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Growth, Survival, and Cohort Formation of Juvenile Lost River (*Deltistes luxatus*) and Shortnose Suckers (*Chasmistes brevirostris*) in Upper Klamath Lake, Oregon, and Clear Lake Reservoir, California—2021–22 Monitoring Report

Open-File Report 2024–1013

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

Cover. Juvenile sucker collected in Hagelstein Pond located off of the eastern shore of Upper Klamath Lake, Oregon. Photograph taken September 23, 2023, by Claire Sturdy, U.S. Geological Survey.

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By Barbara A. Martin, John M. Caldwell, Jacob R. Krause, and Alta C. Harris

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Contents

Figures

Tables

Conversion Factors

International System of Units to U.S. Customary Units

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
hectare (ha)	2.471	acre
square kilometer (km^2)	247.1	acre
square meter (m^2)	10.76	square foot (ft^2)
millimeter square (mm^2)	0.00155	inches square (in^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as:
°F = (1.8 × °C) + 32.

Concentrations of chemical constituents are given in milligrams per liter (mg/L); 1 milligram per liter is equivalent to 1,000 parts per billion (ppb).

Datums

Vertical coordinate information is referenced to the Bureau of Reclamation Vertical Datum.

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

Abbreviations

CL	Clear Lake Reservoir
CPUE	catch per unit effort
KLS	Klamath largescale sucker
KLS and SNS_LR	Klamath largescale suckers and shortnose suckers from the Lost River Basin
LRS	Lost River sucker
PIT	passive integrated transponder
SARP	Sucker Assisted Rearing Program
SNS	shortnose sucker
SD	standard deviation
SL	standard length
UKL	Upper Klamath Lake
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

Growth, Survival, and Cohort Formation of Juvenile Lost River (*Deltistes luxatus*) and Shortnose Suckers (*Chasmistes brevirostris*) in Upper Klamath Lake, Oregon, and Clear Lake Reservoir, California—2021–22 Monitoring Report

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Executive Summary

The work reported in this publication provides updated data and interpretation for sampling years 2015 and 2022 of the juvenile monitoring project. The study objectives, background, study area, species description, and methods remained the same or similar throughout the years, while the executive summary, results, and discussion were updated each year. Therefore much of this paper was originally presented in previous reports (Bart and others 2020a, b; Bart and others, 2021; Burdick and others, 2016; Burdick and others, 2018; Martin and others, 2022) and is repeated here for the reader's convenience.

Populations of federally endangered Lost River (*Deltistes luxatus*) and shortnose suckers (*Chasmistes brevirostris*) in Upper Klamath Lake, Oregon, and Clear Lake Reservoir (hereinafter, Clear Lake), California, are experiencing long-term decreases in abundance. Upper Klamath Lake populations are decreasing not only because of adult mortality, which is relatively low, but also because they are not being balanced by recruitment of young adult suckers into adult spawning aggregations.

Long-term monitoring of juvenile sucker populations is conducted to (1) determine if there are annual and species-specific differences in production, survival, and growth; (2) better understand when juvenile sucker mortality is greatest; and (3) identify potential causes of high juvenile sucker mortality particularly in Upper Klamath Lake. The U.S. Geological Survey (USGS) monitoring program, begun in 2015, tracks cohorts through summer months and among years in Upper Klamath and Clear Lakes. Data on juvenile suckers captured in trap nets are used to provide information on annual variability in age-0 sucker production, juvenile sucker apparent survival, growth, species composition, and health.

Upper Klamath Lake indices of year-class strength suggest that the 2022 age-0 cohort is the lowest since standardized monitoring began. The 2021 cohort, like most cohorts, had moderately low catch rates their first year of life, with a steep drop off during the second year. Although the 2020 cohort persisted through the September 2022 sampling, this cohort was sparsely represented after the first year with no representatives from this cohort captured from July 2021 through July 2022. Despite apparently low fall through spring apparent survival, the relatively large 2019 cohort persisted in our 2020–21 samples, but has not been detected since June 2021. Klamath largescale (*Catostomus snyderi*) and shortnose suckers were only differentiated from each other starting in 2020. Shortnose suckers dominated the age-1 catch in 2020 and 2022, whereas age-1 Klamath largescale suckers were slightly more prevalent in 2021. Although there were occasionally age-2 and older suckers captured, none of these fish were Lost River suckers. Except for 2015, 2017, and 2021, there were more age-0 Lost River suckers than presumed shortnose suckers in Upper Klamath Lake. However, in all years sampled, there were more age-1 presumed shortnose suckers than Lost River suckers.

Age distribution of suckers captured in Clear Lake indicates greater juvenile survival than in Upper Klamath Lake. Most juvenile suckers captured throughout the years were from the 2016 and 2017 cohorts; however, by 2022 most of these fish were no longer susceptible to standard trap nets and were not as prevalent in 2022 juvenile catches, and these suckers presumedly recruited to the adult population. As the 2016 and 2017 cohorts catches declined, so did the catch in overall numbers of suckers. Excluding age-0 catches, the 2016 cohort catches peaked at age-3 and the 2017 catches peaked at age-2. In 2022, the majority of the catch was composed of age-3 to age-5 suckers. The majority of suckers captured in Clear Lake during this multiyear project were classified as the combination of Klamath largescale suckers and shortnose suckers from the Lost River Basin, from the 2016 and 2017 cohorts. The few suckers identified as Lost River or definitive shortnose suckers were from the 2016 and 2017 cohorts. A lack of age-0 suckers captured in Clear Lake during years with low spawning tributary inflow or lake levels suggested

that low water prevented spawning and year class formation. However, recent data indicate that some cohorts with Klamath largescale and shortnose sucker genetics that were not captured as age-0 suckers were detected in later years at age-1 or age-2. This finding indicates that juvenile suckers in Clear Lake may spend one or more years in the tributaries and that these cohorts may primarily be represented by Klamath largescale suckers.

The first 7 years of this monitoring program indicated different patterns in recruitment and survival of juvenile suckers between Upper Klamath and Clear Lakes. Since the monitoring program began in 2015, age-0 sucker catch rates, interpreted as indices of year-class strength, were greatest in Upper Klamath Lake in 2016 and 2019. In those years, Lost River suckers made up the majority of age-0 sucker catches. However, in 2017 and 2020, the age-1 sucker catches from these cohorts were mainly composed of shortnose suckers or suckers with genetic markers of both Klamath largescale and shortnose suckers, indicating a low first year survival for Lost River suckers even when age-0 catches were high. Age-0 suckers do not fully recruit to our sampling gear in Upper Klamath Lake until August, experience high mortality by September, and are almost undetectable in subsequent years. In Clear Lake, suckers are often not captured until age-1 or age-2 and juvenile annual survival appears much greater; however, there does appear to be a drop-off in catch rates as the suckers age and become less susceptible to the fishing gear.

Background

Lost River sucker (*Deltistes luxatus*) and shortnose sucker (*Chasmistes brevirostris*) are jointly listed as endangered under the Endangered Species Act (U.S. Fish and Wildlife Service, 1988). Two of the remaining spawning populations of Lost River sucker and shortnose sucker exist in Upper Klamath Lake (Klamath County, Oregon) and Clear Lake (Modoc County, California; U.S. Fish and Wildlife Service, 2013). The persistence of Upper Klamath Lake Lost River and shortnose sucker populations are threatened by a prolonged lack of recruitment into adult spawning aggregations (National Research Council, 2004; U.S. Fish and Wildlife Service, 2013). The last cohorts to join the adult populations in Upper Klamath Lake were spawned in the early 1990s. Uncertainty exists regarding the role of recruitment limitation to Clear Lake populations because year classes appear to recruit intermittently (Hewitt and Hayes, 2013; Hewitt and others, 2021). In Upper Klamath Lake, decreasing catch rates of age-0 juvenile suckers during summer and minimal catches of age-1 or older juvenile suckers indicate that the lack of recruitment results from high mortality within the first years of life (Burdick and Martin, 2017). In contrast, a more diverse age distribution of juvenile suckers has been documented in Clear Lake, indicating that juvenile sucker survival may be greater in Clear Lake relative to Upper Klamath Lake (Burdick and others, 2015b; Martin and others, 2021).

Recovery of Lost River and shortnose sucker populations requires increasing the number of suckers surviving to maturity. A long-term monitoring program exists for adult suckers at spawning areas aimed at tracking new recruits entering the spawning populations in Upper Klamath Lake and Clear Lake (Hewitt and others, 2015; Hewitt and others, 2021). This adult sucker monitoring program has not detected substantial recruitment into spawning populations, as would be expected 5-14 years after hatch (Buettner and Scoppettone, 1990). Relatively strong cohorts of age-0 suckers were detected in Upper Klamath Lake in 2006 and 2011, but these cohorts did not appear to persist past age-2 (Simon and others, 2013; Burdick and Martin, 2017).

Although the causes of high juvenile mortality are unknown, hypotheses include loss of habitat, poor water-quality, disease, parasites, and predation (mostly by birds; Perkins and others, 2000; Rasmussen, 2011). To help determine the causes and timing of juvenile sucker mortality and to monitor the long-term success of recovery actions, the U.S. Fish and Wildlife Service (USFWS) prioritized the assessment and monitoring of juvenile sucker populations in Upper Klamath Lake and Clear Lake (U.S. Fish and Wildlife Service, 2013; recovery actions 6.1 and 6.2).

Over the last 2 decades, research has been focused on juvenile Lost River and shortnose suckers in Upper Klamath Lake. Juvenile suckers in Upper Klamath Lake were consistently monitored by Simon and others (2013) from 1997 to 2012. The U.S. Geological Survey (USGS) conducted various research projects from 2001 to 2010 and from 2012 to 2015 with the objectives of understanding habitat use, distribution, and health of age-0 and age-1 juvenile suckers. Simon and others (2013) sampled with beach seines, cast nets, and trawls using a consistent study design among years and captured small numbers of suckers relative to USGS, who sampled with trap nets. Locations and sampling gears used were inconsistent across USGS research projects, making these data not ideal for monitoring long-term trends (Burdick and Martin, 2017). Nevertheless, USGS analyzed the 2001 through 2015 USGS dataset to identify patterns in recruitment, survival, and growth of age-0 suckers in Upper Klamath Lake (Burdick and Martin, 2017). Data collected by Simon and others (2013) indicated that the strongest year classes for both species within the 16 years of their record probably occurred prior to 2001 and in 2011. Both studies also found 2006 to be a strong production year for both species of concern (Simon and others, 2013; Burdick and Martin, 2017). Overwinter and summer to autumn survival could not be assessed with data collected in either sampling program because sampling occurred primarily in the summer. The USGS has cautioned that inconsistencies among years in the types of gear used, sample locations, and timing of sample collection could limit inferences made from these historical data (Burdick and Martin, 2017).

The USGS juvenile sucker monitoring program was initiated in 2015 with the objective of generating relative indices of juvenile Lost River and shortnose sucker production, growth, and survival in Upper Klamath Lake and Clear Lake. This monitoring program aims to track cohorts both within and among years. The monitoring program's sample design addresses the inconsistency issues identified by USGS. It also uses trap nets, which are more efficient in catching suckers than active sampling gears such as cast nets, seines, and trawls. Data are anticipated to be useful for identification of environmental variables affecting annual production and survival of young suckers and will be useful for understanding collective effects of recovery actions on production, survival, and growth of juvenile suckers. Through these monitoring efforts, long term trends and environmental variables that affect juvenile sucker population dynamics can be identified and assist in the recovery of endemic suckers in the Upper Klamath Basin.

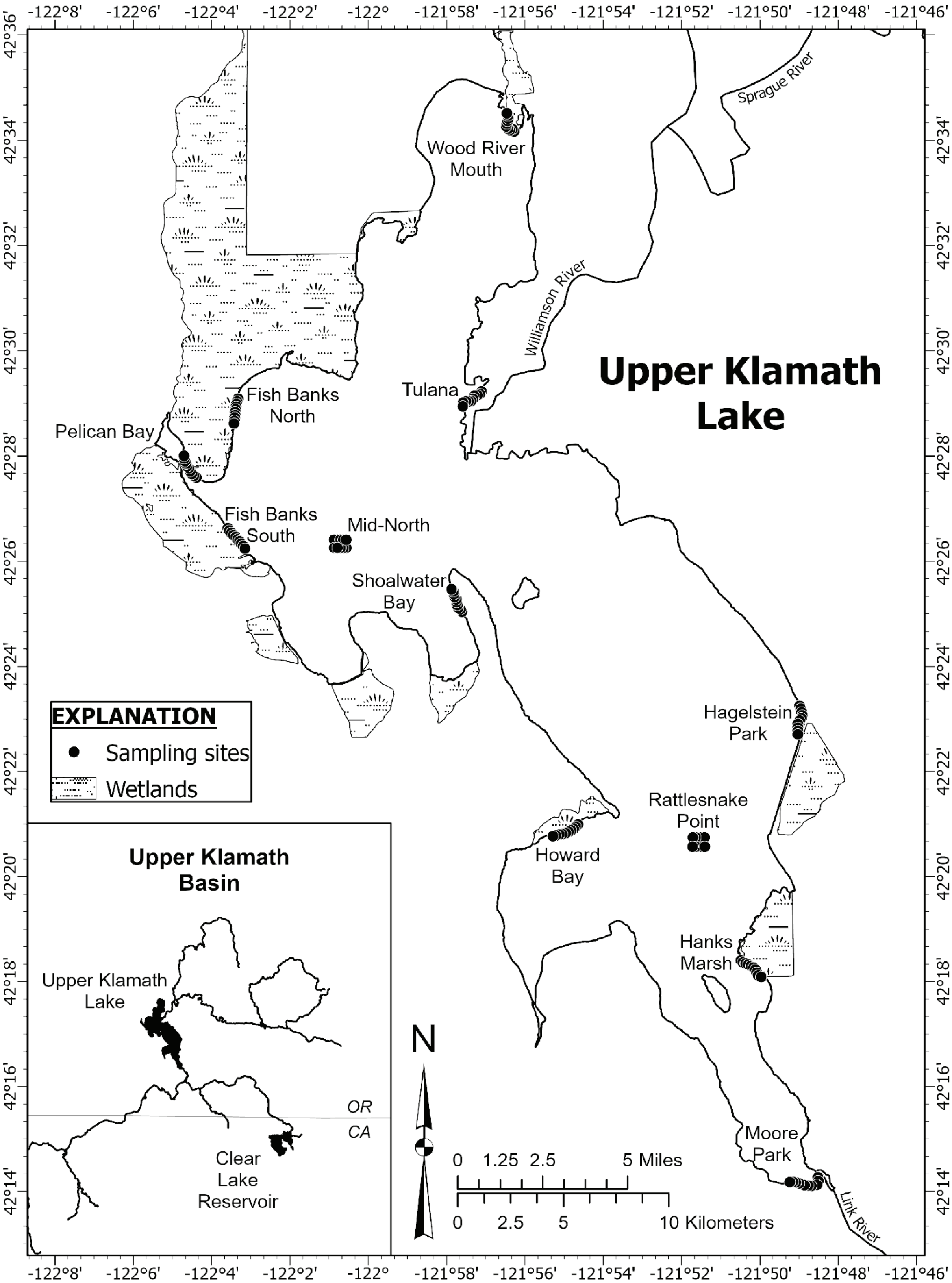
An additional benefit of the juvenile sucker cohort tracking program is the ability to monitor the success of the USFWS Sucker Assisted Rearing Program (SARP) for juvenile suckers (Day and others, 2021). Using passive integrated transponders (PIT), the USFWS PIT-tagged and released about 2,400 SARP suckers in the spring of 2018, 3,000 in the spring of 2019, 1,000 in the fall of 2019, 3,500 in the spring of 2020, 9,900 in the fall of 2020, 6,500 in spring of 2021, 7,000 in fall of 2021, and 8,500 in spring of 2022 (Joshua Gondek, USFWS, written commun., September 23, 2022, and May 18, 2023). The existing juvenile sucker monitoring program provides an opportunity to recapture and track these fish. Sufficient recaptures of tagged fish over time may allow for survival estimates to be generated.

Study Area

Upper Klamath Lake is uniformly shallow, with an average water depth of 2.6 meters (m) and a surface area of 305 square kilometers (km^2) at full pool (National Research Council, 2004). A 6.4–9.5 m deep trench runs along the western shore of the lake. The primary inflows are through the Williamson River on the eastern shore and the smaller Wood River (fig. 1). A small but notable amount of water also enters through two sources: (1) it upwells through the volcanic soils along the lakeshore and (2) it enters the lake as precipitation. A natural volcanic reef at the outlet of the lake was replaced with a dam in 1921 to provide access to a greater volume of water for agriculture (National Research Council, 2004). The dam allows the lake surface elevation to range from about 1,261.0 m to 1,262.8 m (U.S. Geological Survey, 2019). Surface and groundwater inputs exceed down-river flows from about October to about June each year, causing the lake volume to increase. Agricultural water deliveries, down-river water releases to meet instream flow requirements, and to a lesser extent evaporation, exceed water inputs from around June to October each year causing the lake volume to decrease at a predictable rate.

