USE OF RIPARIAN WETLANDS BY LARVAL LOST RIVER, SHORTNOSE, AND KLAMATH LARGESCALE SUCKERS IN THE SPRAGUE RIVER, OREGON

By

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ABSTRACT

USE OF RIPARIAN WETLANDS BY LARVAL LOST RIVER, SHORTNOSE, AND KLAMATH LARGESCALE SUCKERS IN THE SPRAGUE RIVER, OREGON

Stephen A. Zipper

The Lost River sucker, shortnose sucker, and Klamath largescale sucker are three endemic sucker species that inhabit the Upper Klamath River Basin. The Lost River sucker and shortnose sucker were federally listed as endangered under the Endangered Species Act in 1988. Wetland habitat on the Sprague River, Oregon, was restored to provide ecosystem functions such as restoring habitat for fishes. This study characterized use of restored riparian wetland habitat on the Sprague River by larval suckers through catch-per-unit effort, standard length, and daily age distribution by year, location (i.e. three different wetland properties), habitat type (i.e. restored wetland versus the unrestored main stem Sprague River), and distance from the main stem Sprague River. Additionally, relative position in wetland habitat (i.e. upstream or downstream side of wetland) was also analyzed. Identification of larval catostomid species was inconclusive; therefore, all species were combined during data analysis and reporting.

Mean standard length of larval suckers differed among locations, and with Julian day and year; however, it did not differ by habitat type or distance from the main stem Sprague River. Likewise, standard length did not differ between relative positions in wetlands. Linear regression of length at age indicated that sucker larvae captured on the Sprague River (both wetland and main stem) grew approximately 0.27 mm/day. This was greater than previous reported daily growth rates for larval Lost River and shortnose suckers captured in Upper Klamath Lake. Habitat type did not predict daily age or gut fullness levels; further corroborating results from standard length analysis.

Habitat quality (e.g. habitat with wetland characteristics including shallow, warm, and vegetated) and accessibility may be more important than whether the habitat is located within a restored backwater or at the unrestored littoral zone of the main stem Sprague River. Greater growth rates in the Sprague River than in wetlands surrounding Upper Klamath Lake reflect the importance of riverine habitat for safeguarding the future of these endangered species.

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INTRODUCTION

Deltistes luxatus (Lost River sucker), *Chasmistes brevirostris* (shortnose sucker) and *Catostomus snyderi* (Klamath largescale sucker) are three endemic species of catastomid fishes that spawn in the Sprague River upstream of Upper Klamath Lake. The Lost River sucker and shortnose sucker were listed under the Endangered Species Act in 1988 (USFWS 1988). All three of these adfluvial species are highly fecund, long lived, and mature at ages of five years and older (Buettner and Scoppettone 1990). Spawning adults migrate to riverine gravel beds where eggs are deposited and fertilized (Scoppettone and Vinyard 1991). Spawning migrations typically occur during the high flows associated with spring runoff. Fertilization is followed by larval swimup to the surface approximately 10-15 days post-hatch (Cooperman et al. 2010, USFWS 2012), yolk sac absorption, and migration of larvae downstream to Upper Klamath Lake. Juvenile stage onset occurs at approximately 25 millimeters total length (USFWS 2012). population trends because population estimates were inaccurate (USFWS 2007a, 2007b, 2012). Evaluation of the cumulative product of the annual estimates of population change for both Lost River and shortnose sucker populations indicate continuing population decline (USFWS 2012). Large fish die-offs in 1995, 1996, and 1997 have further contributed to the declining status of these suckers, and an estimated 50 percent of the Lost River sucker adult population was thought to have died off during 1996 (USFWS 2007a). Environmental conditions are especially critical for development, growth, and survival during the vulnerable larval stage when mortality rates are typically greatest

(Sogard 1999). Therefore, it is pertinent for studies to be conducted on larval suckers in an attempt to understand their life history associated with habitat use. Earlier research was primarily focused on lacustrine habitat and wetland areas surrounding Upper Klamath Lake. Presently the extent to which these larval suckers reside in a riverine environment is unknown.

The Wetlands Reserve Program, established in 1992, is a United States Department of Agriculture program where easements are established with private property owners for the purpose of restoring or enhancing wetland habitats (Duffy et al. 2011). The intent of the Wetlands Reserve Program is to restore or enhance wetlands to provide habitat for wildlife and fishes, control flooding, improve water quality, and provide other ecosystem services. Examples include relieving easement land of agricultural use or breaching levees to restore river floodplain access. The National Resources Conservation Service implements restoration goals of the Wetlands Reserve Program by assisting landowners in restoration efforts. As of 2008, a total of 26,605 hectares (ha) were enrolled in the Oregon Wetlands Reserve Program. Along the Sprague River, more than 2,400 ha of wetlands and riparian areas have been restored under the Wetlands Reserve Program and the Conservation Reserve Program (USDA 2009). In this study, I evaluated use by larval suckers of three representative National Resources Conservation Service Wetlands Reserve Program wetlands.

Larval suckers rear in wetland areas in the Upper Klamath Basin and congregate around emergent non-woody vegetation in the littoral zones of Upper Klamath Lake (Cooperman and Markle 2000). Observations from my sampling in 2009 revealed that sucker larvae in the Sprague River were localized in backwaters surrounded by vegetation at approximately 13 river kilometers (rkm) upstream of the former Chiloquin Dam. These sucker larvae occupied riparian wetland habitats of relatively shallow low-velocity water. These habitats may represent rearing or nursery habitat that provides food resources, and cover for avoiding predators or high flows (Cooperman and Markle 2004, Markle and Dunsmoor 2007, Burdick 2012, USFWS 2012). Research on larval sucker use of wetlands has primarily focused on areas surrounding Upper Klamath Lake and downstream of the Chiloquin Dam before it was removed in 2008. Cooperman and Markle (2003) found that larval suckers rapidly drifted from the Sprague River to Upper Klamath Lake, sometimes in less than one day, and that their gut fullness was inversely proportional to distance from Upper Klamath Lake. However, the authors only conducted studies as far upstream as Chiloquin Dam, which was 17.3 rkm above Upper Klamath Lake. While these authors' observations may be true of suckers within a day's drift distance to the lake, it fails to explain why suckers would spawn farther upstream, even as far as Beatty, Oregon which is approximately 128 rkm upstream from Upper Klamath Lake. Since larval fish must feed quickly after emerging from gravel (DeVries et al. 1998), they may move to riparian wetland areas in the upstream portions of the Sprague River during downstream migration to Upper Klamath Lake (Klamath Tribes Natural Resources Department 1996). Wetlands are likely to play a major role in survival and growth of larval suckers in upstream reaches of the Sprague River. However, duration of wetland use and extent to which the wetlands support growth of larval suckers remains uncertain. If use of riverine riparian wetlands contribute to survival of the endangered suckers, it is plausible to hypothesize that further wetland restoration would reduce sucker mortality and help to reverse population decline (Crandall et al. 2008).

Objectives

My objectives were:

1. to assess assemblage structure of sucker larvae in representative National Resources Conservation Service Wetlands Reserve Program restored wetlands on the Sprague River;
2. to determine if standard length of larval suckers differed between Wetlands Reserve Program restored wetlands and the unrestored main stem Sprague River;
3. to determine if daily growth of larval suckers differed between Sprague River wetlands and Upper Klamath Lake wetlands by comparing daily age from lapilli otoliths; and
4. to compare feeding rates through relative gut fullness of larval suckers between Wetlands Reserve Program wetlands and the main stem Sprague River.

Study Site

The Sprague River is approximately 139 kilometers (km) long and drains a basin of 4,170 km^2. Flowing from east to west, it is the primary tributary of the Williamson River, and its confluence is 16 km northeast of Upper Klamath Lake. Together these two rivers contribute 50 percent of the discharge to Upper Klamath Lake.

Because larval Lost River, shortnose, and Klamath largescale suckers appear to be restricted to habitat offering shallow vegetated water (Cooperman and Markle 2000), I compared habitat types (i.e. restored wetland backwaters and unrestored main stem habitat) with these characteristics on the Sprague River at three restored Wetlands Reserve Program wetlands upstream of the former Chiloquin Dam site (Figure 1). The first two wetlands were located 3 rkm above the Williamson River Road crossing (approximately 42° 35' 46" N, 121 ° 44' 30" W and 42 ° 36' 34" N, 121 ° 45' 40" W). The third wetland was near Beatty, Oregon (approximately 42 ° 26' 58" N, 121 ° 14' 23" W). Permission to access the wetlands was obtained from landowners prior to sampling. Riparian vegetation surrounded these wetland areas, and there was emergent vegetation and dead submerged grasses in the water. Sampling on the main stem Sprague River occurred in the limited shallow vegetated habitat that the river offered.

