

## ***Green Sturgeon***

The following section presents BDCP species-level Biological Goals and Objectives (BGOs) for Green 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 Green Sturgeon in the context of global goals and objectives developed by the agencies to support recovery planning and key stressors that BDCP will address. Each table reflects a different life stage and a different goal and associated objectives. 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 the BGOs for each life stage are provided after each table.

The goals the BDCP is anticipated to achieve relative to green sturgeon include:

1. Improved survival and abundance within the Plan Area; and
2. Increased spatial distribution and life history diversity (i.e. migration patterns) of green 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 juvenile growth;
3. avoiding and minimizing the potential effects of covered activities;
4. providing connectivity and safe and timely passage of adults; and
5. reducing the impacts of illegal harvest/poaching.

## Green Sturgeon Juvenile Survival

<i>Species life stage and process</i>	Egg, larval, and juvenile green sturgeon Survival, Spatial Distribution
<i>Relevant Global Goals (as provided)</i> <sup>1</sup>  <i>Note: These are <b>not</b> BDCP goals and objectives. BDCP will contribute to meeting these, but will not in-and-of-itself achieve them.</i>	GG4. Population growth- Regular, periodic natural reproduction (measured as larvae) and recruitment (measured as juveniles), and/or trends in reproduction and recruitment sufficient to support the abundance goals over a period of at least 10 years.  GG5. Life history diversity- Stable size and age structure (e.g., relative numbers of juveniles and subadults is proportional to relative number of adults).
<i>Relevant Global Objectives (as provided)</i> <sup>2</sup>	VSP3. Protect and increase life history and genetic diversity VSP4. Increase productivity (population growth rate = births-deaths) CH3. Provide a flow regime (i.e., the magnitude, frequency, duration, seasonality, and rate-of-change of discharge over time) necessary for normal behavior, growth, and survival of all life stages. CH5. Provide water quality including temperature, salinity, oxygen content, other chemical characteristics, and acceptably low levels of contaminants necessary for normal behavior, growth, and viability of all life stages in freshwater riverine, estuarine, and marine habitats.
<i>Stressor(s) addressed by BDCP</i>	Reduced egg, larval, and juvenile survival due to alteration of flows and water temperatures in spawning and nursery reaches. Reduced spatial distribution of egg and larval habitats due to alteration of flows and water temperatures.
<i>BDCP species goals</i>	1. Improved survival and increased abundance of southern DPS green sturgeon within the Plan Area. 2. Increased spatial distribution and life history diversity (i.e. migration patterns) of southern DPS green sturgeon in the Plan Area.
<i>BDCP Early life stage Survival Objective</i>	Increase survival, by providing suitable incubation and rearing conditions (water temperature and flow) in the Bay-Delta and its tributaries, to achieve increased estimated adult-to-juvenile abundance ratio compared to existing estimated conditions under the current CVP/SWP regulatory requirements.
<i>BDCP Early life stage spatial distribution objective</i>	Increase the spatial distribution of suitable incubation and rearing conditions in the Bay-Delta and its tributaries compared to the conditions under the existing CVP/SWP regulatory requirements, by providing suitable flow and water temperatures during spawning, incubation and rearing periods.

<sup>1</sup> Global goals and global objectives presented in the tables were not developed by National Marine Fisheries Service. These do not represent work products of the science advisors and are provided here for reference.

***Rationale:***

Spawning activity of Southern DPS green sturgeon has been documented annually in the upper Sacramento River via egg and larval monitoring at Red Bluff Diversion Dam over the past fifteen years. In 2011, green sturgeon eggs were identified from spawning activity in the Feather River (A. Seesholtz, DWR, pers. comm.). Adult green sturgeon are observed in the Sacramento and Feather rivers between April and July, which can be a period of regulated flows in these rivers. Thus, flow operations may influence whether conditions are suitable for green sturgeon spawning, egg incubation, and larval and juvenile survival. While optimal water temperatures required for egg and larval incubation and development have been identified via laboratory tests (Table 1), flows necessary for spawning remain uncertain.

