Permit.

## 2. Delta Invasive Species

Invasive species are generally defined as non-indigenous species that adversely affect economics, environments, ecological relationships, and/or habitats where they have been introduced (Masters and Norgrove 2010, USEPA 2008). The Delta is among the most invaded ecosystem worldwide, with over 200 invasive, non-native species (Cohen and Carlton 1995). Cohen and Carlton found that non-native species accounted for 40 to 100 percent of common species at many sites (Cohen and Carlton 1995). Introduced species contribute up to 97 percent of the individuals and 99 percent of the biomass in some San Francisco Bay/Delta communities, transforming the ecosystem (Cloern and Jassby 2011).

Invasive species that have adapted to and inhabited the Delta include: non-native Centrarchids (various bass, bluegill, sunfish, crappie), overbite clam (*Corbula amurensis*), Asian clam (*Corbicula fluminea*), several zooplankton species, and invasive plants such as *Egeria densa* and water hyacinth. The presence of invasive species is linked to other changes in the Delta, such as water quality and water flows. In addition, changes in nutrient concentrations over time (i.e. increased nitrogen-to-phosphorous ratios) may be a significant driver of food web changes that are favorable to non-native species (Glibert et al. 2011).

While some non-native species have relatively little effect on the environment, others result in negative ecological and economic impacts in the Delta. Invasive species have altered food webs and habitats, compete with native species for resources, and directly prey upon native species (CDFG 2011). "Problem" invasive species are often grouped into one of two categories: ecosystem engineers or food-web disruptors (Mount et al. 2012). Ecosystem engineers physically alter ecosystem processes, degrading habitat for native species (Mount et al. 2012). *Egeria densa* and water hyacinth are commonly categorized as ecosystem engineers due to their impact on sediment, water clarity, ecosystem diversity, and dissolved oxygen.

Food-web disruptors are species that significantly alter food webs, reducing the quantity or quality of food available for native species (Mount et al. 2012). The presence of invasive clams, and changes in replacement of native zooplankton with non-native zooplankton are examples of food web disruptors in the Delta. The Asian and overbite clams have significantly altered the Delta food web by filtering most phytoplankton from the water, particularly in the western Delta and Suisun Bay. This filtering diminishes food supplies for zooplankton and mysid shrimp, which become scarcer, thus diminishing food supply for fish such as the delta smelt and salmonids that rely on them (Mount et al. 2012). Several studies have found that invasive species (including macrophytes) are the second greatest threat to listed fish species behind habitat loss, impacting 63 percent to 70 percent of listed species (Schultz and Dibble 2012).

## 3. Delta Agriculture

The Delta is an important agricultural area. Farming in the Delta region began in the 1850s following passage of the Swamp and Overflow Act and Reclamation District Act, which provided for the sale of swamp and overflow lands for reclamation (DPC January 2001). Early farmers built a system of levees and irrigation ditches and began growing a variety of vegetables, fruits, and grains. Over time, most farms have shifted from growing diverse crops to growing a few crops, which are rotated (DPC January 2001). Crops that have been important at various times in the Delta include potatoes, asparagus, pears, and sugar beets. Characteristics that make the Delta well-suited to agriculture include: rich soil, ample water, a long growing season, mild climate, and proximity to end markets (DPC May 2001).

California is the fifth largest agricultural economy in the world, producing over 400 plant and animal commodities worth $37.5 billion in 2010 (CDFA 2011). There were over 25 million acres of agricultural land (including grazing land) in California in 2010 (CDFA 2011). In 2010, the Delta region had about 500,000 acres available for agriculture, with 461,000 acres in use (DPC 2011), just over 2 percent of the total agricultural acreage statewide, and approximately 67 percent of Delta land acreage. Of the Delta's 500,000 agricultural acres, approximately 80 percent is classified as prime farmland (DPC 2011).The average annual gross value of the agricultural output of the Delta is typically about two percent of the statewide agricultural output, and was $800 million in 2009. **Table 5-2,** on the next page, summarizes total and Delta agricultural land use in the six Delta counties.

**Table 5-2**
**Total and Agricultural Acres in Delta Counties**

| County | Total County Acres | Total County Agricultural Acres (2010) | Approximate Country Delta Acres | Delta Total Agricultural Delta Acres (in production) (2010) |
|---|---|---|---|---|
| 1. San Joaquin | 912,602 | 737,503 | 317,778 | 214,053 |
| 2. Yolo | 653,452 | 479,858 | 91,861 | 54,986 |
| 3. Sacramento | 636,083 | 328,593 | 118,717 | 66,428 |
| 4. Solano | 582,373 | 358,225 | 88,071 | 72,499 |
| 5. Contra Costa | 514,019 | 146,933 | 104,751 | 48,062 |
| 6. Alameda | 525,338 | 204,233 | 6,422 | 5,352 |
| Total | 3,823,867 | 2,255,345 | 727,600 | 461,380 |

Sources: USDA Census of Agriculture (www.agcensus.usda.gov); DOC, http://www.consrv.ca.gov; Delta Protection Commission 2011. DBW.

**Table 5-3**
**Top Ten Delta Agricultural Crops, Based on 2009 Value**

| Agricultural Product | Annual Gross Value (in millions of dollars) |
|---|---|
| 1. Processing tomatoes | $117.2 |
| 2. Wine grapes | 105.0 |
| 3. Corn | 93.0 |
| 4. Alfalfa | 66.0 |
| 5. Asparagus | 50.1 |
| 6. Pears | 36.7 |
| 7. Turf | 31.6 |
| 8. Potato | 28.6 |
| 9. Almond | 8.8 |
| 10. Watermelon | 8.0 |

Source: Delta Protection Commission 2011

**Table 5-4**
**Top Ten Delta Agricultural Products, Based on 2009 Acreage**

| Agricultural Product | Delta Irrigated Acres |
|---|---|
| 1. Corn | 105,362 |
| 2. Alfalfa | 91,978 |
| 3. Processing tomatoes | 38,123 |
| 4. Wheat | 34,151 |
| 5. Wine grapes | 30,148 |
| 6. Oats | 15,847 |
| 7. Safflower | 8,874 |
| 8. Asparagus | 7,217 |
| 9. Pear | 5,912 |
| 10. Bean, dried | 5,493 |

Source: Delta Protection Commission 2011

**Tables 5-3** and **5-4,** above, identify the top ten Delta agricultural crops in 2009, based on annual average gross value, and acreage. These tables illustrate the diversity of agriculture in the Delta, with no single product dominating either acreage or economic output.

While agriculture is an important component of the Delta's economic infrastructure, it is also one of the many factors that negatively impacts listed species. These negative impacts are the result of several different factors, including the landscape, water diversions, and pesticides. The most significant, and long-term, implications of

agriculture in the Delta are the structural changes that began in the 1850s. The levees and islands created to support agriculture are now part of the current Delta landscape.

There are approximately 1,800 agricultural water diversions in the Delta. During the peak summer irrigation season, diversions from these facilities collectively exceed 5,000 cubic feet per second (URS Corporation May 2007). Most of the irrigation diversions in the Delta are small (30 to 60 cm in diameter) and lack fish screens (Nobriga et al. 2004). Nobriga et al. found that fish entrainment was 99 percent higher in unscreened agricultural diversions than in screened diversions (2004). The overall impact of agricultural diversions on fish depends on a number of factors, including location, size, timing, and operation (Moyle and Bennett 2008).

*Egeria densa* interferes with water pumping at irrigation intakes throughout the Delta with the potential for clogging by *Egeria densa*, resulting in inefficient pumping, increased pumping costs, and possible mechanical failure of pumps. *Egeria densa* and water hyacinth impair the use of fish protective devices such as fish screens (CALFED Vol. 1 ERP 2000).

Increased sedimentation resulting from agriculture and urban practices within the Central Valley is one of the primary causes of salmonid and delta smelt habitat degradation (NMFS 1996). Sedimentation can adversely affect all freshwater stages of listed species by clogging or abrading gill surfaces, adhering to eggs, hampering fry emergence, burying eggs or alevins, reducing primary productivity and photosynthesis, and affecting DO levels (California Department of Water Resources 2007).

Agriculture in the Delta results in significant pesticide use that far outweighs WHCP and EDCP herbicide applications in the project area. In 2010, EDCP conducted treatments in only two of the eleven EDCP counties: Contra Costa, and San Joaquin. **Table 5-5,** on the next page, summarizes 2010 pesticide use report data for fluridone, imazamox, penoxsulam, and diquat for the two counties where EDCP treatments were conducted in 2010. Combined, these two counties utilized 5,180 pounds active ingredient of the four EDCP herbicides (California DPR 2011). The EDCP utilized 1,974 pounds of herbicide active ingredient in 2010 (fluridone only). Fluridone is a specialty aquatic herbicide, and imazamox and penoxsulam are new herbicides, thus EDCP accounted for a relatively high 38 percent of the use of the four EDCP herbicides in Contra Costa and San Joaquin counties in 2010. However, as Table 5-5 illustrates, EDCP utilized only 0.02 percent of the total pesticide used in Contra Costa and San Joaquin counties in 2010.

A recently released study funded through CALFED (Hoogeweg et al. 2011) developed a comprehensive simulation model to evaluate pesticides in the Delta as compared to co-occurrence of species of concern between 2000 and 2009. The study evaluated 40 pesticides identified by the CVRWQB as those of highest risk to aquatic life, focusing on pyrethrins and organophosphates. None of the 40 pesticides evaluated are utilized by WHCP or EDCP. Using a broader watershed approach covering the Sacramento River, San Joaquin River, and Bay-Delta, Hoogeweg et al. estimated that of the approximately

**Table 5-5**
**Comparison of Total and EDCP Herbicide Use in Two Counties with EDCP Treatments in 2010**

| Herbicide | Pesticide[a] Use in Two EDCP Counties in 2010 | EDCP Herbicide[b] Use In Two EDCP Counties Treated in 2010 | EDCP Herbicide Use as Percent of County Total Use |
|---|---|---|---|
| Fluridone | 3,358 | 1,974 | 59% |
| Imazamox ammonium salt | 121 | – | – |
| Penoxsulam | 67 | – | – |
| Diquat dibromide | 1,634 | – | – |
| Total EDCP Herbicides | 5,180 | 1,974 | **38%** |
| Total All Pesticides | 9,881,147 | 1,974 | **0.02%** |

[a] Fluridone, imazamox, penoxsulam, and diquat

[b] Fluridone

Sources: California Department of Pesticide Regulation and DBW. This total use of herbicides includes all reported uses, including EDCP applications.

10 million pounds of active ingredient of the 40 selected pesticides applied per year, 14 percent, or 1.4 million pounds, reach the surface water. The study quantified toxicity thresholds (using risk quotients) for the 40 pesticides, and identified time and location of likely incidents (i.e. when estimated pesticide levels exceeded toxicity thresholds). The areas with greatest potential for concern within the Delta were the southern Delta estuary in San Joaquin County, and the confluence of the Cosumnes River, Dry Creek, and the Mokelumne River. Hoogeweg et al. also evaluated 30,000 water quality testing records from the same 2000 to 2009 time period, and found that approximately 75 percent of the 250 testing locations had exceeded toxicity thresholds at least once, and as many as 185 times. This study illustrates the high degree of pesticide loading to Delta waters, with significant quantities of higher-toxicity pesticides, far exceeding the herbicide risk and use of EDCP.

## 4. Delta Water Quality

The water quality of the Delta has been negatively impacted over the last 150 years (NMFS 2012). The State Water Resources Control Board (SWRCB) regulates water quality in California, through the federal Clean Water Act (CWA), and the Porter-Cologne Water Quality Control Act. The State Water Code gives Regional Water Boards primary responsibility for formulating and adopting water quality control plans in each of the State's nine regions.

There are two plans that jointly specify water quality controls for the Delta: the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan), and the Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins. The Bay-Delta Plan, developed by the SWRCB, is complementary to the Basin Plan developed by the CVRWQB. Water quality plans must

also be approved by the USEPA. In addition, in February 2011, the USEPA initiated an advance notice of proposed rulemaking to seek comments from interested parties on possible USEPA actions to address water quality conditions affecting aquatic resources in the Delta (USEPA 2011). As of mid-2012, the USEPA had received over fifty comments, but taken no further action.

Both plans consist of beneficial uses to be protected, water quality objectives, and a program for implementation of the water quality objectives. A primary goal of the water quality planning process is to identify and protect beneficial uses for surface and groundwater in a given region. **Table 5-6,** right, summarizes seventeen of the beneficial uses for Delta waters. The EDCP is intended to improve beneficial uses of Delta waters.

Water quality objectives are "the limits or levels of water quality constituents or characteristics which are established for the reasonable protection of beneficial uses of water or the prevention of nuisance within a specific area" (Water Code Section 13050(h), in CVRWQCB 2007). In establishing water quality objectives, the Regional Water Boards must consider the following:

- Past, present, and probable future beneficial uses;
- Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto;
- Water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area;
- Economic considerations;

**Table 5-6**
**Beneficial Uses in Delta Waters**

| Beneficial Use | Abbreviation |
|---|---|
| 1. Municipal and domestic supply | MUN |
| 2. Industrial service supply | IND |
| 3. Industrial process supply | PRO |
| 4. Agricultural supply | AGR |
| 5. Groundwater recharge | GWR |
| 6. Navigation | NAV |
| 7. Water contact recreation | REC-1 |
| 8. Non-contact water recreation | REC-2 |
| 9. Shellfish harvesting | SHELL |
| 10. Commercial and sport fishing | COMM |
| 11. Warm freshwater habitat | WARM |
| 12. Cold freshwater habitat | COLD |
| 13. Migration of aquatic organisms | MIGR |
| 14. Spawning, reproduction, and/or early development | SPWN |
| 15. Estuarine habitat | EST |
| 16. Wildlife habitat | WILD |
| 17. Rare, threatened, or endangered species | RARE |

- The need for developing housing within the region;
- The need to develop and use recycled water (Water Code Section 13241).

The SWRCB and Regional Water Boards refine their respective plans over time to take into account new water quality issues. The most recent Bay-Delta Plan was published in December 2006. The CVRWQB is currently revising the Bay-Delta plan, with proposed adoption in February 2013. The revised plan will include new flow objectives for protection of fish and wildlife beneficial uses, salinity,

and other objectives for protection of agricultural beneficial uses, and a program of implementation, monitoring, and special studies. The most recent Basin Plan was revised in October 2011. These plans specify surface water quality objectives for a range of categories, including: bacteria, biostimulatory substances, chemical constituents, color, dissolved oxygen, floating material, methylmercury, oil and grease, pH, pesticides, radioactivity, salinity, sediment, settleable material, suspended material, tastes and odors, temperature, toxicity, and turbidity. The Bay-Delta Plan identifies additional requirements for chloride, salinity, dissolved oxygen, delta outflow, river flows, and export limits. These Bay-Delta Plan water quality objectives are intended to protect municipal, industrial, agricultural, and fish and wildlife beneficial uses. The Bay-Delta Plan requirements supersede those of the Basin Plan.

One mechanism that the CVRWQB uses to implement the Bay-Delta and Basin Plans is a National Pollutant Discharge Elimination System (NPDES) permit. NPDES permits are issued to entities that discharge to waterways, known as point source dischargers. In the 2001, Headwaters, Inc. v. Talent Irrigation case, the Ninth Circuit Court of Appeals held that discharges of pollutants from the use of aquatic pesticides to waters of the United States required coverage under a NPDES permit (CVRWQB 2006).

The DBW obtained an individual NPDES permit in March 2001, and operated under this permit until April 2006. In April 2006, the DBW applied to operate under the General NPDES Permit for the Discharge of Aquatic Pesticides for Aquatic Weed Control in Waters of the United States – General Permit No. CAG990005 (General Permit).

Following the Talent decision, there was some confusion regarding the need to obtain an NPDES permit for aquatic pesticide use. In November 2006, USEPA issued a regulation stating that application of a pesticide in compliance with relevant requirements of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) does not require a NPDES permit when the application is made directly in waters to control pests in the water, or when the application of the pesticide is made to control pests that are over (or near) waters (Federal Register 2006). The rulemaking was based on USEPA's interpretation of the term "pollutant" under the Clean Water Act.

In theory, this regulation eliminated the need for a NPDES permit for EDCP. However, there were at least two legal challenges to this regulation, and SWRCB legal counsel recommended that SWRCB not rescind their general NPDES permits related to aquatic pesticides (SWRCB 2007). The USEPA ruling did mean that agencies operating under the General Permit had the option to terminate their coverage by the General Permit. The DBW elected to maintain coverage under the General Permit until legal challenges to the ruling were resolved. In January 2009, an appeals court vacated the USEPA rule that had allowed pesticides to be applied to U.S. waters without a NPDES permit. This ruling did not change EDCP operations because DBW maintained permit coverage.

The Bay-Delta Plan notes that "the Bay-Delta Estuary itself is one of the largest

ecosystems for fish and wildlife habitat and production in the United States. Historical and current human activities (e.g. water development, land use, wastewater discharges, introduced species, and harvesting), exacerbated by variations in natural conditions, have degraded the beneficial uses of the Bay-Delta Estuary, as evidenced by the declines in populations of many biological resources of the Estuary" (SWRCB 2006).

Pollutants in Delta waterways include: pesticides (chlorpyrifos, DDT, diazinon, furan compounds, and Group A pesticides[1]), exotic species, mercury, salinity, dissolved oxygen, pathogens, and PCBs (CVRWQB 2006). Potential sources of these pollutants include: agriculture, municipal point sources, urban runoff, storm sewers, resource extraction, and hydromodification. More recently, concerns have been raised about ammonia levels in the Delta. CVRWQB is working with researchers at San Francisco State University and University of California, Davis, to evaluate the impact of ammonia in the Delta (CVRWQB 2008). All of the waters within the Delta are listed as impaired by at least one factor, either due to the presence of unacceptable levels of pollutants or lack of maintaining conditions such as adequate dissolved oxygen levels (USEPA 2011).

While evidence of gross pollution in the Delta has been largely eliminated, the recent rapid growth in population and industrial activity in tributary areas has left some problems unsolved and has created new ones. Existing water quality problems may be categorized as (1) eutrophication and associated dissolved oxygen fluctuations, (2) suspended sediments and turbidity, (3) salinity, (4) toxic material, and (5) bacteria.

### Pesticides

Pesticides are found in the water and bottom sediments throughout the Delta. The more persistent chlorinated hydrocarbon pesticides are consistently found at higher levels than the less persistent organophosphate compounds. Sediments in the western Delta have the highest pesticide content. Pesticides have concentrated in aquatic life, but long-term effects and the effects of intermittent exposure are not known. There are now concerns about the aquatic toxicity of pyrethroid-based pesticides (bifenthrin, cyfluthrin, cypermethrin, and permethrin), which have replaced organophosphorus pesticides such as diazinon and chlorpyrifos. Pesticides are applied during specific seasons for specific crops, and there are five flushes of pesticides entering Delta waters: (1) first flush or dormant spray insecticides from orchards in December and January, (2) first flush of herbicides following the first winter storm, (3) spring insecticides applied in March and April, (4) spring and summer detection of rice pesticides, and (5) summer detection of pesticides applied to truck crops (Kuivila and Hladik 2008). Little is known about the potential for interactive toxicity from complex pesticide mixtures and/or pesticides interacting with other chemical, physical, or biological stressors (USEPA 2011).

[1] Group A pesticides include: aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane, endosulfan, and toxaphene.

### Contaminants of Emerging Concern

Contaminants of emerging concern (CECs) include pharmaceuticals, personal care products, solvent stabilizers, flame retardants, pesticides, and other commonly used commercial and industrial compounds (USEPA 2011). There is growing concern, but little data, to adequately assess the ecological implications of CECs in the Delta. Some of these contaminants may be endocrine disrupting chemicals. Endocrine disrupting effects have been seen in silversides, delta smelt, and striped bass in the Delta; however, there are no specific linkages to contaminants in the Delta.

### Eutrophication and Turbidity

Bacteriological quality, as measured by the presence of coliform bacteria, varies depending on the proximity to waste discharges and significant runoff. The highest concentration of coliform organisms is generally in the western Delta and near major municipal waste discharges.

The most serious enrichment in the Delta is due to a high influx of nutrients. Enrichment problems in the Delta occur along the lower San Joaquin River and in certain areas receiving waste discharges but having little or no net freshwater flow. These problems occur mainly in the late summer and coincide with low streamflow, high temperature, and the harvest season when fruit and vegetable canneries are in full operation. In addition to enrichment problems, deepening channels for navigation has further depressed dissolved oxygen levels to the point that at times levels are insufficient to support aquatic life. In the fall, these circumstances, combined with reverse flows due to export pumping, have created conditions unsuitable for salmon passage through the Delta to spawning areas in the San Joaquin Valley.

Warm, shallow, dead-end sloughs of the eastern Delta support populations of potentially toxic planktonic blue-green algae during the summer. Floating, semi-attached and attached aquatic plants such as water primrose *(Ludwigia peploides),* water hyacinth *(Eichhornia crassipes),* hornwort or coontail *(Ceratophyllum demersum),* eurasian milfoil *(Myriophylum spicatum), an*d *Egeria densa* frequently clog Delta waterways during summer. Extensive growth of these plants interferes with small boat traffic and contributes to the total organic load as these plants break loose and move downstream in the fall and winter.

Most Delta waters are turbid as a result of suspended silt, clay, and organic matter. Most of these sediments enter the Delta system with flow from major tributaries. Some enriched areas are turbid as a result of planktonic algal populations, but inorganic turbidity tends to suppress nuisance algal populations in much of the Delta. Continuous dredging to maintain deep channels for shipping also has contributed to turbidity and has been a significant factor in the temporary destruction of bottom organisms through displacement and suffocation.

### Salinity

Salinity control is necessary in the Delta because it is contiguous with the ocean and its channels are at, or below, sea level. Unless repelled by continuous seaward flow of fresh water, ocean water will advance up the estuary

and degrade water quality. During winter and early spring, flows through the Delta are usually above the minimum required to control salinity (described as "excess water conditions"). At least for a few months in summer and during the fall of most years, however, salinity must be carefully monitored and controlled for "balanced water conditions". The Central Valley Project and State Water Project monitor and control salinity, and salinity levels are regulated by the State Water Resources Control Board under its water right authority (through the Bay-Delta and Basin Plans). There are concerns that Delta salinity is increasing as more water is diverted through the SWP and CVP.

Salinity intrusion is a problem mainly during years of below-normal runoff, although in recent years with higher export levels, salinity has also been a concern. The degree of seawater intrusion into the Delta, and thus one source of salinity, is a result of daily tidal fluctuations, freshwater inflow to the Delta from the Sacramento and San Joaquin Rivers, the rate of export at SWP and CVP intake pumps, and the operation of various control structures such as the Delta Cross-Channel Gates and Suisun Marsh Salinity Control System (USBR 2003).

In the eastern Delta, salinity is largely associated with agricultural drainage and the high concentration of salts carried by the San Joaquin River. The Banks and Jones pumping plant operations draw high quality Sacramento River water across the Delta and restrict the low quality area to the southeastern corner. In areas such as dead-end sloughs, irrigation returns cause localized problems. In the western Delta, incursion of saline water from San Francisco Bay is one of the main water quality problems.

### Trihalomethane Precursors

Another concern is that Delta water contains trihalomethane (THM) precursors. THMs are suspected carcinogens produced when chlorine used for disinfection reacts with natural substances during the water treatment process. Dissolved organic compounds that originate from decayed vegetation act as precursors by providing a source of carbon in THM formation reactions. During periods of reverse Delta flow, bromides from the ocean mix with Delta water at the western edge of Sherman Island. When bromides occur in water along with organic THM precursors, THMs are formed that contain bromine as well as chlorine. Drinking water supplies taken from the Delta are treated to meet THM standards, set at 0.080 mg/l, MRDL (maximum residual disinfectant level) (USBR 2003). Contra Costa Water District (CCWD) reports that bromide in the Delta is 6.5 times above the national average (Taugher 2005). To reduce THM formation, CCWD has reduced the amount of chlorine used in their treatment process.

### Sediment and Dissolved Oxygen

Sediment can either act as a sink or as a source of contamination depending on hydrological conditions and the type of habitat the sediment occurs in. Sediment provides habitat for many aquatic organisms and is a major repository for many of the more persistent chemicals introduced in surface waters. In the aquatic environment,

most anthropogenic chemicals and waste materials including toxic organic and inorganic chemicals eventually accumulate in sediment (Ingersoll 1995). A more likely source of exposure of listed species to toxins in sediment is through the food chain, when fish feed on organisms that are contaminated with toxic compounds.

Reductions in sediment levels in the Delta can negatively impact ecosystems. Reductions in suspended particulate matter (SPM) due to construction of dams on rivers flowing into the Delta has altered the turbidity and light attenuation in Delta waters (Cloern and Jassby 2011). This increased water clarity has expanded suitable habitat for *Egeria densa*, and negatively impacted species such as delta smelt that are most abundant in turbid habitats (Cloern and Jassby 2011).

A sufficient level of DO is critical to the health and survival of aquatic species (CDFG 2011). Oxygen depletion can be caused by high water temperatures, the occurrence of decomposing aquatic vegetation, poor channel geometry, low streamflow, poor mixing of stream water with the atmosphere, and the presence of oxygen-depleting substances such as sewage, animal wastes, ammonia, organic nitrogen, and algae (CDFG 2011). Low DO levels in Delta locations, particularly the San Joaquin River and Stockton deep water shipping channel, impact migration of listed salmon. Over a five-year period starting in August 2000, a DO meter recorded channel DO levels at Rough and Ready Island and found 297 days with violations of the 5 mg/l DO criteria for protection of aquatic life (NMFS 2012). Levels of DO below 5 mg/l have been reported as delaying or blocking fall-run Chinook salmon in studies conducted by Hallock et al. (1970).

As noted in DWR (2007) and NMFS (2012), water degradation or contamination can lead to either acute toxicity resulting in death when concentrations are sufficiently elevated, or more typically, when concentrations are lower, to chronic sublethal effects that reduce the physical health of the organism, and lessens it survival over an extended period of time. Mortality may become a secondary effect due to compromised physiology or behavioral changes that lessen the organism's ability to carry out its normal activities. For example, increased levels of heavy metals are detrimental to the health of an organism because they interfere with metabolic functions by inhibiting key enzyme activity in metabolic pathways, decrease neurological function, degrade cardiovascular output, and act as mutagens, teratogens or carcinogens in exposed organisms (Rand et al. 1995; Goyer 1996). For listed species, these effects may occur directly to listed fish or its prey base, which reduces the forage base available to listed species.

## B. Cumulative Effects

Cumulative effects within the ESA include effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the EDCP (50 CRF §402.2). This biological assessment discusses three areas with potential for cumulative effects.

## 1. Spongeplant Control Program

AB 1540 (Buchanan, Chapter 188, Statutes of 2012) was approved by the Legislature on August 15, 2012 and was signed by the Governor on August 27, 2012. AB 1540 adds responsibility for an additional invasive plant to DBW and USDA-ARS existing WHCP and EDCP programs. Spongeplant (*Limnobium laevigatum*) is a native of South America, Central America, and Central Mexico. It is a prolific, floating, flowering plant in the "frogbit" family (Hydrocharitacaea) (Anderson 2011). Spongeplant was first found in California in 2003 in small ponds near Arcata and Redding, and was discovered in the San Joaquin River in 2007.

Spongeplant is smaller than water hyacinth (leaves are 1 to 3 cm in diameter), but has several common characteristics. Spongeplant develops best in slow or still waters (including at the edge of fast-moving rivers); it is normally floating, but can also root in the mud (Akers 2010). Mats are extremely dense (2,500 plants per square meter) and can increase rapidly in size through vegetative reproduction, like water hyacinth and *Egeria densa*. Spongeplant also reproduces by seed, increasing the potential for invasion.

Within the Delta, spongeplant is being found within water hyacinth mats. In these cases, treatment will occur concurrently with water hyacinth treatment (either by mechanical removal or chemical treatment). Glyphosate, 2,4-D, and penoxsulam are effective in treating spongeplant (Akers 2010). Spongeplant has also been found in irrigation canals where water hyacinth is not typically found. Currently, a seven-person CDFA crew has been physically removing spongeplant infestations with excavation equipment.

The environmental impacts of spongeplant are expected to be similar, or perhaps potentially worse, than water hyacinth (Akers 2010). The density of the mats may seal the water's surface, lowering DO and denying open water to waterfowl. Spongeplant may also out-compete native plants, similar to *Egeria densa*. USDA-ARS is currently studying the characteristics of spongeplant in their Rapid Response program in order to better understand how to address this new invasive species.

The addition of spongeplant to DBW's aquatic weed program will still not provide the comprehensive and systematic approach to aquatic invasive plants in the Delta that would be preferred, but it will significantly expand DBW's responsibilities. Because spongeplant is closely aligned with water hyacinth, it is likely that these programs would at some point be integrated.

The CDFA's current approach of physically scooping spongeplant out of irrigation canals and ponds will not work in most of the Delta, thus a program that includes chemical treatment will likely be necessary. The DBW and USDA-ARS envision that a chemical approach could require an amendment to the WHCP Programmatic EIR and a similar consultation process as for the WHCP and EDCP. For this current EDCP consultation processes, the DBW and USDA-ARS are not considering spongeplant. However, there may be new program needs related to spongeplant as soon as January 1, 2013.

## 2. Climate Change

There have been numerous studies and modeling efforts to evaluate the impacts of climate change on the San Francisco Bay and Delta regions (Cloern et al. 2011, and Cayan et al. 2000, Climate Action Team 2010, DWR 2010, Field et al. 1999, Knowles 2008, Wagner et al. 2011, and USBR 2008, in National Research Council 2011). The Delta may be particularly affected by climate change because it is influenced by shifts in ocean conditions and changes in upland watersheds. The region has already seen patterns of increasing winter and spring air temperatures, decreasing contributions of snowmelt to annual precipitation, and a 2.2 cm per decade increase in mean sea level at the entrance of San Francisco Bay since the 1930s (Cloern et al. 2011). Projected changes, as modeled by Cloern et al. 2011, include:

- Increase in air temperature between 0.14°C to 0.42°C per decade
- Increase in sea level between 9.9 cm and 12.3 cm per decade
- Variable impacts on precipitation and unimpaired runoff, depending on the modeling tools
- Decrease in snow melt of between 0.4 percent and 1.1 percent per decade
- Increase in water temperature between 0.1°C and 0.3°C per decade in the Sacramento River and the Delta
- Increase in salinity of 0.33 to 0.46 psu per decade.

A number of other environmental indicators are also expected to change, increasing stress on native species. These include: an increase in number of days when projected water temperature in the Delta exceeds 25°C (the threshold for high mortality of delta smelt), an increase in extreme water heights at the Golden Gate, an increase in number of days when temperatures in the Sacramento River exceed 16°C (a threshold for high mortality of salmonid eggs and pre-emergent fry), and a decrease in flood inundation of the Yolo Bypass (inundation is beneficial to Sacramento splittail and salmonids). Some climate change models indicate a drying trend in California, as well as an increase in frequency and magnitude of severe weather events (ICF International 2012).

These climate changes in the Delta will increase existing conflicts and policy debates regarding resource management, water supply, and land use. Cloern et al. predict that protection of native species will be even more challenging as environmental conditions in the Delta diverge from those to which native species are adapted. It is likely that sustaining populations of delta smelt will become increasingly difficult as Delta water temperatures, clarity, and salinity increase (Cloern et al. 2011). In an analysis of forty years of sampling data, Feyrer et al. (2011) found that climate change posed a serious threat to delta smelt.

Winter-run Chinook salmon may be particularly impacted because spawning occurs in the summer, when temperature increases will be greatest. Salmonids in California already experience temperature conditions at the edge of their tolerance because they are at the southern end of their range (Katz et al. 2012).

At the base of the food web, changes in temperature, flow, and salinity will further

alter plankton and zooplankton communities, which may result in impacts at all levels of the food web. Changes in water supply and diversions will negatively impact listed fish species. Katz et al. (2012) suggest a lag effect whereby the cumulative impact of past actions such as clams, habitat deterioration, and hatcheries will be amplified by climate change.

There is a growing body of literature assessing the relationship between climate change and invasive species (Hellmann et al. 2008, USEPA 2008, Masters and Norgrove 2010, Rahel and Olden 2008). Hellmann et al. identify five mechanisms by which invasive species impacts may be influenced by climate change:

- Altered mechanisms of transport and introduction
- Altered climatic constraints on native species
- Altered distribution of existing invasive species
- Altered impact of existing invasive species
- Altered effectiveness of management strategies for invasive species.

The specific impacts of climate change on a particular invasive species will vary, depending on the location and the characteristics of the species. However, generally, climate change is expected to improve conditions for invasive species (Masters and Norgrove 2010, USEPA 2008, Rahel and Olden 2008). This will further negatively impact native species. Katz et al. (2012) predict that climate change will increase non-native fish that prey on juvenile salmonids.

The impacts of climate change on *Egeria densa* are likely to be mixed. Increased water temperatures could lengthen the ideal growing season. Higher salinity could reduce the range of *Egeria densa* within the Delta.

## 3. Increased Urbanization

The Delta, East Bay, and Sacramento regions, which include portions of Contra Costa, Alameda, Sacramento, San Joaquin, Solano, Stanislaus, and Yolo counties, are expected to increase in population by nearly three (3) million people between 2007 and 2020. Increases in urbanization and housing developments can impact habitat by altering watershed characteristics, and changing both water use and stormwater runoff patterns. For example, the General Plans for the cities of Stockton, Brentwood, Lathrop, Tracy and Manteca and their surrounding communities anticipate rapid growth for several years to come. The anticipated growth will occur along both the I-5 and US-99 transit corridors in the east and Highway 205/120 in the south and west.

Increased growth will place additional burdens on resource allocations, including natural gas, electricity, and water, as well as on infrastructure such as wastewater sanitation plants, roads and highways, and public utilities. Some of these actions, particularly those which are situated away from waterbodies, will not require Federal permits, and thus will not undergo review through the ESA Section 7 consultation process (NMFS 2012). Feyrer's analysis of fish sampling data noted that increased water demand due to urbanization was a serious threat to delta smelt (Feyrer et al. 2011).

Increased urbanization is also expected to result in increased recreational activities in the region. Among the activities expected to increase in volume and frequency is recreational boating. Boating activities typically result in increased wave action and propeller wash in waterways. Boating activities can degrade riparian and wetland habitat by eroding channel banks and mid-channel islands, thereby causing an increase in siltation and turbidity. Wakes and propeller wash also churn up benthic sediments, thereby potentially resuspending contaminated sediments and degrading areas of submerged vegetation. This in turn would reduce habitat quality for the invertebrate forage base required for the survival of juvenile salmonids and green sturgeon moving through the system. Increased recreational boat operation in the Delta is anticipated to result in more contamination from the operation of gasoline and diesel powered engines on watercraft entering bodies of the Delta (NMFS 2012).

Section 6

# Effects of the Action

# 6. Effects of the Action

The purpose of this section is to analyze the potential impacts of EDCP on listed species and/or critical habitats. Effects refer to both stressors (negative impacts) and subsidies (positive impacts) of the action. This analysis includes an assessment of: direct and indirect effects, including conservation and minimization measures, and the effects of the action on species when added to the environmental baseline and cumulative effects in the action area.

The effects of an action depend on the potential impact of the particular stressors of the action, and the presence of listed species and/or critical habitat within the action area. A particular species may be affected by an action, but if they are not present when the action occurs, there is no potential for an adverse effect. Conversely, a species may be present, but the effect of the action may be insignificant, so again there is no potential for an adverse effect. When the species is present within the action area, and the stressor negatively affects the species, there is potential for an adverse effect.

