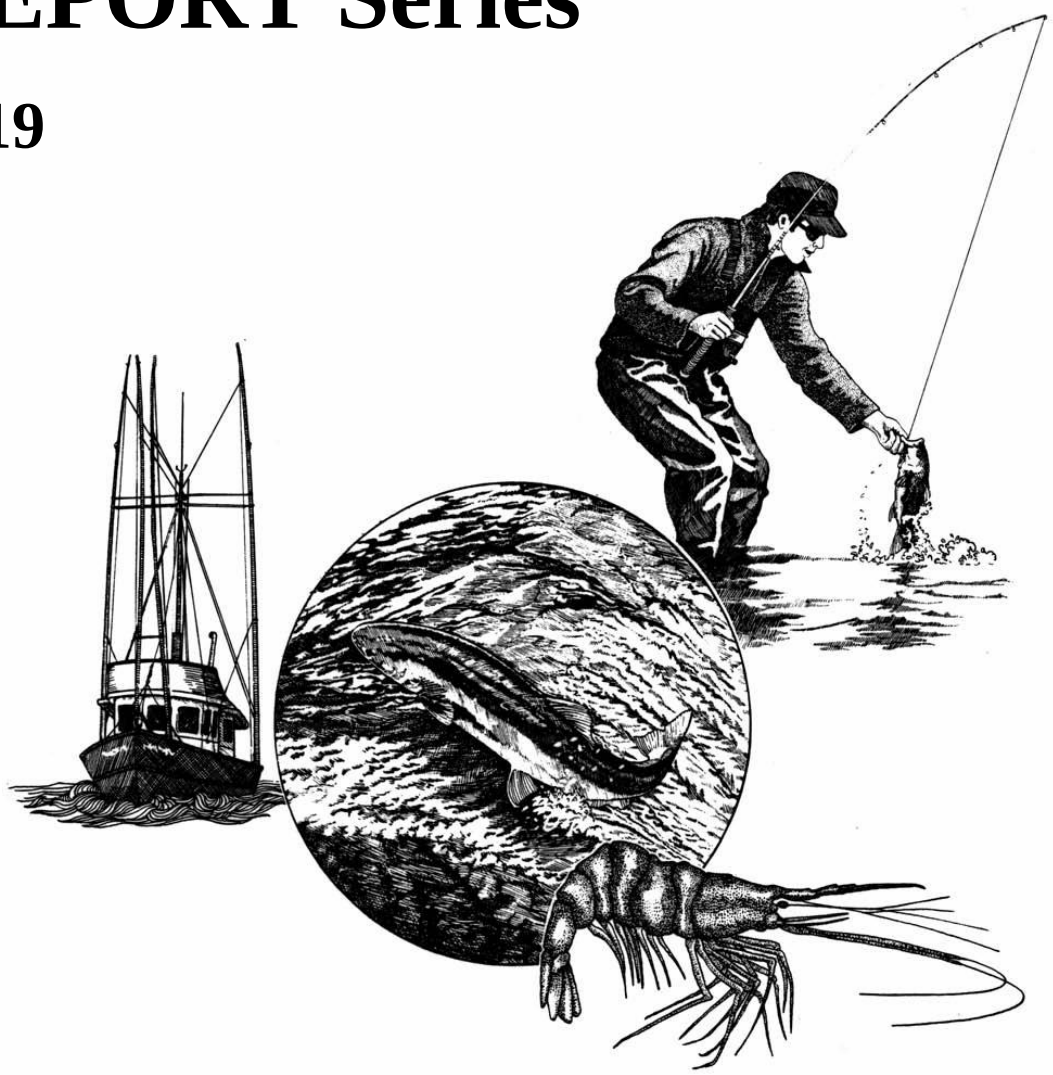
ODFW PROGRESS REPORT Series

2019



Oregon Department of Fish and Wildlife

Warner Sucker Passage Success at the Modified MC Diversion and Distribution in the Upper Twentymile Creek Subbasin

Contract Numbers: F17AC00449 and L15AC00139

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PROJECT TITLE: Warner Sucker Passage Success at the Modified MC Diversion and Distribution in the Upper Twentymile Creek Subbasin

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Photograph of the MC Diversion showing fish bypass box culvert and diversion dam.

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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 from numerous irrigation diversion dams in the tributaries and threats from introduced nonnative fish in the lakes. Recent recovery efforts have focused on providing passage at irrigation diversion dams that currently restrict Warner Sucker movement within the Warner Basin. Our objectives in 2019 were to: 1) re-evaluate Warner Sucker passage success at the modified MC Diversion fish bypass on Twentymile Creek; and 2) assess the upper distribution of Warner Suckers in the Twentymile and Deep creek subbasins. Modification to the MC bypass entailed removing the V-notch weir on the downstream end of the box culvert to improve flow through the bypass. Results from 2019 showed flows through the fish bypass were improved compared to 2018, ranging from 20-40 cfs for the majority of the spring season with occasional stoppages that lasted 1.5 - 9 d. Thirteen of 30 PIT-tagged suckers released below the bypass in 2019 successful passed upstream through the bypass channel and box culvert. The suckers that passed tended to be larger adult-sized individuals, ranging in size from 142-248 mm FL and purportedly migrating upstream to spawn. In addition, the only Redband Trout *Oncorhynchus mykiss* tagged in 2019 and one sucker tagged in 2018 also passed upstream through the bypass. Almost all passage events occurred at night and sucker travel time through the bypass box culvert ranged from a minimum of 5 minutes to a maximum of 20 hours. Several fish made repeated upstream/downstream trips through the bypass culvert. In Deep Creek, we did not collect Warner Suckers in the 1.5-km reach from the Adel-Town Diversion upstream to the Taylor Diversion. Based on 2019 survey and surveys from previous years, it appears that stream-resident Warner Suckers are not extant in Deep Creek. In the Twentymile Creek subbasin, we did not find sucker outside their currently known range. No suckers were found in Cow Head Slough, Rock Creek, Fifteenmile Creek, or Horse Creek in the upper Twelvemile Creek subbasin.

INTRODUCTION

Warner Suckers *Catostomus warnerensis* are endemic to the Warner Basin, a semi-arid endorheic subbasin of the Great Basin in southeastern Oregon, northwestern Nevada, and extreme northeastern California. The presumed historical range of the Warner Sucker consists of the low- to moderate-gradient reaches of the tributaries (Honey, Deep, and Twentymile creeks), the three relatively permanent lakes (Hart, Crump, and Pelican lakes), and several ephemeral lakes during periods of abundant precipitation (U.S. Fish and Wildlife Service 1985; Williams et al. 1990)(Figure 1). Warner Sucker abundance and distribution has declined over the past century and the species was federally listed as threatened in 1985 due to habitat fragmentation as the result of numerous irrigation diversion dams in the tributaries and threats posed by the proliferation of piscivorous nonnative game fishes in the lakes (U.S. Fish and Wildlife Service 1985).

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, Honey, and Deep Creek (below the falls) drainages, and in Pelican, Crump, and Hart lakes, 2) passage is restored within and among the Twentymile, Honey, 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. Although the U.S. Fish and Wildlife Service is currently (2019) reviewing recovery criteria for Warner Sucker, the need for passage and screening improvements in the basin will likely remain critical for recovery. The Warner Basin Aquatic Habitat Partnership (WBAHP), a collaboration of local, state, and federal partners, is committed to the recovery of the Warner Sucker through the completion of passage, screening, and habitat enhancement projects with participating landowners.

