

University of Nevada, Reno

**Population dynamics of the two remaining native lake populations of threatened
Lahontan cutthroat trout**

A thesis submitted in partial fulfillment of
requirements for the degree of Master of Science in
Biology

by

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THE GRADUATE SCHOOL

We recommend that the thesis
prepared under our supervision by

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Threatened Lahontan Cutthroat Trout**

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ABSTRACT

Once widespread across lakes of the western Great Basin and the Sierra Nevada mountains of the United States, native self-sustaining populations of Lahontan cutthroat trout (*Oncorhynchus clarkii henshawi*) remain in two lake ecosystems: eutrophic desert terminal Summit Lake and mesotrophic montane Independence Lake. Maintenance of the life history and genetic diversity within the Summit Lake and Independence Lake populations has been identified as an important goal of Lahontan cutthroat management and restoration efforts. In addition, the Summit population is of significant cultural importance for the indigenous Summit Lake Paiute people. However, little research has been conducted on the population dynamics of lake-dwelling cutthroat trout, especially in desert terminal lakes. Thus, we performed population dynamics research on the Summit Lake and Independence Lake populations to provide direction for their sustainable management and for range wide conservation strategy. At Summit Lake, we quantified the population dynamics (e.g., number of spawning fishes during a 50 year record from 1968-2017, abundance, population growth rate) and performed a sensitivity analysis to identify the life history transitions with the most influence on the population growth rate. Abundance was estimated from a robust design mark-recapture effort. For the population growth rate and sensitivity analyses, we created a stage-classified (Lefkovich) matrix population model with skipped spawning and parameterized it with data from the mark-recapture-detection of individuals in the lake and spawning tributary (Mahogany Creek), as well as data or results from an Independence Lake population viability analysis study. Adult abundance declined steadily (2096 to 661 individuals), and the growth rate indicated a declining population (0.52). The Nonspawning to Nonspawning and Spawning stages (0.53 and 0.11, respectively) had the most influence on the population growth rate. The growth rate was driven by low adult survival (0.51) and the high and low probabilities that a nonspawner would remain a nonspawner (0.82) or become spawner (0.18), respectively. These results contradict previous findings that identify juvenile life stages as the most sensitive parameters in cutthroat trout population studies. In addition, low fecundity (0.85) likely decreased recruitment. Then we compared the population dynamics of the Summit Lake and Independence Lake populations. Using the model described above for each population, we parameterized the models with data and parameters from their respective population studies and compared their population growth rates and

sensitivity analyses. Both population growth rates indicated decline (0.94 and $.52 < 1$, respectively), and the populations shared the third most sensitive parameter - low repeat spawning rates (0.44 and 0.36, respectively). But the difference between the growth rates was large, the Independence Lake growth rate overlapped 1, and the top two sensitive parameters at Independence Lake were fry (0.03) and juvenile survival (0.25). Also, the much higher fecundity at Independence Lake (87) likely contributed to their higher growth rate via recruitment. At Summit Lake, sensitive adult parameters may be indicative of life history adaption to the desert habit, a plastic response to drought, or simply the norm for self-sustaining populations not impacted by invasive species or other adverse factors. Our findings suggest managers should focus their efforts on protecting juveniles in Independence Lake and adults and fecundity in Summit Lake, and to guard against assuming that intra-specific populations have the same population drivers, especially populations in disparate habitats.

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1.0 Chapter 1

PROJECT INTRODUCTION

North American freshwater fauna is declining five times faster than terrestrial fauna. Since the mid-1800s, habitat loss, overfishing and invasive species have severely altered western United States (US) freshwater fish communities. Today climate change predictions for the western US (increased climatic variability that will increase drought frequency and duration, and shift precipitation to more rain and less snow]) threaten to compound these disturbances. These legacy, current and future disturbances synergize into a formidable challenge for conserving western US freshwater fish biodiversity, often necessitating active management of fisheries that are susceptible to further decline and localized extinctions. Cutthroat trout (*Oncorhynchus clarkii spp.*) are salmonids native to the coastal and inland waters of western North America. Comprised of approximately 14 original subspecies, the historic distribution of cutthroat species ranged from Alaska to southern Texas and from the Canadian and US Pacific Coasts to the Rocky Mountains. Ranges and populations of many subspecies have declined over the past century, with two subspecies now extinct. Lahontan cutthroat trout (*Oncorhynchus clarkii henshawi*, Lahontan cutthroat) is the largest (physical size) subspecies and one of three on the US endangered species list. In mid-1800s, Lahontan cutthroat occupied 11 lakes - 6 lakes in the Sierra Nevada Mountains and 5 lakes east in the high desert sagebrush steppe of the western Great Basin - but were extirpated from 9 lakes over the next one hundred years. Independence Lake (California) and Summit Lake (Nevada), representing only 0.4% of the historic lake habitat, contain the last native self-sustaining lake-dwelling populations. The threatened status of Lahontan cutthroat, the similarities and differences between the lakes and their populations, recognition that the populations are unique, and the few comparative population dynamics studies with lake-dwelling cutthroat trout, made these populations ideal study and comparison. Further, the Lahontan cutthroat fishery at Summit Lake is a significant component of the cultural heritage of the Summit Lake Paiute Tribe, as reflected in the tribe's original name, Agai Panina Ticutta, which translates as the Summit Lake Fish Eaters.

Most cutthroat trout population dynamics research has occurred in rivers and streams of the Rocky Mountains and Sierra Nevada Mountains. Few cutthroat trout population studies have focused on lake-dwelling populations in desert terminal lakes or as comparison studies between lake-dwelling populations (within or between cutthroat subspecies). Published literature on Lahontan cutthroat population dynamics has estimated survival rates in the Truckee River and Walker Lake, population growth rates and extinction risk in northern Nevadan creeks, the effects of brook trout removal on egg/fry survival and spawning run numbers at Independence Lake, and described the spawning run and lake-ward migration of juveniles at Summit Lake. Key unpublished research on lake-dwelling populations includes the ecology and viability at Independence Lake, and annual fisheries reports that contain the annual spawning run counts and additional population data at Summit Lake.

This research focused on quantifying the population dynamics of the Summit Lake population, and then comparing the population dynamics of the Independence Lake and Summit lake populations. The specific objectives of Chapter 2 were to: 1) estimate the abundance of the Summit Lake population, 2) determine whether the population is increasing, stable, or decreasing, and 3) identify the life history parameters with the greatest impact on the population trend. The specific objectives of Chapter 3 were to: 1) compare the population level data available at both lakes, 2) create a population model of the lake-dwelling Lahontan cutthroat life history, and 3) compare and contrast the inferences gained from each effort to identify the key life history parameters that influenced the dynamics of the populations. Abundance at Summit Lake was estimated with a robust design mark-recapture method. For the population growth rate and sensitivity analyses, a stage-classified (Lefkovich) matrix population model was developed and then parameterized for Summit Lake with mark-recapture-detection data collected during this study, and for Independence Lake with data and results contained in the population viability analysis (also from mark-recapture-detection methods).

2.0 Chapter 2

Population dynamics of threatened Lahontan cutthroat trout in Summit Lake (USA)

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jamesimmons@nevada.unr.edu 1664 N Virginia St, MS 341, Biology Department, University of Nevada, Reno, NV, 89557**Abbreviated Title:** Population dynamics of threatened Lahontan cutthroat trout**Keywords:** Lahontan cutthroat trout, stage-classified (Lefkovitch) population matrix model, population growth rate, sensitivity analysis, spawning transition, Summit Lake¹Global Water Center, Department of Biology, University of Nevada, Reno, Nevada, United States of America²Marine Science Institute, University of California, Santa Barbara, California, United States of America³Summit Lake Paiute Tribe, Sparks, Nevada, United States of America**Abstract**

Summit Lake (Nevada, USA) is home to one of the last two self-sustaining lake-dwelling populations of threatened Lahontan cutthroat trout (*Oncorhynchus clarkii henshawi*). The trout are of significant cultural importance for the Paiute people indigenous to the Summit Lake area. We quantified the population dynamics (e.g., number of spawning fishes during a 40 year record from 1978-2017, abundance, growth rate) of trout within the lake to provide direction for the design of a sustainable management plan for this species. In addition we performed a sensitivity analysis to identify the population components with the most influence on population growth rate. Population abundance was estimated with a robust design, mark-recapture effort. For the population growth rate and sensitivity analyses, we created a stage-classified (Lefkovitch) matrix population model with skipped spawning. The model was parameterized with data from the mark-recapture or detection of Lahontan cutthroat trout in the lake and spawning tributary (Mahogany Creek) and life history information from the other remaining, native lake

population of trout in Independence Lake, California. Adult abundance of Lahontan cutthroat trout in Summit Lake declined steadily (2096 to 661 individuals), and the growth rate indicated a declining population (0.52). The sensitivity analysis identified the transition rates from the Nonspawning to Nonspawning and Spawning stages (0.53 and 0.11, respectively) as having the greatest contribution to the dynamics of the population. The growth rate was driven by low adult survival (0.51) and the high and low probabilities that a nonspawner would remain a nonspawner (0.82) or become spawner (0.18), respectively. These results contradict previous findings that identify juvenile life stages as the most sensitive parameters in cutthroat trout population studies. Highly sensitive adult parameters may be indicative of life history adaptation to the desert habitat, a plastic response to drought, or simply the norm for self-sustaining populations not impacted by invasive species or other adverse factors. In addition, low fecundity (0.85) contributed little to recruitment. These results suggest that management efforts (e.g., riparian restoration) to enhance fecundity and adult survival are most likely to increase the population growth rate.

2.1 Introduction

Amid the backdrop of global biodiversity decline [1], North American freshwater fauna is declining five times faster than terrestrial fauna [2]. Since the mid-1800s, habitat loss, overfishing and invasive species have severely altered western United States (US) freshwater fish communities [3]. Today climate change predictions for the western US (increased climatic variability that will increase drought frequency and duration, and shift precipitation to more rain and less snow [4-5]) threaten to compound the above disturbances [6-7]. These legacy, current and future disturbances combine into a formidable challenge for conserving western US freshwater fish biodiversity, often necessitating active management of fisheries that are susceptible to further decline and localized extinctions [8].

Cutthroat trout (*Oncorhynchus clarkii* spp.), so named because of the two red slashes under the jaw that make the throat appear to be cut, are salmonids native to the coastal and inland waters of western North America [9]. Comprised of approximately 14 original subspecies, the historic distribution of cutthroat species ranged from Alaska to southern Texas and from the Canadian and US Pacific Coasts to the Rocky Mountains [9-10]. Ranges and populations of many subspecies have declined over the past

century, with two subspecies now extinct [9]. Lahontan cutthroat trout (*Oncorhynchus clarkii henshawi*, Lahontan cutthroat) is the largest (physical size) subspecies [11] and one of three on the US endangered species list [12].

Lahontan cutthroat was the top predator in ancient Lake Lahontan, the large inland sea that covered much of northwestern Nevada and small portions of northeastern California and southeastern Oregon during the Pleistocene. As Lake Lahontan desiccated over subsequent millennia, Lahontan cutthroat became restricted to the remnant streams, rivers and lakes. By the mid-1800s, Lahontan cutthroat occupied 11 lakes, which ranged from the remote northwestern corner of Nevada to the middle portion of the Sierra Nevada Mountains in California, with 6 lakes in the Sierra Nevada Mountains and 5 lakes east in the high desert sagebrush steppe of the western Great Basin. Over the next one hundred years, Lahontan cutthroat were extirpated from 9 lakes. Independence Lake (California) and Summit Lake (Nevada), representing only 0.4% of the historic lake habitat, contain the last native self-sustaining lake-dwelling populations [13]. This precipitous decline in lake-dwelling populations was a major reason the US Fish and Wildlife Service added Lahontan cutthroat to the US endangered species list in 1970 [14].

The Lahontan cutthroat residing in Summit Lake have been recognized as a unique subpopulation [13-14] with important cultural heritage for the region's indigenous people [9,15-16]. The Lahontan cutthroat population's proximity to the Black Rock Desert (Nevada) [13], adaptation to warm eutrophic alkaline waters [11,13,17-18], and its genetic divergence from other populations [19-20], warranted inclusion in the Northwestern Lahontan basin distinct population segment (special population distinction under the US Endangered Species Act) in the Lahontan cutthroat recovery plan [14]. The lake's remote location and restricted access to the watershed by the Summit Lake Paiute Tribe has kept the ecosystem and population relatively undisturbed, buffering it from the disturbances (e.g. invasive salmonid introductions, watershed development, hatchery production) that have devastated most other Lahontan cutthroat populations [21]. The cultural connectivity between the Summit Lake Paiute Tribe and the fishery is reflected in the tribe's original name, Agai Panina Ticutta, which translates as the Summit Lake Fish Eaters [16]. Thus, Lahontan cutthroat at Summit Lake are truly a cultural and ecological stronghold population for the subspecies.

Recognizing the importance of Summit Lake Lahontan cutthroat, efforts have been made in the last 50 years to understand the dynamics and life history of the population by focusing on the magnitude and timing of the fry (age 0 years) migration to the lake [15], estimating overall abundance with hydro acoustic techniques [22], and counting the number of spawners for most years since 1978 [23]. But these activities have not been unified in time through a conceptual or analytical framework. Monitoring population subsets can be an indicator of the population's status, they can also be misleading when viewed outside the context of a comprehensive population dynamics framework. For example, Lahontan cutthroat managers have been alarmed by the declining number of spawners since the late 1990s; but because spawners are a subset of the population, they may not reflect the population's trajectory [24]. Meanwhile, the US Geological Survey conducted a population viability analysis (the probability that a population will exist after a pre-determined timeframe [25]), for the Independence Lake population [26]. Thus concern over the declining spawning run, potential overreliance on population subsets, and the Independence Lake population viability analysis, have further exposed the need for tribal managers of Lahontan cutthroat to model the mechanisms driving the population dynamics at Summit Lake.

In this study, we wanted to answer the following questions: 1) how many individuals comprise the population in Summit Lake, 2) is the population increasing, stable, or decreasing, and 3) what life history components affect the trend? We addressed these questions, respectively, by estimating abundance, the growth rate, and by performing a sensitivity analysis to identify the life history components with the most impact on the growth rate. We estimated abundance with a mark-recapture method. For the growth rate estimation and sensitivity analysis, we developed a stage-classified matrix population model and estimated its parameters with either mark-recapture or mark-recapture-detection methods.

2.2 Materials and methods

Ethics statement

We conducted this study of Lahontan cutthroat in accordance with the approved procedures in US Fish and Wildlife Permit #TE-17827A-4, and Protocol #00679 of the Institutional Animal Care and Use Committee of the University of Nevada, Reno, US.

Study area

Summit Lake (Fig 2.1A and 2.1B) is located in the northwestern corner of Nevada, Humboldt County, US (41.515N -119.063W). Prior to approximately 8,000 years ago, an area north of Pleistocene Lake Lahontan with southward drainage was blocked by a landslide, thereby creating Summit Lake and potentially isolating its Lahontan cutthroat population [27]. The lake is terminal (no outflow) [15,27-28], with relatively shallow and deep northern and southern halves, respectively [28]. The climate is typical of the Great Basin, with warm summers, cold winters and low annual precipitation [29]. With the lake's relatively high surface elevation (1780 m), small surface area (2.8 km²), and relatively shallow depth profile (mean and max. depths of 6 and 15 m, respectively), the lake freezes in the winter, stratifies in the summer (surface temperatures >22 C⁰), and mixes in the spring and fall (dimictic). In addition, the lake is eutrophic, alkaline, and rich in invertebrates and macrophytes [28]. Recently, during the severe drought in the western US [30], the lake elevation dropped approximately 4 m [23].

Mahogany Creek, which flows into the northeast shoreline, is the sole, perennial spawning tributary and thus serves as the primary source of Lahontan cutthroat recruitment for the lake population [15]. The creek is relatively small, with a mean bankfull width of 2.25 m and mean maximum bankfull depth of 0.42 m [31]. Though spawners utilize most of the creek and its tributaries when conditions permit, most spawning occurs in the lower to middle reaches [23]. Depending on environmental conditions, the spawning run and fry migration can occur from March to June and April to November, respectively [15].

The entire lake is contained within the Summit Lake Paiute Reservation (Reservation), established in 1913. Public access to the lake or public fishing has never been allowed. Subsistence fishing is allowed for tribal members only but is regulated [32]. Tribal harvest from the spawning run was relatively high from 1978-1991 (mean~19%±0.10%, min~5%, max~33%) but declined substantially afterward (mean~2%, min~0%, max~8%) [33]. Invasive salmonids have never been established in the lake or creek, but two invasive minnows became established in the lake and lower creek in the early 1970s [15,28]. The invasive minnows seem to exert little to no competition pressure in the lake, but their impact in the creek is less certain (though also thought to exert little competitive pressure) (Chandra, unpublished data). Grazing on the federal and Reservation portions of Mahogany Creek were discontinued in 1974 and 1991, respectively. Grazing in the remainder of the Reservation was minimal from 1990-2004 and has not been allowed henceforth [15,34]. Hatchery supplementation of Lahontan cutthroat derived from Summit Lake ended in 1984, but the supplementations from 1975-1984 were considered to have a negligible impact on the population [35].

Life history

Lake-dwelling Lahontan cutthroat begin life in the spring and early summer as fertilized eggs in redds (nest) excavated in the substrate of spawning tributaries. The alevins (an embryonic stage retaining a portion of the yolk sac for sustenance) generally hatch 4 to 6 weeks later. When the yolk sac is absorbed, the alevins mature to the fry stage and emerge from the gravels. By fall fry will start migration to the lake to rear. However, a small proportion of fry will remain in the tributary and migrate to the lake as 1 or 2 year olds. After year 1, the fry become juveniles. At maturity (3-5 years old), adults reproduce by participating in the annual migration from the lake into a spawning tributary, but most skip at least one year between spawning attempts. The exact timing of the above events depends on location and environmental conditions [13]. The typical lifespan is 5-14 years [36].

Population model

Lahontan cutthroat exhibit a complex life history that cannot be adequately described by age. Juveniles do not mature at the same age and most adults exhibit skipped spawning [13]. Skipped-spawning, in particular, is a key life history trait [37-38] that may be a significant driver of Lahontan cutthroat population dynamics. Thus, following the guidance of Caswell (for species with more complex life histories) [39] and previous research [40], we formulated Lahontan cutthroat as a stage structured population model. First, we created a life history model (Fig 2.2, Table 2.1) comprised of five life history stages and nine parameters. For simplicity, and based on our field collection efforts, we assumed that individuals mature over three juvenile size stages. The Fry and Juvenile A and B size stages are Fry < 100 mm, $100 \text{ mm} \leq \text{Juvenile A} < 199 \text{ mm}$, and $200 \text{ mm} \leq \text{Juvenile B} < 299 \text{ mm}$. The two adult stages, Spawning or Non-spawning, are defined by size ($300 \text{ mm} \leq$) and whether or not an individual spawned in the given year, respectively. The nine model parameters comprise one fecundity ($f_{1,5}$) parameter, which applies only to spawning adults, and eight stage transition probability parameters. The stage transition probability parameters ($p_{2,1}-p_{5,5}$) are the probabilities that individuals will survive and transition to another stage. The Fry and Juvenile A stage transition probabilities are simply the survival rates to the next stage (ϕ_F and ϕ_{JA} , respectively). The spawning transition probabilities ($p_{4,3}-p_{5,5}$) are the product of the Juvenile B or adult survival rates (ϕ_{JB} and ϕ_A , respectively) multiplied by the respective stage spawning probability ($s_{4,3}-s_{5,5}$). Then we constructed a female stage-classified (Lefkovich) matrix population model (Fig 2.3). One sex population matrix models assume an equal adult sex ratio because an unequal ratio could bias the population growth rate estimate. However, because cutthroat trout species typically exhibit an adult female to male ratio > 1 [26,41], we made the common assumption of female dominance, that the female vital rates dominate the population's dynamics [39]. Unless otherwise specified, all parameter and data references pertain to females only.

Field methods

Fry trap

In 2016 and 2017, we captured migrating young (Fry, Juveniles A and B) with the same temporary fry trap utilized during the Independence Lake population viability analysis study [26]. The fry trap (see Appendix 5.2 for further description) can be configured to intercept or allow passage [26], and was installed approximately 375 m upstream from the creek mouth, and was removed from the creek after the capture efforts. Based on the timing of the spawning runs, the estimated emergence of fry from their eggs [13], and prior research on migrating young at Summit Lake [15], we estimated the migrations to occur from July through November in 2016 and 2017. In 2016, the trap was operated primarily during the weekdays (Monday-Thursday or Friday) from mid-July to mid-November. During four weeks in September when there was stagnant water, the fish trap was not operated to eliminate negative influences on the fry. In 2017, the trap was operated with a mix of weekday or longer periods (which included weekdays and weekends-Friday or Saturday and Sunday) from late August to early November. Captures were processed for fork length (mm) and then released downstream.

Passive Integrated Transponder (PIT) tag effort

We implemented a mark-recapture method - in which captured Lahontan cutthroat were marked, returned to the lake, and recaptured - to estimate survival rates [42]. Passive integrated transponder (PIT) tags - a cylindrically-shaped, glass encased chip that contains a unique number, and implanted into the body - were used to mark individuals [43]. New captures ≥ 100 mm were implanted with a Biomark© 12 mm full duplex PIT tag that contained a unique 15-digit number. New captures ≥ 250 mm were tagged in the pelvic girdle, and $100 \text{ mm} \leq$ new captures < 250 mm were tagged in the abdominal cavity between the pectoral and pelvic fins. We clipped the adipose fin of new captures to subsequently identify recapture and assess tag loss. CO₂ gas was used for anesthesia, and captures recuperated in net pens in the lake (alongside the boat) before release. We recorded the following data from each capture: fork length (mm), mass (kg), trap depth (ft), sex (male, female, or unknown), new capture or recapture, and PIT tag number.

Netting effort

We used fyke (trap) nets [44] to minimize capture harm and mortality. Trap nets have many advantages. They are generally used in shallow water (but can be set to depths up to 15 m) to intercept fish travelling close to and parallel to the shoreline (lake-dwelling Lahontan cutthroat utilize the littoral zone to varying degrees during the year [45-47]); exert less stress, harm, mortality, or selectivity than other passive methods such as gill nets; standardize effort more easily by using the same equipment and length of time repeatedly; and are designed for stillwater habitats such as lakes (see Appendix 5.3 for further description) [44].

We executed a robust design mark-recapture effort [48] in the lake to estimate total abundance and the juvenile and adult survival rates for the population model. The robust design framework simultaneously estimates these parameters by using primary and secondary sampling periods. The primary periods are spaced far enough in time to create an open population (birth or deaths) to estimate survival; and the secondary periods, contained within each primary period, are close enough in time to create a closed population (no births or deaths) to estimate abundance for each primary period [48].

We recognized that the spawning run would create an open population (high emigration and mortality) with respect to the lake sampling, so we chose the primary and secondary periods to not overlap with the spawning run. Our three primary periods were pre-spawn (March–April), post-spawn (June–July), and fall (October–November), and the secondary periods were consecutive calendar weeks within these primary periods. The dates and lengths of the respective primary periods changed every year (due to weather, timing of the spawning run, etc.) but remained consistent overall.

We designed and executed a spatially stratified, semi-random sampling plan to minimize bias. First, we divided the entire lake into 4 sampling zones (Fig 2.1B). Then depending on staff availability, we used either 5, 8, or 10 trap nets during each primary period. With five nets, one net was assigned to each zone and the fifth net was a rover; with 8 nets, two nets were assigned to each zone; and with ten nets, two nets were assigned to each zone and the ninth and tenth nets were rovers. The rover(s) was rotated daily among the zones to keep the sampling effort as uniform as possible. Most net sets were approximately 20-24 hours. Daily, after pulling and processing the captures, the assigned and roving nets were moved to a

different location within their assigned zone or between the zones, respectively. For each net set, we recorded the following data: zone number, GPS location, date and time of set and pull, and depth (ft).

Sampling bias may have occurred in two processes. Mesh size (0.5 and 1 in.) allowed small individuals to pass through, and the large trap nets precluded sampling of shallow, heavily vegetated areas where juveniles may have been concentrated [49]. Also, the trap nets were set primarily from the shoreline to 50 m into the lake, capturing fish close to shore and possibly resulting in seasonal or behavioral capture biases [46-47]. However, we are confident that some of the bias was corrected with a ground truthing step (described below) we added to model selection.

PIT antenna

A permanent stationary PIT antenna, spanning the entire width and depth of the creek, is located approximately 750 m upstream from the mouth. The antenna is designed to detect PIT-tagged individuals traveling up or downstream. The estimates for total spawners, fecundity, and spawning probabilities relied on the annual lists of PIT-tagged spawners detected by the antenna. We made four assumptions to generate the lists. First, lake-dwelling Lahontan cutthroat spawn annually, are obligate tributary spawners, and infrequently enter or reside in tributaries outside of the spawning run [13,31]. Next, every individual that entered the creek during the run was classified a spawner, although actual spawning could not be confirmed. Thus, an individual's initial detection signaled participation, an exit detection signaled survival, no exit detection signaled death, and zero detections signaled no participation. Last, we assumed that the detection rate of the antenna was approximately 100% [31].

Fish weir

Located approximately 3.5 km upstream from the creek mouth, the Summit Lake Paiute Tribe has a permanent weir facility (fish weir) that blocks the entire creek. The fish weir captures the spawning trout migrating further upstream. Depending on environmental conditions and the duration of the run, the Summit Lake Paiute Tribe generally operates the weir from March to June with daily checks. The following data is collected from each capture: sex (male, female, or unknown), mass (kg), fork length

(mm), and PIT number (if present). After processing, the fish are released upstream to continue their migration. With the weir (and its predecessor), the Summit Lake Paiute Tribe has monitored the spawning run since 1978 [23].

Analyses

Fecundity

We defined fecundity, $f_{1,5}$, as the number of female young (Fry, Juvenile A or B) migrating to the lake per female spawner. To estimate the total number of young (Fry, Juvenile A or B) migrating to the lake, we added the physical counts to extrapolated counts. When the trap was configured for passage, we calculated the number of passing young by averaging the physical counts from the last day before and the first day after the passage period and multiplying by the number of passage days. These extrapolated counts were summed and then added to the physical counts to get the annual migration totals. Next, because we did not count every female that entered the creek during the runs, we calculated the number of female spawners by dividing the number of tagged females detected by the antenna with the proportion of tagged vs. total female spawners caught at the fish weir. We then multiplied the total young captured by half (assuming a 1:1 sex ratio for simplicity, because prior lake-dwelling cutthroat trout population modeling has made the same assumption [40], and because recent research with brown trout suggests an equal ratio may not be unreasonable [50]) and divided by the total female spawners to derive fecundity.

