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2017 Warner Sucker Investigations (Warner lakes and lower Honey Creek)

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Photograph of the Warner Mountains with Hart Lake in the foreground.

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Abstract— Warner Suckers *Catostomus warnerensis* are endemic to the lakes and tributaries of the Warner Basin, southeastern Oregon. The species was listed as threatened by the U.S. Fish and Wildlife Service in 1985 due to habitat fragmentation and threats from introduced nonnative fishes. Recent recovery efforts have focused on providing passage at irrigation diversion dams that limit Warner Sucker movement within the Warner Basin. Additionally, the Warner Lakes, which support large populations of nonnative predatory fishes, dried completely in 2015 following several years of drought, then refilled in 2016–2017. Complete drying of the lakes, which last occurred in the early 1990s, reduces the numbers of nonnative predatory fishes in the lakes and may result in increased Warner Sucker recruitment and abundance when the lakes refill. Our 2017 objectives were to: 1) describe the abundance (catch-per-unit-effort) and size structure of native and nonnative fishes captured in Hart and Crump lakes following the lake drying event, and 2) evaluate Warner Sucker passage success at the recently constructed Honey Creek Rookery Diversion fishway. In 2017, fish abundance in Hart and Crump Lakes was low, compared to past sampling, and primarily small-sized fish were captured. Few Warner Suckers were captured (n=5) and the fish assemblages in the lakes were dominated by native Tui Chub *Siphateles thalassinus* and nonnative Black Crappie *Pomoxis nigromaculatus*. We documented the successful upstream passage of Warner Suckers at the Rookery Diversion fishway at a range of stream discharges (0.71–2.63 m^3/s).

INTRODUCTION

Warner Suckers *Catostomus warnerensis* are endemic to the Warner Basin, an endorheic subbasin of the Great Basin in southeastern Oregon and northwestern Nevada. Historically, the species was abundant and its range included three permanent lakes (Hart, Crump, and Pelican), several ephemeral lakes, and three major tributary drainages (Honey, Deep, and Twentymile creeks) (U.S. Fish and Wildlife Service 1985). Warner Sucker abundance and distribution has declined over the past century and it was federally listed as threatened in 1985 due to habitat fragmentation and threats posed by the proliferation of piscivorous nonnative game fishes (U.S. Fish and Wildlife Service 1985).

Warner Suckers inhabit the lakes and low gradient stream reaches of the Warner Basin. The Warner Sucker metapopulation is comprised of both stream-dwelling and lake-dwelling fish. The stream-dwelling Warner Suckers inhabit and spawn in Honey, Deep, and Twentymile creeks. The lake-dwelling Warner Suckers typically exhibit a lacustrine-adfluvial life history; however, upstream migration may be blocked by low stream flows during low water years or by irrigation diversion dams. When this happens, spawning and rearing may occur in nearshore areas of the lakes (White et al. 1990), where large populations of lake-dwelling nonnative fishes likely reduce recruitment by preying on young Warner Suckers (U.S. Fish and Wildlife Service 1998). The stream-dwelling Warner Suckers display a fluvial life-history pattern and spawn in the three major tributary drainages. Threats specific to the stream-dwelling Warner Suckers include water withdrawals for irrigation and impacts to their habitat from grazing. Stream-dwelling Warner Suckers recolonized the lakes after past drying events in the mid-1930's and early-1990s.

The Recovery Plan for the Threatened and Rare Native Fishes of the Warner Basin and Alkali Subbasin (U.S. Fish and Wildlife Service 1998) sets recovery criteria for delisting Warner Suckers. These criteria require that: 1) a self-sustaining metapopulation is distributed throughout the Twentymile Creek, Honey Creek, and Deep Creek (below the falls) drainages, and in Pelican, Crump, and Hart lakes, 2) passage is restored within and among the Twentymile Creek, Honey Creek, and Deep Creek (below the falls) drainages so that the individual populations of Warner Suckers can function as a metapopulation, and 3) no threats exist that would likely threaten the survival of the species over a significant portion of its range.

Recently there has been a focused effort to provide fish passage at migration barriers throughout the basin (criterion two) (Scheerer et al. 2017). Honey Creek has eight irrigation diversion dams which create barriers that limit fish movement. To partially address passage issues in this basin, the Lake County Soil and Water Conservation District and Oregon Department of Fish and Wildlife (ODFW) worked with contractors in 2013–2014 to modify the downstream-most fish barrier in Honey Creek, the Rookery Diversion, by constructing a fishway designed to allow passage by both Warner Suckers and Redband Trout *Oncorhynchus mykiss*. The new fishway is ~40 m long with 12 pools (cells) that are divided by weirs that have 0.23 m square orifices on the fishway floor for Warner Sucker passage, 0.30 m weir drops for Redband Trout passage, and a simulated streambed floor (artificial boulders) in the downstream half of the fishway. The fishway was designed for a passage period of April–June, orifice velocities of 1.16 m/s, weir v-slot velocities ranging from 0.29–

1.35 m/s, fishway discharges ranging from 0.01–4.74 m^3/s (see Appendix A for a m^3/s to cfs conversion table), a minimum pool depth of 0.15 m, and a jump height of 0 m (Appendix B; Ryan McCormick, ODFW, personal communication).

The Warner Lakes completely dried in 2015, following several years of drought. These events are infrequent, with previous drying of the lakes occurring in the 1930s and early-1990s. These drying events tend to temporarily improve the recruitment of native fishes, including Warner Suckers, into the lakes and reduce the abundance of nonnative fishes in the lakes (Allen et al. 1996). It is plausible that increased recruitment and abundance of Warner Suckers in the lakes should increase the likelihood of gene flow among populations of Warner Suckers occupying different tributary streams; at least among those occupying the currently accessible, lower stream reaches downstream of the irrigation diversions. This gene flow and the potential for recolonization of previously occupied habitats, if a local extinction event were to occur, is critical for a functioning metapopulation (Hanski and Gilpin 1997).

Our 2017 objectives were to: 1) describe the abundance (catch-per-unit-effort (CPUE)) and size structure of native and nonnative fishes captured in Hart and Crump lakes, and 2) evaluate Warner Sucker passage success at the recently constructed fishway on Honey Creek's Rookery Diversion.