No water temperature compliance locations are established for green sturgeon egg incubation and larval rearing on the CVP/SWP rivers in which they are known to spawn. The CVP/SWP maintains water temperatures and flows on the Sacramento and Feather rivers during the spring and summer for winter run and spring run Chinook salmon, respectively. These measures maintain optimal water temperature conditions for a portion of the green sturgeon spawning, incubation, and rearing period. This objective aims to reduce water temperature alterations on CVP and SWP rivers to meet known optimal water temperature conditions required for incubating eggs and rearing larvae. Annual monitoring on the Sacramento and Feather rivers will provide information regarding the presence of green sturgeon adults, eggs, and larvae and inform as to the effectiveness in meeting the objective.

Flow characteristics necessary for spawning, incubating eggs and larval rearing are unknown, although research occurring under the current NMFS BO will provide information characterizing optimal conditions for these green sturgeon life stages. If linkages between Sacramento River white sturgeon population and hydraulic processes are similar to green sturgeon, white sturgeon may be a reasonable surrogate for green sturgeon.

Flow relationships for white sturgeon were examined by the California Department of Fish and Game (CDFG) and greater flows during the late spawning and early life history stages between April and July resulted in greater young-of-the-year (YOY) production (Kohlhorst et al. 1991, Fish 2010). Recruitment was significantly positively correlated with outflow in all months from April to July, but there was no correlation with mean daily volume of diversions. This objective aims to minimize Sacramento and Feather River flow reductions, due to CVP and SWP operations, that may impact egg and larval survival and successful juvenile recruitment. Juvenile green sturgeon develop critical osmoregulatory capacities between their first and second year that permit them to enter saltwater at a size of 75cm and weight of 1.5kg (Allen and Cech 2007), thus restored subtidal freshwater and brackish habitats can provide important habitats for juvenile green sturgeon. Outflow may indirectly influence juvenile survival by modifying the availability of these freshwater and low-salinity restored habitats in the Delta and Suisun Bay during green sturgeon's first year of life.

Table 1. Optimal and suboptimal water temperatures for green sturgeon egg incubation and larval rearing from Van Eenennaam et al. 2005 and Allen et al. 2006a.

	Suboptimal low temperatures	Optimal temperature range	Suboptimal upper temperatures
Eggs/Larvae	<9°C	11-17 °C	19-23°C
Young-of-year juveniles		15-19°C	21-27°C

## Green Sturgeon Juvenile Growth

<i>Species life stage and process</i>	Juvenile green sturgeon Growth, Spatial Distribution
<i>Relevant Global Goals (as provided)<sup>2</sup></i>  <i>Note: These are <b>not</b> BDCP goals and objectives. BDCP will contribute to meeting these, but will not in-and-of-itself achieve them.</i>	GG4. Population growth- Regular, periodic natural reproduction (measured as larvae) and recruitment (measured as juveniles), and/or trends in reproduction and recruitment sufficient to support the abundance goals over a period of at least 10 years.
<i>Relevant Global Objectives (as provided)<sup>2</sup></i>	VSP4. Increase productivity (population growth rate = births-deaths)  CH1. Provide abundant prey items for larval, juvenile, subadult, and adult life stages in freshwater riverine, estuarine, and marine habitats.  CH5. Provide water quality including temperature, salinity, oxygen content, other chemical characteristics, and acceptably low levels of contaminants necessary for normal behavior, growth, and viability of all life stages in freshwater riverine, estuarine, and marine habitats.  CH8. Provide a diversity of depths necessary for shelter, foraging, and migration of juvenile, subadult, and adult life stages in estuarine habitats  CH9. Provide sediment quality (i.e. chemical characteristics) necessary for normal behavior, growth, and viability of all life stages.
<i>Stressor(s)</i>	Reduction in the extent, access to, and/or quality of key natural in-Delta habitats providing food resources, water quality, and sediment quality required for green sturgeon.
<i>BDCP Species Goal</i>	<i>Improved survival and increased abundance of southern DPS green sturgeon within the Plan Area.</i>
<i>BDCP juvenile growth objective</i>	<i>Increase the extent (i.e. access to and quality) of Bay-Delta habitats producing benthic invertebrates, including shrimp, amphipods, isopods, annelid worm, and crabs to 50% pre-corbicula invasion levels.</i>

<sup>2</sup> Global goals and global objectives presented in the tables are as provided by the National Marine Fisheries Service (see Appendix C). These do not represent work products of the science advisors and are provided here for reference.

