**Delta Smelt - DRAFT**

**BDCP Logic Chains for Covered Fish Species**

***Note to Reviewers:***

*The following presents a draft set of straw BDCP biological objectives for a spring-run Chinook Salmon. Per the recommendations of the independent science review panel, the objectives have been structured to address specific stressors as identified in existing documents such as existing recovery plans, biological opinions, and/or DRERIP life history conceptual models. A standardized table is used for each objective to provide specificity regarding the objective. Terms used in the table such as “Indicator” and “Attribute” are defined in Attachment 1. Additional components of the logic chain such as expected outcomes, conservation measures, and monitoring metrics are not presented herein. However, portions of the objective table are specifically intended to provide information relevant for these additional components. Efforts to link specific species objectives to broader natural community objectives and ecosystem objectives will be conducted once the species objectives have been reviewed and finalized.*

***Disclaimers:***

1. *Some of the objectives presented herein are hypothetical. These objectives are introduced to stimulate further discussion.*
2. *The Global Goals and Global Objectives presented below are not BDCP goals and objectives. BDCP will contribute to the achievement of these global goals and objectives.*

**Table of Contents**

[Global Goal 2](#_Toc275273488)

[Global Objective 2](#_Toc275273489)

[Stressors/Limiting Factors 2](#_Toc275273490)

[Stressor #1: Food Web (overbite clam) 3](#_Toc275273491)

[Stressor #2: Altered co-occurrence with prey 4](#_Toc275273492)

[Stressor #3: Toxicity (pesticides, Cu, MeHg, Se, microcystis, wastewater) 5](#_Toc275273493)

[Stressor #4: Temperature 6](#_Toc275273494)

[Stressor #5: Water Transparency 7](#_Toc275273495)

[Stressor #6: Altered flows 8](#_Toc275273496)

[Stressor #7: Entrainment. 9](#_Toc275273497)

[References 10](#_Toc275273498)

[Attachment 1: Objective Worksheet 11](#_Toc275273499)

# Global Goal

Establish self-sustaining populations of Delta smelt that will persist indefinitely.

# Global Objective

Maintain abundance of delta smelt in accordance with the following criteria: delta smelt numbers or total catch must equal or exceed 239 for 2 out of 5 years and not fall below 84 for more than two years in a row. Distributional and abundance criteria can be met in different years (from: USFWS Recovery Plan Distribution and Abundance Criteria).

# Stressors/Limiting Factors

The following stressors/limiting factors were adapted from Nobriga and Herbold (2009) and USFWS (date). Not all of the stressors listed below are proposed to be addressed by BDCP.

|  |  |  |
| --- | --- | --- |
| ***ID*** | ***Stressor*** | ***Summary Description*** |
| **Stressors Addressed by BDCP** | | |
| **1** | Food limitation due to overbite clam | Food availability and food web disruptions. |
| **2** | Food limitation due to altered co-occurrence with prey | Food availability and food web disruptions affecting juveniles. |
| **3** | Water quality - Toxicity (pesticides, Cu, MeHg, Se, microcystis, wastewater) | Effect of contaminants and microcystis on productivity. |
| **4** | Water quality - Temperature | Effect of water temperature on productivity as well as on role of other stressors. |
| **5** | Water quality - Water transparency | Effect on distribution and survival (including predation). |
| **6** | Altered flows | Altered distribution due to diversions and gate operations. |
| **7** | Entrainment | Direct mortality due to project and non-project diversions. |
| **Stressors Not Addressed by BDCP** | | |
| **8** | Climate change | Effects of climate change are considered, but no specific objectives proposed. |

### Stressor #1: Food Web (overbite clam)

The overbite clam directly competes with delta smelt for calanoid copepods and it grazes phytoplankton that would otherwise support the production of copepods and other historically important delta smelt prey (e.g., mysid shrimp). The impact of overbite clams on the food web supporting delta smelt likely interact with other stressors to affect delta smelt viability (Nobriga and Herbold, 2009).

