GREEN STURGEON
Acipenser medirostris
NOAA NMFS: Threatened
CDFG: Species of Special Concern

Species Account

Status and Description. The green sturgeon (*Acipenser medirostris)*, specifically the Southern Distinct Population Segment (DPS) that includes Sacramento River basin spawners, was listed as a threatened species by the National Marine Fisheries Service, National Oceanic and Atmospheric Administration (NOAA NMFS) on April 7, 2006. The California Department of Fish and Game (CDFG) designated the green sturgeon as a species of special concern.

Sturgeons are some of the largest and longest-lived bony fishes in the world. They are easily identified by their rows of bony scutes, lack of scales, heterocercal (asymmetrical and sharklike) tails, and adaptations for preying on benthic invertebrates. These adaptations include: long snouts, dangling whisker-like barbels to detect prey, and subterminal mouths with toothless protrusible jaws (Moyle 2002).

The closely related Sakhalin sturgeon (*A. mikadoi*, now extirpated from most of its historic range in Asia and the northwestern Pacific) was considered conspecific with the green sturgeon. It was reclassified on the basis of significant DNA differences (Adams et al. 2002).

In San Francisco Bay and the Sacramento-San Joaquin Estuary (the Delta), green sturgeon co-occur with and are similar in life history and appearance to white sturgeon (*A. transmontanus*). Both species are anadromous. Green sturgeon are distinguished by having an olive green color dorsally (some are gray or golden brown), narrow snouts with barbels closer to the mouth than the tip, 23-30 scutes per lateral row, one ventral scute behind the dorsal fin and another behind the anal fin, and generally sharper and more pointed scutes than the white sturgeon. The dorsal fin has 33-36 rays and the anal fin 22-28. Adult green sturgeon are typically 130 to 200 cm total length and weigh up to 90 kg; fish longer than 200 cm are females (Moyle 2002). In young of the year, green sturgeon differ from white sturgeon in having 35 to 40 dorsal fin rays, 30 or fewer lateral scutes, and 15 to 19 rakers on the first gill arch (white sturgeon have more of each of these features) (Moyle 2002). Although adult white sturgeon reach larger maximum sizes than green sturgeon, juvenile green sturgeon grow more rapidly than white sturgeon when raised in comparable captive conditions (Kohlhorst 2001).

Range, Populations, and Activity. Green sturgeon are found in coastal waters from Mexico to the Bering Sea and in rivers of British Columbia, Washington, Oregon, and California as far south as the Sacramento River (Moyle 2002). NOAA NMFS has defined two distinct population segments by a boundary immediately south of the Eel River; the only known spawning grounds of the Southern DPS are within the Sacramento River drainage. The two populations may co-occur throughout their saltwater range but exhibit a high degree of fidelity to their spawning sites (NOAA NMFS 2003). The Northern DPS is a substantially larger population and NOAA NMFS considers it a Species of Concern that does not warrant listing as a threatened species under the ESA (NOAA NMFS 2006).

Historically, green sturgeon spawned in a number of rivers south of the Eel River and in a variety of habitats at higher elevations than the current spawning sites in the mainstem Sacramento River. The construction of Shasta Dam (1938-1945) and Keswick Dam (1941-1950) cut off access to former

spawning habitat in the upper reaches of the Sacramento River. Historic Feather River spawning grounds are blocked by Oroville Dam (constructed in 1961-1968) (NOAA NMFS 2006). Spawning that currently occurs in the lower Feather River does not contribute significantly to green sturgeon numbers (Biological Review Team 2005). The San Joaquin River or its tributaries may have supported a spawning population before they were extensively altered from their natural condition beginning in the 1940s (Moyle 2002; NOAA NMFS 2003, 2006; Biological Review Team 2005). There is evidence that white sturgeon occur in the San Joaquin River that includes recent spawning, but there is no data confirming the presence of green sturgeon there (Biological Review Team 2005).

Green sturgeon abundance data and studies of population dynamics are lacking in part because in the past the species had little commercial or sport fishing value compared to the more abundant white sturgeon (Moyle 2002, NOAA NMFS 2003). Apparently, green sturgeon have always been relatively uncommon in the Sacramento-San Joaquin river system (Moyle et al. 1995). Moyle (2002) inferred from CDFG's studies of white sturgeon in San Pablo Bay that numbers of adult green sturgeon varied from 140 to 1,600 over the years 1954 to 1987. NOAA NMFS examined the CDFG data from 1954 on and concluded abundance was generally stable, but cautioned of problems with the estimates stemming from the lack of green sturgeon-focused studies and inconsistent levels of data collection effort (NOAA NMFS 2003). It subsequently listed the Southern DPS in part because data on fish salvaged from entrainment in water export facilities in the Delta showed a sharp decrease in numbers of juvenile sturgeon after 1986 (Adams et al. 2002, NOAA NMFS 2006).