METHODS

Abundance and Size Structure of Native and Nonnative Fishes in Hart and Crump Lakes

We used trap nets to sample the fish assemblages in Hart and Crump lakes (Figures 1 and 2). We sampled from 2 May – 22 June 2017 using 18 trap nets. The trap nets had wide rectangular openings that measured 0.9 m tall by 1.8 m wide and narrowed to a vertical slot that was 0.9 m tall by 0.22 m wide, followed by four or five funneling hoops that measured 0.76 m in diameter with 0.15 m diameter fyke openings. Nets were a total of 3.7 m long with a lead net measuring 15 m long by 0.9 m tall. All nets had 19 mm mesh size. We set the nets off-shore in pairs, with their lead nets tied together and weighed each down with two 3.6–4.5 kg stockless anchors (one at each end). We accessed the nets using a 6.1 m sled boat powered by a 150 horsepower jet outboard motor or a 4.9 m sled boat powered by a 50 horsepower outboard motor. We set nets on Mondays, checked and reset them approximately every 24 h, and removed them from the water after checking them on Thursdays (three overnight net sets per week). We recorded the trap net locations from a Garmin® hand-held global positioning system.

We identified all of the fish that we captured to species and counted them. We measured the fork length (FL) of each Warner Sucker to the nearest 5 mm. We measured the fork length to the nearest 5 mm of a subsample of the other fish species that we collected. We determined the sex of each Warner Sucker, when possible, using a combination of the following characteristics: presence of breeding tubercles on male fish, presence of eggs or milt, anal fin morphology (Coombs et al.

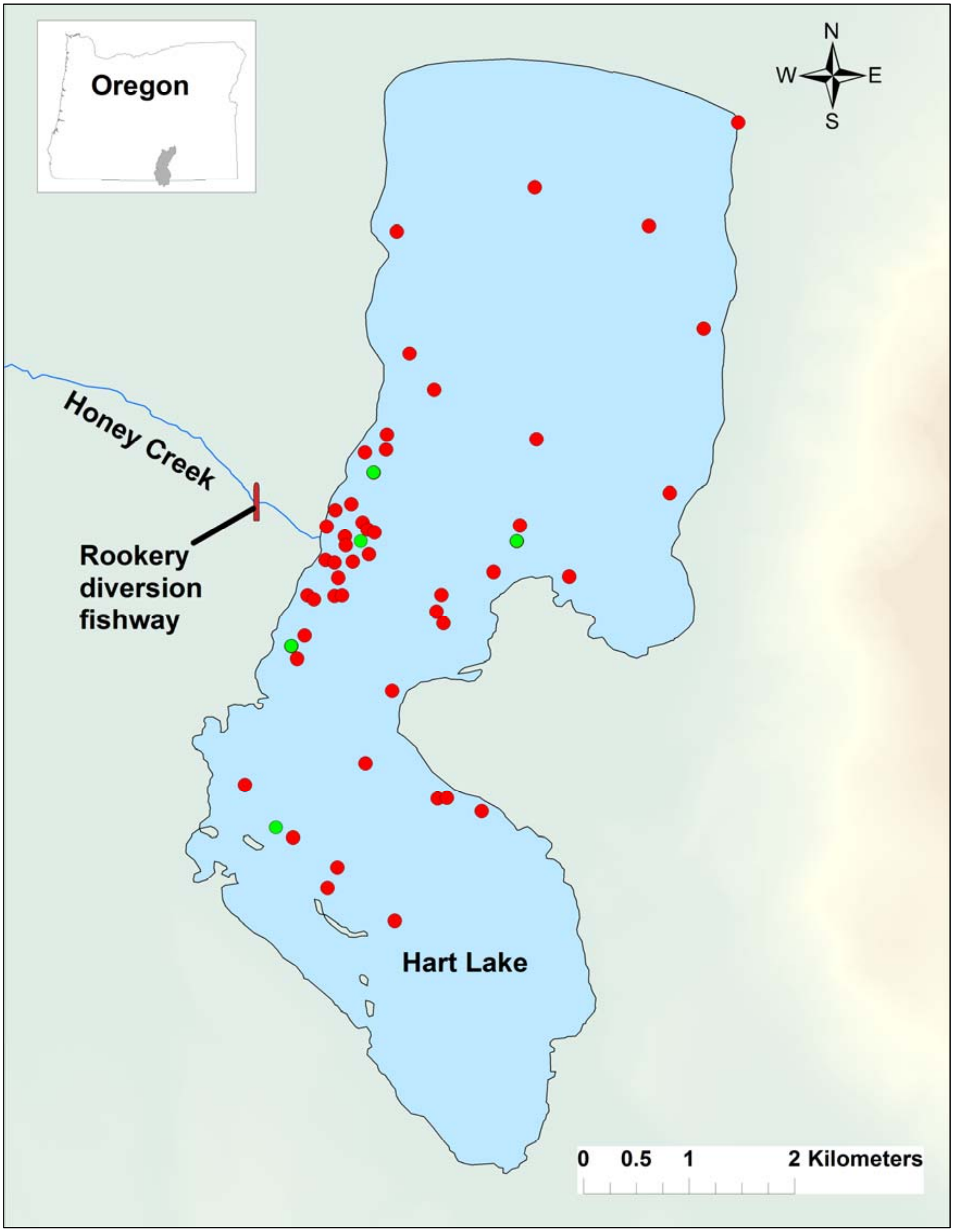

Figure 1. Locations of trap nets fished in Hart Lake (all circles), spring 2017. Locations where Warner Suckers were collected are represented by green circles. Also shown is the location of the Rookery Diversion fishway on Honey Creek.

