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Monitoring of Endangered Klamath Basin Suckers Translocated from Lake Ewauna to Upper Klamath Lake, Oregon, 2014–2017

Open-File Report 2019–1085

U.S. Department of the Interior
U.S. Geological Survey

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DAVID BERNHARDT, Secretary

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as:

°F = (1.8 × °C) + 32.

Abbreviations

FL	fork length
FWS	U.S. Fish and Wildlife Service
KLS	Klamath largescale sucker
LRS	Lost River sucker
PIT	passive integrated transponder
Reclamation	Bureau of Reclamation
SNS	shortnose sucker
TNC	The Nature Conservancy
UKL	Upper Klamath Lake

Monitoring of Endangered Klamath Basin Suckers Translocated from Lake Ewauna to Upper Klamath Lake, Oregon, 2014−2017

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Executive Summary

Data from a 4-year capture and transport program were used to assess translocation as a management strategy for two long-lived, federally endangered catostomids in the Upper Klamath Basin, Oregon. Lost River (*Deltistes luxatus*) and shortnose (*Chasmistes brevirostris*) suckers, two species endemic to the Klamath Basin, were translocated from Lake Ewauna to Upper Klamath Lake in each of 4 years (2014–2017) in an effort to augment existing spawning populations in Upper Klamath Lake. Lake Ewauna, downstream of Upper Klamath Lake and connected to it by the Link River, has small populations of Lost River and shortnose suckers. Upper Klamath Lake has the largest remaining population of Lost River suckers and one of the largest remaining populations of shortnose suckers. Adult suckers were captured in Lake Ewauna, tagged with passive integrated transponder (PIT) tags, and translocated to the Williamson River, a spawning tributary that flows into Upper Klamath Lake. We monitored initial success of translocation efforts with encounters from remote PIT tag antennas and physical recaptures.

A total of 659 suckers were translocated from Lake Ewauna to the Williamson River (40 in 2014, 384 in 2015, 172 in 2016, and 63 in 2017). All individuals that were translocated were assumed to be one of the endangered taxa, but recaptures indicated that some translocated suckers were misidentified and were instead Klamath largescale suckers (*Catostomus snyderi*), a non-listed species that is also endemic to the Upper Klamath Basin. Other recaptures of translocated individuals revealed conflicts in species identification between the two endangered taxa as well. Due to species identification conflicts, we analyzed translocated individuals by cohort (year of translocation) and sex only. Specifically, we documented encounters of translocated individuals at spawning locations and throughout the Upper Klamath Lake watershed, analyzed frequency of return to spawning sites, assessed fidelity to spawning sites, and monitored migration timing over three full years (2015, 2016, and 2017). Remote PIT tag antennas at 11 sites and 5 physical capture locations were part of a monitoring network to re-encounter translocated individuals. In contrast to other years of the study, high flows in the Williamson River in 2017 prevented the installation of a river-wide weir and upstream trap with associated PIT-tag antennas that routinely detect large numbers of tagged fish. As a result, re-encounter probabilities in 2017 were expected to be lower than 2015 and 2016.

Between 62 and 87 percent of the individuals from the four translocated cohorts were encountered at least once at spawning locations in the Upper Klamath Lake watershed, similar to results for resident spawning suckers used for comparison. Encounters at spawning locations were highest during the year of translocation (50–76 percent), but were lower than for resident suckers in their year of capture and release, and decreased in subsequent years (30−52 percent). The lowest numbers of encounters at spawning sites were in 2017, the year without the Williamson River weir in operation.

This was consistent with low re-encounters among resident individuals in 2017. Throughout the Upper Klamath Lake watershed, most translocated individuals were re-encountered in the Williamson River (78 percent), the original site of release and a known spawning tributary, and few emigrated back to Lake Ewauna (5 percent). Similarly, for more than 8,000 resident Lost River and shortnose suckers captured at pre-spawn staging areas in Upper Klamath Lake from 2015 to 2017, most were re-encountered at the Williamson River (69 percent) and a few (less than 1 percent) were encountered in the Link River.

We assessed frequency of return to spawning sites as well as spawning site fidelity for translocated fish encountered at spawning locations in multiple years. Resident Lost River and shortnose suckers across all three subpopulations in Upper Klamath Lake are known to exhibit high return frequencies and a high degree of spawning site fidelity. Resident Lost River suckers have been well documented to spawn in two subpopulations, one that migrates up the Williamson and Sprague rivers, and the other that spawns at a series of springs along the eastern shoreline of Upper Klamath Lake. Resident shortnose suckers are known to spawn in the Williamson and Sprague Rivers. Translocated suckers showed strong fidelity to the Williamson River across spawning seasons, with fewer encounters at other known spawning locations−the Sprague River and shoreline springs. Whether release of translocated individuals into the Williamson River affected subsequent encounters is unknown. Nonetheless, over 3 years of monitoring, translocated fish from the 2015 cohort showed a higher tendency than residents to be encountered at multiple different spawning sites rather than showing fidelity to just one site (20 percent compared to less than 3 percent). At an individual level, translocated fish monitored for at least two spawning seasons returned to spawning areas at similar frequencies to residents in most years. However, compared to resident fish, translocated fish were less likely to be encountered in their year of release (about 75 percent compared to 82–97 percent), and more likely to never be encountered at a spawning site through 2017 (about 15 percent compared to 5−7 percent). Less frequent returns to spawning sites among translocated individuals may be explained by post-release mortality or fish adjusting to new environmental conditions and new spawning sites. More years of monitoring with the Williamson River weir in place are needed to confirm spawning site fidelity for individuals and to estimate survival with capture-recapture.

The capture, transport, and release of translocated individuals did not appear to have an adverse effect on migration timing in the Williamson River. Migration timing of resident and translocated fish was compared by monitoring encounters at the upstream Williamson River weir trap and a river-wide array of antennas upstream of the weir. Migration timing of translocated cohorts was very similar to that of resident individuals even during the year of translocation. Although fewer individuals from each translocated cohort were encountered at the Williamson River in subsequent years after translocation, migration timing of those that returned continued to coincide with that of resident individuals. Water temperature, known to be an important variable that triggers migration of resident suckers, may also be the most important driver in migration among translocated suckers. Translocated individuals were also released into the Williamson River during the peak encounters of migrating resident individuals in 2015, 2016, and 2017. Thus, social cues in combination with environmental cues may influence migratory behavior and timing.

Despite relatively high encounters of translocated individuals following release into the Williamson River and evidence of spawning site fidelity, additional years of monitoring are needed to determine success or failure from translocation efforts. Few studies have documented translocation efforts for long-lived fish and survival estimates over time are needed. Monitoring of this translocation study can be incorporated into the existing long-term monitoring program of PIT-tagged Lost River and shortnose suckers in Upper Klamath Lake. Continuing to monitor the return of translocated individuals to the Williamson and Sprague Rivers may be the best measure of near-term success to examine whether translocated cohorts and individuals have become established in Upper Klamath Lake and are augmenting existing spawning populations. Translocation may be considered as a mitigation strategy for dam operations at the outlet of Upper Klamath Lake and one component of a broader recovery strategy that is focused on continuing to address the factors that are contributing to the decline of endangered suckers in the Klamath Basin.

Introduction

Two long-lived and obligate lake-dwelling catostomids, the Lost River sucker (LRS; *Deltistes luxatus*) and shortnose sucker (SNS; *Chasmistes brevirostris*), are endemic to the Upper Klamath Basin in southern Oregon and northern California (Scoppettone and Vinyard, 1991). Both species perform spawning migrations from lakes to tributary rivers between March and June each year. During these spawning migrations, populations of LRS and SNS historically supported a subsistence fishery for indigenous peoples (National Research Council, 2004) and a recreational snag fishery that was closed in 1987 (Markle and Cooperman, 2002). Annual harvests of LRS and SNS in spawning tributaries to Upper Klamath Lake declined from over 10,000 fish in 1968 to 687 fish in 1985 (Scoppettone and Vinyard, 1991; Markle and Cooperman, 2002). Age data acquired from a 1986 fish die-off of adult LRS in Upper Klamath Lake found that most adults (95 percent) were 19–30 years old with little recruitment over the previous 15 years (Scoppettone and Vinyard, 1991). Both LRS and SNS were listed as endangered under the Endangered Species Act in 1988 (U.S. Fish and Wildlife Service, 1988).

Factors attributed to the declines of LRS and SNS include damming and diversion of rivers, poor water quality resulting from timber and agricultural practices, loss of habitat, competition with and predation by non-native species, dredging and draining of wetlands (U.S. Fish and Wildlife Service, 1988; National Research Council, 2004), and predation by piscivorous colonial waterbirds (Evans and others, 2016). The combination of these factors has resulted in a reduction in range and abundance of both species by over 95 percent (U.S. Fish and Wildlife Service, 1988). Although the historic range of LRS and SNS included most lakes in the Upper Klamath Basin, the present range is limited primarily to Upper Klamath Lake, Oregon, and Clear Lake Reservoir, California, with smaller populations in Lake Ewauna, Gerber Reservoir, Tule Lake, and the Lost River (National Research Council, 2004). The largest population of LRS and one of the largest remaining populations of SNS reside in Upper Klamath Lake (Hewitt and others, 2017).

Another non-listed sucker species that is endemic to the Upper Klamath Basin, the Klamath largescale sucker (KLS; *Catostomus snyderi*), shares habitat with both LRS and SNS but is primarily a resident in rivers and large streams. Although each of the Klamath Basin sucker species exhibit some level of reproductive isolation by maintaining distinct spawning locations and different timing of their spawning migrations (Martin and others, 2013; Dowling and others, 2016), confusion in species identification occurs among all three of these sucker species, especially at smaller sizes. Confusion in morphological identification is most common between KLS and SNS. Indeed, suckers in the Upper Klamath Basin appear to have evolved a basin-wide syngameon, wherein gene exchange over evolutionary time has resulted in introgressive hybridization with species maintaining unique morphological traits (Dowling and others, 2016).

Although LRS and SNS are long-lived species, with age estimates for LRS exceeding 50 years and age estimates for SNS exceeding 30 years (National Research Council, 2004; Terwilliger and others, 2010), the lack of significant recruitment of new individuals into Upper Klamath Lake spawning populations since the 1990s is concerning (Hewitt and others, 2017). Because the probability of re-encountering suckers tagged with passive integrated transponder (PIT) tags at spawning sites in Upper Klamath Lake and the Williamson River is typically very high (greater than 0.90), the lack of recruitment is not thought to result from a lack of spawning (Hewitt and others, 2017). Water quality issues in Upper Klamath Lake caused by hypereutrophic conditions and massive blooms of the cyanobacterium *Aphanizomenon flos-aquae* continue to be a concern for adult suckers (Hewitt and others, 2012). Adult fish die-offs, which are thought to have been related to poor water quality conditions (low concentrations of dissolved oxygen, elevated concentrations of ammonia, and high pH) following algal bloom crashes, occurred during the summers of 1986, 1995, 1996, 1997 (Perkins and others, 2000a; National Research Council, 2004), 2003 (U.S. Geological Survey, unpub. data, 2003), and 2017 (U.S. Geological Survey, unpub. data, 2017). However, crashes of algae blooms and subsequent poor water quality tend to occur in some places and at some times in Upper Klamath Lake each year, so the mechanisms leading to adult sucker die-offs are not clear. The lack of recruitment success for both LRS and SNS has led to several management programs by U.S. Fish and Wildlife Service (hereinafter, FWS) and the Bureau of Reclamation (hereinafter, Reclamation) that include captive propagation, analysis of flow reduction at the Link River Dam to minimize effects of entrainment on larval and juvenile suckers, and capture and transport of endangered suckers from Lake Ewauna to Upper Klamath Lake (a process known as translocation; National Marine Fisheries Service and U.S. Fish and Wildlife Service, 2013).

Translocation studies have been used increasingly as a management action for freshwater fish to establish new populations or augment existing populations of a threatened species (Lintermans, 2013; Todd and Lintermans, 2015). Translocation is the intentional release of captive-reared or wild-caught individuals into the wild for one of three purposes: (1) establishing a new a population in a new range, (2) re-establishing a population that has become extinct within a specific range, and (3) augmenting threatened or endangered populations (Wolf and others, 1996). Augmentation is defined as supplementing an existing wild population with individuals from another population (George and others, 2009). Many studies focus on translocation as a conservation tool to relocate endangered freshwater fish to non-native habitats in cases where in situ management is not possible (Olden and others, 2010; Adams and others, 2014). For purposes of this report, we focus on translocation efforts to augment threatened and endangered populations within the same watershed. Translocation efforts are not intended to be an alternative to addressing causal factors that contributed to the decline of endangered species (George and others, 2009; Cochran-Biederman and others, 2014); rather, translocation is recommended to be a temporary management approach and within the same river basin of a species' historical range (Olden and others, 2010).

Success of previous translocation efforts has been mixed. The Humpback chub (*Gila cypha*) was translocated from the Little Colorado River to a tributary of the Colorado River above an impassable waterfall in Grand Canyon National Park, Arizona. Although there is evidence of reproduction from translocated Humpback chub at their site of translocation, results also showed high emigration rates (53 percent), with most emigration taking place during the first year following release (Spurgeon and others, 2015). A study of Macquarie perch (*Macquaria australasica*) that were translocated upstream of an impassable waterfall in the Queanbeyan River, Australia, in 1980 found a small reproducing population of translocated fish over 10 years after release with consistent recruitment for the following 5 years (Lintermans, 2013). However, a prolonged drought (1997–2010) was the likely cause for the population eventually becoming undetectable, which highlights the importance of monitoring over appropriate temporal and spatial scales prior to determining success (Lintermans, 2013; Cochran-Biederman and others, 2014). To our knowledge, few studies document efforts that translocated long-lived, endangered fish from a smaller, wild population to augment a larger spawning population of wild conspecifics in a connected water body.