**BDCP Objective #1**

Provide suitable habitat areas where overbite clams have not established.

|  |  |
| --- | --- |
| **Relation to Global Objective** | Limits the growth rate and size of larvae, juveniles, and adults to the extent that there are effects on large areas or multiple patches of habitat. |
| **Indicator** | Occurrence of overbite clams |
| **Location** | Cache Slough, Suisun Marsh, West Delta, Cosumnes/Mokelumne, South Delta (?) |
| **Attribute** | Spatial extent and density of clams in a given area |
| **Quantity or State** | Presence/absence of overbite clam and clam density. Establish threshold density based on reference conditions. |
| **Time Frame** | Within 15 years of permit issuance? |

### Stressor #2: Altered co-occurrence with prey

There are strong correlations between the apparent spatial-temporal “co-occurrence” of early life stage delta smelt with their prey and abundance of maturing adults in the subsequent autumn (r2 > 0.90 for larvae and > 0.70 for juveniles; BJ Miller and Tom Mongan, San Luis and Delta Mendota Water Authority, unpublished data). Similarly, Kimmerer (2008) recently published a statistically significant correlation between summer biomass of calanoid copepods in the low-salinity zone and an index of delta smelt survival from summer-autumn. Co-occurrence with prey is a secondary stressor stemming from species invasions and environmental manipulation that is affected by other stressors, including the spatial distribution of suitable delta smelt habitat (a function of X2, water quality, and submerged vegetation), water temperature, overbite clam grazing, entrainment of the food web components that support delta smelt (e.g., Jassby et al. 2002; Durand, 2008), and pesticide loading (Werner, et. al., 2008), and possibly Microcystis blooms that poison copepods.

**BDCP Objective #2**

Increase cumulative abundance of preferred prey (Eurytemora, Pseudodiaptomus, Cyclopidae sp, etc.) that co-occur with early life stage and adult delta smelt.

|  |  |
| --- | --- |
| **Relation to Global Objective** | Limits the growth rate and size of larvae, juveniles, and adults to the extent that there is a landscape scale effect on habitat quality. |
| **Indicator** | Prey items such as Eurytemora, Pseudodiaptomus, Cyclopidae sp. |
| **Location** | Cache Slough, Suisun Marsh, West Delta, Cosumnes/Mokelumne, South Delta |
| **Attribute** | Abundance of preferred prey within specific locations at specific times. |
| **Quantity or State** | A statistically measurable trajectory of increasing cumulative abundance of preferred prey.  *Note: Need to develop a workplan on how this metric would be developed.* |
| **Time Frame** | June to October.  Within 20 years of permit issuance? |

### Stressor #3: Toxicity (pesticides, Cu, MeHg, Se, microcystis, wastewater)

Water toxicity can act as a stressor either directly through physiological impairment of the fish themselves or indirectly by suppressing the supporting food web. For example, pyrethroid pesticides are a likely source of zooplankton mortality (Werner et al. 2008), and a factor influencing fish health and survival (Floyd et al. 2008). Similarly, toxicity work has indicated that delta smelt may be exceptionally sensitive to ammonia toxicity (Werner et al. 2008). Further, ammonium ion may inhibit phytoplankton blooms (Wilkerson et al. 2006; Dugdale et al. 2007). Ammonium ion also may provide a competitive edge to toxic *Microcystis aeruginosa* over diatoms that are more edible to zooplankton (Takamura et al. 1987), possibly leading to lower zooplankton productivity (Ger et al. 2009).

**BDCP Objective #3**

Reduce delta smelt exposure to contaminants and other toxins, including microcystis.

|  |  |
| --- | --- |
| **Relation to Global Objective** | A key limiting factor to the species population’s natural productivity, spatial distribution and/or diversity. |
| **Indicator** | Water quality parameters. |
| **Location** | BDCP Planning Area |
| **Attribute** | * Concentration (µg/L) of;   + ammonium,   + pyrethroids, * Microcystis abundance * Dissolved oxygen levels (mg/L) * Water temperature (°C) |
| **Quantity or State** | ???? |
| **Time Frame** | TBD |

### Stressor #4: Temperature

Some locations in the estuary exceed the thermal limits of delta smelt during winter and summer. The laboratory-derived lower and upper temperature tolerances of juvenile delta smelt are 7.5ºC (46ºF) and 25.4ºC (78ºF), respectively (Swanson et al. 2000). In addition to lethal limits, water temperatures increase the stress associated with food limitation, exposure to contaminants, and low dissolved oxygen concentrations, causing mortality at levels below laboratory-derived lethal limits (e.g. Kumaraguru and Beamish 1981; Marine and Cech 2004; Bennett et al. 2008).

