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Memorandum

DATE: 22 October 2020
TO: Roland Sanford, Chris Lee, and Alex Rabidoux, Solano County Water Agency (SCWA)
FROM: Tim Salamunovich, TRPA Fish Biologists
RE: Fall 2019 through Summer 2020 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 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 the 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 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,

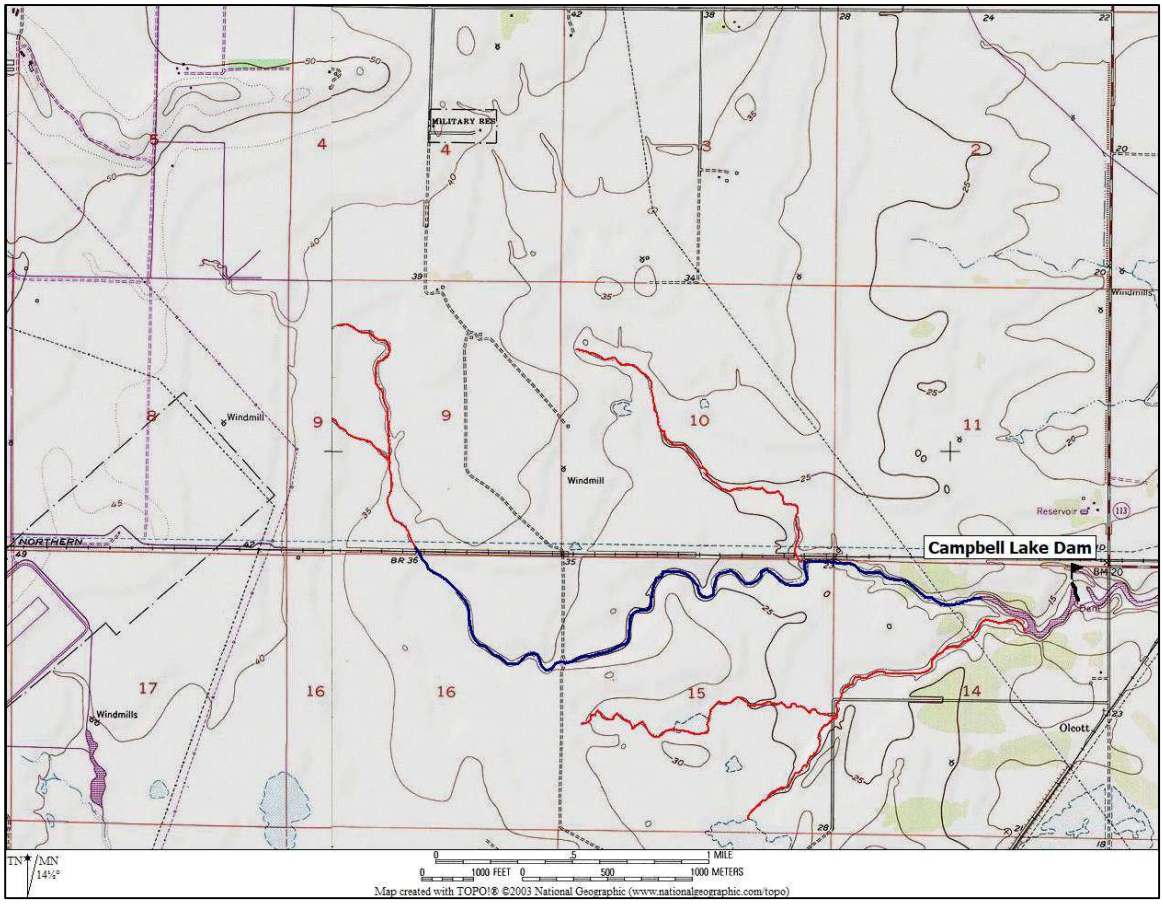

Figure 1. Map showing the upper Barker Slough drainage area upstream of Campbell Lake Dam. The blue line is the active Barker Slough channel; red lines denote relict channels that are active only during floods.

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 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 deeply incised and while most of the channel was open water, there were several large stretches of