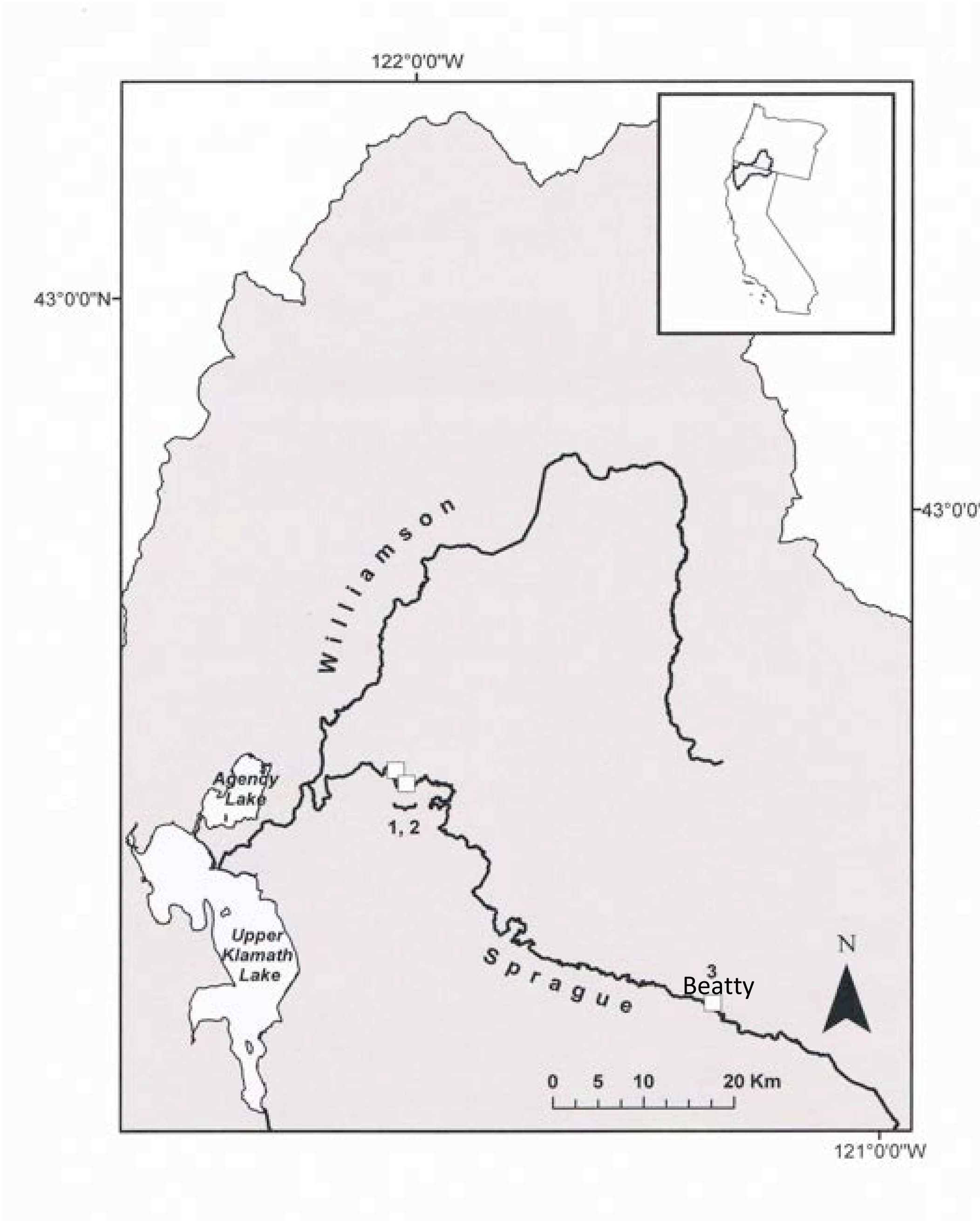

Figure 1. Map of the Upper Klamath River Basin (inset top right) with National Resources Conservation Service Wetlands Reserve Program restored wetlands sampled as indicated by numbers 1, 2, and 3.

MATERIALS AND METHODS

Field Sample Collection and Processing

Sampling was conducted biweekly from April to June for a total of 13 days in 2009 and weekly from March to June for a total of 33 days in 2010. During both years, all captured fishes were identified to species or genus and measured for standard length to the nearest millimeter. However, identification of larval suckers to species was not feasible in the field and a permit for take of larval suckers was not secured in 2009. In 2010, standard length of larval suckers was measured in the field, fish were euthanized, and larvae were preserved in 70 percent ethanol in separate vials with unique identification tags. All sampling was conducted under Humboldt State University Institutional Animal Care and Use permit number 08/09.F.59.A.

Two types of gear were used to collect fishes: trap nets and dip nets. Trap nets were constructed from 62.5 liter (L) plastic tubs with three mesh sides of 220 µm and one side with a funnel (Figure 2a). The design was similar to that of a trap net with a single funneled entrance. Trap wings measuring 1.5 m in length (mesh size 220 µm) were attached to both sides of each trap net with reinforcing bar (rebar) and served to guide fishes into the trap (Figure 2b). The opposite side of each trap wing was secured to the substrate with rebar. In addition, a mesh partition (mesh size 1.0 cm) was placed in the center of the trap to limit in-trap predation by larger predators. A square brick was placed in the bottom of each trap to help keep the trap secured to the substrate.

a)

b)

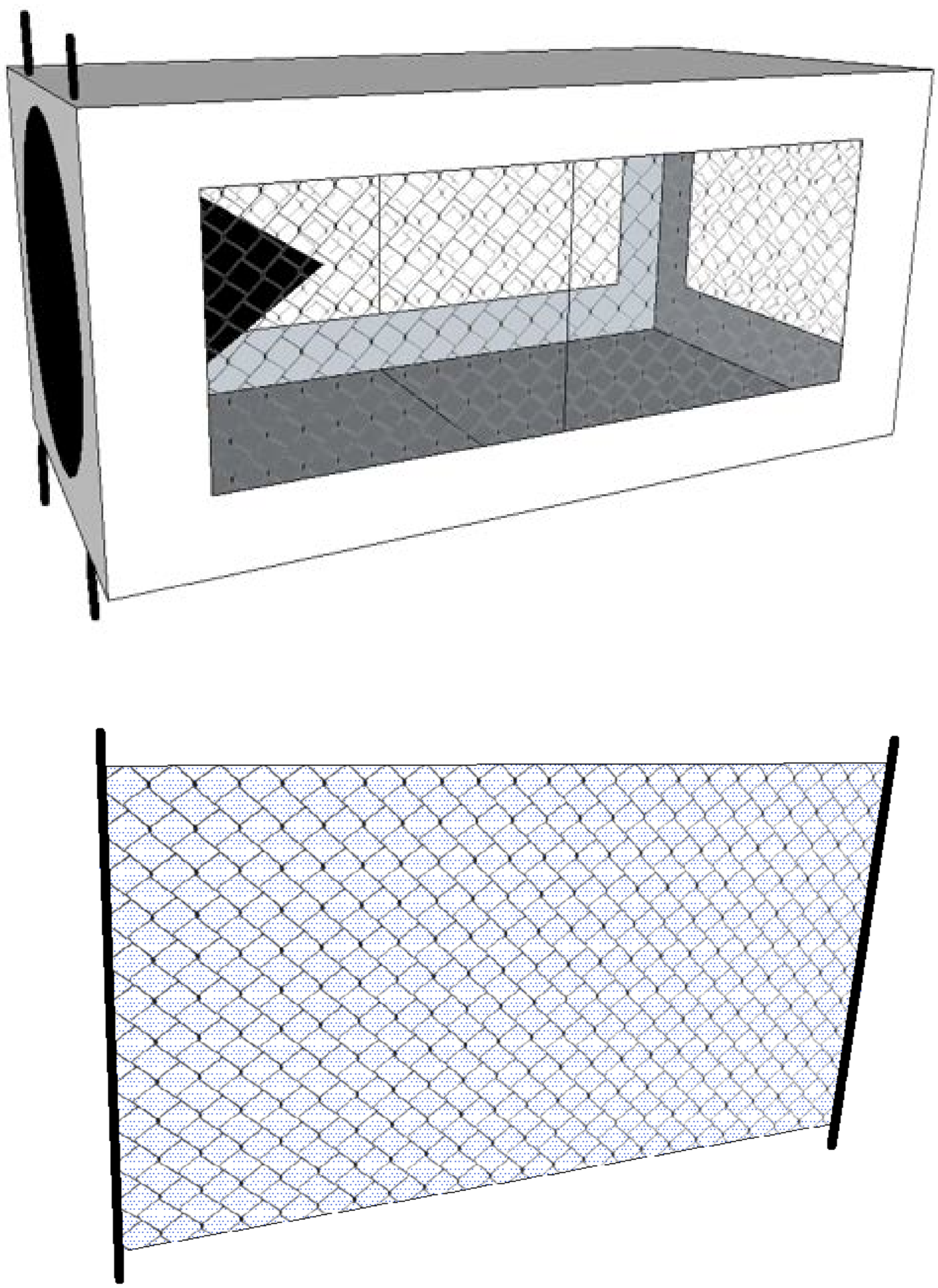

Figure 2. Trap net: (a) consisting of 62.5 L plastic box with three mesh sides (220 μm), entrance funnel, divider panel, and reinforcing bar posts and (b) one mesh wing with rebar attached to both ends (one end attached to trap, one end to secure opposite end of trap wing to substrate).