The bottom of Upper Klamath Lake is covered with fine organic detritus composed primarily of decaying diatoms and cyanobacteria. Shoreline wetlands in the northern part of the lake are heavily vegetated with wocus (*Nuphar* sp.), tules (*Schoenoplectus acutus*), and willows (*Salix* sp.). Massive annual blooms of the blue-green cyanobacterium *Aphanizomenon flos-aquae* (AFA) influence summer water-quality dynamics in Upper Klamath Lake (Eldridge and others, 2012a, b). Algal blooms are associated with dissolved oxygen concentrations that can range from supersaturation to anoxia within diel cycles. Extreme summer water-quality conditions can include water temperatures greater than (>) 24 degrees Celsius (°C), dissolved-oxygen less than (<) 2 milligrams per liter (mg/L), pH greater than or equal to (≥) 10, and microcystin toxin concentrations 40–60 parts per billion (ppb; Eldridge and others, 2012a, b).

Clear Lake, in the upper Lost River watershed, was historically a natural lake covering approximately 6,500 hectares (ha; fig. 2). An associated wetland and meadow were to the east of the lake. The Bureau of Reclamation built a dam on the Lost River near the lake outlet in 1910 to enable seasonal water regulation. The dam enlarges the lake and inundates the historical wetland area in most years, which expands the lake by about 3,900 ha (Buettner and Scoppettone, 1991). The present-day Clear Lake has two distinct parts that are connected by a wide, shallow channel: the shallower former marsh on the eastern side and the deeper historical lake on the western side. Willow Creek, which enters the eastern lobe of the reservoir near the dam, has the major spawning area and provides the only substantial inflows. Boles Creek, which flows into Willow Creek supports a minimal amount of spawning habitat. Inflows into Clear Lake primarily occur in the winter or spring and the tributaries become intermittent by mid-summer. Water is released through the Clear Lake Dam into the Lost River to provide spring and summer irrigation to the Langell Valley in Oregon. At a lake surface elevation of about 1,378.6 m, the two parts of the lake become disconnected. At lake-surface elevations around 1,378.9 m, access to Willow Creek is impeded for spawning suckers (Hewitt and others, 2021). Water can be delivered down river below the point of disconnection between the lobes until the lake surface elevation reaches the operational floor at 1,378.3 m. The eastern lobe almost completely dries out when the lake surface elevation declines to about 1,377.7 m, which happened in 2014, 2015, and 2022. Because of these dynamics, the lake depth can fluctuate by more than 3 m among and within years (Bureau of Reclamation, 2019).



Base modified from U.S. Geological Survey digital data;
Universal Transverse Mercator, zone 10 north;
World Geodetic System of 1984

Figure 1. Locations of sample sites used to capture juvenile suckers in Upper Klamath Lake, Klamath County, Oregon, 2021–22.

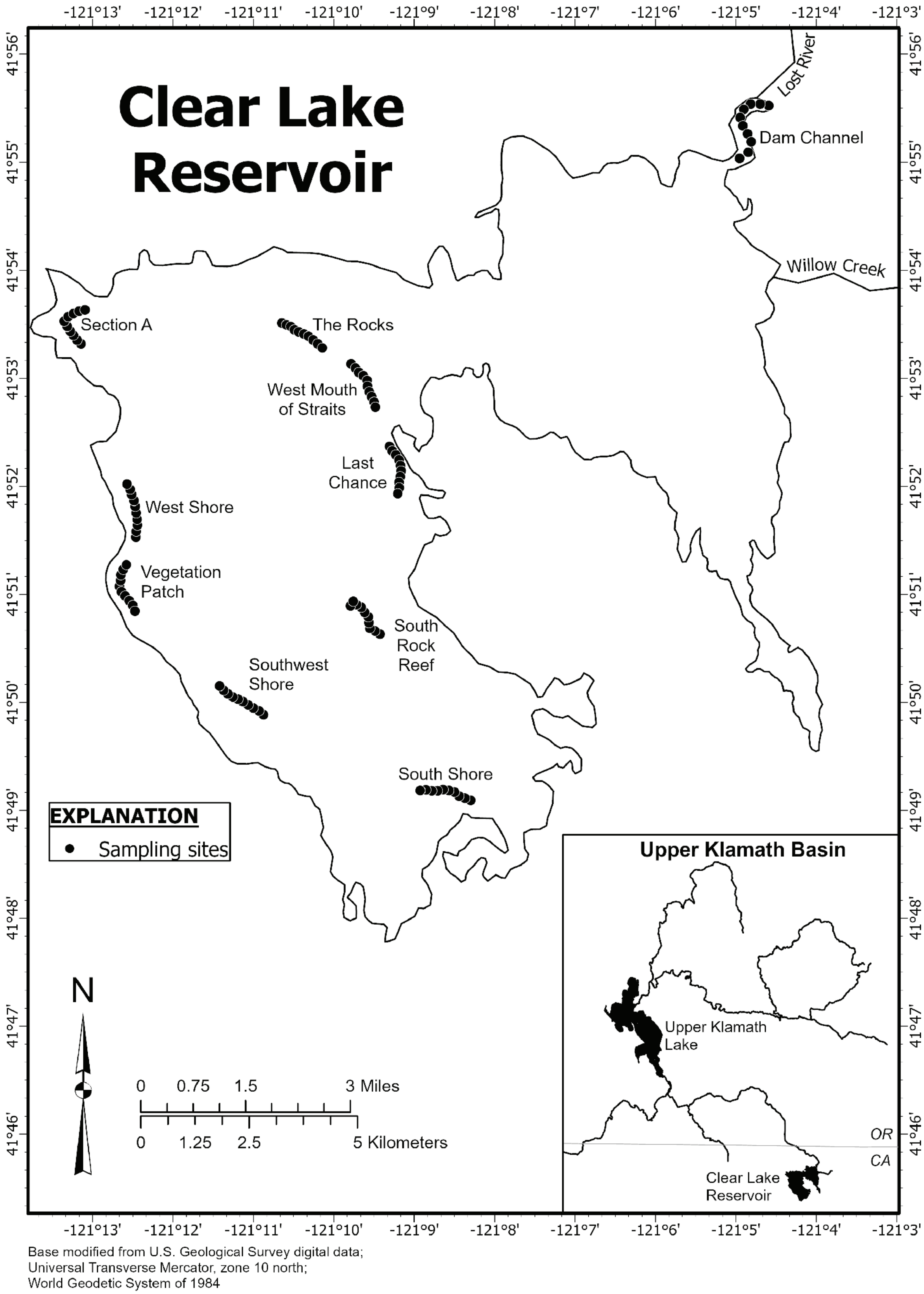


Figure 2. Locations of sample sites used to capture juvenile suckers in Clear Lake Reservoir, Modoc County, California, 2021–22.

Clear Lake is in the USFWS's Clear Lake National Wildlife Refuge, and the upper watershed is almost entirely within the U.S. Forest Service's Modoc and Fremont-Winema National Forests. The area around the lake is rocky with sagebrush (*Artemisia* sp.) steppe plant communities and western juniper (*Juniperus occidentalis*), whereas the upper watershed is a ponderosa pine (*Pinus ponderosa*) forest (Buettner and Scoppettone, 1991). The bottom of Clear Lake Reservoir is covered with claylike sediment and occasional large lava rocks. The lake is turbid, which is likely the result of wind coupled with shallow water and fine sediments. When compared to Upper Klamath Lake, summer water temperatures have greater diel fluctuations and better water-quality in Clear Lake. Water temperatures in Clear Lake reach up to 26 °C, dissolved-oxygen ≥5 mg/L, pH around 8.5, and no detectable microcystin toxin (Burdick and others, 2015a).

Species

Lost River and shortnose suckers are long-lived lake dwelling Catostomids that make springtime spawning migrations to lake shore or tributaries as early as age-5 for shortnose suckers and age-6 for Lost River suckers, but average at age-6 for shortnose suckers and age-9 for Lost River suckers (Buettner and Scoppettone, 1990). Upper Klamath Lake populations typically spawn from March to June, whereas Clear Lake populations spawn from February to April (Hewitt and others, 2021; Burdick and others, 2015b). Additionally, Klamath largescale suckers (*Catostomus snyderi*), the least lake dependent of the Upper Klamath Basin suckers, are also in Upper Klamath and Clear Lakes (Moyle, 2002). Spawning migrations start when spawning tributary water temperatures exceed 10 °C in Upper Klamath Lake and can be as low as 2 °C in Clear Lake (Hewitt and others, 2017; Hewitt and others, 2021). Larvae of Upper Klamath Lake river spawning populations out-migrate at night in May and early June to in-lake rearing habitats within several days of emerging from gravel (Cooperman and Markle, 2003). Clear Lake sucker larvae out-migrate from Willow Creek during April and May (Sutphin and Tyler, 2016). Age-0 juvenile suckers of both taxa are widely distributed throughout Upper Klamath Lake by late-July and August, with several studies indicating no evidence of directed migrations during this time period (Hendrixson and others, 2007; Burdick and others, 2009b; Burdick and Hewitt, 2012). However, previous entrainment studies and Bureau of Reclamation catches of juvenile suckers at their Fish Evaluation Station suggest a pulse of suckers going down the Link River in mid-August (Gutermuth and others, 2000a, b). These results suggest that although there does not appear to be a directed migration, there are suckers that leave the system via the Link River. Age-1 suckers are much less abundant than age-0 suckers, and immature suckers age-2 and older are rarely encountered in Upper Klamath Lake. The oldest Lost River sucker sampled was estimated to be 57 years, and the oldest shortnose sucker was estimated to be 33 years (Terwilliger and others, 2010).

Historically, both species were able to support a subsistence fishery. Decreasing population trends started to become evident by the 1960s (Markle and Cooperman, 2002). Regular recruitment to the spawning populations in Upper Klamath Lake has not been documented since the early 1970s (Scoppettone, 1986; Terwilliger and others, 2010). The fishery was closed in 1987 (Markle and Cooperman, 2002; Janney and others, 2008), but poor survival of juvenile suckers persisted in Upper Klamath Lake populations post-closure. Whereas adult survival is typically high, populations are limited by occasional (sometimes massive) adult fish die-off events and little to no recruitment to the spawning populations (Krause and others, 2022).

Methods

Sample Design

Suckers were sampled with trap nets to assess species-specific annual variability in production and growth, as well as annual and seasonal variability in survival of juvenile suckers in Upper Klamath and Clear Lakes. The timing of the sampling periods was selected based on previous catch data in Upper Klamath Lake. Specifically, we targeted age-1 suckers in early June, the start of age-0 sucker catches in July, the peak of age-0 sucker catches in August, and the tail end of age-0 sucker catches in September (Burdick and Martin, 2017). In 2015, sampling was conducted over three 3-week periods simultaneously in Upper Klamath and Clear Lakes. An evaluation of the study design in 2015 indicated that with increased effort concentrated into shorter time periods growth and differences in catch rates between sampling periods could be better described. Starting in 2016, sampling was conducted during 1 week in each month with weekly sampling alternated between lakes within each sampling month. A July sampling period was added in 2018 to capture early age-0 suckers. Sampling occurred in the same calendar weeks each year within each lake, with the exception of July 2018. Poor air quality resulting from wildfires limited access to Upper Klamath Lake and delayed the sampling effort by 1 week when compared to previous years.

The catch data in this report is only relevant to suckers from about 45 to 300 millimeters (mm) standard length (SL) based on the trap net selectivity. Small age-0 suckers (<45 mm SL) have a low catchability in trap nets (Burdick and Martin, 2017). Because adult suckers (>300 mm SL) are captured at high rates in spring and fall trammel net sampling and infrequently in summer trap net sampling, we presume trap nets select for smaller suckers relative to trammel nets (Hewitt and Hayes, 2013).

Fixed sampled sites were selected in a variety of habitats throughout both lakes to reduce potential sample bias caused by spatial heterogeneity in the densities, species, ages, size or health of suckers. Age-0 suckers greater than 45 mm SL are homogenously distributed by species and size within Upper Klamath Lake (Hendrixson and others, 2007; Burdick and Hewitt, 2012). However, age-1 suckers are more likely to be found in shallow (<1 m deep) near-shore habitats in the spring and deep water (about 2 m) in the summer (Bottcher and Burdick, 2010). Spatial patterns among age-classes of suckers have not been identified in Clear Lake (Burdick and Rasmussen, 2012). Sample areas were either 1-kilometer long sections of shoreline or 300 square meters (m^2) offshore areas. Within each area, 10 fixed sites were identified as accessible given a variety of water levels. In 2021 and 2022, as in past years, we attempted to set nets at 8 sites at each area in Upper Klamath Lake and 7 sites at each area in Clear Lake during each sampling period (tables 1 and 2). However, because of low water levels in 2021, only one established site at the Tulana area in Upper Klamath Lake was sampled in June, July, and August. Supplemental sites were sampled at the mouth of the Tulana wetlands in July and August of 2021. In September of 2021, neither the established site nor the supplemental sites were accessible for the Tulana area. In Clear Lake, the dam channel area was only accessible in June and was not sampled in July, August, or September because of low water levels. Furthermore, in 2022 only three of the sites at the dam channel were set. To address the concern of catches at fixed sites not being reflective of the sucker population, random sites were sampled during all sample years. Previous work has found no significant difference between fixed verses random sites (Burdick and others, 2016). In order to compare catches between years, only fixed sites are reported in this publication.

Sample locations were adjusted for water depth each year. Sites that were shallow and near shore in low water years of 2015 and 2016 were often in more than 3 m of water and far from shore from 2017 to 2020. Because juvenile sucker catch rates with trap nets decrease at depths greater than 3 m (Burdick and Hewitt, 2012), few juvenile suckers were captured at this depth. We adjusted sample locations by going to the 2015 and 2016 locations, then driving directly toward shore from the original site until we were in less than 3 m of water before setting the trap nets. In 2021 and 2022 sampling sites, the 2015 and 2016 locations were too shallow to set nets. Therefore, the crews attempted to go to the preset locations, but set the nets further from shore before they reached the preset location.

Fish Handling and Sampling

Sampling was conducted with rectangular trap nets with mouth dimensions of 0.61 × 0.91 m, a 10-m-lead, and 3 internal fykes. Standard length and fork length were recorded for each captured individual. The leading left pectoral fin ray was removed at the proximal joint for aging. Fin rays were not collected from small suckers (35–60 mm SL) from Upper Klamath Lake since they were presumed to be age-0 fish based on length at date of capture (Burdick and Martin, 2017). We compared the length and number of annuli on fish with fin rays collected to length of suckers without fin rays collected to validate our length-based age assumptions. A small (about 2 square millimeters [mm^2]) piece of tissue from the caudal fin was collected for genetic identification to species. All collected suckers were measured, aged either by fin ray or presumed age-0, and identified to species via genetic analysis. The exception being three suckers captured during 2021 and four suckers captured during 2022 in Clear Lake, that had either missing genetics and or missing ages. Emaciation, deformities, macro parasites, petechial skin hemorrhaging, and other abnormalities afflictions were recorded. Individuals were scanned for a PIT-tag to document recaptures from prior juvenile sampling efforts and hatchery program releases. If no tag was detected, a PIT-tag was inserted into the ventral abdominal musculature anterior to the pelvic girdle when the individual was larger than 60 mm SL and lake conditions did not compromise sucker health (Burdick, 2011). Suckers were released at their site of capture.

Aging Juvenile Suckers

To estimate sucker age, fin rays were mounted in epoxy, sectioned, and viewed by two experienced readers using transmitted light under magnification (Quist and others, 2012). The number of annuli was determined in blind reads by two readers, with each reader having no knowledge of the other's annuli count. When both readers agreed on a number of annuli, that number was presumed to be the correct age and was used in analyses. If there was disagreement in the annuli count, the two readers viewed the structure together and came to a consensus or a third reader acted as a tie breaker. Suckers from both lakes were either aged or assumed to be age-0 when 60 mm SL or less.

Species Identification

To identify juvenile suckers to species, we applied genetic identification methods described by Smith and others (2020 and 2023). Caudal fin tissue was collected from juvenile suckers from each lake, dried, and analyzed at the USFWS Abernathy Fish Health Center in Abernathy, Washington. Individuals were assigned to their reporting/species group described in Smith and others (2023) using genetic stock identification (GSI) implemented in the R package rubias (Moran and Anderson, 2019). The rubias package is a Bayesian approach to the conditional GSI model which includes a leave-one-out cross validation and simulation method to enhance GSI accuracy (Anderson and others, 2008). A mean posterior probability threshold of 0.9 was selected for accepting individual assignments. Only individuals assigned to a reporting/species group above this threshold were

Table 1. Number of nets set for juvenile suckers by area and sampling period in Upper Klamath Lake, Oregon, 2021 and 2022.