Spawning numbers and parameters

We estimated the total and female spawners from 2015–2017. Because the fish weir is not located at the mouth of the creek, the fish weir counts do not represent the total spawners participating in the run. We estimated total spawners by dividing the number of tagged individuals detected by the antenna by the ratio of tagged to total individuals captured at the fish weir.

We defined spawning probability (s) as the probability of a pubescent juvenile or an adult spawning or not in a given year. We estimated the Juvenile B to the spawning stage probabilities ($s_{4,3}$, $s_{5,3}$)

by taking the proportion of Juvenile B individuals that participated in the spawning run each year. For 2015, we used the Juvenile B individuals tagged during the spring lake sampling. For 2016, we used the Juvenile A (because they will be Juvenile B during the following year's spawning run) individuals tagged in the spring and fall 2015 samplings, and the Juvenile B individuals tagged in the pre-spawn 2016 sampling. Similarly for 2017, we used the Juvenile A individuals tagged in the spring and fall 2016 samplings, and the Juvenile B individuals tagged in the pre-spawn 2017 sampling. Because juveniles are difficult to sex, for simplicity we assumed the same probability for females and males each year [40].

We calculated the adult spawning probabilities ($s_{4,4}$ - $s_{5,5}$) from the detection of tagged individuals through the PIT antenna. This data produced an annual list of individuals that spawned and survived or didn't spawn. Spawning survivors from the previous year were compared to the spawners the following year to determine $s_{5,5}$ and $s_{5,4}=1-s_{5,5}$. Likewise, non-spawners and spawners from the previous and the following years, respectively, were compared to calculate $s_{4,5}$ and $s_{4,4}=1-s_{4,5}$. We also included the detections from female survivors that were tagged at the fish trap during the 2015 and 2016 spawning runs.

To estimate the 2015–2016 spawning probabilities, we first identified the individuals that spawned or didn't spawn in 2015 by comparing the list of tags deployed during the spring 2015 lake sampling to the tags detected during the 2015 spawning run. Then we divided the number of 2015 survivors by the number of survivors that were detected during the 2016 spawning run to obtain $s_{4,5}$ and $s_{4,5}=1-s_{5,5}$. Next we divided the number of 2015 non-spawners by the number of those individuals that were detected during the 2016 spawning run to obtain $s_{4,5}$ and $s_{4,4}=1-s_{4,5}$.

For 2016–2017, we followed a similar but slightly modified process to account for additional tags in the system. The pool of potential 2016 spawners comprised the following groups: the 2015 spawning survivors, 2015 non-spawners, and the tags deployed in the fall 2015 and prior to the spawning run in 2016. We compared this potential pool to the list of 2016 spawners to identify the spawners and non-spawners for 2016. Then we divided the number of 2016 spawning survivors by the number of those individuals that were detected during the 2017 spawning run to obtain $s_{4,5}$ and $s_{4,5}=1-s_{5,5}$. Next we divided the number of 2016 non-spawners by the number of those individuals that were detected during the 2017 spawning run to

obtain $s_{4,5}$ and $s_{4,4}=1-s_{4,5}$. Finally, we used the mean of the 2015–2016 and 2016–2017 probabilities for the model.

We multiplied the respective annual survival rates and spawning probabilities to obtain the spawning transition rates: $p_{5,3} = \varphi_{JB} \times s_{5,3}$, $p_{4,3} = \varphi_{JB} \times s_{4,3}$, $p_{5,5} = \varphi_A \times s_{5,5}$, $p_{4,5} = \varphi_A \times s_{4,5}$, $p_{5,4} = \varphi_A \times s_{5,4}$, and $p_{4,4} = \varphi_A \times s_{4,4}$ (Table 1.1).

Abundance and survival

We used Program Mark [51] to estimate abundance. We selected the robust design Pradel survival and lambda model [52] with the Huggins' p and c closed capture data type [53-54] so that we could use covariate data (sex, fork length, and trap depth) to model the survival and capture/recapture rates [51], and because it was a simpler model for our data set - we didn't need to (nor could we) estimate the additional parameters (e.g., temporary emigration rates) in the standard robust design model. Models were developed with biologically relevant combinations of covariates (linear, quadratic, and interaction terms) and temporal and behavioral variation. Then we performed Akaike information criterion (AIC) model selection to identify the top model [55-56]. The abundance estimates were derived from this model.

Because the Summit Lake system and the lake population are closed, our survival estimates reflected true survival (φ) rather than apparent survival (survival in presence of immigration and emigration, which underestimates true survival) [42]. We estimated the juvenile (φ_{JA} , φ_{JB}) and adult (φ_A) survival rates. For Fry, $p_{2,1}$, we planned to use the survival rate estimated in the Independence Lake population viability analysis [23]. We again used Program Mark [51] to identify the top model, following the same process described above for abundance. Then we created a Bayesian version of the top model to estimate survival. We used the R package *R2jags* [57-58] and the JAGS program [59] to construct and run a Bayesian MCMC (Markov Chain Monte Carlo) model with the following uniform priors for the survival (φ_A), capture (p_{CAPTURE}), and recapture (c) parameters, respectively: uniform (0.6, 0.95), uniform (0.01, 0.1), and uniform (0.01, 0.1). We ran the model with 3 chains of 25,000 iterations and a 5,000 iteration burn-in period, and assessed convergence with the Gelman Rubin diagnostic < 1.1 [60]. The model run provided the posterior mean and standard deviation for adult survival. Then we converted the mean

estimate into an annual survival rate for the population model. We validated the Bayesian MCMC model with a data cloning procedure [61]. Data cloning, by replicating the data set an increasing number (k) of times, uses the Bayesian MCMC framework to provide maximum likelihood estimates (MLE) for model parameters. If the Bayesian model is consistent with the MLE model (Program Mark top model), then the posterior mode and MLE estimate should be the same or very close. Large differences between the estimates could indicate failure of the MCMC chains to actually converge or non-identifiability of some parameters [61].

Population growth rate and sensitivity analysis

Population growth rates less than, equal to, or greater than 1 indicate that the population is decreasing, stable, or increasing, respectively. A sensitivity analysis calculates the change in the population growth rate for a one percent change in a given model parameter, while holding the other parameters constant. The purpose of these analyses is to identify the population's trajectory and the parameters that have the greatest impact on that trajectory [39].

We quantified the uncertainty in these analyses by estimating their probability distributions. First, we applied the coefficient of variation (CV) from adult survival to each stage survival rate and spawning probability. Then, from this population model comprised of a normal distribution (and same CV) for each parameter, we estimated the population growth rate and performed the sensitivity analysis. Using the *popbio* package in R [57,62], we generated 10,000 random samples from the standard normal distribution $N(0, 1)$. Then, in turn, we applied each sample to each parameter distribution in the model to select the respective parameter value, and ran the population growth rate and sensitivity analyses. This produced a histogram with a mean and standard deviation for the population growth rate and the sensitivity of each model parameter.

2.3 Results

In 2016 and 2017, the fry trap was operated for 52 and 45 days (mean= 49 ± 4), respectively. We captured 246 and 428 Fry (mean= 337 ± 91) and 70 and 160 Juvenile A or B (mean= 115 ± 45). The extrapolated totals were 145 and 408 Fry (mean= 277 ± 132) and 54 and 163 Juvenile A or B (mean= 109 ± 55). The total young counts were 515 and 1159 (mean= 837 ± 322), with a combined total 1674 (Table 2.2).

The mark-recapture effort was conducted from late March 2015 to early November 2017 (approximately 2 years and 3 months) for a total of 8 primary (seasons) and 39 secondary (weeks) periods (Table 2.3). The number of weeks per primary period ranged from 2 (pre spawn 2016 and 2017) to 12 (spring 2015) (mean= 5 ± 3). We deployed 630 net sets, ranging from 31 (pre-spawn 2016) to 121 (fall 2015) per primary period (mean= 79 ± 33) (Table 2.4). The total effort resulted in 1690 captures. Captures per primary period ranged from 81 (post-spawn 2016) to 448 (spring 2015), with mean= 211 ± 108 . We tagged 1289 individuals and 328 were recaptured (Table 2.5).

From 2015-2017, respectively, the antenna detected 238, 341, 353 spawning trout (mean= 311 ± 52), of which 107, 200, 233 were female (mean= 180 ± 53). At the fish weir, 268, 465, 446 spawning trout were caught, the proportion of tagged vs. total spawning trout was 0.38, 0.40, and 0.44 (mean= 0.41 ± 0.02), and the female proportion was 0.48, 0.39, 0.48 (mean= 0.45 ± 0.04). Thus, from 2015-2017 we estimated total spawning trout as 619, 862, 803 (mean 761 ± 103), and total female spawners as 225, 513, 471 (mean= 403 ± 127) (Tables 2.6 and 2.7). Since 1978 (a few years after the last hatchery stocking), the fish weir spawning run averaged 1198 ± 583 , with a maximum and minimum of 2400 (1999) and 269 (2015), respectively (Fig 2.4, Table 2.8).

For 2016 and 2017 combined, we calculated the mean fecundity rate= 0.85 ± 0.027 (Table 2.9). We estimated 1674 migrating young, comprised of 1227 Fry and 447 Juvenile A or B individuals (Table 2.2). Assuming a 1:1 sex ratio, 837 females migrated to the lake. We captured 244 tagged and 312 non-tagged females at the fish weir, and the antenna detected 433 tagged females (Table 2.7). Thus we estimated 988 total female spawners. The fecundity rate was 0.50 in 2016, the lower of the two years.

The spawning probabilities for $s_{5,3}$ and $s_{4,3}$ were mean= 0.49 ± 0.018 and 0.51 ± 0.018 , $s_{5,5}$ and $s_{4,5}$ were mean= 0.58 ± 0.05 and 0.42 ± 0.05 , and $s_{5,4}$ and $s_{4,4}$ were mean= 0.18 ± 0.06 and 0.82 ± 0.06 , respectively (Tables 2.10 and 2.11). The spawning transition rates for $p_{5,3}$ and $p_{4,3}$ were mean= 0.25 ± 0.008 and 0.26 ± 0.008 , $p_{5,5}$ and $p_{4,5}$ were mean= 0.36 ± 0.012 and 0.28 ± 0.009 , and $p_{5,4}$ and $p_{4,4}$ were mean= 0.11 ± 0.004 and 0.53 ± 0.017 , respectively (Table 2.9).

We used a subset of the capture histories to estimate abundance and survival. First, because we captured few juveniles, we could not accurately estimate their abundance or survival and thus removed juveniles from these analyses. Next, to better meet the closed population assumptions for each primary period, we removed the last 4 weeks (late April and all of May 2015) of capture data from the first primary period. Those weeks were the height of the 2015 spawning run, so many spawners were unavailable for capture in the lake. This data culling resulted in 35 weeks of capture history data, consisting of 1082 adult (male, female, and unknown sex) and 678 female adult capture histories to estimate adult abundance and adult survival, respectively. The adult female to male ratio was approximately 2:1, not uncommon at Summit Lake or with other lake-dwelling Lahontan cutthroat populations [15,26].

We introduced a ground truthing step to the model selection process for the top model for adult abundance ($n=1082$ capture histories). When we reviewed the top models, we found that some of their estimates or upper confidence limit values were lower than the spawning run counts at the fish weir for 2015-2017. Knowing that these estimates could not be correct (because they represented all adults, not just spawners), we added a ground-truthing step to the model selection process. In this step, we compared the estimates from candidate model set (Table 2.12) against the known spawning run numbers at the fish weir and the estimated total spawning run numbers (2015–2017) (Table 2.6), which are based on the fish weir numbers. Then to minimize subjective bias, we selected as the top model the first model in which total estimated spawning run was below or contained within the confidence interval of the abundance estimate for the spring or pre-spawn abundance estimate for the corresponding year. From this ground-truthed top model we obtained the abundance estimates (Fig 2.5, Table 2.13). The ground-truthed top model had constant survival, and capture/recapture rates that varied per primary period with two (covariate) interaction terms. The first interaction term was fork length and trap depth, and the second was sex and trap

depth. The adult population estimates declined monotonically during the study period, from 2096 individuals in spring 2015 to 661 individuals in Fall 2017 (Fig 2.5, Table 2.13). From 1997-2017, the spawning run decreased linearly (adjusted $r^2=0.85$, $p=1.271e-08$) from 1925 to 438 (77%). The lowest spawning run since 1978 was 269 individuals in 2015 [23].

For adult survival ($n=678$), the top model had constant survival and capture/recapture rates, and no covariates (Table 2.14). The Bayesian version of the top model estimated adult survival with a posterior mean of 0.51 ± 0.016 (Table 2.15). The CV was 0.032. The Gelman Rubin diagnostic was $1.01 < 1.1$, signifying that the 3 chains converged. The data cloning diagnostic indicated that the survival estimate from the Bayesian model was approaching the MLE estimate [46] (Table 2.16). Because we could not estimate juvenile survival from our data, we used juvenile survival from the Independence Lake population viability analysis [26] (Table 2.17).

We applied the CV of adult survival (0.032) to all of the model parameters to generate their probability distributions (Table 2.9). The population growth rate was $\text{mean}=0.52\pm 0.03$ (Fig 2.6). The top three sensitivity parameters were $p_{5,4}$ (0.70 ± 0.0007), $p_{4,4}$ (0.66 ± 0.003), $p_{5,5}$ (0.31 ± 0.00009), respectively (Table 2.18).

2.4 Discussion

The Summit Lake population (using the spawning run as a surrogate for abundance) has exhibited a long term boom/bust cycle [63] with high interannual variability (Figure 2.4). Predator-prey dynamics can cause long term boom/bust cycles or high interannual variability [63] but is not a driver at Summit Lake. The invasive minnows are not a large proportion of the population's diet, and there is enough food in the lake for the Lahontan cutthroat and minnow populations (Chandra, unpublished data). Without other major influences from 1978-2017, the cycle was driven by tribal harvest, drought, and density dependence. From 1978-1991, the population declined amid high tribal harvest (mean~ $18\%\pm 10\%$, min~5%, max~33% [33]) of the spawning run and drought (1987-1991) [15]. Harvest decreases population abundance primarily via direct mortality but can also cause adverse demographics shifts [64-65]. Drought increases direct mortality via decreased habitat and increased water temperature (with less oxygen) and is strongly

correlated (via lower streamflows) with reduced returning females, egg densities, and recruitment [66-69]. From 1992-1999, the population increased approximately five fold when tribal harvest was substantially reduced (since 1992 mean~2%±2%, min~0%, max~8% [33]) and nondrought conditions returned in 1995. That the population increased despite three more years of drought indicates that high tribal harvest was a negative influence and that density dependence replaced tribal harvest as a driver of the cycle henceforth. The overall population decline from 2000-2017 was initiated by an overshoot of the apparent carrying capacity that was then compounded by two droughts from 2007-2009 and 2012-2016 [30,63-64]. When carrying capacity is exceeded, competition (e.g., density dependent processes) reduces trout abundance by lowering population fitness [63,65]. The high interannual variability was driven by high interannual precipitation (e.g., density independent processes). High variability in abundance and precipitation, via the strong correlation between streamflow and recruitment, has been observed with the lake-dwelling Lahontan cutthroat population at Independence Lake as well as other cutthroat and non-cutthroat trout populations [26,69].

Our declining adult abundance and population growth rate estimates corroborate the declining spawning run trend and that the recent drought was likely the primary stressor reducing the population. Our result is significant because it was the lowest rate in our literature review (0.68 – 1.35, Table 2.19) and drought has yet to be implicated as a primary driver for lake-dwelling trout population dynamics (Table 2.19). Declining growth rates were estimated for the lake-dwelling Lahontan and Yellowstone cutthroat (*Oncorhynchus clarkii bouvieri*) populations at Independence Lake (California) and Yellowstone Lake (Wyoming), respectively. However, their confidence intervals overlapped 1, and invasive salmonids were implicated as the cause for the declining rates [26,40]. Angling harvest, invasive species, and a hatchery strain have been proffered as causing negative population growth rates for other North American lake-dwelling trout populations [65,70-74]. Drought (along with invasive salmonids and agricultural dewatering) has been implicated in the declines of river- or stream-dwelling cutthroat trout populations [75-78].

Given the boom/bust cycle, the recent decline in the spawning run, and the legacy effects of drought [66,68], what is the long term prognosis for the Summit Lake population? A boom/bust pattern does not necessarily signal a population at risk of extirpation [63], and trout populations have exhibited

comebacks from precipitous declines and drought [69]. The reduced density dependent pressures [65] of the current bust period and continued non-drought conditions and low tribal harvest should initiate a population rebound. The corresponding increase of 2016 and 2017 spawning runs with increased precipitation may be evidence for a comeback (Table 2.6). However, the 2016-2017 spawning runs could have been simply the reaction to increased precipitation while the adult population continues to decline. In addition, the prognosis seems uncertain for cutthroat populations across western US because of the: approximately equal proportion of increasing or decreasing population growth rates in surveyed populations (Table 2.19), unknown impacts of climate change [6], substantial presence and interaction with invasive species, and unknown effects of future land and water use [79].

At Summit Lake, the declining adult population and population growth rate likely involved the interplay of low fecundity and low transition rates to the Spawning stage. Fecundity was essentially zero. The estimate was low compared to the Independence Lake population (~87 [26]), approximately one half the fecundity at Summit Lake in 1994 (~1.5, also a drought period [15]), and approximately four times lower than the lowest estimate reported for other lake-dwelling cutthroat populations (Table 2.20). If the Summit Lake population was characterized by low fecundity in recent years, the adult population would have had little to zero recruitment. Given that fecundity is strongly correlated with streamflow (precipitation) [69], it is plausible that the drought consistently suppressed fecundity in recent years. Drought induced mechanisms (e.g., less spawning habitat, poor quality eggs, decreased egg hatch rates, reduced larval or fry survival, and high temperature thermal barriers impeding fry migration [7,80]) could have produced the low numbers of migrating young. Also, because we cannot confirm the previous years' fecundity, other factors may have been involved. Another possibility is that even with the strong correlation to streamflow (precipitation), cutthroat trout populations may still exhibit high interannual variability in fecundity. For example, the annual number of migrant young ranged from 0 to 27,046 (9980 ± 8659) for the Independence Lake population, with some years of more streamflow producing less migrating young, and vice versa [26]. Bonneville, Yellowstone, Colorado (*Oncorhynchus clarki pleuriticus*), and hybrid (Colorado and Yellowstone) cutthroat trout have also exhibited high interannual variability in fecundity

[81-82]. High interannual variability of fecundity suggests that pulse recruitment may also be an important driver for lake-dwelling Lahontan cutthroat trout populations [83-86].

The population growth rate at Summit Lake was most sensitive to the Nonspawning and Spawning transition rates. Our results are significant because they have been predicted but not observed. Stapp and Hayward [40] predicted that the adult stages would be the most sensitive because lake-dwelling Yellowstone cutthroat are relatively long-lived (similar to other long-lived species). However, the researchers were surprised to find that the population growth rate was most sensitive to juvenile survival. This finding has been repeated or implicated in most of the trout (including cutthroat trout) population dynamics studies we reviewed (Table 2.19), with two possible exceptions. For a group of stream-dwelling Westslope cutthroat populations, adult survival was identified as a sensitive parameter but juvenile parameters were still more sensitive, adult survival was held constant across the populations, and the sensitivity of adult survival varied between the populations [77]. Finally, though a matrix model was not used to estimate the population growth rate and a sensitivity analysis was not performed, low adult survival (via high spawning mortality and poor overwintering habitat) was hypothesized to have the greatest impact on a river population of bull trout [74].

The Nonspawning and Spawning transition rates are the product of adult survival and the respective nonspawning or spawning probabilities. Borrowing from the concept of remnant populations (for plants) [87], natural selection may favor adult survival over fecundity or juvenile survival for species or populations in harsh or highly variable habitats with limited resources (e.g.; deserts). In these environments, natural selection may favor the ability for adults to survive long enough to produce offspring upon the return of favorable conditions.

Female adult survival at Summit Lake was approximately mid-range to the adult survival from three other Lahontan cutthroat studies, but it still may be considered low (Table 2.21). The Walker Lake, Nevada (also a desert terminal lake) study estimated adult survival at 0.44 in 1999 (highest rate of the study period) [88]. True survival was estimated, but hatchery Lahontan cutthroat, which can exhibit lower fitness than wild conspecifics [89-90], were used for the experiments; and at approximately 11 g/L, the TDS level in 1999 was already beyond the level to significantly reduce survival [91-92]. The Truckee River (Nevada)

study had the lowest rate (0.36) [93], but three factors may have biased that estimate downward. Apparent survival (which is always lower than true survival) was estimated [42], hatchery Lahontan cutthroat were used [89-90], and the size of the fish used indicated that they were either large juveniles or first year adults, which could have still been subject to high competition and predation pressure by the more abundant wild populations of brown and rainbow trout in the Truckee River [13]. Independence Lake had the highest rate. Though the Independence Lake population shares the lake with invasive salmonids, the population is wild and had favorable climate conditions [94] during their population viability analysis [25]. Thus, rather than cast doubt, the lower estimates in these studies may support that the Summit Lake estimate in our study was low and the result of an extreme factor such as drought.

Summit Lake adult survival may have decreased via drought mechanisms in Mahogany Creek and the lake. Lower streamflows reduced habitat, which increased the stress of spawning activities (redd and mate search, competition or defense) [7] and decreased predation refugia [95]. Summit Lake Paiute Tribe biologists observed a high proportion of postspawners in poor condition and terrestrial and avian predation [96-97]. In addition, increased water temperatures (less oxygen) [98] probably increased the stress of spawning activities and the mortality of postspawners [7]. Indirect mechanisms included stressors that may have reduced survival over time (e.g., via lowered immunity [7]). In the creek, increased spawning stress probably reduced energy for future survival; and in the lake, the lake level drop (~27%, [23]) and resulting evapoconcentration (increased solute concentration [99]) likely reduced the population's optimal habitat between the warmer surface layer and anoxic bottom layer [28], and increased the chemical stress. Evapoconcentration has negatively affected lake-dwelling Lahontan cutthroat and other fish in Walker Lake (another desert terminal lake in the region) [91-92]. Spawning mortality was 74%, 48%, 47% (Table 2.22) from 2015-2017 (with increasing precipitation) and 89% and 65% in 1993 and 1994 (the last two years of an eight year drought [15]), respectively. These spawning mortality estimates are generally higher than the estimates for lake-dwelling Yellowstone cutthroat at Yellowstone Lake (48%, 31%, and 13%) [40].

Skipped spawning is hypothesized to be a life history adaptation to balance the lifetime trade-off between survival and reproduction. Females maximize fitness by maximizing lifetime egg production or

progeny. However, when energetically costly spawning activities (e.g. migration) threaten post spawn survival (jeopardizing future spawning attempts), surviving to subsequent years may be selected over near term spawning. The energy that would have been devoted to spawning can be redirected to growth, with larger individuals typically producing more (and higher quality) eggs. Through survival and growth, individuals may maximize fitness via skipped spawning [37]. Thus, skipped spawning may be a particularly advantageous strategy for species and populations in highly variable and extreme environments. As a relatively long-lived species that exhibits skipped spawning, lake-dwelling Lahontan cutthroat of Summit Lake may exhibit this life history strategy.

Estimating the probability of spawning the year after not spawning (and thus remaining a nonspawning adult) was a unique feature of this study. For example, Stapp and Hayward [40] assumed that a skipped spawning event would always be followed by a spawning attempt. In the literature, we did not find similar estimates for any trout populations. Thus for comparison we calculated the same probability for the lake-dwelling Lahontan cutthroat at Independence Lake, using their individual spawning histories [26]. The stark difference in probabilities (86% at Independence Lake) highlights that the comparatively low probability at Summit Lake may have had significant negative impact on population growth, and was likely the reason why the nonspawning transitions were the most sensitive parameters. Given the rationale for skipped spawning behavior, it is plausible that a greater proportion of adults will move to the nonspawning stage and stay there during drought.

The repeat Spawning transition was the third most sensitive parameter at Summit Lake. The probability of repeat spawning at Summit Lake seems toward the high end for trout (including cutthroat trout) populations. Repeat spawning probabilities for Yellowstone and Lahontan cutthroat at Yellowstone and Independence Lakes were 34% and 64%, respectively [26,40], and 88%, <50%, 42% for lake trout populations [38,71]. The Yellowstone cutthroat estimate was derived by analyzing scales [40]; the Independence Lake estimate was calculated from their individual spawning run histories [26]; the lake trout studies performed sampling in one year only and determined the proportion of spawners from the state of the reproductive organs [38,71]. Thus with different methods, and some that didn't track individuals over time, the estimates may be difficult to compare. The closest comparison is with the Lahontan cutthroat at

Independence Lake [26]. The probabilities were similar, but considering again that small changes in vital rates can have large impacts on population growth [100], the lower rate at Summit Lake may have been significant.

Intertwined drought mechanisms in the creek and lake likely increased skipped spawning by reducing reproductive energy. The stressors mentioned above (for adult survival) could have also negatively impacted reproduction [7,99,101]. Next, because lake-dwelling Lahontan cutthroat obtain a large percentage of nutrition from the littoral zone [46-47,49,102], the reduced littoral zone may have reduced the nutritional intake for adults and juveniles. Fewer juveniles may have entered or completed puberty (retarded gonad development), which may also be argued as skipped spawning [46,103-108]. Last, low streamflows triggered less participation in the spawning runs [109]. In 2016-2017, the increase in the repeat spawning and nonspawning to spawning probabilities, and the larger spawning runs, support these mechanisms.

The above average precipitation during the Independence Lake population viability analysis [26, 94] may have resulted in comparatively high juvenile survival rates that biased our sensitivity analysis to the adult stages. Given that the Summit Lake fecundity and transition rates to the spawning stage were lower than at Independence Lake, Summit Lake fry and juvenile survival could have been lower as well. Fry and juvenile survival can be decreased by drought in many ways [7]. Cannibalism may have increased on juveniles forced out of the littoral zone [109]. However, the Independence Lake population estimates are approximately mid-range compared to other trout (including cutthroat trout) populations (Table 2.23) and thus may not have biased our results in either direction. In addition, the results of the sensitivity analysis did not change when we halved the Fry and Juvenile A and B survival rates. Thus, it is unlikely that fry and juvenile survival could have been the most sensitive parameters during this study.

