TRPA Fish Biologists
890 L Street
Arcata, CA 95521
(707) 630-5220

Memorandum

DATE: March 7, 2022
TO: Roland Sanford, Chris Lee, and Alex Rabidoux, Solano County Water Agency (SCWA)
FROM: Tim Salamunovich, TRPA Fish Biologists
RE: Fall 2020 through Fall 2021 Upper Barker Slough Fish Surveys – Final Report

Background

Barker Slough is a major tributary to Lindsey Slough and is part of the Cache Slough complex located in the northwest corner of the Sacramento-San Joaquin River Delta at the downstream end of the Yolo Bypass. Barker Slough stretches southeast from the northeast end of Travis Air Force Base to its mouth at the junction with Lindsey Slough, which is near the junction of the Lindsey Slough and Calhoun Cut. The entire Barker Slough drainage lies within southeastern Solano County. The lower 2 miles of Barker Slough is tidal and the Barker Slough Pump Plant, part of the State Water Project's North Bay Aqueduct (NBA) Project, is located at Slough Mile (SM) 1.6. The NBA Project provides drinking water for up to 500,000 people in urban areas of Napa and Solano Counties. Most of the length of Barker Slough is ranched, and in some areas, cattle have free access to the slough. Water coming from the slough has been shown to have high amounts of organic carbon, bacterial coliform, turbidity and salts that exceed drinking water standards (Kennedy Jenks 2019). Two small dams are located on Barker Slough upstream of the NBA. The first unnamed earthen dam is located on Barker just downstream of Highway 113 at SM 2.2; the second dam, located at SM 3.7, is known as Campbell Lake Dam. The upper Barker Slough Project area refers to the portion of the basin that lies upstream of the Campbell Lake Dam (Figure 1).

Outflows from Campbell Lake appear to increase carbon and/or plankton concentrations downstream into Barker Slough, with high runoff flushing organic matter, nutrients, and sediment from the lake (Durand et al. 2019). These inputs from the upper Barker Slough basin, which detract from the quality of the water at the NBA Project pumps,

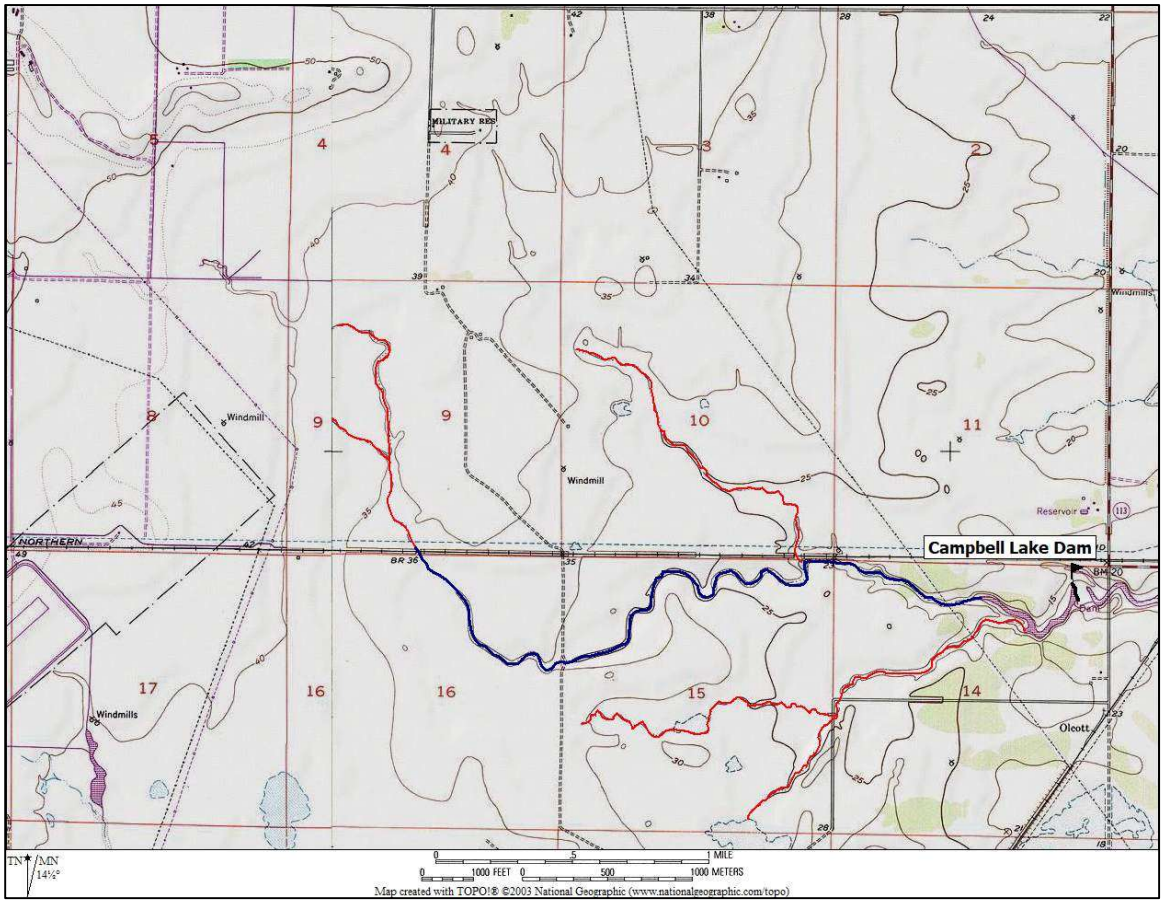

Figure 1. Map showing the upper Barker Slough drainage area upstream of Campbell Lake Dam. The blue line is the active Barker Slough channel; red lines denote relict channels that are active only during floods.

provide valuable materials for later utilization by microorganisms, phytoplankton, and zooplankton and fish (Durand et al. 2019).

The upper Barker Slough area drains about 14.8 square miles of lowlands that are part of the Greater Jepson Prairie Ecosystem characterized by flat topography punctuated by meandering low elevation drainages. Elevations range 10 to 70 feet above sea level and the average annual precipitation is 17-20 inches (Witham 2006). The Project area for this study comprised 2.3 miles of upper Barker Slough about 1 mile upstream of Campbell Lake Dam, between SM 4.8 and SM 7.1 (Figure 2). The channel in this area is

