Higgins, Damian <damian_higgins@fws.gov>

Fwd: [EXTERNAL] RE: Request for Peer Review - Lost River Sucker and Shortnose Sucker

Mark Belk <mark_belk@byu.edu> Mon, Aug 13, 2018 at 9:54 AM
To: "Russell, Daniel" <daniel_russell@fws.gov>
Cc: "Higgins, Damian" <damian_higgins@fws.gov>, Josh Rasmussen <josh_rasmussen@fws.gov>

Hi Dan,

Attached is my review of the Lost River and Shortnose Sucker SSA. Sorry for taking it right to the due date. Hope it proves useful. I have attached both the matrix response and a track-changes copy of the SSA.

Thanks,

Mark

Mark C. Belk, Professor of Biology

Brigham Young University

Editor, *Western North American Naturalist*

801-422-4154

From: Russell, Daniel <daniel_russell@fws.gov>
Sent: Thursday, June 14, 2018 11:44 AM
To: Mark Belk <mark_belk@byu.edu>
Cc: Higgins, Damian <damian_higgins@fws.gov>; Josh Rasmussen <josh_rasmussen@fws.gov>
Subject: Request for Peer Review - Lost River Sucker and Shortnose Sucker

Dear Dr. Belk:

The U.S. Fish and Wildlife Service (Service) is soliciting independent scientific reviews of the information contained in our 2018 draft Species Status Assessment for the Endangered Lost River Sucker and Shortnose Sucker. Once finalized, this Species Status Assessment report (SSA report) will provide the underlying science to inform decision-making for future conservation efforts needed for these two species. You were identified by our Klamath Fish and Wildlife Office as a potential peer reviewer based on your area of expertise.

This request is provided in accordance with our July 1, 1994, peer review policy (USFWS 1994, p. 34270) and our current internal guidance. This request also satisfies the peer review requirements of the Office of Management and Budget’s "Final Information Quality Bulletin for Peer Review." The purpose of seeking independent peer review of the SSA is to ensure use of the best scientific and commercial information available; to ensure and maximize the quality, objectivity, utility, and integrity of the information upon which we base a variety decisions under the Act; and to ensure that reviews by recognized experts are incorporated into our final decision processes. Please let us know if you would like us to provide any of the referenced materials to help facilitate your review.

Please note that we are not seeking advice on policy or recommendations on the legal status of the species, nor on how the Bureau of Reclamation's Klamath Project may affect the species. Rather, we request that peer reviewers focus their review on identifying and characterizing scientific uncertainties, and on ensuring the accuracy of the biological and land and water use information in the SSA. Specifically, we ask peer reviewers to focus their comments on the following:

(1) Have we assembled and considered the best available scientific and commercial information relevant to this species?

(2) Is our analysis of this information correct?

(3) Are our scientific conclusions reasonable in light of this information?

Our updated peer review guidelines also require that all peer reviewers fill out a conflict of interest form. We will carefully assess any potential conflict of interest or bias using applicable standards issued by the Office of Government Ethics and the prevailing practices of the National Academy of Sciences (http://www.nationalacademies.org/coi/index.html). Divulging a conflict does not invalidate the comments of the reviewer; however, it will allow for transparency to the public regarding the reviewer's possible biases or associations. If we receive comments from a reviewer that we deem to have a substantial conflict of interest, we will evaluate the comments in light of those conflicts, and may choose not to give weight to those comments if the conflict is viewed as problematic. You may return the completed conflict of interest form either prior to or with your peer review.

So that we may fully consider any input and coordinate other peer review comments as we develop the final SSA, and ensure adequate time to evaluate all comments, we are requesting peer review comments by August 13. If you are willing to peer review but are unable to complete your assessment during this time period, please let me know when we may anticipate receiving your comments. We will summarize and respond to the substantive comments raised by all peer reviewers and use the information, as appropriate, in the final SSA.

While we welcome your peer review comments in any format you are most comfortable using, it would be especially helpful if you could use the attached Comment Matrix Excel spreadsheet. This will make it easier to compile and keep a record of all the comments received and then incorporate them into our report. We would also appreciate receiving a copy of your Curriculum Vitae for our records. Please be aware that your completed review of the SSA, including your name and affiliation, will be included in the administrative record for this evaluation and will be available to interested parties upon request.

If you have any questions about the draft SSA report, or our peer review process in general, please feel free to contact me at any time at (916) 978-6191. Please submit your comments and associated materials to the contact information below. If emailing your responses, you may use the Reply All feature, and that way your comments will also go directly to the project leads for this SSA report.

Thank you for your consideration.

Sincerely,

Dan Russell

****

Daniel Russell - Regional Listing Coordinator

Pacific Southwest Regional Office, Region 8
U.S. Fish and Wildlife Service
2800 Cottage Way, Room W-2606
Sacramento, CA 95825

Office (916) 978-6191

Cell (916) 335-9060

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3 attachments

Sucker SSA V3 - Belk.docx
6873K

SSA Review Comment Matrix - Belk.xlsx
15K

conflict of interest - Belk.pdf
197K

Reviewer Name	Chapter	Page	Line #	Comment
Mark C. Belk	executive summary	iii		These conclusions are based on the assumption that survival rates continue in the future similar to the recent past; however, if **survival should increase** due to ageing populations, then we expect the declines to accelerate. ***I believe you mean if survival should decrease or mortality should increase.***
Mark C. Belk	2	3	64 and 67	You use the word "genera" on line 64 before you introduce it as a bolded term for the glossary in line 67
Mark C. Belk	2	6	118-120	This sentence is missing something
Mark C. Belk	2	6	122	Just say "hybridization is common".
Mark C. Belk	2	6	123	Qualify this sentence as in the Klamath Lake system, because the previous sentence applies to all catastomids.
Mark C. Belk	2	6, 7	129-132	I would qualify this somewhat to indicate that the previous isolating barriers may have been compromised by recent anthropogenic activities or something of that nature. Currently it reads like the species are just in this inevitable stage of convergence with no reference to their changing environment.
Mark C. Belk	2	9	191	(Hewitt Forthcoming), is this a full name, or does it mean something by Hewitt is forthcoming? In which case use a comma and lower case for the term forthcoming.
Mark C. Belk	2	9	191-194	Use of the word "quivering" here is out of place and not germaine to the description.
Mark C. Belk	2	11	223	"at 20 and 30 mm (0.8-1.2 in) total length". Does this refer to two different species?
Mark C. Belk	2	11	228-234	These sentences need some work to make them more clear and readable.
Mark C. Belk	2	11	242-243	"Lost River and shortnose suckers can generally be classified into five life stages that occur at various times throughout the year: migration, spawning, larval, juvenile, and adult (Table 1). " This sentence needs clarification. If they are life stages then they occur throughout the lifetime not over the course of a year. You are mixing life stages with annual events
Mark C. Belk	2	12	248-249	I don't like the way this table is organized. It confuses life stages with annual events.
Mark C. Belk	2	12	254	Don't start using acronyms here for the species names. Spell them out as you have previously.
Mark C. Belk	2	12	251-273	Writing is a bit rough in this entire section. Revise for clarity and specificity.
Mark C. Belk	2	13	277-295	Writing is a bit rough in this entire section. Revise for clarity and specificity. For example, do you really mean that the suckers were moving at rapid velocities while they were spawning (i.e., "suckers were observed to spawn at velocities of 15 – 82 cm/sec ")?
Mark C. Belk	2	13	302	This is an odd place to first reference total length. I think you gave estimates of total length of adults previously in the species descriptions.
Mark C. Belk	2	16	1…	For some odd reason line numbering started anew on page 16
Mark C. Belk	2	17	48	I think there is only one extant *Deltistes* species, don't use "such as" here.
Mark C. Belk	2	17	62-63	Jargon! Just say a population growth rate that averages one or greater, or better yet say a population that maintains a stable size (i.e., growth rate equal to one), or increases.
Mark C. Belk	2	17-19	58-126	This whole section is a bit rough. The writing is unclear in several areas because of lack of specificity. It is redundant with previous statements, and painfully obvious in some statements. I think it could be better summarized and shortened with some careful editing.
Mark C. Belk	2	19	152	Is this water surface area, or the general outline of the basin as a whole?
Mark C. Belk	2	20-21	182-200	This whole discussion is a bit unclear. You should be clear that introgression is an immediate threat unless you want to lose the distinctive species that now exist. Introgression does not maintain species integrity even though it can increase genetic diversity. Even in 50 years, populations and species can lose considerable genetic integrity. The discussion that the scope of review is only 50 years is a bit of a copout. It looks like shortnose sucker will likely be lost as a consequence of genetic introgression in the next 30-40 years. You should be more rigorous in your discussion of these issues. Otherwise you leave yourselves open to the argument that extinction of these species is just a natural process that is playing out with no culpability on our part.
Mark C. Belk	3	25	274	*Aphanizomenon flos-aquae* (AFA) What is this? Is it a plant or something else?

Mark C. Belk	3	25	281-282	Not sure that you can classify increased drought trends as non-anthropogenic. It may be that it occurs on a longer and larger scale, but it certainly has an anthropogenic component.
Mark C. Belk	3	35	616	That was a long time ago. Any newer measures?
Mark C. Belk	3	38	721-723	I would be careful with this. The positive aspects of the introgression process operates on small populations that have been bottle-necked, but it has the down side of reducing integrity of the species in a specific area.
Mark C. Belk	3	39	755	More specific and metric
Mark C. Belk	5	55-56		This analysis is OK, but it seems overly simplistic by assuming recruitment is 0. It seems that there is some evidence of limited recruitment in some years in the recent past because the populations would be at even lower levels if recruitment had been exactly 0 for more than 20 years. What does the size distribution look like and is there evidence of less than 20-year old fish? How has the size distribution changed through the last 40 years? If you are certain that recruitment has been exactly 0 for the last 20-30 years, then you don't even need an analysis to sya that the population will be near extinction in 50 years.

Mark C. Belk

Species Status Assessment for the Endangered Lost River Sucker and Shortnose Sucker

Klamath Falls Fish and Wildlife Office
Pacific Southwest Region
U.S. Fish and Wildlife Service

2018

ACKNOWLEDGEMENTS

This Species Status Assessment was prepared through coordination among several biologists from the Pacific Southwest Region of the U.S. Fish and Wildlife Service.

Principal Authors

Evan S. Childress, Ph.D. – Klamath Fish and Wildlife Office

Josh E. Rasmussen, Ph.D. – Klamath Fish and Wildlife Office

Supporting Team Members

Daniel Blake – Klamath Falls Fish and Wildlife Office

Serena Doose – Yreka Fish and Wildlife Office

Bjorn Erickson, Ph.D. – Pacific Southwest Region

Ryan Fogerty – Yreka Fish and Wildlife Office

Damian Higgins – Pacific Southwest Region

Michael Schwemm, Ph.D. – Nevada Fish and Wildlife Office

Elizabeth Willy – Klamath Falls Fish and Wildlife Office

EXECUTIVE SUMMARY

The Lost River sucker (*Deltistes luxatus*) and shortnose sucker (*Chasmistes brevirostris*) are two closely related fish species which occur in the lakes of the upper Klamath Basin in central southern Oregon and northern California. Even though the species were never widely distributed, they were extremely abundant until populations began to decline sometime in the late 1960's. Continued declines resulted in closure of the recreational fishery for the suckers and ultimately listing in 1988 as endangered under the Endangered Species Act of 1973, as amended.

This Species Status Assessment is not intended to replace the previous review documents nor their subsequent revisions. The objective is for the Species Status Assessment document to be easily updated as new information becomes available, to act as a "state-of-the-science" repository. All functions of the Endangered Species Program from listing to Section 7 consultation to recovery planning will rely on the document as a basis for synthesizing the status of the species in a rigorous, scientific manner. As such, the Species Status Assessment will be a living document upon which many other documents such as listing rules, recovery plans, and 5-year reviews will be based.

The Species Status Assessment structure includes an integrated approach of assessing the needs of the species (Chapter 2), the current condition of the species (given past and present ecosystem dynamics – Chapters 3 and 4, respectively), and identifying the likely future condition of the species given probable future ecosystem conditions (Chapter 5). Species' needs are described for individuals nested within populations nested within species. The condition of the species is inherently reflected in the demographic rates (such as annual survival rates) of the species, but the Species Status Assessment couches these dynamics in three fundamental principles of conservation biology: Resiliency, Redundancy, and Representation. Resiliency is the ability of a population or a species to endure disturbance, such as rebounding in numbers after a disturbance-related decline. This characteristic is typically associated with population size, growth rate, or habitat quality, all of which may affect resiliency. The capacity of a population or species to endure especially catastrophic or widespread disturbance due to the existence of numerous sub-populations or populations is called redundancy. Having numerous more or less distinct groups can increase the probability of a species or population surviving a catastrophic event. In conservation, as with chickens, it makes sense to not put all of your eggs in the same basket. Lastly, representation is the term used to describe the fact that diversity can promote the viability of a species because higher diversity increases the likelihood that a species or population can adapt to prevailing environmental conditions. Typically representation is considered in terms of the distribution of genetic diversity within and among populations, but ecological diversity (such as life history traits) is also an important component.

Overall resiliency for this Lost River sucker is generally low, primarily because redundancy is critically low. There are only three distinct spawning populations: Upper Klamath Lake-springs, Upper Klamath Lake-river, and Clear Lake Reservoir. Two of the remaining populations (Clear Lake Reservoir and Upper Klamath Lake-springs) have very low numbers and are at a high risk of localized catastrophic events. The

Clear Lake Reservoir population is completely separated from the others. As a species, Lost River sucker appear to be relatively genetically distinct.

Shortnose sucker also suffer from low resiliency as a species, despite having relatively high apparent redundancy compared to Lost River sucker given that shortnose have more populations than Lost River sucker. The low resiliency is due to the extremely low numbers in most populations, lack of access to suitable spawning habitat for several populations, and mixed genetics for others. There are currently only three known spawning populations (Upper Klamath Lake, Clear Lake Reservoir, and Gerber Reservoir). The number of populations is effectively reduced when we consider the high levels of genetic introgression with Klamath largescale sucker, and all of the populations are characterized by low abundance.

Based on the future scenarios we analyzed here, it is likely that the Lost River sucker will continue to decline precipitously if conditions in Upper Klamath Lake remain unchanged. The species may still remain in 50 years, but it is likely that it will be critically few in numbers. Given that the only other spawning population of this species, Clear Lake Reservoir, is extremely small, a substantial reduction in Upper Klamath Lake will put the species perilously close to extinction. These conclusions are based on the assumption that survival rates continue in the future similar to the recent past; however, if survival should increase due to ageing populations, then we expect the declines to accelerate. This could significantly truncate our frame of reference.

If current conditions continue, we also expect the shortnose sucker population in Upper Klamath Lake to become extirpated within the next 30-40 years. Projections suggest that this population will decline by 78% over the next 10 years to a level below 5,000 total individuals. This would result in only two populations remaining for the species, both of which are highly genetically introgressed with the Klamath largescale sucker and geographically isolated behind dams without fish passage.

Both species are likely to realize greater stability from implementation of the rearing program, but landscape-scale improvements to nutrient loads in Upper Klamath Lake will be necessary to achieve full recovery. The dire conditions of Lost River sucker in Clear Lake Reservoir suggest that recovery of the species will likely be unattainable given the likely scenarios analyzed here and the requirement to have a viable population in the Lost River basin as well as the Upper Klamath Lake drainage. Recovery of the species is likely to require substantially more drastic actions than the few considered here. Recovery of shortnose sucker appears more achievable in the Lost River sub-basin under the scenarios assessed, but uncertainties about the overall impacts of genetic introgression must be clarified and addressed.

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CHAPTER 1 – INTRODUCTION

The Lost River sucker (*Deltistes luxatus*) and shortnose sucker (*Chasmistes brevirostris*) are two closely related fish species which occur in the lakes of the upper Klamath Basin in central southern Oregon and northern California. Even though the species were never widely distributed (being wholly restricted to the lakes of the upper Klamath Basin), they were extremely abundant (Cope 1879, p. 785; Bendire 1889, p. 444) until populations began to decline sometime in the late 1960's. Continued declines resulted in closure of the recreational fishery for the suckers and ultimately listing in 1988 as endangered under the Endangered Species Act of 1973, as amended (USFWS 1988, pp. 27130).

Since listing, extensive research has been conducted on the ecology[1] of the species and the dynamics of their ecosystem. Numerous reviews of this research have occurred, including a recovery plan (USFWS 1993, entire) which was revised in 2013 (USFWS 2013b, entire), reviews of the status of each species (USFWS 2007a, 2007b, 2013a; 2013c, entire), and Section 7 consultations under the Endangered Species Act. This Species Status Assessment is intended to provide a single, comprehensive review of the species' ecology and environmental conditions, past and present, to evaluate its general conservation trajectory and status, so that it can provide a framework to support the many other reviews and documents.

This Species Status Assessment is not intended to replace these previous documents nor their subsequent revisions. The objective is for the Species Status Assessment document to be easily updated as new information becomes available, to act as a "state-of-the-science" repository. All functions of the Endangered Species Program from listing to Section 7 consultation to recovery planning will rely on the document as a basis for synthesizing the status of the species in a rigorous, scientific manner. As such, the Species Status Assessment will be a living document upon which many other documents such as listing rules, recovery plans, and 5-year reviews will be based.

The Species Status Assessment structure includes an integrated approach of assessing the needs of the species (Chapter 2), the current condition of the species (given past and present ecosystem dynamics – Chapters 3 and 4, respectively), and identifying the likely future condition of the species given probable future ecosystem conditions (Chapter 5). Species' needs are described for individuals nested within populations nested within species. The condition of the species is inherently reflected in the demographic rates (such as annual survival rates) of the species, but the Species Status Assessment couches these dynamics in three fundamental principles of conservation biology: Resiliency, Redundancy, and Representation (Evans et al. 2016b, p. 6). Resiliency is the ability of a population or a species to endure disturbance, such as rebounding in numbers after a disturbance-related decline. This characteristic is typically associated with population size, growth rate, or habitat quality, all of which may affect resiliency. The capacity of a population or species to endure especially catastrophic or widespread disturbance due to the existence of numerous sub-populations or populations is called

[1] **For a glossary of technical terms used in this report reference Appendix I. Words that appear in the glossary are bolded at the first appearance in the text.**

redundancy. Having numerous more or less distinct groups can increase the probability of a species or population surviving a catastrophic event. In conservation, as with chickens, it makes sense to not put all of your eggs in the same basket. Lastly, representation is the term used to describe the fact that diversity can promote the viability of a species because higher diversity increases the likelihood that a species or population can adapt to prevailing environmental conditions. Typically representation is considered in terms of the distribution of genetic diversity within and among populations, but ecological diversity (such as life history traits) is also an important component.

To evaluate the ecological status of these two sucker species, we present here the breadth of current and future conditions of the species and their habitat, and we use these to gauge the species' overall resiliency, redundancy, and representation to better understand the probability of these species persisting into the near future. This report provides a thorough assessment of biology and ecology of the suckers and assesses demographic risks, threats, and limiting factors in the context of near-term viability. It is often a challenge to determine the relevant time period for these analyses. We have selected a window of up to 50 years because this spans multiple generations and is relevant in the context of some of the longer-term environmental dynamics. In many instances, the ecology of the species is very similar or data may be lacking for one of the species. We generally address the species together in these cases, unless there is specific information that warrants a specific distinction.

CHAPTER 2 – SPECIES ECOLOGY

This chapter outlines the ecological needs or requirements of the species. We interpret needs as the suite of conditions necessary to promote survival, stability, and viability at whatever level considered (i.e., individual, population, or species). Our assessment is based on what we consider to be fundamental to the ecology of the species. We begin by identifying the taxonomy, genetics, and historical range of the species. We then describe the life history of the species, and lastly, we present the ecological needs of the individuals, populations, and species each in turn, under the presumption that each is built on the needs of the former.

Taxonomy and Species Description

Both species are members of the Catostomidae family, commonly called suckers. This family of fish is comprised of 76 species and 14 genera, 97 percent of which only occur in North or Central America (Cooke et al. 2005, p. 319). These species have been classified into a subfamily, Catostominae, that accounts for the majority of species in the family, and within this subfamily both species belong to a tribe (Catostomini) that includes the **genera** *Chasmistes*, *Deltistes*, *Xyrauchen* (i.e. the razorback sucker), and *Catostomus* (Smith 1992, p. 795), but the taxonomic relationship of the species and genera within the tribe are somewhat unresolved (Harris and Mayden 2001, p. 232).

Lost River Sucker

The Lost River sucker (*Deltistes luxatus*) was first described by Cope (1879, p. 784) from Upper Klamath Lake specimens as *Chasmistes luxatus*. Because of unique triangular gill rakers that are not found in any other closely related sucker species, the species was elevated as the **monotypic** genus *Deltistes* in 1896 (Seale, p. 269). The morphological distinctiveness of *Deltistes* was subsequently corroborated by analysis of fossil material of extinct species with similar diagnostic characteristics (Miller and Smith 1967, pp. 5-11). The Lost River sucker is currently recognized as the only surviving member of the genus (Nelson et al. 2004, p. 79).

Lost River sucker are large, long-lived cypriniform fishes, achieving sizes up to 0.8 m (2.6 ft) and 4.5 kg (9.9 lbs.) (Figure 1). They are distinguished by an elongated body and sub-terminal mouth with a deeply notched, sparsely **papillose** and narrow lower lip (Scoppettone and Vinyard 1991, p. 359) (Figure 2). Their coloration is dark on the back and sides fading to yellow or white on the belly. The body is also extensively covered with small white nodules known as tubercles, particularly on spawning adults.

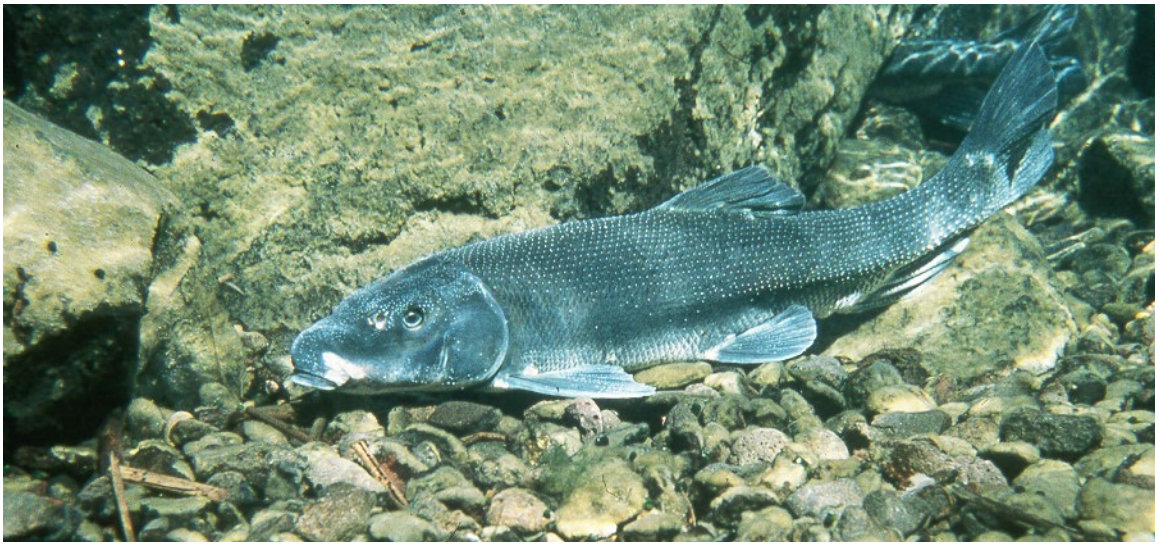


Photo by Tupper Blake, used with permission.

Figure 1 An adult Lost River sucker photographed while resting during the spawning season at the eastern shoreline springs of Upper Klamath Lake. The white speckles on the body are known as tubercles.

<u>Shortnose Sucker</u>

The *Chasmistes* genus includes three **extant** species: shortnose sucker (*Chasmistes brevirostris*), June sucker (*Chasmistes liorus*), and cui-ui (*Chasmistes cujus*), all of which are narrowly **endemic** within the remnant lakes of the western United States and all of which are listed as endangered under the Endangered Species Act. Extinct species from this genus have also been identified from the fossil record (Miller and Smith 1981, p. 4).

The shortnose sucker was also first described by Cope (1879, p. 785). This species is generally distinguished by a smaller head relative to the overall body size than Lost River sucker and by its oblique, terminal mouth, and thin, fleshy lips (Figure 2and Figure 3). The lower lip is deeply notched, giving the appearance of two separate lobes, which are also narrow and nearly absent of papilla for the most part. Shortnose sucker reach approximately 0.65 m (2.1 ft) and 3.5 kg (7.7 lbs.). They have similar coloration to Lost River suckers with a dark back and sides and a white or silvery belly (Moyle 2002, p. 202), but they tend to have fewer tubercles, which are found mostly on the **caudal peduncle** of males during the spawning season.

Photos by J. Rasmussen, USFWS.

Figure 2 The three sucker species of the upper Klamath Basin: shortnose sucker (top), Lost River sucker (middle), and Klamath largescale sucker (bottom). The head and mouth shots are of the same individual. The shape of the head and lower lips are often diagnostic among the species. Images are not at the same scale.

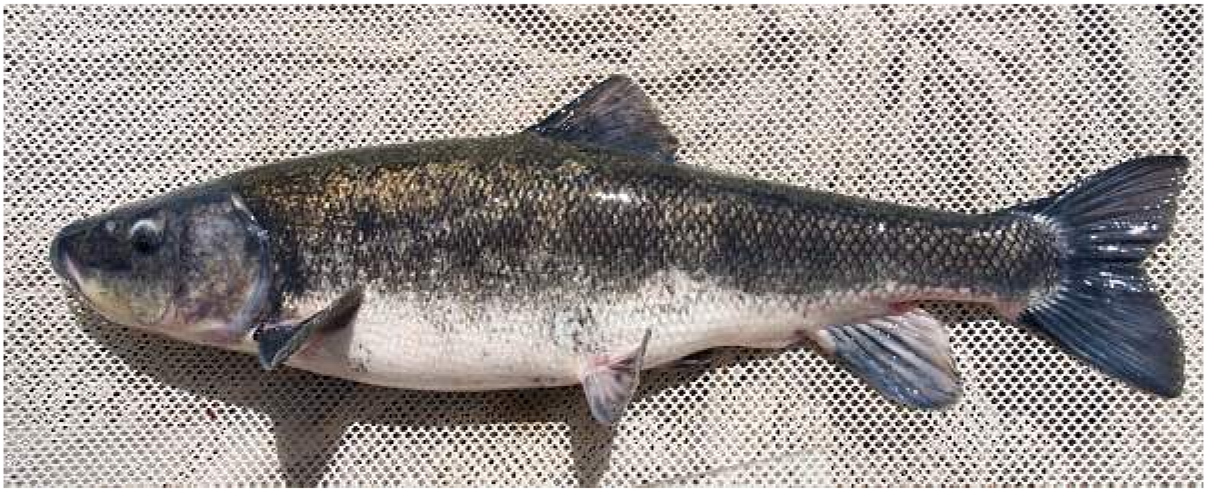


Photo by Ron Larson, USFWS

Figure 3 A Shortnose sucker adult captured in the Williamson River during the spawning run.

Genetics

As is common for the Catostomid family, Lost River and shortnose sucker possess **tetraploid genomes**. The Klamath Basin sucker community (including the two listed species as well as the non-listed Klamath largescale sucker [*Catostomus snyderi*] and Klamath smallscale sucker [*Catostomus rimiculus*]) appear to have all diverged from a common ancestor despite being classified as three distinct genera (Dowling et al. 2016, p. 20). **Mitochondrial DNA** and **microsatellite markers** indicate that **introgressive hybridization** has occurred to varying levels among the four Klamath Basin sucker species Most notably, high levels of introgressive hybridization between shortnose sucker and Klamath largescale sucker make it impossible to distinguish between the two species using current molecular data (Tranah and May 2006, p. 312; Dowling et al. 2016, p. 19). Despite this, morphological and ecological distinctions are maintained to some degree, but individuals displaying physical characters intermediate to shortnose sucker and Klamath largescale sucker are also common, particularly in the Gerber and Clear Lake Reservoir populations (Markle et al. 2005, p. 480). The ecological distinctions primarily are due to the Klamath largescale and smallscale suckers typically inhabit rivers and streams, as opposed to lakes for the listed species. Lost River suckers are relatively genetically distinct from the other species, although some evidence of hybridization with the other species does exist (Dowling et al. 2016, p. 21).

Hybridization is not uncommon among Catostomidae species (Dowling and Secor 1997, p. 604). Nevertheless, in the Klamath Lakes system, it is clear that suitable conditions have existed in the past for distinct species to evolve. This is usually due to some sort of process or barrier that prevents groups from interbreeding. The barrier could be physical, but it could also be ecological in nature, such as adaptation to different habitats. It is unclear whether the conditions that permitted the distinct species to evolve in the first place are only recently developed and so not enough time has elapsed for complete genetic distinction to occur or whether the barriers are simply not strong enough to achieve complete **divergence** (Dowling et al. 2016, p. 19). There is some evidence, however, that the shortnose sucker and Klamath largescale sucker in particular are in the process of **converging** given the apparent reduction of morphological distinction between the two species compared to older specimens (Dowling et al. 2016, p. 20).

Historical Range and Distribution

Lost River sucker and shortnose sucker are endemic to the upper Klamath Basin, including the Lost River sub-basin (Figure 4). Historical documented occurrences of one or both species include Upper Klamath Lake (Cope 1879, pp. 784-785) and Tule Lake (Bendire 1889, p. 444), but the species likely occupied all of the major lakes within the upper Klamath Basin, including Lower Klamath Lake, Lake Ewauna, and Clear Lake. In addition to inhabiting the lakes throughout the upper basin, the species historically utilized all major tributaries to the lakes for spawning and rearing. For example, the species ascended the Williamson River in the thousands and were "taken and dried in great numbers by the Klamath and Modoc Indians" (Cope 1879, p. 785). Historically, large sucker spawning migrations also occurred from Tule Lake up the Lost River to near Olene and Big Springs near Bonanza (Bendire 1889, entire). Suckers were also known to spawn in great numbers at several springs and seeps along the eastern shoreline of Upper Klamath Lake, including Barkley (Bendire 1889, p. 444) and at other spring-dominated areas in the northwestern corner of the lake, including Harriman, Crystal, and Malone Springs.