Thus, to analyze the potential impacts of EDCP on listed species and/or critical habitats, this section first summarizes the presence of listed species within the action area, and then considers the potential direct and indirect effects of EDCP actions. This section is organized as follows:

*A. Listed Species in the Action Area*
*B. Overview of EDCP Stressors*
*C. Direct Effects of EDCP*
*D. Indirect Effects of EDCP*
*E. Direct and Indirect Effects of Interrelated or Interdependent Actions*
*F. Effects Considering Environmental Baseline and Cumulative Effects*
*G. Subsidies of EDCP*
*H. Alternative Actions.*

## A. Listed Species in the Action Area

The potential exists for impacts to occur to native and listed fish species under EDCP, since these fish do occur in the general project area, whether or not they occur in *Egeria densa* beds specifically. This section discusses the potential for exposure of special status and other fish to EDCP treatments.

Although not specific to *Egeria densa* beds, the Stockton Fish and Wildlife Office of the USFWS conducts an annual monitoring program for juvenile

Delta fisheries. The focus is on Chinook salmon, however the program identifies, tracks, and monitors all fish species sampled at several beach seine and trawl locations. These studies provide time-series data on fish abundance and assemblages in six Delta regions, and support previous findings that the most abundant fish species captured in the Delta are non-indigenous (Hanni 2005).

Recently published studies analyzing historical fish survey data (Grimaldo et al. 2012, Sommer et al. 2011) have evaluated native fish abundance and location within the Delta. Grimaldo et al. (2012) evaluated spatial and temporal distribution of fish at a reference location and three restored marshes between April 1998 and July 1999. Only 2 percent of the 47,000 fish found were native species, including only 202 Chinook salmon and ten delta smelt. Introduced fish, especially centrarchid fishes, were abundant in submersed aquatic vegetation (SAV), while native fish were more abundant in tidal sloughs.

Study results in 2005 (the last year for which summary reports are available), for the monitoring period May 1 through August 31 (coinciding with EDCP activity) captured a total of 56,793 fish and 51 different species (Hanni 2005). Although over fifty different species were captured in total, a small number of species made up the majority of fish. Between one and six species made up at least 75 percent of the sample in each region (Hanni 2005). The most abundant fish captured were introduced inland silversides and red shiners, each 27 percent of the total. The most commonly captured native fish were Sacramento suckers (8 percent), and Sacramento splittail (2 percent). Fish assemblage stability measured between May and August from 1995 to 2005 was moderately stable in most regions, and most stable in the Lower Sacramento River region (Hanni 2005). Fish diversity during the same time period showed a declining trend, except in the South Delta, although data is highly variable and it is difficult to make definitive inferences (Hanni 2005).

Consistent with these trends, 2000 to 2006 beach seine surveys generally found an increase in non-native fish and a decrease in native fish (Hanni and Chapman 2006). More recent studies show a significant shift in the make-up of fish species in the Delta, with fewer native species. California Department of Fish and Game's (CDFG) Resident Fish Survey in 1981/1982 found 18 percent natives and 35 percent bass and sunfish, while a University of California, Davis study in 2009/2010 found only 4 percent natives and 74 percent bass and sunfish (Conrad et al. 2010b).

Location of fish species within the Delta also influences the potential for exposure to EDCP treatment herbicides. Sommer's evaluation of migration patterns of delta smelt (Sommer et al. 2011) found that delta smelt are present year-round at Cache Slough (a site that has not been treated for *Egeria densa*). Delta smelt migration from Suisun Marsh and the western edge of the Delta to upstream spawning sites typically begins after the first winter storms bring the "first flush" of freshwater. While migrating smelt reach upstream spawning areas within a month, they typically hold in those areas until they begin spawning between late February and May. Delta smelt were not found in the southern Delta during summer months (Sommer et al. 2011), and were more

abundant in Sacramento River fish survey sites than San Joaquin River survey sites (Nobriga et al. 2005). Most EDCP treatments, to date, have not been in the Sacramento River.

The information provided on treatment season dates and periods of spawning, migration, and emigration of special status fish species in the Delta indicates that there may be some overlap between special status fish in the Delta and EDCP treatments. Another component of this analysis is to identify the extent to which special status fish species are likely to be present in *Egeria densa* beds during treatment dates and times. These studies demonstrate that it is unlikely that special status species, including delta smelt, Chinook salmon, and Central Valley steelhead will be present in *Egeria densa*. Less is known about the specific locations of green sturgeon within the Delta.

Shallow vegetated areas function as nurseries for small fish, providing relatively abundant food and shelter from predators. Some native fish of the Delta, including the threatened/endangered delta smelt, are known to use aquatic vegetation for spawning and rearing (McGowan 1998). Likewise, juvenile salmon may use shallow water during their migrations through the Delta. However, studies find that delta smelt were more abundant in offshore habitats (Norbiga et al. 2004), and four native species, Chinook salmon, delta smelt, hitch, and starry flounder were not detected at Mildred Island, a sample site with the greatest extent of submerged aquatic vegetation (primarily *Egeria densa*) (Norbiga et al. 2005). An evaluation of the importance of tidal wetland restoration to native fish species found that fish communities of freshwater tidal wetlands and associated near-shore habitats are dominated by alien species, and that the most common plant species in these habitats in the Delta are *Egeria densa* and tules (Brown 2003). Marshall et al. (2006) note that native species prefer rocky substrate, while non-natives generally prefer aquatic vegetation.

Use of dense aquatic vegetation, such as *Egeria densa,* by fish is not well documented. Although some studies report that dense beds of *Egeria densa* provide habitat for certain fish, other studies suggest that depressed oxygen levels (depending on time and depth) and reduced temperature characteristic of beds are limiting to certain species (Cook and Urmi-Koneg 1984). A study evaluating behavior of juvenile bluegill and largemouth bass in a Wisconsin lake found that fish species have variable preferences for plant densities, with juvenile bluegill preferring moderately dense vegetation and largemouth bass preferring lower plant densities or the periphery of plant beds (Harnel et al. 2001). Plant habitats in this study typically consisted of two or more plants, while *Egeria densa* often forms in extremely dense monospecific mats.

A series of recent studies of the role of *Egeria densa* in the increasing abundance of the non-native largemouth bass in the Delta found that juvenile largemouth bass acquire fish prey in habitats with intermediate or heavy submersed aquatic vegetation (SAV) (Conrad et al. 2010a, Vella et al. 2010). These studies have been evaluating the link between the increase in number (and size) of largemouth bass in the Delta that has paralleled the increase in *Egeria densa*. The increase in largemouth bass has occurred during a period when native fish in the Delta

have declined. Conrad's studies show that juvenile largemouth bass are strongly associated with SAV throughout the year, and the models suggest that *Egeria densa* is important to success of juveniles, perhaps for protection from predators and juvenile bass prey may be more abundant in *Egeria densa* mats (Conrad et al. 2011). *Egeria densa* is the predominant SAV present in the Delta (Santos et al. 2011), making up 85 percent of the SAV biomass sampled at 33 sites throughout the Delta between October 2008 and October 2010 (Conrad et al. 2011).

According to Brown, Conrad, and others, *Egeria densa* is a major agent of ecosystem change, altering basic abiotic properties of ecosystems, which results in increased predation on and competition for native fishes. In fact, previous research indicates that *Egeria densa* is an ecosystem engineer (Champion and Tanner 2000; Brown 2003), which is defined as 'a species that directly or indirectly modulates the availability of resources (other than themselves) by causing physical state changes in biotic or abiotic materials' (Jones et al. 1994, 1997, Drexler 2006). *Egeria densa* reduces water velocity, increases sedimentation, and increases water clarity (Conrad et al. 2011). The increase in water clarity likely favors visual, lie-in-wait predators such as largemouth bass (Conrad et al. 2011).

Researchers at San Francisco State University, under contract with the DBW, studied the use of *Egeria densa* beds by Delta smelt, splittail, migratory salmonids, and other fish of the Sacramento-San Joaquin Estuary (McGowan 1998, McGowan and March 1998). Pop nets and light traps were used to collect fish in *Egeria densa* beds. Additionally, piles of *Egeria densa* mechanically harvested during other DBW experiments were sampled and sorted in their entirety for fish and invertebrates. (See McGowan 1998 for an explanation of sampling methods.) Samples were collected from May through late October at six sites in the Delta: Sandmound Slough, Seven Mile Slough, White Slough, Big Break Marina, Franks Tract, and Little Venice Island. A total of 257 pop-net samples and 193 light trap samples were collected over the sampling period. In the pop-net samples, 2,181 individual fish were collected; 840 fish were collected in the light traps, and 671 fish, crabs, and tadpoles were sorted from the harvested *Egeria densa*.

A total of fourteen (14) species of fish were collected from the sampling effort as shown in **Figure 6-1,** on the next page. Of the fourteen species of fish collected, only one is a native species (prickly sculpin). According to McGowan (1998), species collected were typical non-native residents of the Delta. Small individuals of bluegill, sunfish, largemouth bass, threadfin shad, and inland silversides dominated the catches. No sensitive species such as delta smelt, juvenile Chinook, or steelhead were collected. These data should provide a fairly accurate indication of which fish species may be found in *Egeria densa* beds during EDCP operations, since the sampling was conducted during many of the same months that project operations would occur. Five of the fourteen species identified by McGowan were also among the dominant Delta species captured in beach seine and trawl studies in 2005: inland silverside, golden shiner, mosquito fish, threadfin shad, and red shiner (Hanni, 2005).

**Figure 6-1**
**Fish Collected in *Egeria densa* Beds within the Delta**

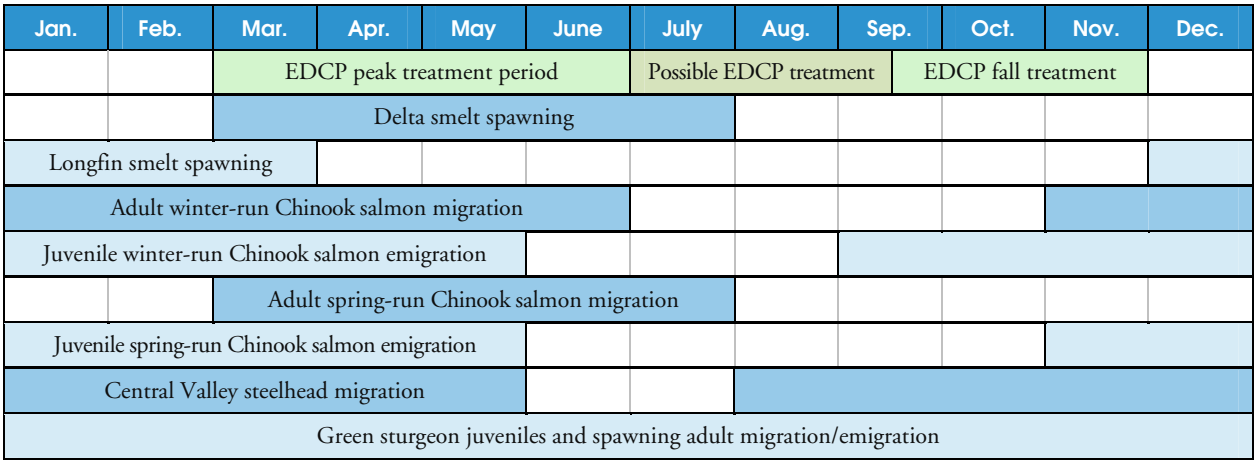
| Species | Invasive (I) | Big Break | Frank's Tract | Little Venice | Seven Mile Slough | Sandmound Slough | White Slough |
|---|---|---|---|---|---|---|---|
| Blue gill | I | X | X | X | X | X | X |
| Redear | I | | | X | X | X | X |
| Largemouth bass | I | X | X | X | X | X | X |
| Black crappie | I | | | | X | X | X |
| Warmouth | I | | | | X | X | X |
| Golden shiner | I | | | | | X | |
| Red shiner | I | X | | | X | | |
| Cyprinidae | I | | | | | X | |
| Inland silverside | I | X | X | X | X | X | X |
| Killifish | I | X | X | | X | X | |
| Mosquito fish | I | X | | X | | X | X |
| Threadfin shad | I | X | | X | X | X | X |
| Brown bullhead | I | | | | | X | |
| Prickly sculpin | | X | | | X | | |

McGowan's findings are similar to those of Grimaldo and Hymanson, who report that introduced fish species and Chinese mitten crabs were most abundant in *Egeria densa* stands in the Delta, as opposed to other submerged macrophyte habitat types (Grimaldo and Hymanson 1999). Further, these researchers found that native fish were far less frequent inhabitants of the *Egeria densa* beds. The findings of McGowan and Grimaldo and Hymanson suggest that *Egeria densa* is not typically used by native fish species or specifically any threatened, endangered, or special status species as habitat or as a migration corridor.

Turbidity (as measured by Secchi depth) and specific conductivity are good predictors of delta smelt occurrence (Feyrer et al. 2007). Delta smelt are more likely to be found in areas with higher turbidity levels, and relatively lower specific conductivity (lower saline levels). At any particular fish survey time and location, delta smelt are primarily found in offshore habitats (Nobriga et al. 2004, Nobriga et al. 2005). Recent studies have found that *Egeria densa* negatively impacts delta smelt by reducing turbidity and overwhelming littoral (near shore) habitats (USFWS 2008). Similarly, Chinook salmon are most common in open water shoals (Grimaldo et al. 2012).

DBW conducts EDCP treatments between March (selected areas only) and November, with the majority of treatments in April through June. The EDCP treatment period also coincides temporarily with the migration and emigration of certain runs of Chinook salmon through the Delta, and the presence

**Figure 6-2**
**Proposed Period of EDCP Treatments; Periods of Peak Spawning in the Delta; and Migration and Emigration of Special Status Fish Species through the Sacramento-San Joaquin River System**




of delta smelt, longfin smelt, and green sturgeon in the Delta. **Figure 6-2,** above, summarizes the timing of listed fish presence in the Delta based on descriptions in Section 4. Survey data indicate that it is not likely that fish will be directly in *Egeria densa*. However, given the locations of EDCP treatments and listed fish spawning and migratory patterns, it is possible that some listed fish may be present near EDCP treatment sites. Although unlikely, individual listed fish may, on occasion, be present near EDCP treatment sites, with potential for exposure to EDCP treatment chemicals in treatment sites or receiving waters.

While giant garter snakes and valley elderberry longhorn beetles may be present within EDCP action area, the potential for exposure to EDCP activities is low. Giant garter snakes bask on grassy banks and on branches over the water's edge where herbicide applications will not occur (USFWS 1993). In regards to WHCP, USFWS (1995) expected giant garter snakes to move out of the area as boat crews approached in motor driven boats; one would expect similar behavior toward EDCP boats. In addition, giant garter snakes are known to inhabit emergent, rather than submersed, aquatic vegetation. To avoid covering giant garter snake burrows with disposed weeds, EDCP will only dispose of handpicked *Egeria densa* in approved disposal locations, away from the water's edge and sensitive habitats.

Valley elderberry shrubs are located within EDCP project area in scattered locations along the shoreline. The valley elderberry longhorn beetle inhabits shrubs with stems greater than one-inch in diameter. EDCP treatments occur only in the water, and there is no aerial herbicide spraying, thus eliminating the potential for drift. There is an extremely low likelihood of exposure of shrubs to herbicide-treated water for an adequate time to result in negative effects due to wave wash, if a plant was located immediately adjacent to a treatment site.

## B. Overview of EDCP Stressors

The EDCP consists of an integrated management approach to control invasive *Egeria densa* in the Delta and its tributaries. The program consists primarily of chemical treatment, supported by limited diver assisted handpicking, diver operated suction-harvesting, and benthic barriers. Most of the potential EDCP stressors result from chemical treatments. Below, we briefly discuss other potential stressors and describe potential for adverse effects.

- Diver assisted handpicking consists of trained SCUBA divers handpicking *Egeria densa* plants from the root. Divers may use small hand tools if necessary to ensure that the root is removed. The small scale and low-impact nature of these activities will not adversely affect listed species or critical habitats
- Diver-operated suction harvesting consists of trained SCUBA divers handpicking and removing *Egeria densa* (also from the root) with suction hoses. Plants are deposited in the support boat, barge, or nearby dock and disposed of in approved locations away from the water and sensitive habitats. The small scale and low-impact nature of these activities are not likely to adversely affect listed species or critical habitat, although there could be potential for direct effects due to sediment toxicity and disturbance due to the presence of divers and equipment. These potential effects are discussed below
- Benthic barriers consists of a physical cover over aquatic weeds, preventing sunlight from reaching the plants. The barrier material can be synthetic or natural. While certain barrier materials allow for gas exchange and do not negatively impact benthic macroinvertebrates, this approach has the potential for indirect effects on listed species due to the possible impact on benthic macroinvertebrates under the mats. This potential effect is discussed below
- Chemical treatment consists of treatment crews utilizing approved herbicides in *Egeria densa* mats. This approach has the potential for direct effects to listed species due to toxic effects on fish, effects on water quality, bioaccumulation of herbicides, and disturbance by treatment crew boats. Chemical treatment has the potential for indirect effects to listed species and critical habitats due to loss of native plants, food web effects, and low dissolved oxygen. The potential effects of chemical treatment will be evaluated below.

## C. Direct Effects of EDCP

Direct effects are caused by the action and occur at the time of the action.

### 1. Toxicity of Herbicides to Listed Species

The potential for direct toxic affects to listed species depends on the proximity of listed species, concentrations of herbicides, and length of exposure.

#### *Concentrations of EDCP Herbicides in, and Adjacent, to Treatment Sites and Water Quality Effects*

There are two factors to evaluate related to herbicide concentrations following EDCP treatments: (1) the concentration as it relates to NPDES guidelines and Basin Plan limits to maintain water quality, and (2) the concentration as it relates to toxic levels. The EDCP has been monitoring herbicide concentrations (primarily fluridone) following EDCP treatments since the program's inception in 2001. Section 3 summarizes

recent monitoring data for fluridone, and prior monitoring data for diquat. Because the two new EDCP herbicides have not been utilized in the Delta, to date, there is no prior data. Section 3 also provides calculated acute and chronic concentrations of fluridone, penoxsulam, imazamox, and diquat. The acute calculations are based on the highest herbicide application rate, and the chronic calculations are based on conservative dilution estimates, on historical data for fluridone, and prior studies. Given the tidal flow in the Delta, both the acute and chronic concentration calculations are conservative.

In reality, mixing of any herbicide that reaches the water occurs through the entire depth of water at the site, and tidal movement and through water Delta flow dilutes herbicides even further. The Delta is not a stationary water environment, thus, the concentration of herbicide immediately after treatment is not stable, but rather readily dilutes (in addition to degradation pathways). There are two tidal cycles in the Delta every day, with typical water fluctuations of three to five feet in each cycle. In addition, the Delta functions in a complex hydrological system consisting of inflows from rivers and reservoirs, Delta exports, and tidal fluctuations.

Approximately 30 $km^3$ of freshwater enter the Delta (and then San Francisco Bay) annually, with peak flows in early March (Knowles 2000). Freshwater inflows and Delta exports are the major influences of salinity in the Delta. Illustrating the movement of water within the Delta, the X2 salinity line (distance of the near-bottom 2 psu isohaline line from the Golden Gate) varies by up to 30 km during the course of a year (Knowles 2000).

Historical water quality monitoring data demonstrates that actual herbicide concentrations decrease rapidly in the Delta following treatment. Water samples taken downstream of the treatment site at two to three feet depth one-hour post treatment show actual herbicide levels that are at least an order of magnitude below the herbicide application rate.

USEPA's standard ecological assessment approach to evaluate the potential for toxic effects on terrestrial and aquatic animals and plants is based on comparing a calculated risk quotient (RQ) to specified levels of concern (LOC). The RQ is equal to the water chemical concentration (expected environmental concentration, or EEC) divided by an acute or chronic toxicity value: RQ = Exposure/Toxicity. Protocol requires using the lowest available toxicity values for relevant species in the scientific literature in order to ensure that RQ values are conservative.

LOC's are unit-less values determined by the USEPA's Office of Pesticide Programs. When the RQ is higher than the specified LOC, it is an indication of the need for further investigation of that particular chemical application. RQ exceedances do not themselves indicate impacts. **Table 6-1,** on the next page, provides the USEPA's LOCs. USEPA's interpretation of LOC risks is as follows (USEPA 2007):

- Acute high risk: potential for acute risk is high; regulatory action may be warranted in addition to restricted use classification
- Acute restricted use: the potential for acute risk is high, but this may be mitigated through restricted use classification
- Acute endangered species: the potential for acute risk to endangered species is

high, but this may be mitigated through restricted use classification

- Chronic risk: the potential for chronic risk is high; regulatory action may be warranted.

This Biological Assessment utilizes historical and calculated herbicide concentrations to determine compliance with NPDES water quality standards and USEPA risk calculations.

**Table 6-2,** below, provides the maximum application rate of herbicide in the treatment site, which we utilize for a conservative estimate of EEC for calculating acute toxicity RQ values. Table 6-2 also provides a conservative in-water concentration for the purpose of calculating chronic EDCP risk quotient (RQ) values, and the NPDES water limits or monitoring triggers for EDCP herbicides.

**Table 6-1**
**Aquatic Animal Levels of Concern**

| Risk Presumption | Risk Quotient[1] | Level of Concern |
|---|---|---|
| Acute High Risk | EEC/LC50 or EC50 | 0.5 |
| Acute Restricted Use | EEC/LC50 or EC50 | 0.1 |
| Acute Endangered Species | EEC/LC50 or EC50 | 0.05 |
| Chronic Risk | EEC/MATC or NOEC | 1 |

Source: USEPA, 2007.

**Table 6-2**
**Maximum Active Ingredient Concentrations for EDCP Herbicides For RQ Calculations and NPDES Maximum Limitations**

| Herbicide Active Ingredient | Concentration for RQ Acute Calculation (in treatment sites) | Concentration for RQ Chronic Calculation (in treatment sites) | NPDES Maximum Limitation (in receiving waters) |
|---|---|---|---|
| Fluridone | 30 ppb | 3 ppb | 560 ppb |
| Penoxsulam | 50 ppb | 10 ppb | 10.1 ppm |
| Imazamox | 250 ppb | 100 ppb | NA |
| Diquat dibromide | 0.37 ppm* | 15.9 ppb | 20 ppb |

* The instantaneous diquat c.e. concentration in the treatment site at the label application rate is higher than the NPDES maximum limit for receiving waters. This concentration rapidly dilutes in Delta waters.

[1] LC50 is the lethal concentration for 50 percent of the test species. EC50 is the effective concentration (for a defined endpoint) for 50 percent of the target. MATC is the maximum acceptable toxicant concentration. NOEC is the Non-observable effect concentration.

There is currently no trigger for imazamox, as this herbicide was recently approved for aquatic use in California. The SWRCB will develop a monitoring trigger or water limit for this herbicide, most likely before the start of the 2013 treatment season. The EDCP will not utilize imazamox until a monitoring trigger has been specified.

The RQ concentrations for all four EDCP herbicides are conservative. Acute RQ tests are based on a 96-hour (or in some cases 48-hour) toxicity test. Our EDCP RQ calculations utilize the application rate concentration; however, monitoring results demonstrate that actual herbicide concentrations even one hour after treatment are significantly lower than application rates due to mixing, water movement, and binding with sediment. USEPA utilizes a less conservative geometric mean when determining environmental concentrations for acute RQ calculations (Washington DOE 2002). This value is calculated by multiplying the concentration of the herbicide occurring during the four day exposure period and then calculating the $4^{th}$ root. For diquat, the geometric mean concentration results in an effective environmental concentration (EEC) for the RQ calculation that is much lower than the application rate – for example at a 0.224 ppm application rate, the typical concentration was calculated to be 0.059 ppm for the 96-hour acute exposure level (Washington DOE 2002).

For chronic RQ calculations, we utilize actual Delta concentrations following EDCP treatment for fluridone and diquat, and conservative estimated concentrations for penoxsulam and imazamox based on likely application rates and herbicide dilution patterns seen with fluridone.

The acute RQ concentrations in Table 6-2 represent maximum EECs. The EDCP complies with NPDES guidelines and basin plan limits to maintain water quality, thus water quality is not adversely affected by the program. The application rate for diquat is higher than the NPDES guideline, 0.37 ppm versus 0.20 ppm (or 20 ppb). However, the 0.37 ppm level will be the maximum applied in the treatment site. In downstream waters, where NPDES requirements are relevant, diquat levels are likely to be lower, as shown in prior monitoring.

The remainder of this subsection summarizes toxicity data and RQ calculations for each of the current and new EDCP treatment herbicides.

### *Toxicity of Fluridone to Listed Fish Species*

Fluridone use is unlikely to have direct adverse impacts to fish exposed during or following treatments. Under EDCP, fluridone will be applied to achieve a water column concentration of one (1) to ten (10) ppb (0.001 ppm to 0.01 ppm), with most applications designed to achieve a one (1) to three (3) ppb range. This concentration is well below that known to result in lethal effects to fish species. Results of CDFG fathead minnow toxicity tests (using fluridone treated sample water (Sonar)) found no difference in toxicity for samples with detectable, and non-detectable, levels of fluridone between 2002 and 2005 (DBW 2006).

Pest control recommendations, prepared by a licensed pest control advisor, are used for EDCP fluridone applications. Fluridone will be applied at a concentration of five (5)

to thirty (30) ppb per application. Given dilution and water flow in each treatment site, this treatment protocol is designed to maintain a range of one (1) to ten (10) ppb of fluridone in the water column during the treatment period.

For fluridone treatments, EDCP measures the concentration of fluridone during the treatment period. EDCP staff collect water samples regularly throughout the treatment period. The SePRO laboratory, an EDCP contractor, tests fluridone concentrations in these water samples using FasTEST, an immunoassay test. FasTEST results are intended to be used to adjust application rates to optimize ambient fluridone concentrations throughout the treatment period. As shown in Section 3, FasTEST results suggest that ongoing fluridone concentrations throughout the treatment period are significantly lower than the LC50 values reported below.

Research on fluridone impacts to various fish species are summarized below and presented in **Table 6-3**, on the following page. Where information was available, Table 6-3 identifies the fluridone formulation. There are relatively few new toxicity studies conducted within the last five years on the acute or chronic toxicity of fluridone to fish. A 2008 human health and ecological risk assessment of fluridone conducted for the US Forest Service referenced fish toxicity studies conducted between 1978 and 1994 (SERA 2008).

Two more recent studies demonstrate the lack of toxic impact of fluridone on fish. Curran (2007) evaluated the olfactory-mediated behavior in juvenile salmonids exposed to fluridone as a means of measuring sublethal effects on salmonids. Juvenile salmonids did not avoid waters with fluridone (Sonar AS) concentrations of 0.90 and 0.09 ppm. Curran noted that the absence of avoidance indicated that juvenile salmonids may not move to untreated habitats when exposed to herbicide, but that conversely, absence of avoidance behavior suggests that juvenile salmonids might not leave protective plant habitats during treating, perhaps a safer alternative. Curran also evaluated olfactory performance in salmonids exposed to aquatic herbicides, using juvenile rainbow trout as surrogates. This study measured the extent to which fish demonstrated avoidance behavior following 96 hours of exposure to 0.90 or 0.09 ppm fluridone (Sonar AS). Treated fish showed no difference from controls, indicating that exposure to the herbicide did not impair olfactory performance, which is important to normal fish behavior. Both concentrations tested by Curran are significantly higher than the maximum EDCP application rate of 0.03 ppm.

Jacob (2008) evaluated the ecological effects of fluridone in pond cultured catfish. Fluridone is one of the few herbicides permitted for macrophyte control for aquaculture. The study measured number of fish harvested per cubic meter, survival percent, and yield (grams per cubic meter). Ponds were treated with AVAST, a “generic Sonar” product similar to Sonar AS, with concentrations starting at 0.33 ppm and dropping after approximately 15 days to 0.07 ppm. Fish were measured after 80 days. As compared to controls, fluridone treated water generated higher fish harvest rates, survival percentages, and yield. These beneficial effects on fish occurred at concentrations higher than EDCP application rates.

**Table 6-3**
**Response of Various Fish Species to Fluridone at LC50 Values**

| Species | LC50 (ppm) | Time Period | Reference |
|---|---|---|---|
| Rainbow trout | 11.7 | 96-hour test | USEPA 1986 |
| Rainbow trout | 10.4 +/-3.9 | 96-hour test (technical grade and Sonar AS) | Hamelink et al. 1986 |
| Bluegill | 12.0 | 96-hour test | USEPA 1986 |
| Bluegill | 10.4 +/-3.9 | 96-hour test (technical grade and Sonar AS) | Hamelink et al. 1986 |
| Fathead minnow | 10.4 +/-3.9 | 96-hour test (technical grade and Sonar AS) | Hamelink et al. 1986 |
| Sheepshead minnow | 10.4 +/-3.9 | 96-hour test (technical grade and Sonar AS) | Hamelink et al. 1986 |
| Channel catfish | 10.4 +/-3.9 | 96-hour test (technical grade and Sonar AS) | Hamelink et al. 1986 |
| Smallmouth bass | 7.6 | 96-hour test (technical grade and Sonar AS) | Paul et al. 1994 |
| Smallmouth bass | 4.5 | 96-hour test NOEC (Sonar AS) | Paul et al. 1994 |
| Largemouth bass | 13 | 96-hour test (Sonar AS) | Paul et al. 1994 |
| Largemouth bass | 9.6 | 96-hour test NOEC (Sonar AS) | Paul et al. 1994 |
| Walleye | 1.8 | 96-hour test (Sonar AS) | Paul et al. 1994 |
| Walleye | 0.78 | 96-hour test NOEC (Sonar AS) | Paul et al. 1994 |
| Bluegill | 2 | NOEC | Habig 2004 |
| Rainbow trout | 4.2 | 96-hour test | Habig 2004 |
| Fathead minnow | 22 | 96-hour test | Habig 2004 |
| Channel catfish | 8.2 | 96-hour test | Habig 2004 |
| Sheepshead minnow | 10.7 | 96-hour test | Habig 2004 |
| Sheepshead minnow | 3.1 | NOEC | Habig 2004 |
| Chinook smolts* | >5.76 | 96-hour test (Sonar PR) | Habig 2004 |
| Chinook smolts | 0.725 | NOEC (Sonar PR) | Habig 2004 |
| Delta smelt, larval* | 6.1 | 96-hour test (Sonar) | DBW 2003 |
| Delta smelt, larval* | 1.28 | NOEC (Sonar) | DBW 2003 |
| Sacramento splittail, larval | 4.8 | 96-hour test (Sonar) | CDFG-ATL 2003 |
| Sacramento splittail, larval | 1.3 | 96-hour NOEC (Sonar) | CDFG-ATL 2003 |
| Sacramento splittail, larval | 2.8 | 96-hour LOEC (Sonar) | CDFG-ATL 2003 |
| Sacramento splittail, juvenile | 23.8 | 96-hour test (Sonar) | DBW 2003 |
| Sacramento splittail, juvenile | 19.3 | NOEC (Sonar) | DBW 2003 |
| Fathead minnow, larval | 6.2 | 96-hour test (Sonar) | DBW 2003 |
| Fathead minnow, larval | 1.88 | NOEC (Sonar) | DBW 2003 |

* Study utilized in RQ calculation.

There are a number of studies that demonstrate low fish toxicity to fluridone:

- Habig (2004) reported NOEC levels from three fluridone studies. The bluegill NOEC level was 2 ppm, sheepshead minnow NOEC was 3.1 ppm. Habig also conducted acute toxicity testing, utilizing Sonar PR, and determined a NOEC for Chinook smolt of 0.725 ppm. All three of these levels are well above EDCP fluridone treatment concentrations
- Habig (2004) also reported 96-hour LC50 results for five fish species, including rainbow trout (4.2 ppm), fathead minnow (22 ppm), channel catfish (8.2 ppm), sheepshead minnow (10.7ppm), and Chinook smolts (>5.76ppm)

- The USEPA (1986) reports that the LC50 for rainbow trout (*Salmo gairdneri*) and bluegill (*Lepomis macrochirus*) exposed to fluridone for a 96-hour period was 11.7 ppm and 12.0 ppm respectively, approximately 1,000 times greater than the maximum target water column concentration for EDCP of 10 ppb
- Results of numerous acute and chronic toxicity tests conducted by Hamelink and others (1986) revealed similar findings. These researchers found 96-hour LC50 concentrations of 10.4 +/- 3.9 ppm for the representative fish used in their study: rainbow trout (*Salmo gairdneri*), fathead minnows (*Pimephales promelas*), channel catfish (*Ictalurus punctatus*), bluegills (*Lepomis macrochirus*), and sheepshead minnows (*Cyprinodon variegatus*). Channel catfish fry exposed to fluridone concentrations of 0.5 ppm were not significantly affected. Catfish fry growth was reported as reduced at fluridone concentrations of 1.0 ppm. Chronic exposure of fathead minnows to mean concentrations of 0.48 ppm did not produce adverse effects
- Fluridone concentrations of 0.95 and 1.9 ppm resulted in reduced survival of fathead minnows within 30 days of hatching (Hamelink and others 1986), values well above potential chronic exposure during EDCP treatments
- USEPA (1986) also lists a Maximum Acceptable Toxicant Concentration (MATC) of greater than 0.48 ppm, but less than 0.96 ppm, for exposure of fathead minnow fry (*Pimephales promelas*) to fluridone. This indicates that no treatment related effects to fathead minnows were observed at or below 0.48 ppm
- Paul et al. (1994) measured 24, 48, 72, and 96 hour LC50 values for smallmouth and largemouth bass using Sonar AS. Toxicity values for Paul are based on analytical measurements of fluridone. Paul found LC50 values of 7.6 ppm and 13 ppm, respectively, for smallmouth and largemouth bass after 96 hours of exposure. LC50 values for walleye were lower, at 1.8 ppm, but still orders of magnitude greater than EDCP concentrations.

**Table 6-4,** on the next page, identifies results of subchronic and chronic aquatic toxicity testing with fluridone on fish. These tests illustrate that even maintaining fluridone concentrations at a treatment site for 8 to 16 weeks is not likely to have any adverse impacts on fish.

In an independent study of aquatic pesticide toxicity within the Delta, the San Francisco Estuary Institute (SFEI) conducted the Aquatic Pesticide Monitoring Program (APMP) (Siemering et al. 2008). The APMP, funded by the SWRCB, was part of the settlement of the 2001 *Headwaters, Inc. v. Talent Irrigation District* decision regarding the requirement to obtain an NPDES permit for aquatic pesticide use. The purpose of the APMP was to evaluate water quality impacts associated with the use of aquatic pesticides, and to evaluate non-chemical alternatives.

For fluridone, the SFEI analysis utilized water concentrations from Clear Lake and Merced Irrigation District, not EDCP (Siemering 2008). Nevertheless, the calculated RQ values for Chinook salmon LC50, *Pimephales promelas* (fathead minnow) LC50, and delta smelt NOEC were all well below the LOC values.

In another study, SFEI analyzed DBW EDCP monitoring results, calculating RQ values and the number of LOC exceedances for monitoring data from 2003 to 2005. For the 189 RQs that SFEI calculated for the three year period, there were no LOC exceedances for fish (Siemering 2006).

**Table 6-4**
**Subchronic and Chronic Aquatic Toxicity Testing Results**

| Species | Type of Test | Result (mg/L or ppm) | Reference |
|---|---|---|---|
| Fathead minnow | Full lifecycle plus $F_1$ growth/survival | NOEC = 0.48 | Habig 2004 |
| Fathead minnow | Full lifecycle plus $F_1$ growth/survival | Reduced survival of minnows exposed to 0.95 and 1.9 (technical grade and Sonar AS) | Hamelink et al. 1986 |
| Channel catfish | Early life stage | NOEC = 0.5 | Habig 2004 |
| Channel catfish fry | Early life stage | Growth NOEC =1 (Sonar AS) | Hamelink et al. 1986 |
| Chinook salmon* | Early life stage | Growth NOEC = 0.848<br>Gill histopath NOEC = 0.222 (Sonar PR) | Habig 2004 |

* Study utilized in RQ calculation.