In 2013, Reclamation proposed a management strategy in coordination with FWS to implement capture and transport (hereinafter, translocation) of LRS and SNS from Lake Ewauna to Upper Klamath Lake (fig. 1). Lake Ewauna is known to contain small populations of LRS and SNS, though connectivity between populations in Lake Ewauna and Upper Klamath Lake may be compromised by the Link River Dam. Entrainment at the Link River Dam has been viewed as a problem for LRS and SNS populations in Upper Klamath Lake (National Research Council, 2004), and the translocation proposal was designed to meet requirements outlined in the National Marine Fisheries Service and U.S. Fish and Wildlife Service May 2013 Biological Opinions (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 2013). Because of particularly poor water quality in Lake Ewauna and the Klamath River downstream (Sullivan and others, 2009), the agencies considered Lake Ewauna to be a sink habitat for entrained larval and juvenile suckers, with little or no potential for these individuals to survive and reproduce. Translocation was viewed as an effort to augment existing spawning populations in Upper Klamath Lake, and could also provide insight into potential translocation of suckers in lower reservoirs of the Klamath River prior to removal of four large dams scheduled to begin in 2021. Reclamation estimated that up to 2,000 LRS and SNS would be relocated during this effort. These estimates came from sampling conducted by Reclamation in Lake Ewauna from 2008 to 2011, in which 1,662 suckers (LRS, SNS, and KLS) were captured, PIT-tagged, and released back into Lake Ewauna (U.S. Bureau of Reclamation, unpub. data, 2012).

Upper Klamath Lake is connected to Lake Ewauna by the Link River, which includes a fish ladder at the Link River Dam (fig. 1). The fish ladder was designed specifically for suckers, and passage of PIT-tagged fish has been monitored by USGS since 2008 with antennas placed in the ladder cells from the bottom to the top. Monitoring from 2008 to 2011 recorded detections of 3–26 individual suckers on the Link River Ladder PIT tag antennas in a given year, although this is likely an underestimate of usage since there are an unknown number of suckers without PIT tags in Lake Ewauna. From 2008 to 2017, 182 suckers were detected on the ladder antennas, and the vast majority entered the ladder from the Link River and successfully navigated through all of the ladder cells. In addition to the antennas in the ladder, a river-wide array of antennas was installed across the Link River 1.5 km below the dam in 2015. From 2015 to 2017, a total of 206 PIT-tagged suckers were encountered on the array; about 40 percent of those individuals were encountered in multiple years. Whether adult suckers in Lake Ewauna successfully spawn in the Link River is unknown.

In this report, we analyze data from endangered suckers translocated from a smaller, wild population in Lake Ewauna to an existing larger, wild population in Upper Klamath Lake from 2014 to 2017, to evaluate initial success or failure of translocation efforts. We examined encounters at spawning locations, spawning site fidelity among years, and migration timing during the spawning season. Resident LRS (non-translocated) in Upper Klamath Lake are known to exhibit a high degree of spawning site fidelity between two subpopulations in Upper Klamath Lake, one that migrates up the Williamson and Sprague Rivers, and the other that spawns at the shoreline springs along the eastern shore of Upper Klamath Lake (fig. 1; Janney and others, 2008; Hewitt and others, 2012). Resident SNS are known to spawn in the Williamson and Sprague Rivers. Whether translocated suckers would be encountered at known spawning locations of the resident populations in Upper Klamath Lake and exhibit spawning site fidelity over time is unknown. Furthermore, timing of spawning migrations is strongly correlated with rising temperatures near or greater than 10 and 12 degrees Celsius (°C) for LRS and SNS, respectively (Hewitt and others, 2012; Hewitt and others, 2014). If translocated suckers were observed migrating to known spawning sites in the Williamson and Sprague Rivers, timing of this migration and whether it would coincide with the migration of resident suckers was unknown. We predicted that migration timing would be different in the year of translocation as fish were adjusting to their new environment. In addition, we assessed all encounters of translocated individuals from the year of translocation through 2017 to determine how many translocated individuals were re-encountered following release. Cumulative summaries of encounters by translocated cohort and encounter location are provided. Encounter locations consist of an established suite of monitoring locations throughout the Upper Klamath Lake watershed for physical captures and remote PIT tag detection antennas. We attempt to provide insight into the initial success or failure of a 4-year translocation effort of LRS and SNS to augment existing spawning populations of wild suckers.

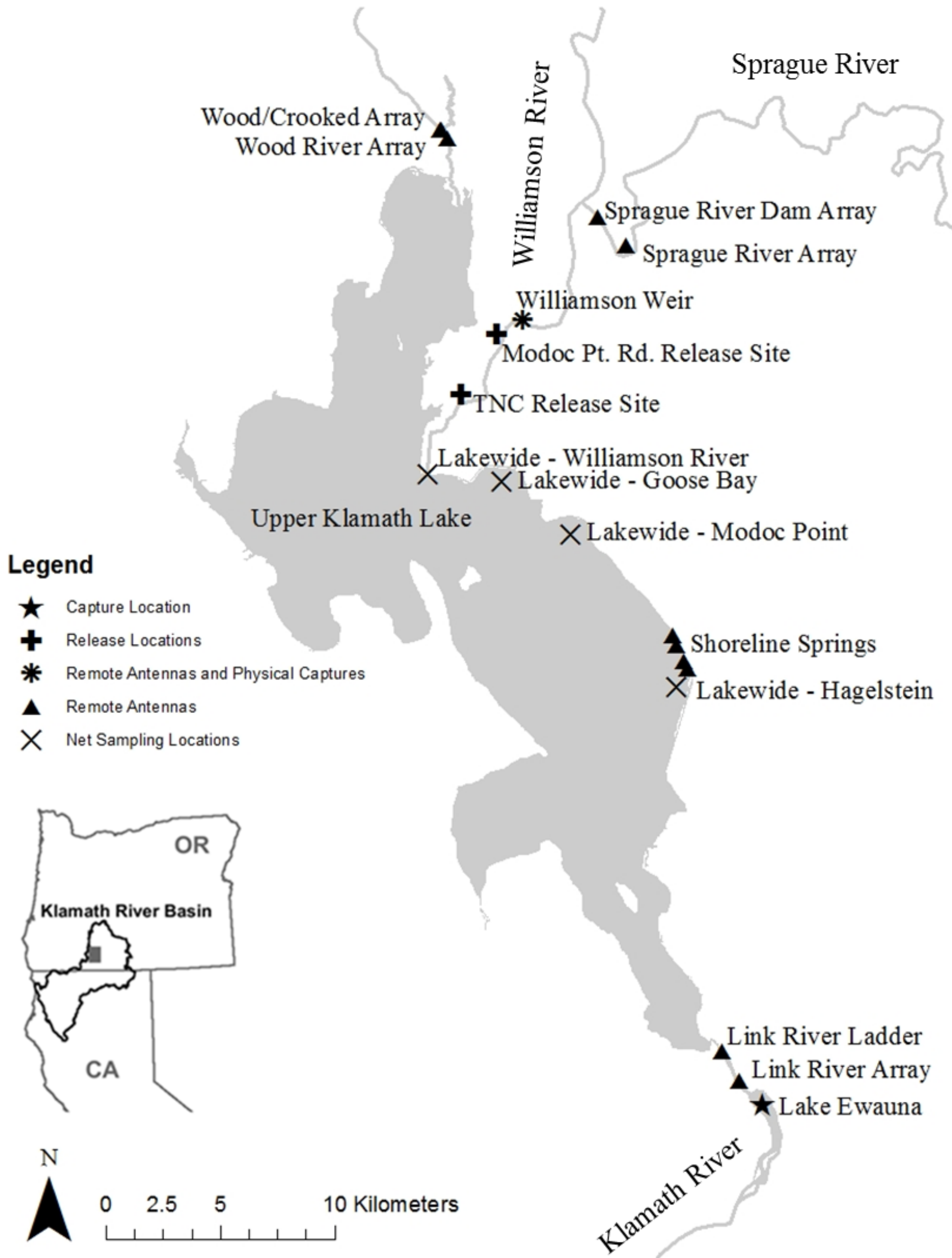

Figure 1. Map showing capture location in Lake Ewauna, release locations in the Williamson River, and monitoring locations in Upper Klamath Lake and its tributaries (remote antennas and net sampling), for Lost River suckers, shortnose suckers, and Klamath largescale suckers tagged by passive integrated transponder (PIT) tags. The inset shows the Klamath River Basin and the location of Upper Klamath Lake in south-central Oregon. [TNC, The Nature Conservancy]

Methods

Sampling and Fish Handling

Suckers were captured in Lake Ewauna and translocated to two release sites on the Williamson River: The Nature Conservancy (hereinafter, TNC) boat launch at Tulana in 2014, 2015, and 2017; and the Sportsman's River Retreat boat ramp off Modoc Point Road in 2016 (fig. 1). The TNC and Modoc Point Road release sites are 5.6 and 1.7 km downstream of the Williamson River weir, respectively. Between 2014 and 2017, fish were sampled during four periods in Lake Ewauna: during autumn 2014 (November 4−December 4), spring 2015 (March 3−April 16), spring 2016 (March 14−April 21), and spring 2017 (March 14−May 1). Trammel nets (91.4-m long; 1.8-m high) were used to capture adult suckers and consisted of two 30-cm mesh outer panels, one 3.8-cm mesh inner panel, a foam-core float line, and a lead-core bottom line. Nets were set in Lake Ewauna near or off-shore, either parallel or perpendicular to shore near the mouth of the Link River and along the eastern shoreline. Specifics regarding effort and catch per unit effort (CPUE) within years can be found in the 2016 Annual Report for the 2013 Biological Opinions (U.S. Bureau of Reclamation, 2017).

Suckers captured in Lake Ewauna were identified to species and sex, measured for fork length (FL), scanned for the presence of a PIT tag, held in net pens, transferred to aerated holding tanks, and translocated to their release site (fig. 1). If a PIT tag was not detected, one with a unique identification number was inserted into the ventral abdominal musculature anterior to the pelvic girdle and recorded in the Klamath River Basin PIT Tag Database operated by the USGS. Suckers identified as KLS were released back into Lake Ewauna. Suckers identified as LRS and SNS were held and translocated to the Williamson River. Guidelines for sucker handling were developed by Reclamation (U.S. Bureau of Reclamation, 2008). Specifics regarding handling and translocation of LRS and SNS in addition to captures of non-sucker fish species can be found in Reclamation's 2016 Annual Report (U.S. Bureau of Reclamation, 2017). All individuals translocated within a specific year were assigned to a cohort specific to that year (for example, all individuals translocated in 2014 were known as the 2014 cohort).

For comparison to translocated cohorts, we analyzed cohorts of resident (non-translocated) suckers captured in Upper Klamath Lake by USGS from 2015 to 2017. We included all resident suckers, recaptured and newly tagged, that were captured and released at Lakewide sampling locations, which included the lower Williamson River, Goose Bay, and Modoc Point (fig. 1). This group of resident fish was captured at sites nearest in proximity to the release site of translocated fish in the Williamson River, and was assumed to have a comparable history of encounters to translocated fish. Fish captured at the Hagelstein Lakewide sampling location were excluded since this site was not near the release location for translocated fish. Resident fish were captured by USGS in the spring using similar sampling and handling procedures as the Lake Ewauna translocated fish, except that resident fish were released at their site of capture after processing.

Translocated Sucker Identification Conflicts and Analysis Resolution

Reclamation and USGS physical recaptures of suckers that were captured in Lake Ewauna from 2014 to 2017 provided an indication that there were conflicts in field identification of both species and sex for captured individuals. Both non-translocated and translocated suckers that were captured in Lake Ewauna and had previous or subsequent physical captures were summarized in confusion matrices to evaluate conflicts in identification. These matrices were not an attempt to evaluate the capture history of each individual and determine the "correct" species and sex, but rather were a simple way to evaluate confusion on identification. Only individuals captured during a Lake Ewauna translocation year with a previous or subsequent physical capture by Reclamation or USGS were included in the matrices. The vertical axis was the identification (ID) in the year of capture in Lake Ewauna for an individual with at least two physical captures in its full record in the database. The horizontal axis was any previous or subsequent capture ID. Captures of fish identified as KLS are included in the matrices because of their confusion with the other species. Individuals were captured as LRS (female or male), SNS (female or male), or KLS (female or male), and recaptured as either the same or different species and sex, thus creating a 6 × 6 matrix. Individuals with no species or sex conflicts in the matrix appear along the diagonal with the same capture and recapture identification (for example, LRS male translocated in 2015 and recaptured as LRS male in 2017). Individuals with species or sex conflicts in the matrix appear outside of the diagonal with a different capture and recapture identification (for example, LRS male previously captured in 2009 and translocated upon capture as SNS female in 2016). This was an effort to develop a list of translocated suckers for each cohort (year of translocation) that avoided as many identification conflicts as possible for subsequent analyses.

Remote Passive Integrated Transponder Tag Detection Systems and Physical Capture Sites

In addition to the physical captures in Lake Ewauna, translocated suckers were opportunistically detected on remote PIT tag antennas that were installed by USGS in Upper Klamath Lake and its tributaries (fig. 1). Hewitt and others (2010) found that remote antennas dramatically improved the re-encounter probability of previously PIT-tagged suckers, and these antennas also provided useful information regarding the fate of translocated suckers. All remote antennas were in operation during the translocation study, with two exceptions: the Link River array was installed and began operating in December 2015; and the Williamson River weir was not installed in 2017 due to high flows. At the weir site, in years other than 2017, one PIT tag antenna was installed in each of the upstream and downstream traps during the spawning migration. The downstream trap was left open, but the upstream trap was also used to physically capture migrating suckers. In 2017, the weir and these associated traps were not installed, but the river-wide array of antennas upstream of the weir was in operation. Translocated suckers were also physically captured elsewhere by USGS before or after their capture by Reclamation in Lake Ewauna. Trammel net sampling locations used by USGS, collectively referred to as Lakewide sampling, include sites in the lower Williamson River, Goose Bay, Modoc Point area, and near Hagelstein Park (fig. 1).

