White Sturgeon

The following section presents BDCP species-level Biological Goals and Objectives (BGOs) for White Sturgeon, and the rationale behind these BGOs.

Species-Specific Goals and Objectives

Following the Logic Chain approach, the tables below list BDCP species-level BGOs for White Sturgeon in the context of global goals and objectives developed by the agencies to support recovery planning and key stressors that BDCP will address. The global goals and objectives at the top of the table do not reflect BDCP goals and objectives, but rather represent broader goals and objectives developed by state and federal resource agencies relative to full species recovery. BDCP will contribute to meeting these goals and objectives, but will not in-and-of-itself achieve them. Rationales for each life stage of goal and objectives are provided after each table.

The goals of the BDCP relative to white sturgeon are to achieve:

1. Improved survival and abundance within the Plan Area; and
2. Increased spatial distribution and life history diversity (i.e. migration patterns) of white sturgeon in the Plan Area.

Specific, measureable species-level objectives to achieve these goals focus on:

1. Improving juvenile survival;
2. Increasing food to support productivity;
3. Minimizing the potential effects of covered activities;
4. Providing connectivity and safe and timely passage of adults; and
5. Reducing the impacts of poaching.

Species:	**White Sturgeon**	
Global Goals / Objectives: *Note: These are **not** BDCP goals and objectives. BDCP will contribute to meeting these, but will not in-and-of-itself achieve them.*	**Goals** GG1. Abundance - Increase abundance of 15-year-old white sturgeon to levels not less than 11,000 fish for a period of at least 10 years[1]. GG2. Population growth – Demonstrate a stable or increasing trend in subadult and adult abundance over a ten year period that is consistent with abundance goal GG1. GG3. Population growth – Demonstrate trends in reproduction (measured as larvae) and recruitment (measured as juveniles) sufficient to support the abundance goals for a period of at least 10 years. GG4. Structure/Distribution – Ensure white sturgeon continue to utilize all currently occupied areas within the Bay-Delta and its tributaries and are able to take advantage of any unoccupied areas which arise from restoration activities. GG5. Life history diversity- Maintain a stable size and age structure (e.g., relative numbers of juveniles and subadults is proportional to relative number of adults).	**Objectives** VSP1: Increase abundance VSP2: Increase spatial distribution VSP3: Protect and increase life history and genetic diversity VSP4: Increase productivity GO1. Promote the development of a white sturgeon fishery management plan such that (1) it would identify performance metrics (e.g., abundance, harvest rates, and survival rates for particular cohorts) for monitoring and management purposes, and (2) the California Fish and Game Commission would adopt and/or form a policy around it. HOO1. Provide abundant prey items for larval, juvenile, subadult, and adult life stages in freshwater, estuarine, and marine habitats. HOO2. Provide substrates suitable for egg deposition and development, larval development, and subadult and adult holding and spawning. HOO3. Provide a flow regime (i.e., the magnitude, frequency, duration, seasonality, and rate-of-change of discharge over time) necessary for optimal behavior, growth, and survival of all life stages. HOO4. Provide sufficient flows to allow adults to successfully orient to the incoming flow and migrate upstream to spawning grounds. HOO5. Provide water quality including temperature, salinity, oxygen content, and other chemical characteristics for optimal behavior, growth, and viability of all life stages in freshwater, estuarine, and marine habitats. HOO6. Decrease contaminants to levels low enough for optimal behavior, growth, and viability of all life stages in freshwater, estuarine, and marine habitats. HOO7. Provide migratory pathways for the safe and timely passage within freshwater, estuarine, or marine habitats and between

[1] This would be used as an initial benchmark until a sturgeon fisheries management plan can be developed and adopted by the California Fish and Game Commission (see GO1) which would establish a new abundance benchmark.