[**Abbreviations:** N, north; W, west; Jun, June; Jul, July; Aug, August; Sep, September]

Area	Latitude	Longitude	Number of nets set in 2021				Number of nets set in 2022			
			Jun	Jul	Aug	Sep	Jun	Jul	Aug	Sep
Wood River mouth	42° 34' 18.84″ N	121° 56' 27.44″ W	8	8	8	8	8	8	8	8
Fish Banks north	42° 28' 53.18″ N	122° 03' 22.89″ W	8	8	8	8	8	8	8	8
Fish Banks south	42° 26' 25.19″ N	122° 03' 20.45″ W	8	8	8	8	8	8	8	8
Pelican Bay	42° 27' 48.44″ N	122° 04' 37.62″ W	8	8	8	8	8	8	8	8
Tulana	42° 29' 05.56″ N	121° 57' 19.40″ W	1	8	8	0	8	8	8	8
Shoalwater Bay	42° 25' 16.54″ N	121° 57' 45.27″ W	8	8	8	8	8	8	8	8
Hagelstein	42° 23' 00.79″ N	121° 48' 56.44″ W	8	8	8	8	8	8	8	8
Howard Bay	42° 20' 49.72″ N	121° 54' 57.38″ W	8	8	8	8	8	8	8	8
Hanks Marsh	42° 18' 17.85″ N	121° 50' 13.72″ W	8	8	8	8	8	8	8	8
Moore Park	42° 14' 06.57″ N	121° 48' 46.31″ W	8	8	8	8	8	8	8	8
Mid-North	42° 26'0 0.91″ N	122° 00' 56.35″ W	8	8	8	8	8	8	8	8
Rattlesnake Point	42° 20' 34.57″ N	121° 51' 03.79″ W	8	8	8	8	8	8	8	8
		Total nets set	89	96	96	88	96	96	96	96

Table 2. Number of nets set for juvenile suckers by area and sampling period in Clear Lake Reservoir, California, 2021 and 2022.

[**Abbreviations:** N, north; W, west; Jun, June; Jul, July; Aug, August; Sep, September]

Area	Latitude	Longitude	Number of nets set in 2021				Number of nets set in 2022			
			Jun	Jul	Aug	Sep	Jun	Jul	Aug	Sep
Dam to Willow Creek mouth (dam channel)	41° 55' 24.80″ N	121° 04' 56.75″ W	7	0	0	0	3	0	0	0
The Rocks	41° 53' 25.75″ N	121° 10' 26.15″ W	7	7	7	7	7	7	7	7
West mouth of straits	41° 52' 58.76″ N	121° 09' 35.24″ W	7	7	7	7	7	7	7	7
Section A	41° 53' 31.72″ N	121° 13' 21.14″ W	7	7	7	7	7	7	7	7
West shore	41° 51' 48.77″ N	121° 12' 28.12″ W	7	7	7	7	7	7	7	7
Last Chance Island	41° 52' 11.56″ N	121° 09' 10.31″ W	7	7	7	7	7	7	7	7
Vegetation patch	41° 51' 04.47″ N	121° 12' 40.10″ W	7	7	7	7	7	7	7	7
South rock reef	41° 50' 47.41″ N	121° 09' 34.39″ W	7	7	7	7	7	7	7	7
South shore	41° 49' 11.02″ N	121° 08' 34.03″ W	7	7	7	7	7	7	7	7
Southwest shore	41° 50' 00.46″ N	121° 11' 07.77″ W	7	7	7	7	7	7	7	7
		Total nets set	70	63	63	63	66	63	63	63

categorized to species for subsequent analyses. Fish that could not be assigned to species based on the above criteria were considered indeterminate. The current genetic technique to separate Klamath largescale from shortnose suckers was built upon known species from the Upper Klamath Basin; however, there is still uncertainty in separating these species in the Lost River Basin (Smith and others, 2020). There is a possibility that the selected markers do not translate into proper assignment of species in the Lost River Basin. A few shortnose suckers were genetically identified in the Lost River system, but most were not separated from Klamath largescale suckers and therefore were classified as the combination of Klamath largescale suckers and shortnose suckers from the Lost River Basin. Previous genetic techniques could only separate Lost River suckers from a mix of shortnose and Klamath largescale suckers (Hoy and Ostberg, 2015). In order to compare genetics across years, a category of combined shortnose and Klamath largescale suckers was included.

Indices of Juvenile Sucker Year-Class Strength and Apparent Survival

To describe annual relative (among cohorts, species, and lakes) year-class strength and age-0 sucker production, we calculated (1) the proportion of August nets to catch one or more age-0 sucker (successful age-0 nets), (2) the mean August catch per unit effort (CPUE) for age-0 suckers in successful age-0 nets, and (3) the total August age-0 CPUE as the number of suckers in each taxa divided by the number of nets set. August catches were used because this time frame represented the peak of age-0 sucker catches. We assessed age-0 summer apparent survival by comparing CPUE by year-class between the August and September sampling periods. To provide an index to compare between years, September age-0 CPUE was divided by August age-0 CPUE. If the September CPUE was greater than the August CPUE, >1 was reported indicating that suckers were recruiting to the gear at a greater rate in September than in August. We also calculated an index of fall through spring apparent survival for each year-class as the ratio of age-1 CPUE in June divided by age-0 CPUE from September from the previous year. If age-0 CPUE was zero and age-1 CPUE was greater than zero, then results were reported as >1.

We assumed that sampling efficiency was similar between years and within year sampling periods. The presence of vegetation, substrate type, and water depth have minor effects on detection probability of juvenile suckers (Burdick and others, 2008). By using the same fixed sites throughout relatively homogenous habitat with little to no vegetation, habitat variables were assumed similar at sampled sites between years. Furthermore, due to water management in Upper Klamath Lake water depth is similar each August, minimizing any effects on capture probability.

Observations on External Afflictions

We summarized the prevalence and intensity of external afflictions on juvenile suckers to compare the health of suckers between years and lakes and to identify causes of sucker mortality. We notated afflictions that are either common or potentially associated with mortality such as *Lernaea* sp., petechial hemorrhaging, and lamprey wounds (Markle and others, 2014; Burdick and others, 2015a). Afflictions were quantified and compared to affliction counts from previous years.

Gear Selectivity

A gear comparison study was enacted to understand if gear type selectivity was affecting catch of juvenile suckers in Upper Klamath Lake. Hoop nets (0.91-m diameter round opening, with five wire hoops for structural support, two internal round traps nets, a 9.1-m lead and two 4.6-m wing nets), large trap nets (1.2 × 16-m lead, a 1.2 × 1.8 × 1-m rectangular frame, and four 1-m diameter circular hoops [1 m apart]), and standard trap nets, as described above, were fished concurrently at five sites during June, July, and August of 2016 and five sites during July, August, and September of 2017. Sites included Fish Banks North, Fish Banks South, Mid-North, Moore Park (2016 only), Rattlesnake Point, and Shoalwater Bay (2017 only). Nets were set and fish processed using the same methods as the standard juvenile monitoring protocol. Because data did not meet the assumption of normality, the nonparametric Kruskal-Wallis test with Dunn's multiple comparison tests were used to compare size of suckers captured and catch rates among sampling gears. A correction factor for comparing gear types was calculated by dividing the mean CPUE of large trap nets by the mean CPUE of the other gears. Burdick and Martin (2017) had indicated that their analysis could have been more complete if such a correction factor existed.

A gear comparison study was enacted to understand how standard trap nets affect sucker catches in Clear Lake. A seine (6 m long, 1.3 m high with 5 mm mesh), trammel nets (91.4 m long, 1.8 m deep; with two outer panels [30 centimeter (cm) bar], one inner panel [3.8 cm bar], a foam core float line and a lead core bottom line), and standard trap nets were used to sample suckers from June—September 2016 and 2017. Trammel nets were set for 2–3 hours during daylight hours whereas standard trap nets were fished overnight as with standard juvenile monitoring. The seine was positioned 8–15 m from dry land and parallel to shore, and then pulled directly toward shore until it was beached and fish could be removed. Fish were processed using the same methods as the standard juvenile monitoring protocol. Because data did not meet the assumption of normality, the nonparametric Kruskal-Wallis test with Dunn's multiple comparison tests were used to compare size of suckers captured and catch rates among sampling gears.

Results

Upper Klamath Lake Year-Class Strength and Apparent Survival

During the 2021 juvenile monitoring sampling, 85 suckers from 3 cohorts were captured in Upper Klamath Lake. Ninety-two percent were age-0 (table 3; fig. 3), 6 percent were age-1, and 2 percent were age-2. Of the 78 age-0 suckers, 35 were Lost River sucker, 41 were shortnose sucker, and 2 were Klamath largescale suckers (table 3). Age-0 suckers ranged from 36 mm to 92 mm SL (fig. 4). A total of five age-1 suckers from the 2020 cohort and two age-2 suckers from the 2019 cohort were captured throughout the sampling season in 2021 (fig. 3). Of the five age-1 suckers captured in Upper Klamath Lake, one was a Lost River sucker, one was a shortnose sucker, and three were Klamath largescale sucker. There was one age-2 shortnose sucker and one age-2 Klamath Largescale sucker that were captured in 2021. The age-1 suckers were less than or equal to 165 mm SL, whereas the age-2 suckers were 144 and 171 mm SL (fig. 5). During 2021, no captured suckers originated from USFWS SARP.

During the 2022 juvenile monitoring sampling, 19 suckers from 3 cohorts were captured in Upper Klamath Lake. Sixty-eight percent were age-0 (table 3; fig. 3), 21 percent were age-1, and 11 percent were age-2. Of the 13 age-0 suckers, 9 were Lost River sucker, 3 were shortnose sucker, and 1 was a Klamath largescale sucker (table 3). Age-0 suckers ranged from 55 to 80 mm SL (fig. 4). A total of four age-1 suckers from the 2021 cohort and two age-2 suckers from the 2020 cohort were captured throughout the sampling season in 2022 (fig. 3). Of the four age-1 suckers captured during 2022 in Upper Klamath Lake, none were Lost River suckers, three were shortnose suckers, and one was a Klamath largescale sucker (table 3). There was one age-2 shortnose sucker and one age-2 Klamath Largescale sucker that were captured in 2022. The age-1 suckers were ≤130 mm SL, whereas the age-2 suckers were 143 and 190 mm SL (fig. 5). During 2022, no captured suckers originated from USFWS SARP.

August CPUE of age-0 suckers for all sucker species combined in Upper Klamath Lake was low in 2021 and 2022. The 2022 August CPUE was the lowest on record whereas the 2021's August CPUE was similar to those recorded in 2018. There was an even mix of Lost River and shortnose suckers captured in August of 2021, whereas most of the age-0 suckers captured during August of 2022 were Lost River suckers (table 4). Age-0 Lost River Sucker CPUE in 2021 was similar to 2018 and 2020, but larger than in 2017 and 2022, and only about 10 percent of CPUE in 2016 (table 4). Age-0 Lost River Sucker CPUE in 2022 was similar to 2017, with both representing the lowest on record (table 4). The 2021 shortnose sucker CPUE was similar to that in 2017 and was lower than in most other sampling years except for 2018, 2020, and 2022. The 2022 shortnose sucker CPUE was similar to 2018 and 2020, with all three being the lowest on record (table 4).

The CPUE from the 2019 and 2020 cohort declined through 2021 and 2022 sampling. CPUE of the 2019 cohort decreased to near zero starting in July 2020 and were last captured in June 2021 (table 5). CPUE of the 2020 cohort started to decline in August of 2020 and was also last detected in September of 2022 (table 6). CPUE of the 2021 cohort started to decline in August of 2021 and was last detected in July of 2022 (table 7). Contrary to other years, the 2021 cohort appeared to be fully recruited to the gear already in July (table 7), whereas the 2022 cohort did not recruit to the gear until August (table 8). Age-0 catch rates for the 2021 cohort declined between July and August and again between August and September (table 7), whereas age-0 catch rates for the 2022 cohort declined between August and September (table 8).

Table 3. Catch per net and percentage of age-0 suckers for each taxa captured in Upper Klamath Lake, Oregon, 2021 and 2022.

[Number of total and age-0 suckers captured by each taxa, the catch per net (catch per unit effort), and percentage of each taxa that were age-0 are given. Taxa were identified based on their genetic information from genetic stock identification results. **Abbreviations:** <, less than; CPUE, catch per unit effort]

Taxa	Upper Klamath Lake 2021				Upper Klamath Lake 2022			
	Number suckers	Number age-0	Age-0 CPUE	Age-0 (percent)	Number suckers	Number age-0	Age-0 CPUE	Age-0 (percent)
Lost River suckers	36	35	0.09	97	9	9	0.02	100
Shortnose suckers	43	41	0.08	94	7	3	0.01	43
Klamath largescale suckers	6	2	0.03	71	3	1	<0.01	33
All taxa suckers	85	78	0.21	92	19	13	0.03	68

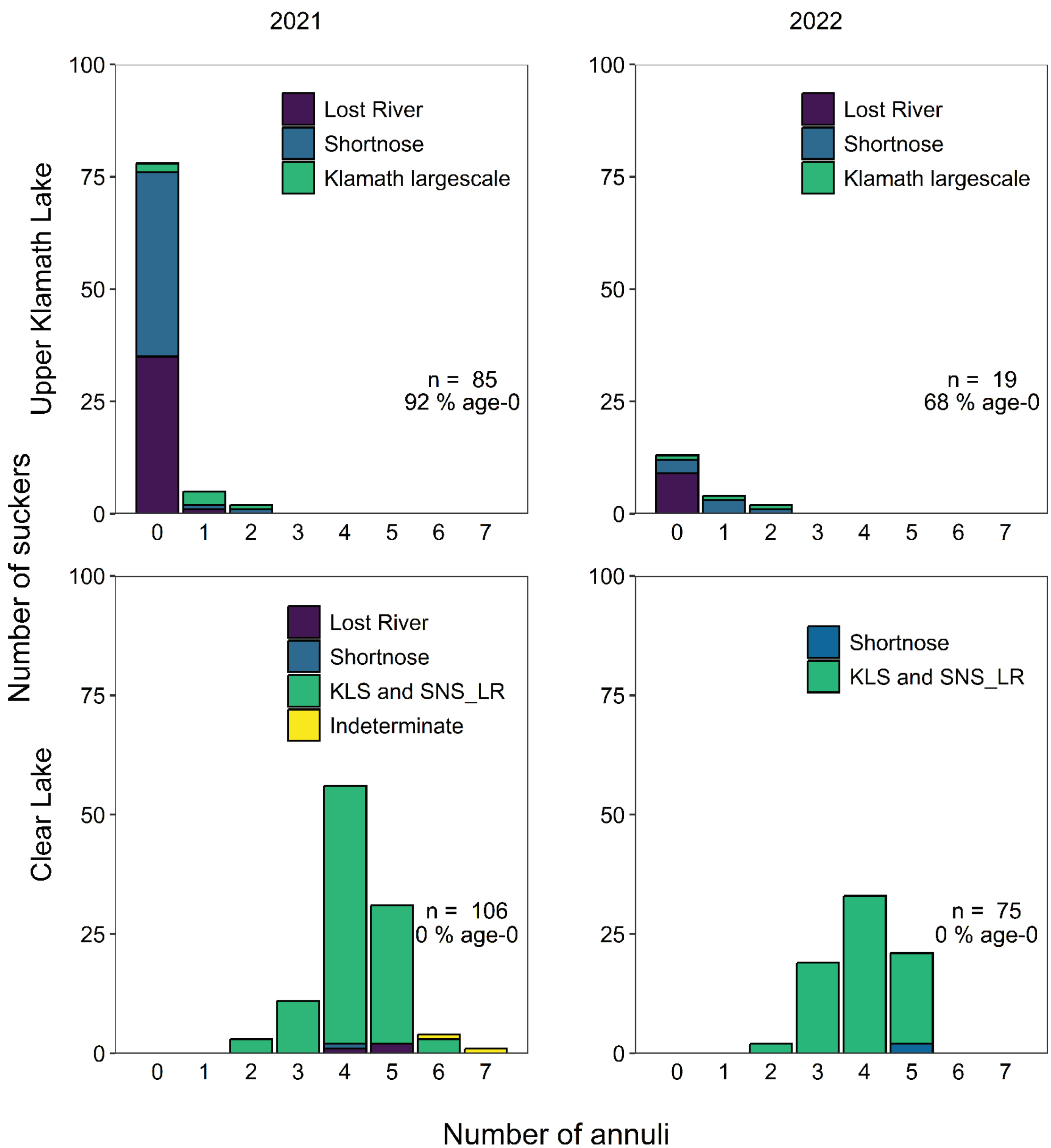


Figure 3. Number of annuli on suckers collected from Upper Klamath Lake, Oregon, and Clear Lake Reservoir, California, 2021 and 2022. Number of fish in each panel (*n*) and percentage of the total number of suckers in each graph that had no annuli on fin rays (age-0) are given. KLS and SNS_LR refers to suckers classified as Klamath largescale suckers (*Catastomus snyderi*) or shortnose suckers (*Chasmistes brevirostris*) from the Lost River Basin.