The Warner Sucker population is comprised of both stream-dwelling and lake-dwelling fish. The lake-dwelling Warner Suckers typically exhibit an adfluvial life history; however, upstream spawning 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). The stream-dwelling Warner Suckers exhibit a fluvial life-history and spawn in the tributary drainages.

The status of the population in Deep Creek is currently unknown. The historic distribution of Warner Sucker was purported to be throughout the stream below Deep Creek Falls. Presently, Warner Sucker appear to be confined to the lower half of the stream below Starveout Diversion (White et al. 1990; Scheerer et al 2007). This reach has a direct connection to Crump Lake via an artificial channel, and suckers in this reach are purportedly progeny of lake-resident spawners (Monzyk 2019). No suckers have been observed upstream of the Town diversion in recent surveys (White et al. 1990; Allen et al. 1994; Scheerer et al. 2007). However, private land access to the reach between Starvevout Diversion upstream to O'Keefe Diversions has not been

granted in recent years, so the existence of a resident population in this reach is still uncertain.

Stream-dwelling Warner Suckers are known to occupy 21 km of stream in the Twentymile Creek subbasin. Their upper distribution is purported to be in Twelvemile Creek near the California/Nevada border with the upstream-most occurrence recorded approximately 300 m downstream from the confluence with Fifteenmile Creek (Tait et al. 1995, Allen et al. 1994). However, there is a report of a single Warner Sucker (93 mm FL) captured in West Barrel Creek, a tributary of Cow Head Slough, in northeastern California (Scoppettone and Rissler 2003). The lower distribution is purported to be just downstream of the MC canal on the valley floor. No Warner Suckers have been observed in the canal system between the MC Canal and Crump Lake (Coombs et al. 1979; Scheerer et al. 2007), with the exception of a few individuals collected <1 km downstream of the Cahill Diversion that marks the lower end of the MC Canal (Scheerer et al. 2007) (Figure 1). In Twentymile Creek upstream of the confluence with Twelvemile Creek, Hayes (1978) collected adult suckers approximately 2 km upstream of the confluence.

Prior to major irrigation alterations, Twentymile Creek spread out through several distributary channels into the low-lying marshland upon entering the valley floor and annually flooded a large area in the spring. Beginning in the late-1930's through the 1950's, substantial alterations to the tributary and valley floor in the form of irrigation dams, canals, and dykes altered the habitat in the lower reach (Hunt 1964). A 15-mile dike system (flood ditch) was constructed along the eastern side of the southern valley forcing Twentymile Creek flood waters to bypass the marshlands and flow north to Greaser Reservoir (Figure 1). At the head of the flood ditch, a low-head dam (MC Dam) and headworks were constructed to control flow into an irrigation canal (MC Canal) that carried water along the west side of the valley (Hunt 1964). The dam creates head for water to be diverted into the irrigation canal through three 0.91-m diameter culverts, with flow through each culvert controlled with slide gates. The MC Canal, also considered to be the lower portion of Twentymile Creek, provides 1.5 km of sucker habitat before it is diverted into smaller irrigation canals at the Cahill Diversion (Figure 1). Scheerer et al. (2017) estimated 963 Warner Suckers resided in the MC Canal in 2016. High water velocities and shallow depths through the culverts are believed to impede upstream fish passage, thereby disconnecting fish residing in the canal to the rest of Twentymile Creek during high flow periods. To address passage issues at the MC Diversion, the WBAHP worked with River Design Group, Inc. in 2017 to construct a fish-friendly bypass at the MC Diversion.

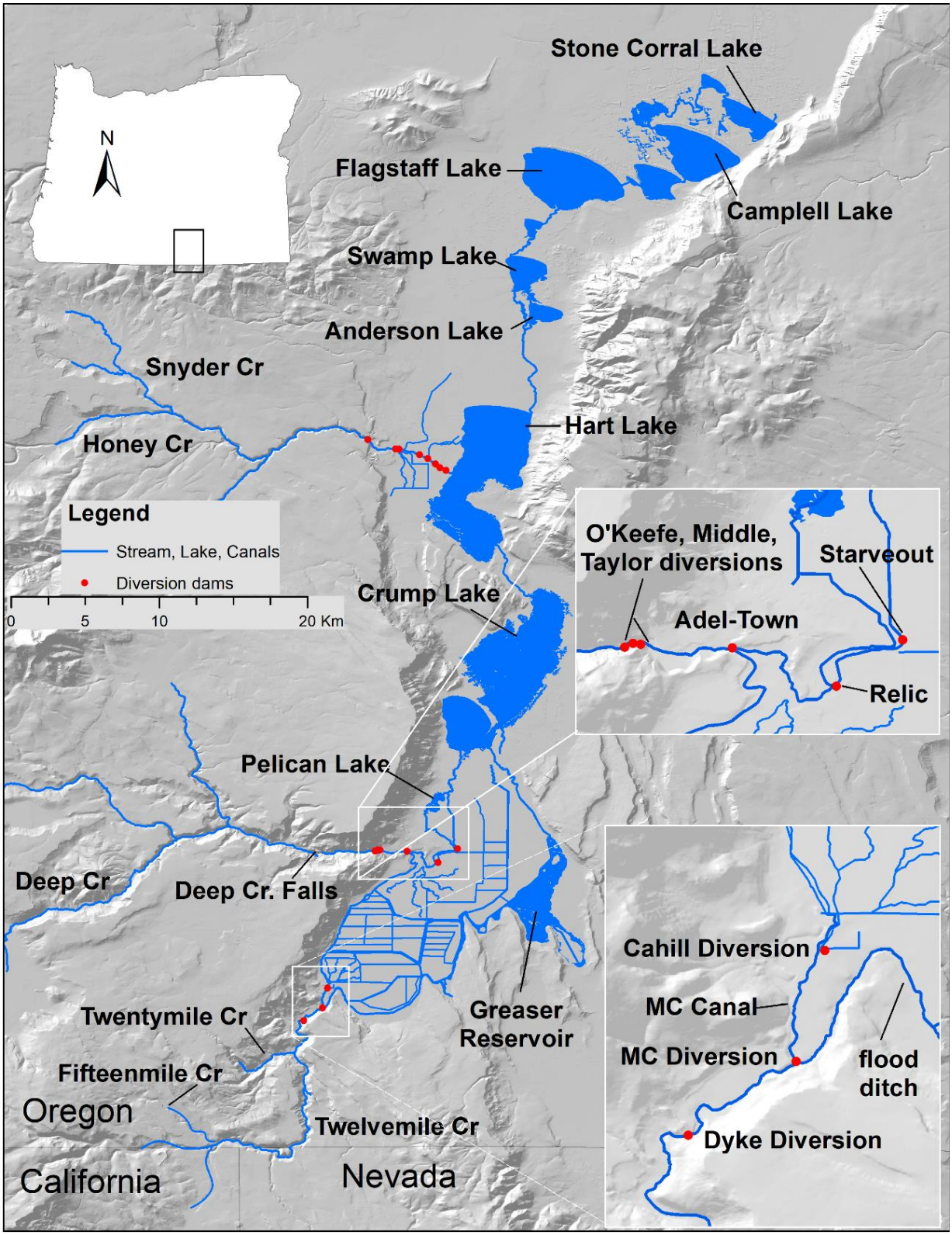

Figure 1. Map of the Warner Basin showing lakes, canals, streams, and irrigation diversion dams**.** Not shown is Bluejoint Lake, the northern-most lake in the basin. Insets show location of diversion dams on lower Twentymile and Deep creeks.