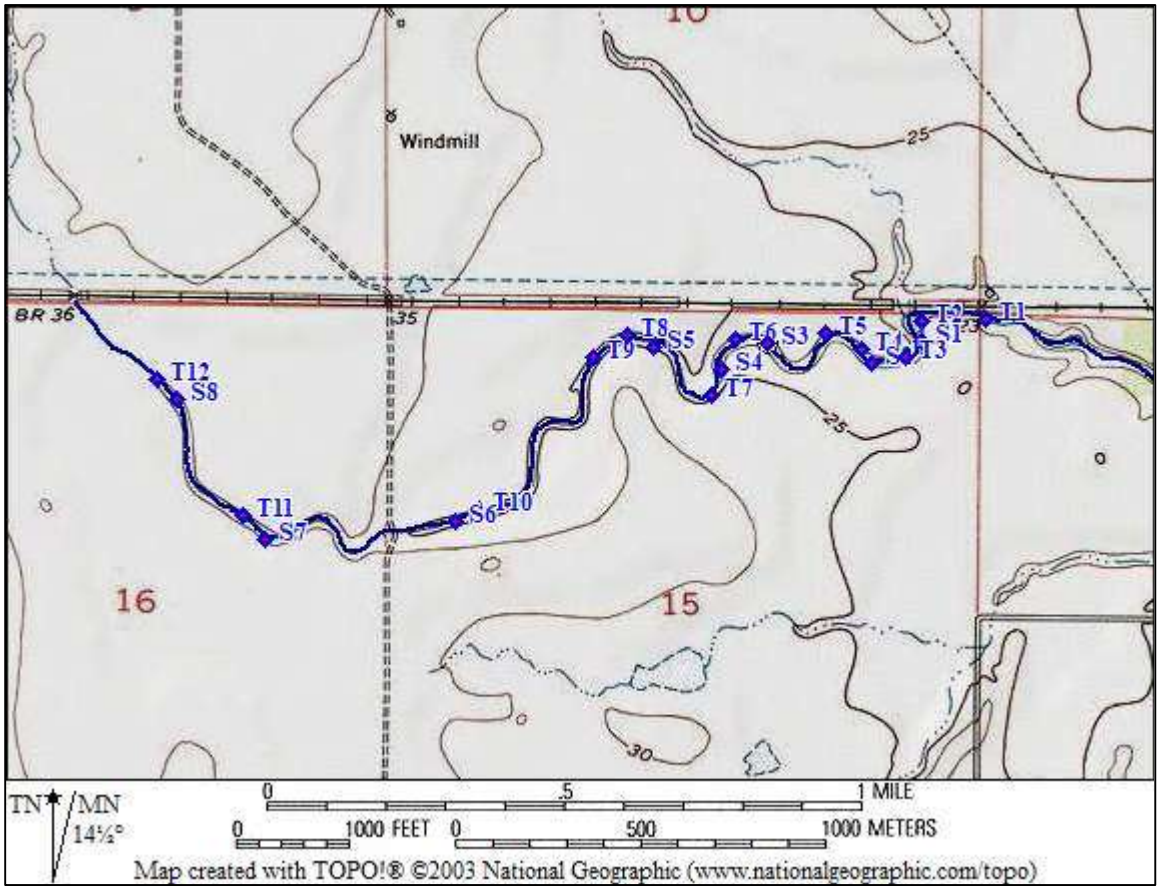

Figure 2. Map of the upper Barker Slough Project area showing the location of the eight seining (S) and twelve minnow trapping (T) sites sampled during the five seasonal fish surveys conducted between late October 2020 and mid-November 2021.

deeply incised and while most of the channel was open water, there are several large stretches of channel choked with wetland vegetation comprised of a mixture of sedges and reeds (Photographs 1 through 3). The upper Barker Slough study area is privately owned. Most of the study area is part of the Dally Ranch, with a short, 0.6-mile long section near the upstream end of the study area owned by Canon Station, LLC, that serves as a compensatory mitigation bank site under the Clean Water Act Section 404 regulations. It is important to note that the entire Barker Slough channel through the study area is completely fenced and cattle are excluded from the active water channel.

Photograph 1. Upper Barker Slough during August 2019 site visit.

Photograph 2. Upper Barker Slough during August 2019 site visit.

Photograph 3. Upper Barker Slough during August 2019 site visit. Note channel chocked with sedges and reeds.

Solano County Water Agency (SCWA), which manages the NBA Project downstream, has studied the erosion problems in upper Barker Slough and is interested in promoting restoration projects to limit bank erosion, restore native riparian vegetation, and benefit water quality throughout the Barker Slough basin. TRPA Fish Biologists was contracted to conduct periodic seasonal surveys to document existing fish and aquatic resources in upper Barker Slough. TRPA Fish Biologists worked closely with Alex Rabidoux from SCWA to obtain landowner permission to access the study area. The original project area reconnaissance site visit (August 2019) and the first three seasonal fish surveys (October 2019, February 2020, and June 2020) were reported on in a previous report (Salamunovich 2020). This report will present the results of the five season fish surveys conducted between October 2020 and November 2021.

Methods

Fish surveys were conducted using 1/8”-mesh 25’ X 4’ pole seines through open-water areas along the upper Barker Slough Project area. Depending on the configuration of the slough channel and the location of the ending beach location where a seine could be landed, the pole seine was deployed from bank to bank and then swept through the water for some distance and then landed at an area of open bank shore. Usually, two separate seine hauls were conducted at each site, one in the upstream direction and one in the downstream direction. The length of sample reaches at each site varied based on where seines could be deployed and recovered. Typically, 60 to 100 feet of slough habitat sampled during each seine haul (upstream of downstream) at each site. Once on shore, the float and lead lines were slowly gathered together and captured fish were collected into a central bag area where they could be removed by hand or a small dip net into a waiting bucket of clean slough water equipped with a small battery-powered aerator. Captured fish were then identified and measured to the nearest millimeter fork length (FL) (or total length [TL] for mosquitofish, stickleback, and sculpin) and released. If numerous individuals from a species were captured, a subsample were measured, and the remainder were counted. Multiple seine hauls were conducted if few fish were captured during the first haul, or an unsatisfactory haul was made during the first seine haul.

In addition to seine samples, minnow traps were used to sample fish in upper Barker Slough. Gee 9’ X 17.5” 1/8”-mesh exotic fish traps were deployed along the study area (Photographs 4 and 5). These galvanized steel wire traps have two throats with 1" openings on each end. Buoyed float lines aided in deployment and retrieval. Minnow traps were baited using a small chunk (about 0.2 ounce) piece of commercially available chicken-blood catfish bait, whose strong-scent was designed to attract fish into the traps. The bait was wrapped and tied in a fine mesh gauze fabric to deter trapped fish from completely consuming bait and reducing the attraction to traps.

Photograph 4. Gee minnow trap used for the upper Barker Slough fish surveys.

Photograph 5. Minnow trap deployed in Barker Slough, November 2021.

Traps were allowed to soak for about 21 hours (range 18 to 26 hours) before retrieval. Captured fish were dumped into a bucket of clean slough water equipped with a small battery-powered aerator. Captured fish were then identified and measured to the nearest millimeter FL or TL and released.

Several water quality parameters including water temperature, dissolved oxygen, conductivity, salinity, and pH were measured with hand-held meters at the time of seine sampling. Only water temperatures were recorded at the time of minnow trap deployment and retrieval. A small hand-held global positioning system was used to determine latitude/longitude coordinates at each sample site and used to relocate sites on subsequent trips.

It should be noted that surveys provide data on the relative abundance of fishes at each study sites and should not be construed as suitable for determining population estimates.

Results

Eight seine sites and twelve minnow trap sites distributed along the 2.3-mile-long project area were surveyed during each of the five seasonal sampling periods: October 24-26, 2020; February 2-4, 2021; April 26-28, 2021; July 25-27, 2021; and November 15-17, 2021. Three days were typically required to complete each sampling event, with traps deployed in the upper half of the project area on the afternoon of day one. Seine sampling in that area was conducted the next morning and early afternoon, followed by retrieval of the traps deployed the previous afternoon. Minnow traps were then re-deployed in the lower half of the project area in the late afternoon. Seine sampling in the lower project area was conducted the next morning followed by retrieval of the traps deployed the previous afternoon. The Fall 2021 sampling was originally scheduled for late October 2021, which coincided with the conclusion of an historic regional rain event, known as a "bomb cyclone", that channeled an atmospheric river into the North Bay Area and resulting in rainfall records throughout the region. The mean four-day rainfall for the period of October 21-24, 2021, recorded at the three closest Department of

Water Resources California Irrigation Management Information System (CIMIS) gages that surround the upper Barker Project area (Carneros/Winters/Hastings Tract East) was 5.7 inches. The monthly average for the entire month of October for these gages during the previous ten years (2011-2020) was 0.59 inches. When we arrived on site for the Fall 2021 survey on October 25th, the entire project area was running at flood flow and the slough was out of channel, with water levels 4 to five feet above normal (Photographs 6 through 8). The Fall 2021 survey were postponed for three weeks until water levels in the slough had returned to normal levels and conditions for safely wading and seining were present.