		gradients of these habitats. HOO8. Provide a diversity of depths necessary for shelter, foraging, and migration of juvenile, subadult, and adult life stages in estuarine habitats.
Stressors addressed by BDCP:	Habitat loss/modification, Predation, Entrainment, Dredging, Passage impediments, Flow alterations, Temperature, Food web, Invasive species, Water quality, Harvest/angling impacts, Natural river morphology, Contaminants	
BDCP Species Survival and Abundance Goal:	Improved white sturgeon survival and abundance within the Plan Area.	
BDCP Early Life Stage Survival Objective:	*Increase estimated spawner adult abundance-to-juvenile abundance ratio compared to existing condition CVP/SWP regulatory requirements by maintaining optimal incubation and rearing conditions in the Bay-Delta and its tributaries.*	
BDCP Species Survival Objective:	Determine impact of entrainment to the white sturgeon population and reduce it by 50%.	
BDCP Species Survival Objective:	Quantify indirect and direct impacts on white sturgeon from construction or maintenance dredging related to BDCP activities on food resources, water quality, and sediment quality and minimize adverse effects thereafter.	
BDCP Adult Abundance Objective:	Reduce illegal harvest of subadult and adult white sturgeon in the Plan Area by the previous year's observed quantity.	
BDCP Species Productivity Objective:	Increase the access to and quality of Bay-Delta prey which includes crustaceans, annelids, mollusks, fish, and midges to 50% pre-corbula invasion levels.	
BDCP Species Distribution and Diversity Goal:	Increase spatial distribution and life history diversity (i.e. migration patterns) of white sturgeon in the Plan Area.	
BDCP Subadult and Adult Distribution Objectives:	1. Provide unimpeded connectivity between the Sacramento River and Yolo Bypass to ensure safe and timely passage of adult white sturgeon between January and May. 2. Provide safe and timely passage around or through BDCP operational gates, barriers, and diversions.	
BDCP Early Life Stage Distribution Objective:	Increase the spatial distribution of incubation and rearing areas in the Bay-Delta and its tributaries compared to existing condition CVP/SWP regulatory requirements by providing optimal flow and temperature regimes during the spawning and rearing periods.	

Rationale for Species-specific Goals and Objectives

Species Abundance and Survival Goal: Increased survival of white sturgeon, particularly the early life history stages, is expected to have significant beneficial impacts on populations. Recruitment failure for North American sturgeon during the earliest life history stages seems to be a significant population limitation (Duke et al. 1999, Hildebrand et al. 1999, Korman and Walters 2001). Kohlhorst et al. (1991) suggested early life history stages are the critical limiting stage in the San Francisco Bay-Delta's self-sustaining white sturgeon population. Insufficient flows, increased predation, warm water temperatures, decreased dissolved oxygen and increased salinity are potential limiting factors for white sturgeon during the freshwater and brackish early life history stages.

Harvest and poaching may be one of the greatest stressors for adult white sturgeon. Length-frequency distributions obtained from CDFG sturgeon population studies from 1990 through 2006 revealed a lack of individuals greater than 183 cm TL (Schaffter and Kohlhorst 1999, CDFG, unpublished data). Even considering gear bias from the study, a deficiency of fish this size is concern because of their high fecundity and importance to population stability (Donnellan and Gingras 2007, Boreman 1997). Fishing regulation changes in 2007 included a 3-fish annual bag limit and the maximum size limit of a harvestable fish was reduced from 183 to 167 cm. The new fishing regulations appear to have helped the harvest reduction since the proportion of catch went from 64% in 2006 to 23% in 2008.

Currently, the USFWS CVPIA Program has been tracking 15-year-old white sturgeon as a gage of the population trend. However, the California Fish and Game Commission has not adopted the CVPIA doubling goal which is an important policy factor to consider since they regulate the fishery. Evaluation of CDFG sturgeon study length-frequency distributions in the future may determine whether this slot size reduction leads to conservation of remaining large, fecund fish (albeit not from poachers). Cohorts from good recruitment years of the mid- and late 1990s are reaching maturity and the current regulations should be evaluated annually to confirm they are protecting these adults and assuring production of younger cohorts. Formation of a new sturgeon fisheries management plan is suggested to provide a future benchmark and is listed as a global adult abundance objective (GO1).

Global species abundance and survival goals include: GG1, GG2, and GG3.