Encounters at U.S. Geological Survey Monitoring Locations

Spawning Site Encounters

To determine whether translocated fish were being encountered at known spawning locations following their release, encounters at spawning locations were summarized by cohort each year. For purposes of this analysis, known spawning locations include the Williamson River, Sprague River, and shoreline springs. It should be noted that most individuals encountered at the Sprague River were also encountered at the Williamson River, and individuals that visit both are considered part of the same spawning population. We used encounters at remote PIT tag antennas at all spawning areas in addition to physical captures at the Williamson River weir and shoreline springs during the spawning season from March to June each year.

Cumulative Encounters

To determine where translocated fish were being encountered at USGS monitoring locations in the Upper Klamath Lake watershed following translocation (fig. 1), cumulative summaries of individual encounters were created for each cohort from the year of translocation through 2017. Cumulative encounters of translocated suckers at USGS PIT tag antennas and in physical captures were also summarized by location for the 2014, 2015, 2016, and 2017 cohorts together. Encounters at Lake

Ewauna include only physical recaptures that followed translocation to Upper Klamath Lake (individuals that returned to Lake Ewauna through Link River Dam). Lakewide captures refer to annual spring trammel net sampling by USGS. Individuals could be encountered at more than one location. Individual encounters at the same monitoring site in multiple years were only counted once in the cumulative summaries. For comparison to translocated cohorts, we also analyzed individual encounters of resident suckers in Upper Klamath Lake at USGS monitoring locations from 2015 to 2017. Cumulative encounters were assessed over the entire year and were not limited to the spawning season.

Spawning Site Fidelity

Cohort Level

To determine whether translocated suckers exhibited spawning site fidelity at a cohort level, we analyzed the number and percentage of each cohort's return to three known spawning sites each year, including their year of translocation. For example, 123 females from the 2015 translocation cohort were encountered in the Williamson River in 2015. In 2016, 84 females from this cohort were encountered in the Williamson River; those 84 individuals include fish that were also encountered in 2015 as well as fish that were first encountered in 2016. The 2014 and 2015 cohorts both had 3 years of analysis for spawning site fidelity (2015−2017) because the 2014 cohort was translocated in autumn 2014 after the spawning season. The 2016 cohort had 2 years of analysis for spawning site fidelity and the 2017 cohort had only 1 year to document spawning sites.

Individual Level

We examined individual return histories for translocated suckers in the 2015 and 2016 cohorts to evaluate the frequency with which fish returned to spawning sites after they were first encountered at a spawning site. For this analysis, we summarized the return histories of individual fish rather than cohorts but combined all spawning locations (Williamson River, Sprague River, and shoreline springs). For example, 131 females from the 2015 translocation cohort were encountered at a spawning site in 2015. Sixty-nine of those females were encountered at a spawning site in 2016, and 41 were encountered at a spawning site in 2017. We provide summaries by sex, excluding fish of unknown sex, and we exclude the 2014 cohort because of small sample sizes.

To assess individual fidelity to spawning sites, we tabulated spawning location encounters for individuals that were encountered at spawning locations in multiple years. Whether individual suckers actually spawned was unknown. Individuals were assigned to one of three categories: river fish, springs fish, or mixed (encounters at both the river and the springs). The 2014 and 2015 translocated cohorts had 3 years (2015, 2016, and 2017) to analyze individual spawning site fidelity, and the 2016 cohort had 2 years (2016 and 2017). A summary of spawning site fidelity was provided for each of these translocated cohorts. Encounters at non-spawning locations were not included in this analysis.

For both the analysis of individual spawning site fidelity and individual return histories based only on spawning location encounters, results for the translocated cohorts were compared to results for the cohorts of resident individuals captured at Lakewide locations. Lakewide locations for resident fish were restricted to sites in closest proximity to the release site of translocated fish (Goose Bay, Modoc Point, and the Williamson River). The probability of being captured and the probability of being detected are assumed to be the same between resident and translocated individuals.

Migration Timing

To determine whether migration of translocated suckers up the Williamson River coincided with the migration of non-translocated (resident) suckers, we plotted run timing for each translocated cohort and all resident LRS and SNS by year. Run timing was assessed for 2015, 2016, and 2017, and summarized as counts of individual first encounters by date from March to June each year. Encounters included detections at the Williamson River weir upstream trap and the array of antennas upstream of the weir, as well as physical captures in the upstream trap. This allowed for the highest likelihood of encountering tagged fish during their upstream migration in all years. In 2017, the Williamson River antenna array was the only source of detections for upstream migrants. We also assessed whether migration timing in the year of translocation differed from subsequent years in which cohorts had 1 year or more to adjust to their new environment.

Results

Capture and Translocation Summary

Reclamation captured 850 individual suckers during Lake Ewauna sampling from 2014 to 2017, including 484 SNS, 171 LRS, 179 KLS, and 16 unidentified suckers (table 1). During autumn 2014, 42 suckers were captured (20 SNS, 19 LRS, 2 KLS, and 1 unidentified sucker). Of these, 39 suckers identified as LRS or SNS and 1 unidentified sucker were held and translocated to TNC's Tulana boat launch on the Williamson River (fig. 1). During spring 2015, 488 suckers were captured (288 SNS, 93 LRS, 97 KLS, and 10 unidentified suckers), and 381 identified as LRS or SNS and 3 unidentified were held and translocated to TNC's Tulana boat launch. One LRS and one SNS with no PIT tag were also captured during 2015 but were excluded from this analysis. During spring 2016, 247 suckers were captured (135 SNS, 37 LRS, 74 KLS, and 1 unidentified sucker), and 172 identified as LRS and SNS were held and translocated to the Sportsman's River Retreat boat launch on the Williamson River at Modoc Point Road (fig. 1). During spring 2017, 73 suckers were captured (41 SNS, 22 LRS, 6 KLS, and 4 unidentified suckers), and 63 identified as LRS and SNS were held and translocated to TNC's Tulana boat launch.

Table 1. Numbers of suckers captured, by species and sex, and total number translocated during sampling efforts in Lake Ewauna, Oregon, 2014–2017.

[Numbers in parentheses were the number of suckers translocated by species and sex from Lake Ewauna. There was one individual translocated as an SNS female in 2014 with a later recapture as a KLS female in Lake Ewauna in 2016. There were two KLS females that were captured and released in Lake Ewauna in 2014 with later recaptures as KLS females in 2015. There were two individuals translocated as SNS males in 2015 with later recaptures as KLS males in Lake Ewauna in 2016. There were eight KLS females that were captured and released in Lake Ewauna in 2015 with later recaptures as KLS females in Lake Ewauna in 2016. There was one KLS male that was captured and released in Lake Ewauna in 2015 with a later recapture as a KLS male in Lake Ewauna in 2016. There was one KLS female that was captured and released in Lake Ewauna in 2015 with a later recapture as a KLS male in Lake Ewauna in 2016. **Abbreviations**: F, female; M, male; Unid., unidentified sucker at time of capture]

	Species							
	SNS		LRS		KLS			Total
Year	F	M	F	M	F	M	Unid.	captured
2014	12 (12)	8 (8)	10 (10)	9 (9)	2 (0)	0 (0)	1 (1)	42
2015*	130 (130)	158 (158)	60 (60)	33 (33)	61(0)	36 (0)	10 (3)	488
2016	84 (84)	51 (51)	25 (25)	12 (12)	53 (0)	21 (0)	1 (0)	247
2017	19(19)	22 (22)	11 (11)	11 (11)	3 (0)	3 (0)	4 (0)	73
Total	245 (245)	239 (239)	106 (106)	65 (65)	119 (0)	60 (0)	16 (4)	850 (659)

*One SNS female (no tag) and one LRS male (no tag) were excluded from the 2015 summary.

Translocated Sucker Identification Conflicts and Analysis by Sex

Analysis of individuals from the 2014–2017 sampling efforts that were recaptured by Reclamation or USGS indicated conflicts in both species and sex identification. Of the 42 suckers captured in 2014 (table 1), 11 were captured previously or subsequently and used in a matrix to identify conflicts in species and sex identification (table 2). Of these, there were four conflicts in species identification and zero conflicts in sex identification. These conflicts appear outside of the diagonal. There were seven identifications with no species or sex conflicts; these appear along the diagonal.

Table 2. Summary of individuals captured in Lake Ewauna, Oregon, in 2014, by species and sex, compared with species and sex identification from previous or subsequent capture.

[The species and sex identification at capture in 2014 is along the vertical axis and the species and sex identification from previous or subsequent capture is along the horizontal axis. Counts of individuals with no conflicts in species or sex identification are along the diagonal shaded in light gray. Cells shaded in dark gray with white text indicate conflicts in species identification. **Abbreviations**: LRS, Lost River sucker; SNS, shortnose sucker; KLS, Klamath largescale sucker; F, female; M, male]

		Other Capture						
		LRS F	LRS M	SNS F	SNS M	KLS F	KLS M	Total
2014 Capture	LRS F	*3*	0	**1**	0	0	0	4
	LRS M	0	*0*	0	0	0	**1**	1
	SNS F	0	0	*1*	0	**2**	0	3
	SNS M	0	0	0	*1*	0	0	1
	KLS F	0	0	0	0	*2*	0	2
	KLS M	0	0	0	0	0	*0*	0

In 2015, 488 suckers were captured (table 1), and 179 were also captured previously or subsequently. These 179 suckers were used in a matrix to identify conflicts in species and sex identification (table 3). There were 30 conflicts in species identification, 6 conflicts in sex identification, and 3 conflicts with both species and sex identification. Although 140 of the 179 individuals from 2015 had no species or sex identification conflicts, 2015 had the most conflicts in identification compared to the other years (22 percent of recaptured suckers). Fifteen of the 33 conflicts in species identification were translocated as an endangered SNS with earlier or later captures as a non-endangered KLS. Several individuals that were recorded as unidentified sucker at some point in their capture history were not included in the 2015 matrix. These individuals included one unidentified female in 2015 that had a later recapture as an SNS female in 2017 by USGS, two SNS females in 2015 with previous captures as unidentified females by Reclamation, and one unidentified male in 2015 recaptured in 2015 as an unidentified male by Reclamation.

Table 3. Summary of individuals captured in Lake Ewauna, Oregon, in 2015, by species and sex, compared with species and sex identification from previous or subsequent capture.

[The species and sex identification at capture in 2015 is along the vertical axis and the species and sex identification from previous or subsequent capture is along the horizontal axis. Counts of individuals with no conflicts in species or sex identification are along the diagonal shaded in light gray. Cells shaded in medium gray with black text indicate conflicts in sex identification. Cells shaded in dark gray with white text indicate conflicts in species identification. Cells shaded in black with white text indicate conflicts in species and sex identification. **Abbreviations**: LRS, Lost River sucker; SNS, shortnose sucker; KLS, Klamath largescale sucker; F, female; M, male]

		Other Capture						
		LRS F	LRS M	SNS F	SNS M	KLS F	KLS M	Total
2015 Capture	LRS F	*13*	0	**8**	**1**	0	0	22
	LRS M	**2**	*4*	0	**3**	0	0	9
	SNS F	**1**	**1**	*47*	**2**	**7**	0	58
	SNS M	0	**2**	**1**	*48*	0	**8**	59
	KLS F	**1**	0	0	0	*15*	**1**	17
	KLS M	**1**	0	0	0	0	*13*	14

Of the 247 suckers captured in 2016 (table 1), 70 were captured previously or subsequently. These 70 suckers were used in a matrix to identify conflicts in species and sex identification (table 4). There were 8 conflicts in species identification and 7 conflicts in sex identification. Of the 70 individuals, 55 had no species or sex identification conflicts.

Table 4. Summary of individuals captured in Lake Ewauna, Oregon, in 2016, by species and sex, compared with species and sex identification from previous or subsequent capture.

[The species and sex identification at capture in 2016 is along the vertical axis and the species and sex identification from previous or subsequent capture is along the horizontal axis. Counts of individuals with no conflicts in species or sex identification are along the diagonal shaded in light gray. Cells shaded in medium gray with black text indicate conflicts in sex identification. Cells shaded in dark gray with white text indicate conflicts in species identification. **Abbreviations**: LRS, Lost River sucker; SNS, shortnose sucker; KLS, Klamath largescale sucker; F, female; M, male]

		Other Capture						
		LRS F	LRS M	SNS F	SNS M	KLS F	KLS M	Total
2016 Capture	LRS F	*3*	**1**	**1**	0	0	0	5
	LRS M	0	*2*	0	**1**	0	0	3
	SNS F	0	0	*18*	**3**	0	0	21
	SNS M	0	0	0	*15*	0	0	15
	KLS F	0	0	**3**	0	*15*	**2**	20
	KLS M	0	0	0	**3**	**1**	*2*	6

In 2017, 73 suckers were captured (table 1); 12 were captured previously or subsequently and used in a matrix to identify conflicts in species and sex identification (table 5). There was one conflict in species identification and zero conflicts in sex identification. Several individuals were not included in the 2017 matrix. These individuals included one SNS female that was translocated in 2017 with two previous captures as an unidentified female in 2009 by Reclamation and two previous captures as an SNS female in 2011 by Reclamation, one SNS male that was translocated in 2017 with two previous captures as an unidentified male in 2009 by Reclamation, and one SNS male that was translocated in 2017 with a previous capture in 2010 as an LRS of unknown sex.

Table 5. Summary of individuals captured in Lake Ewauna, Oregon, in 2017, by species and sex, compared with species and sex identification from previous or subsequent capture.