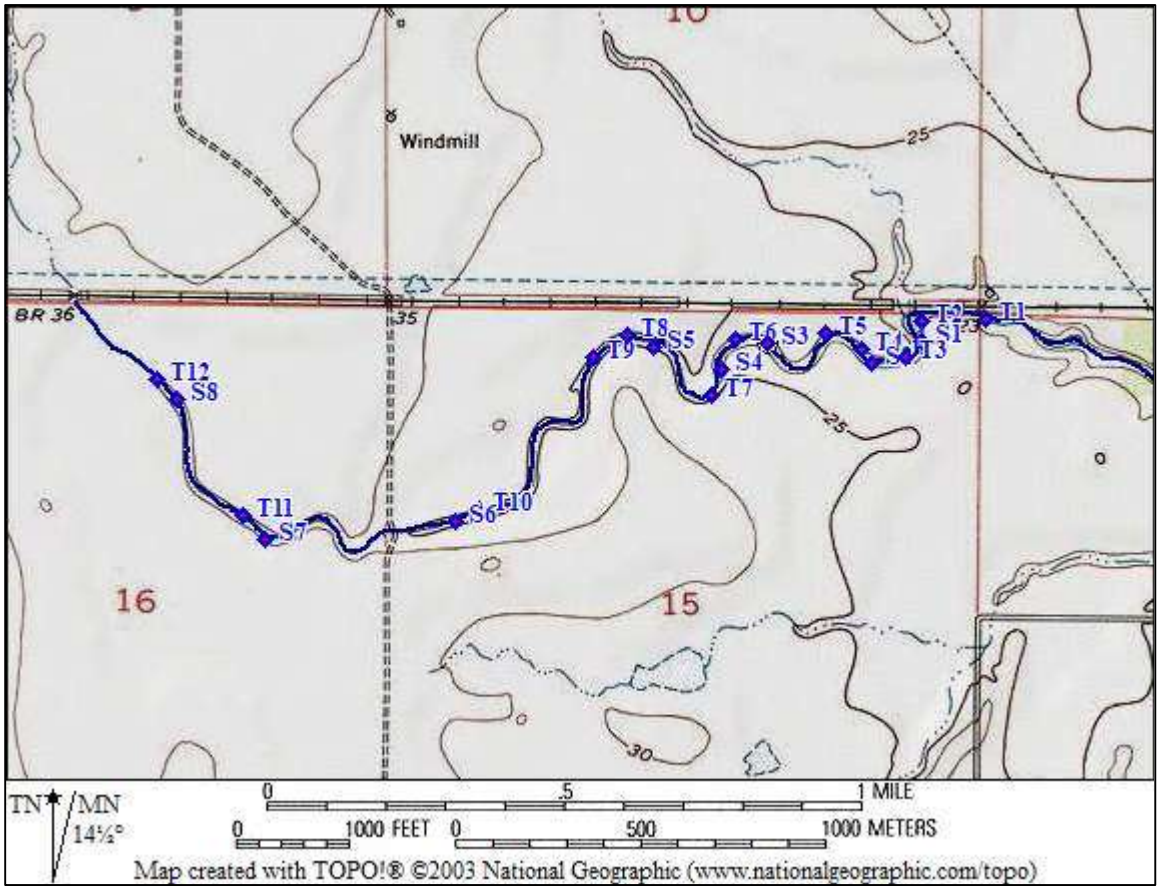

Figure 2. Map of the upper Barker Slough Project area showing the location of the Eight seining (S) and twelve minnow trapping (T) sites sampled during the late October 2019 through late June 2020 fish surveys.

channel that were choked with wetland vegetation comprised of a mixture of sedges and reeds (Photographs 1 through 3). 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 mitigation bank site. 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 channel.

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

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.

water quality throughout the Barker Slough basin. TRPA Fish Biologists was contracted to conduct preliminary surveys to document information on the existing aquatic resources in upper Barker Slough.

Methods

The upper Barker Slough study area is privately owned. TRPA Fish Biologists worked closely with Alex Rabidoux from Solano County Water Agency to obtain landowner access to the study area. A reconnaissance site visit was conducted in early August 2019 to evaluate habitat conditions and determine how and where sampling might be conducted. At that time, there was about 0.75 cfs (visual estimate) of flow in upper Barker Slough derived from the Solano Irrigation District canal network just north of the study area, which delivers irrigation water to adjacent agriculture and ranch operations. During this site visit numerous small, but identified, fish were seen at many locations

and several western pond turtles (*Actinemys marmorata*) were observed. Potential seine sites having open water and shallow water bank habitat were identified.

Fish surveys were conducted using 25' X 4' pole seines. During the late October 2019 and the first day of the mid-February 2020 survey, a 1/16"-mesh pole seine was used. On the remaining survey days, when water was lower, this net was found to be too fine-meshed and trapped too much mud during seine hauls. Instead, a 1/8"-mesh net, which trapped less mud, was used to capture fish in upper Barker Slough. Depending on the configuration of the slough channel and the location of the ending beach location, the pole seine was deployed from bank to bank and then swept through the water (either upstream or downstream) for some distance and then dragged to shore. The length of sample reaches at each site varied based on where seines could be deployed and recovered. Generally, 60 to 75 feet of slough habitat was seined 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 using 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 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 wrapped and tied in a fine mesh gauze fabric to prevent bait consumption by trapped fish. It was hoped that this strong-scented

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

Photograph 5. Minnow trap deployed in Barker Slough, 22 October 2019.

odorous bait would attract fish into the traps. Traps were allowed to soak for a minimum of 4 to 5 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 counted before being released. If unusual fish species were captured, they were 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 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 project area were surveyed during each sampling period (Figure 2; Table 1). Two days were required to complete each sampling event. The original intent was to sample quarterly from Fall 2019 through Summer 2020; however, concerns about travelling to conduct field work during the initial phases of the Corona virus pandemic prevented the spring 2020 sampling event. Three surveys were conducted: late October 2019, mid-February 2020, and late June 2020 (Table 1).