**BDCP Objective #4**

Minimize exposure of larval, juvenile, and adult delta smelt to adverse water temperatures.

|  |  |
| --- | --- |
| **Relation to Global Objective** | Water temperature regulation for the benefit of delta smelt will lower the incidence of related mortality and contribute to achieving the recovery plan abundance targets. |
| **Indicator** | Water temperature and occurrence of larval, juvenile, and adult delta smelt |
| **Location** | BDCP Planning Area |
| **Attribute** | Water temperature and presence/absence of juvenile delta smelt |
| **Quantity or State** | \_\_\_% reduction of larval, juvenile, and adult delta smelt exposed to water temperatures equal to or greater than 25.4ºC |
| **Time Frame** | Through the life of the program |

### Stressor #5: Water Transparency

Delta smelt distribution is strongly associated with turbid water (Nobriga et al. 2005; Feyrer et al. 2007; Nobriga et al. 2008). The lack of suitably turbid conditions is a primary stressor that is also a component of delta smelt habitat. Larval feeding success is enhanced by turbidity (Baskerville-Bridges et al. 2004). Long-term monitoring shows the distribution of juvenile delta smelt is strongly influenced by water transparency (Nobriga and Herbold, 2009).

**BDCP Objective #5**

Utilize turbidity events as management triggers.

|  |  |
| --- | --- |
| **Relation to Global Objective** | Water transparency is a key limiting factor to the species population’s natural productivity, spatial distribution and/or diversity |
| **Indicator** | Turbidity |
| **Location** | Select monitoring stations in the Delta |
| **Attribute** | Suspended sediment |
| **Quantity or State** | ???? |
| **Time Frame** | December through June |

### Stressor #6: Altered flows

At all life stages, delta smelt distribution is controlled by freshwater flow; small larvae are distributed furthest from the low salinity zone (LSZ) and juveniles and maturing adults are often distributed at the upstream edge of the LSZ (Hobbs et al. 2007; Nobriga et al. 2008). The distribution of maturing delta smelt depends on freshwater flow and turbidity. Adults are cued to move by freshets during winter-spring (Grimaldo et al. 2009).

During low outflow conditions, delta smelt move into the Delta to spawn. Delta hydrodynamics and resulting entrainment in water diversions are primary stressors that affect delta smelt mortality (Erkkila 1950; Stevens and Miller 1983; Moyle et al. 1992; Kimmerer 2008) – see Stressor #7 below for objective regarding entrainment.

**BDCP Objective #6**

Avoid flow and hydrodynamic conditions that promote movement of spawning adults into the southern delta.

|  |  |
| --- | --- |
| **Relation to Global Objective** | Reduction in delta smelt entrainment resulting from flow alterations will positively affect species productivity. |
| **Indicator** | Old and Middle river flows |
| **Location** | Southern Delta |
| **Attribute** | Net flows |
| **Quantity or State** | Reduced occurrence of spawning delta smelt in the southern Delta. |
| **Time Frame** | Winter – Spring.  5 water year running average basis |

### Stressor #7: Entrainment

Delta smelt are vulnerable to entrainment in the SWP and CVP diversions during winter-spring spawning migrations and during their larval and early juvenile periods in the spring-early summer, but the relationship between river flows and entrainment in the SWP and CVP diversions varies by life stage (Kimmerer 2008). See DRERIP Conceptual Model, page 23 for details.

**BDCP Objective #7**

Reduce entrainment loss of delta smelt at project diversions.

|  |  |
| --- | --- |
| **Relation to Global Objective** | USFWS 1996 Recovery Plan |
| **Indicator** | Entrainment loss |
| **Location** | South Delta facilities |
| **Attribute** | Number of delta smelt spawning adults, juveniles, and larvae. |
| **Quantity or State** | Reduce entrainment of delta smelt (normalized by water year type):   * adults by \_\_% * juveniles by \_\_% * larvae by \_\_% |
| **Time Frame** | December to March. Within 20 years of permit issuance |

# References

Baskerville-Bridges, B, Lindberg, JC, Doroshov, SI. 2004. The effect of light intensity, alga concentration, and prey density on the feeding behavior of delta smelt larvae. American Fisheries Society Symposium 39:219-228.

Bennett, WA, Hobbs, JA, Teh, S. 2008. Interplay of environmental forcing and growth-selective mortality in the poor year-class success of delta smelt in 2005. Final Report to the Interagency Ecological Program.

Dugdale, RC, Wilkerson, FP, Hogue, VE, Marchi, A. 2007. The role of ammonium and nitrate in spring bloom development in San Francisco Bay. Estuarine, Coastal, and Shelf Science 73:17-29.

Durand J. 2008. Delta Foodweb Conceptual Model. Sacramento (CA): Delta Regional Ecosystem Restoration Implementation Plan.

Erkkila, LF, Moffett, JW, Cope, OB, Smith, BR, Nelson, RS. 1950. Sacramento-San Joaquin Delta fishery resources: effects of Tracy Pumping Plant and Delta cross channels. Special Scientific Report. Fisheries 56. US Fish and Wildlife Service.

Floyd, EY, Geist, JP, Werner, I. 2008. Acute, sublethal exposure to a pyrethroid insecticide alters behavior, growth, and predation risk in larvae of the fathead minnow (*Pimephales promelas*). Environmental Toxicology and Chemistry 27:1780-1787.