[The species and sex identification at capture in 2017 is along the vertical axis and the species and sex identification from previous or subsequent capture is along the horizontal axis. Counts of individuals with no conflicts in species or sex identification are along the diagonal shaded in light gray. Cells shaded in dark gray with white text indicate conflicts in species identification. **Abbreviations**: LRS, Lost River sucker; SNS, shortnose sucker; KLS, Klamath largescale sucker; F, female; M, male]

		Other Capture						
		LRS F	LRS M	SNS F	SNS M	KLS F	KLS M	Total
2017 Capture	LRS F	*0*	0	1	0	0	0	1
	LRS M	0	*3*	0	0	0	0	3
	SNS F	0	0	*7*	0	0	0	7
	SNS M	0	0	0	*0*	0	0	0
	KLS F	0	0	0	0	*1*	0	1
	KLS M	0	0	0	0	0	*0*	0

Overall, 32 percent (272) of the 850 fish captured in Lake Ewauna during the 4 years had previous or subsequent captures. Of those, 17 percent (46) had a conflict in species identification and 6 percent (16) had a conflict in sex identification. The 2015 and 2016 cohorts had larger numbers of translocated individuals compared to 2014 and 2017, and those years thus had the largest number of conflicts in species and sex identification. We assume that fish with no previous or subsequent captures have the same probability of uncertain identification as recaptured fish. We determined that the conflicts in species identification, which were more prevalent than conflicts in sex identification in all years, were enough to prevent further analysis by species among translocated cohorts. Thus, we decided to use a list of translocated individuals distinguished by sex only for all subsequent analyses. As a result, direct comparisons at a species level of translocated cohorts with residents could not be made. We analyzed individuals with no known sex conflicts as translocated males or females. These included translocated individuals that had additional physical captures with no sex conflicts and translocated individuals with no other physical captures. Individuals with known sex conflicts were analyzed as translocated individuals of unknown sex. Translocated individuals were assumed to be primarily of the endangered taxa, LRS and SNS, but there was the possibility of a non-endangered KLS being translocated by an incorrect species identification. In our analysis, the number of translocated individual suckers for 2014, 2015, 2016, and 2017 were 40, 384, 172, and 63, respectively (table 6).

Table 6. Number of suckers, by sex and year, that were translocated from Lake Ewauna to Upper Klamath Lake, Oregon, in 2014–2017, and included in further analyses.

[Conflicts in species identification between or among captures for recaptured individuals prevented further analyses from distinguishing translocated individuals by species]

Year	Sex			Total
	Female	Male	Unknown	
2014	23	17	0	40
2015	188	188	8	384
2016	105	63	4	172
2017	30	33	0	63
Total	346	301	12	659

To compare the size composition of suckers translocated from Lake Ewauna with the size composition of resident LRS and SNS in Upper Klamath Lake, we compared plots of measured fork lengths using only individuals of known sex (fig. 2). In 2015, eight translocated fish were excluded from the fork length analysis, seven with sex conflicts and one unidentified sucker with unknown sex. In 2016, four translocated fish were excluded from the fork length analysis, all of which had conflicts in sex identification. The sample size for translocated suckers in 2014 was small, but the median fork length for females was substantially smaller (366 mm) and the median fork length for males slightly smaller (436 mm) in that year than the other 3 years. Across the other years, the median fork length for translocated females was similar at about 485 mm and the median fork length for translocated males was similar at about 450 mm. The distribution of fork lengths for resident LRS and SNS were similar among years in 2015, 2016, and 2017, with LRS showing 5−10 mm of growth per year and SNS showing very little growth, as expected (Hewitt and others, 2017; fig. 2). Because USGS trammel net sampling in Upper Klamath Lake occurs in the spring, there were no resident captures in autumn 2014 that offered a comparison to the translocated cohort of 2014. The vast majority of resident LRS, both males and females, were larger than the males and females in the translocated cohorts. The median fork length of resident LRS females was 675−689 mm, and the median fork length of resident LRS males was 609−625 mm. Median fork lengths for resident SNS were more similar to the translocated suckers (females about 460 mm, males about 430 mm).

Although species identification for many translocated suckers is uncertain, the size composition for translocated suckers suggests that the vast majority of them were SNS or KLS, the two smaller species (fig. 2). This result is consistent with the overall species composition represented in the original field identifications, where about 20 percent were identified as LRS (table 1). Translocated suckers larger than 550 mm are likely to have been LRS.

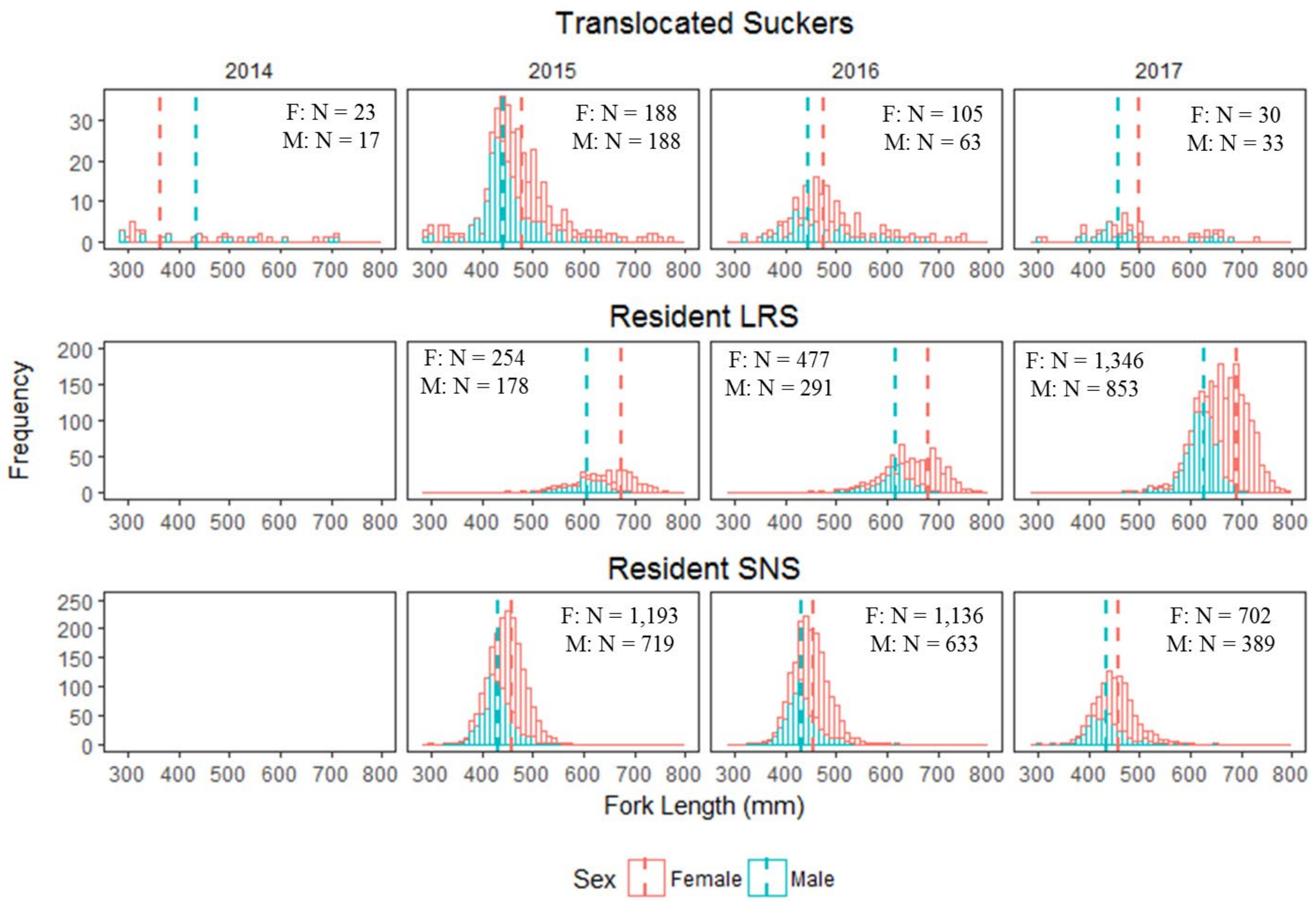

Figure 2. Graphs showing fork lengths of suckers captured in Lake Ewauna and translocated to Upper Klamath Lake, Oregon, as well as fork lengths of resident LRS and SNS in Upper Klamath Lake, 2014–2017. Vertical dashed lines show the median fork length for each sex in each year. [LRS, Lost River sucker; SNS, shortnose sucker; F, female; M, male; N, number of individuals]

Encounters at U.S. Geological Survey Monitoring Locations

Spawning Site Encounters

We summarized encounters of translocated individuals during the spawning season at known spawning locations (Williamson River, Sprague River, and shoreline springs in Upper Klamath Lake) by cohort and sex for each year. The percentage of translocated individuals encountered at spawning locations was highest during the year of translocation (50–76 percent) and decreased for all cohorts in subsequent years following translocation (table 7). Excluding the autumn 2014 cohort, the cohort with the fewest translocated individuals, the percentage of encounters at spawning locations was even higher in the year of translocation (62–76 percent).

Table 7. Summary of suckers in translocated cohorts that were re-encountered at spawning locations in Upper Klamath Lake and its tributaries, Oregon, by U.S. Geological Survey remote passive integrated transponder (PIT) tag antennas and physical captures, 2015–2017.

[In the Encountered column, the count (N) of the total number of individuals in the entire cohort that were encountered in that year is given, along with the percentage of the entire cohort that was encountered. The total number of individuals in the cohorts were: 40 in 2014; 384 in 2015; 172 in 2016; and 63 in 2017. **Abbreviation**: %, percent]

Year	Female	Male	Unknown	Encountered
2014 Translocated cohort				
Year	**N = 23**	**N = 17**	**N = 0**	**N (%)**
2015	8	12	0	20 (50%)
2016	9	6	0	15 (38%)
2017	10	6	0	16 (40%)
2015 Translocated cohort				
Year	**Female N = 188**	**Male N = 188**	**Unknown N = 8**	**Encountered N (%)**
2015	133	139	5	277 (72%)
2016	90	105	4	199 (52%)
2017	64	54	1	119 (31%)
2016 Translocated cohort				
Year	**Female N = 105**	**Male N = 63**	**Unknown N = 4**	**Encountered N (%)**
2016	78	49	3	130 (76%)
2017	35	15	2	52 (30%)
2017 Translocated cohort				
Year	**Female N = 30**	**Male N = 33**	**Unknown N = 0**	**Encountered N(%)**
2017	18	21	0	39 (62%)

The vast majority of translocated individuals were encountered at spawning locations at least once after translocation (62–87 percent), but some from each cohort were encountered only at other locations or were not encountered at all. Of the 2014 translocated cohort, 12 individuals (9 females and 3 males) were not encountered after translocation, and 1 individual (1 female) was translocated as an SNS, recaptured in Lake Ewauna and identified as a KLS in 2016, and then released back into Lake Ewauna. Of the 2015 translocated cohort, 41 individuals (24 females, 14 males, and 3 unknown) were not encountered after translocation; 10 individuals were encountered at Lakewide–Modoc (1 male) or the Link River array/ladder (2 females and 7 males); and the tag from 1 female was found on a waterbird colony in Upper Klamath National Wildlife Refuge. Of the 2016 translocated cohort, 23 individuals (16 females and 7 males) were not encountered after translocation, and 4 individuals were encountered at Lakewide–Modoc (1 male) or the Link River array (2 females and 1 male). Of the 2017 translocated cohort, 22 individuals (11 females and 11 males) were not encountered after translocation and 2 individuals (1 female and 1 male) were encountered at the Link River array and ladder.

For comparison to the translocated suckers, we summarized encounters at known spawning locations for resident cohorts in each year by species and sex (table 8). The percentage of resident individuals encountered at spawning locations was highest during the initial year of capture and release (47–93 percent) and decreased for all cohorts in subsequent years. Excluding the 2017 cohort, the year with only 1 year of monitoring and without the Williamson River weir, the percentage of encounters at spawning locations was even higher in the year of capture and release (85–93 percent) and was higher than for translocated cohorts. Across all years of monitoring, and similar to translocated cohorts, 47–93 percent of resident cohorts were encountered at spawning locations at least once.

Table 8. Summary of suckers in resident cohorts, by species and sex, that were re-encountered at spawning locations in Upper Klamath Lake and its tributaries, Oregon, by U.S. Geological Survey remote passive integrated transponder (PIT) tag antennas and physical captures, 2015–2017.

[In the Encountered column, the count (N) of the total number of individuals in the entire cohort that were encountered in that year is given, along with the percentage of the entire cohort that was encountered. The total number of individuals in the cohorts were: 2,344 in 2015; 2,537 in 2016; and 3,290 in 2017. **Abbreviations**: LRS, Lost River sucker; SNS, shortnose sucker; %, percent]

	2015 Resident cohort				
	LRS		**SNS**		
Year	**Female N = 254**	**Male N = 178**	**Female N = 1,193**	**Male N = 719**	**Encountered N (%)**
2015	229	172	975	618	1,994 (85%)
2016	206	152	882	521	1,761 (75%)
2017	74	48	434	210	766 (33%)
	2016 Resident cohort				
	LRS		**SNS**		
Year	**Female N = 477**	**Male N = 291**	**Female N = 1,136**	**Male N = 633**	**Encountered N (%)**
2016	444	278	1,057	579	2,358 (93%)
2017	192	112	540	259	1,103 (43%)
	2017 Resident cohort				
	LRS		**SNS**		
Year	**Female N = 1,346**	**Male N = 853**	**Female N = 701**	**Male N = 390**	**Encountered N (%)**
2017	590	342	400	211	1,543 (47%)

Cumulative Encounters

Of the 659 suckers translocated, 561 (85 percent) were re-encountered somewhere following translocation and in subsequent years (table 9). Of the 8,171 resident suckers, 6,190 (76 percent) were re-encountered somewhere following release and in subsequent years (table 10). The low number of encounters among residents in 2017 (47 percent) was similar to the low numbers of encounters among translocated fish in 2017, and resulted from the lack of operating the Williamson River weir. Because most of the encounters occurred during monitoring at spawning locations, the percentages by cohort are similar to those given above for spawning location encounters for both translocated and resident fish.

