PROGRESS REPORTS

2013

FISH DIVISION

Oregon Department of Fish and Wildlife

Evaluating Warner Sucker Swimming Performance to Inform Passage Design in the Warner Basin, Oregon

ANNUAL PROGRESS REPORT

FISH RESEARCH PROJECT
OREGON

PROJECT TITLE: **Evaluating Warner Sucker Swimming Performance to Inform Passage Design in the Warner Basin, Oregon**

PROJECT NUMBERS: USFWS cooperative agreement F12AC01064

PROJECT PERIOD: 1 January 2013 - 31 December 2013

Photograph of the swimming performance chamber.

Paul D. Scheerer

and

Shaun Clements

Oregon Department of Fish and Wildlife
28655 Highway 34, Corvallis, Oregon 97333

This project was financed with funds administered by the U.S. Fish and Wildlife Service.

CONTENTS

INTRODUCTION

Warner suckers (*Catastomus warnerensis*) are listed as threatened under the federal Endangered Species Act (U.S. Fish and Wildlife Service 1985). One of the reasons for their listing is fragmentation of populations, resulting from the construction of impassable irrigation diversion dams that block movements within and between tributary streams (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 the species that require that: (1) a self-sustaining metapopulation is distributed throughout the tributary drainages and lakes in the Warner basin; and (2) passage is restored within and among these drainages so that individual populations of Warner suckers can function as a metapopulation. To address these criteria and facilitate fish migration, we are beginning to enroll landowners in fish passage improvement projects. However, there is currently no data on the swimming performance of Warner sucker to inform the design of passage structures. Our objective was to evaluate the swimming performance of Warner sucker. Our data can be used to inform the design of future passage structures in the basin.

METHODS

<u>Experimental apparatus</u>

Swimming performance studies are conducted in controlled laboratory settings where engineered flumes are used to ensure uniform water velocities. We used a modified Blažka swimming performance chamber, which consisted of a clear acrylic cylindrical tube, measuring 90 cm long and 15 cm in diameter, immersed in a 284 L rectangular plywood mixing reservoir (Blažka et al. 1960; Barton and Schreck 1987). Inside this tube was a secondary clear acrylic cylindrical tube, measuring 36 cm long and 9.5 cm in diameter. The secondary tube was fitted with baffles to ensure uniform flow. The baffles consisted of 5 cm sections of plastic drinking straws packed in both ends and held in place with plastic mesh screen. The downstream baffle was fitted with a plastic collar for easy removal. The inner acrylic tube was held in place with stainless steel set screws and could be quickly removed from the outer tube. To provide visual reference for swimming orientation, the secondary tube was marked with black stripes on the sides of the upstream end. The secondary tube was fitted over a propeller with a shaft that extended through the inner and outer tubes and the reservoir. The propeller shaft was attached via pulley and belt to a variable speed 375 watt motor, regulated by a variable-voltage rheostat. The propeller shaft was detachable and the outer acrylic tube was hinged to facilitate loading and unloading of the fish. The propeller shaft pulley was connected to a tachometer. We calibrated the tunnel by correlating tachometer readings with current velocities, estimated using pitot tubes. To measure current velocity, the pitot tubes (paired, small diameter (1 mm), stainless steel tubes) were inserted into the inner swimming chamber through adjacent ports, and oriented in opposite directions (upstream and downstream) and at equal heights, to measure velocity and static pressures of the flowing water. The difference between these pressures is a function of flow within the flow chamber (U.S. Geological Survey 2001). We aerated the pump reservoir throughout the experiment and supplied flow-through, fresh water at a rate of 0.4 L/min.

Swimming performance experiments

We collected four largescale suckers on 29 April 2013 from the Willamette River near Corvallis and used these fish to test the operation of the experimental swimming performance chamber. We collected 24 Warner suckers on 13 May 2013 from the experimental population at the Summer Lake Wildlife Management Area in Summer Lake, Oregon. We chose this sample size to provide an estimate of the variation in swimming performance for different sized suckers, while minimizing the impacts to the experimental population. We held the Warner suckers at the Oregon State University Fish Performance and Genetics Laboratory in Corvallis, Oregon. We acclimated the fish in two 400 L outdoor holding tanks, fed by 14.0^{0}C well water, for 24 h prior to initiation of the study. We did not feed the fish during the acclimation period, because digestion requires a substantial blood flow and prolonged swimming in recently fed fish reduces swimming performance by 10-15% (Farrell et al. 2001).