Although green sturgeon likely have lifespans of up to 60-70 years, they are slow to mature (Moyle 2002). The minimum age of maturity is 15 years in males and 17 years in females. Spawning occurs from late spring to early summer and peaks in mid-April to mid-June (Moyle 2002, NOAA NMFS 2003). Females spawn at intervals of 2 to 4 years or more (NOAA NMFS 2003, 2009), producing 60,000 to 140,000 eggs which are thought to hatch approximately 200 hours after spawning (Moyle 2002). Larvae begin feeding at 10 days post hatch (dph) and metamorphose to juveniles by 45 days (NOAA NMFS 2003). Juveniles complete their outmigration from spawning areas to saltwater at 1 to 3 years old, mostly as yearlings (Moyle et al. 1995, Moyle 2002, NOAA NMFS 2003). Most juvenile outmigration occurs in summer-fall (Moyle et al. 1995).

Habitat Use. Green sturgeon is one of the most marine-oriented members of the sturgeon family, not often present in freshwater except during spawning and early life stages (Moyle 2002). Spawning occurs in fast-moving, deep (more than 5 m), cold water over substrates of gravel, large cobble, boulders, bedrock, or clean sand (Moyle 2002, Moyle et al. 1995, NOAA NMFS 2008, NOAA NMFS 2009). At 10 dph, larvae are thought to begin moving in a generally downstream direction (NOAA NMFS 2008). Juveniles in the Delta feed mainly on benthic crustaceans, especially shrimp and amphipods, but also other bottom-dwelling invertebrates and small fishes (Moyle et al. 1995, NOAA NMFS 2008). There are no recent studies of green sturgeon food preferences. It is known that as white sturgeon grow larger they have a more varied diet including an increasing proportion of fish and, in Suisun Bay, the introduced overbite clam (*Potamocorbula amurensis*), a species that became widespread and overabundant soon after its arrival in the 1980s (Moyle 2002).

Green sturgeon are present in the Delta year-round. Inmigration of spawners begins in early spring and continues into summer. Post-spawning outmigration begins in spring and may continue for most of the year. Some adults exhibit "summer holding" behavior, residing in deep pools in the Sacramento River until fall or winter. Tagged adults have been observed to remain in the river

through December and outmigrate during higher flows. Juveniles are widespread in the Delta throughout the year. During summer adults and subadults (subadults are defined as individuals that have entered saltwater but not yet reached sexual maturity) occur in Suisun Bay and the waters between it and the Sacramento River, probably to feed and optimize growth (NOAA NMFS 2008).

Green sturgeon adults and subadults in the Delta tolerate wide ranges and fluctuations of temperature, salinity, and dissolved oxygen. They generally occupy near-surface waters over shallow depths (less than 10 m) when moving directionally and the benthic zone when foraging. Juveniles may depend on shallower depths (1-3 m) for their rearing and foraging habitat (NOAA NMFS 2008).

Researchers have documented movements of adults into coastal lagoons and bays in late summer to early fall, unrelated to spawning (NOAA NMFS Office of Protected Resources website).

Population Levels and Occurrence in Plan Area. Green sturgeon are mainly associated with the open water portions of the marshes and sloughs within the Coastal Marsh Natural Community. Green sturgeon are known to be present in small numbers in the Delta, Suisun Bay, and San Pablo Bay; however, as discussed above, good data on population levels do not exist at this time.

Dispersal. Juveniles disperse into saltwater after spending 1 to 4 years in freshwater. Subadults remain in estuaries near their natal rivers or disperse to other West Coast estuaries or bay and ocean waters up to 110 m deep (NOAA NMFS 2009). Most green sturgeon migrate north before returning to spawn (Adams et al. 2002, NOAA NMFS 2003).

Subadults are known to migrate upstream into the Sacramento River though it is not known why (NOAA NMFS 2008).

Threats to the Species. All species of sturgeon have become less abundant, some dramatically so, because of overharvesting and loss or degradation of habitat. Green sturgeon are vulnerable because of their long lifespans, late maturity, low fecundity, episodic spawning, and specialized spawning habitat requirements (Moyle 2002; NOAA NMFS 2001, 2003). The Southern DPS is additionally at risk due to its apparent low numbers (NOAA NMFS 2006). Because of the green sturgeon's life history strategy, depleted populations are slow to recover (Adams et al. 2002).

Due to the lack of studies of green sturgeon ecology and conservation, effects of risk factors are for the most part inferred from data on white sturgeon or other co-occurring, anadromous species.

The primary threats to the Southern DPS of green sturgeon are loss of spawning habitat due to dams and the concentration of spawning activity into a single area in the upper Sacramento River below Shasta Dam, leaving the population vulnerable to catastrophic events such as the 1977-78 drought that caused the year class of winter-run chinook salmon (*Oncorhynchus tshawytscha*) to fail and the 1991 Cantara herbicide spill that killed almost all aquatic organisms for 45 miles downstream (NOAA NMFS 2006, NOAA NMFS Biological Review Team 2005).

In the Delta, Suisun Bay, and San Pablo Bay green sturgeon are threatened by exposure to chemical contaminants; food web disruption and predation by non-native species; entrainment in water project facilities, power generation facilities, and dredging operations; construction and maintenance of

shoreline and in-water structures; and potential insufficient freshwater outflows (NOAA NMFS 2006, 2008).