Based on our results, lake-dwelling Lahontan cutthroat at Summit Lake may have life history adaptation(s) (high sensitivity of adult survival and skipped spawning) for desert habitat. Lahontan cutthroat are tolerant of relatively warm, alkaline water [11,13,17-18], and the Summit Lake population is genetically distinct (likely due to its isolation) from other Lahontan cutthroat populations [19-20]. In addition, considering recent research that demonstrates the life history adaptations of salmonids in different

habitats [111], and variation of population dynamics (within and between populations) in a variable environment [112], it is plausible that the Summit Lake population has specific life history traits for the desert environment. However, additional hypotheses may explain our results. The potential life history adaptation(s) may apply to all lake-dwelling cutthroat trout in desert systems, or to all lake-dwelling cutthroat trout populations— montane or desert, or more broadly (based on Stapp and Hayward's [40] prediction) to most or all native lake-dwelling trout populations. In the studies for which juvenile survival had the highest sensitivity, invasive predation and an inferior hatchery strain were hypothesized to be causes for the low fry and juvenile survival. Therefore, without invasive predation or other negative influences, high adult sensitivities may be the norm for self-sustaining lake-dwelling trout populations. Last, the high adult sensitivities may simply be a plastic response by lake-dwelling cutthroat trout populations to handle drought.

Most cutthroat trout population dynamics research has been conducted in the rivers, streams, and lakes of the Rocky and Sierra Nevada Mountains. This study has highlighted the importance of understanding cutthroat trout population dynamics in desert terminal lakes. Climate change has already increased hybridization and invasion between cutthroat trout and invasive trout [113-114] and will likely threaten cutthroat trout persistence by increasing stochastic (genetic, demographic, environmental) vulnerability via a host of factors [115]. Because they live at the habitat extremes for high air and water temperatures and low precipitation, desert cutthroat trout populations may be the first at risk and the most impacted by climate change. Lake-dwelling cutthroat trout populations especially may serve as sentinels to the impacts of climate change on other cutthroat trout ecosystems and populations, just as lakes have been shown to be sentinels of climate change in general [116]. The relatively pristine state of the population and watershed makes Summit Lake ideal for continued research and comparison to other cutthroat trout and trout populations and systems (Table 2.19).

Limitations of Study and Opportunities for Research

This study quantified population dynamics over a short period of time which encompassed a period of prolonged drought, so future research should focus on extending the study to determine the long term population trend and prognosis under variable biotic (including density dependence [65]) and abiotic conditions (preferably with a good mix of above, below and average precipitation years), and to improve parameter estimates. New sampling methods can be employed to capture more juveniles (e.g. boat electroshocking or smaller nets in the shallow zones) and sample areas further from shore (e.g. longer or larger trap nets). And a more accurate survival estimation model (such as Barker models) could be used. Next, stable, declining, or increasing trends may warrant different management strategies, especially within the context of climate change [6,8]. Little research exists at this level for lake-dwelling cutthroat trout. Last, given the amount of data, we started with a relatively simple stage-classified model. A more complex population model, such as a two-sex (to address unequal sex ratios) integrated population model (IPM), should be considered. IPMs are a relatively new and popular class of population models because they can utilize data from multiple sources (e.g., the antenna and fish trap data) and reduce parameter uncertainty to provide more accurate estimates [117].

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2.5 References

1. Butchart SH, Walpole M, Collen B, van Strien A, Scharlemann JP, Almond RE, et al. Global biodiversity: indicators of recent declines. *Science*. 2010;328(5982):1164-68.
2. Ricciardi A, Rasmussen JB. Extinction rates of North American freshwater fauna. *Conserv Biol*. 1999;13:1220-2.
3. Burkhead NM. Extinction rates in North American freshwater fishes, 1900-210. *Bioscience*. 2012;62(9):798-808.
4. Cayan DR, Dettinger MD, Pierce D, Das T, Knowles N, Ralph FM, et al. Natural variability, anthropogenic climate change, and impacts on water availability and flood extremes in the western United States. In Miller KA, Hamlet AF, Kenney DS, Redmond KT, editors. *Water policy and planning in a variable changing climate*. Boca Raton: CRC Press; 2016. p. 17-42.
5. Harpold AA, Dettinger M, and Rajagopal S. Defining snow drought and why it matters. *Eos* 2017;98 <https://doi.org/10.1029/2017EO068775>.
6. Lynch AJ, Myers BJ, Chu C, Eby LA, Falke JA, Kovach RP, et al. Climate change effects on North American inland fish populations and assemblages. *Fisheries*. 2016;41(7):346-61.
7. Whitney JE, Al-Chokhachy R, Bunnell DB, Caldwell CA, Cooke SJ, Eliason EJ, et al. Physiological basis of climate change impacts on North American inland fishes. *Fisheries*. 2016;41(7):332-45.
8. Paukert C, Glazer BA, Hansen GJA, Irwin BJ, Jacobson PC, Kershner JL, Shuter BJ, Whitney JE, Lynch AJ. Adapting inland fisheries management to a changing climate. *Fisheries*. 2016;41(7):374-84.
9. Trotter P. *Cutthroat: native trout of the West*. 2nd ed. Berkeley: University of California Press; 2008.
10. Loxterman JL, Keeley ER. Watershed boundaries and geographic isolation: patterns of diversification in cutthroat trout from western North America. *BMC Evol Biol*. 2012;12(1):38.
11. Vigg S, Koch DL. Upper lethal temperature range of Lahontan cutthroat trout in waters of different ionic concentration. *Trans Am Fish Soc*. 1980;109:336-9.
12. U.S. Fish and Wildlife Service [Internet]. Falls Church, Virginia (USA): U.S. Fish and Wildlife Service; May 7, 2018. Environmental conservation online system; April 17, 2017 [cited 7 May 2018]; [3 screens]. Available from: <https://ecos.fws.gov/ecp0/pub/SpeciesReport.do?groups=E&listingType=L&mapstatus=1>.
13. Gerstung ER. Status, life history, and management of the Lahontan cutthroat trout. In: Gresswell RE, editor. *Status and management of interior stocks of cutthroat trout*. Bethesda: American Fisheries Society; 1988. p. 93-106.
14. Coffin PD, Cowan WF. Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) recovery plan. Portland, OR: U.S. Fish and Wildlife Service, Region 1; 1995. 108 p.
15. Vinyard GL, Winzeler A. Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) spawning and downstream migration of juveniles into Summit Lake, Nevada. *West N Am Nat*. 2000;60(3):333-41.

16. Summit Lake Paiute Tribe [Internet]. Sparks, Nevada (USA): Summit Lake Paiute Tribe; 2018. Our Story; 2018 [cited 2018 Jan 22]; [1 screen]. Available from: <http://www.summitlaketribe.org/about-us.html>.
17. Wilkie MP, Wood C. The adaptations of fish to extremely alkaline environments. *Comp Biochem Physiol B Biochem Mol Biol*. 1996;113(4):665-73.
18. Dickerson BR, Vinyard GL. Effects of high chronic temperatures and diel temperature cycles on the survival and growth of Lahontan cutthroat trout. *Trans Am Fish Soc*. 1999;128:516-21.
19. Gall and Loudenslager 1981. Biochemical genetics and systematics of Nevada trout populations. Final Report to Nevada Department of Wildlife, Reno.
20. Nielsen JL, Sage GK. Population genetic structure in Lahontan cutthroat trout. *Trans Am Fish Soc*. 2002;131:376-88.
21. La Rivers I. Fishes and fisheries of Nevada. Reno: University of Nevada Press; 1994.
22. Marino DA. Summary report for hydroacoustic survey of Summit Lake, Nevada, 30 September – 2 October, 1996. Seattle, Washington (USA): BioSonics, Inc.; 1997. 78 p.
23. Youmans R, Zeyer R, Mathews K, Cowan W. 2016 Annual Narrative Report. Sparks, Nevada (USA): Summit Lake Paiute Tribe; 2017. 35 p. Report No.: Fisheries Management Services Contract Number A10AV00358.
24. De Lara M, Doyen L, Guilbaud T, Rochet M. Is a management framework based on spawning-stock biomass indicators sustainable? A viability approach. *ICES J Mar Sci*. 2007;64:761–7.
25. Boyce, MS. Population viability analysis. *Annu Rev Ecol Syst*. 1992;23:481-506.
26. Rissler PH, Scopettone GG, Shea S. Life history, ecology and population viability analysis of the Independence Lake strain Lahontan cutthroat trout (*Oncorhynchus clarkii henshawi*). Reno: U.S. Geological Survey, Western Fisheries Research Center; 2006.
27. Curry BB, Melhorn WN. Summit Lake landslide and geomorphic history of Summit Lake basin, northwestern Nevada. *Geomorphology*. 1990;4:1-17.
28. Vigg S. Limnological survey of Summit Lake, Nevada. Reno, NV: Desert Research Institute, Bioresources Center; 1983. 45 p.
29. Xue T, Tang G, Sun L, Wu Y, Liu Y, Dou Y. Long-term trends in precipitation and precipitation extremes and underlying mechanisms in the U.S. Great Basin during 1951–2013. *J Geophys Res Atmos*. 2017;122:6152–69.
30. Wise E. Five centuries of US West Coast drought: occurrence, spatial distribution, and associated atmospheric circulation patterns. *Geophys Res Lett*. 2016;43:4539–46. doi:10.1002/2016GL068487.
31. Campbell T, Simmons J, Sáenz J, Zeyer R, Jerde CL, Cowan W, Chandra S, Hogan Z. Population connectivity of adfluvial and stream-resident Lahontan cutthroat trout: Implications for resilience, management, and restoration. *Can J Fish Aquat Sci*. Forthcoming 2018.
32. Summit Lake Paiute Tribe [Internet]. Sparks, Nevada (USA): Summit Lake Paiute Tribe; 2018. Minutes-Resolutions; 2018 [cited 2018 May 7]; [3 screens]. Available from: <http://www.summitlaketribe.org/minutes-resolutions.html>.

33. 1968-2016 Summit Lake Paiute Tribe annual narrative reports. Sparks, Nevada (USA): Summit Lake Paiute Tribe.
34. Novak-Echenique P, Youmans R. Summit Lake Indian Reservation Range Management Plan. Sparks, Nevada (USA): United States Department of Agriculture, Natural Resources Conservation Service and Summit Lake Paiute Tribe; March 2013. 38 p.
35. Cowan WF. Interpretation of pertinent statistics concerning the Summit Lake fisheries management program, 1968-1990. Winnemucca, Nevada (USA): Summit Lake Paiute Tribe; 1991. 7 p.
36. U.S. Fish and Wildlife Service [Internet]. Falls Church, Virginia (USA): U.S. Fish and Wildlife Service; May 7, 2018. Lahontan cutthroat trout, *Oncorhynchus clarkii henshawi*; April 16, 2014 [cited 7 May 2018]; [6 screens]. Available from: https://www.fws.gov/nevada/protected_species/fish/species/lct.html.
37. Rideout RM, Rose GA, Burton MP. Skipped spawning in female iteroparous fishes. *Fish Fish*. 2005;6:50-72.
38. Sitar S, Jasonowicz A, Murphy C, Goetz F. Estimates of skipped spawning in lean and siscowet lake trout in southern Lake Superior: implications for stock assessment. *Trans Am Fish Soc*. 2014;143:660-72.
39. Caswell H. Matrix population models: construction, analysis and interpretation. Second edition. Sunderland: Sinauer Associates; 2001.
40. Stapp P, Hayward GD. Effects of an introduced piscivore on native trout: insights from a demographic model. *Biol Invasions*. 2002;4:299-316.
41. Meyer KA, Schill DJ, Elle FS, Lamansky Jr. JA. Reproductive demographics and factors that influence length at sexual maturity of Yellowstone cutthroat trout in Idaho. *Trans Am Fish Soc*. 2003;132:183-95.
42. Williams BK, Nichols JD, Conley MJ. Analysis and management of animal populations. San Diego: Academic Press; 2002.
43. Gibbons JW, Andrews KM. PIT tagging: simple technology at it best. *Bioscience*. 2004;54(5):447-54.
44. Hubert WA, Pope KL, Dettmers JM. Passive Capture Techniques. In: Zale AV, Parrish DL, Sutton TM, editors. *Fisheries Techniques*. 3rd ed. Bethesda: American Fisheries Society; 2012. p. 223-65.
45. Sigler WF, Helm WT, Kucera PA, Vigg S, Workman GW. Life history of the Lahontan cutthroat trout, *Salmo clarki henshawi*, in Pyramid Lake, NV. *Great Basin Nat*. 1983;43(1):1-29.
46. Beauchamp DA, Vecht, SA, Thomas GL. Temporal, spatial, and size-related foraging of wild cutthroat trout in Lake Washington. *Northwest Sci*. 1992;66(3):149-59.
47. Baldwin CS, Beauchamp DA, Gubala CP. Seasonal and diel distribution and movement of cutthroat trout from ultrasonic telemetry. *Trans Am Fish Soc*. 2002;131:143-58.
48. Kendall WL, Pollock KH. The robust design in capture-recapture studies: a review and evaluation by Monte Carlo simulation. In: McCullough DR, Barrett RH, editors. *Wildlife 2001: populations*. London: Elsevier; 1992. p. 31-43.

49. Nowak GM, Tabor RA, Warner EJ, Fresh KL, Quinn TP. Ontogenetic shifts in habitat and diet of cutthroat trout in Lake Washington, Washington. *N Am J Fish Manag.* 2004;24:624–35.
50. Morán P, Labbé L, Garcia de Leaniz C. The male handicap: male-biased mortality explains skewed sex ratios in brown trout embryos. *Biol Lett.* 2016;12(12):20160693.
51. White GC, Burnham KP. Program MARK: survival estimation from populations of marked animals. *Bird Stud.* 1999;46:120–39.
52. Pradel R. Utilization of capture–mark–recapture for the study of recruitment and population growth rate. *Biometrics.* 1996;52(2):703–09.
53. Huggins RM. On the statistical analysis of capture experiments. *Biometrika.* 1989;76:133–40.
54. Huggins RM. Some practical aspects of a conditional likelihood approach to capture experiments. *Biometrics.* 1991;47:725–32.
55. Akaike H. Information theory as an extension of the maximum likelihood principle. In Petrov BN, Csaki F, editors. *Second International Symposium on Information Theory.* Akademiai Kiado. p. 267–81. 1973.
56. Burnham KP, Anderson DR. *Model selection and multimodel inference: a practical information-theoretic approach.* Second edition. New York: Springer; 2002.
57. R Core Team. *R: A language and environment for statistical computing.* Vienna, Austria: R Foundation for Statistical Computing; 2016. Available from: <http://www.R-project.org/>
58. Su Y, Yajima M. R2Jags: using R to run 'JAGS'. R package version 0.5-7. 2015. Available from: <https://cran.r-project.org/web/packages/R2jags>
59. Plummer M. *JAGS: A program for analysis of Bayesian graphical models using Gibbs sampling;* 2016; Vienna, Austria.
60. Gelman A, Rubin DB. Inference from iterative simulation using multiple sequences. *Stat Sci.* 1992;7:457–511.
61. Lele SR, Dennis B, Lutscher F. Data cloning: easy maximum likelihood estimation for complex ecological models using Bayesian Markov chain Monte Carlo methods. *Ecol Lett.* 2007;10:551–63. DOI: 10.1111/j.1461-0248.2007.01047.x.
62. Stubben C, Milligan B, Nantel P. Popbio: construction and analysis of matrix population models. R package version 2.4.3. 2016. Available from: <https://CRAN.R-project.org/package=popbio>
63. Sinclair AR, Fryxell JM, Caughley G. *Wildlife ecology, conservation and management.* Second edition. Malden: Blackwell Publishing LTD; 2006.
64. Gresswell RE, editor. *Status and management of interior stocks of cutthroat trout.* Bethesda: American Fisheries Society; 1998.
65. Johnston FD, Post JR. Density-dependent life-history compensation of an iteroparous salmonid. *Ecol Appl.* 2009;19(2):449–67.
66. Elliott JM, Hurley MA, Elliott JA. Variable effects of droughts on the density of a seat-trout *Salmo trutta* population over 30 years. *J Appl Ecol.* 1997;34:1229–38.

67. Humphries P, Baldwin D. Drought and aquatic ecosystems: an introduction. *Freshw Biol.* 2003;48:1141-46.
68. Matthews WJ, Marsh-Matthews E. Effects of drought on fish across axes of space, time, and ecological complexity. *Freshw Biol.* 2003;48:1232-53.
69. Lobon-Cervia J. Why, when and how do fish populations decline, collapse and recover? The example of brown trout (*Salmo trutta*) in Rio Chaballos (northwestern Spain). *Freshw Biol.* 2009;54:1149–62.
70. Cox BS, Guy CS, Fredenberg WA, Rosenthal LR. Baseline demographics of a non-native lake trout population and inferences for suppression from sensitivity-elasticity analyses. *Fish Manag Ecol.* 2013;20:390–400.
71. Ng EL, Fredericks JP, Quist MC. Population dynamics and evaluation of alternative management strategies for nonnative lake trout in Priest Lake, Idaho. *N Am J Fish Manag.* 2016;36(1):40-54.
72. High B, Meyer K, Schill DJ, Mamer ERJ. Distribution, abundance, and population trends of bull trout in Idaho. *N Am J Fish Manag.* 2008;28:1687-1701.
73. Brenden TO, Bence JR, Lantry BF, Lantry JR, Schaner T. Population dynamics of Lake Ontario lake trout during 1985-2007. *N Am J Fish Manag.* 2011;31:962-79.
74. Budy PE, Bowerman T, Al-Chokhachy R, Conner M, Schaller H. Quantifying long-term population growth rates of threatened bull trout: challenges, lessons learned, and opportunities. *Can J Fish Aquat Sci.* 2017;74:2131-43.
75. Budy P, Thiede GP, McHugh P. Quantification of the vital rates, abundance, and status of a critical, endemic population of Bonneville cutthroat trout. *N Am J Fish Manag.* 2007;27:593–604.
76. Meyer KA, Larson EI, Sullivan CL, High B. Trends in the distribution and abundance of Yellowstone cutthroat trout and nonnative trout in Idaho. *J Fish Wildl Manag.* 2014;5(2):227-42.
77. Carim KJ, Vindenes Y, Eby LA, Barfoot C, Vøllestad LA. Life history, population viability, and the potential for local adaptation in isolated trout populations. *Glob Ecol Conserv.* 2017;10:93-102.
78. Kennedy P, Meyer K. Trends in abundance and the influence of bioclimatic factors on Westslope cutthroat trout in Idaho. *J Fish Wildl Manag.* 2015;6(2):305-17.
79. Penaluna BE, Abadia-Cardoso A, Dunham JB, Garcia-De Leon FJ, Gresswell RE, Luna AR, et al. Conservation of native Pacific trout diversity in western North America. *Fisheries.* 2016;41(6):286-300.
80. Recsetar M, Bonar S. Survival of Apache trout eggs and alevins under static and fluctuating temperature regimes. *Trans Am Fish Soc.* 2013;142:373–79.
81. Knight CA. Spawning attributes and early life-history strategies of adfluvial cutthroat trout in Strawberry Basin, Utah [masters thesis]. Logan, UT; Utah State University; 1997. p. 115
82. Drummond RA, McKinney TD. Predicting the recruitment of cutthroat trout fry in Trappers Lake, Colorado. *Trans Am Fish Soc.* 1965;94(4):389-93.
83. Ebert TA, Schroeter SC, Dixon JD. Inferring demographic processes from size-frequency distributions: effect of pulsed recruitment on simple models. *Fish Bull.* 1993;91:237-43.

84. Pfister CA. The role and importance of recruitment variability to a guild of tide pool fishes. *Ecology*. 1996;6:1928-41.
85. Tang S, Chen L. Density-dependent birth rate, birth pulses and their population dynamic consequences. *J Math Biol*. 2002;44:185-99.
86. Bergstad OA, Hansen Hø, Jørgensen T. Intermittent recruitment and exploitation pulse underlying temporal variability in a demersal deep-water fish population. *ICES J Mar Sci*. 2014;71(8):2088–2100. doi:10.1093/icesjms/fst202.
87. Eriksson O. Functional roles of remnant plant populations in communities and ecosystems. *Glob Ecol Biogeogr*. 2000;9(6):443-49.
88. Sedinger JS, Blomberg EJ, VanDellen AW, Byers S. Environmental and population strain effects on survival of Lahontan cutthroat trout in Walker Lake, Nevada: a Bayesian approach. *N Am J Fish Manag*. 2012;32:515–22.
89. Kostow K. Differences in juvenile phenotypes and survival between hatchery stocks and a natural population provide evidence for modified selection due to captive breeding. *Can J Fish Aquat Sci*. 2004;61:577–89.
90. Araki H, Berejikian BA, Ford MJ, Blouin MS. Fitness of hatchery-reared salmonids in the wild. *Evol Appl*. 2008;1(2):342–55.
91. Dickerson BR, Vinyard GL. Effects of high levels of total dissolved solids in Walker Lake, Nevada, on survival and growth of Lahontan cutthroat trout. *Trans Am Fish Soc*. 1999; 128:507–15.
92. Marioni N. Effects of declining lake levels on fish populations in Walker Lake, NV [masters thesis]. Reno, NV; University of Nevada; 2007. p. 134
93. Alexiades AV, Peacock MM, Al-Chokhachy R. Movement patterns, habitat use, and survival of Lahontan cutthroat trout in the Truckee River. *N Am J Fish Manag*. 2012;32:974–83.
94. Margulis SA, Cortés G, Giroto M, Durand M. A Landsat-era Sierra Nevada snow reanalysis (1985–2015). *J Hydrometeor*. 2016;17:1203-21.
95. Magoulick DD, Kobza RM. The role of refugia for fishes during drought: a review and synthesis. *Freshw Biol*. 2003;48:1186-1198.
96. Saenz J, Zeyer R, Cowan W. 2014 Annual Narrative Report. Sparks, Nevada (USA): Summit Lake Paiute Tribe; 2015. 29 p. Report No.: Fisheries Management Services Contract Number A10AV00358.
97. Zeyer R, Sáenz J, Cowan W. 2015 Annual Narrative Report. Sparks, Nevada (USA): Summit Lake Paiute Tribe; 2016. 34 p. Report No.: Fisheries Management Services Contract Number A10AV00358.
98. Helfman GS, Collette BB, Facey DE, Bowen BW. The diversity of fishes: biology, evolution, and ecology. 2nd edition. Chichester: Wiley-Blackwell; 2009.
99. Horne A, Goldman C. *Limnology*. 2nd ed. New York: McGraw-Hill, Inc.; 1994.
100. Houde ED. Fish early life dynamics and recruitment variability. *Am Fish Soc Symp*. 1987;2:17-29.

101. Schreck C, Contreras-Sanchez W, Fitzpatrick M. Effects of stress on fish reproduction, gamete quality, and progeny. *Aquaculture*. 2001;197:3–24.
102. Nowak GM, Quinn TP. Diel and seasonal patterns of horizontal and vertical movements of telemetered cutthroat trout in Lake Washington, Washington. *Trans Am Fish Soc*. 2002;131:452–62.
103. Tocher DR. Metabolism and functions of lipids and fatty acids in teleost fish. *Reviews in fisheries science*. 2003;11(2): 107-84.
104. Valdebenito II, Gallegos PC, Effer BR. Gamete quality in fish: evaluation parameters and determining factors. *Zygote*. 2015;23(2):177-97. doi: 10.1017/S0967199413000506.
105. Hill H, Twibell R, Conway J, Gannam A, Seals J. Influence of lineage, broodstock conditioning, and hormone injection on Gila trout reproductive success and egg fatty acid composition. *N Am J Aquac*. 2013;75:393-403.
106. Izquierdo MS, Fernández-Palacios H, Tacon AG. Effect of broodstock nutrition on reproductive performance of fish. *Aquaculture*. 2001;197:25-42.
107. Pickova J, Brännäs E, Andersson T. Importance of fatty acids in broodstock diets with emphasis on Arctic char (*Salvelinus alpinus*) eggs. *Aquac Int*. 2007;15:305–11.
108. McBride RS, Somarakis S, Fitzhugh GR, Albert A, Yaragina NA, Wuenschell MJ, Alonso-Fernández A, Basilone G. Energy acquisition and allocation to egg production in relation to fish reproductive strategies. *Fish Fish*. 2015;16:23-57.
109. Jonsson B, Jonsson N, Hansen LP. Factors affecting river entry of adult Atlantic salmon in a small river. *J Fish Biol*. 2007;71:943–56.
110. Baldwin CM, Beauchamp DA, Van Tassell JJ. Bioenergetic assessment of temporal food supply and consumption demand by salmonids in the Strawberry Reservoir food web. *Trans Am Fish Soc*. 2000;129:429–50.
111. Blair GR, Rogers DE, Quinn TP. Variation in life history characteristics and morphology of sockeye salmon in the Kvichak River system, Bristol Bay, Alaska. *Trans Am Fish Soc*. 1993;122:550-9.
112. Vincenzi S, Mangel M, Jesenšek D, Garza JC, Crivelli AJ. Within- and among-population variation in vital rates and population dynamics in a variable environment. *Ecol Appl*. 2016;26(7):2086-2102.
113. Muhlfeld CC, Kovach RP, Jones LA, Al-Chokhachy R, Boyer MC, Leary RF, Lowe WH, Luikart G, Allendorf FW. Invasive hybridization in a threatened species is accelerated by climate change. *Nat Clim Chang*. 2014;4(7):620-4.
114. Roberts JJ, Fausch KD, Hooten MB, Peterson DP. Nonnative trout invasions combined with climate change threaten persistence of isolated cutthroat trout populations in the southern Rocky Mountains. *N Am J Fish Manag*. 2017;37:314-25.
115. Williams JE, Haak AL, Neville HM, Colyer WT. Potential consequences of climate change to persistence of cutthroat trout populations. *N Am J Fish Manag*. 2009;29:533-48.
116. Adrian R, O'Reilly CM, Zagarese H, Baines SB, Hessen DO, Keller W, et al. Lakes as sentinels of climate change. *Limnol Oceanogr*. 2009;54(6):2283–97.