After acclimation, we individually netted fish from the holding tank and anesthetized them with MS-222 (30 mg/L) buffered to pH 7. We weighed, measured, and sexed each fish, then placed it into the swimming performance chamber and allowed it to recover for 10 min. After each fish fully recovered from the MS-222, we conducted the critical swimming performance trials (U_{crit}). We adjusted water velocity in the chamber to 0.5 body lengths (BL) per second (~1.0 cm/s; ~0.33 ft/s) and held the fish at this velocity for 30 min. After 30 min, we increased water velocity in standard steps of 0.5 BL/s at 15 min intervals, until the fish was fatigued and was pushed to the back of the flume. We reduced the pump speed significantly until the fish began to swim again, and then rapidly brought it back up to the exhaustion speed. We ended the time measurement the second time the fish quit swimming, which typically occurred in less than 10 s. After fatigue, we reduced the water velocity to 0 cm/s and allowed the fish to rest for 30 min, and then we challenged the fish a second time. We used data from both tests to define the critical swimming speed of the fish, and compared the results of the two tests to estimate the degree of repeatability of individual fish's swimming performance. After the second trial, we removed the fish from the flume and returned it to the holding tank. We used a combination of fish length, fish weight, and external pigmentation for future identification. We applied an external mark (small dorsal fin notch) to three fish where these characters overlapped with other similar sized fish. We measured the U_{crit} in all 24 fish, allowed the fish to recovery for 24-48 h, and then conducted burst speed challenges. To estimate burst speed swimming performance (U_{burst}), we acclimated fish as above, then increased water velocity by 0.5 body lengths per second at 1 min intervals, until the fish was fatigued and pushed to the back of the flume. We reduced the pump speed significantly until the fish began to swim again, and then rapidly brought it back up to the exhaustion speed. We ended the time measurement the second time the fish quit swimming. After this trial, we removed the fish from the flume and returned it to the holding tank.

RESULTS

We estimated swimming speeds (U_{crit} and U_{burst}) for 23 Warner suckers, ranging in size from 131-198 mm fork length. Two fish were in poor condition (numerous lesions with fungus) and were not used for the experiment. At lower velocities, most suckers exhibited burst-coast swimming behavior, as defined by (Castro-Santos 2005), then shifted to mostly continuous swimming behavior at higher velocities. The mean U_{crit} for the Warner suckers was 37 cm/s (1.2 ft/s) with a range was 6-61 cm/s (0.2-2.0 ft/s) and the mean U_{burst} was 46 cm/s (1.5 ft/s) with a range of 6-79 cm/s (0.2-2.6 ft/s). The U_{crit} and U_{burst} values were slightly higher for the larger, adult suckers (>150 mm FL; N=14), with means of 46 cm/s (1.5 ft/s; range 24-61 cm/s) and 55 cm/s (1.8 ft/s; 27-79 cm/s), respectively (Table 1). Measurement of U_{crit} was highly repeatable for individual suckers (Figure 1). When differences occurred between U_{crit} trials, most fish (9 out of 10) tired at a lower water velocity (mean: -7.6 cm/s) on the second trial, compared to the first trial.

We observed a positive relationship between fish length and swimming performance, although we noted substantial variability among fish of the same approximate length (Figure 2). Similarly, there was a positive relationship between fish performance in the U_{crit} and the U_{burst} trials. If an individual performed well in the U_{crit} trial they typically performed well in the U_{burst} trial. Most individual fish performed at a higher level in the U_{burst} trials than the U_{crit} trials (Figure 3). We found no relationship between swimming performance and time of day (Figure 4).

DISCUSSION

In the desert of Oregon's Warner basin, the diversion of streams for irrigation has created barriers to the seasonal migration of native fishes. Many of the irrigation diversions in the basin are ~80 years old and in need of replacement (B. Mayer, Oregon Water Resources Department, personal communication). Fishways, which allow upstream-migrating fish to ascend natural and artificial stream barriers, were not included in the original design and construction of most of these structures. However, it is encouraging that local landowners are increasingly willing, with financial assistance, to replace these structures and improve conditions for Warner suckers and redband trout *Oncorhynchus mykiss*. We conducted our current study to collect species-specific data for Warner suckers to inform fish passage design.