Early Life Stage Survival Objective: Kohlhorst et al. (1991 suggested the early life history stages of white sturgeon are a critical limiting stage in the self-sustaining white sturgeon population in the San Francisco Bay-Delta so it is important to minimize factors that may limit reproductive success and recruitment. Sufficient river flows are needed to disperse white sturgeon larvae into rearing habitat in the delta and bay and likely reduce in-river predation. April to July mean monthly river outflow correlates positively with the abundance index of YOY white sturgeon (Kohlhorst et al. 1991). Several water quality parameters can affect the survival and growth of the various life stages of white sturgeon (Table 1). Warm water temperatures which may affect a portion of the spawning season can reduce egg and larval survival. Sufficient dissolved oxygen (>80 mmHg) is important as juvenile white sturgeon demonstrated reduced activity in hypoxia which leads to a reduction in growth. Earlier life stages have even higher dissolved oxygen requirements of 7.5 mg/L. Juvenile white sturgeons have higher salinity tolerance than

YOY and could tolerate up to 25 ppt when acclimated in experiments (McEnroe and Cech 1985). However, stress observed at greater than 15 ppt may influence growth and survival (Tashjian et al. 2007). The BDCP objective to “Increase estimated spawner adult abundance-to-juvenile abundance ratio compared to existing condition CVP/SWP regulatory requirements by maintaining optimal incubation and rearing conditions in the Bay-Delta and its tributaries” aims to meet known optimal conditions required for incubating eggs and rearing larvae on CVP and SWP rivers.

Table 1. Optimal and suboptimal water quality parameters for white sturgeon from DRERIP white sturgeon conceptual model.

	Suboptimal low temperatures	Optimal temperature range	Suboptimal upper temperatures	Dissolved Oxygen	Salinity
Eggs/Larvae	<8 °C	14-16 °C	17-20 °C	>7.5 mg/l	<2 ppt
YOY juveniles		<20 °C	20-25 °C	80 mmHg	<15 ppt
Older juveniles		<20 °C	>25 °C		15-25 ppt
Spawning adults		11-20 °C	<25 °C		35 ppt

Global species abundance and survival goals include: VSP1, VSP3, VSP4, HOO3, HOO4, HOO5,

Species Survival Objective: Agricultural operations, power plants, and the state and federal water project facilities entrain down-migrating larvae, juvenile, and adult white sturgeon in varying degrees that depend on life stage and location. There is little documentation of entrainment at agricultural and power plant diversions. No sturgeon were observed by Nobriga et al. (2004) during their agricultural diversions entrainment study on the Sacramento River in the North Delta. However, South Delta water diversions were a source of mortality for white sturgeon during the high-flow years of 1982 and 1983. White sturgeon entrainment at the state and federal pumps varies and estimates ranged from zero upward to the thousands between 1981 and 2006. Larger juvenile sturgeons (>200 mm) had lower entrainment with angled bar racks and louvers (Amaral et al. 2002). Adult sturgeon have been impinged on the ‘trash racks’ at the state’s Skinner Fish Facility in the south delta (R. Gartz, CDFG, personal communication). The BDCP objective to “Determine impact of entrainment to the white sturgeon population and reduce it by 50%” aims to address entrainment impacts. This objective intends to quantify and minimize the adverse effects of entrainment encountered by white sturgeon in Bay-Delta and its tributaries and initiate the development of necessary actions to minimize adverse effects.

White sturgeon are an extremely benthic-oriented species and as such have the potential to be directly and indirectly affected by BDCP activities that require construction and maintenance dredging. This dredging may impact benthic food resources, water quality, and sediment quality, and could cause direct mortality of white sturgeon. The BDCP objective to “Quantify indirect and direct impacts on white sturgeon from construction or maintenance dredging related to BDCP activities on food resources, water quality, and sediment quality and minimize adverse effects thereafter” aims to address construction and dredging impacts. This objective intends to quantify and minimize the adverse effects in the lower Sacramento River and Bay-Delta utilized by white sturgeon. Currently, the effects of construction and maintenance dredging within the Central Valley on white sturgeon are unknown. Monitoring of food resources, water quality, and sediment quality prior to BDCP construction or dredging activities will provide information to evaluate potential impacts to white sturgeon and initiate the development of necessary actions to minimize adverse effects.

Global species survival objectives include: VSP1, VSP3, VSP4, and HOO7.