A number of studies have evaluated the effects of whole lake fluridone treatments for invasive weed control on resident fish. Bremigan et al. (2005) found that small largemouth bass grew better in lakes that had been treated with 5 to 8 ppb fluridone (maintaining over 2 ppb concentration) for over 60 days than in untreated lakes. Maceina and Slipke (2004) found neutral or positive impacts on young largemouth bass in coves treated with fluridone as compared to untreated coves. Largemouth bass are known to favor submersed aquatic vegetation (Maceina and Sliple 2004), so they might be expected to be negatively impacted by controlling SAV. Parsons et al. (2009) found that whole lake treatment in Washington State at 10 to 26 ppb improved growth of largemouth bass and pumpkinseed fish, while reducing growth of the invasive small yellow perch in the two years following treatment. Valley and Bremigan (2002) studied the effects of selective removal of Eurasian watermilfoil using low-dose fluridone applications in Michigan lakes and found no negative effects on age-0 largemouth bass.

The following is the conclusion of Habig (2004), as it relates to the toxicity of fluridone used in EDCP to salmon:

> *"The available evidence indicates that migrating salmon will not be adversely impacted by exposure to fluridone at the concentrations used in the EDCP. The concentrations of fluridone used in the EDCP are several orders of magnitude below the acute toxicity value for the most sensitive species, and margins of safety based on testing of chinook salmon smolts are even larger than those calculated using data on juvenile trout because the salmon smolts were less sensitive to fluridone under acute testing than juvenile trout. The concentrations of fluridone used in the EDCP are also at least one order of magnitude below the NOECs for sublethal effects on trout and salmon smolts based on acute toxicity data. Concentrations of fluridone used in the EDCP are also well below the NOECs from longer-term (subchronic and chronic) testing on salmon and other, more commonly tested species. These data indicate that even with long-term continuous exposure there is a large margin of safety (approximately 50-fold) between maximum fluridone concentrations measured in routine monitoring for the EDCP and*

*no-observed effect or lowest-observed effect concentrations determined from testing.*

*The seawater challenge tests conducted with salmon also indicate that adverse effects are very unlikely on key sublethal indices such as enzyme activities and ion regulation following abrupt transfer of smolts exposed to fluridone from freshwater to nearly full-strength seawater. Tested concentrations were similar to or exceeded the maximum short-term concentrations that migrating smolts might encounter in an area treated with fluridone. The results of these tests consistently indicate no adverse effects on physiological adaptation to seawater under a more stressful regime than occurs under natural conditions, where migrating fish would encounter gradually increasing saline concentrations rather than an abrupt transfer.*

*Many of the calculated safety factors are conservative because of the very short duration (transient) for upper-end measured concentrations found in the short-term EDCP dissipation study compared to longer, continuous exposure regimes used in testing. The time-dose-response principle indicates that significantly higher concentrations (one to two orders of magnitude) than the upper end concentrations measured in the short-term dissipation study would be required to elicit the types of responses observed in testing because of the very short duration of the upperend concentrations found in the short-term dissipation study compared to exposure regimes used in testing. Therefore, based on both standard toxicity testing and specialized tests conducted to address questions raised by NOAA Fisheries, and short-term and longer-term measured concentrations of fluridone in the EDCP, all the available data indicate that fluridone as used in the EDCP would not be expected to adversely impact migrating populations of salmon, particularly with a short-term exposure."* (Habig 2004, p.19)

**Table 6-5**
**RQ Calculations for fluridone**

| Species | EEC/LC 50 | RQ |
|---|---|---|
| Chinook salmon smolts | 0.03 ppm/ 5.76 ppm | 0.0052 (acute) |
| Larval delta smelt | 0.03 ppm/ 6.1 ppm | 0.0049 (acute) |
| Chinook salmon early life stage | 0.003 ppm/ 0.222 ppm | 0.014 (chronic) |
| Larval delta smelt | 0.003 ppm/ 1.28 ppm | 0.002 (chronic) |

**Table 6-5,** above, provides the RQ calculations for fluridone. For a finding of no adverse acute effect on an endangered species, the acute RQ value should be below a LOC of 0.05. For no chronic risk, the RQ should be below the LOC of 1, utilizing a no observable effect concentration (NOEC) or maximum acceptable toxicant concentration (MATC). As Table 6-5 illustrates, the RQ values for both species are well below the endangered species and chronic risk LOC values.

These findings indicate that the concentrations at which fluridone applications are applied throughout the treatment period, the subsequent fluridone concentrations measured between applications, and the post-treatment fluridone concentrations, are significantly below all published LC50 values and NOECs for fish. In conclusion, there is not expected to be any toxic affects to fish (including all sensitive species) from EDCP fluridone applications.

### *Toxicity of Penoxsulam to Listed Fish Species*

Penoxsulam is classified as practically non-toxic to freshwater and marine/estuarine fish,

based on results of acute toxicity testing (USEPA January 2007). Species with LD50 values of greater than 100 ppm fall into the practically non-toxic category. Chronic toxicity studies show no treatment-related effects to growth and reproduction in freshwater fish at concentrations up to 10.2 ppm (USEPA January 2007), a concentration approximately 1,000 times greater than the estimated long-term concentration of penoxsulam in following EDCP treatment. The acute toxicity LC50 results in USEPA's Ecological Risk Assessment (USEPA January 2007) are also non-observable adverse effect concentrations (NOAEC), as there were no observable effects at the highest concentrations tested. Similarly, in the chronic toxicity testing, there were no observable effects at 10.2 ppm, the highest concentration of penoxsulam tested. **Table 6-6,** on the next page, summarizes toxicity testing results for several fish species for penoxsulam and degradates.

Because penoxsulam is a relatively new herbicide (USEPA approval in 2007), there are few studies evaluating penoxsulam toxicity in the open literature. Most evaluations of penoxsulam ecotoxicity rely on the USEPA registration data (Washington DOE 2012, FOOTPRINT PPDB 2009). One study of the impact of penoxsulam in rice field conditions on carp found mixed signs of oxidative stress after 7, 21, or 72 days of penoxsulam exposure (Cattaneo et al. 2010). However, this study yielded inconsistent results between exposure time and measures of oxidative stress in different tissue (brain, liver, lungs), which could not be duplicated in the laboratory (Cattaneo et al. 2010), suggesting need for further evaluation. In addition, exposure levels were 23 ppb, more than double the estimated concentration of penoxsulam during EDCP treatment. Furthermore, the calculated post-treatment EDCP 10 ppb level would be expected to be conservative based on the experience with fluridone concentrations declining due to tidal flow, mixing, and dilution. Thus, EDCP treatments are not likely to result in levels that could produce this potential sub-lethal effect.

**Table 6-7,** on the next page, provides the RQs for penoxsulam. Both the acute toxicity RQ and the chronic risk RQ are well below the LOC levels (0.05 and 1, respectively). These results indicate that penoxsulam use for EDCP treatments will not result in direct acute or chronic toxicity to fish.

### *Toxicity of Imazamox to Listed Fish Species*

USEPA classified imazamox as practically non-toxic to fish. Supporting its low toxicity, imazamox was approved by USEPA as a "reduced risk" herbicide, and is the only synthetic herbicide granted a food residue tolerance exemption from USEPA (USFWS March 2012). The acute toxicity tests submitted to USEPA for the registration process found no observable effects at the highest concentrations of imazamox tested (approximately 100 ppm) (SERA 2010). There are relatively few toxicity studies evaluating the impact of imazamox on fish (or other) species; most cited studies were part of the USEPA pesticide registration process. Results of acute and chronic toxicity testing of imazamox in fish are provided in **Table 6-8,** on the next page. No bioactive metabolites inducing toxicity greater than the parent compound were found in literature screening (Environ 2012).

### Table 6-6
**Response of Various Fish Species to Penoxsulam at LC50 Values**

| Species | Chemical | LC50 | Time Period | Reference |
|---|---|---|---|---|
| Rainbow trout *(Oncorhynchus mykiss)** | Technical grade penoxsulam | >102 ppm | 96-hr | USEPA January 2007 |
| Rainbow trout | Degradates and end-use products | None | 96-hr | USEPA January 2007 |
| Bluegill sunfish *(Lepomis macrochirus)* | Technical grade penoxsulam | >103 ppm | 96-hr | USEPA January 2007 |
| Bluegill sunfish | Galleon or equivalent | >147 ppm | 96-hr | USEPA January 2007 |
| Bluegill sunfish | Degradates | None | 96-hr | USEPA January 2007 |
| Common carp *(Cyprinus carpio)* | Technical grade penoxsulam | >101 ppm | 96-hr | USEPA January 2007 |
| Common carp | Degradates and end-use products | None | 96-hr | USEPA January 2007 |
| Fathead minnow *(Pimephales promelas)** | Technical grade penoxsulam | 10.2 ppm (NOAEC) | 36 days | USEPA January 2007 |

* Study utilized in RQ calculation.

### Table 6-7
**RQ Calculations for Penoxsulam**

| Species | EEC/LC 50 | RQ |
|---|---|---|
| Rainbow trout | .05 ppm/ 102 ppm | 0.00049 (acute) |
| Fathead minnow | .01 ppm/ 10.2 ppm | 0.00098 (chronic) |

### Table 6-8
**Response of Various Fish Species to Imazamox at LC50 Values**

| Species | Chemical | LC50 | Time Period | Reference |
|---|---|---|---|---|
| Bluegill sunfish *(Lepomis macrochirus)* | Imazamox (technical) | >119 ppm NOEC=119 ppm | 96-hr | USEPA 2008 |
| Rainbow *trout (Onchorhynchus mykiss)* | Imazamox (technical) | >122 ppm NOEC=122 ppm | 96-hr | USEPA 2008 |
| Sheepshead minnow *(Cyprinodon variegates)** | Imazamox (technical) | >94.2 ppm NOEC=94.2 ppm | 96-hr | SERA 2010 |
| Rainbow trout | Imazamox (technical) | 122 ppm | 28-day | European Commission 2002 |
| Rainbow trout* | Imazamox (technical) | 11.8 ppm | 96-day | European Commission 2002 |

* Study utilized in RQ calculation.

**Table 6-9**
**RQ Calculations for Imazamox**

| Species | EEC/LC 50 | RQ |
|---|---|---|
| Sheepshead minnow *(Cyprinodon variegates)* | 0.250 ppm/ 94.2 ppm | 0.0026 (acute) |
| Rainbow *trout (Onchorhynchus mykiss)* | 0.10 ppm/ 11.8 ppm | 0.0085 (chronic) |

The calculated RQ values, in **Table 6-9,** above, indicate that imazamox will not directly affect listed fish species. Both acute and chronic toxicity RQ values are well below the LOCs for endangered species. A recently completed assessment of the use of imazamox (Clearcast) to control Japanese eelgrass in Washington State also found no significant risks to fish (and aquatic invertebrates) (Environ 2012).

### *Toxicity of Diquat to Listed Fish Species*

In regards to USEPA toxicity classifications, diquat dibromide has a range of classifications for fish, depending on the species. For most species, diquat dibromide is classified as slightly toxic (LC50 values of >10 ppm to 100 ppm). However, species such as largemouth bass and walleye, are more sensitive, with LC50 values of <10 ppm, while test results for some species such as bullhead and common carp, have LC50 values of over 100 ppm, in the practically non-toxic category (Washington DOE 2002).

As conditions of the early biological opinions, and in order to better understand the potential effects of EDCP on fish species in the Delta, DBW commissioned CDFG to conduct several studies of acute and chronic toxicity during the first few years of the program. Riley and Finlayson (2004a) examined the acute toxicity of diquat (as Reward) to larval delta smelt, larval fathead minnow, and larval Sacramento splittail. The 96-hour LC50 values for the larval form of these three species were 1.1 ppm, 0.43 ppm, and 3.7 ppm, respectively. Both larval fathead minnow LC50 values were close to the diquat dibromide application rate.

Chronic toxicity testing by Riley and Finlayson (2004b) utilized only larval fathead minnows, building on the previous study. The 7-day LC50 for fathead minnow was 0.40 ppm, and the 7-day MATC for larval fathead minnow was 0.37 ppm, the maximum application rate.

Washington DOE (2002) summarizes numerous fish species acute toxicity studies for diquat (as c.e.). In evaluating laboratory toxicity studies as compared to diquat exposure in the environment, it is important to consider that the actual diquat concentrations drop significantly after application, with a half-life of 0.75 days (Washington DOE 2002). Diquat is more toxic to some fish species and life stages, in particular sac-fry of several bass species, with LC50 values ranging from 0.54 ppm to 3.9 ppm. However, even these sensitive species are not adversely affected by field conditions following diquat treatments (Washington DOE 2002). Cold water species, including salmonids, are less sensitive to diquat in laboratory studies, with LC50 values in the 10 ppm to 30 ppm range.

Laboratory studies raise concerns about the effects of diquat on Coho salmon parr to smolt metamorphosis, with increased mortality when exposed to seawater as

compared to controls at 5 ppm to 20 ppm diquat exposure (Washington DOE 2002). These exposures are several times higher than instantaneous diquat concentrations following EDCP treatment. However, lower concentrations (0.5 ppm diquat, closer to the 0.37 application rate) interfered with the ability of Coho salmon to migrate downstream. Timing diquat treatments to avoid periods when salmonids may be migrating through the Delta could reduce the potential for negative effects on migration. Dodson and Mayfield (1979, in Washington DOE 2002) found that diquat concentrations as low as 0.5 ppm decreased swimming speed in rainbow trout from 22.6 cm/second to 14.1 cm/second.

Tremblay (2003) conducted an in situ study of diquat exposure to the shortfin eel in the Avon River, New Zealand. Tremblay evaluated a number of biomarkers (liver mixed-function oxygenases, lysozyme activity, and plasma itellogenin) in eels exposed to diquat treatment of *Egeria densa* at a peak concentration of 3.51 ppm (decreasing after 1 hour to undetectable levels). Diquat had no significant effects on the physiological endpoints measured in eels caged downstream from a treatment area during a three-week exposure period (Tremblay 2003).

In a study of farmed catfish, Mitchell et al. (2010) found that short (10 minute) daily exposures of channel catfish eggs to 0.25 ppm diquat reduced fungus and increased hatch rates compared to controls (56 percent to 34 percent). The ten-minute per day exposure occurred during the entire incubation period.

There are relatively few studies on chronic toxicity of diquat to fish species, primarily because chronic exposure to diquat in the field is unlikely due to diquat binding to sediment. The only "well run" chronic toxicity test (28-days) for diquat was conducted on fathead minnow, and yielded a MATC of 0.2 ppm (Washington DOE 2002).

**Table 6-10,** on the next page, summarizes toxicity studies for diquat. This table focuses on studies conducted specifically for EDCP, plus studies of listed species or surrogates. There are dozens of other fish diquat toxicity LC50 studies in the literature, with a wide range of results, as noted above. However, the larval and *Oncorhynchus* spp. studies in Table 6-15 provide a good indication of toxicities relevant to EDCP. **Table 6-11,** on the next page, summarizes the RQ values for diquat dibromide. Using our conservative EEC estimates, RQ values are below the LOC levels for acute exposure to Chinook salmon and rainbow trout, and chronic exposure to fathead minnow. However, based on the application rate of 0.37 ppm diquat and toxicity studies on larval delta smelt, the RQ of 0.4 is greater than the acute endangered species LOC of 0.05, and the acute restricted use LOC of 0.10, indicating the potential need for use restrictions when delta smelt may be present near sites treated with diquat. It is worth noting that using the USEPA's geometric mean diquat concentration of 0.059 ppm for the RQ calculation would result in a LOC of 0.05. This lower RQ is equal to the LOC for acute endangered species exposure.

**Table 6-10**
**Response of Various Fish Species to Diquat at LC50 Values**

| Species | LC50 | Time Period | Reference |
|---|---|---|---|
| Larval delta smelt *(Hypomesus transpacificus)** | 1.1 ppm | 96-hour | Riley and Finlayson 2004a |
| Larval fathead minnow *(Pimephales promelas)* | 0.43 ppm | 96-hour | Riley and Finlayson 2004a |
| Larval Sacramento splittail *(Pogonichthys macrolepidotus)* | 3.7 ppm | 96-hour | Riley and Finlayson 2004a |
| Larval fathead minnow *(Pimephales promelas)* | 0.40 ppm | 7-day | Riley and Finlayson 2004b |
| Larval fathead minnow *(Pimephales promelas)* | 0.37 ppm | 7-day | Riley and Finlayson 2004b |
| Coho salmon (fingerling) *(Oncorhynchus kisutch)** | 20.5 ppm | 96-hour | Washington DOE 2002 |
| Coho salmon (yearling) *(Oncorhynchus kisutch)* | 30 ppm | 96-hour | Washington DOE 2002 |
| Rainbow trout (fingerling)* *(Oncorhynchus mykiss)* | 9.46 ppm | 96-hour | Washington DOE 2002 |
| Rainbow trout (fingerling) *(Oncorhynchus mykiss)* | 15 ppm | 96-hour | Washington DOE 2002 |
| Rainbow trout (fingerling) *(Oncorhynchus mykiss)* | 37.8 ppm | 48-hour | Washington DOE 2002 |
| Chinook salmon (58 to 96 mm length) *(Oncorhynchus tshawytscha)* | 16 ppm | 48-hour | Washington DOE 2002 |
| Fathead minnow (fingerling) *(Pimephales promelas)* | 7.6 ppm | 96-hour | Washington DOE 2002 |
| Fathead minnow (47 mm length) *(Pimephales promelas)* | 70 ppm | 96-hour | Washington DOE 2002 |
| Fathead minnow (eggs to fry) *(Pimephales promelas)** | 0.2 ppm MATC | 34-days Endpoint – weight reduction | Washington DOE 2002 |
| Eastern brook trout (eggs to sac-fry) *(Salvelinis fontanalis)* | 3.8 ppm MATC | Length not reported Endpoint = abnormal sac-fry | Washington DOE 2002 |

* Study utilized in RQ calculation (as c.e.).

**Table 6-11**
**RQ Calculations for Diquat**

| Species | EEC/EC 50 | RQ |
|---|---|---|
| Larval delta smelt | 0.37 ppm/ 1.1 ppm | 0.34 (acute) |
| Coho salmon | 0.37 ppm/ 20.5 ppm | 0.018 (acute) |
| Rainbow trout | 0.37 ppm/ 9.46 ppm | 0.039 (acute) |
| Fathead minnow (eggs to fry) | 0.0159 ppm/ 0.2 ppm | 0.080 (chronic) |

Table 6-12

**Concentrations of Test Solutions and Calculated Exposure Ranges for Fluridone and Diquat from CDFG Garter Snake Acute Toxicity Study**

| Herbicide | Concentrations of Test Solutions (mg/l or ppm) | Experimental Oral Exposure Range (mg/kg) | Experimental Dermal Exposure Range (mg/kg) |
|---|---|---|---|
| Fluridone (Sonar) | 0.029 mg/L | 2.60 to 2.98 x $10^{-4}$ | 2.60 to 2.98 x $10^{-4}$ |
| Diquat (Reward) | 0.66 mg/L | 0.006 to 0.007 | 0.006 to 0.007 |

### *Toxicity of EDCP Herbicides to Reptiles and Amphibians*

As compared to fish, there is significantly less information related to the toxic effects of EDCP herbicides and adjuvants to amphibians and reptiles. However, the limited information that is available indicates that toxic impacts to amphibians and reptiles resulting from EDCP are highly unlikely.

Generally, amphibians are thought to be more sensitive to chemical exposure than reptiles, because of their thinner skin and the fact that they inhabit both water and land. As a result, amphibian toxicity studies are often used to infer toxicity effects on reptiles, when specific reptile studies are not available. In addition, bird toxicity studies represent surrogates for terrestrial phase amphibians and reptiles, and fish may be surrogates for aquatic phase amphibians (USEPA January 2007).

Because of the scarcity of reptile studies, one of the conditions of EDCP's initial USFWS Biological Opinion was to conduct snake toxicity testing of EDCP herbicides (fluridone and diquat). The DBW provided funding to the CDFG to conduct acute oral and dermal toxicity studies on garter snakes (Hosea et al. 2004). CDFG utilized two surrogate species of garter snakes, common garter snake, *Thamnophis sirtalis*, and western terrestrial garter snake, *Thamnophis elegans*. These garter snake species are closely related to the threatened giant garter snake, *Thamnophis gigas*.

Snakes were exposed both orally and dermally to a solution of herbicide or control (distilled water). Both herbicides were at concentrations equivalent to, or greater than, EDCP treatment rates.

**Table 6-12,** above, provides the concentrations of test solutions and actual exposure range (in mg/kg body weight). CDFG observed the snakes for seven days following treatment. There were no acute lethal or sublethal effects. Snakes did not exhibit significant alterations in behavior following treatment, and did not develop skin lesions or other physical abnormalities. There was no significant difference in post exposure weight change between test groups. CDFG reported that "if snakes were inadvertently sprayed directly or were to consume any of the undiluted spray solution, there should be no acute toxicity" (Hosea et al. 2004).

**Table 6-13,** on the next page, summarizes toxicity studies of reptiles, amphibians, or bird surrogates to current and potential EDCP herbicides.

Acute dietary fluridone studies in ducks and quails found no signs of toxicity at

**Table 6-13**
**Toxicity of Reptiles and Amphibians to EDCP Herbicides**

| Species | Chemical | LC50 | Time Period | Reference |
|---|---|---|---|---|
| Bobwhite quail *(Colinus virginianus)* | Fluridone | >5,000 ppm | 8-day | SERA 2008 |
| Mallard duck *(anas platyrhynchos)** | Fluridone | >5,000 ppm | 8-day | SERA 2008 |
| Mallard duck *(anas platyrhynchos)** | Penoxsulam (technical) | >1,900 ppm | 14-day | USEPA September 2007 |
| Mallard duck* | Imazamox (technical) | >1,950 ppm | 96-hr | USEPA 2008 |
| Japanese quail* | Diquat dibromide | 264 ppm | 8-day | Washington DOE 2002 |
| Ring-necked pheasant | Diquat dibromide | 734 ppm | 8-day | Washington DOE 2002 |
| Bobwhite quail | Diquat dibromide | 575 ppm | 8-day | Washington DOE 2002 |
| Leopard frog *(Rana pipiens)* | Diquat dibromide | 1.7 ppm (MATC) | 14-day | Washington DOE 2002 |
| African clawed toad *(Xenopus laevis)* | Diquat dibromide | 0.64 ppm (MATC) | 14-day | Washington DOE 2002 |

* Utilized for RQ calculation.

concentrations of up to 5,000 ppm (SERA 2008). There were no amphibian or reptile toxicity studies for fluridone (SERA 2008).

There is no amphibian or reptile toxicity testing data for penoxsulam. USEPA utilizes bird and fish toxicity testing to evaluate the terrestrial and aquatic impacts to amphibian and reptile species. Penoxsulam is practically non-toxic to fish and bird species. Testing for toxicity of penoxsulam in birds during a 14-day test period did not result in an LC50 calculation at the highest concentration tested of 1,900 ppm (USEPA September 2007).

There is no amphibian or reptile toxicity testing data for imazamox. USEPA utilizes bird and fish toxicity testing to evaluate the terrestrial and aquatic impacts to amphibian and reptile species. Imazamox is practically non-toxic to fish and bird species. Like the toxicity testing for fish, there were no concentrations of imazamox tested in birds that resulted in any signs of toxicity (SERA 2010).

There are no acute toxicity studies of diquat dibromide in reptiles or amphibians. Chronic (14-day) toxicity studies of diquat in early life-state amphibians found NOEC, MATC, and LOEC values of 1.08 ppm, 1.7 ppm, and 2.7 ppm of cation equivalent, respectively, for the leopard frog. Similar studies in the African clawed frog found NOEC, MATC, and LOEC values of 0.54 ppm, 0.64 ppm, and 0.68 ppm (Washington DOE 2002). Diquat dibromide cation toxicity testing in several bird species found 8-day dietary LC50 values ranging from 264 ppm to 734 ppm (Washington DOE 2002).

**Table 6-14,** on the next page, provides the acute RQ calculations for bird surrogates. For all four herbicides, the RQ values are well below LOCs.

**Table 6-14**
**RQ Calculations for Amphibians, Reptiles, or Bird Surrogates**

| Herbicide | Species | EEC/LC 50 | RQ |
|---|---|---|---|
| Fluridone | Mallard duck | 0.03 ppm/5,000 ppm | 0.000006 |
| Penoxsulam | Mallard duck | 0.05 ppm/1,900 ppm | 0.000026 |
| Imazamox | Mallard duck | 0.25 ppm/ 1,950 ppm | 0.00013 |
| Diquat dibromide | Japanese quail | 0.37 ppm/ 264 ppm | 0.0014 |

***Exposure to Sediments from Diver-Operated Suction Harvesting***

There is a potential for diver-operated suction harvesting to temporarily disturb sediments when *Egeria densa* is removed. Disturbed sediments may be suctioned through the hose, and then filtered back into the Delta, along with water. To the extent that there are toxic contaminants in the sediment, fish that are present near the operation could be temporarily exposed.

The San Francisco Estuary Institute (SFEI) conducts an annual Regional Monitoring Program in the San Francisco Estuary that includes sediment toxicity monitoring. There are two monitoring sites located within EDCP project area, one near the mouth of the Sacramento River, and one near the mouth of the San Joaquin River (SFEI 2010). SFEI determines concentrations of approximately forty contaminants, and also conducts 10-day toxicity testing of amphipods and 48-hour toxicity testing of larval mussels, using collected sediment samples. SFEI determines likely toxicity of a given sample site based on the number of exceedances of Effects-Range Low (ERL) and Effects Range-Medium (ERM) values. A given number of exceedances of these values are likely to result in toxic effects. The calculated mean ERM quotients, another toxicity indicator, for the two river sites were among the lowest of the 27 sample locations in the San Francisco Estuary. In 2010, sediment from the Sacramento River and San Joaquin River sample sites were toxic to larval mussels, but did not result in a threshold of ERL or ERM values to indicate that they were potentially toxic sites (SFEI 2010).

While there is potential for toxicity due to exposure to Delta sediments, fish are not likely to be negatively impacted by exposure to sediments from diver-operated suction harvesting. It is highly unlikely that sediments stirred up by suction harvesting will remain suspended for a long enough time period to result in toxic exposure. Furthermore, fish are not likely to remain present in the areas that are being suction harvested due to the presence of boats, divers, motors, and suction harvesting equipment.

To avoid potential for impacts due to disturbed sediment, EDCP will monitor turbidity levels during and immediately after diver-operated suction harvesting operations. If turbidity levels are above NPDES thresholds (50 Nephelometric Turbidity Units (NTU) in the Central Delta and 150 NTU in the remaining project area), EDCP will consider options such as revising suction

harvesting operations and utilizing sediment curtains to localize turbidity impacts.

## 2. Bioaccumulation of EDCP Herbicides

The EDCP is not likely to result in direct effects due to bioaccumulation of herbicides. Bioaccumulation is an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in organisms whenever they are taken up and stored faster than they are broken down (metabolized) or excreted. Bioaccumulation of chemicals in herbicides can occur in plant or animal tissues due to direct uptake or exposure, or in animal tissues by consumption and ingestion of other plant or animal species that have bioaccumulated these chemicals.

### *Fluridone*

Studies indicate that fluridone has a low potential for accumulation in fish and other aquatic organisms (USEPA 1986). The CDFG analyzed Chinook salmon smolts for residues of fluridone and the primary fluridone metabolite, 4-hydroxy fluridone in 2005 (Hosea 2006). The smolts were collected at three sites in the Delta during regular trawls monitoring salmon movement in the Delta. All smolts were from either the Feather River or Merced hatcheries. No residues of >10ppb of either fluridone or 4-hydroxy fluridone were detected in any of the smolt samples. The study determined that salmon are not concentrating fluridone in their tissues, and presented several possible reasons: (1) dilution of fluridone after treatment, (2) short residence time of smolts in treatment areas, and (3) rapid adsorption of fluridone to sediments and suspended solids, reducing bioavailability.

Several researchers have observed instances of low bioaccumulation of fluridone and its metabolites; even though these studies generally involved exposure to much higher concentrations of the chemical than would be used under EDCP. West and others identified total average bioconcentration factors (BCF) for total fluridone residues of 1.33 for edible tissue, 7.38 for inedible tissue, and 6.08 for whole body (West et al. 1983). These data were obtained from 175 fish samples collected between one day and 12 months after treatment. West concluded that the low BCF in all fish species indicated that residues will not accumulate in fish as a result of fluridone applications. Residues in fish from lake trials were much lower than those from pond trials, reflecting the lower fluridone levels in lake water. In zooplankton, the bioconcentration factor of fluridone ranged from 0 to 10, and fluridone was not detected in zooplankton once it had dissipated from the water (West et al. 1979).

Muir and others reported bioconcentration factors of up to 85 in duckweed following exposure to 5.0 ppm of fluridone in water (West et al. 1983). West and others reported bioconcentration factors ranging from 0 to 15.5 in vascular plants following exposure to 0.10 ppm of fluridone in water (West et al. 1979). These peak values of fluridone residues were followed by a decline in concentrations as fluridone dissipated from the water column.

Kamarianos et al. (1989) found that Fluridone levels in carp after exposure to

0.042 ppm fluridone (in the form of Sonar AS) reached a maximum on the 13th day after treatment of 484 ug/kg, and decreased steadily from that point to 30.7 ug/kg after 84 days. The fluridone major metabolite (1-methyl-3-(4-hydroxyphenyl)-5-[3-(trifluroomethyl)phenyl]-4(iH)-pyridone) was not detected in any fish sample. Kamarianos concluded that there were no detrimental effects in fish productive aquatic ecosystems treated with fluridone.

Muir et al. (1982) evaluated uptake and bioconcentration of fluridone (concentration in the organism divided by concentration in the environment) in juvenile rainbow trout and chironomid larvae. While the larvae had slightly higher bioconcentration values (128 versus 91), both were well below the value considered low. Exposure in this study consisted of 0.05 ppm fluridone for up to 120 hours, and then placement in clean water to measure herbicide clearance.

No circumstance was identified in the scientific literature where fluridone irreversibly accumulated in biological tissues and remained after the dissipation of the chemical from the water column. SePRO Corporation reports that studies have shown that fluridone does not accumulate in fish tissue to any significant degree, and that the relatively minor amounts of fluridone that are absorbed by fish are eliminated as the concentrations of fluridone in the water decline (SePRO 2006). In conclusion, is unlikely that fluridone use at the concentrations proposed under the EDCP would result in bioaccumulation to any significant degree or in any way that would result in adverse impacts to fish (or other aquatic organisms).

***Penoxsulam***

USEPA considers penoxsulam to have low potential to bioaccumulate in aquatic organisms (USEPA September 2007). A European risk assessment also determined a low bioaccumulation potential for penoxsulam in birds and mammals (Washington DOE 2012). The bioconcentration factor of penoxsulam in crayfish after 14 days exposure was 0.02 ml/g (values less than 100 are considered low) (USEPA September 2007, FOOTPRINT 2009).

***Imazamox***

The potential for bioconcentration of imazamox is low (HSDB Database 2012). Imazamox did not significantly bioaccumulate in bluegill sunfish, and concentrations of imazamox in whole fish and edible tissue were less than the minimum detectable limit (USEPA 2008).

***Diquat Dibromide***

Diquat dibromide does not bioaccumulate in fish and aquatic invertebrate species (Washington DOE 2002). Those species that do adsorb diquat rapidly eliminated more than 50 percent of the herbicide within a few days, with the possible exception of bivalves, which may continue to release diquat for more than 28 days (Washington DOE 2002). The highest bioconcentration factor found in invertebrates was approximately 32, well below levels considered high. Bioconcentration factors in several fish species were less than one (Washington DOE 2002).

Diquat does adsorb in plants, with concentrations of over 1,000 ppm found in macrophytes and algae following treatment

at less than one ppm diquat (Washington DOE 2002). Plants are an important removal pathway of diquat from water, and research suggests that diquat is adsorbed to the surfaces of plants by an ion exchange mechanism (Washington DOE 2002). Bacteria associated with the surface of dead and dying plants degrade about 32 percent of the plant-bound diquat, with the remainder rapidly binding to sediment, where it becomes biologically inactive.

### 3. Disturbance from Treatment and Monitoring Boats

Boat noise has been identified as inducing the startle and alarm responses in fish (Scholik and Yan 2002). These responses cause fish to flee an area (Boussard 1981). Boat noise has also been shown to temporarily reduce auditory sensitivity of some fish species (Scholik and Yan 2002). However, the Delta is already heavily used by motorboats, and the current level of *Egeria densa* and other vegetation management activities using boats have been conducted for over 25 years. Thus, fish are likely habituated to a substantial degree of boat-related noise.

The EDCP is not expected to result in significant additional boat disturbance to fish. EDCP's limited use of diver-operated suction harvesting and placement of benthic barriers are likely to cause any fish that are present at the time to move away from divers and equipment. To the extent that EDCP activities induce a "flee" response, it may be beneficial for fish to temporarily remove themselves from treatment areas, in the unlikely event that fish are present in *Egeria densa* beds. On any given day, the actual area potentially subject to disturbance will be minimal as compared to the Delta waters available to fish.

## D. Indirect Effects of EDCP

Indirect effects are caused by the action and are later in time, but are still reasonably certain to occur. There is potential for limited, and temporary, indirect effects on special status fish species as a result of EDCP treatments. Below, we describe three potential mechanisms of indirect effects: loss of native aquatic plants, food web effects, and low dissolved oxygen.

### 1. Loss of Native Plant Species

While there is some herbicide selectivity of target species, by definition EDCP herbicides are generally toxic to plants at specified treatment levels. Native plant species most at risk from EDCP treatments include other submersed aquatic vegetation and/or nearby emergent vegetation. There is some limited chance that vegetation on banks adjacent to EDCP treatment sites could be subject to water wash of herbicide-treated water. The concentration and exposure time (CET) of such events is not likely to be high enough to cause toxic effects. EDCP treatment crews will follow mitigation measures to reduce the potential for overwash. In addition, *Egeria densa* grows in dense, monospecific mats, thus further reducing the potential for impacts to non-target plant species.

An indirect impact to fish, including special status species, could occur through alteration of spawning, rearing, and foraging habitat. The definition of harm under the Endangered Species Act (ESA) prevents major acts of

habitat destruction and degradation that prevent a species from breeding, feeding, and sheltering (Mueller 1994). Special status fish species could be impacted by removal of large beds of aquatic plants that they use as habitat. As explained, available data does not indicate that any threatened, endangered, or special status fish species use *Egeria densa* beds for spawning, rearing, or forage. Nor have any migratory fish, such as steelhead or Chinook salmon, been observed in *Egeria densa* beds. However, while there is no evidence that *Egeria densa* beds function as habitat for these fish, it is possible that in some limited instances they do serve habitat functions.

However, this potentially adverse impact would likely be more than offset by the benefits derived from opening up substrate for native aquatic plants. Removal of *Egeria densa* would likely result in improvements to fish habitat, by enabling native aquatic vegetation (e.g., pond weed) to colonize areas previously dominated by *Egeria densa*. While *Egeria densa* is generally too dense for spawning, rearing, and foraging by native fish, native aquatic vegetation, which is generally less dense, is ideal for these functions.