The design of fishways has focused primarily on anadromous fishes, and as a result doesn't always include features that are relavent to other native freshwater fishes. Design of fish passage structures has been found to be species specific (Peake 2008a; Tillinger and Stein 1996; Myrick and Ceck 2004; Ward et al. 2003) and requires data on the swimming performance of the species of interest. Swimming performance data for suckers are rare. Bunt et al. (1999) and Jones et al. (1974) found the maximum water velocities used by white suckers *Catostomus commersoni* and longnose suckers *C.s catostomus* were 96 cm/s and 70 cm/s, respectively. Bailey (2004) described a fishway design for razorback suckers *Xyrauchen texanus* that had 122 cm/s attraction flows and substrate flows less than 60 cm/s. Peake (2008b) concluded that water velocities at the sustrate should not exceed 91 cm/s to allow white suckers to successfully move through a 50 m long culvert. In addition, Ward et al. (2003) evaluated the extent of differences in swimming performance among species of desert catostomids and found high variability. The ability to withstand high water velocities was significantly higher for desert suckers *C. clarki* (93 cm/s) and bluehead suckers *C. discobolus* (87 cm/s) than for Sonoran suckers *C. insignis* (56 cm/s) and flannelmouth suckers (46 cm/s). Our swimming performance results for Warner suckers (37-55 cm/s) were most similar to these latter species.

It is important that the range of sizes of the target species is considered when designing fishways and swimming performance studies (Ward et al. 2002). Jones et al. (1974) found that fish length had a signficant effect on swimming performance, with increased performance at larger sizes. For example, larger (20-30 cm) longnose and white suckers can achieve critical swimming velocities two to three times that of smaller (5-10 cm) suckers (Baker and Voltapka 1990; Jones et al. 1974). Similarly, we found that swimming performance doubled as Warner sucker length increased from approximately 130 to 200 mm.

Another factor affecting swimming performance and fish passage effectiveness is water temperature (Larnier 2002; Peak 2008b; Hasler et al. 2009; Tillinger and Stein 1996). Myrick and Cech (2004) found for most fish species tested, as temperature increased so did swimming performance. Ward et al (2002) found that a decease in water temperature from 20°C to 10°C resulted in an average decrease in the swimming ability of age-0 (25-114 mm TL) flannelmouth suckers *Catostomus latipinnis* by 40 percent. Thus it is important to match laboratory temperatures when evaluating swimming perfomance with stream temperatures during the periods of fish migration. In our study, the water temperature in the laboratory (14°C) was near the lower end of the range of stream temperatures we have observed (12-25°C) during sucker spawning migrations in the field (Scheerer et al. 2011).

The design of fishways must also take into consideration fish behavior. Castro-Santos (2005) and Castro-Santos et al. (2013) found that most fishes swam near the bottom of experimental flumes. At lower velocities (4.5-7.5 cm/s), white suckers swam in the corners of the flume, presumably taking advantage of the lower velocities there, but avoided walls and corners, which create unequal pressures that destablize fish, at higher velocities (Castro-Santos 2005). There are also large differences in fish species capacity/propensity to leap. Passage designs for salmonids, which have a high capacity to leap, typically include a series of drop structures. In contrast, passage designs for suckers, which have a low capacity (propensity) to leap, typically include slotted vertical baffles, which are designed to minimize velocity barriers and allow fish to swim through the fish ladder while expending less energy and effort typically required of other fish ladder designs (i.e., jumping over weirs or swimming through submerged orifices) (Korson et al. 2008; U.S. Bureau of Reclamation 2006). Other sucker-friendly passage designs include the addition of substrate roughness to ladders, such as imbedded cobbles and boulders, to reduce mean velocities (up to 50 percent). Boulder placement in test flumes have allowed razorback suckers to swim through higher velocities than previously thought, by using the boulders as resting eddies as they proceed upstream through higher velocity sections (Bailey 2004).