The design of the fish bypass at the MC Diversion consists of a fish-friendly box culvert located adjacent to the three old culverts and an 89-m bypass canal connecting the box culvert to the MC Canal (Figure 2). A slide gate controls flow entering the 1.82-m^2 box culvert that has a floor elevation of 1378.6 m above mean sea level (MSL). The initial design included a concrete V-notch weir at the downstream end of the box culvert that was set at 1379.5 m MSL to regulate flow and depth inside the culvert. However, during bypass operation in 2018, the weir was determined to be overly restrictive and caused forebay elevations to regularly overtop the dam. To prevent water from flowing over the dam, irrigators generally operated the bypass below designed flow rates, resulting in poor passage success by Warner Suckers (Monzyk and Meeuwig 2018). To remedy the issue, the bypass culvert was modified in the fall of 2018 by removing the V-notch weir so the outlet elevation was set approximately 1379 MSL (Figure 3).

Our objectives in 2019 were to: 1) reevaluate Warner Sucker passage success through the modified fishway at the MC Diversion on Twentymile Creek; and 2) assess the upper distribution of Warner Sucker in the Twentymile and Deep creek subbasins.

METHODS

MC Passage Evaluation.- We installed and operated five Passive Integrated Transponder (PIT) antennas upstream and downstream from the MC Diversion fish bypass (Figure 2) to assess passage success of PIT-tagged Warner Suckers released below the structure. Antennas were installed around the downstream end of the culvert (antenna 1), in the interior of the box culvert 1.5 m downstream of the slide gate (antenna 2); and 2 m in front of the slide gate of the box culvert (antenna 3). Antennas were also installed in the bypass channel near the confluence with the MC Canal (antenna 4) and in the MC canal upstream of the confluence (antenna 5) to assess fish route selection and travel time in the bypass channel.

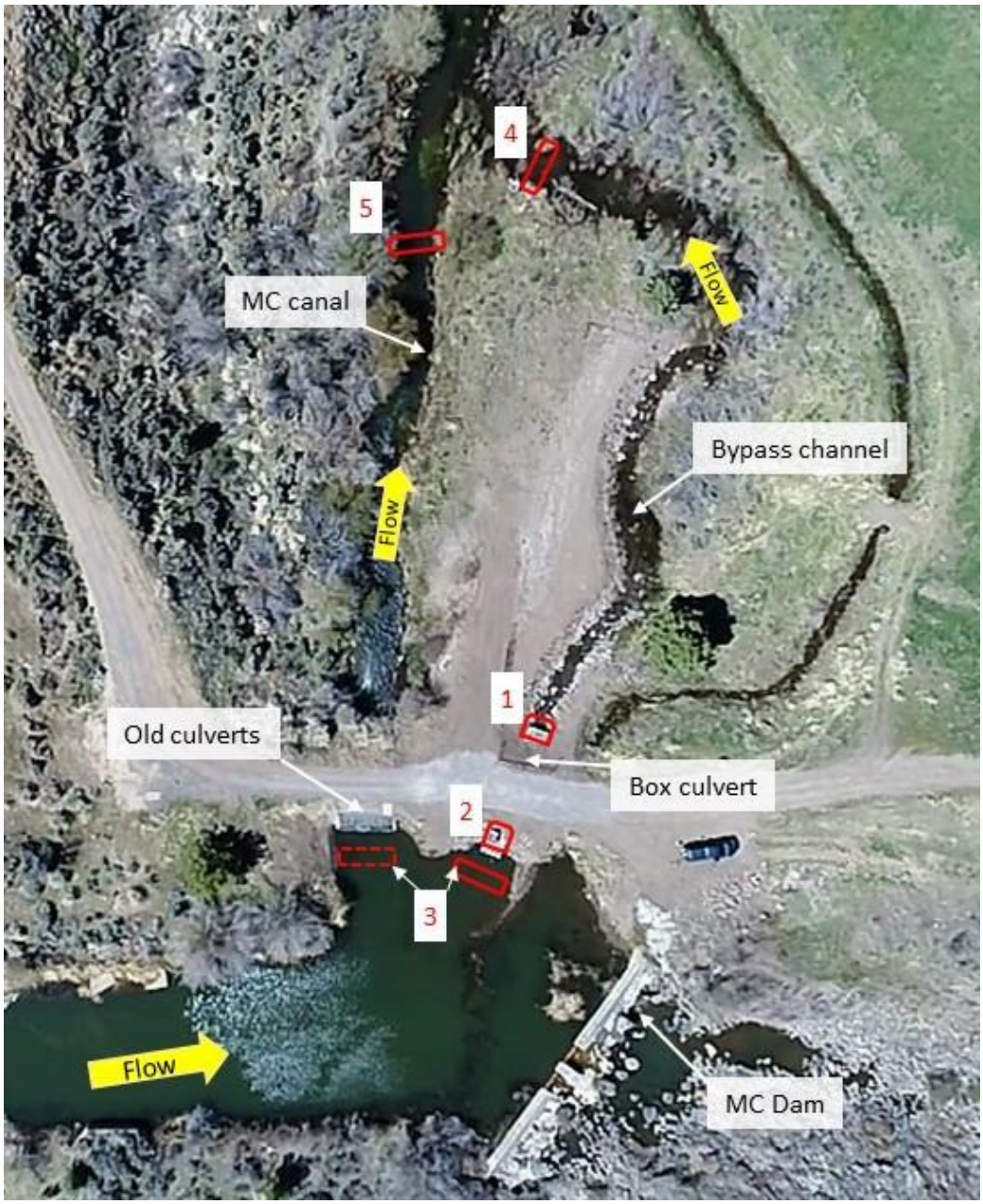

Figure 2. Plan view of MC Diversion fish passage project with antenna locations. The five PIT antenna locations are shown in red. Antenna 1 was moved to in front of the old culverts on 24 July after bypass dewatered with location shown with dashed line.

Figure 3. Photos of MC bypass culvert showing original V-notch weir (A) and modified downstream opening (B).

Antenna 3 was repositioned upstream of the old culverts on 24 July, after stream flows decreased and the box culvert became dewatered. At this time all streamflow was through the old culverts. Antennas 3, 4, and 5 were swim-over antennas fixed to the substrate whereas antennas 1 and 2 were swim-through antennas that wrapped around the box culvert. We installed a continuous detection beacon on antenna 1 to test continuity of operation of the antenna arrays. Antennas were operated from 13 March–15 August, 2019.

We installed water level loggers (Onset HOHBO® U20L) on 26 March in the box culvert and the MC Canal (upstream of the bypass confluence) that recorded water level every 15 minutes. We measured flow through the box culvert at various stream flows with water velocities measured with a Marsh-McBirney portable flow meter. We used the relationship between measured flow and water level in the box culvert to estimate flow through the bypass every 15 minutes during the study period.

A limitation of the passage monitoring approach is the assumption that PIT-tagged suckers will want to migrate upstream through the bypass system when they are released downstream. Fish that do not pass through the bypass system may not reflect a limitation of its effectiveness, but rather variability in fish behavior. To increase the likelihood that fish will attempt to pass through the bypass system, we skewed are PIT-tagging to larger suckers (adults) in early spring, with the assumption that they would be more likely to migrate upstream to spawn.