At the time of listing (1988), Lost River sucker and shortnose sucker were known to occupy Upper Klamath Lake and its tributaries and outlet (Klamath Co., Oregon), including a "substantial population" of shortnose sucker in Copco Reservoir (Siskiyou Co., California), as well as collections of both species from Iron Gate Reservoir (Siskiyou Co., California) and J.C. Boyle Reservoir (Klamath Co., Oregon). Remnants and/or highly hybridized populations were also documented to occur in the Lost River system (Klamath Co., Oregon, and Modoc and Siskiyou Co., California) including both species in Clear Lake Reservoir (Modoc Co., California), but it was apparently presumed that Lost River sucker populations in Sheepy Lake, Lower Klamath Lake, and Tule Lake (Siskiyou Co. California) had been "lost" (USFWS 1988, p. 27130). Although not stated explicitly, shortnose sucker within Gerber Reservoir (Klamath Co., Oregon) were likely part of the "highly hybridized populations" in the Lost River Basin referenced in the listing.

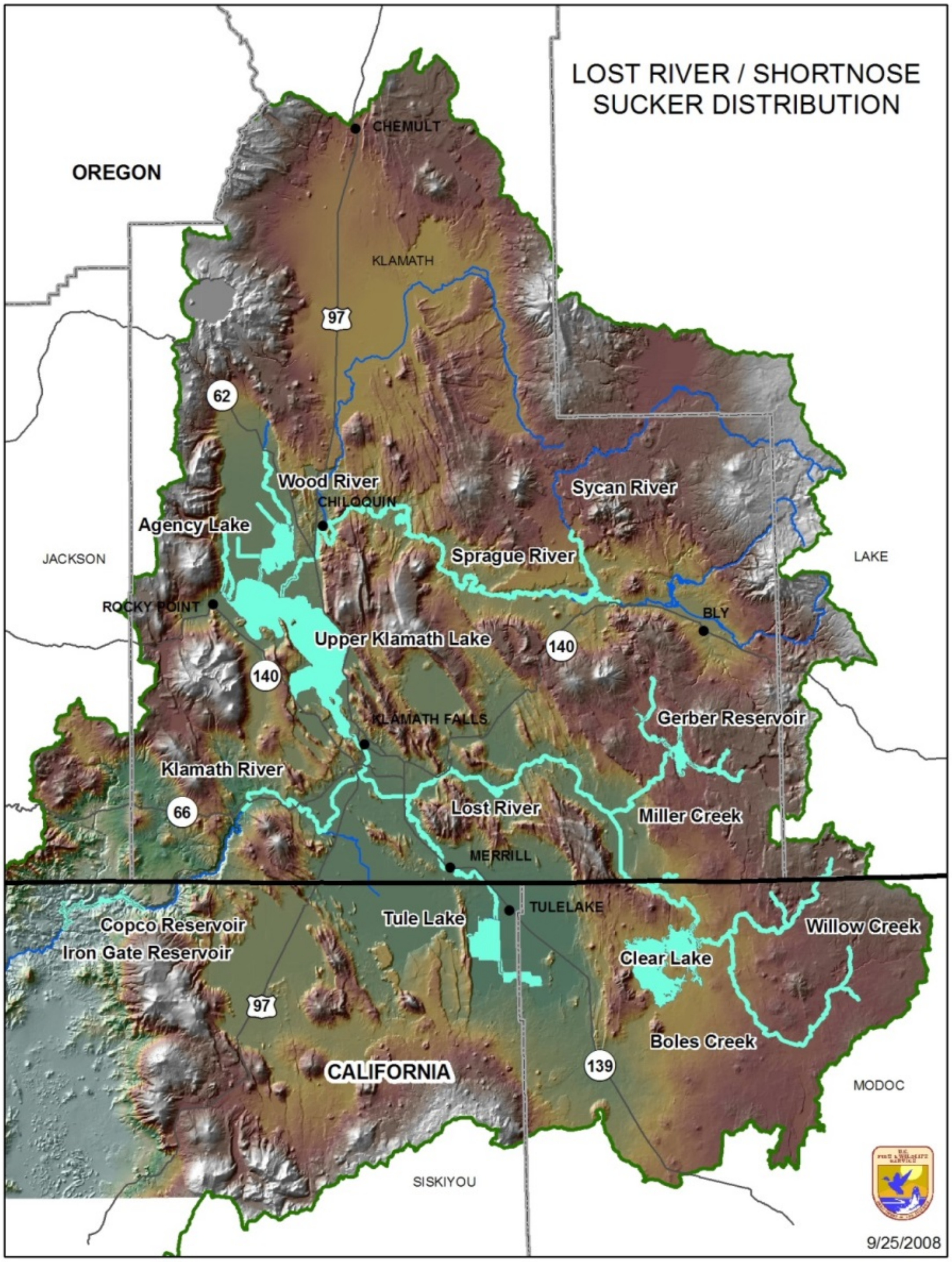


Figure 4 The Lost River and shortnose sucker are endemic to the lakes and rivers of the Upper Klamath Basin in south, central Oregon and north, central California. Lower Klamath Lake and Sheepy Lake are not depicted on the map because populations no longer occur there.

Life History

Lost River sucker and shortnose sucker are large-bodied, long-lived species. The oldest individual for which age has been estimated is 57 years for Lost River sucker and 33 years for shortnose sucker (Buettner and Scoppettone 1991, p. 21; Terwilliger et al. 2010, p. 244). Juveniles grow rapidly until reaching sexual maturity sometime between age four and nine years of age for Lost River sucker and between four and six years of age for shortnose sucker (Perkins et al. 2000b, pp. 20 & 21). On average, approximately 90 percent of adults of both species survive from year to year, which enables populations to persist through periods with unfavorable spawning or recruitment conditions (Hewitt et al. 2017b, pp. 15 & 21). Once achieving sexual maturation, Lost River sucker are expected to live on average 12.5 years based on annual survival rates (Hoenig 1983, entire; USFWS 2013b, p. 12). Similarly, shortnose sucker adults are estimated to live on average 7.4 years after having joined the adult population. Thus, for those individuals surviving to adulthood, we expect an average total life span of 20 years for Lost River sucker and 12 years for shortnose sucker, based on the average time to maturity and average adult life spans. Females produce a large number of eggs per year: 44,000 to 236,000 for Lost River sucker and 18,000 to 72,000 for shortnose sucker, of which only a small percentage survive to become juveniles. No direct measurements of larval survival have been made for these species, but a generally accepted value of larval mortality for stable populations of freshwater fish to reach the juvenile stage is approximately 96.4 percent (Houde 1989, p. 479; Houde and Bartsch 2009, p. 31). Larger, older females often produce substantially more eggs and, therefore, can contribute relatively more to production than a recently matured female. The effects of **senescence** on the survival and reproduction of these two species are unknown at present, but the phenomenon of senescence appears to be widespread among vertebrates and the populations in Upper Klamath lake are clearly ageing (Hewitt et al. 2017b, pp. 19, 23, & 29).

Both species are **obligate** lake dwellers, typically only leaving lakes during spawning migrations. Spawning occurs from February through May. Most populations spawn in tributary rivers or streams, but a subset of the Upper Klamath Lake population of Lost River sucker spawns at groundwater upwelling areas along the eastern lakeshore. Spawning at the lakeshore springs occurs primarily in April and early May (Hewitt et al. 2014, p. 9). Individuals of both species appear to spawn every year in Upper Klamath Lake (E. Janney, U.S. Geological Survey, personal comment). The number of individuals participating in spawning runs from Clear Lake varies dramatically across years as a function of access to the spawning stream, which depends on stream flow and lake levels (Hewitt Forthcoming). Spawning consists of females quivering to broadcast their eggs, which are fertilized most commonly by two accompanying males (also quivering), though the number may be as high as seven males jockeying for close position to the female (Buettner and Scoppettone 1990, pp. 17 & 44) (Figure 5). There is no parental care of the eggs. Fertilized eggs quickly settle within the top few inches of the gravel substrate and hatch around one week later. Larvae emerge from the gravel approximately 10 days after hatching at about 7 to 10 mm (0.2 to 0.6 in) total length and are mostly transparent with a small yolk sac (Coleman et al. 1988, p. 27).

Photo by G. Scoppettone, USGS

Figure 5 Cui-ui suckers spawning in the same manner of group broadcast spawning used by the suckers of the upper Klamath Basin.

Photo by R. Larson, USFWS

Figure 6 A sucker larvae from the upper Klamath Basin. This sucker is approximately 3 -4 weeks old and is transitioning into the juvenile stage because no yolk sac remains and the rays of the fins are nearly completely developed.

Generally, Lost River and shortnose sucker larvae spend little time in rivers after **swim-up**, drifting downstream to the lakes at about 14 mm (0.55 in) in length around 20 days after hatching (Cooperman and Markle 2003, pp. 1146 - 1147) (Figure 6). In the Williamson and Sprague Rivers (Upper Klamath Lake population) and Willow Creek (Clear Lake Reservoir population), larval drift downstream from the spawning grounds begins in April and is typically completed by July with the peak in mid-May (Scoppettone et al. 1995, p. 19). Little is known about the drift dynamics of the larvae that hatch at the eastern shoreline springs in Upper Klamath Lake. Most downstream movement occurs at night near the water surface (Ellsworth et al. 2010, pp. 51-53).

Once in the lake, larvae inhabit near-shore areas (Cooperman and Markle 2004, entire). Larval density is generally higher within and adjacent to emergent vegetation than in areas devoid of vegetation (Cooperman and Markle 2004, p. 370). However, the two species appear to have slightly different habitat usage as larvae; shortnose sucker larvae predominantly use nearshore areas adjacent to and within emergent vegetation, but Lost River sucker larvae tend to occur more often in open water habitat than near vegetated areas (Burdick and Brown 2010, p. 19).

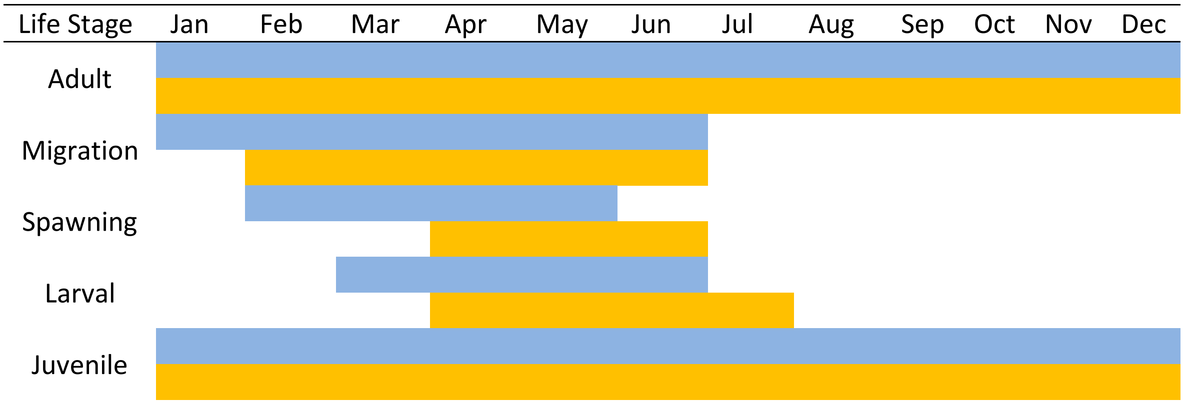
Larvae transform into juveniles in mid-July at 20 and 30 mm (0.8-1.2 in) total length, and they then transition from predominantly feeding at the surface to feeding near the lake bottom (Markle and Clauson 2006, p. 496). One-year-old juveniles occupy shallow habitats during April and May, but have been observed moving into deeper areas along the western shore of Upper Klamath Lake in late spring until dissolved oxygen levels become reduced (Bottcher and Burdick 2010, p. 12; Burdick and Vanderkooi 2010, pp. 9 - 10). Juveniles in their first year are expected to have relatively high mortality rates compared to adults, but we don't have estimates specific to these species. Under normal conditions, we do expect mortality rates will become less severe as juveniles age. It is somewhat difficult to discuss the intervening period between the first year and sexual maturation because we have extremely few data about this life stage, primarily because they don't exist. We assume these older juveniles generally possess characteristics of adults (see below), with the exception of reproductive maturity, and utilize habitats similar to adults as well.

Adult Lost River sucker and shortnose sucker are widely distributed in Upper Klamath Lake during the fall and winter, but in the spring, congregations form in the north-east quadrant of the lake prior to moving into tributaries or shoreline areas for spawning. Less is known about populations in Gerber and Clear Lake Reservoirs (Leeseberg et al. 2007, entire). However, in Clear Lake adults appear to inhabit the western lobe of the reservoir more so than the eastern lobe (Barry et al. 2009, p. 3), which is probably due to its greater depth.

Individual Needs

Lost River and shortnose suckers can generally be classified into five life stages that occur at various times throughout the year: migration, spawning, larval, juvenile, and adult (Table 1). The timing of occurrence of each life stage is similar between the two species, with the main difference occurring during spawning and incubation.

Table 1 Life Stage Diagram (adapted from Reiser et al. 2001, p. 4-3). Lost River sucker are represented by blue and shortnose sucker are represented by yellow.



Migration

Adults in Upper Klamath Lake appear to strongly cue on water temperature to initiate spawning migrations up the Williamson River. Migrations will begin only after appropriate water temperatures have been achieved: 10°C (50°F) for LRS and 12°C (54°F) for SNS (Hewitt et al. 2017a, pp. 11 & 24), and numbers of individuals running upstream will continue depending on whether the water temperature is trending warmer or cooler (Hewitt et al. 2014, pp. 36 & 37). This means that a cold snap will result in fewer individuals migrating during that period. Migration in Willow Creek (Clear Lake population) appears to be triggered by a general rise in stream temperatures rather than exceedance of a specific temperature threshold regardless of the absolute value of the temperature (Hewitt Forthcoming).

To spawn successfully, adult suckers need safe access to quality spawning habitat and adequate mates. Attributes of high quality spawning habitat are outlined below in the section describing the needs for spawning. For river spawning habitat, access can be limited by shallow water near river outlets or low flows within rivers (Hewitt Forthcoming). For lakeshore spring spawning habitat, access and availability can be reduced by shallow depths or dewatering at springs due to low lake levels (Burdick et al. 2015b, entire). Lost River and shortnose suckers may be more vulnerable to avian predation during spawning than at other times of the year because they must move through shallow habitat to spawn at some sites (Hewitt Forthcoming). We do not know specific flow requirements or thresholds for these species, but we generally believe that they are capable of navigating past most natural features within their range under average hydrologic conditions. As an example, a shortnose sucker individual was documented in 2016 traversing approximately 35 km (21.7 mi) up Willow Creek during the spawning migration. To do so, the individual climbed two extremely steep sections of between 4.8 and 6.2 percent gradient for nearly 0.7 km (0.43 mi) and 0.37 (0.23 mi), respectively (J. Rasmussen, U.S. Fish and Wildlife Service, unpublished data).

Spawning

Spawning occurs from February through May. In Upper Klamath Lake spawning adults have been consistently observed to only enter the Williamson River for spawning when appropriate water temperatures have been achieved: 10°C (50°F) for LRS and 12°C (54°F) for SNS (Hewitt et al. 2017a, pp. 11 & 24). Spawning activity is typically observed over mixed gravel or cobble substrates in depths typically less than 0.46 m (1.5 ft) ranging from 0.12 to 0.70 m (0.4 to 2.3 ft) in rivers and shoreline springs. Gravel is rock ranging in size from 2 – 64 mm (0.8 – 2.5 in) in diameter, and cobble ranging in size from 65 – 256 mm (2.5 – 10 in) in diameter. Eggs require flowing water and relatively open substrate that permits sufficient aeration (both from ambient dissolved oxygen [DO] levels and from removal of silt and clays that can smother the egg). These conditions are also important for the elimination of waste materials from the egg during incubation. Lost River suckers were observed to spawn at velocities of 15 – 82 cm/sec (0.49 - 2.69 ft/sec; Coleman et al. 1988, p. iv). Eggs also require appropriate temperatures to support timely development. Coleman et al. (1988, p. iv) observed that Lost River sucker eggs hatched 8 days after fertilization at 13.5°C (56.3°F). Colder temperatures (7°C [45°F]) were observed to delay egg development by at least two weeks (J. E. Rasmussen, unpublished data). Eggs also need some protection against potential predators and disease, such as small spaces in gravel, although there are no data to clarify what are optimal conditions. The small spaces between gravel pieces in the substrate help to restrict access from potential predators, and also limit the number of eggs that can randomly clump together, which could reduce the spread of diseases such as certain fungi that can grow on developing eggs.

Larvae

Generally, larval needs prior to swim-up are similar to those of eggs. Larvae need gravel for roughly the first two weeks after hatching and flowing water that is well aerated and clean. Prior to swim-up larvae also need gravel to provide some protection from predation and disease. Similar to eggs, gravel restricts access by predators and causes developing larvae to be somewhat dispersed, which reduces the transmission of disease. Approximately 10 days after hatching, when larvae reach about 7 to 10 mm (0.2 in to 0.6 in) **total length** and are still mostly transparent with a small yolk sac, they emerge out of the gravel (Coleman et al. 1988, p. 27; Buettner and Scoppettone 1990, pp. 24 & 46).

Generally, larvae spend little time in rivers after swim-up, but quickly drift downstream to the lakes. However, Hayes and Rasmussen (2017, pp. 131-132) found evidence of LRS rearing in the Sprague River as juveniles, presumably because these individuals did not outmigrate as larvae. This is likely a very small component of the population overall. In the Williamson and Sprague Rivers, larval movement away from the spawning grounds begins in April and is typically completed by July. Downstream movement mostly occurs at night near the water surface (Ellsworth et al. 2010, p. 51). Once in the lake, larvae typically inhabit near-shore areas (Cooperman 2004, p. 84). Larval density is generally higher within and adjacent to **emergent vegetation** than in areas devoid of vegetation (Cooperman and Markle 2004, p. 373).The role of submergent vegetation is unclear because it is generally not present during most of the larval period due to the larval period occurring before the growing season. Outmigrating larvae require sufficient flows through the river or creek, ultimately out-letting into a lake habitat. This **corridor** presumably also needs either fringe (e.g., emergent vegetation) or benthic (e.g., gravel) structure to provide areas for the larvae to rest and hide during daylight hours.

Once in the lake environment, larvae require habitat with appropriate water quality (Table 2), sufficient food, and structure that provides refuge from predators and turbulence. One study found that larvae need a pH below approximately 10.35, un-ionized ammonia (NH_3) below 0.48 mg/L (LRS) and 1.06 mg/L (SNS), temperatures below 31°C (88°F), and dissolved oxygen (DO) above 2.1 mg/L (Saiki et al. 1999, p. 40). These values reflect conditions that were lethal to 50 percent of individuals after 96 hours of exposure. It is likely that conditions much better than these are needed for the individuals to thrive

Table 2 Upper median lethal concentrations (LC_{50}s) for pH, un-ionized ammonia (NH_3), and water temperature (TEMP), and lower LC_{50}s for dissolved oxygen (DO) to larval (35 days) and juvenile (3-7 months) Lost River (LR) and shortnose (SN) suckers at 24-h exposure intervals during 96-h-long tests. From Saiki et al. (1999, p. 40).

Variable	Species	Life Stage	Weight (g)	24 h		48 h		72 h		96 h	
pH	LR	Larva	NW[a]	10.42	(10.38±10.47)	10.39	(10.32±10.46)	10.36	(10.27±10.46)	10.35	(10.26±10.45)
	LR	Juvenile	0.28±0.49	10.66	(10.59±10.74)	10.62	(10.54±10.71)	10.39	(10.12±10.67)	10.3	(9.94±10.67)
	SN	Larva	NW[a]	10.38	(10.31±10.46)	10.38	(10.31±10.46)	10.38	(10.31±10.46)	10.38	(10.31±10.46)
	SN	Juvenile	1.01±1.11	10.69	(10.61±10.77)	10.66	(10.61±10.72)	10.58	(10.56±10.61)	10.39	(10.22±10.56)
NH3	LR	Larva	NW[a]	0.56	(0.52±0.61)[c]	0.51	(0.47±0.55)[c]	0.49	(0.45±0.54)[c]	0.48	(0.44±0.52)c
(mg/L)	LR	Juvenile	0.49±0.80	1.02	(1.01±1.04)	0.92	(0.82±1.04)	0.89	(0.77±1.04)	0.78	(0.70±0.86)
	SN	Larva	NW[a]	1.29	(0.83±2.00)	1.24	(0.82±1.88)	1.19	(0.79±1.78)	1.06	(0.73±1.53)
	SN	Juvenile	0.53±2.00	0.51	(0.30±0.87)	0.48	(0.28±0.82)	0.54	(0.35±0.82)	0.53	(0.34±0.82)
TEMP	LR	Larva	NW[a]	31.93	(31.82±32.04)[c]	31.85	(31.69±32.01)[c]	31.77	(31.58±31.96)[c]	31.69	(31.47±31.91)[c]
(°C)	LR	Juvenile	0.48±0.86	30.76	(30.04±31.50)	30.76	(30.04±31.50)	30.65	(30.04±31.27)	30.51	(29.99±31.04)
	SN	Larva	NW[a]	31.85	(31.75±31.96)	31.85	(31.75±31.96)	31.85	(31.75±31.96)	31.82	(31.75±31.90)
	SN	Juvenile	0.54±0.64	31.07	(29.44±32.80)	30.35	(29.44±31.28)	30.35	(29.44±31.28)	30.35	(29.44±31.28)
DO	LR	Larva	NW[a]	2.01	(1.90±2.13)	2.1	(2.07±2.13)	2.1	(2.07±2.13)	2.1	(2.07±2.13)
(mg/L)	LR	Juvenile	0.39±0.86	1.58	(1.35±1.86)	1.58	(1.35±1.86)	1.62	(1.41±1.86)	1.62	(1.41±1.86)
	SN	Larva	NW[a]	1.92	(1.89±1.96)	2.04	(1.90±2.18)	2.09	(1.90±2.29)	2.09	(1.90±2.29)
	SN	Juvenile	0.39±1.15	1.14	(0.84±1.55)	1.34	(1.15±1.55)	1.34	(1.15±1.55)	1.34	(1.15±1.55)

[a] NW, test animals were not weighed[b]. This test was not repeated; the 95 percent confidence interval was calculated from statistical procedures used to estimate the LC_{50} value.

As larvae are in the process of transitioning to juveniles, they finish the remains of their yolk sac and begin eating external food. This includes midge (Chironomidae) larvae and adults as well as small crustaceans (Markle and Clauson 2006, pp. 494-495). Emergent vegetation provides cover from non-native predators (such as non-indigenous fathead minnows; *Pimephales promelas*) and habitat for prey items (Cooperman and Markle 2004, p. 375; Crandall 2004, p. 3). Such areas may also provide refuge from wind-blown currents and turbulence, as well as areas of warmer water temperature which may promote accelerated growth (Crandall 2004, p. 5; Cooperman et al. 2010, p. 36). These areas of emergent vegetation tend to occur along the fringes of the lakes in shallow areas.

Juveniles

It appears that individual juvenile needs are relatively similar to late-stage larvae, with some distinctions. Larvae transform into juveniles by mid-July at about 25 mm (1 in) total length. In addition to the midge and crustacean prey items, juveniles may take other macroinvertebrates (such as caddis flies) or an indistinguishable material comprised of sand, filamentous algae, and other digested materials (Markle and Clauson 2006, p. 495). However, no diet data exist beyond early summer of their first year. Juvenile suckers primarily use relatively shallow (less than approximately 1.2 m [3.9 ft]) vegetated areas, but may also begin to move into deeper, un-vegetated off-shore habitats (Buettner and Scoppettone 1990, pp. 32, 33, & 51; Hendrixson et al. 2007a, pp. 15 - 16; Burdick et al. 2008, pp. 427 - 428; Bottcher and Burdick 2010, pp. 12 - 14; Burdick and Brown 2010, pp. 42, 45, & 50). One-year-old juveniles occupy shallow habitats during April and May, but may afterwards move into deeper areas along the western shore of Upper Klamath Lake until DO levels become reduced (Bottcher and Burdick 2010, p. 17; Burdick and Vanderkooi 2010, pp. 10, 11, & 13). Once DO levels in this deeper area become suboptimal, juveniles appear to move into shallower areas throughout the rest of the lake.

Minimum water quality needs for juveniles are also similar to larval needs but juveniles appear to be slightly more tolerant of poor water quality (Table 2). Lastly, several predator groups are known to prey on juvenile suckers, including fish and birds, and they also are subject to impacts from numerous diseases and parasites. Individuals need habitat structure or depth to avoid predation, and individuals also require water quality conditions within appropriate ranges to reduce stress and thereby minimize the vulnerability to predators and pathogens.

Adults

Adult Lost River sucker and shortnose sucker require distinct growth and spawning habitats. The growth habitat, found in lakes, is simply the habitat adults utilize for feeding and growing. This habitat is found in the lakes of the Upper Klamath Basin. Spawning habitat is typically found in the tributary rivers to these lakes. However, a subset of Lost River sucker use lakeshore springs as their spawning habitat in Upper Klamath Lake. Few shortnose sucker are also detected at these lakeshore sites, but the low numbers suggest that they are likely just vagrant individuals not attempting to spawn. In their growth habitat, adult suckers require adequate food, water quality, and refuge from predation. Although adult sucker are hardier than juveniles and larvae, they are still susceptible to poor water quality, which can be associated with **die-offs**. Thus, adult suckers require adequate water quality within their growth habitat or at least refugia from poor water quality conditions in their primary habitat. The specifics of water quality dynamics and conditions will be discussed further in Chapter 3.

Specific information on the diet of Lost River sucker or shortnose sucker adults is lacking; however, their morphology and the diets of closely related species yield some insight. *Chasmistes* species, including shortnose sucker, have **terminal** or **subterminal** mouths and **branched gill rakers** (Miller and Smith 1981, p. 7) which are presumed to be adaptations for straining zooplankton from the water column (Miller and Smith 1981, p. 1; Scoppettone and Vinyard 1991, p. 359). *Deltistes* species such as the Lost River sucker, have triangular gill rakers and mouths oriented more ventrally (toward the bottom), which suggests that they are dependent more on benthic organisms, such as macroinvertebrates.

Based on radio-telemetry studies of suckers in Upper Klamath Lake, adults of both species tend to occupy areas with water depths of greater than 2 m (6.6 ft). Selection of these deeper than average habitats may reflect the distribution of their prey or it may confer protection from avian predators, which can consume suckers as large as 730 mm (28.7 in) (Evans et al. 2016a, p. 1262). Sucker adults are known to utilize shallower habitat when seeking water quality refugia in spring-fed areas, such as Pelican Bay (Banish et al. 2009, p. 159-160). These spring-dominated sites likely provide better water quality conditions because the water is typically cooler (cooler water can hold more oxygen than warmer water) and clearer because of water flow in the area.

Population Needs

Just as individuals have specific needs to survive and prosper, populations also have ecological requirements for maintaining stability and resiliency. We define these population needs as the resources or conditions necessary to sustain a genetically diverse population over tens to hundreds of years. Long-term sustainability can be characterized by population growth rate that averages unity (or greater) over the time period of interest. This value represents the average proportional change in population size from one year to the next. It is to be expected that all populations will experience some **stochasticity**. For example, some years a decline in numbers occurs (growth rate < 1) and other years produce an increase (growth rate > 1), but overall a stable resilient population will generally average a growth rate of 1. The needs of a stable population are those conditions necessary to produce this average growth value over a period of time. The needs of an already depressed population include conditions that promote an average growth value of > 1 until the population reaches the environment's carrying capacity.

For most fish species, it is often possible to generate estimates of the number of adults only because of challenges in capturing smaller life stages. In the long-term, the growth rate patterns in the adults will reflect the dynamics of all life stages. Furthermore, adults typically comprise the most stable, long-term component of the population, and therefore, here we generally consider population needs as they impact the adults. Annual changes in population size (adults) are driven by two primary demographic factors: survival and recruitment. For long-term demographic stability, recruitment must be sufficiently large to offset losses from mortality. Under normal conditions, the long lifespan and high adult survival of Lost River and shortnose sucker life-history offset their low annual recruitment. Likewise, periodic events of unusually high recruitment contribute strongly to sustaining these species in the long term. So, in very general terms, populations of these species need conditions that permit high adult survival and successful spawning and rearing of enough individuals to offset average adult mortality.

Adequate recruitment rates depend on successful spawning and sufficiently high early-life survival rates. Successful spawning depends upon access to high quality spawning habitat. As discussed above, spawning typically occurs in tributary rivers, but Lost River sucker also spawn at springs emerging along lakeshores. Access to these habitats can depend on water levels both in the lake and in some cases the tributary rivers. For lakeshore spring spawning habitat, access and availability is dependent on the water levels of Upper Klamath Lake. Sufficiently high survival rates at early life-stages depend on meeting the individual needs of eggs, larvae, and juveniles as discussed above.

Adult survival rates must be high enough to sustain the adult populations through periods of low recruitment. There is limited information on the historical frequency and magnitude of recruitment for Lost River and shortnose sucker, so delimiting specific requirements for adult survival is challenging. The survival of adults within a given population is primarily dependent on the extent to which the individual needs described above are met.

Beyond typical recruitment and survival rates, **catastrophic events** can dramatically reduce the abundance within populations and even lead to extirpation. An example would be an extreme degradation of water quality (e.g., dissolved oxygen). For populations that are low in numbers, a widespread catastrophic event has the potential to eliminate a significant proportion of individuals that could result in a loss of stability or even viability. Population resiliency is the ability of the population to rebound from such events. To be resilient to such events and minimize the probability of extirpation, sucker populations must be large enough to both avoid immediate demographic concerns as well as maintain genetic diversity. In addition to a large population size, resiliency further depends on subsequent recruitment for populations to rebound to preexisting levels.