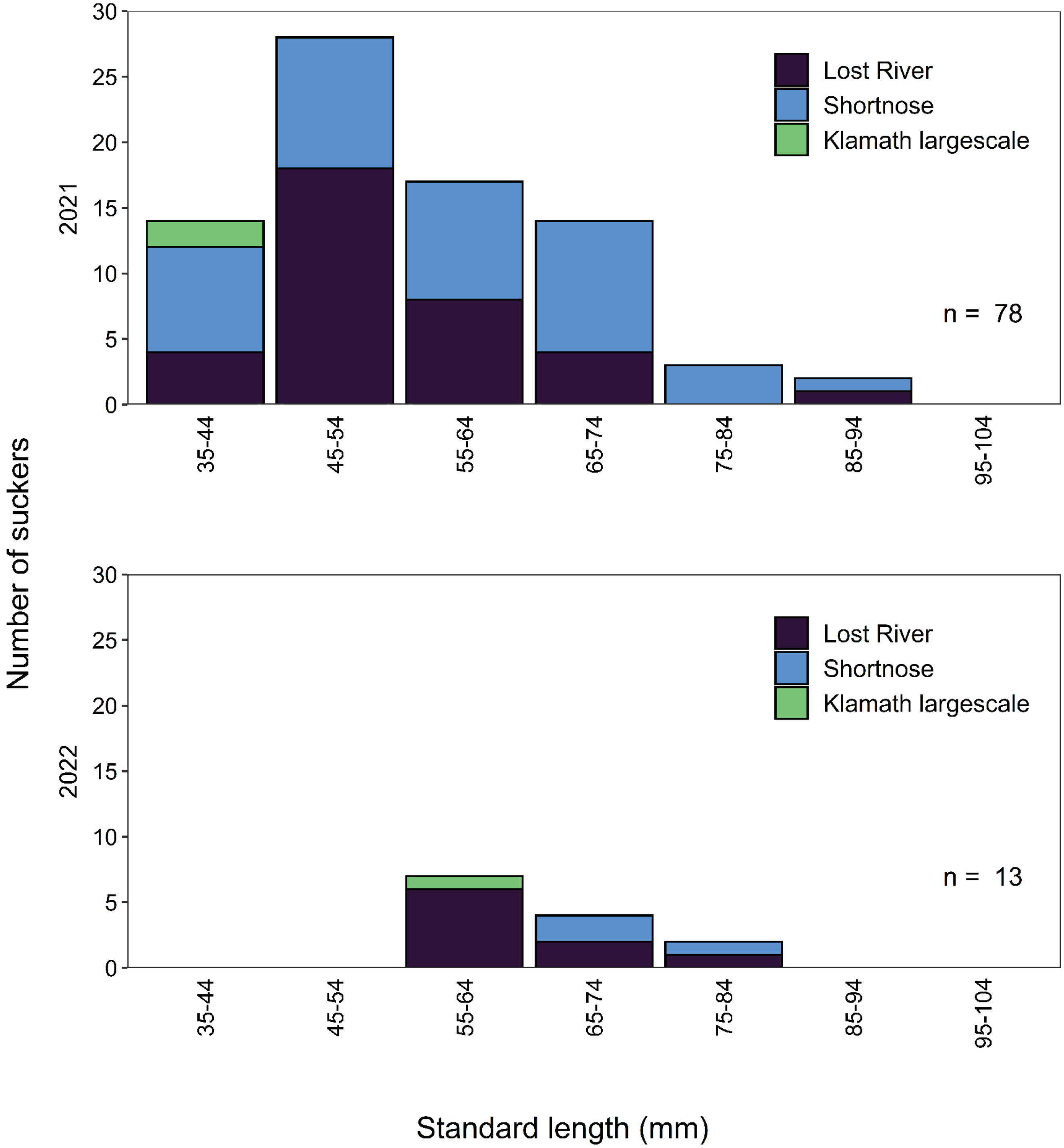


Figure 4. Standard lengths of age-0 suckers collected at fixed locations in Upper Klamath Lake, Oregon, 2021 and 2022. Number of fish are given (*n*). Standard length is shown in millimeters (mm).

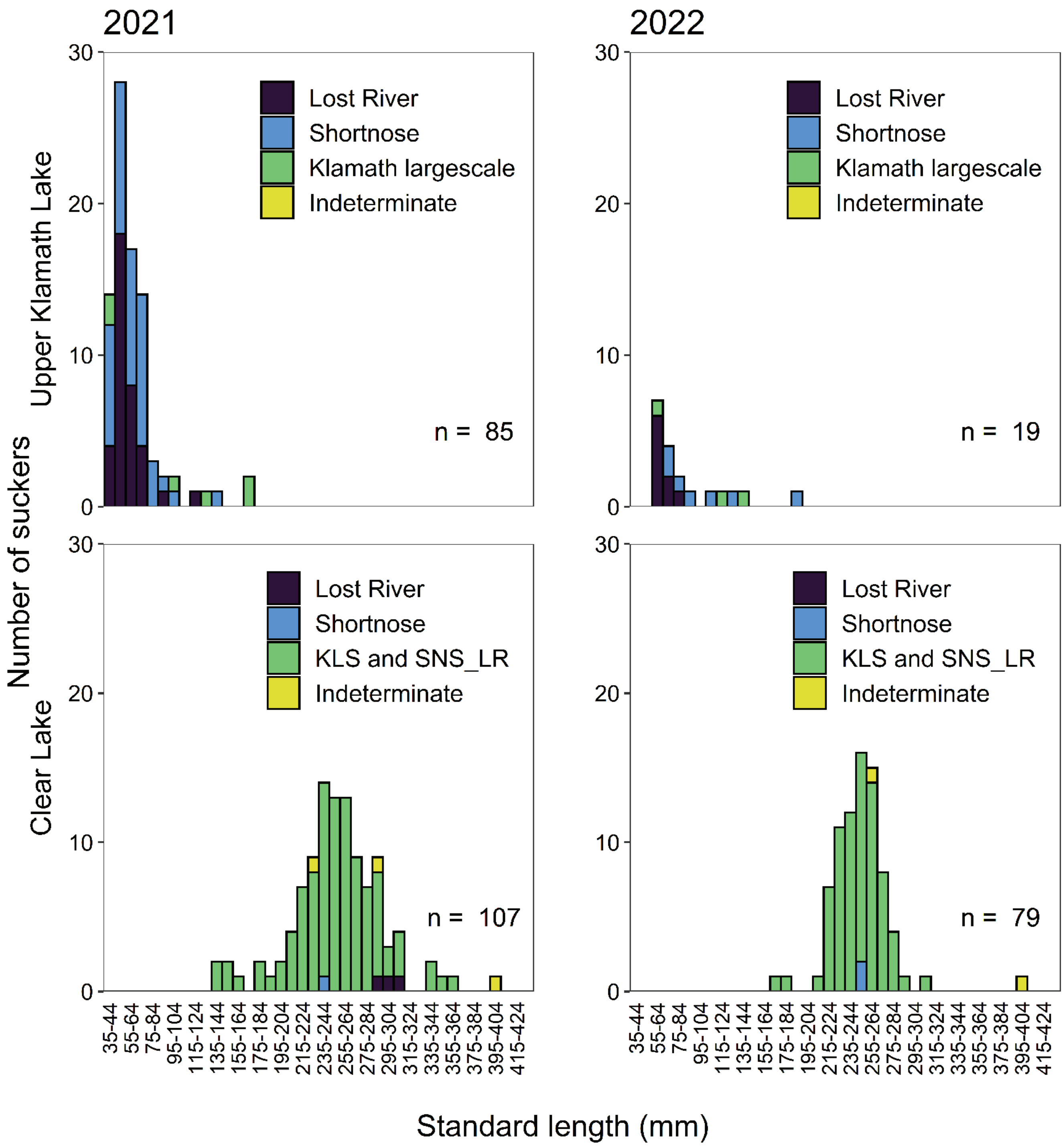


Figure 5. Standard lengths of all suckers collected at fixed locations in Upper Klamath Lake, Oregon, and Clear Lake Reservoir, California, 2021 and 2022. Number of fish in each panel are given (*n*). KLS and SNS_LR refers to suckers classified as Klamath largescale suckers (*Catastomus snyderi*) or shortnose suckers (*Chasmistes brevirostris*) from the Lost River Basin. Standard length is shown in millimeters (mm).

Table 4. Catch statistics for August age-0 suckers from Upper Klamath Lake, Oregon, 2015–22.

[Total capture per unit effort was calculated as the number of fish captured per net set and includes suckers from which we did not collect genetic samples. Taxa were identified based on genetic identification. Indeterminant refers to individuals that could not be assigned to a species since the mean posterior probability was less than 0.95 (2015–19) or 0.9 (2020–22). Prior to 2020 shortnose (*Chasmistes brevirostris*) and Klamath largescale suckers (*Catastomus snyderi*) could not be separated; therefore, to compare among years these taxa are combined. **Abbreviations:** *n*, number of suckers; Aug, August; SNS/KLS, suckers with a mixture of genetic markers from shortnose suckers and Klamath largescale suckers; CPUE, capture per unit effort]

Parameter	Aug 2015 (98 nets)	Aug 2016 (96 nets)	Aug 2017 (96 nets)	Aug 2018 (88 nets)	Aug 2019 (96 nets)	Aug 2020 (96 nets)	Aug 2021 (96 nets)	Aug 2022 (96 nets)
Lost River suckers								
n	38	120	7	12	60	15	12	8
Total CPUE	0.38	1.25	0.07	0.14	0.62	0.16	0.13	0.08
Shortnose suckers, Klamath largescale suckers, and SNS/KLS								
n	49	34	12	2	35	3	12	1
Total CPUE	0.49	0.35	0.12	0.02	0.36	0.03	0.13	0.01
Indeterminant								
n	31	59	12	7	113	1	0	0
Total CPUE	0.31	0.61	0.12	0.08	1.18	0.01	0.00	0.00
Total suckers								
n	120	222	31	21	279	19	25	9
Total CPUE	1.20	2.31	0.32	0.24	2.91	0.20	0.26	0.09

Apparent survival of all suckers from August to September varied by year with the overall highest apparent survival occurring in 2018, 2020, 2021, and 2022 (table 9). However, survival indices in these years were driven by the high apparent survival of the combination of shortnose and Klamath largescale suckers, which had larger catches in September than in August. This indicates that these suckers were likely recruiting to the nets in September (table 9). Shortnose suckers/Klamath largescale suckers had greater apparent survival from August to September than Lost River suckers within most years (table 9). The 2017 and 2019 cohorts were the only ones that had greater August to September apparent survival for Lost River suckers, with survival indices high in 2019 and low in 2017 (table 9). The remaining Lost River cohorts had low apparent survival with indices ≤0.20. The August to September apparent survival for the 2015, 2016, and 2019 cohorts of shortnose/Klamath largescale suckers was moderate (indices ranged from 0.35 to 0.49), whereas it was zero for the 2017 cohort. When considering only genetically identified shortnose suckers, August to September survival indices were 0.19 in 2021 and greater than 1.00 in 2020 and 2022. This indicates that the 2021 cohort of shortnose suckers had poor survival from August to September 2021.

Fall through spring apparent survival varied by taxa and cohort. The 2017 shortnose/Klamath largescale sucker cohort had the highest fall through spring survival index. Shortnose/Klamath largescale suckers had greater fall through spring survival than Lost River suckers within most years (table 10), the exception being the 2015 cohort of Lost River suckers. The 2015 Lost River sucker cohort had the highest fall through spring survival index (0.75), whereas the 2020 cohort had a moderate index (0.33), compared to the indices (0–0.06) for the remainder of Lost River sucker cohorts (table 10). Shortnose/Klamath largescale suckers had the highest fall through spring survival indices for the 2017 and 2019 cohorts (>1 and 0.92), with moderate fall through spring survival indices for the 2015 and 2020 cohorts (0.33 and 0.44; respectively), and poor fall through spring survival indices for 2016, 2018, and 2021 cohorts (table 10). The 2021 cohort of genetically identified shortnose suckers had poor fall through spring survival index of 0.00 from September to June. Although the 2021 cohort was not detected in June of 2022, it was detected after June 2022.

Table 5. Catch statistics for the 2019 cohort of suckers from Upper Klamath Lake, Oregon.

[Percentage of nets to successfully capture one or more suckers by each taxa, mean and standard deviation catch per net (catch per unit effort, or CPUE) in nets that successfully captured one or more sucker, and total suckers captured in all nets set (Total CPUE) are given for each seasonal sampling period. Total CPUE was calculated as the number of fish captured per net set. Taxa were identified based on genetic identification. Indeterminant refers to individuals that could not be assigned to a species since the mean posterior probability was less than 0.9. Prior to 2020, shortnose (*Chasmistes brevirostris*) and Klamath largescale suckers (*Catastomus snyderi*) could not be separated; therefore, to compare among years these taxa are combined. **Abbreviations:** Jul, July; Aug, August; Sep, September; Jun, June; SNS/KLS; suckers with a mixture of genetic markers from shortnose suckers and Klamath largescale suckers; SD, standard deviation; NA, used instead of standard deviations that are not applicable because of low sample sizes]

Parameter	Jul 22–26, 2019 (96 nets)	Aug 5–9, 2019 (96 nets)	Sep 9–13, 2019 (95 nets)	Jun 15–19, 2020 (96 nets)	Jul 20–23, 2020 (96 nets)	Aug 3–6, 2020 (96 nets)	Sep 21–25, 2020 (96 nets)	Jun 21–25, 2021 (89 nets)
Lost River suckers								
Percentage	8	22	19	2	0	0	1	0
Mean (SD)	4.75 (4.46)	2.86 (5.67)	2.50 (1.50)	1.00 (0.00)	0.00 (NA)	0.00 (NA)	1.00 (NA)	0.00 (NA)
Total CPUE	0.40	0.62	0.47	0.02	0.00	0.00	0.01	0.00
Shortnose suckers, Klamath largescale suckers, and SNS/KLS								
Percentage	8	17	9	10	0	3	0	2
Mean (SD)	1.75 (0.89)	2.19 (3.04)	1.44 (0.73)	1.20 (0.42)	0.00 (NA)	1.00 (0.00)	0.00 (NA)	1.00 (0.00)
Total CPUE	0.15	0.36	0.14	0.12	0.00	0.03	0.00	0.02
Indeterminant								
Percentage	8	24	26	0	0	0	0	0
Mean (SD)	5.12 (7.43)	4.91 (8.75)	1.92 (1.29)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)
Total CPUE	0.43	1.18	0.50	0.00	0.00	0.00	0.00	0.00
Total suckers								
Percentage	16	36	38	10	0	3	1	2
Mean (SD)	6.20 (10.42)	7.97 (22.64)	3.17 (2.97)	1.40 (0.70)	0.00 (NA)	1.00 (0.00)	1.00 (NA)	1.00 (0.00)
Total CPUE	0.97	2.91	1.19	0.15	0.00	0.03	0.01	0.02

Table 6. Catch statistics for the 2020 cohort of suckers from Upper Klamath Lake, Oregon.

[Percentage of nets to successfully capture one or more sucker by each taxa, mean and standard deviation catch per net (catch per unit effort, or CPUE) in nets that successfully captured one or more sucker, and total suckers captured in all nets set (Total CPUE) are given for each seasonal sampling period. Total CPUE was calculated as the number of fish captured per net set. Taxa were identified based on genetic identification. Indeterminant refers to individuals that could not be assigned to a species since the mean posterior probability was less than 0.9. **Abbreviations:** Jul, July; Aug, August; Sep, September; SD, standard deviation; NA, used instead of standard deviations that are not applicable because of low sample sizes]

Parameter	Jul 20–23, 2020 (96 nets)	Aug 3–6, 2020 (96 nets)	Sep 21–25, 2020 (96 nets)	Jun 21-25, 2021 (89 nets)	Jul 19–23, 2021 (96 nets)	Aug 9–13, 2021 (96 nets)	Sep 13–17, 2021 (88 nets)	Jun 13–17, 2022 (96 nets)	Jul 18–22,2022 (96 nets)	Aug 8–12, 2022 (96 nets)	Sep 12–16, 2022 (96 nets)
Lost River suckers											
Percentage	3	10	3	1	0	0	0	0	0	0	0
Mean (SD)	1.00 (0.00)	1.50 (0.71)	1.00 (0.00)	1.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)
Total CPUE	0.03	0.16	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shortnose suckers											
Percentage	0	3	6	1	0	0	0	0	0	1	0
Mean (SD)	0.00 (NA)	1.00 (0.00)	1.33 (0.52)	1.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	1.00 (NA)	0.00 (NA)
Total CPUE	0.00	0.03	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Klamath largescale suckers											
Percentage	0	0	1	3	0	0	0	0	0	0	1
Mean (SD)	0.00 (NA)	0.00 (NA)	1.00 (NA)	1.00 (0.00)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	1.00 (NA)
Total CPUE	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Indeterminant											
Percentage	0	1	0	0	0	0	0	0	0	0	0
Mean (SD)	0.00 (NA)	1.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)
Total CPUE	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total suckers											
Percentage	3	15	9	6	0	0	0	0	0	1	1
Mean (SD)	1.00 (0.00)	1.36 (0.63)	1.33 (0.50)	1.00 (0.00)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	0.00 (NA)	1.00 (NA)	1.00 (NA)
Total CPUE	0.03	0.20	0.12	0.06	0.00	0.00	0.00	0.00	0.00	0.01	0.01

Table 7. Catch statistics for the 2021 cohort of suckers from Upper Klamath Lake, Oregon.