We captured Warner Suckers in Twentymile Creek upstream of the MC Diversion from 26 March – 02 May April 2019 using hoop nets (0.63 m diameter, 7 mm mesh) with a single 10-m or dual 7-m wing nets. Nets were set overnight in pool habitats. We measured fork length (FL, nearest mm) on all captured suckers, and PIT tagged all suckers ≥95 mm FL that appeared healthy. Fish ≥120 mm FL were tagged with a 23-mm half-duplex tag and fish <120 mm FL were tagged with a 12-mm half-duplex tag. All

tagged fish were released downstream of the MC bypass in a pool just downstream of the MC Canal and bypass channel confluence (downstream of antennas 4 and 5). In addition to the suckers, one Redband Trout *Oncorhynchus mykiss* was tagged and released below the bypass. Fish detection data from the antennas were uploaded approximately once a month to assess passage timing and success. We estimated travel time through the bypass culvert as the difference between time of first detection on Antenna1 and Antenna 3.

Upper Distribution Surveys.- From 08 July – 15 August, we surveyed reaches of upper Twelvemile Creek and several tributaries (Cow Head Slough; Rock Creek; Horse Creek; and Fifteenmile Creek) for the presence of Warner Sucker. In addition, we surveyed Twentymile Creek upstream of the confluence with Twelvemile Creek and Deep Creek from the Adel-Town Diversion upstream to the Taylor Diversion (Figure 1). Backpack electrofishing was the primary method used, however, we used hoop nets in portions of Twentymile Creek and Deep Creek that had pools with sufficient depth to set nets (>0.5 m depth).

RESULTS

MC Passage Evaluation.- A total of 35 Warner Suckers and four Redband Trout were captured from 26 March – 02 May in 22 hoop net sets in Twentymile Creek upstream of the MC Diversion. We tagged 30 suckers ranging in size from 95–248 mm FL (Appendix Table 1) and one 146-mm FL Redband Trout. All tagged fish were released downstream of the bypass channel.

The continuous detection beacon on Antenna 1 indicated that the antenna array at the bypass culvert (Antennas 1-3) operated without interruption throughout the study period. Antennas 4 and 5, however, suffered from low power and only operated intermittently during the study period, so we were not able to estimate travel time in the bypass channel.

We measured flow rate through the bypass culvert on four occasions to develop the relationship between flow rate and HOBO sensor depth that was used to estimated bypass flow throughout the study period (appendix Figure 1). The bypass generally operated at flows ranging from 20-40 cfs throughout the spring, with occasional periods of low flow (<2 cfs) lasting 1.5 - 9 d of when the slide gate was partially or completely shut (Figure 4). Overall, flows through the bypass were >20 cfs for the majority of the time from April through June.

A total of 13 suckers (43%) tagged in 2019 successfully passed upstream through the MC bypass. The remaining suckers tagged in 2019 (n=17) were either never detected after release or only detected on antennas 4 and 5 (Appendix Table 1). In addition, a sucker tagged and released below the bypass channel in 2018 successfully passed

upstream through the bypass culvert in 2019. The suckers that passed tended to be the larger individuals, ranging in size from 142-248 mm FL (Figure 5).

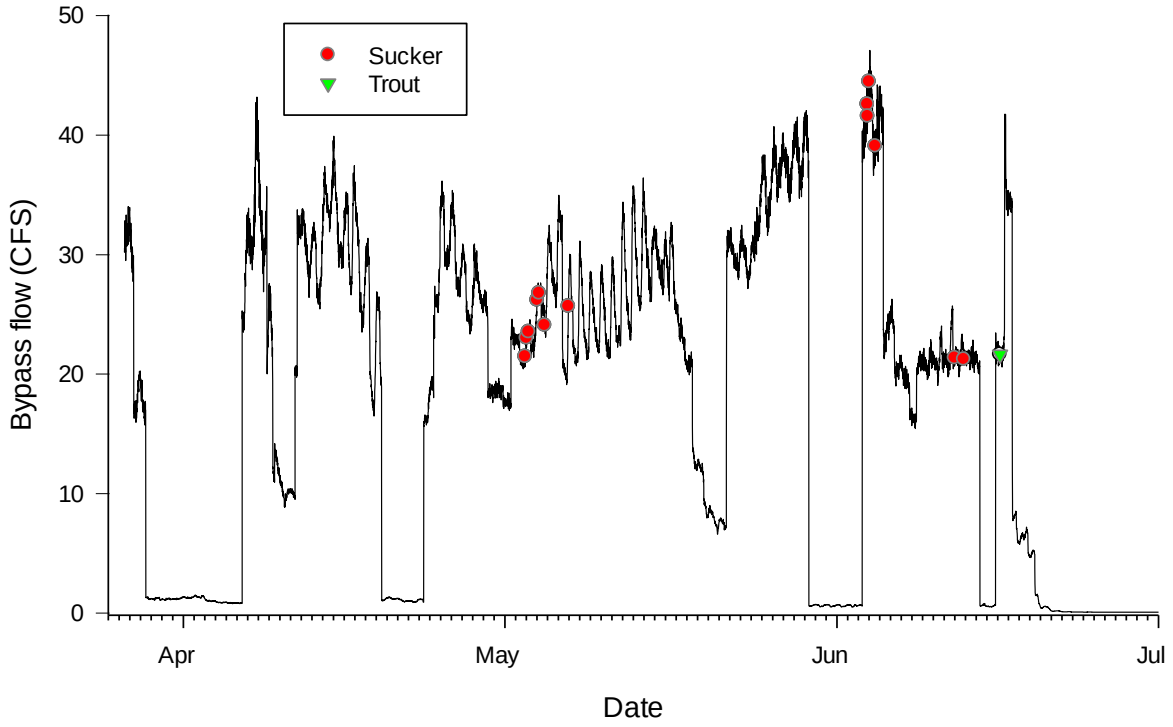

Figure 4. Estimated flow through the bypass culvert and fish passage events at the MC Diversion during the spring study period, 2019. Some suckers made repeated upstream and downstream passes but only the first upstream passage event is shown.

Passage through the culvert occurred in two periods: early May and early June. Four suckers passed on 03 June, the day bypass flow resumed following a 5-d shutdown period (Figure 4). Nearly all passage events occurred at night. Travel time through the box culvert ranged from a minimum of 5 minutes to a maximum of over 20 hours (Table 1). One sucker (PIT code 1829037B) successfully passed through the bypass culvert on 02 May then proceeded to swim downstream through the culvert and back upstream again three more times over the course of the following two days.

Several suckers (n=9) that successfully passed upstream eventually returned back downstream of the bypass in mid- to late-June, purportedly after spawning upstream. Two suckers (codes 18290396 and 182903A8) returned downstream through the bypass culvert in mid-June. The other suckers that returned downstream were detected on antenna 5 in the MC Canal from 20-25 June, purportedly passing downstream through the old culverts after the bypass culvert was dewatered on 17 June.

The one Redband Trout passed upstream through the bypass culvert on 16 June. Travel time through the culvert for this fish was 3 minutes. The passage event occurred

at night approximately 9 h after flow resumed through the culvert after a 2-day period of no flow (Figure 4).