Sucker populations must also be large enough to withstand the deleterious effects of low genetic diversity. One way to characterize this diversity is termed representation, as described above. Representation is the concept that the breadth of genetic and ecological diversity is represented within and among populations at appropriate levels. Larger populations tend to have higher **effective population size**, which is a measure of genetic diversity of the breeding population. Populations with low effective population size are more vulnerable to inbreeding depression and genetic drift and may be less able to adapt to changing environmental conditions. Small populations are also vulnerable to **demographic effects**, such as random swings in sex-ratio that may reduce population growth rates and effective population size. In other words, small populations may experience random variations in mortality or spawning that generate fewer individuals in one of the sexes than is necessary to maintain stability or viability. The effective population size required for maintaining Lost River and shortnose suckers is difficult to determine. No population of either species has been evaluated for inbreeding depression, effective number of breeders, or limiting demographic ratios.

Lastly, maintaining genetically intact and diverse populations of suckers requires minimization of the effects of hybridization. Hybridization affects the species at both the population and species levels in similar ways, which are detailed below. In summary, the population needs for these species include the environmental conditions that support survival at all life stages (see Individual Needs Section) and sufficiently high numbers of individuals within each population to ensure population resiliency and genetic representation.

Species Needs

As with the idea that population needs are met the extent to which individual needs are met, the same holds true for species needs. In other words, for a species to persist, it requires a sufficient number of resilient and representative populations, known as redundancy (Evans et al. 2016b, p. 6). Redundancy is defined as having replicate populations throughout the range of the species, so that if one or more populations experience catastrophic loss or extirpation, the species as a whole continues to persist. It is difficult to quantify how much redundancy is needed by a species to ensure long term persistence of a species, but it is clear that species with fewer populations are at greater risk of extinction. We believe that pre-settlement distribution is a reasonable starting point because this is the distributional extent of the species under historic natural conditions.

Given this, we presume that Lost River and shortnose sucker need two or more resilient and representative populations for each species which possess the characteristics described in the preceding section. Upper Klamath and Clear Lake populations of both species are required at a minimum for the long-term persistence of the species. These two water bodies are the largest and most stable within the range of the species. We cannot conceive a scenario where recovery and stability could be achieved without viable populations in each of these water bodies. Having these two populations provides some redundancy, but additional populations will certainly increase protection against extinction. Additional populations could include Gerber Reservoir, Tule Lake, and Lake Ewauna, among others. Small populations of both species occur in all but Gerber Reservoir (which is only currently occupied by shortnose sucker), but the lack of access to spawning habitat, appropriate environmental conditions, and/or genetic purity reduce overall resiliency in these areas and limit their utility in providing redundancy.

Geographic extent of the range of a species is generally an important component of redundancy. The farther apart populations are, the less likely they will be affected to the same degree by the same catastrophic event. Even under pre-European settlement conditions, these species' maximum range was very restricted at only approximately 9,000 km^2 (3,500 mi^2).

The second condition required for species persistence, representation, relates to the level and extent of diversity among the populations of a species. This typically refers to genetic diversity, but can also be applied to ecological diversity. Species require a range of genetic and ecological diversity to be represented throughout their populations to ensure adaptability as environmental conditions change. Not every population will possess the complete range of variation, but it is important for the long-term viability of species to have variation within and among populations. Diversity increases the likelihood that a species as a whole will be able to persist through environmental changes because the chances are greater that there is a variant within the species that can resist or take advantage of new conditions (Hallerman 2003, p. 405; Evans et al. 2016b, p. 6).

It is difficult to quantify representation, much less what is required by a species to ensure persistence. Genetic diversity is often measured within populations by the number of **genetic loci** with greater than one **allele**, or the number of alleles at a specific locus, or even simple **heterozygosity** at a single locus (Billington 2003, pp. 75-83). Differences in allele frequencies and **genotypes** are often used to assess genetic diversity among populations. Ecological diversity can be quantified by comparing the **richness** (the number of types of ecological variants, including behavioral or life history variants, or **phenotypical variants** within a species or population) or the **evenness** (the relative proportion of the variants) within and among populations. Nevertheless, assigning specific required or minimum diversity values is not straightforward (Hallerman 2003, p. 407).

Several important landscape-level dynamics can affect species diversity. Connectivity among populations to allow for dispersal of migrants can promote genetic diversity by ensuring that genetic variants are spread among populations. Restriction of connectivity among populations can result in the loss of genetic diversity due to processes such as a **genetic bottleneck** or the **founder effect**. Connectivity to diverse habitats throughout the landscape at the species and population level can also promote ecological diversity by providing unique and diverse niches that individuals and populations can take advantage of, which may result in local adaption and increased genetic diversity. These issues of connectivity and diversity are often referred to as **metapopulation dynamics**, and they often function on a relatively long time scale.

Genetic introgression is another process that can have significant impacts to species representation. When barriers to **reproductive isolation** between species are incomplete those species can exchange genes. Depending on the dynamics, this may be detrimental to species genetic and ecological diversity via **genetic swamping** or it may provide new genes that beneficially increase genetic diversity (Dowling and Secor 1997, entire). As noted above, introgression is relatively common among many species of sucker (Dowling et al. 2016, p. 3).

Discussion of the concept of representation within the species is important; nevertheless, we are currently unable to identify anything more specific than the qualitative, generic needs described above. Over evolutionary time scales, the Lost River and shortnose suckers require access to diverse habitats throughout the landscape and connectivity among populations that will promote genetic and ecological diversity. However, for this assessment we are evaluating species needs and conditions over the next 50 years. Across this restricted time frame, access to diverse habitats is still very important, but connectivity among populations is perhaps not a requirement to ensure species persistence in the time frame relevant to this document because the benefits and drawbacks related to this process are typically operating on a time scale beyond this narrow scope considered here. Furthermore, the species need appropriate levels of introgression and genetic diversity at the population and landscape scale to ensure species viability and adaptability.

CHAPTER 3 – CAUSES AND EFFECTS OF CURRENT ENVIRONMENTAL CONDITIONS

The purpose of this chapter is to identify and explain the most relevant factors that relate to the current biological and environmental condition of Lost River and shortnose suckers. The current condition of the species will be addressed in Chapter 4. Here we discuss those anthropogenic and environmental factors that affect the habitat and demographics of the species.

Habitat Loss and Alteration

Loss and alteration of habitats (including spawning and rearing habitats) were major factors leading to the listing of both species (USFWS 1988, pp. 27131-27132) and continue to be significant impediments to recovery. Both species utilize a spectrum of aquatic habitats during some stage of the life cycle, including river or stream habitats, open-water lake habitats, and the wetlands areas along banks and shores. However, alterations or total loss of habitats have occurred throughout the species' range. The most dramatic examples of wholesale habitat loss include Tule Lake (roughly 36,000 hectares [89,000 acres] lost) and Lower Klamath Lake (roughly 40,700 hectares [100,500 acres] lost) (National Research Council 2004, p. 53). These two lakes were both terminal bodies with a single major tributary, which were dammed in 1910 or diked in 1917 (respectively) to completely block inflows (National Research Council 2004, pp. 55 & 56). This resulted in a loss of approximately 392 km^2 (151 mi^2) or 88 percent of Tule Lake and 362 km^2 (140 mi^2) or 95 percent of Lower Klamath Lake (National Research Council 2004, p. 96). As the lake levels receded, the exposed lake bottoms were converted to agricultural uses. Prior to damming, Tule Lake hosted what was probably the largest population of Lost River sucker (Bendire 1889, p. 44). Anecdotal reports suggest that populations of Lost River sucker also occurred in Lower Klamath Lake (Cope 1879, p. 72), although we are not aware of any pre-1917 reports on scientific fish surveys of the Lower Klamath Lake prior to modification. Notable habitat loss also occurred in Upper Klamath Lake. Approximately 70 percent of the original 20,400 hectares (50,400 acres) of wetlands surrounding the lake, including the Wood River Valley (Figure 7), was diked, drained, or significantly altered between 1889 and 1971 (Gearhart et al. 1995, p. 7). In some cases, additional habitat that is more or less suitable for suckers was also created when reservoirs were created behind Gerber Dam and enlarged behind Clear Lake Dam.

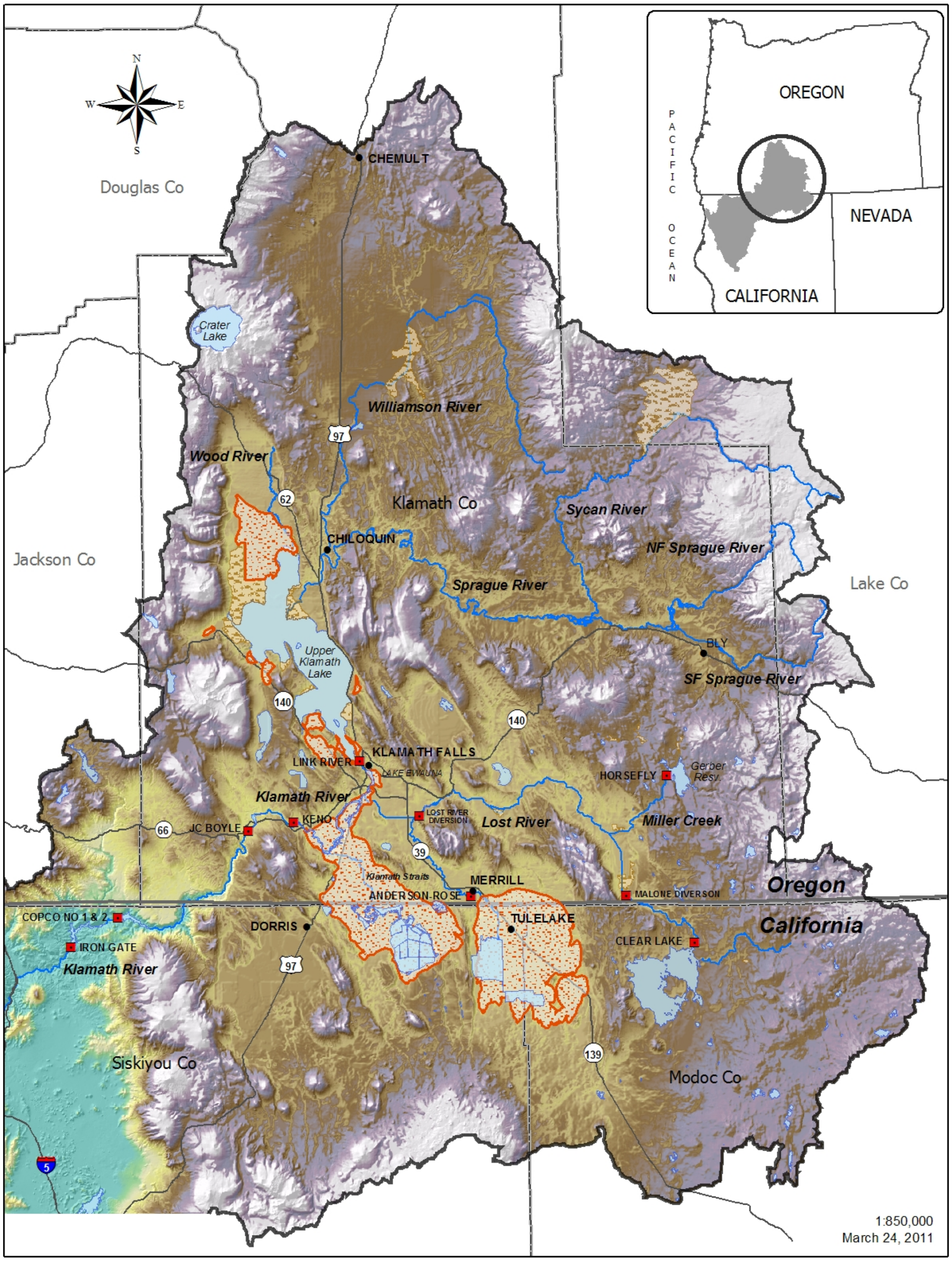


Figure 7 The upper Klamath Basin indicating areas of lost aquatic and wetland habitat that have been lost since 1900 with current conditions overlain. The lost areas are outlined in orange.

Habitat was effectively lost to the populations as passage to those areas was blocked. Barriers that limit or prevent access to spawning habitat were also identified as threats when the species were listed. Chiloquin Dam was cited as the most influential barrier because it restricted access to potentially 95 percent of historic river spawning habitat in the Sprague River for the populations in Upper Klamath Lake (USFWS 1988, p. 27131). However, this dam was removed in 2008, improving access to approximately 120 km (75 mi) of river for spawning. Both species have been detected upstream of the dam site during the spawning season, albeit in very small numbers (Martin et al. 2013, p. 8). Additionally, several dams or water control structures hinder or completely impede movements of the species throughout their historic range. These include Gerber Dam (Figure 8), Clear Lake Dam (Figure 9), Anderson Rose Dam (Figure 10), Harpold Dam, Lost River Diversion Dam, Malone Dam, as well as numerous smaller check dams and the like (BOR 2000, entire). All of the more substantial dams (i.e., the named ones above) were installed approximately 100 hundred years ago, and none of them have any structures that would permit volitional fish passage. For example, suckers attempting to run up the Lost River from Tule Lake are only able to travel 12 km (7.5 mi) before access is blocked by the Anderson-Rose Dam. The connection between Upper Klamath Lake and downstream environments was questionable for many decades because of a dilapidated fish passage ladder on the Link River Dam. This condition was improved with the completion of a sucker-friendly fish ladder completed in 2005.

Photo by Bureau of Reclamation.

Figure 8 The Gerber Dam spilling under a high water year (2017) into Miller Creek. The dam rarely spills. Water is typically passed downstream through gates near the bottom of the dam. The dam is approximately 26 m (85 ft) high.

Photo by Bureau of Reclamation.

Figure 9 The newly reconstructed Clear Lake Dam (2004), looking downstream towards the headwaters of the Lost River. The remains of the earthen footprint of the original Clear Lake Dam (constructed in 1910) is the flat "peninsula" just upstream of the dam. The new dam is 12.8 m (42 ft) tall.

Photo by USFWS.

Figure 10 Anderson-Rose Diversion Dam looking upstream. The dam is 7 m (23 ft) high. The Lost River channel is in the bottom left of the picture and only receives flow as spill over the dam. This is a complete barrier to fish passage within the river. The head of the J Canal (and associated diversion structures) are the main cement structures in the center-right of the picture.

Another equally important type of barrier is limited hydrologic connection to spawning or rearing habitat. This can be due to natural climatic patterns or result from human actions, such as water management for agricultural irrigation. For example, low lake levels adversely affect Clear Lake Reservoir sucker populations by limiting access to Willow Creek, the only known spawning tributary (Buettner and Scoppettone 1991, p. 8). Likewise, the amount of suitable shoreline spawning habitat in Upper Klamath Lake is significantly affected by even minor changes in lake elevation (Burdick et al. 2015b, p. 483). Several spring-spawning populations, including Tecumseh Springs, Big Springs, and Barkley Springs, have been extirpated, in part due to reduced connectivity.

Historically, wetlands comprised hundreds of thousands of hectares throughout the range of the species (Akins 1970, pp. 42-50; Bottorff 1989, p. ii; Gearhart et al. 1995, p. 16), some of which likely functioned as crucial habitat for larvae and juveniles. Other wetlands may have played vital roles in the quality and quantity of water. Loss of ecosystem functions such as these, due to alteration or separation of the habitat, is as detrimental as physical loss of the habitat. For example, increases in sediment input to the lake and occurrence of *Aphanizomenon flos-aquae* (AFA) coincide with loss of riparian and wetland areas associated with agricultural development above Upper Klamath Lake (Bradbury et al. 2004, p. 164). Volumes of fringe wetland habitats (including depths and area) greater than 15,000 m^3 have been associated with higher larval survival in Upper Klamath Lake (Cooperman et al. 2010, p. 34). Of the approximately 102 km^2 (39.3 mi^2) of wetlands still connected to Upper Klamath Lake, relatively little functions as rearing habitat for larvae and juveniles, partly due to lack of connectivity with current spawning areas and habitat alterations.

Not all modification or curtailment of sucker habitat is solely from **anthropogenic** causes; climatic trends, resulting from both anthropogenic causes and natural variation, also play an important role. Since 1981, six of the ten lowest inflows into Upper Klamath Lake occurred after 2001 (Bureau of Reclamation, unpublished data, 2010). Upper Klamath Lake, Clear Lake Reservoir and Gerber Reservoir are all operated as reservoirs to supply irrigation water for agricultural purposes. Upper Klamath Lake levels are affected by drought, because it is relatively shallow (average depth in summer = 2.2 m [7.1 ft]), and because during droughts irrigation water usage is typically increased to offset lower than normal soil moisture in agricultural fields. Lake levels are an important component necessary to establish a strong annual cohort of juveniles in Upper Klamath Lake (E. Childress, U.S. Fish and Wildlife Service, unpublished data). In Upper Klamath Lake, minimum lake levels of approximately 4140 ft above sea level during the summer appear to increase the likelihood of a strong annual sucker cohort (dependent on the occurrence of other factors) (E. Childress, unpublished data). Lake levels in Clear Lake Reservoir are even more sensitive to droughts given the limited local precipitation and broad, shallow **bathymetry** of the lake itself. The lake is a shallow water body with a large surface area, which generates high evaporation rates. In a drought, these dynamics are exacerbated because the volume to surface area relationship becomes even more skewed. Severe or prolonged droughts likely negatively impact all Lost River sucker and shortnose sucker life stages throughout their range.

This myriad of habitat modifications can alter numerous ecological processes, although it is often challenging to infer direct causal pathways between individual modifications and tangible biological outcomes. Populations that historically operated as a metapopulation with periodic connection are now totally isolated. This can impact genetic and ecological representation within and among populations. Even if the movement of individuals among the various populations historically was rare, this could still provide the opportunity for beneficial genetics or adaptations to become established throughout the range of the species. Both of these processes increase the resiliency to the species as the populations are better able to respond to the environmental conditions. Extirpation of numerous large populations and subpopulations will reduce the population redundancy of the species, and likely diversity as well. Lastly, with less rearing habitat (perhaps as little as 25 percent of historic amounts), the overall numbers of individuals that habitats can support is also greatly reduced.

Water Quality

The characteristics of the water in lakes and streams result from complex interactions among the geology, land use (historic and present), and climate of the region. The upper basin is comprised of several uplifted basins with numerous volcanic centers scattered throughout (O'Connor et al. 2014, pp. 4-6). Because of the volcanic inputs, the soils of the basin tend to be naturally high in phosphorus, which nutrient drives much of the primary productivity and subsequent water quality associations. Land use that shapes the flux of nutrients within the system can also affect water quality by increasing (grazing and logging) or decreasing (wetlands) nutrient loads, among other impacts. The climate of the basin is classified by the Köppen-Geiger as temperate (C) with dry (s), warm (b) summers (Peel et al. 2007, p. 1639) with most of the precipitation falling in the form of snow. Each water quality parameter that likely has significant impacts on the sucker species is summarized below. It should be noted that the vast majority of specific information on patterns and dynamics applies to Upper Klamath Lake, and as such most of the following information will deal specifically with that lake. Information for other water bodies in the range of the species is very sparse, but will be noted when available.

Dissolved Oxygen

The amount of oxygen (O_2) dissolved in water is controlled by water temperature and pressure. Water can hold much less oxygen than air (about 20-40 times less), and the capacity of water to hold oxygen in solution decreases as temperature increases (Graham 1990, p. 137). Important inputs of oxygen to lakes include diffusion from the atmosphere, inflow from streams and rivers, and photosynthesis from plants and **cyanobacteria**. Respiration due to decomposition of decaying organic matter is the major source of oxygen uptake in lakes, but photosynthetic plants during dark periods will also respire and uptake oxygen. Given that oxygen diffuses through water about 10,000 times slower than it does through air (Graham 1990, p. 137), the dynamics of inputs and uptake can create zones of extremely low oxygen concentrations.

Dissolved oxygen concentrations in spawning streams during the spawning migrations is generally not considered to be harmful to suckers because of the cold temperatures and churning of water in riffle areas, which increases oxygen concentrations. Concentrations in the Upper Klamath Lake range annually from near 0 mg/L to greater than 10 mg/L, with notable spatial and temporal variation (Morace 2007, pp. 32-39). In Upper Klamath Lake, high nutrient loading (particularly phosphorus) causes massive, widespread blooms of *Aphanizomenon flos-aquae* (discussed in the Nutrients section below). As the bloom crashes, bacterial decomposition of the large quantities of organic matter consumes dissolved oxygen which often produces anoxic (0 mg/L of dissolved oxygen) conditions in at least some locations in Upper Klamath Lake. The severity of the dissolved oxygen depletion in Upper Klamath Lake varies depending on the size and timing of the bloom, wind action to mix the water column, and temperature. At times dissolved oxygen levels in Upper Klamath Lake are continuously below the Oregon Department of Environmental Quality (ODEQ) criterion of 5.5 mg/L for support of warm water aquatic life for weeks at a time during the summer (Kann 2017, p. 35). Hypoxic dissolved oxygen concentrations (generally < 4 mg/L) occur most frequently in late July and August (Morace 2007, p. 12). Decomposition of blue-green algae from Upper Klamath Lake through the Link River is the primary driver of low oxygen in the Keno Impoundment, including Lake Ewauna (Sullivan et al. 2010, p. 19). Dissolved oxygen within the Lost River has been listed as an impairment for the system (U.S. Environmental Protection Agency 2008, p. 40).

Lethal levels of dissolved oxygen were determined in laboratory settings for larval and juvenile Lost River and shortnose suckers by Saiki et al. (1999, entire) over a 4-day period (96 hours). Sublethal levels of DO were also determined for Lost River sucker juveniles by Meyer and Hansen (2002, entire) over a 14-day period. In both of those experiments, the range of DO concentrations that was lethal to at least 50 percent of the individuals exposed (LC_{50}) was from 1.34 to 2.10 milligrams per liter (mg/L). Dissolved oxygen levels in Upper Klamath Lake and downstream of the Keno impoundment during the summer period are often at or below these levels. Adult mortality events have also been observed following the crash of algal blooms when dissolved oxygen often drops below 4.0 mg/L (Perkins et al. 2000a, p. 19).

Nutrients (nitrogen/ammonia & phosphorus)

The Upper Klamath Basin has naturally high levels of nutrients in the soils, particularly phosphorus (Bradbury et al. 2004, p. 159) due to the numerous surrounding volcanoes that have been active in the recent geologic past. Runoff and erosion deliver phosphorus downstream to lakes, elevating them from the naturally eutrophic state to hypereutrophic. In Upper Klamath Lake, phosphorus concentrations vary seasonally and spatially but can be quite high and are believed to largely reflect influences of agricultural activity (wetland drainage and pasture irrigation), timber harvest, and water management. Irrigated pasture has been identified as a substantial nutrient source to Upper Klamath Lake (Ciotti et al. 2010, entire). Manure and fertilizers that are applied to the landscape often find their way into downstream lakes, providing additional contributions of phosphorus and nitrogen that further add to eutrophication of those receiving lakes. The elevated levels of phosphorus in Upper Klamath Lake also contributed to shifts in the algal community, which are now dominated by the non-toxic cyanobacteria AFA. Details of algal dynamics are further discussed in the “Chlorophyll-a and Algal Toxins” section below.

The dynamics of nutrient cycling in Upper Klamath Lake were highly affected by the loss and modification of fringe wetlands converted to other land uses. There are two major pathways by which wetlands impact nutrient dynamics: 1) trapping and immobilization of nutrients and sediments; and 2) production of dissolved organic matter. By slowing down water currents and decreasing wave action, wetlands act as sediment traps and temporary storage for water where wetland plants can help to immobilize nutrients through uptake and subsequent burial in the soil (Bradbury et al. 2004, p. 156). Marsh peats and organic soils typically act as sinks for nutrients and organic matter under natural conditions because decomposition is slower in anoxic soils than deposition of new material (Snyder and Morace 1997, p. 44). When wetlands are drained, the exposure of peat soils to air and oxygenated water leads to the release of sequestered nutrients and organic matter through accelerated decomposition (Snyder and Morace 1997, p. 42).

The nutrient and sediment dynamics in the remaining wetlands around Upper Klamath Lake also may have changed due to changes in the dynamics of lake elevations. A natural rock reef that marked the terminus of Upper Klamath Lake and the beginning of its outflow, the Link River, acted as a sill and kept the minimum lake level at 1262 m (4140 ft). Lowering of the reef and subsequent construction of Link River Dam (1921) allowed water to be stored and managed for agriculture purposes, which meant higher than historical levels during storage periods and lower levels during usage periods (Figure 11). Lake level fluctuations went from a potential range of approximately 1 m (3ft) historically to 2 m (6 ft) (National Research Council 2004, p. 99). The wetlands that were not diked and drained for agricultural purposes can be temporarily dewatered when lake levels are low. Virtually all of the fringe marsh areas of the lake are dewatered at a lake level of 4138 ft, and approximately half is dewatered at a lake elevation of 4140 ft (Reiser et al. 2001, 5.6-5.7). Similar to the effects of draining wetlands, temporarily exposing intact wetlands to air and oxygenated water during periods of low lake elevation likely increases decomposition of organic matter and leads to nutrient release (Snyder and Morace 1997 pp. 41-42).

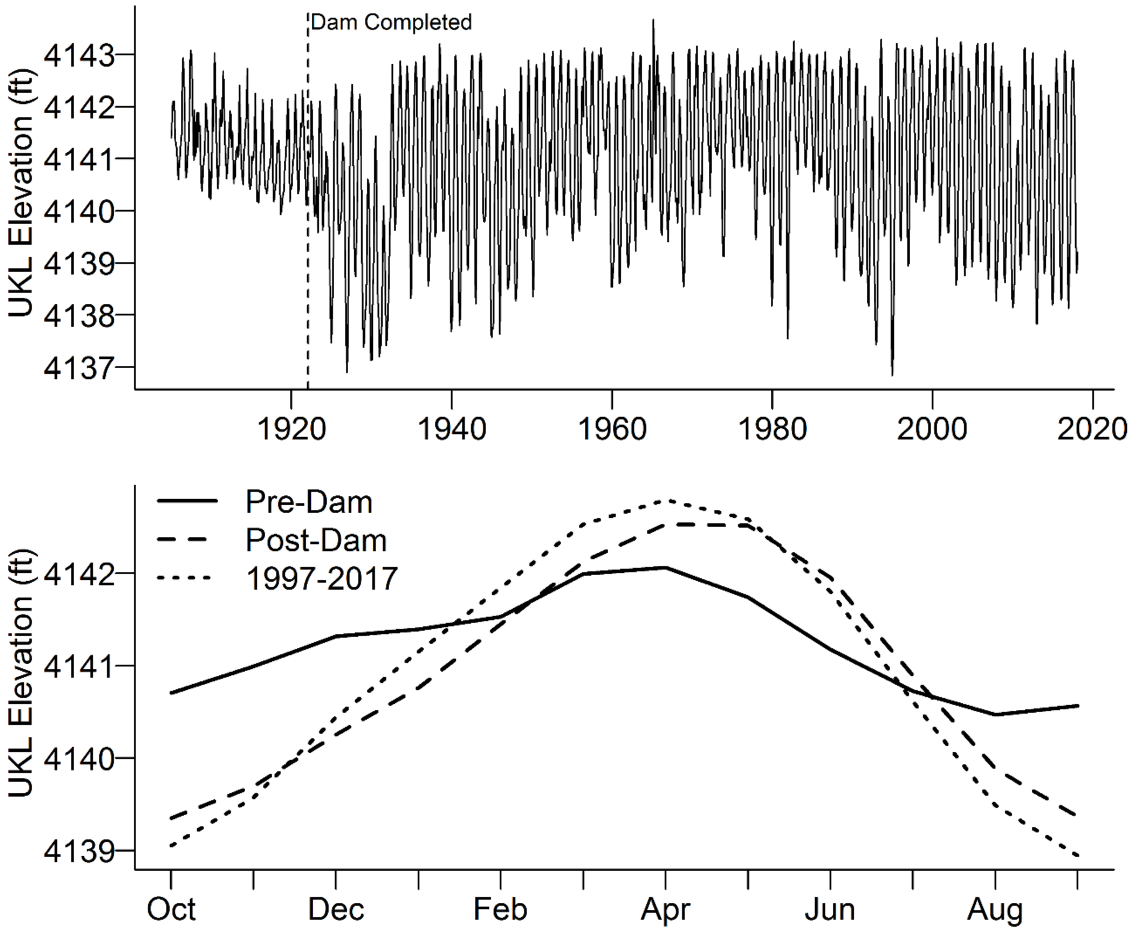


Figure 11 Historical Upper Klamath Lake end of month elevations. The lower panel shows averages across the pre-dam (1905-1921), post-dam (1922-2017), and 1997-2017 periods.

In the Lost River portion of the basin, crop cultivation is the dominant land use and utilizes water from Clear Lake and Gerber Reservoirs as well as from Upper Klamath Lake (via private and Bureau of Reclamation Klamath Project canal systems). Ammonia concentrations in the Lost River are slightly lower in the upper reaches of the system (U.S. Environmental Protection Agency 2008, p. 41), which ultimately increases nutrient loading in Tule Lake sumps at the terminus of the Lost River. Nutrient concentrations are nearly tripled as the water moves from the bottom of the Lost River system through the refuges and the Klamath Straits Drain (U.S. Environmental Protection Agency 2008, p. 38).

Timber harvest has also contributed to water quality issues in Upper Klamath Basin lakes and rivers/streams but is not as influential a contributor as agricultural activities. During the 20th century, removal of trees and disturbance of the landscape during harvest led to erosion and increased sediment and nutrient delivery (Eilers et al. 2004, pp. 8 & 15). However, best management practices are in place to minimize the effects, at least from Federal activities.