There was continuous flow through the upper Barker Slough project area at the time of each survey, though the visually estimated stream flow appeared to diminish over the course of the entire survey period (Table 1; Photographs 6 and 7).

The first survey in late October 2019 followed a wet water year in the Sacramento Valley according to the Sacramento Valley 40-30-30 Hydrologic Classification Index, while the February and June 2020 surveys occurred during and following a dry winter

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.

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	22-Oct-19	1/16	60/60	0.50	9:30	15.1	59.2	384.2	474.0	0.2	3.90	39.5	6.8
S2	22-Oct-19	1/16	60	0.50	10:40	15.4	59.7	392.9	481.0	0.2	3.59	36.7	6.8
S3	22-Oct-19	1/16	60	0.50	12:18	16.0	60.8	416.0	502.0	0.2	3.66	37.8	6.8
S4	21-Oct-19	1/16	50		9:45	15.2	59.4	401.0	494.6	0.2	4.90	49.7	6.7
S5	21-Oct-19	1/16	30	0.50	12:16	16.5	61.7	410.6	489.2	0.2	5.52	58.5	6.8
S6	21-Oct-19	1/16	75	0.50	13:08	17.5	63.5	407.2	474.9	0.2	5.94	63.4	6.8
S7	21-Oct-19	1/16	100	0.50	14:38	17.8	64.0	407.9	473.1	0.2	6.49	69.9	6.8
S8	21-Oct-19	1/16	40	0.50	16:19	18.3	64.9	407.8	466.7	0.2	5.59	60.7	6.8
T1	22-Oct-19		6.11		14:18	18.3							
T2	22-Oct-19		5.72		14:06	18.6	65.5						
T3	22-Oct-19		5.27		13:50	17.7	63.9						
T4	22-Oct-19		4.93		13:38	17.0	62.6						
T5	22-Oct-19		4.70		13:25	16.9	62.4						
T6	22-Oct-19		4.33		13:12	16.7	62.1						
T7	21-Oct-19		9.13		17:53	18.2	64.8						
T8	21-Oct-19		7.32		17:42	18.2	64.8						
T9	21-Oct-19		7.00		17:33	18.4	65.1						
T10	21-Oct-19		6.43		17:13	18.2	64.8						
T11	21-Oct-19		4.57		15:42								
T12	21-Oct-19		5.37		16:45								

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	11-Feb-20	1/8	80/60/60	0.33	8:29	7.7	45.9	1,905	2,850	1.5	9.30	80.9	8.7
S2	11-Feb-20	1/8	60/75	0.33	8:58	8.0	46.4	1,904	2,815	1.5	9.20	80.8	8.8
S3	11-Feb-20	1/8	60/70	0.33	10:05	9.0	48.2	1,950	2,820	1.5	10.30	92.3	9.0
S4	10-Feb-20	1/16	90	0.33	9:43	6.7	44.1	1,855	2,855	1.5	9.27	76.4	8.8
S5	10-Feb-20	1/16	85	0.33	10:48	7.6	45.7	1,914	2,880	1.5	11.65	100.7	9.0
S6	10-Feb-20	1/16	70	0.33	11:35	9.8	49.6	2,009	2,829	1.5	13.42	122.7	9.2
S7	10-Feb-20	1/16	80	0.33	13:18	12.0	53.6	2,102	2,808	1.5	13.20	126.9	9.5
S8	10-Feb-20	1/16	40	0.33	14:39	12.3	54.1	2,105	2,780	1.5	12.20	118.6	9.4
T1	11-Feb-20		3.25		10:53	9.9	49.8						
T2	11-Feb-20		3.28		11:00	10.5	50.9						
T3	11-Feb-20		3.33		11:05	9.5	49.1						
T4	11-Feb-20		3.37		11:09	9.8	49.6						
T5	11-Feb-20		3.38		11:15	9.2	48.6						
T6	11-Feb-20		3.48		11:23	9.3	48.7						
T7	10-Feb-20		7.63		16:36	11.0	51.8						
T8	10-Feb-20		7.60		16:24	11.8	53.2						
T9	10-Feb-20		7.63		16:21	11.6	52.9						
T10	10-Feb-20		7.55		16:02	14.3	57.7						
T11	10-Feb-20		7.38		15:35	13.2	55.8						
T12	10-Feb-20		7.48		15:23	11.5	52.7						