Conrad et al. (2011) found that *Egeria densa* made up an average of 85 percent of SAV at 33 sample sites throughout the Delta during the two year period from October 2008 to October 2010. Thus, any *Egeria* treatment would have minimal impact on other plant species or habitats.

A study of long-term non-target plant toxicity of fluridone pellets at Clear Lake, California, there was some toxicity, but no clear pattern of toxic effects on *Typha* (cattail) (Siemering et al. 2005). Further analysis of study results found that *Typha* toxicity was more closely related to sediment size, dissolved organic carbon, and mercury concentration, than to fluridone exposure.

The selectivity of fluridone, the primary EDCP herbicide, is well documented through 25 years of use and scientific studies on the response of many native aquatic plant species. The scientific literature shows that selectivity outcomes can be influenced by use rate and specific plant species present (for example, duckweed is a target species controlled at higher concentrations than those used in the Delta). The cumulative evidence supports fluridone selectivity to native aquatic plant communities and related ecological benefits when used for management of invasive submersed aquatic plants such as *Egeria densa*.

Several studies in the scientific literature demonstrate fluridone's selectivity at in-water concentrations consistent with that currently used in the Delta for *Egeria densa* management. Bremigan et al. (2005) evaluated whole lake fluridone treatments, maintaining 2 ppb for over sixty days, and found that even in mixed plant beds in the treatment lakes, fluridone reduced Eurasian watermilfoil cover without reducing native plant cover. Madsen et al. (2002) compared untreated and treated lakes (5 ppb fluridone) and found that treatments did not significantly impact native plant species diversity or cover in the year of treatment, or through 15 months post-treatment. Native plant cover was maintained at levels of over 70 percent in the year of treatment and at one year post-treatment. Two years following whole lake fluridone treatments to control hydrilla in Georgia, native plants were

predominant (Maceina and Slipke 2004). In a study in mesocosm tanks, Netherland et al. (1997) found that 5 ppb fluridone for sixty to ninety days selectively controlled Eurasian watermilfoil, but that non-target species did not differ from untreated controls. This study showed that initial treatment rate, length of exposure, and initial biomass of the plants, are key factors to consider in designing treatment protocols. In addition, once the invasive weed was controlled, there was extensive recovery of non-target species (Netherland et al. 1997).

Penoxsulam is a relatively slow-acting herbicide, with reddening followed by plant death over 60 to 120 days. Penoxsulam exhibits toxicity to aquatic vascular plants, with an EC50 of 0.003 mg/l for duckweed, and a NOAEC of 0.001 mg/l, based on reduction of frond number (USEPA January 2007). Koschnick et al. (2007) evaluated the effect of penoxsulam on five Florida native emergent plants, and found differing sensitivities, although there was inhibition of root growth for all species. Concentrations were higher than those expected for *Egeria densa* treatment, at 25 ppb, 75 ppb, 150 ppb, and 300 ppb exposures for 66 days (Koschnick et al. 2007). Pickerelweed and sagittaria were the most sensitive species to penoxsulam, followed by bulrush, and two grasses, maidencane and panicgrass. Pickerelweed showed reduced root and shoot growth at 25 ppb penoxsulam, while panicgrass showed signs of leaf tip effects at 300 ppb, well above EDCP levels. In this study, the invasive weed hydrilla was controlled at 25 ppb penoxsulam (Koschnick et al. 2007).

A recent study to determine the dose response of selected submersed and emergent native species to penoxsulam (as Galleon) found that most native plants were unaffected by penoxsulam exposure at 3, 6, and 12 ppb for 60 days (Madsen et al. 2011). These exposures are in the range of likely EDCP penoxsulam concentrations. There was a growth regulating effect to elodea as a result of low dose penoxsulam exposure. Floating and emergent plants were not affected by penoxsulam at the concentrations tested (Madsen et al. 2011). While there is limited information on the effects of penoxsulam on native aquatic plants, likely penoxsulam exposures of 10 ppb could impact submersed aquatic plants located in or immediately adjacent to *Egeria densa* treatment sites.

Imazamox is faster acting than the other two ALS inhibitors, with visual symptoms appearing within 1 week and complete death within six weeks. The EC50 of imazamox to duckweed (Lemna gibba) is 11 ppb (0.011 mg/l). Duckweed is the most sensitive aquatic plant species (USEPA 2008). The NOEC for duckweed is 4.5 ppb. Imazamox EC50 values were 55 ppb for 4-day exposure and 29 ppb for 7-day exposure (SERA 2010).

Koschnick et al. (2007) found the five native Florida emergent plants to be less sensitive to imazamox than penoxsulam at the same exposure levels (25 ppb, 75 ppb, 150 ppb, and 300 ppb for 66 days). Bulrush exposed to 300 ppb imazamox was shorter, but showed no reduction in biomass, while maidencane and panicgrass showed no effects at 300 ppb. Pickerelweed and sagittaria showed some reduction in root and shoot growth at 25 ppb and 75 ppb (Koschnick et al. 2007).

Madsen (2011) also evaluated imazamox in his study to determine the dose response of

selected submersed and emergent native species. Elodea was the only submersed plant affected by imazamox (with growth regulating effects similar to penoxsulam) (Madsen et al. 2011). Arrowhead and bulrush were not affected by imazamox at the concentrations tested (200, 100, 50, and 25 ppb for 1, 3, or 7 days). However, white waterlily was affected at the maximum application rate and exposure time (Madsen et al. 2011). While there is limited information on the effects of imazamox on native aquatic plants, likely imazamox exposures of 100 ppb could impact some species of submersed aquatic plants located in or immediately adjacent to *Egeria densa* treatment sites.

Diquat is a fast-acting herbicide, with effects visible within a few days, and plant death often occurring within two weeks. As a contact herbicide, diquat is expected to cause high risk to most species located within a treatment area; however aquatic macrophytes outside a treatment area are not likely to be impacted (Washington DOE 2002). Diquat at concentrations of 0.25 to 0.5 ppm (above the 0.37 ppm maximum EDCP rate) controlled several species, including pondweed (*Potamogeton pectinatus*), coontail (*Ceratophyllum demersum*), American waterweed, Elodea canidensis, naiad (*Najas flexilis*), and *Eleacharis acicularis* (Washington DOE 2002).

Often, species treated with diquat will return to an area within two months. Certain species are tolerant of diquat, including duckweed, *Chara* spp., curlyleaf pondweed, Richardson's pondweed, Robbin's pondweed, *Nuphar* spp., and *Nymphaea* spp. (Washington DOE 2002). Long-term effects of diquat on native plants can be beneficial. Parsons et al. (2007) evaluated the impact of diquat on macrophytes at Battle Ground Lake in Washington, and found that up to two years following treatment, diquat treatments controlled *Egeria densa*, but did not adversely affect native plants in areas where *Egeria densa* had been eliminated.

The potential for impacts to native plants resulting from EDCP herbicide treatments depends on the amount of exposure, concentration of herbicide, and proximity of sensitive habitats, wetlands, and special status plants. Exposures following EDCP treatments are likely to be limited to plants located in, or immediately adjacent to treatment sites, as EDCP chemical applications are made directly into the water.

Depending on the herbicide and concentration in water, treatment of *Egeria densa* could result in insignificant loss of native submersed aquatic vegetation growing in and around treatment areas. Shallow vegetated habitat is believed to be important to spawning success of delta smelt, although delta smelt are more likely to be found in areas with higher turbidity levels, and recent studies have found that *Egeria densa* negatively impacts delta smelt by reducing turbidity and overwhelming littoral (near shore) habitats (USFWS 2008).

Loss of cover, rearing, and forage area of special status species could constitute an indirect effect under certain conditions. However, *Egeria densa* outcompetes native vegetation, resulting in sites dominated by this weed, and with few native plants. The benefit to native submersed aquatic vegetation from removal of *Egeria densa* is expected to outweigh losses due to herbicide toxicity.

While loss of habitat is an important impact to consider, it is unlikely that EDCP would result in significant loss of native

aquatic vegetation. There is a potential risk to sensitive habitats, wetlands, and special status plants due to herbicide exposure; however, the likelihood of such effects occurring is low. Herbicide application will be focused directly on dense stands of *Egeria densa* in treatment sites, decreasing the possibility that herbicides will come in contact with sensitive plants, or result in impacts to sensitive habitats or wetlands.

The EDCP's limited use of diver handpicking and suction harvesting is not likely to significantly impact native plants. Eichler et al. (1993) evaluated the effect of suction harvesting of another submersed invasive week, Eurasian watermilfoil, at seven sites in Lake George, New York. The study found an average of 93 percent reduction in watermilfoil density, with removal efficiencies remaining high (86 percent to 94 percent) one year following treatment (Eichler et al. 1993). Watermilfoil was the most abundant species prior to harvesting, and declined to the fifth most abundant species following harvesting. The number of species present post-harvesting increased in all seven sites. Eichler et al. summarized that impacts on the native plant community in suction harvested areas appeared to be relatively minor, and balanced by benefits such as increased number of species and reduced percentage of cover of aquatic plants.

Limited use of benthic barriers to control *Egeria densa* will impact any other submersed plant species under the mats. Eichler et al. (1995) found that no plants survived under benthic barriers, but some plants grew under screen barriers. Once the barriers were removed, native species (and some invasive species) recolonized the treated areas (Eichler et al. 1995). The EDCP will limit use of benthic barriers to sites that are dominated by *Egeria densa*, which out-competes native submersed vegetation.

The loss of native plants that could affect listed species or habitats as a result of EDCP is likely to be insignificant due to: (1) application of herbicides underwater in dense, primarily mono-specific *Egeria densa* mats, (2) selectivity of EDCP herbicides, especially fluridone, to *Egeria densa*, (3) lack of use of Egeria densa beds by native fish species, and (4) small scale of herbicide application compared to Delta program area.

## 2. Food Web Effects

### *Macroinvertebrates*

Special status fish species or native resident or migratory fish could be indirectly impacted if EDCP decreases the abundance of invertebrates, such as zooplankton, upon which these fish feed. While there is potential for toxic impacts to invertebrates due to EDCP, significant food web effects are unlikely.

Juvenile Chinook salmon feed on various aquatic and terrestrial insects, crustaceans, chironomid larvae and pupae, caddisflies (in fresh water), and *Neomysis, Cammarus*, and *Crangon* in more saline water (Wang 1986). Steelhead feed on terrestrial and aquatic insects, amphipods, crustaceans and small fish (Wang 1986). Juvenile green sturgeon feed on *Neomysis mercedis* and amphipods (Corophium) (Radtke 1966). Adults may feed on sand lances, clams, and shrimp (Moyle 1995).

Juvenile delta smelt primarily eat copepods, planktonic crustaceans, small insect larvae,

and mysid shrimp, while older fish feed almost exclusively on copepods (Moyle 1976). Over recent years, there have been significant declines in delta smelt's preferred food resources due to invasive species such as the overbite clam (Bennett 2005).

Generally, control of macrophytes does not appear to negatively impact macroinvertebrates. In a study comparing the long-term effects of macrophyte and algae management in two lakes in New York (one treated and one not), Harman et al. (2005) found no difference in richness and diversity of the biota between the lakes. Taxonomic richness and diversity were similar in the treated and non-treated lakes. Similarly, Kovalenko et al. (2008) evaluated degree of stomach fullness in fish over four treated and untreated lakes in Minnesota. Kovalenko et al. found that the degree of stomach fullness in fish was not correlated to the proportion of invasive plants or habitat complexity. The study concluded that macrophyte control in the lakes did not affect the characteristics of fish feeding, and that fish were able to find their preferred prey in treated and untreated lakes. Bremigan et al. (2005) found no differences in zooplankton diets of fish in treated versus untreated lakes. Treated lakes maintained similar fluridone levels to EDCP, at over 2 ppb for sixty days.

Ferreiro et al. (2011) used fractal dimension analysis of four SAVs to examine whether more complex habitats provide more niches and increased macroinvertebrate abundance. The study found that *Egeria densa* had the lowest structural heterogeneity of the four weeds (i.e. was least complex). While the abundance of small macroinvertebrates was greater in more complex plants, the total biomass was similar between more and less complex plants. Less complex plants had fewer, but larger, macroinvertebrates. Macroinvertebrates found in *Egeria densa* beds included copepods, dipterans, hydra, amphipods, and cladocera. These species may be consumed by listed fish species.

**Table 6-20,** on the next three pages, summarizes toxicity data for invertebrate species at various life stages for fluridone, penoxsulam, imazamox, and diquat dibromide. The EC50 toxicity endpoint for aquatic invertebrates and plants is the concentration of chemical that can be expected to cause a defined non-lethal effect in 50 percent of the test population. For macroinvertebrates, typical endpoints are immobilization, reductions in growth, and reproductive effects.

Fluridone use will not result in a decrease in invertebrate abundance in or around EDCP treatment sites. Under the EDCP, fluridone will be applied at a rate of 5 to 30 ppb (0.005 to 0.03 ppm). This concentration is well below that which is lethal to aquatic invertebrates, as demonstrated in numerous studies. Research indicates that fluridone is toxic to aquatic invertebrates only at high concentrations. Similar to fish toxicity studies of fluridone, there are relatively few recent evaluations of invertebrate toxicity to fluridone. The SERA (2008) evaluation of fluridone invertebrate toxicity cited studies published between 1978 and 1986. This lack of new studies reflects the low toxicity and length of time fluridone has been in use.

One more recent study of the ecological effects of fluridone in pond cultures of catfish (Jacob, 2008), evaluated the impact of fluridone (AVAST formulation) on phytoplankton and

**Table 6-20**
**Response of Various Invertebrate Species to EDCP Chemicals, at LC50/EC50 Values** *Page 1 of 3*

| Species | Chemical | EC50 | Time Period | Reference |
|---|---|---|---|---|
| *Procambarus clarkii* (crayfish) | Fluridone | 105.9 ppm | 96-hour test | Trumbo 1998 |
| *Physa* sp. (snail) | Fluridone | 130.8 ppm | 96-hour test | Trumbo 1998 |
| *Diaptomus* sp. (microcrustacean) | Fluridone | 12.0 ppm | Not indicated | Naqvi and Hawkins 1989 |
| *Eucyclops* sp. (") | Fluridone | 8.0 ppm | Not indicated | Naqvi and Hawkins 1989 |
| *Alonella* sp. (") | Fluridone | 13.0 ppm | Not indicated | Naqvi and Hawkins 1989 |
| *Cypria* sp. (") | Fluridone | 13.0 ppm | Not indicated | Naqvi and Hawkins 1989 |
| "Representative invertebrates"[a] | Fluridone | 4.3+/-3.7 ppm | 96-hour test | Hamelink et al. 1986 |
| Daphnid (water flea) | Fluridone | 3.6 ppm | 48-hour EC50 | Habig 2004 |
| Daphnid | Fluridone | 2.0 ppm | NOEC | Habig 2004 |
| *Ceriodaphnia dubia* | Fluridone (Sonar) | 6.9 ppm | 7-day test | Riley and Finlayson 2004b |
| *Ceriodaphnia dubia* | Fluridone (Sonar) | 7.2 ppm | 96-hour test | Riley and Finlayson 2004b |
| *Ceriodaphnia dubia* | Fluridone (Sonar) | 3.35 ppm | 7-day MATC | Riley and Finlayson 2004b |
| *Ceriodaphnia dubia* | Fluridone (Sonar) | 2.43 ppm | 7-day NOEC | CDFG-ATL 2003 |
| *Ceriodaphnia dubia* | Fluridone (Sonar) | 4.6 ppm | 7-day LOEC | CDFG-ATL 2003 |
| Amphipod | Fluridone | 2.1 ppm | 96-hour test | Habig 2004 |
| Midge* | Fluridone | 1.3 ppm | 48-hour EC50 | Habig 2004 |
| Pink shrimp | Fluridone | 2.4 ppm | 96-hour test | Habig 2004 |
| Pink shrimp | Fluridone | 0.6 ppm | NOEC | Habig 2004 |
| Eastern oyster | Fluridone | >0.62 ppm | 96-hour shell deposition EC50 and NOEC | Habig 2004 |
| Eastern oyster | Fluridone | 6.8 ppm | 48-hour embryo-larval EC50 | Habig 2004 |
| Eastern oyster | Fluridone | 5.1 ppm | 48-hour embryo-larval NOEC | Habig 2004 |
| Blue crab | Fluridone | 34 ppm | 96-hour test | Habig 2004 |
| Blue crab | Fluridone | 13.4 ppm | NOEC | Habig 2004 |
| Daphnid* | Fluridone | NOEC = 0.2 | 21-day lifecycle | Habig 2004 |

**Table 6-20**
**Response of Various Invertebrate Species to EDCP Chemicals, at LC50/EC50 Values** *(continued)* *Page 2 of 3*

| Species | Chemical | EC50 | Time Period | Reference |
|---|---|---|---|---|
| Amphipod | Fluridone | Growth NOEC = 0.6 | 60-day growth | Habig 2004 |
| Midge | Fluridone | Emergence NOEC = 0.6 | 30-day adult emergence | Habig 2004 |
| *Daphnia magna* | Penoxsulam (technical) | >98 ppm | 48-hr | USEPA September 2007 |
| *Daphnia magna* | Penoxsulam degradates | >96 ppm to >100 ppm | 48-hr | USEPA September 2007 |
| *Daphnia magna* | Penoxsulam degradates | >1 ppm to >1.6 ppm | 48-hr | USEPA September 2007 |
| Midge (*Chironomus* sp.) | Penoxsulam (technical) | >140 ppm | 48-hr | USEPA September 2007 |
| Amphipod (*Gammarus* sp.) | Penoxsulam (technical) | >126 ppm | 48-hr | USEPA September 2007 |
| *Daphnia magna** | Penoxsulam Galleon/equivalent | >90.1 ppm | 48-hr | USEPA September 2007 |
| *Daphnia magna** | Penoxsulam (technical) | 9.76 ppm<br>2.95 ppm NOAEC<br>9.76 ppm LOAEC | 21-day | USEPA September 2007 |
| *Chironomus reparius* | Penoxsulam (technical) | 7.1 ppm NOAEC<br>15 ppm LOAEC | 28-day | USEPA September 2007 |
| *Daphnia magna** | Imazapyr (technical) | >97.1 ppm NOEC | 21-day | AMEC Geomatrix 2009 |
| *Daphnia magna* | Imazamox (technical) | >122 ppm<br>122 ppm NOEC | 96-hr | USEPA 2010 |
| Mysid shrimp* (*Mysidopsis bahia*) | Imazamox (technical) | >94.3 ppm<br>94.3 ppm NOEC | 96-hr | SERA 2010 |
| *Daphnia magna** | Imazamox (technical) | 137 ppm | 21-day | European Commission 2002 |
| *Ceriodaphnia dubia* | Diquat dibromide (Reward) | 0.14 ppm | 96-hour | Riley and Finlayson 2004b |
| *Ceriodaphnia dubia* | Diquat dibromide (Reward) | 0.078 ppm | 7-day | Riley and Finlayson 2004b |
| *Ceriodaphnia dubia* | Diquat dibromide (Reward) | 0.015 ppm | 7-day MATC | Riley and Finlayson 2004b |
| *Ceriodaphnia dubia* | Diquat dibromide (Reward) | 0.012 ppm | 7-day NOEC | CDFG-ATL 2003 |
| *Daphnia magna* | Diquat dibromide | 1.62 ppm | 48-hour | Washington DOE 2002 |

**Table 6-20**
**Response of Various Invertebrate Species to EDCP Chemicals, at LC50/EC50 Values** *(continued)* *Page 3 of 3*

| Species | Chemical | EC50 | Time Period | Reference |
|---|---|---|---|---|
| Eastern oyster *(Crassostrea virginica)* | Diquat dibromide | 141 ppm | 96-hour | Washington DOE 2002 |
| Copepod (*Eucyclops* spp.) | Diquat dibromide | 25.164 | 48-hour | Washington DOE 2002 |
| Amphipod *(Hyallella azteca)** | Diquat dibromide | 0.048 ppm | 96-hour | Washington DOE 2002 |
| Amphipod *(Hyallella azteca)* | Diquat dibromide | 6.8 ppm | 96-hour | Washington DOE 2002 |
| Pocket shrimp *(Mysidopsis bahia)* | Diquat dibromide | 0.42 ppm | 96-hour | Washington DOE 2002 |
| Caddisfly (*Limnephilus* spp.) | Diquat dibromide | 33 ppm | 96-hour | Washington DOE 2002 |
| *Daphnia magna** | Diquat dibromide | 0.045 ppm MATC<br>0.036 ppm NOEC<br>0.057 ppm LOEC | 21-days Endpoint = reproduction and growth | Washington DOE 2002 |

* Test utilized for RQ calculations.

[a] "Representative invertebrates" used in the study included amphipods, midges, daphnids, crayfish, blue crabs, eastern oysters, and pink shrimp.

zooplankton. Jacob found that at label application rates and ten times label application rates (0.09 ppm and 0.90 ppm), fluridone total zooplankton biomass was similar between treated and non-treated water. There were minor differences in zooplankton species make-up between control and treated ponds.

Yi et al. (2011) found differential toxicity of Sonar AS and technical grade fluridone for male water mites. With Sonar AS, 70 percent of the mites showed signs of toxicity at 10 ppb, the lowest concentration tested. Yi found a 96-hour EC50 of less than 10 ppb. This concentration is at the upper end of likely EDCP fluridone concentrations, which historically have been less than 3 ppb. This study shows that using Sonar AS, there may be a risk to water mites at currently recommended application rates. This finding is counter to those of many other previous studies, which used fluridone formulations and technical grade fluridone (Yi et al., 2011). This study does reflect findings of Jacob (2008), that there may be differential species toxicity of invertebrates to fluridone. While there may be some temporary reduction in food prey due to fluridone, the effects on special status fish are likely to be minimal given the small acreage of the Delta that will be treated, as compared to total food prey population available in the entire waterbody.

The literature indicates that EDCP fluridone treatments will not result in lethal or sublethal effects to invertebrates present at treatment sites. Prior studies, including those conducted specifically for the EDCP, are as follows:

- Habig (2004) reported results of a number of toxicity tests of fluridone on invertebrates. He reported no observable effect levels (NOEC) of 2 ppm in daphnid, 0.6 ppm in pink shrimp, 5.1 ppm in embryo-larval Eastern oyster, and 13.4 ppm in blue crab. These NOEC levels are several times higher than EDCP concentrations
- The CDFG-ATL found a 7-day LC50 value of 6.9 ppm fluridone for *Ceriodaphnia dubia*, and statistically significant differences between individual total average reproduction at fluridone concentrations above 4.6 ppm (CDFG-ATL, 2003), both levels are two orders of magnitude greater than EDCP treatment concentrations
- In an EDCP specific study, CDFG testing in 2002 found no difference in *Ceriodaphnia dubia* survival rates in water samples with, and without, detectable fluridone in both 2002 and 2003 (CDFG 2003, Riley and Finlayson 2004b)
- Habig (2004) also reported results of a number of LC50 tests, also finding levels several times above EDCP treatment concentrations. LC50 and EC50 concentrations in daphnid, amphipod, midge, pink shrimp, eastern oyster, and blue crab ranged from 2.1 ppm to 34 ppm
- Trumbo (1998) conducted toxicity tests with Sonar and determined the 96-hour LC50 value for crayfish (*Procambarus clarkii*) and snails (*Physa sp.*) to be 105.9 mg/l and 130.8 mg/l (as fluridone) respectively
- Parka et al. (1978) noted that 0.3 ppm of fluridone in water did not significantly reduce total numbers of benthic organisms. However, at the exaggerated rate of 1.0 ppm of fluridone in the water, the total number of benthic organisms was significantly reduced when compared to a control population
- Naqvi and Hawkins (1989) reported Sonar LC50 values of 12.0 ppm, 8.0 ppm, 13.0 ppm and 13.0 ppm for the microcrustaceans *Diaptomus sp.*, *Eucyclops sp.*, *Alonella sp.*, and *Cypria sp.*, respectively
- Habig (2004), and Hamelink et al. (1986) reported results of a variety of chronic and subchronic toxicity tests on fish and invertebrates. The lowest impact level reported, a 0.2 ppm NOEC level for daphnids, is well above the EDCP treatment concentrations for fluridone
- Hamelink et al. (1986) found that for invertebrates, an average 48-hour or 96-hour LC50 or EC50 (depending on the organism) was 4.3 +/- 3.7 ppm. The representative invertebrates used in the study included amphipods, midges, daphnids, crayfish, blue crabs, eastern oysters, and pink shrimp
- In chronic toxicity tests conducted by Hamelink et al. (1986), no effects were observed in daphnids, amphipods, and midge larvae at fluridone concentrations of 0.2, 0.6, and 0.6 ppm, respectively.

The DBW conducted an analysis of water quality and toxicity using monitoring data gathered from 2001 to 2005. The DBW collected several hundred pre-treatment and post-treatment water samples and delivered these to CDFG laboratories to conduct five different toxicology tests. Based on examination of toxicology test results from post-treatment water samples, it appears that fluridone treatments did not have a significant or consistent adverse effect on the test organisms (survival or growth) used by the laboratories (including the water flea, *Ceriodaphnia dubia*) (DBW 2006).

USEPA (September 2007) reported testing results for penoxsulam and metabolites on invertebrate species as part of the Ecological Risk Assessment. Tests were conducted for

the pesticide registration process. Many of the degradate tests utilized only one concentration (approximately 1 ppm), and had no mortality or immobilization effects. Some tests utilized a range of concentrations, up to approximately 100 ppm, also with no mortality. Thus, the EC50 values for penoxsulam in Table 6-20 are conservative, and essentially equal to NOAEC levels (USEPA September 2007).

Acute toxicity testing with an end-use product equivalent or equal to Galleon (penoxsulam) found no toxicity to *Daphnia magna* at the maximum concentration of 90.1 ppm. There was minor immobilization impairment (5 percent to 10 percent) at the mid-range concentrations tested, but not the low and high concentrations (7.92 ppm and 90.1 ppm). The study determined that the 48-hour NOEAC level, based on mortality or immobilization, was 90.1 ppm (USEPA September 2007). Chronic toxicity testing of technical grade penoxsulam on *Daphnia* and chironomids found NOAEC levels of 2.95 ppm and 7.1 ppm, respectively, well above the application rate and expected concentrations for EDCP treatments.

USEPA registration studies found that imazamox is practically non-toxic to aquatic invertebrates. As with fish, there are relatively few studies for this herbicide. The 96-hour EC50 values for *Daphnia magna* and mysid shrimp were close to 100 ppm, with no mortality and no signs of toxic effects at the highest concentrations tested (SERA 2010). Chronic toxicity testing also found no effect at imazamox concentrations greater than 100 ppm (European Commission 2002).

DBW commissioned studies of diquat (Reward) impacts on the cladoceran, *Ceriodaphnia dubia* (water flea), conducted by CDFG. The 96-hour EC50 for *C. dubia* was 0.14 ppm. The seven day EC50 was 0.078 ppm, and the seven day MATC was 0.015 ppm (Riley and Finlayson 2004b). These results indicate that there is the potential for impacts to cladocerans following treatment with diquat.

The DBW conducted an analysis of water quality and toxicity using monitoring data gathered from 2001 to 2005. The DBW collected several hundred pre-treatment and post-treatment water samples (many from inside the treatment area) and delivered these to CDFG laboratories to conduct five different toxicology tests. Based on examination of toxicology test results from post-treatment water samples, eight of the 13 diquat samples that exceeded 20 ppb did have an adverse effect on the test organisms (survival or growth) used by the laboratories (including the water flea, *Ceriodaphnia dubia*) (DBW 2006).

Studies in the literature on the effects of diquat on macroinvertebrates show a range of results, with some species more sensitive than others. Three species of invertebrates are highly susceptible to diquat: *Hyalella Azteca* (EC50 = 0.048 ppm), pocket shrimp (EC50 = 0.42 ppm), *Daphnia pulex* (EC50 = 0.16 ppm), and apple snail (EC50 = 0.34 ppm) (Washington DOE 2002). However, other species such as mayflies (EC50 = 16 ppm), oysters (EC50 = 55 to 141 ppm), *Daphnia magna* (EC50 = >1 ppm), and bloodworms (EC50 >100 ppm) are less susceptible to diquat. Chung et al. (2008) found a 96-hour LC50 of 1.624 ppm for larval grass shrimp, found in estuarine ecosystems, higher than potential EDCP exposure.

**Table 6-21**
**RQ Calculations for Invertebrates for EDCP Herbicides**

| Herbicide | Species | EEC/ EC50 | RQ (LOC = 0.05) |
|---|---|---|---|
| Fluridone | Midge | 0.03 ppm / 1.3 ppm | 0.023 (acute) |
| Fluridone | Daphnid | 0.003 ppm / 0.2 ppm | 0.015 (chronic) |
| Penoxsulam | *Daphnia magna* | .05 ppm / 90.1 ppm | 0.00055 (acute) |
| Penoxsulam | *Daphnia magna* | .01 ppm / 9.76 ppm | 0.001 (chronic) |
| Imazamox | *(Mysidopsis bahia)* | 0.25 ppm / 94.3 ppm | 0.0026 (acute) |
| Imazamox | *Daphnia magna* | 0.1 ppm / 137 ppm | 0.00073 (chronic) |
| Diquat dibromide | *Hyallella Azteca* | 0.037 ppm / 0.048 ppm | **0.77 (acute)** |
| Diquat dibromide | *Daphnia magna* | 0.0159 ppm / 0.036 ppm | 0.44 (chronic) |

Washington DOE concludes that "invertebrates will not be entirely safe from the effects of diquat" (p. 196), similar to earlier EDCP conclusions that resulted in limiting use of diquat. While diquat poses a greater risk to macroinvertebrates than the other three EDCP herbicides, several factors reduce the potential for negative effects to invertebrates following diquat treatment. The actual concentration of diquat in water decreases rapidly, particularly in the presence of sediment, as evidenced by the half-life of 0.75 days. In the typical diquat application scenario for EDCP, spot applications of a maximum of 0.37 ppm, one would expect concentrations of diquat to dissipate to levels of less than 0.042 ppm to 0.021 ppm in 48 to 96 hours (Washington DOE 2002). These levels are close to, but not substantially higher than, the EC50 levels for the most sensitive invertebrate species. Limiting the area that is treated with diquat will further reduce the potential for significant effects on zooplankton. Finally, Wilson (1968, in Washington DOE 2002) noted that affected invertebrate species may be replaced by species of a similar size class, resulting in an overall minimal impact due to diquat.

**Table 6-21,** above, provides the RQ values for EDCP herbicides for various potential invertebrate prey. Acute RQ values below the LOC of 0.5 and chronic RQ values below one, would indicate no adverse effect on invertebrates, which endangered species may utilize for food sources. With the exception of the acute diquat RQ value, all calculated RQ values are orders of magnitude below the LOC.

The potential impacts of EDCP treatments on macroinvertebrates are minimal as compared to the scope of the Delta-wide food web. Kovalenko et al. (2009) found that removal of invasive water milfoil from Minnesota lakes did not affect stomach fullness or fish feeding. Fish were able to find preferred prey in their changing habitat, in an environment significantly more closed than the Delta. Factors other than macrophytes and macrophyte control are greater influences on macroinvertebrates. In a study evaluating

27 years of benthic assemblage data at four locations along the salinity gradient in the Delta, Peterson and Vayssieres (2010) found that macroinvertebrate composition was heavily influenced by changes in salinity and by the invasion of the clam, *Corbula amurensis* that began in 1987.

Even with the potential for temporary exceedances of acute LOC values for diquat, effects on native fish feeding are likely to be minimal. Several studies have shown that fish feed on the resources available in a particular moment (Pelicice and Agostinho 2006). The ability of fish to feed on resources available may be particularly important to their survival in the Delta. Over the last forty years, there have been large spatial and temporal changes in zooplankton community abundance and species composition (Winder and Jassby 2011). During this time period, local macroinvertebrate fauna, particularly copepods and mysids, have been replaced with introduced species (Winder and Jassby 2011). These changes in zooplankton communities and abundance far exceed the scale of potential EDCP impacts at individual treatment sites.

Depending on the material type, benthic barriers may temporarily reduce benthic invertebrate populations directly under the mat due to poor water circulation and low dissolved oxygen. However, studies utilizing newer mat materials do not appear to impact benthic invertebrates, as compared to mats utilized in the 1980s and 1990s.

Engel (1984) evaluated two types of stationary blankets and a removable screen in a Wisconsin lake, and found that after three months, macroinvertebrate populations under the screens were one-third of that in control sites. However, Engel found that live chironomid larvae covered the upper surface of all screens. Engel did not evaluate macroinvertebrate populations after the mats or screen were removed.

Ussery et al. (1997) and Payne et al. (1993) evaluated the effects of synthetic fabric barriers on macroinvertebrate communities at three different locations: a Wisconsin reservoir, a lake in Alabama on the Tennessee River, and U.S. Army Corps research ponds in Texas. In all three locations, their studies found that macroinvertebrate populations declined and community characteristics shifted under the barriers as compared to controls, but that populations quickly recovered after the barriers were removed. Effects were more significant in warmer waters, and were likely a result of low dissolved oxygen under the mats (Ussery et al. 1997, Payne et al. 1993). These studies noted that loss of productive invertebrate habitat occurred only directly under the mat while the mat was in place and that loss of productive habitat can be compensated for by beneficial aspects of barriers (i.e. effective removal of invasive weeds) (Ussery et al. 1997).

The Tahoe Resource Conservation District (TRCD) sponsored a study by University of Nevada, Reno (UNR), to evaluate the effects of barrier placement on benthic invertebrates in Tahoe Keys (UNR 2011). This study compared benthic invertebrate samples under barriers and in control sites pre-treatment, and at 7 and 50 days post treatment (the original schedule for sampling at 0 days was adjusted due to inclement weather). The UNR found

that patterns in benthic invertebrate density did not differ significantly between control and treatment plots for any of the major invertebrate taxa (UNR 2011). The study found that invertebrates were either able to persist under the barriers, or to rapidly recolonize. In both the control and treatment sites, density of benthic invertebrates was patchy, and appeared to be driven mainly by substrate type.

USDA-ARS and DBW have not determined if, and where, to apply benthic barriers. However, any EDCP barriers will utilize a material similar to that used by TRCD, and will be placed in very few total acres. This will help to avoid potential impacts to benthic invertebrates under the barriers.

***Phytoplankton***

Macroinvertebrates depend on phytoplankton, which serve as the base of the food web. Phytoplankton plays a fundamental role in primary productivity (Jassby et al. 2003). There is potential for EDCP treatments to affect algae within treatment sites, which could in turn affect macroinvertebrates. However, the potential impact of EDCP treatments on phytoplankton is minimal compared to larger scale influences on phytoplankton in the Delta. Jassby et al. (2002) examined Delta-wide primary productivity (the rate at which plants incorporate inorganic carbon into organic matter) between 1975 and 1995. During the 21-year time period, primary productivity in the Delta varied by a factor of five. Factors that contributed to the variability included: (1) decreased phytoplankton mass due to the invasion of the clam *Corbula amurensis*, (2) long-term declines in total suspended solids leading to increased water transparency and phytoplankton growth rate, (3) river inflow affecting biomass and growth rates through fluctuations in flushing and total suspended solids, and (4) an unknown factor resulting in a long-term decline in winter phytoplankton growth rate (Jassby et al. 2002).

An analysis of phytoplankton (as chlorophyll-a) in the Delta and Suisun Marsh between 1996 and 2005 found increases in much of the Delta and substantial declines in Suisun Marsh (Jassby 2008). Chlorophyll-a, a green pigment in plants, is used as an approximate index of algal biomass (Jassby et al. 2003). Overall, there has been a long-term declining trend in chlorophyll-a from the 1970s to 2005, as well as a decline in larger-celled phytoplankton, which are preferred food sources (Kimmerer et al. 2012). Delta chlorophyll-a sampling levels between 1987 and 2006 have rarely risen about the threshold level of 10 μg per liter that is considered the point at which crustacean zooplankton become food-limited (Jassby 2008, Kimmerer et al. 2012). Suisun Marsh, which is highly affected by *Corbula amurensis*, has seen even greater declines in chlorophyll-a (Jassby 2008).