There are two forms of ammonia in solution: ionized and un-ionized. The latter is more toxic to fish, and the proportion of each is determined by the temperature and pH of the water. Larvae require un-ionized ammonia to be below 0.48 milligrams/Liter (mg/L; LRS) and 1.06 mg/L (SNS) (Saiki et al. 1999, p. 40). The lowest significant partial-mortality concentration of un-ionized ammonia determined for larval Lost River suckers is 0.69 mg/L at a pH of 9.5 (Lease et al. 2003, p. 496). The highest un-ionized ammonia concentrations easily exceed these concentrations at the deepest sites in Upper Klamath Lake during late July, coincident with blue-green algae bloom decline and low dissolved oxygen levels.

Primary Productivity & Algal Toxins

Cyanobacteria (commonly known as blue-green algae) are common within many water bodies throughout the world. Cyanobacteria are unique bacteria in that they photosynthesize similar to plants, with oxygen as a by-product (Graham et al. 2016, p. 3). The influence of blue-green algae throughout an ecosystem can be substantial (Karjalainen et al. 2007, entire). Both physical (temperature and turbidity, for example) and chemical (dissolved oxygen and pH, among others) properties of water are strongly affected by the presence of these organisms, as well as direct effects through toxins. The relationships of the relevant chemical properties are addressed in other sections of this chapter.

Populations or communities of cyanobacteria are often able to exploit the favorable conditions of Upper Klamath Lake to produce rapid and widespread blooms during the summer. Shading of the water column can result, affecting temperature. The associated organic matter with a massive bloom may also affect turbidity and potential disrupt the ability of larvae or juveniles to feed, perhaps by disrupting their vision (Engström-Öst et al. 2006, p. 112; Engström-Öst and Mattila 2008, p. 278). No specific data for Upper Klamath Lake suckers have been collected regarding this hypothesis.

Some species of blue-green algae may produce toxins, such as microcystin. Microcystin has been implicated in what is called netpen liver disease (Andersen et al. 1993, entire), which can result in high rates of mortality of fish, particularly salmonids (Kent 1990, p. 21). *Microcystis aeruginosa*, a species capable of producing microcystin, has been observed in Upper Klamath Lake. The toxin itself has also been detected in Upper Klamath Lake in potentially toxic concentrations (Caldwell Eldridge et al. 2012, p. 12). Much smaller abundance of *M. aeruginosa* occurs during the summer, compared to AFA, but *M aeruginosa* is believed to be responsible for the production of microcystin in the lake, with concentrations in 2007–2008 peaking at 17 µg/L. Additional microcystin data collection in Upper Klamath Lake is ongoing, including studies of possible effects of algal toxins on native suckers. Juvenile suckers can be exposed through ingestion of microcystin as they feed on chironomid larvae.

Upper Klamath Lake currently experiences enormous algal blooms annually from June to October (Kann 1997, p. 5). The complex timing and magnitude of the blooms vary among years and spatially; thus, it is difficult to link these dynamics to physical factors (Morace 2007, entire). Examination of lake sediment cores in Upper Klamath Lake has identified shifts in the relative abundance of the type of phytoplankton within the last two centuries. Starting in the second half of the 19th century, increases of diatom species indicated increased nutrient enrichment coincident with the arrival by settlers of European descent

(Bradbury et al. 2004, p. 159). Similarly, the cyanobacterium AFA, which flourishes in phosphorus-rich environments, appeared in the late 19th century and became highly dominant in the system over the course of the 20th century (Bradbury et al. 2004, p. 162). The timing of shifts to an AFA dominated system suggests that the drainage of fringe wetlands around Upper Klamath Lake was a main cause of its current hypereutrophic condition (Bradbury et al. 2004, p. 164).

Historically, the presence of vast areas of fringe wetlands throughout Upper Klamath Lake likely suppressed AFA blooms through the decomposition of organic matter and filtering of nutrient inputs. Byproducts of decomposition of Upper Klamath Lake marsh vegetation (such as tannins) have been demonstrated to inhibit growth of AFA (Haggard et al. 2013, pp 17 - 19). Additionally, dissolved organic matter stains water a dark color, which reduces light penetration, and therefore, primary production (Solomon et al. 2015, p. 378). Dissolved organic matter can also directly bind nutrients making them inaccessible to primary producers (Jones 1992 p. 77). The historical presence of high concentrations of dissolved organic matter in Upper Klamath Lake is suggested by an early description of the water as having "a dark color and a disagreeable taste, occasioned apparently by decayed tule" (Williamson and Abbot 1855, p. 67). Another observer noted that the lake bottom was primary composed of large quantities of decomposing wetland vegetation (Evermann and Meek 1897, p. 62). The diking and draining of marshes around Upper Klamath Lake described above in the wetland habitat section likely reduced dissolved organic matter along with its inhibitory effect on AFA (Haggard et al. 2013, pp 19-21).

pH

Levels of pH in the Klamath Basin vary daily, seasonally, and by location. PH levels in a eutrophic system during the summer months tend to fluctuate widely, often on a daily basis. During times of high algal productivity, water pH is usually between 9.0 and 10.0 during the daytime (Kann 2017, p. 8) because the cyanobacteria are photosynthesizing, which consumes dissolved carbon dioxide from the water. Dissolved carbon dioxide in the water is in equilibrium with carbonic acid. So, when carbon dioxide is consumed during photosynthesis, some of the carbonic acid converts to carbon dioxide, thereby reducing the dissolved acid in the water and increasing (making more basic) the pH of the water. The reverse happens at night when the blue-green algae respire and whenever bacteria decompose organic matter, such as dead blue-green algae cells. Because of these dynamics, blue-green algal photosynthesis and respiration cycles can cause pH to fluctuate by up to 2 pH units over a 24-hour period. Elevation of pH values that occur in Upper Klamath Lake in excess of 10 for sustained periods can significantly impact larval and juvenile survival for suckers.

Generally, pH in the reach from Link River Dam through the Keno Impoundment increases from spring to early summer and decreases in the fall; however, there are site-dependent variations in the observed trend. Peak values can exceed the ODEQ allowed maximum of 9.0. Values in the Tule Lake Refuge consistently exceed a pH of 9, which is the maximum numeric objective, and values in the upstream Klamath Straits Drain often exceed the maximum numeric objective (U.S. Environmental Protection Agency 2008, p. 41).

Looking at pH exposure values in Lost River sucker fry held in net pens in Upper Klamath Lake, Stone et al. (2017, p. 8) determined that pH values exceeding 10 decrease the probability of their survival by 38 percent. Saiki et al. (1999) also determined that pH levels between 10.3 and 10.39 were lethal for 50 percent of larval and juvenile Lost River and shortnose suckers exposed (in a laboratory setting) over 96 hours. Elevation of pH values that occur in Upper Klamath Lake in excess of 10 for sustained periods is likely to significantly impact larval and juvenile fry survival.

Temperature

Natural temperature regimes in water bodies are controlled primarily by absorption of solar radiation (Wetzel 2001, pp. 72 & 73). The flux of heat in lakes is largely associated with the surface, and so alterations to the surface area or depth of a lake (such as impoundments) will likely impact the thermal regime. Based on USGS water quality **Sondes** deployed in Upper Klamath Lake that record temperatures hourly, temperatures exceeding 28°C (82.4°F), which has been identified as a high stress threshold for Lost River and shortnose suckers (Loftus 2001, pp. 2-11), did not occur at four of five sites in the years 2008 to 2017. Temperatures higher than 28°C (82.4°F) did occur in some years in the upper water column along Eagle Ridge, the deepest section of the lake, but the duration was less than 6 hours in all years except 2017. Temperatures exceeding 25°C (77°F), the low stress threshold for suckers (Loftus 2001, pp. 2-11), were more common and occurred in most years at most sites, with single events lasting for multiple days in some cases. These frequencies are similar to the findings from temperature measurements during the 1990s, which indicated frequent low stress events but only very rare high stress conditions (Loftus 2001, pp. 3 & 4).

The temperature range lethal to at least 50 percent of larval and juvenile Lost River and shortnose suckers over 96 hours is between 30.0 to 31.9°C (86.0 – 89.4°F)(Saiki et al. 1999, p. 40). This indicates the two sucker species have tolerance limits for surviving in many lakes/reservoirs of the Upper Klamath Basin where suckers occur. Looking at water temperature fluctuation effects in Lost River Sucker juveniles held in net pens in Upper Klamath Lake, Stone et al. (2017, p. 9) determined (through statistical modeling of collected data), that increased temperatures decrease the probability of survival, and that each 2.5°C (4.5°F) increase in temperature decreased fry survival by 47 percent. In Upper Klamath Lake, shallow lake morphology combined with water level manipulations may create rapid temperature fluctuations that may affect sucker survival. This emphasizes the importance of thermal relief that is provided by springs in Upper Klamath Lake and the flows from the Sprague, Williamson, and Wood Rivers - particularly during the summer period. It has also been noted that daily and seasonal variation in temperatures in Clear Lake could create stressful conditions for suckers (Burdick et al. 2015a, pp. 19 - 21).

Indirect and Synergistic Effects on Suckers

The collapse of large algal blooms has been linked with fish die-offs in Upper Klamath Lake, which have been observed periodically since at least the 1960s. The development of algal blooms raise pH and un-ionized ammonia concentrations to levels that are considered stressful to suckers. Although the observed mortality appears to be linked most directly to low oxygen, chronic stress due to high pH, ammonia, and temperature earlier in the season may increase sucker susceptibility to low oxygen conditions (Perkins et al. 2000a, p. 29). Hourly measurements of water quality data collected over the summers of 2013 and 2014 in Clear Lake indicated that dissolved oxygen, pH, and ammonia were less dynamic than in Upper Klamath Lake and did not cross stress thresholds for suckers (Burdick et al. 2015a, pp. 19 - 21). We do not have adequate data for Gerber Reservoir to understand its water quality dynamics.

Poor water quality conditions also cause indirect impacts, such as increasing sucker susceptibility to disease, parasites, and predators through increased stress levels and altered behavior. Stressful conditions, such as low DO, increase the probability of infection with bacteria and parasites, as well as disease, which often does not manifest without stressful conditions that weaken fish immune systems (Herman 1990, pp. 46-50). Thus, suckers with compromised immune systems have a higher probability of dying due to infection. Similarly, altered behavior due to stressful water quality conditions is likely to lead to higher rates of predation. When larval and juvenile suckers were exposed to low DO, they had difficulty swimming and exhibited gasping behavior at the water surface (Saiki et al. 1999, p. 41). In the wild, this behavior would increase exposure to avian predation (Evans et al. 2016a). Additionally, adult suckers seek refuge from poor water quality in spring influenced areas that have clear water and are shallower than preferred depths; increased visibility and reduced depth may increase exposure of adults to avian predation as well. Thus, exposure to poor water quality is likely to increase mortality from other stressors. More detail on the effects of disease, parasites, and predation on suckers is provided in following sections.

Harvest

Migrating suckers were a historically important food source for the Klamath Tribes and were harvested in large numbers during the spring months. (Bendire 1889, p. 444; Evermann and Meek 1897, p. 60). Settlers of European descent also depended on sucker migrations as a source of food and oil. Some efforts at commercial harvest were made for food and fish oil. Historical accounts of sucker harvest from the late 19th century describe a large fishery on the Lost River for fish migrating upstream from Tule Lake (Bendire 1889, p. 444; Gilbert 1897, p. 6). This fishery was eliminated by the construction of dams on the Lost River and the draining of Tule Lake for agricultural purposes. However, a large recreational fishery for suckers eventually developed in the Williamson and Sprague Rivers. In 1967, the Klamath Falls fisheries agent for the Oregon Fish and Game Commission was quoted in the newspaper as stating, “we’ve estimated that about 100,000 pounds—that’s 50 tons—of mullet [suckers] were snagged out of the two rivers in a three-week period” (Cornacchia, The Register-Guard, 07 May 1967). This snag fishery, which targeted primarily Lost River sucker but included shortnose sucker (Bienz and Ziller 1987, p. X), existed in the Williamson and Sprague Rivers up to 1987 when the Oregon Fish and Game Commission outlawed harvest of both species.

Up until 1987, fishing pressure during the spawning migration likely contributed to population declines in Lost River and shortnose sucker in the Williamson and Sprague Rivers, but the magnitude of the effect is difficult to discern due to a lack of data on population sizes and harvest quantities during most of the 20th century. At present, some Lost River and shortnose sucker are captured while anglers target other species in Upper Klamath Lake; however, the numbers are likely small, and anglers are required by law to immediately release the fish.

Climate Change

Annual average temperatures in the Upper Klamath Basin are expected to rise 2.1 to 3.6 °F from the 1960-1990 baseline by the decade of 2035-2045 due to climate change (Risley et al. 2012, p. 4; Barr et al. 2010, p. 8). At present, lethal temperatures for suckers are uncommon, but stressful temperatures for suckers occur with regularity (see the above section on Temperature). Climate change will increase the frequency and duration of these stressful temperature events and is likely to make high stress events more common.

Changes in precipitation are highly uncertain. Annual precipitation may increase or decrease overall under climate change (Barr et al. 2010, p. 8; Risley et al. 2012, p. 4). However, climate models consistently predict that a larger proportion of annual precipitation and run-off will occur as rain events in the winter (Barr et al. 2010, p. 9; Risley et al. 2012, p. 8). Warmer temperatures during the winter are also projected to reduce the proportion of precipitation falling as snow. Precipitation in the form of snow acts somewhat as a buffer for the hydrologic system, providing more gradual and manageable input into the lakes than rain. It is more difficult to predict the effects of precipitation changes to suckers, but they will alter the dynamics of spring flows, reducing the size of snow-melt runoff during the spawning season. This may restrict access to spawning areas in smaller watersheds, such as those entering Clear Lake and Gerber Reservoir, and reduce reproductive success when spawning is possible because larval production is correlated with the magnitude of spring flows (E. Childress, U.S. Fish and Wildlife Service, in preparation).

Klamath Basin Sucker Assisted Rearing Program

The USFWS started an assisted rearing program for Lost River and shortnose sucker in 2015 to supplement populations in Upper Klamath Lake through augmentation. The primary target of the effort is shortnose sucker, but the lack of an efficient way to identify larvae and juveniles means that both species are collected and reared. The Bureau of Reclamation proposed funding such a program as a way to improve the environmental baseline of the species to minimize impacts to suckers that may result from Klamath Project operations with a 10-year target of releasing a total of 8,000 to 10,000 suckers with lengths of at least 200 mm. The USFWS funded expansion of the program to an annual target level of 5,000 suckers through 2019 in an effort to meet goals outlined in the recovery plan.

The program was designed to maximize genetic diversity and maintain natural behaviors post-release as much as possible (Day et al. 2017, pp. 306 & 307). Larvae are collected as they drift downstream in the Williamson River, so no brood stock are maintained and the effects of artificial breeding are avoided. Collection efforts are currently spread across the drift season to maximize the genetic variability.

Juveniles are stocked into semi-natural ponds and growth depends on a combination of natural and artificial feed.

The first release of reared suckers into Upper Klamath Lake occurred in spring 2018, so the proportion of released individuals that will join the spawning population is unknown. Thus, the assisted rearing program is likely to be a source of recruitment for both shortnose and Lost River sucker in Upper Klamath Lake, but the impact on population trajectories will be uncertain until information on survival and recruitment probabilities of released individuals is available.

Environmental Contaminants

Contaminants from agricultural application of pesticides could be deleterious to suckers. However, an evaluation of pesticide use on Tule Lake National Wildlife Refuge concluded that the type and concentration of chemical applications were unlikely to harm suckers in Tule Lake (Haas 2007, p. 3). Mercury deposited from the atmosphere can be highly toxic to fish and wildlife when it is converted into methylmercury. Methylation is stimulated by repeated inundation and drying, which occurs in the wetlands around Upper Basin Lakes as well as on the lands of Tule Lake and Lower Klamath National Wildlife Refuges where lands are rotated between agricultural use and wetland habitat for waterfowl (Eagles-Smith and Johnson 2011, pp. 27-28). However, mercury concentrations measured in suckers and other fish from the Upper Klamath Basin in 1988-1989 were below the national average for all fish (Sorenson and Schwarzbach 1991, p. 41). Overall, there is not strong evidence that contaminants have contributed substantially to the decline of sucker populations in the Upper Klamath Basin.

Predation

Lost River and shortnose suckers evolved with substantial predation pressure on larvae and juveniles from native fish species, including redband trout (*Oncorhynchus mykiss newberrii*), blue chub (*Gila coerulea*), and Tui chub (*Gila bicolor*). Non-native fishes are a potential threat through predation or as sources of exotic diseases/parasites. Approximately 20 fish species have been accidentally or deliberately introduced into the upper Klamath River basin. These comprised about 85 percent of fish biomass in Upper Klamath Lake when the suckers were listed (Scoppettone and Vinyard 1991 p. 375, National Research Council 2004 p. 188-189). The introduced fish species most likely to affect Lost River sucker and shortnose sucker are the fathead minnow and yellow perch (*Perca flavescens*). Additional **exotic**, predatory fishes found in sucker habitats, although typically in relatively low numbers, include bullheads (*Ameiurus* species), largemouth bass (*Micropterus salmoides*), crappie (*Pomoxis* species), green sunfish (*Lepomis cyanellus*), pumpkinseed (*Lepomis gibbosus*), and Sacramento perch (*Archoplites interruptus*) (Koch et al. 1975 p 17, Logan and Markle 1993 pp 27-29).These fish may prey on young suckers and compete with them for food or space (Markle and Dunsmoor 2007, pp. 573-577).

Fathead minnows were first documented in the Klamath Basin in the 1970s and are now the most numerous fish species in Upper Klamath Lake (Simon and Markle 1997 p 146). Controlled experiments have demonstrated that adult fathead minnows prey on sucker larvae (Markle and Dunsmoor 2007, p. 573). In Upper Klamath Lake, higher fathead minnow abundances were associated with lower sucker survival rates (Markle and Dunsmoor 2007, p. 576). Likewise, as indirect evidence, higher larval sucker survival rates were also associated with greater water depth and shoreline vegetative cover, habitat which helps larvae avoid predation (Markle and Dunsmoor 2007, pp. 575 - 576). These data suggest that predation by overly-abundant fathead minnows may be an important threat to larval sucker survival and that loss of emergent wetland habitat may exacerbate this. Other non-native fishes may also pose a threat to Lost River sucker and shortnose sucker; however, little **quantitative** information exists to indicate their influence on sucker abundance and distribution.

Several species of birds can prey on Lost River sucker and shortnose sucker. Bald eagles have been observed preying on spawning suckers at Ouxy Springs (one of five areas where Lost River sucker spawn along the eastern shoreline of Upper Klamath Lake) and spawning areas near the Chiloquin Dam site. In Clear Lake Reservoir, radio-tags and Passive Integrated Transponders (PIT tags) of individuals of both species have been located on islands associated with nesting colonies of American white pelican (*Pelecanus erythrorhynchus*), double-crested cormorant (*Phalacrocorax auritus*), and great blue heron (*Ardea herodias*). Pelicans and double-crested cormorants can target juveniles and adults. There are also numerous other species of piscivorous birds, including terns, grebes, and mergansers, that may prey on juvenile and larval suckers throughout their range. Avian predation can be responsible for mortality of up to 8.4 percent of available juveniles and 4.2 percent of available adults annually in Clear Lake (Evans et al. 2016a, pp. 1261 & 1262). It is difficult to determine whether avian predation has increased or decreased relative to historic levels, but bird populations in general in the Klamath Basin have certainly declined from historic numbers. So, it is more likely that the absolute amount of predation has also diminished.

The primary effect of predation to the species is a reduction of numbers (i.e., resiliency), particularly of the smaller life stages. Predation on spawning adults also increases mortality rates of this crucial, sensitive life stage. Additionally, predation may alter behavior of targeted life stages. For example, predation on adults at spawning sites may limit the amount of time spent on the spawning ground. Alternatively, juveniles may select less optimal habitat if predation pressure is higher, which could be reflected in individual condition and eventually survival rates. These types of impacts could potentially have effects on diversity (i.e., representation) if differential predation occurs among various genetic groups due to differences in life history strategies or geographic locations. However, data are still relatively sparse on how predation is specifically impacting the survival rates of these species.

Disease and Parasites

Parasites were not identified as a threat at the time of listing, but recent information suggests they could be a threat to the suckers (Kent et al. 2017, entire). Kent et al. found substantial heart worms that indicate significant impacts to juvenile suckers, but the data set is not large enough to determine conclusively. Anchor worm parasitism on **age-0** suckers appears to be highly variable from year to year in Upper Klamath Lake (Bottcher and Burdick 2010, p 15), ranging from 0 to 40 percent annual infection rates between 1995 and 2008 (Simon and Markle 2007, pp. 15 & 19). Parasites can lead to direct mortality, provide a route for pathogens to enter fish (since they create a wound), or can make fish more susceptible to predation by altering behavior (Robinson et al. 1998, p. 599). Parasites were certainly part of the historical ecological landscape of the species, but it is possible that the advent of a hyper-abundant introduced species has also increased the higher number of potential hosts in the system. This could then increase the absolute number of parasites in the system, which could increase the infection rates of suckers. This phenomenon is known as parasite spillback.

The effects of parasitism and disease are effectively identical to the effects of predation presented above, namely a reduction of numbers or alteration of behavior that can ultimately be expressed as a reduction in average survival rates of a given life stage. We currently do not have enough information to accurately assess the degree to which parasites negatively impact sucker survival and productivity.

Sucker larvae also face threats from predation, disease, and parasites in Upper Klamath Lake; however, the scale of these impacts is largely unknown. Larvae are subject to predation by both native and non-native fish, including the non-native fathead minnow, the most abundant fish in Upper Klamath Lake. Laboratory trials have demonstrated that yellow perch, fathead minnow, blue chub, Tui chub, Klamath Lake sculpin (*Cottus princep*s), and slender sculpin (*Cottus tenuis*) all prey on sucker larvae (Markle and Dunsmoor 2007, p. 571; Hereford et al. 2016b, p. 8-12). The abundance of fathead minnow was also negatively correlated with abundance of sucker larvae around the margins of Upper Klamath Lake (Markle and Dunsmoor 2007, p. 573). The population level implications of this predation, as well as the impacts of disease and parasites, are largely unknown.

Parasites (Hereford et al. 2016a, p. 35) and predators (Markle and Dunsmoor 2007, p. 571; Evans et al. 2016a, p. 1260) have both been identified as an ultimate source of mortality for some juvenile suckers that would likely be increased under chronic stress. For example, low dissolved oxygen leads to gasping behavior in juvenile suckers (Saiki et al. 1999, p. 41), which increases exposure to avian predators near the lake surface. Initial study indicates that a minimum of 6-8 percent but more likely approximately 12-16 percent of juvenile suckers in Upper Klamath Lake are consumed by nesting pelicans and cormorants; juvenile suckers are likely susceptible to predation by other species such as Caspian terns, western grebes, and common mergansers (Evans et al. 2016a, p. 1265). Additionally, poor water quality is also likely to increase susceptibility of juvenile suckers to diseases and parasites. In a study of juvenile Lost River sucker survival in *in situ* cages in Upper Klamath Lake, most moribund fish were infested with *Ichthyobodo*, a protozoan parasite typically found in skin and gills (Hereford et al. 2016a, p. 35).

Hybridization and Introgression

Hybridization is a single interbreeding event between individuals of two species. Introgression is the subsequent incorporation of genetic materials into the genome of the species as a result of numerous hybridization events (i.e., back crossing). Introgression is common among suckers in general and well documented among the Klamath Catostomids, particularly between SNS and KLS (Dowling et al. 2016, p. 3). In theory, divergence between individuals of the one species is caused by some selective pressure that favors particular alternative strategies in life history, morphology, or other factors. As the groups become more dissimilar, reinforcement of the distinction can occur as barriers to reproduction arise.

Less complete barriers can allow gene flow (introgression) between the groups. The most typical result is dilution of the adaptations that characterize each individual species, generating intermediate forms and loss of specific characters that promoted distinction between the species. Ongoing introgressive hybridization is generally viewed as a negative effect because it potentially reduces diversity (representation), and the less numerically dominant species (and genes) is replaced by the alternate species. Additionally, this process may also reduce fitness if individuals are less specialized phenotypically to exploit specific niches within an environment. Depending on the degree of this reduction it could result in lower survival rates and reduced resiliency. It is also possible that introgression increases diversity by introducing new and beneficial mutations into species genomes. This would possibly increase diversity both within and among populations (Dowling et al. 2016, p. 2).

Water Management

The Bureau of Reclamation manages several reservoirs in the upper Klamath Basin to provide water for the 250,000-acre Klamath Project, which was established in 1905 as the second federal water project in the nation. The largest reservoirs include Upper Klamath Lake, Clear Lake Reservoir (both are modified natural lakes) and Gerber Reservoir. Numerous other public and private control structures are scattered throughout the range of the species. Water management creates the possibility of **entrainment** through water control structures into canals, ditches, and other modified habitats. Here we use the term entrainment to mean the transport (typically involuntary) of suckers at any life stage through any water control structure, regardless of whether it is into a canal or the **tailwaters** below a dam on an otherwise natural river.

We classify structures associated with water management into two types: those intended to impound water (such as dams) and structures intended to divert water at diversion points into canals. Much of the information associated with impoundment structures, particularly dams, is addressed above in the section on Habitat Loss. These structures alter the nature of the habitat both upstream and downstream, most often in ways detrimental to the viability of the species. For example, habitat below Clear Lake Dam no longer functions as a migration corridor for spawning individuals because of impassable barriers, and does not provide optimal habitat for **outmigrating** larvae given the unnatural flow patterns through the system. Conversely, the habitat above the dam has changed from a system with a large vegetated wetland associated with open water prior to the dam to a nearly homogenous open-water system with few emergent plants in most years. The impacts of lake levels on the species are addressed in the Habitat Loss and Water Quality sections of Chapter 3 above.

Suckers are most often entrained into canals or other unsuitable habitats. At the time of listing, thousands of suckers, including some adults, were entrained each year into the A Canal, the largest diversion canal in the upper basin. The impact of entrainment into this particular irrigation point of the Klamath Project was reduced by construction of screening facilities over the A Canal; although larvae are still at risk. Under the present design, fish screened from entering the A Canal are returned via pipeline to Upper Klamath Lake at a point that is near the river gates of the Link River Dam (Marine and Gorman 2005, p. 1). The most significant diversion is the A Canal near the outlet of Upper Klamath Lake. This canal diverts between 500 cubic feet per second (cfs) to 1,000 cfs between April and October (BOR 2000, p. 23). To reduce the impact to adult and juvenile sucker, the canal was fitted with a fish screen in 2003 (NMFS and USFWS 2013, p. 102). Adults are blocked from entering the A Canal by a trash rack with vertical slits that allows water to pass, but blocks anything greater than a couple of inches wide. The screen itself is behind the trash rack, and effectively prevents fish larger than 20 mm (0.8 in) in length from proceeding into the canal. An estimated 10-40 percent of fish between 10 and 14 mm (0.4 and 0.6 in) pass through the screen (Simon and Markle 2013, pp. 31-32,72). The fish screen has reduced adult and juvenile entrainment by approximately 73-94 percent; still, 10,000s to 100,000s of larvae of each species are entrained annually into the A Canal (Simon and Markle 2013, pp. 31-32). The screen prevents juveniles from moving into the A Canal by diverting them in a bypass channel that uses gravity to transport fish for release into the Link River just below the dam or pumps the fish through a track that eventually releases them back into Upper Klamath Lake about 0.5 km (0.31 mi) above the Link River dam. The pumps that divert fish back to Upper Klamath Lake are typically only operated during mid-July through September; so all larvae that reach this point either pass through to the A Canal or are diverted downstream into the Link River.

Substantial entrainment also occurs at the river gates of the Link River Dam (Marine and Lappe 2009, pp. 1-4) (Figure 12). More water passes through the Link River Dam than through the A Canal, but no fish screen has been installed due to logistical constraints; thus, larger numbers of larvae are likely to be entrained at the Link River Dam than at the A Canal (Simon and Markle 2013, pp. 32-33), but ultimately both systems insert the larvae at the same point in the Link River. During the late summer of 2006 through 2009, over 3,500 age-0 juvenile suckers were collected in the Link River just below the dam with intermittent sampling of a fraction of the channel (Laeder and Wilkens 2010, pp. 3-6; Wilkens 2010, p. 2). The Committee on Endangered and Threatened Fishes in the Klamath River Basin of the National Research Council recommended screening to prevent downstream losses at Link River Dam (National Research Council 2004, p. 348). Gutermuth *et al.* (2000, pp. 15-17) also documented tens of thousands of young suckers entrained at the PacifiCorp hydropower canals and turbines associated with the Link River Dam. These East Side and West Side hydroelectric diversion facilities (operated by PacifiCorp) that draw near the Link River Dam and run roughly parallel to the Link River are currently shut down between July 15 and November 15 to reduce entrainment when vulnerable life stages of listed suckers are present. PacifiCorp has also completed a Habitat Conservation Plan (PacifiCorp 2013, entire). The company plans to limit the operations of these canals for power production, and, if approved, to eventually shut them down (PacifiCorp 2013, p. 64). Flows are now only used for maintenance and to provide relatively small amounts of irrigation water.

Figure 12 The Link River Dam (constructed 1921) looking north towards Upper Klamath Lake. The cement extension on the left of the dam is the newly constructed (2004) fish ladder to permit passage for suckers and other species. The patch of white in the river immediately upstream of the dam is the original rock reef that maintained the elevations of Upper Klamath Lake. The channels that were carved into the reef to allow for lower lake levels can be seen along the shores on either side. The dam is 6.7 m (22 ft) tall.