Table 9. Cumulative summary, by sex, of 561 individuals out of 659 translocated suckers that were re-encountered from the year of translocation (cohort year) through 2017 in the Upper Klamath Basin, Oregon.

[**Abbreviations**: N, number of individuals; %, percent]

	Translocated suckers				
Cohort year	Female N	Male N	Unknown N	Re-encountered N (%)	Total N
2014	14	14	0	28 (70%)	40
2015	164	174	5	343 (89%)	384
2016	90	55	4	149 (87%)	172
2017	19	22	0	41 (65%)	63

Table 10. Cumulative summary, by species and sex, of 6,190 individuals out of 8,171 resident suckers that were re-encountered from the year of capture (cohort year) through 2017 in the Upper Klamath Basin, Oregon.

[**Abbreviations**: N, number of individuals; %, percent]

	Resident suckers					
	LRS		SNS			
Cohort year	Female N	Male N	Female N	Male N	Re-encountered N (%)	Total N
2015	244	173	1,120	680	2,217 (95%)	2,344
2016	455	282	1,085	600	2,422 (95%)	2,537
2017	591	346	402	212	1,551 (47%)	3,290

Cumulative encounters of translocated individuals were dominated by encounters in the Williamson River compared to all other monitoring locations (fig. 3). Cumulative encounters at the Williamson River included 517 individuals. When each translocated cohort was analyzed individually for cumulative encounters, the Williamson River continued to be dominant among encounter locations (Appendix; fig. 1-1). There was a tendency for encounters to decrease with increasing distance away from the translocation release site in the Williamson River. For instance, the Sprague River Dam array, less than 10 km upstream of the Williamson River weir, had the second highest number of individual encounters (106 individuals), and the Link River array/ladder and Lake Ewauna, the sites furthest away from the release sites, had some of the lowest numbers of encounters (fig. 3). Encounters at the Link River array/ladder (33 individuals) and Lake Ewauna (3 individuals) indicated that some translocated individuals moved back to their original site of capture. Lake Ewauna encounters were limited to Reclamation's recaptures during the translocation sampling period (2014–2017), as no other sampling in Lake Ewauna was performed and no PIT tag antennas are present in the lake. There were a relatively high number of encounters among translocated individuals at the shoreline springs (75 encounters), although most were from the 2015 cohort (60 encounters).

Cumulative encounters for resident suckers, those limited to Lakewide sampling locations for this analysis (Goose Bay, Modoc Point, and the Williamson River; fig. 1), indicated similar encounter trends to translocated suckers (fig. 3). Most resident individuals (5,607 individuals) were encountered at the Williamson River weir with the second highest number of encounters at the Sprague River Dam site (1,183 individuals). When each resident cohort was analyzed individually for cumulative encounters, the Williamson River continued to be dominant among encounter locations (Appendix; fig. 1-2). A relatively high number of encounters among resident LRS at the shoreline springs (355 individuals) were from members of the LRS subpopulation that spawns at that location. Among resident individuals there were very low numbers of encounters at locations farthest away from the release site, which included the Link River array/ladder (8 individuals) and Lake Ewauna (0 individuals).

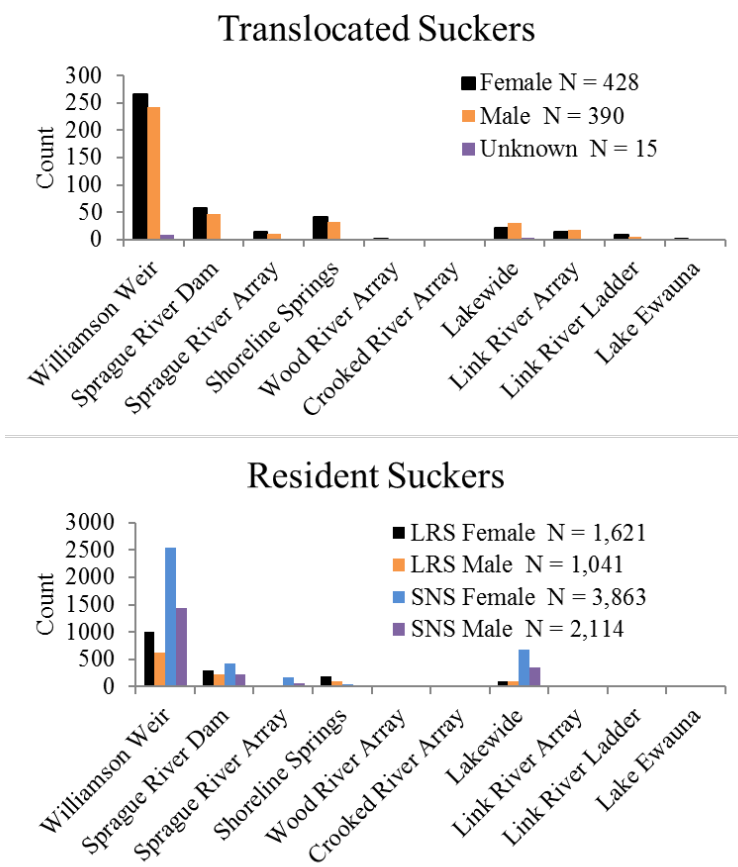

Figure 3. Graphs showing cumulative encounters of translocated suckers (all cohorts combined) and resident suckers at U.S. Geological Survey monitoring locations in the Upper Klamath Basin, Oregon, 2015–2017. Individual suckers may have been encountered at more than one monitoring location. Sample size (N) indicates the total number of encounters from all locations. Note change in y-axis between translocated and resident suckers. [LRS, Lost River sucker; SNS, shortnose sucker]

Spawning Site Fidelity

Cohort Level

We analyzed spawning site fidelity for translocated suckers by cohort at three known spawning sites (Williamson River, Sprague River, and shoreline springs), although whether individual suckers spawned was unknown. All cohorts were translocated to the Williamson River, and re-encounters over time indicated spawning site fidelity for the Williamson River in comparison to the Sprague River and shoreline springs in all years for all cohorts (table 11). Individuals encountered in the Williamson River and the Sprague River are considered to be part of the same spawning population.

Encounters at known spawning locations were highest during the year of translocation (table 11). For the 2014 cohort, 19 individuals were encountered at the Williamson River in 2015 and 15 individuals were encountered at the Williamson River in 2016 and 2017. The 2014 cohort recorded the least amount of difference in encounters at spawning sites among years, particularly at the Williamson River, although there were only 40 individuals translocated in 2014. For the 2015 cohort, a year with 384 translocated suckers, the number of encounters at the Williamson River declined by more than half from 2015 to 2017. The decline in encounters was most substantial between 2016 and 2017, which is mostly attributable to the weir and associated traps and PIT tag antennas not being installed in 2017 because of the high flows. Despite the smaller number of individuals encountered at the other spawning locations, the Sprague River and shoreline springs, the decline in encounters across years was less substantial at those locations. Similar to the 2015 cohort, the percentage of the 172 suckers translocated in 2016 that were encountered at the Williamson River declined by more than half from 2016 to 2017. Of the 63 individuals translocated in 2017, 31 individuals were encountered at the Williamson River. Although the number of individuals translocated was small in 2017, the 2017 cohort had the largest percentage of individuals encountered at the shoreline springs.

Table 11. Summary of suckers in translocated cohorts that were re-encountered at known spawning locations in Upper Klamath Lake and its tributaries, Oregon, by U.S. Geological Survey remote passive integrated transponder (PIT) tag antennas and physical captures during the 2015–2017 spawning seasons.

[Some individuals were encountered at multiple spawning locations, most often the Williamson and Sprague Rivers. In the Encountered column, the count (N) of the total number of individuals in the cohort that were encountered at that location in that year is given, along with the percentage of the cohort that was encountered at that location in that year. The total number of individuals in the cohorts were: 40 in 2014; 384 in 2015; 172 in 2016; and 63 in 2017. **Abbreviation**: %, percent]

Year	Spawning location	Female	Male	Unknown	Encountered
2014 Translocated cohort					
Year	**Spawning location**	**Female N = 23**	**Male N = 17**	**Unknown N = 0**	**Encountered N (%)**
	Williamson R.	8	11	0	19 (48%)
2015	Sprague R.	1	3	0	4 (10%)
	Springs	0	1	0	1 (3%)
	Williamson R.	9	6	0	15 (38%)
2016	Sprague R.	2	3	0	5 (13%)
	Springs	0	0	0	0 (0%)
	Williamson R.	9	6	0	15 (38%)
2017	Sprague R.	3	1	0	4 (10%)
	Springs	0	0	0	0 (0%)
2015 Translocated cohort					
Year	**Spawning location**	**Female N = 188**	**Male N = 188**	**Unknown N = 8**	**Encountered N (%)**
	Williamson R.	123	134	4	261 (68%)
2015	Sprague R.	17	22	1	40 (10%)
	Springs	19	16	1	36 (9%)
	Williamson R.	84	102	4	190 (49%)
2016	Sprague R.	16	14	1	31 (8%)
	Springs	11	12	0	23 (6%)
	Williamson R.	48	38	1	87 (23%)
2017	Sprague R.	22	13	0	35 (9%)
	Springs	11	10	0	21 (5%)
2016 Translocated cohort					
Year	**Spawning location**	**Female N = 105**	**Male N = 63**	**Unknown N = 4**	**Encountered N (%)**
	Williamson R.	77	47	3	127 (74%)
2016	Sprague R.	11	4	1	16 (9%)
	Springs	4	1	0	5 (3%)
	Williamson R.	32	13	1	46 (27%)
2017	Sprague R.	6	2	0	8 (5%)
	Springs	1	1	1	3 (2%)
2017 Translocated cohort					
Year	**Spawning location**	**Female N = 30**	**Male N = 33**	**Unknown N = 0**	**Encountered N (%)**
	Williamson R.	14	17	0	31 (49%)
2017	Sprague R.	2	2	0	4 (6%)
	Springs	5	3	0	8 (13%)

Individual Level

We analyzed the frequency of return to spawning sites for translocated individuals in the 2015 and 2016 cohorts. The majority of males and females in the 2015 translocated cohort (approximately 72 percent) were encountered at spawning sites in 2015 (table 12). Of these, just over half were re-encountered at spawning sites again in 2016, and then half of those encountered in both 2015 and 2016 were again encountered at spawning sites in 2017. A small number (8; 3 percent) of individuals encountered in 2015 were not encountered in 2016 but were encountered again in 2017. Only 11 percent of the 2015 translocated individuals were encountered at a spawning site for the first time in 2016, but about half of those as well were then re-encountered at spawning sites in 2017. Approximately 3 percent of 2015 translocated individuals were encountered at spawning sites for the first time in 2017. Fifty individuals from this cohort (13 percent) of known sex had not been encountered at spawning sites through 2017.

A very similar proportion of the males and females in the 2016 translocated cohort (approximately 76 percent) were encountered at spawning sites in 2016, their year of release. Of these, only 28 percent were also encountered at spawning sites in 2017. Similar to the 2015 cohort, approximately 8 percent of translocated individuals from this cohort were encountered for the first time in their second year, 2017. Twenty-seven individuals (16 percent) had not been encountered at spawning sites through 2017.

Table 12. Frequency of return to spawning sites in Upper Klamath Lake and its tributaries, Oregon, for suckers in the 2015 and 2016 translocated cohorts, separated by the year of their first encounter.

[Five females and three males in the 2015 translocated cohort were encountered in 2015, not encountered in 2016, and re-encountered again in 2017 (not included in table). **Abbreviation**: N, number of individuals]

		2015 Translocated cohort	
Year of first encounter	**Spawning year**	**Female (N = 188)**	**Male (N = 188)**
2015	2015	131	138
	2016	69	82
	2017	41	35
2016	2016	20	22
	2017	9	11
2017	2017	9	4
		2016 Translocated cohort	
Year of first encounter	**Spawning year**	**Female (N = 105)**	**Male (N = 63)**
2016	2016	78	49
	2017	26	10
2017	2017	9	5

In the 2015 and 2016 resident LRS and SNS cohorts used for comparison, the proportion of individuals that were encountered at spawning sites in the same year they were released at Lakewide was higher than for the translocated suckers (82−86 percent for SNS and 90−97 percent for LRS; table 13). The proportion of individuals in the 2015 cohorts that were encountered in 2015 and then also in 2016 was also substantially higher for resident suckers (77−88 percent compared to about half). However, the proportion of SNS encountered in both 2015 and 2016 that were again encountered at spawning sites in 2017 was about half, similar to translocated fish. The proportion of resident LRS encountered in both 2015 and 2016 that were again encountered at spawning sites in 2017 was somewhat lower (35−36 percent). The number of individuals from the 2015 LRS cohort that were encountered at spawning sites for the first time in 2016 was small (15; 6 percent). For the 2015 SNS cohort, approximately 11 percent of females were encountered at spawning sites for the first time in 2016, and about half of those were also encountered in 2017. Approximately 8 percent of males were encountered at spawning sites for the first time in 2016, and 26 percent of those were also encountered in 2017. Very few individuals from the 2015 resident cohorts were encountered at spawning sites for the first time in 2017.

For the 2016 resident cohorts, about half of the individuals encountered at spawning sites in 2016 were also encountered in 2017 (42−44 percent for LRS and 49–56 percent for SNS), which was higher than for the 2016 translocated cohort but similar to the 2015 resident and translocated cohorts. Only small numbers of individuals were encountered at spawning sites for the first time in 2017. Less than 5 percent of LRS from either of the resident cohorts and 6−7 percent of SNS had not been encountered at spawning sites through 2017, lower than for translocated fish.