Trap net sampling was only conducted in 2010. Because larval suckers have been observed to drift at night (Cooperman and Markle 2003), traps were fished during hours of darkness to capture migrating suckers. Trap net sets encompassed one crepuscular cycle; they were set in the afternoon and checked in the morning. Trap nets were set in pairs, with one trap oriented to capture immigrating suckers and one to trap emigrating suckers for each specific wetland habitat. Traps were placed in shallow low-velocity habitat surrounded by vegetation to encourage larval movement into the traps and were located along upstream and downstream sides of wetlands. Placement of traps was determined by visually inspecting flow into and out of wetland areas and then placing traps in pathways of flow. In addition to these paired trap sets, two traps were set to intercept any larval suckers migrating in the littoral zone of the main stem Sprague River. Due to the steep drop off and profile of riverbanks, locations for placement were limited for main stem river traps. Traps were placed in shallow vegetated areas along the river margin where possible. I used eight traps at Location 1 (four wetland, two main stem, two wetlands behind floodgates), six traps at location 2 (four wetland, two main stem), and four traps at location 3 (two wetland, two main stem). Only two wetland traps were deployed at location 3 because available habitat at that location was limited. A theoretical setup of trap placement is provided (Figure 3). A catch was defined as any fish in the trap or between the trap wings.

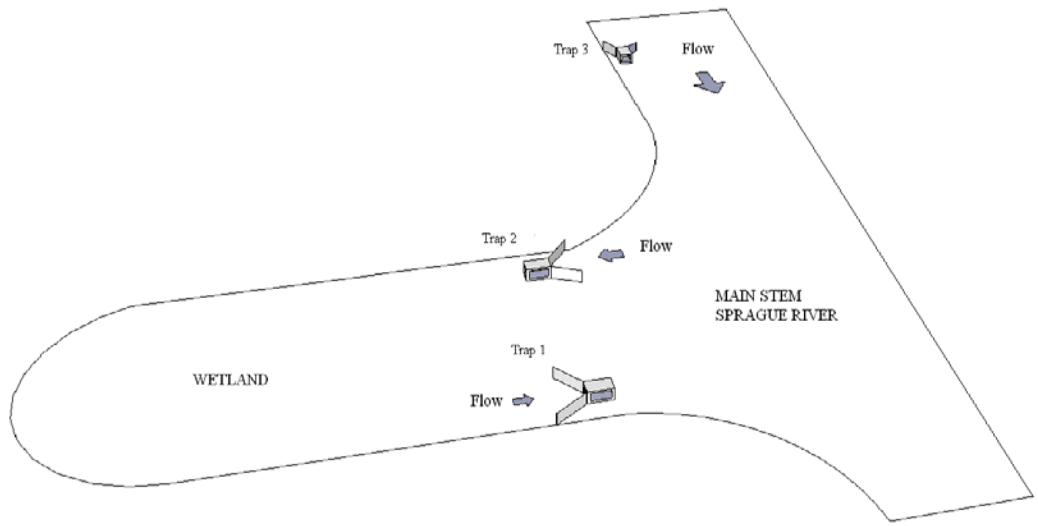

Figure 3. Idealized example of wetland and main stem trap placement. Trap 1 is set to capture emigration of larval suckers from the wetland and is located on the upstream side relative to the main stem, trap 2 for immigration and downstream side relative to the main stem, and trap 3 for main stem.

Dip net sampling consisted of timed 3-minute swiping of a dip net (220 µm mesh) in areas surrounding the traps immediately before trap nets were retrieved. Average distance from the river was measured for each unit of effort.

Laboratory Sample Processing and Identification

All larval suckers retained for laboratory analysis were measured for standard length in the laboratory and identified to species where possible. Current identification methods cannot distinguish among larval phases of all three sucker species inhabiting the Sprague River. However, the Lost River sucker can be distinguished from shortnose and Klamath largescale sucker (Simon 2004). Therefore, I identified larval suckers as Lost River, shortnose/Klamath largescale sucker, or unknown. I used melanophore patterns, vertebral counts, and/or myomere counts to identify larval suckers. Identification of specimens ≤ 14 mm standard length were conducted using melanophore patterns, and specimens > 14 mm were identified via vertebral counts and/or myomere counts.

Identification through melanophore patterns followed descriptions of Simon (2004). Melanophore patterns were observed under an underlit dissecting microscope at 10X to 20X power. A greater number of more condensed dorsal melanophores at the base of the head and along the entirety of the dorsum is characteristic of shortnose/Klamath largescale suckers (Figure 4).

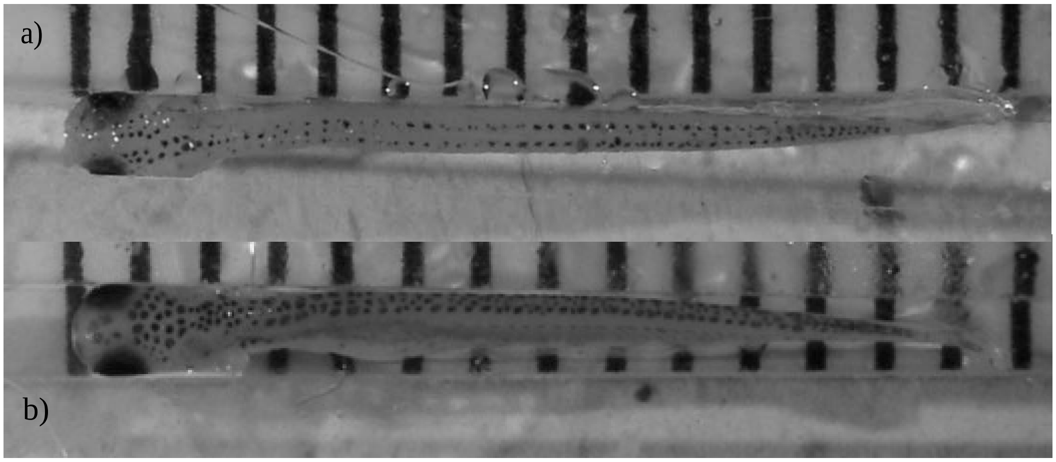

Figure 4. Melanophore pattern of (a) Lost River sucker and (b) shortnose/Klamath largescale sucker at 13 mm standard length.

Following identification by melanophore pattern, all samples were cleared and/or stained for further identification after Potthoff (1984). Samples were first alcohol dehydrated for seven days with a solution of 50 percent H_2O and 50 percent of 95 percent alcohol. Specimens ≤ 14 mm standard length were placed in alizarin red for 10 minutes followed by immediate removal and storage in 100 percent glycerin. Solution holding specimens > 14 mm standard length were neutralized after dehydration with a saturated sodium borate solution for two days. Specimens were subsequently stained with 1.0 percent potassium hydroxide with alizarin red for a maximum of four days.

Resolution of species identity for individuals > 14 mm standard length relied on vertebral counts and/or myomere counts to identify specimens. Markle et al. (2005) determined there were 41-44 post-Weberian vertebrae for shortnose suckers and 44-48 for Lost River suckers. They also reported a 1:1 ratio in Lost River suckers and shortnose/Klamath largescale suckers between the number of myomeres and number of vertebrae. Vertebral counts and/or myomere counts were made using dissecting microscope after clearing and staining of specimens.

