State of California
Department of Fish and Wildlife

Memorandum

Date: **January 31 2024**

To: Nick Bauer
Senior Environmental Scientist; Supervisor
Department of Fish and Wildlife
North Central Region
1701 Nimbus Road, Suite A
Rancho Cordova, CA 95670

Cc: CDFW North Central Region Fish Files

From: Marc Beccio; Environmental Scientist
Department of Fish and Wildlife
1701 Nimbus Road, Suite A
Rancho Cordova, CA 95670

Subject: Juvenile Green Sturgeon mortalities on the Wallace Weir Fish Collection Facility picket fish screen and entrainment investigation.

Purpose

The purpose of this report is to document the occurrence and salvage of southern Distinct Population Segment (sDPS) juvenile green sturgeon (*Acipenser medirostris*) on the Wallace Weir Fish Collection Facility picket weir fish screens. We also address the likely entrainment point from the Sacramento River and the route taken through an extensive irrigation and drainage canal system to the Wallace Weir; as well as observations on growth rates compared to juvenile green sturgeon rearing in the Sacramento River. In late August and early September 2023, two juvenile green sturgeon were captured in crayfish traps deployed by a commercial crayfish harvester in an irrigation canal near Cortena. Both fish were dead upon discovery in the traps and had estimated fork lengths of 110-120 mm. The likely entrainment point was determined to be the Glenn-Colusa Irrigation District Diversion Canal (GCIDDC) at rkm 332. This was calculated by tracing the canal system from the point of capture using Google Earth Pro software. GCID personnel confirmed that the canal where the juvenile green sturgeon were captured is a lateral diversion of the GCIDDC.

Background

Green sturgeon spawning has been documented in a 93 kilometer (km) section of the Sacramento River from Hamilton City (rkm 332.5) upstream to Cottonwood (rkm 426) (Poytress et al. 2013). Green sturgeon spawning has also been documented in the Feather River (Seesholtz et al. 2015) and the Yuba River (CDFW 2018). Spawning in the Sacramento River typically occurs from mid-April through July, although some spawning may occur as late as mid-August in wet water years (personal communication with Bill Poytress). The sDPS Green Sturgeon Recovery Plan states: *Green sturgeon larvae disperse at approximately 12 days post hatch in the laboratory (Kynard et al. 2005). Larval activity is primarily nocturnal, with peaks in migration between dusk and dawn (Kynard et al. 2005; Poytress et al. 2011). Larvae utilize benthic structure (Van Eenennaam et al. 2001; Deng et al. 2002; Kynard et al. 2005) and seek refuge within crevices but will forage over hard surfaces (Nguyen and Crocker 2007). Larval abundance and distribution may be influenced by spring and summer outflow and recruitment may be highest in wet years, making water flow an important habitat parameter (Heublein et. al. 2017).* Larvae continue to rear in the vicinity of their spawning habitat and are considered juveniles at approximately 45 days post-hatch (Heublein *et. al.*2017). Juveniles typically begin downstream migration after late fall or early winter rain events result in flow increases (Hansen *et. al.* 2022). Once downstream migration is initiated, there is no evidence to suggest upstream migration within the Sacramento River occurs until adulthood. Therefore, it is highly likely that juvenile green sturgeon entrained within the GCID service area or the KLRC would exhibit the same migration behavior. CDFW telemetry data for Age-1+ juvenile green sturgeon tagged in the Sacramento River near Sherman Island suggest limited upstream movement, with only a few individuals detected as far upstream as the Cache Slough Complex, a distance of approximately 20 kilometers. Juvenile green sturgeon are also benthic oriented and have not been observed to jump, therefore it is highly unlikely that the four juvenile green sturgeon observed on the WWCF fish screen picket weir were in the KLRC downstream of the WWCF. The 2023 water year was classified as a wet water year, and recruitment of green sturgeon to the larval and early juvenile life stages appears to be the highest in at least 20 years as evidenced by the number of fish captured at the Red Bluff Diversion Dam rotary screw traps and the US Fish and Wildlife-Red Bluff juvenile green sturgeon trawl study (personal communication with Josh Gruber, US Fish and Wildlife-Red Bluff).