Changes in phytoplankton communities can result in differing nutrient values. For example, diatoms and cryptophytes are generally more nutritious for many zooplankton species than cyanobacteria (Jassby 2008). Researchers have concluded that long-term declines of phytoplankton in the Delta have contributed to long-term declines in fish abundance; however, phytoplankton decline does not appear to be a major factor in the more recent pelagic organism decline (Kimmerer et al. 2012).

Algal toxicity studies evaluate the EC50, the concentration at which there is a 50 percent reduction in the log-phase growth after a time period (Washington DOE 2001). EC50 values higher than EDCP herbicide concentrations would indicate a potential for treatments to acutely negatively affect algal growth. **Table 6-22,** on the next page, provides several species' EC50 values for EDCP herbicides.

The effects of fluridone on phytoplankton composition and densities depend on duration of exposure and species. In an evaluation of the effect of two 125 ppb applications of fluridone in fish ponds, Struve et al. (1991) found that fluridone was not effective in consistently reducing phytoplankton densities or chlorophyll-a concentrations. Fluridone did not selectively eliminate blue-green algae, which is a less-preferred food source (Struve et al. 1991). This study had significantly higher application rates than EDCP, and a somewhat shorter 39 day exposure period.

The results of field studies of fluridone exposure on algae are not consistent (Washington DOE 2002). One study utilizing high (1,000 ppb) exposures found only transient decreases in phytoplankton over a 22 day period (Arnold 1979 in Washington DOE 2002). Another study found a substantial decrease in phytoplankton density at 42 ppb exposure over 84 days (Kamarianos et al. 1989 in Washington DOE 2002). Both of these studies had higher exposure levels than EDCP. Two additional studies (Chen et al. 2003 and Sandmann and Frase 1993, in Washington DOE 2002) found that green algae and blue-green algae demonstrated resistance to fluridone. The fact that there are resistant algae strains may account for some of the inconsistencies in study results. Washington DOE (2002) summarized that fluridone can be applied at application rates that will control target species without substantial risks to any groups of aquatic algae.

One more recent study of the ecological effects of fluridone in pond cultures of catfish (Jacob, 2008), evaluated the impact of fluridone (AVAST formulation) on phytoplankton and zooplankton There were decreases in phytoplankton between control and treated ponds, as some fluridone is toxic to some phytoplankton, given its mode of action. However, phytoplankton levels in fluridone treated ponds showed signs of recovery by the end of the 12-week treatment cycle. Fluridone exposure in this study was 0.09 ppm and 0.90 ppm, significantly higher than EDCP exposures. The Jacob study was a Midwestern catfish pond experiment treated with higher herbicide doses, and the results are difficult to correlate with any confidence to the dynamic, more natural conditions of the Delta when treated at lower concentrations of fluridone for *Egeria densa* control. Also, in 3 of 4 fluridone-only treated ponds in the Jacob et al. study, a significant biomass of macrophytes existed after treatment, but in one pond, there was a 6-times increase in macrophyte biomass. Therefore, some macrophytes persisted and potentially increased during treatment. These plants would compete with planktonic algae for nutrients and other limiting resources, and their growth may have come at the expense of planktonic primary production. This is a confounding factor in the Jacob study's interpretation of the noted changes in pond phytoplankton community.

## Table 6-22
### Responses of Standard Algal, Diatom, and Cyanobacteria species to EDCP Herbicides

| Species | Chemical | EC50 (NOEC) | Time Period | Reference* |
|---|---|---|---|---|
| *Nitella furcata* (green algae) | Fluridone | 0.02 mg/l | 6 days<br>Endpoint = chlorophyll bleaching | SERA 2008 |
| *Chlamydomonas eugametos* (green algae) | Fluridone | 0.329 mg/l NOEC<br>3.329 mg/l LOEC | 48-hours<br>Endpoint = growth inhibition | SERA 2008 |
| *Oscillatoria agardhii* (blue-green algae)* | Fluridone | 0.020 mg/l LOEC | 96-hours<br>Endpoint = carotenoids | SERA 2008 |
| *Oscillatoria agardhii* (blue-green algae) | Fluridone | 0.020 mg/l NOEC<br>0.040 mg/l LOEC | 96-hours<br>Endpoint = biomass | SERA 2008 |
| *Anabaena cylindrical* (blue-green algae) | Fluridone | 5.6 mg/l<br>0.50 mg/l NOEC | 96-hours<br>Endpoint = nitrogen fixation | SERA 2008 |
| *Scenedesmus quadricauda* (green algae) | Penoxsulam (technical) | 0.092 mg/l<br>NOAEC 0.005 mg/l | 96-hr<br>Endpoint = cell density | USEPA September 2007 |
| *Scenedesmus quadricauda* (green algae)* | Penoxsulam (Galleon/ equivalent) | 0.094 mg/l<br>NOAEC 0.009 mg/l | 96-hr<br>Endpoint = biomass | USEPA September 2007 |
| *Scenedesmus quadricauda* (green algae) | Penoxsulam degradates | > 1.0 mg/l to<br>> 10 mg/l<br>(same for NOAEC) | 96-hr<br>Endpoints = growth rate, biomass, none | USEPA September 2007 |
| *Navicula pelliculosa* (freshwater diatom) | Penoxsulam (technical) | > 49.6 mg/l<br>(same for NOAEC) | 120-hr<br>Endpoint = none | USEPA September 2007 |
| *Anabaena flos-aquae* (blue-green algae) | Penoxsulam (technical) | 0.27 mg/l<br>NOAEC 1.94 mg/l | 120-hr<br>Endpoint = cell density, biomass | USEPA September 2007 |
| *Navicula pelliculosa* (freshwater diatom)* | Imazamox | > 0.040 mg/l | 120-hours<br>Endpoint = growth reduction | USEPA 2008 |
| *Selenastrum capricornutum* (green algae)* | Imazamox | > 0.040 mg/l | 120-hours<br>Endpoint = growth reduction | USEPA 2008 |
| *Anabaena flos-aquae* (blue-green algae) | Imazamox | > 0.040 mg/l | 120-hours<br>Endpoint = growth reduction | USEPA 2008 |
| *Anabaena flos-aquae* (blue-green algae) | Diquat dibromide | 0.05 mg/l | 168-hours<br>Endpoint = growth reduction | Washington DOE 2002 |
| *Anabaena flos-aquae* (blue-green algae) | Diquat dibromide | 0.042 mg/l | 72-hours<br>Endpoint = chlorophyll levels | Washington DOE 2002 |
| *Selenastrum capricornutum* (green algae) | Diquat dibromide | 0.48 mg/l | 168-hours<br>Endpoint = growth reduction | Washington DOE 2002 |
| *Selenastrum capricornutum* (green algae)* | Diquat dibromide | 0.019 mg/l | 96-hours<br>Endpoint = growth reduction | Washington DOE |
| *Chlorella vulgaris* (green algae) | Diquat dibromide | 0.395 mg/l | 168-hours<br>Endpoint = growth reduction | Washington DOE |
| *Navicula pelliculosa* (freshwater diatom) | Diquat dibromide | 0.065 mg/l | 168-hours<br>Endpoint = growth reduction | Washington DOE |
| *Euglena gracilis* (Euglenophyte) | Diquat dibromide | 2.94 mg/l | 168-hours<br>Endpoint = growth reduction | Washington DOE |

* Test utilized in RQ calculation.

In total, the weight of scientific literature supports that fluridone is not a functional algaecide and any transitory and inconsistent effects—direct or indirect—on phytoplankton from fluridone treatment should be assessed judiciously against the impact of dense *Egeria densa* infestations on the broader ecological function of infested systems (per Santos et al. 2011 and other studies), including Delta planktonic primary production.

Relative to phytoplankton specifically, Vanderstuckken et al. (2011) recently documented in mesocosm studies that *Egeria densa* suppressed phytoplankton through nutrient competition and allelopathic effects. Nutrient competition resulted from *Egeria densa* reducing nutrient concentrations in the water column. Vanderstuckken et al. found a strong negative direct effect of *Egeria densa* on phytoplankton due to biological mechanisms. *Egeria densa* also affected the phytoplankton community structure, reducing dominance of *Scenedesmus*.

Toxicity testing for USEPA registration of penoxsulam found EC50 values for various microalgae that were higher than the expected penoxsulam concentration immediately following EDCP treatments (USEPA September 2007). Netherland et al. (2009) evaluated the effects of 100 ppb penoxsulam on beneficial and harmful algae and found mixed effects. Penoxsulam reduced chlorophyll-a in some of the harmful species, and some of the beneficial species, after 14 days exposure. Based on the range of algae toxicity data for penoxsulam, Washington DOE (2012) concluded that penoxsulam may result in some suppression of algae, but that use rates are generally lower than those that would cause algal toxicity.

Imazamox has limited toxicity to algae species, and does not provide broad spectrum algal control (Netherland et al. 2009). EC50 values for several algal species were greater than 40 ppb, below possible concentrations following EDCP treatments. Washington State University researchers found that imazamox had no toxic effect on sea lettuce and red algae when Clearcast was applied at 16 ounces per acre (Environ 2012). SERA (2010) concluded that in-water imazamox treatments might result in slight to moderate growth inhibition of some algal species

The effect of diquat on phytoplankton is mixed. Schaffer and Sebetich (2004) evaluated the effect of three concentrations of diquat dibromide on phytoplankton growth using the $C^{14}$ assimilation method. The lowest diquat concentration, 0.118 mg/liter, stimulated phytoplankton productivity at a rate of 117 percent as compared to controls. The two higher concentrations of diquat, 1.18 mg/l and 11.8 mg/l, inhibited phytoplankton productivity equivalent to 45 percent and 19 percent of controls, respectively. The EDCP maximum application concentration is 0.37 mg/l, more than three times lower than the 1.18 mg/l concentration that resulted in phytoplankton inhibition. In addition, due to the rapid binding of diquat to sediment and tidal movement, the concentration of diquat following EDCP treatment is likely to be closer to the 0.118 mg/l level.

Studies on the effects of diquat on phytoplankton summarized in Washington DOE (2002) also had mixed results. Diquat may affect growth of some, but not all, species of algae at the maximum 0.37 ppm use rate. The result may be a temporary shift

in the diversity of phytoplankton, with less sensitive species becoming more dominant. Because inhibiting effects on phytoplankton growth in the field are limited to the first few days after diquat treatment, it seems unlikely that diquat will have a significant direct impact on phytoplankton growth sufficient to adversely impact the food chain (Washington DOE 2002).

**Table 6-23,** on the next page, provides the RQ values for each EDCP herbicide utilizing the lowest EC50 and the highest immediate post-treatment level of herbicide. For penoxsulam and imazamox, the RQ values are below the LOC for aquatic plants of 1.0 (USEPA 2012). For fluridone and diquat, the RQ values are just above the LOC for aquatic plants, indicating potential for some effects on algal growth due to fluridone and diquat treatment. However, it is important to balance the RQ results with studies such as Vanderstuckken et al. (2011), and note that these mixed and localized potential impacts on algae are minimal as compared to the system-wide changes in phytoplankton in the Delta.

Given the limited nature and scale of potential impacts, it is unlikely that there would be significant adverse effects to special status, resident native, or migratory fish from EDCP impacts on the Delta food web. Given the (1) low levels of herbicides utilized, (2) low toxicity of EDCP herbicides to macroinvertebrates (with the exception of diquat, which will be used in limited situations); (3) limited and mixed potential for effects on algae and phytoplankton; and (4) limited treatment acreage, the potential for food web effects to impact special status fish, resident native or migratory fish, is likewise low.

### 3. Dissolved Oxygen Effects

Dissolved oxygen is the content of oxygen found in water. DO is determined by temperature, weather, water flow, nutrient levels, algae, and aquatic plants. Generally, a higher level of DO is beneficial. Fish begin to experience oxygen stress or exhibit avoidance at levels below 5 mg/liter (5 ppm). DO levels drop in warmer temperatures, and increase with precipitation, wind, and water flow. Running water, such as tidal water in the Delta, dissolves more oxygen than still water. High levels of nutrients in water reduce DO levels, while algae and aquatic plants can increase DO through photosynthesis, but decrease DO through respiration and decomposition. DO levels fluctuate throughout the day, and are typically lowest in the morning and peak in the afternoon. In deep, still waters, DO levels are lower in the hypolimnion (bottom layer of water) because there is little opportunity for oxygen replenishment from the atmosphere.

There is the potential that following herbicide treatment, the biomass of decaying *Egeria densa* will create a large biological oxygen demand, resulting in decreases in dissolved oxygen. These decreases in dissolved oxygen could adversely affect fish species and aquatic invertebrates present at the treatment location, and generally impair sensitive riparian or wetland habitats. The extent of the DO impact depends on the speed at which *Egeria densa* decomposes following treatment (which is herbicide dependent) and the extent to which tides and wind move decaying plants away from the original location (which is variable).

Decreases in dissolved oxygen due to rapid decomposition of plant material are not expected to occur following the use of

**Table 6-23**
**RQ Calculations for EDCP Herbicides for Algae, Cyanobacteria, and Diatom**

| Herbicide | Species | EEC/EC50 | RQ |
|---|---|---|---|
| Fluridone | *Oscillatoria agardhii* (blue-green algae) | 0.03 ppm / 0.02 ppm | **1.5** |
| Penoxsulam | *Scenedesmus quadricauda* (green algae) | .05 ppm / .094 ppm | 0.53 |
| Imazamox | Diatom and algae | 0.25 ppm/ 0.40 ppm | 0.62 |
| Diquat dibromide | *Selenastrum capricornutum* (green algae) | 0.037 ppm / 0.019 ppm | **1.9** |

fluridone. Fluridone is a slow-acting systemic herbicide that can take 30 to 60 days to produce its herbicidal effect on the target population (SePRO 2006). Thus, addition of organic material into the water column would be slow. McLaren/Hart Environmental Corp. cite various researchers (Parka and others 1978, Struve and others 1991) who reported that Sonar applications of up to 0.125 ppm did not result in significant decreases in dissolved oxygen content. In field tests conducted by Arnold (1979), fluridone in an aqueous solution at application rates of up to 1.0 ppm did not change water quality parameters as measured by dissolved oxygen, pH, biochemical oxygen demand (BOD), color, dissolved solids, hardness, nitrate, specific conductance, total phosphates, and turbidity. Struve et al. (1991) found no difference in DO (or other water quality measures) between fish ponds treated with two applications of 125 ppb fluridone and controls over a 39 day period. Millie et al. (1990) cited several studies that found that fluridone application resulted in little change in DO content due to slow vegetation decline.

EDCP tracks two sets of DO monitoring. At every herbicide application, treatment crews take DO samples immediately prior to treating, and immediately post-treatment. These levels would be expected to be similar, as they occur a few hours apart and the potential for lowering DO due to decaying *Egeria densa* would not occur immediately post-treatment. EDCP treatment crews took over 340 pre-treatment and 340 post-treatment DO monitoring samples between 2007 and 2012. There was no significant difference between the pre- and post-treatment samples, and even the lowest measured DO levels were above 5.0. The average pre-treatment DO measurement was 8.8 mg/L, and the average post-treatment DO measurement was 9.0 mg/L. The maximum measurements were 13.1 mg/L and 13.8 mg/L for pre- and post-treatment, respectively, and the minimum measurements were 5.1 mg/L and 5.6 mg/L for pre- and post-treatment, respectively.

EDCP also conducts DO monitoring during all water quality sampling events. **Table 6-24,** on the next page, summarizes the 2011 DO monitoring results at the five sites treated that year. EDCP treatments during 2011 started on April 12th, and lasted approximately 10 weeks per site, with some follow-up treatments in the fall at some locations. EDCP environmental scientists continued monitoring at each site until fluridone levels were non-detectable (fluridone was the only herbicide applied in

**Table 6-24**
**EDCP Dissolved Monitoring Results (2011)**

| Site | Monitoring Dates | Total DO Samples | A&B Sites | C Sites | Difference (C-A&B) |
|---|---|---|---|---|---|
| Discovery Bay (93) | 5 (April through November) | 43 | 10.39 | 9.87 | -0.52 |
| Piper Slough (107) | 4 (April through August) | 20 | 8.44 | 8.29 | -0.15 |
| Taylor Slough (110) | 5 (April through August) | 25 | 7.98 | 7.94 | -0.04 |
| Franks Tract (173) | 5 (April through August) | 30 | 8.51 | 8.18 | -0.33 |
| Franks Tract (175) | 4 (April through July) | 12 | 8.62 | 8.85 | 0.23 |
| **Average** | | **26** | **8.79** | **8.63** | **-0.16** |

2011). DO within, and downstream, of treatment sites (A and B sites, respectively) were slightly higher than controls (C sites), and there was no significant difference in DO levels during the course of the treatment season between A& B sites and C sites. DO levels at all times and locations were well above levels considered unsafe for fish.

Penoxsulam is a slow acting herbicide, similar to fluridone, and is not expected to impact dissolved oxygen levels in treated waterbodies (Washington DOE 2012). Imazamox, while faster acting than fluridone and penoxsulam, is also a systemic herbicide. As a result, it should have minimal impact on dissolved oxygen in a treated waterbody (Washington DOE 2012). Penoxsulam and imazamox herbicide labels do not have any requirements related to dissolved oxygen.

Diquat is a fast-acting contact herbicide. The rapid decay of plant material following diquat treatment can result in reduced dissolved oxygen content (Washington DOE 2002). To avoid DO impacts, the herbicide label specifies that no more than one-third to one-half of a water body should be treated at diquat at one time, with a waiting period of 14 days for follow-up treatment of the remaining area. The EDCP will follow diquat label requirements to reduce the potential for DO impacts. Because diquat will only be used for limited spot treatments within EDCP, the actual area treated is likely to be much smaller than the label limitation.

In conclusion, there are no expected impacts to fish habitat due to decreases in dissolved oxygen levels following fluridone, penoxsulam, imazamox, and limited diquat applications. However, EDCP will continue to mitigate for potential reductions in dissolved oxygen levels. EDCP field crews will take dissolved oxygen readings prior to treatments and will not initiate a treatment if measured dissolved oxygen levels are between 3.0 and 5.0 mg/L (current Basin Plan standards). EDCP environmental scientists will continue to measure post-treatment dissolved oxygen levels, and adjust treatment protocols, if necessary, should DO levels decline to levels unsafe for fish. The EDCP will also implement long-term DO monitoring to better understand the natural diurnal fluctuations in DO in *Egeria densa* mats.

## E. Direct and Indirect Effects of Interrelated or Interdependent Actions

There are no interrelated or interdependent actions of EDCP.

## F. Effects Considering Environmental Baseline and Cumulative Effects

The EDCP operates as a minor component within a complex and highly-manipulated environmental baseline. Below, we briefly describe the potential EDCP effects within the context of the environmental baseline and cumulative effects.

### *Environmental Baseline Effects*

The EDCP is legislatively mandated program intended to control invasive *Egeria densa* within the Delta and its tributaries. Left unchecked, *Egeria densa* has significant negative effects on the ecosystem and human activity. The subsidies section, below, describes the potential benefits resulting from *Egeria densa* control.

The WHCP is also a legislatively mandated program intended to control invasive water hyacinth within the Delta. Water hyacinth is a floating plant, and generally does not grow within *Egeria densa*. EDCP treatments and WHCP treatments occur within the same overall time period and within the same project area. However, individual site treatments will typically take place in different locations, and also at different time periods within the respective treatment seasons. Most EDCP treatments occur during April and May. Most WCHP treatments occur between June and August. The same two-person crews conduct treatments, and usually only work on one program in any given day. In addition, both EDCP and WHCP treatment herbicides exhibit low toxicity to fish, macroinvertebrates, and algae, and are thus not likely to adversely affect listed fish species, either individually or in combination.

The growing dominance of invasive species in the Delta increases the need for control programs such as the EDCP. Invasive species in the Delta have already altered the food web, habitats, and water quality. Long-term changes resulting from climate change are likely to further enhance conditions for many invasive species, including *Egeria densa*. Invasive species control programs such as the WHCP and EDCP will be increasingly necessary in order try to prevent the Delta ecosystem from further degradation.

The impact of agricultural practices in the Delta are substantial, and have become part of the economic and ecological landscape of the Delta. EDCP activities operate at a significantly smaller scale, and with significantly lesser impacts, as it relates to pesticide use, the area in which agriculture and EDCP operations overlap. The EDCP seeks to minimize herbicide use and to use herbicides with improved toxicity profiles in order to reduce the potential for additional pesticide burden on the Delta beyond that resulting from agricultural use.

Delta water quality has been degraded by historical and current human activities. The EDCP operates within the guidelines of the SWRCB and Regional Water Board plans and NPDES permits. EDCP activities follow water quality guidelines and mitigation measures, and do not result in further decline of beneficial uses of the Delta, and in fact promote beneficial uses of the Delta.

***Cumulative Effects***

The Spongeplant Control Program (AB 1540, Buchanan, Chapter 188, Statutes of 2012) was approved by the Legislature on August 15, 2012, and signed by the Governor on August 27, 2012. AB 1540 adds responsibility for an additional invasive plant to DBW and USDA-ARS existing WHCP and EDCP programs. The Spongeplant Control Program will operate in similar locations within the Delta as the EDCP, and with similar treatment approaches as the WHCP. The additive effects of spongeplant control to existing WHCP and EDCP activities is not likely to result in significantly greater or new potential impacts to listed species.

The impacts of climate change in the Delta will likely result in gradual changes to Delta ecosystems and to the political landscape in which the Delta is managed. These changes will occur over the long-term, and EDCP activities will not substantially change the nature of climate change impacts on listed species.

Effects of urbanization on the Delta and listed species will likely increase the need for EDCP treatment activities. Further decline of water quality and habitats may increase potential for *Egeria densa* invasions. In addition, increased recreational activity in the Delta could result in the need for additional *Egeria densa* control.

EDCP activities, taken within the context of the environmental baseline and cumulative effects, are not likely to result in additional adverse effects to listed species. There is potential for these environmental baseline and cumulative effects to increase the need and importance of *Egeria densa* control to help maintain natural habitats within a changing and degrading Delta.

## G. Subsidies of EDCP

Submersed aquatic vegetation, such as *Egeria densa*, can play a positive role in maintaining functioning aquatic ecosystems through their impact on hydrology, sedimentation, nutrient cycling, and habitat (Santos et al. 2011). However, once they reach an invasive state, SAVs alter normal ecosystem functions and become detrimental, rather than beneficial. *Egeria densa* has been classified as an ecosystem engineer because of the extent of its impacts through the ecosystem (Yarrow et al. 2009, Strayer 2010, Mount et al. 2012). *Egeria densa* impacts water currents, air-water sediment exchanges, the amount of surfaces available for chemical reactions and biotic attachments, and changes in the amount and quality of primary production and detritus (Strayer 2010). *Egeria densa* in the Delta out-competes native plants and changes habits and relationships for other aquatic species, from phytoplankton to fish. The inverse of these negative effects of *Egeria densa* is that controlling *Egeria densa* in the Delta and its tributaries reduces and/or eliminates negative consequences.

As with all invasive species control programs, EDCP activities seek to balance the need to minimize the potential effects of control with the benefits of control. While one core intent of the EDCP is to improve navigation and public safety in the Delta, the broader benefits of the EDCP to the Delta ecosystem are likely more significant and more lasting. Below, we focus on subsidies of the EDCP in the context of listed fish species. By removing invasive *Egeria densa*, EDCP activities lead to four primary interrelated subsidies: (1) reduced physiochemical impacts, (2) biological benefits,

(3) reduced potential for significant detrimental impacts, and (4) increased ecosystem restoration opportunities.

The negative impacts of *Egeria densa* in the Delta are closely interrelated, as are the potential subsidies of *Egeria densa* control. **Figure 6-3,** on the next page, provides a simplified schematic summarizing some of the interrelated physiochemical and biological impacts of *Egeria densa* (from Yarrow et al. 2009). As Yarrow et al. note, dense *Egeria densa* coverage decreases water turbulence, which decreases resuspension of sediments and increases sedimentation. This increases the amount of light available in the water, maintaining a clear water state and increasing *Egeria densa* photosynthesis. *Egeria densa* also reduces nutrients in the water column, negatively impacting phytoplankton, the base of the food web. *Egeria densa* provides protective habitat for zooplankton (although often not native species), which feed on, and further negatively impact, phytoplankton. Yarrow et al. (2009) note that ultimately, increased sediment might negatively impact *Egeria densa* (the (-)*) in Figure 6-3.

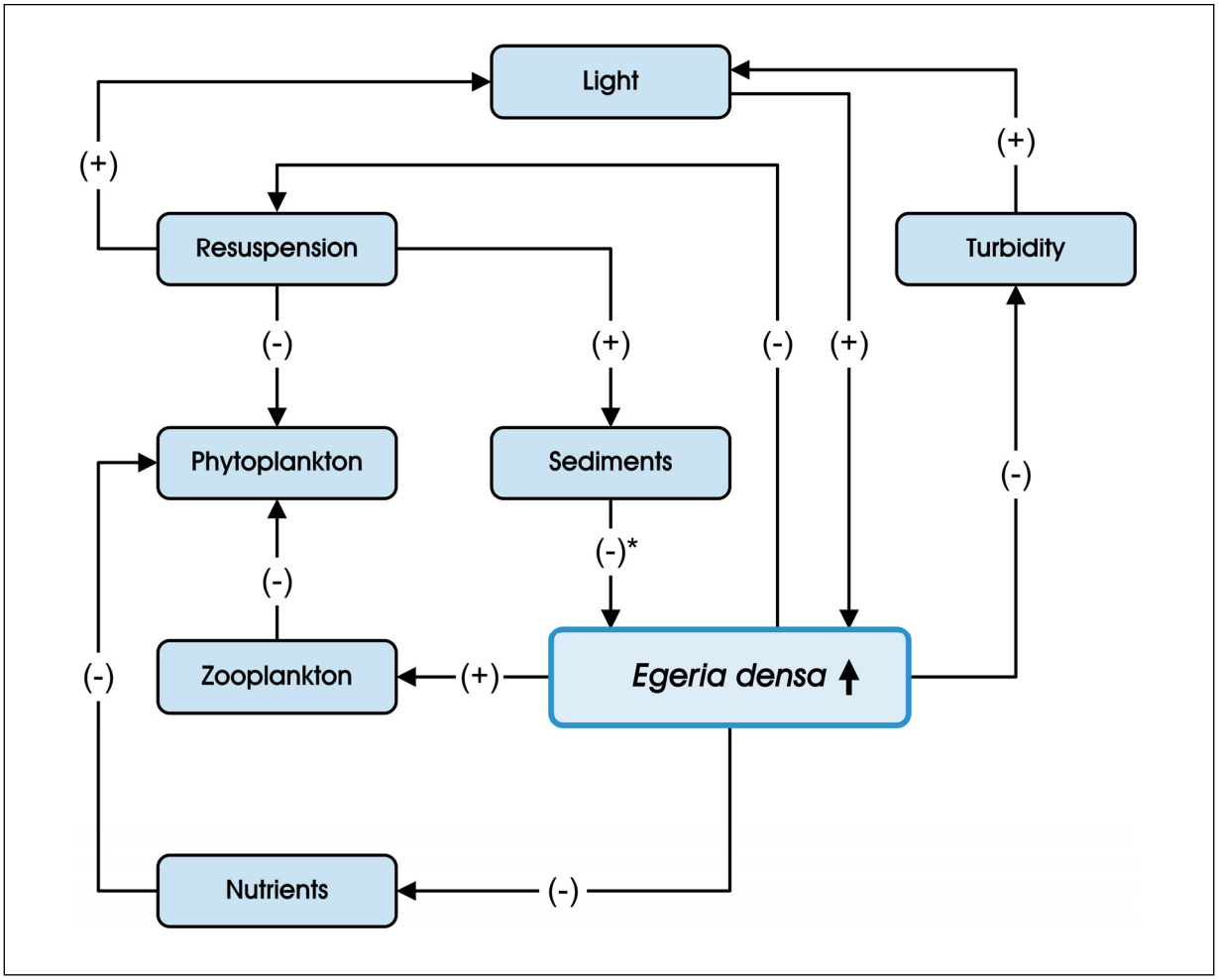
### *Reduced Physiochemical Impacts*

Control of *Egeria densa* can minimize the significant physiochemical impacts caused by *Egeria densa* invasions. Reduction of the large monospecific mats that have invaded much of the Delta, and will be the focus of EDCP treatments, will limit the ability of the plant to exert these negative effects. *Egeria densa* changes the physical and chemical environment it inhabits. Water temperature in *Egeria densa* colonies is 1°C to 5°C higher than surrounding open water because the plants absorb more solar radiation (Santos et al. 2009). Salmonids are sensitive to water temperature, and the Delta is already in the southern (and warmer) end of their range (Katz et al. 2012).

*Egeria densa* sequesters nutrients (nitrogen and phosphorous), and depletes phosphorous in the sediment (Yarrow et al. 2009, Mazzeo et al. 2003). *Egeria densa* also appropriates nutrients such as bicarbonate under low-light conditions (Lacoul and Freedman 2006), further limiting phytoplankton and native aquatic macrophytes. *Egeria densa* facilitates benthic anoxia, as the density of the plants creates a barrier between surface and bottom waters (Champion 2000). Benthic anoxia results in mortality of plants and benthic invertebrates. Low dissolved oxygen levels are detrimental to fish (Newcomb and Pierce 2010).

*Egeria densa's* impact on water flow and turbidity are a primary reason it has been classified as an ecosystem engineer. *Egeria densa* lowers water velocity (Merz et al. 2008, Yarrow et al. 2009). The lower water velocity results in sedimentation of suspended particles in the water, contributing to increased water clarity. This reduction in turbidity has been amplified in the Delta through invasion of Asian clams and reduced sedimentation due to dams (Cloern and Jassby 2012). As shown in Figure 6-3, the lower turbidity results in improved light, which favors growth of *Egeria densa*, which further reduce nutrients (and light) available for phytoplankton. *Egeria densa* roots further stabilize the sediment, reducing resuspension of sediment and the influx of nutrients that would result from resuspension (Champion 2000). This reduction in turbidity has additional biological effects, as discussed below.

**Figure 6-3**
***Egeria densa* as an Ecosystem Engineer**




Source: Adapted from Yarrow et al. (2009) p. 306

Current conditions in the Delta are conducive to the growth and spread of *Egeria densa*. If *Egeria densa* is allowed to grow uncontrolled in the Delta environment, this invasive species will continue to alter the physical and chemical properties of the areas it inhabits, further negatively impacting native species and habitats, and promoting a cycle that favors further invasions and ecosystem deterioration (Cloern and Jassby 2012, Strayer 2010).

### *Biological Benefits*

The biological benefits of *Egeria densa* control are related to the negative physiological and chemical impacts of *Egeria densa*, as well as its ability to out-compete native plants. *Egeria densa* negatively affects sediment seed banks, which in turn reduces the resilience of the aquatic system to disturbances (Yarrow et al. 2009). Exotic species such as *Egeria densa* reduce the distribution and abundance of native plant communities in the Delta (Santos et al.

2009). In 2007, *Egeria densa* was reported to have displaced most of the native submersed aquatic plant species in the Delta (Lund et al. 2007). Santos et al. (2011) surveyed Delta aquatic plants in 2007 and 2008 and found that over 50 percent of submersed plant patches consisted of monospecific *Egeria densa*, and when *Egeria densa* did co-occur with other species, it was dominant. The increase in invasive plant species was associated with a significant decrease in the richness of native species and native species biomass (Santos et al. 2011). Invasive fish species, in turn, favor invasive plant beds (McGowan 1998, Hanni 2005, Grimaldo and Hymanson 1999).

As noted above, the reduced nutrients and light (caused by increased *Egeria densa* growth) controls the growth of phytoplankton around infestations (Yarrow et al. 2009, Mazzeo et al. 2003). This can act to reduce the potential for algae blooms, but can also limit productivity at the base of the food web.

An evaluation of fish community ecology in different habitat types (low velocity channel edges and shallow habitats) in the Delta found that fish assemblage was influenced by SAV (Nobriga et al. 2005). The study found that native fish and recreationally important nonnative fish (striped bass) do not make extensive use of vegetated habitats. However, Conrad et al. (2010a, 2010b, 2011) have found that *Egeria densa* promotes abundance of young of the year of the invasive species, largemouth bass. Conrad el al. hypothesize that *Egeria densa* provides protection from predators, and that macroinvertebrate prey may be more abundant. Adult largemouth bass were not strongly associated with *Egeria densa*.

While *Egeria densa* supports invasive fish species, it negatively impacts listed fish species. Recent studies have found that *Egeria densa* negatively impacts delta smelt by reducing turbidity and overwhelming littoral (near shore) habitats (USFWS 2008). A study examining the impact of *Egeria densa* and three other aquatic macrophytes on Chinook salmon spawning beds in the Mokelumne River found that spawning females avoided areas where these plants were rooted (Merz et al. 2008). The Merz et al. study was evaluating enhanced gravel beds placed to improve spawning, and found that the reduced river velocities surrounding the invasive weeds increased deposition of fine sediment, covering the course substrate fish prefer.

Given the significant negative impacts of *Egeria densa* on the Delta ecosystem, control of this invasive weed is likely to improve, not degrade, the biological system.

#### *Reduced Potential for Significant Detrimental Impacts*

The Delta is already a severely degraded ecosystem that favors further invasions of non-native species. In heavily invaded systems such as the Delta, invasions create "no analogue" systems (Strayer 2010). In these situations, management becomes more difficult, and the results more unpredictable. Cloern and Jassby (2012) note that "biological invasions challenge the integrity of natural plant and animal communities and confound conservation plans to preserve endangered species" (p.11).

While the Delta will never return to its original natural state, control of *Egeria densa* is one step in preventing further degradation.

For example, to date, EDCP has focused most control efforts on the Central Delta, but potential for negative impacts to Chinook salmon spawning (Merz et al. 2008) increase the need for early removal of river infestations. The expanded understanding of the impacts of reduced turbidity on delta smelt also highlight the need to improve habitat for this fragile species.

***Increased Ecosystem Restoration Opportunities***

*Egeria densa* control is integral to the extensive efforts at the federal, state, and local level to improve the Delta ecosystem. Hestir et al. (2008) note that *Egeria densa* threatens the success of restoration efforts in the Delta. Control of *Egeria densa* in Delta waterways expands habitat suitable for native species.

Nobriga et al. (2005) suggest that restoration strategies that maintain and enhance natural riverine and estuarine habitats (as compared to ones maximizing productivity – i.e. dense weeds) would be better for native species. Potentially, the best evidence for selective management of *Egeria densa* in the Delta is documentation of native aquatic plant responses from past management. USDA-ARS and DBW have observed that management in recent years has led to the expansion of native macrophyte species in conjunction with control of *Egeria densa.*

Habitat improvements following *Egeria densa* treatment are likely to be similar to treatments for other invasive species. Allan (2006) evaluated native plant biomass following treatment of alligatorweed with imazapyr or triclopyr. Early and heavy treatment of alligatorweed with either herbicide resulted in a greater biomass of native plants later in the treatment season and after one year. Allan found that the timing and rate of application influenced return of native plants, a result that is likely species and ecosystem-specific.