117. Tenan S, Iemma A, Bragalanti N, Pedrini P, De Barba M, Randi E, et al. Evaluating mortality rates with a novel integrated framework for nonmonogamous species. *Conserv Biol.* 2016;30(6):1307–19.
118. Peacock M. Biology 431 Ichthyology Lecture 8: Juveniles, adults, and age and growth. Lecture presented at; University of Nevada Reno; 2014.
119. Al-Chokhachy R, Budy P. Demographic characteristics, population structure, and vital rates of a fluvial population of bull trout in Oregon. *Trans Am Fish Soc.* 2008;137(6):1709-22.
120. Syslo JM, Guy CS, Bigelow PE, Doepke PD, Ertel BD, Koel TM. Response of non-native lake trout (*Salvelinus namaycush*) to 15 years of harvest in Yellowstone Lake, Yellowstone National Park. *Can J Fish Aquat Sci.* 2011;68:2132–2145.
121. Mills KH, Chalanchuk SM, Allan DJ. Abundance, annual survival, and recruitment of unexploited and exploited lake charr, *Salvelinus namaycush*, populations at the Experimental Lakes Area, northwestern Ontario. *Environ Biol Fishes.* 2002;64:281–292.
122. Bowerman T, Budy P. Incorporating movement patterns to improve survival estimates for juvenile bull trout. *N Am J Fish Manag.* 2012;32(6):1123-36.
123. Uhte P, Al-Chokhachy R, Zale AV, Shepard BB, McMahon TE, Stephens T. Life history characteristics and vital rates of Yellowstone cutthroat trout in two headwater basins. *N Am J Fish Manag.* 2016;36:1240–53.
124. Rissler P. Independence Lake 2014 Update. Reno, Nevada (USA): Status update presented at; LCT (Lahontan cutthroat trout) Interagency Meeting; 2015.
125. Jones J. California's most significant droughts: comparing historical and recent conditions. Sacramento, California (USA): California Natural Resources Agency, Department of Water Resources; February 2015. 126 p.

2.6 Tables and figures

Table 2.1. Parameter definitions for the lake-dwelling Lahontan cutthroat stage-classified life history and population matrix models (Figs 2.2 and 2.3, respectively).

<i>Parameter</i>	<i>Support</i>	<i>Derivation</i>	<i>Description</i>
$f_{1,5}$	$\{0, 1, 2, \dots\}$	F/S	Recruitment: average number of female Fry (F , <100 mm) that return to the lake per female that spawned (S)
$p_{2,1}$	$\{0 < p_{2,1} < 1\}$	φ_F	Fry survival to Juvenile A (100 mm ≤ Juvenile A < 199 mm) stage
$p_{3,2}$	$\{0 < p_{3,2} < 1\}$	φ_{JA}	Juvenile A survival to Juvenile B (200 mm ≤ Juvenile B < 299 mm) stage
$p_{4,3}$	$\{0 < p_{4,3} < 1\}$	$\varphi_{JB} \times s_{4,3}$	Proportion of Juvenile B that survive (φ_{JB}) and transition to Non-spawning adults ($s_{4,3} \geq 300$ mm)
$p_{4,4}$	$\{0 < p_{4,4} < 1\}$	$\varphi_A \times s_{4,4}$	Proportion that survive as Non-spawning adult (φ_A) but stay in Non-spawning adult stage ($s_{4,4}$)
$p_{4,5}$	$\{0 < p_{4,5} < 1\}$	$\varphi_A \times s_{4,5}$	Proportion of Spawning adults that survive (φ_A) and transition to Non-spawning adults ($s_{4,5}$)
$p_{5,3}$	$\{0 < p_{5,3} < 1\}$	$\varphi_{JB} \times s_{5,3}$	Proportion of Juvenile B that survive (φ_{JB}) and transition to Spawning adults ($s_{5,3} \geq 300$ mm)
$p_{5,4}$	$\{0 < p_{5,4} < 1\}$	$\varphi_A \times s_{5,4}$	Proportion of Non-spawning adults that survive (φ_A) and transition to Spawning adults ($s_{5,4}$)
$p_{5,5}$	$\{0 < p_{5,5} < 1\}$	$\varphi_A \times s_{5,5}$	Proportion that survive as Spawning adults (φ_A) and stay as Spawning adults ($s_{5,5}$)

Table 2.2. Summary of the captured and extrapolated (E.) Fry and juvenile (Juv = Juvenile A or B) counts from the fry trap in 2016 and 2017, Summit Lake, Nevada, USA.

<i>Year</i>	<i>Start and End Dates</i>	<i># Days</i>	<i>Fry</i>	<i>Juv</i>	<i>E. Fry</i>	<i>E. Juv</i>	<i>Total</i>
2016	July 14 – November 14	52	246	70	145	54	515
2017	August 24 – November 7	45	428	160	408	163	1159
<i>Mean</i>	-	49	337	115	277	109	837
<i>SE</i>	-	-	129	64	186	77	455

Table 2.3. The start and end dates for the 8 primary lake sampling periods from spring 2015 to fall 2017, Summit Lake, Nevada, USA.

<i>Primary Period</i>	<i>Year</i>	<i>Season</i>	<i>Start and End Dates</i>
1	2015	Spring	March 4 – May 20
2	2015	Fall	October 5 – November 8
3	2016	Pre-spawn	April 5 – April 14
4	2016	Post-spawn	May 31 – June 22
5	2016	Fall	October 17 – November 6
6	2017	Pre-spawn	March 29 – April 5
7	2017	Post-spawn	June 12 – July 2
8	2017	Fall	October 11 – November 8

Table 2.4. Summary of the fyke (trap) net sets during the lake mark-recapture effort for lake-dwelling Lahontan cutthroat at Summit Lake, Nevada, USA, 2015–2017. Z1=sampling zone 1, and so forth (Fig 2.1B).

<i>Year</i>	<i>Period</i>	<i>Z1</i>	<i>Z2</i>	<i>Z3</i>	<i>Z4</i>	<i>Total</i>
2015	Spring	37	18	5	11	71
	Fall	28	33	24	36	121
	Pre-spawn	10	5	9	7	31
2016	Post-spawn	20	26	19	25	90
	Fall	14	15	18	16	63
	Pre-spawn	9	8	8	7	32
2017	Post-spawn	25	24	28	29	106
	Fall	29	29	29	29	116
Total	-	172	158	140	160	630
Mean	-	22	20	18	20	79
SD	-	9	9	9	10	33

Table 2.5. Summary of lake dwelling Lahontan cutthroat captured during the lake mark-recapture effort at Summit Lake, Nevada, USA, 2015–2017.

<i>Year</i>	<i>Period</i>	<i>New captures</i>	<i>Recaptures</i>	<i>Individual recaptures</i>	<i>Total captures</i>
2015	Spring	333	115	87	448
	Fall	237	42	37	279
	Pre-spawn	171	68	37	239
2016	Post-spawn	48	33	30	81
	Fall	119	33	33	152
	Pre-spawn	153	52	52	205
2017	Post-spawn	87	30	25	117
	Fall	141	28	27	169
Total	-	1289	401	328	1690
Mean	-	161	50	41	211
SD	-	84	28	19	108

The New captures category is the number of new (without a Passive Integrated Transponder - PIT - tag) individuals captured. The Recaptures category is the number of captures of PIT tagged individuals, including each capture of individuals recaptured more than once. The Individual recaptures category is the number of tagged individuals recaptured, not including the additional recaptures of individuals recaptured more than once.

Table 2.6. Estimated annual number of spawning lake-dwelling Lahontan cutthroat trout at Summit Lake, Nevada, USA, 2015–2017.

<i>Year</i>	<i>Fish Weir Tags</i>	<i>Fish Weir Captures</i>	<i>Fish Weir Tag Proportion</i>	<i>PIT Antenna Tags</i>	<i>Estimated Total Spawners</i>
2015	103	268	0.38	238	619
2016	184	465	0.40	341	862
2017	196	446	0.44	353	803
Mean	161	393	0.41	311	761
SE	51	109	0.03	63	127

Estimates derived by dividing the number of tagged individuals detected at the PIT (Passive Integrated Transponder) antenna located near the mouth of Mahogany Creek by the proportion of tagged vs. non-tagged individuals captured at the Mahogany Creek fish weir.

Table 2.7. Estimated annual number of spawning female lake-dwelling Lahontan cutthroat trout at Summit Lake, Nevada, USA, 2015–2017.

<i>Year</i>	<i>Fish Weir Tags</i>	<i>Fish Weir Captures</i>	<i>Fish Weir Tag Proportion</i>	<i>PIT antenna Tags</i>	<i>Estimated Total Female Spawners</i>
2015	67	141	0.48	107	225
2016	103	263	0.39	200	513
2017	141	293	0.48	233	471
Mean	104	232	0.45	180	403
SE	37	81	0.05	65	156

Estimates derived by dividing the number of tagged females detected at the PIT (Passive Integrated Transponder) antenna located near the mouth of Mahogany Creek by the proportion of tagged vs. non-tagged females captured at the Mahogany Creek fish weir.

Table 2.8. Number of Lahontan cutthroat spawners at Independence and Summit Lakes from 1978–2017 [23, 26, 124, email communication Nature Conservancy Independence Lake Preserve].

<i>Year</i>	<i>Independence Lake</i>	<i>Summit Lake</i>
1978	*	1763
1979	*	2380
1980	*	2122
1981	*	1176
1982	*	756
1983	*	621
1984	*	639
1985	*	638
1986	*	996
1987	*	855
1988	*	936
1989	*	859
1990	*	718
1991	*	472
1992	*	1290
1993	*	1255
1994	*	1648
1995	*	949
1996	*	1443
1997	*	1925
1998	69	1956
1999	66	2400
2000	129	2017
2001	115	1947
2002	69	1379
2003	30	1722
2004	54	1843
2005	98	*
2006	43	*
2007	134	950
2008	164	1030
2009	176	1160
2010	238	1150
2011	*	1008
2012	181	1107
2013	178	876
2014	110	357
2015	165	269
2016	162	463
2017	*	438
MEAN	121	1198
SE	58	583

*Data not collected or available.

Table 2.9. Summary of parameter estimates for the stage-classified (Lefkovitch) population models of lake-dwelling Lahontan cutthroat captured at Independence and Summit Lakes, California and Nevada, USA, 1997–2005 and 2015–2017, respectively [26].

<i>Parameter</i>	<i>Description</i>	<i>Independence Lake</i>	<i>Summit Lake</i>
$f_{1,5}$	Fecundity	87±2.78	0.85±0.027
$p_{2,1}$	Fry survival	0.03±0.001	0.03±0.001
$p_{3,2}$	Juvenile A survival	0.25±0.008	0.25±0.008
$p_{4,3}$	Juvenile B to adult NSP* transition	0.15±0.005	0.26±0.008
$p_{4,4}$	Adult NSP to NSP transition	0.10±0.003	0.53±0.017
$p_{4,5}$	Adult SP* to NSP transition	0.24±0.008	0.28±0.009
$p_{5,3}$	Juvenile B to adult SP transition	0.35±0.011	0.25±0.008
$p_{5,4}$	Adult NSP to SP transition	0.58±0.019	0.11±0.004
$p_{5,5}$	Adult SP to SP transition	0.44±0.014	0.36±0.012

*NSP=Non-spawning stage, SP=Spawning stage.

Table 2.10. Juvenile B (Fig 2.2) probability rates of becoming a Spawning ($s_{5,3}$) or Non-spawning ($s_{4,3}$) adult (≥ 300 mm) for lake-dwelling Lahontan cutthroat trout at Summit Lake, Nevada, USA, 2015–2017.

<i>Year</i>	$s_{5,3}$	$s_{4,3}$
2015 (n=23)	0.48	0.52
2016 (n=12)	0.67	0.33
2017 (n=34)	0.32	0.68
Mean	0.49	0.51
SE	0.18	0.18

Table 2.11. Adult (≥ 300 mm) spawner to spawner ($s_{5,5}$) and nonspawner to spawner ($s_{5,4}$) probability estimates for lake-dwelling Lahontan cutthroat trout at Independence and Summit Lakes, California and Nevada, USA, 1997–2005 and 2015–2017, respectively [26].

<i>Lake</i>	<i>Transition period</i>	$s_{5,5}$	$s_{5,4}$
Independence	1997 - 2005	0.64 (n=122)	0.86 (n=51)
	2015 - 2016	0.54 (n=46)	0.13 (n=48)
Summit	2016 - 2017	0.61 (n=175)	0.22 (n=130)
	Mean	0.58	0.18
	SE	0.05	0.06

Table 2.12. Model selection results for survival (ϕ), population growth (λ), capture ($p_{CAPTURE}$), and recapture (c) rates of adult (male, female, and unknown sex, ≥ 300 mm) lake-dwelling Lahontan cutthroat captured during the lake mark-recapture effort (n=1082) at Summit Lake, Nevada, USA, 2015-2017.

<i>Model</i>	<i>AICc</i> ^a	<i>Delta AICc</i> ^b	<i>AIC weight</i>	<i>Model likelihood</i>	<i>K</i> ^c	<i>Deviance</i>
ϕ - λ (.), $p_{CAPTURE}$ - c ($t, fl+td+td^2+sex*td$)	9985.4859	0.0000	0.90245	1.0000	22	9940.7324
ϕ - λ (.), $p_{CAPTURE}$ - c ($t, sex+fl+td+td^2$)	9990.2263	4.7404	0.08435	0.0935	22	9945.4728
ϕ - λ (.), $p_{CAPTURE}$ - c ($t, fl+td+td^2$)	9994.1185	8.6326	0.01205	0.0134	21	9951.4310
ϕ - λ (.), $p_{CAPTURE}$ - c ($t, fl+td+sex*td$)	9999.4639	13.9780	0.00083	0.0009	21	9956.7764
ϕ - λ (.), $p_{CAPTURE}$ - c ($t, fl+sex*td$)	10002.0477	16.5618	0.00023	0.0003	20	9961.4232
ϕ - λ (.), $p_{CAPTURE}$ - c ($t, sex+fl$)	10004.2779	18.7920	0.00007	0.0001	20	9963.6534
ϕ - λ (.), $p_{CAPTURE}$ - c (t, fl)	10007.0467	21.5608	0.00002	0.0000	19	9968.4821
ϕ - λ (.), $p_{CAPTURE}$ - c ($t, td+td^2+sex*td$)	10012.1262	26.6403	0.00000	0.0000	21	9969.4387
ϕ - λ (.), $p_{CAPTURE}$ - c ($t, fl*td+sex*td$) - Ground-truthed model ^f	10023.7652	38.2793	0.00000	0.0000	20	9983.1407
ϕ - λ (.), $p_{CAPTURE}$ - c ($t, td+fl*td$)	10024.4784	38.9925	0.00000	0.0000	20	9983.8539
ϕ - λ (.), $p_{CAPTURE}$ - c ($t, sex+sex*fl$)	10026.9505	41.4646	0.00000	0.00000	20	9986.3260
ϕ - λ (.), $p_{CAPTURE}$ - c ($t, sex+fl*td$)	10029.3043	43.8184	0.00000	0.00000	20	9988.6798
$\phi, \lambda, p_{CAPTURE}, c$ (.)	10468.6464	483.1605	0.00000	0.0000	4	10460.617

^a AIC (Akaike Information Criterion) for small sample size.

^b Difference between model AIC_c and model with the lowest AIC_c.

^c No. of model parameters.

^d (.)=rate constant across sampling periods.

^e t =parameter varies across primary sampling periods.

^f This model considered the top because it most closely resembles the estimated spawning runs, 2015-2017 (Table 2.6).

AIC (Akaike Information Criterion) model selection was performed. Sex, fork length (fl), and trap depth (td) covariates were included with linear, quadratic, and interaction terms.

Table 2.13. Abundance (\hat{N}_t), and survival (ϕ), population growth (λ), capture ($p_{CAPTURE}$), and recapture (c) rate estimates for the ground-truthed AIC (Akaike Information Criterion) model (Table 2.12) of adult (male, female, and unknown sex, ≥ 300 mm) lake-dwelling Lahontan cutthroat captured during the lake mark-recapture effort (n=1082) at Summit Lake, Nevada, USA, 2015–2017.

<i>Parameter</i>	<i>Estimate</i>	<i>Standard Error</i>	<i>95% CI</i>	
			<i>Lower</i>	<i>Upper</i>
\hat{N}_1	2096	426	1428	3134
\hat{N}_2	1519	268	1090	2161
\hat{N}_3	1326	194	1006	1778
\hat{N}_4	1246	267	826	1896
\hat{N}_5	999	168	726	1394
\hat{N}_6	890	144	658	1233
\hat{N}_7	774	147	541	1131
\hat{N}_8	661	132	460	990
ϕ (.)	0.75	0.021	0.708	0.789
λ (.)	0.91	0.020	0.862	0.941
$p_{CAPTURE1}$	0.015	0.003	0.01	0.022
$p_{CAPTURE2}$	0.026	0.004	0.019	0.036
$p_{CAPTURE3}$	0.088	0.012	0.067	0.114
$p_{CAPTURE4}$	0.013	0.002	0.009	0.018
$p_{CAPTURE5}$	0.032	0.005	0.024	0.042
$p_{CAPTURE6}$	0.12	0.017	0.088	0.156
$p_{CAPTURE7}$	0.038	0.007	0.027	0.053
$p_{CAPTURE8}$	0.055	0.012	0.036	0.083
c_1	0.055	0.009	0.04	0.076
c_2	0.029	0.006	0.019	0.043
c_3	0.060	0.024	0.027	0.127
c_4	0.067	0.023	0.033	0.128
c_5	0.009	0.007	0.002	0.037
c_6	0.05	0.024	0.019	0.126
c_7	0.023	0.012	0.009	0.061

c_8	0.009	0.005	0.003	0.026
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The numbers in the parameter names (ex. \hat{N}_1) indicate the eight primary sampling periods in chronological order, and (.) indicates the parameter is constant across the primary sampling periods. CI=profile likelihood confidence interval.

Table 2.14. Model selection results for survival (ϕ_A), population growth (λ), capture ($p_{CAPTURE}$), and recapture (c) rates of adult (≥ 300 mm) female lake-dwelling Lahontan cutthroat captured during the lake mark-recapture effort (n=678) at Summit Lake, Nevada, USA, 2015-2017.

<i>Model</i>	<i>AIC_c^a</i>	Δ <i>AIC_c^b</i>	<i>AIC weight</i>	<i>Model likelihood</i>	<i>K^c</i>	<i>Deviance</i>
$\phi - \lambda$ (.) ^d , $p_{CAPTURE} - c$ (.,td+td ²)	6525.1697	0.0000	0.97660	1.0000	6	6513.0704
$\phi_A, \lambda, p_{CAPTURE}, c$ - (.) ^d	6532.6321	7.4624	0.02340	0.0240	4	6524.5849

^a AIC (Akaike Information Criterion) for small sample size.

^b Difference between model AIC_c and model with the lowest AIC_c.

^c No. of model parameters.

^d (.)=rate constant across sampling periods.

AIC (Akaike Information Criterion) model selection was performed, and listed above is the only model for which all of the parameters estimated correctly. Sex, fork length (fl), and trap depth (td) covariates were included with linear, quadratic, and interaction terms.

Table 2.15. Bayesian posterior distribution parameter estimates of top AIC model (Table 2.14) for adult (≥ 300 mm) female lake-dwelling Lahontan cutthroat trout captured during the lake mark-recapture effort (n=678) at Summit Lake, Nevada, USA, 2015–2017.

<i>Parameter</i>	<i>Mean</i>	<i>Standard deviation</i>	<i>Quantiles</i>				
			<i>2.5%</i>	<i>25%</i>	<i>50%</i>	<i>75%</i>	<i>97.5%</i>
\hat{N}_1	-	-	-	-	-	-	-
\hat{N}_2	646	83	503	587	642	698	825
\hat{N}_3	1772	246	1345	1596	1758	1924	2301
\hat{N}_4	332	44	255	300	329	359	427
\hat{N}_5	553	74	425	501	549	599	712
\hat{N}_6	1545	215	1173	1392	1533	1679	2007
\hat{N}_7	616	82	473	557	611	667	792
\hat{N}_8	637	83	492	578	632	689	817
ϕ (.)	0.80	0.025	0.749	0.781	0.799	0.816	0.846
$p_{CAPTURE}$ (.)	0.039	0.006	0.029	0.035	0.039	0.043	0.051
c (.)	0.026	0.004	0.019	0.024	0.026	0.029	0.035

The numbers in the parameter names (ex. \hat{N}_1) indicate the eight primary sampling periods in chronological order, and (.) indicates the parameter is constant across the primary sampling periods. \hat{N}_1 is not reported.

Table 2.16. Data cloning results.

<i>k</i>	φ_A	<i>Model</i>
1	0.52	Bayes: φ_A (.), $p_{CAPTURE}$ and c (t), FL, n=504
2	0.55	Bayes: φ_A (.), $p_{CAPTURE}$ and c (t), FL, n=1008
3	0.57	Bayes: φ_A (.), $p_{CAPTURE}$ and c (t), FL, n=1512
4	0.59	Bayes: φ_A (.), $p_{CAPTURE}$ and c (t), FL, n=2016
5	0.60	Bayes: φ_A (.), $p_{CAPTURE}$ and c (t), FL, n=2520
NA	0.74	MLE: φ_A , $p_{CAPTURE}$ and c (.), n=504

k is the number of replicate data sets. The model(s) components are female survival (φ_A), capture ($p_{CAPTURE}$), and recapture (c) rates, and fork length (FL). The data did not include the final two primary sampling periods (post-spawn and fall 2017). (.)=rate constant across primary periods; (t)=rate changes across primary periods; MLE=best model in Program Mark that estimated female survival (Table 2.14); Bayes=Bayesian model similar to MLE.

Table 2.17. Parameters estimates for the stage-classified population matrix model of Independence Lake, California, USA [26].

<i>Parameter</i>	<i>Support</i>	<i>Description</i>
$f_{1,5}$	{0, 1, 2, ...}	From Table 1*: Average fry per female: 174 Assume a sex ratio 1:1 Then average number recruited female fry (F) are $0.5 * 174 = 87$
$p_{2,1}$	{ $0 < p_{2,1} < 1$ }	From Table 4*: Average survivorship (φ_F) of ages 0 and 1 is 0.027
$p_{3,2}$	{ $0 < p_{3,2} < 1$ }	From Table 4*: Average survivorship (φ_{JA}) of ages 1 and 2 is 0.25 .
$p_{4,3}$	{ $0 < p_{4,3} < 1$ }	From Table 4*: Assume the survival is from age class 2 to age class 3 (Juvenile B to Spawning adult) = 0.5. From Appendix A Table 2 the proportion of instances of spawners and non spawners transitioning to non-spawning activity is 44/122 and 7/51. Therefore, we tentatively estimate the transition probability as $51/173 = 0.3$. The transition probability is therefore estimated as $0.5 * 0.3 = 0.15$
$p_{4,4}$	{ $0 < p_{4,4} < 1$ }	From Table 4*: Assume no survival difference between Spawning and Non-spawning adults $\varphi_A = 0.6824$. From Appendix A Table 2 the proportion of instances of Non-spawning adults remaining as non spawners is 0.014. Therefore this transition probability is estimated as $0.68 * 0.14 = 0.1$

$p_{4,5}$	$\{0 < p_{4,5} < 1\}$	From Table 4*: Assume the adult survival 0.68. From Appendix A Table 2 the proportion of instances of spawners transitioning to Non-spawning activity is 44/122 (0.36). The transition probability is therefore estimated as $0.68 * 0.36 = \mathbf{0.25}$
$p_{5,3}$	$\{0 < p_{5,3} < 1\}$	From Table 4*: Assume the survival is from age class 2 to age class 3 (Juvenile B to Spawning adult) = 0.5. From Appendix A Table 2 the proportion of instances of spawners and non spawners transitioning to Spawning activity is 78/122 and 44/51. Therefore, we tentatively estimate the transition probability as $122/173 = 0.71$. The transition probability is therefore estimated as $0.5 * 0.71 = \mathbf{0.35}$
$p_{5,4}$	$\{0 < p_{5,4} < 1\}$	From Table 4*: Assume the adult survival 0.68. From Appendix A Table 2 the proportion of instances of non spawners transitioning to Spawning activity is 44/51 (0.86). The transition probability is therefore estimated as $0.68 * 0.86 = \mathbf{0.59}$
$p_{5,5}$	$\{0 < p_{5,5} < 1\}$	From Table 4*: Assume no survival difference between Spawning and Non-spawning adults $S=0.68$. From Appendix A Table 2 the proportion of instances of Spawning adults remaining as spawners is 0.64. Therefore this transition probability is estimated as $0.68 * 0.64 = \mathbf{0.44}$

*Table references are from the Appendix section of the 2006 Independence Lake population viability analysis report [26].

Table 2.18. Results of the sensitivity analyses of the stage-classified (Lefkovich) population models of lake-dwelling Lahontan cutthroat captured at Independence and Summit Lakes, California and Nevada, USA, 1997–2005 and 2015–2017, respectively [26]. Values are percentages.

<i>Parameter</i>	<i>Description</i>	<i>Independence Lake</i>	<i>Summit Lake</i>
$f_{1,5}$	Fecundity	0.002±0.000008	0.007±0.0004
$p_{2,1}$	Fry survival	5.14±0.03	0.23±0.01
$p_{3,2}$	Juvenile A survival	0.56±0.003	0.025±0.001
$p_{4,3}$	Juvenile B to adult NSP transition	0.21±0.004	0.012±0.001
$p_{4,4}$	Adult NSP to NSP transition	0.12±0.003	0.66±0.003
$p_{4,5}$	Adult SP to NSP transition	0.30±0.01	0.29±0.002
$p_{5,3}$	Juvenile B to adult SP transition	0.31±0.011	0.013±0.001
$p_{5,4}$	Adult NSP to SP transition	0.18±0.002	0.70±0.0007
$p_{5,5}$	Adult SP to SP transition	0.43±0.007	0.31±0.00009

*NSP=Non-spawning stage, SP=Spawning stage.

Table 2.19. Survey of population dynamics studies for cutthroat trout and other trout species.