Relative gut fullness of preserved larvae was visually assessed on a categorical scale following Cooperman and Markle (2003) as empty, low (>0-20 percent), medium (21-50 percent), medium-high (51-75 percent), and high (>75 percent). Otoliths were extracted from all sucker larvae and used to assess daily age to determine growth rates. A dissecting microscope fitted with a polarized lens was used to locate and extract all otoliths. Since most of the sucker larvae had not produced asterisci, only the sagittae and lapilli were extracted and mounted. Otoliths from identified sucker larvae were processed following Terwilliger and Markle (2003), but with a modification to the suggested adhesive. Otoliths were mounted onto glass slides using "wet'n'wild®", a clear nail protector (Markwins Beauty Products, Inc., City of Industry, California). Most otoliths were readable without polishing or sanding. Otoliths requiring further processing were polished with 3 μm or 6 μm diamond lapping film (Allied High Tech Products, Rancho Dominguez, California). Since sagitta were noted to have irregular growth with formation of tails and rostrums (Figure 5), only the lapilli were used for aging as they produced the most accurate readings (Hoff et al. 1997) for larval suckers. Daily growth rings were counted at least twice by the same reader to determine daily age. A perimeter was drawn around the otoliths to calculate approximate otolith surface area. Daily age was estimated using 500X total magnification with aid of an oil immersion lens (MEIJI® Model# 10824, MEIJI Techno Co., San Jose, California). Otoliths were read and measured using ImagePro® Plus software (Version 7.0, Media Cybernetics Inc., Rockville, Maryland) and a compound microscope mated with a Lumenera® Infinity 1 camera (Lumenera Corp., Ottowa, Ontario, Canada). Hoff et al. (1997) determined that sucker larvae had both sagitta and lapilli at hatching and defined daily growth ring deposition as a light-dark band transition. Daily age was determined by enumerating all daily growth rings (light-dark band) starting at the first ring proximal to the primordium. When possible, daily growth rings were counted along the long axis of the lapillus to the outermost ring distal to the primordium. After all otolith daily rings were counted, a 20

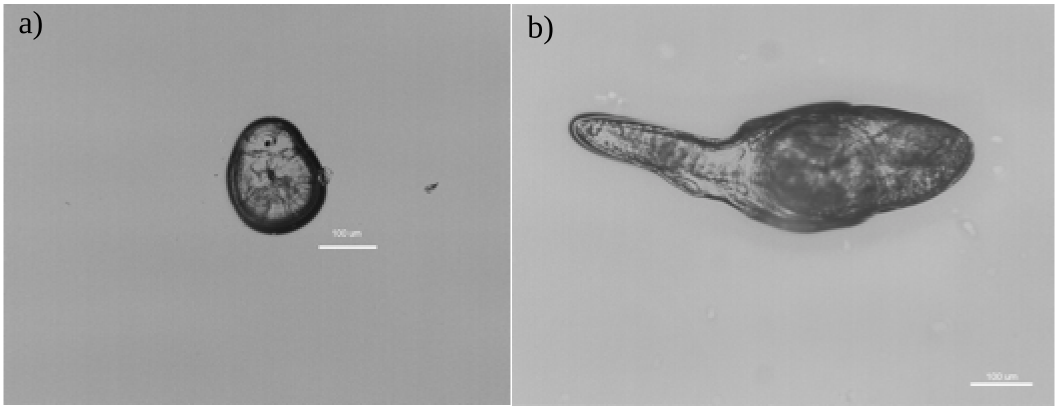

Figure 5. Sagittal otoliths from shortnose/Klamath largescale suckers differing in standard lengths: (a) 14 mm (b) 24 mm. Notice morphometric change in sagittal shape. Scale bar is 100 µm.

percent random sample was drawn from all otoliths for age verification. When aging was within five percent of the first age determination, the age was deemed verified. However, if aging was more than a five percent difference from the first age determination, aging was performed a third time with the mean count being the final age.

Data Analysis

Because only two Lost River suckers were identified with the majority of identified specimens as being shortnose or Klamath largescale suckers or unidentifiable, statistical analysis was conducted disregarding species. Additionally, data analysis was not conducted on trap net data because trap nets failed to capture larval suckers.

A primary objective of this study was to determine if growth of larval suckers occupying riparian Wetlands Reserve Program wetlands differed from growth of larval suckers occupying the main stem Sprague River. I analyzed standard length of larval suckers to address this objective. Larval sucker standard length was analyzed in relationship to the following variables: year, Julian day, location, habitat type (wetland or main stem Sprague River), and location within wetland habitat (upstream or downstream position relative to flow). All variables were tested for significance at $\alpha = 0.05$. Analysis of variance (ANOVA) included all above referenced variables, and data was log transformed when necessary. Post-hoc multiple comparison tests were conducted to further evaluate significant differences between variables using Student's *t* test or Welch's *t* test with Bonferroni's adjustment for multiple comparisons.

Another objective of this study was to determine daily growth using daily age determinations. Standard length measured in the laboratory was initially regressed against standard length measured in the field to determine relative accuracy of field measurements and possible substitution for standard length measured in the field. I then addressed this objective using linear regression analysis to determine relationships daily age and standard length measured in the laboratory. This model provided a relative daily growth estimate that could be compared to growth rates from Upper Klamath Lake wetlands reported by Markle et al. (2009). Differences in mean daily age by Julian day, location, habitat type, and distance from the main stem Sprague River were analyzed with ANOVA with post-hoc multiple comparison tests run to further evaluate these differences. Data was log transformed when necessary. Post hoc analysis was conducted using Student's *t* test with Bonferroni's adjustment for multiple comparisons.

Catch-per-unit effort by location and habitat type were evaluated for differences and used for inferring habitat preference. This analysis was done for
dip net sampling in 2010.

Differences in relative gut fullness between habitat types and locations were analyzed using proportional odds logistic regression. Predictor variables were evaluated for significance by evaluating the 95 percent confidence interval for each variable as well as Wald's z values.

RESULTS

Catch Data

Sampling in 2009 and 2010 yielded 522 suckers caught by means of dip net, trap net, and electroshock fishing; however, not all samples were used in the analysis. Three hundred and forty-five suckers measured for standard length were used in the pooled 2009 and 2010 data set (Table 1). No suckers were caught in the Sprague River main stem habitat during sampling in 2009. Sampling in 2009 revealed larval suckers were localized to shallow littoral zones of wetlands of location 1 and location 2. During the 2009-sampling season, no suckers were caught at location 3 located at Beatty, OR. However, suckers were caught in the Sprague River primarily at location 3 in 2010. All suckers collected in 2010, with the exception of two sucker larvae and six sub-adults, were captured during dip net sampling. Results revealed location 1 produced 57.4 percent of total larval sucker catch, location 2 produced 26.1 percent, and location 3 produced 16.5 percent (Table 1). Catch-per-unit effort varied among locations (Table 2). However, catch-per-unit effort was similar between wetland and main stem habitat.

Several non-catostomid fishes were captured during sampling in 2009 and 2010 (Table 3). Blue chub (*Gila coerulea*) comprised the majority of species captured fish in 2009, and sculpin (*Cottis* spp) were the majority in 2010 (Table 3). Both native and non-native species were captured during sampling in 2009 and 2010, and native species were the majority (94.5 percent) of non-catostomid species (Table 3).

Table 1. Total catch (N) and percentage of larval suckers in 2009 and 2010 by location and habitat type.

Year	Location	Habitat Type	N	Percentage
2009	Location 1	Wetland	130	62.8
2009	Location 1	River	0	0
2009	Location 1	Total (wetland and river)	130	62.8
2009	Location 2	Wetland	77	37.2
2009	Location 2	River	0	0
2009	Location 2	Total (wetland and river)	77	37.2
2009	Location 3	Wetland	0	0
2009	Location 3	River	0	0
2009	Location 3	Total (wetland and river)	0	0
2009	All locations	Wetland (total)	207	100
2009	All locations	River (total)	0	0
2009	All locations	Total (wetland and river)	207	100
2010	Location 1	Wetland	68	81
2010	Location 1	River	0	0
2010	Location 1	Total (wetland and river)	68	50.4
2010	Location 2	Wetland	11	13.1
2010	Location 2	River	2	3.7
2010	Location 2	Total (wetland and river)	13	9.6
2010	Location 3	Wetland	5	6
2010	Location 3	River	52	96.3
2010	Location 3	Total (wetland and river)	54	40
2010	All locations	Wetland	86	61.4
2010	All locations	River	54	38.6
2010	All locations	Total (wetland and river)	135[b]	100
2009 & 2010	Location 1	Wetland	198	68
2009 & 2010	Location 1	River	0	0
2009 & 2010	Location 1	Total (wetland and river)	198	57.4
2009 & 2010	Location 2	Wetland	88	30.2
2009 & 2010	Location 2	River	2	3.7
2009 & 2010	Location 2	Total (wetland and river)	90	26.1
2009 & 2010	Location 3	Wetland	5	1.7
2009 & 2010	Location 3	River	52	96.3
2009 & 2010	Location 3	Total (wetland and river)	57	16.5
2009 & 2010	All locations	Wetland	291	84.3
2009 & 2010	All locations	River	54	15.7
2009 & 2010	All locations	Total (wetland and river)	345[a]	100

[a] Additional three observations due to missing values in individual years.
[b] Five missing values due to unknown location of capture.