It is important to note that control of *Egeria densa* is just one step in restoring native habitats. Removal of invasive plants does not necessarily mean that native plants will grow in their place (Reid et al. 2009). In a survey of Australian land managers, 52 percent reported that sites treated for invasive weeds were re-colonized by a mix of native and non-native species, 33 percent were re-colonized by native species, 2 percent were re-colonized by the invasive plant, and 7 percent had no vegetation following treatment (Reid et al. 2009). This survey primarily addressed terrestrial treatments, but points out that invasive weed treatment is a first step, but not the only step, in ecosystem restoration. This is particularly true in a heavily modified environment such as the Delta, where new invasions are occurring daily.

## H. Alternative Actions

The 2001 EDCP Environmental Impact Report (EIR) (DBW 2001) identifies a number of alternative control methods that were rejected as infeasible, and seven alternatives that were evaluated, but not implemented. These seven alternatives include the No Project alternative. The alternative methods rejected as infeasible included three options that are considered in this document for limited applications and/or evaluation: hand removal, bottom barriers, and biological

control. Other alternatives that were rejected as infeasible were:

- Flow rate manipulation
- Water level manipulation
- Reduced light penetration (using dyes)
- Nutrient limitations.

The seven alternatives considered in the EIR consist of various combinations of methods that were selected. The 2001 EIR selected alternative included chemical treatments with diquat (Reward), fluridone (Sonar) and mechanical harvesting, and two-year copper (Komeen) trials. Reflecting the evolution of the program, the 2006 Second Addendum to the 2001 EIR removed the two-year Komeen trials and conditionally removed mechanical harvesting from EDCP (DBW 2006). The seven alternatives considered in 2001 were as follows:

- No project
- EDCP with Reward and Sonar; two-year Komeen trials
- EDCP with Reward, Sonar, and mechanical harvesting, no Komeen trials
- EDCP with Reward, Sonar; no Komeen trials
- EDCP with Reward, Sonar, mechanical harvesting, and Komeen; no Komeen trials
- EDCP with Reward, Sonar, and Komeen; no Komeen trials
- EDCP with mechanical harvesting; no Komeen trials.

With the exception of the no program alternative, each of the above alternatives consists of implementing certain components of an integrated management approach. In the analysis conducted in 2001, these alternatives had different potential efficacy levels and environmental impacts. For example, there was concern about the long-term impact of Komeen treatments in the Delta, which is why this option was tested in a two-year trial, and then removed from the program. With mechanical harvesting, there were concerns related to cost, and the potential for release of fragments. Given the program developments since 2001, DBW and USDA-ARS can better select an integrated program that incorporates new herbicides and approaches that were not feasible in 2001 or 2006, and at the same time remove those methods that have greater negative environmental impacts.

Section 7

# Other Relevant Information

# 7. Other Relevant Information

This section of the Biological Assessment provides supporting information and studies. All materials referenced below are provided in the **EDCP Biological Assessment – Supplemental Materials Binder.**

## A. Studies to Evaluate Treatment Alternatives, Efficacy, and to Identify New Treatment Options

Since 1998, USDA-ARS and DBW have conducted or sponsored a number of additional studies to evaluate treatment alternatives, efficacy, and identify new treatment options. Many of these additional studies were requested as part of previous USFWS or NMFS consultations. The following thirteen (13) studies are provided in the Supplemental Materials Binder in Tabs 7 through 19. In addition, PDF files of each report are provided on the accompanying CD-ROM.

- *Fluridone (4AS) Dissipation During Typical Application of Sonar (4AS),* Lars W.J. Anderson, Ph.D., USDA-ARS Exotic and Invasive Weed Research (2005) (Tab 7)
- *Residue of Fluridone and Diquat Dibromide in Sediment from the Sacramento-San Joaquin Delta, California, 2002-2005*, Robert C. Hosea, California Department of Fish and Game (2005) (Tab 8)
- *Residue of Fluridone in Chinook Salmon Smolts from the Sacramento-San Joaquin Delta, California, 2005,* Robert C. Hosea, California Department of Fish and Game (2005) (Tab 9)
- *An Evaluation of Potential Effects of Fluridone on Pacific Salmon in the California Delta,* Clifford Habig, Ph.D., SePRO (2004) (Tab 10)
- *Experimental Studies of the Effects of Temperature, Salinity and Light Intensity of Growth of Egeria densa,* Steven Obrebski and Robin Rooth, Romberg Tiburon Center, San Francisco State University (2003) (Tab 11)
- *Acute Oral and Dermal Toxicity of Aquatic Herbicides and a Surfactant to Garter Snakes,* Robert C. Hosea, California Department of Fish and Game (2004) (Tab 12)
- *Chronic Toxicities of Herbicides Used to Control Water Hyacinth and Brazilian Elodea on Neonate Cladoceran and Larval Fathead Minnow,* Frank Riley and Sandra Finlayson, California Department of Fish and Game (2004) (Tab 13)

- *Acute Toxicities of Herbicides Used to Control Water Hyacinth and Brazilian Elodea on Larval Delta Smelt and Sacramento Splittail,* Frank Riley and Sandra Finlayson, California Department of Fish and Game (2004) (Tab 14)
- *Ceriodaphnia dubia (water flea) Static Definitive Chronic Toxicity Test Data (7-day) for Exposure to Various Aquatic Herbicides,* California Department of Fish and Game, Aquatic Toxicology Laboratory (2003) (Tab 15)
- *Pogonichthys macrolepitdotus (Sacramento Splittail) Static Definitive Acute Toxicity Test Data (96-hour) for Exposure to Various Aquatic Herbicides,* California Department of Fish and Game, Aquatic Toxicology Laboratory (2003) (Tab 16)
- *Mapping Invasive Plant Species in the Sacramento-San Joaquin Delta Region Using Hyperspectral Imagery,* Susan L. Ustin, Ph.D., et al, Center for Spatial Technologies and Remote Sensing (CSTARS), California Space Institute Center of Excellence (CalSpace), UC Davis (2004) (Tab 17)
- *Dissipation and Movement of Sonar, and Komeen Following Typical Applications for Control of Egeria densa in the Sacramento/San Joaquin Delta and Production Viability of E. Densa Fragments Following Mechanical Harvesting,* Lars W.J. Anderson, USDA-ARS, Aquatic Weed Control Research Laboratory, Invasive Weed Research Unit, U.D. Davis (1998) (Tab 18)
- *Effects of Control Methods on the Egeria densa Community*, Steve Obrebski, Terry Irwin, and Jennifer Pearson, Romberg Tiburon Center, San Francisco State University (1998). (Tab 19)

## B. Herbicide Labels

Labels and Material Safety Data Sheets (MSDS) for each of the current and new EDCP herbicides are provided in the Supplemental Materials Binder in Tabs 20 through 26. Labels are provided in the following order:

- SonarOne Label (Tab 20)
- SonarOne MSDS (Tab 20)
- Sonar PR Label (Tab 21)
- Sonar PR MSDS (Tab 21)
- Sonar Q Label (Tab 22)
- Sonar Q MSDS (Tab 22)
- Sonar AS Label (Tab 23)
- Sonar AS MSDS (Tab 23)
- Galleon SC Label (Tab 24)
- Galleon SC MSDS (Tab 24)
- Clearcast Label (Tab 25)
- Clearcast MSDS (Tab 25)
- Reward Label (Tab 26)
- Reward MSDS. (Tab 26)

## C. EDCP Site List

**Exhibit 7-1,** with an example on the next page, summarizes characteristics of each EDCP treatment site. The full exhibit is provided in Tab 28 of the Supplemental Materials Binder. The total site acres included in Exhibit 7-1 is 50,442 acres. This is less than the combined Delta and Southern Site water acres of 67,799, because there are water acres that are not treated within the EDCP. Exhibit 7-1 is sorted so that the 22 sites that have been treated in the last six years (2007 to 2012) are listed first. The remaining 299 sites are within the EDCP

## Exhibit 7-1 (EXAMPLE)

### EDCP Treatment Site List, History, and Characteristics



| # | Site Number[1] | Treated in 2007 | Treated in 2008 | Treated in 2009 | Treated in 2010 | Treated in 2011 | Treated in 2012 | Total Pounds Fluridone a.i. (2007-12) | Treated in April | Treated in May |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 26 | | | 2009 | | | 2012 | 191.5 | April | May |
| 2 | 32 | | | 2009 | 2010 | | 2012 | 1,185.0 | April | May |
| 3 | 34 | | | 2009 | | | | 84.8 | April | |
| 4 | 36 | | | 2009 | | | | 18.9 | April | |
| 5 | 37 | | | 2009 | 2010 | | 2012 | 714.8 | April | May |
| 6 | 38 | | | | | | 2012 | 150.0 | | |
| 7 | 39 | | | | | | 2012 | 10.5 | | |
| 8 | 62 | | | | | | 2012 | 167.5 | | |
| 9 | 79 | | | | | | 2012 | 27.5 | | |
| 10 | 93 | | | | | 2011 | 2012 | 1,122.0 | April | May |
| 11 | 107 | | | | | 2011 | 2012 | 301.0 | April | May |
| 12 | 108 | | | | | | 2012 | 40.5 | | |
| 13 | 109 | | | | | 2011 | 2012 | 531.0 | | |
| 14 | 110 | | | | | 2011 | 2012 | 434.5 | | |
| 15 | 111 | | | | | 2011 | | 74.0 | April | May |
| 16 | 112 | | | | | 2011 | 2012 | 465.0 | | |
| 17 | 173 | 2007 | 2008 | | 2010 | 2011 | | 9,080.8 | April | May |
| 18 | 174 | 2007 | 2008 | | 2010 | 2011 | 2012 | 8,480.9 | April | May |
| 19 | 175 | 2007 | 2008 | | 2010 | 2011 | 2012 | 5,761.9 | April | May |
| 20 | 203 | | | | | | 2012 | 543.5 | | |
| 21 | 252a | | | | | | 2012 | 173.8 | | |
| 22 | 252b | | | | | | 2012 | 173.8 | | |
| 23 | 1 | | | | | | | | | |
| 24 | 2 | | | | | | | | | |
| 25 | 3 | | | | | | | | | |
| 26 | 4 | | | | | | | | | |
| 27 | 5 | | | | | | | | | |
| 28 | 6 | | | | | | | | | |
| 29 | 7 | | | | | | | | | |
| 30 | 8 | | | | | | | | | |
| 31 | 9 | | | | | | | | | |
| 32 | 10 | | | | | | | | | |
| 33 | 11 | | | | | | | | | |
| 34 | 12 | | | | | | | | | |
| 35 | 13 | | | | | | | | | |

[1] Where sites were split between new counties under the new mapping approach, they are labeled "a" and "b".

Blue shaded sites were treated between 2007 and 2012.

project area. This exhibit provides the following information for each EDCP site:

- Site Number
- Years in which the site was treated between 2007 and 2012
- Total pounds of fluridone (active ingredient) applied in the site between 2007 and 2012
- Months in which the site was treated
- County
- Location name
- Water type (tidal or riverine)
- Site water acres.

## D. EDCP Treatment Map

In addition to full-size copies of maps provided in Section3, this subsection identifies one map provided to highlight actual treatment sites and treatment polygons for EDCP between 2007 and 2012. The following full-size map is provided in Tab 28 of the Supplemental Materials Binder:

- **Exhibit 7-2 – 2012 *Egeria densa* Control Program Treatment Sites:** identifies most of the treatment sites from 2007 to 2012, highlighting only the actual treatment polygons, and providing a large scale illustration of Site 32 (Disappointment Slough), showing the treatment polygon as compared to the site.

Section 8

# Conclusions

# 8. Conclusions

This section of the Biological Assessment (BA) provides USDA-ARS and DBW's conclusions regarding the overall effects of EDCP on the following USFWS and NMFS listed species and critical habitats:

- USFWS Listed Species and Critical Habitats
  1. Threatened delta smelt and Threatened delta smelt Critical Habitat
  2. Threatened giant garter snake
  3. Threatened valley elderberry longhorn beetle
  4. Candidate Threatened San Francisco Bay-Delta Distinct Population Segment (DPS) of longfin smelt
- NMFS Listed Species and Critical Habitats
  1. Endangered Sacramento River winter-run Chinook salmon and Endangered Sacramento River winter-run Chinook salmon Critical Habitat
  2. Threatened Central Valley spring-run Chinook salmon and Threatened Central Valley spring-run Chinook salmon Critical Habitat
  3. Threatened Central Valley steelhead and Threatened Central Valley steelhead Critical Habitat
  4. Threatened Southern DPS of North American green sturgeon and Threatened Southern DPS of North American green sturgeon Critical Habitat.

The following effects determinations are based on analyses of the exposure and response of species and habitat to the stressors resulting from EDCP, as described in prior sections of this BA. This section is organized as follows:

*A. Conclusions Regarding USFWS Listed Species and Critical Habitats*

*B. Conclusions Regarding NMFS Listed Species and Critical Habitats.*

## A. Conclusions Regarding USFWS Listed Species and Critical Habitats

### 1. Threatened delta smelt and Threatened delta smelt Critical Habitat

#### Threatened delta smelt

The information and analysis presented in this BA is the basis of the finding that EDCP warrants an effect determination of Likely to Adversely Affect for Threatened delta smelt. However, effects are likely to be temporary and relatively minor.

A determination of Likely to Adversely Affect is warranted based on the following rationale:

- Delta smelt are documented in the EDCP project action area, although delta smelt have not been found in *Egeria densa* beds
- EDCP will operate in selected sites during March, and throughout the Delta, which includes critical habitat, from April through November. Adult delta smelt move from the LSZ into Delta spawning habitats during the winter, and spawn in the Delta between February and May. Juveniles generally migrate back to the LSZ by summer
- EDCP will modify habitat conditions in the project action area
- Three of the four current and proposed EDCP herbicides (fluridone, penoxsulam, and imazamox) will not result in direct acute, chronic, or sub-chronic toxic effects to delta smelt based on treatment application rates, scientific studies, and resulting extremely low RQ values. However, the potential for interaction of herbicides with other contaminants in the project area is unknown
- Under conservative assumptions, one of the four current EDCP herbicides (diquat) may result in direct toxic effects to larval delta smelt, based on a RQ value of 0.34, indicating the potential need for diquat use restrictions when delta smelt may be present
- Three of the four current and proposed EDCP herbicides (fluridone, penoxsulam, and imazamox) will not result in direct acute or chronic toxic effects to macroinvertebrate prey species that delta smelt depend on for food supply
- Under conservative assumptions, one of the four current EDCP herbicides (diquat) may result in direct toxic effects to macroinvertebrate prey species that delta smelt depend on for food supply. However, given limited use of diquat within the program area, effects on food supply are likely to be insignificant
- Current and proposed EDCP herbicides will not significantly negatively affect primary productivity in the project action area, thus EDCP will not in turn affect macroinvertebrate food supply
- EDCP operations will not result in reduced dissolved oxygen that could harm delta smelt; fluridone, penoxsulam, and imazamox treatments are not expected to reduce DO levels. Diquat is applied following label and treatment protocols to reduce DO impacts. Removal of *Egeria densa* will lead to increased dissolved oxygen levels in formerly infested areas
- EDCP will avoid treatment at sites in which delta smelt are likely to be present (based on IEP surveys and regular discussions with USFWS). During the March through June period in which delta smelt may still be spawning and/or rearing in areas of the north or west Delta, EDCP will not treat in those sites prior to discussing potential treatments with USFWS (121a, 121b, 122 to 131, 262, 267, 272, and 277)
- EDCP boat operations, diver assisted handpicking, diver-operated suction harvesting, and placement of benthic barriers could temporarily negatively impact delta smelt that might be in treatment sites, although fish are not likely to be present in *Egeria densa* mats.

### Threatened delta smelt Critical Habitat

The information and analysis presented in this BA is the basis of the finding that EDCP warrants an effect determination of Likely to Adversely Affect for Threatened delta smelt

Critical Habitat. However, effects of EDCP on delta smelt critical habitat are likely to be temporary, minor, and ultimately beneficial.

A determination of Likely to Adversely Affect is warranted based on the following rationale:

- Critical habitat has been designated within the project action area
- Adult delta smelt move from the LSZ into Delta spawning habitats during the winter, and spawn in the Delta between February and May. Juveniles generally migrate back to the LSZ by summer
- EDCP will involve modification of aquatic habitat (removal of *Egeria densa* and limited potential for submersed native plant loss in treatment sites)
- EDCP will not impact the PCEs for delta smelt critical habitat, including water quality, river flow, and salinity
- EDCP could temporarily degrade delta smelt spawning habitat PCE, but is not likely to impact spawning activities. Delta smelt are thought to spawn in nearshore habitats and shallow edges in sloughs. Most spawning occurs between February and May; EDCP treatments will not take place before May in areas thought to be common spawning grounds. Delta smelt are thought to lay eggs at night, and eggs are adhesive and stick close to the bottom on sand and pebbles, further minimizing potential for adverse effects
- EDCP operations will not destroy or adversely modify critical habitat because the potential for loss of native plants is highly unlikely given EDCP operation practices, low herbicide concentrations, mitigation measures, and the fact that *Egeria densa* grows in dense mono-specific mats. EDCP operations will ultimately improve habitat as native plants can reestablish in waters that were previously infested with *Egeria densa*.

## 2. Threatened giant garter snake

The information and analysis presented in this BA is the basis of the finding that EDCP warrants an effect determination of May Affect, Not Likely to Adversely Affect for Threatened giant garter snake.

A determination of May Affect is warranted based on the following rationale:

- Giant garter snakes are present within EDCP treatment sites
- EDCP will modify habitat conditions in the project action area.

A determination of Not Likely to Adversely Affect is warranted based on the following rationale:

- While giant garter snakes have been seen in habitats adjacent to some EDCP treatment sites, this species is extremely shy and not likely to be present during EDCP treatments. Giant garter snakes bask on grassy banks and on branches over the water's edge where herbicide applications will not occur. EDCP treatment crews conduct environmental observation surveys prior to conducting treatments, and do not treat if giant garter snakes are present. Over a ten-year period, treatment crews twice identified snakes that might have been giant garter snakes (or common garter snakes), and did not treat at that location. However, because giant garter snakes are shy, they might have been present but not seen
- EDCP treatment protocols include mitigation measures to minimize potential for herbicides to reach banks, if giant garter snakes were unseen, but present
- Current and proposed EDCP herbicides will not result in direct acute or chronic toxic effects to giant garter snakes based on treatment

application rates, scientific studies, and resulting extremely low RQ values

- EDCP boat operations, diver assisted handpicking, diver-operated suction harvesting, and benthic barriers are unlikely to negatively impact giant garter snakes that might be in treatment sites, and snakes are not likely to be present in dense *Egeria densa* mats
- Handpicked or suction harvested *Egeria densa* will be deposited in approved disposal sites, not on levee banks or crevices in which giant garter snakes might be located during October through April.

## 3. Threatened valley elderberry longhorn beetle

The information and analysis presented in this BA is the basis of the finding that EDCP warrants an effect determination of May Affect, Not Likely to Adversely Affect for Threatened valley elderberry longhorn beetle.

A determination of May Affect is warranted based on the following rationale:

- Valley elderberry plants are located within the project action area, on the shoreline adjacent to EDCP treatment sites.

A determination of Not Likely to Adversely Affect is warranted based on the following rationale:

- EDCP treatments require a 50 foot buffer zone to protect valley elderberry shrubs, host plant of valley elderberry longhorn beetles, along the shoreline. In addition, treatments are conducted downwind of valley elderberry shrubs
- EDCP herbicides are applied directly into the water, resulting in essentially no potential for drift to adjacent valley elderberry shrubs
- EDCP treatment protocols also include provisions to reduce potential for wave wash of treated water over shoreline plants. In the event of unexpected wave wash of herbicide treated water, low EDCP herbicide application rates are highly unlikely to result in adequate concentration and exposure time (CET) to harm valley elderberry shrubs
- EDCP environmental scientists conduct pre- and post-season surveys to determine if valley elderberry shrubs are harmed by treatments, and have seen no impacts in more than ten years of surveys.

## 4. Candidate Threatened San Francisco Bay-Delta DPS of longfin smelt

The information and analysis presented in this BA is the basis of the finding that EDCP warrants an effect determination of May Jeopardize, Likely to Jeopardize for Candidate Threatened San Francisco Bay-Delta DPS of longfin smelt. However, effects are likely to be temporary and relatively minor.

A determination of May Jeopardize is warranted based on the following rationale:

- San Francisco Bay-Delta DPS of longfin smelt are documented in the EDCP project action area, although longfin smelt have not been found in *Egeria densa* beds
- EDCP will operate in selected sites during March, and throughout the Delta, from April through November. Longfin smelt are believed to spawn in freshwater in the lower reaches of the Sacramento River and San Joaquin River between November and June, but are most likely to be found in the Delta between November and March.

Larvae, juveniles, and adults have been found in the Delta; however, most of this species' life cycle is spent in brackish or marine waters

- EDCP will modify habitat conditions in the project action area.

A determination of Likely to Jeopardize is warranted based on the following rationale:

- Three of four current and proposed EDCP herbicides (fluridone, penoxsulam, imazamox) will not result in direct acute, chronic, or sub-chronic toxic effects to longfin smelt based on treatment application rates, scientific studies, and resulting extremely low RQ values
- Under conservative assumptions, one of the four current EDCP herbicides (diquat) may result in direct toxic effects to larval longfin smelt, based on a RQ value of 0.34 (for larval delta smelt), indicating the potential need for diquat use restrictions when longfin smelt may be present
- Three of four current and proposed EDCP herbicides (fluridone, penoxsulam, imazamox) will not result in direct acute or chronic toxic effects to macroinvertebrate prey species that longfin smelt depend on for food supply
- Under conservative assumptions, one of the four current EDCP herbicides (diquat) may result in direct toxic effects to macroinvertebrate prey species that longfin smelt depend on for food supply. However, given limited use of diquat within the program area, effects on food supply are likely to be insignificant
- Current and proposed EDCP herbicides will not significantly negatively affect primary productivity in the project action area, thus EDCP will not in turn affect macroinvertebrate food supply
- EDCP operations will not result in reduced dissolved oxygen that could harm longfin smelt; fluridone, penoxsulam, and imazamox treatments are not expected to reduce DO levels. Diquat is applied following label and treatment protocols to reduce DO impacts. Removal of *Egeria densa* will lead to increased dissolved oxygen levels in formerly infested areas
- EDCP will not conduct treatments during three of the five months when longfin smelt are most likely to be present in the Delta, and will not treat at locations in which longfin smelt are likely to be present in November and March
- EDCP boat operations, diver assisted handpicking, diver-operated suction harvesting, and placement of benthic barriers could temporarily negatively impact longfin smelt that might be in treatment sites, although fish are not likely to be present in *Egeria densa* mats.

## B. Conclusions Regarding NMFS Listed Species and Critical Habitats

### 1. Endangered Sacramento River winter-run Chinook salmon and Endangered Sacramento River winter-run Chinook salmon Critical Habitat

#### Endangered Sacramento River winter-run Chinook salmon

The information and analysis presented in this BA is the basis of the finding that EDCP warrants an effect determination of May Affect, Likely to Adversely Affect for Endangered Sacramento River winter-run Chinook salmon. However, effects are likely to be temporary and relatively minor.

A determination of May Affect is warranted based on the following rationale:

- Sacramento River winter-run Chinook salmon are documented in the EDCP project action area, although salmonids are not found in *Egeria densa* beds
- EDCP will operate in selected sites during March, and throughout the Delta, which includes critical habitat, from April through November. Adult Sacramento River winter-run Chinook salmon migrate through the Delta to up river spawning sites between November and June. Juveniles spend approximately 40 days emigrating through the Delta, and are primarily present from November through early May
- EDCP will modify habitat conditions in the project action area.

A determination of Likely to Adversely Affect is warranted based on the following rationale:

- Current and proposed EDCP herbicides will not result in direct acute, chronic, or sub-chronic toxic effects to Chinook salmon based on treatment application rates, scientific studies, and resulting extremely low RQ values
- Three of four current and proposed EDCP herbicides (fluridone, penoxsulam, and imazamox) will not result in direct acute or chronic toxic effects to macroinvertebrate prey species that salmonids depend on for food supply
- Under conservative assumptions, one of the four current EDCP herbicides (diquat) may result in direct toxic effects to macroinvertebrate prey species that salmonids depend on for food supply. However, given limited use of diquat within the program area, effects on food supply are likely to be insignificant
- Current and proposed EDCP herbicides will not significantly negatively affect primary productivity in the project action area, thus EDCP will not in turn affect macroinvertebrate food supply
- EDCP operations will not result in reduced dissolved oxygen that could harm salmonids; fluridone, penoxsulam, and imazamox treatments are not expected to reduce DO levels. Diquat is applied following label and treatment protocols to reduce DO impacts. Removal of *Egeria densa* will lead to increased dissolved oxygen levels in formerly infested areas
- EDCP will not conduct treatments at sites in which Chinook salmon are present (based on IEP and CDFG surveys and regular discussions with NMFS) during the March through June period in which adults or juvenile Sacramento River winter-run Chinook salmon may be migrating through the Delta
- EDCP boat operations, diver assisted handpicking, diver-operated suction harvesting, and placement of benthic barriers could temporarily negatively impact salmonids that might be in treatment sites, although salmonids are not likely to be present in *Egeria densa* mats.

### Endangered Sacramento River winter-run Chinook salmon Critical Habitat

The information and analysis presented in this BA is the basis of the finding that EDCP warrants an effect determination of May Affect, Likely to Adversely Affect for Endangered Sacramento River winter-run Chinook salmon Critical Habitat. However, effects of EDCP on Sacramento River winter-run Chinook salmon critical habitat are likely to be temporary, minor, and ultimately beneficial.

A determination of May Affect is warranted based on the following rationale:

- Critical habitat has been designated within the project action area, although salmonids are not likely to be present in *Egeria densa* beds
- Adult Sacramento River winter-run Chinook salmon migrate through the Delta to up river spawning sites between November and June. Juveniles spend approximately 40 days emigrating through the Delta, and are primarily present from November through early May
- Three of the four PCEs for winter-run Chinook salmon critical habitat are within EDCP treatment sites: freshwater rearing habitat, freshwater migration corridors, and estuarine areas
- EDCP will involve modification of aquatic habitat (removal of *Egeria densa* and limited potential for submersed native plant loss in treatment sites).

A determination of Likely to Adversely Affect is warranted based on the following rationale:

- EDCP will not degrade freshwater rearing habitat characteristics, which include: habitat complexity, adequate food supply, and protection from predators. Habitats modified with *Egeria densa* do not exhibit habitat complexity; removal of *Egeria densa* through EDCP activities provides opportunities for native plants to reestablish in those areas, thus increasing habitat complexity. EDCP activities will not significantly impact food supply or protection from predators in freshwater rearing habitats
- EDCP will not degrade freshwater migration corridor habitat characteristics, which include: waterways free from obstruction, water quality and quantity, natural cover, and food supply. EDCP activities could improve migration corridors if those corridors are infested with *Egeria densa*. Ultimately, removal of *Egeria densa* from migration corridors will improve DO. EDCP activities will not impact water quality or quantity, natural cover, or food supply in freshwater migration corridors
- *Egeria densa* growth declines in estuarine areas with saline levels greater than 1.2 ppt, and does not grow above 5 ppt. In estuarine areas where *Egeria densa* grows, EDCP will not degrade estuarine habitat characteristics, which include: waterways free from obstruction, water quality and quantity, and natural cover. EDCP activities could improve estuarine areas if those areas are infested with *Egeria densa*. Ultimately, removal of *Egeria densa* from estuarine areas will improve DO. EDCP activities will not impact water quality or quantity, or natural cover in estuarine areas
- EDCP operations will not destroy or adversely modify critical habitat because the potential for loss of native plants is unlikely given EDCP operation practices, mitigation measures, and the fact that *Egeria densa* grows in dense mono-specific mats. Chinook salmon are not found in *Egeria densa* mats, and *Egeria densa* does not provide the complex and productive habitat favored by the species. EDCP operations will ultimately improve habitat as native plants can reestablish in waters that were previously infested with *Egeria densa*
- EDCP will not conduct treatments at sites in which Chinook salmon are present (based on IEP and CDFG surveys and regular discussions with NMFS) during the March through June period in which adults or juvenile Sacramento River winter-run Chinook salmon may be migrating through the Delta.

## 2. Threatened Central Valley spring-run Chinook salmon and Threatened Central Valley spring-run Chinook salmon Critical Habitat

### Threatened Central Valley spring-run Chinook salmon

The information and analysis presented in this BA is the basis of the finding that EDCP warrants an effect determination of May Affect, Likely to Adversely Affect for Threatened Central Valley spring-run Chinook salmon. However, effects are likely to be temporary and relatively minor.

A determination of May Affect is warranted based on the following rationale:

- Central Valley spring-run Chinook salmon are documented in the EDCP project action area, although salmonids are not found in *Egeria densa* mats
- EDCP will operate in selected sites during March, and throughout the Delta, which includes critical habitat, from April through November. Adult Central Valley spring-run Chinook salmon migrate through the Delta to up river spawning sites between January and June. Most juveniles emigrate through the Delta from November through early May. Some fish may over-summer in spawning grounds and not emigrate until the onset of intense fall storms
- EDCP will modify habitat conditions in the project action area.

A determination of Likely to Adversely Affect is warranted based on the following rationale:

- Current and proposed EDCP herbicides will not result in direct acute, chronic, or sub-chronic toxic effects to Chinook salmon based on treatment application rates, scientific studies, and resulting extremely low RQ values
- Three of the four current and proposed EDCP herbicides (fluridone, penoxsulam, and imazamox) will not result in direct acute or chronic toxic effects to macroinvertebrate prey species that salmonids depend on for food supply
- Under conservative assumptions, one of the four current EDCP herbicides (diquat) may result in direct toxic effects to macroinvertebrate prey species that salmonids depend on for food supply. However, given limited use of diquat within the program area, effects on food supply are likely to be insignificant
- Current and proposed EDCP herbicides will not significantly negatively affect primary productivity in the project action area, thus EDCP will not in turn affect macroinvertebrate food supply
- EDCP operations will not result in reduced dissolved oxygen that could harm salmonids; fluridone, penoxsulam, and imazamox treatments are not expected to reduce DO levels. Diquat is applied following label and treatment protocols to reduce DO impacts. Removal of *Egeria densa* will lead to increased dissolved oxygen levels in formerly infested areas
- EDCP will not conduct treatments at sites in which Chinook salmon are present (based on IEP and CDFG surveys and regular discussions with NMFS) during the March through June period in which adults or juvenile Central Valley spring-run Chinook salmon may be migrating through the Delta
- EDCP boat operations, diver assisted handpicking, diver-operated suction harvesting, and placement of benthic barriers could temporarily negatively impact salmonids that might be in treatment sites, although salmonids are not likely to be present in *Egeria densa* mats.

### Threatened Central Valley spring-run Chinook salmon Critical Habitat

The information and analysis presented in this BA is the basis of the finding that EDCP warrants an effect determination of May Affect, Likely to Adversely Affect for Threatened Central Valley spring-run Chinook salmon Critical Habitat. However, effects of EDCP on Central Valley spring-run Chinook salmon critical habitat are likely to be temporary, minor, and ultimately beneficial.

A determination of May Affect is warranted based on the following rationale:

- Critical habitat has been designated within the project action area, although salmonids are not likely to be present in *Egeria densa* mats
- Adult Central Valley spring-run Chinook salmon migrate through the Delta to up river spawning sites between January and June. Most juveniles emigrate through the Delta from November through early May. Some fish may over-summer in spawning grounds and not emigrate until the onset of intense fall storms
- Three of the four PCEs for spring-run Chinook salmon critical habitat are within EDCP treatment sites: freshwater rearing habitat, freshwater migration corridors, and estuarine areas
- EDCP will involve modification of aquatic habitat (removal of *Egeria densa* and limited potential for submersed native plant loss in treatment sites).

A determination of Likely to Adversely Affect is warranted based on the following rationale:

- EDCP will not degrade freshwater rearing habitat characteristics, which include: habitat complexity, adequate food supply, and protection from predators. Habitats modified with dense *Egeria densa* do not exhibit habitat complexity; removal of *Egeria densa* through EDCP activities provides opportunities for native plants to reestablish in those areas, thus increasing habitat complexity. EDCP activities will not significantly impact food supply or protection from predators in freshwater rearing habitats
- EDCP will not degrade freshwater migration corridor habitat characteristics, which include: waterways free from obstruction, water quality and quantity, natural cover, and food supply. EDCP activities could improve migration corridors if those corridors are infested with *Egeria densa*. Ultimately, removal of *Egeria densa* from migration corridors will improve DO. EDCP activities will not impact water quality or quantity, natural cover, or food supply in freshwater migration corridors
- *Egeria densa* growth declines in estuarine areas with saline levels greater than 1.2 ppt, and does not grow above 5 ppt. In estuarine areas where *Egeria densa* grows, EDCP will not degrade estuarine habitat characteristics, which include: waterways free from obstruction, water quality and quantity, and natural cover. EDCP activities could improve estuarine areas if those areas are infested with *Egeria densa*. Ultimately, removal of *Egeria densa* from estuarine areas will improve DO. EDCP activities will not impact water quality or quantity, or natural cover in estuarine areas
- EDCP operations will not destroy or adversely modify critical habitat because the potential for loss of native plants is unlikely given EDCP operation practices, mitigation measures, and the fact that *Egeria densa* grows in dense mono-specific mats. Chinook salmon are not found in *Egeria densa* mats, and *Egeria densa* does not provide the complex and productive habitat favored

by the species. EDCP operations will ultimately improve habitat as native plants can reestablish in waters that were previously infested with *Egeria densa*

- EDCP will not conduct treatments at sites in which Chinook salmon are present (based on IEP and CDFG surveys and regular discussions with NMFS) during the March through June period in which adults or juvenile Central Valley spring-run Chinook salmon may be migrating through the Delta.

## 3. Threatened Central Valley steelhead and Threatened Central Valley steelhead Critical Habitat

### Threatened Central Valley steelhead

The information and analysis presented in this BA is the basis of the finding that EDCP warrants an effect determination of May Affect, Likely to Adversely Affect for Threatened Central Valley steelhead. However, effects are likely to be temporary and relatively minor.

A determination of May Affect is warranted based on the following rationale:

- Central Valley steelhead are documented in the EDCP project action area, although steelhead are not found in *Egeria densa* beds
- EDCP will operate in selected sites during March, and throughout the Delta, which includes critical habitat, from April through November. Central Valley steelhead migrate through the Delta to up river spawning sites between August and March. Juveniles usually remain in fresh water for the first year, and then migrate through the Delta to the ocean between November and May. Steelhead are found in the Delta predominantly during migration, but may use the lower reaches of the Sacramento River and Delta for rearing
- EDCP will modify habitat conditions in the project action area.

A determination of Likely to Adversely Affect is warranted based on the following rationale:

- Current and proposed EDCP herbicides and adjuvants will not result in direct acute, chronic, or sub-chronic toxic effects to steelhead based on treatment application rates, scientific studies, and resulting extremely low RQ values
- Three of four current and proposed EDCP herbicides (fluridone, penoxsulam, and imazamox) will not result in direct acute or chronic toxic effects to macroinvertebrate prey species that steelhead depend on for food supply
- Under conservative assumptions, one of the four current EDCP herbicides (diquat) may result in direct toxic effects to macroinvertebrate prey species that steelhead depend on for food supply. However, given limited use of diquat within the program area, effects on food supply are likely to be insignificant
- Current and proposed EDCP herbicides will not significantly negatively affect primary productivity in the project action area, thus EDCP will not in turn affect macroinvertebrate food supply
- EDCP operations will not result in reduced dissolved oxygen that could harm steelhead; fluridone, penoxsulam, and imazamox are not expected to reduce DO levels. Diquat is applied following label and treatment protocols to reduce DO impacts. Removal of *Egeria densa* will lead to increased dissolved oxygen levels in formerly infested areas
- EDCP will not conduct treatments at sites in which Central Valley steelhead are present (based on IEP and CDFG surveys and regular discussions with

NMFS) during the March and August periods in which adults or juvenile Central Valley steelhead may be migrating through the Delta

- EDCP boat operations, diver assisted handpicking, diver-operated suction harvesting, and placement of benthic barriers could temporarily negatively impact steelhead that might be in treatment sites, even though fish are not likely to be present in *Egeria densa* mats.