Larval and early-stage juvenile green sturgeon have relatively poor swimming capabilities and are therefore susceptible to impingment on water diversion screens or entrainment by unscreened water diversions (Polleto et. al. 2014). The GCIDDC has a fish screen that meets the current screening criteria for CDFW and the National Marine Fisheries Service to prevent entrainment of juvenile salmonids. While the screen is not designed to prevent entrainment of sturgeon eggs, larvae, or early-stage juveniles, the maximum allowable screen opening size of 2.38 mm should in theory prevent entrainment of all green sturgeon life stages. Green sturgeon eggs have an average diameter of 4.34 mm (Van Eenennaam et. al. 2006); post-hatch larvae average 13.7 mm in length. Yolk sac larval diameter was not measured in this study but is likely similar as the eggs. It is therefore unlikely that green sturgeon eggs or newly hatched larvae passed through the GCIDDC fish screen though there may be impingement concerns. At this time, it is unknown if the GCIDDC fish screen was damaged, temporarily lifted from the diversion canal for maintenance repairs, or not installed correctly though a more detail analysis of the GCID screen designs may be helpful given that larvae tend to utilize benthic structure and seek refuge within crevices. Any of these scenarios could result in the entrainment of larval or early-stage juvenile green sturgeon.

Wallace Weir

The Wallace Weir Flow Control Structure and Fish Collection Facility is located in the Knights Landing Ridge Cut (KLRC) approximately 9.7 kilometers southwest of the town of Knights Landing (**Figure 1)**. The Wallace Weir Flow Control structure consists of an earthen berm armored with rip rap and six concrete box culverts which convey water through the structure. Obermeyer bladder dams are located on the upstream side of each culvert to regulate flow and upstream stage height for water diversion. The volume of water that flows in to the KLRC is controlled by the Knights Landing Outfall Gates. The downstream side of each culvert has bottom hinged metal fish screen picket weirs that prevent fish from swimming upstream of the weir and into the KLRC and Colusa Basin Drainage Canal (CBDC). The screens are raised and lowered via an overhead hoist and cable system mounted on the downstream end of the retaining walls. The Obermeyer dams and picket weir fish screens are controlled through a user interface housed in a control building on the top of the levee west of the weir. The fish screens can be programmed to raise and lower at different time intervals. Lowering of the fish screens is also triggered by the amount of force being applied to the screens. This is done to prevent debris build up which could cause a mechanical failure and result in an uncontrolled drop of the screens. Water flowing down the KLRC enters the culverts and flows through the fish screens. Numerous resident fish species in the KLRC and in the CBDC may become impinged on the screens if they redistribute downstream where they are subjected to desiccation or predation (**Figure 2)**.