Table 2. Catch (N), total sampling time (minutes) and catch-per-unit effort (CPUE) of dip net sampling for larval suckers by location and habitat type in 2010.

Location (habitat type)	N	Time	CPUE
Location 1 (wetland)	58	1080	0.16
Location 2 (wetland)	12	687	0.05
Location 3 (wetland)	5	146	0.1
Total (wetland)	75	1913	0.12
Location 1 (river)	0	372	0
Location 2 (river)	2	339	0.02
Location 3 (river)	47	450	0.31
Total (river)	49	1161	0.13
Location 1 (wetland and river)	58	1452	0.12
Location 2 (wetland and river)	14	1026	0.04
Location 3 (wetland and river)	52	596	0.26
Total (wetland and river)	124	3074	0.12

Table 3. Number (N) of non-catostomid fish species captured during 2009 and 2010 sampling and associated percentages.

Status	Species	N (2009)	N (2010)	Total	Percentage of total
Native	Blue chub	137	253	390	20.3
Native	Tui chub	12	95	107	5.6
Native	Unknown chub	10	271	281	14.6
Native	Speckled dace	40	44	84	4.4
Native	Lamprey	0	8	8	0.4
Native	Sculpin	36	865	901	46.9
Native	Rainbow trout	4	41	45	2.3
Non-native	Bullhead catfish (brown and black)	29	5	34	1.8
Non-native	Fathead minnow	23	8	31	1.6
Non-native	Bass (unknown species)	1	14	15	0.8
Non-native	Yellow perch	17	7	24	1.3
Total	All species combined	309	1611	1920	100

Species Distribution

During 2010 sampling season, 58 suckers were identified to species, of which 39 species were identified by melanophore pattern and 19 were identified by vertebral count. Total larval and early juvenile catch during 2010 consisted of 66 percent shortnose/Klamath largescale suckers, three percent Lost River suckers, and 31 percent unidentifiable sucker species (Table 4). Due to the small representation of Lost River suckers (N=2) and large representation of shortnose/Klamath largescale suckers (N=38) and unidentifiable sucker species (N=18) (Table 4), further analysis pooled data among sucker species.

Relative Gut Fullness

Relative gut fullness was positively correlated with standard length (Wald's z = 2.927, P = 0.003), but it was not affected by Julian day, distance from the main stem, location, or habitat type (wetland versus river, Wald's z = -0.067, P = 0.946). Mean relative gut fullness was approximately equal across all locations (Table 5). Mean gut fullness of individuals was approximately 51-75 percent among all locations and habitats.

Table 4. Total catch (N) and percentage of larval sucker species caught in three sampling locations in 2010.

Species	Location	N	Percentage
Shortnose/Klamath largescale sucker	Location 1	7	46.7
Lost River sucker	Location 1	2	13.3
Unknown	Location 1	6	40
All species	Location 1	15	25.9
Shortnose/Klamath largescale sucker	Location 2	5	83.3
Lost River sucker	Location 2	0	0
Unknown	Location 2	1	16.7
All species	Location 2	6	10.3
Shortnose/Klamath largescale sucker	Location 3	25	71.4
Lost River sucker	Location 3	0	0
Unknown	Location 3	10	28.6
All species	Location 3	35	60.3
Shortnose/Klamath largescale sucker	Unknown	1	50
Lost River sucker	Unknown	0	0
Unknown	Unknown	1	50
All species	Unknown	2	3.5
Shortnose/Klamath largescale sucker	All locations	38	65.5
Lost River sucker	All locations	2	3.4
Unknown	All locations	18	31
All species	All locations	58	100

Table 5. Gut fullness levels following Cooperman and Markle (2003) relative gut fullness measures (N = number of suckers, 1 = low (>0-20%), 2 = medium (21-50%), 3 = medium-high (51-75%), and 4 = high (>75%)) for larval suckers caught by location and habitat type.

Location	Habitat type	N	Level 1	Level 2	Level 3	Level 4	Mean
Location 1	Wetland	18	2	3	6	7	3
Location 1	River	0	0	0	0	0	-
Location 1	Total	18	2	3	6	7	3
Location 2	Wetland	5	0	2	1	2	3
Location 2	River	2	0	1	1	0	2.5
Location 2	Total	7	0	3	2	2	2.9
Location 3	Wetland	5	3	0	0	2	2.2
Location 3	River	41	9	5	4	23	3
Location 3	Total	46	12	5	4	25	2.9

Standard Length Analysis: Pooled 2009 and 2010 Data

Standard length differed between years ($F_{1,320}$ = 51.609, $P < 0.001$), among Julian days ($F_{1,320}$ = 138.416, $P < 0.001$), and locations ($F_{2,320}$ = 12.485, $P < 0.001$); however, not between habitat types ($F_{1,320}$ = 0.071 , P = 0.79). Mean standard length increased with Julian day. Standard length of larval suckers was smaller at location 1 than at location 2 (t_{273} = -5.146, $P < 0.001$) but did not differ between locations 1 and 3 (t_{235} = -0.158, P = 0.874) nor between locations 2 and 3 (t_{137} = 2.393, P = 0.018). Length of larval suckers did not differ among upstream or downstream sides of wetlands, or the main stem Sprague River ($F_{2,249}$ = 0.046, P = 0.955). Overall, mean standard length of larval suckers was 15.9 mm in 2009 and 14.1 mm in 2010. In 2009, standard length ranged from 10.0-24.0 mm and in 2010 it ranged from 9.0-28.0 mm (Table 6).

Length Distributions and Analysis: 2010 Data

In 2010, distance of fish samples from the river was recorded, which had not been recorded in 2009. Therefore, a separate analysis was conducted for standard length data collected in 2010. Due to some departure from normality, standard length data were transformed using a natural log transformation. Standard length differed among locations ($F_{2, 122}$ = 6.946, P = 0.001) and Julian days ($F_{1, 122}$ = 108.860, $P < 0.001$), but not between habitat types ($F_{1, 122}$ = 0.485, P = 0.488) or distance ($F_{1, 122}$ = 0.167, P = 0.682). Mean standard length increased with Julian day.

Table 6. Number (N), mean standard length (mm), standard deviation (SD) of the mean, and range of standard lengths of larval suckers collected in three locations and two habitat types on the Sprague River, Oregon in 2009 and 2010.

Year	Location	Habitat type	N	Mean	SD	Range
2009	Location 1	NA	128	15.2	2.3	10.0-22.0
2009	Location 2	NA	76	17.2	2.7	11.0-24.0
2009	Location 3	NA	0	--	--	--
2009	All locations	Wetland	201	15.9	2.6	10.0-24.0
2009	All locations	River	0	--	--	--
2010	Location 1	NA	59	13.4	1.6	10.0-17.0
2010	Location 2	NA	13	12.3	1.5	10.0-15.0
2010	Location 3	NA	51	15.4	5.3	9.0-28.0
2010	All locations	Wetland	75	13.2	1.6	10.0-17.0
2010	All locations	River	48	15.5	5.4	9.0-28.0
2009 & 2010[a]	Location 1	NA	187	14.6	2.3	10.0-22.0
2009 & 2010[a]	Location 2	NA	89	16.5	3.1	10.0-24.0
2009 & 2010[a]	Location 3	NA	51	15.4	5.3	9.0-28.0
2009 & 2010[a]	All locations	Wetland	276	15.1	2.7	10.0-24.0
2009 & 2010[a]	All locations	River	48	15.5	5.4	9.0-28.0

[a] The total for locations (1,2,3) and habitat type (wetland, river) do not match in 2009 & 2010 data because of three suckers with unknown habitat type in 2009.

Mean standard length of suckers at location 2 was, on average, 1.1mm shorter than suckers downstream at location 1 (Table 6); however, sample size at location 2 was small (n = 13). Welch's *t* tests with Bonferroni's adjustment and testing of significance at α = 0.05/3 or 0.017 revealed differences in standard length between location 2 and location 3 ($t_{52.253}$ = -3.042, P = 0.004); however, standard length at locations 1 and 2 ($t_{16.976}$ = 2.286, P = 0.035) did not differ, nor did standard length at locations 1 and 3 ($t_{61.557}$ = 1.797, P = 0.077).