**Rationale:**

Juvenile green sturgeon are observed to spend one to three years in freshwater and brackish regions of the Bay-Delta. Green sturgeon are able to survive in seawater after approximately one and a half years. Juvenile green sturgeon are general consumers and are documented to feed on a diverse assemblage of prey (Table 2). The Bay-Delta food web has undergone significant changes due to invasive species, flow alterations, and changes in sediment load. Many of these changes have been documented as hypotheses to explain the pelagic organism decline (POD). The ecological changes observed in the Bay-Delta likely have impacted the access and quality of food used by juvenile green sturgeon.

This objective aims to increase growth of juvenile green sturgeon and restore key habitat elements for juvenile green sturgeon by increasing access to and quality of habitats within the Plan Area that produce benthic invertebrates. All benthic invertebrates in the Bay-Delta do not provide equivalent quality. Available benthic food items have changed during the recent past, and invasive *Corbula* has replaced native mollusks and shrimps. It is possible that this shift has led to dietary dilution, increased bioaccumulation of contaminants, and/or reduced growth of green sturgeon occupying the estuary, although the importance of this shift is unknown for green sturgeon. BDCP conservation measures related to invasive species and restoration of tidal and subtidal habitats may be implemented to meet this objective.

Table 2. Documented prey of juvenile green sturgeon in the San Francisco Bay-Delta and potential surrogate sturgeon species.

Species	Prey	Citation
Bay-Delta green sturgeon	Mysid shrimp and amphipods ( <i>Corophium</i> sp.)	Radtke 1966
Lower Columbia River white sturgeon, lake sturgeon, pallid sturgeon (Possible freshwater surrogates)	Oligochaetes, amphipods ( <i>Corophium</i> sp.), smaller fish, fish eggs	Muir et al. 2000, Gerrity et al. 2006, Nilo et al. 2006
Missouri River Shovelnose and Pallid sturgeon, (Possible freshwater surrogate)	Seasonally abundant drift and benthic invertebrates	Wanner et al. 2007

**Green Sturgeon Adult Survival**

<i>Species life stage and process</i>	Juvenile, Subadult, and Adult green sturgeon Survival, growth
<i>Relevant Global Goals (as provided)</i> <sup>3</sup>  <i>Note: These are <b>not</b> BDCP goals and objectives. BDCP will contribute to meeting these, but will not in-and-of-itself achieve them.</i>	GG1. Abundance- Based on abundance estimates made with relative confidence (e.g. multi-year averages, abundance estimates with low confidence intervals) measure adult (>150cm TL) effective population size to be greater than 500 and census population size greater than 2,500, which is roughly equivalent to a 5-year spawning periodicity of adults.  GG2. Structure/Distribution- Represent historical distribution and minimize catastrophic risks by occupying at least one additional independent or dependent population within the historical range of the sDPS green sturgeon.  G3. Population growth- Consistent with abundance goal (GG1), a stable or increasing trend in subadult and adult abundance over a ten year period.
<i>Relevant Global Objectives (as provided)</i> <sup>4</sup>	VSP 1. Increase abundance  VSP 2. Increase spatial distribution  VSP4. Increase productivity (population growth rate = births-deaths)  CH1. Provide abundant prey items for larval, juvenile, subadult, and adult life stages in freshwater riverine, estuarine, and marine habitats.  CH5. Provide water quality including temperature, salinity, oxygen content, other chemical characteristics, and acceptably low levels of contaminants necessary for normal behavior, growth, and viability of all life stages in freshwater riverine, estuarine, and marine habitats.  CH8. Provide a diversity of depths necessary for shelter, foraging, and migration of juvenile, subadult, and adult life stages in estuarine habitats  CH9. Provide sediment quality (i.e. chemical characteristics) necessary for normal behavior, growth, and viability of all life stages.
<i>Stressor(s)</i>	Reduction in the extent, access to, and/or quality of key natural in-Delta habitats providing food resources, water quality, water quality, and sediment quality required for green sturgeon.
<i>BDCP species goal</i>	<i>Improved survival and increased abundance of southern DPS green sturgeon within the Plan Area.</i>
<i>Recommended Adult survival objective</i>	<i>Develop early quantification of impacts from BDCP related construction or maintenance dredging on food resource, water quality, and sediment quality, as well as potential direct effects, related to other BDCP covered activities on</i>