Juvenile and larval suckers that are entrained through the Link River Dam or the bypass channel of the A Canal screen are most likely transported by flows in the Link River to Lake Ewauna where poor water quality conditions are common. Extremely low dissolved oxygen concentrations (< 1 milligram/liter) occur annually, often for multiple months (Kirk et al. 2010, p. 2.36). Thus, larval and juvenile suckers are unlikely to survive in Lake Ewauna after entrainment at Link River Dam. Historically some larvae and juveniles were likely transported to Lower Klamath Lake, which may have provided additional rearing habitat and suckers could subsequently return to Upper Klamath Lake, but Lower Klamath Lake was largely drained for agricultural use, and the remaining wetlands are no longer hydrologically connected to Lake Ewauna for fish passage. Thus, age-0 suckers that leave Upper Klamath Lake through the Link River encounter poor water quality without the additional suitable habitat that was historically available. These suckers are likely lost from the Upper Klamath Lake population. Small numbers of suckers that passed through the fish screen as larvae are recovered as juveniles from the canal system each year when it is drained in late fall, but most larvae that pass through the screen are presumed to die.

Until recently, most suckers that pass through the gates at Link River Dam, or that survive passage through the hydroelectric facilities, were believed to be entirely lost from the breeding population. It was assumed that these fish either die in poor summer water quality conditions in Keno Reservoir, or pass further downstream into reservoirs along the Klamath River, from which upstream passage is blocked. However, recent surveys by the Bureau of Reclamation have detected a relatively small population residing in Lake Ewauna, indicating that some percentage of suckers persist following passage through the Link River Dam gates or the hydroelectric facilities. A new fish ladder was also constructed at Link River Dam in 2004 through which adult suckers have been documented (using PIT tag readers) moving upstream through Link River. Nevertheless, the number of detections of tagged fish traversing the fish ladder from Link River into Upper Klamath Lake each year typically numbers around 25 individuals.

There are also significant unscreened diversion structures that divert water from Lake Ewauna, including the Lost River Diversion Channel and Ady Canal, but we aren't aware of any data indicating the amounts of entrainment through these structures. In addition to major diversion points, several hundred small, typically unscreened diversions in tributary streams and rivers and the lakes proper may also affect Lost River sucker and shortnose sucker. In 2001, the Bureau of Reclamation reported 193 diversions within the Klamath Project that were "directly connected to endangered sucker habitat below Upper Klamath Lake," with only three of these diversions equipped with fish screens (Bureau of Reclamation 2001: 2). The Bureau also noted there are at least 24 large diversions outside of the Klamath Project service area but within the range of the species that have the potential of entraining suckers (Bureau of Reclamation 2001: 3). The influence on sucker abundance and recovery of these diversions is unknown.

The Clear Lake Dam was rebuilt in 2003. The gates were screened at this time to prevent any fish larger than 30 mm (1.18 in) from being entrained through the dam into a system that generally lacks suitable sucker habitat. However, challenges with seating the screen well in the substrate at times does permit juveniles to pass through the dam in addition to larvae. Sutphin and Tyler (2016, p. 10) estimated that more than 260,000 larval suckers and 3,659 juvenile suckers were entrained through the dam from late April to late July 2013. The gates at Gerber Reservoir are unscreened and can permit all life stages of shortnose sucker to pass into Miller Creek (which becomes dewatered each year after the irrigation season), but we do not have any estimates of how many are actually entrained.

CHAPTER 4 – CURRENT CONDITION

In this chapter we describe the current status (in terms of resiliency, redundancy, and representation) of Lost River and shortnose sucker across their range. To avoid unnecessary repetition, we try to minimize the discussion of the habitat conditions and effects, which are discussed in detail in Chapter 3. The purpose of this chapter is not so much to present the relative changes in resiliency, redundancy, and representation compared to historic levels, but to describe the current levels of these parameters.

It is clear that the abundance of suckers has greatly diminished compared to historic levels – a reduction in resiliency. Also, the loss of a number of suitable lake habitats and their associated populations has reduced redundancy for both species. However, the specific causes of these conditions are often complex and at times unclear. We have created a simplistic conceptual model to present what we consider to be the most likely, or relevant, causal factors (Figure 13).

Resiliency, redundancy, and representation are all inter-related. For example, the two spawning subpopulations of Lost River sucker in Upper Klamath Lake are redundant, which increases the resiliency of the population as a whole. In the sections below we describe the conditions for each of the 3 R's of conservation while noting the areas of connection among the three.

Population Resiliency

Upper Klamath Lake contains the largest remaining populations of both Lost River and shortnose suckers with approximately 100,000 adult Lost River sucker river-spawners, 8,000 adult Lost River sucker shoreline-spring-spawners, and 19,000 adult shortnose suckers (Figure 14). Nevertheless, the resiliency of these populations has been dramatically reduced compared to historic levels. We consider the resiliency of both species in this population to be very low, although Lost River sucker are somewhat more resilient than shortnose sucker because they have greater numbers and two spawning subpopulations. The low resiliency is due to numerous inter-related factors. The primary cause for both species is a lack of recruitment of new individuals to the adult populations. This lack of recruitment has led to sharp declines in population sizes (Hewitt et al. 2017a, p. 30). The primary limiting factor for the population appears to be juvenile survival because successful reproduction occurs annually and adult survival is relatively high.

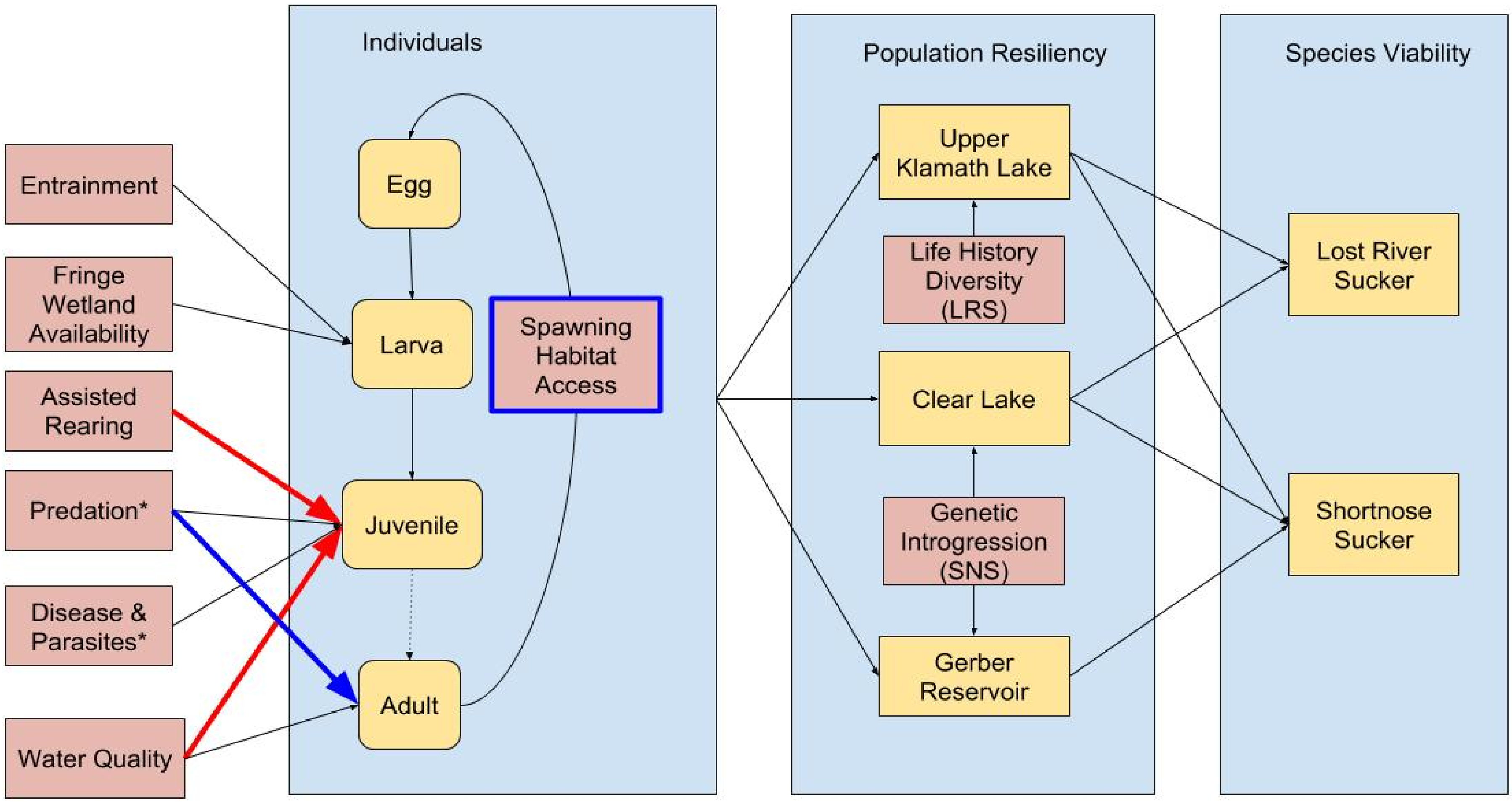


Figure 13 A simplistic conceptual model of the likely or most relevant causal factors impacting the status of the species. The pink boxes represent the causal factors, with arrows pointing to life stages or populations that we believe the factor affects. Bolded arrows represent factors believed to be strongest for that life stage, and the colored arrows (and box outline) indicate specific populations: red = Upper Klamath Lake, blue = Clear Lake Reservoir, and black = all populations. Individuals are affected by the specific causal factor and subsequently provide resiliency to the populations, as indicated by the middle blue box. Population-level causal factors are indicated here. Lastly, population contributes to the viability of the species. The attribute of redundancy is portrayed in the number of populations of each species.

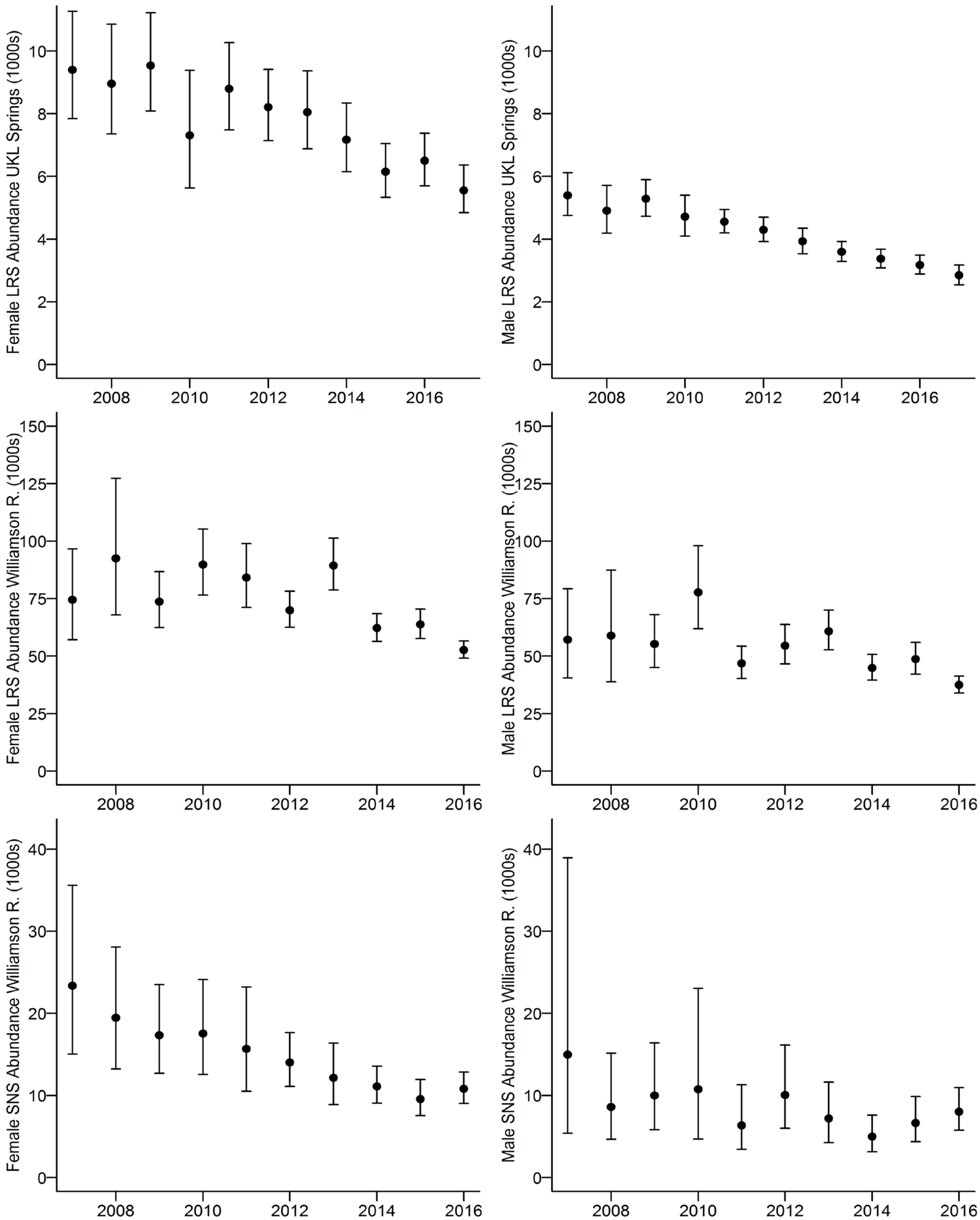


Figure 14 Estimated abundance of spawning Lost River and shortnose sucker from Upper Klamath Lake. Points represent the mean estimate and error bars indicate the 95 percent credible interval.

The Lost River sucker population that spawns in the Williamson River drainage has declined by approximately 60 percent since 2002 (Hewitt et al. 2017a, p. 22). In 2016, there were an estimated 49,074-56,546 (95 percent credible interval) female Lost River sucker and 33,920-41,251 (95 percent confidence interval) males spawning in the Williamson River (E. Childress, unpublished data). Lost River sucker that spawn at the lakeshore groundwater seeps is much smaller than the river-spawning population of Lost River sucker, with an estimated 4,847-6,360 (95 percent confidence interval) females and 2,538-3,170 (95 percent confidence interval) males spawning in 2017 (Figure 14, E. Childress, unpublished data). Similar to the Williamson River population, this lakeshore spawning population has declined an estimated 56 percent since 2002 (Hewitt et al. 2017a, p. 16). The shortnose sucker population in Upper Klamath Lake has also declined substantially since 2001, losing approximately 75 percent between 2001 and 2014 (Hewitt et al. 2017a, p. 25). Despite the steep declines in Upper Klamath Lake populations of Lost River and shortnose sucker, the size of the populations still provides some resilience to typical disturbances, but these levels are likely relatively miniscule when compared to historic levels.

Both species spawn successfully in the Sprague River, producing larvae that drift downstream to Upper Klamath Lake. Captures of 1,000s to 10,000s of larvae from the Sprague and Williamson Rivers (Cooperman and Markle 2003, 1146-1147; Ellsworth and Martin 2012, p. 32) conservatively suggest that combined larval production of both species is on the order of 100,000s to 1,000,000s; note that these numbers are ballpark estimates and not a characterization of inter-annual variation, which is also substantial. Despite the removal of Chiloquin Dam on the Sprague River in 2008, the majority of spawning activity still occurs downstream of the former dam site with less than 10 percent of fish moving beyond the historic dam site. It is uncertain whether spawning further upstream would result in higher reproductive success or increased size or condition of larvae when they return to Upper Klamath Lake. Successful spawning in the Sprague River suggests that the needs of both species for spawning access and suitable egg incubation habitat are met; however, information on historical conditions is not available to compare with the limited data on recent years of larval production, so it is not possible to evaluate if current conditions are suboptimal in the Williamson and Sprague Rivers.

Lost River sucker also spawn successfully at groundwater seeps along the Upper Klamath Lake margin. There is typically access to these areas between February and May; however, lake elevations lower than approximately 4141.40-4142.0 ft (1262.3-1262.5 m) reduce the number of spawning individuals and the amount of time spent on the spawning grounds (Burdick et al. 2015b, pp. 487 & 488). Upper Klamath Lake elevations less than 4142.0 ft (1262.5 m) occurred by May 31 in six years between 1975 and 2017, which is equivalent to 14 percent of spawning seasons. Thus, lake elevations have the potential to negatively impact spawning for Lost River sucker, but this has rarely occurred over the last 43 years.

Production of sucker larvae in Upper Klamath Lake varies annually but occurs in all years. Sucker larvae are found in higher densities within and adjacent to emergent wetlands (Cooperman and Markle 2004, p. 370). The availability of these habitats varies with lake elevation (Dunsmoor et al. 2000, p. 19). Before the installation of Link River Dam, minimum annual lake elevations were typically greater than 4140.0 ft (1262.3 m) (Figure 11), with most of the fringe wetland habitat inundated during much of the summer.

Mean end-of-July lake elevations were similar between the pre-dam period and recent years 1997 and 2017 (Figure 11).However, end-of-month lake elevations in August and September are substantially lower under modern water management practices compared to pre-dam elevations and substantially reduce the amount of inundated wetland habitat. Although the population level implications of this management change are difficult to determine, reductions in available wetland habitat are likely to decrease larval and juvenile survival and thereby reduce the resiliency of the populations.

The number of juveniles captured during sampling efforts typically decreases in late summer, and very few individuals are captured at age-1 or older (Burdick and Martin 2017, p. 30), suggesting complete **cohort** failure each year. These declines occur during the periods with the most degraded water quality conditions in Upper Klamath Lake, but a clear empirical link between water quality parameters and mortality rates has not been conclusively established. One prominent hypothesis is that water quality is directly responsible for the unnaturally high levels of juvenile mortality. Another is that water quality interacts with other sources of mortality to lead to the persistent cohort failure by causing chronic stress that renders the individuals more susceptible to forms of predation or infection (as described in Chapter 3). The specific causes of repeated cohort failure at the juvenile stage are a critical uncertainty preventing recovery because juvenile mortality is the primary factor that contributes to the low resilience of both Lost River and shortnose sucker populations in Upper Klamath Lake.

Adult survival for Lost River and shortnose sucker is consistently high in Upper Klamath Lake, though annual survival rates vary somewhat between the species and spawning locations. Both spawning subpopulations of Lost River sucker in Upper Klamath Lake have experienced an average annual survival rate of 0.91 percent between 2002 and 2013 (range: 0.80-0.96 percent) (Hewitt et al. 2017a, pp. 15 & 21). Shortnose sucker experienced average annual survival rates of 0.84 percent between 2001 to 2013 (range: 0.69 – 0.95 percent) (Hewitt et al. 2017a, p. 28). Survival estimates of other populations are not possible due to a lack of data.

Clear Lake Reservoir currently supports the largest populations of both endangered suckers in the Lost River drainage. Data for the Clear Lake populations are very limited compared to those in Upper Klamath Lake, but we can make some generalizations. Recent monitoring data suggest that the status of both species in Clear Lake Reservoir is tenuous given low resiliency.

Despite our inability to accurately estimate absolute abundance of the populations due to the lack of robust data, the low numbers of captures and recaptures suggests that these populations are smaller than those in Upper Klamath Lake. This is particularly true for Lost River sucker. Between 2004 and 2010, only 1,360 individual Lost River sucker were captured in Clear Lake Reservoir (Hewitt and Hayes 2013, p. 5). In comparison, captures in Upper Klamath Lake of Lost River sucker averaged over 2,000 individuals annually with more than 12,000 individuals captured during this same time period (Hewitt et al. 2017a, p. 12). Clear Lake is sampled in the fall whereas Upper Klamath Lake is sampled in spring and the fish may be more congregated in preparation for spawning migrations, but the sheer magnitude of the difference suggests that the Lost River sucker population in Clear Lake Reservoir is much smaller than the Lost River sucker population in Upper Klamath Lake. The Clear Lake Lost River sucker population also appears to be much smaller than the Clear Lake Reservoir shortnose sucker population. Over the 2004 to 2010 period, 4.5 times as many individual shortnose sucker (6,240 individuals) were captured in Clear Lake Reservoir compared to Lost River sucker (Hewitt and Hayes 2013, p. 6). The average annual captures of individual SNS in Clear Lake Reservoir (1,040 per year) is comparable to Upper Klamath Lake rates (1,350 individuals) and may suggest that the population sizes are similar.

Several factors may contribute to the low population resiliency in Clear Lake Reservoir. One is access to spawning habitat. When conditions permit access, adults ascend Willow Creek, the single major tributary flowing into Clear Lake Reservoir, spawn successfully, and produce juvenile cohorts in Clear Lake Reservoir (Buettner and Scoppettone 1991, 47-48; Sutphin and Tyler 2016, 10). However, adult access to Willow Creek is limited by lake levels and sufficiently high stream flows, and successful larval production also depends on stream flows high enough to permit subsequent downstream migration of drifting larvae (Hewitt, forthcoming).

One important source of larval mortality in Clear Lake Reservoir is predation by several native or non-native aquatic species, including blue chub, fathead minnow, Sacramento perch, or bullfrog. Also, entrainment by flows through the Clear Lake dam into the Lost River appears to be a significant impact to suckers and juveniles. Although a fish screen was installed when Clear Lake dam was replaced in 2002, it is estimated over 250,000 larval and 3,600 juveniles suckers were entrained through the dam in 2013 (Sutphin and Tyler 2016, p. 10). Nevertheless, when spawning conditions are suitable for producing strong annual cohorts (estimated to be slightly less than half of the years (Hewitt, forthcoming)) juveniles, particularly shortnose sucker, can survive to recruit to the adult population. Evidence for this is seen in the multiple age classes of juveniles captured during sampling (Burdick and Rasmussen 2013, p. 14), as well as the diverse size class distributions of adults (Hewitt forthcoming, p. 33). Lost River sucker adults in Clear Lake Reservoir possess restricted size class distributions (Hewitt forthcoming, p. 31). The cause of this distinction is not clear, nor are there generally accepted hypotheses that could be discussed.

Gerber Reservoir is only inhabited by shortnose sucker and the non-listed Klamath largescale sucker. This population of shortnose sucker is considered similar in population dynamics to Clear Lake Reservoir populations, but data are much sparser. Surveys of the population in Gerber Reservoir were last conducted in 2006. Based on mark-recapture data from 2004 (Leeseberg et al. 2007, entire), 2005, and 2006 (Barry et al. 2007, entire), the population of shortnose sucker may have been as high as 42,000 individuals. In 2015, drought conditions reduced water levels within the reservoir to approximately 1 percent of the maximum storage. This undoubtedly reduced shortnose sucker numbers because of the limited available habitat, but we don't have specific data to accurately estimate the extent of this reduction although BOR will be initiating population monitoring work in 2018.

The outlet of Gerber Reservoir does not have a fish screen, so suckers are vulnerable to entrainment downstream into Miller Creek, which historically connected to the Lost River, but is now completely blocked and diverted for irrigation purposes. Small numbers of juvenile suckers (10s to 100s per year) have been caught in Miller Creek (Shively et al. 2000, p. 89; Hamilton et al. 2003, 3-4), but the proportion of juveniles entrained and the population impacts of entrainment are unknown.

Resiliency of the other populations scattered throughout the range of the species is considered to be very low based on limited surveys (Desjardins and Markle 2000, pp. 14 & 15; Hodge and Buettner 2009, pp. 4 - 6; Kyger and Wilkens 2010, p. 3).

Redundancy

Redundancy of populations for these species has always been relatively low. Pre-settlement populations probably numbered no more than four for each species. Redundancy for both species has been greatly reduced due to the destruction of at least two major populations (Lower Klamath Lake and Tule Lake) as well as numerous subpopulations or spawning locations, namely at springs throughout Upper Klamath Lake and the Lost River. The draining of Tule Lake and Lower Klamath Lake for agricultural use essentially eliminated two of the major water bodies inhabited by both species. Lower Klamath Lake is completely extirpated and Tule Lake has a very small number of individuals that lack access to suitable spawning habitat. Because of this, Tule Lake isn't considered to provide substantial redundancy for the species. These water bodies represented two of the three major lake/marsh complexes in the Upper Klamath Basin; the remaining one is Upper Klamath Lake, which supports the largest extant populations of both species.

Although large swaths of habitat were destroyed throughout the range of the species, some of the developments for agricultural use increased available habitat for Lost River and shortnose suckers. In particular, Clear Lake was enlarged and lake elevations were stabilized by the creation of Clear Lake Reservoir. This increased the amount of accessible habitat available for this population, but it is unclear how this may have also affected the quality of habitat – for better or for worse. Clear Lake Reservoir supports populations of both Lost River and shortnose sucker at present. Additionally, the construction of a dam on Miller Creek to create Gerber Reservoir in the Lost River drainage created new **lacustrine** habitat in the reservoir that currently supports a population of shortnose sucker. Reservoirs constructed for hydropower production along the main stem of the Klamath River also support small numbers of suckers, but there is no evidence that these populations reproduce. Removal of these Klamath River dams is being planned so it is very unlikely that these populations will provide redundancy for the species in the future. Suckers were historically able to move among the various lake habitats, at least during periods of high water. There are important differences in the status and threats to the remaining populations, so the details for each location will be discussed separately.

In terms of redundancy within a population, only the Lost River sucker in Upper Klamath Lake currently have more than one substantial spawning subpopulations. This provides some redundancy, albeit small, because of the low number of spring-spawners and the temporal and spatial overlap of spawners and adult habitat. For example, climate change will likely reduce snow pack and therefore reduce spring run-off in the river because of warmer temperatures and more precipitation falling as rain (Markstrom et al.

2012, entire; Risley et al. 2012, entire). These changes may reduce spawning success in the Williamson and Sprague Rivers, but are unlikely to impact the groundwater seeps in the same way.

There are four primary spawning areas along the eastern shoreline (Sucker, Silver Building, Ouxy, and Cinder springs), which are all within 6 km (3.7 mi) of each other. This proximity makes these spawning sites of reduced utility in resisting catastrophic disturbances. In addition to these extant spawning locations, there were additional historical spawning subpopulations at Barkley Springs, Harriman Springs and likely other springs throughout Upper Klamath Lake. These subpopulations have disappeared completely, greatly reducing the redundancy within the population. This loss increases the sensitivity of the population to widespread or catastrophic disturbances.

Both species in Clear Lake are entirely dependent on the Willow Creek watershed for spawning habitat. Lost River sucker utilize the lower portions of the creek as far as the confluence with Boles Creek, as well as Boles Creek (a tributary to Willow Creek) as far as Avanzino Reservoir (approximately 43 km [27 mi]). Shortnose sucker ascend both Willow Creek and Boles Creek much further than LRS (approximately 143 km [89 mi]). This provides a small amount of resilience for the SNS population in Clear Lake Reservoir, but the linkage between the two streams suggests that the redundancy benefit provided is minimal. It is not clear why LRS do not utilize the higher reaches of Willow Creek, especially because LRS are the species that travel the greater distance in the Sprague River.

There are at least two distinct spawning tributaries for shortnose sucker in the Gerber Reservoir system: Barnes Valley Creek and Ben Hall Creek. Approximately 88 percent of the adults leaving Gerber Reservoir to spawn ascend Barnes Valley Creek. The presence of two spawning streams creates some redundancy within the population that may help to increase the probability of successful spawning each year, as well as reduce the risk of localized catastrophic events, but the unbalanced utilization of the sites may reduce that benefit somewhat.

Listed Klamath suckers also occur in small numbers in a handful of other waterbodies. These populations are comprised almost exclusively of shortnose sucker, but a handful of Lost River sucker have also been detected. The shortnose sucker are found in Lake Ewauna, Tule Lake, the main stem reservoirs, and the Lost River proper (Shively et al. 2000, pp. 82 - 86). Lake Ewauna probably functions as a subpopulation to Upper Klamath Lake to some degree. Hundreds of listed suckers (both species) have been captured, tagged, and translocated to Upper Klamath Lake from Lake Ewauna since 2010 (Kyger and Wilkens 2010, p. 3; Banet, U.S. Geological Survey Forthcoming). Similarly, hundreds of individuals of both species were captured in Tule Lake during a three-year effort (Hodge and Buettner 2009, pp. 4 - 6). A two-year effort in the main stem reservoirs on the Klamath River (Desjardins and Markle 2000, pp. 14 - 15) produced slightly more than 200 captures, 99 percent of which were shortnose sucker. The number of catches given the effort suggests that these populations possess very few individuals. Lost River sucker only occur in Tule Lake in addition to the populations discussed above (Shively et al. 2000, pp. 87 - 89). All of these minor populations possess extremely low resiliency due to a combination of degraded habitat, low numbers, and restricted access to suitable spawning habitat.

Representation

Representation of diversity within and among populations of each species is difficult to quantify. **Hybridization** and **introgression** between shortnose sucker and Klamath largescale sucker is well documented, and evidenced by both phenotypic intermediates in morphology (Markle et al. 2005, p. 476) and lack of discrimination using molecular markers (Dowling et al. 2016, p. 19). However, morphological distinctiveness of species varies by location (Markle et al. 2005, p. 476). Spawning between these species is partially isolated temporally and spatially (Markle et al. 2005, p. 480). In Upper Klamath Lake morphological attributes of both species are more or less maintained, while other populations such as Gerber and Clear Lake reservoir show a spectrum of morphological intermediates(Dowling et al. 2005, pp. 21 & 22). Despite genetic evidence of hybridization, the access to a diversity of habitats presumably maintains adaptation of both species.

Genetic representation is reduced for both species in Clear Lake Reservoir as compared to conspecifics in Upper Klamath Lake. Both species were observed to have lower heterozygosity and allelic richness compared to conspecifics in Upper Klamath Lake (Smith and VonBargen 2015, p. 24). Lower genetic diversity could be due to the population being derived from a limited number of individuals trapped when the dam was installed (i.e., founder effects) or simply due to genetic drift associated with small population size. Additionally, lack of connectivity with other populations also further depresses genetic diversity via reduced gene flow. Of more importance, the shortnose sucker population in Clear Lake Reservoir is highly introgressed with Klamath largescale sucker (Tranah and May 2006, p. 313; Dowling et al. 2016, entire). Shortnose sucker are more genetically similar to Klamath largescale within the same subbasin than they are to conspecifics from the other subbasin (Smith and VonBargen 2015, p. 14). Within the Lost River subbasin, shortnose sucker and Klamath largescale sucker can be difficult to distinguish morphologically. This can potentially erode species distinctiveness (genetic representation) within the population as well as reduce the abundance of phenotypic shortnose sucker (i.e., abundance of individuals that possess the morphology associated with shortnose sucker and thereby reduce the overall resiliency of the species within the reservoir). Genetic representation within the Gerber Reservoir population is very similar to that of Clear Lake Reservoir. The shortnose sucker are highly introgressed with Klamath largescale, and the population is completely disconnected from other populations.