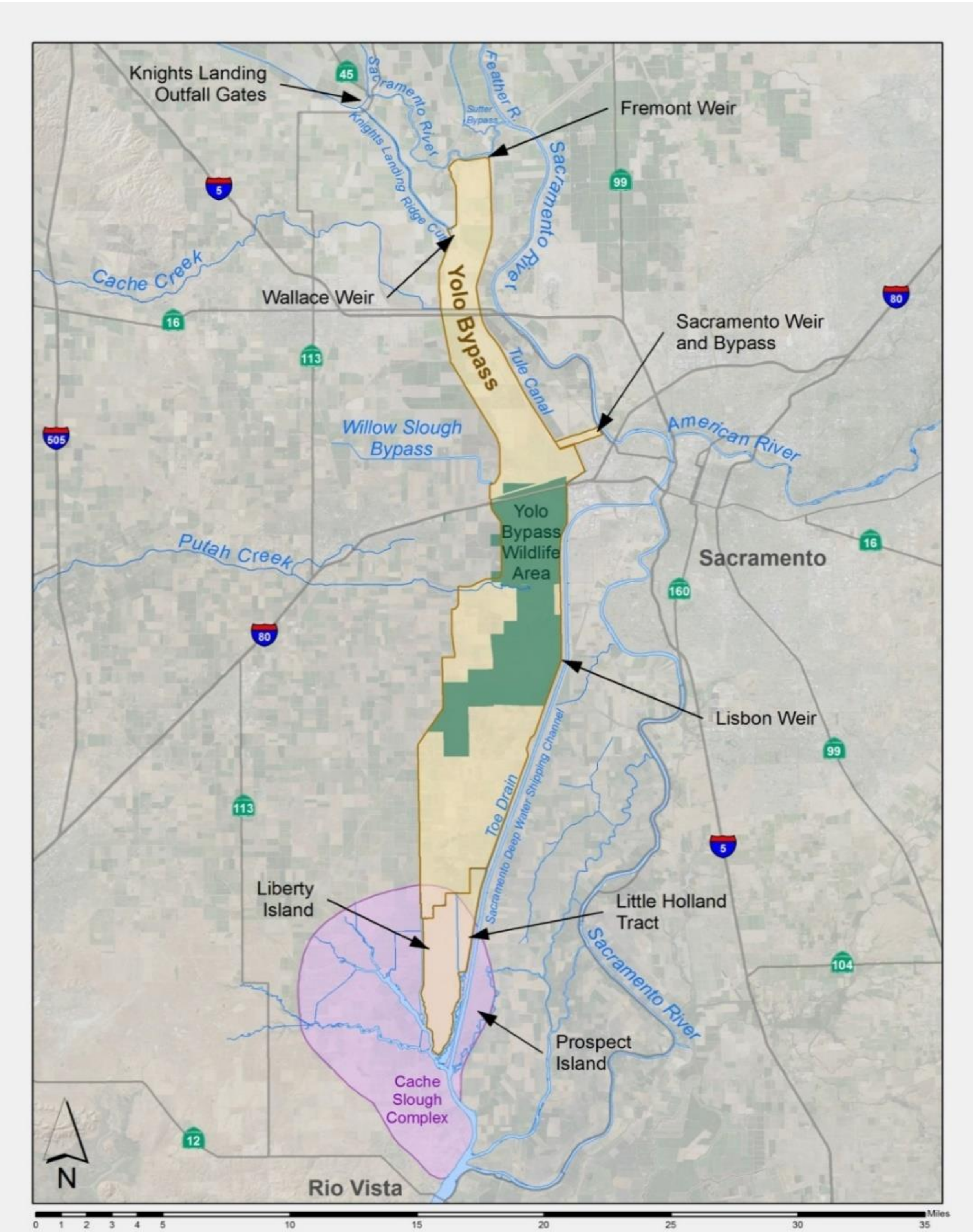

Figure 1. Map of the Yolo Bypass showing the Knights Landing Outfall Gates, Wallace Weir, and the Cache Slough Complex.

Figure 2. WWFCF fish screen picket weirs showing impingment of fish that were traveling downstream in the KLRC. Photograph taken 10 May 2019.

Juvenile green sturgeon mortalities observed on WWFCF picket weir fish screens

On 23 January 2024, CDFW Environmental Scientist Shig Kubo observed a dead juvenile green sturgeon on one of the WWFCF picket weir fish screens during a routine WWFCF salvage check (**Figures 3 and 4**). The fish likely ended up on the screen while traveling downstream in the KLRC sometime after the 22 January WWFCF salvage check. The fish was measured and retained for research purposes. On 24 January 2024, CDFW Environmental Scientist Shig Kubo observed two more juvenile green sturgeon on the WWFCF picket weir fish screens (**Figures 5 and 6**). One fish was still alive but in very poor condition, the other was partially consumed by a predatory mammal, likely a river otter, with only a portion of the body intact. The live juvenile green sturgeon was transported to the Elkhorn Boat Launch facility for release but died prior to release and was retained along with the partial carcass for research purposes.

Figure 3. Juvenile green sturgeon mortality on WWFCF picket weir fish screen; 23 January 2024.

Figure 4. Close up photo of juvenile green sturgeon mortality on WWFCF picket weir fish screen; 23 January 2024. Fork length = 290 mm; weight = 140 g.

Figure 5. Juvenile green sturgeon salvaged from the WWFCF picket weir fish screen; 24 January 2024. The fish was in very poor condition and did not survive. Fork length = 302 mm; weight = 149 g.

Figure 6. Partial carcass of a juvenile green sturgeon salvaged from the WWFCF picket weir fish screen; 24 January 2024. The carcass girth appeared to be slightly larger than the girth of the two intact fish.

A fourth juvenile green sturgeon with a fork length of 290 mm, at total length of 302 mm, and a weight of 140 g was found on the WWFCF picket weir fish screens on 12 February 2024. It is highly unlikely that the juvenile green sturgeon observed on WWFCF picket weir fish screens entered the KLRC via Sacramento River weir overtopping events. The timing of the overtopping events and the size and life stages of the juvenile green sturgeon support this determination. The two juvenile green sturgeon that were captured in crayfish traps deployed in the irrigation canal could not have been entrained by weir overtopping events, as there are no flood control weirs that are hydrologically connected to the GCID service area or the CBDC.