<i>λ or Trend</i>	<i>Potential Causes(s)</i>	<i>Species</i>	<i>System or State</i>	<i>Period</i>	<i>Reference</i>
0.52	drought	LC	Summit Lake, Nevada	2015-2017	This study
0.94	invasives	LC	Independence Lake, California	1997-2005	Rissler et al. 2006 [26]
0.77-1.21	invasives drought	BC	Logan River, Utah	2001-2005	Budy et al. 2007 [75]
Stable or increasing	logging or land management practices catch and release angling biotic interactions with other salmonids	WC	Idaho (streams)	1959-2012*	Kennedy and Meyer 2015 [78]
0.68-1.1 (10 of 12 populations decreasing)	low stream base flow from agricultural dewatering invasives	WC	Montana (streams)	2010-2013	Carim et al. 2017 [77]
0.94	invasives	YC	Yellowstone Lake, Wyoming	1950s-1990s*	Stapp and Hayward 2002 [40]
0.98	invasives drought	YC	Idaho (streams)	1980s, 1999-2000, 2010-2011	Meyer et al. 2014 [76]
Declining	low juvenile survival due	LT	Lake Ontario, U. S. and Canada	1985-2007	Brenden et al. 2011 [73]

	to hatchery strain				
1.35	rapid growth from early stage colonization	LT	Swan Lake, Montana	2007-2008	Cox et al. 2013 [70]
1.03	density dependence-carrying capacity	LT	Priest Lake, Idaho	2013	Ng et al. 2016 [71]
Increasing: 28 fold in adult abundance	angling changed to zero harvest	BT	Lower Kananaskis Lake, Alberta, Canada	1992-2002	Johnston et. al 2007 [65]
Stable or increasing	increased mean annual streamflow reduced winter mortality due to milder winters	BT	Idaho (lakes, rivers, streams)	since 1994*	High et al. 2008[72]
0.92-1.01	high post spawning mortality (possibly due to high water temperatures and low flows) poor overwintering habitat	BT	South Fork Walla Walla River, Oregon	2002-2011	Budy et al. 2017 [74]

*Period varied for individual streams.

Species abbreviations: LC=Lahontan cutthroat (*Oncorhynchus clarkii henshawi*), BC=Bonneville cutthroat (*Oncorhynchus clarkii utah*), WC = Westslope cutthroat (*Oncorhynchus clarkii lewisi*), YC=Yellowstone cutthroat (*Oncorhynchus clarkii bouvieri*), LT=lake trout (*Salvelinus namaycush*), BT=bull trout (*Salvelinus confluentus*).

Table 2.20. Fecundity comparison across cutthroat subspecies and systems.

<i>Fecundity</i>	<i>Species</i>	<i>System</i>	<i>Reference</i>
0.85	LC	Summit Lake, Nevada	This study
1.5	LC	Summit Lake, Nevada	Vinyard 2000 [15]
23	BC	Strawberry Reservoir, Utah (Indian Creek)	Knight 1997 [81]
61	BC	Strawberry Reservoir, Utah (Trout Creek)	Knight 1997 [81]
87	LC	Independence Lake, California	Rissler et al. 2006 [26]
175	CC, YC, HC	Trappers Lake, Colorado (Cabin Creek)	Drummond & McKinney 1965 [82]

Estimates taken directly from study or calculated from data contained in study. Species abbreviations: LC=Lahontan cutthroat (*Oncorhynchus clarkii henshawi*), BC=Bonneville cutthroat (*Oncorhynchus clarkii utah*), CC=Colorado cutthroat (*Oncorhynchus clarkii pleuriticus*), YC=Yellowstone cutthroat (*Oncorhynchus clarkii bouvieri*), HC=hybrids of CC and YC.

Table 2.21. Adult survival comparison between Lahontan cutthroat (LC, *Oncorhynchus clarkii henshawi*), Bonneville cutthroat (BC, *Oncorhynchus clarkii utah*), lake trout (LT, *Salvelinus namaycush*), and bull trout (BT, *Salvelinus confluentus*) in various systems.

<i>Survival</i>	<i>Species</i>	<i>System</i>	<i>Reference</i>
0.27-0.35	LC	Gance Creek, Nevada	Peacock [118]
0.36	LC	Truckee River, Nevada	Alexiades et al. 2012 [93]
0.15–0.44	LC	Walker Lake, Nevada	Sedinger et al. 2012 [88]
0.51	LC	Summit Lake, Nevada	This study
0.54	BC	Logan River, UT	Budy et al. 2007 [75]
0.68	LC	Independence Lake, CA	Rissler et al. 2006 [26]
0.20–0.70	BT	South Fork Walla Wall River, OR	Al-Chokhachy & Budy 2008 [119]
0.90	LT	Yellowstone Lake, WY	Syslo et al. 2011 [120]
0.69-0.91	LT	Experimental Lakes Area, Ontario, Canada	Mills et al. 2002 [121]
0.92	LT	Swan Lake, Montana	Cox et al. 2013 [70]

Table 2.22. Annual spawning mortality rates for lake-dwelling Lahontan cutthroat at Summit Lake, Nevada, USA, 2015–2017.

<i>Year</i>	<i>Mortality rate</i>
2015 (n=250)	0.74
2016 (n=403)	0.48
2017 (n=423)	0.47
Mean	0.56
SE	0.15

Table 2.23. Juvenile survival comparison across trout species in various systems. Species abbreviations: LC=Lahontan cutthroat (*Oncorhynchus clarkii henshawi*), BC=Bonneville cutthroat (*Oncorhynchus clarkii utah*), YC=Yellowstone cutthroat (*Oncorhynchus clarkii bouvieri*), BT=bull trout (*Salvelinus confluentus*), LT=lake trout (*Salvelinus namaycush*).

<i>Survival</i>	<i>Species</i>	<i>System</i>	<i>Reference</i>
0.09 ^a	BT	South Fork Walla Wall River, OR	Al-Chokhachy & Budy 2008 [119]
0.22–0.23 ^b	BT	Skiphorton Creek, OR	Bowerman & Budy 2012 [122]
0.08–0.34 ^c	LC	Gance Creek, NV	Peacock [118]
0.41–0.47 ^b	BC	Logan River, UT	Budy et al. 2007 [75]
0.03 – 0.50^c	LC	Independence Lake, CA	Rissler et al. 2006 [26]
0.44–0.69 ^d	YC	Spread Creek, WY	Uthe et al. 2016 [123]
	YC	Shields River, Montana	Uthe et al. 2016 [123]
0.0043–0.78 ^c	LT	Priest Lake, Idaho	Ng et al. 2016 [71]
0.0043–0.78 ^c	LT	Swan Lake, Montana	Cox et al. 2013 [75]

^a2 or 3 year old: average rate for study period.

^bFirst value is 1 year old and second value is 2 year old.

^cFirst value is fry survival and the second value is 2 year old survival.

^dExcluding fry.

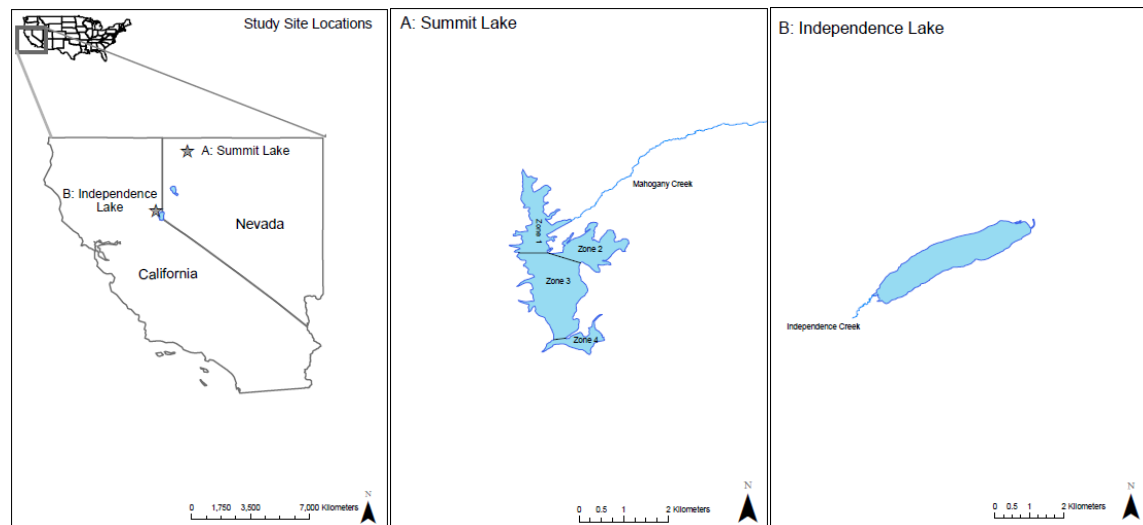


Figure 2.1. Summit Lake (Nevada, USA) and Independence Lake (California, USA), including their sole, perennial spawning tributaries, Mahogany Creek and Independence Creek (panels A and B), respectively. Panel A also displays the 4 sampling zones at Summit Lake.

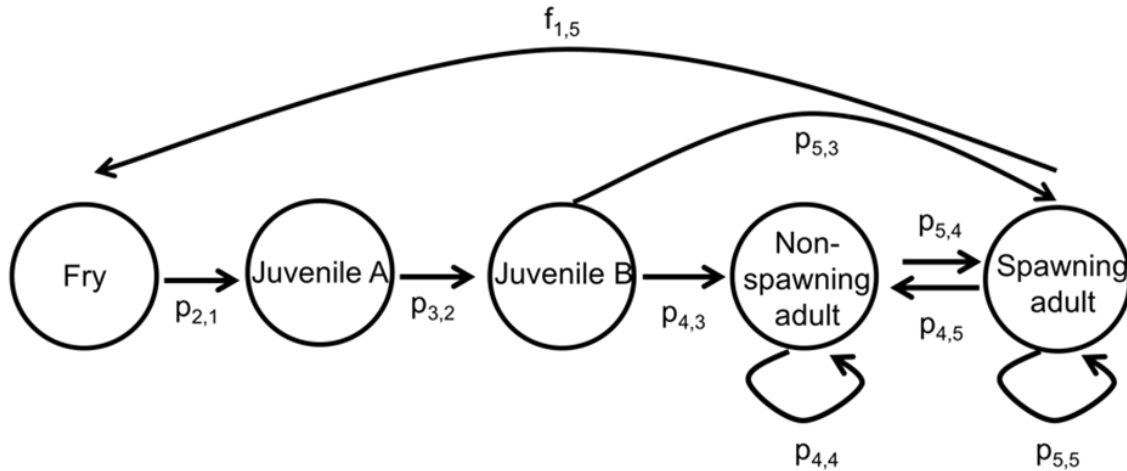


Figure 2.2. Life history model of lake dwelling Lahontan cutthroat at Independence and Summit Lakes, California and Nevada, USA, respectively. The diagram depicts the relationships and annual transition parameters ($f_{1,5} - p_{5,5}$) between the key life stages. $f_{1,5}$ is fecundity; $p_{2,1}$ and $p_{3,2}$ are the survival rates for Fry (<100 mm) and Juvenile A ($100 \text{ mm} \leq \text{Juvenile A} < 199$ mm); $p_{4,3}$ and $p_{5,3}$ are the transition rates for Juvenile B ($200 \text{ mm} \leq \text{Juvenile B} < 299$ mm) to a Non-spawning or Spawning adult (≥ 300 mm); $p_{4,4}$ and $p_{4,5}$ are the transition rates for Non-spawning adults to remain a Non-spawning adult or become a Spawning adult; and $p_{5,4}$ and $p_{5,5}$ are the transition rates for Spawning adults (≥ 300 mm) to remain a Spawning adult or become a Non-spawning adult, respectively. $0 < p_{2,1} - p_{5,5} < 1$ and $f_{1,5} \in \{0, 1, 2, \dots\}$.

$$\begin{bmatrix} 0 & 0 & 0 & 0 & f_{1,5} \\ p_{2,1} & 0 & 0 & 0 & 0 \\ 0 & p_{3,2} & 0 & 0 & 0 \\ 0 & 0 & p_{4,3} & p_{4,4} & p_{4,5} \\ 0 & 0 & p_{5,3} & p_{5,4} & p_{5,5} \end{bmatrix}$$

Figure 2.3. Stage-classified (Lefkovich) population matrix model for the lake-dwelling Lahontan cutthroat populations at Independence and Summit Lakes, California and Nevada, USA, respectively. The matrix is constructed with the stages, relationships, and transition parameters from the cutthroat trout life history model (Figure 2.2). $f_{1,5}$ is fecundity; $p_{2,1}$ and $p_{3,2}$ are the survival rates for Fry (<100 mm) and Juvenile A ($100 \text{ mm} \leq \text{Juvenile A} < 199$ mm); $p_{4,3}$ and $p_{5,3}$ are the transition rates for Juvenile B ($200 \text{ mm} \leq \text{Juvenile B} < 299$ mm) to a Non-spawning or Spawning adult (≥ 300 mm); $p_{4,4}$ and $p_{4,5}$ are the transition rates for Non-spawning adults to remain a Non-spawning adult or become a Spawning adult; and $p_{5,4}$ and $p_{5,5}$ are the transition rates for Spawning adults (≥ 300 mm) to remain a Spawning adult or become a Non-spawning adult, respectively. $0 < p_{2,1} - p_{5,5} < 1$ and $f_{1,5} \in \{0, 1, 2, \dots\}$.

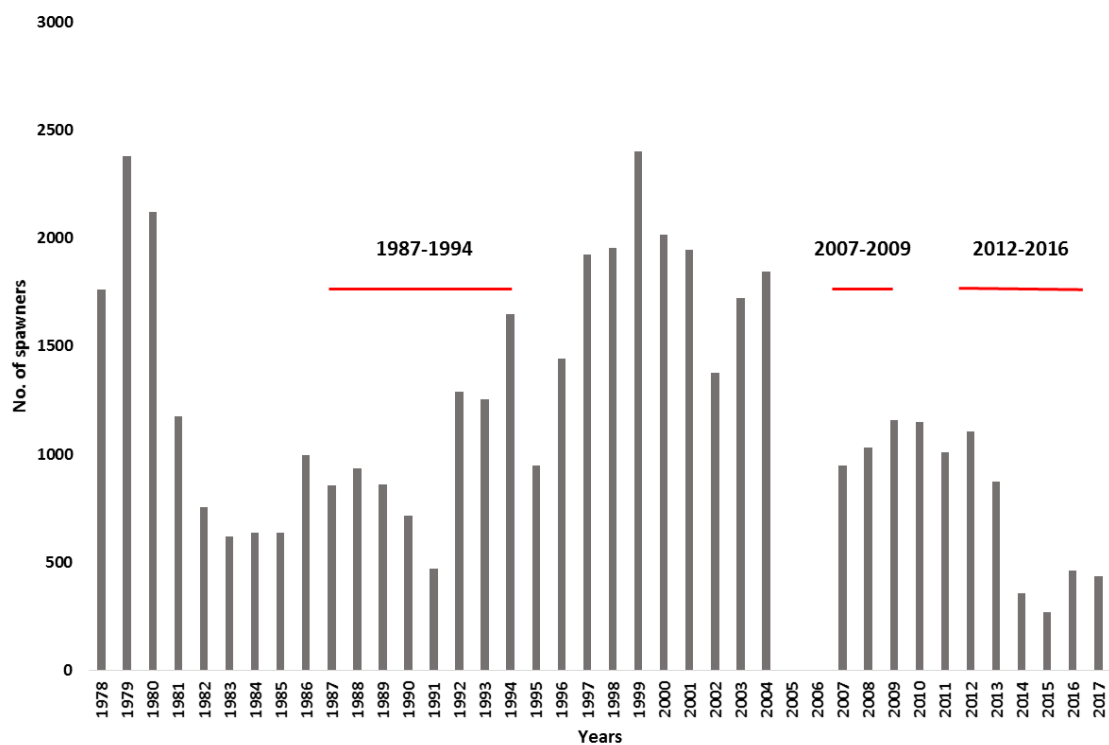


Figure 2.4. Annual number of Lahontan cutthroat spawners captured at the Summit Lake (Nevada, USA) fish weir on Mahogany Creek from 1978–2017, excluding 2004–2005. Data provided by the Summit Lake Paiute Tribe [23]. Red horizontal lines represent drought periods [15,30,125].

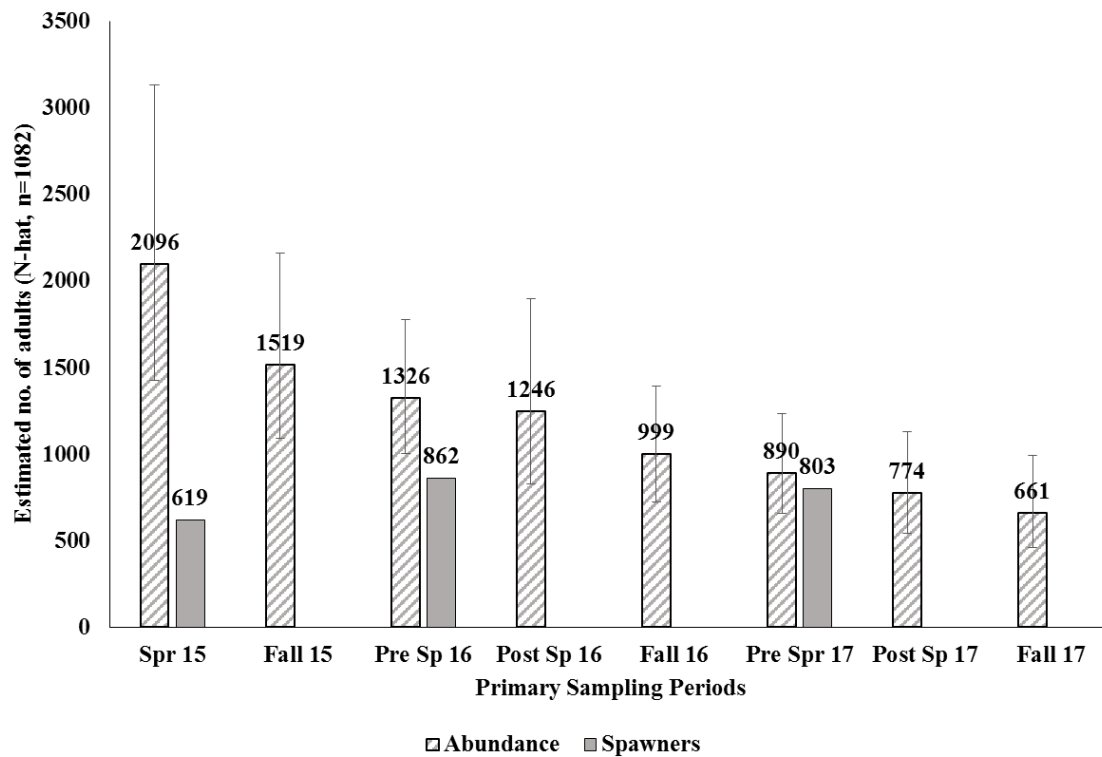


Figure 2.5. Adult (≥ 300 mm) abundance estimates ($n=1082$) of lake-dwelling Lahontan cutthroat trout at Summit Lake, NV, USA, 2015–2017. The estimates were derived from the top ground truthed model from AIC (Akaike Information Criterion) model (Table 2.12) selection of the lake mark-recapture effort. The abundance estimates and primary sampling periods are located on the x and y axes, respectively. The error bars are 95% profile likelihood confidence intervals.

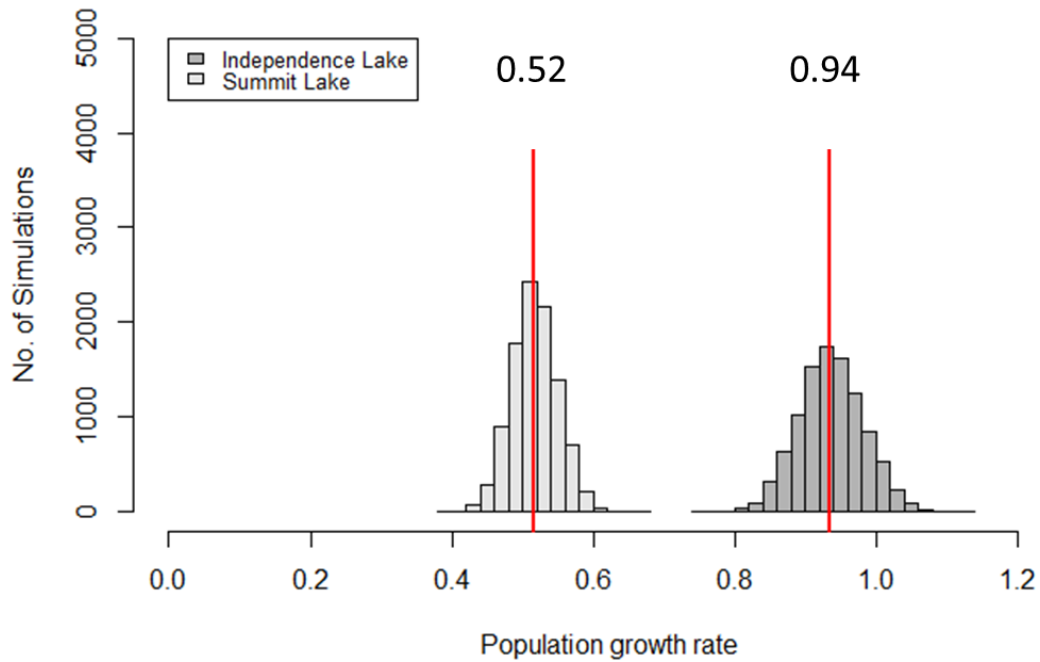


Figure 2.6. Population growth rate comparison of female lake-dwelling Lahontan cutthroat at Independence and Summit Lakes, California and Nevada, USA, 1995–2005 and 2015–2017, respectively [26]. Each histogram was generated from a simulation that calculated the dominant eigenvalue of the stage-classified population matrix model (Figure 2.3), using the estimated parameter distributions (Table 2.9), for each population. The number of simulations and the population growth rates are located on the x and y axes, respectively. The means and standard deviations are listed below. The red vertical lines indicate the means of the histograms.

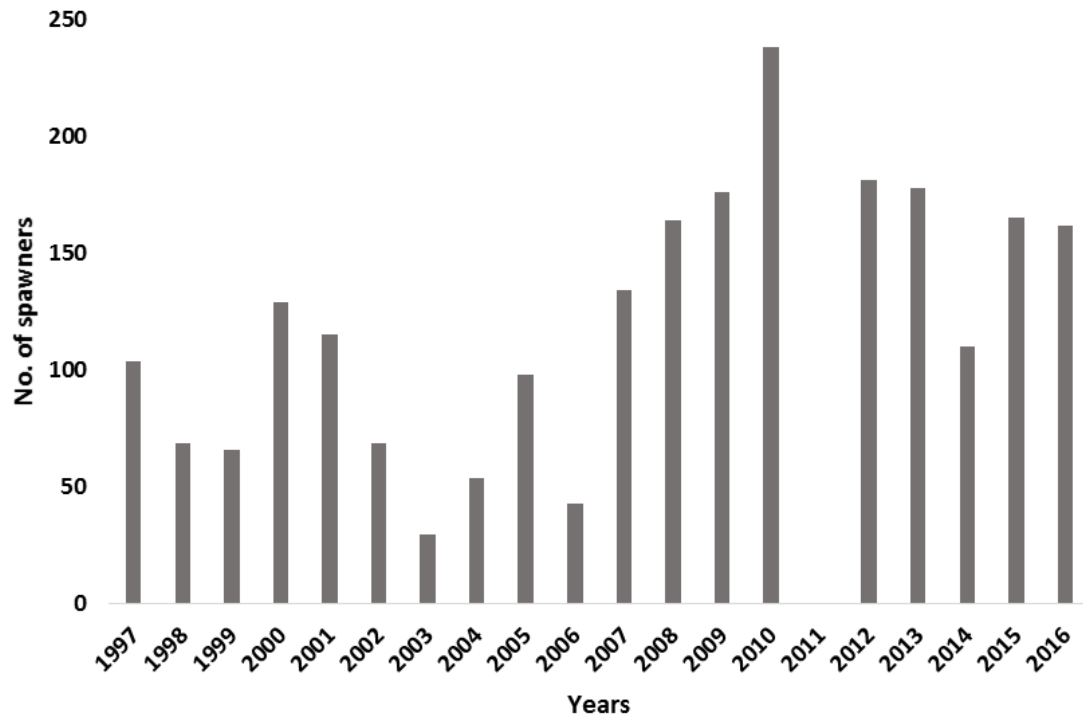


Figure 2.7. Annual number of Lahontan cutthroat spawners captured at the fish weir located in Upper Independence Creek (Independence Lake, California, USA) from 1997-2016. Data provided by [26, 124, email correspondence Nature Conservancy Independence Lake Preserve].

3.0 Chapter 3

Population dynamics of threatened Lahontan cutthroat trout from the last two remnant lakes with natural recruitment

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Abstract

Once widespread across lakes of the western Great Basin and the Sierra Nevada mountains of the United States, native self-sustaining populations of Lahontan cutthroat trout (*Oncorhynchus clarkii henshawi*, Lahontan cutthroat) now occur in just two lake ecosystems: eutrophic desert terminal Summit Lake and mesotrophic montane Independence Lake. Maintenance of the life history and genetic diversity within the Summit Lake and Independence Lake Lahontan cutthroat populations has been identified as an important goal of Lahontan cutthroat management and restoration efforts. However, little research has been done to quantify the population dynamics and critical life history transitions for lake dwelling cutthroat trout populations. We compared the population dynamics of Lahontan cutthroat trout in the two lakes to provide direction for range wide conservation strategy. We compared their population growth rates, and performed sensitivity analyses to identify the population components with the most impact on population growth rates. We applied a stage-classified (Lefkovitch) matrix population model (with skipped spawning) to both populations, and parameterized the models using data and parameters from Lahontan cutthroat trout population studies at both lakes. The Independence and Summit Lake population growth rates both

indicated decline (0.94 and $.52 < 1$, respectively), and they shared the third most sensitive parameter, low repeat spawning rates (0.44 and 0.36, respectively). But the difference between the growth rates was large, and the top two sensitive parameters were different between the populations. Fry (0.03) and juvenile survival (0.25) had the most impact at Independence Lake; whereas, low transition rates from nonspawning to spawning or nonspawning (0.11 and 0.53, respectively) had the most impact at Summit Lake. Also, the large difference between Independence Lake and Summit Lake fecundity (87 and 0.85, respectively) likely had large effects on their growth rates. The findings suggest managers need to focus their efforts on protecting juvenile life stages in Independence Lake and adult stages in Summit Lake and to guard against assuming that intra-specific populations have the same population drivers, especially populations with disparate biotic and abiotic conditions.