<sup>3</sup> Global goals and global objectives presented in the tables are as provided by the National Marine Fisheries Service (see Appendix C). These do not represent work products of the science advisors and are provided here for reference.

	<i>green sturgeon and avoid and minimize adverse effects thereafter.</i>
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**Rationale:**

Green sturgeon use the lower Sacramento River and Bay-Delta as juvenile, subadult, and adults. Green sturgeon have been observed to travel off the bottom using currents to move between habitats, but spend extensive periods foraging and rearing on the bottom. Covered activities as part of BDCP are likely to require construction and maintenance dredging. This dredging may impact benthic food resources, water quality, and sediment quality, and could cause direct mortality of green sturgeon.

This objective aims to quantify and minimize any adverse effects on green sturgeon key natural habitats in the lower Sacramento River and Bay-Delta. The effects of BDCP related construction and maintenance dredging activities are unknown. Pre-activity monitoring of food resources, water quality, and sediment quality prior to implementation will provide information to evaluate potential impacts to green sturgeon and activities necessary to avoid and minimize adverse effect.

**Green Sturgeon Life History Diversity and Spatial Distribution**

<p><i>Species life stage and process</i></p>	<p>Subadult and Adult green sturgeon Life history diversity, Spatial Distribution</p>
<p><i>Relevant Global Goals (as provided)<sup>4</sup></i></p> <p><i>Note: These are <b>not</b> BDCP goals and objectives. BDCP will contribute to meeting these, but will not in-and-of-itself achieve them.</i></p>	<p>GG1. Abundance- Based on abundance estimates made with relative confidence (e.g. multi-year averages, abundance estimates with low confidence intervals) measure adult (&gt;150cm TL) effective population size to be greater than 500 and census population size greater than 2,500, which is roughly equivalent to a 5-year spawning periodicity of adults.</p> <p>GG2. Structure/Distribution- Represent historical distribution and minimize catastrophic risks by occupying at least one additional independent or dependent population within the historical range of the sDPS green sturgeon.</p>
<p><i>Relevant Global Objectives (as provided)<sup>4</sup></i></p>	<p>VSP 1. Increase abundance VSP 2. Increase spatial distribution</p> <p>CH3. Provide a flow regime (i.e., the magnitude, frequency, duration, seasonality, and rate-of-change of discharge over time) necessary for normal behavior, growth, and survival of all life stages.</p> <p>CH4. Provide sufficient flow into estuaries connected to the Sacramento River to allow adults to successfully orient to the incoming flow and migrate upstream to spawning grounds.</p> <p>CH6. Provide migratory pathways for the safe and timely passage of sDPS fish within freshwater riverine, estuarine, or marine habitats and between gradients of these habitats.</p> <p>CH8. Provide a diversity of depths necessary for shelter, foraging, and migration of juvenile, subadult, and adult life stages in estuarine habitats.</p> <p>CH9. Provide sediment quality (i.e. chemical characteristics) necessary for normal behavior, growth, and viability of all life stages.</p>
<p><i>Stressor(s)</i></p>	<p>Reduction in the extent and access to timely migratory pathways required for green sturgeon.</p>
<p><i>BDCP species goal</i></p>	<p>Increased spatial distribution and life history diversity (i.e. migration patterns) of green sturgeon in the Plan Area.</p>
<p><i>BDCP Subadult and Adult Objectives</i></p>	<ol style="list-style-type: none"> <li>1. <i>Provide unimpeded connectivity between the Sacramento River and Yolo Bypass to ensure safe and timely passage of adult Southern DPS green sturgeon between January and May.</i></li> <li>2. <i>Provide safe and timely passage related to BDCP operational gates, barrier, and diversions.</i></li> </ol>

<sup>4</sup> Global goals and global objectives presented in the tables are as provided by the National Marine Fisheries Service. These do not represent work products of the science advisors and are provided here for reference.