In Honey Creek in the Warner basin, the Rookery Diversion, which is the lowest (downstream) of eight irrigation diversions, was replaced in 2013. The design for the Rookery Diversion structure consisted of a ladder with a series of 15 rectangular pools, measuring 1.5 m wide by 2.3 m long, and which vary in depth between 1.2 m (upstream pool) and 0.3 m (downstream pool). The total drop for the structure is 1.5 m with 0.12 m drop between pools. The pools are separated by aluminum weir boards with notched weir slots (0.3 m deep, 0.25 m wide at top) for redband trout passage and submerged orofices (0.15 m square) on the substrate for sucker passage. Artificial boulders were added to the substrate to provide roughness to the lower five pools from the entrance into the turning pool (Figure 5). The calculated (estimated) water velocity through the orofices is 10.7 cm/s (3.5 ft/s).

In the Warner basin, there are future plans to replace multiple irrigation diversion structures, including six additional diversions on Honey Creek (Figure 6). It is important to monitor the effectiveness of the current designs to provide data to improve future passage structure design (Hoffman et al. 2012). In 2014, we propose to install passive integrated transponder (PIT) antennas in the Rookery Diversion structure and monitor passage success of PIT-tagged suckers during their spring spawning migration. Because roughness (artificial boulders) was only added to the lower pools of this ladder, we will also assess passage success at various locations in the structure and determine whether these are needed, or need to be modified, in future designs.

ACKNOWLEDGEMENTS

We gratefully acknowledge assistance with experimental and technical design provided by Kyle Hanson (US Fish and Wildlife Service), Matt Mesa and Lisa Weiland (US Geological Survey), and Bryan Norland (National Oceanic and Atmospheric Administration). We thank Rob Chitwood and Olivia Hakanson (Oregon State University Fish Performance and Genetics' Lab) for fish rearing and Dr. Helen Diggs, OSU, for fish health assessment. This study was conducted in adherence to standard operating procedures of appropriate animal care under Oregon State University Institutional Animal Care and Use Committee Animal Care and Use Permit #4416 and under the U.S. Fish and Wildlife Service Federal Fish and Wildlife Native Endangered Species Recovery Permit #TE-818627-10.

REFERENCES

Bailey, P. 2004. Fish Passageway design in the Upper Colorado River Basin. Wetlands Engineering and River Restoration 2001: 1-10.

Baker, C. O., and F. E. Votapka. 1990. Fish passage through culverts. Technology and Development Center: U.S Department of Agriculture- Forest Service, San Dimas, CA. 67p.

Barton, B. A., and C. B. Schreck. 1987. Metabolic cost of acute physical stress in juvenile steelhead. Transactions of the American Fisheries Society 116:257-263.

Blažka, P., M. Volf, and M. Cepela. 1960. A new type of respirometer for the determination of the metabolism of fish in an active state. Physiologia Bohemoslovenica 9:553-558.

Brett, J. R., and C. A. Zala. 1975. Daily patterns of nitrogen excretion and oxygen consumption of sockeye salmon (*Oncorhynchus nerka*) under controlled conditions. Journal of the Fisheries Research Board of Canada 32:2479-2486.

Bunt, C. M., C. Katopodis, and R. S. McKinley. 1999. North American Journal of Fisheries Management 19:793-803.

Castro-Santos, T. 2005. Optimal swim speeds for traversing velocity barriers; an analysis of volitional high-speed swimming behavior of migratory fishes. The Journal of Experimental Biology 208:421-432.

Castro-Santos, T., F. Javier Sanz-Ronda, and J. Ruiz-Legazpi. 2013. Breaking the speed limit- comparative sprinting performance of brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*).

Farrell, A. P., H. Thorarensen, M. Axelsson, C. E. Crocker, A. K. Gamperl, and J. J. Cech, Jr. 2001. Gut blood flow in fish during exercise and severe hypercapnia. Comparative Biochemistry and Physiology Part A 128:551-563.

Hasler, C. T., C. D. Suski, K. C. Hanson, S. J. Cooke, D. P. Philipp, and B. L. Tufts. 2009. Effects of water temperature on laboratory swimming performance and natural activity levels of adult largemouth bass. Canadian Journal of Zoology 87:589-596.

Hoffman, R. L., J. B. Dunham, and B. P. Hanson. 2012. Aquatic organism passage at road-stream crossings- synthesis and guidelines for effectiveness monitoring. U. S. Geological Survey Open-File Report 2012-1090, Corvallis, Oregon. 64 p.

Jones, D. R., J. W. Kiceniuk, and O. S. Bamford. 1974. Evaluation of the swimming performance of several fish species from the Mackenzie River. Journal of the Fisheries Research Board of Canada 31:1641-1647.