3.1 Introduction

North American freshwater fauna is declining five times faster than terrestrial fauna [1]. Since the mid-1800s, habitat loss, overfishing and invasive species have led to population declines and extirpations of freshwater fish fauna in the western U.S. [2]. Looking forward, climate change predictions for the western U.S., of increased climatic variability that will manifest as increased drought frequency and duration and a decreased proportion of precipitation as snow [3-4], threaten to compound these disturbances [5-6]. This combination of disturbances is a formidable challenge for conserving freshwater fish biodiversity in the western U.S., thus highlighting the need to actively manage threatened freshwater fish species [7].

Cutthroat trout (*Oncorhynchus clarkii* spp.), so named because of the red slashes under the jaw that resemble blood, are salmonids native to the coastal and inland waters of western North America [8]. The approximate 14 subspecies originally ranged from Alaska to southern Texas and from the Canadian and U.S. Pacific Coasts to their Rocky Mountains [8-9]. However, over the past century two subspecies have been extirpated [8], and Lahontan cutthroat trout (*Oncorhynchus clarkii henshawi*, Lahontan cutthroat), the largest subspecies [10], is one of three on the U.S. endangered species list [11]. In the early 1800s, Lahontan cutthroat occupied 11 lakes (including Lake Tahoe, California and Pyramid Lake,

Nevada), with 6 lakes in the Sierra Nevada Mountains and 5 lakes east in the western Great Basin. By 1970, Independence Lake (California) and Summit Lake (Nevada), representing only 0.4% of the historic lake habitat, and support the last two native self-sustaining lake-dwelling populations [12].

Because of the sharp decline in lake habitat and populations, the Independence and Summit Lake populations have long been recognized as unique subpopulations of special management and conservation concern [13]. Consequently, at Independence Lake the baseline ecology of the population was studied in the late 1960s [14], hatchery operations were conducted in the 1970s, and the spawning run has been monitored annually since 1997 (intermittently from 1894-1996) [15,16,email communication Nature Conservancy Independence Lake Preserve]. At Summit Lake, the spawning run has been monitored annually for most years since 1978 [17], and a hatchery operated for most years from 1968 to 1984 [18]. With the completion of the Lahontan cutthroat recovery plan in 1995 and the populations' assignments to different distinct population segments (created based on geographical, ecological, behavioral, or genetic factors), Independence and Summit Lakes were confirmed as stronghold populations [13]. The combination of the distinct population segment assignments, the recovery plan's recommendation to better understand the range wide population ecology of Lahontan cutthroat, recognition of the analytical limitations of past monitoring efforts that focused on specific population segments (such the spawning runs) [19], and concern by local and regional managers of the low or declining spawning runs at both lakes in recent decades (compared to historic numbers), further heightened the need and fueled efforts to better understand the populations' dynamics.

From 1997-2005, the U.S. Geological Survey performed a population viability analysis (the probability that the population will remain viable after a pre-determined number of years, [20]), at Independence Lake (hereafter Independence study) [15]. From 2015-2017, population dynamics research was conducted at Summit Lake (hereafter Summit study) [21]. The completion of these studies provided the opportunity to consolidate the increased knowledge of lake-dwelling Lahontan cutthroat population dynamics across its historic habitat spectrum. The threatened status of Lahontan cutthroat, the importance of these populations, the recent increase and decline in the annual spawning counts at Independence and Summit Lakes, the suite of similarities and differences between the lake systems and the populations, and

the few comparative population dynamics studies with lake-dwelling cutthroat trout, make these populations ideal candidates for comparison. In this study, we compared: 1) the long term spawning run record at both lakes to identify trends and drivers, 2) the population growth rates during their population dynamics study periods, and 3) compared and contrasted the inferences gained from each effort to identify the key life history parameters that are driving the dynamics of these populations. Comparing the population dynamics from these last two threatened populations suggest insights into potential management actions for each ecosystem and the need for expanding models to include an understanding of future hydroclimatic mediated changes when recovering these populations.

3.2 Materials and methods

Study sites

Independence and Summit Lakes (Fig 3.1) are similar in surface area (2.5 km² vs. 2.8 km²), elevation (2118 m versus 1780 m), the size of spawners (mean=507 mm for both populations, 1997-2005 excluding 2004, and 2015-2016), and both lakes are closed systems with only one perennial spawning tributary, Upper Independence Creek and Mahogany Creek, respectively. But the lakes are located in disparate ecosystems (montane Sierra Nevada Mountains versus high desert sagebrush steppe), and have different maximum depths (45 m versus 15 m), primary productivities (mesotrophic versus eutrophic), numbers of invasive salmonid species (3 versus 0), number of invasive cyprinids (0 versus 2), and mean annual spawner counts (121 versus 1178 from 1997-2016 (Table 3.1)), respectively [15,16,22-24,email communication Nature Conservancy Independence Lake Preserve]. Further, Independence Lake had mostly non-drought conditions during their Independence study [25], whereas Summit Lake's surface elevation dropped almost 4 m (approximately 27%) during the recent severe drought across the western U.S. (2012-2016) [26-27].

Life history

Lake-dwelling Lahontan cutthroat begin life in the spring and early summer as fertilized eggs in redds (nest) excavated in the substrate of spawning tributaries. The alevins (an embryonic stage retaining a portion of the yolk sac for sustenance) generally hatch 4 to 6 weeks later. When the yolk sac is absorbed, the alevins mature to the fry stage and emerge from the gravels. By fall fry will start migration to the lake to rear. However, a small proportion of fry will remain in the tributary and migrate to the lake as 1 or 2 year olds. After year 1, the fry become juveniles. At maturity (3-5 years old), adults reproduce by participating in the annual migration from the lake into a spawning tributary, but most skip at least one year between spawning attempts. The exact timing of the above events depends on location and environmental conditions [12]. The typical lifespan is 5-14 years [28].

Population model

Lahontan cutthroat exhibit a complex life history that cannot be adequately described by age. Juveniles do not mature at the same age and most adults exhibit skipped spawning [12]. Skipped-spawning, in particular, is a key life history trait [29-30] that may be a significant driver of Lahontan cutthroat population dynamics. Thus, following the guidance of Caswell [31] (for species with more complex life histories) and previous research [32], we used stages to model Lahontan cutthroat population dynamics. First, we created a life history model comprised of five life history stages, one fecundity parameter, and eight stage transition probability parameters (Fig 3.2, Table 3.2). For simplicity, and based on our field collection efforts, we assumed individuals mature over three juvenile stages; the adult stages are Nonspawning and Spawning; fecundity ($f_{i,s}$) applies to spawning adults only; and the stage transition probability parameters ($p_{2,1}-p_{5,5}$) are the probabilities that individuals will survive and transition to another stage. The Fry (<100 mm) and Juvenile A ($100 \text{ mm} \leq \text{Juvenile A} < 199$ mm) stage transition probabilities are simply the survival rates to the next stage (ϕ_F and ϕ_{JA} , respectively). The spawning transition probabilities ($p_{4,3}-p_{5,5}$) are the product of the Juvenile B ($200 \text{ mm} \leq \text{Juvenile B} < 299$ mm) or adult ($300 \text{ mm} \leq \text{adult}$) survival rates (ϕ_{JB} and ϕ_A , respectively) multiplied by the respective stage spawning probability ($s_{4,3}-s_{5,5}$).

From this life history model, we constructed a female stage-classified (Lefkovitch) matrix population model (Fig 3.3). One sex population matrix models assume an equal adult sex ratio because an unequal ratio could bias the population growth rate estimate. Because both studies had comparable female-dominated sex ratios (which is typical for Lahontan cutthroat and other cutthroat trout species [33]), we made the common assumption of female dominance, that the female vital rates dominate the populations' dynamics [31]. In addition, the population growth rate estimates would likely be biased in the same direction and result in little difference between the population growth rates. Unless otherwise specified, all parameter and data references will pertain to females only. The below sections describe how we collected the data, obtained the parameter estimates, and performed the population analyses. Based on an age-length relationship from previous research on lake-dwelling Lahontan cutthroat at Summit Lake [Chandra, unpublished data], the stages are similar to the age classes in the Leslie life history table of the Independence study [15]. Thus, for the Independence Lake population model, we equated the 0, 1, 2, and ≥ 3 year ages to the Fry, Juvenile A and B, and Nonspawning and Spawning stages, respectively.

Data

Unless otherwise specified, the data was collected from 1997-2005 (excluding 2004) at Independence Lake [15] and from 2015-2017 at Summit Lake [21].

Fry Trap

The same fry trap (see Appendix 5.2 for further description) was used in both studies to count the annual migration of young (Fry, Juveniles A and B). The fry trap could be configured to allow or deny passage and was only deployed in the creeks for the migration capture efforts [15,21]. Every year at Upper Independence Creek, the fry trap was installed approximately 80-100 m upstream from the creek mouth. Captures were processed on weekdays (Monday–Friday) but were allowed to pass through on the weekends (Saturday and Sunday) during the migration period (late August to early November). Date, fork length (mm), and mass (nearest 0.01 g) were recorded for 10 individuals each weekday. After processing, captures

were released downstream. The fry trap was operated until fewer than 10 individuals were captured in a 24 hour period [15].

At Mahogany Creek, the fry trap was installed at same location in 2016 and 2017, approximately 375 m upstream from the creek mouth. In 2016, the fry trap was operated primarily during the weekdays (Monday-Thursday or Friday) from mid-July to mid-November. During four weeks in September when there was stagnant water, the fry trap was not operated to eliminate negative influences on the migrating young per rules set forth in the collections permit. In 2017, the fry trap was operated with a mix of weekday or longer periods (which included weekdays and weekends-Friday or Saturday and Sunday) from late August to early November. Captures were processed for fork length (mm) and then released downstream [21].

Mark-recapture effort

Both studies executed mark-recapture methods (albeit different) - in which captured Lahontan cutthroat were marked, returned to the lake or creek, and recaptured - to estimate the juvenile and adult survival rates or abundance [34]. Passive integrated transponder (PIT) tags - a cylindrically-shaped, glass encased chip that contains a unique number, and implanted into the body – were used to mark the individuals [43]. At Independence Lake, tricaine methanesulfonate (ms-222) was used for anesthesia. Sex (male, female, or unknown), fork length (mm), passive integrated transponder PIT number, and date were recorded for each capture. Captures recuperated in a live tank before release into the lake or Upper Independence Creek. New captures at the fish weir or during the netting or hook and line efforts were implanted with a tag below the dorsal fin on the left side, and the adipose fin was clipped. During the net and hook and line effort in the lake, $140 \text{ mm} \leq \text{new captures} < 250 \text{ mm}$ were implanted with a PIT tag in the abdominal cavity, and the left pelvic fin was clipped [15].

CO₂ gas was used for anesthesia at Summit Lake. New captures $\geq 100 \text{ mm}$ were implanted with a Biomark© 12 mm full duplex PIT tag that contained a unique 15-digit number. New captures $\geq 250 \text{ mm}$ were tagged in the pelvic girdle, and $100 \text{ mm} \leq \text{new captures} < 250 \text{ mm}$ were tagged in the abdominal cavity between the pectoral and pelvic fins. We clipped the adipose fin of new captures to subsequently identify

recapture and assess tag loss. We recorded the following data from each capture: fork length (mm), mass (kg), trap depth (m), sex (male, female, or unknown), new capture or recapture, and PIT number. Captures recuperated in net pens (alongside the boat) before release into the lake [21].

Netting and hook and line effort

Fyke (trap) nets and hook and line angling [35] were used for the mark capture of juveniles and adults in Independence Lake. The trap nets (3-6 nets) were deployed overnight, between 2 to 25 m in the thermocline, and intermittently from June to November every year [15]. The Independence Lake study did not contain details regarding the sampling procedure in the lake. Thus we were unable to determine if there any potential sampling bias.

In Summit Lake, a robust design sampling framework [36] was utilized, and trap nets were also used for the capture effort but not hook and line angling. The sampling periods were March-May and October-November in 2015, and generally pre-spawn (March–April), post-spawn (June–July), and fall (October–November) thereafter. Also, a spatially stratified, semi-random plan was designed to minimize sampling bias. The lake was divided into 4 sampling zones (Fig 3.1). Up to 10 nets were used every period, and the nets were moved daily within and among the zones to keep the sampling effort as uniform as possible throughout the lake. Most net sets were approximately 20-24 hours and ranged from approximately 1–12 m in depth [21]. Bias may have occurred in two aspects of the sampling. First, the trap nets were size selective, primarily catching individuals above 300 mm. The mesh size (0.5 and 1 inch) may have allowed small juveniles to pass through, and the large size and design of the trap nets precluded sampling of shallow, heavily vegetated areas where fry and juveniles may have been concentrated [37]. Second, with the trap nets anchored primarily to the shoreline, our effort concentrated on catching fish close to shore, which may have resulted in seasonal or behavioral capture biases [38-39].

Tracking PIT tagged spawners at Summit Lake

A PIT antenna was used at Summit Lake only. The permanent stationary PIT antenna, spanning the entire width and depth of the creek, was located approximately 750 m upstream from the mouth of

Mahogany Creek. The antenna detects every PIT-tagged individual traveling up- or downstream. The Summit Lake estimates for total spawners, fecundity, and spawning probabilities relied on the annual lists of PIT-tagged spawners detected by this antenna. Four assumptions were made to generate the lists. First, lake-dwelling Lahontan cutthroat populations have an annual spawning run and are obligate tributary spawners [12] that infrequently enter or reside in tributaries when not spawning. Next, every individual that entered the creek during the run was classified a spawner, although actual spawning could not be confirmed. Then, an individual's initial detection signaled participation, an exit detection signaled survival, no exit detection signaled death, and zero detections signaled no participation. Last, the detection rate of the antenna was assumed at approximately 100% [40].

Fish weirs

In 1997 spawners entering Upper Independence Creek were captured with two trap nets set at the creek mouth and fished overnight daily. Thereafter, spawners were captured with a temporary weir deployed annually. The weir was installed approximately 100 m upstream from the creek mouth, spanned the entire width and depth of the creek, and was monitored from May through July. Due to installation when flows permitted, some spawners were missed. Also, smaller individuals may have passed through the weir. However, because the weir was located near the creek mouth, the total number of spawners was recorded after weir installation. To minimize harassment, the weir was removed prior to all of the spawners returning to the lake [15].

In Mahogany Creek, spawners were captured with a permanent weir facility, which spans the entire width and depth of the creek, located approximately 3.5 km upstream from the creek mouth. The weir is operated generally from March to June, and is checked daily. After the spawning run, the weir is configured to allow passage. The following data is collected from each capture: sex (male, female, or unknown), mass (kg), fork length (mm), and PIT number (if present). However, because the weir is not located near the creek mouth, and a large portion of spawning occurs downstream of the weir, the count at the weir does not approximate the total number of spawners [21].

Parameterization

Fecundity

Fecundity ($f_{1,5}$) was defined as the number of female young (Fry, Juvenile A or B) migrating to the lake per female spawner. The annual number of migrating young (Fry, Juvenile A or B) was estimated by combining physical counts to extrapolated counts. At Independence Lake, the number of young allowed to pass through the fry trap on the weekends was extrapolated based on the previous and subsequent 24 hour periods [15]. At Summit Lake, the number of young allowed to pass through the fry trap was similarly extrapolated based on the previous and subsequent 24 hour periods of the passage periods. For Independence Lake fecundity, the number of females caught at the weir was used. For Summit Lake fecundity, because not every female that entered the creek was counted, the number of female spawners was calculated by dividing the number of tagged females detected by the antenna with the proportion of tagged females vs. total female spawners caught at the fish weir. Then the total young captured was multiplied by half (assuming a 1:1 sex ratio for simplicity, because prior lake-dwelling cutthroat trout population modeling has made the same assumption [32], and because recent research with brown trout suggests an equal ratio may not be unreasonable [41]) and divided by the total female spawners [21].

Survival

Independence Lake and Summit Lake are closed systems [15, 23], so the survival estimates reflect true survival (ϕ) rather than apparent survival (with immigration and emigration, which underestimates true survival) [34]. For Independence Lake, the Cormack-Jolly-Seber [34] and the Joint Live-Recapture/Live Resight/Tag-Recovery (Barker) [42] models in Program Mark [43] were used to estimate the Independence Lake juvenile (ϕ_{JA} , ϕ_{JB}) and adult survival (ϕ_A) rates, respectively. Fry survival (ϕ_F) was estimated by factoring out the age 0 year to 1 year component from fry to adulthood survival [15].

At Summit Lake, juvenile (ϕ_{JA} , ϕ_{JB}) and adult (ϕ_A) survival rate estimates were attempted. However, few juveniles were captured, so their survival could not be estimated. The age 0, 1, and 2 yr. survival rates from the Independence study were used for the Fry and Juvenile A and B survival rates in the

Summit Lake model, respectively [21]. To better meet the closed population assumptions for adult survival, the last 4 weeks (late April and all of May 2015 – height of spawning run so many spawners not available for capture in the lake) of data from the first primary period were removed, which resulted in 678 adult capture histories. In Program Mark [43], we selected the Pradel robust design survival and lambda model [44] with the Huggins' p and c closed capture data type [45-46] so that we could use covariate data (sex, fork length, and trap depth) to model the survival and capture/recapture rates. We identified the top model by ground truthing (2015-2017 estimated total spawning runs vs. the model abundance estimates for those periods) the AIC ranked models [21,47-48]. Then a Bayesian version of the top model was created to estimate survival. R package *R2jags* [49-50] and the JAGS program [51] were used to construct and run a Bayesian MCMC (Markov Chain Monte Carlo) model with the following uniform priors for the survival (ϕ_A), capture ($p_{CAPTURE}$), and recapture (c) parameters, respectively: uniform (0.6, 0.95), uniform (0.01, 0.1), and uniform (0.01, 0.1). The model was run with 3 chains of 25,000 iterations and a 5,000 iteration burn-in period, and convergence was assessed with the Gelman Rubin diagnostic < 1.1 [52]. The model run provided the posterior mean and standard deviation for adult survival. The mean estimate was then converted into an annual survival rate for the population model. The Bayesian MCMC model was validated with a data cloning procedure. Data cloning, by replicating the data set an increasing number (k) of times, uses the Bayesian MCMC framework to provide maximum likelihood estimates (MLE) for model parameters. If the Bayesian model is consistent with the MLE model (Program Mark top model), then the posterior mode and MLE estimate should be the same or very close. Large differences between the estimates could indicate that the models are dissimilar, the Bayesian priors are unexpectedly informative (when they are intended to be uninformative), or the model's parameters are not identifiable using the data collected using the data collected [53].

Spawning probabilities and transitions

Spawning probability (s) was defined as the probability of spawning (or not) for a Juvenile B or adult in a given year. However, because the Independence study did not track the exit of individuals, we needed to use a different calculation for their estimates. Using the capture history of spawners caught at the

Upper Independence Creek weir, we estimated the spawning probabilities ($s_{4,4}$ - $s_{5,5}$) by taking the proportion of instances of changing from one spawning stage to another. The Independence study did not contain the data needed to estimate the probabilities from Juvenile B to the spawning stages ($s_{4,3}$, $s_{5,3}$), so for simplicity we assumed $s_{4,3}$ and $s_{5,3}$ to be one-half, which is close to the Summit Lake probabilities. [15,21].

At Summit Lake, the Juvenile B to the spawning stage probabilities ($s_{4,3}$, $s_{5,3}$) were estimated by taking the proportion of Juvenile B individuals that participated in the spawning run each year. Because juveniles are difficult to sex, for simplicity we assumed the same probability for females and males each year [32]. The adult spawning probabilities ($s_{4,4}$ - $s_{5,5}$) were calculated from the detection of tagged individuals through the PIT antenna. This produced an annual list of individuals that spawned and survived or didn't spawn. Spawning survivors from the previous year were compared to the spawners the following year to determine $s_{5,5}$ and $s_{5,4}=1-s_{5,5}$. Likewise, nonspawners and spawners from the previous and the following years, respectively, were compared to calculate $s_{4,5}$ and $s_{4,4}=1-s_{4,5}$. The mean of the 2015–2016 and 2016–2017 probabilities were used for the model. The respective annual survival rates and spawning probabilities were multiplied to obtain the spawning transition rates for both models: $p_{5,3}=\phi_{JB} \times s_{5,3}$, $p_{4,3}=\phi_{JB} \times s_{4,3}$, $p_{5,5}=\phi_A \times s_{5,5}$, $p_{4,5}=\phi_A \times s_{4,5}$, $p_{5,4}=\phi_A \times s_{5,4}$, and $p_{4,4}=\phi_A \times s_{4,4}$ [21] (Table 3.2).

Evaluation

We quantified uncertainty in the population growth rates and the parameter sensitivities by estimating their normal probability distributions. First, we applied the CV from Summit Lake adult survival to every parameter in both models. Next, we generated 10,000 random samples from the standard normal distribution $N(0, 1)$. Then we used each sample (in turn) to select the respective value from each parameter distribution in both models, and ran the population growth rate and sensitivity analyses using the *popbio* package [54] in R. Last, we derived the mean and standard deviations for the population growth rates and parameter sensitivities [21].

3.3 Results

Independence Lake fecundity was 87 ± 2.78 (Table 3.3). Independence Lake Fry, Juvenile A and B, and adult survival were estimated at 0.027 ± 0.0009 , 0.25 ± 0.008 , 0.50 ± 0.016 , and 0.68 ± 0.022 , respectively (Tables 3.3-3.4). The spawning probabilities for $s_{5,3}$ and $s_{4,3}$ were mean of 0.7 ± 0.02 and 0.3 ± 0.01 , $s_{5,5}$ and $s_{4,5}$ were mean of 0.64 ± 0.02 and 0.36 ± 0.01 , and $s_{5,4}$ and $s_{4,4}$ were mean of 0.86 ± 0.03 and 0.14 ± 0.004 , respectively (Tables 3.5, 3.6). The spawning transition rates for $p_{5,3}$ and $p_{4,3}$ were mean of 0.35 ± 0.01 and 0.15 ± 0.005 , $p_{5,5}$ and $p_{4,5}$ were mean of 0.44 ± 0.01 and 0.24 ± 0.008 , and $p_{5,4}$ and $p_{4,4}$ were mean of 0.58 ± 0.02 and 0.10 ± 0.003 , respectively (Table 3.4). The population growth rate was mean 0.94 ± 0.05 (Fig 3.4). The top three sensitivity parameters for Independence Lake were $p_{2,1}$ (5.14 ± 0.03), $p_{3,2}$ (0.56 ± 0.003), $p_{5,5}$ (0.43 ± 0.007) (Table 3.7). The spawning run has increased linearly from 1997-2016 (adjusted $r^2=0.39$, $p=0.004$) [15,21].

Summit Lake fecundity was 0.85 ± 0.027 (Table 3.4). Because we had insufficient data to estimate juvenile survival, we used juvenile survival from the Independence study (Tables 3.3-3.4). For adult survival ($n=678$), the top model had constant survival and capture/recapture rates, and no covariates (Table 3.8). The Bayesian version of the top model estimated a posterior mean of 0.51 ± 0.016 [21]. The Gelman Rubin diagnostic was $1.01 < 1.1$, and the coefficient of variation was 0.032. The data cloning diagnostic indicated that the survival estimate from the resulting Bayesian model was essentially the MLE for this model and there was no influence of the prior distributions on the inferences (Table 3.9). The spawning probabilities for $s_{5,3}$ and $s_{4,3}$ were mean= 0.49 ± 0.018 and 0.51 ± 0.018 , $s_{5,5}$ and $s_{4,5}$ were mean= 0.58 ± 0.05 and 0.42 ± 0.05 , and $s_{5,4}$ and $s_{4,4}$ were mean= 0.18 ± 0.06 and 0.82 ± 0.06 , respectively (Tables 3.5-3.6). The spawning transition rates for $p_{5,3}$ and $p_{4,3}$ were mean= 0.25 ± 0.008 and 0.26 ± 0.008 , $p_{5,5}$ and $p_{4,5}$ were mean= 0.36 ± 0.012 and 0.28 ± 0.009 , and $p_{5,4}$ and $p_{4,4}$ were mean= 0.11 ± 0.004 and 0.53 ± 0.017 , respectively (Table 3.4). The population growth rate was mean= 0.52 ± 0.03 (Fig 3.4). The top three sensitivity parameters were $p_{5,4}$ (0.70 ± 0.0007), $p_{4,4}$ (0.66 ± 0.003), $p_{5,5}$ (0.31 ± 0.00009), respectively (Table 3.7). The spawning run has declined linearly from 1999–2017 (adjusted $r^2=0.78$, $p=3.90e-06$) [15,21].

3.4 Discussion

Independence Lake and Summit Lake contain stronghold populations of lake-dwelling Lahontan cutthroat that are critical for conserving the subspecies. Thus quantifying the population dynamics for each lake, which are exposed to different climate regimes and have different basal productivity, is crucial for crafting sustainable range wide management strategy. The similarities and differences between the lake systems and their spawning runs, concern for the spawning run trends, and the recently completed population dynamics research at both lakes presented the opportunity to compare the dynamics of these unique populations. We compared their population growth rates and the population parameters with the most influence on the growth rates. The analyses exposed significant differences and similarities that Lahontan cutthroat managers should find useful in their planning efforts.

The Independence Lake population growth rate indicated decline during the Independence study, but the long term trend indicates the opposite. Using the spawning run as a surrogate for the entire population, the population trend was positive since 1997, and the population mean after the Independence study almost doubled. Alternatively, with the 2016 population approximately equal to the population mean since 2005 (Table 3.1) (Fig 3.5) [15-16,email communication The Nature Conservancy Independence Lake Preserve], the population may have increased after the Independence study and then stabilized. The Independence Lake population currently appears (at minimum) stable at a higher abundance than during the Independence study, but continued increase is also possible.