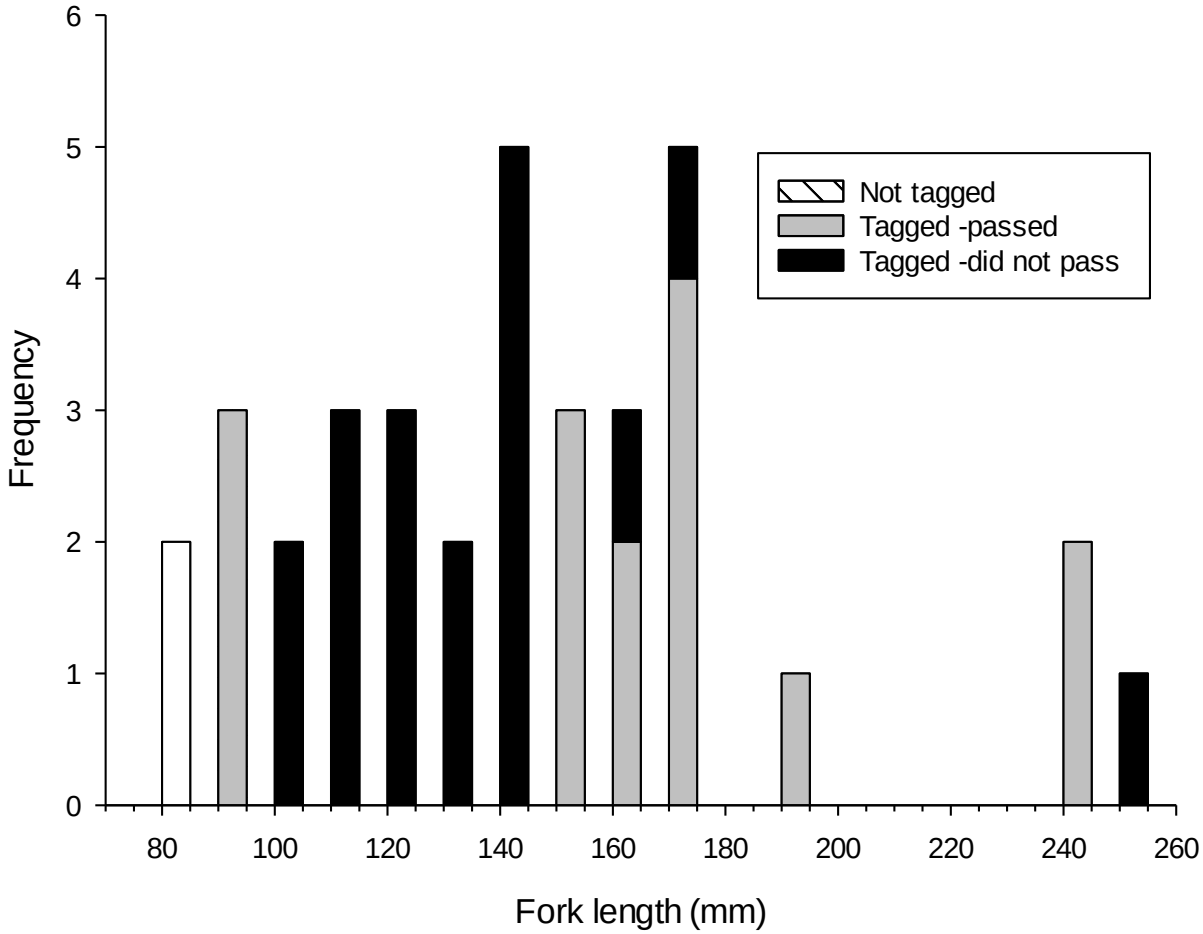

Figure 5. Length frequency of Warner Suckers captured above the MC Diversion in 2019 and their tagging and passage status. Tagged fish were released downstream of the bypass channel.

Table 1. Warner Sucker size, passage date and time, travel time, and bypass flows at the MC bypass culvert, 2019.

PIT code	Fork length (mm)	Entry date	Entry time (PST)	Travel time through culvert	Bypass cfs
1829037B	240	02-May [b]	20:35	0h 26m	21
182903BF	183	02-May	20:39	0h 18m	21
18290397	231	02-May	21:14	0h 20m	21
182903A6	157	03-May	0:23	0h 33m	22
18290396	170	03-May [b]	4:28	0h 55m	24
1829039C	248	04-May	0:14	0h 7m	22
182903CF	161	04-May	1:37	16h 38m	23
158E725F	164	06-May	3:07	20h 26m	34
182903A8	150	03-Jun	19:54	0h 39m	40
182903A1	147	03-Jun	20:51	0h 10m	41
158E7298	142	03-Jun	21:21	17h 23m	43
158E7255	156	03-Jun	21:42	2h 40m	43
158EC8AD	170	11-Jun	23:48	0h 5m	21
15AB3C35	96 [a]	12-Jun	19:58	0h 20m	22

[a] Tagged in 2018.
[b] Multiple upstream/downstream passage events through bypass culvert. Only the first passage event reported.

Upper Distribution.- In Deep Creek between the Adel-Town Diversion upstream to the Taylor Diversion, we conducted 14 hoop net sets and electrofished 210 m of stream from 14-15 August. No Warner Suckers were collected in this 1.5-km reach. Other fish species collected included Speckled Dace *Rhinichthys osculus*, Redband Trout, and Tui Chub *Siphateles thalassinus*[1]. Stream temperatures during sampling were 15.5°C. There were eight pools in the reach, some with beaver activity. Filamentous algae was common in the pools but aquatic vegetation was sparse.

We sampled a total of 11.9 km in the Twentymile Creek subbasin. No Warner Suckers were collected in Cow Head Slough, Horse Creek, Rock Creek, or Fifteenmile Creek. Access to West Barrel Creek in the Cow Head subbasin was denied by the landowners so confirmation of Warner Suckers residing in this system was not possible. Cow Head Slough and the upper reach of Rock Creek were intermittent by summer with a series of isolated pools providing the only habitat. Lower Rock, Fifteenmile, and Horse creeks were spring fed and had perennial flow. Tui Chub were collected in Cow Head Slough and Speckled Dace were collected in all tributaries except Fifteenmile Creek, where only Redband Trout were collected.

[1] Using taxonomic nomenclature recommended by Harris (2000) and Chen et al. (2009) for Tui Chub in the Warner Basin, including the Cow Head Slough population.

In Twelvemile Creek, the upstream-most location a sucker was collected was 1.9 km upstream from the Rock Creek confluence, on the Oregon side of the Oregon/Nevada border (Figure 6). In Twentymile Creek, the farthest upstream a sucker was collected was 0.26 km upstream from the confluence with Twelvemile Creek (Figure 6).