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	30-Jun-20	1/8	60	0.10	7:26	16.9	62.4	595	702	0.3	7.30	76.8	9.7
S2	30-Jun-20	1/8	100	0.10	8:11	18.7	65.7	616	699	0.3	7.09	76.5	10.0
S3	30-Jun-20	1/8	90	0.10	9:36	18.8	65.8	779	885	0.4	6.18	67.8	7.4
S4	29-Jun-20	1/8	90	0.10	9:56	18.1	64.6	613	705	0.3	7.66	82.8	6.9
S5	29-Jun-20	1/8	80	0.10	11:56	20.5	68.9	696	775	0.4	8.38	95.7	6.9
S6	29-Jun-20	1/8	50/70	0.10	12:50	26.8	80.2	911	882	0.4	8.24	105.0	9.7
S7	29-Jun-20	1/8	90	0.10	14:15	26.1	79.0	1,229	1,219	0.6	11.78	150.0	9.6
S8	29-Jun-20	1/8	45	0.10	15:58	24.0	75.2	708	719	0.4	5.49	68.0	8.6
T1	30-Jun-20		16.45		11:09	19.3							
T2	30-Jun-20		16.32		10:55	26.1	79.0						
T3	30-Jun-20		16.13		10:36	19.3	66.7						
T4	30-Jun-20		16.10		10:27	19.0	66.2						
T5	30-Jun-20		15.98		10:16	18.5	65.3						
T6	30-Jun-20		15.92		10:02	18.7	65.7						
T7	29-Jun-20		10.40		17:52	21.9	71.4						
T8	29-Jun-20		9.93		17:36	26.2	79.2						
T9	29-Jun-20		9.78		17:31	26.7	80.1						
T10	29-Jun-20		9.20		17:10	30.2	86.4						
T11	29-Jun-20		8.40		16:48	28.5	83.3						
T12	29-Jun-20		7.72		16:23	24.8	76.6						

Photograph 6. Fish survey seine site S2 on 8 August 2019 (A) versus 30 June 2020 (B).

Photograph 7. Fish survey seine site S8 on 21 October 2019 (A) versus 29 June 2020 (B).

(Department of Water Resources (DWR), California Data Exchange Center, Water Supply Index WSIHIST). During the 2019 Water Year a total of 21.43 inches of precipitation was recorded at the Hasting Tract East Station, located six miles east of the project area, compared to only 7.60 inches recorded during the 2020 Water Year (DWR California Irrigation Management Information System database). This rainfall disparity likely impacted the hydrology and habitat conditions in upper Barker Slough over the survey period.

Water Quality

All the water quality parameters showed a seasonal variability over the course of the eight-month long survey period (Table 1). As might be expected, water temperatures varied between seasons, with the coolest water temperatures (average of 10.2°C [50.4°F]) occurred during the winter surveys conducted in mid-February, while the warmest water temperatures (average of 22.5°C [72.4°F]) occurred during the summer surveys conducted in late June. Also noteworthy was the diurnal variation in water temperatures during each of the three surveys, with morning water temperatures being considerably cooler than afternoon water temperatures during each of the efforts. In October the difference between the morning and afternoon water temperatures averages was 2.4°C (4.3°F), while the diurnal differences were 3.3°C (5.9°F) in February and 6.7°C (12.0°F) in the late June surveys.

Diurnal variation in dissolved oxygen was also noted during each of the three surveys, with morning dissolved oxygen saturation levels being considerably lower than afternoon levels during each of the efforts (Table 1). In October, the difference between the morning and afternoon saturations was 16 percent, while the diurnal differences were 31 percent in February and 28 percent in the late June surveys.

Water conductivity (including the temperature corrected specific conductivity), salinity, dissolved oxygen levels (including percent saturation), and pH, all exhibited marked seasonal patterns, with lower levels for all the parameters in the fall (late October 2019) survey, the highest measurements in the summer (late June 2020) surveys, and more

moderate levels in the winter (early February) survey (Table 1). It is not clear why the conductivities and salinity readings were so high during the winter compared to either the fall or summer surveys. This area of Barker Slough is upstream of Campbell Lake Dam and outside the Cache Slough Complex tidal zone.

Fish Sampling

Seining, while more labor intensive than the passive minnow trapping, was the most effective sampling method for capturing fish during the upper Barker Slough surveys. Minnow traps captured an average of 31.5% of the fish (range of 25.7% to 35.2 percent) over the three surveys compared to seining that captured an average of 68.5% of the fish (range of 64.8 to 74.3 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, two thirds were exotic, or non-native, species.

Over the course of the three surveys, a total of 7,695 fish were captured in the upper Barker Slough study area, with a near even fraction of the total captures represented by native (51.6%) and exotic (48.4%) fish (Table 2). The overall fish captures during all three surveys was dominated by threespine stickleback (*Gasterosteus aculeatus*), a native species, and western mosquitofish (*Gambusia affinis*), a non-native species, which made up 40.5% and 37.9% of the total catch, respectively. Both these fish species are small, rarely exceeding 60 mm (2.4 inches) in length (Moyle 2002). Both species are adapted to life in shallow sluggish water habitats with a wide range of temperature and salinity conditions.

Examination of the surveys by season show that fewer fish were captured during the February survey (n=1,502), compared to either the October (n=3,238) or June survey (n=2,955; Table 2). Native fishes slightly outnumbered exotic fishes in the total catches during both the October and February surveys. More non-native fish than native fish were captured during the June survey (Table 2). During all three surveys, more exotic species were captured compared to the number of native species.

Table 2. Capture data for the three fish monitoring surveys on upper Barker Slough, late October 2019 through late June 2020. Totals include both measured and counted fish.