### Threatened Central Valley steelhead Critical Habitat

The information and analysis presented in this BA is the basis of the finding that EDCP warrants an effect determination of May Affect, Likely to Adversely Affect for Threatened Central Valley steelhead Critical Habitat. However, effects of EDCP on Central Valley steelhead critical habitat are likely to be temporary, minor, and ultimately beneficial.

A determination of May Affect is warranted based on the following rationale:

- Critical habitat has been designated within the project action area
- Central Valley steelhead migrate through the Delta to up river spawning sites between August and March. Juveniles usually remain in fresh water for the first year, and then migrate through the Delta to the ocean between November and May. Steelhead are found in the Delta predominantly during migration, but may use the lower reaches of the Sacramento River and Delta for rearing
- Three of the four PCEs for Central Valley steelhead critical habitat are within EDCP treatment sites: freshwater rearing habitat, freshwater migration corridors, and estuarine areas
- EDCP will involve modification of aquatic habitat (removal of *Egeria densa* and limited potential for submersed native plant loss in treatment sites).

A determination of Likely to Adversely Affect is warranted based on the following rationale:

- EDCP will not degrade freshwater rearing habitat characteristics, which include: habitat complexity, adequate food supply, and protection from predators. Habitats modified with *Egeria densa* do not exhibit habitat complexity; removal of *Egeria densa* through EDCP activities provides opportunities for native plants to reestablish in those areas, thus increasing habitat complexity. EDCP activities will not significantly impact food supply or protection from predators in freshwater rearing habitats
- EDCP will not degrade freshwater migration corridor habitat characteristics, which include: waterways free from obstruction, water quality and quantity, natural cover, and food supply. EDCP activities could improve migration corridors if those corridors are infested with *Egeria densa*. Ultimately, removal of *Egeria densa* from migration corridors will improve DO. EDCP activities will not impact water quality or quantity, natural cover, or food supply in freshwater migration corridors
- *Egeria densa* growth declines in estuarine areas with saline levels greater than 1.2 ppt, and does not grow above 5 ppt. In estuarine areas where *Egeria densa* grows, EDCP will not degrade estuarine habitat characteristics, which include: waterways free from obstruction, water quality and quantity, and natural cover. EDCP activities could improve estuarine areas if those areas are infested with *Egeria densa*. Ultimately, removal of *Egeria densa*

from estuarine areas will improve DO. EDCP activities will not impact water quality or quantity, or natural cover in estuarine areas

- EDCP operations will not destroy or adversely modify critical habitat because the potential for loss of native plants is unlikely given EDCP operation practices, mitigation measures, and the fact that *Egeria densa* grows in dense mono-specific mats. Steelhead are not found in *Egeria densa* mats, and *Egeria densa* does not provide the complex and productive habitat favored by the species. EDCP operations will ultimately improve habitat as native plants can reestablish in waters that were previously infested with *Egeria densa*
- EDCP will not conduct treatments at sites in which Central Valley steelhead are present (based on IEP and CDFG surveys and regular discussions with NMFS) during the March and August periods in which adults or juvenile Central Valley steelhead may be migrating through the Delta.

## 4. Threatened Southern DPS of North American green sturgeon and Threatened Southern DPS of North American green sturgeon Critical Habitat

### Threatened Southern DPS North American green sturgeon

The information and analysis presented in this BA is the basis of the finding that EDCP warrants an effect determination of May Affect, Likely to Adversely Affect for Threatened Southern DPS North American green sturgeon. However, effects are likely to be temporary and minor.

A determination of May Affect is warranted based on the following rationale:

- Threatened Southern DPS of North American green sturgeon are documented in the EDCP project action area, although green sturgeon have not been found in *Egeria densa* beds
- Southern DPS North American green sturgeon juveniles (two to three years of age) inhabit the Delta. Adult Southern DPS North American green sturgeon migrate through the Delta to Upper Sacramento River spawning grounds between mid-February and May
- EDCP will modify habitat conditions in the project action area.

A determination of Not Likely to Adversely Affect is warranted based on the following rationale:

- Current and proposed EDCP herbicides will not result in direct acute, chronic, or sub-chronic toxic effects to green sturgeon based on treatment application rates, scientific studies, and resulting extremely low RQ values
- Three of four current and proposed EDCP herbicides (fluridone, penoxsulam, and imazamox) will not result in direct acute or chronic toxic effects to macroinvertebrate and fish prey species that green sturgeon depend on for food supply
- Under conservative assumptions, one of the four current EDCP herbicides (diquat) may result in direct toxic effects to macroinvertebrate prey species that green sturgeon depend on for food supply. However, given limited use of diquat within the program area, effects on food supply are likely to be insignificant
- Current and proposed EDCP herbicides will not significantly negatively affect primary productivity in the project

action area, thus EDCP will not in turn affect macroinvertebrate food supply

- EDCP operations will not result in reduced dissolved oxygen that could harm green sturgeon; fluridone, penoxsulam, and imazamox treatments are not expected to reduce DO levels. Diquat is applied following label and treatment protocols to reduce DO impacts. Removal of *Egeria densa* will lead to increased dissolved oxygen levels in formerly infested areas
- EDCP use of benthic barriers will not negatively affect benthic macroinvertebrates that green sturgeon may utilize for prey. EDCP will utilize barrier materials that do not impact benthic macroinvertebrates
- EDCP boat operations, diver assisted handpicking, diver-operated suction harvesting, and placement of benthic barriers could temporarily negatively impact green sturgeon that might be in treatment sites, even though fish are not likely to be present in *Egeria densa* mats.

### Threatened Southern DPS North American green sturgeon Critical Habitat

The information and analysis presented in this BA is the basis of the finding that EDCP warrants an effect determination of May Affect, Likely to Adversely Affect for Threatened Southern DPS North American green sturgeon Critical Habitat. However, effects of EDCP on North American green sturgeon critical habitat are likely to be temporary, minor, and ultimately beneficial.

A determination of May Affect is warranted based on the following rationale:

- Critical habitat has been designated within the project action area
- Adult Southern DPS North American green sturgeon migrate through the Delta to up river spawning sites between mid-February and May. Juveniles typically spend their second and third years in the Delta
- EDCP will involve modification of aquatic habitat (removal of *Egeria densa* and limited potential for submersed native plant loss in treatment sites).

A determination of Likely to Adversely Affect is warranted based on the following rationale:

- EDCP will not degrade critical habitat PCEs for green sturgeon, which include: food resources (benthic invertebrates and fish), water flow, water quality, migration corridors, water depth diversity, or sediment quality. EDCP activities will not impact water flow or water depth diversity. EDCP activities could improve migration corridors if those corridors are infested with *Egeria densa*. Ultimately, removal of *Egeria densa* from migration corridors will improve DO. EDCP activities will not negatively impact water quality or food sources.
- EDCP activities will not negatively affect sediment quality. Of the four current and potential EDCP herbicides, only diquat binds readily to sediment, where it becomes biologically inactive. Herbicide treatments will not result in sediment concentrations that would be detrimental to green sturgeon
- EDCP operations will not destroy or adversely modify critical habitat because the potential for loss of native plants is unlikely given EDCP operation practices, mitigation measures, and the fact that *Egeria densa* grows in dense mono-specific mats. EDCP operations will ultimately improve habitat as native plants can reestablish in waters that were previously infested with *Egeria densa*.

[This page intentionally left blank.]

Section 9

# List of Documents

# 9. List of Documents

This section of the Biological Assessment identifies reports and documents provided as part of this consultation. These documents are provided under separate cover or within the EDCP Biological Assessment – Supplemental Materials Binder.

## A. Materials Provided in the Supplemental Materials Binder

The following documents are provided in Tabs 1 to 6 of the Supplemental Materials Binder:

- NMFS EDCP Letter of Concurrence 2012/01688 (Tab 1)
- USFWS EDCP Biological Opinion 1-1-04-F-0148 (Tab 2)
- EDCP Annual Report – 2011(Tab 3)
- EDCP Environmental Observations and Weed Survey Form (Tab 4)
- DRAFT Statewide NPDES permit (June 27, 2012) (Tab 5)
- Selected Scientific Literature (Tab 6).

## B. Materials Provided on CD-ROM

The following materials are also provided:

- PDF of this EDCP Biological Assessment – CD-ROM
- PDF of Selected Scientific Literature and Studies (in the Supplemental Materials Binder) – CD-ROM.

[This page intentionally left blank.]

Section 10

# Literature Cited

# 10. Literature Cited


1. Akers, Patrick Sr. 2010. Pest Profile: South American spongeplant. California Department of Food and Agriculture. Sacramento, Ca. 5pp.
2. Allen, Shannon. 2006. Restoration of native plants through chemical control of alligatorweed *(Alternanthera philoxeroides)* at Eufaula National Wildlife Refuge. Auburn University, Alabama. 108pp..
3. Anderson, Lars W.J. 2004a. Diquat dissipation during typical applications for Control of Egeria densa. USDA-ARS. Davis, CA.
4. Anderson, Lars W.J. 2004b. Fluridone (4AS) dissipation during typical applications of Sonar (4AS). USDA-ARS. Davis, CA.
5. Anderson, Lars. 2011. New aquatic weed threatens the Sacramento-San Joaquin Delta. UC Weed Science – Agriculture and Natural Resources Blogs. June 20, 2011. http://ucanr.org.
6. Arnold, W. 1979. Fluridone – A new aquatic herbicide. J. Aquat. Plant Manage. 17:30-33 pp.
7. Battin J et al. 2007. Projected Impacts of Climate Change on Salmon Habitat Restoration. Proceedings of the National Academy of Sciences, vol. 104 no. 16
8. Bennett, William A.. September 2005. Critical assessment of the delta smelt population in the San Francisco Estuary, California. *San Francisco Estuary and Watershed Science* 3, no.2. http://repositories.cdlib.org/jmie/sfews/vol3/iss2/art1.
9. Blankenship and Associates. 2004. Clear Lake ecological risk assessment. Prepared for County of Lake. 152pp.
10. Boussard, A. 1981. The reactions of roach (*Rutilus rutilus*) and rudd (*Scardinius erythrophthalmus*) to noises produced by high speed boating. Pages 188–200 in *Proceedings of 2nd British Freshwater Fisheries Conference, Southampton*.
11. Bremigan M.T., S.M. Hanson, P.A. Soranno, K.S. Cheruvelil, and R.D. Valley. 2005. Aquatic vegetation, largemouth bass, and water quality responses to low-dose fluridone two years post treatment, Journal of Aquatic Plant Management. 43: 65-75
12. Brown, Larry R. 2003. "Will Tidal Wetland Restoration Enhance Populations of Native Fishes?" San Francisco Estuary and Watershed Science 1, no.1 (October 2003), 1-42.
13. Bultemeier, Brett W., A. Puri, W.t. Haller, and V.V. Vandiver, Jr.. 2009. Residue profile and efficacy comparisons between two liquid formulations of fluridone. J. Aquatic Plant Management. 47: 63-65.
14. CALFED Bay Delta Program. 2000. Ecosystem Restoration Program (ERP) Volume 1. Sacramento, California: Prepared for the CALFED Bay Delta Program. CD-ROM version.
15. California Department of Boating and Waterways (DBW). 2001. *Egeria densa* Control Program Environmental Impact Report. Sacramento, California.

## Literature Cited *(continued)*


16. California Department of Boating and Waterways (DBW). 2006. Second Addendum to 2001 Environmental Impact Report with Five-Year Program Review and Future Operations Plan. Sacramento, California.
17. California Department of Boating and Waterways. 2001. Water Hyacinth Control Program Biological Assessment. Sacramento, California.
18. California Department of Fish and Game, Aquatic Toxicology Laboratory (DFG-ATC). 2003. "Aquatic Toxicology Laboratory Report" (Rancho Cordova, California: DFG-ATL, July 28, 2003).
19. California Department of Food and Agriculture. 2011. California Agricultural Statistics Review. Sacramento, CA.
20. California Natural Diversity Database (CNDDB). 2006. Sacramento, California. California Department of Fish and Game, Wildlife and Habitat Data Analysis Branch.
21. California Natural Resources Agency. July 25, 2012. Governor Brown and Obama Administration outline path forward for Bay Delta Conservation Plan (press release). Sacramento, California. 4pp.
22. California State Water Resources Control Board (SWRCB). December 2006. Water quality control plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Sacramento, California. California Water Boards. 48pp.
23. California State Water Resources Control Board (SWRCB). 2007. Memo: new pesticide regulation. To Tom Howard, Acting Executive Director, from Michael A.M. Lauffer, Chief Counsel, Sacramento, California. SWRCB. 5pp.
24. Cattaneo, Roberta, Barbara Clasen, Vania Lucia Loro, Charlene Cavalheiro de Menezes, Bibiana Moraes, Adriana Santi, Candida Toni, Luis Antonio de Avila, and Renato Zanella. 2011. Toxicological responses of *Cyprinus carpio* exposed to the herbicide penoxsulam in rice field conditions. Journal of Applied Toxicology. 31:626-632.
25. California Department of Fish and Game (CDFG). 2011. DRAFT Conservation Strategy for Restoration of the Sacramento-San Joaquin Delta Ecological Management Zone and the Sacramento and San Joaquin Valley Regions. Ecosystem Restoration Program. Sacramento, CA.
26. CDFG. July 2005. The status of rare, threatened and endangered plants and animals in California, 2000-2004. Sacramento, California. CDFG.
27. Center for Lakes and Reservoirs. *Egeria densa* Project. 2012. Portland State University. http://www.clr.pdx.edu/projects/plants/egeria.php. Accessed August 30, 2012.
28. Central Valley Regional Water Quality Control Board (CVRWQCB). 2006. Statewide general National Pollution Discharge Elimination System Permit for the discharge of aquatic pesticides for aquatic weed control in waters of the United States, general permit no. CAG990005. Rancho Cordova, California. CVRWQCB.
29. CVRWQCB. 2008. Study to evaluate potential effects of ammonia on delta smelt, status update – 20 July 2008. Sacramento, CA. CVRWQCB. 2pp.
30. Champion, P.D., and C.C. Tanner. 2000. Seasonality of macrophytes and interaction with flow in a New Zealand lowland stream. Hydrobiologia. Vol. 441. No. 1: 1-12.
31. Champion, P.D.. 2000. Egeria densa – an alien invasive plant responsible for the devegetation of New Zealand shallow lakes. Thirteenth Australian Weeds Conference.
32. Cloern J.E. and Jassby A.D.. 2012. Drivers of change in estuarine-coastal ecosystems: discoveries from four decades of study in San Francisco Bay. Reviews of Geophysics, 50, RG4001/2012. 33pp.

## Literature Cited *(continued)*


33. Cloern, J.E., N. Knowles, L.R. Brown, D. Cayan, M. D. Dettinger, T.L. Morgan, D.H. Schoelhamer, M.T. Stacey, M. van der Wegen, R. W. Wagner, and A.D. Jassby. 2011. Projected evolution of Caliofrnia's San Francisco Bay-Delta River System in a Century of Climate Change. PLoS ONE. 6(9): e24465.doi:10.1371/journal.pone.0024465.

34. Cohen, A.N., and J.T. Carlton. 1995. Nonindigenous aquatic species in a United States estuary: A case study of the biological invasions of the San Francisco Bay and Delta. Prepared for the United States Fish and Wildlife Service, Washington D.C. and the National Sea Grant College Program Connecticut Sea Grant. 218pp.

35. Conrad, J.L., K.L. Weinersmith, M.J. Young, A.J. Bibian, P.B. Moyle, and A. Sih. 2011. Invaders helping invaders: expansion of largemouth bass in the Sacramento-San Joaquin Delta facilitated by Brazilian Waterweed, *Egeria densa*. American Fisheries Society National Meeting, September 6, 2011.

36. Conrad, J.L., K.L. Weinersmith, M.J. Young, D. de Carion, E. Hestir, M. Santos, P. Crain, S. Ustin, P.B. Moyle, and A. Sih. 2010a. Rising abundance of largemouth bass in the littoral zone of Sacramento-San Joaquin delta: the role of *Egeria densa*. IEP Workshop. May 26, 2010.

37. Conrad, J.L., K.L. Weinersmith, M.J. Young, D. de Carion, E. Hestir, M. Santos, P. Crain, S. Ustin, P.B. Moyle, and A. Sih. 2010b. More big bass: understanding the role of largemouth bass as top predators in the littoral zone. Delta Science Council Conference. September 2010.

38. Cook, C.D.K and K. Urmi-Konig. 1984. A revision of the genus Egeria (Hydrocharitaceae). Aquatic Botany, 19, 73-96 pp.

39. County of Lake. January 2005. Draft Program EIR, Clear Lake Integrated Aquatic Plant Management Plan. Lake County, California.

40. Curran, Catherine Anne. 2007. Olfactory-mediated behavior in juvenile salmonids exposed to aquatic herbicides. Masters thesis, University of Washington.

41. CVRWQCB. 2008. Study to evaluate potential effects of ammonia on delta smelt, status update – 30 July 2008. Sacramento, California. CVRWQCB. 2pp.

42. Delta Protection Commission (DPC). January 2001/May 2001. Update on agriculture in the primary zone of the Delta. Sacramento, California. Delta Protection Commission.

43. Delta Protection Commission. 2011. Economic Sustainability Plan for the Sacramento-San Joaquin Delta, Public Draft. Sacramento, CA.

44. Delta Vision Blue Ribbon Task Force. June 2008. Delta Vision Strategic Plan Preliminary Draft. Sacramento, California. Task Force. 86pp.

45. Department of Pesticide Regulation (DPR). 2011. Summary of Pesticide Use Report Data 2010. Sacramento, CA. www.cdpr.ca.gov.

46. Department of Water Resources (DWR) and U.S. Bureau of Reclamation. 1994. Biological assessment: effects of the Central Valley Project and State Water Project on delta smelt and Sacramento splittail. Prepared for the USFWS. Sacramento, California.

47. Department of Water Resources (DWR). 2007. Deep Water Shipping Channel Aeration Demonstration Project Biological Assessment for Operations. Prepared by Jones & Stokes. Sacramento, CA.

48. DWR. March 2008. Notice of preparation, environmental impact report and environmental impact statement for the Bay Delta Conservation Plan. Sacramento, California. DWR. 12pp.

49. Dow Agro Sciences. 2008. Product safety assessment, penoxsulam. 233-00438-MM-0908.

## Literature Cited *(continued)*


50. Drexler, Judith, et. al. 2006. "Effects of the invasive aquatic plant, *Egeria densa,* on native fish habitat in the Sacramento-San Joaquin Delta (Proposal), U.S. Geological Survey.
51. ECOXTOX Database System (2001). United States Environmental Protection Agency, Office of Research and Development, Database of Aquatic and Terrestrial Ecology.
52. Eichler, Lawrence W., R.T. Bombard, J.W. Sutherland, and C.W. Boylen. 1993. Suction harvesting of Eurasian watermilfoil and its effect on native plant communities. Journal of Aquatic Plant Management. 31:144-148.
53. Eichler, Lawrence W., R.T. Bombard, J.W. Sutherland, and C.W. Boylen. 1995. Recolonization of the littoral zone by macrophytes following the removal of benthic barrier material. Journal of Aquatic Plant Management. 33:51-54.
54. Emerine, Sherrie E., R.J. Richardson, S.L. True, A.M. West, and R.L. Roten. 2010. Greenhouse response of six aquatic invasive weeds to imazamox. J. Aquat. Plant. Management. 48:105-111.
55. Engel, Sandy. 1984. Evaluating stationary blankets and removable screens for macrophyte control in lakes. Journal of Aquatic Plant Management. 22:43-48.
56. Environ. July 2012. Screening-Level Ecological Risk Assessment of the Proposed Use of the Herbicide Imazamox to Control Invasive Japanese Eelgrass (Zostera japonica) in Willapa Bay, Washington State. Prepared for Washington State University. Washington. 82pp.
57. European Commission. 2002. Commission working document review report for the active substance imazamox. Health & Consumer Protection Directorate-General. November 29, 2002. 24pp.
58. EXTOXNET. (2003). Extension Toxicology Network, pesticide information profiles. Oregon State University. http://extonet.orst.edu.
59. EXTOXNET. 1993. Diquat dibromide. Cornell University, Northeastern Integrated Pest Management Center. http://pmep.cce.cornell.edu. Accessed November 2, 2012.
60. Federal Register. April 15, 2004. Volume 69, Number 73, 19975.
61. Federal Register. April 2, 2012. Endangered and threatened wildlife and plants; 12-month finding on a petition to list the San Francisco Bay-Delta population of the longfin smelt as endangered or threatened; proposed rule. 50 CFR Part 17. 19756-19797.
62. Federal Register. August 19, 2011. Endangered and threatened wildlife and plants; 90-day finding on a petition to delist the valley elderberry longhorn beetle. 50CRF Part 17. 51929-51931.
63. Federal Register. March 17, 2010. Endangered and threatened wildlife and plants: revised designation of critical habitat for California red-legged frog; final rule. 50 CRF Part 17: 12816.
64. Federal Register. November 27, 2006. Application of pesticides to waters of the United States in compliance with FIFRA. 71:227:68483-68492.
65. Federal Register. October 9, 2009. Endangered and threatened wildlife and plants: final rulemaking to designate critical habitat for the threatened Southern Distinct Population Segment of North American green sturgeon; final rule. 50 CRF Part 226. 52300-52351.
66. Ferreiro, Nicolas, C. Feijoo, A. Giorgi, and L. Leggieri. 2011. Effects of macrophyte heterogeneity and food availability on structural parameters of the macroinvertebrate community in a Pampean stream. Hydrobiologia. 664:199-211.
67. Feyrer, Frederick, Ken Newman, Matthew Nobriga, and Ted Sommer. 2011. Modeling the effects of future outflow on the abiotic habitat of an imperiled estuarine fish. Estuaries and Coasts. 34:120-128.

## Literature Cited *(continued)*


68. Feyrer, Frederick, Mathhew L. Nobriga, and Ted R. Sommer. 2007. Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. Can. J. Fish Aquat. Sci. 64:723-734.

69. Finlayson, Brian. 2003. (Cited as DBW, 2003). Aquatic toxicology laboratory report. Department of Fish and Game, Rancho Cordova, California.

70. FOOTPRINT (2006). The FOOTPRINT Pesticide Properties DataBase. Database collated by the University of Hertfordshire as part of the EU-funded FOOTPRINT project (FP6-SSP-022704). http://www.eu-footprint.org/ppdb.html. Accessed July 26, 2012.

71. Forbis, A. 1984. Acute Toxicity of ARSENAL Herbicide to Daphnia magna. Unpublished study performed by Analytical Bio-Chemistry Laboratories Inc., Columbia, Missouri. Laboratory Project No. 32181. Study submitted by American Cyanamid Company, Agricultural Research Division, Princeton NJ. Study initiated October 16, 1984 and submitted October 25, 1984. EPA MRID Number 001537-79.

72. Frodge, Jonathan D., G.L. Thomas, and G.B. Pauley. 1990. Effects of canopy formation by floating and submergent aqatic macrophytes on the water quality of two shallow Pacific Northwest lakes. Aquatic Botany. 38:231-248.

73. Galhano, Victor, Jose Gomes-Laranjo, Eduardo Fernandez-Valiente, Romeu Videira, and Francisco Peixoto. 2011. Impact of herbicides on non-target organisms in sustainable irrigated rice production systems: state of knowledge and future prospects. In, Herbicides and the Environment. Andres Kortekamp, ed. In-Tech Publishing, Croatia. 746pp. www.intechopen.com/books/herbicides-and-environment.

74. Getsinger, K.D. and C.R. Dillon. 1984. Quiescence, growth and senescence of *Egeria densa* in Lake Marion. Aquatic Botany. 20:329-338.

75. Getsinger, Kurt D., Angela G. Poovey, LeeAnn Glomski, Jeremy G. Slade, and Robert J. Richardson. 2011. Utilization of herbicide concentration/exposure time relationships for controlling submersed invasive plants on Lake Gaston, Virginia/North Carolina. U.S. Army Corps of Engineers. Vicksburg, Mississippi. 74pp.

76. Glibert, P.M., D. Fullerton, J.M. Burkholder, J.C. Cornwell, and T.M. Kana. 2011. Ecological stoichiometry, biogeochemical cycling, invasive species, and aquatic food webs: San Francisco Estuary and comparative systems. Reviews in Fisheries Science. 19:358-417.

77. Goyer, R.A.. 1996. Toxic effects of metals. In C.C. Klassen (editor), Casarett & Doull's Toxicology: the Basic Science of Poisons, fifth edition, pages 691-736. McGraw Hill. New York, NY.

78. Greenfield, B.K. and T.P. McNabb. 2004. Chapter 2: Control costs, operation, and permitting issues for non-chemical plant control: case studies in the San Francisco Bay-Delta region, California. Journal of Aquatic Plant Management. In: Aquatic Pesticide Monitoring Program Nonchemical Alternatives Year 3 Report. Oakland, California. San Francisco Estuary Institute. 15-24.

79. Greenfield, Ben K., Nicole David, Jennifer Hunt, and Geoffrey Siemering. April 2004. Aquatic Pesticide Monitoring Program: Review of Alternative Aquatic Pest Control Methods for California Waters. San Francisco Estuary Institute. Oakland, California. 106pp.

80. Grimaldo, Lenny and Zachary Hymanson. 1999. What is the Impact of the Introduced Brazilian Waterweed *Egeria densa* to the Delta Ecosystem? *Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter*, Vol. 12, No. 1, Winter 1999, 43 p.

81. Grimaldo, Lenny, Robert E. Miller, Chris M. Peregrin, and Zachary Hymanson. 2012. Fish assemblages in reference and restored tidal freshwater marshes of the San Francisco Estuary. San Francisco Estuary and Watershed Science. 10(1):1-21.

## Literature Cited *(continued)*


82. Gunnison, Douglas, and J.W. Barko. 1992. Factors influencing gas evolution beneath a benthic barrier. Journal of Aquatic Plant Management. 30: 23-28.

83. Habig, Clifford. 2004. An evaluation of potential effects of fluridone on Pacific salmon in the California Delta. Exponent Laboratory. Washington, D.C..

84. Hallock, R.J., R.F. Elwell, and D.H. Fry, Jr.. 1970. Migrations of adult king salmon, *Oncorhynchus tshawytscha*, in the San Joaquin Delta. California Fish and Game. Sacramento, CA. 92p.

85. Hamelink, J.L., D.R. Buckler, F.L. Mayer, D.U. Palawski, and H.O. Sanders. 1986. Toxicity of fluridone to aquatic invertebrates and fish. Environ. Toxicol. and Chemistry. 5: 87-94.

86. Hanni, Jason, and Eric Chapman. 2006. Native and non-native species richness in the Sacramento and San Joaquin River Delta. 4th Biennial CalFed Science Conference. http://www.fws.gov/stockton/jfmp/docs/Hanni%20&%20Chapman%20CALFED%20Native%20vs%20nonnative.pdf

87. Hanni, Jason. 2005. "USFWS Seasonal Fishery Catch and a Follow Up Investigation of Fish Fauna Assemblages in the Sacramento-San Joaquin River Delta and Bays," *IEP Newsletter* 18, no. 3 (Fall 2005): 3-8.

88. Harman, Willard N., L.P. Hingula, and C.E. Macnamara. 2005. Does long-term macrophyte management in lakes affect biotic richness and diversity? J. Aquat. Plant Manage. 43:57-64.

89. Harnel, Sherry L. Eric D. Dibble, and K. Jack Killgore. 2001. "Foraging Behavior of Fishes in Aquatic Plants" (Vicksburg, Mississippi: U.S. Army Corps of Engineers Engineer Research and Development Center, February 2001).

90. Hellmann, J.J., J. E. Byers, B.G. Bierwagen, and J.S. Dukes. 2008. Five potential consequences of climate change for invasive species. Conservation Biology. 22(3):534-543.

91. Herbold, B. 1987. Patterns of co-occurrence and resource use in a noncoevolved assemblage of fishes. Ph.D. dissertation. Univ. of Calif. Davis.

92. Herbold, B. and P.B. Moyle. 1989. The ecology of the Sacramento-San Joaquin Delta: a community profile. Washington D.C.. USFWS National Wetlands Research Center.

93. Hestir, Erin L., S. Khanna, M.E. Andrew, M.J. Santos, J.H. Viers, J.A. Greenberg, S.S. Rajapakse, and S.L. Ustin. 2008. Identification of invasive vegetation using hyperspectral remote sensing in the California Delta ecosystem. Remote Sensing of Environment. 112:4043-4047.

94. Heublein JC, Kelly JT, Crocker CE, Klimley AP, Lindley ST. 2009 Migration of green sturgeon, *Acipenser medirostris*, in the Sacramento River. Environ Biol Fish 84:245-258 doi 10.1007/s10641-008-9432-9.

95. Hoogeweg, C.G., W.M. Williams, R. Breuer, D. Denton, B. Rook, and C. Watry. 2011. Spatial and Temporal Quantification of Pesticide Loadings to the Sacramento River, San Joaquin River, and Bay-Delta to Guide Risk Assessment for Sensitive Species. CALFED Science Grant #1055. November 2, 2011. 293 pp.

96. Hosea, R.C., K.Z. Bjurstrom, and E.E. Litrell. 2004. Acute oral and dermal toxicity of aquatic herbicides and a surfactant to garter snakes. Rancho Cordova, California. California Department of Fish and Game, Pesticide Investigations Unit. 22pp.

97. Hosea, R.C.. 2005. Residue of Fluridone and Diquat Dibromide in Sediment from the Sacramento-San Joaquin Delta, California, 2002-2005. California Department of Fish and Game.

98. HSDB. Accessed July 23, 2012. National Library of Medicine HSDB Database .Imazamox. www.toxnet.hlm.hig.gov.

## Literature Cited *(continued)*


99. Hutchinson, Jeffrey T., Gregory E. MacDonald, and Kenneth A. Langeland. 2007. The potential for herbicide resistance in non-native plants in Florida's natural area. Natural Areas Journal. 27(3): 258-263.

100. ICF International. Appendix 2.C Climate Change Overview, Administrative Draft, Bay Delta Conservation Plan. April 2012. [ICF 00610.10]. Sacramento, CA. Prepared for: California Department of Water Resources, Sacramento, CA.

101. Ingersoll, C.G. 1995. Sediment tests. In G.M. Rand (editor), Fundamentals of Aquatic Toxicology: Effects, Environmental Fate, and Risk Assessment, second edition, pages 231-255. Taylor and Francis. Bristol, Pennsylvania.

102. Isenberg, Phillip, Monica Florian, Richard M. Frank, Thomas McKernan, Sunne Wright McPeak, William K. Reilly, and Raymond Seed. October 2008. Delta Vision Strategic Plan. Sacramento, California. Governor's Delta Vision Blue Ribbon Task Force.

103. Israel J.A. and A.P. Klimley. 2008 Life History Conceptual Model for North American Green Sturgeon (*Acipenser medirostris*) University of California, Davis.

104. Jacob, Annie Philip. 2008. Ecological effects of chemicals used in pond culture of catfish and percid fishes. Dissertation, The Ohio State University.

105. Jassby, Alan D. 2008. Phytoplankton in the upper San Francisco Estuary: recent biomass trends, their causes and their trophic significance. San Francisco Estuary and Watershed Science. 6(1):1-24.

106. Jassby, Alan D., James E. Cloern, and Anke B. Müller-Solger. 2003. Phytoplankton fuels Delta food web. California Agriculture. 57(4):104-109.

107. Jassby, Alan D., James E. Cloern, and Brian E. Cole. 2002. Annual primary production: patterns and mechanisms of change in a nutrient-rich tidal ecosystem. Limnol. Oceanogr. 47(3):698-712.

108. Joyce, J. C. and V. Ramey. 1986. Aquatic herbicide residue literature review. Center for Aquatic Plants. Institute of Food and Agricultural Sciences,University of Florida, Gainesville, FL. 50 pp.

109. Kamarianos, A., J. Altiparmakis, X. Karamanlis, D. Kufidis, Th. Kousouris, G. Fotis, and S. Kilikidis. 1989. Experimental evaluation of fluridone effectiveness on fish productive aquatic ecosystems. J. Aquat. Plant Management. Vol. 27: 24-26.

110. Katz, Jacob, Peter B. Moyle, Rebecca M. Quinones, Joshua Israel, and Sabra Purdy. 2012. Impending extinction of salmon, steelhead, and trout (Salmonidae) in California. Environ. Biol. Fish. DOI 10.1007/s10642-012-9974-8.

111. Khanna, S., M.J. Santos, S. Ustin. 2009. American Geophysical Union, Fall Meeting 2009. Abstract #B21A-0321.

112. Kimmerer, Wim J., Alexander E. Parker, Ulrika E. Lidström, and Edward J. Carpenter. 2012. Short-term and interannual variability in primary production in the low-salinity zone of the San Francisco Estuary. Estuaries and Coasts. 35:913-929.

113. Knowles, Noah. 2000. Natural and human influences on freshwater flows and salinity in the San Francisco Bay-Delta estuary and watershed. IEP Newsletter, Volume 13, No. 1:15-23.

114. Koschnick, Tyler J., M.D. Netherland, and W.T. Haller. 2007. Effects of three ALS-inhibitors on five emergent native plant species in Florida. Journal of Aquatic Plant Management. 45:47-51.

115. Kovalenko, K., E.D. Dibble, and R. Fuji. 2009. Fish feeding in changing habitats: effects of invasive macrophyte control and habitat complexity. Ecology of Freshwater Fish. 18:305:313.

## Literature Cited *(continued)*


116. Kuivila, Kathryn M. and Michelle L. Hladik. 2008. Understanding the occurrence and transport of current-use pesticides in the San Francisco Estuary watershed. San Francisco Estuary and Watershed Science. 6(3):1-19.

117. Lacoul, Paresh and Bill Freedman. 2006. Environmental influences on aquatic plants in freshwater ecosystems. Environmental Review. 14:89-136.

118. Lancar, L. and K. Krake. 2002. Aquatic weeds and their management. International Commission on Irrigation and Drainage. 65pp.

119. Langeland, K., M. Netherland, and W. Haller. 2009. Efficacy of herbicide active ingredients against aquatic weeds. University of Florida IFAS Extension. SS-AGR-44.

120. Lund, J., E. Hanak, W. Fleenor, R. Howitt, R. Mount, and P. Moyle. 2007. Envisioning futures for the Sacramento-San Joaquin Delta. Public Policy Institute of California. San Francisco, California.

121. Maceina, Michael J. and Jeffery W. Slipke. 2004. The use of herbicides to control hydrilla and the effects on young largemouth bass population characteristics and aquatic vegetation in Lake Seminole, Georgia. Journal of Aquatic Plant Management. 42: 5-11.

122. Madsen, John D., K.D. Getsinger, R.M. Steward, C.S. Owens. 2002. Whole lake fluridone treatments for selective control of Eurasian watermilfoil: II. Impacts on submersed plant communities. Lake and Reservoir Management. 18(3):191-200.

123. Madsen, John D., Ryan M. Wersal, and Cheryl McLaurin. 2011. Sensitivity of native aquatic plant species to imazamox (Clearcast) and penoxsulam (Galleon). 30th Annual Western Aquatic Plant Management Society. March 28 to 30, 2011. Westminster, Colorado.