Given that green sturgeon are known to spawn in the upper Sacramento River, likely points of entry for larval sturgeon in the GCID service area irrigation canals are from large scale diversions off of the Sacramento River. The single largest point of diversion for the service area is at the GCIDDC fish screen at river mile 205. Larval and juvenile green sturgeon have been captured in rotary screw traps deployed in the GCID oxbow downstream of the diversion, particularly during the spring and summer of wet water type years. **Table 1** presents GCID rotary screw trap capture data from 1996 through 2006 for larval and juvenile green sturgeon. Capture data for larval or juvenile green after 2006 are currently unavailable.

Table 1. GCID rotary screw trap larval and juvenile green sturgeon capture data, 1996 through 2006. Data for 1998 is either unavailable or no green sturgeon were captured in 1998.

Year	Water type	Number captured	Mean fork length (mm)	Fork length range (mm)	Capture date range
1996	Wet	342	36.5	23 to 179	3/14 to 12/19
1997	Wet	237	47	24 to 340	5/6 to 11/20
1999	Wet	291	36.5	25 to 92	6/11 to 10/30
2000	Above normal	32	54	25 to 550	5/30 to 10/29
2001	Dry	33	37.6	20 to 250	1/11 to 8/16
2002	Dry	7	32.5	26 to 44	5/4 to 6/1
2003	Above normal	9	40	27 to 116	6/12 to 9/14
2004	Below normal	6	72.5	31 to 272	5/23 to 10/27
2005	Above normal	31	34.7	24 to 51	6/27 to 9/5
2006	Wet	6	33	30 to 36	7/16 to 8/5

Google Earth Pro software was used to determine the most likely route(s) taken by the juvenile green sturgeon captured in crayfish traps from the likely entrainment point at the GCIDDC to the point of capture in an irrigation canal in late August and early September 2023; and the four juvenile green sturgeon observed at the WWFCF 23-24 January and 12 February 2024 (**Figure 7**). The route highlighted in yellow is approximately 97 miles from the point of entrainment at the GCIDDC to the WWFCF.

The six juvenile green sturgeon observed in GCID service area irrigation canals and drainage ditches suggest that considerably more green sturgeon were likely entrained at the GCIDDC, most likely when they were in the larval or early juvenile life stages and more susceptible to entrainment due to their weak swimming capabilities. Juvenile green sturgeon entrained in the GCID service area are likely lost to the population unless weir overtopping events result in flow increases within the KLRC are that are high enough to facilitate passage over the Wallace Weir fish screen picket weirs. It is important to determine if the fish screens at the GCIDDC were indeed damaged or out of the water or if there are other structural aspects that may lead to larval sturgeon entrainment. The timing and duration of these events is crucial to understanding the magnitude of the juvenile green sturgeon entrainment event.

The length and weight of the three intact juvenile green sturgeon observed at the WWFCF were considerably larger than the 2023 brood year juvenile green sturgeon captured in the Sacramento River in the vicinity of Red Bluff (**Table 1**). Water temperatures in the GCIDDC and Colusa Trough and Colusa Basin Drainage Canal are considerably higher than those in the reaches of the Sacramento River where juvenile green sturgeon rear. Water temperatures in the Colusa Basin Drainage Canal likely approach or exceed 30° C during the hottest months of the year. Sadella et. al. (2008) reported the lethal temperature range of northern Distinct Population Segment (DPS) juvenile green sturgeon to range from 33.7° C to 34.2° C. Mayfield *et. al.* (2004) determined that growth rates for laboratory reared juvenile northern Distinct Population Segment (DPS) green sturgeon were greatest between 15° C and 19° C. Southern DPS green sturgeon likely have maximum growth rates at higher temperatures given that they have evolved in the Sacramento River system where water temperatures are typically warmer than where juvenile northern DPS green sturgeon rear.