Unlike the shortnose sucker, hybridization and introgression involving the endangered Lost River sucker does not appear to be extensive (Dowling et al. 2016, 18). At present, both endangered suckers in Upper Klamath Lake are characterized by population sizes large enough to maintain genetic diversity and prevent the negative effects of inbreeding. We cannot make similar conclusions about other populations because we lack accurate estimates of population sizes.

The draining of Tule Lake and Lower Klamath Lake and the construction of dams and irrigation structures has isolated the populations such that there is no exchange of individuals between the major remaining populations in Upper Klamath Lake, Gerber Reservoir, and Clear Lake, and the system no longer functions as a metapopulation. This reduction of redundancy and connectivity could also have negative impacts on representation of diversity within the species.

Maintenance of ecological and phenotypic distinction between shortnose sucker and Klamath largescale in Upper Klamath Lake suggest that introgression between these species does not threaten the resiliency of the endangered shortnose sucker population in Upper Klamath Lake. However, the resiliency of the shortnose sucker populations in Clear Lake Reservoir and Gerber Reservoir may be reduced because fewer individuals possessing the distinct genetics and ecology of the species occur.

Species Level Conditions

Lost River Sucker

Overall resiliency for this species is generally low, primarily because redundancy is critically low (Table 3). There are only three distinct spawning populations: Upper Klamath Lake-springs, Upper Klamath Lake-river, and Clear Lake Reservoir. Two of the remaining populations (Clear Lake Reservoir and Upper Klamath Lake-springs) have very low numbers and are at a high risk of localized catastrophic events, such as fish kills due to poor water quality. The Clear Lake Reservoir population is completely separated from the others. The population that spawns at the eastern shoreline springs of Upper Klamath Lake is unique for both species; it is the only known spawning congregation outside of a river environment. This is a form of ecological redundancy that could provide resilience in Upper Klamath Lake in the face of relatively minor or localized disturbances. However, juveniles produced from both spawning populations are subject to similar conditions in Upper Klamath Lake, and both experience recruitment failure as a result of juvenile mortality.

As a species, Lost River sucker appear to be relatively genetically distinct. Only about 2.0 percent of Lost River sucker mitochondrial DNA suggests introgression with other species. This is the lowest of all the sucker species within the basin (Dowling et al. 2016, pp. 12-13). Nevertheless, the known genetic distinction from shortnose sucker is still relatively low (Hoy and Ostberg 2015, p. 675). Given these conditions the species was determined previously to have a high degree of the threat of extinction and a low recovery possibility (recovery priority number 4C) (USFWS 2013a, p. 3).

Shortnose sucker

Shortnose sucker also suffer from low resiliency as a species, despite having relatively high apparent redundancy compared to Lost River sucker. The low resiliency is due to the extremely low numbers in most populations, inadequate access to suitable spawning habitat for most populations, and genetic impurity in most populations (i.e., impaired representation). There are currently only three known spawning populations (Upper Klamath Lake, Clear Lake Reservoir, and Gerber Reservoir). There may be an additional two populations (Lake Ewauna and Topsy Reservoir – a Klamath main stem reservoir) where spawning could potentially occur, albeit in very small numbers. In Upper Klamath Lake there are fewer shortnose sucker than Lost River sucker, by nearly an order of magnitude, but shortnose sucker is more abundant than Lost River sucker in the Lost River subbasin overall. However, the number of populations is effectively reduced when we consider the high levels of genetic introgression with Klamath largescale sucker, and all of the populations are characterized by low abundance. Given these dynamics the species overall has been determined previously to have a high threat of extinction and a low recovery probability (recovery priority number 5C) (USFWS 2013c, p. 3).

Table 3 Population attributes for endangered suckers in the upper Klamath Basin. Locations are UKL – Upper Klamath Lake, CLR – Clear Lake Reservoir, GBR – Gerber Reservoir, and others (such as reservoirs on the Klamath River, Lake Ewauna, and Tule Lake sump 1A).

Species	Location	Population Size	Reproductive Success	Larval/Juvenile Entrainment	Larval/Juvenile Survival	Adult Survival	Resiliency	Representation	Redundancy (species)
SNS	UKL	Moderate	Presumed Adequate	Moderate	Low/Zero	High	Low	Moderate	
SNS	CLR	Moderate	Intermittent	Moderate	Moderate	Moderate	Low	Impaired	Moderate
SNS	GBR	Low	Intermittent	Moderate	Presumed Adequate	Presumed Adequate	Low	Impaired	
LRS	UKL	High	Presumed Adequate	Moderate	Low/Zero	High	Moderate	Moderate	Low
LRS	CLR	Low	Intermittent	Moderate	Moderate	Moderate	Very Low	Unknown	
LRS/SNS	Other	Low	Low/Zero	Moderate	Low/Zero	Presumed Adequate	Very Low	Unknown	NA

CHAPTER 5 — FUTURE CONDITION

The purpose of this chapter is to identify plausible scenarios that may occur in the future, and provide assessments of how we believe specific populations of Lost River sucker and shortnose sucker will respond. Where data are sufficient we strive to be quantitative, but in many cases limited data compel us toward qualitative assessment. We assess the scenarios over a window of approximately 50 years, which was chosen to be long enough that biologically meaningful changes could occur in the ecosystem and/or the demography of the species, but short enough to provide some confidence in projections.

We address the two major populations (Upper Klamath Lake and Clear Lake Reservoir) of each species separately, including a status quo scenario as well other threat-specific scenarios. These populations are treated separately because the major threats, and therefore solutions to population declines, differ between the systems. The Gerber Reservoir shortnose sucker population is expected to behave similarly to the population in Clear Lake Reservoir. Similar scenarios were not completed for other smaller populations (e.g., Lake Ewauna, Tule Lake) due to a lack of data to support realistic scenarios and the minimal contribution of these populations to species viability. Any number of hypothetical scenarios could have been addressed, but our intent here is to only include scenarios that are both plausible and relevant. In some instances, we were unable to specifically address relevant threats because no plausible scenarios could be developed that would relate to changes in the dynamics of that threat. For example, creating feasible scenarios that involved alteration of the rates of genetic introgression between shortnose sucker and Klamath largescale sucker proved difficult. In other cases (parasite infection rates for example), scenarios were not considered because we did not believe that those factors currently play a major role in population dynamics, and probable outcomes would apparently differ very little from the status quo.

Several factors create difficulties in projecting Lost River and shortnose sucker population responses into the future. Ecosystem function and species ecology are complex, and data are lacking on important demographic rates (such as egg viability, larval survival, etc.) as well as their responses to changes in the environment. Most importantly, the lack of adequate data on recruitment rates for any population—and the lack of recruitment in Upper Klamath Lake specifically—make it difficult to evaluate the response of this critical demographic rate to changes in environmental conditions with much certainty. The magnitude of direct and indirect ecological pathways, as well as interactive effects, also presents a noteworthy information gap. The sections below reflect our best understanding of the probable outcomes to these select possible future scenarios. Nevertheless, we believe this exercise is beneficial because it provides a framework to characterize expectations and illuminate potential management priorities to achieve recovery.

Upper Klamath Lake

Status Quo

Populations of Lost River sucker and shortnose sucker in Upper Klamath Lake do not appear to be successfully recruiting. New, small individuals are not found among spawning adults, which would be expected if younger individuals were joining the spawning population, and juveniles disappear from the system within the first 1-2 years of life. If we assume that this pattern continues into the future, future population trajectories can be simulated simply using estimates of current population size and adult annual survival rates. This analysis was conducted combining abundance estimates (E.S. Childress, unpublished data, Figure 14) and annual survival estimates (Hewitt et al. 2017a, pp. 15, 21, & 28) to simulate population trajectories for 50 years (J. Rasmussen and E.S. Childress, unpublished data). Current population sizes are estimated to be approximately 90,000 Lost River sucker spawning in the Williamson and Sprague Rivers, 8,000 Lost River suckers spawning at the lakeshore groundwater seeps, and 19,000 shortnose suckers. Annual survival estimates were sex-specific and simulated as random draws from a distribution fit to the empirically-derived survival estimates. In this approach, each simulation provides a unique trajectory, and together they represent the range of expected outcomes given the model assumptions.

Without additional recruitment, these simulations indicate point estimates for the probability of extirpation of SNS males from Upper Klamath Lake are 47 percent by year 2040 and greater than 99 percent by year 2046 (Figure 15 a,b). Females have a higher average annual survival rate and are projected to remain in the system longer with a probability of extirpation of 42 percent by year 2046 and greater than 99 percent by year 2054. Similarly, the LRS groundwater seep spawning population is projected to lose all males with a probability of 48 percent by year 2047 and 99 percent by year 2052 (Figure 15 c,d). Females from this population are projected to persist in small numbers at the end of 50 years (2067) with an average projection of 150 remaining individuals (range: 0-295). The larger numbers of LRS remaining in the Williamson River spawning population lead to projections of 0 percent probability of extirpation in spite of slightly lower annual survival rates than the groundwater seep population. However, the number of remaining individuals is projected to be quite small with an average estimate of 317 males (range: 80-904) and 1,341 females (range: 824-1,972).

These results portend a dire future for Upper Klamath Lake sucker populations if conditions do not change. Shortnose sucker would be completely lost, substantially reducing the redundancy of SNS overall through the loss of one of the three existing populations. Loss of SNS from Upper Klamath Lake would also substantially reduce representation because it is the least genetically introgressed with KLS and is the only remaining population with clear morphological distinction between the species. LRS may not be completely lost from the system after 50 years, but resiliency would be dramatically reduced. The small number of remaining individuals would be less resilient to disturbance events, and life history diversity would be lost through the elimination of one of two spawning populations. Further, reduced population resiliency would likely result in the loss of rare alleles, and as such, potentially limit adaptive ability to future environments. Representation would also be substantially reduced through a genetic bottleneck. At present, the LRS Upper Klamath Lake population represents one of two extant populations and by far the largest population; its loss or reduction to 1-2 percent of current abundance would put the species on the brink of extinction.

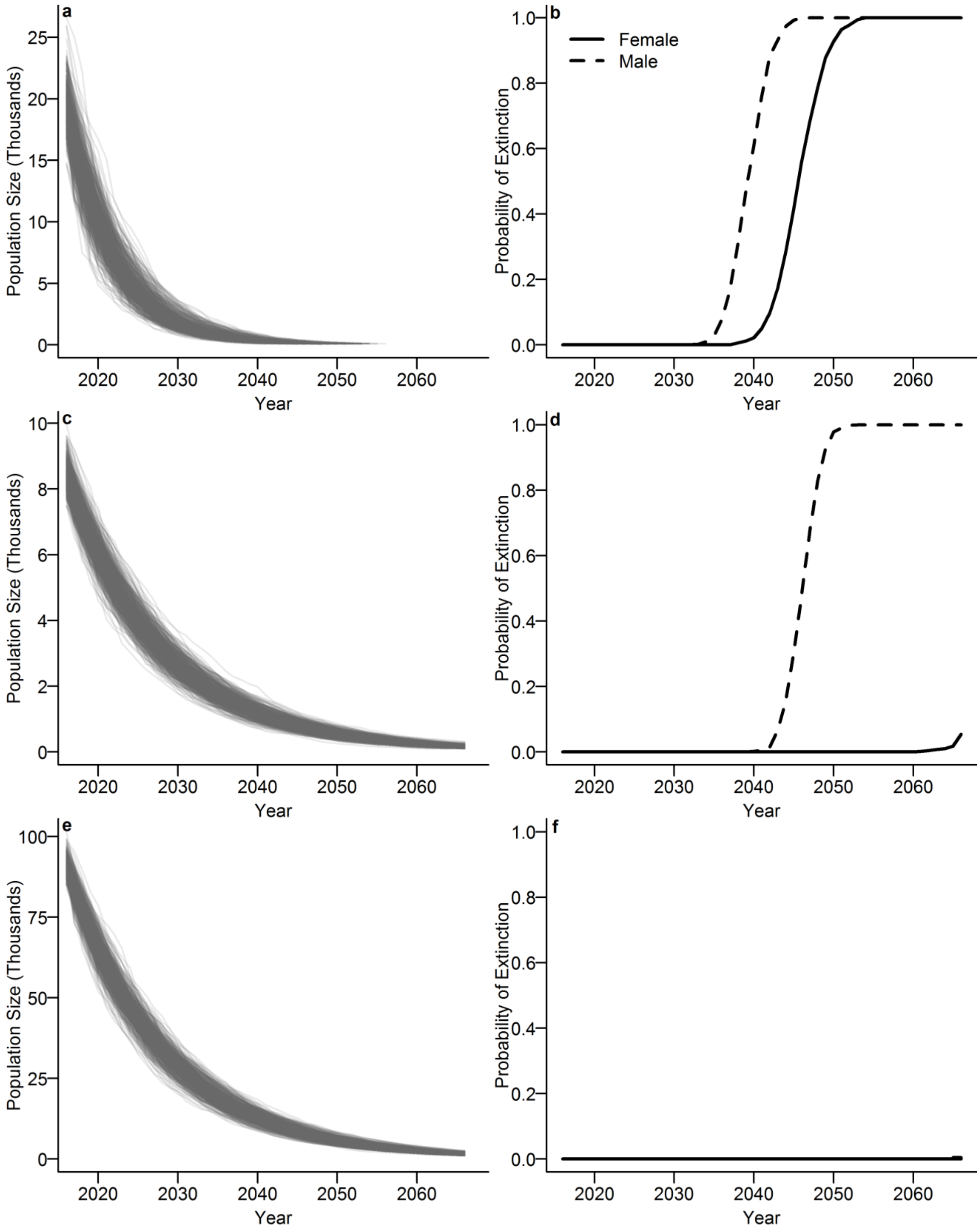


Figure 15 Simulated population trajectories (a,c,e) and probability of extinction (b,d,f) for Upper Klamath Lake sucker populations of shortnose sucker (a,b), Lost River sucker spawning at the lakeshore groundwater seeps (c,d), and Lost River sucker spawning in the Williamson River (e,f). These trajectories assume no new recruitment of individuals to the adult spawning population (reproduced from Rasmussen and Childress, unpublished data).

Klamath Basin Sucker Assisted Rearing Program

One way to improve recruitment in the face of complete early life mortality is through an assisted rearing program. As discussed in Chapter 3, an assisted rearing program was initiated in 2015 with the dual goals of offsetting the harm and harassment of age 0 suckers during the operation of the Bureau of Reclamation's Klamath Irrigation Project and improving the status of SNS in Upper Klamath Lake population through successful recruitment. At present, this effort targets the release of 3,500 subadults (i.e., juveniles between 1 – 4 years old) per year that were collected as larvae from the Williamson River. The first release, which is likely to be substantially smaller than the target, occurred in spring 2018. The current program rears larvae of both endangered SNS and LRS, as identification during early life-stages is problematic. As identification methods become available, efforts will increasingly target SNS. The scale of the Klamath Basin Sucker Assisted Rearing Program is likely to be adjusted in the future to meet recovery goals for both species. Therefore, we present projections for Upper Klamath Lake sucker populations with the addition of varying numbers of individuals for varying durations.

The full details of the modeling and the statistical methods are detailed elsewhere (Rasmussen and Childress, unpublished data); however, two assumptions are important for interpretation of the results presented here. First, annual survival in the future was assumed to remain similar to what was been observed in the years 2002-2015. Second, stocked individuals were assumed to enter the population at age 4 and survive at the same rates as adults. This second assumption was necessary because no information on early life survival or the survival of reared individuals in the wild was available. However, this assumption means that actual production of stocked individuals would need to be higher than the nominal rates presented here to achieve the same results. Higher production would be necessary to offset mortality prior to reaching age 4.

Projections indicate that even relatively low production of age-4 individuals can greatly reduce the probability of extinction in 50 years (Figure 16). However, they also indicate that short-duration stocking efforts, even at relatively high levels, will not be effective at sustaining abundance. Stocking at rates that would produce at least 2,500 age-4 shortnose sucker per year for the next 50 years would be required to sustain the population at or above its current level. Although a shorter duration effort could achieve the same result, it would still require 35 to 40 years of stocking 10,000 individuals annually. Lower levels of Lost River sucker stocking would be necessary to maintain the groundwater seep spawning population because of lower starting population size and higher survival rates. As few as 500 age-4 individuals per year for the next 50 years would be required to sustain current population abundance; alternatively, 10,000 individuals could be stocked for ~20 years, which would lead to strong initial population growth and a subsequent decline, but a similar population size would be expected after 50 years (Figure 16). Despite relatively high annual survival rates, a higher starting population size of the Lost River sucker population in the Williamson River means that at least 5,500 age-4 individuals would be necessary to maintain the population at its current abundance. A shorter duration program could achieve the same results, but it would still require 10,000 individuals for at least 40 years.

One significant uncertainty for rearing efforts to maintain the Lost River sucker population at the lakeshore groundwater seeps is whether Lost River suckers hatched at the lakeshore will return to spawn at the same location. Although there is strong site fidelity for spawning adults, who return to the same spawning location very consistently year after year (Burdick et al. 2015b, 484-485), it is not known whether they establish their spawning location based on early life imprinting, genetic predisposition, attraction to spawning congregations upon maturity, or some other mechanism. Depending on the mechanism, reared Lost River sucker collected at the lakeshore spawning grounds or in the Williamson River may recruit to either population.

The results of these projections suggest that assisted rearing has the potential to maintain Upper Klamath Lake sucker populations over the next 50 years even in the absence of natural recruitment if current adult survival rates continue into the future. However, production of reared individuals would need to be higher than current levels to achieve stable abundance for all of the populations. Significant uncertainties remain about survival and recruitment rates for reared individuals, which will influence the reliability of the estimates presented here. As reared individuals are repatriated to Upper Klamath Lake and monitored for survival and recruitment, it will be possible to refine projections to reduce uncertainty and improve the program's ability to meet particular population targets.

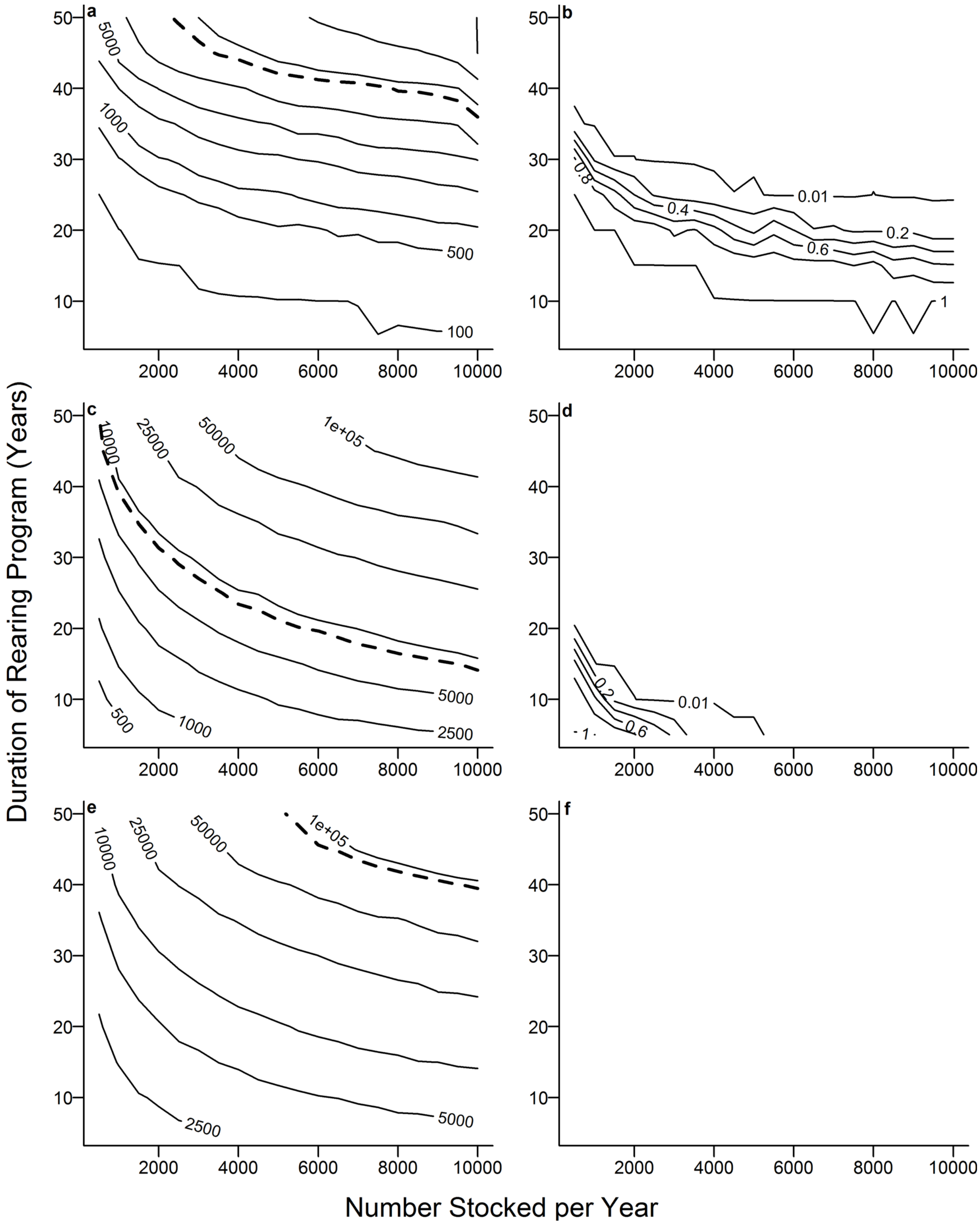


Figure 16. Median projected population size (a,c,e) and probability of extirpation (b,d,f) after 50 years for Upper Klamath Lake sucker populations of shortnose sucker (a,b), Lost River sucker spawning at the lakeshore groundwater seeps (c,d), and Lost River sucker spawning in the Williamson River (e,f) for assisted rearing scenarios at different scales and durations. Panel f is blank because the expected probability of extirpation is 0 across all scenarios for Lost River sucker spawning in the Williamson River. In the underlying models, stocked individuals are assumed to be the only source of recruitment. (reproduced from Rasmussen and Childress, unpublished data)

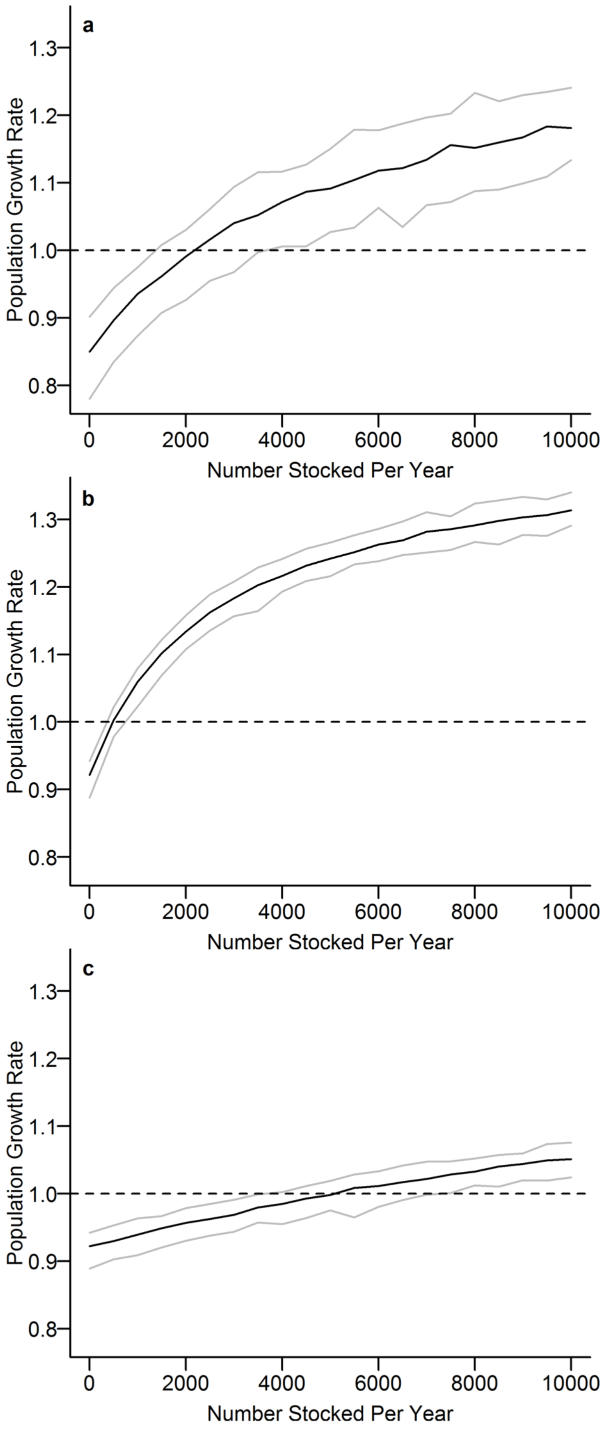


Figure 17 Short-term population growth rates (y-axis) in Upper Klamath Lake in response to stocking rates (x-axis) for shortnose suckers (a). Lost River suckers spawning at lakeshore groundwater seeps (b), and Lost River suckers spawning in the Williamson and Sprague Rivers (c). Black lines indicate the median result from simulations and 95 percent of the simulation results are contained within the gray lines.

Water Quality Improvements

Recent and ongoing restoration efforts aim to reduce phosphorus inputs to Upper Klamath Lake and are likely to benefit sucker populations via improvements to water quality. In this scenario, we evaluate the likely effects of reductions in phosphorus loading on sucker populations in Upper Klamath Lake. The Oregon Department of Environmental Quality has identified a target of 40 percent reduction in external phosphorus loading to Upper Klamath Lake from 1992-1998 levels as the state water quality standard (Boyd et al. 2002). Over the past two decades, there has been substantial effort to reduce nutrient inputs to Upper Klamath Lake through projects such as restoration of lake fringe wetlands and reduction of water use and nutrient export from grazed lands (Walker et al. 2012, p. 4). There is some indication that restoration efforts may have already reduced annual phosphorus loads approximately 11 percent below 1992-1998 averages, though there is substantial uncertainty due to interannual variation from environmental conditions (Walker et al. 2012, pp. 31 & 32). The draining and agricultural use of historical wetlands around Upper Klamath Lake has been a major source of nutrients (Snyder and Morace 1997, pp. 29 - 33), and there are continued efforts to restore these lands to wetlands. One notable pending effort plans to inundate approximately 14,000 acres of drained wetland habitat around the former Agency Lake Ranch and Barnes Ranch on the western shore of Agency Lake. Other efforts include fencing to prevent cattle access to creek beds and treatment wetlands for agricultural run-off. Meeting the phosphorus targets identified by Oregon Department of Environmental Quality (Boyd et al. 2002) is likely a best case scenario for the impact of such restoration efforts on phosphorus loads, so we assumed a 40 percent reduction in phosphorus inputs as the basis for this scenario and the analysis presented below. Phosphorus is often the limiting nutrient in freshwater systems, and it is believed to be the driving nutrient in this system.

A mechanistic model of the influence of phosphorus inputs to phosphorus availability, storage, and algal biomass is available from a recent study (Wherry and Wood 2017, entire). The model relies on a combination of empirically-derived and theoretically-based parameters. Given concurrent data on dissolved oxygen dynamics, the model does a good job of recreating phosphorus and algal dynamics. For predictions without reliance on oxygen data, which is necessary for future projections, the model still captures phosphorus dynamics but is less reliable in predicting algal biomass. The model indicates there is a lag between reduction in phosphorus inputs and reduction in phosphorus availability in Upper Klamath Lake due to recycling of phosphorus contained in lake sediments. It is likely to take over three decades for the system to reach new, lower equilibrium phosphorus concentrations after a 40 percent reduction in phosphorus inputs, but most of the benefit would occur much earlier. Approximately half of the reduction in actively cycled sediment phosphorus is projected to happen within the first five years and over two-thirds is projected to occur within a decade (Wherry and Wood 2017, Figure 18).

Reducing phosphorus inputs to Upper Klamath Lake is likely to reduce the magnitude of algal blooms and their deleterious effects, such as high pH and ammonium, and low dissolved oxygen. The predictive mechanistic model does not capture the extreme peaks of algal biomass or the crashes very well, so interpretation of the impacts of reduced phosphorus availability is necessarily more qualitative. Still, there is strong evidence that phosphorus limits the growth and magnitude of algal blooms in Upper

Klamath Lake, including a strong correlation between total phosphorus and algal biomass in Upper Klamath Lake, suppression of bioavailable phosphorus during bloom development and almost complete sequestration of phosphorus in algal biomass during blooms (Walker et al. 2012, pp. 2 & 3). Thus, reduction in phosphorus availability should reduce the magnitude of algal blooms. Elevated pH and un-ionized ammonium and low dissolved oxygen are all byproducts of the algal dynamics in Upper Klamath Lake. As the bloom develops, pH becomes elevated and as it crashes dissolved oxygen decreases during decomposition. Un-ionized ammonium concentrations tend to peak between these two phases because ammonium is released during decomposition but presence in the un-ionized form depends on high pH. Reducing the magnitude of the algal bloom should reduce the frequency of extreme pH, un-ionized ammonium, and dissolved oxygen levels since these are all a direct result of the extreme algal dynamics. The mechanistic model described above predicts a reduction of 44 percent in algal biomass peaks with a 40 percent reduction in phosphorus inputs. Interestingly, proportional reductions in algal biomass were predicted to be smaller for 10 percent and 20 percent reductions in phosphorus inputs with only 4 percent and 13 percent reductions in algal biomass, respectively. Although the specific reductions are difficult to assess at present, the frequency of deleterious water quality conditions should be substantially reduced by a 40 percent reduction in phosphorus inputs within 5-10 years of initiation of declines with continued improvements for 30 years.