Adult Abundance Objective: The life history characteristics of white sturgeon (e.g., late maturing, infrequent spawning) coupled with the cyclic recruitment in the Sacramento River population make them susceptible to overexploitation. Harvest and poaching may be one of the greatest stressors for adult white sturgeon. Maintaining levels of spawning stock biomass per recruit is critical to sturgeon conservation. It has been suggested that maintaining an adult biomass of at least 20% (Goodyear 1993) to 50% (Boreman et al. 1984) should be targeted for rebuilding. Similar to the Sacramento population, Boreman (1997) found that levels of fishing mortality for Columbia River white sturgeon would maintain 30% to greater than 60% of the maximum lifetime egg production of the population. This suggests the Sacramento white sturgeon fishery mortality is low enough that the population is viable, but not always in a rebuilding dynamic. The development of white sturgeon fisheries management plan (GO1) would provide a strong foundation of information for protecting and enhancing the white sturgeon population.

Illegal poaching of white sturgeon is a serious and increasing threat to the population (M. Gingras, CDFG, personal communication). While the mortality rates and magnitude of this illegal activity are unquantifiable, they may be quite high. For example, Schaffter and Kohlhorst (1999) postulated that poaching played a role in the decreasing trend in annual survival rates during the 1990s. There is a tremendous financial incentive for poachers to exploit this population and this incentive has become evident with the several organized poaching rings that have been exposed and prosecuted since 2000. The BDCP Objective to “Reduce illegal harvest of subadult and adult white sturgeon in the Plan Area by the previous year’s observed quantity” aims to quantify the impacts poaching and minimize it.

Global adult abundance objectives include: VSP1, VSP3, and GO1.

Species Productivity Objective: The amount of available intertidal habitat for juvenile and adult foraging which is important to juvenile growth and reproductive maturation of adults has decreased in the Bay-Delta. White sturgeon are opportunistic generalists in regards to prey (Table 2). However, benthic food items in the Bay-Delta estuary have changed in the recent past especially since the establishment of invasive overbite clam (Corbula amurensis; Carlton et al. 1990, Alpine and Cloern 1992, Kimmerer et al. 1994). Invasive invertebrates have replaced native mollusks and shrimps. Kogut (2008) found the overbite clam, a major component of the white sturgeon diet, was able to pass alive through the digestive tract. It is possible that foraging on less edible non-native clams has caused dietary dilution, increased internal exposure to contaminants, and/or reduced growth of white sturgeon occupying the estuary. No studies have evaluated white sturgeon diets since these ecological changes occurred; however, dietary studies to be funded by USFWS are planned to begin in 2012 (Z. Jackson, USFWS, personal communication). BDCP conservation measures related to invasive species and restoration of tidal and subtidal habitats may be implemented to meet this objective. The BDCP objective to “Increase the access to and quality of Bay-Delta prey which includes crustaceans, annelids, mollusks, fish, and midges to 50% pre-corbula invasion levels" aims to increase growth and productivity of white sturgeon and restore critical habitats which would increase access to and quality of prey items.

Table 2. Documented prey of white sturgeon in the San Francisco Bay-Delta.

Life stage	Prey	Citation
Young-of- the-year	Amphipods (Corophium spinicorne), shrimp (Neomysis mercedis), and larval and adult midges (Tendipedidae)	Schreiber 1960
Juveniles (<39cm)	mysid shrimp and amphipods (Corophium)	Radtke (1966)
Older juveniles	Herring and their eggs (Clupea harengus pallasi), American shad (Alosa sapidissima), starry flounder (Platichthys stellatus), and goby	Radtke 1966, McKechnie and Fenner 1971

Global species productivity objectives include: VSP1, VSP2, VSP3, VSP4, HOO1, and HOO8.

Distribution and Diversity Goals: White sturgeon are highly migratory fish and unimpeded connectivity between habitats and safe and timely passage are critical to increase spatial distribution of spawning and reduce opportunities for adult mortality. There are several passage impediments that white sturgeon may encounter while migrating through the Delta and its tributaries. Distribution and diversity goals can be met through implementation of seasonal sturgeon fish passage at Fremont Weir and operational monitoring programs at BDCP gates, barriers, and diversions to increase spatial distribution and life history diversity (i.e. migration patterns) of white sturgeon in the Plan Area.

Global distribution and diversity goals include: GG4 and GG5.