Management efforts, climate, or natural population dynamics may have driven the purported positive trend. In the 1950s, fishing was prohibited in Upper Independence Creek and near the mouth. In the 1970s, rainbow and brook trout (*Oncorhynchus mykiss* and *Salvelinus fontinalis*, respectively) stocking was discontinued, angler harvest of Lahontan cutthroat in the lake was prohibited, and hatchery operations were conducted. However, the 1970s introduction (and subsequent proliferation) of kokanee salmon (*Oncorhynchus nerka*) has been a counterweight to these efforts. In 1993, over three hundred thousand Independence Lake strain Lahontan cutthroat fingerlings were planted in the lake. No management changes were enacted during the Independence study. The cumulative effect and longevity of the above conservation efforts and favorable climate (via snow water equivalent that was average to above average

[25]) during the Independence study may have bolstered the population to near stability against the negative competition or predation interactions with the nonnative salmonids (brook trout, kokanee salmon, brown trout-*Salmo trutta* [55-59]) in Upper Independence Creek and the lake [15]. After the Independence study, brook trout removal efforts (to eliminate brook trout predation) have been conducted annually to increase Lahontan cutthroat fry survival in Upper Independence Creek [60, email communication The Nature Conservancy]. The effort has been successful at eliminating most (if not all) brook trout [16, email Nature Conservancy Independence Lake Preserve]. From 2006-2010 the estimated egg production, number of migrating young, and egg-fry survival increased, and the effort has been linked to the increased spawning runs after the Independence study [60], and may have pushed the population growth rate to above one. Small changes in vital rates (e.g., fry survival) can produce large effects in a population's dynamics [61]. Another explanation for the increasing population trend is that the population was already increasing. The population growth rate histogram (Fig 3.4) had a small region above one, suggesting an increasing growth rate during the Independence study that continued afterward, which also suggests that the removal efforts may have had little impact on or further increased an already increasing growth rate. Or, a combination of the above factors may have been responsible. In recent years, drought conditions (2012-2016) [25-26]), which can reduce cutthroat trout abundance [62-64]), may have contributed to the spawning run declines observed after the peak in 2010 [16, email communication Nature Conservancy Independence Lake Preserve] (Table 3.1, Fig 3.5).

However, the population trend at Summit Lake is the opposite. The spawning run trend since 1999 is negative (eighty-one percent decline), and the declining population growth rate and adult abundances estimated in the Summit Lake study provide further evidence for a declining population [21]. Natural population cycling and climate seem to have been the primary drivers of the decline. Grazing on the federally managed and Summit Lake Paiute Reservation (Reservation) portions of Mahogany Creek were discontinued in 1974 [65] and 1991 [66], respectively; grazing within the remaining Reservation has been minimal since 1991 (with none since 2004) [66]; hatchery operations ended in 1984 (with the last few years considered to have a negligible impact on the population [67]); invasive salmonids have never been established in the system and the invasive minnows seem to exert little to no competition pressure

[Chandra, unpublished data]; tribal harvest has averaged a low percentage (approximately 2 percent) of the spawning run since 1992 [68]; and public access and fishing have not been allowed since the formation of the Reservation. Thus with relatively minimal human disturbance on the population and system in the last thirty years (approximately), the trend is likely due to other causes. Animal and fish populations commonly oscillate between high/low (boom/bust) numbers in periodic cycles due to biotic (e.g., density dependence) and abiotic (e.g., climate) factors [69]. The population seemed to overshoot carrying capacity in 1999 to initiate the current declining trend. Then severe, prolonged droughts in 2007-2009 and 2012-2016 exacerbated the decline to produce the declining population results observed during the Summit study [24-25,70].

Despite the long term decline and recent study results, the population's prognosis for the near or long term remains uncertain. Fish populations can rebound quickly from drought [63], and trout populations can experience precipitous declines with strong returns [71]. When precipitation increased successively in 2016 and 2017, the spawning run, number of migrating young, and transitions to the spawning stage increased, and spawning mortality decreased (Table 3.10). In addition, potentially reduced density dependent pressures from a smaller population may fuel a comeback (Table 3.1, Fig 3.6) [72]. But continued decline may continue and should be approached with caution. Given the consistent decline in adult abundance, the increased spawning numbers during the last two years could have simply been due to increased spawning participation as the population continues to decline. Drought had a long-term lag effects on a brown trout population via reduced densities of returning females and their eggs [73]. In either scenario, near term climatic conditions are certain to play a significant role in the population's trajectory, with continued drought conditions likely to drive the population downward, and non-drought conditions potentially giving the population a respite to recover.

The difference in population growth rates was likely driven by the interplay of fecundity, fry and juvenile survival, and the Nonspawning and Spawning transition rates. Independence Lake fecundity was extremely high compared to fecundities observed during the Summit Lake study [15,21] and in 1994 (~ 1.5, [65]), and approximately one and a half to three and a half times higher than the lake-dwelling cutthroat trout populations in Strawberry Reservoir, Utah (Bonneville cutthroat, *Oncorhynchus clarki utah*) and

Trapper's Lake, Colorado (Yellowstone cutthroat, *Oncorhynchus clarkii bowieri*, Colorado cutthroat, *Oncorhynchus clarki pleuriticus*, and their hybrids) (Table 3.11). The Summit Lake estimates were observed at the end or overlapping the end of prolonged drought periods. At Trappers Lake, fecundity increased as precipitation increased but declined after a threshold. The lowest fecundity (74) was observed during the lowest precipitation year. At Strawberry Reservoir, the lowest fecundity (75) was observed during a high precipitation year; the precipitation level may have been too high. Given enough years of prolonged drought, it is reasonable that fecundity levels may reach the low levels of the Summit Lake studies. Conversely, enough years of good precipitation may produce the high fecundity observed during the Independence Lake study. Compared to the Summit study, the high fecundity during the Independence study may have contributed more recruits to the adult population.

Summit Lake fecundity was likely affected by drought-induced processes in Mahogany Creek [76-77]. Low streamflows [78] decreased spawning habitat (resulting in increased energy expenditure for redd search, competition, or protection [6,79]) and refuge from terrestrial and avian predators [80]. SLPT biologists observed, particularly in 2015 (lowest precipitation of the drought), that many postspawners (especially males) were scarred (from mate search, competition and defense [81]) and that terrestrial and avian predation was prominent (spawner carcasses on the banks, wildlife camera photos of predators near the creek, and witness of bird predation or harassment on spawners) [82-84]. Low streamflows and higher water temperatures (temperature-oxygen squeeze [85]) reduced spawner migration distance (increased locomotive stress [79]), and decreased egg hatch rates, fry survival, and fry migration (stagnant flow and a thermal barrier in the lower creek during the summer) [6,71,86]. Conversely, higher streamflows have been linked to higher numbers of migrating fry or larger recruitment classes via a reverse of the above mechanisms [71,74]. In addition, Lahontan cutthroat fecundity can have high inter-annual variability. For example, during the Independence study the annual number of migrant young ranged from 0 to 27,046 (mean=9,980±8660) [15]). The peak occurred in 1997, which was also the biggest spawning run of the Independence study, and favorable climate leading up to and including that year (with snow water equivalent average to above average from 1995-1997 [25]) may have also fueled the high number [71, 74]. The variability suggests that pulse recruitment can be important for lake-dwelling Lahontan cutthroat

populations [61,71,87-90]. Additional years of data are needed from Summit Lake to detect a difference, and determine the drivers, in fecundity between the populations.

The sensitivity analyses for both studies identified Fry and Juvenile A survival and the Nonspawning and Spawning transition rates as having the most impact on the population growth rates. For Independence Lake, Fry and Juvenile A survival were the first and second most sensitive parameters, respectively (Table 3.7). Though performed differently, the sensitivity analysis of the Independence study also identified fry and juvenile survival as the most sensitive parameters [15]. California Department of Fish and Wildlife fisheries biologists have recommended kokanee control since the 1970s, after witnessing the dramatic decline of the Lahontan cutthroat spawning run following the introduction of kokanee in the mid-1950s [60,91]. During the Independence study, kokanee was the primary nonnative salmonid captured in the lake, with brook trout much less abundant and brown trout rare. Thus Independence study researchers conjectured that kokanee competition or predation reduced fry and juvenile survival in the lake [15,55]. After the Independence study, the brook trout removal study in Upper Independence Creek discovered Lahontan cutthroat fry in the stomachs of brook trout. This led the researchers (all but one of which participated in the Independence study) to hypothesize that brook trout predation may have also been reducing fry survival [60]. Interestingly, despite predation and competition in the lake and creek, the Independence Lake fry and juvenile survival estimates were still approximately mid-range compared to other (mostly non-cutthroat) river or stream trout populations (fry and juvenile survival studies for lake-dwelling cutthroat trout are few) (Table 3.12). Relatively high fry and juvenile survival rates may be required for adfluvial Lahontan cutthroat population growth.

Low fry and juvenile survival, resulting in low adult recruitment, could partially explain the low spawning runs and declining adult abundance during the Summit Lake study. The study did not estimate fry and juvenile survival, but given that its fecundity and transition rates to the spawning stage were lower than the Independence study, fry and juvenile survival also could have been lower. However, it is unlikely that lower fry and juvenile survival rates would have changed the results of the sensitivity analysis. We halved the rates, but the Nonspawning and Spawning transition remained the most sensitive parameters. In Mahogany Creek, predation is usually not a factor, except possibly from cannibalism [92], and competition

is low or nonexistent with the nonnative minnows (although native to the Lahontan basin) [65, Chandra, unpublished data]. In the lake, cannibalism and competition with the minnows seem to be the same as in the creek under non-drought conditions [Chandra, unpublished data]. Drought-induced mechanisms may have decreased fry and juvenile survival in the lake. Fry and juveniles prefer the nearshore littoral zone [93]. The lake level drop [27] reduced this habitat. In addition, the resulting evapoconcentration increased the salts concentration and the temperature-oxygen squeeze to shrink the lake's optimal trout habitat (between the relatively warm surface waters and the anoxic water layer at the bottom) in the remaining littoral zone and throughout the rest of the lake [23,94-95]. Reduced chemical and thermal refugia decreased fry and juvenile survival by increasing direct mortality [6], lowering immunity [6], or increasing the vulnerability to cannibalization by pushing fry and juveniles away from the cover and safety of the littoral zone into deeper water [92,96]. However, cannibalization may not have been a factor because Summit Lake Lahontan cutthroat are not considered to be as piscivorous as their Pyramid Lake and Independence Lake counterparts [12,15,93,97,Chandra, unpublished data]. Evapoconcentration has negatively affected other lake-dwelling Lahontan cutthroat and fish populations (Walker Lake, Nevada) [98].

For Summit Lake, the transition rates from the Nonspawning stage were key (Table 3.7) [21]. A low proportion of nonspawners became spawners the following year, but the Independence Lake population exhibited the opposite behavior for their nonspawners. The third most sensitive parameter for the Independence and Summit Lake populations was the Spawning to Spawning transition rate, signifying that repeat spawning was important for both populations. But again Independence Lake had the higher rate (Table 3.7) [15]. The spawning stage transitions are the product of survival and the respective spawning or nonspawning probabilities.

Independence Lake adult survival was high compared to Summit Lake, as well as Lahontan cutthroat populations in Walker Lake (desert terminal lake) [99] and the Truckee River (Table 3.13) [100]. The Walker Lake and Truckee River studies utilized methods that likely biased their estimates downward. At Walker Lake, the highest rate was the first year of the study (1999). No nonnative trout reside in the lake and true survival was estimated, but hatchery Lahontan cutthroat were used, which can exhibit lower fitness

than wild conspecifics [101-102], and the total dissolved solids level (approximately 11 g/L) at the beginning of the study was already high enough to significantly reduce survival. The Truckee River study had the lowest rate, but three factors may have biased the estimate downward: apparent survival (which is always lower than true survival) was estimated, hatchery Lahontan cutthroat were used, and the size of the fish planted in the river indicated that they were either large juveniles or first year adults, which could have still faced high competition and predation pressure by the wild populations of nonnative brown trout and rainbow trout [103-105], which are the most abundant trout populations in the river [100]. The Independence and Summit Lake populations are wild and their studies estimated true survival. But unlike the Summit Lake population, the Independence Lake population shared the lake with nonnative salmonids and had favorable climate during the Independence study, respectively [15]. Thus with different estimation methods, the use of hatchery Lahontan cutthroat, the presence or absence of nonnative trout, and extreme environmental conditions, it is difficult to determine how adult survival compares between Independence and Summit Lakes and against other Lahontan cutthroat populations. When compared to other trout populations, Independence Lake adult survival was still on the high end (Table 3.13). Less mortality in the lake or the spawning run, via favorable climate [25], may have led to this relatively high survival. In Summit Lake, less refugia from the drought directly or indirectly (lowered immunity and depleted energy reserves) reduced survival. In Mahogany Creek, drought conditions decreased survival from increased spawning mortality or depleted energy reserves that led to subsequent mortality in the lake [6,21,65].

The spawning probabilities were higher during the Independence Lake study than the Summit Lake study [15,21]. Comparing spawning probability estimates across additional studies was difficult because of the variety of methods. The skipped spawning estimates of lake trout populations in the Priest Lake, Idaho and Lake Ontario were one year snapshots based on the status of the reproductive organs, and the methods for determining the repeat spawning estimates for the lake-dwelling Yellowstone cutthroat at Yellowstone Lake were unclear [106-108]. Although the methods in the Independence Lake and Summit Lake studies were not the same, the methods were the most similar and accurate because they attempted to track the spawning attempts and mortality of individuals across multiple years. The spawning transitions

were the most sensitive parameters for Summit Lake because of low adult survival and low spawning probabilities.

At Summit Lake, the stress imposed by evapoconcentration likely led to less spawning via intertwined mechanisms. The increased stress from evapoconcentration shunted energy from growth and reproduction [6,109]. Further, lake-dwelling Lahontan cutthroat obtain a large percentage of nutrition by feeding in the littoral zone [92,110-112]. The reduced littoral zone decreased nutritional intake [109] and energy for growth and reproduction [113-117] and thus may have motivated increased cannibalism on juveniles that were forced out of the littoral zone [92]. These processes combined to produce less juveniles entering or completing puberty (retarded gonad development), reduced production or development of eggs [118], or increased skipped spawning in adults [29-30]. In addition, low flows and high temperatures in Mahogany Creek triggered less participation in spawning run [119]. At Independence Lake, with relatively high adult survival and a favorable climate, the sensitivity of repeat spawning probability likely resulted from energy being shunted from growth and reproduction due to competition and predation pressure from kokanee.

Broader scale questions regarding life history traits become salient when we overlay the different study climates onto the disparate habitats. Independence received mostly above average snowpack during the Independence study [15], whereas the Summit study [21] began at the tail end of a severe drought and did not receive above average snowpack until two years later. This context has lead us to consider four scenarios to explain the results of this comparison study. First, the sensitivity of the adult transitions at Summit may be due to life history adaptation to the desert environment. Borrowing from the concept of remnant populations [120], under harsh and variable environmental conditions natural selection may favor the survival of Lahontan cutthroat adults until environmental conditions are more favorable for reproduction. Second, the adult sensitivities may be simply a phenotypic plastic response to the desert environment; or third, the adult sensitivities may be simply a temporary result of the drought and that under sustained above average snowpack the Summit Lake sensitivities would be similar to the Independence study [15]; or fourth, a combination of the three. Identifying the correct scenario is important for

understanding the variation in life history traits of lake-dwelling Lahontan cutthroat populations, and thus may have long term management implications.

In summary, our comparison reveals that the Independence and Summit Lake population dynamics had more differences than similarities. Independence Lake had a positive trend in the spawning run, a higher population growth rate, and higher adult survival and transition rates into the spawning stage. Both population growth rates indicated decline, but the Independence Lake rate was much higher and had a small probability of stability or growth. The most sensitive parameters for Independence Lake were Fry and Juvenile survival, which may in part have neutralized the much higher fecundity. The most sensitive parameters for Summit Lake were the Nonspawning stage transitions. Both populations (though higher at Independence), however, shared repeat spawning as the third most sensitive parameter. The results support that recruitment and proportionally more spawners were the main drivers for the relatively healthier population dynamics at Independence Lake. We postulate, in part, that the non-drought conditions during the Independence study contributed to their relatively healthier population dynamics, with essentially a reverse of the likely drought effects at Summit Lake [21]. Lahontan cutthroat are adapted to warmer, alkaline waters [10,121-122], but the cascading, compounding, and cumulative effects of the drought likely pushed the population beyond optimal reproduction and survival at Summit Lake compared to Independence Lake.

Management implications

Lahontan cutthroat managers at Independence Lake should focus on increasing fry and juvenile survival and repeat spawning. Twelve years have elapsed since the population viability analysis [15], so it is unknown whether fry and juvenile survival remain the most sensitive parameters. However, given the results from the brook trout removal effort, it is reasonable for the primary focus to remain on fry and juvenile survival. Continued monitoring of the creek is necessary to prevent future brook trout invasions, but the focus should shift to suppressing kokanee [55] because nonnative suppression efforts have been demonstrated to benefit native adfluvial trout populations [123]. In addition to lowering the lake level to destroy the nearshore kokanee redds [16], managers may utilize methods (such as netting) from the (current

and developing) lake trout suppression model at Yellowstone Lake. Last, removing the angling limits on nonnative fish may prove effective. Angling pressure almost drove the bull trout population of Lower Kananaskis Lake to extinction [72]. Reducing the predation and competition pressures (thus stress) of nonnatives may provide more energy for reproduction to increase repeat spawning [109].

Tribal managers should focus on increasing fecundity and the transition rates to the Spawning stage. Mahogany Creek, tribal harvest, and lake water quality may be the vehicles through which to achieve the above goals. Though much improved in recent years, stretches of Mahogany Creek remain degraded from past livestock grazing and irrigation modifications. Restoration of degraded stretches of the instream and riparian corridor [23,65] should improve or increase habitat for the entire spawning cycle, including spawner survival [6]. Instream remediation could include the restoration of sedimented spawning grounds to increase the quantity and quality of redds [124]. Riparian corridor remediation, via the planting of native vegetation [124], should decrease terrestrial and avian predation [76], reduce water temperatures via shading [124], and increase food sources [125-126]. Next, to protect the tribe's long-term cultural bond to the fishery [8,65], we recommend that tribal harvest be eliminated or substantially reduced during periods of population decline. In addition, the normal harvest level should be reevaluated. Relatively high harvest levels in the past may have contributed to a population decline [21]. Livestock grazing was substantially reduced in 1990 (with none since 2004). Tribal managers should continue to develop other revenue sources to substitute for grazing permits, and should consider acquiring the last privately owned section of shoreline, which is exposed to grazing [65-66]. These actions should create financial and physical buffers to protect and improve water quality (i.e., minimize sedimentation and nutrient input from erosion and waste) [127], which should in turn reduce stress and provide more energy for individual trout growth and reproduction.

The broader management implications for the subspecies derive from considerations of life history adaptations or traits. First, adults may be the appropriate conservation target for lake-dwelling Lahontan cutthroat populations in desert habitats. Second, with the genetic separation between the Independence Lake and Summit Lake populations [128], restoring Lahontan cutthroat lake systems may require that transplants or hatchery plants be sourced from similar systems (montane or desert), which further highlights

the need to sustain the Independence and Summit Lake populations as healthy strongholds. If, however, the population differences are due simply to plasticity, then transplants and hatchery plants can be sourced from any population. Regardless of whether life history adaptation or plasticity is driving the Independence Lake and Summit Lake populations, at minimum managers may need to shift to different conservation strategies (juvenile or adult) based on habitat (montane or desert) or climate (drought or non-drought). This comparative study demonstrates that Lahontan cutthroat managers should be wary to apply a one size fits all management strategy to conserve lake-dwelling Lahontan cutthroat across its disparate range.

Future research

The themes of life history adaptation vs. plasticity and climate change should fuel future research. Disentangling whether life history adaptation or plasticity is the main driver behind the populations' differences will require continued research at Summit Lake to make the study length comparable to the Independence study [15] and to improve parameter estimates. In addition, better estimates can be obtained by including more abiotic (e.g., precipitation) and biotic (e.g., density dependence) covariates and improving the population model by applying a two-sex integrated population model (IPM) that utilizes all available data (ex., additional PIT antenna and fish trap data) and addresses potential sex ratio bias [129-130]. Last, additional or improved sampling techniques should be investigated to capture more juveniles and reduce potential sampling bias [21]. For juveniles, boat electrofishing in the shallow nearshore may be productive; and for sampling bias, more effort in the open water and the middle of the water column, so that effort is spread away from the shoreline and lake bottom (along with different net types to accomplish this), may prove beneficial.

How the populations will react to climate change adds another layer of complexity to the potential population dynamics differences. Climate change is predicted to push cutthroat trout populations to cooler, higher elevations [131], but little is known regarding how climate change will shift their population dynamics [123]. Shifting population dynamics may have large management implications. Further, with lakes as sentinels of climate change [132], and most cutthroat trout population dynamics research focused on streams and rivers [Tables 3.11-3.13], research should focus on lake-dwelling cutthroat trout

populations within a whole-lake ecological context. Lahontan cutthroat researchers and managers should investigate how climate change will impact the whole-lake ecology and population dynamics of lake-dwelling Lahontan cutthroat across the native range [123].

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3.5 References

1. Ricciardi A, Rasmussen JB. Extinction rates of North American freshwater fauna. *Conserv Biol.* 1999;13:1220-2.
2. Burkhead NM. Extinction rates in North American freshwater fishes, 1900-210. *Bioscience.* 2012;62(9):798-808.
3. Cayan DR, Dettinger MD, Pierce D, Das T, Knowles N, Ralph FM, et al. Natural variability, anthropogenic climate change, and impacts on water availability and flood extremes in the western United States. In Miller KA, Hamlet AF, Kenney DS, Redmond KT, editors. *Water policy and planning in a variable changing climate.* Boca Raton: CRC Press; 2016. p. 17–42.
4. Harpold AA, Dettinger M, and Rajagopal S. Defining snow drought and why it matters. *Eos* 2017;98 <https://doi.org/10.1029/2017EO068775>.
5. Lynch AJ, Myers BJ, Chu C, Eby LA, Falke JA, Kovach RP, et al. Climate change effects on North American inland fish populations and assemblages. *Fisheries.* 2016;41(7):346-61.
6. Whitney JE, Al-Chokhachy R, Bunnell DB, Caldwell CA, Cooke SJ, Eliason EJ, et al. Physiological basis of climate change impacts on North American inland fishes. *Fisheries.* 2016;41(7):332-45.
7. Paukert C, Glazer BA, Hansen GJA, Irwin BJ, Jacobson PC, Kershner JL, Shuter BJ, Whitney JE, Lynch AJ. Adapting inland fisheries management to a changing climate. *Fisheries.* 2016;41(7):374-84.
8. Trotter P. *Cutthroat: native trout of the West.* 2nd ed. Berkeley: University of California Press; 2008.
9. Loxterman JL, Keeley ER. Watershed boundaries and geographic isolation: patterns of diversification in cutthroat trout from western North America. *BMC Evol Biol.* 2012;12(1):38.
10. Vigg S, Koch DL. Upper lethal temperature range of Lahontan cutthroat trout in waters of different ionic concentration. *Trans Am Fish Soc.* 1980;109:336-9.
11. U.S. Fish and Wildlife Service [Internet]. Falls Church, Virginia (USA): U.S. Fish and Wildlife Service; May 7, 2018. Environmental conservation online system; April 17, 2017 [cited 7 May 2018]; [3 screens]. Available from: <https://ecos.fws.gov/ecp0/pub/SpeciesReport.do?groups=E&listingType=L&mapstatus=1>.
12. Gerstung ER. Status, life history, and management of the Lahontan cutthroat trout. In: Gresswell RE, editor. *Status and management of interior stocks of cutthroat trout.* Bethesda: American Fisheries Society; 1988. p. 93-106.
13. Coffin PD, Cowan WF. Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) recovery plan. Portland, OR: U.S. Fish and Wildlife Service, Region 1; 1995. 108 p.
14. Lea TN. Ecology of the cutthroat trout. *Salmo clarkii henshawi*, in Independence Lake, California. M.Sc. Thesis. University of California, Berkeley. 1968.
15. Rissler PH, Scopettone GG, Shea S. Life history, ecology and population viability analysis of the Independence Lake strain Lahontan cutthroat trout (*Oncorhynchus clarkii henshawi*). Reno (NV): U.S. Geological Survey, Western Fisheries Research Center; 2006.

16. Rissler P. Independence Lake 2014 Update. Reno, Nevada (USA): Status update presented at; LCT (Lahontan cutthroat trout) Interagency Meeting; 2015.
17. Youmans R, Zeyer R, Mathews K, Cowan W. 2016 Annual Narrative Report. Sparks, Nevada (USA): Summit Lake Paiute Tribe; 2017. 35 p. Report No.: Fisheries Management Services Contract Number A10AV00358.
18. Cowan WF. Interpretation of pertinent statistics concerning the Summit Lake fisheries management program, 1968-1990. Winnemucca, Nevada (USA): Summit Lake Paiute Tribe; 1991. 7 p.
19. De Lara M, Doyen L, Guilbaud T, Rochet M. Is a management framework based on spawning-stock biomass indicators sustainable? A viability approach. *ICES J Mar Sci.* 2007;64:761–7.
20. Boyce, MS. Population viability analysis. *Annu Rev Ecol Syst.* 1992;23:481-506.
21. Simmons J. Population dynamics of the lake-dwelling population of threatened Lahontan cutthroat trout at Summit Lake, Nevada. M.Sc. Thesis, The University of Nevada, Reno, NV. 2018.
22. Brown RL, McCune WJ, editors. Independence Lake limnologic study. Sacramento (CA): State of California, The Resources Agency, Department of Water Resources, Central District; 1977. 50 p.
23. Vigg S. Limnological survey of Summit Lake, Nevada. Reno (NV): Desert Research Institute, Bioresources Center; 1983. 45 p.
24. The Nature Conservancy [Internet]. Arlington, Virginia (USA): The Nature Conservancy; 2018. Independence Lake Angling Regulations; 2018; [cited 2018 Jan 22]; [3 screens]. Available from: <https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/nevada/independence-lake-fishing-information.pdf>
25. Margulis SA, Cortés G, Giroto M, Durand M. A Landsat-era Sierra Nevada snow reanalysis (1985–2015). *J Hydrometeor.* 2016;17:1203-21.
26. Wise E. Five centuries of US West Coast drought: occurrence, spatial distribution, and associated atmospheric circulation patterns. *Geophys Res Lett.* 2016;43:4539–46. doi: 10.1002/2016GL068487.
27. Youmans R, Zeyer R, Mathews K, Cowan W. 2016 Annual Narrative Report. Sparks, Nevada (USA): Summit Lake Paiute Tribe; 2017. 35 p. Report No.: Fisheries Management Services Contract Number A10AV00358.
28. U.S. Fish and Wildlife Service [Internet]. Falls Church, Virginia (USA): U.S. Fish and Wildlife Service; May 7, 2018. Lahontan cutthroat trout, *Oncorhynchus clarkii henshawi*; April 16, 2014 [cited 7 May 2018]; [6 screens]. Available from: https://www.fws.gov/nevada/protected_species/fish/species/lct.html.
29. Rideout RM, Rose GA, Burton MP. Skipped spawning in female iteroparous fishes. *Fish Fish.* 2005;6:50-72.
30. Sitar S, Jasonowicz A, Murphy C, Goetz F. Estimates of skipped spawning in lean and siscowet lake trout in southern Lake Superior: implications for stock assessment. *Trans Am Fish Soc.* 2014;143:660–72.
31. Caswell H. Matrix population models: construction, analysis and interpretation. 2nd ed. Sunderland: Sinauer Associates, Inc.; 2001.

