

early 1990s it appears that green sturgeon have expanded into additional spawning habitat in the upper Sacramento above Hamilton City due to the re-operation of the RBDD (CDFG, 2002). There is uncertainty about the abundance of green sturgeon and the size of the spawning population in the Sacramento River. The CDFG population estimates for San Pablo Bay, which presumably include Sacramento River spawners, are in the range of hundreds to thousands of fish, but there are several problems with the estimates that make them difficult to interpret or rely upon. Similarly, there are no historical estimates of spawning population abundance available to make an assessment of the extent to which spawning populations have declined. The lack of population monitoring data is clearly problematic, but it is not a risk factor directly affecting the status of the DPS.

According to the CDFG, there is no evidence that green sturgeon historically spawned in the San Joaquin River and juveniles that have been found in the lower San Joaquin River are most likely from the spawning population in the Sacramento River (CDFG, 2002). It is uncertain whether green sturgeon ever spawned in the upper Sacramento River above Shasta Dam, but CDFG has speculated that they may have based on the apparent expansion of spawning above Hamilton City in the early 1990s when RBDD was re-operated (CDFG, 2002). The most likely loss of historical spawning habitat for green sturgeon in the central valley may be in the Feather River as a result dam construction and warm water releases (CDFG, 2002), but anecdotal evidence suggests that adult green sturgeon still occur there in high flow years, presumably for spawning. Based on this information, it is uncertain how much green sturgeon spawning habitat historically occurred in the central valley or how much has been lost, and whether or not lost spawning habitat is a significant risk factor for this DPS.

The state and Federal pumping facilities in the Sacramento-San Joaquin Delta export water from the Delta and in the process entrain many fish species including juvenile green sturgeon which are salvaged and returned to the Delta. Expanded estimates of salvage are made annually by CDFG and these data have been collected and compiled since 1968 at the state facility and since 1981 at the Federal facility. The status review qualitatively reviewed the expanded salvage data for the available time series to determine whether there were any trends. The data series indicates that salvage (an indicator of entrainment)

has varied substantially over time, but was much higher prior to the mid-1980s. From the mid-1980s to present, salvage declined substantially at both facilities and has remained very low thereafter. Limited length-frequency data indicates that only juvenile green sturgeon were salvaged at the two facilities. Interpretation of these data is difficult since there have been problems with species identification (distinguishing white and green sturgeon) and the expanded salvage estimates are based on actual counts from brief sampling periods (CDFG 2002). Given the low level of entrainment and salvage that has occurred since the mid-1980s and the problems with interpreting the available data, it is uncertain to what extent water exports and the associated entrainment of green sturgeon is a risk factor for this DPS. In the case of white sturgeon, however, year class strength is related to freshwater flows in late winter and spring rather than Delta exports (CDFG 2002). If this is the case for green sturgeon, which is more marine oriented than white sturgeon, then Delta exports are not likely to be an important risk factor.

The introduction of exotic species in the San Francisco Bay estuary is an ongoing problem, but the most likely effect on green sturgeon is through changes in trophic interactions (CDFG, 2002). For example, the overbite clam, which first was observed in the Bay in 1988, is now the most common food item of white sturgeon and has been found in the diet of green sturgeon (CDFG, 2002). This species may be replacing other clam species in the diet of white and possibly green sturgeon, but it is not possible to assess the impacts of such changes at present. Assessing the impacts of such trophic changes and the extent to which they increase risks to green sturgeon in this DPS will require additional information on the comparative trophic benefits of these new prey and information on the extent to which they bioaccumulate contaminants.

There is no specific information available regarding contaminant loads or impacts on green sturgeon, although there is information on contaminant loads for white sturgeon (CDFG 2002). For example, there is evidence that white sturgeon may have contained high Polychlorinated Biphenyl (PCB) levels in the past (Kohlhorst, 1980), though more recent data show lower levels of contamination suggesting that earlier data may have been incorrect (CDFG, 2002). There is also evidence that white sturgeon in the estuary accumulate selenium, but tissue concentrations

have varied over time without a trend and do not seem to be size related (White et al., 1989). Given the available information, it is uncertain to what extent green sturgeon are impacted by contaminants in this DPS. Based on the fact that white sturgeon spend more time in the estuary and green sturgeon are more marine oriented, CDFG suggests that green sturgeon are probably less vulnerable than white sturgeon to the effects of contaminant bioaccumulation in the San Francisco Bay estuary (CDFG, 2002).

Concerns were raised in the status review that summer temperatures in the Sacramento River were near the lethal limits for larval green sturgeon; however, there is no direct evidence that elevated temperatures are adversely affecting spawning and larval development. In the Sacramento River, green sturgeon are thought to spawn in the spring and summer primarily from Hamilton City to as far upstream as perhaps Keswick Dam (NMFS, 2002; CDFG, 2002). Re-operation of RBDD in the early 1990s to improve upstream passage for winter-run chinook is also thought to have provided a substantial increase in green sturgeon spawning habitat above the facility (CDFG, 2002). Spawning of green sturgeon in the upper Sacramento River above the RBDD is supported by the annual collection of juvenile green sturgeon in fish trapping operations at the RBDD (1995–2001) and the Glenn-Colusa Irrigation District (1986–2001) between the months of May and August (see Figures 13 and 14 in NMFS 2002). Since the early 1990s, significant efforts and measures have been implemented by the Bureau of Reclamation and NMFS to control water temperatures in the upper Sacramento River between the RBDD and Keswick dam in the late spring and early summer so that winter-run chinook salmon can successfully reproduce there. Under the current protocols, water temperatures upstream from RBDD are generally controlled by releases from Shasta and Keswick Dams so that they do not exceed 56 degrees Fahrenheit (or 13.3 degrees Centigrade) from mid April through the end of September. This period of temperature control appears to coincide with green sturgeon spawning, egg incubation, and larval development in the upper river, and therefore, the temperature control efforts for winter-run chinook are likely to benefit and protect green sturgeon as well. Temperatures cannot be controlled downstream of RBDD or in the Sacramento-San Joaquin Delta, so elevated temperatures could potentially