[Percentage of nets to successfully capture one or more sucker by each taxa, mean and standard deviation catch per net (catch per unit effort, or CPUE) in nets that successfully captured one or more sucker, and total suckers captured in all nets set (Total CPUE) are given for each seasonal sampling period. Total CPUE was calculated as the number of fish captured per net set. Taxa were identified based on genetic identification. Indeterminant refers to individuals that could not be assigned to a species since the mean posterior probability was less than 0.9. **Abbreviations:** Jul, July; Aug, August; Sep, September; SD, standard deviation; NA, used instead of standard deviations that are not applicable because of low sample sizes]

Parameter	Jul 19–23, 2021 (96 nets)	Aug 9–13, 2021 (96 nets)	Sep 13–17, 2021 (88 nets)	Jun 13–17, 2022 (96 nets)	Jul 18–22, 2022 (96 nets)
Lost River suckers					
Percentage	7	7	1	0	0
Mean (SD)	2.86 (3.48)	1.71 (1.25)	1.00 (NA)	0.00 (NA)	0.00 (NA)
Total CPUE	0.21	0.12	0.01	0.00	0.00
Shortnose suckers					
Percentage	4	7	8	0	3
Mean (SD)	3.25 (2.06)	1.71 (0.76)	2.29 (2.56)	0.00 (NA)	1.00 (0.00)
Total CPUE	0.14	0.12	0.18	0.00	0.03
Klamath largescale suckers					
Percentage	2	0	0	1	0
Mean (SD)	1.00 (0.00)	0.00 (NA)	0.00 (NA)	1.00 (NA)	0.00 (NA)
Total CPUE	0.02	0.00	0.00	0.01	0.00
Total suckers					
Percentage	9	10	8	1	3
Mean (SD)	4.00 (5.52)	2.50 (1.78)	2.43 (2.51)	1.00 (NA)	1.00 (0.00)
Total CPUE	0.38	0.26	0.19	0.01	0.03

Table 8. Catch statistics for the 2022 cohort of suckers from Upper Klamath Lake, Oregon.

[Percentage of nets to successfully capture one or more sucker by each taxa, mean and standard deviation catch per net (catch per unit effort, or CPUE) in nets that successfully captured one or more sucker, and total suckers captured in all nets set (Total CPUE) are given for each seasonal sampling period. Total CPUE was calculated as the number of fish captured per net set. Taxa were identified based on genetic identification. Indeterminant refers to individuals that could not be assigned to a species since the mean posterior probability was less than 0.9. **Abbreviations:** Jul, July; Aug, August; Sep, September; SD, standard deviation; NA, used instead of standard deviations that are not applicable because of low sample sizes]

Parameter	Jul 18–22, 2022 (96 nets)	Aug 8–12, 2022 (96 nets)	Sep 12–16, 2022 (96 nets)
Lost River suckers			
Percentage	0	3	1
Mean (SD)	0.00 (NA)	2.67 (2.08)	1.00 (NA)
Total CPUE	0.00	0.08	0.01
Shortnose suckers			
Percentage	0	0	3
Mean (SD)	0.00 (NA)	0.00 (NA)	1.00 (0.00)
Total CPUE	0.00	0.00	0.03
Klamath largescale suckers			
Percentage	0	1	0
Mean (SD)	0.00 (NA)	1.00 (NA)	0.00 (NA)
Total CPUE	0.00	0.01	0.00
Total suckers			
Percentage	0	3	4
Mean (SD)	0.00 (NA)	3.00 (2.65)	1.00 (0.00)
Total CPUE	0.00	0.09	0.04

Table 9. August to September survival indices for age-0 suckers in each taxa captured in Upper Klamath Lake, Oregon, 2015–21.

[Total suckers include suckers from which we did not collect genetic samples. Taxa were identified based on genetic identification. Prior to 2020 shortnose (*Chasmistes brevirostris*) and Klamath largescale suckers (*Catastomus snyderi*) could not be separated; therefore, to compare among years these taxa are combined. **Abbreviations and symbols:** >, greater than; SNS/KLS, suckers with a mixture of genetic markers from shortnose suckers and Klamath largescale suckers]

Taxa	2015	2016	2017	2018	2019	2020	2021	2022
Lost River suckers	0.16	0.16	0.15	0.00	0.75	0.20	0.08	0.12
Shortnose suckers, Klamath largescale suckers, and SNS/KLS	0.49	0.35	0.00	>1.00	0.37	>1.00	>1.00	>1.00
Total suckers	0.35	0.19	0.03	0.65	0.41	0.63	0.68	0.44

Table 10. September age-0 to June age-1 survival indices of suckers in each taxa captured in Upper Klamath Lake, Oregon, for cohorts from 2015 to 2020.

[Total suckers include suckers from which we did not collect genetic samples. Taxa were identified based on genetic identification. Prior to 2020 shortnose (*Chasmistes brevirostris*) and Klamath largescale suckers (*Catastomus snyderi*) could not be separated; therefore, to compare among years these taxa are combined. **Abbreviations and symbols:** >, greater than; SNS/KLS, suckers with a mixture of genetic markers from shortnose suckers and Klamath largescale suckers]

Taxa	2015	2016	2017	2018	2019	2020	2021
Lost River suckers	0.75	0.06	0.00	0.00	0.04	0.33	0.00
Shortnose suckers, Klamath largescale suckers, and SNS/KLS	0.33	0.20	>1.00	0.14	0.92	0.44	0.06
Total suckers	0.52	0.23	>1.00	0.13	0.12	0.41	0.05

Clear Lake Reservoir Year-Class Strength and Apparent Survival

The majority of suckers captured in Clear Lake Reservoir in 2021 and 2022 were classified as Klamath largescale suckers and shortnose suckers from the Lost River Basin. These fish were 3–5 years old and ranged from 142 to 335 mm SL (figs. 3, 5). In 2021, there were two age-2 suckers and three age-6, and one recaptured sucker that was assumed to be age-7. In 2022, there was one age-2 sucker captured. One age-2 sucker, classified as a Klamath largescale sucker and shortnose sucker from the Lost River Basin was tagged in June 2021 (153 mm SL) and recaptured in September 2021 (175 mm SL). None of the 106 unique suckers captured in Clear Lake Reservoir during the 2021 or the 79 suckers captured in 2022 juvenile monitoring sampling were age-0 or age-1 (fig. 3; table 11). Only 3 of the 106 suckers captured in 2021 were classified as Lost River suckers; 1 was classified as a shortnose sucker and 3 did not have genetic samples taken (figs. 3, 5). Two of the suckers that did not have genetic samples taken were morphologically identified as Klamath largescale suckers and were known recaptures from previous years (285 and 399 mm SL). Only 2 of the 79 suckers captured in 2022 were classified as shortnose suckers; none was classified as Lost River sucker; and 2 did not have genetic samples taken (figs. 3, 5). All suckers classified as Lost River or shortnose suckers were from the 2016 and 2017 cohorts.

The age distribution of suckers in Clear Lake indicates that juvenile suckers are surviving beyond the juvenile life stage. In 2021, the largest sucker captured in Clear Lake was 399 mm SL. It was not aged because it was a recaptured sucker that had originally been captured and tagged in a different study. The largest sucker captured in 2022 was 402 mm SL and was not aged (fig. 3). The oldest sucker captured in 2021 appeared to be an age-7 sucker. It was initially captured in 2020 and was identified as age-6 at that time. The oldest aged sucker captured in 2022 was age-5 and 306 mm SL. In 2021, we captured five age-6 suckers from the 2015 cohort. The most abundant cohorts captured in 2021 were from 2016 (age-5), 2017 (age-4) and 2018 (age-3), whereas the most abundant cohorts captured in 2022 were from 2017 (age-5), 2018 (age-4), and 2019 (age-3). In 2021, two age-2 suckers from the 2019 cohort were captured (one captured twice). In 2022, only one age-2 sucker from the 2020 cohort was represented in our catches. No age-0 or age-1 suckers were captured in Clear Lake in 2021 or 2022.

Table 11. Catch statistics for August age-0 suckers from Clear Lake Reservoir, California, 2015–22.

[Total catch per unit effort was calculated as number of suckers captured divided by the number of nets set. Taxa were identified based on genetic identification. Indeterminant refers to individuals that could not be assigned to a species since the mean posterior probability was less than 0.9. Prior to 2020 shortnose (*Chasmistes brevirostris*) and Klamath largescale suckers (*Catastomus snyderi*) could not be separated; therefore, to compare among years these taxa are combined. **Abbreviations:** *n*, number of suckers; Aug, August; SNS/KLS, suckers with a mixture of genetic markers from shortnose suckers and Klamath largescale suckers; CPUE, catch per unit effort]

Parameter	Aug 2015 (70 nets)	Aug 2016 (70 nets)	Aug 2017 (70 nets)	Aug 2018 (69 nets)	Aug 2019 (70 nets)	Aug 2020 (70 nets)	Aug 2021 (63 nets)	Aug 2022 (63 nets)
Lost River suckers								
n	0	2	4	0	0	0	0	0
Total CPUE	0.00	0.03	0.06	0.00	0.00	0.00	0.00	0.00
Shortnose suckers, Klamath largescale suckers, and SNS/KLS								
n	0	15	2	0	0	0	0	0
Total CPUE	0.00	0.21	0.03	0.00	0.00	0.00	0.00	0.00
Indeterminant								
n	0	1	0	0	0	0	0	0
Total CPUE	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Total suckers								
n	0	18	6	0	0	0	0	0
Total CPUE	0.00	0.26	0.09	0.00	0.00	0.00	0.00	0.00

There were several year-classes of suckers that were not captured as age-0 suckers; however, these year-classes were captured for the first time starting at as early as age-1 (table 12). The peak of the 2015 cohort catches was during the September 2017 sampling effort, or when the cohort was age-2 (table 12). Very few fish from the 2015 cohort were captured in 2021 and by 2022 these fish may have been too large to recruit into our trap nets. The 2016 cohort catches peaked during September 2016 when the cohort was age-0 and were no longer detected in our sampling gear in 2022. The 2017 cohort catch peaked during the June 2019 sampling effort when the cohort was age-2. The 2018, 2019, and 2020 cohort catches all peaked during June 2022 sampling effort when the cohorts were age-4, age-3, and age-2, respectively. However, catch rates for the 2018 and 2019 cohorts were consistently low throughout the years other than 2022. Only the 2016 and 2017 cohorts were detected for the first time at age-0. The 2015, 2018, and 2019 cohorts were first detected at age-1. The 2020 cohort was first detected in 2022 with one age-2 fish detected. The 2021 and 2022 cohorts have not yet been detected and if detected in 2023 would be detected at age-2 and age-1 respectively.

Table 12. Catch statistics for the 2015–22 cohorts of shortnose/Klamath largescale suckers (*Chasmistes brevirostris/Catastomus snyderi*) from Clear Lake Reservoir, California.

[Percentage of nets to successfully capture one or more shortnose/Klamath largescale sucker (*Chasmistes brevirostris/Catastomus snyderi*) by each cohort, mean and standard deviation catch per net (catch per unit effort, or CPUE) in nets that successfully captured one or more sucker, and total suckers captured in all nets set (Total CPUE) are given for each seasonal sampling period. CPUE was calculated as the number of fish per net set. Total CPUE was calculated as number of suckers captured divided by the number of nets set. **Abbreviations and symbols:** –, no data; Jun, June; Aug, August; Sep, September; Jul, July; NA, not applicable (put in place of standard deviations that are not applicable because of low sample sizes); SD, standard deviation]

Sampling period	Cohort							
	2015	2016	2017	2018	2019	2020	2021	2022
	Percent							
Jun 2015 (70 nets)	0	–	–	–	–	–	–	–
Aug 2015 (70 nets)	0	–	–	–	–	–	–	–
Sep 2015 (70 nets)	0	–	–	–	–	–	–	–
Jun 2016 (70 nets)	0	0	–	–	–	–	–	–
Aug 2016 (70 nets)	0	14	–	–	–	–	–	–
Sep 2016 (70 nets)	4	54	–	–	–	–	–	–
Jun 2017 (69 nets)	1	4	0	–	–	–	–	–
Aug 2017 (70 nets)	6	34	3	–	–	–	–	–
Sep 2017 (70 nets)	10	19	3	–	–	–	–	–
Jun 2018 (70 nets)	7	19	13	0	–	–	–	–
Jul 2018 (70 nets)	4	31	33	0	–	–	–	–
Aug 2018 (69 nets)	6	20	27	0	–	–	–	–
Sep 2018 (70 nets)	1	13	16	0	–	–	–	–
Jun 2019 (70 nets)	1	17	23	10	0	–	–	–
Jul 2019 (70 nets)	1	27	27	7	0	–	–	–
Aug 2019 (70 nets)	1	27	26	7	0	–	–	–
Sep 2019 (70 nets)	3	9	3	1	0	–	–	–
Jun 2020 (70 nets)	7	17	15	6	0	0	–	–
Jul 2020 (70 nets)	4	13	10	1	1	0	–	–
Aug 2020 (70 nets)	3	13	16	4	3	0	–	–
Sep 2020 (70 nets)	1	4	6	0	0	0	–	–
Jun 2021 (70 nets)	1	16	21	3	1	0	0	–
Jul 2021 (63 nets)	2	10	17	3	0	0	0	–
Aug 2021 (63 nets)	0	3	10	8	0	0	0	–
Sep 2021 (63 nets)	0	5	8	3	2	0	0	–
Jun 2022 (66 nets)	0	0	15	20	12	2	0	0
Jul 2022 (63 nets)	0	0	3	14	5	0	0	0
Aug 2022 (63 nets)	0	0	2	6	3	0	0	0

Table 12. Catch statistics for the 2015–22 cohorts of shortnose/Klamath largescale suckers (*Chasmistes brevirostris/Catastomus snyderi*) from Clear Lake Reservoir, California.—Continued

[Percentage of nets to successfully capture one or more shortnose/Klamath largescale sucker (*Chasmistes brevirostris/Catastomus snyderi*) by each cohort, mean and standard deviation catch per net (catch per unit effort, or CPUE) in nets that successfully captured one or more sucker, and total suckers captured in all nets set (Total CPUE) are given for each seasonal sampling period. CPUE was calculated as the number of fish per net set. Total CPUE was calculated as number of suckers captured divided by the number of nets set. **Abbreviations and symbols:** –, no data; Jun, June; Aug, August; Sep, September; Jul, July; NA, not applicable (put in place of standard deviations that are not applicable because of low sample sizes); SD, standard deviation]