	Oct-19	Feb-20	Jun-20	Total
Native Fishes				
Hitch			16 (29-104 FL)	16
California roach	9 (17-44 FL)	9 (19-54 FL)		18
Threespine stickleback	1,817 (25-56 TL)	775 (28-57 TL)	527 (22-61 TL)	3,119
Prickly sculpin	13 (49-84 TL)		804 (27-75 TL)	817
Exotic Fishes				
Golden shiner	31 (29-104 FL)	26 (36-82 FL)	99 (19-103 FL)	156
Fathead minnow	241 (19-76 FL)	237 (21-73 FL)	117 (21-71 FL)	595
Mississippi silverside	27 (24-57 FL)	6 (26-65 FL)	12 (28-60 FL)	45
Western mosquitofish	1,097 (11-55 TL)	446 (16-43 TL)	1,375 (12-52 TL)	2,918
Black bullhead	3 (59-146 TL)	2 (61-99 TL)		5
Bluegill sunfish		1 (27 FL)		1
Warmouth sunfish			1 (74 FL)	1
White crappie			4 (37-52 FL)	4
Total # Individuals	3,238	1,502	2,955	7,695
# native fish	1,839	784	1,347	3,970
# exotic fish	1,399	718	1,608	3,725
Total # species	8	8	9	12
# native species	3	2	3	4
# exotic species	5	6	6	8
Shannon's Diversity (ln)	1.014	1.130	1.322	1.317
Eveness (H'/Hmax)	0.487	0.543	0.601	0.530

During the first survey in October 2019, fish captures were dominated by stickleback, which composed 56.1% of the total fish captured in the fall (Table 2). Mosquitofish contributed 33.9% of the catch, while another non-native fish, fathead minnow (*Pimephales promelas*), added another 7.4 percent.

Though only about half as many fish were captured during the winter survey, a similar pattern to the fall sampling was noted (Table 2). During this February 2020 survey, fish captures were dominated by stickleback, which composed 51.6% of the total fish captures, followed by mosquitofish, which contributed 29.7% of the catch. Fathead minnow made up 15.8% of the fish captures during the upper Barker Slough winter surveys.

By late June 2020, non-native mosquitofish dominated the survey total catch, contributing 46.5% of the total catch (Table 2). The native fish, prickly sculpin (*Cottus asper*), made up 27.2% of the overall summer survey catch, while sticklebacks, which had dominated the catches in the two earlier seasonal surveys, only made up 17.8 percent of the total catch.

Examination of the fish length frequencies show that most of the fish captured during the surveys in upper Barker Slough were small-bodied fish less than 110 mm in length (4.3 inches; Figures 3-6). The largest fish captured were two non-native black bullhead catfish (*Ameiurus melas*), which were seined at Seine Site 8 in the October 2019 fall survey and measured between 131 mm and 146 mm TL (5.2 to 5.7 inches; Figure 5).

Other non-fish species captured during the three surveys included non-native red swamp crayfish (*Procambarus clarkii*) and unidentified mysid shrimp. The crayfish were noted throughout the entire study area during all three survey periods. The mysids were only noted during the February 2020 winter sampling and only at one of the lower seine haul sites.