There was continuous flow through the upper Barker Slough project area at the time of each survey (Table 1). The first four surveys considered in this report were conducted between late October 2020 and late July 2021 and occurred during a dry water year in the Sacramento Valley according to the Sacramento Valley 40-30-30 Hydrologic Classification Index, while the final survey in November 2021 following an unusually wet late fall season winter. During the ten-month period over which the first four surveys occurred (October 2020 through July 2021) an average of 6.06 inches of total precipitation occurred at the three CIMIS gages nearest to the upper Barker Project area. During the six weeks prior to the mid-November 2021 survey, 7.13 inches of rain was recorded at the same three CIMIS gages (three gage average).

Water Quality

All the water quality parameters showed a seasonal variability over the course of the thirteen-month long survey period (Table 1). As might be expected, water temperatures varied between seasons, with the coolest water temperatures (average of 11.4°C [52.54°F]) occurred during the winter surveys conducted in early February, while the warmest water temperatures (average of 20.1°C [68.1°F]) occurred during the summer surveys conducted in late July. Also noteworthy was the diurnal variation in water temperatures during the surveys, with morning water temperatures being considerably cooler than afternoon water temperatures during the efforts. In October 2020 the difference between the morning and afternoon water temperatures averages was 5.8°C

Photograph 6. Upper Barker Slough downstream of Minnow Trap Site 9 on (A) 25 October 2021 immediately after record breaking regional rainfall and (B) three weeks later, on 15 November 2021. Note the abandoned from loader in the background.

Photograph 7. Upper Barker Slough at Minnow Trap Site 10 on (A) 2 February 2021 and (B) nine months later, on 25 October 2021 immediately after record breaking regional rainfall. Note cattle gate in background.

Photograph 8. Upper Barker Slough at Seine Site 4 on (A) 25 October 2021 immediately after record breaking regional rainfall (arrow denotes location of seine site) and (B) three weeks later, on 15 November 2021.

Table 1. Site/gear type identification (S=seine; T=trap), sample date, seine mesh size, seine distance or trap soak time, discharge estimate, time of day, water temperature, conductivity, salinity, dissolved oxygen, and pH levels for the upper Barker Slough fish surveys, October 2020 through November 2021.

Site	Date	seine mesh (in)	seine distance* (ft) trap soak time (hr)	Q_{est} (cfs)	Time	Water Temp °C	Water Temp °F	Conductivity µS/cm	Specific Conductivity	Salinity	Dissolved Oxygen mg/L	Dissolved Oxygen % saturation	pH
S1	26-Oct-20	1/8	60-60	3.0	8:07	9.7	49.5	457.0	645.0	0.3	10.91	95.2	7.8
S2	26-Oct-20	1/8	80-80	3.0	8:55	8.6	47.5	437.6	637.0	0.3	11.07	96.9	7.9
S3	26-Oct-20	1/8	60-70-50	3.0	10:18	8.8	47.8	399.2	579.0	0.3	9.54	84.1	7.9
S4	25-Oct-20	1/8	100	3.0	8:20	14.1	57.4	419.2	530.0	0.3	7.74	76.3	7.2
S5	25-Oct-20	1/8	100-100	3.0	9:54	14.2	57.6	425.6	536.0	0.3	6.66	66.1	8.0
S6	25-Oct-20	1/8	100-100	3.0	11:03	15.0	59.0	438.4	542.0	0.3	9.13	92.1	7.7
S7	25-Oct-20	1/8	75-85	3.0	12:50	15.8	60.4	479.0	580.0	0.3	10.45	107.7	8.2
S8	25-Oct-20	1/8	40	3.0	14:40	16.2	61.2	517.0	621.0	0.3	11.60	120.8	8.4
T1	26-Oct-20		18.92		11:55	8.8	47.8						
T2	26-Oct-20		18.87		11:44	10.1	50.2						
T3	26-Oct-20		18.82		11:35	9.8	49.6						
T4	26-Oct-20		18.75		11:27	9.7	49.5						
T5	26-Oct-20		18.72		11:20	9.7	49.5						
T6	26-Oct-20		18.68		11:10	9.1	48.4						
T7	25-Oct-20		23.08		16:18	16.2	61.2						
T8	25-Oct-20		22.95		16:04	16.4	61.5						
T9	25-Oct-20		23.00		15:58	16.6	61.9						
T10	25-Oct-20		22.97		15:42	16.7	62.1						
T11	25-Oct-20		22.93		15:20	16.7	62.1						
T12	25-Oct-20		23.03		15:07	16.7	62.1						

Site	Date	seine mesh (in)	seine distance (ft) trap soak time (hr)	Q_{est} (cfs)	Time	Water Temp °C	Water Temp °F	Conductivity µS/cm	Specific Conductivity	Salinity	Dissolved Oxygen mg/L	Dissolved Oxygen % saturation	pH
S1	4-Feb-21	1/8	50-60	0.50	7:45	7.2	45.0	419	632	0.3	9.01	74.1	7.7
S2	4-Feb-21	1/8	100-30-60	0.50	8:40	7.2	45.0	430	647	0.3	9.16	75.8	7.8
S3	4-Feb-21	1/8	100-70	0.50	10:08	15.0	59.0	489	730	0.4	7.52	64.4	7.8
S4	3-Feb-21	1/8	60-40	0.50	8:10	6.1	43.0	358	513	0.2	8.86	78.6	7.7
S5	3-Feb-21	1/8	75-75	0.50	9:00	7.2	45.0	368	531	0.3	9.10	78.0	7.7
S6	3-Feb-21	1/8	80-60	0.50	9:50	7.8	46.0	379	542	0.3	9.22	79.7	7.7
S7	3-Feb-21	1/8	30-100	0.50	10:48	15.6	60.0	409	574	0.3	8.85	78.2	7.7
S8	3-Feb-21	1/8	40-50	0.50	11:40	15.0	59.0	440	616	0.3	7.63	67.5	7.7
T1	3-Feb-21		20.38		15:11	11.9	53.4						
	4-Feb-21				11:34	9.4	48.9						
T2	3-Feb-21		20.22		15:02	13.4	56.1						
	4-Feb-21				11:15	9.6	49.3						
T3	3-Feb-21		20.27		14:43	12.0	53.6						
	4-Feb-21				10:59	8.5	47.3						
T4	3-Feb-21		20.32		14:31	12.0	53.6						
	4-Feb-21				10:50	8.7	47.7						
T5	3-Feb-21		20.32		14:24	11.5	52.7						
	4-Feb-21				10:43	7.8	46.0						
T6	3-Feb-21		20.35		14:10	11.0	51.8						
	4-Feb-21				10:31	7.6	45.7						
T7	2-Feb-21		23.48		14:26	13.7	56.7						
	3-Feb-21				15:55	11.0	51.8						
T8	2-Feb-21		22.93		14:44	15.4	59.7						
	3-Feb-21				13:40	11.9	53.4						
T9	2-Feb-21		22.58		14:59	15.7	60.3						
	3-Feb-21				13:34	12.0	53.6						
T10	2-Feb-21		22.02		15:14	16.2	61.2						
	3-Feb-21				13:15	12.2	54.0						
T11	2-Feb-21		21.25		15:41	14.3	57.7						
	3-Feb-21				12:56	11.9	53.4						
T12	2-Feb-21		20.72		15:55	14.8	58.6						
	3-Feb-21				12:38	10.7	51.3						