Sampling period	Cohort							
	2015	2016	2017	2018	2019	2020	2021	2022
	Percent—Continued							
Sep 2022 (63 nets)	0	0	2	3	6	0	0	0
	Mean SD							
Jun 2015 (70 nets)	0.00 NA	–	–	–	–	–	–	–
Aug 2015 (70 nets)	0.00 NA	–	–	–	–	–	–	–
Sep 2015 (70 nets)	0.00 NA	–	–	–	–	–	–	–
Jun 2016 (70 nets)	0.00 NA	0.00 NA	–	–	–	–	–	–
Aug 2016 (70 nets)	0.00 NA	1.50 0.53	–	–	–	–	–	–
Sep 2016 (70 nets)	1.00 0.00	3.05 4.92	–	–	–	–	–	–
Jun 2017 (69 nets)	1.00 NA	1.00 0.00	0.00 NA	–	–	–	–	–
Aug 2017 (70 nets)	1.25 0.50	1.75 1.15	1.00 0.00	–	–	–	–	–
Sep 2017 (70 nets)	3.14 3.58	1.69 1.11	1.00 0.00	–	–	–	–	–
Jun 2018 (70 nets)	1.00 0.00	1.31 0.75	1.33 0.50	0.00 NA	–	–	–	–
Jul 2018 (70 nets)	1.33 0.58	1.23 0.43	1.22 0.52	0.00 NA	–	–	–	–
Aug 2018 (69 nets)	1.00 0.00	1.50 0.76	1.05 0.23	0.00 NA	–	–	–	–
Sep 2018 (70 nets)	1.00 NA	1.22 0.44	1.36 0.67	0.00 NA	–	–	–	–
Jun 2019 (70 nets)	1.00 NA	1.33 0.65	2.12 1.26	1.71 1.11	0.00 NA	–	–	–
Jul 2019 (70 nets)	1.00 NA	1.16 0.50	1.42 0.84	1.40 0.55	0.00 NA	–	–	–
Aug 2019 (70 nets)	1.00 NA	1.42 0.69	1.11 0.32	1.20 0.45	0.00 NA	–	–	–
Sep 2019 (70 nets)	1.00 0.00	1.33 0.82	1.00 0.00	1.00 NA	0.00 NA	–	–	–
Jun 2020 (70 nets)	1.20 0.45	1.25 0.62	1.55 0.93	1.00 0.00	0.00 NA	0.00 NA	–	–
Jul 2020 (70 nets)	1.00 0.00	1.67 0.87	1.14 0.38	1.00 NA	1.00 NA	0.00 NA	–	–
Aug 2020 (70 nets)	1.00 0.00	1.67 1.00	1.36 0.92	1.00 0.00	1.00 0.00	0.00 NA	–	–
Sep 2020 (70 nets)	1.00 NA	1.00 0.00	1.00 0.00	0.00 NA	0.00 NA	0.00 NA	–	–
Jun 2021 (70 nets)	1.00 NA	1.45 0.69	1.60 0.91	1.00 0.00	1.00 NA	0.00 NA	0.00 NA	–
Jul 2021 (63 nets)	1.00 NA	1.17 0.41	1.55 0.82	1.00 0.00	0.00 NA	0.00 NA	0.00 NA	–
Aug 2021 (63 nets)	0.00 NA	1.00 0.00	1.33 0.52	1.00 0.00	0.00 NA	0.00 NA	0.00 NA	–
Sep 2021 (63 nets)	0.00 NA	1.00 0.00	1.00 0.00	1.00 0.00	1.00 NA	0.00 NA	0.00 NA	–

Table 12. Catch statistics for the 2015–22 cohorts of shortnose/Klamath largescale suckers (*Chasmistes brevirostris/Catastomus snyderi*) from Clear Lake Reservoir, California.—Continued

[Percentage of nets to successfully capture one or more shortnose/Klamath largescale sucker (*Chasmistes brevirostris/Catastomus snyderi*) by each cohort, mean and standard deviation catch per net (catch per unit effort, or CPUE) in nets that successfully captured one or more sucker, and total suckers captured in all nets set (Total CPUE) are given for each seasonal sampling period. CPUE was calculated as the number of fish per net set. Total CPUE was calculated as number of suckers captured divided by the number of nets set. **Abbreviations and symbols:** –, no data; Jun, June; Aug, August; Sep, September; Jul, July; NA, not applicable (put in place of standard deviations that are not applicable because of low sample sizes); SD, standard deviation]

Sampling period	Cohort							
	2015	2016	2017	2018	2019	2020	2021	2022
Mean SD—Continued								
Jun 2022 (66 nets)	0.00 NA	0.00 NA	1.50 0.71	1.23 0.44	1.12 0.35	1.00 NA	0.00 NA	0.00 NA
Jul 2022 (63 nets)	0.00 NA	0.00 NA	1.00 0.00	1.22 0.44	1.00 0.00	0.00 NA	0.00 NA	0.00 NA
Aug 2022 (63 nets)	0.00 NA	0.00 NA	1.00 NA	1.25 0.50	1.00 0.00	0.00 NA	0.00 NA	0.00 NA
Sep 2022 (63 nets)	0.00 NA	0.00 NA	1.00 NA	1.00 0.00	1.25 0.50	0.00 NA	0.00 NA	0.00 NA
Total CPUE								
Jun 2015 (70 nets)	0.00	–	–	–	–	–	–	–
Aug 2015 (70 nets)	0.00	–	–	–	–	–	–	–
Sep 2015 (70 nets)	0.00	–	–	–	–	–	–	–
Jun 2016 (70 nets)	0.00	0.00	–	–	–	–	–	–
Aug 2016 (70 nets)	0.00	0.21	–	–	–	–	–	–
Sep 2016 (70 nets)	0.04	1.66	–	–	–	–	–	–
Jun 2017 (69 nets)	0.01	0.04	0.00	–	–	–	–	–
Aug 2017 (70 nets)	0.07	0.60	0.03	–	–	–	–	–
Sep 2017 (70 nets)	0.31	0.31	0.03	–	–	–	–	–
Jun 2018 (70 nets)	0.07	0.24	0.17	0.00	–	–	–	–
Jul 2018 (70 nets)	0.06	0.39	0.40	0.00	–	–	–	–
Aug 2018 (69 nets)	0.06	0.30	0.29	0.00	–	–	–	–
Sep 2018 (70 nets)	0.01	0.16	0.21	0.00	–	–	–	–
Jun 2019 (70 nets)	0.01	0.23	0.49	0.17	0.00	–	–	–
Jul 2019 (70 nets)	0.01	0.31	0.39	0.10	0.00	–	–	–
Aug 2019 (70 nets)	0.01	0.39	0.29	0.09	0.00	–	–	–
Sep 2019 (70 nets)	0.03	0.11	0.03	0.01	0.00	–	–	–
Jun 2020 (70 nets)	0.08	0.21	0.24	0.06	0.00	–	–	–
Jul 2020 (70 nets)	0.04	0.21	0.11	0.01	0.01	0.00	–	–
Aug 2020 (70 nets)	0.03	0.21	0.21	0.04	0.03	0.00	–	–
Sep 2020 (70 nets)	0.01	0.04	0.06	0.00	0.00	0.00	–	–
Jun 2021 (70 nets)	0.01	0.23	0.34	0.03	0.01	0.00	0.00	–

Table 12. Catch statistics for the 2015–22 cohorts of shortnose/Klamath largescale suckers (*Chasmistes brevirostris/Catastomus snyderi*) from Clear Lake Reservoir, California.—Continued

[Percentage of nets to successfully capture one or more shortnose/Klamath largescale sucker (*Chasmistes brevirostris/Catastomus snyderi*) by each cohort, mean and standard deviation catch per net (catch per unit effort, or CPUE) in nets that successfully captured one or more sucker, and total suckers captured in all nets set (Total CPUE) are given for each seasonal sampling period. CPUE was calculated as the number of fish per net set. Total CPUE was calculated as number of suckers captured divided by the number of nets set. **Abbreviations and symbols:** –, no data; Jun, June; Aug, August; Sep, September; Jul, July; NA, not applicable (put in place of standard deviations that are not applicable because of low sample sizes); SD, standard deviation]

Sampling period	Cohort							
	2015	2016	2017	2018	2019	2020	2021	2022
Total CPUE—Continued								
Jul 2021 (63 nets)	0.02	0.11	0.27	0.03	0.00	0.00	0.00	–
Aug 2021 (63 nets)	0.00	0.03	0.13	0.08	0.00	0.00	0.00	–
Sep 2021 (63 nets)	0.00	0.05	0.08	0.03	0.02	0.00	0.00	–
Jun 2022 (66 nets)	0.00	0.00	0.23	0.24	0.14	0.02	0.00	0.00
Jul 2022 (63 nets)	0.00	0.00	0.03	0.17	0.05	0.00	0.00	0.00
Aug 2022 (63 nets)	0.00	0.00	0.02	0.08	0.03	0.00	0.00	0.00
Sep 2022 (63 nets)	0.00	0.00	0.02	0.03	0.08	0.00	0.00	0.00

Afflictions

Suckers in Upper Klamath Lake often had more macro parasites, deformities, and skin afflictions than suckers in Clear Lake. The primary affliction observed during the 2021 and 2022 monitoring seasons in both lakes was *Lernaea* sp. Other afflictions observed were lamprey wounds on eight Clear Lake suckers in 2021 and four suckers in 2022, and petechial hemorrhages on one Upper Klamath Lake sucker in 2021. In 2021 and 2022, we did not observe any fish with black spot (metacercariae of *Bolbophorus* spp.) from either lake (table 13).

Missing or deformed opercula were only observed on one Upper Klamath Lake sucker in 2021 (table 14). It was an age-0 shortnose sucker that had both opercula missing or deformed. Opercular deformities tend to be more common in Lost River suckers than shortnose suckers. Opercular deformities occurred in Lost River suckers from 0 to 62 percent of the time within each year, whereas this deformity occurred less than 10 percent of the time in shortnose suckers within each year.

All *Lernaea* sp. observations in age-0 suckers occurred from Upper Klamath Lake (table 15). In both 2021 and 2022, age-1 and older suckers in Upper Klamath Lake had a lower proportion of fish with *Lernaea* sp. attached than those in Clear Lake (table 16). In 2021, there were more *Lernaea* sp. reported per individual sucker in both lakes with the most attached to an individual juvenile sucker reported as 21 from an age-0 Lost River sucker in Upper Klamath Lake. Although this parasite was a relatively common occurrence in both Upper Klamath Lake and Clear Lake, there were no obvious signs that *Lernaea* sp. causes direct mortality of juvenile suckers.

Petechial hemorrhaging of the skin on age-0 fish was only observed in one Upper Klamath Lake sucker in 2021 (table 17). The proportion of age-0 suckers in Upper Klamath Lake with petechial hemorrhaging in 2021 was low relative to previous years, and nonexistent in 2022 (table 17). In 2021 and 2022, petechial hemorrhaging was not observed on age-1 and older suckers in both lakes (table 18).

Gear Selectivity

The majority of suckers captured in all three gear types (large trap nets, standard trap nets and hoop nets) used in Upper Klamath Lake were age-0 suckers during both years (fig. 6; table 19). In 2016, SL did not vary among gear types (Kruskal-Wallis, $p=0.456$). In 2017, SL varied by gear type (Kruskal-Wallis, $p<0.001$) likely because the standard trap nets captured few but larger individuals, 4 of which were greater than 100 mm SL. Age-0 and age-1 juvenile suckers were captured in all three gear types.

Catch rates in Upper Klamath Lake varied greatly among gear types (Kruskal-Wallis, $p<0.001$; table 19). Dunn multiple comparison tests indicated that large trap nets had the highest catch rates ($p<0.001$), whereas hoop nets and standard trap nets had similar catch rates ($p=0.568$). Given that standard trap nets captured few fish in 2017, the 2016 catch rates were used to calculate the correction factor for comparison of hoop nets and standard trap nets to large trap nets. The resulting correction factors were 4.8 for hoop nets and 5.4 for standard trap nets.

Each gear type (standard trap net, trammel net, and seine) in Clear Lake captured different size classes of sucker (Kruskal-Wallis, $p<0.001$; fig. 7; table 20). Dunn multiple comparison tests indicated that all gear types captured different sizes (all $p<0.001$). Trammel nets primarily captured adults, seines captured small juveniles, and standard trap nets captured juveniles greater than 54 mm and few adults. The difference in sizes between seines and standard trap nets indicates that standard trap nets are biased for larger juveniles (>54 mm SL).

Table 13. Proportions of age-0 suckers with black spot (metacercariae of *Bolbophorus* sp.), Upper Klamath Lake, Oregon, and Clear Lake Reservoir, California, 2015–22.

[Sample size of age-0 suckers captured given in parentheses. Total suckers captured includes suckers from which we did not collect genetic samples. Taxa were identified based on genetic identification. Indeterminant refers to individuals that could not be assigned to a species since the mean posterior probability was less than 0.9. Prior to 2020, shortnose (*Chasmistes brevirostris)* and Klamath largescale (*Catastomus snyderi*) suckers could not be separated; therefore, for comparison purposes we combined shortnose suckers, and suckers classified as the combination of Klamath largescale suckers and shortnose suckers from the Lost River Basin for suckers captured in 2020–22. **Abbreviations:** CL, Clear Lake Reservoir; UKL, Upper Klamath Lake; SNS/KLS, suckers with a mixture of genetic markers from shortnose suckers and Klamath largescale suckers; NA, proportions that are not applicable because no age-0 fish were captured]

Taxa	UKL 2015	CL 2015	UKL 2016	CL 2016	UKL 2017	CL 2017	UKL 2018	CL 2018	UKL 2019	CL 2019	UKL 2020	CL 2020	UKL 2021	CL 2021	UKL 2022	CL 2022
Lost River suckers	0.07 (41)	NA	0.01 (136)	0.00 (10)	0.00 (8)	0.00 (4)	0.00 (12)	NA	0.00 (143)	NA	0.00 (21)	NA	0.00 (33)	NA	0.00 (9)	NA
Shortnose and Klamath largescale suckers	0.07 (61)	NA	0.07 (44)	0.00 (131)	0.00 (12)	0.00 (4)	0.00 (10)	NA	0.00 (62)	NA	0.00 (12)	NA	0.00 (43)	NA	0.00 (4)	NA
Indeterminant	0.03 (37)	NA	0.01 (67)	0.01 (2)	0.00 (12)	0.00 (1)	0.00 (13)	NA	0.00 (202)	NA	0.00 (1)	NA	0.00 (0)	NA	0.00 (0)	NA
Total suckers	0.06 (141)	NA	0.02 (257)	0.00 (179)	0.00 (32)	0.00 (9)	0.00 (37)	NA	0.00 (486)	NA	0.00 (34)	NA	0.00 (78)	NA	0.00 (13)	NA

Table 14. Proportions of age-0 suckers with missing or deformed opercula, Upper Klamath Lake, Oregon, and Clear Lake Reservoir, California, 2015–22.

[Sample size of age-0 suckers captured given in parentheses. Total suckers captured includes suckers from which we did not collect genetic samples. Taxa were identified based on genetic identification. Indeterminant refers to individuals that could not be assigned to a species since the mean posterior probability was less than 0.9. Prior to 2020, shortnose (*Chasmistes brevirostris)* and Klamath largescale (*Catastomus snyderi*) suckers could not be separated; therefore for comparison purposes we combined shortnose suckers, and suckers classified as the combination of Klamath largescale suckers and shortnose suckers from the Lost River Basin for suckers captured in 2020–22. **Abbreviations:** CL, Clear Lake Reservoir; UKL, Upper Klamath Lake; SNS/KLS, suckers with a mixture of genetic markers from shortnose suckers and Klamath largescale suckers; NA, proportions that are not applicable because no age-0 fish were captured]

Taxa	UKL 2015	CL 2015	UKL 2016	CL 2016	UKL 2017	CL 2017	UKL 2018	CL 2018	UKL 2019	CL 2019	UKL 2020	CL 2020	UKL 2021	CL 2021	UKL 2022	CL 2022
Lost River suckers	0.05 (41)	NA	0.11 (136)	0.00 (10)	0.62 (8)	0.00 (4)	0.00 (12)	NA	0.10 (143)	NA	0.00 (21)	NA	0.00 (33)	NA	0.00 (9)	NA
Shortnose and Klamath largescale suckers	0.08 (61)	NA	0.02 (44)	0.00 (131)	0.08 (12)	0.00 (4)	0.00 (10)	NA	0.00 (62)	NA	0.00 (12)	NA	0.02 (43)	NA	0.00 (4)	NA
Indeterminant	0.08 (37)	NA	0.12 (67)	0.00 (2)	0.08 (12)	0.00 (1)	0.00 (13)	NA	0.03 (202)	NA	0.00 (1)	NA	0.00 (0)	NA	0.00 (0)	NA
Total suckers	0.07 (141)	NA	0.10 (257)	0.00 (179)	0.22 (32)	0.00 (9)	0.00 (37)	NA	0.05 (486)	NA	0.00 (34)	NA	0.01 (78)	NA	0.00 (13)	NA

Table 15. Proportions of age-0 suckers with attached *Lernaea sp.*, Upper Klamath Lake, Oregon, and Clear Lake Reservoir, California, 2015–22.

[Sample size of age-0 suckers captured given in parentheses. Total suckers captured includes suckers from which we did not collect genetic samples. Taxa were identified based on genetic identification. Indeterminant refers to individuals that could not be assigned to a species since the mean posterior probability was less than 0.9. Prior to 2020, shortnose (*Chasmistes brevirostris)* and Klamath largescale (*Catastomus snyderi*) suckers could not be separated; therefore for comparison purposes we combined shortnose suckers, and suckers classified as the combination of Klamath largescale and shortnose suckers from the Lost River Basin for suckers captured in 2020-2022. **Abbreviations:** CL, Clear Lake Reservoir; UKL, Upper Klamath Lake; SNS/KLS, suckers with a mixture of genetic markers from shortnose suckers and Klamath largescale suckers; NA, proportions that are not applicable because no age-0 fish were captured]

Taxa	UKL 2015	CL 2015	UKL 2016	CL 2016	UKL 2017	CL 2017	UKL 2018	CL 2018	UKL 2019	CL 2019	UKL 2020	CL 2020	UKL 2021	CL 2021	UKL 2022	CL 2022
Lost River suckers	0.80 (41)	NA	0.46 (136)	0.00 (10)	0.12 (8)	0.25 (4)	0.33 (12)	NA	0.22 (143)	NA	0.05 (21)	NA	0.12 (33)	NA	0.00 (9)	NA
Shortnose and Klamath largescale suckers	0.11 (61)	NA	0.18 (44)	0.04 (131)	0.33 (12)	0.25 (4)	0.00 (10)	NA	0.11 (62)	NA	0.25 (12)	NA	0.05 (43)	NA	0.00 (4)	NA
Indeterminant	0.46 (37)	NA	0.34 (67)	0.00 (2)	0.33 (12)	0.00 (1)	0.08 (13)	NA	0.16 (202)	NA	0.00 (1)	NA	0.00 (0)	NA	0.00 (0)	NA
Total suckers	0.40 (141)	NA	0.38 (257)	0.03 (179)	0.28 (32)	0.22 (9)	0.14 (37)	NA	0.16 (486)	NA	0.12 (34)	NA	0.08 (78)	NA	0.00 (13)	NA

Table 16. Proportions of age-1 and older suckers with attached *Lernaea sp.*, Upper Klamath Lake, Oregon, and Clear Lake Reservoir, California, 2015–22.