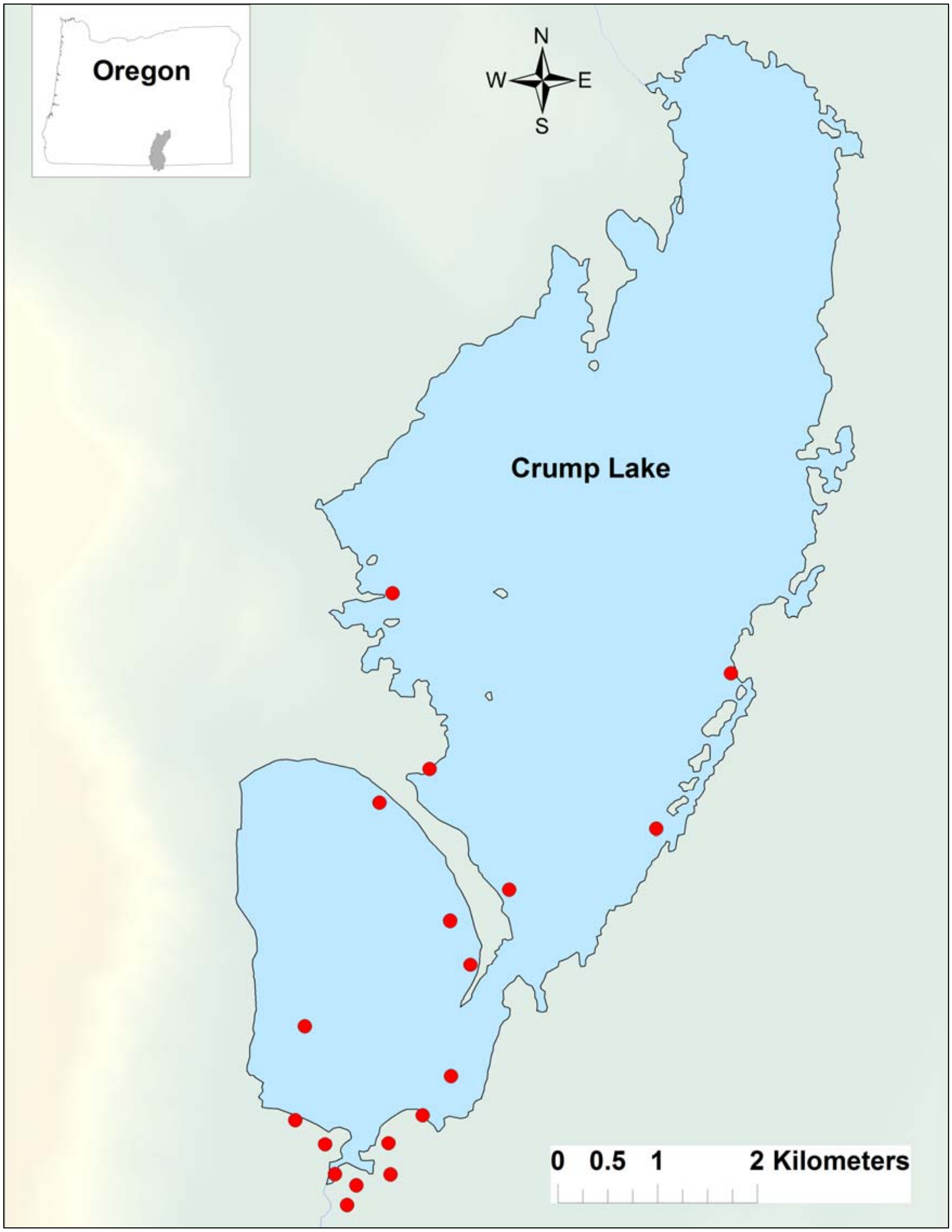

Figure 2. Locations of trap nets (red circles) fished in Crump Lake, spring 2017. Note, even though it appears that trap nets were set on dry land in the southern area of Crump Lake, these areas were flooded during the sampling period. No Warner Suckers were captured in Crump Lake in 2017.

1979), and spawning coloration. We checked all captured Warner Suckers for the presence of Passive Integrated Transponder tags (PIT tags) with a hand held PIT-tag reader. If a tag was present, we recorded the tag code. If a tag was not present, we anesthetized the fish with tricaine methanesulfonate (MS-222; 20 g/l) buffered with sodium bicarbonate (20 g/l), made a small ≤0.5 cm incision in the ventral body cavity, and inserted a 23 x 3 mm half-duplex PIT tag into the peritoneal cavity. PIT tags were scanned and the tag codes recorded prior to insertion. We disinfected all surgery equipment prior to surgery with isopropyl alcohol and applied an antibiotic (oxytetracycline) to the scalpel and the PIT tag prior to surgery and tag insertion. Following processing, we allowed each fish to recover and then released it near its capture location, with the exception of four Warner Suckers that we released into the pool downstream of the Rookery Diversion's fishway for fish passage assessment (see below). We described fish abundance for all species captured as catch-per-unit-effort (CPUE), where one unit of effort was one overnight trap net set, and compared the 2017 CPUE with results from previous surveys.

Warner Sucker Passage Assessment

We installed and operated two fixed, PIT-tag antennas in the recently constructed fishway at the Rookery Diversion on lower Honey Creek (Figure 1) to evaluate Warner Sucker passage success. We installed these antennas on the downstream-most and upstream-most fishway orifices. We tested antenna performance and downloaded tag detection data weekly. PIT-tag detection beacons installed at both antennas were continuously detected throughout the duration of the study, indicating that there was no break in antenna function. We monitored the movement of twelve Warner Suckers that we collected from Summer Lake Wildlife Management Area (WMA) and translocated into the downstream-most cell of the fishway (n=6) or into the pool downstream of the fishway (n=6) on 30 May 2017. We collected the fish from the Summer Lake WMA using a Smith-Root® LR-12 backpack electrofisher and transported them to Honey Creek in an insulated and aerated 1,875 liter, truck mounted fish tank. Additionally, we monitored the movement of four Warner Suckers that we captured in Hart Lake (see above) and released into the pool downstream of the fishway between 6–20 June 2017. We measured water velocities on 1 June 2017 in the upstream-most weir orifice and weir v-slot using a Marsh-McBirney® flow meter and compared these measurements with modelled pre-construction estimates of water velocities.

RESULTS

Abundance and Size Structure of Native and Nonnative Fishes in Hart and Crump Lakes

We captured low numbers of fish in the trap nets in 2017 compared to previous trapping efforts, including only five Warner Suckers, all of which were captured in Hart Lake (Figure 1). The 2017 Warner Sucker CPUE (0.02 fish per trap night) was the second lowest on record in Hart Lake and lowest on record in Crump Lake. The 2017 CPUE in Hart Lake was less than 2% of the peak CPUEs in 1990, 1994, 1996, 1997, and 2001 (Table 1). CPUEs for the other fish species captured were also substantially lower than those from 2012, the most recent sampling effort prior to drying of the lakes (Table 2). In 2017, the total trap net catch and CPUE of

Table 1. Warner Sucker catch-per-unit-effort (CPUE) for trap nets fished in Hart and Crump lakes, 1990-2017.