Site	Date	seine mesh (in)	seine distance (ft) trap soak time (hr)	Q_{est} (cfs)	Time	Water Temp °C	Water Temp °F	Conductivity µS/cm	Specific Conductivity	Salinity	Dissolved Oxygen mg/L	Dissolved Oxygen % saturation	pH
S1	28-Apr-21	1/8	50-50	0.50	7:59	14.4	58.0	506	639	0.3	5.58	53.9	7.5
S2	28-Apr-21	1/8	75-80	0.50	8:40	15.6	60.0	553	693	0.3	4.78	46.9	7.5
S3	28-Apr-21	1/8	80-100	0.50	10:32	26.1	79.0	704	869	0.4	8.67	85.7	7.7
S4	27-Apr-21	1/8	50-75	0.50	8:03	14.4	58.0	412	541	0.3	6.88	69.4	7.6
S5	27-Apr-21	1/8	50-50	0.50	9:33	21.7	71.0	433	599	0.3	7.21	68.7	7.7
S6	27-Apr-21	1/8	60-75	0.50	10:15	21.7	71.0	468	577	0.3	8.93	89.6	8.1
S7	27-Apr-21	1/8	70	0.50	11:27	23.3	74.0	547	642	0.3	8.83	92.3	8.3
S8	27-Apr-21	1/8	30-50	0.50	13:15	28.9	84.0	589	672	0.3	7.24	73.8	8.1
T1	27-Apr-21		19.13		17:36	17.3	63.1						
	28-Apr-21				12:27	15.2	59.4						
T2	27-Apr-21		19.22		17:13	21.2	70.2						
	28-Apr-21				12:15	19.1	66.4						
T3	27-Apr-21		19.07		16:55	19.7	67.5						
	28-Apr-21				12:02	17.8	64.0						
T4	27-Apr-21		19.12		16:47	20.0	68.0						
	28-Apr-21				11:51	17.9	64.2						
T5	27-Apr-21		19.03		16:25	19.6	67.3						
	28-Apr-21				11:38	17.2	63.0						
T6	27-Apr-21		18.85		16:12	18.3	64.9						
	28-Apr-21				11:20	15.4	59.7						
T7	26-Apr-21		25.02		14:50	16.7	62.1						
	27-Apr-21				15:51	18.5	65.3						
T8	26-Apr-21		24.48		15:06	16.9	62.4						
	27-Apr-21				15:35	20.7	69.3						
T9	26-Apr-21		24.18		15:16	16.8	62.2						
	27-Apr-21				15:27	21.2	70.2						
T10	26-Apr-21		23.68		15:29	16.8	62.2						
	27-Apr-21				15:10	22.6	72.7						
T11	26-Apr-21		22.73		15:54	17.6	63.7						
	27-Apr-21				14:38	22.1	71.8						
T12	26-Apr-21		22.22		16:07	17.8	64.0						
	27-Apr-21				14:20	17.5	63.5						

Table 1. Site/gear type identification (S=seine; T=trap), sample date, seine mesh size, seine distance or trap soak time, discharge estimate, time of day, water temperature, conductivity, salinity, dissolved oxygen, and pH levels for the upper Barker Slough fish surveys, October 2020 through November 2021. (continued)

Site	Date	seine mesh (in)	seine distance (ft) trap soak time (hr)	Q_{est} (cfs)	Time	Water Temp *C	Water Temp *F	Conductivity µS/cm	Specific Conductivity	Salinity	Dissolved Oxygen mg/L	Dissolved Oxygen % saturation	pH
S1	27-Jul-21	1/8	60-60-80	0.50	7:20	17.9	64.2	403	466	0.2	6.59	68.8	6.8
S2	27-Jul-21	1/8	75-100	0.50	8:25	17.5	63.5	358	418	0.2	6.79	71.1	7.5
S3	27-Jul-21	1/8	100	0.50	9:58	17.4	63.3	362	424	0.2	9.45	98.5	7.0
S4	26-Jul-21	1/8	30-100	0.50	7:15	15.9	60.6	456	549	0.3	7.49	75.4	7.0
S5	26-Jul-21	1/8	45-100	0.50	8:55	15.3	59.5	483	594	0.3	7.46	74.9	7.0
S6	26-Jul-21	1/8	75-90	0.50	10:15	17.9	64.2	553	639	0.3	8.83	93.5	7.6
S7	26-Jul-21	1/8	90-100	0.50	11:35	19.1	66.4	593	667	0.3	7.58	82.6	7.8
S8	26-Jul-21	1/8	50-75	0.50	13:05	18.5	65.3	616	702	0.3	8.14	87.2	7.5
T1	26-Jul-21		19.38		15:11	19.3	66.7						
	27-Jul-21				11:34	18.4	65.1						
T2	26-Jul-21		19.33		15:02	21.3	70.3						
	27-Jul-21				11:15	18.4	65.1						
T3	26-Jul-21		19.33		14:43	21.0	69.8						
	27-Jul-21				10:59	18.0	64.4						
T4	26-Jul-21		19.28		14:31	21.5	70.7						
	27-Jul-21				10:50	17.9	64.2						
T5	26-Jul-21		19.27		14:24	21.1	70.0						
	27-Jul-21				10:43	17.7	63.9						
T6	26-Jul-21		19.22		14:10	19.5	67.1						
	27-Jul-21				10:31	17.6	63.7						
T7	25-Jul-21		24.47		14:26	22.7	72.9						
	26-Jul-21				15:55	19.6	67.3						
T8	25-Jul-21		23.97		14:44	25.8	78.4						
	26-Jul-21				13:40	21.3	70.3						
T9	25-Jul-21		23.80		14:59	22.8	73.0						
	26-Jul-21				13:34	21.4	70.5						
T10	25-Jul-21		23.25		15:14	27.5	81.5						
	26-Jul-21				13:15	21.5	70.7						
T11	25-Jul-21		22.57		15:41	26.6	79.9						
	26-Jul-21				12:56	19.9	67.8						
T12	25-Jul-21		22.10		15:55	23.4	74.1						
	26-Jul-21				12:38	18.4	65.1						