[Number of age-1 and older suckers given in parentheses]

Lake	2015	2016	2017	2018	2019	2020	2021	2022
Upper Klamath Lake	0.21 (14)	0.44 (16)	0.12 (16)	0.50 (4)	0.00 (6)	0.19 (21)	0.14 (7)	0.17 (6)
Clear Lake Reservoir	0.35 (17)	0.08 (53)	0.05 (137)	0.03 (214)	0.10 (200)	0.19 (129)	0.36 (105)	0.22 (79)

Table 17. Proportions of age-0 suckers in each of the three taxa that had petechial hemorrhages on the skin in Upper Klamath Lake, Oregon, and Clear Lake Reservoir, California, 2015–22.

[Sample size of age-0 suckers given in parentheses. Total suckers captured includes suckers from which we did not collect genetic samples. Taxa were identified based on genetic identification. Indeterminant refers to individuals that could not be assigned to a species since the mean posterior probability was less than 0.9. Prior to 2020, shortnose (*Chasmistes brevirostris)* and Klamath largescale (*Catastomus snyderi*) suckers could not be separated; therefore for comparison purposes we combined shortnose suckers, and suckers classified as the combination of Klamath largescale and shortnose suckers from the Lost River Basin for suckers captured in 2020–22, **Abbreviations:** CL, Clear Lake Reservoir; UKL, Upper Klamath Lake; SNS/KLS, suckers with a mixture of genetic markers from shortnose suckers and Klamath largescale suckers; NA, proportions that are not applicable because no age-0 fish were captured]

Taxa	UKL 2015	CL 2015	UKL 2016	CL 2016	UKL 2017	CL 2017	UKL 2018	CL 2018	UKL 2019	CL 2019	UKL 2020	CL 2020	UKL 2021	CL 2021	UKL 2022	CL 2022
Lost River suckers	0.56 (41)	NA	0.23 (136)	0.00 (10)	0.00 (8)	0.00 (4)	0.17 (12)	NA	0.08 (143)	NA	0.00 (21)	NA	0.00 (33)	NA	0.00 (9) NA	NA
Shortnose and Klamath largescale suckers	0.28 (61)	NA	0.14 (44)	0.02 (131)	0.08 (12)	0.00 (4)	0.00 (10)	NA	0.06 (62)	NA	0.09 (12)	NA	0.02 (43)	NA	0.00 (4)	NA
Indeterminant	0.35 (37)	NA	0.16 (67)	0.00 (2)	0.08 (12)	0.00 (1)	0.00 (13)	NA	0.07 (202)	NA	0.00 (1)	NA	0.00 (0)	NA	0.00 (0)	NA
Total suckers	0.38 (141)	NA	0.19 (257)	0.01 (179)	0.06 (32)	0.00 (9)	0.05 (37)	NA	0.07 (486)	NA	0.03 (34)	NA	0.01 (78)	NA	0.00 (13)	NA

Table 18. Proportions of age-1 and older suckers with petechial hemorrhages of the skin in Upper Klamath Lake, Oregon, and Clear Lake Reservoir, California, 2015–20.

[Number of age-1 and older suckers given in parentheses]

Lake	2015	2016	2017	2018	2019	2020	2021	2022
Upper Klamath Lake	0.07 (14)	0.06 (16)	0.12 (16)	0.50 (4)	0.17 (6)	0.00 (21)	0.00 (7)	0.00 (6)
Clear Lake Reservoir	0.06 (17)	0.00 (53)	0.00 (137)	0.03 (214)	0.07 (200)	0.03 (129)	0.00 (105)	0.00 (79)

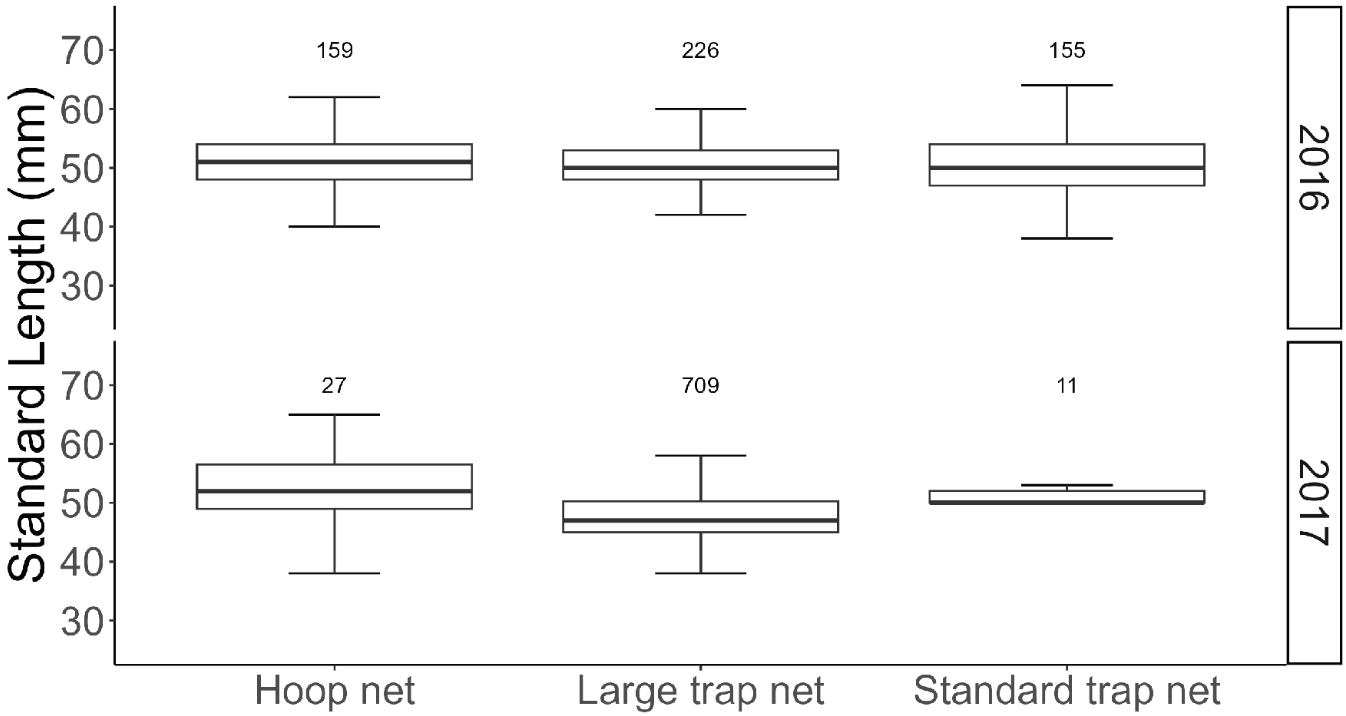


Figure 6. Comparison of standard lengths of suckers sampled June–August 2016 and July–September 2017 with three gear types (hoop nets, large trap nets, and standard trap nets) in Upper Klamath Lake, Oregon. Boxes show the 25th and 75th percentiles, bold lines in the boxes are the median, whiskers indicate the largest value within 1.5 times interquartile range above 75th percentile and the smallest value within 1.5 times interquartile range below 25th percentile. Outliers have been removed to better highlight comparisons between interquartile ranges. Standard length is shown in millimeters (mm).

Table 19. Catch statistics comparing three gear types used in Upper Klamath Lake, Oregon 2016 and 2017.

[Total effort represents the cumulative number of hours that nets were in the water fishing. **Abbreviations:** hrs, hours; CPUE, catch per unit effort; SL, standard length; SD, standard deviation; mm, millimeter]

Gear type	Number of samples	Total effort (hrs)	Total suckers	Mean CPUE	Mean SL (mm) ± SD	Percent age-0 suckers	Mean age-0 CPUE
			2016				
Hoop net	42	1,008.05	159	0.151	52 ± 6	100	0.151
Large trap net	13	307.30	226	0.740	52 ± 7	99	0.730
Standard trap net	72	1,589.28	155	0.092	52 ± 13	98	0.090
			2017				
Hoop net	82	1,833.23	27	0.014	65 ± 35	88	0.012
Large trap net	56	1,307.39	709	0.539	52 ± 38	98	0.526
Standard trap net	78	1,710.47	11	0.006	124 ± 142	63	0.004

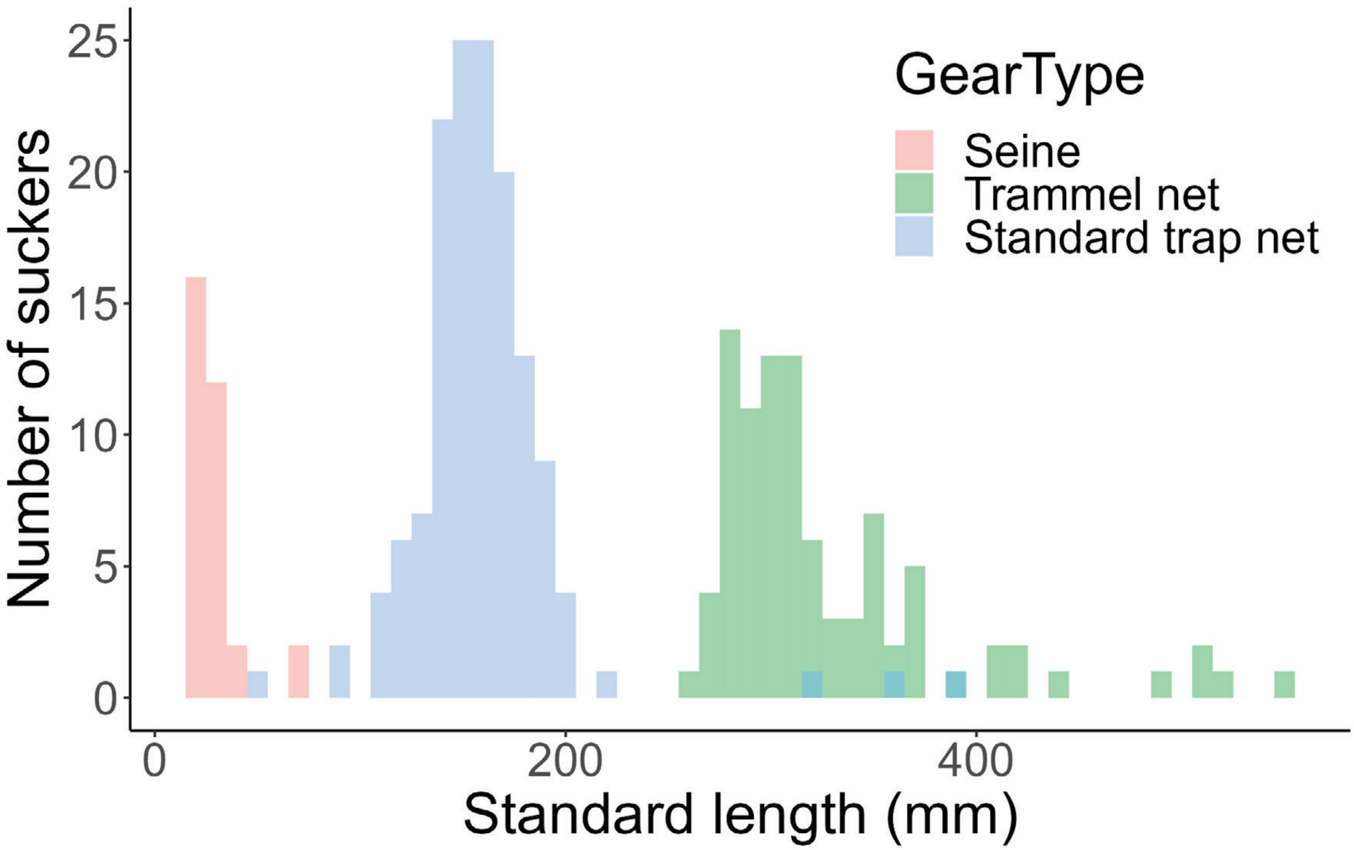


Figure 7. Comparison of standard lengths of suckers sampled June, August and September 2016 and June and September 2017 with three gear types (standard trap nets, seines, and trammel nets) in Clear Lake, California.

Table 20. Catch statistics comparing three gear types used in Clear Lake, California 2016 and 2017.

[Total effort represents the cumulative number of hours that nets were in the water fishing. **Abbreviations:** hrs, hours; SL, standard length; mm, millimeter; ±, plus or minus; SD, standard deviation]

Gear type	Number of samples	Total effort (hrs)	Total suckers	Mean SL (mm) ± SD	Minimum SL (mm)	Maximum SL (mm)
			2016			
Seine	21	2.96	15	37 ± 14	27	70
Trammel net	9	22.30	87	324 ±53	265	555
			2017			
Seine	41	6.75	18	22 ± 6	20	26
Trammel net	12	25.11	6	408 ± 90	312	519
Standard trap net	188	4,637.74	119	161 ± 38	54	387

Discussion

Upper Klamath Lake

The lack of substantial recruitment to the spawning population continues to be the bottleneck for the recovery of shortnose and Lost River suckers in Upper Klamath Lake. Since the early 2000s, the abundance of both species has decreased by more than 40 percent (Hewitt and others, 2018). Nearly all adult suckers in Upper Klamath Lake are older than the average life span expected for each species, and shortnose suckers are approaching the maximum known age for their species (Hewitt and others, 2018; Krause and others, 2022). As the adult sucker populations diminish, we continue to catch small numbers of juvenile suckers during our monitoring efforts. Without the balance of recruitment by new individuals to the spawning population, Lost River and shortnose suckers will continue their downward population trend in Upper Klamath Lake.

The scarcity of age-1 and older suckers in Upper Klamath Lake is likely attributable to juvenile mortality. Several observations support the presumption that mortality, rather than reduced gear selectivity or emigration from sampled areas, explains the reduction in catch by age. Most of our catch in Clear Lake were age-2 and older suckers, indicating older, larger fish are vulnerable to our trap nets and therefore gear selectivity does not contribute to the lack of age-1 and older suckers in Upper Klamath Lake. A substantial lack of recruitment to the adult populations in Upper Klamath Lake indicates that juvenile suckers have unsustainably low survival rates (Hewitt and others, 2018). A lack of directed movement toward the lake's outlet suggests that emigration is not the primary reason for a lack of older juvenile suckers in Upper Klamath Lake (Burdick and others, 2009b).

Although mortality is substantial for Lost River and shortnose suckers, it appears to be greater for juvenile Lost River than shortnose suckers as seen by the fall through spring survival indices. Although earlier years did not separate out shortnose suckers from Klamath largescale suckers, there was a separation between these two species starting in 2020. Age-1 catch was composed of a greater number of shortnose suckers than Lost River or Klamath largescale suckers in 2020 and 2022, whereas Klamath largescale suckers composed a greater portion of the age-1 catch in 2021. There is always the possibility that the index for past years reflects a greater portion of Klamath largescale suckers surviving to age-1; however, the lack of age-1 Klamath largescale suckers captured during 2020 and the low number captured in 2022 and the identification of more shortnose suckers than Klamath largescale suckers using vertebrae counts in past studies (Burdick and others, 2008, 2009a; Burdick and Brown, 2010) suggest that the past 7 years may also have a minimal proportion of age-1 Klamath largescale suckers. Burdick and Martin (2017) reported the same survival trend; however, they were unable to determine why there were differences in species mortality rates. We hypothesize that Lost River suckers, which hatch earlier than shortnose suckers, may encounter unfavorable environmental conditions (for example, water quality or food availability) at a critical juncture in their development.