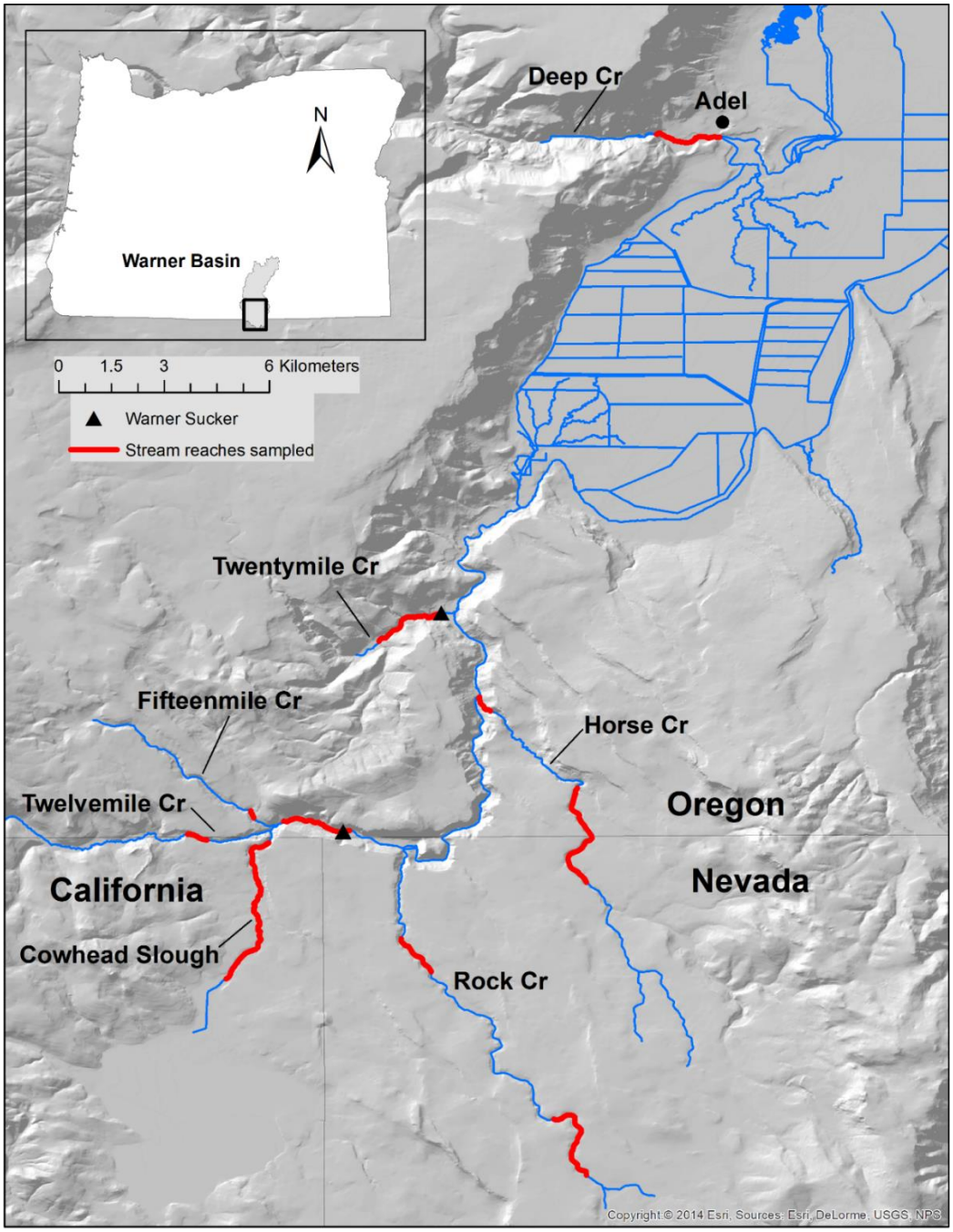

Figure 6. Map of Deep and Twentymile creeks showing stream reaches sampled for the presence of Warner Suckers and upstream-most locations where suckers were found, 2019.

DISCUSSION

A total of 14 Warner Suckers successfully passed upstream through the modified fishway at the MC Diversion on Twentymile Creek in 2019, a marked improvement from 2018 when only 1 of 27 fish passed (Monzyk and Meeuwig 2018). The modification to the box culvert resulted in the bypass operating more consistently and at higher flows in 2019 compared to 2018, however there were periods of flow interruption when the bypass gate was shut that may have delayed upstream passage. Several fish passed upstream on 03 June, the day flow resumed following a 5-d period of no bypass flow. Similarly, the tagged trout passed immediately after a 2-d period of no flow. It's unclear if these fish were holding in the bypass channel when flows were shut off and resumption of flow spurred their upstream movement. Flow into the MC canal is determined by irrigation needs downstream, among other factors. Ensuring that consistent flow exist through the bypass during the spawning season (May-June) would improve its efficacy.

The lack of smaller-sized fish passing through the fishway was likely due to their immaturity. Warner suckers mature around age 3, when they are about 130 mm FL (Monzyk et al. 2019), so the suckers detected passing through the fishway in 2019 were likely mature adults migrating upstream to spawn. Upstream detections occurred over two distinct periods (early May and early June), suggesting that there may have been two spawning periods in 2019.

The late-June return to the MC Canal of over half the adult-sized suckers that had passed upstream may have been the result of a natural downstream-migrating behavior of Warner Suckers after spawning. Tyus and Karp (1990) reported Razorback Suckers *Xyrauchen texanus* making round-trip movements during their spawning season. Additionally, Scheerer et al. (2017) reported that several fish that were initially PIT-tagged upstream of the MC diversion were later detected in the MC Canal. The MC Canal offers high quality habitat (deep, vegetated pools) with no non-native fish species, so it may serve as good resting habitat after spawning. Water velocities through the old culverts by late-June, after stream flows decreased and the bypass culvert became dry, did not appear prohibitive to upstream movement. Scheerer et al. (2015) noted one sucker was able to pass upstream through the old culverts during a low flow period in 2015 (stream flow measured at the upstream gage was 13 cfs during the passage event – ODFW unpublished data).

With the completion of passage structures at the MC and Dyke diversions, Warner Suckers and Redband Trout now have access to all the habitat in the Twentymile Creek subbasin upstream of the Cahill Diversion. For Warner Suckers, this includes over 21 km of stream they are known to occupy. Our distribution surveys in the upper Twentymile Creek subbasin did not find Warner Suckers beyond where they have previously been reported to occur. The upper-most location in Twelvemile Creek in 2019 was approximately 1.5 km downstream from their upper-most location reported during snorkel survey in 1994 (Tait et al. 1995, Allen et al. 1994). In Twentymile Creek, the upper-most sucker location in 2019 was approximately 1.7 km downstream from

where their upper-most location was reported during electrofishing surveys in 1978 (Hayes 1978). Although the small tributary streams of Rock and Horse creeks contained several deep vegetated pools that could conceivably support Warner Suckers (Appendix Figure 2), the steep gradients near their confluences with Twelvemile Creek may prevent suckers from utilizing the habitat.

Warner Suckers residing downstream of the MC Canal (below the Cahill Diversion) are not able to pass upstream over the diversion since outflow occurs as a vertical drop over dam boards. Providing passage at Cahill Diversion is a trade-off between the benefit of connecting the relatively short reach of sucker habitat below the diversion and the possible risk of allowing range expansion of non-native fish that currently reside in the canal system downstream of the diversion. Approximately 0.8 km downstream of the Cahill Diversion, standpipes and control structures in the irrigation ditches act as vertical drop barriers to non-native fish, so there is a possibility to provide upstream fish passage for this reach and still prevent non-native range expansion (Troy Brandt, RDG-personal communication). Although passage at the Cahill Diversion may currently rank low given the other passage priorities in the basin, the WBAHP may want to consider passage at this site in the future.

Deep Creek.- The absence of Warner Suckers in the 1.5-km reach of Deep Creek between the Adel-Town Diversion and the Taylor Diversion suggest that the stream-resident population has been extirpated from Deep Creek. Previous surveys upstream of the reach (O'Keefe Diversion to Deep Creek Falls: a 2.9-km reach) did not detect suckers (White et al. 1990; Allen et al. 1994; Scheerer et al. 2007). Nearly all suckers collected in Deep Creek in past surveys, including all adults, have been downstream of Starveout Diversion, the second diversion upstream from the "mouth" (White et al. 1990; Scheerer et al 2007). The only recent evidence of suckers occurring upstream of Starveout Diversion was a single sucker (116 mm FL) captured in 2007 in the pool formed by the diversion dam (Scheerer et al. 2007). The diversion dam appears to block upstream movement of lake-resident adults from Crump Lake based on radio-telemetry studies (Scheerer et al. 2006), and juvenile suckers caught below Starveout Diversion are likely progeny of lake-resident spawners.