Site	Date	seine mesh (in)	seine distance (ft) trap soak time (hr)	Q_{est} (cfs)	Time	Water Temp *C	Water Temp *F	Conductivity µS/cm	Specific Conductivity	Salinity	Dissolved Oxygen mg/L	Dissolved Oxygen % saturation	pH
S1	17-Nov-21	1/8	40-45	0.50	7:35	13.0	55.4	2,054	2,664	1.4	4.38	41.9	
S2	17-Nov-21	1/8	75-100	0.50	8:08	12.2	54.0	1,999	2,650	1.4	6.57	61.7	
S3	17-Nov-21	1/8	100-100	0.50	8:59	11.0	51.8	2,045	2,789	1.5	9.74	89.3	
S4	16-Nov-21	1/8	40-100	0.50	7:40	13.2	55.8	2,048	2,645	1.4	2.71	26.0	
S5	16-Nov-21	1/8	100-100	0.50	8:43	13.2	55.8	1,931	2,495	1.3	8.34	80.3	
S6	16-Nov-21	1/8	60-80	0.50	9:42	13.7	56.7	2,083	2,657	1.4	8.19	79.8	
S7	16-Nov-21	1/8	120-120	0.50	10:38	14.6	58.3	2,146	2,679	1.4	8.55	85.4	
S8	16-Nov-21	1/8	40-80	0.50	12:55	17.0	62.6	2,292	2,704	1.4	7.58	79.2	
T1	16-Nov-21		18.62		16:13	14.7	58.5						
	17-Nov-21				10:50	14.1	57.4						
T2	16-Nov-21		18.58		16:04	16.3	61.3						
	17-Nov-21				10:39	13.1	55.6						
T3	16-Nov-21		18.63		15:54	15.6	60.1						
	17-Nov-21				10:32	12.6	54.7						
T4	16-Nov-21		18.73		15:40	15.1	59.2						
	17-Nov-21				10:24	11.7	53.1						
T5	16-Nov-21		18.75		15:33	15.9	60.6						
	17-Nov-21				10:18	11.5	52.7						
T6	16-Nov-21		18.20		15:18	16.6	61.9						
	17-Nov-21				9:30	11.3	52.3						
T7	17-Nov-21		25.77		13:12	14.4	57.9						
	18-Nov-21				14:58	16.5	61.7						
T8	16-Nov-21		25.30		8:28	13.1	55.6						
	17-Nov-21				14:51	11.9	53.4						
T9	17-Nov-21		24.98		13:40	14.8	58.6						
	18-Nov-21				14:39	17.2	63.0						
T10	17-Nov-21		24.33		13:53	15.2	59.4						
	18-Nov-21				14:13	17.7	63.9						
T11	17-Nov-21		23.52		14:17	15.8	60.4						
	18-Nov-21				13:48	17.2	63.0						
T12	17-Nov-21		22.90		14:38	15.5	59.9						
	18-Nov-21				13:32	15.8	60.4						

(10.4°F), while the diurnal differences were 3.4°C (6.1°F) in early February 2021, 0.4°C (0.8°F) in late April 2021, 4.1°C (7.4°F) in late July 2021, and 3.0°C (5.4°F) in the mid-November 2021 surveys.

Diurnal variation in dissolved oxygen was also noted during three of the five surveys, with morning dissolved oxygen saturation levels being lower than afternoon levels during each of the efforts (Table 1). In October 2020, the difference between the morning and afternoon saturations was 29 percent, while the diurnal differences were 7 percent in late July 2021, and 13 percent in the mid-November 2021 surveys. No afternoon oxygen readings were collected during the early February 2021 surveys. There was no difference in the diurnal oxygen readings during the April 2021 surveys.

Water conductivity (including the temperature corrected specific conductivity), salinity, and pH, did not show significant seasonal patterns during the four surveys conducted between October 2020 and July 2021 (Table 1). The means for salinities over this nine-month period only ranged from 0.26 to 0.31 parts per thousand (ppt), while the mean conductivities ranged from 412 to 527 microSiemens per centimeter (μS/cm). However, by the time of the Fall 2021 survey the mean salinity was 1.4 ppt and the mean conductivity was 2,075 μS/cm. It is not clear why the conductivities and salinity readings were so elevated by the time of the mid-November 2021 survey. Perhaps the flood flows that occurred three weeks prior resulted in higher total dissolved solids from the floodplain flows that affected the salinities and conductivities. This area of Barker Slough is upstream of Campbell Lake Dam and outside the Cache Slough Complex tidal zone, so it seems unlikely that water from lower Barker Slough (i.e., downstream of Campbell Lake Dam) could have affected the slough upstream of the dam.

Fish Sampling

Seining, while more labor intensive than the passive minnow trapping, was the most effective sampling method for capturing fish during all five of the upper Barker Slough surveys conducted between October 2020 and November 2021. Seining captured an average of 81 percent of the total fish (range of 66.3 to 95.8 percent) over the five

surveys compared to minnow traps that captured an average of 19 percent of the total fish (range of 4.2 to 33.7 percent).

Twelve different species of fish were captured in upper Barker Slough over the three surveys periods (Table 2). Of these twelve species captured over the eight-month survey period, seven were exotic, or non-native, species (i.e., 58 percent of the species counts).

Over the course of the five surveys, a total of 5,260 fish were captured in the upper Barker Slough study area, with native species representing 72 percent of the total captures and exotic fish contributing only 28 percent (Table 1). The overall fish captures during all five surveys was dominated by threespine stickleback (*Gasterosteus aculeatus*) and prickly sculpin (*Cottus asper*), both native species, which made up 39.5 percent and 30.9 percent of the total catch, respectively. The most abundant non-native fish over the survey period included both western mosquitofish (*Gambusia affinis*) and fathead minnow (*Pimephales promelas*), which contributed 10.8 percent and 9.9 percent of the total catch.

Examination of the surveys by season show that fewer fish were captured during the Winter February 2021 survey (n=173), compared to any of the other four surveys total captures ranged from 1,000 to 1,600 fish (Table 2). During this Winter 2021 survey, non-native fish were more abundant in the total catches than native fish. Native fishes slightly outnumbered exotic fishes in the total catches during both the Fall surveys (October 2020 and November 2021). During the Spring (April 2021) and Summer (July 2021) surveys, native fishes were much more abundant in the upper Barker catches than no-native fishes. During four of the five species, more exotic species were captured compared to the number of native species. The one exception was for the Spring April 2021 surveys when the species counts (n=-3) were the same for both native and exotic species.

Table 2. Capture data for the five fish monitoring surveys on upper Barker Slough, late October 2020 through mid-November 2021. Totals include both measured and counted fish.

	Oct-20	Feb-21	Apr-21	Jul-21	Nov-21	Total
Native Fishes						
Hitch	46 (45-93 FL)	2 (60-84 FL)	12 (59-102 FL)	8 (46-92 FL)	11 (34-94 FL)	79
California roach	6 (25-36 FL)					6
Sacramento sucker					1 (170 FL)	1
Threespine stickleback	380 (34-59 TL)	45 (21-66 TL)	866 (19-71 TL)	529 (28-55 TL)	256 (41-60 TL)	2,076
Prickly sculpin	244 (41-82 TL)	26 (43-100 TL)	674 (23-89 TL)	442 (30-101 TL)	238 (36-106 TL)	1,624
Exotic Fishes						
Golden shiner	17 (48-88 FL)					17
Fathead minnow	130 (25-72 FL)	43 (23-61 FL)	29 (34-68 FL)	99 (21-62 FL)	219 (30-73 FL)	520
Mississippi silverside	13 (43-67 FL)	4 (23-60 FL)	5 (55-92 FL)	3 (32-68 FL)	44 (31-80 FL)	69
Western mosquitofish	332 (14-52 TL)	54 (21-44 TL)	24 (22-49 TL)	94 (22-56 TL)	65 (21-87 TL)	569
Black bullhead	1 (182 TL)			115 (22-28 TL)	160 (38-67 TL)	276
Green sunfish sunfish		1 (123 FL)			2 (49-51 FL)	3
Largemouth bass	1 (107 FL)			8 (50-78 FL)	11 (34-142 FL)	20
Total # Individuals	1,170	175	1,610	1,298	1,006	5,260
# native fish	676	73	1,552	979	506	3,786
# exotic fish	494	102	58	319	501	1,474
Total # species	10	7	6	8	10	12
# native species	4	3	3	3	4	5
# exotic species	6	4	3	5	6	7
Shannon's Diversity (ln)	1.572	1.507	0.888	1.411	1.745	1.527
Eveness (H'/Hmax)	0.683	0.775	0.495	0.678	0.758	0.615

During the first survey covered in this report, in October 2020, fish captures were dominated by stickleback, which composed 32.5 percent of the total fish captured in the fall (Table 2). Non-native mosquitofish contributed 28.4 percent of the catch, while another native fish, prickly sculpin, added another 20.9 percent.