	Hart Lake		Crump Lake	
Year	Trap nights	CPUE	Trap nights	CPUE
1990	122	1.56	9	1.78
1991	175	0.59	0	-
1993	70	0.00	35	0.00
1994	40	2.33	15	0.20
1995	104	0.18	40	0.03
1996	252	3.31	36	0.31
1997	137	1.41	60	0.03
2001	63	2.79	24	0.21
2006	214	0.19	238	0.25
2008	473	0.16	258	0.10
2010	0	-	199	0.20
2012	434	0.34	276	0.13
2017	312	0.02	108	0.00

all fish species combined was only 2.2% and 3.4%, respectively, of the 2012 values. The size structures of fishes captured in the lakes were generally skewed towards smaller-sized individuals (Figure 3), possibly a result of recent recruitment of smaller individuals from tributaries and irrigation canals following the complete drying of the lakes in 2015. Note, stream-dwelling fishes in the Warner Basin are generally smaller, regardless of age, than lake-dwelling suckers (Scheerer et al. 2016).

The proportional contribution of native and nonnative fishes to the 2017 catch was noticeably different from their contributions to the 2012 catch, with an increased proportion of native fishes in the 2017 catch (Figure 4). Tui Chub *Siphateles thalassinus* were the most abundant native fish sampled in 2017. In 2017 we also noted a substantial increase in the proportion of Black Crappie *Pomoxis nigromaculatus* and decrease in the proportion of White Crappie *P. annularis* and

Table 2. Comparison of the 2017 and 2012 catch, sampling effort (trap nights), catch-per-unit-effort (CPUE), and proportion of each fish species in the total trap net catch (entire sampling season) in Hart Lake, Crump Lake, and Hart and Crump lakes combined (Both). Native fishes: WSU= Warner Sucker, TC= Tui Chub, RBT= Redband Trout. Nonnative fishes: WC= White Crappie, BC= Black Crappie, LMB= Largemouth Bass, and BBU= Brown Bullhead.

2017

Lake	Species	Catch	Trap nights	CPUE	Proportion
Hart	WSU	5	312	0.014	0.014
Hart	TC	261	312	0.725	0.737
Hart	RBT	0	312	0.000	0.000
Hart	WC	1	312	0.003	0.003
Hart	BC	86	312	0.239	0.243
Hart	LMB	0	312	0.000	0.000
Hart	BBU	1	312	0.003	0.003
		87	312	0.242	

Lake	Species	Catch	Trap nights	CPUE	Proportion
Crump	WSU	0	108	0.000	0.000
Crump	TC	87	108	0.806	0.424
Crump	RBT	0	108	0.000	0.000
Crump	WC	2	108	0.019	0.010
Crump	BC	115	108	1.065	0.561
Crump	LMB	0	108	0.000	0.000
Crump	BBU	1	108	0.009	0.005
		205	108	1.898	

Lake	Species	Catch	Trap nights	CPUE	Proportion
Both	WSU	5	420	0.011	0.009
Both	TC	348	420	0.744	0.623
Both	RBT	0	420	0.000	0.000
Both	WC	3	420	0.006	0.005
Both	BC	201	420	0.429	0.360
Both	LMB	0	420	0.000	0.000
Both	BBU	2	420	0.004	0.004
		559	420	1.194	

2012

Lake	Species	Catch	Trap nights	CPUE	Proportion
Hart	WSU	148	434	0.343	0.010
Hart	TC	1,710	434	3.958	0.118
Hart	RBT	12	434	0.028	0.001
Hart	WC	9,650	434	22.338	0.664
Hart	BC	1,336	434	3.093	0.092
Hart	LMB	17	434	0.039	0.001
Hart	BBU	1,670	434	3.866	0.115
		14,543	434	33.664	

Lake	Species	Catch	Trap nights	CPUE	Proportion
Crump	WSU	37	276	0.134	0.003
Crump	TC	544	276	1.971	0.051
Crump	RBT	2	276	0.007	0.000
Crump	WC	7,287	276	26.402	0.682
Crump	BC	1,152	276	4.174	0.108
Crump	LMB	2	276	0.007	0.000
Crump	BBU	1,653	276	5.989	0.155
		10,677	276	38.685	

Lake	Species	Catch	Trap nights	CPUE	Proportion
Both	WSU	185	710	0.261	0.007
Both	TC	2,254	710	3.175	0.089
Both	RBT	14	710	0.020	0.001
Both	WC	16,937	710	23.855	0.672
Both	BC	2,488	710	3.504	0.099
Both	LMB	19	710	0.027	0.001
Both	BBU	3,323	710	4.680	0.132
		25,220	710	35.521	