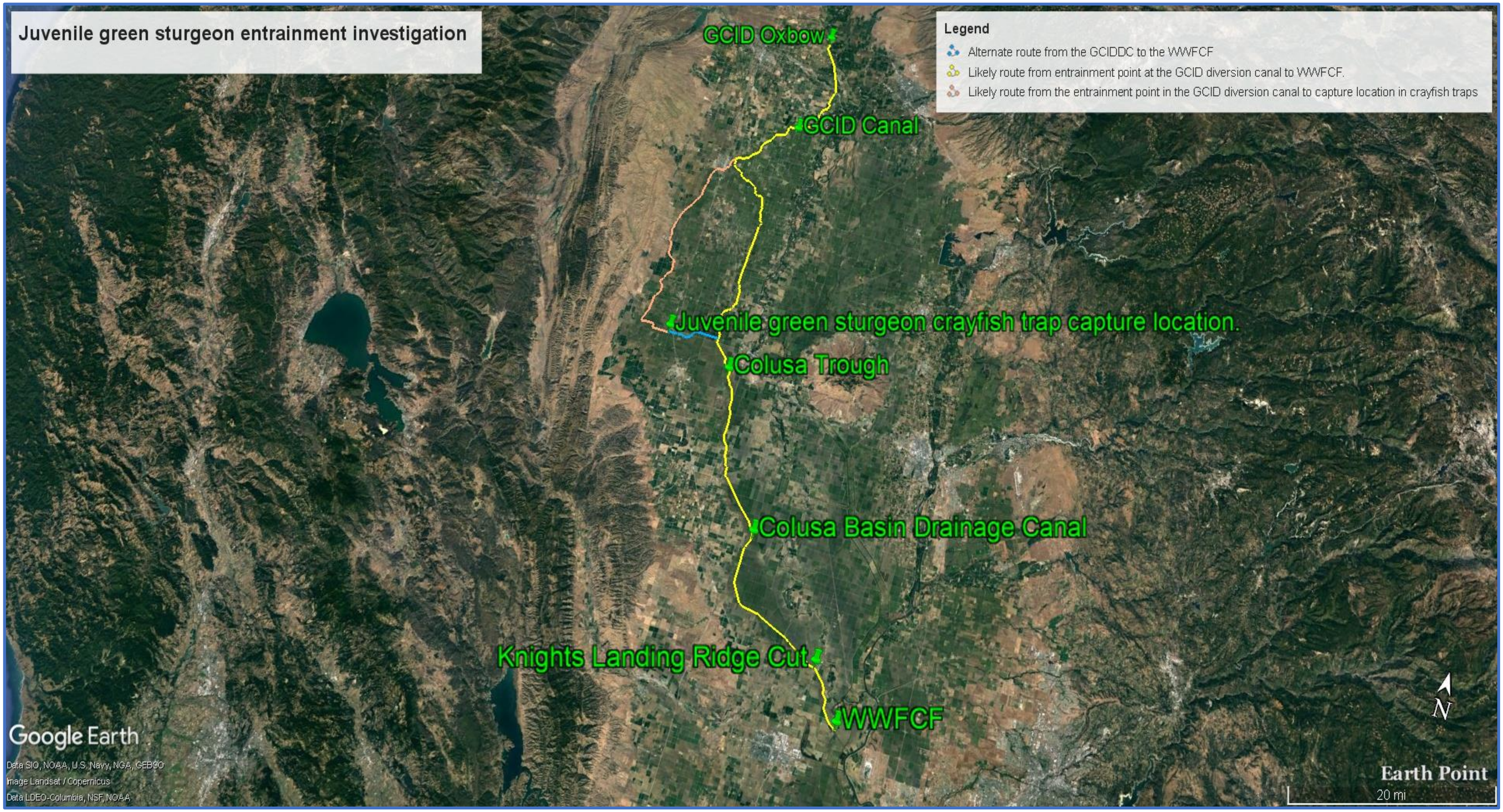

Figure 7. Likely juvenile green sturgeon entrainment point at the GCID diversion canal and travel route to the WWFCF.

Benthic macroinvertebrate abundance in the irrigation canals and drainage ditches is likely an unlimited prey source for juvenile green sturgeon and would facilitate rapid growth. A stomach content analysis was conducted on the two intact juvenile sturgeon salvaged from the WWFCF. Stomachs of both fish contained small quantities of thoroughly digested material and no discernable benthic macroinvertebrates.

Table 1. Size comparison of juvenile green sturgeon observed at the WWFCF, and recent sample of juvenile green sturgeon captured in the USFWS-Red Bluff RST at the Red Bluff Diversion Dam and the USFWS-Red Bluff Otter Trawl survey near Red Bluff. The sizes of the juvenile green sturgeon salvaged at the WWFCF were significantly greater than those captured in the rearing habitat of the upper Sacramento River (*ANOVA p-value <0.01 for both length and weight*).