Korson, C., T. Tyler, and C. A. Williams. 2008. Link River dam fish ladder: fish passage results, 2005-2007. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon. 13 p.

Larnier, M. 2002. Biological factors to be taken into account in the design of fishways, the concept of obstructions to upstream migration. Chapter 3, Bulletin Francais de la Pêche et de la Pisciculture 364 supplement: 28-36.

Myrick, C. A., and J. J Cech. 2004. Comparative swimming performances of four California stream fishes. Environmental Biology of Fishes 58:289-295.

Peake, S. J. 2008a. Behavior and passage performance of northern pike, walleyes, and white suckers in an experimental raceway. North American Journal of Fisheries Management 28:321-327.

Peake, S. J. 2008b. Swimming performance and behavior of fish species endemic to Newfoundland and Labrador: a literature review for the purpose of establishing design and water velocity criteria for fishways and culverts. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2843: 52 p.

Scheerer, P. D., S. E. Jacobs, M. Terwilliger, S. A. Miller, S. Gunckel, S. E. Richardson, and M. Heck. 2011. Status, distribution, and life history investigations of Warner suckers, 2006-2010. Oregon Department of Fish and Wildlife, Information Report #2011-02, Salem. 78 p.

Stevens, E. D., A. Sutterlin, and T. Cook. 1998. Respiratory metabolism and swimming performance in growth hormone transgenic Atlantic salmon. Canadian Journal of Fisheries and Aquatic Sciences 55:2028-2035.

Tillinger, T. N., and O. R. Stein. 1996. Fish passage through culverts in Montana; a preliminary investigation. Report to the Montana Department of Transportation Research, Development and Technology Transfer Program. Montana State University, Bozeman, Montana. 42 p.

U.S. Bureau of Reclamation. 2006. Designer's operating criteria: Link River dam fish ladder. Design summary specification no. 20-C0574. Technical Service Center, Denver, Colorado. 28+ p.

U.S. Fish and Wildlife Service. 1985. Endangered and threatened wildlife and plants; Determination that the Warner Sucker is a threatened species and designation of critical habitat. Federal Register 50(188):39117-39123.

U.S. Fish and Wildlife Service. 1998. Recovery Plan for the Native Fishes of the Warner Basin and Alkali Subbasin. Portland, Oregon. 86 p.

U.S. Geological Survey. 2001. Swim tunnel velocity determination using pitot tubes. Laboratory technical operating procedure LAB000.0, Columbia River research lab, Cook, WA. 2 p.

Ward, D. L, O. E. Maughan, and S. A. Bonar. 2002. Effects of temperature, fish length, and exercise on swimming performance of age-0 flannelmouth sucker. Transactions of the American Fisheries Society 131:492-497.

Ward, D. L., A. A. Schultz, and P. G. Matson. 2003. Differences in swimming ability and behavior in response to high water velocities among native and nonnative fishes. Environmental Biology of Fishes 68:97-92.

Table 1. Results from swimming performance tests conducted using Warner suckers.

	Swimming speed (cm/s)				
	U_{crit}				U_{burst}
Fork length (mm)	Trial 1	Trial 2	Mean	S.E.	
131	26.3	19.8	23.0	3.2	26.2
139	14.0	21.0	17.5	3.5	27.9
142	42.7	42.7	42.7	0.0	49.8
142	7.1	7.0	7.1	0.1	49.8
145	7.3	7.3	7.3	0.0	7.3
145	29.1	29.0	29.0	0.1	36.3
148	37.1	37.2	37.1	0.0	59.4
150	45.1	37.5	41.3	3.8	45.1
150	15.0	7.6	11.3	3.7	14.9
151	45.4	37.8	41.6	3.8	53.0
153	38.4	30.8	34.6	3.8	38.4
155	23.3	23.2	23.2	0.1	38.9
155	38.9	31.1	35.0	3.9	54.4
157	55.1	55.2	55.1	0.0	55.1
158	47.5	39.6	43.6	4.0	47.5
168	59.0	58.8	58.9	0.1	75.8
177	26.6	17.7	22.1	4.5	26.6
182	54.7	54.9	54.8	0.1	73.0
190	47.6	47.5	47.6	0.0	57.2
194	58.4	58.2	58.3	0.1	58.4
195	29.3	29.3	29.3	0.0	48.9
197	49.4	49.4	49.4	0.0	59.3
198	59.4	49.7	54.6	4.9	79.4