Though total catch for the Winter 2021 was only 175 fish, a similar pattern to the fall sampling was noted (Table 2). During this February 2021 survey, fish captures were dominated by mosquitofish, which composed 30.9 percent of the total fish captures, followed by threespine sticklebacks, which contributed 25.7 percent of the catch. Fathead minnow made up 24.6 percent of the fish captures during the upper Barker Slough Winter surveys.

By the time of the Spring survey in late April 2021, native threespine stickleback and prickly sculpin dominated the survey total catch, contributing 53.8 and 41.9 percent of the of the total catch (Table 2). The non-native fathead minnow and mosquitofish made up only 1.8 and 1.5 percent of the Spring catch, respectively.

By the time of the late July 2021 Summer survey, native threespine stickleback and prickly sculpin continued to dominate the upper Barker Slough survey total catch, contributing 40.8 and 34.1 percent of the of the total catch (Table 2). The non-natives: black bullhead (*Ameiurus melas*), fathead minnow and mosquitofish each contributed between seven and nine percent of the Summer catch.

During the Fall 2021 surveys in November (and following the October high flow event), native threespine stickleback and prickly sculpin continued to dominate the upper Barker Slough survey total catch, contributing 25.4 and 23.6 percent of the of the total catch (Table 2). Non-native fathead minnow and black bullhead made up only 21.7 and 15.9 percent of the Fall 2021 catch, respectively.

Examination of the fish length frequencies show that over 97 percent of the fish captured during the surveys in upper Barker Slough were small-bodied fish less than 80 mm in length (3.1 inches; Figures 3-6). Only two fish captured during the five surveys measured more than six inches in length. The first was a 182 mm TL black bullhead

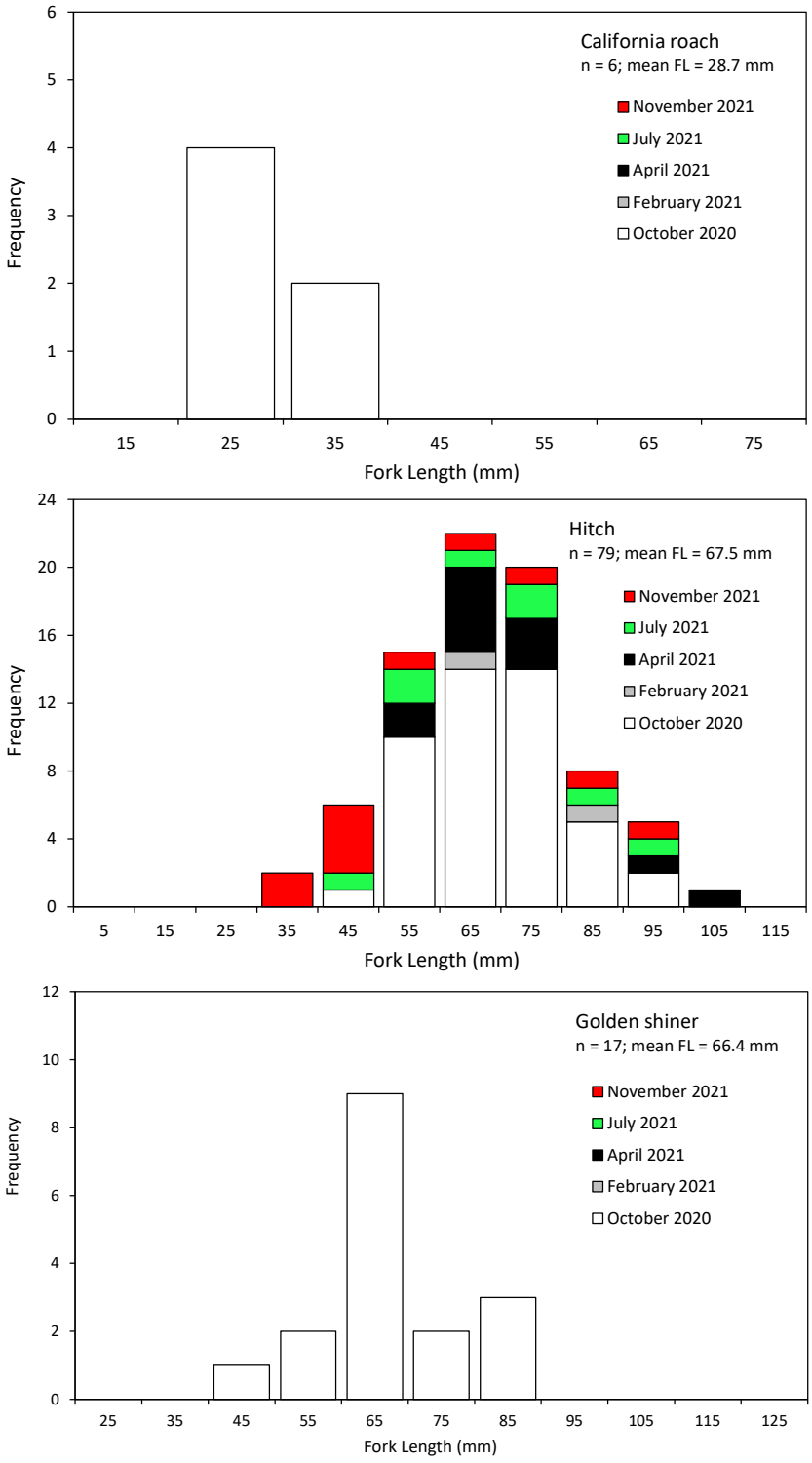

Figure 3. Length frequencies for fish captured from upper Barker Slough project area during the late October 2020 through mid-November 2021 fish surveys.