Age Distributions: Otolith Analysis (2010)

Daily age and otolith measurements were recorded for 51 different larval sucker specimens. A correlation matrix plot (Figure 6) was constructed using otolith surface area, otolith age, and standard length measured in the laboratory. All variables were positively correlated (Pearson's correlation r > 0.9) for all combinations of variables (Figure 6). Surface area and standard length were both shown to increase with age and are depicted in Figures 7, 8, and 9.

Standard length measured in the laboratory proved to be a good predictor of standard length measured in the field (global $F_{1,51}$ = 525.1, P < 0.001, adjusted R^2 = 0.910). The linear regression equation indicating standard length measured in the laboratory versus daily age was standard length = 6.201 + 0.269*age (Figure 10) and indicates growth rate was 0.27 mm/day. The slope was greater than previously published slopes of 0.12 for Lost river sucker and 0.15 for shortnose suckers (Markle et al. 2009), (global $F_{1,51}$ = 161.9, P < 0.001). In this study, daily age differed with Julian day

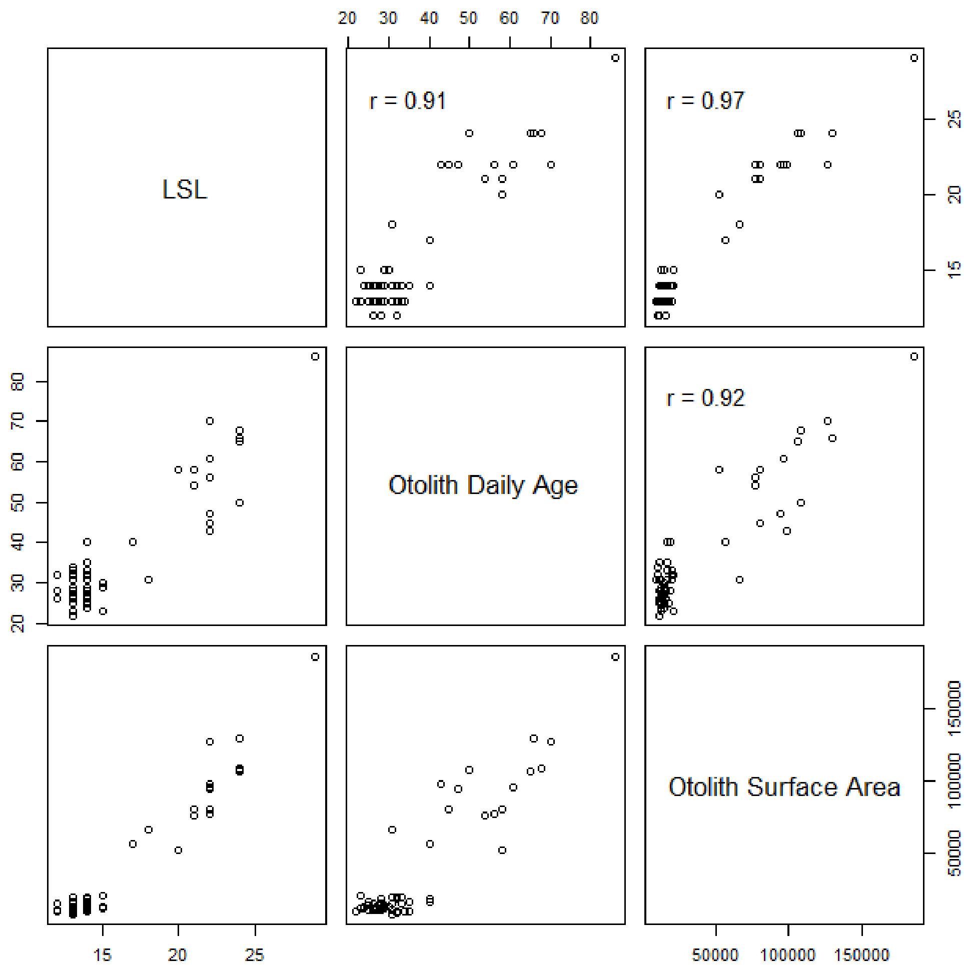

Figure 6. Correlation matrix plot with Pearson correlation values for otolith measurements laboratory standard length, otolith daily age, and otolith surface area.

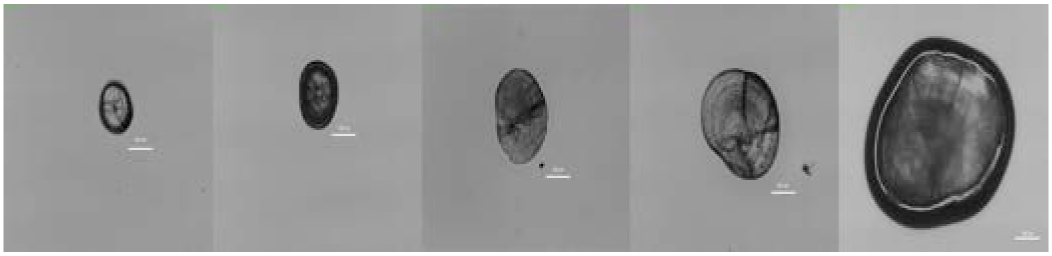

Figure 7. Lapilli otoliths from shortnose/Klamath largescale suckers showing surface area increase with standard length (from left to right: 13 mm, 15 mm, 17 mm, 21 mm, and 29 mm).

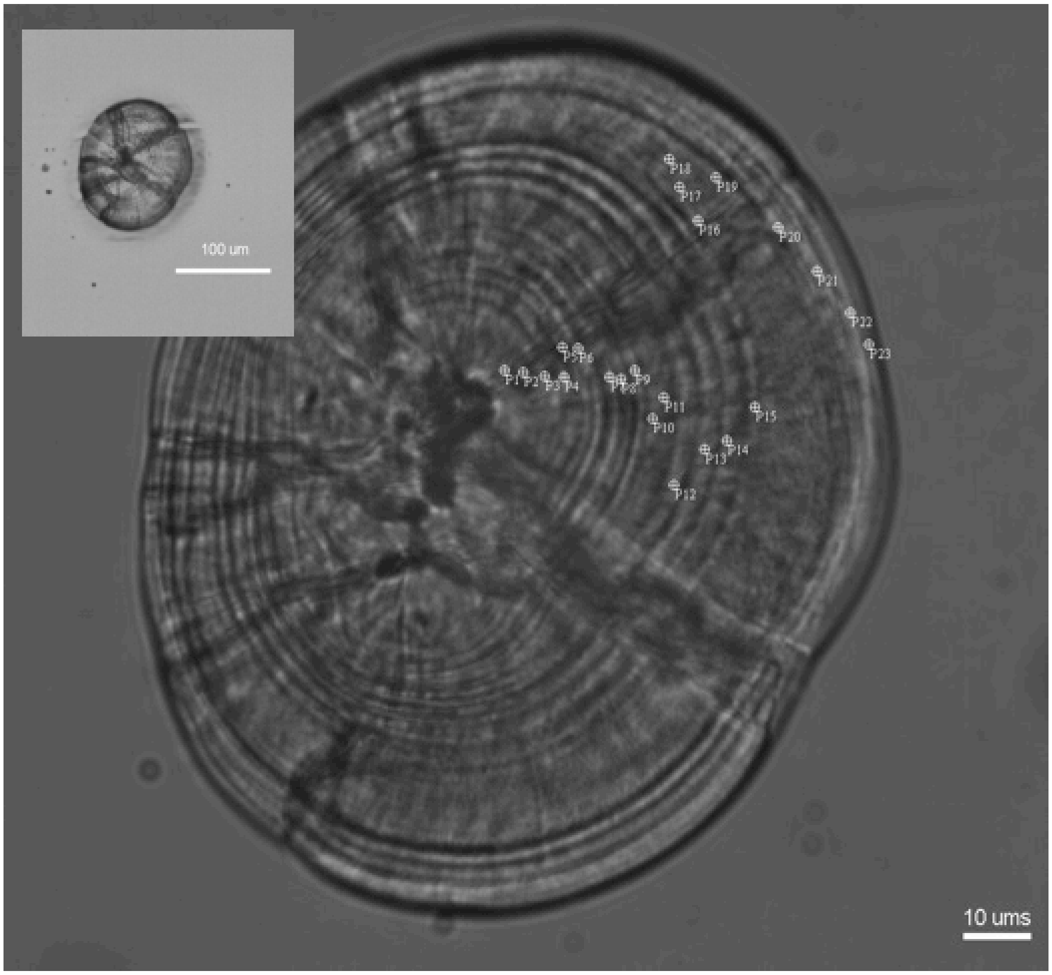

Figure 8. Lapillus from a 13 mm standard length shortnose/Klamath largescale sucker. Otolith age is 23 days. Symbols and numbers indicate daily age at each point.