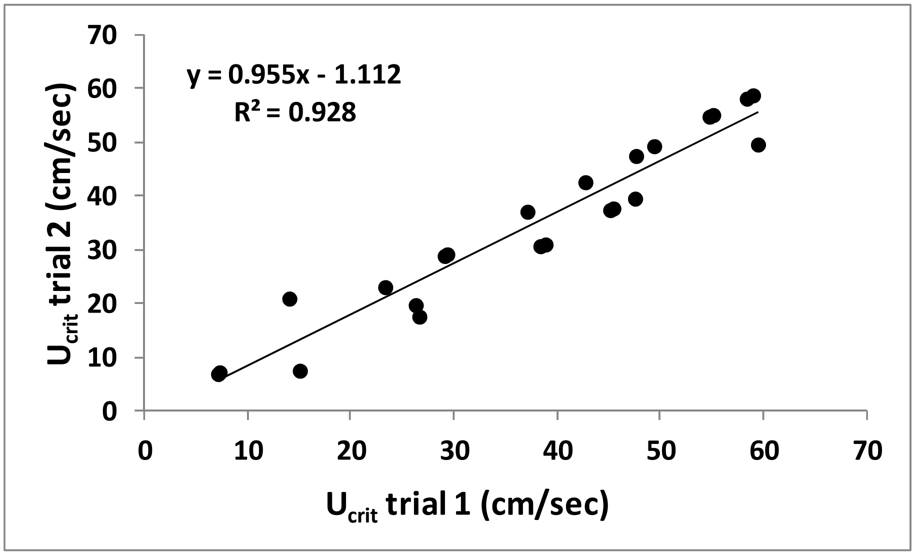

Figure 1. Repeatability of Warner sucker swimming performance (U_{crit}). The dotted line is the linear regression of trial 2 on trial 1.

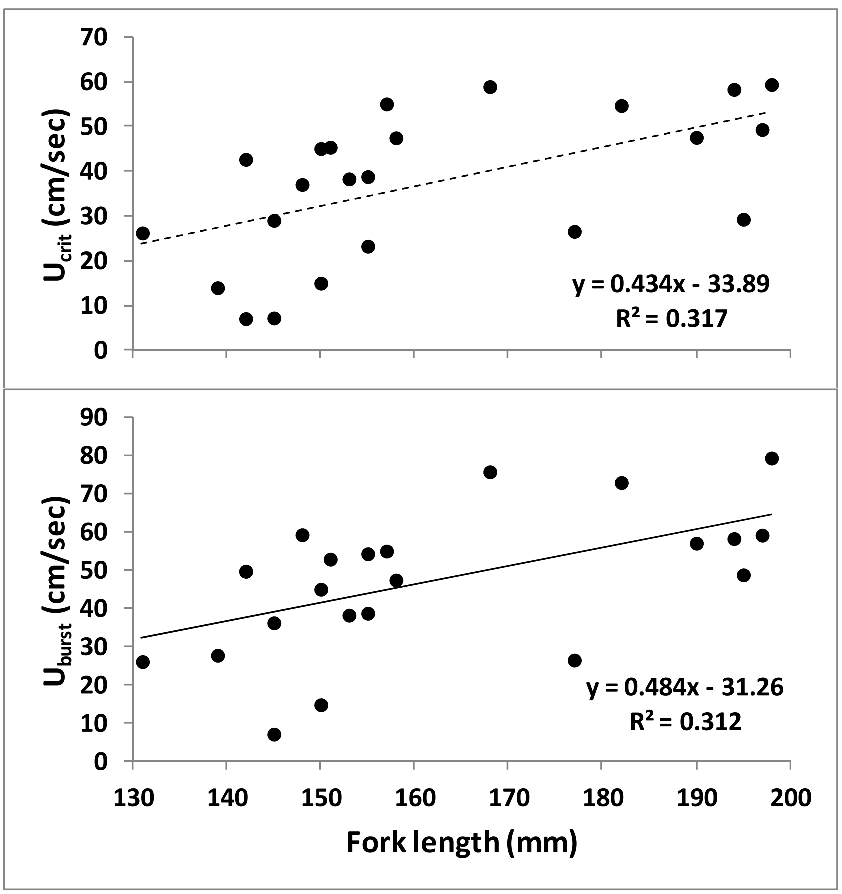

Figure 2. Relationship between swimming performance (U_{crit} and U_{burst}) and fish length.