The quality and quantity of habitat in Deep Creek to support a stream-resident sucker population is less than the other major tributaries. Twentymile and Honey creeks have approximately 21 km and 30 km of occupied stream habitat, respectively, with much of it comprised of deep vegetated pools that are associated with Warner Sucker abundance (Scheerer et al. 2011). Deep Creek below the falls is only 15 km long, but not all of it is quality sucker habitat. Much of the habitat between the falls and the Taylor Diversion is high gradient with few pools. The 1.5-km reach sampled in this study was some of the better habitat in the system, consisting of several deep pools, but still lacking aquatic vegetation. Below the Town Diversion the stream can become intermittent in the summer as stream flow is diverted into irrigation ditches for stock watering. Besides the diversion dams, lower Deep Creek has been modified extensively to improve conditions for cattle grazing. Historically, Deep Creek split into several distributary channels near the location of the Adel-Town Diversion and flooded meadows and marshland on the

valley floor. The northeastern-most of these channels terminated in a large tule *Schoenoplectus acutus* marsh just downstream of the present-day Relic Diversion (Stricklin and Perry 1923) (Appendix Figure 3). The marsh extended for ~2 km to the southeastern shore of Pelican Lake and was likely the main route lake-resident sucker in Crump and Pelican lakes took to reach Deep Creek[2]. Presently, Deep Creek bypasses Pelican Lake via an artificial 3-km long diked channel that begins downstream of the Relic Diversion and ends at a natural slough that connects Crump and Pelican Lake. Pelican Lake is now purportedly fed only by irrigation canal return flow and seepage (Kobetich 1977). Even with this artificial extension of Deep Creek, the amount of usable habitat for Warner Suckers is less than the other tributaries.

The effect of small habitat patch area and isolation on local population extinction is well established in metapopulation dynamics (Hanski 1998). Given the relatively limited spatial extent of habitat in Deep Creek, restoring fish passage will likely be essential for long-term persistence of a stream population. Currently, lake-resident suckers entering Deep Creek are not able to migrate beyond Starveout Diversion. Passage at Adel-Town Diversion is being provided via the construction of a rock ramp this year, however, the benefit of the passage improvement will not be fully realized until passage is also provided at Starveout Diversion. Completion of passage projects at these two diversions should allow Crump Lake fish to recolonize the upstream habitat.

Given the limited amount of habitat for Warner Suckers in Deep Creek, ensuring that it is high quality will also help a stream population to persist. Suckers would benefit from riparian habitat enhancement upstream and downstream of the Town Diversion. The 1.5-km reach surveyed in this study contained several pools, but the habitat was also degraded by grazing. This reach may act as the core area of any stream-resident population given that high gradients upstream and intermittent flows downstream may limit sucker numbers elsewhere. We recommend that the WBAHP reach out to the landowners to gage interest in assistance in riparian restoration strategies.

A Deep Creek population of Warner Suckers would also benefit from a restoration of Deep Creek flow with Pelican Lake. Currently, any adult suckers in Pelican Lake seeking to spawn in Deep Creek have to swim downstream through the lake's outflow channel to reach the artificial channel and lower Deep Creek, and this requirement may be prohibitive to successful spawning. The lack of connection of Deep Creek water with Pelican Lake likely causes greater frequency of lake desiccation than would have occurred historically. We recommend that the WBAHP gage interest from landowners in restoring connectivity of Deep Creek water with Pelican Lake, possibly through a Wetland Reserve Easement.

[2] Tule *Schoenoplectus acutus* generally grows in deeper water (up to 1.5m deep) than salt grass *Distichlis spicata* (~5cm) so their presence likely indicates the deeper areas of marsh. (https://www.fs.fed.us/database/feis/plants/graminoid/schacu/all.html)

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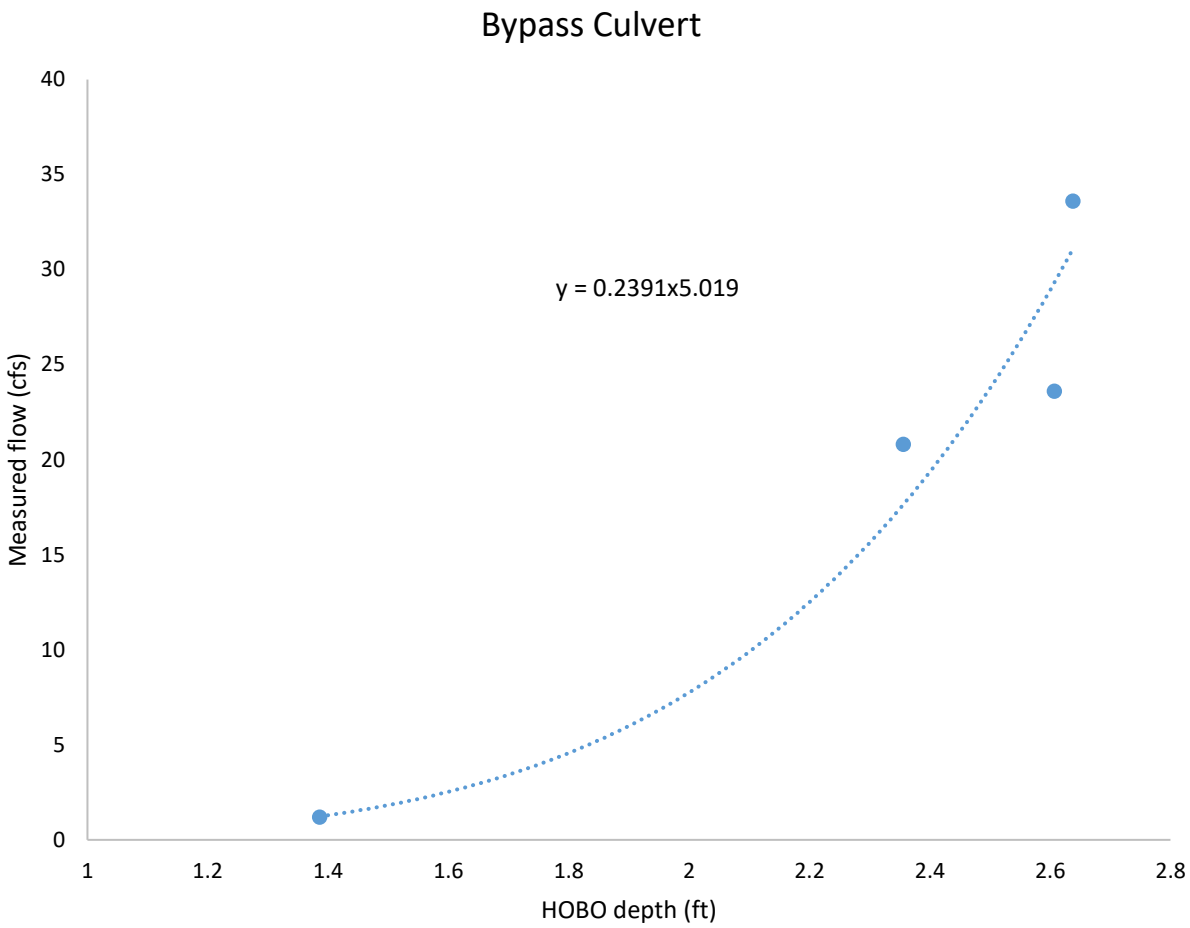
APPENDIX

Appendix Table 1. Tagging date, location, and antenna detection summary of Warner Suckers and a Redband Trout at the MC bypass, 2019. Antenna locations can be found in Figure 2. Antennas 1-3 were on the bypass culvert and Antennas 4-5 were near the bypass channel confluence with the MC canal.