***Rationale:***

Green sturgeon are highly migratory fish, often passing rapidly between freshwater and marine habitats. These individuals are usually quickly ascending northern Central Valley rivers to undertake immediate spawning or emigrating following over-summering to physiologically-optimal marine habitats for foraging. Unimpeded connectivity between habitats and safe and timely passage are critical features of the Central Valley rivers which increase spatial distribution of spawning and reduce opportunities for adult mortality. These objectives can be met through implementation of seasonal sturgeon fish passage at Fremont Weir and operational monitoring programs at BDCP gates, barriers, and diversions. Prior to implementing these objectives, BDCP gates, barriers, and diversions information on green sturgeon travel times, directionality, and disposition should be used to characterize potential impacts and determine measureable outcome regarding necessary safe and timely passage.

## Green Sturgeon Poaching

<i>Species life stage and process</i>	Subadult and Adult green sturgeon Survival
<i>Relevant Global Goals (as provided)</i> <sup>5</sup>  <i>Note: These are <b>not</b> BDCP goals and objectives. BDCP will contribute to meeting these, but will not in-and-of-itself achieve them.</i>	GG1. Abundance- Based on abundance estimates made with relative confidence (e.g. multi-year averages, abundance estimates with low confidence intervals) measure adult (>150cm TL) effective population size to be greater than 500 and census population size greater than 2,500, which is roughly equivalent to a 5-year spawning periodicity of adults.  GG3. Population growth- Consistent with abundance goal (GG1), a stable or increasing trend in subadult and adult abundance over a ten year period.  GG5. Life history diversity- Stable size and age structure (e.g., relative numbers of juveniles and subadults is proportional to relative number of adults).
<i>Relevant Global Objectives (as provided)</i> <sup>4</sup>	VSP 1. Increase abundance  VSP 2. Increase spatial distribution  CH6. Provide migratory pathways for the safe and timely passage of sDPS fish within freshwater riverine, estuarine, or marine habitats and between gradients of these habitats.
<i>Stressor(s)</i>	Poaching, incidental take via bycatch.
<i>BDCP species Goal</i>	<i>Improved survival and increased abundance of southern DPS green sturgeon within the Plan Area..</i>
<i>BDCP Adult objective</i>	<i>Determine through annual targeted studies the significance of poaching to the population and based upon study results, reduce poaching of subadult and adult green sturgeon in the Plan Area by the previous year's observed quantity.</i>

**Rationale:**

Green sturgeon are long lived; males may reproduce as early as 14 years old, while females grow older prior to maturing as early as 16 years old (Van Eenennaam et al. 2005). Historically, green sturgeon were harvested as bycatch in commercial fisheries. The states of Washington, Oregon, and California eliminated legal sportsfishing and commercial bycatch of green sturgeon between 2006 and 2008. While uncommon, green sturgeon are still captured in Pacific Northwest and Sacramento River sports fisheries. The retention of green sturgeon is no longer allowed in California or the Pacific coast, except in tribal fisheries on the Klamath River (Adams et al. 2007). Poaching for sturgeon seems to be a threat in the

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Sacramento River and Feather River, and green sturgeon may be illegally harvested during in-river white sturgeon fisheries. Chronic stress (i.e., chasing, confinement, or depth reduction) has been observed to influence the bioenergetics of green sturgeon, though it did not influence their swimming performance (Lankford et al. 2005). Thus, handling of green sturgeon is likely to have a minimal effect on survival. Manager's understanding for the effect of fishing-associated mortality on green sturgeon is low, thus targeted studies and law enforcement is necessary to reduce poaching of subadult and adult green sturgeon. Implementation of increased warden activities in the Sacramento and Feather rivers, as well as Bay-Delta, will maintain the abundance of green sturgeon and protect spawning adults.