We expect that these improvements would increase juvenile survival rates such that natural recruitment could occur. Although there is some uncertainty about the cause of total juvenile mortality, reductions in juvenile capture tend to overlap or follow the period of the worst water quality in late summer (Bottcher and Burdick 2010), suggesting that water quality is a major component of juvenile mortality, but it is currently impossible to estimate the magnitude of the effect size. Improved water quality could also increase adult survival because die-offs are associated with low dissolved oxygen events; however, adult survival is relatively high under current conditions (Hewitt et al. 2017). Reproductive success and larval survival are less likely to be influenced by improvements to water quality because they occur outside the period of poor water quality; however, if fringe wetland restoration is the method for reducing phosphorus, increased habitat availability for larvae may increase larval survival and growth rates. Due to the relatively high adult survival rates, even low annual recruitment could sustain or increase population abundances (Rasmussen and Childress in prep). Alternatively, relatively rare, highly successful recruitment years could also sustain the populations (Rasmussen and Childress in prep). Therefore, we expect that the reduction in phosphorus inputs to Upper Klamath Lake could stabilize or increase the Upper Klamath Lake populations primarily through reductions in juvenile mortality within 10-30 years. However, the lag in the effects of reduced phosphorus inputs means that recruitment is not likely to occur within the first 5-10 years after restoration, which would lead to sharp declines in abundance (Figure 15). Combining reductions in phosphorus inputs with a rearing program that could sustain population abundance until the benefits of restoration are realized would lead to much faster recovery and reduced probability of extinction.

Clear Lake Reservoir

Given the relatively limited data on populations in Clear Lake Reservoir it is not possible to simulate population scenarios with enough confidence that would justify using this approach. Instead we rely on expert opinion and assessment of probable outcomes given certain broad scenarios and our understanding of the ecology of Lost River and shortnose sucker. We determined that two future scenarios were plausible for the Lost River and shortnose sucker in Clear Lake Reservoir: status quo and improved access to spawning habitat. As with the scenarios for Upper Klamath Lake, we considered the likely outcome to these scenarios within the next 50 years.

Status Quo

The status quo scenario assumes that biological rates and trends over the next 50 years will be similar to the recent history. We assume that environmental conditions and variation, such as water management, agricultural practices, or many other factors, will continue essentially as they have been in last two decades or so. However, our status quo scenario does assume that climate variation will be as predicted by broad climatic models.

Since the 1950s, climatic patterns of western North America generally have trended towards less snowfall (the primary source of precipitation in the upper Klamath basin), earlier snowmelt, and subsequently earlier peak spring runoff (Hamlet et al. 2005, pp. 11 & 12; Stewart et al. 2005, pp. 1140 & 1141; Knowles et al. 2006, pp. 4548 - 4547). Current climate models indicate that these trends are likely to continue into the future (Barnett et al. 2008, p. 1082). A suite of climate models predict that over the next 100 years the mean flow of the Sprague River will increase during winter months but decrease during the spawning period (Markstrom et al. 2012, pp. 121 - 123; Risley et al. 2012, pp. 3 - 5). We expect similar patterns will occur in the Clear Lake Reservoir watershed.

Lost River Sucker

The population of Lost River sucker in Clear Lake Reservoir is characterized by very low population size, limited recruitment, and spawning within a single stream. If current environmental conditions persist we expect that similar population dynamics will also persist. Climatic conditions consistent with current trends are likely to negatively impact the population through changes to habitat and/or vulnerability to predation. Access to spawning habitat could become even more restricted due to reduced spring flows, further reducing resiliency by limiting annual larval production. Less precipitation overall will result in restricted habitat availability (in the reservoir or in persistent pools within the otherwise dry stream channel) that could result in degraded water quality or elevated predation from aquatic or avian sources. With the low population resiliency at present and likely further reductions in the future, the population is especially vulnerable to catastrophic events, such as extreme or extended droughts. Therefore we believe there is a high probability that the population of Lost River sucker will be extirpated from Clear Lake Reservoir within the next 50 years.

Shortnose Sucker

The shortnose sucker population in Clear Lake Reservoir is somewhat more abundant than the Lost River sucker, suggesting greater resiliency. Although, the SNS population spawns in two streams compared to one, the streams do not function independently because one is a tributary to the other, which provides minimal if any redundancy to Clear Lake Reservoir populations. Nevertheless, data suggest that periodic reproduction and subsequent recruitment do occur within the population.

Considerations for the shortnose sucker population under the status quo scenario are only slightly more complex. Similar outcomes to those outlined above for the Lost River sucker are likely: reduced resiliency because of reduced larval production, increased predation, and/or habitat degradation. An additional outcome likely to affect the SNS population if current trends continue is dilution of the genome via persistent introgression with Klamath largescale sucker (KLS). This can result when individuals become crowded into less spawning habitat. A potentially analogous example occurred in Utah Lake when the June sucker (*Chasmistes liorus liorus*) and Utah sucker (*Catostomus ardens*) overlapped during spawning in severe drought conditions of the early 1930s to such a degree that it was concluded that “pure” June sucker no longer existed; all remaining individuals were genetically introgressed and now identified as *Chasmistes liorus mictus* (Miller and Smith 1981). Such a situation may arise in Clear Lake Reservoir with SNS and could lower resiliency by reducing the phenotypic integrity of SNS.

It is very likely that if current conditions are unchanged the number of shortnose suckers in Clear Lake Reservoir will be reduced, thereby reducing resiliency. We cannot quantify the degree to which this will increase the risk of extirpation of the species, other than to note that it is possible that extirpation will occur within the next 50 years.

Improved Spawning Access

Access to spawning habitats for both species in Clear Lake Reservoir is affected by streamflow, reservoir water levels, and potentially the configuration of the stream channel just above the mouth of the creek. When water levels are high the reservoir connects directly to the spawning tributary at the mouth of Willow Canyon, but under lower water conditions there can be as much as an additional 3 km (1.9 mi) from the mouth of the canyon to the point where the creek connects to the reservoir. This connection is approximately 1.5 km (0.9 mi) above the dam, and may be as much as 8.6 km (5.3 mi) from the nearest suitable adult habitat – the area in between is often wetted but very shallow. These factors often interact, and in nearly half of the recent years adults have been prevented from reaching the spawning grounds.

This scenario assumes that all potential impacts are unchanged from current conditions (status quo), with the exception that the frequency with which the adults are able to access the spawning habitat is increased. This could occur by several mechanisms: improvements to water management to produce higher water levels during the spawning period with greater frequency or physical reconfiguration of the channel within the reservoir to facilitate passage of migrating adults. A naturally wetter climatic cycle could also produce the similar outcomes. However, we don't specify the mechanism here, nor do we quantify the degree to which the increased access occurs. Our limited data restricts us from reliably analyzing such specific scenarios.

We believe that improved access to spawning grounds would benefit Lost River sucker and shortnose sucker in the similar ways. Both would produce annual cohorts more regularly that would eventually contribute numbers to the adult populations. This would increase the resiliency of the population to respond to periodic catastrophic events, but we are unable to postulate the degree to which this would impact the risk of extirpation of the populations.

Gerber Reservoir

In many respects, the ecology of the shortnose sucker population residing in Gerber Reservoir is very similar to the one in Clear Lake Reservoir. The population is apparently comprised of relatively few individuals, many of which are genetically and phenotypically introgressed with Klamath largescale suckers. The system possesses limited spawning areas and is subject to massive declines in reservoir habitat due to drought and water management. These conditions suggest that the population would be considerably challenged by adverse weather and catastrophic events. We are unable to assess specific scenarios critically because we lack sufficient data to grant confidence in any specific conclusions. Nevertheless, we believe that it is probable that conditions and population responses are likely similar to the scenarios described above for shortnose sucker within Clear Lake Reservoir.

Species-level Effects

Based on the scenarios included here, it is likely that the Lost River sucker will continue to decline precipitously if conditions in Upper Klamath Lake remain unchanged. The species may still remain in 50 years, but it is likely that it will be critically few in numbers. Given that the only other spawning population of this species, Clear Lake Reservoir, is extremely small, a substantial reduction in Upper Klamath Lake will put the species perilously close to extinction. These conclusions are based on the assumption that survival rates continue similar to the recent past; however, if survival should increase due to ageing populations, then we expect the declines to accelerate. This could significantly truncate our time frame of reference.

If current conditions continue, we expect the shortnose sucker population to become extirpated within the next 30-40 years. It is no less alarming that projections suggest that SNS populations will decline by 78% over the next 10 years to a level below 5,000 total individuals if conditions persist. This would result in only two populations remaining for the species, both of which are highly genetically introgressed with the Klamath largescale sucker and geographically isolated behind dams without fish passage.

Both species are likely to realize greater stability from implementation of the rearing program, but landscape-scale improvements to nutrient loads in Upper Klamath Lake will be necessary to achieve full recovery. The dire conditions of Lost River sucker in Clear Lake Reservoir suggest that recovery of the species will likely be unattainable given the likely scenarios analyzed here and the requirement to have a viable population in the Lost River basin as well as the Upper Klamath Lake drainage. Recovery of the species is likely to require substantially more drastic actions than the few considered here. Recovery of shortnose sucker appears more achievable in the Lost River sub-basin under the scenarios assessed, but uncertainties about the overall impacts of genetic introgression must be clarified and addressed.

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APPENDIX I: GLOSSARY

Age-0 – in fish, the first year of life is called age-0.

Allele – one of two or more alternative forms of genes that are found at the same place on a chromosome.

Anthropogenic – referring to a condition or effect that has originated from human activities.

Bathymetry – the description of contours of the bottom of lakes to permit measurement of the depth of water.

Branched Gill Rakers – The gill structure of fish are comprised of three components: gills (the outermost) which are used in breathing; a middle bony gill arch that supports the gills; and the gill rakers (the innermost) which are small bony projections that point into the mouth cavity. These can be simple nubs or highly branched structures that serve to protect the gills and filter food particles.

Catastrophic Events – these are widespread events (such as natural disasters) that highly destructive to populations and habitat.

Caudal Peduncle – this is the tail region of the body of a fish, located between the anal fin and the start of the tail fin.

Cohort – a group of fish that share the same birth year.

Converging – this is the process if two separate species becoming similar in traits.

Corridor – an area that links two habitats through which fish travel to reach habitats where they will reside for different purposes, such as a link between rearing and spawning habitat.

Cyanobacteria – are a type of bacteria that obtain their energy from photosynthesis. These organisms are often referred to as "blue-green algae," but are not strictly algae because of their internal cell structure.

Demographic Effects – demography is the study of population-level statistics such as birth and death rates, or the proportion of males and females in the population. Changes in these rates and values are considered demographic effects.

Die-Offs – localized mass mortality of fish within a relatively short period of time.

Divergence – the process by which two or more populations of an ancestral species change over time to become different in some ways from each other.

Effective Population Size – the number of individuals in a population who contribute offspring to the next generation. This can be viewed on a genetic level related to the diversity of alleles contributed to the next generation.

Emergent Vegetation – plants that are rooted in the lake bottom but have leaves and stems that extend out of the water. These are often found in relatively shallow areas along the shorelines of the lake and typically do not tolerate prolonged inundation of the entire plant.

Endemic – a species that is native to and restricted to a certain area of interest.

Entrainment – in this case, when organisms, especially larval or juvenile suckers, are pulled along with the force of moving water. This may be through natural features, such as a river corridor or into irrigation canals or other similar structures, such as dams and hydroelectric facilities.

Evenness – a measure of biodiversity that refers to the relative proportions of species in an environment. A community with nearly equal numbers from each species will be more even than one in which one species makes up the majority of biomass.

Exotic – a species that is not native to an environment; introduced

Extant – still in existence; not destroyed, lost, or extinct

Founder Effect – the reduced genetic diversity that results when a population is descended from a small number of individuals

Genera – the plural of genus, which is the principal taxonomic (identification) category that ranks above species and below family and comprises the first part of a scientific name.

Genetic Bottleneck – a sharp reduction in the size of a population due to natural or anthropogenic causes. This can result in a dramatic loss of genetic diversity.

Genetic Introgression – the incorporation of genes from one species into the gene pool of another by repeated hybridization and backcrossing.

Genetic Loci (singular **Locus)** – a fixed location on a chromosome, such as the position of a specific gene

Genetic Swamping – gene flow (see genetic introgression) from a common species to a rarer species such that local genotypes are replaced by hybrids.

Genotype – the genetic makeup of an organism.

Heterozygosity – when a gene locus of an organism contains different alleles.

Hybridization – interbreeding between two species.

Introgression – see genetic introgression

Introgressive Hybridization – see genetic introgression

Lacustrine – relating to or associated with lakes.

Metapopulation Dynamics – the dynamics of a group of populations of the same species that are separated by space but can interact as individuals move among the populations.

Microsatellite Markers – short, repetitive DNA sequences that typically have a relatively high mutation rate than other areas of the genome and so can be relatively diverse.

Mitochondrial DNA – DNA that is found within the mitochondria of the cell rather than the chromosomes of the nucleus.

Monotypic – having only one representative, such as a genus with only single species.

Obligate – (adjective) restricted to a particular function or mode of life.

Outmigrating – to leave one region to settle in another, especially as part of a large-scale and continuing movement of population.

Papillose – bearing or covered with small round projections or bumps on a part of the body.

Phenotypical Variants – individuals with alternative forms or states of a specific characteristic.

Quantitative – related to the measuring of something by the quantity rather than the quality.

Reproductive Isolation – the condition whereby individuals from different species are unable to interbreed because various evolutionary mechanisms, behavior, or physiology prevents successful reproduction.

Richness – a measure of biodiversity; the absolute number of species within a community regardless of their relative numbers (evenness).

Senescence – the condition or process of deterioration with age that produces reduced survival or reproductive rates.

Sondes – devices with sensors used to measure various water parameters, such as temperature or dissolved oxygen concentrations.

Stochasticity – a pattern of random occurrence.

Subterminal – in fish, a mouth that is oriented intermediate to a mouth that points directly forward (terminal) and one that points down (inferior).

Swim-Up – the event when larval fish emerge from the gravel to enter the water column, often en masse.

Tailwaters – waters in the channel below a dam

Terminal – in fish, a mouth that points forward.

Tetraploid Genomes – a genome that is comprised of four homologous sets of chromosomes. In other words, a set of chromosomes that is comprised of four copies of each type of chromosome, two copies from each parent.

Total Length – in fish, the distance between the snout of the fish and the trailing tip of the tail fin.

Fwd: [EXTERNAL] SSA Review Comments - Lost River Sucker and Shortnose Sucker

1 message

Daniel Russell <daniel_russell@fws.gov> Mon, Aug 13, 2018 at 3:53 PM
To: damian_higgins@fws.gov, josh_rasmussen@fws.gov

Sent from my iPhone

Begin forwarded message:

> **From:** Mark Buettner <mark.buettner@klamathtribes.com>
> **Date:** August 13, 2018 at 6:44:43 PM EDT
> **To:** "daniel_russell@fws.gov" <daniel_russell@fws.gov>
> **Subject: [EXTERNAL] SSA Review Comments - Lost River Sucker and Shortnose Sucker**
>
> Mr. Russell,
>
> I have reviewed the Species Status Assessment for the Endangered Lost River Sucker and Lost River Sucker. This is a very useful document and I like the fact that it will be updated as new information becomes available. I also appreciate having the glossary of definitions. Overall, I am in agreement with the technical information cited and the interpretation of what it means in terms of long-term survival of the Lost River Sucker and Shortnose Sucker. I do think the declining trend of Upper Klamath Lake LRS and SNS populations based on the simulated population trajectories is too optimistic and that extirpation is likely to occur sooner than the model projections (Figure 15). Because the remaining adult LRS and SNS in UKL are 20-30 years old and nearing the end of their maximum life expectancy, I think it would be reasonable to assume that annual mortality rates will be higher than they have been from 2001-2015. It might be useful to add a more pessimistic view of likely population trends to compute population trajectories and probability of extinction because of the uncertainty of future adult annual survival rates and projected survival of reared individuals. Also, based on recent climate trends, there may be an increased risk of catastrophic adult sucker die-offs impacting future annual mortality rates.
>
> Thanks again for allowing the Klamath Tribes to review this document.
>
> Sincerely,
>
> Mark Buettner
>
> Environmental Scientist

---

4 attachments

noname.html
1K

CV Mark Buettner 5-21-18.doc
76K

SSA Review Comment Matrix- Mark Buettner Klamath Tribes.xlsx
11K

noname.html
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Reviewer Name	Chapter	Page	Line #	Comment
Mark Buettner	2	11	3rd para	Include a brief discussion of age-0 habitat use
Mark Buettner	2	11	4th para	Include statement on the summer distribution of suckers - northern 1/3 of UKL
Mark Buettner	2	17	2nd para	Parker et al. 2000 includes adult sucker food habits from Clear Lake
Mark Buettner	2	17	2nd para	Buettner and Scoppettone 1990 includes age-0 food habits from Upper Klamath L.
Mark Buettner	3	27	3rd para	No Ciotti et al. 2010 reference in literature cited
Mark Buettner	3	31	2nd para	No Haggard et al. 2013 reference in literature cited
Mark Buettner	3	33	1st para	Refer to Piaskowski and Buettner 2003 for extensive analysis of Gerber wq
Mark Buettner	3	34	1st para	Include impacts of sucker sampling for research purposes (USGS)
Mark Buettner	3	41	2nd para	BOR conducted entrainment monitoring in LRDC and Miller Hill pumping station. Check with Torrey Tyler BOR fish biologist for appropriate report.
Mark Buettner	5	55	2nd para	Probability of extirpation could be in 10 years for SNS based on current adult annual survival rates, no recruitment and maximum life expectancy of 30 years.
Mark Buettner	5	58	2nd para	I think the modeling is too optimistic. Using age-4 is not appropriate because that is the youngest age fish mature. Average maturity of 5 or 6 would be better. Also, the modeling assumes that annual adult mortality rates continue at their current rate of about 10% per year. Although we do not have data to verify this but general ecological principles suggest mortality rates should increase in old aged fish as they approach maximum life expectancy. There should be more conservative annual mortality rates.

Higgins, Damian <damian_higgins@fws.gov>

Re: Request for Peer Review - Lost River Sucker and Shortnose Sucker

1 message

Burdick, Summer <sburdick@usgs.gov> Mon, Jul 30, 2018 at 11:05 AM
To: "Russell, Daniel" <daniel_russell@fws.gov>
Cc: "Higgins, Damian" <damian_higgins@fws.gov>, Josh Rasmussen <josh_rasmussen@fws.gov>, Eric Janney <ecjanney@usgs.gov>

Daniel,

Thank you or the opportunity to review this species status assessment. I have attached my review and a signed conflict of interest disclosure form. Please let me know if you have questions.

Summer Burdick
USGS - Fish Biologist
(541) 273-8689 x 209
2795 Anderson Ave.
Suite 106
Klamath Falls, Oregon, 97603

On Thu, Jun 14, 2018 at 10:49 AM, Burdick, Summer <sburdick@usgs.gov> wrote:

> I will complete this review by August 13th.
>
> Summer Burdick
> USGS - Fish Biologist
> (541) 273-8689 x 209
> 2795 Anderson Ave.
> Suite 106
> Klamath Falls, Oregon, 97603
>
> On Thu, Jun 14, 2018 at 10:39 AM, Russell, Daniel <daniel_russell@fws.gov> wrote:
>
>> Dear Dr. Burdick:
>>
>> The U.S. Fish and Wildlife Service (Service) is soliciting independent scientific reviews of the information contained in our 2018 draft Species Status Assessment for the Endangered Lost River Sucker and Shortnose Sucker. Once finalized, this Species Status Assessment report (SSA report) will provide the underlying science to inform decision-making for future conservation efforts needed for these two species. You were identified by our Klamath Fish and Wildlife Office as a potential peer reviewer based on your area of expertise.
>>
>> This request is provided in accordance with our July 1, 1994, peer review policy (USFWS 1994, p. 34270) and our current internal guidance. This request also satisfies the peer review requirements of the Office of Management and Budget's "Final Information Quality Bulletin for Peer Review." The purpose of seeking independent peer review of the SSA is to ensure use of the best scientific and commercial information available; to ensure and maximize the quality, objectivity, utility, and integrity of the information upon which we base a variety decisions under the Act; and to ensure that reviews by recognized experts are incorporated into our final decision processes. Please let us know if you would like us to provide any of the referenced materials to help facilitate your review.
>>
>> Please note that we are not seeking advice on policy or recommendations on the legal status of the species, nor on how the Bureau of Reclamation's Klamath Project may affect the species. Rather, we

request that peer reviewers focus their review on identifying and characterizing scientific uncertainties, and on ensuring the accuracy of the biological and land and water use information in the SSA. Specifically, we ask peer reviewers to focus their comments on the following:

(1) Have we assembled and considered the best available scientific and commercial information relevant to this species?

(2) Is our analysis of this information correct?

(3) Are our scientific conclusions reasonable in light of this information?

Our updated peer review guidelines also require that all peer reviewers fill out a conflict of interest form. We will carefully assess any potential conflict of interest or bias using applicable standards issued by the Office of Government Ethics and the prevailing practices of the National Academy of Sciences (http://www.nationalacademies.org/coi/index.html). Divulging a conflict does not invalidate the comments of the reviewer; however, it will allow for transparency to the public regarding the reviewer's possible biases or associations. If we receive comments from a reviewer that we deem to have a substantial conflict of interest, we will evaluate the comments in light of those conflicts, and may choose not to give weight to those comments if the conflict is viewed as problematic. You may return the completed conflict of interest form either prior to or with your peer review.

So that we may fully consider any input and coordinate other peer review comments as we develop the final SSA, and ensure adequate time to evaluate all comments, we are requesting peer review comments by August 13. If you are willing to peer review but are unable to complete your assessment during this time period, please let me know when we may anticipate receiving your comments. We will summarize and respond to the substantive comments raised by all peer reviewers and use the information, as appropriate, in the final SSA.

While we welcome your peer review comments in any format you are most comfortable using, it would be especially helpful if you could use the attached Comment Matrix Excel spreadsheet. This will make it easier to compile and keep a record of all the comments received and then incorporate them into our report. We would also appreciate receiving a copy of your Curriculum Vitae for our records. Please be aware that your completed review of the SSA, including your name and affiliation, will be included in the administrative record for this evaluation and will be available to interested parties upon request.

If you have any questions about the draft SSA report, or our peer review process in general, please feel free to contact me at any time at (916) 978-6191. Please submit your comments and associated materials to the contact information below. If emailing your responses, you may use the Reply All feature, and that way your comments will also go directly to the project leads for this SSA report.

Thank you for your consideration.

Sincerely,
Dan Russell

****
Daniel Russell - Regional Listing Coordinator
Pacific Southwest Regional Office, Region 8
U.S. Fish and Wildlife Service
2800 Cottage Way, Room W-2606
Sacramento, CA 95825
Office (916) 978-6191
Cell (916) 335-9060
****

2 attachments

Conflict of Interest Disclosure Form_signed.pdf
621K

Review of Species Status Assessment for the Endangered Lost River Sucker and Shortnose Sucker.docx
37K

Review of Species Status Assessment for the Endangered Lost River Sucker and Shortnose Sucker

Provided by Summer Burdick Fish Biologist USGS

Substantial Comments:

This document provides a good overview of the status of the Lost River and shortnose suckers throughout their range. Most of the relevant literature is reviewed and correctly characterized. The places where literature review was incomplete or inaccurate are noted below. Unfortunately, numerous false statements about water-quality were made in this document, not cited, and reinforced long-standing false assumptions. Except for the water-quality section, this SSA was well written and easy to follow. I made suggestions for improvement throughout the document.

Framing the status of the two species with the three Rs was helpful and provided insight as to where to focus recovery efforts for these species (as stated on page 64). What I saw as obvious conclusions about recovery actions to be taken, however, was not reflected in the scenarios examined. This SSA made it clear to me that recovery of Lost River and shortnose sucker depends on 1) reestablishing more populations or spawning sub-populations (especially outside of the Upper Klamath Lake area), 2) managing metapopulation dynamics among disconnected populations and 3) maintaining or recovering current populations. On page 64 you state that only scenarios that were plausible, relevant and could be evaluated with available data could be examined. For these reasons the focus was entirely on number 3 ignoring potential actions related to numbers 1 and 2. While I agree that it would be difficult to quantitatively assess scenarios that address 1 and 2, actions that improve redundancy and resiliency are very important. I would like to see scenarios related to the improvement of smaller populations including but not limited to Gerber and Clear Lake areas.

Plausible recovery actions that might address numbers 1 and 2 at the species level that have previously been discussed include, reestablishment or restoration (increasing numbers) of spawning subpopulations in the Wood River sub basin or at Harriman Springs, removing a barrier to spawning habitat at the mouth of the Lost River, and determining the status of spawning populations in the upper Sprague River near Beatty Gap, Lake Ewana, or Topsy Reservoir. Although briefly discussed screening diversions off Lake Ewana was not included in a scenario. These actions would directly address number 1 and lead to improvement of redundancy and resiliency but are not mentioned in this SSA. On page 29 in the first paragraph of the Species Needs section you discuss how very important redundancy is, but then it is not addressed in the list of actions you might take to achieve it. There were actions in the recovery plan that seem to be mostly ignored in this document. I am also surprised that no scenarios related to alternative Upper Klamath Lake level management were included.

On pages 29 and 30 you discuss the importance of genetic diversity and metapopulations dynamics for long-term stability of the species. Did you consider a scenario that addresses connectivity among populations?

The assessment of potential success of the sucker assisted rearing program (SARP) scenario was overly optimistic. This scenario was evaluated on the assumption that fish would be released at age-4. So far the fish have been released younger and at a mean size of < 150 mm TL (U.S. FWS data. J. Groves pers. Com. July 11 2018). It was assumed that released juvenile suckers would survive at the same high rates as adults. The reason given for this assumption was that there is not data on juvenile sucker survival to suggest otherwise, which is false. Juvenile suckers (age-0 to 5; mostly shortnose) in Clear Lake, where water-quality is generally better, have annual survival rates of 37-44% (Burdick et al. 2016, p18-19). Most importantly, and a fact nearly completely ignored, is that the offspring of SARP fish have a zero probability of survival in Upper Klamath Lake. Therefore, unless SARP continues forever or a solution to the lack of juvenile survival in the lake is solved this program will not result in sustainable recovery. Are you planning to maintain any effort to determine and solve the problem of juvenile sucker survival in the wild? The SARP scenario is evaluated based on numbers of adults as justified on page 27. In the case of the SARP scenario this justification isn't valid. The success should be evaluated based on the size of wild produced and reared adults (a second generation of adults). If the program was evaluated based on wild adults the projected success would be minimal at best. Without determining and solving the problem of wild juvenile sucker survival, SARP will likely fail to stabilize populations.

The discussion of water-quality improvements in Upper Klamath Lake is limited to phosphorus reduction through riparian and wetland restoration. There was a conference and resulting document (http://www.stillwatersci.com/case_studies.php?cid=68) on ways to improve water-quality in Upper Klamath Lake. This document provided several plausible options for reducing phosphorus and overall water-quality improvements in Upper Klamath Lake, including some that could be effective in a much shorter timeframe. Why were these not discussed? Furthermore, what is the basis for thinking that reductions in P will achieve full recovery (page 76)? I think it is an overly optimistic assumption that you can make water quality improvements that will turn sucker populations around in Upper Klamath Lake.

In several places in this document results from unpublished quantitative analyses were reported. There was not of enough information given in this document to evaluate the validity of these estimates. The methods need to be reported in a place that is accessible to the public BEFORE being cited. You could include them in an appendix to this document or in a separate document, but citing unavailable analyses is not acceptable. Below I comment on some of the results of these analyses in detail.

One of the primary goals of this documents was to evaluate the future population projections for suckers. Projections of population size into the future under all scenarios are overly optimistic because the maximum life spans of these species were not considered. Population predictions under the SARP scenario are additionally overestimate future population sizes because they assume that introduced juvenile suckers will have similar survival rates as adults. This second issue is acknowledged on page 68, but nothing is done to correct it in the analyses.

Detailed page-by-page comments:

Page numbers in table of contents are incorrect.

Page 3, first sentence. LRS and SNS also exist in rivers.

Page 3, third paragraph, "In conservation, as with chickens, it makes sense to not put all of your eggs in the same basket", This sentence, which is repeated on page 11, is not appropriate. This is not a report about chickens. In addition, putting all your effort in very few actions seems to be the approach taken in this SSA.

Page 3 first sentence of last paragraph, "Overall resiliency for this Lost River suckers is …" delete "this"

Page 3 second sentence of last paragraph. – There are possibly spawning groups in other locations. I don't know if you could call these populations or sub-populations due primarily to their presumed small numbers. I think you could say there are only three know distinct spawning populations. Or known relatively large populations. Also, you go back and forth in the document between calling the UKL river and UKL springs groups sub-populations, spawning populations or populations.

Page 4 last sentence in first partial paragraph on this page. "As a species, Lost River suckers appear to be relatively genetically distinct." Do you mean that there is genetic distinction within the species among populations or between Lost River sucker and other species?

Page 4 first line of the first full paragraph says that shortnose have more populations than Lost River suckers. However most of the document talks about 3 populations for each species, LRS-UKL-River, LRS-UKL-Springs, LRS-CL, SNS-UKL-River, SNS-CL, and SNS-Gerber. If you are going to call the LRS spawning groups subpopulations then you need to be consistent throughout the document.