Capture location	Date	Total Length (mm)	Fork length (mm)	Weight (g)
WWFCF	1/23/24	303	290	140
WWFCF	1/24/24	328	302	149
WWFCF	2/12/24	304	290	140
Sacramento River rkm 350-394	11/16 to 12/19/23	108 to 266; mean = 163.6	99 to 238; mean = 155.5	6.3 to 98.5; mean = 28.7

While larval green sturgeon that survive to older juvenile phases apparently have much higher growth rates in the GCIDDC and Colusa Basin Drainage Canal network, entrainment from the diversions on the Sacramento River ultimately negatively impacts recruitment. Fish entrained in the canal systems are unable to return to the Sacramento River and are ultimately lost to the population. In addition to large scale diversions with fish screens which meet criteria specified by CDFW and the Nation Marine Fisheries Service, there are also over 3,000 unscreened diversions that also may entrain juvenile green sturgeon (Mussen *et. al.* 2014). The Recovery Plan for the Southern Distinct Population Segment of North American Green Sturgeon lists entrainment of sDPS green sturgeon larvae and juveniles as a medium research priority, however given these recent observations of juvenile green sturgeon entrainment, research to determine the sources and magnitude of entrainment events is warranted.

References

CDFW 2018. 2018 Yuba River Sturgeon Spawning Study. Available at: https//:nrm.dfg.ca.gov/documents/ContextDocs.aspx?cat=R2-Fish

Deng, X., J. P. Van Eenennaam, and S. I. Doroshov. 2002. Comparison of Early Life Stages and Growth of Green and White Sturgeon. American Fisheries Society Symposium 28:237-248.

Hansen, A. C., R. D. Chase, , J. Tobias, J. R. Kock, R., W. Perry, J. J. Gruber, W. R. Poytress, W. R. 2022. Juvenile Green Sturgeon (*Acipenser medirostris*) Movement During Autumn and Winter in the Lower Sacramento River, California, 2016–20. Open-File Report 2022-1091. Prepared in cooperation with the U.S. Army Corps of Engineers.

Heublein, J C.; Bellmer, R. J. Chase, R. D., Doukakis, P, Gingras, M. Hampton, D., Israel, J. A. Jackson, Z. J., Johnson, R. C., Langness, O. P., Luis, S., Mora, E. Moser, M. L., Rohrbach, L., Seesholtz, A. M., Sommer, T. 2017. NOAA technical memorandum NMFS;NOAA-TM-NMFS-SWFSC ; 588;DOI : http://doi.org/10.7289/V5/TM-SWFSC-588.

Mussen T.D., Cocherell D., Poletto J.B., Reardon J.S., Hockett Z., Ercan A., (2014) Unscreened Water-Diversion Pipes Pose an Entrainment Risk to the Threatened Green Sturgeon, *Acipenser medirostris*. PLOS ONE 9(1): e86321. https://doi.org/10.1371/journal.pone.0086321

Poletto, J. B., D. E. Cocherell, N. Ho, J. J. Cech, A. P. Klimley, and N. A. Fangue. 2014a. Juvenile Green Sturgeon *(Acipenser medirostris)* and White Sturgeon *(Acipenser transmontanus)* Behavior near Water-Diversion Fish Screens: Experiments in a Laboratory Swimming Flume. Canadian Journal of Fisheries and Aquatic Sciences 71(7):1030-1038.

Poytress, W. R., J. J. Gruber, J. P. Van Eenennaam, and M. Gard. 2015. Spatial and Temporal Distribution of Spawning Events and Habitat Characteristics of Sacramento River Green Sturgeon. Transactions of the American Fisheries Society 144(6):1129-1142.

Sardella B.A., Sanmarti E., Ku¨ltz D. 2008. The acute temperature tolerance of green sturgeon (Acipenser medirostris) and the effect of environmental salinity. J. Exp. Zool. 309A:477–483.

Seesholtz, A. M., M. J. Manuel, and J. P. Van Eenennaam. 2014. First Documented Spawning and Associated Habitat Conditions for Green Sturgeon in the Feather River, California. Environmental Biology of Fishes 98(3):905-912.

Van Eenennaam, J. P., J. Linares, S. I. Doroshov, D. C. Hillemeier, T. E. Willson, and A. A. Nova. 2006. Reproductive Conditions of the Klamath River Green Sturgeon. Transactions of the American Fisheries Society 135(1):151-163.