Table 13. Frequency of return to spawning sites in Upper Klamath Lake and its tributaries, Oregon, for suckers in the 2015 and 2016 resident cohorts, separated by the year of their first encounter.

[Two females and two males in the 2015 resident Lost River sucker (LRS) cohort and 14 females and seven males in the 2015 resident shortnose sucker (SNS) cohort were encountered in 2015, not encountered in 2016, and re-encountered again in 2017 (not included in table). **Abbreviation**: N, number of individuals]

Year of first encounter	Spawning year	Female	Male
2015 Resident LRS cohort			
Year of first encounter	**Spawning year**	**Female (N = 254)**	**Male (N = 178)**
2015	2015	229	172
	2016	192	151
	2017	66	45
2016	2016	14	1
	2017	5	1
2017	2017	1	0
2015 Resident SNS cohort			
Year of first encounter	**Spawning year**	**Female (N = 1,193)**	**Male (N = 719)**
2015	2015	975	614
	2016	753	464
	2017	367	189
2016	2016	129	57
	2017	46	13
2017	2017	4	0
2016 Resident LRS cohort			
Year of first encounter	**Spawning year**	**Female (N = 477)**	**Male (N = 291)**
2016	2016	444	278
	2017	181	108
2017	2017	10	4
2016 Resident SNS cohort			
Year of first encounter	**Spawning year**	**Female (N = 1,136)**	**Male (N = 633)**
2016	2016	1,056	579
	2017	521	244
2017	2017	16	11

Translocated individuals encountered at spawning locations in at least 2 years showed strong fidelity to river spawning locations and there was little difference between the sexes (fig. 4). Across the three cohorts, only seven individuals (4 females, 3 males) showed fidelity to the springs and six of those were from the 2015 translocated cohort. For the 2014 translocated cohort, only one male was encountered both at the springs and in the river and included in the mixed group; all other individuals (94 percent) showed fidelity to the river. We found that 59 percent of individuals in the 2014 cohort were encountered in 2 of 3 years and 41 percent were encountered in all 3 years. For the 2015 cohort, 139 of the 181 individuals (77 percent) with spawning encounters in multiple years showed fidelity to the river, but a relatively high number of individuals (36; 20 percent) were included in the mixed group. Similar to the 2014 cohort, we found that 56 percent of individuals in the 2015 cohort were encountered in 2 of 3 years and 44 percent were encountered in all 3 years. Individuals encountered in all 3 years had more chances to be encountered at both the river and the springs and thus be included in the mixed group, but this does not seem to explain the relatively high number of mixed group fish from the 2015 cohort. For the 2016 cohort, one male showed fidelity to the springs and two females were included in the mixed group; all other individuals (92 percent) showed fidelity to the river.

Similar to the translocated suckers, most individuals in the 2015 and 2016 resident LRS and SNS cohorts showed high fidelity to river spawning sites and there was little difference between the sexes. With the exception of LRS in the 2016 cohort, over 92 percent of individuals showed fidelity to the river across the 2 or 3 years of encounters. For LRS in the 2016 cohort, a relatively large proportion of individuals from the Lakewide sampling showed fidelity to the springs (26 percent). In contrast to the 2015 translocated individuals, the proportion of resident cohorts that were encountered at multiple spawning locations and were included in the mixed group was never more than 3 percent. No resident SNS showed fidelity to the springs. Among individuals monitored for three spawning seasons, we found that most individuals were encountered in 2 of 3 years (69 percent for resident LRS; 57 percent for resident SNS). Fewer residents were encountered every year (31 percent for resident LRS; 43 percent for resident SNS). In 3 years of monitoring, almost identical proportions of resident SNS and translocated individuals were encountered at spawning sites 2 of 3 years or all 3 years.

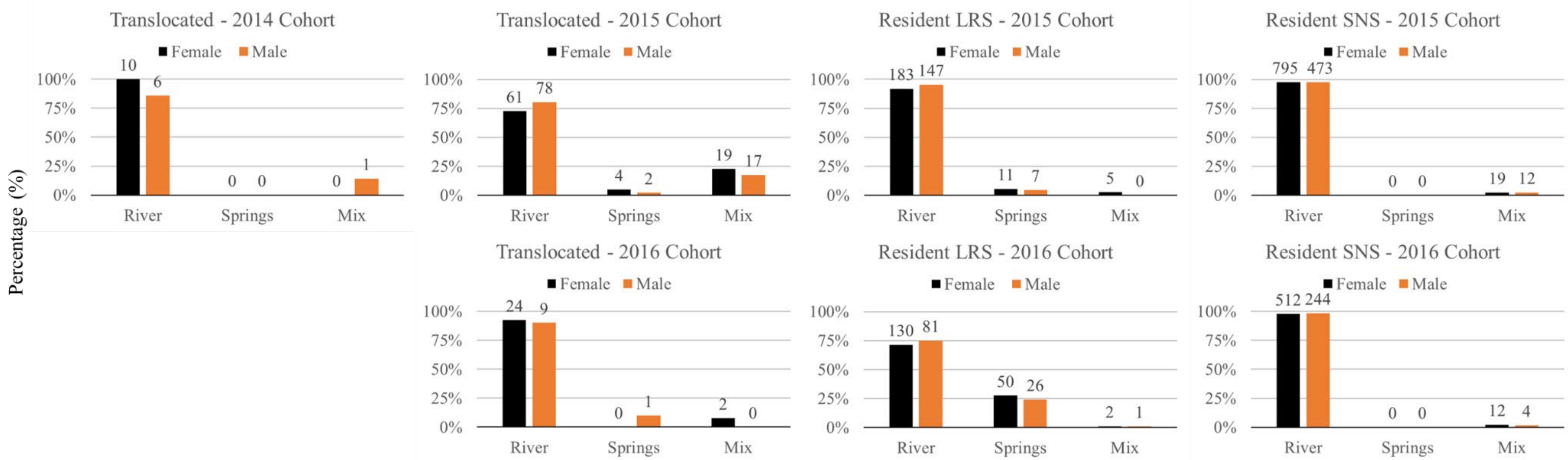

Figure 4. Graphs showing spawning site fidelity for cohorts of translocated and resident suckers at spawning locations in Upper Klamath Lake and its tributaries, Oregon, 2015–2017. Based on encounters in 2 or 3 years, individuals were assigned as showing fidelity to one of three categories: river, springs, or mixed (both river and springs). Numbers above the bars indicate sample sizes and are subsets of individuals from each cohort. Refer to figure 2 for total numbers of individuals in each translocated and resident cohort. [LRS, Lost River sucker; SNS, shortnose sucker]

Migration Timing

Translocated individuals demonstrated similar timing in their migration up the Williamson River compared to resident LRS and SNS, and migrations occurred when average daily water temperatures were increasing and between 10 and 12 °C (figs. 5, 6, and 7). The 2015 migration was the first year to study migration timing of translocated cohorts (2014 and 2015 cohorts; fig. 5). The 2014 and 2015 translocated cohorts had peak encounters that were similar to peak encounters of resident suckers in late March and mid-April during the 2015 migration. Due to the small numbers of translocated individuals from the 2014 translocated cohort, run timing is not as clear. The largest peak of the 2015 translocated cohort coincided with the largest peak of resident LRS and one of the largest peaks of resident SNS. The second largest peak of the 2015 translocated cohort also coincided with the largest peak of resident SNS. After the main migration of both resident and translocated suckers from late March to early May, small numbers of translocated fish from both the 2014 and 2015 cohorts were encountered at the Williamson River in June and early July outside the window of migration for resident suckers.

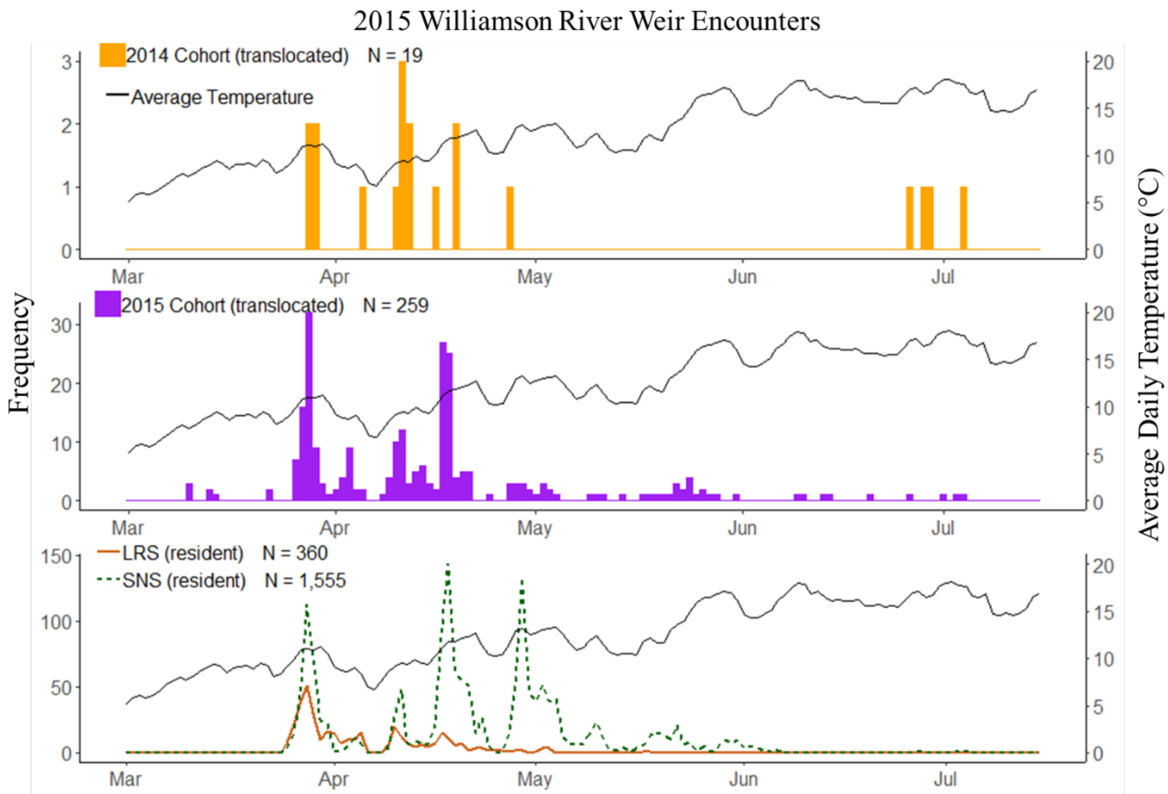

Figure 5. Graphs showing encounters during the 2015 spawning migration in the Williamson River, Oregon, for translocated sucker cohorts (2014 and 2015) and resident Lost River suckers (LRS) and shortnose suckers (SNS). [N, number of individuals encountered]

The 2016 migration was the second year to study migration timing of translocated cohorts (2014, 2015, and 2016 cohorts; fig. 6). The translocated cohorts had peak encounters that coincided with the peak encounters of resident suckers in April, with a brief pause in the middle of the month caused by a decline in water temperature. Smaller numbers of both translocated and resident fish migrated in early May. Similar to 2015, small numbers from all of the translocated cohorts were encountered in the Williamson River in late June.

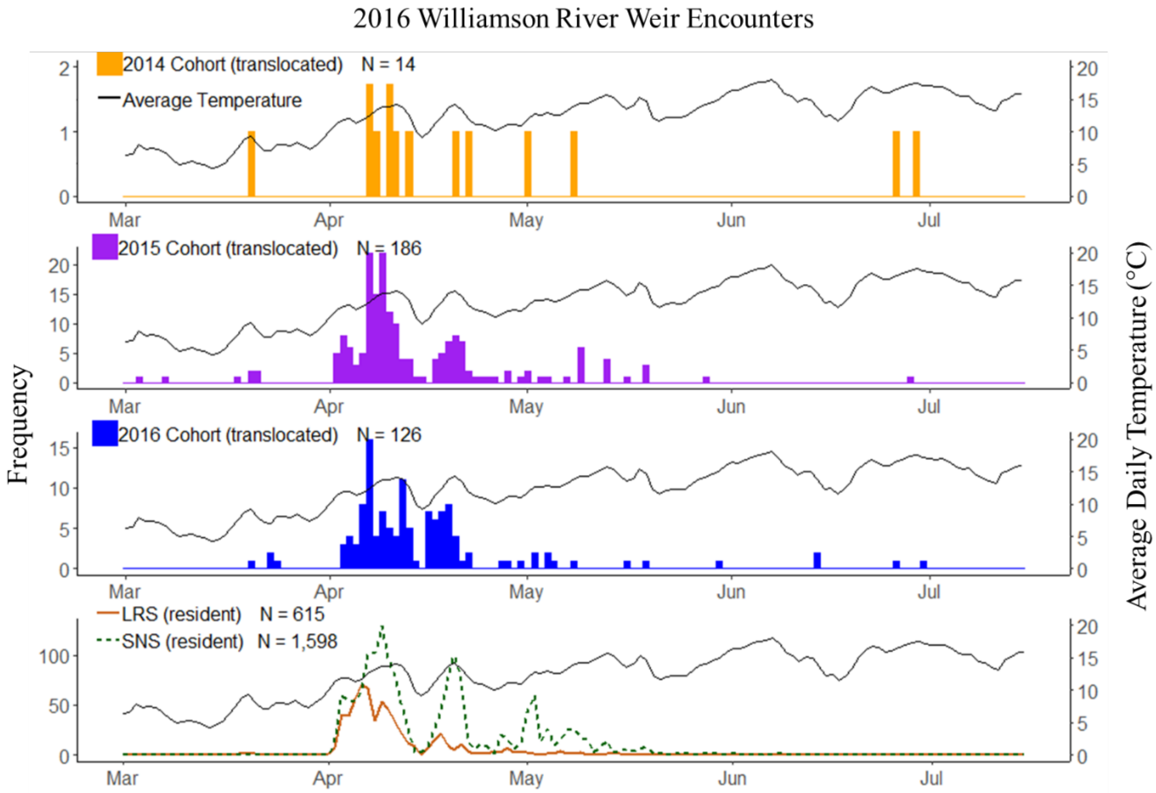

Figure 6. Graphs showing encounters during the 2016 spawning migration in the Williamson River, Oregon, for translocated sucker cohorts (2014, 2015, and 2016) and resident Lost River suckers (LRS) and shortnose suckers (SNS). [N, number of individuals encountered]

The 2017 migration was the third year to study migration timing of translocated cohorts (2014, 2015, 2016, and 2017; fig. 7). Similar to 2016, all translocated cohorts had peak encounters that coincided with peak encounters of resident suckers in April and early May, with a brief pause in migration in late April caused by a decline in water temperature. As in previous years, very few translocated fish were encountered in the river later in June and July. Comparing translocated cohorts among migration years, the translocated fish appeared to have similar timing in migration to resident suckers in the year of translocation as well as subsequent years.