There are several possible explanations for why we only detected one of the thousands of PIT-tagged suckers that were released into Upper Klamath Lake from the SARP program through 2022. Given the large size of Upper Klamath Lake, these are relatively small numbers of fish to detect, even when ignoring post-release mortality. PIT-tag antennas operating in the Link River at the outlet of Upper Klamath Lake and in the Williamson and Sprague Rivers have detected less than 1 percent of the SARP fish released from 2018 through 2022 (151 out of 41,800 as of December 31, 2022), indicating that directed emigration was an unlikely explanation for the disappearance of these fish (Krause and others, 2023). Furthermore, the majority of the 151 detected fish (76 percent) were detected in 2021, whereas 21 percent were detected in 2022. As of the writing of this report, USGS crews have detected 248 (<1 percent) of the PIT tags from SARP-released suckers on bird colonies cumulatively from 2018 through 2022 scanning efforts, indicating bird predation may be a factor in the survival of some SARP fish (Evans and others, 2016). However, Evans and others (2022) estimated that predation rates on SARP fish ranged from 4.3 (95 percent credible interval = 2.9–6.7 percent) to 8.5 percent (6.3–12.7 percent) percent annually from 2018 through 2020, indicating that colonial bird predation accounts for a small percentage of the mortality of these suckers.

Although it is typical for survival to be low in the early life stages of fish (Houde, 1989), near-complete disappearance of entire cohorts within the first 2 years is of concern. High fecundity may be a life-history strategy to overcome high mortality for juvenile suckers in the Klamath Basin, but near complete mortality is unsustainable (Rasmussen and Childress, 2018). Although age-0 apparent survival was intermediate from August–September for the 2019 cohort compared to age-0 apparent survival of other cohorts, the fall through spring apparent survival of the 2019 cohort was low, resulting in a substantial loss of this cohort. Given that the adult populations of Lost River and shortnose suckers have decreased by more than 50 percent since the early 2000s (Hewitt and others, 2018), there would have to be a substantial recruitment event in the coming years for both species to recover. As of the writing of this report, we have no indication that such an event is imminent.

Clear Lake Reservoir

With greater juvenile sucker survival than in Upper Klamath Lake, intermittent recruitment of new spawners has been documented for Clear Lake populations (Hewitt and Hayes, 2013). The mechanisms behind intermittent cohort success are not completely understood. Hypotheses include

(1) limited access to spawning habitat in dry years and (2) differential juvenile sucker mortality among years. It has been shown that varying rates of juvenile sucker mortality are associated with differential rates of avian predation among years that are mediated by water levels and fish size, especially for small fish (Evans and others, 2022). Another hypothesis of why survival is better in Clear Lake than Upper Klamath Lake include the differences in water quality between the two lakes, and that the Clear Lake population is believed to be composed mainly of Klamath largescale suckers, which can rear in the river before entering the lake.

A lack of age-0 suckers captured in the low water years of 2014 and 2015 in Clear Lake Reservoir led Burdick and others (2016) to conclude cohorts were not formed in those years. Lake-surface elevations less than 1,378.9 m prevented adult suckers from migrating up the spawning tributaries in the spring of both years (Hewitt and others, 2021), and during the current sampling year of 2022 (fig. 8). Burdick and others (2016) had concluded that spawning did not occur without access from the lake to the river. After high flows in the Willow Creek drainage increased lake-surface elevations in 2016 (fig. 8), the 2014 and 2015 cohorts were detected in Clear Lake Reservoir. The 2014 cohort was collected through 2020 and the 2015 cohort was collected through 2021. Lack of collection of these cohorts after these time frames was most likely due to the suckers being too large to recruit to the standard trap nets used during our surveys. The presence of the 2015 juvenile cohort in Clear Lake challenged the Burdick and others' (2016) presumption that high springtime lake elevations are required to form year-classes in Clear Lake Reservoir (Bart and others, 2020a). We suspect that the majority of the 2015 cohort are offspring of stream resident Klamath largescale suckers that only recruited to Clear Lake when high water flushed them from the tributaries. Although the current genetic techniques can separate Klamath largescale suckers from shortnose suckers in the Klamath Basin, there is still uncertainty in separating these species in the Lost River Basin (Smith and others, 2020). Suckers from the 2015 cohort were genetically classified as the combination of Klamath largescale suckers and shortnose suckers from the Lost River Basin. However, a stream resident life history is consistent with these fish being Klamath largescale suckers.

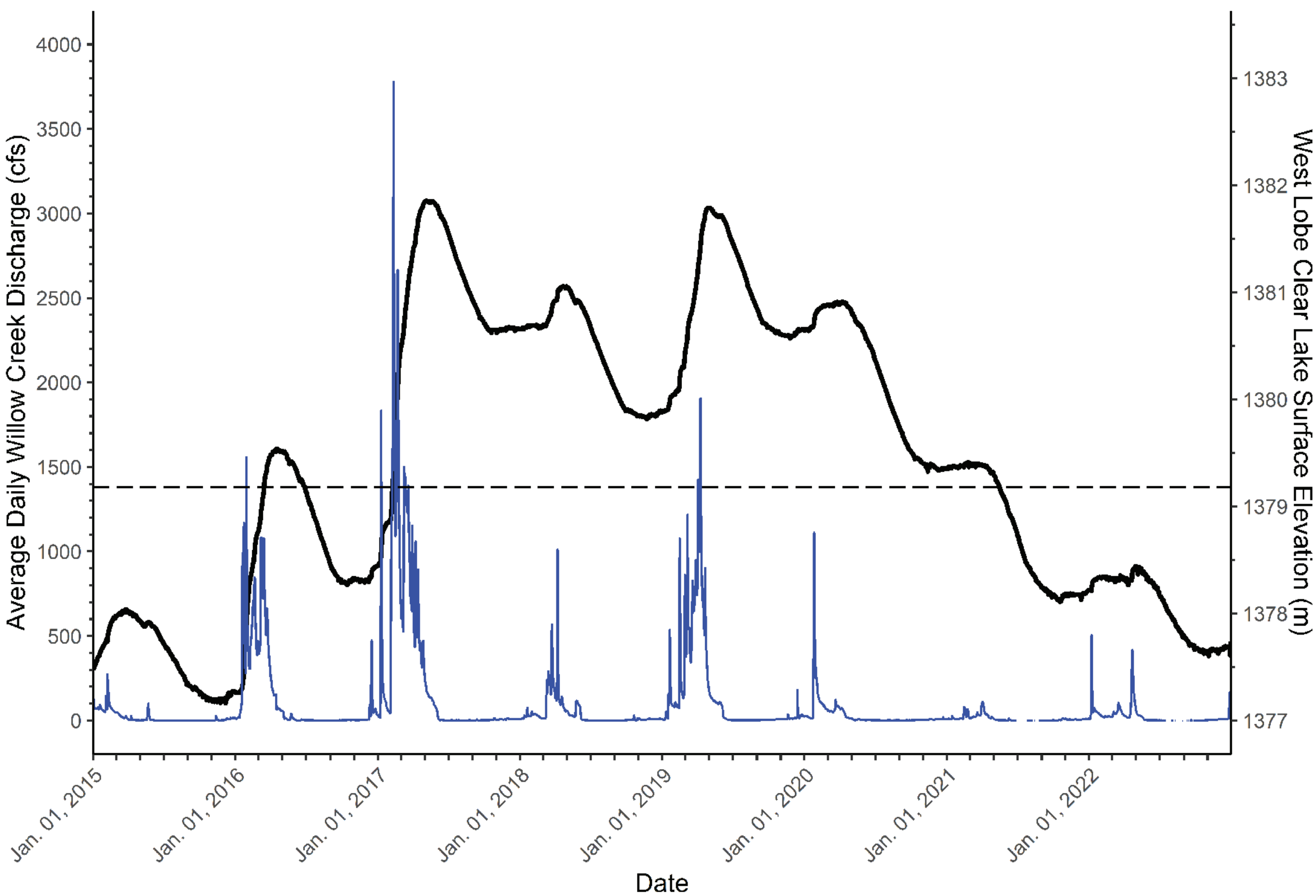


Figure 8. Lake-surface elevation, Clear Lake Reservoir, California, and average stream for Willow Creek, California, 2015–22. The surface elevation indicating separation between Clear Lake Reservoir and Willow Creek is the straight horizontal dashed line at 1,378.8 meters. Surface elevations are in meters (m) above Bureau of Reclamation Vertical Datum.

The lack of access between the tributaries and Clear Lake does not explain why age-0 sucker catches were absent in 2018–21. Lake levels were relatively high, and adult suckers were detected on remote PIT-tag arrays migrating into Willow Creek during springs of 2018–19, indicating that spawning likely occurred (Hewitt and others, 2021). With higher water levels and access to Willow Creek for spawning habitat, we expected to see large numbers of age-0 suckers in Clear Lake from 2018 to 2021, but this was not the case. Creek flows were relatively low in all years except for 2016, 2017, and 2019 (fig. 8). Furthermore, the duration of high flows in 2016, 2017, and 2019 appeared long enough to support spawning (fig. 8). The high water discharge years coincide with the observance of age-0 suckers in 2016 and 2017, but not 2019. It would appear that 2019 should have had proper conditions for age-0 suckers to be present; however, there was a huge fire in 2019 that burned along the shoreline (https://en.wikipedia.org/wiki/Tucker_Fire, and personal observation) and may have negatively impacted this year class in the lake. In the remaining years, a lack of sufficient spring discharge could have prevented age-0 suckers from outmigration to the lake thus trapping suckers in disconnected pools. Juvenile and adult suckers have been documented in disconnected pools and reservoirs throughout the Willow and Boles Creek drainages during summer 2018 (Martin and others, 2021).

Genetic analysis of the sucker species in Clear Lake indicate that there are very few Lost River or definitive shortnose suckers. The only cohorts represented by Lost River and shortnose suckers are the 2016 and 2017 cohorts. To date, the genetically identified group of Klamath Largescale and shortnose suckers from the Lost River Basin represent all cohorts tracked through this study except for the 2021 and 2022 cohorts. Given our continued pattern of catching cohorts once they are past age-0 or age-1, sampling Clear Lake in 2023 is needed to confirm the possible existence of the 2021 and 2022 cohorts. This information combined with the above cohort tracking indicates that the category of Klamath Largescale and shortnose suckers from the Lost River Basin most likely represents Klamath Largescale suckers.

Clear Lake surface elevation and Willow Creek flows may affect the annual rate of bird predation on suckers (Hewitt and others, 2021). Double-crested cormorants (*Nannopterum auritum*) and American white pelicans (*Pelecanus erythrorhynchos)* prey upon vulnerable suckers as they enter Willow Creek to spawn. Hewitt and others (2021) hypothesized that adult sucker mortality is greatest when lake-surface elevation ranges from 1,378.9 to 1,379.2 m above mean sea level during the spawning migration. Several cohorts that cease to be captured in trammel net catches at the age of first spawning may indicate that young or small adult suckers are especially vulnerable to bird predation. When the lake-surface elevation is less than 1,378.9 m or if instream flows are very low, suckers cannot access spawning habitat in Willow Creek and are therefore less susceptible to predation. The formation of nesting islands for American white pelican and double-crested cormorant at lake-surface elevations greater than 1,378.9 m provides protection for the birds' eggs from predators, resulting in greater numbers of birds to be present for a longer period (Evans and others, 2016). As lake-surface elevation increases above 1,378.9 m, bird islands shrink in size, thus reducing bird nesting habitat and the number of nesting birds available to prey on suckers. At lake-surface elevation above 1,379.2 m, deep water also provides cover for migrating suckers (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 2013). Poor survival of suckers that first attempt to spawn in low-water years may explain the absence of some cohorts from adult sucker sampling.

Afflictions

Opercular deformities, which are more common for Lost River than shortnose suckers, make the gills more vulnerable to parasites and poor water quality and ultimately increase the chance of mortality. Because there were no age-1 or older suckers in Upper Klamath Lake with deformed opercula, there is the potential that it is serious enough of an affliction that it increases the probability of mortality before fish can reach older ages. However, we did see opercular deformities in several of the age-4 suckers classified as the combination of Klamath largescale suckers and shortnose suckers from the Lost River Basin in Clear Lake in 2020, indicating there may be additional confounding factors. Although this affliction has been observed on other sucker species (Barkstedt and others, 2018), the exact cause of deformed opercula is difficult to determine. Potential explanations could be inbreeding, hybridization (Winemiller and Taylor, 1982; Tringali and others, 2001), nutrient deficiency (Chávez de Martínez, 1990; Lall, 2002), heavy metals, pesticides, high egg incubation temperature (Boglione and others, 2013) or a combination of these factors.

Lernaea sp. parasitism is one of the most common afflictions on juvenile suckers captured in both lakes, occurring to some degree in all sampling years. Wounds that form at *Lernaea* sp. attachment sites may provide a pathway for bacterial infection (Berry and others, 1991). Inflammation associated with *Lernaea* sp. attached to juvenile suckers from Upper Klamath Lake is most often limited to a focal area in the skin and skeletal muscle directly surrounding the attachment site, indicating this parasite is unlikely to cause systemic infections that result in mortality (Burdick and others, 2015a). However, when an individual sucker is highly parasitized with *Lernaea* sp. as seen during 2021, when 1 individual supported 21 of these parasites, the likelihood of adverse effects increases. Several studies indicate that infestation of *Lernaea* increase with increased temperatures, with ideal transmission occurring from 23 to 30 °C (Marcogliese, 1991; Sánchez-Hernández, 2017).

The causes of petechial hemorrhaging, which generally appears more frequently on suckers from Upper Klamath Lake, are unknown. Petechial hemorrhages of the skin are a common observation in Upper Klamath Lake and have been documented since affliction monitoring began in 2014 (Burdick and others, 2015a). Petechial hemorrhages of the skin have been found to be caused by irritants including abrasion, bacteria, or toxins (Ferguson and others, 2011). The low prevalence of observed hemorrhages in Clear Lake relative to Upper Klamath Lake indicates that abrasions caused by our method of capture is unlikely to be the primary reason for the hemorrhaging. Burdick and others (2018) examined the hemorrhages microscopically and did not observe associated bacterial disease or other parasites. Janik and others (2018) observed petechial hemorrhaging on collected fish from Upper Klamath Lake canals; however, they could not observe it through histology, which indicated that the infection was likely confined to the skin.

Lamprey wounds were seen in both lakes but are likely not a large source of mortality. All lamprey species in the Upper Klamath Basin are native (Kostow, 2002). Given the low prevalence of lamprey wounds and that lamprey have coevolved with suckers in the Klamath Basin, it is unlikely that they are the primary cause of annual juvenile sucker year-class failure.

Incidence of black spot was hypothesized to be associated with high mortality of juvenile suckers (Markle and others, 2014). In previous years monitoring, black spot was only recorded on a small proportion of fish, and during the 2018–22 monitoring seasons, there were no suckers with black spot (Bart and others 2020a, b; Bart and others, 2021; Martin and others, 2022). In years when black spot was observed, it was more prevalent in Upper Klamath Lake than in Clear Lake (Burdick and others, 2016, 2018; Bart and others, 2020b). There is the potential that we are missing cases of black spot in suckers when it is not externally visible. Markle and others (2020) found that out of 55 fish observed without external black spot, 10 had internal muscle or gill infections of black spot. Although this would indicate that black spot is underrepresented in our data, there is no indication from our data that it is a substantial source of mortality for juvenile suckers.

Gear Selectivity

Various gears have been used to capture suckers in Upper Klamath and Clear Lakes since USGS began sampling for juvenile suckers in 2001. In Upper Klamath Lake, the primary gears used to collect juvenile suckers from 2001 through 2006 were large trap nets and hoop nets. Starting in 2007, the primary gear used was standard trap nets (Burdick and Martin, 2017). Burdick and Martin (2017) stated that in order to compare the gear types from different years a comparison factor needed to be determined based on the different gear types being fished simultaneously. After finding that catch rates differed among gear types, which prevented direct comparisons, we calculated a correction factor based on the 2016 sampling. However, given that only 1 year of data was used in the calculation, the resulting adjusted CPUEs should be considered approximate and comparisons to actual CPUEs should be made cautiously.

When comparing gear types, the inferences on the size selectivity differed by lake system. Gear types in Upper Klamath Lake did not appear to have a size bias given that all gears caught age-0 suckers. However, because minimal numbers of age-1+ juveniles were captured in Upper Klamath Lake, it is unclear how the size selectivity differs between gears for older juveniles. In previous Clear Lake studies, trammel nets had been used to collect subadult and adult suckers, whereas standard trap nets and seines had been used to collect juvenile suckers (Burdick and Rasmussen, 2012; Hewitt and others, 2021; Martin and others, 2022). Comparison of these gear types corroborated our suspicions that seines selected for the smaller juvenile suckers, standard trap nets selected for larger juvenile suckers and subadult suckers, whereas trammel nets selected for the subadult and adult suckers. Age-0 suckers were collected in both the seines and standard trap nets indicating that both sampling techniques are able to detect age-0 suckers if they are present in Clear Lake in any given year. However, seining proved to be a difficult and somewhat ineffective method of capturing suckers because of the presence of large boulders or deep muck.

Acknowledgments

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For information about the research in this report, contact:
Director, Western Fisheries Research Center
U.S. Geological Survey
6505 NE 65th Street
Seattle, Washington 98115-5016
https://www.usgs.gov/centers/wfrc

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