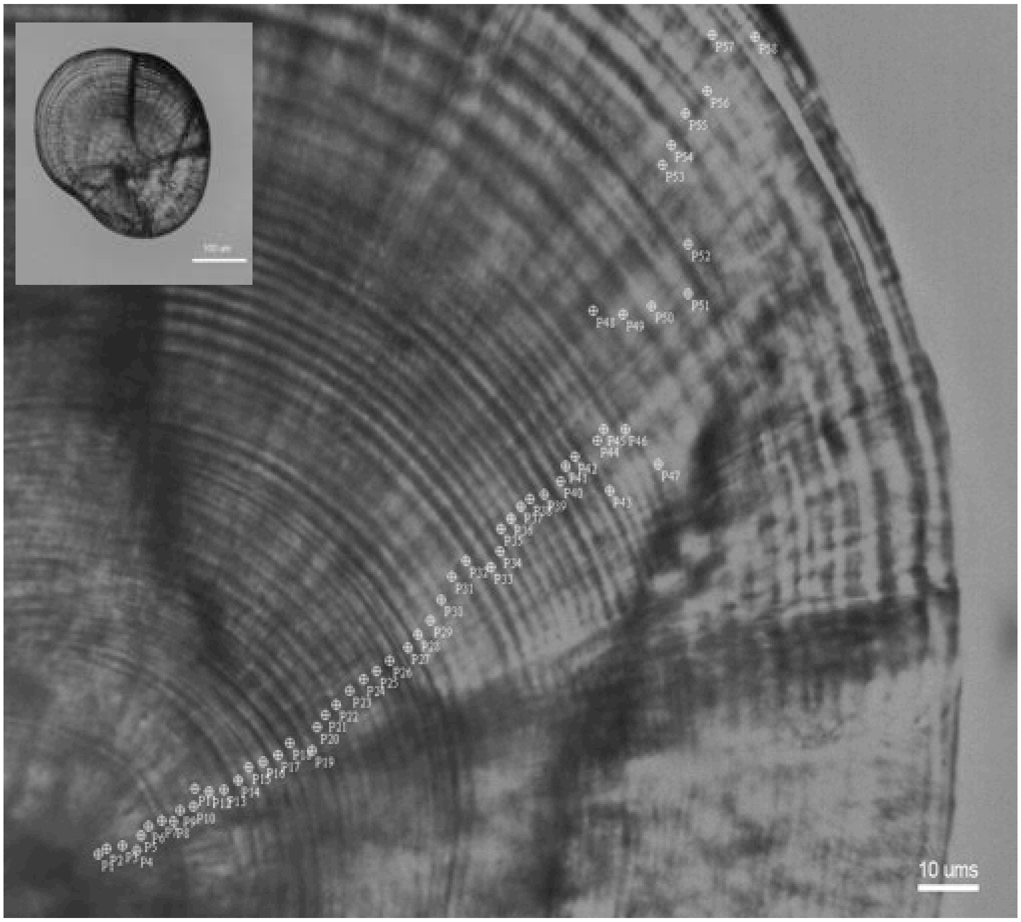

Figure 9. Lapillus from a 21 mm standard length shortnose/Klamath largescale sucker. Otolith age is 59 days. Symbols and numbers indicate daily age at each point.

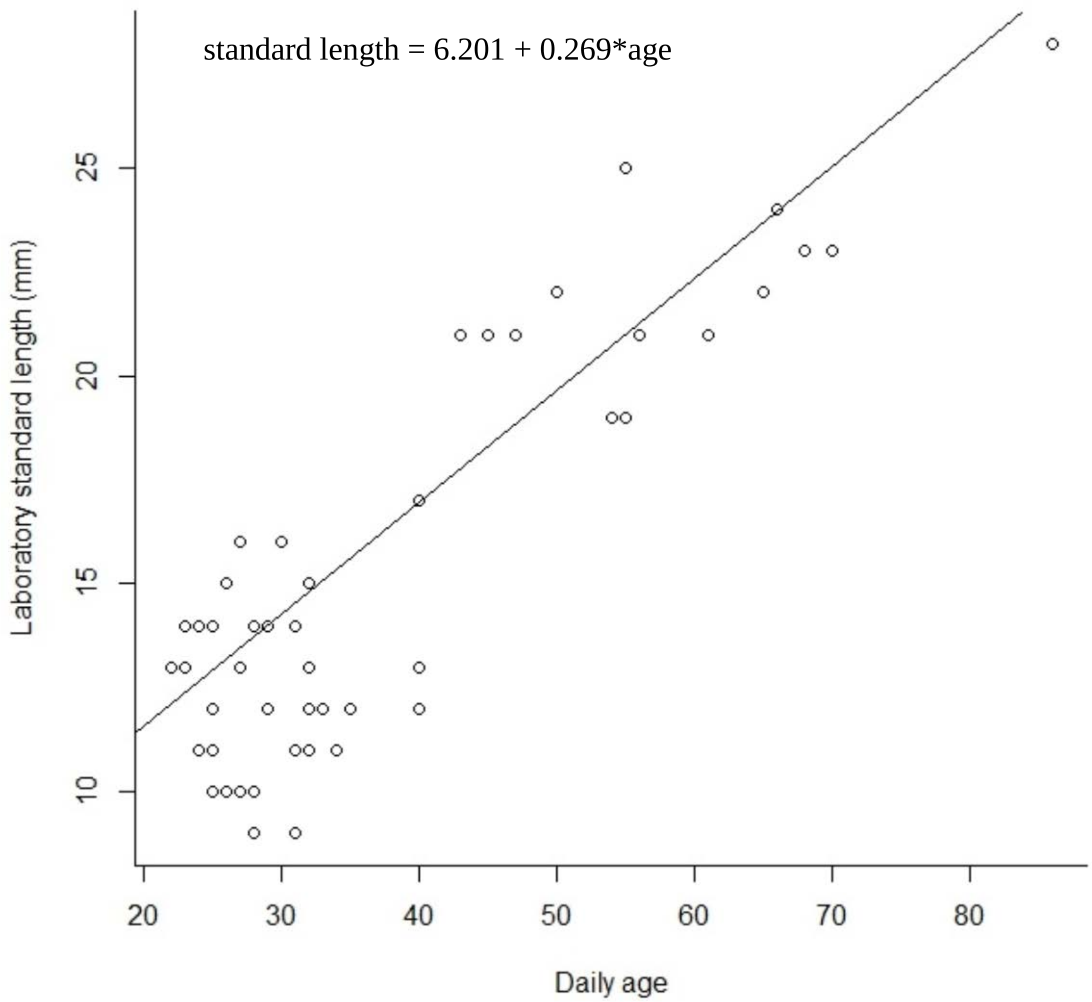

Figure 10. Daily age of lapilli otolith by laboratory measured standard length (mm) with equation from linear regression. Diagonal line represents regression line from linear regression of otolith age by laboratory standard length (laboratory standard length ~ daily age). Adjusted $R^2 = 0.838$.

($F_{1,54}$ = 195.640, $P < 0.001$), location ($F_{2,54}$ = 6.164, $P = 0.004$) and standard length ($F_{1,54}$ = 115.337, $P < 0.001$, but not with habitat type ($F_{1,54}$ = 3.683, $P = 0.061$) or distance from the main stem Sprague River ($F_{1,54}$ = 0.267, $P = 0.608$).

Daily age of larval suckers was significantly greater at location 3 than at location 1 (t_{50} = -2.791, $P = 0.007$), but did not differ between locations 1 and 2 (t_{22} = 0.454, P = 0.654) nor between location 2 and 3 (t_{39} = -2.480, $P = 0.017$). Daily ages at which suckers were sampled at locations 1, 2, and 3 were 32 days, 29 days, and 42 days respectively. The oldest suckers were found at location 3 (Table 7), the most upstream location.

Table 7. Distribution of otolith age, in days, during sampling in 2010 by location, habitat type, number aged (n), mean age, standard deviation (SD), and age range.

Location	Habitat type	n	Mean age	SD	Age range
Location 1	Wetland	15	26.87	4.53	22-40
Location 2	Wetland	4	28.75	3.3	25-33
Location 3	Wetland	3	33.33	5.86	29-40
All locations	Wetland	22	28.09	4.86	22-40
Location 1	River	0	--	--	--
Location 2	River	2	27	0	27
Location 3	River	29	44.28	16.45	25-86
All locations	River	31	43.16	16.47	25-86

DISCUSSION

Larval suckers used restored Wetland Reserve Program wetlands within the Sprague River, Oregon. While length of larval suckers differed between years and among locations, it is unclear whether differences reflected location (i.e. property) or natural variation. Two years of data collection and one year with low sample sizes (e.g. 13 larval suckers measured for standard length at location 2 in 2010) likely contributed to variability. However, catch data indicated that substantial growth does occur in the riverine environment, which is evidenced by capture of late larval and early juvenile size classes (e.g. 28 mm standard length).