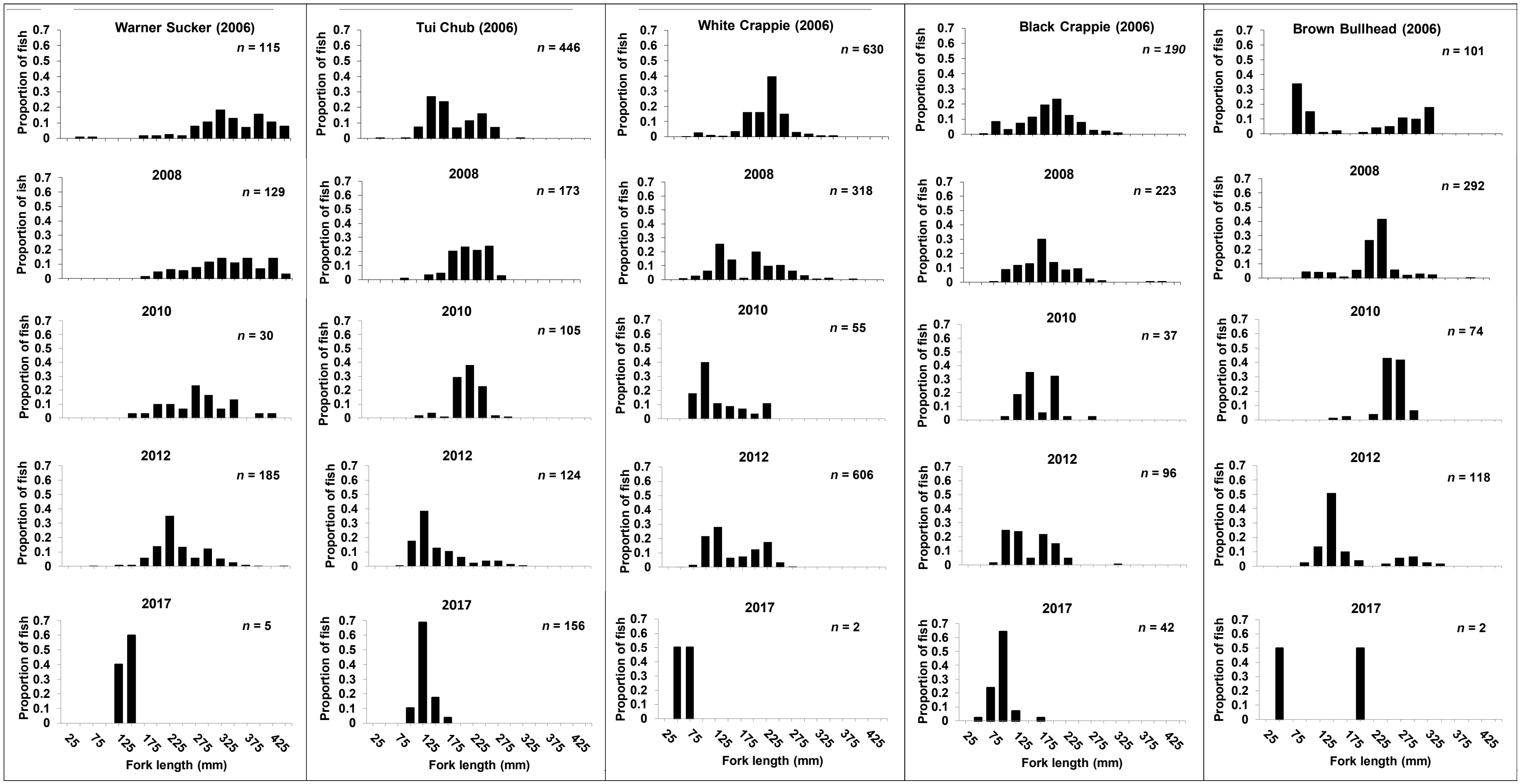

Figure 3. Length-frequency histograms for fishes collected from Hart and Crump lakes, 2006–2017.

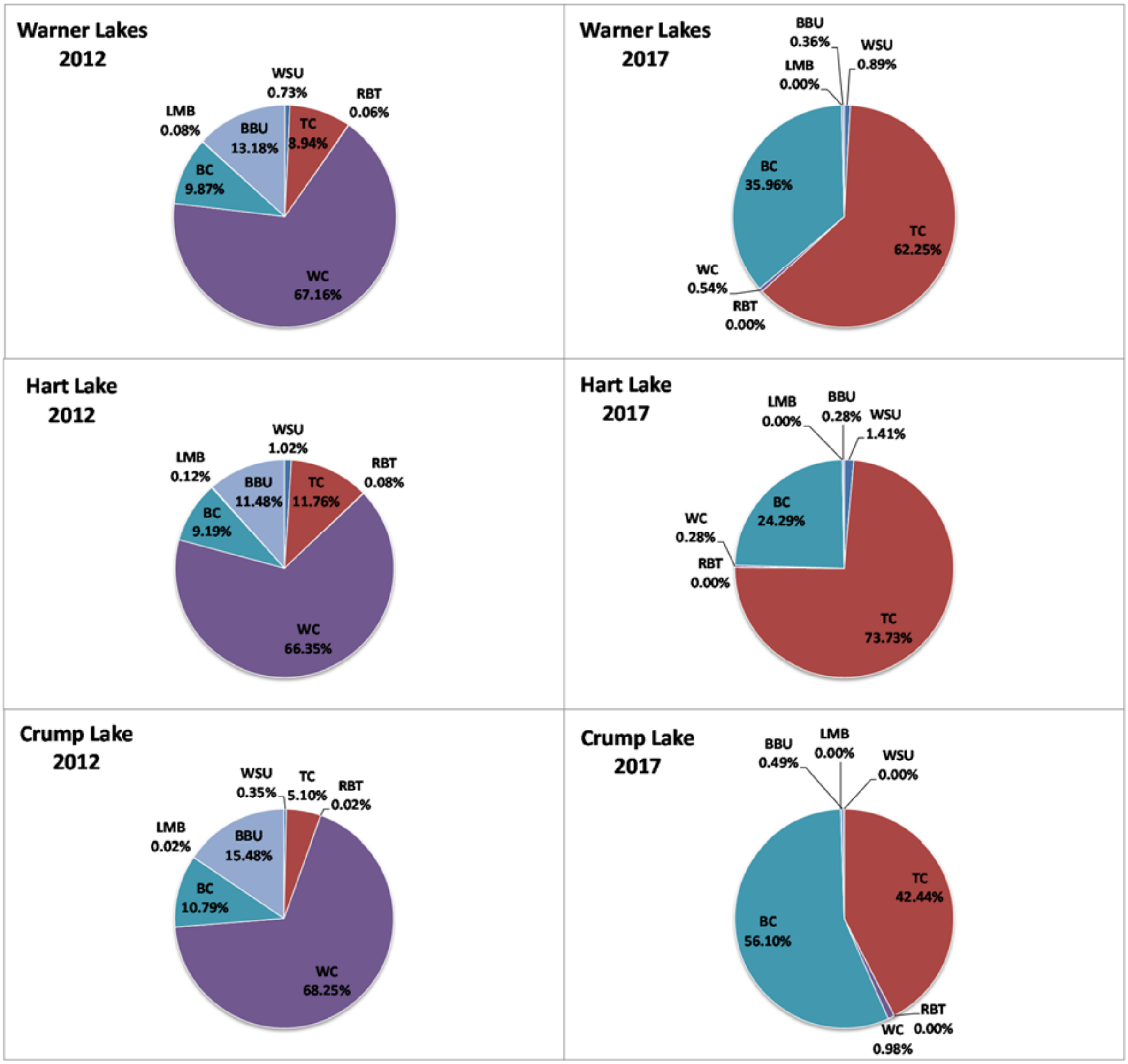

Figure 4. Contribution of native and nonnative fishes to the trap net catch in Hart and Crump lakes in 2017 (post-drying), both individually and combined, compared to 2012 (pre-drying). Native fishes: WSU= Warner Sucker, TC= Tui Chub, RBT= Redband Trout. Nonnative fishes: WC= White Crappie, BC= Black Crappie, LMB= Largemouth Bass, and BBU= Brown Bullhead.

Brown Bullhead *Ameiurus nebulosus* in the catch of nonnative fishes compared to 2012. Changes in fish species composition in the Warner lakes have occurred frequently since sampling was first initiated in 1990. Trap net catch was dominated by nonnative fishes in most years, with the exception of years following lake drying (1994–1997 and 2017), when native fishes dominated the catch (Table 3; Figure 5). Native Tui Chub were the most common native fish species captured during all prior sampling efforts. Warner Suckers consistently represented a small proportion of the total trap net catch (0.3–6.1%).