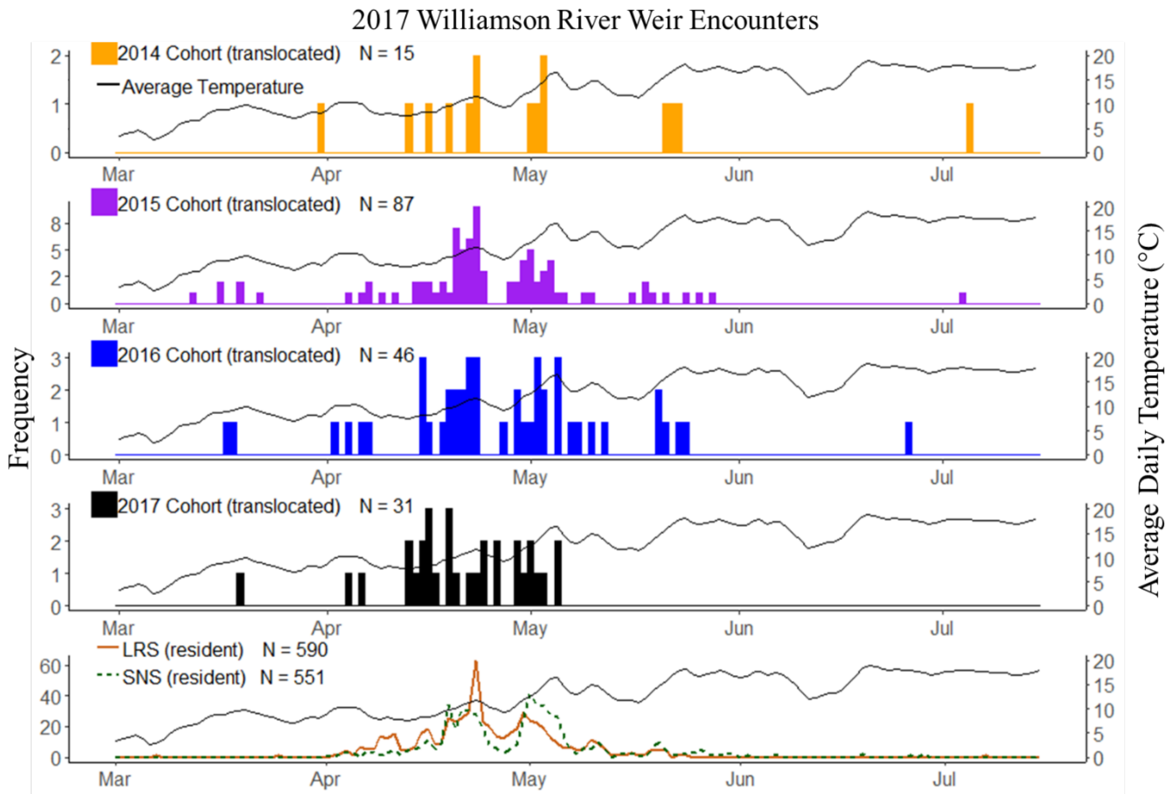

Figure 7. Graphs showing encounters during the 2017 spawning migration in the Williamson River, Oregon, for translocated sucker cohorts (2014, 2015, 2016, and 2017) and resident Lost River suckers (LRS) and shortnose suckers (SNS). [N, number of individuals encountered]

Discussion

The goal of this study was to translocate endangered Lost River and shortnose suckers from Lake Ewauna to augment larger, existing spawning populations in Upper Klamath Lake. Despite uncertainty in species identification and the potential translocation of some Klamath largescale suckers, the vast majority of translocated individuals were one of the endangered taxa. Most of the translocated suckers have been encountered at least once following their release into the Williamson River, primarily at spawning sites, with few translocated individuals returning to Lake Ewauna. Most encounters among translocated suckers as well as resident suckers used for comparison occurred in the Williamson River. The highest encounters at spawning locations among translocated cohorts occurred during the year of translocation. However, the proportions of individuals encountered at spawning locations in the year of release were higher among residents. For both translocated and resident individuals, return frequencies were typically about 50 percent in most comparisons of encounters from 1 year to the following year. Although more translocated individuals were never encountered at spawning sites compared to residents, we found evidence of substantial spawning site fidelity among translocated individuals monitored for two or more years. The vast majority of translocated individuals showed fidelity to spawning sites in the Williamson and Sprague Rivers, similar to resident LRS and SNS, but individuals from the 2015 translocated cohort were more likely than residents to be encountered at spawning locations at both the river and shoreline springs. Across the 3 years of monitoring, migration timing of translocated individuals in the Williamson River coincided closely with the migration of resident suckers in the year of translocation as well as subsequent years. Substantial declines in the proportions of translocated individuals that were encountered in the Williamson River in years following translocation, as compared to resident suckers, provides some reason for concern in using translocation as a management strategy to augment existing spawning populations for endangered suckers in the Klamath Basin. However, encounters in 2017 may be misleading because the Williamson River weir and its associated PIT tag antennas were not installed, as evidenced by the lower encounters among resident suckers in 2017. Translocation could be considered as a mitigation strategy for dam operations at the outlet of Upper Klamath Lake, and one component of a broader recovery strategy that is focused on continuing to address the factors that are contributing to the decline of endangered suckers in the Klamath Basin.

Translocation has been viewed as a management tool to augment existing spawning populations of endangered species (Wolf and others, 1996), and most inferences from translocation studies have been provided by monitoring of varied extent and intensity following translocation (Minckley, 1995; Seddon and others, 2007). Although the primary goal of the sucker translocation program was accomplished for the pre-determined 3 years (2014−2016) from the 2013 Biological Opinions (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 2013), as well as one additional year in 2017, it may be too early to determine success or failure of this effort. This is the first translocation of endangered suckers in the Upper Klamath Basin in connected water bodies that has been studied, although a previous project in 2010 captured 413 suckers from Tule Lake, California and relocated them to Upper Klamath Lake (Courter and others, 2010). Monitoring by USGS re-encountered 225 of the 413 relocated fish. Approximately half of the relocated individuals were re-encountered in 2010, but only 7 percent or less were re-encountered in subsequent years. Fates of the fish that were not re-encountered are unknown, but delayed mortality following release may be a contributing factor. Elsewhere, a translocation effort for Macquarie perch in the Queanbeyan River, Australia, was initially viewed as a failure 5 years after the translocation, with little evidence of survival and no evidence of recruitment. This determination was reversed over 20 years after translocation when a self-sustaining population of Macquarie perch was confirmed to be established at the translocation site (Lintermans, 2013). A reintroduction experiment for adult lake sturgeon (*Acipenser fulvescens*) in the Mattagami River, Canada, found wild recruits 5−11 years after reintroduction to a river segment fragmented by dams (Boothroyd and others, 2018). Numerous studies highlight the importance of long-term monitoring for evaluating translocation or reintroduction efforts (Lintermans, 2013; Cochran-Biederman, 2014; Boothroyd and others, 2018).

Four goals are outlined to determine success or failure of translocation efforts: (1) survival of translocated individuals; (2) establishment of translocated populations; (3) evaluating population growth (quality and quantity), assuming initial success; and (4) disseminating results of translocation efforts to expand our understanding of using translocation as a conservation tool (Minckley, 1995). Additional years of monitoring are needed of translocated Lake Ewauna suckers to make an accurate assessment of survival through capture-recapture methods, especially given the lack of detection capability at the Williamson River weir in 2017. Success could be viewed as any number of individuals that join the resident spawning populations in Upper Klamath Lake during migrations each year. However, a numbers goal was not defined in this way prior to the Lake Ewauna translocation effort. Beyond survival, continued return of translocated suckers to the Williamson and Sprague Rivers may be the best measure of near-term success, indicating that translocated fish have become established in Upper Klamath Lake and have augmented existing spawning populations. Evaluating population growth for a relatively small number of translocated individuals over time is more complicated and would require genetic parentage analysis (Boothroyd and others, 2018), which is not currently possible for these species due to taxonomic confusion (Dowling and others, 2016).

Defining success of translocation efforts for long-lived fish such as Lost River and shortnose suckers seems to be new as few case studies or reviews are available (Lintermans, 2013). Indeed, the Lake Ewauna sucker translocation program is one of the first studies to our knowledge to document translocation of endangered, long-lived species in a connected system to augment existing spawning populations. Although the declines in encounters observed in years following translocation at a cohort level are concerning, one of the guidelines for translocation studies is to evaluate and adapt protocols of translocation based on regular monitoring, which could take over a decade for long-lived species (George and others, 2009; Cochran-Biederman and others, 2014). Whereas other studies of long-lived species and reintroductions have had inconsistent monitoring due to expansive study areas and lack of funding (Minckley, 1995; Cochran-Biederman and others, 2014), the long-term monitoring program of LRS and SNS in Upper Klamath Lake is well-established and has provided intensive monitoring since the early 2000s. USGS will continue monitoring the fate and encounters of translocated suckers and will have some of the first evidence to assess success or failure of translocating a long-lived fish. With data from 2018 and future years, we should be able to estimate survival for the larger cohorts of fish translocated in 2015 and 2016 over the following years using methods similar to those used in Upper Klamath Lake (Hewitt and others, 2018).

Entrainment of larvae and juvenile LRS and SNS at the Link River Dam has been considered a factor in the decline of these species (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 2013). However, captures of adult suckers in Lake Ewauna may indicate that some proportion of entrained larvae and juveniles survive to become adults. Emigration of adult suckers from Upper Klamath Lake, where tens of thousands of resident individuals are PIT-tagged, is relatively rare. Only a few hundred of the resident fish in Upper Klamath Lake have been detected on PIT tag antennas in the Link River Dam fish ladder (since 2008) and the lower Link River (since 2015), and only 1 of the 659 suckers that were captured in Lake Ewauna and translocated was originally tagged in Upper Klamath Lake. Additionally, none of the 1,662 suckers from the 2008–2011 Reclamation sampling in Lake Ewauna were previously captured or tagged in Upper Klamath Lake. In contrast, recaptures of resident suckers are much more common using similar gear in USGS trammel net sampling in Upper Klamath Lake (32 percent for LRS and 43 percent for SNS in 2015; Hewitt and others, 2017).

Historically, dispersal of juvenile and adult LRS and SNS from Upper Klamath Lake to downstream lakes such as Lake Ewauna was likely more common and a component of the life history of these populations. Connectivity among Basin water bodies and flow regimes have been significantly altered with the construction of the Link River Dam, irrigation development, and instream flow requirements downstream. As a result, managers consider entrainment to be higher due to current lake management (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 2013). Radio telemetry studies found that after the spawning migration the majority of LRS and SNS reside in the northern end of Upper Klamath Lake (Reiser and others, 2001; Banish and others, 2009). This finding may explain why emigration by adults from Upper Klamath Lake populations to downstream reservoirs is rare. The current adult spawning populations of LRS and SNS in Upper Klamath Lake may have developed an adaptive life history strategy that eliminates the need to utilize habitats downstream even if they were once used historically. Whether the life history of suckers in Lake Ewauna has adapted to using the Link River as a spawning area is unknown. A radio telemetry study in Lake Ewauna found 8 of 37 radio-tagged suckers at the base of the Link River Falls in May 2002 (Piaskowski, 2003). Interestingly, all radio-tagged suckers moved into the Link River in late June 2002 as water quality conditions declined and remained in the river until September when water quality improved. This may provide evidence that the Link River serves as both a spawning location and refuge for the population of suckers in Lake Ewauna, although more intensive monitoring in Lake Ewauna is needed to evaluate this possibility.

Among translocated suckers, higher encounters during the year of translocation in the Williamson River may be influenced by the proximity of the release site to the Williamson River weir. The year of translocation is the only year in which translocated individuals would have an assisted head start to the spawning areas in the Williamson and Sprague Rivers, although translocated individuals did have to migrate upstream at least 1.7–5.5 km to be encountered at the weir site or locations further upstream. The 'assisted' migration route is shorter than migrations made by resident suckers or translocated suckers in years following release that would begin from Upper Klamath Lake. Most translocated suckers encountered in multiple years appear to exhibit spawning fidelity to the Williamson River, the site of their release. Whether the release of translocated individuals into the Williamson River influenced future encounters at the Williamson River spawning location is unknown, and questions remain on how Lost River sucker spawning populations in Upper Klamath Lake maintain their independence. If translocation efforts were to continue, a future experiment could release translocated fish at the shoreline springs and compare encounters to the translocated cohorts released in the Williamson River. This study could provide insight into whether the strong spawning site fidelity among resident Lost River suckers in Upper Klamath Lake is determined by imprinting or is a result of learned behavior.