124. Madsen, John D.. 2000. Advantages and disadvantages of aquatic plant management techniques. US Army Engineer Research and Development Center Environmental Laboratory. Originally in North America Lake Management Society, LakeLine. 20 (1):22-34. Available at: http://www.aquatics.org/pubs/madsen2.htm.

125. Marshall, M., H. Webb, and R. Wilder. 2006. Spatial and temporal patterns in use by native and non-native fish larvae of a recently flooded island in the Sacramento-San Joaquin river delta. U.S. Fish and Wildlife Service.

126. Masters, Greg and Lindsey Norgrove. 2010. Climate Change and Invasive Alien Species. CABI Working Paper 1. 30pp.

127. Mazzeo, Nestor, L. Rodriquez-Gallego, C. Kruk, M. Meerhoff, J. Gorga, G. Lacerot, F. Quintans, M. Loureiro, D. Larrea, and F. Garcia-Rodrguez. 2003. Effect of *Egeria densa* Planch. Beds on a shallow lake without piscivorous fish. Hydrobiologia 1.2: 1-12.

128. McGowan, Michael F. 1998. Fishes associated with submersed aquatic vegetation, *Egeria densa*, in the Sacramento-San Joaquin delta in 1998 as sampled by pop nets. Romberg Tiburon Center, San Francisco State University. Unpublished report prepared for the California Department of Boating and Waterways.

129. McGowan, Michael F. and Al Marchi. 1998. Fishes collected in submersed aquatic vegetation, *Egeria densa*, in the Delta. *Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter*, Vol. 11, No. 1, Winter 1998, pp. 9-10.

130. McLaren/Hart Environmental Engineering Corporation, 1995. Use of the Registered Aquatic Herbicide Fluridone (Sonar) in the State of New York; Generic Environmental Impact Statement. Prepared for SePRO Corporation. Warren, New Jersey.

## Literature Cited *(continued)*


131. Merz, Joseph E., J.R. Smith, M.L. Workman, J.D. Setka, and B. Mulcaey. 2008. Aquatic macrophyte encroachment in Chinook salmon spawning beds: lessons learned from gravel enhancement monitoring in the lower Mokelumne River, California. North American Journal of Fisheries Management. 28(5):1568-1577.

132. Michael, J.L. and S.S. Ruiz-Córdova. 2006. Physical, chemical, and biological impacts of intensive forest management of streams draining watersheds in the coastal plain of Alabama. US Forest Service. Presented to the IUFRO 4.04.02 Planning and Economics of Fast-Growing Plantations Meeting. October 10-13, 2006. South Carolina.

133. Michel, Albrecht, Renee S. Arias, Brian E. Scheffler, Stephen O. Duke, Michael Netherland, and Franck E. Dayan. 2004. Somatic mutation-mediated evolution of herbicide resistance in the nonindigenous invasive plant hydrilla *(Hydrilla verticillata)*. Molecular Ecology. 13:3229-3237.

134. Millie, D.F., D.A. Greene, and P.B. Johnsen. 1990. Effects of the carotenoid-inhibiting herbicide, fluridone, on *Oscillatoria agardhii* Gomont (cyanobacteria). Aquatic Toxicology. Vol. 16: 41-52.

135. Mitchell, Andrew J., David L. Straus, Bradley Farmer, and Ray Carter. 2010. Comparison of percent hatch and fungal infestation in channel catfish eggs after copper sulfate, diquat dibromide, formalin, and hydrogen peroxide treatment. USDA Agricultural Research Service, Lincoln, Nebraska. http://digitalcommons.unl.edu/usdaarsfacpub.

136. Mossler, M.A., D.G. Shilling, S.L. Albrecht, and W.T. Haller. 1991. Microbial degradation of fluridone. J. Aquat. Plant Management. Vol. 29: 77-80.

137. Mount, J., W. Bennett, J. Curand, W. Fleenor, E. Hanek, J. Lund, and P. Moyle. 2012. Aquatic Ecosystem Stressors in the Sacramento-San Joaquin Delta. Public Policy Institute of California. Sacramento, CA. 23pp.

138. Moyle, P. 1976. Inland fishes of California. University of California Press, Berkeley. 405 pp.

139. Moyle, P.B., and W.A. Bennett. 2008. The future of the Delta ecosystem and its fish. Technical Appendix to Lund et al. (2007).

140. Mueller, T.L. 1994. Guide to the Federal and California Endangered Species Laws. Planning and Conservation League Foundation, Sacramento, CA. 111 pp. + appendices.

141. Muir, D.C.G. and N.P. Grift. 1982. Fate of fluridone in sediment and water in laboratory and field experiments. J. Agric. Food Chem. 30: 237-241 pp.

142. Muir, D.C.G., N.P. Grift, B.E. Townsend, D.A. Metner, and W.L. Lockhart. Comparison of the uptake and bioconcentration of fluridone and terbutryn by rainbow trout and *Chironomus tentans* in sediment and water systems. Arch. Environmen. Contam. Toxicol. Vol. 11: 595:602.

143. Naqvi, S.M. and R.H. Hawkins. 1989. Responses and LC50 values for selected microcrustaceans exposed to Spartan, Malathion, Sonar, Weedtrine-D and Oust pesticides. Bull. Environ. Contam. Toxicol. 43: 386-393 pp.

144. National Research Council. 2011. A Review of the Use of Science and Adaptive Management in California's Draft Bay Delta Conservation Plan. National Academies Press. Washington DC. 69pp.

145. Nawrocki, Justin J.. 2011. Environmental and physiological factors affecting submersed aquatic weed management. Thesis, North Carolina State University. http://www.lib.ncsu.edu/resolver/1840.16/7126. 187pp.

146. Netherland, M.D., C.A. Lembi, and L.M. Glomski. 2009. Potential for selective activity of the ALS inhibitors penoxsulam, bispyribac-sodium, and imazamox on algae responsible for harmful blooms. Journal of Aquatic Plant Management. 47:147-150.

## Literature Cited *(continued)*


147. Netherland, M.D., K.D. Getsinger, and J.D. Skogerboe. 1997. Mesocosm evaluation of the species-selective potential of fluridone. Journal of Aquatic Plant Management. 35:41-50.

148. New York State Department of Environmental Conservation. April 2005. A Primer on Aquatic Plant Management in New York State, Chapter 6, Local/Shoreline Management Activities. New York State. Available at: www.dec.ny.gov/docs/water_pdf/ch6p2.pdf.

149. Newcomb, James, and Leslie Pierce. October 2010. Low dissolved oxygen levels in the Stockton Deep Water Shipping Channel, adverse effects on salmon and steelhead and potential beneficial effects of raising dissolved oxygen levels with the aeration facility. Department of Water Resources. 27pp.

150. NMFS (National Marine Fisheries Service). 1996. Factors for decline: a supplement to the notice of determination for west coast steelhead under the Endangered Species Act. National Marine Fisheries Service, Protected Resource Division, Portland OR and Long Beach CA.

151. NMFS. February 2005. Green Sturgeon (*Acipenser medirostris*) Status Review Update. Santa Cruz, CA. NOAA-Fisheries, Southwest Fisheries Science Center, Biological Review Team.

152. NMFS. June 2005. Updated status of Federally Listed ESUs of West Coast salmon and steelhead, NOAA Technical Memorandum NMFS-NWFSC-66 . Seattle, Washington. NOAA-Fisheries.

153. NMFS. April 2006. Water hyacinth control program biological and conference opinion. Long Beach, CA. NOAA-Fisheries Southwest Region. 123pp.

154. NMFS. 2007. 2007 recovery outline for the evolutionarily significant units of winter-run and spring-run Chinook salmon (*Oncorhynchus tshawytscha*) and the distinct population segment of California Central Valley steelhead (*O. mykiss*). NOAA-Fisheries, Southwest Region. May 7, 2007. 41pp.

155. NMFS (National Marine Fisheries Service). 2009. Biological Opinion and Conference Opinion on the Long Term Operations of the Central Valley Project and State Water Project.

156. NMFS. 2009. Biological opinion and conference opinion of the proposed long-term operations of the Central Valley Project and State Water Project. Southwest Region Office. Long Beach, CA.

157. NMFS (National Marine Fisheries Service_. 2011 Endangered Species Act Section 7 Consultation Biological Opinion Environmental Protection Agency Registration of Pesticides 2,4-D, Triclopyr BEE, Diuron, Linuron, Captan, and Chlorothalonil.

158. NMFS. 2011. Recovery of Green Sturgeon. Southwest Region.

159. NMFS. June 2011. Biological Opinion, Environmental Protection Agency, Registration of Pesticides: 2,4-D, Triclopyr BEE, Diuron, Linuron, Captan, and Chlorothalonil. Washington D.C.

160. NMFS. June 30, 2011. More than 200 fish rescued from Sacramento River bypass. http://www.nmfs.noaa.gov/stories. Accessed December 21, 2011.

161. NMFS. August 2011a. 5-Year Review: Summary and Evaluation of Sacramento River Winter-run Chinook Salmon ESU. Southwest Region. Long Beach, CA. 38pp.

162. NMFS. August 2011b. 5-Year Review: Summary and Evaluation of Central Valley Spring-run Chinook Salmon ESU. Southwest Region. Long Beach, CA. 34pp.

163. NMFS. August 2011c. 5-Year Review: Summary and Evaluation of Central Valley Steelhead DPS. Southwest Region. Long Beach, CA. 34pp.October 5, 2011. http://swr.nmfs.noaa.gov/gs/jd/gs_index.htm. Accessed July 11, 2012.

164. NMFS. March 2012. Biological Opinion on the proposed construction and operation of the South Delta Temporary Barriers Program in San Joaquin County for 2012. Southwest Region, Long Beach, California. March 8, 2012. 134pp.

## Literature Cited *(continued)*


165. Nobriga, Matthew L. et al. 2004. "Evaluating Entrainment Vulnerability to Agricultural Irrigation Diversions: A Comparison among Open-Water Fishes," *American Fisheries Society Symposium* 39 (2004): 281-295.

166. Nobriga, Matthew L., Frederick Feyrer, Randall Baxter, and Michael Chotkowski. 2005. Fish community ecology in an altered river delta: spatial patterns in species composition, life history strategies, and biomass. *Estuaries* 28(5):776-785.

167. Nobriga, Matthew L., Zoltan Matica, and Zachary P. Hymanson. 2004. Evaluating entrainment vulnerability to agricultural irrigation diversions: a comparison among open water fishes. American Fisheries Society Symposium. 39:281-295.

168. Parka, S.J., W.R. Arnold, M.C. McCowen, and C.L. Young. 1978. Fluridone: a new herbicide for use in aquatic weed control systems. International Symposium on Aquatic Weeds. Amsterdam.

169. Parsons, Jenifer K., A. Couto, K.S. Hamel, and G.E. Marx. 2009. Effect of fluridone on macrophytes and fish in a coastal Washington lake. Journal of Aquatic Plant Management. 47:31-40.

170. Parsons, Jenifer K., K.S. Hamel, and R. Wierenga. 2007. The impact of diquat on macrophytes and water quality in Battle Ground Lake, Washington. Journal of Aquatic Plant Management. 45: 35-39.

171. Paul, E.A., H.A. Simonin, J. Symula, R.W. Bauer. 1994. The toxicity of diquat, endothall, and fluridone to the early life stages of fish. *J. of FreshwaterEcology*, Vol. 9, Number 3, pp. 229-239 pp.

172. Payne, Barry S., Andrew C. Miller, and Thomas Ussery. 1993. Effects of benthic barriers on macroinvertebrate communities. U.S. Army Corps of Engineers Technical Report A-93-5, Waterways Experiment Station.

173. Pelicice, F.M., and A.A. Agostinho. 2006. Feeding ecology of fishes associated with *Egeria* spp. Patches in a tropical reservoir, Brazil. Ecology of Freshwter Fish. 15:10-19.

174. Pennington, Toni Garrett. 2007. Seasonal changes in allocation, growth, and photosynthetic responses of the submersed macrophyte *Egeria densa* Planch. (Hydrocharitaceae) from Oregon and California. Dissertation. Portland State University. 153pp.

175. Pesticide Action Network (PAN). 2001. "Pesticide Database," PAN, www.pesticidinfo.org.

176. Peterson, Heather A. and Vayssieres, Marc. 2010. Benthic assemblage variability in the upper San Francisco Estuary. San Francisco Estuary and Watershed Science. 8(1): 1-27.

177. Petr. T. 2000. Interactions between fish and aquatic macrophytes in inland waters. Food and Agriculture Organization of the United Nations (FAO), Fisheries and Aquaculture Department. Rome. FAO Fisheries Technical paper 396.

178. Pfeuffer, Richard J.. (1990) Technical memorandum: herbicide monitoring program for n-methylformamide and fluridone (Sonar). Water Quality Division, Department of Research and Evaluation, South Florida Water Management District. West Palm Beach, Florida.

179. Powles, Stephen B. 2008. Evolved glyphosate-resistant weeds around the world: lessons to be learnt. Pest Management Science. 64(4)360-365.

180. Radtke, L.D. 1966. Distribution of smelt, juvenile sturgeon, and starry flounder in the Sacramento-San Joaquin Delta with observations on food of sturgeon. Ecological studies of the Sacramento-San Joaquin Delta.

181. Rahel, Frank J. and Julian D. Olden. 2008. Assessing the effects of climate change on aquatic invasive species. Conservation Biology. 22(3):521-533.

## Literature Cited *(continued)*


182. Rand, G.M., P.G. Wells, and L.S. McCarty. 1995. Introduction to aquatic toxicology. In G.M. Rand (editor), Fundamentals of Aquatic Toxicology: Effects, Environmental Fate, and Risk Assessment, second edition. Pages 3-66. Taylor and Francis. Bristol, Pennsylvania.

183. Reid, Adele M., L. Morin, P.O. Downey, K. French, and J.G. Virtue. 2009. Does invasive plant management aid the restoration of natural ecosystems? Biological Conservation. 142:2342-2349.

184. Richardson, Robert J. 2008. Aquatic plant management and the impact of emerging herbicide resistance issues. Weed Technology. 22(1):8-15.

185. Riis, Tenna, B. Olesen, J.S. Clayton, C. Lambertini, H. Brix, and B.K. Sorrell. 2012. Growth and morphology in relation to temperature and light availability during the establishment of three invasive aquatic plant species. Aquatic Botany. 102:56-64.

186. Riley, Frank and Sandra Finlayson. 2004b. (Cited as DBW, 2004) Chronic Toxicities of Herbicides Used to Control Water Hyacinth and Brazilian Elodea on Neonate Cladocern and Larval Fathead Minnow. California Department of Fish and Game, Aquatic Toxicology Laboratory. Elk Grove, California.

187. Riley, Frank and Sandra Finlayson.2003. Acute Toxicities of Herbicides Used to Control Water Hyacinth and Brazilian Elodea on Larval Delta Smelt and Sacramento Splittail (Elk Grove, California: DFG, June 8, 2004), also DFG-ATL. "Aquatic Toxicology Laboratory Report" (Rancho Cordova, California: DFG-ATL, June 23, 2003).

188. San Francisco Estuary Institute (SFEI). 2010. RMP Annual Monitoring Results: A Report of the Regional Monitoring Program for Water Quality in the San Francisco Estuary. SFEI Contribution No. 661. Oakland, California.

189. Santos, M.J., S. Khanna, E.L. Hestir, M.E. Andrew, S.S. Rajapakse, J.A. Greenberg, L.W.J. Anderson, and S.L. Ustin. 2009. Use of hyperspectral remote sensing to evaluate efficacy of aquatic plant management. Invasive Plant Science and Management. 2:216-229.

190. Santos, M.J., L.W. Anderson, and S.L. Ustin. 2011. Effects of invasive species on plant communities: an example using submersed aquatic plants at the regional scale. Biol. Invasions. Vol. 13: 443-457.

191. Schaffer, J.D., and M.J. Sebetich. 2004. Effects of aquatic herbicides on primary productivity of phytoplankton in the laboratory. Bulletin of Environmental Contamination and Toxicology. 72:1032-1037.

192. Scholik, A. R., and Yan, H. Y. 2002. Effects of boat engine noise on the auditory sensitivity of the fathead minnow, Pimephales promelas. Environmental Biology of Fishes 63:203–209.

193. Schultz, Rachel and Eric Dibble. 2012. Effects of invasive macrophytes on freshwater fish and macroinvertebrate communities: the role of invasive plant traits. Hydrobiologia. 684:1-14.

194. SePRO 2010. Clearcast aquatic herbide label. SePRO Corporation. Indiana.

195. SePro Corporation. 2006. "Sonar* An Effective Herbicide that Poses Negligible Risk to Human Health and The Environment," SePro Corporation, www.sepro.com.

196. SePRO. 2011. Galleon SC aquatic herbicide label. SePRO Corporation. Indiana.

197. Siemering, G.S., J. Hayworth, and A. Melwani. February 2005. Aquatic Pesticide Monitoring Program final report. Oakland, California. San Francisco Estuary Institute. 51pp.

198. Siemering, Geoff, J. Hayworth, A. Melwani, D. Crane, A. Mekebri, and G. Blondina. 2005. Aquatic Pesticide Monitoring Program Phase 3 (2004) Monitoring Project Report. San Francisco Estuary Institute. SFEI Contribution 391.

## Literature Cited *(continued)*


199. Siemering, Geoff. 2006. Technical Report for the Interagency Ecology Program (IEP) Pelagic Organism Decline (POD) Workgroup. San Francisco Estuary Institute. Oakland, CA. 14pp.

200. Siemering, Geoffrey S., Jennifer D. Hayworth, and Ben K. Greenfield. 2008. Assessment of potential aquatic herbicide impacts to California aquatic ecosystems. Archives of Environmental Contamination and Toxicology. DOI 10.1007/s00244-008-9137-2.

201. Smith, D.W., L.D. Lyman, and R.L. Leblanc. 1991. Potential formation of N-methylformamide (NMF) from fluridone in New England. J. Aquat. Plant Management. Vol. 29: 115-116.

202. Sommer, T., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, B. Herbold, W. Kimmerer, A. Mueller-Solger, M. Nobriga, and K. Souza. 2007. The collapse of pelagic fishes in the Upper San Francisco Estuary. Fisheries. American Fisheries Society. 32:6:270-277.

203. Sommer, Ted, Francine H. Mejia, Matthew L. Nobriga, Frederick Feyrer, and Lenny Grimaldo. 2011. The spawning migration of delta smelt in the upper San Francisco Estuary. San Francisco Estuary and Watershed Science. 9(2)1-16.

204. Sorrell, B.K. and F.I. Dromgoole. 1987. Oxygen transport in the submerged freshwater macrophyte *Egeria densa* Planch. I. oxygen production, storage and release. Aquatic Botany. 28:63-80.

205. Strayer, David L.. 2010. Alien species in fresh waters: ecological effects, interactions with other stressors, and prospects for the future. Freshwater Biology. 55(Supp. 1):152-174.

206. Struve, M.R., J.H. Scott, and D.R. Bayne. 1991. Effects of fluridone and terbutryn on phytoplankton and water quality in isolated columns of water. Journal of Aquatic Plant Management. 29:67-76.

207. SWRCB. January 2, 2007. Memo: new pesticide regulation. To Tom Howard, Acting Executive Director, from Michael A.M. Lauffer, Chief Counsel. Sacramento, California. SWB. 5pp.

208. Syngenta. 2005. Reward Landscape and Aquatic Herbicide (label). Greensboro, NC.

209. Syracuse Environmental Research Associates (SERA). 2008. Fluridone Human Health and Ecological Risk Assessment Final Report. For the USDA/Forest Service, Southern Region. Atlanta, Georgia.

210. Syracuse Environmental Research Associates (SERA). 2010. Imazamox Human Health and Ecological Risk Assessment Final Report. For the USDA/Forest Service, Southern Region. Atlanta, Georgia.

211. Tatum, Vickie L., Dennis L. Borton, William R. Streblow, Jefffrey Louch, and James P. Shepard. 2011. Acute toxicity of commonly used forestry herbicide mixtures to *Ceriodaphnia dubia* and *Pimephales promelas*. Environmental Toxicology. DOI 10.1002/tox.

212. Taugher, Mike. December 26, 2005. Water quality can be hard to swallow. Contra Costa Times.

213. Tremblay, L.A. 2003. Biomarkers in eel to evaluate effects of diquat in a Christchurch river. Landcare Research, CENTOX. Lincoln, New Zealand.

214. Trumbo, J. 1998. Environmental monitoring of hydrilla eradication activities in Clear Lake, 1997. California Department of Fish and Game, Office of Spill Prevention and Response, Administrative Report 98-3, Sacramento, CA.

215. USACE Engineer Research and Development Center. 2005. Diver dredge. Available at: http://el.erdc.usace.army.mil/pmis/MechanicalControls/MechanicalControlInfo.aspx?mechID=4.

216. United States Army Corps of Engineers (USACE). April 2012a. Benthic Barriers. UNSCE. GLMRIS.ANL.GOV.

## Literature Cited *(continued)*


217. United States Bureau of Reclamation (USBR). August 2008. Biological assessment on the continued long-term operations of the Central Valley Water Project and the State Water Project. Sacramento, California. USBR Mid-Pacific Region. 1,089 pp.

218. USACE. April 2012b. Dredging and Diver Dredging. USACE. GLMRIS.ANL.GOV.

219. United States Bureau of Reclamation. July 2003. Environmental water account draft environmental impact statement and environmental impact report. Sacramento, California. USBR.

220. USEPA. 1986. Pesticide Fact Sheet – Fluridone. Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency, Washington, D.C.

221. United States Environmental Protection Agency (USEPA). May 1997. Pesticide fact sheet, imazamox (Raptor herbicide). Office of Prevention, Pesticides, and Toxic Substances. Washington D.C..

222. USEPA. 2004. Ecological Risk Assessment for the Section 3 Registration of the New Chemical Penoxsulam for Uses on Rice. Environmental Fate and Effects Division (EFED). Washington DC. 55pp.

223. USEPA. January 2007. Ecological Risk Assessment: Section 3, New Uses on Turf and for Control of Aquatic Vegetation in Aquatic Environments, Penoxsulam. Environmental Fate and Effects Division (EFED). Washington DC. 188pp.

224. USEPA. August 2007. Appendix F: The Risk Quotient Method and Levels of Concern. Washington D.C. 3pp.

225. USEPA. February 2008. Effects of Climate Change on Aquatic Invasive Species and Implications for Management and Research. Office of Research and Development. Washington DC.

226. USEPA Environmental Fate and Effects Division (EFED). September 2008. Ecological Risk Assessment Evaluating Imazamox for the Proposed New Use on Clearfield Rice. Washington DC. 85pp.

227. USEPA. February 2011. Water Quality Challenges in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Unabridged Advanced Notice of Proposed Rulemaking. Region 9. San Francisco, California. 84pp.

228. United States Environmental Protection Agency (USEPA). 2012. Risk Assessments. http://www.epa.gov/oppefed1/ecorisk_ders/toera_risk.htm. Accessed June 26, 2012.

229. United States Fish and Wildlife Service (USFWS). 1995. U.S. Department of Interior Intra-Service Section 7 Evaluation – and Pesticide Use Proposals for the Stone Lakes National Wildlife Refuge.

230. USFWS. March 31, 2004. 5-Year Review *Hypomesus transpacificus* (delta smelt). Sacramento, CA. USFWS, Sacramento Fish and Wildlife Office.

231. USFWS. 2008. Biological Opinion on the Coordinated Operations of the Central Valley Project and State Water Project in California. December 15, 2008. Sacramento, CA.

232. USFWS. 2009. Spotlight Species 5-Year Action Plan 2010-2014, Valley elderberry longhorn beetle. Sacramento Fish and Wildlife Office, Sacramento, CA.

233. USFWS. September 2010. 5-Year Review of Delta smelt. USFWS Bay-Delta Fish and Wildlife Office. Sacramento, CA.

234. USFWS. March 29, 2012. San Francisco Bay-Delta population of longfin smelt to be designated a candidate for Endangered Species Act protection. Pacific Southwest Region, Press Release. Accessed June 7, 2012.

235. USFWS. March 7, 2012. Letter from Ken. S. Berg to Kelly Susewind, Washington Department of Ecology regarding imazamox. Washington Fish and Wildlife Office, Lacey Washington. 8pp.

## Literature Cited *(continued)*


236. University of Nevada, Reno (UNR). 2011. Unpublished and untitled study prepared for Tahoe Resource Conservation District. December 8, 2011.

237. URS Corporation. May 2007. Status and Trends of Delta-Suisun Services. Sacramento, California. California Department of Water Resources. 53pp.

238. Ussery, Thomas A., H.L. Eakin, B.S. Payne, A.C. Miller, and J.W. Barko. 1997. Effects of benthic barriers on aquatic habitat conditions and macroinvertebrate communities. Journal of Aquatic Plant Management. 35:69-73.

239. Valley, Rahman D. and M.T. Bremigan. 2002. Effects of selective removal of Eurasian watermilfoil on age-0 largemouth bass piscivory and growth in Southern Michigan Lakes. Journal of Aquatic Plant Management. 40:79-87.

240. Vanderstuckken M, N Mazzeo, W Van Colen, SAJ Declerck, and K Muylaert. 2011. Biological control of phytoplankton by the subtropical submerged macrophytes *Egeria densa* and *Potamogeton illinoensis*: a mesocosm study. Freshwater Biology. 56(9):1837-1849.

241. Vanderstukken, Martin. 2012. Control of phytoplankton by submerged macrophytes – the role of competition in relation to zooplankton grazing. Associate K.U. Leuven. July 8, 2012.

242. Vella, M., C. Nelson, and J.L. Conrad. 2010. Seasonal patterns in largemouth bass diet composition in the Sacramento-San Joaquin delta. California Department of Water Resources and U.C. Davis.

243. Walsh, G. Cabrera, Y. Magali Dalto, Federico M. Mattioli, Raymond I. Carruthers, and Lars W. Anderson. 2012. Biology and ecology of Brazilian elodea (*Egeria densa*) and its specific herbivore, *Hydrellia* sp., in Argentina. BioControl. Published online, August 4, 2012. DOI 10.1007/s10526-012-9475-x. 15pp.

244. Wang, C.S. 1986. Fishes of the Sacramento-San Joaquin Estuary and adjacent waters, California: a guide to the early life histories. Prepared for the Interagency Ecology Study Program for the Sacramento-San Joaquin Estuary. Technical Report 9.

245. Wang, Johnson, C.S. 1986. Fishes of the Sacramento-San Joaquin Estuary and adjacent waters, California: A guide to the early life histories. Prepared for the Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary. Technical Report 9.

246. Washington Department of Ecology (DOE). 2002. Appendix A: Final Risk Assessment for Diquat Dibromide. Prepared by Kathleen Emmett, Washington DOE Water Quality Program. Olympia, Washington. 354pp.

247. Washington Department of Ecology (DOE). Accessed October 17, 2012. Aquatic plant management – bottom screens. Washington DOE. www.ecy.wa.gov.

248. Washington Department of Ecology (DOE). Accessed October 23, 2012. Aquatic plant management – diver dredging. Washington DOE. www.ecy.wa.gov.

249. Washington Department of Ecology (DOE). January 2012. Environmental impact statement for penoxsulam, imazamox, bispyribac-sodium, flumioxazin, & carfentrazone-ethy. State of Washington. Publiciation no. 00-10-04-Addendum1. 98pp.

250. West , S.D., E.W. Day, and R.O. Burgen. 1979. Dissipation of the experimental aquatic herbicide fluridone from lakes and ponds. J. Agric. Food. Chem. 27: 1067-1072 pp.

251. West, S.D., R.O.Burger, G.M. Poole, and D.H. Mowrey. 1983. Bioconcentration and field dissipation of the aquatic herbicide fluridone and its degradation product in aquatic environments. J. Agric. Food Chem. 31: 579-585 pp.

## Literature Cited *(continued)*


252. Westerdahl, H.D. and K.D. Getsinger. 1988. Aquatic plant identification and herbicide use guide, Volumes I and II. Mississippi. U.S. Army Corps of Engineers, Waterways Experiment Station.

253. Wetland Goals. 1997. Draft species narratives for fish and macroinvertebrates. September 1997. San Francisco Bay Area Wetlands Ecosystem Goals Project.

254. Williams J.G.. (no year listed) Life-History Conceptual Model for Chinook Salmon and Steelhead *(Oncorhynchus tshawytscha and O. mykiss).* Sacramento-San Joaquin Delta Regional Ecosystem Restoration Implementation Plan.

255. Winder, Monika and A.D. Jassby. 2011. Shifts in zooplankton community structure: implications for food web processes in the upper San Francisco Estuary. Estuaries and Coasts. 34:675-690.

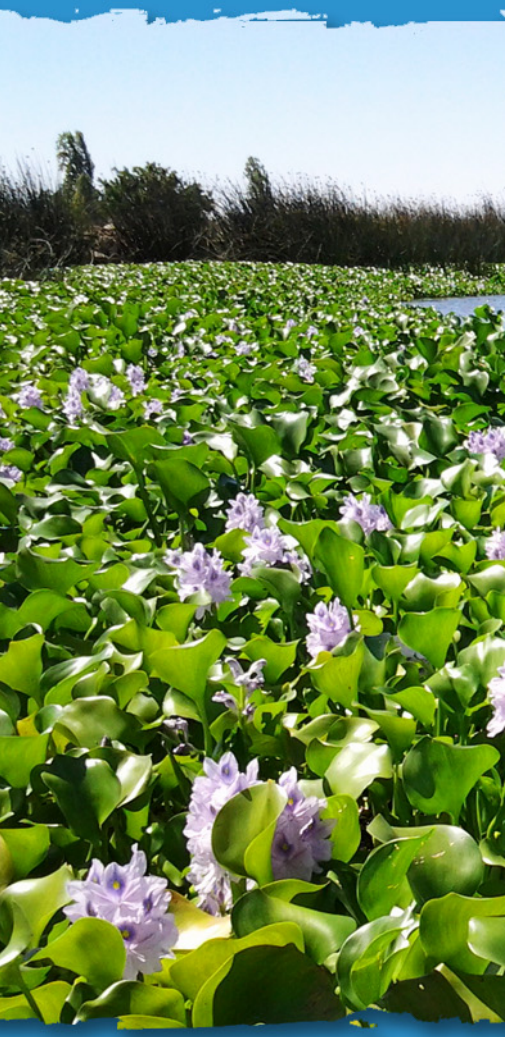
256. Wisconsin Department of Natural Resources. 2012. Penoxsulam Chemical Fact Sheet. Madison, WI. DNR PUB-WT-977 2012.

257. Yarrow, Matthew, Victor H. Marin, Max Finlayson, Antonio tironi, Luisa E. Delgado, and Fernanda Fischer. 2009. The ecology of *Egeria densa* Plancon (Liliopsida: Alismatales): A wetland ecosystem engineer? Revista Chilena de Historia Natural. 82:299-313.

258. Yi, Sandra A., B.M. Francis, W.M. Jarrell, and D.J. Soucek. 2010. Toxicological effects of the aquatic herbicide, fluridone, on male water mites (Hydrachnidaiae: Arrenurus: Megaluracarus. Ecotoxicology. Vol. 20: 81-87.

Section 11

# List of Contacts/ Contributors/Preparers



# 11. List of Contacts/ Contributors/Preparers

The following individuals were contacted and interviewed during the course of preparing this Biological Assessment:

1. Toni G. Pennington. Personal communication October 31, 2012, regarding *Egeria densa* growth and treatments. Tetra-Tech.
2. Jim Brockett. Personal communication October 24, 2012, regarding benthic barriers and diver-assisted suction harvesting. Tahoe Resource Conservation District.
3. Schuler, Scott. Personal communications September 11, 2012, October 9, 2012, and November 2, 2012, concerning herbicide treatments. SePRO Corporation.
4. Skibo, Andrew, Ph.D., Personal communication September 11, 2012, concerning herbicide treatments. SePRO Corporation.
5. Derma-Safe Company. Personal communication October 24, 2012, regarding benthic barriers.

The following individuals contributed to preparation of this Biological Assessment:

- United States Department of Agriculture, Agricultural Research Service
  - Ray Carruthers, Ph.D., Research Ecologist/Research Leader
  - Lars W.J. Anderson, Ph.D. (retired)
- California Department of Boating and Waterways
  - Lucia Becerra, Acting Director
  - Terri Ely, Senior Environmental Scientist
  - Jennifer Malcolm, Environmental Program Manager
  - Geoff Newman, Environmental Scientist
  - Ken Yelle, Field Supervisor
  - Angela Llaban, Environmental Scientists

The following individuals provided technical assistance in preparing this Biological Assessment:

- NewPoint Group, Inc.
  - Wendy B. Pratt
  - James A. Gibson, Ph.D.

[This page intentionally left blank.]

Section 12

# Supplemental Materials Binder Table of Contents

# 12. Supplemental Materials Binder Table of Contents


**Tab 1** – NMFS EDCP Letter of Concurrence 2012/01688

**Tab 2** – USFWS EDCP Biological Opinion 1-1-04-F-0148

**Tab 3** – EDCP Annual Report – 2011

**Tab 4** – EDCP Environmental Observations and Weed Survey Form

**Tab 5** – DRAFT Statewide NPDES permit (June 27, 2012)

**Tab 6** – Selected Scientific Literature

**Tab 7** – Fluridone (4AS) Dissipation During Typical Application of Sonar (4AS)

**Tab 8** – Residue of Fluridone and Diquat Dibromide in Sediment from the Sacramento-San Joaquin Delta, California, 2002-2005

**Tab 9** – Residue of Fluridone in Chinook Salmon Smolts from the Sacramento-San Joaquin Delta, California, 2005

**Tab 10** – An Evaluation of Potential Effects of Fluridone on Pacific Salmon in the California Delta

**Tab 11** – Experimental Studies of the Effects of Temperature, Salinity and Light Intensity of Growth of Egeria densa

**Tab 12** – Acute Oral and Dermal Toxicity of Aquatic Herbicides and a Surfactant to Garter Snakes

**Tab 13** – Chronic Toxicities of Herbicides Used to Control Water Hyacinth and Brazilian Elodea on Neonate Cladoceran and Larval Fathead Minnow

**Tab 14** – Acute Toxicities of Herbicides Used to Control Water Hyacinth and Brazilian Elodea on Larval Delta Smelt and Sacramento Splittail

**Tab 15** – *Ceriodaphnia dubia* (water flea) Static Definitive Chronic Toxicity Test Data (7-day) for Exposure to Various Aquatic Herbicides

**Tab 16** – *Pogonichthys macrolepitdotus* (Sacramento Splittail) Static Definitive Acute Toxicity Test Data (96-hour) for Exposure to Various Aquatic Herbicides

**Tab 17** – Mapping Invasive Plant Species in the Sacramento-San Joaquin Delta Region Using Hyperspectral Imagery

**Tab 18** – Dissipation and Movement of Sonar, and Komeen Following Typical Applications for Control of Egeria densa in the Sacramento/San Joaquin Delta and Production Viability of *E. Densa* Fragments Following Mechanical Harvesting

**Tab 19** – Effects of Control Methods on the *Egeria densa* Community

**Tab 20** – SonarOne Label and MSDS

**Tab 21** – Sonar PR Label and MSDS

**Tab 22** – Sonar Q Label and MSDS

**Tab 23** – Sonar AS Label and MSDS

**Tab 24** – Galleon SC Label and MSDS

**Tab 25** – Clearcast Label and MSDS

**Tab 26** – Reward Label and MSDS

**Tab 27** – Estimated Efficacy of EDCP Methods

**Tab 28** – Maps and Exhibits

USDA

CALIFORNIA DEPARTMENT OF BOATING AND WATERWAYS
EST. 1957