Adult Distribution and Diversity Objective: River flow is diverted through the Yolo and Sutter Bypasses for flood control purposes during periods of high flow associated with winter storms. As waters recede in these systems, passage options become very limited and white sturgeon on their way to the spawning grounds can become stranded which leaves them vulnerable to poaching, desiccation, scavenging, and death unless they are rescued (Z. Matica, Department of Water Resources, pers. comm.). The Fremont Weir and Tisdale Weir are documented barriers to white sturgeon and the California Department of Fish and Game occasionally has to conduct rescue operations of sturgeon (and other fishes) at these structures. A recent set of studies provide design and operational criteria for sturgeon passage at Fremont Weir (DWR 2007). Modifications to the migratory corridor for white sturgeon particularly within the Yolo Bypass-Freemont Weir and Sutter Bypass-Tisdale Weir to insure that fish passage delays are minimized fall within the BDCP objective to "Provide unimpeded connectivity between the Sacramento River and Yolo Bypass to ensure safe and timely passage of adult white sturgeon between January and May."

Spawning adults may be delayed in reaching spawning grounds in the Sacramento River due to misleading water flows through the south and central delta while white sturgeon upmigrating in the San Joaquin River may be confused by Sacramento River flows entering the south delta via the DCC. Beside causing delays, the Delta Cross Channel can block passage. Delta exports and diversions can also affect Delta flow rates and hydrodynamics resulting in migration delays (NMFS 1997). Low dissolved oxygen conditions in the area of the Sacramento Deep Water Ship Channel can also act as a physical barrier to migration. The BDCP objective to "Provide safe and timely passage around or through BDCP operational gates, barriers, and diversions" aims to insure that fish passage delays are minimized.

Information on white sturgeon travel times, directionality, and disposition should be used to characterize potential impacts and measureable outcomes regarding safe and timely passage before implementing the adult distribution and diversity objectives.

Global adult distribution and diversity objectives include: VSP2, VSP3, VSP4, HOO7, and HOO8.

Early Life Stage Distribution and Diversity Objective: It appears that white sturgeon initiate two downstream migrations. However, downstream constriction of spawning habitat due to physical barriers may reduce larval survival due to a mismatch between the available habitats and the physiological tolerances of white sturgeon (Table 1). Larvae immediately disperse after hatching for up to six days (Conte et al. 1988, Kynard and Parker 2005) and then in the fall the YOY make another downstream migration for wide dispersal to rearing habitat throughout the lower rivers and delta (McCabe and Tracey 1994; Kynard and Parker 2005). It is unknown if they use tidal reverse flows in the lower Sacramento River to maintain a distribution primarily in freshwater. Juvenile sturgeon can use a broad range of habitats defined by their temperature, dissolved oxygen, and salinity tolerances (Table 1).

Habitat preferences for rearing by larval and YOY white sturgeon are basically unknown. White sturgeon from other Pacific northwestern river systems are associated with a variety of substrates, including mud, silt, sand, hard clay, gravel, cobble, boulder, and bedrock but appeared to prefer a pea gravel substrate in the 12-22 mm size range (Parsley et al. 1993, Bennett et al. 2007). Regardless of substrate, YOY white sturgeon from the lower Columbia River preferred water deeper than 12.5 m (McCabe and Tracey 1994). The presence of early life stages in riparian and floodplain habitats is very limited (Van der Leeuw et al. 2006), though these habitats have been speculated to be important for spawning recruitment (Coutant 2004).

Very little specific information is available on the distribution of juvenile white sturgeon in the Sacramento-San Joaquin system. A single study describing juvenile white sturgeon distribution indicates that the Sacramento River and most of the delta is utilized by this life stage (Radtke 1966). As white sturgeon salinity tolerance increases with size, they can access greater quantities of habitat in the Delta and Bays. Subtidal and intertidal habitat use is inadequate but abiotic factors likely dictate their seasonal habitat use. Complicating matters, laboratory studies indicate that temperature stress increases oxygen consumption needs (Geist et al 2005). The BDCP objective to "Increase the spatial distribution of incubation and rearing areas in the Bay-Delta and its tributaries compared to existing condition CVP/SWP regulatory requirements by providing optimal flow and temperature regimes during the spawning and rearing periods" aims to make more habitats available to the early life stages of sturgeon.

Global early life stage distribution and diversity objectives include: VSP2, VSP3, VSP4, HOO2, HOO7, and HOO8.