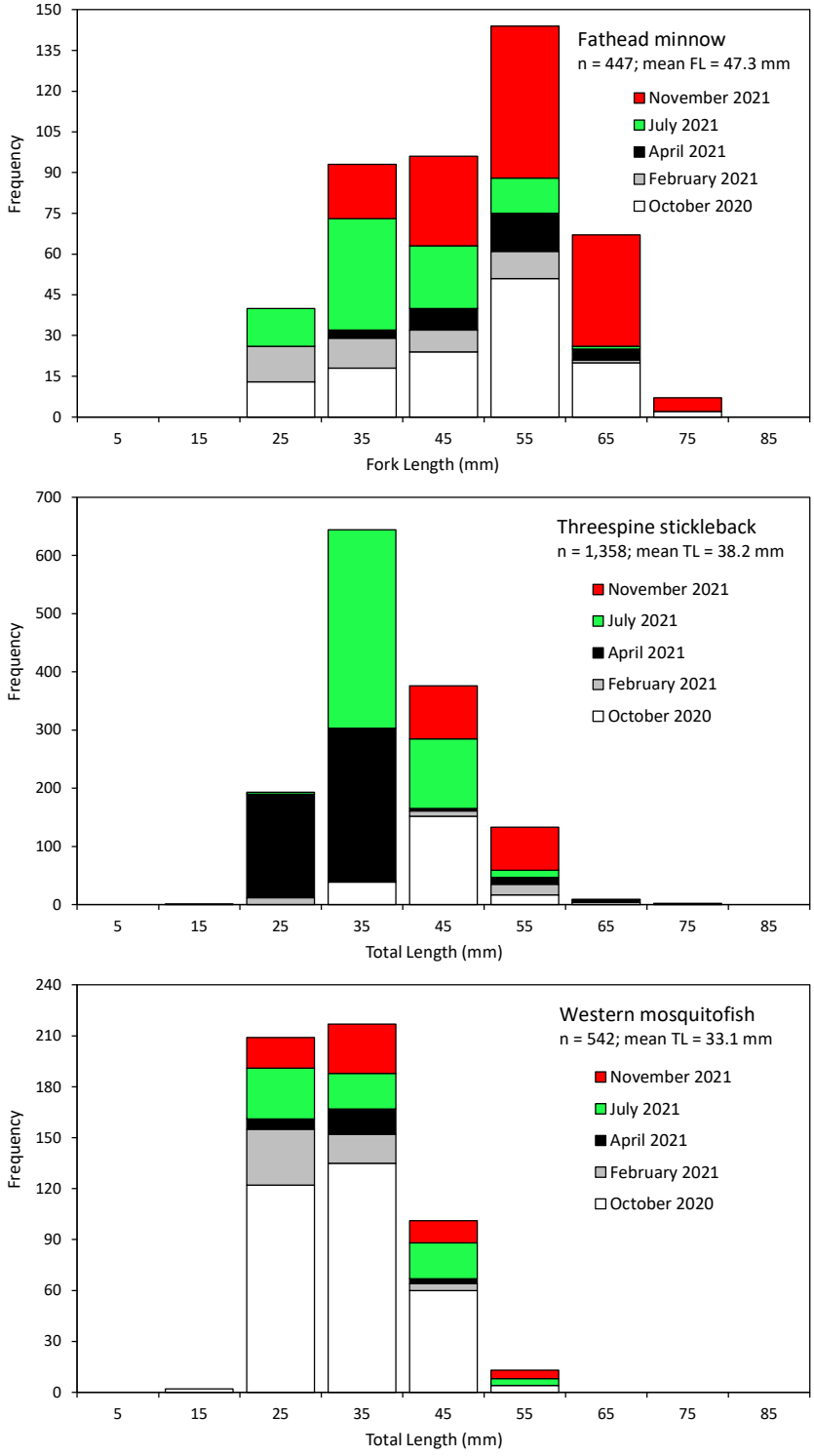

Figure 4. Length frequencies for fish captured from upper Barker Slough project area during the late October 2020 through mid-November 2021 fish surveys.

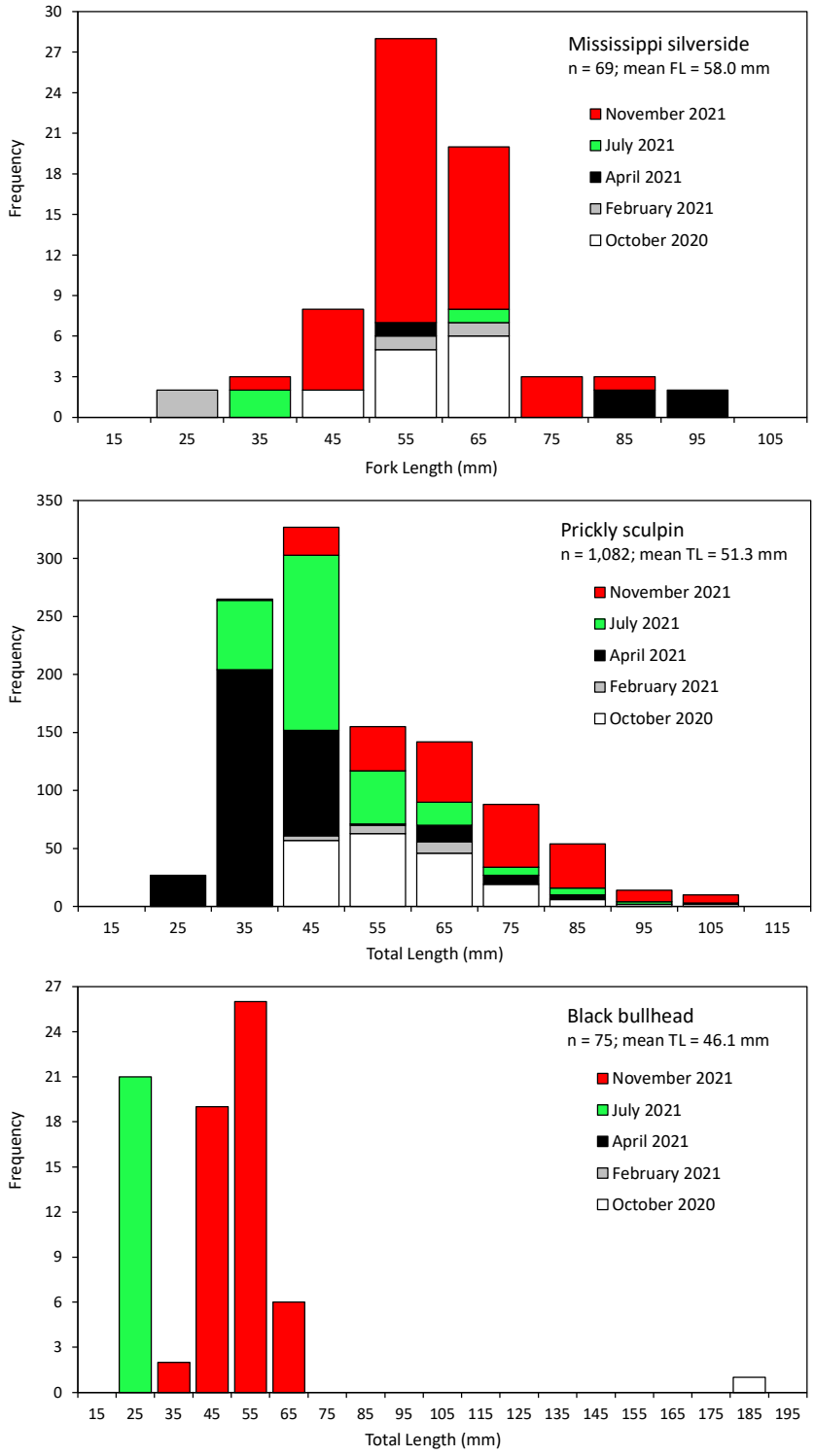

Figure 5. Length frequencies for fish captured from upper Barker Slough project area during the late October 2020 through mid-November 2021 fish surveys.