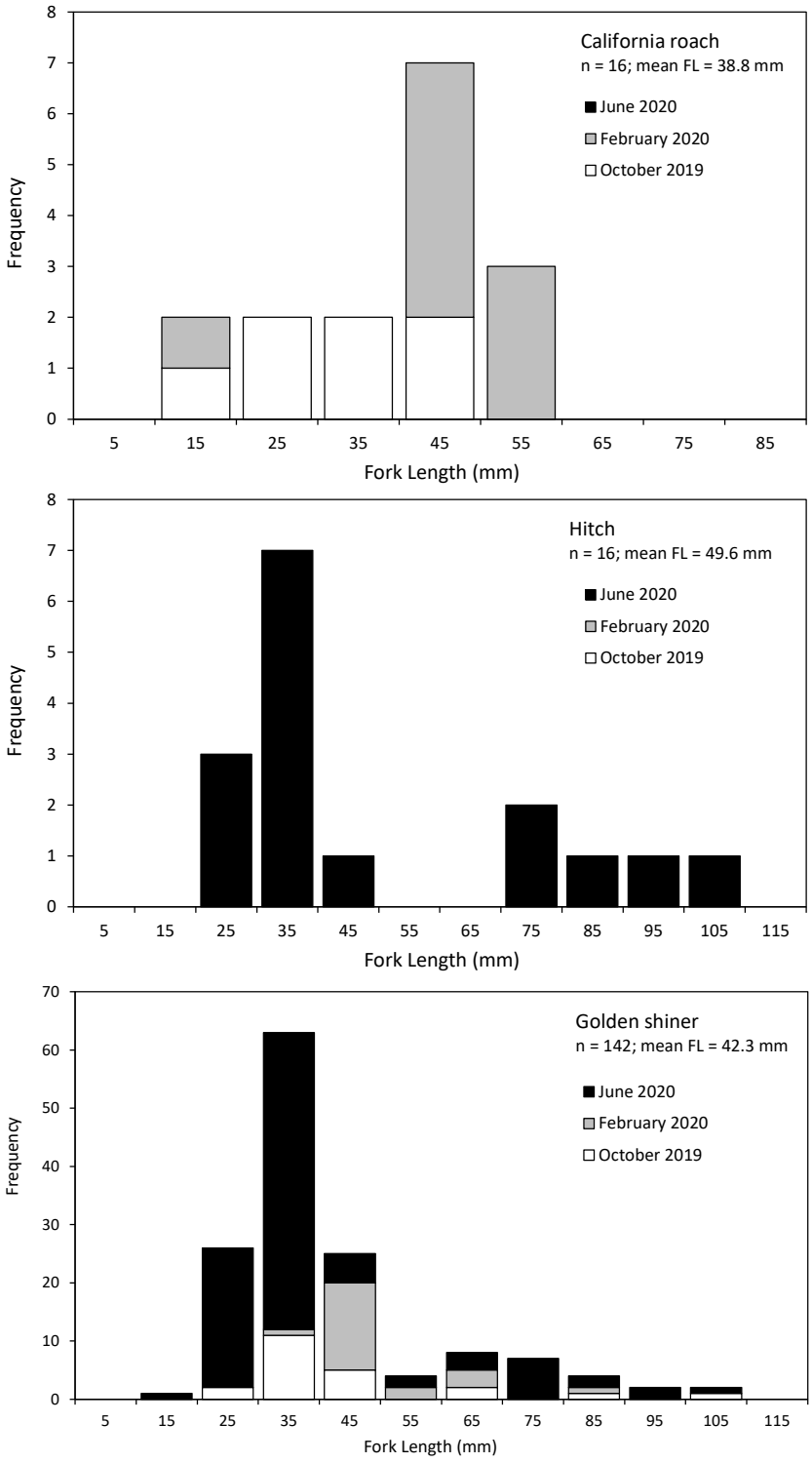

Figure 3. Length frequencies for fish captured from upper Barker Slough project area during the late October 2019 through late June 2020 fish surveys.