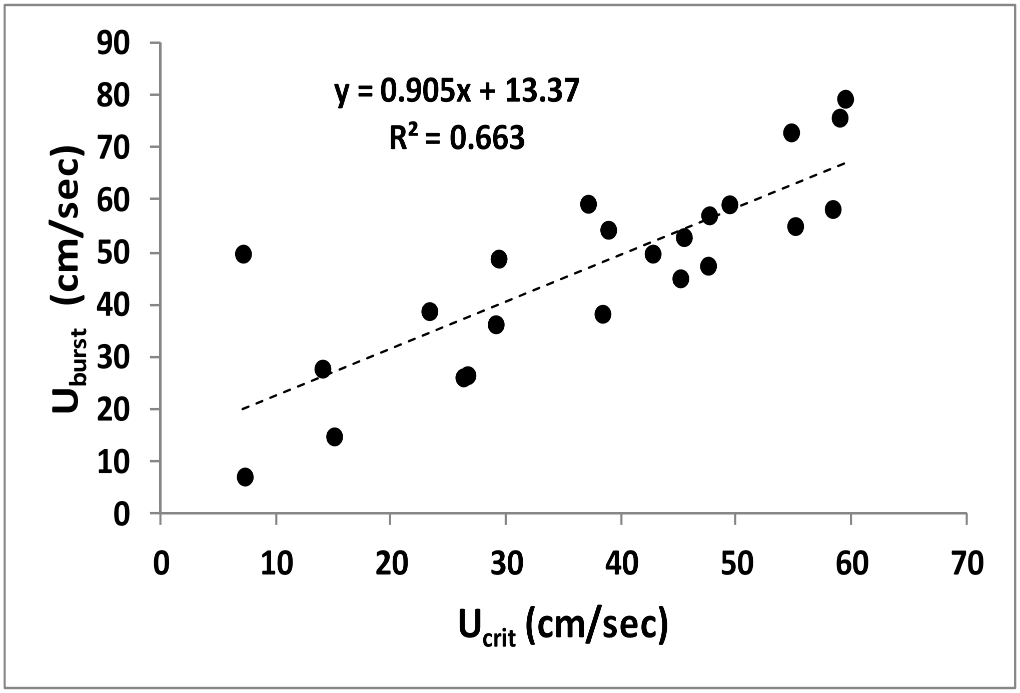

Figure 3. Relationship between U_{crit} and U_{burst} for Warner suckers.