Warner Sucker Passage Assessment

We documented five Warner Suckers (155–215 mm) passing successfully upstream through the fishway at the Rookery Diversion from 30 May to 15 July 2017, at stream discharges ranging from 0.71–2.63 m^3/s. Note, however, that stream discharge at the fishway, which is located several kilometers downstream from the stream gage, was likely less than stream discharge recorded at the gage because water is diverted for irrigation from seven diversions located between the gage and the fishway. Four of the six Warner Suckers that we released into the fishway passed upstream through the structure and two moved downstream out of the fishway (Table 4). Only one of the ten Warner Suckers that we released into the pool downstream of the fishway passed upstream through the structure. This fish was the largest fish released into the pool (215 mm) and was substantially larger than the other nine fish that we released into the pool (mean: 139 mm; range: 110-160 mm). Overall, the mean fork length of the five fish that successfully passed

Table 3. Proportions of native and nonnative fishes in the trap net catch from the Warner lakes, 1990-2017. Also included are the total trap net catch, total trap net effort, and catch-per-unit-effort (CPUE) for all fish species combined. Note, native fishes are the Warner Sucker, Tui Chub, and Redband Trout. Nonnative fishes are White Crappie, Black Crappie, Largemouth Bass, and Brown Bullhead.

Species	1990	1991	1993	1994	1995	1996	1997	2001	2006	2008	2010	2012	2017
Warner Sucker	0.02	0.06	0.00	0.03	0.00	0.06	0.01	0.04	0.01	0.00	0.01	0.01	0.01
Tui Chub	0.03	0.17	0.63	0.49	0.82	0.84	0.79	0.08	0.28	0.19	0.35	0.09	0.62
Redband Trout	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White Crappie	0.40	0.42	0.29[a]	0.01	0.02	0.00	0.05	0.09	0.55	0.31	0.34	0.67	0.01
Black Crappie	0.18	0.19		0.43	0.14	0.09	0.11	0.12	0.13	0.20	0.17	0.10	0.36
Largemouth Bass	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Brown Bullhead	0.37	0.16	0.04	0.04	0.02	0.01	0.04	0.67	0.04	0.30	0.13	0.13	0.00
Natives	0.05	0.23	0.64	0.52	0.83	0.90	0.80	0.12	0.29	0.19	0.36	0.10	0.63
Nonnatives	0.95	0.77	0.36	0.48	0.18	0.10	0.20	0.88	0.71	0.81	0.64	0.90	0.37
Total catch	9,578	1,675	73	3,590	6,532	15,234	24,936	4,890	20,835	29,861	3,086	25,220	559
Trap nights	131	175	105	89	144	288	197	87	452	731	199	708	420
CPUE	73.0	9.6	0.7	65.2	45.4	52.9	126.6	56.2	44.7	40.8	15.3	35.6	1.3

[a]The sampling crew did not distinguish between Black Crappie and White Crappie.

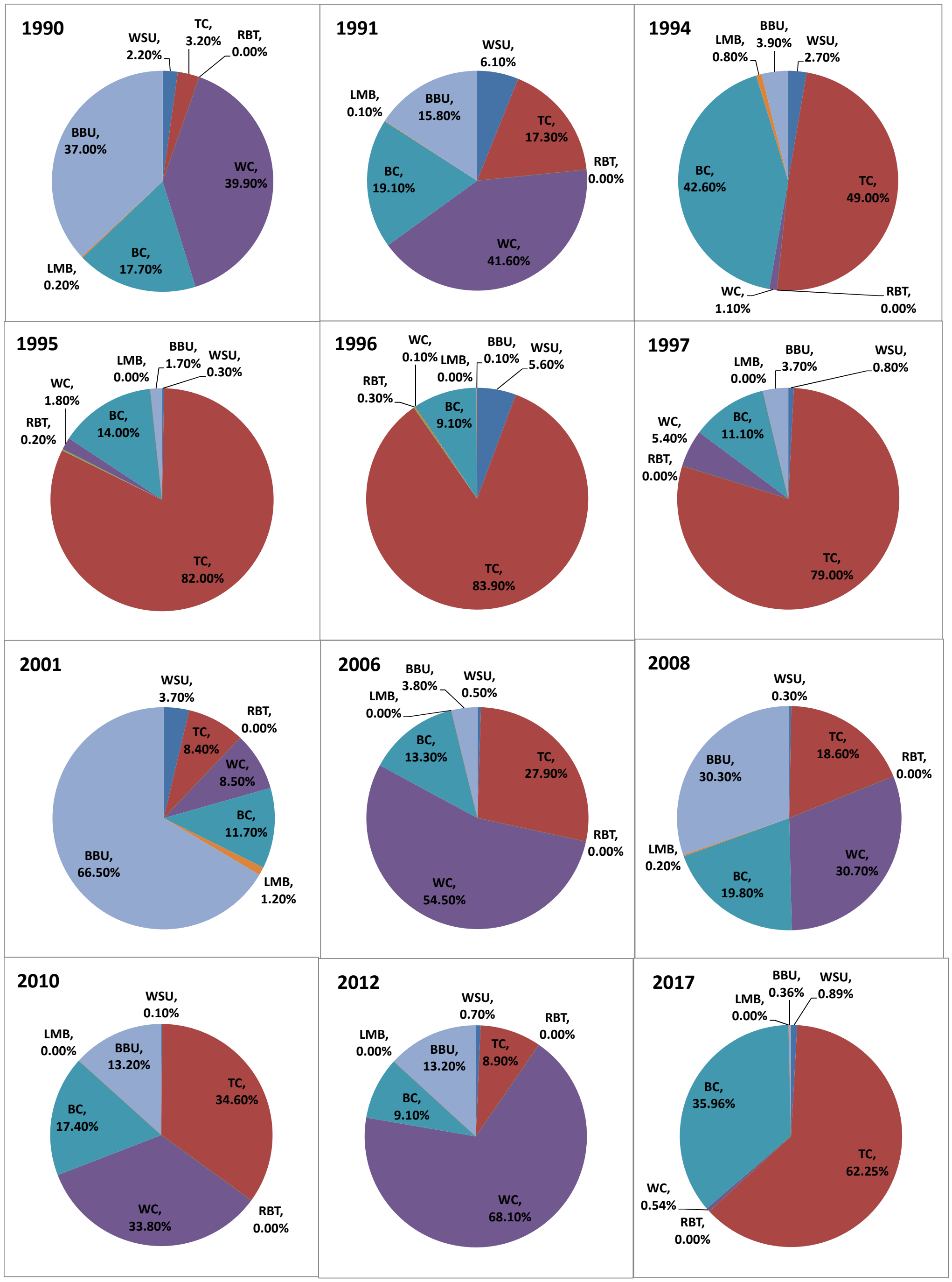

Figure 5. Contribution of native and nonnative fishes to the trap net catch in Hart and Crump lakes, 1990–2017. Native fishes: WSU= Warner Sucker, TC= Tui Chub, RBT= Redband Trout. Nonnative fishes: WC= White Crappie, BC= Black Crappie, LMB= Largemouth Bass, and BBU= Brown Bullhead. Note, the lakes dried completely in 1992–1993 and in 2015.