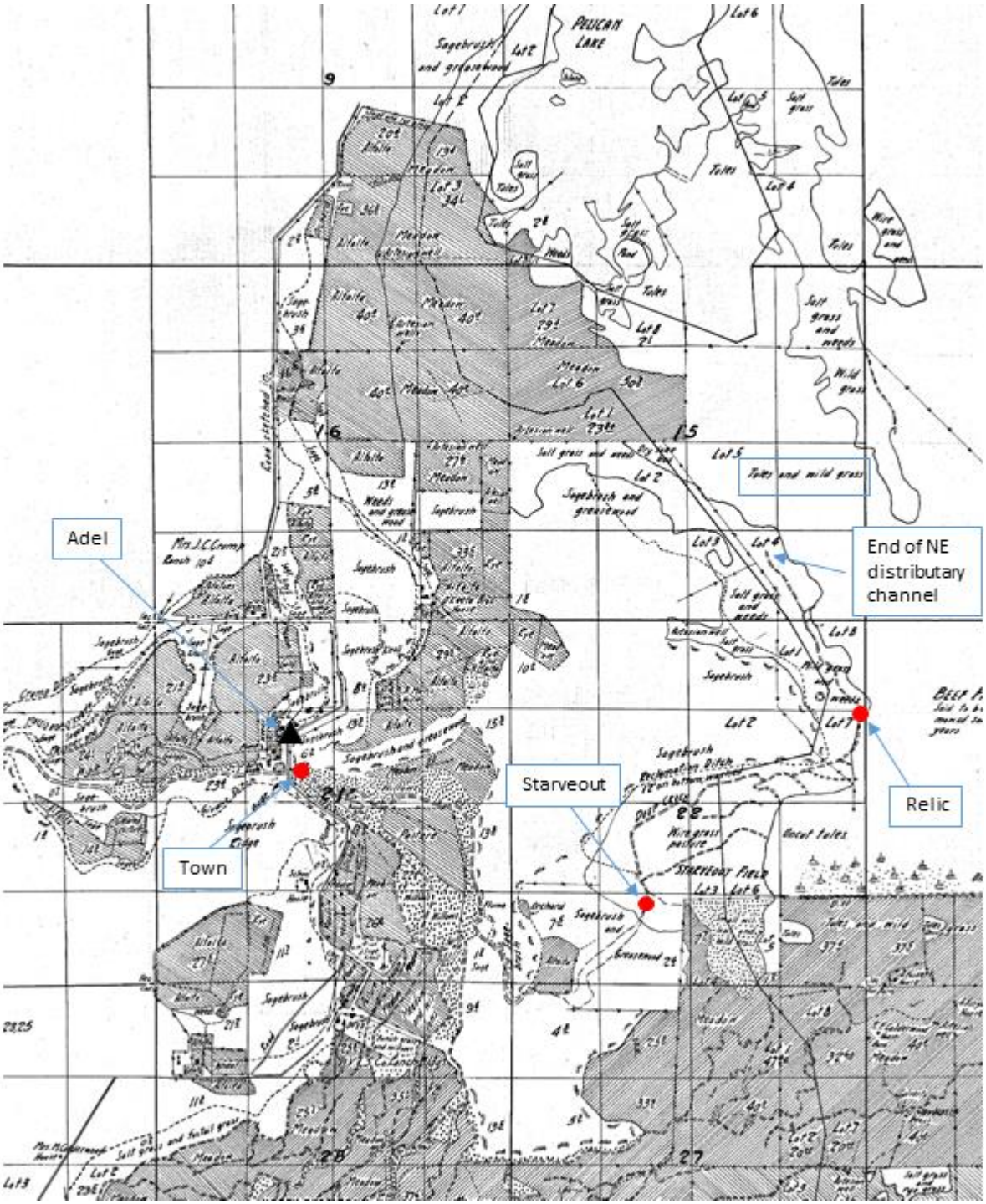
Release Date	UTM (11T) Easting	UTM (11T) Northing	Species	Fork length (mm)	PIT tag size (mm)	PIT Code (hexidecimal)	Antenna 1	2	3	4	5
04/17/18	254864	4658979	Sucker	96[a]	12	15AB3C35	Y	Y	Y		Y
03/26/19	255045	4660718	Sucker	95	12	15AB3C2E				Y	Y
03/26/19	255045	4660718	Sucker	98	12	15AB3BF4					
03/26/19	255045	4660718	Sucker	101	12	15AB3C0B				Y	Y
03/26/19	255045	4660718	Sucker	101	12	15AB3C28					
03/26/19	255023	4661077	Sucker	131	23	158EC8C3					
03/26/19	255045	4660718	Sucker	131	23	158EC8F6					
03/26/19	255045	4660718	Sucker	137	23	158E7281					Y
03/26/19	255045	4660718	Sucker	156	23	158E7255	Y	Y	Y		Y
04/11/19	255045	4660718	Sucker	107	12	15AB3C03					Y
04/11/19	255045	4660718	Sucker	115	12	15AB3BFA				Y	Y
04/11/19	255023	4661077	Sucker	115	12	15AB3C00					
04/11/19	255045	4660718	Sucker	116	12	15AB3C3E					
04/11/19	255045	4660718	Sucker	122	23	158EC8BB					
04/11/19	255045	4660718	Sucker	128	23	182903C3					
04/11/19	255023	4661077	Sucker	136	23	182903B9					
04/11/19	255045	4660718	Sucker	142	23	158E7298	Y	Y	Y	Y	Y
04/11/19	*255023*	*4661077*	*Trout*	*146*	*23*	*182903B3*	*Y*	*Y*	*Y*		
04/11/19	255023	4661077	Sucker	151	23	18290383					
04/11/19	255045	4660718	Sucker	164	23	158E725F	Y	Y	Y	Y	Y
04/11/19	255045	4660718	Sucker	170	23	158EC8AD	Y	Y	Y		Y
05/02/19	255045	4660718	Sucker	136	23	18290394					
05/02/19	255045	4660718	Sucker	147	23	182903A1	Y	Y	Y		Y
05/02/19	255045	4660718	Sucker	150	23	182903A8	Y	Y	Y		Y
05/02/19	255045	4660718	Sucker	157	23	182903A6	Y	Y	Y		Y
05/02/19	255045	4660718	Sucker	161	23	182903CF	Y	Y	Y		Y
05/02/19	255045	4660718	Sucker	162	23	182903C2					
05/02/19	255045	4660718	Sucker	170	23	18290396	Y	Y	Y		
05/02/19	255045	4660718	Sucker	183	23	182903BF	Y	Y	Y		
05/02/19	255045	4660718	Sucker	231	23	18290397	Y	Y	Y		Y
05/02/19	255045	4660718	Sucker	240	23	1829037B	Y	Y	Y		
05/02/19	255045	4660718	Sucker	248	23	1829039C	Y	Y	Y		

[a] Size when tagged in 2018.



Appendix Figure 1. Flow and depth sensor relationship measured at the downstream end of the bypass box culvert, 2019. Power equation was used to estimate flow through culvert based on recorded depth sensor measurements throughout the study period.

Appendix Figure 2. Photo of a typical Horse Creek pool near the Oregon/Nevada border.



Appendix Figure 3. Map of South Warner Valley where Deep Creek enters valley floor from a survey conducted in the summer of 1921. Survey from Stricklin and Perry (1923). Location of present-day diversion dams and other features added for visual reference. Note that NE channel ends in tule marsh. Tule *Schoenoplectus acutus* generally grows in deeper water (up to 1.5m deep) than salt grass *Distichlis spicata* (~5cm), so likely indicate the deeper areas of the marsh.

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