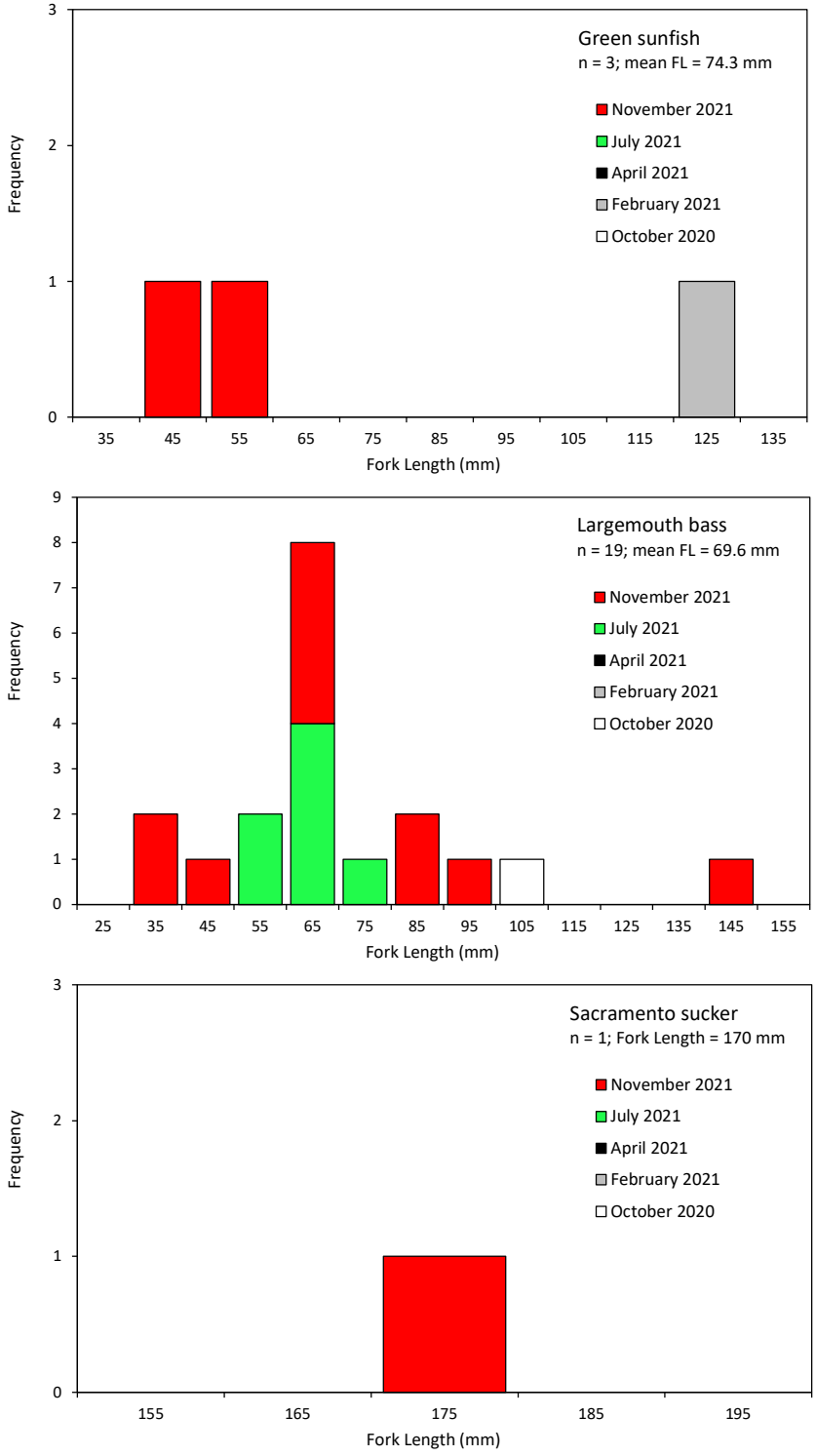

Figure 6. Length frequencies for fish captured from upper Barker Slough project area during the late October 2020 through mid-November 2021 fish surveys.

seined in the October 2020 survey (Figure 5) and the second was a 170 mm FL sucker seined in the November 2021 survey (Figure 6).

Other non-fish species captured during the five surveys included non-native red swamp crayfish (*Procambarus clarkii*) and the native western pond turtle (*Actinemys marmorata*). The crayfish were noted throughout the entire study area during all five survey periods. The western pond turtle mysids were only noted during the February 2021 winter sampling and only at one of the lower seine haul sites (Photograph 9).

Photograph 9. Western pond turtle at Seine Site 2, 4 February 2021.

Discussion

Despite the relatively low flow conditions that prevailed during all five surveys, fish were present throughout the 2.3-mile-long upper Barker Slough study area throughout the October 2020 through November 2021 survey period. The seasonal and diurnal variations in the water quality parameters noted during the surveys did not appear to impact the fishes present in the project area. Over the course of the five seasonal surveys conducted over the 12.5-month period some seasonal variations in total catches were noted. During the two Fall surveys (October 2020 and November 2021) the catches were near evenly split between California native fish and exotic fish. During the Winter survey (February 2021) non-native fish were more abundant than native fish, though very few fish were captured overall during this survey. By the time of the Spring (April 2021) and Summer (July 2021) surveys native fish dominated the upper Barker Slough fish catches.

Threespine stickleback and prickly sculpin made up most of the native fishes captured during the surveys, while mosquitofish and fathead minnows made up most of the non-native fish captured. All the fish captured were relatively small and over 99 percent of the fish captured by either seining or trapping were less than 100 millimeters (3.9 inches) in length. None were over 170 mm (6.6 inches) in length.

Williamson et al. (2021) reported on multiple year fish surveys throughout the Cache-Lindsey Slough Complex, which includes sites just downstream of the upper Barker Slough Project area. They reported season changes in their otter trawl and electrofishing catches similar to our observations, with lower catches of fish during the Winter compared to other seasons.

Durand et al. (2019) and Williamson (2021) reported on the multi-year (2013-2020) seasonal fish surveys in lower Barker Slough (BK1) near the NBA Project, about 3.2 miles downstream of our upper Barker Slough Project area. These surveys near the NBA project found non-native centrarchids, primarily largemouth bass (*Micropterus salmoides*), black and white crappie, and bluegill sunfish dominating the fish populations

along with non-native threadfin shad (*Dorosoma petenense*). Native fish, mostly Sacramento sucker (*Catostomus occidentalis*), hitch (*Lavinia exilicauda*) and prickly sculpin, were also captured but were only a minor component of the lower Barker Slough fish. These results suggest a significant difference in the fish populations between the tidal lower Barker Slough area (Durand et al. 2019; Williamson et al. 2021) and the non-tidal upper Barker Slough basin upstream of Campbell Lake (this report).

There were no observations of any rare vernal pool species such as fairy shrimp, tadpole shrimp, or California tiger salamander during any of the five upper Barker Slough surveys. These species appear to be limited to nearby adjacent ephemeral pool habitats of the Jepson Prairie Preserve, but were not found in the permanently wetted, deeply entrenched, slough habitat characterized by upper Barker Slough. Fairy shrimp and tadpole shrimp are restricted to temporary waters such as vernal pools (Witham and Mawdsley 2012).

Literature Cited

Durand, J., C. Jasper, B. Williamson, A. Kruger, T. O'Rear, and Rusty Holleman. 2019. North Delta Arc Study 2019 Annual Report: Cache and Lindsey Slough water quality, productivity, and fisheries. University of California, Davis Center for Watershed Sciences Report P1596025 prepared by for Solano County Water Agency. Davis, CA. 76p.

Kennedy Jenks. 2019. Westside Sacramento Integrated Regional Water Management Plan Update. Volume II - Appendices. 1349p.

Moyle, P.B. 2002. Inland Fishes of California. University of California Press. Berkeley, CA. 502p.

Salamunovich, T. 2020. Fall 2019 through Summer 2020 Upper Barker Slough Fish Surveys – Final Report. 20 October 2020 Memorandum from TRPA Fish Biologists to Solano County Water Agency. Vacaville, CA. 21p.

Williamson, B., K. Luke, D. Stompe, C. Newell, T. O'Rear, and J. Durand. 2021. North Delta Arc Study 2020 Annual Report: Cache-Lindsey Slough Complex water quality, productivity, and fisheries. University of California, Davis Center for Watershed Sciences Report prepared by for Solano County Water Agency. Davis, CA. 53p.

Witham, C.W. 2006. Greater Jepson Prairie ecosystem regional management plan. Prepared for Solano Land Trust, Fairfield, CA. 253p. + Appendices.

Witham, C.W., and K. Mawdsley, editors. 2012. Jepson Prairie Preserve Handbook, 3rd edition. Jepson Prairie Docent Program, Solano Land Trust, Fairfield, CA. 80p.