Table 4. Details of the Warner Suckers captured in the Warner Lakes and Summer Lake WMA and for those released into Honey Creek for the passage assessment, spring 2017.

Date captured	Location captured	PIT tag number	Fork length (mm)	Sex	Release location	Pit antenna detection
30-May-17	Summer Lake WMA	361679067	190	F	Fishway	passed 28-June
30-May-17	Summer Lake WMA	361679082	130	F?	Pool	
30-May-17	Summer Lake WMA	361656968	155	F	Fishway	passed 30-May
30-May-17	Summer Lake WMA	361679065	110	M	Pool	
30-May-17	Summer Lake WMA	361656979	165	M	Fishway	passed 15-July
30-May-17	Summer Lake WMA	361656930	150	F	Pool	
30-May-17	Summer Lake WMA	361679025	160	F	Fishway	moved downstream out of fishway 30-May
30-May-17	Summer Lake WMA	361656920	215	F	Pool	passed 29-June
30-May-17	Summer Lake WMA	361678998	165	F	Fishway	passed 31-May
30-May-17	Summer Lake WMA	361679092	140	M?	Pool	
30-May-17	Summer Lake WMA	361679083	150	F	Fishway	moved downstream out of fishway 30-June
30-May-17	Summer Lake WMA	361656932	125	F	Pool	
6-Jun-17	Hart Lake	361656918	130	M	Hart Lake	
12-Jun-17	Hart Lake	361656959	160	F	Fishway	
14-Jun-17	Hart Lake	361679002	155	F	Fishway	
15-Jun-17	Hart Lake	361679086	145	M	Fishway	
20-Jun-17	Hart Lake	361679098	150	M	Fishway	

upstream was 178 mm (range: 155–215 mm), whereas the mean fork length of the eleven fish that did not pass through the structure was 143 mm (range: 110–160 mm). Passage duration through the fishway varied from 1.1 h to 46.2 d, with a mean of 21.1 d.

Water velocities measured on 1 June 2017 in the orifice on the upstream weir panel ranged from 0.89 m/s near the substrate to 1.19 m/s in the middle of the orifice. Water velocity measured at the weir slot was 1.39 m/s. These measurements were nearly identical to model-projected velocities in the orifices (1.16 m/s) and weir slots (0.29–1.35 m/s). Discharge at the stream gage was 2.89 m^3/s on 1 June 2017. Discharge through the fishway was not estimated, but was less than that recorded at the stream gage due to observed irrigation withdrawals upstream of the fishway, yet downstream of the gage.

DISCUSSION

Irrigation diversions restrict movement and gene flow of Warner Suckers within tributaries, among tributaries, and among lakes and tributaries in the Warner Basin. Recent recovery actions have focused on improving fish passage by replacing or reconstructing aging irrigation diversion structures, most of which were constructed decades ago without fishways or screening. A fishway designed to facilitate passage of Warner Suckers and Redband Trout was installed on lower Honey Creek at the Rookery Diversion in 2013–2014. In the present study we documented successful upstream passage of Warner Suckers (155–215 mm) through this fishway at a wide range of stream discharges (0.71–2.63 m^3/s). Successful passage of Warner Suckers has also been observed at a similarly designed fishway constructed in 2013–2014 at the Dyke Diversion on lower Twentymile Creek (Scheerer et al. 2016; 2017).

We documented successful passage of Warner Suckers through the fishway at the Rookery Diversion; however, many of the Warner Suckers (nine of ten) that we released downstream of the fishway failed to pass upstream. It is unclear whether these fish did not pass because they lacked motivation to migrate upstream, whether they had difficulty locating the fishway's lower orifice, whether some of the smaller-sized fish had difficulty achieving swimming speeds necessary to overcome fishway orifice velocities, or some combination of these.

Warner Suckers in the Warner lakes may be motivated to migrate upstream to locate suitable spawning habitat (US Fish and Wildlife Service 1985). Warner Suckers mature at approximately 155-160 mm (Scheerer et al. 2016). The two Warner Suckers that were released into the fishway and that moved downstream out of the fishway and seven of the nine fish released into the pool downstream of the fishway and that did not pass upstream were less than 155 mm. Fish larger than 155 mm were rare in both the Warner Lakes and in our sample collected from Summer Lake WMA in 2017. Additionally, only 1 of the 12 Warner Suckers collected at Summer Lake WMA showed signs of maturation when captured (a 110 mm FL male fish that had red coloration on its side and expressed milt, but did not pass through the fishway). Consequently, the several fish used in this study may have lacked the impulse to pass upstream through the fishway at the Rookery Diversion.

The Rookery Diversion's fishway has a similar design to the fishway installed at the Dyke Diversion on Twentymile Creek with one main design difference: simulated cobble substrate was added within the Dyke Diversion fishway, but not within the Rookery Diversion fishway. At the Rookery Diversion, artificial boulders were added to the concrete on the floor of the fishway, but these artificial boulders were only added to the lower half of the fishway. A lack of channel roughness in the upper half of the fishway may have been a factor limiting or delaying passage of some of the Warner Suckers in the current study.

ODFW investigations from 2006–2017 indicate that the Warner Sucker populations in Crump and Hart Lakes are depressed compared to levels in the mid-1990's (Allen et al. 1994; 1995; 1996; Scheerer et al. 2006; 2008; 2012). During the recent droughts (2009–2011 and 2013–2016), CPUE in Hart and Crump lakes was some of the lowest on record and recent CPUE estimates have declined more than 90% compared to peak Warner Sucker catches in the 1990s. In 2017 the CPUE for all fishes combined was the second lowest on record (1.2 fish per trap night). The lowest CPUE on record for all fishes combined occurred in 1993, the year following the previous, complete lake drying that occurred in 1991–1992 (Table 3). Lake drying events can function to reset the fish assemblages in the lakes by substantially reducing the abundance of nonnative predatory fishes, thus facilitating successful Warner Sucker recruitment from the tributaries (Allen et al. 2004; 2005; 2006). In 2017 Warner Sucker abundance in the lakes was low. Following the 1991—1992 lake drying event, it took four years after the lakes refilled before Warner Sucker abundance peaked (Table 1), thus it may be several more years before Warner Sucker abundance increases and can be documented. To promote recovery, suppression of nonnative fishes in the lakes, mimicking lake drying, is a tool that managers have considered to enhance Warner Sucker recruitment and early survival in the lakes.