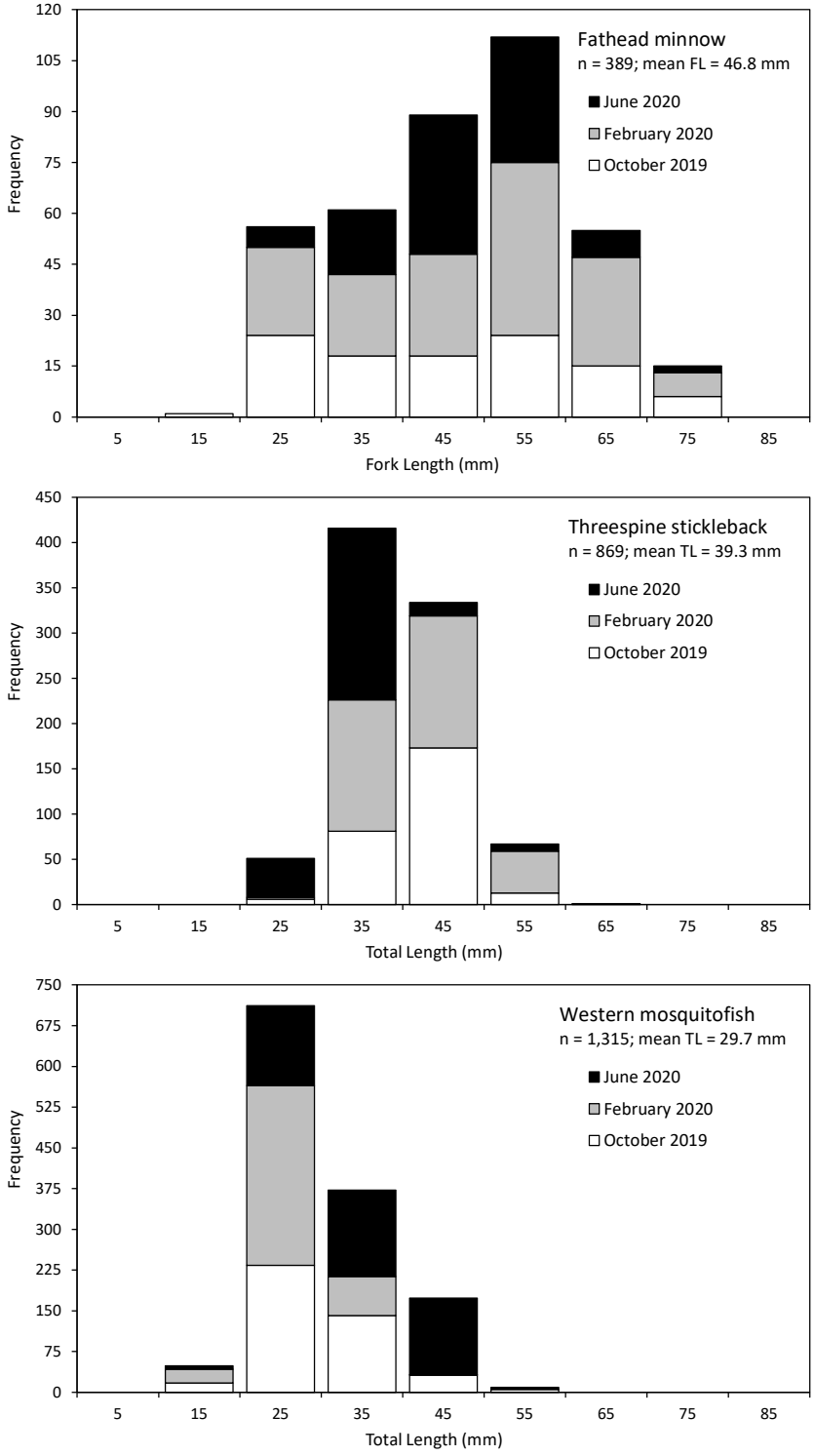

Figure 4. Length frequencies for fish captured from upper Barker Slough project area during the late October 2019 through late June 2020 fish surveys.

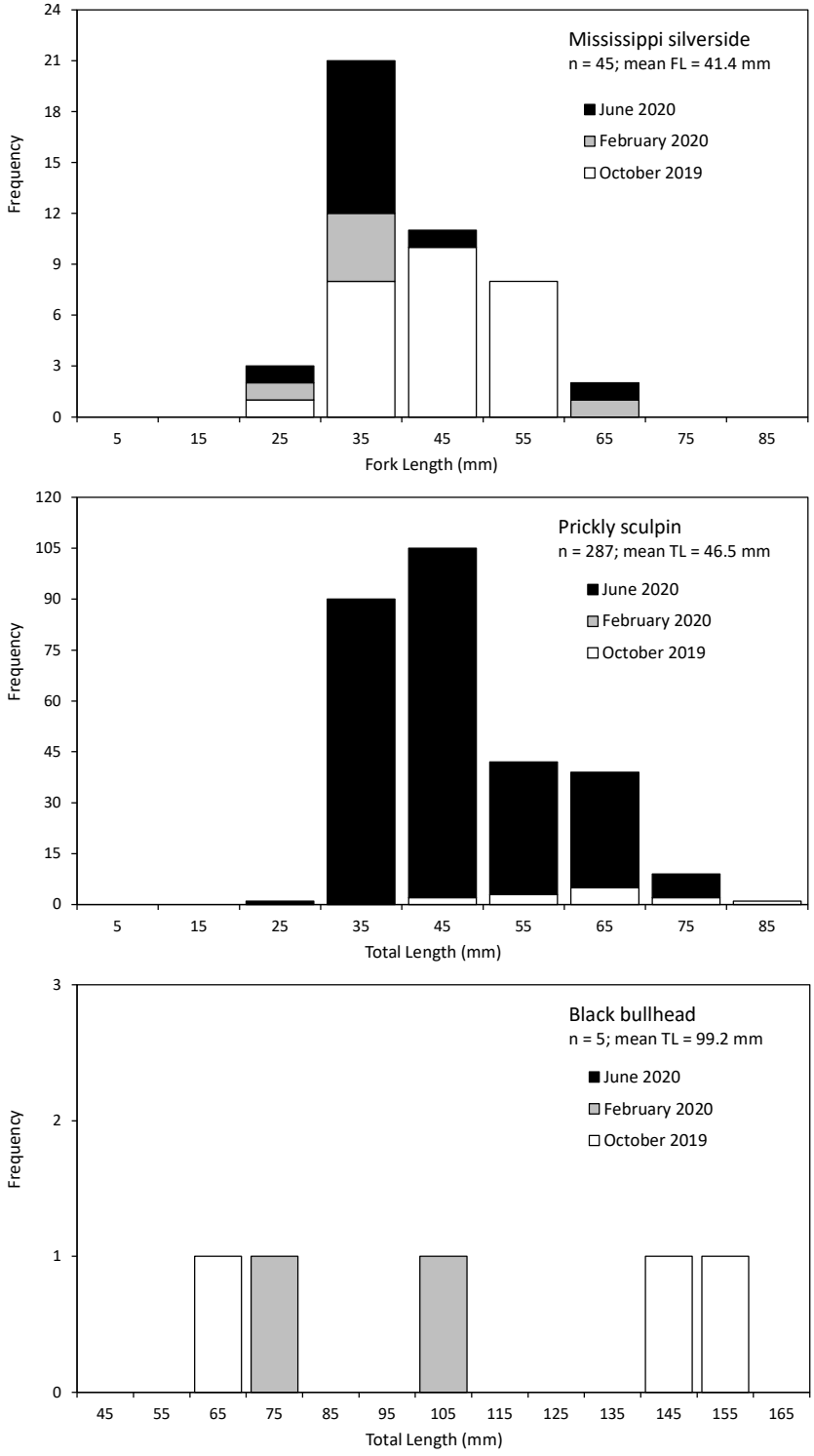

Figure 5. Length frequencies for fish captured from upper Barker Slough project area during the late October 2019 through late June 2020 fish surveys.