Bioaccumulation of pesticides, PCBs, and industrial chemicals including mercury, arsenic, and selenium by white sturgeon has been shown to adversely affect development and decrease reproductive success and it is assumed that accumulation of contaminants poses a similar threat to green sturgeon (NOAA NMFS 2010). Increased levels of agricultural pesticides in the Sacramento River and the Delta are thought to have harmed larvae of striped bass (*Morone saxatilis)*, another surrogate species used in the absence of green sturgeon-specific data (NOAA NMFS 2006). Toxins from pesticide use and algal blooms have been implicated in the decline of the pelagic food web in the Delta (Armor et al. 2005, NOAA NMFS 2006).

The San Francisco Bay-Delta system is well known to be heavily impacted by introduced species. The non-native overbite clam has proliferated in Suisun Bay. It has become a major food item for white sturgeon and was found in an adult green sturgeon caught locally in 2001 (Adams et al. 2002, NOAA NMFS Biological Review Team 2005). Overbite clams bioaccumulate selenium and may also cause adverse changes in the food web that supports green sturgeon (NOAA NMFS 2003, 2005). New evidence suggests green sturgeon are more readily affected by selenium toxicity than white sturgeon, which may cause reproductive failure and result in decreased recruitment (NOAA NMFS 2010). Striped bass are known to prey on chinook salmon in the Sacramento River and although this threat is difficult to quantify it is assumed that some threat to green sturgeon exists (NOAA NMFS 2006).

Juvenile green sturgeon occur year round near the intake pumps of state and federal water export facilities in the Delta and substantial numbers become entrained. Some are salvaged and returned to the Delta. The mortality rate despite salvage efforts is not known but entrainment is an ongoing concern (Adams et al. 2002, NOAA NMFS 2006). Power generation facilities with cooling water intakes pose a similar hazard. Water project operations present further barriers to adult spawning migration and juvenile rearing and dispersal at locations throughout the Sacramento River basin and the Delta (NOAA NMFS 2006, 2010). Adult sturgeon are often trapped in the Yolo Bypass where they pass over the Fremont Weir during high flows but cannot use the existing fish ladder to go back upstream. They face a high risk of poaching or desiccation unless they are rescued (California Department of Resources 2005, Harrell and Sommer 2006).

Dredging operations have the potential to entrain juvenile and adult green sturgeon because these fish occur in the benthic zone and move slowly. Dredging may also exacerbate the threat of chemical contamination by disturbing sediments and releasing contaminants from sequestration. Since juveniles are present in San Francisco, San Pablo, and Suisun Bays at all times of year, existing restrictions on when dredging can be done will not protect green sturgeon. It is possible this threat can be mitigated by the use of dredging equipment with design features that minimize the possibility of entrainment. However, the existing dredging program for the San Francisco Bay region may not be protective enough of green sturgeon (NOAA NMFS 2010).

Construction and maintenance of shoreline and in-water structures could cause erosion, disturb sediments, and alter foraging and juvenile rearing habitat in the Delta, Suisun Bay, and San Pablo Bay. These activities are likely to be subject to the prohibitions in NOAA NMFS' section 4(d) regulations (NOAA NMFS 2010).

Year class strength of white sturgeon and several other surrogate species depends on sufficiently high mean daily freshwater outflows into the Delta and San Francisco Bay in April to July (NOAA NMFS 2005). Low flows represent a significant threat to green sturgeon as well, as adults require freshwater outflows to initiate migration toward spawning grounds (NOAA NMFS 2008).

Other threats include elevated water temperatures on the lower Feather River that may kill larvae or limit their growth, commercial and recreational fishing (although California, Oregon, and Washington have adopted much tighter regulations in response to listing of the Southern DPS, bycatch in commercial fisheries and continues), and poaching (NOAA NMFS 2006, 2010).

Critical Habitat. NOAA NMFS designated critical habitat for the Southern DPS of green sturgeon on October 9, 2009. Critical habitat within the Plan Area includes:

- Pelagic and marsh areas of San Pablo Bay and Suisun Bay.
- Green Valley Creek, which drains into Suisun Bay, upstream to the limit of tidal influence at mean higher high water
- The following streams which drain into the Delta: Cache Slough, Lindsey Slough, Shag Slough, Haas Slough, Miner Slough, Steamboat Slough, and the Sacramento River.
- The Yolo Bypass, considered an important rearing area for juveniles that is also used by migrating adults in high flow years.

Mare Island U.S. Army Reserve Center is excluded from critical habitat. All other areas within the Plan Area that are subject to tidal influence are included in critical habitat up to the elevation of mean higher high water. Also included in critical habitat are freshwater riverine areas of the Sacramento River and Yolo Bypass that fall within the Plan Area (NOAA NMFS 2009).

Conservation Issues. The main impacts of the Covered Activities authorized under the Solano Project HCP/NCCP are expected to be ones associated with urban and agricultural runoff, dredging to maintain flood control channels, and shoreline uses.

A formal consultation between NOAA NMFS and the U.S. Corps of Engineers resulted in the determination that sand mining operations in Suisun Bay were unlikely to affect threatened green sturgeon (NOAA NMFS 2010).

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