Page 4 last line of first full paragraph. What is your criteria for calling a group of fish a population? There are small or very small groups of suckers in other places besides the three lakes most discussed. Some of these have even been documented to spawn and produce larvae (Tule Lake/Lower Lost River) and some have small fish that may indicate recruitment (Lake Ewana, maybe Beatty Gap, maybe Topsy). Is your criteria based on a number of adult fish, or a number of life stages, connectedness with other groups, or the amount of information available? I think it is correct to focus on Upper Klamath, Clear, and Gerber Lakes as these appear to have the largest numbers of individuals. I just wonder if the assessment isn't undervaluing the small aggregations of fish and what the justifications for excluding small groups is. Inclusion of these small groups might change your assessment of redundancy. You would might find that the small groups are so vulnerable to extirpation that the assessment of resiliency would probably remain the about the same.

Page 4 second to last line in second full paragraph. "…if survival should increase due to aging populations, then we expect the declined to accelerate." I think you mean if survival should decrease.

Page 4 last full paragraph. "Both species are likely to realize greater stability from implementation of the rearing program, but landscape-scale improvements to nutrient loads in Upper Klamath Lake will be necessary to achieve full recovery" "stability" is an over sell of the benefits of the rearing program as 1) the rearing program is only proposed for the UKL populations and 2) stability depends on continuing the rearing program forever. The evidence that improvements to water-quality will measurably improve natural recruitment of suckers Upper Klamath Lake is weak at best. I include more detailed comments on these two points below.

Page 4 last paragraph. The second full sentence doesn't make sense.

Much of the text in the executive summary is directly copied in the main body of the report. It is generally better to choose different wording for the executive summary.

Page 10, second paragraph foot note doesn't apply to word "ecology"

Page 10 second paragraph. NRC 2004 should probably be cited.

Chapter 2 is well written and complete except for the minor exceptions listed here.

The genetic section of chapter 2 might benefit from some revisions to the organization. For example, the first sentence in the first paragraph isn't really the topic sentence for the information that follows. Also, the second to last sentence in the first full paragraph is awkward. Otherwise the genetic information is accurate and informative.

Page 16, first paragraph of historic range. The Buck Island and Wood River spawning aggregations are not named.

Page 18 first paragraph of Life History section sentence "Larger, older females often produce substantially more eggs and, therefore, can contribute relatively more to production than recently matured female. The last word should be "females" and a citation would be appropriate.

Page 18 you repeatedly say that spawning occurs from February to May and cite Hewitt reports, but Hewitt reports all day March to May. I think the difference is in that most suckers are spawning from March to May while some also spawn in February and early June. If you choose to go with the most it should probably be changed to March to May and if you choose to go with the entire time from mid-Feb to mid-June.

Figure 6. Why did you use a picture of cui-ui? Similar photos of Lost River suckers exist.

Page 20 second full paragraph. One-year-old fish were not observed on the western shore in the spring but on the east side of the trench in about 5 m of water. The key difference being that they were observed over mud where there were plentiful midges not near boulders in 8-15 m of water.

Page 20 second full paragraph. This the first place where you say we do not have estimates of mortality specific to juvenile age-1+ SNS. This is not true. See Burdick, S.M., Ostberg, C.O., Hereford, M.E., and Hoy, M.S., 2016, Juvenile sucker cohort tracking data summary and assessment of monitoring program, 2015: U.S. Geological Survey Open-File Report 2016–1164, 30 p., http://dx.doi.org/10.3133/ofr20161164. Pages 18-19.

Page 22 first paragraph. Statements are made about the need for eggs to have flowing water. Either that is false for the UKL LRS shoreline site or all eggs at the shoreline site die. I don't see a citation for this statement so maybe it is a false assumption.

Page 22 first full paragraph in Larvae section needs a citation (Cooperman and Markle outmigration paper).

Page 22 sentence, "The role of submergent vegetation is unclear because it is generally not present during most of the larval period due to the larval period occurring before the growing season". The point may also be made that in Clear Lake submergent vegetation can be nearly absent in high water years and extremely abundant in low water years. This is seemingly in contrast to statements made on page 56.

Page 23 last paragraph in the larvae section. Water quality tolerances for larvae are given but the duration that conditions must persist at these thresholds to cause mortality are not discussed.

Page 23 last 2 sentences in the Larvae section. There are uncited statements that better water quality than thresholds reported by Saiki et al (1999) are needed for larval suckers to thrive. These sentences are in contradiction with Meyer and Hansen (2002) who showed that sub-lethal effects only occur at lethal water-quality thresholds. If you have a different source for this statement it should be cited.

Page 26 If you are going to list fish that have been shown to eat sucker larvae in buckets or tanks then you should include a lot more than fathead minnows (Hereford et al. 2016 – OFR20161094). If you want to talk about predators positively shown to eat larval suckers in the wild the list would only include yellow perch.

Page 26 in Juveniles section. There is no difference in the number of juvenile suckers captured in vegetated and unvegetated areas. Or in the number captured near or off shore. If suckers are moving off shore it is during the larval to juvenile transition period (before mid-July) not after they become juveniles.

Page 26 the statement is made that there are fish predators of juvenile suckers and no citation is given. Which fish predators are you talking about? Nearly all the fish that occupy both Upper Klamath Lake and Clear Lake are too small to eat even a 50 mm sucker. The exceptions are redband trout that leave the lake when water temperatures reach 18 C (Armstrong presentation), potentially bullhead which are limited to fringe wetlands in UKL where they are uncommon and the mouth of Willow Creek in CL. However, bullheads wouldn't even eat larval suckers when they were in a bucket with them and no other food. Maybe Sarcamento Perch in CL. There are large chubs in Upper Klamath Lake but they have a small gape and can't eat juvenile suckers.

Page 26 last paragraph of the juvenile section. Someplace in this section it might be okay to mention the need for protection from parasite or disease spill back due to high numbers of non-suckers.

Page 28 top of the page "Under normal conditions, the long lifespan and high adult survival of Lost River and shortnose sucker life-history offset their low annual recruitment" What are normal conditions. Under conditions that have been documented in recent history this is not true. Do you mean under stable conditions? Or pre-1960's conditions?

Page 28 near top of page "Likewise, periodic events of unusually high recruitment contributed strongly to sustaining these species in the long term" In the Upper Klamath Lake population periodic recruitment is a recent and unsustainable condition. There is evidence in the age data in Upper Klamath Lake that prior to the late 1960's recruitment happened every year. We don't know that recruitment was historically periodic in Clear Lake prior to dam construction either.

Page 28 3rd full paragraph. Resiliency was defined previously and the sentence "Population resiliency is the ability …" can be deleted. In the sentence after that it says that to be resilient populations need to be large. They also need to be diverse in either life history, morphology and or genetically– right?

Page 35 3rd full paragraph. "Lake levels are an important component necessary to establish a strong annual cohort of juveniles in Upper Klamath Lake (E. Childress, U.S. Fish and Wildlife Service, unpublished data). In Upper Klamath Lake, minimum lake levels of approximately 4140 ft above sea level during the summer appear to increase the likelihood of a strong annual sucker cohort". First of all this data wasn't collected by E. Childress it was collected by D. Markle. Secondly, I strongly believe that you should never cite unpublished analyses. Why not put enough information in this document or an appendix to this document to that the analysis can be evaluated? The statements about lake elevation and cohort strength are not critical to this document and they are highly politically inflammatory. Based on the PowerPoint I saw on this topic, the analysis had some serious shortcomings. The input data used was of inappropriate extrapolations of very sparse catch data in surface fishing cast nets. Suckers are not surface oriented fish so these nets are inappropriate.

The input data points consisted of very poor annual estimates of lake wide young of year sucker population sizes estimated in a small number of years (maybe 11 years or so). The estimates in the input data set had large confident intervals themselves. At least one year that would have debunked any minor detectable correlation between lake elevation and the number of juvenile suckers in the lake (2017) was not included in the analysis. An AIC approach was used to evaluate a series of models that each had 1-3 parameters (3 when interactions were considered). If I remember right the most parsimonious model was a 2 parameter lake elevation and spring inflow model, or the 3 parameter interactive effects of lake elevation and spring inflow. Two or 3 parameter models fit to 11 data points are way over fit and are highly likely to give spurious results.

Within the small number of years in the data set, only 3 fit into the category of higher population estimates and higher lake elevation. These three had strong leverage (small sample size problem) on the results and happen to have been years with high spring inflow. Notably no years in the data set had both high spring inflow and low lake elevation or low spring inflow and high lake elevation. In other words, there appeared to be a correlation between inflow and lake elevation. This correlation caused me to wonder if the apparent very minor detected effect of lake elevation wasn't due to inflow instead (ie. production rather than survival in the lake effects). Furthermore, no measure of confidence around the estimates of lake effect were shown, causing me to wonder if estimates were valid. The estimated effect sizes were minor. When you consider that input data were estimates themselves with very wide confidence bounds I strongly doubt that they were significant. Finally, I take issue with the wording, "establish a strong annual cohort of juveniles". A strong annual cohort would result in recruitment to the adult stage, which did not occur for any of the cohorts used in this analysis. I strongly advise that these statements be removed from this document and the analysis on which they are based undergoes a solid juried peer review. I worry that if text is not removed, this SSA will be cited in the future for saying lake elevation effects juvenile sucker cohort strength, when this is not primary literature and no primary literature exists to make this point.

Water Quality Section starting on page 36 – I found many editorial issues in this section and suggest a careful edit. I point out few examples of editorial issues below, but did not take the time make suggestions on organization or wording. Many strong and sometimes false statements are made in this section without citations.

Page 36 third sentence in Water Quality section doesn't make sense "which nutrient derives much of …"

Page 36 "as temperature (C) with dry (s), warm (b) summers" Are you missing numbers here? Should this say characterized instead of classified?

Page 36 The first paragraph under Dissolved Oxygen seems to be only kind of relevant to this document.

Page 36 first sentence in second paragraph under Dissolved Oxygen. "Is" should be "are" because "concentrations" is s plural word.

Page 36 Concentrations in "the" Upper Klamath Lake. Delete "the". I assume you are talking about point samples, in which case the maximum DO can be greater than 15 mg/L in parts of the lake. Lake wide data can be pulled directly from NWIS web page and for one site is found in Burdick et al 2017 (OFR20171134, p 15).

The second paragraph of the water quality section starting on page 36 is lacking citations. To find the relevant data try searching this web page there are numerous peer reviewed reports on this topic. (https://pubs.er.usgs.gov/) Jake Kann also has a paper that explains the effects of lake elevation, wind action, and temperature on bloom dynamics. You might also read Helser et al. 2004 “A Bayesian Risk Analysis of Unsuitable Dissolved Oxygen Concentrations…”

Page 37 “bacterial decomposition of the large quantities of organic matter consumes dissolved oxygen which often produces anoxic conditions” This is an awkward sentence. Often is subjective. If you are going to use this subjective term, I would say often produces hypoxic conditions and occasionally produces anoxic conditions. A citation should be provided. To find one you could search https://pubs.er.usgs.gov/ for authors Hoilman, Lindenberg, Wood, Eldridge, or Kannarr. You can also pull all these data from NWIS directly. Helser et al. 2004 does a pretty decent job of summarizing the probability of very low oxygen events (< 1.5 mg/L). They occur much less frequently than you might expect and in some years not at all, which doesn’t sound like often to me.

Page 37 the sentence starting, “At times dissolved oxygen levels in Upper Klamath Lake are …”. Why are you citing ORDEQ criterion for warm water aquatic life when much more sucker specific criteria are available? This threshold of 5.5 mg/L is irrelevant to this document. The threshold in the sentence afterward is also irrelevant for the species in this document.

Page 37 the proper term for blue-green algae is cyanobacteria.

Page 37 second paragraph sentence starting, “Dissolved oxygen levels in Upper Klamath Lake and downstream…” If you are talking about point samples then this is true. However, in the sentences above you give durations that the conditions must exist for morality to occur. In Upper Klamath Lake and probably also in the north end of Lake Ewauna, these conditions rarely and in some years never occur for the durations used in the lab trials that you mention. Therefore, the statement made in this sentence is misleading.

Page 37 sentence starting “Adult mortality events have also…” While the cited report says that mortality occurred below 4 mg/L this analysis was based on a predetermined threshold of 4 mg/L rather than using data to determine a threshold. A careful read of this report and examination of the figures in the report lead me and may lead you to a different conclusion than the one stated by the authors at the end of the report.

Page 37 first paragraph under Nutrients section sentence starting, “In Upper Klamath Lake, phosphorous …” you say P can be “quite high” why not give a concentration and a citation?

Page 37 sentence starting, “Manure and fertilizers that are applied …” I didn’t realize this was a substantial issue in the Upper Klamath Basin, can you provide a citation?

Page 37 sentence starting, “The elevated levels of phosphorus…” needs a citation. Also, if you are going to use the abbreviation AFA it needs to be defined at first use.

Page 40 first full paragraph. The sentence “The highest un-ionized ammonia…” This statement may have been true based on Klamath Tribes data for years between 1997 and 2003 when 10-35% of the tribes point samples exceeded the 0.48 mg/L threshold. Concentrations were less than 0.48 mg/L in no more than 2% of measurements in 2 years from 1990 to 1996 and 2 years from 2004 to 2010 (Klamath Tribes Data). Given the sensitivity of ammonia measurements to clean sample methods, I think a careful examination of the quality control data in the Klamath Tribes 1997 to 2003 data set needs to be conducted before using these data. I have never seen the quality control data reported for these data. USGS data available on NWIS also shows very low un-ionized ammonia occurring in samples collected since 2003, and quality control data are reported. This statement is also misleading in the context of this report because suckers don't use the deepest sites in Upper Klamath Lake.

Page 40. In the second paragraph under Primary Production and Algal Toxins citations are needed for the first and second sentences. Also in the third sentence larval suckers do not co-occur with heavy cyanobacteria blooms in Upper Klamath Lake and "larvae" be removed from this sentence. Suckers have transitioned to the juvenile life stage by the time cyanobacteria blooms are heavy.

Page 41. Citations are lacking throughout the first paragraph under pH. The last line in this paragraph needs a citation and it is not entirely true. Larval suckers are not present when pH >10. How long is "sustained"? Also see the values in table 2 for effects on suckers. In the paragraph at the top of page 42 you cite Stone et al (2017) saying they showed that pH > 10 caused mortality of suckers. That is almost but not quite true. Stone et al showed that high pH was correlated with high mortality and then speculate that the mortality was due to some other factor that co-occurred with high pH. This could be for example large diel fluctuations in DO.

Page 41 second paragraph on pH. A summary of pH relative to 9 isn't very helpful. What we need to know is how frequently pH exceeds thresholds relevant to suckers.

Page 41 in the last sentence before Temperature, you state that high pH is likely to impact larval suckers. Very few suckers if any are still larvae when pH is > 10.

Page 41 first sentence after Temperature. "Natural temperature regimes water bodies are…." What does that mean?

Page 42 sentence that starts, "Looking at water temperature fluctuation effects…." This is a poorly constructed sentence. Within what range of temperatures was this effect tested? Surely there is not a linear effect from 0 to 30C.

Page 42 sentence that starts, "In Upper Klamath Lake, shallow lake morphology combined with water level manipulations…" I think you can just say shallow water. Also, there are a lot of data on water temperature at various lake elevations. Why not actually look at the data and see if this happens rather than make assumption and uncited statements.

Page 42 sentence "It has also been noted that daily …" I reread what I wrote. I report variation in temperature, but you are the ones saying that these variations are stressful. You need to site the source for calling these conditions stressful.

Indirect and Synergistic Effects on Suckers (pages 42-43)

First sentence needs a citation

Second sentence needs a citation. See previous comments about ammonia concentrations.

Third sentence cites speculation in Perkins that is not an analysis of empirical data. Furthermore, Meyers and Hansen (2002) show that high pH followed by low DO did not increase mortality more than for fish exposed to low DO.

Fourth sentence “data water quality data” needs to be corrected. Also, ammonia was not measured hourly in either lake it was measured weekly. Ammonia was not only less dynamic in CL it was essentially non-detectable.

Be sure to check first use of all abbreviations before use to make sure they are defined in the text.

Page 43 first sentences in the second paragraph under Indirect and Synergistic Effects on Suckers needs a citation.

Page 43 – Suckers with compromised immune systems have a higher probability of dying due to infection, but is there any evidence that any conditions you talk about compromise immune systems of suckers? Assumptions are being made here.

Page 43 first full paragraph. “When larval and juvenile suckers are exposed to…” I think you need to state how low the DO was when effect was observed. Hypoxia has many definitions most of which don’t cause any effects on suckers.

Page 43 sentence that starts, “Additionally, adult suckers seek refuge…” citation needed. Banish et al.

Page 43 first sentence after Harvest. There is an extra period.

Page 45 first paragraph. What size fish were released?

Page 45 second sentence of the first full paragraph. I think you can say that you hope that the SARP fish will be a source of recruitment but I wouldn’t say it is likely. The rest of this sentence makes the point about uncertainty, but likely needs to be removed. Based on data collected so far, I would say there is a great deal of uncertainty about the probability that SARP fish will survive to recruitment.

Page 43 in the predation section, you could mention J. Armstrong work that says that red band trout avoid the lake when water temperatures are greater than 18C. As such, there are essentially no fish predators in mid-summer that are large enough to eat a juvenile sucker. There are bird predators.

Page 43 the sentence that starts, “The fish species most likely …” This only applies to larvae for Fathead Minnows. A small portion (< 10%) of yellow perch found in UKL are large enough to eat small juvenile suckers; most are about the same size as age-0 suckers. Burdick et al 2012 page 9 and Fig 4 (the striped boxed are yellow perch and the white ones are suckers – sorry the caption on that figure was incomplete).

Based on gape size measurements of fish captured in trap nets in UKL blue chub, fatheads, tui chub, can only eat larvae. Yellow perch, lamprey, bullheads (if they eat suckers at all), and trout could also eat juvenile suckers. When brown bullheads (n=2) were put in a bucket with larval suckers they didn’t eat them Hereford et al (2016, p 11). Of the fish species that ate larval suckers in a bucket and for which QC tests were good (sculpin, blue chub, yellow perch, and tui chub), genetic gut probes only found sucker DNA in the guts of wild yellow perch, but sample sizes were small.

End of page 45 and top of page 46. Higher fathead minnow catch rates were associated with lower sucker catch rates. “Abundance” and “survival” should be removed from this sentence.

Page 46 sentence that starts, “These data suggest….” Fathead minnow lay eggs on substrate such as vegetation found in wetlands. Therefore, wetland inundation may in fact be required to maintain fathead minnow populations. Perhaps an alternative approach would be to periodically drain the wetlands to knock back fathead minnow populations. Also note that fathead minnows were until this year the most abundant fish species in Clear Lake where suckers do appear to survive to adulthood. See Burdick report, 2017 I think.

Page 46 under Disease and Parasites. Note that Kent found heart worms in large presumed age-1 suckers and not in small presumed age-0 juveniles.

Parasites section – Why is icthyobodo not mentioned?

Page 47 top of page – Can you provide a citation for spillback?

Page 47 – third full paragraph. When you talk about low dissolved oxygen causing gasping at the surface, it should be noted that this dissolved oxygen is very low when this happens. I think Saiki and Foott give levels of < 1 mg/L. In the USGS cages we didn’t notice this until DO < 1 mg/L see Hereford et al. mesocosm report. Also, it has been hypothesized but not demonstrated that gasping at the surface increases predation by birds.

Page 47 Add a citation for “poor water quality is also likely to increase susceptibility of juvenile suckers to diseases and parasites” At least one paper indicates the opposite to be true. Morris et al. (2006, p 260-261), suggested that ammonia had a direct toxic effect on the bacterial pathogen (*Flavobacerium columnare*) used in their study of Lost River suckers that counter acted any negative effect that ammonia may have had on the immune function of the fish. The immune function was not tested.

Last paragraph on page 49. Larvae are not “entrained” when they pass over Link River Dam. Larval suckers have always dispersed down the Link River as part of their natural life cycle (page 50). The statement on page 50 “larval and juvenile suckers are unlikely to survive in Lake Ewauna after entrainment at Link River Dam” is false. Recent work indicates that the north end of Lake Ewauna has water quality comparable if not better than Upper Klamath Lake (Data in NWIS). Small and presumed young adult or older juvenile suckers that are not found in Upper Klamath Lake, have been found in Lake Ewauna (page 50 top of second paragraph). This indicates that sucker survival may be better in Lake Ewauna than Upper Klamath Lake. This is all described in your report. Suckers that pass over Link River Dam are not entrained they are spared from certain death in Upper Klamath Lake. Therefore, they are not entrained.

Page 50 first full paragraph. Why is there not more effort to screen diversions from Keno Res/Lake Ewauna?

Page 50 first sentence in second full paragraph says Clear Lake Dam was rebuilt in 2003 in the figure 9 caption on page 23 says it was rebuilt in 2004.

Page 54 and 55. Given that estimates in figure 14 and on page 55 are unpublished, you need to give more information on how they were derived and what data were used. The apparent increase in population size in some years in some populations is a red flag to me. Given near zero recruitment in these populations, that shouldn't happen and probably indicates a problem with the methods.

Page 55 second paragraph. There is a typo "Damon" should be "Dam on".

Page 55 a citation should be given for the statement, "Despite the removal of Chiloquin Dam on the Sprague River…"

Page 55 the data used to conclude, "Upper Klamath Lake elevations less than 4142.0 ft …" should be cited.

Page 55 first line in last paragraph – citation such as from authors Ellsworth or Martin needed.

Page 55 last paragraph. This paragraph is missing a few citations. If nothing else cite the raw data and methods that you looked at to make the conclusions stated here.

Page 56, top of page. Given that wetlands are inundated in July when larvae use them but not in August when suckers have transitioned into juveniles, the last sentence in this paragraph is false. Lack of inundated wetlands in August and September can't affect larval suckers because suckers have transitioned to juveniles by that point in time. See statements made in this report on page 22 about larval to juvenile transition timing. Suckers don't appear to depend on wetlands as much if at all as juveniles. In fact, juvenile suckers (species combined) are equally likely to be captured off shore as near shore in August (Many USGS reports on this topic dating back to early 2000s). Wetlands aren't necessary for suckers to survive to adulthood, because if they were suckers wouldn't survive so well in Clear Lake. I think a lot of assumptions have been made about how important wetlands are to juvenile suckers when there is really no evidence. Juvenile suckers need for wetlands has been overstated in the literature for years without evidence. This is a good place to correct the record.

Page 56 second paragraph starting "The number of juveniles.." maybe restate that this paragraph is about Upper Klamath Lake.

Page 57 last line in the first full paragraph starting "However, adult access…" Hewitt didn't study larval production in Clear Lake. Once it is published, you can cite his work to say that access to spawning prevented fish from migrating up stream. If you compare the years that fish had access to Willow Creek (Hewitt's work) to the age distribution of juveniles in Clear Lake (Burdick et al. 2018 p 19) you can say that cohorts of SNS or LRS were not produced in years when few or no suckers migrated upstream in the spring. The take home message is basically the same as what you said, just without making assumptions about the unstudied larval life stage.

Page 57 second sentence in 2nd full paragraph, I think the word larval is missing.

Page 58 last sentence/paragraph about resiliency of other populations. You say resiliency is very low but you don't say why until page 59.

Page 58 first paragraph under redundancy. You use "populations" throughout the report to mean spawning groups, sub-populations populations. Here you are using it to mean true populations but earlier you counted the river and springs spawning groups as populations.

Page 60 second to last line in first paragraph. There is a typo "intermediates(Dowling" needs a space.

Page 60, third paragraph. What do you make of the juvenile sucker genetics data in Burdick et al 2018 page 20 for example that show probabilities of genetic assignment to species using 18 markers? Carl Ostberg a USGS geneticist is confident that these fish were LRS SNS hybrids. Is your statement here based on skepticism of those results for juvenile suckers? If so maybe you could state why those are not considered good data.

Page 61 Why do you say shortnose have greater redundancy than Lost River? You only name three spawning populations – same as for Lost River.

The Wood River sub-population/spawning population/small group of fish is never mentioned among the smaller groups of suckers.

Page 63 table SNS in UKL have about 10K individuals and the population size is called Moderate. You say that the SNS GBR population is low with a population of 42K (page 57). The estimate of 42K is shaky to begin with (and methods for estimating is are not given and should be), but how do you get to less than 10K? Did you assume that more than ¾ of the fish in Gerber died recently? Is that just based on a low water event? Without more information on how you came up with a smaller population size for Gerber than for SNS CL I assume this is a mistake.

Page 65 – You cite unpublished analyses with some important implications. It would be much better if the methods were published here or elsewhere so that a real peer review can be conducted. How did you come up with these population estimates? What data were used? What assumptions were made? Here is an example of where spawning groups are called "Populations".

Page 65 Do your population simulations assume adult survival will remain the same despite an aging population? It seems reasonable to assess a scenario in which older adult survival rates decline. See your statement about this on page 4. The oldest shortnose sucker aged was only 33 years and maximum life span of Lost River sucker was 57 (page 18). You could use that information to include a maximum life span in your model. Because nearly all the adult suckers in the population today were hatched in 1991, your estimates based on current adult mortality rates and current population size and are too optimistic. Unless suckers surprise us and live longer than has ever been documented before, or recruitment occurs, we can expect complete or near complete extirpation of Upper Klamath Lake by the year 2024 for SNS (1991+33) and by the year 2048 (1991+57) for LRS. This is much more dire than your assessment concludes.

Page 65 There is some uncertainty about low levels of recruitment in shortnose sucker populations in Upper Klamath Lake. The length data indicates that there could be small numbers of SNS recruits whereas the mark-recapture analysis is twitchy and uncertain about low levels of recruitment. What would your models do if you presumed low levels of annual SNS recruitment at rates based the length data? You could look at the Hewitt reports to estimate a low recruitment rate from length data.

Page 65 in the Status Quo scenario, you might also just mention what is generally expected to happen to other populations and small groups of fish. Do you think that these small groups might persist in small numbers or blink out?

Page 68 sentence that starts "At present, this effort targets…" I thought the target was based on size not age at release?

Page 68 What size or age were the fish released in spring of 2018?

Page 68 – second paragraph. I don't think you should cite unpublished analysis and methods. You need to report them here or cite a publication or they cannot be adequately reviewed. You could include them in an appendix if no place else.

Page 68 second paragraph sentence starting, "This second assumption …" As mentioned above there are juvenile sucker survival estimates for Clear Lake that could be used.

Page 69 I think this is a good place to reiterate that no matter how many adult suckers you produce though SARP none of the off spring are expected to survive on their own in Upper Klamath Lake and therefore this scenario is one that would have to be continued forever.

You only evaluate 2 scenarios the status quo and SARP with age-4 suckers. The Water-quality section on page 70 doesn't' really read like a scenario. Is it supposed to be? This seems like part of the status quo.

In the section on P reduction you say it is going to take 3 decades to reach the 40% reduction goal through riparian and wetland restoration. Why not evaluate other water-quality improvements such at alum treatments at the mouth of the Wood or Williamson Rivers or oxygen injections and/or bubblers?

The last paragraph on page 72 that ends on page 73 needs citations.

Page 73 The first sentence in the first full paragraph that starts, "We expect that these improvements would increase…." What is this expectation based on? All the empirical data we have on water quality conditions that kill juvenile suckers indicates that the conditions that occur throughout most of Upper Klamath Lake right now shouldn't kill juvenile suckers. Compare Saiki et al 1999, Meyer and Hansen, 2002, Castelburry and Cech… Morris et al … Hereford et al 2017 and Lease et al. 2003 to lake water quality data on NWIS. The exception is that water quality in Howard Bay, Shoalwater Bay and Ball Bays are worse than other areas. Unless juvenile suckers are congregating in these bays they should be fine with water-quality that presently occurs in UKL. The juvenile sucker distribution data collected by USGS from 2007 to 2009 throughout Upper Klamath Lake indicated wide spread use of the lake not congregations of suckers in the bays or areas of poor water quality. Even if fish use these bays why do you think they wouldn't just move out of them when water-quality gets bad? That is what the adults do. I agree that there should be some improvement in survival from improved water-quality (at least in the bays), but to expect water-quality improvements to reduce the juvenile sucker mortality problem to the point that we see recruitment to the adult stage seems overly optimistic to me.

Just a few years ago there was great interest in restoring spawning populations in the Wood River and in Harriman Springs. Why not evaluated a scenario in which these populations are restored?

Why didn't you evaluate alternate lake level management scenarios? For example, what if the lake were drawn down lower or held a foot higher? Or what if you managed the lake elevation for more variability to promote wetland diversity? What if you prescribed occasional years of low water in Upper Klamath Lake to help to reduce fathead minnow spawning habitat?

Page 74 –Bottom of page 74 you say SNS spawn in 2 streams and LRS in one. But LRS spawn in Boles Creek too. I think you say they spawn up to Avanzino Reservoir earlier.

Page 75 last sentence in the first full paragraph. This may already be occurring.

Page 75 – I think you can do a better job of describing how you would manage sucker access to Clear Lake tribs. Can you give water levels? Can you say how many years in the last decade that water level management specifically would have provided more access to spawning habitat? See latest Hewitt report.

Page 76 first sentence in second paragraph under Species-level Effects. Which shortnose sucker population are you talking about here? UKL?

Page 76 first line in third paragraph under Species-level Effects. I disagree with this statement. The SARP program will not provide greater stability for the wild population of suckers. Unless the cause of juvenile mortality in the UKL populations is discovered SARP will only ever provide a short-term fix or a fix that will require human intervention forever. A population dependent upon a hatchery like operation is not stable. I think you can say that SARP is necessary to prevent extinction in the short term but stability of the Upper Klamath Lake populations cannot be achieved until you determine and correct the cause of mortality for juvenile suckers. Unless effort is put into finding out the cause of natural juvenile sucker mortality, the SARP program will never lead to recovery of the species. The evidence that reduction in nutrient loads will lead to juvenile sucker survival is weak at best. Most evidence indicates that water-quality conditions in most Upper Klamath Lake are survivable for young suckers. While improving water-quality is a good thing overall, there is no indication that it will achieve full recovery. There is a decent chance that the primary cause of juvenile sucker mortality in Upper Klamath Lake is not water-quality.

Bottom of page 76 – Given the dire situation for Lost River suckers, why are actions related to the reestablishment of more Lost River sucker populations not given greater consideration?