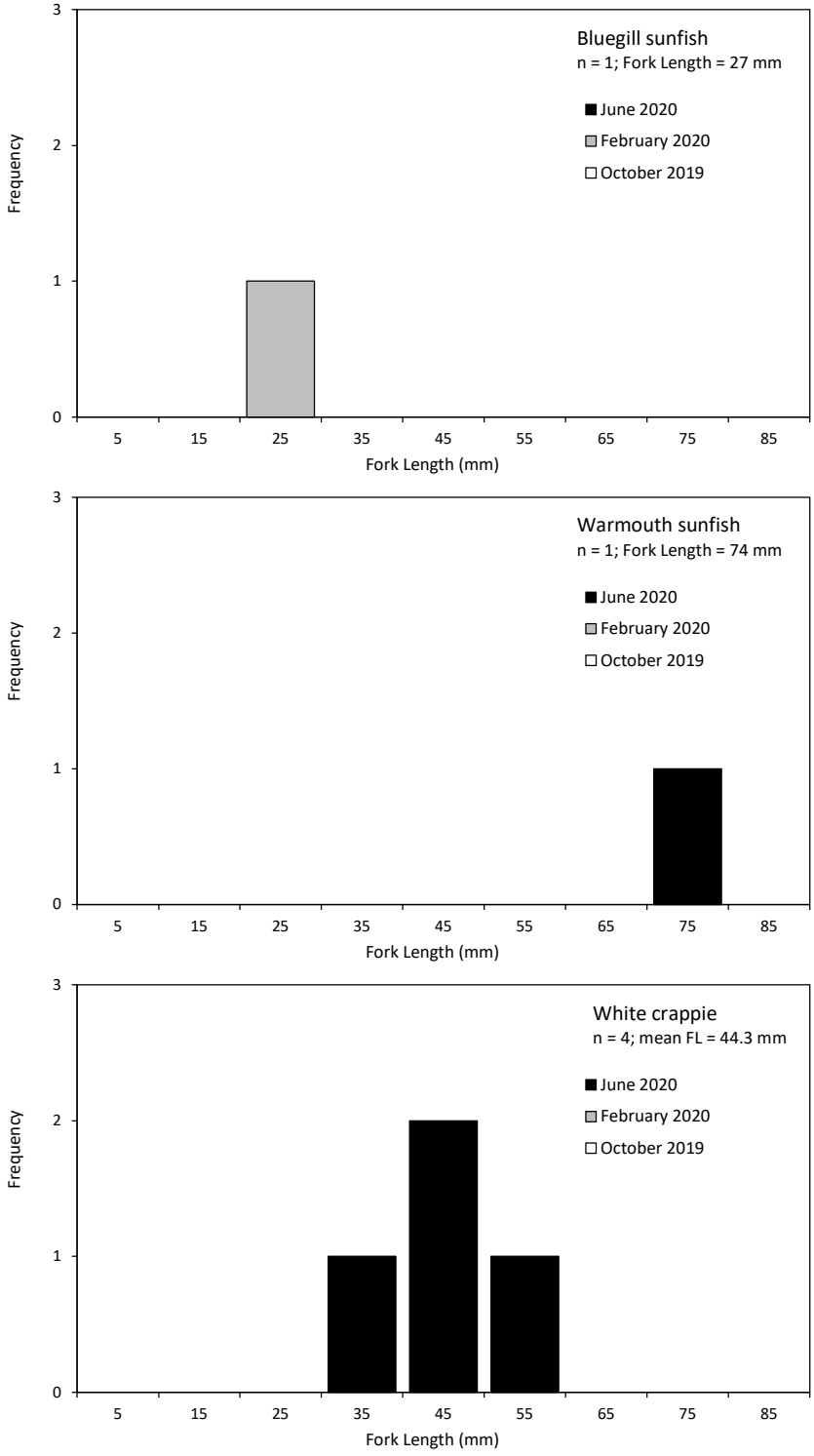

Figure 6. Length frequencies for fish captured from upper Barker Slough project area during the late October 2019 through late June 2020 fish surveys.

Discussion

Despite the relatively low flow conditions that prevailed during all three surveys, fish were present throughout the 2.3-mile long upper Barker Slough study area throughout the fall through summer 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. Despite some slight season variations, the catches during each of the surveys were near evenly split between California native fish and exotic fish. 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 none were over 150 mm (6 inches) in length.

Durand et al. (2019) conducted multiple year fish surveys throughout the Cache-Lindsey Slough Complex. Their closest survey station was located in lower Barker Slough 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 (Durand et al. 2019). These results suggest a significant difference in the fish populations between the tidal lower Barker Slough area and non-tidal upper barker Slough basin upstream of Campbell Lake.

There were no observations of any rare vernal pool species such as fairy shrimp, tadpole shrimp, or California tiger salamander during any of the three 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

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