Translocated individuals were generally comparable to residents in both their spawning site fidelity and return frequencies to spawning sites, with a few exceptions. With regard to spawning site fidelity, more translocated fish from the 2015 cohort mixed between known spawning locations compared to residents. Although more data from the 2016 translocated cohort could change this conclusion, translocated fish appear to be transitioning from a former spawning location, possibly in the Link River, to new spawning locations in the Williamson River and at shoreline springs. Some resident LRS and SNS used in our analysis have been returning to the same spawning sites for up to 20 years, with a high degree of spawning site fidelity (Hewitt and others, 2017). With regard to return frequencies to spawning sites, differences between translocated and resident suckers included the 2015 resident cohorts in 2016 as well as the 2016 resident cohorts in 2017 (higher return frequency than translocated individuals). All other comparisons indicate return frequencies were about half for both translocated and resident individuals. However, spawning encounters in the year of release were much higher for residents, as expected. Notably, translocated fish were twice as likely to never be encountered at spawning locations compared to residents. We also found evidence that some individuals were encountered at spawning locations for two of the three spawning seasons, but not all (2014 and 2015 translocated cohorts). One explanation is skipped spawning, which is common among other long-lived species such as shortnose sturgeon (*Acipenser brevirostrum*; Dadswell, 1979), Atlantic cod (*Gadus morhua*; Jørgensen and others, 2006), and white sucker (*Catostomus commersoni*; Doherty and others, 2010). Skipped spawning occurred to some extent in 2010 for LRS that spawn at the shoreline springs in Upper Klamath Lake because of exceptionally low lake elevation during the spawning season (Burdick and others, 2015). However, re-encounter probabilities for resident suckers from all spawning populations in Upper Klamath Lake are typically very high and show that skipped spawning is rare (Hewitt and others, 2017). Re-encounters in 2018 and in future years with an operating weir may show more similarity among cohorts for spawning site fidelity and will reveal whether fewer translocated fish are encountered at spawning sites over time.

In addition to skipped spawning, other explanations for translocated suckers not being encountered at spawning sites include: (1) PIT tag loss; (2) mortality following release into the Williamson River; (3) fish taking time to adjust to new environmental conditions and spawning locations; and (4) fish not being mature adults that would be expected to visit spawning sites. Loss of PIT tags is an unlikely explanation since Reclamation tagging procedures are similar to those used by USGS, and USGS tag loss rates are less than 1 percent over 3 or more years (Hewitt and others, 2018). Mortality following release for the translocated suckers will be evaluated with capture-recapture survival estimates once data from future years have been collected with the weir in place, thus properly accounting for variation in re-encounter probabilities. Due to the uncertainty in species identification for translocated suckers, we cannot reliably relate the sizes of translocated suckers to published information on size at maturity. Furthermore, robust maturity ogives have not been published for either LRS or SNS as a function of either size or age. Based on sampling of spawning adults, Janney and others (2008) considered individuals to be new spawners if LRS were smaller than 525 mm (males) or 550 mm (females) and SNS were smaller than 375 mm (males) or 400 mm (females). These thresholds could be considered upper limits to size at maturity. Sampling of spawning adults in the Williamson River by USGS in past years showed that SNS males were commonly ripe at 325 mm and females at 350 mm; LRS males were commonly ripe at 475 mm and LRS females at 500 mm. Because the vast majority of the translocated suckers were one of the two smaller species, SNS or KLS, and few translocated suckers were smaller than 375 mm, we consider it unlikely that many of the translocated fish were immature. Nonetheless, some small translocated suckers (less than 350 mm), particularly in 2014 and 2015, may not have been mature adults.

In contrast to our prediction, the capture, transport, and release of translocated individuals did not appear to have an adverse effect on their migration timing in the Williamson River. Interestingly, migration timing of translocated cohorts was similar to that of resident individuals even during the year of translocation. This finding demonstrates that water temperature may be the primary driver of migration timing for both translocated and resident suckers. It is well established that LRS move upstream when water temperatures are rising and reach 10 °C and SNS exhibit similar migratory behavior once temperatures reach 12 °C (Hewitt and others, 2014). There may also be a social aspect to migratory behavior of suckers, something that has been shown in common carp (*Cyprinus carpio*), another long-lived migratory freshwater fish. Both species form pre-spawning aggregations outside of river mouths and migrate in well-defined groups at specific times once water temperatures reach a certain threshold (Chizinski and others, 2016). Numerous other sucker species form large spawning aggregations, including white sucker in the midwestern United States, largescale sucker (*Catostomus macrocheilus*) in Washington, Sacramento sucker (*Catostomus occidentalis*) in California, and Warner sucker (*Catostomus warnerensis*) in Oregon (Moyle, 2002; Scheerer and others, 2016). This behavior demonstrates a flexible and adaptive life history strategy influenced by environmental and social cues (Chizinski and others, 2016), and may be similar to the strategy of suckers in Upper Klamath Lake that are found in pre-spawn staging areas in the northeastern part of the lake prior to their migrations in the Williamson and Sprague Rivers (Hewitt and others, 2017).

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Appendix 1. Cumulative Encounters–Individual Cohorts

Cumulative encounters of translocated individuals at USGS monitoring locations, separated by cohort, demonstrate that encounters in the Williamson River were dominant for all cohorts compared to all other monitoring locations (fig. 1-1). A total of 27, 317, 142, and 31 individuals were encountered at the Williamson River weir site from the 2014, 2015, 2016, and 2017 translocated cohorts, respectively. Depending on the cohort and the number of years monitored following translocation, the number of encounters at the other monitoring locations varied. The 2015 and 2017 cohorts had relatively high numbers of encounters at the shoreline springs, one of three known spawning areas and the spawning location farthest away from the release site in the Williamson River.

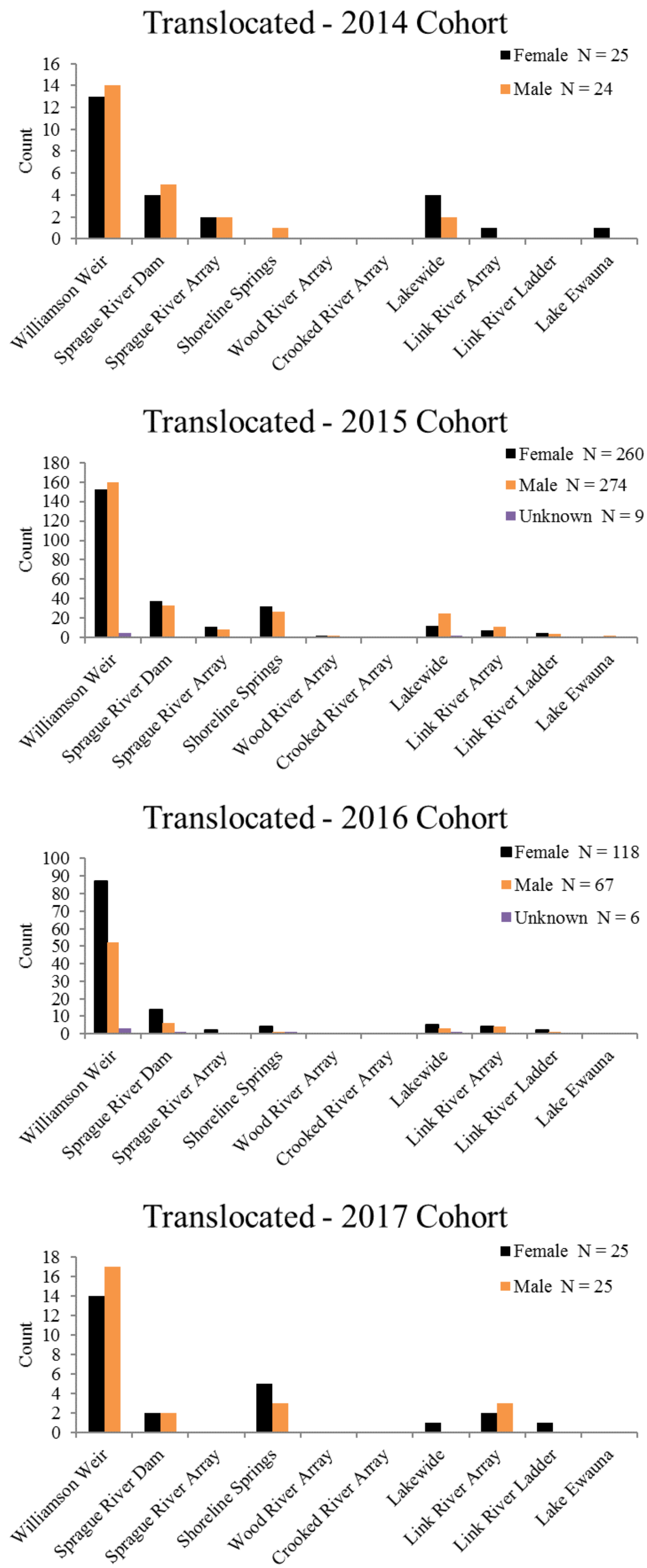

Figure 1-1. Cumulative encounters of translocated suckers, separated by cohort and sex, at U.S. Geological Survey monitoring locations in the Upper Klamath Basin, Oregon, 2015–2017. Individual suckers may have been encountered at more than one monitoring location. Sample size (N) indicates the total number of encounters from all locations. Note change in y-axis among translocated cohorts.

Cumulative encounters of resident individuals at USGS monitoring locations, separated by cohort, demonstrate that encounters in the Williamson River were dominant for all cohorts compared to all other monitoring locations (fig. 1-2). A total of 2,168, 2,287, and 1,144 individuals were encountered at the Williamson River weir site from the 2015, 2016, and 2017 resident cohorts, respectively. Depending on the cohort and the number of years monitored following release, the number of encounters at the other monitoring locations varied. Encounters at the shoreline springs were primarily LRS that are part of a separate subpopulation that spawns at that location. Cumulatively, Lakewide sites had the second highest number of encounters by cohort with the exception of the 2017 cohort that had more encounters at the Sprague River Dam site. The higher number of Lakewide captures for the 2015 and 2016 cohorts, primarily among SNS, may be due to an additional year or years of Lakewide sampling compared to the 2017 resident cohort.

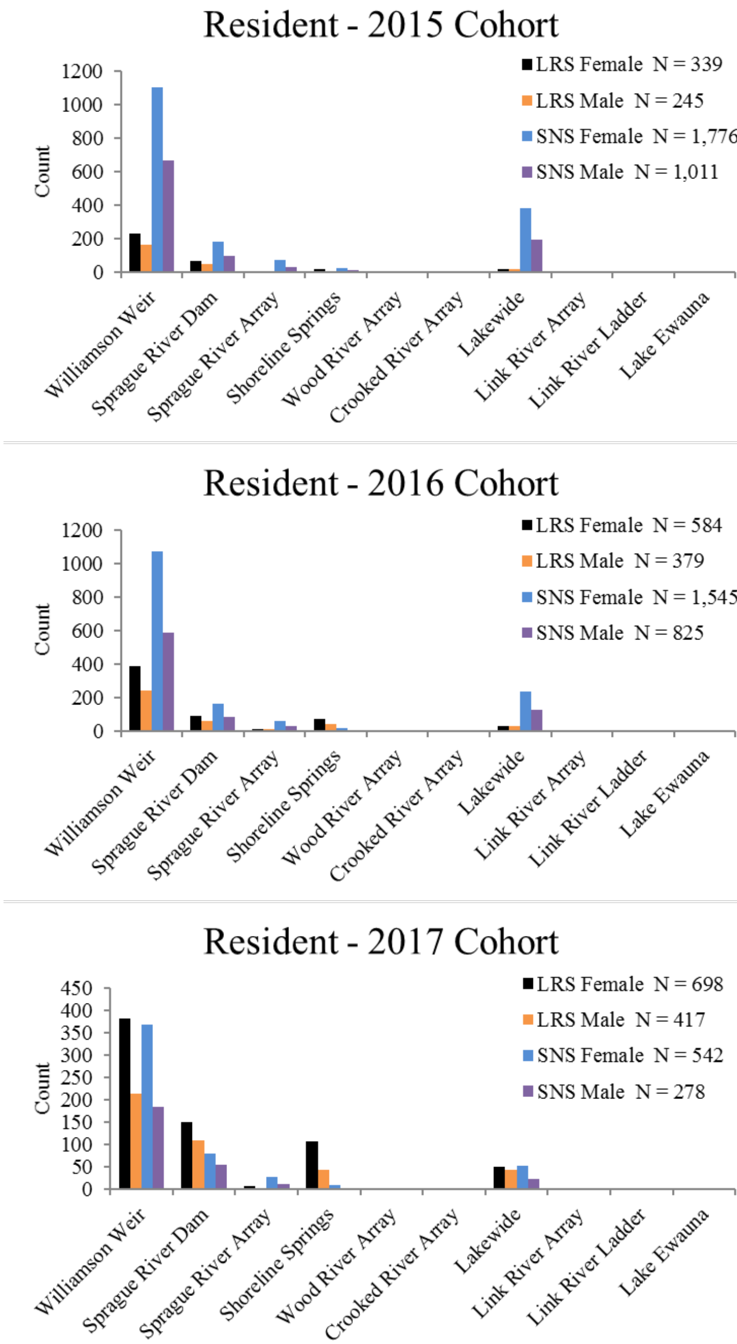

Figure 1-2. Cumulative encounters of resident suckers, separated by cohort, species, and sex, at U.S. Geological Survey monitoring locations in the Upper Klamath Basin, Oregon, 2015–2017. Individual suckers may have been encountered at more than one monitoring location. Sample size (N) indicates the total number of encounters from all locations. Note change in y-axis among resident cohorts. [LRS, Lost River sucker; SNS, shortnose sucker]

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