Ger, KA, Teh, SJ, Goldman, CR. 2009. Microcystin L-R toxicity on dominant copepods *Eurytemora affinis* and *Pseudodiaptomus forbesi* of the upper San Francisco Estuary. Science of the Total Environment 407: 4852-4857.

Grimaldo, LF, Sommer, T, Van Ark, N, Jones, G, Holland, E, Moyle, P, Smith, P, Herbold, B. Factors affecting fish entrainment into massive water diversions in a freshwater tidal estuary: can fish losses be managed? North American Journal of Fisheries Management 29:1253-1270.

Hobbs, JA, Bennett, WA, Burton, J, Gras, M. 2007. Classification of larval and adult delta smelt to nursery areas by use of trace elemental fingerprinting. Transactions of the American Fisheries Society 136:518-527.

Jassby, AD, Cloern, JE, Cole, BE. 2002. Annual primary production: patterns and mechanisms of change in a nutrient-rich tidal ecosystem. Limnology and Oceanography 47:698-712.

Kimmerer, WJ. 2008. Losses of Sacramento River Chinook salmon and delta smelt to entrainment in water diversions in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science 6:. http//repositories.cdlib.org/jmie/sfews/vol6/iss2/art2.

Kumaraguru, AK, Beamish, FWH. 1981. Lethal toxicity of permethrin (NRDC-143) to rainbow trout, Salmo gairdneri, in relation to body weight and water temperature. Water Research 15:503-505.

Marine, KR, Cech, JJ, Jr. 2004. Effects of high water temperature on growth, smoltification, and predator avoidance in juvenile Sacramento River Chinook salmon. North American Journal of Fisheries Management 24:198-210.

Moyle, PB, Herbold, B, Stevens, DE, Miller LW. 1992. Life history and status of delta smelt in the Sacramento-San Joaquin Estuary, California. Transactions of the American Fisheries Society 121:67-77.

Nobriga, M. and Herbold B. (2009). The little fish in California’s Water Supply: A Literatre Review and Life-History Conceptual Model for delta smelt (Hypomesus transpacificus) for the Delta Regional Ecosystem Restoration and Implementation Plan (DRERIP). Reviewed. 57 pp.

Nobriga, ML, Feyrer, F, Baxter, RD, Chotkowski, M. 2005. Fish community ecology in an altered river delta: spatial patterns in species composition, life history strategies and biomass. Estuaries 28:776-785.

Nobriga, ML, Sommer, TR, Feyrer, F, Fleming, K. 2008. Long-term trends in summertime habitat suitability for delta smelt, *Hypomesus transpacificus*. San Francisco Estuary and Watershed Science 6: http//repositories.cdlib.org/jmie/sfews/vol6/iss1/art1.

Stevens, DE, Miller, LW. 1983. Effects of river flow on abundance of young Chinook salmon, American shad, longfin smelt, and delta smelt in the Sacramento-San Joaquin river system. North American Journal of Fisheries Management 3:425-437.

Swanson, C, Reid, T, Young, PS, Cech, JJ, Jr. 2000. Comparative environmental tolerances of threatened delta smelt (*Hypomesus transpacificus*) and introduced wakasagi (*H. nipponensis*) in an altered California estuary. Oecologia 123:384-390.

Takamura, N, Iwakuma, T, Yasuno, M. 1987. Uptake of 13C and 15N (ammonium, nitrate, and urea) by *Microcystis* in Lake Kasumigaura. Journal of Plankton Research 9:151-165.

Werner I, Anderson S, Larsen K, and Oram J. 2008. Chemical stressors conceptual model. Sacramento (CA): Delta Regional Ecosystem Restoration Implementation Plan.

Wilkerson, FP, Dugdale, RC, Hogue, VE, Marchi, A. 2006. Phytoplankton blooms and nitrogen productivity in San Francisco Bay. Estuaries and Coasts 29:401-416.

# Attachment 1: Objective Worksheet

|  |  |
| --- | --- |
| **Indicator** | What will be measured?  Species, habitat, ecological process, physical condition… |
| **Location** | Where will it be achieved? |
| **Attribute** | What aspect of the indicator will be measured?  Population size, density, cover, presence/absence, reproductive rate… |
| **Quantity or State** | What measurable condition or change is expected?  Increase, decrease, maintain or limit negative impact?  *Quantity*: 500 individuals, 20% cover, 30% increase …  *Quality*: Weed-free, all life stages present, cover class 4… |
| **Time Frame** | When will this be achieved? |