There was no evidence that larger, older larval suckers were associated with wetland habitat versus main stem habitat. Likewise, habitat type (i.e. wetland and main stem Sprague River) did not prove to be a significant predictor of relative gut fullness. The presence of larval suckers on the main stem Sprague River at location 3 (Beatty, Oregon) does not negate the important role of wetland habitat for larval suckers. Rather, sucker larvae presence in main stem habitat at location 3 suggests that accessible shallow vegetated habitat may be more important to the fish than wetland or riverine habitat per se. Results show larval suckers utilize shallow vegetated habitat within the littoral zones of Upper Klamath Lake for predator avoidance (Markle and Dunsmoor 2007) and nutrient uptake (Cooperman and Markle 2004, USFWS 2012). Similar habitat types in the Sprague River, whether on the main stem or in a backwater, likely serve the same purpose of acting as refuge for larval suckers.

The growth rate I found for larval suckers in the Sprague River is significantly faster than the growth rates estimated by Markle et al. (2009) of 0.12 mm/day for Lost River suckers and 0.15 mm/day for shortnose suckers in Upper Klamath Lake. Faster growth rates in the Sprague River may reduce mortality rates associated with small size (Peterson and Wroblenski 1984) and further promote recruitment to the juvenile stage. Daily age also differed between upstream and downstream locations. While these locations were not chosen at random, significant differences in mean age may suggest that differing life histories of suckers occur in the lower reaches than in the upper reaches of the Sprague River. Larval suckers may reside in the lower reaches for a shorter time compared to the upper reaches where there may be some increased river residency (USFWS 2012).

Martin et al. (2013) indicated there may be a population of Lost River sucker that inhabit the upper reaches of the Sprague River, and these adults would not be represented in Passive Inductive Transponder tag spawning migration studies conducted near Upper Klamath Lake. These larger, older larval and early juvenile suckers captured in 2010 provide evidence that close proximity to Upper Klamath Lake is not a necessity for survival, and indicate that these suckers have been in the Sprague River for an extended period of time. The collections provide further evidence that there may be a unique riverine population as hypothesized by Martin et al. (2013). They also found that after the Chiloquin Dam was removed in 2008, upstream spawning migration primarily increased only for Klamath largescale suckers. Therefore, most larval suckers caught at location 1 and 2 are likely Klamath largescale suckers; however, this still remains unknown since there is difficulty distinguishing larval shortnose suckers from Klamath largescale suckers. With recent information about run timing of different sucker species (Martin et al. 2013) and information about different life history strategies of suckers in Upper Klamath Lake (Cooperman and Markle 2003), daily age and catch data from this study provide further evidence of differing life history strategies between upstream and downstream suckers on the Sprague River.

Drought in the Upper Klamath River Basin impacted water availability and the hydrologic regime during the 2009 and 2010 sampling seasons. Suckers were not captured at the most upstream site at Beatty (i.e. location 3) in 2009, but that location produced 40 percent of the total catch in 2010 (Table 1). As both 2009 and 2010 were characterized as dry years (Martin et al. 2013), larval suckers may not have been able to access restored wetland habitat at this location. However, this location had a large amount of shallow and vegetated habitat at the littoral zone of the main stem, which provided habitat for larval suckers.

With the lack of wetland connectivity to the river, suckers may need to travel farther to find shallow, vegetated areas suitable for feeding or protection. Increased exposure to non-vegetated areas (Markle and Dunsmoor 2007) and drift time may increase mortality rates. Because wetlands play an important role in survival of larval suckers, lack of wetland connectivity with the river may force larval suckers to drift longer and thereby increase susceptibility to predation or mortality by some other means. However, when water levels are low and wetlands are not easily accessible, main stem river habitat may also be extremely important. Therefore, the presence of both backwater wetland habitat and habitat with wetland characteristics (e.g., shallow and vegetated) on the main stem may serve to provide habitat for larval suckers in both wet and dry years. Brunson and Christopherson (2005) showed that drought conditions resulted in lower initial larval razorback sucker (*Xyrauchen texanus*) densities during inundation of floodplain habitat in the following year. If this is true for Lost River and shortnose suckers, it is important that wetlands are structured or modified to ensure connectivity each year. Likewise, the presence of main stem larval habitat may also prove important during low water years. If larval sucker follow the trend noted by Brunson and Christopherson (2005), low water years may pose a cumulative negative effect on larval sucker densities in this important habitat.

Many factors likely contribute to the mortality of these species including water quality, predation, algal blooms, and habitat degradation (USFWS 1988, 1993, 2001, National Research Council 2004, Markle and Dunsmoor 2007, Burdick and Hewitt 2012, USFWS 2012). Predation likely contributes to some decline in larval sucker numbers, although to date only one predation study in regards to these endangered species has been conducted (Markle and Dunsmoor 2007). Markle and Dunsmoor (2007) showed that fathead minnows did prey upon on larval suckers, and survival increased with presence of vegetated cover. Catch data from this study indicated that several other species occupied the three sampled wetlands on the Sprague River. Of these species, five non-native species were captured; one species (fathead minnow) known to prey upon on larval suckers and four (brown bullhead catfish, black bullhead catfish, yellow perch, and bass) that potentially prey upon on larval suckers (Wydoski and Wick 1998, USFWS 1999, Brunson and Christopherson 2005, USFWS 2012). Predation can have large impacts on sucker species, and predation by walleye and white bass have been attributed to large declines in the June sucker population (USFWS 1999). Although restoration of wetlands may also create habitat for non-native predatory fish as evidenced by catch data from this study, wetland restoration is important to the recovery of endangered fishes (Brunson and Christopherson 2005). While the proportion of non-native predatory fishes captured in this study was low, the degree of impact these predators may have on the larval sucker population is unclear.

With declining populations of these two endangered sucker species and poor recruitment to spawning age (Janney et al. 2008, Hewitt et al. 2011, Burdick 2012), it is imperative that further studies are conducted on all ontogenetic stages. This study has provided evidence of larval sucker presence in three wetland locations on the Sprague River and provides useful knowledge in accomplishing task 1.4.1 (i.e. determining the importance of in-stream rearing habitats for larvae and juveniles in the Sprague River) of the revised recovery plan (USFWS 2012). While this study has documented larval and early juvenile suckers at upstream reaches of the Sprague River near Beatty, Oregon, further research is warranted to determine the degree of river residency of suckers inhabiting the upper reaches of the Sprague River. Likewise, increased sampling effort and the addition of more sampling locations would further help evaluate the importance of wetlands and wetland like habitat on the Sprague River.

Because the riverine environment may play a key role in survival of these endangered species, comparative studies should be conducted to determine differences between larval suckers caught on the Sprague River and in wetland areas of Upper Klamath Lake. Wetlands provide ideal rearing habitat for these endangered larval suckers (Erdman and Hendrixson 2009), and lack of these habitats exacerbate problems with high mortality of early life stages (Burdick 2012) ultimately preventing recruitment to spawning age. Restoration of vegetated habitat is a common goal for multiple catostomid species including the June suckers (*Chasmistes liorus*) and cui-ui (*Chasmistes cujus*), two other lake suckers in North America (USFWS 1992, Andersen et al. 2006). Like the shortnose and Lost River sucker, June suckers and cui-ui rely on complex vegetated habitat (USFWS 1992, Andersen et al. 2006). The razorback sucker also utilizes vegetated wetland habitat for rearing during the larval stage (Wydoski and Wick 1998, Brunson and Christopherson 2005). Wydoski and Wick (1998) found that there was little to no survival of larval razorback suckers in shallow habitat devoid of vegetation. Similar to restoration goals for the Lost River and shortnose suckers, further restoration of wetland habitat through lowering of levees is a goal for the recovery of many species including the razorback sucker (Brunson and Christopherson 2005, Hedrick et al. 2009). Recovery of Lost River sucker and shortnose suckers will likely require multiple actions including further restoration of wetland habitat, improving water quality, and reducing the effects of predatory fishes (USFWS 2007a, USFWS 2007b). This study indicates that restoration of wetland habitat should consider future water availability to structure and design wetlands habitat on the Sprague River to ensure habitat connectivity. While there is no present hatchery supplementation for these species (USFWS 2012), hatchery supplementation is expected to benefit June sucker populations (Andersen et al. 2006) and may benefit the Lost River and shortnose sucker.

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