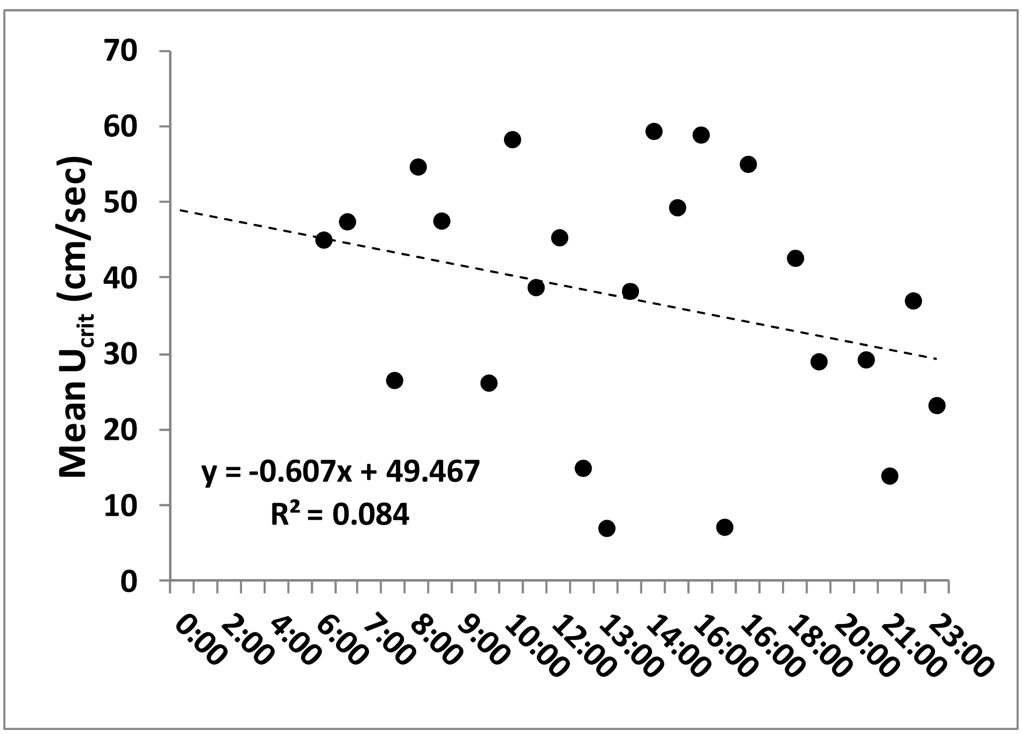

Figure 4. Relationship between fish performance (U_{crit}) and time of day.

Figure 5. Photograph of the weir panels and artificial boulders in the Rookery Diversion passage structure on lower Honey Creek.

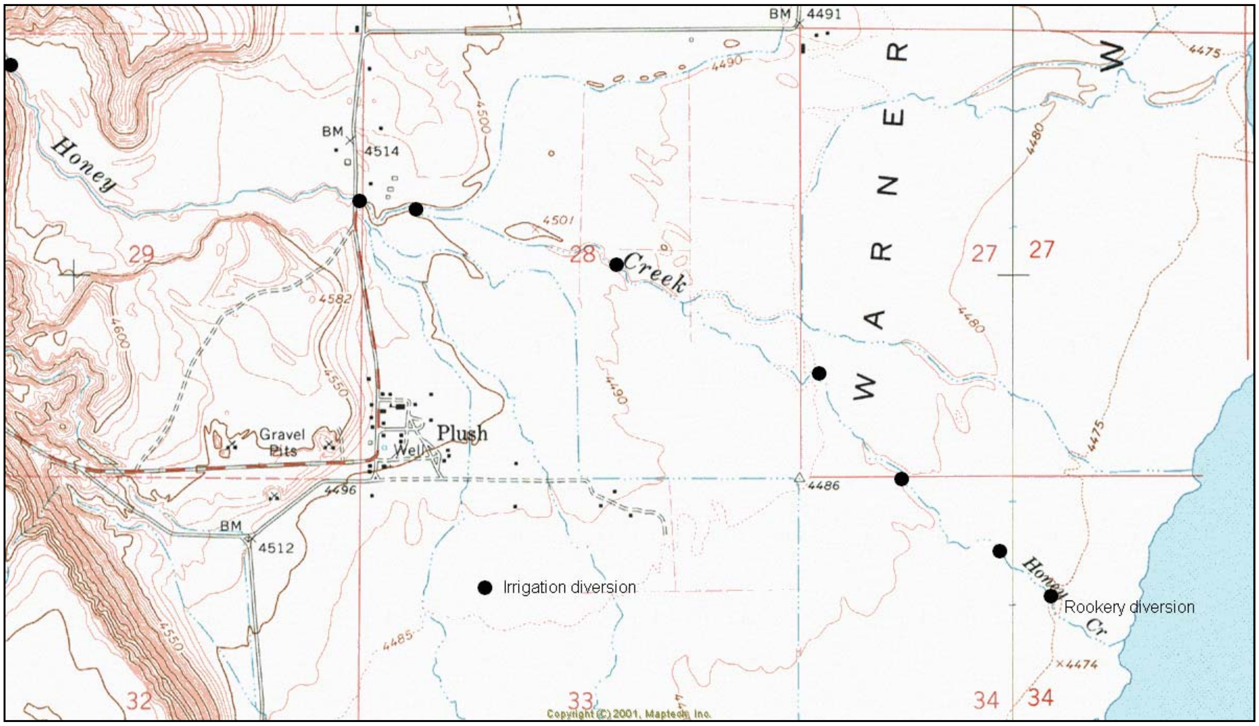

Figure 6. Map showing the eight irrigation diversions on lower Honey Creek. The downstream most diversion, the Rookery diversion, was replaced in 2013. There are plans to replace the lower seven diversions.

OREGON
Fish & Wildlife

3406 Cherry Ave. NE
Salem, Oregon 97303