Warner Suckers are abundant and widely distributed in the tributaries within the Warner Basin (Scheerer et al. 2007, 2011; Richardson et al. 2009), but connectivity among the lakes and tributaries continues to be restricted by unscreened, and mostly un-laddered, irrigation diversions. The numerous diversion dams and unscreened irrigation canals in the basin act to fragment the habitat of Warner Suckers and are a major obstacle to meeting recovery criteria. Specifically, fragmentation of habitat within the Warner Basin reduces or precludes the potential for a naturally functioning Warner Sucker metapopulation. Therefore, future management within the basin will likely include continued work with private landowners to install and evaluate passage improvement projects. In 2018, we plan to monitor Warner Sucker passage effectiveness on Twentymile Creek at the MC Diversion's fishway (rock ramp), which will be constructed in the fall of 2017. We will assess whether this design allows passage, whether modifications to the design of this fishway are warranted, or both.

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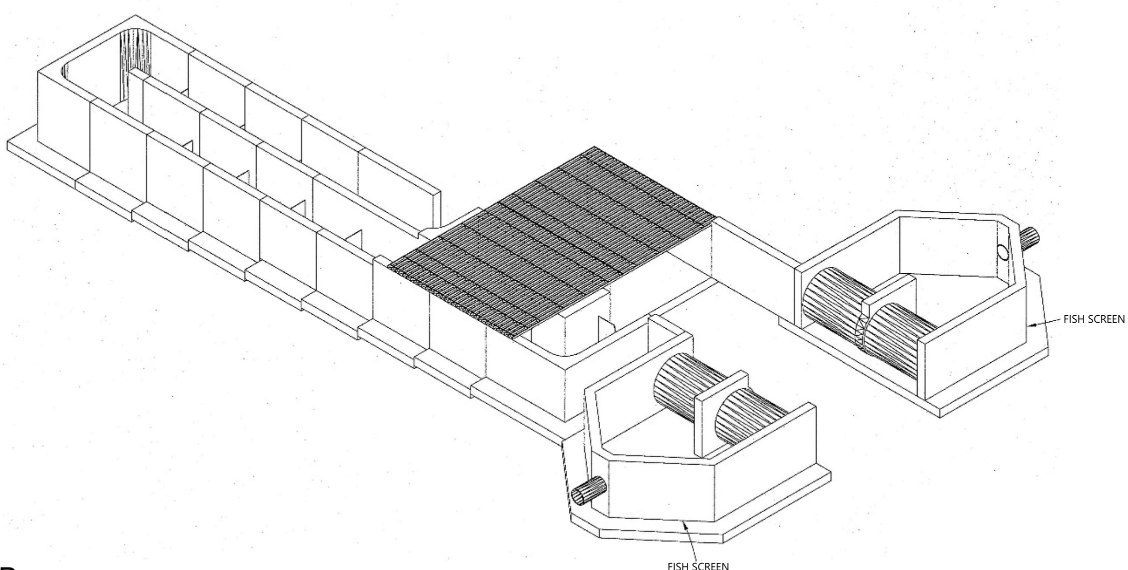
Appendix A. Chart to convert cubic meters per second (m^3/s) to cubic feet per second (cfs). Formula: multiply m^3/s by 35.31 to obtain cfs.

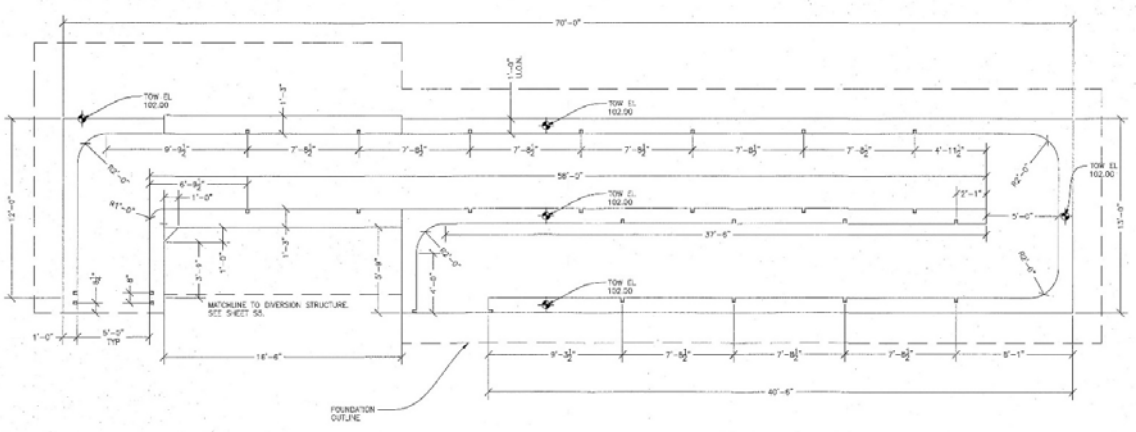
m^3/s	cfs
0.125	4.4
0.25	8.8
0.5	17.7
1	35.3
2	70.6
3	105.9
4	141.2
5	176.6
6	211.9
7	247.2
8	282.5
9	317.8
10	353.1
11	388.4
12	423.7
13	459.0
14	494.3
15	529.7
16	565.0
17	600.3
18	635.6
19	670.9
20	706.2

Appendix B. Diagrams of the Rookery Diversion fishway (prepared by R. L. McCormick, ODFW). (A) 3-dimension overhead schematic, (B) 2-dimension top-down schematic, and (C) aluminum weir panel schematic.

A.



B.



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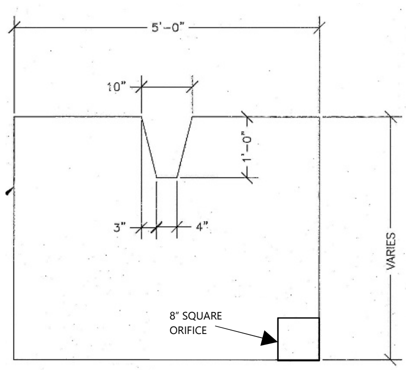

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