32. Stapp P, Hayward GD. Effects of an introduced piscivore on native trout: insights from a demographic model. *Biol Invasions*. 2002;4:299–316.
33. Meyer KA, Schill DJ, Elle FS, Lamansky Jr. JA. Reproductive demographics and factors that influence length at sexual maturity of Yellowstone cutthroat trout in Idaho. *Trans Am Fish Soc*. 2003;132:183-95.
34. Williams BK, Nichols JD, Conley MJ. Analysis and management of animal populations. San Diego: Academic Press; 2002.
35. Hubert WA, Pope KL, Dettmers JM. Passive Capture Techniques. In: Zale AV, Parrish DL, Sutton TM, editors. *Fisheries Techniques*. 3rd ed. Bethesda: American Fisheries Society; 2012. p. 223-65.
36. Kendall WL, Pollock KH. The robust design in capture-recapture studies: a review and evaluation by Monte Carlo simulation. In: McCullough DR, Barrett RH, editors. *Wildlife 2001: populations*. London: Elsevier; 1992. p. 31-43.
37. Nowak GM, Tabor RA, Warner EJ, Fresh KL, Quinn TP. Ontogenetic shifts in habitat and diet of cutthroat trout in Lake Washington, Washington. *N Am J Fish Manag*. 2004;24:624–35.
38. Beauchamp DA, Vecht, SA, Thomas GL. Temporal, spatial, and size-related foraging of wild cutthroat trout in Lake Washington. *Northwest Sci*. 1992;66(3):149–59.
39. Baldwin CS, Beauchamp DA, Gubala CP. Seasonal and diel distribution and movement of cutthroat trout from ultrasonic telemetry. *Trans Am Fish Soc*. 2002;131:143–58.
40. Campbell T, Simmons J, Sáenz J, Zeyer R, Jerde CL, Cowan W, Chandra S, Hogan Z. Population connectivity of adfluvial and stream-resident Lahontan cutthroat trout: Implications for resilience, management, and restoration. *Can J Fish Aquat Sci*. Forthcoming 2018.
41. Morán P, Labbé L, Garcia de Leaniz C. The male handicap: male-biased mortality explains skewed sex ratios in brown trout embryos. *Biol Lett*. 2016;12(12):20160693.
42. Barker RJ. Joint modeling of live-recapture, tag-resight, and tag-recovery data. *Biometrics*. 1997;53:666-77.
43. White GC, Burnham KP. Program MARK: survival estimation from populations of marked animals. *Bird Stud*. 1999;46:120–39.
44. Pradel R. Utilization of capture–mark–recapture for the study of recruitment and population growth rate. *Biometrics*. 1996;52(2):703–09.
45. Huggins RM. On the statistical analysis of capture experiments. *Biometrika*. 1989;76:133–40.
46. Huggins RM. Some practical aspects of a conditional likelihood approach to capture experiments. *Biometrics*. 1991;47:725–32.
47. Akaike H. Information theory as an extension of the maximum likelihood principle. In Petrov BN, Csaki F, editors. *2nd International Symposium on Information Theory*. Budapest: Akademiai Kiado; 1973. pp. 267-81.
48. Burnham KP, Anderson DR. Model selection and multimodel inference: a practical information-theoretic approach. 2nd ed. New York: Springer-Verlag New York, Inc.; 2002.

49. R Core Team. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2016. Available from: <http://www.R-project.org/>.
50. Su Y, Yajima M. R2Jags: using R to run 'JAGS'. R package version 0.5-7. 2015. Available from: <https://cran.r-project.org/web/packages/R2jags>.
51. Plummer M. JAGS: A program for analysis of Bayesian graphical models using Gibbs sampling. In: Proceedings of the 3rd International Workshop on Distributed Statistical Computing. vol. 124. Vienna; 2003. p. 125.
52. Gelman A, Rubin DB. Inference from iterative simulation using multiple sequences. Stat Sci. 1992;7:457–511.
53. Lele SR, Dennis B, Lutscher F. Data cloning: easy maximum likelihood estimation for complex ecological models using Bayesian Markov chain Monte Carlo methods. Ecol Lett. 2007;10:551–63. doi: 10.1111/j.1461-0248.2007.01047.x.
54. Stubben C, Milligan B, Nantel P. Popbio: construction and analysis of matrix population models. R package version 2.4.3. 2016. Available from: <https://CRAN.R-project.org/package=popbio>.
55. Shedd KR, von Hippel FA, Willacker JJ, Hamon TR, Schlei OL, Wenburg JK, Miller JL, Pavey SA. Ecological release leads to novel ontogenetic diet shift in kokanee (*Oncorhynchus nerka*). Can J Fish Aquat Sci. 2015;72: 1718–1730.
56. Shemai B, Sallénave R, Cowley DE. Competition between hatchery-raised Rio Grande cutthroat trout and wild brown trout. N Am J Fish Manag. 2007;27:315–25.
57. Wang L, White RJ. Competition between wild brown trout and hatchery greenback cutthroat trout of largely wild parentage. N Am J Fish Manag. 1994;14:475-87.
58. Kruse CG, Hubert WA, Rahel FJ. Status of Yellowstone cutthroat trout in Wyoming waters. N Am J Fish Manag. 2000;20:693-705.
59. McGrath CC, Lewis Jr. WM. Competition and predation as mechanisms for displacement of greenback cutthroat trout. Trans Am Fish Soc. 2007;136:1381–92.
60. Scopettone GG, Rissler PH, Shea SP, Somer W. Effect of brook trout removal from a spawning stream on an adfluvial population of Lahontan cutthroat trout. N Am J Fish Manag. 2012;32(3):586-96. DOI: 10.1080/02755947.2012.675958.
61. Houde ED. Fish early life dynamics and recruitment variability. Am Fish Soc Symp. 1987;2:17-29.
62. Meyer KA, Larson EI, Sullivan CL, High B. Trends in the distribution and abundance of Yellowstone cutthroat trout and nonnative trout in Idaho. J Fish Wildl Manag. 2014;5(2):227-42.
63. Humphries P, Baldwin DS. Drought and aquatic ecosystems: an introduction. Freshw Biol. 2003;48:1141-6.
64. Matthews WJ, Marsh-Matthews E. Effects of drought on fish across axes of space, time and ecological complexity. Freshw Biol. 2003;48:1232-53.
65. Vinyard GL, Winzeler A. Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) spawning and downstream migration of juveniles into Summit Lake, Nevada. West N Am Nat. 2000;60(3):333-41.

66. Novak-Echenique P, Youmans R. Summit Lake Indian Reservation Range Management Plan. Sparks, Nevada (USA): United States Department of Agriculture, Natural Resources Conservation Service and Summit Lake Paiute Tribe; March 2013. 38 p.
67. Cowan WF. Interpretation of pertinent statistics concerning the Summit Lake fisheries management program, 1968-1990. Winnemucca, Nevada (USA): Summit Lake Paiute Tribe; 1991. 7 p.
68. 1968-2016 Summit Lake Paiute Tribe annual narrative reports. Sparks, Nevada (USA): Summit Lake Paiute Tribe.
69. Sinclair AR, Fryxell JM, Caughley G. Wildlife ecology, conservation and management. 2nd ed. Malden: Blackwell Publishing Ltd; 2006.
70. Jones J. California's most significant droughts: comparing historical and recent conditions. Sacramento, California (USA): California Natural Resources Agency, Department of Water Resources; February 2015. 126 p.
71. Lobon-Cervia J. Why, when and how do fish populations decline, collapse and recover? The example of brown trout (*Salmo trutta*) in Rio Chaballos (northwestern Spain). *Freshw Biol.* 2009;54:1149–62.
72. Johnston FD, Post JR. Density-dependent life-history compensation of an iteroparous salmonid. *Ecol Appl.* 2009;19(2):449–67.
73. Elliott JM, Hurley MA, Elliott JA. Variable effects of droughts on the density of sea-trout *Salmo trutta* over 30 years. *J Appl Ecol.* 1997;34:1229-38.
74. Drummond RA, McKinney TD. Predicting the recruitment of cutthroat trout fry in Trappers Lake, Colorado. *Trans Am Fish Soc.* 1965;94(4):389-93.
75. Knight CA. Spawning attributes and early life-history strategies of adfluvial cutthroat trout in Strawberry Basin, Utah. M.Sc. Thesis. Utah State University, Logan. 1997.
76. Hakala JP, Hartman KJ. 2004. Drought effect on stream morphology and brook trout (*Salvelinus fontinalis*) populations in forested headwater streams. *Hydrobiologia.* 2004;515:203-13.
77. Harvey BC, Nakamoto RJ, White JL. Reduced streamflow lowers dry-season growth of rainbow trout in a small stream. *Trans Am Fish Soc.* 2006;135:998-1005.
78. Campbell T, Simmons J, Sáenz J, Zeyer R, Jerde CL, Cowan W, Chandra S, Hogan Z. Population connectivity of adfluvial and stream-resident Lahontan cutthroat trout: Implications for resilience, management, and restoration. *Can J Fish Aquat Sci.* Forthcoming 2018.
79. Fenkes M, Shiels HA, Fitzpatrick JL, Nudds RL. The potential impacts of migratory difficulty, including warmer waters and altered flow conditions, on the reproductive success of salmonid fishes. *Comp Biochem Physiol A Mol Integr Physiol.* 2016;193:11-21.
80. Penaluna BE, Dunham JB, Noakes DG. Instream cover and shade mediate avian predation on trout in semi-natural streams. *Ecol Freshw Fish.* 2016;25:405-11.
81. Quinn TP. The behavior and ecology of Pacific salmon and trout. Vancouver: UBC Press; 2005.
82. Saenz J, Zeyer R, Cowan W. 2014 Annual Narrative Report. Sparks, Nevada (USA): Summit Lake Paiute Tribe; 2015. 29 p. Report No.: Fisheries Management Services Contract Number A10AV00358.

83. Youmans R, Zeyer R, Mathews K, Cowan W. 2015 Annual Narrative Report. Sparks (NV): Summit Lake Paiute Tribe; 2016. 35 p. Report No.: Fisheries Management Services Contract Number A10AV00358.
84. Sáenz J, Cowan W, Youmans R, Zeyer R, Gibson E. Status of Summit Lake LCT: 2014 spawning run and future research needs in the Summit Lake basin. Summit Lake Paiute Tribe, LCT Interagency Meeting, Reno, NV, 2015 Jan 14-15. This comes first, should be 72.
85. Helfman GS, Collette BB, Facey DE, Bowen BW. The diversity of fishes: biology, evolution, and ecology. 2nd edition. Chichester: Wiley-Blackwell; 2009.
86. Recsetar M, Bonar S. Survival of Apache trout eggs and alevins under static and fluctuating temperature regimes. *Trans Am Fish Soc.* 2013;142:373–79.
87. Pfister CA. The role and importance of recruitment variability to a guild of tide pool fishes. *Ecology.* 1996;6:1928-41.
88. Bergstad OA, Hansen HØ, Jørgensen T. Intermittent recruitment and exploitation pulse underlying temporal variability in a demersal deep-water fish population. *ICES J Mar Sci.* 2014;71(8):2088–2100. doi:10.1093/icesjms/fst202.
89. Ebert TA, Schroeter SC, Dixon JD. Inferring demographic processes from size-frequency distributions: effect of pulsed recruitment on simple models. *Fish Bull.* 1993;91:237-43.
90. Tang S, Chen L. Density-dependent birth rate, birth pulses and their population dynamic consequences. *J Math Biol.* 2002;44:185-99.
91. Gerstung ER. Management plan for Lahontan cutthroat trout of Independence Lake. Sacramento (CA): California Department of Fish and Game, Inland Fisheries Branch; 1977.
92. Baldwin CM, Beauchamp DA, Van Tassell JJ. Bioenergetic assessment of temporal food supply and consumption demand by salmonids in the Strawberry Reservoir food web. *Trans Am Fish Soc.* 2000;129:429–50.
93. Nowak GM, Tabor RA, Warner EJ, Fresh KL, Quinn TP. Ontogenetic shifts in habitat and diet of cutthroat trout in Lake Washington, Washington. *N Am J Fish Manag.* 2004;24:624–35.
94. Horne A, Goldman C. *Limnology.* 2nd ed. New York: McGraw-Hill, Inc.; 1994.
95. Rowe DK, Chisnall BL. Effects of oxygen, temperature and light gradients on the vertical distribution of rainbow trout, *Oncorhynchus mykiss*, in two North Island, New Zealand, lakes differing in trophic status. *N Z J Mar Freshwater Res.* 1995;29:421-34.
96. Tabor RA, Wurtsbaugh WA. Predation risk and the importance of cover for juvenile rainbow trout in lentic systems. *Trans Am Fish Soc.* 1991;120:728–38.
97. Sigler WF, Helm WT, Kucera PA, Vigg S, Workman GW. Life history of the Lahontan cutthroat trout, *Salmo clarki henshawi*, in Pyramid Lake, NV. *Great Basin Nat.* 1983;43(1):1-29.
98. Marioni N. Effects of declining lake levels on fish populations in Walker Lake, NV. M.Sc. Thesis. The University of Nevada, Reno. 2007.

99. Sedinger JS, Blomberg EJ, VanDellen AW, Byers S. Environmental and population strain effects on survival of Lahontan cutthroat trout in Walker Lake, Nevada: a Bayesian approach. *N Am J Fish Manag.* 2012;32:515–22.
100. Alexiades AV, Peacock MM, Al-Chokhachy R. Movement patterns, habitat use, and survival of Lahontan cutthroat trout in the Truckee River. *N Am J Fish Manag.* 2012;32:974–83.
101. Kostow K. Differences in juvenile phenotypes and survival between hatchery stocks and a natural population provide evidence for modified selection due to captive breeding. *Can J Fish Aquat Sci.* 2004;61:577–89.
102. Araki H, Berejikian BA, Ford MJ, Blouin MS. Fitness of hatchery-reared salmonids in the wild. *Evol Appl.* 2008;1(2):342–55.
103. Seiler SM, Keeley ER. Morphological and swimming stamina differences between Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*), rainbow trout (*Oncorhynchus mykiss*), and their hybrids. *Can J Fish Aquat Sci.* 2007;64:127–35.
104. Seiler, S.M. Ecological and environmental investigations of competition between native Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*), rainbow trout (*Oncorhynchus mykiss*) and their hybrids. Ph.D. Dissertation. Idaho State University, Pocatello. 2007.
105. Seiler SM, Keeley ER. A comparison of aggressive and foraging behaviour between juvenile cutthroat trout, rainbow trout, and F1 hybrids. *Anim Behav.* 2007;74:1805–12.
106. Ng EL, Fredericks JP, Quist MC. Population dynamics and evaluation of alternative management strategies for nonnative lake trout in Priest Lake, Idaho. *N Am J Fish Manag.* 2016;36(1):40–54.
107. Sitar S, Jasonowicz A, Murphy C, Goetz F. Estimates of skipped spawning in lean and siscowet lake trout in southern Lake Superior: implications for stock assessment. *Trans Am Fish Soc.* 2014;143:660–72.
108. Jones RD, Carty DG, Greswell RE, Gunther KA, Lentsch LD, Mohrman J. Fishery and aquatic management program in Yellowstone National Park. Yellowstone National Park, Wyoming (USA). U.S. Fish and Wildlife Service; 1985. Tech. Rep. 1984. 189 p.
109. Schreck C, Contreras-Sanchez W, Fitzpatrick M. Effects of stress on fish reproduction, gamete quality, and progeny. *Aquaculture.* 2001;197:3–24.
110. Beauchamp DA, Vecht, SA, Thomas GL. Temporal, spatial, and size-related foraging of wild cutthroat trout in Lake Washington. *Northwest Sci.* 1992;66(3):149–59.
111. Baldwin CS, Beauchamp DA, Gubala CP. Seasonal and diel distribution and movement of cutthroat trout from ultrasonic telemetry. *Trans Am Fish Soc.* 2002;131:143–58.
112. Nowak GM, Quinn TP. Diel and seasonal patterns of horizontal and vertical movements of telemetered cutthroat trout in Lake Washington, Washington. *Trans Am Fish Soc.* 2002;131:452–62.
113. Tocher Dr. Metabolism and functions of lipids and fatty acids in teleost fish. *Reviews in fisheries science.* 2003;11(2): 107–84.
114. Valdebenito II, Gallegos PC, Effer BR. Gamete quality in fish: evaluation parameters and determining factors. *Zygote.* 2015;23(2):177–97. doi: 10.1017/S0967199413000506.

115. Hill H, Twibell R, Conway J, Gannam A, Seals J. Influence of lineage, broodstock conditioning, and hormone injection on Gila trout reproductive success and egg fatty acid composition. *N Am J Aquac.* 2013;75:393-403.
116. Izquierdo MS, Fernández-Palacios H, Tacon AG. Effect of broodstock nutrition on reproductive performance of fish. *Aquaculture.* 2001;197:25-42.
117. Pickova J, Brännäs E, Andersson T. Importance of fatty acids in broodstock diets with emphasis on Arctic char (*Salvelinus alpinus*) eggs. *Aquac Int.* 2007;15:305-11.
118. McBride RS, Somarakis S, Fitzhugh GR, Albert A, Yaragina NA, Wuenschell MJ, Alonso-Fernández A, Basilone G. Energy acquisition and allocation to egg production in relation to fish reproductive strategies. *Fish Fish.* 2015;16:23-57.
119. Jonsson B, Jonsson N, Hansen LP. Factors affecting river entry of adult Atlantic salmon in a small river. *J Fish Biol.* 2007;71:943-56.
120. Eriksson O. Functional roles of remnant plant populations in communities and ecosystems. *Glob Ecol Biogeogr.* 2000;9(6):443-49.
121. Wilkie MP, Wood C. The adaptations of fish to extremely alkaline environments. *Comp Biochem Physiol B Biochem Mol Biol.* 1996;113(4):665-73.
122. Dickerson BR, Vinyard GL. Effects of high chronic temperatures and diel temperature cycles on the survival and growth of Lahontan cutthroat trout. *Trans Am Fish Soc.* 1999;128:516-21.
123. Kovach RP, Al-Chokhachy R, Whited DC, Schmetterling DA, Dux AM, Muhlfeld CC. Climate, invasive species and land use drive population dynamics of a cold-water specialist. *J Appl Ecol.* 2017;54:638-47. doi: 10.1111/1365-2664.12766.
124. Williams JE, Neville HM, Haak AL, Colyer WT, Wenger SJ, Bradshaw S. Climate change adaptation and restoration of western trout streams: opportunities and strategies. *Fisheries.* 2015;40(7):304-17.
125. Nakano S, Kawaguchi Y, Taniguchi Y, Miyasaka H, Shibata Y, Urabe H, et al. Selective foraging on terrestrial invertebrates by rainbow trout in a forested headwater stream in northern Japan. *Ecol Res.* 1999;14:351-60.
126. Nakano S, Miyasaka H, Kuhara N. Terrestrial-aquatic linkages: riparian arthropod inputs alter trophic cascades in a stream food web. *Ecology.* 1999;80(7):2435-41.
127. Hubbard RK, Newton GL, Hill GM. Water quality and the grazing animal. Lincoln, Nebraska (USA): Publications from USDA-ARS / UNL Faculty; 2004. Available from: <http://digitalcommons.unl.edu/usdaarsfacpub/274>.
128. Nielsen JL, Sage GK. Population genetic structure in Lahontan cutthroat trout. *Trans Am Fish Soc.* 2002;131:376-88.
129. Tenan S, Iemma A, Bragalanti N, Pedrini P, De Barba M, Randi E, et al. Evaluating mortality rates with a novel integrated framework for nonmonogamous species. *Conserv Biol.* 2016;30(6):1307-19.
130. Gerber LR, White ER. Two-sex matrix models in assessing population viability: when do male dynamics matter? *J Appl Ecol.* 2014;51:270-8.

131. Williams JE, Isaak DJ, Imhof J, Hendrickson DA, McMillan JR. Cold-water fishes and climate change in North America. Science. In: Elias S, editor. Reference Module in Earth Systems and Environmental Sciences. New York: Elsevier; 2015. p. 1-10. Available from:<http://dx.doi.org/10.1016/B978-0-12-409548-9.09505-1>.
132. Adrian R, O'Reilly CM, Zagarese H, Baines SB, Hessen DO, Keller W, et al. Lakes as sentinels of climate change. *Limnol Oceanogr.* 2009;54(6):2283–97.
133. Al-Chokhachy R, Budy P. Demographic characteristics, population structure, and vital rates of a fluvial population of bull trout in Oregon. *Trans Am Fish Soc.* 2008;137(6):1709-22.
134. Bowerman T, Budy P. Incorporating movement patterns to improve survival estimates for juvenile bull trout. *N Am J Fish Manag.* 2012;32(6):1123-36.
135. Peacock M. Biology 431 Ichthyology Lecture 8: Juveniles, adults, and age and growth. Lecture presented at; University of Nevada Reno; 2014.
136. Budy P, Thiede GP, McHugh P. Quantification of the vital rates, abundance, and status of a critical, endemic population of Bonneville cutthroat trout. *N Am J Fish Manag.* 2007;27:593–604.
137. Uhte P, Al-Chokhachy R, Zale AV, Shepard BB, McMahon TE, Stephens T. Life history characteristics and vital rates of Yellowstone cutthroat trout in two headwater basins. *N Am J Fish Manag.* 2016;36:1240–53.
138. Ng EL, Fredericks JP, Quist MC. Population dynamics and evaluation of alternative management strategies for nonnative lake trout in Priest Lake, Idaho. *N Am J Fish Manag.* 2016;36(1):40-54.
139. Cox BS, Guy CS, Fredenberg WA, Rosenthal LR. Baseline demographics of a non-native lake trout population and inferences for suppression from sensitivity-elasticity analyses. *Fish Manag Ecol.* 2013;20:390–400.
140. Syslo JM, Guy CS, Bigelow PE, Doepke PD, Ertel BD, Koel TM. Response of non-native lake trout (*Salvelinus namaycush*) to 15 years of harvest in Yellowstone Lake, Yellowstone National Park. *Can J Fish Aquat Sci.* 2011;68:2132–2145.
141. Mills KH, Chalanchuk SM, Allan DJ. Abundance, annual survival, and recruitment of unexploited and exploited lake charr, *Salvelinus namaycush*, populations at the Experimental Lakes Area, northwestern Ontario. *Environ Biol Fishes.* 2002;64:281–292.

3.6 Tables and figures

Table 3.1. Number of Lahontan cutthroat spawners at Independence and Summit Lakes from 1978–2017 [15-17, email communication Nature Conservancy Independence Lake Preserve].

<i>Year</i>	<i>Independence Lake</i>	<i>Summit Lake</i>
1978	*	1763
1979	*	2380
1980	*	2122
1981	*	1176
1982	*	756
1983	*	621
1984	*	639
1985	*	638
1986	*	996
1987	*	855
1988	*	936
1989	*	859
1990	*	718
1991	*	472
1992	*	1290
1993	*	1255
1994	*	1648
1995	*	949
1996	*	1443
1997	104	1925
1998	69	1956
1999	66	2400
2000	129	2017
2001	115	1947
2002	69	1379
2003	30	1722
2004	54	1843
2005	98	*
2006	43	*
2007	134	950
2008	164	1030
2009	176	1160
2010	237	1150
2011	*	1008
2012	181	1107
2013	178	876
2014	110	357
2015	165	269
2016	162	463
2017	*	438
<i>Mean</i>	120	1198
<i>SE</i>	57	583

*Data not collected or available.

Table 3.2. Parameter definitions for the lake-dwelling Lahontan cutthroat stage-classified life history and population matrix models (Figs 3.2 and 3.3, respectively) [21].

<i>Parameter</i>	<i>Support</i>	<i>Derivation</i>	<i>Description</i>
$f_{1,5}$	$\{0, 1, 2, \dots\}$	F/S	Recruitment: average number of female fry (F, <100 mm) that return to the lake per female that spawned (S)
$p_{2,1}$	$\{0 < p_{2,1} < 1\}$	φ_F	Fry survival to Juvenile A (100 mm ≤ Juvenile A < 199 mm) stage
$p_{3,2}$	$\{0 < p_{3,2} < 1\}$	φ_{JA}	Juvenile A survival to Juvenile B (200 mm ≤ Juvenile B < 299 mm) stage
$p_{4,3}$	$\{0 < p_{4,3} < 1\}$	$\varphi_{JB} \times s_{4,3}$	Proportion of Juvenile B that survive (φ_{JB}) and transition to non-spawning adults ($s_{4,3}$, ≥300 mm)
$p_{4,4}$	$\{0 < p_{4,4} < 1\}$	$\varphi_A \times s_{4,4}$	Proportion that survive as non-spawning adult (φ_A) but stay in non-spawning adult stage ($s_{4,4}$)
$p_{4,5}$	$\{0 < p_{4,5} < 1\}$	$\varphi_A \times s_{4,5}$	Proportion of spawning adults that survive (φ_A) and transition to non-spawning adults ($s_{4,5}$)
$p_{5,3}$	$\{0 < p_{5,3} < 1\}$	$\varphi_{JB} \times s_{5,3}$	Proportion of Juvenile B that survive (φ_{JB}) and transition to spawning adults ($s_{5,3}$, ≥300 mm)
$p_{5,4}$	$\{0 < p_{5,4} < 1\}$	$\varphi_A \times s_{5,4}$	Proportion of non-spawning adults that survive (φ_A) and transition to spawning adults ($s_{5,4}$)
$p_{5,5}$	$\{0 < p_{5,5} < 1\}$	$\varphi_A \times s_{5,5}$	Proportion that survive as spawning adults (φ_A) and stay as a spawning adults ($s_{5,5}$)

Table 3.3. Parameters estimates for the stage-classified population matrix model of Independence Lake, California, USA.

<i>Parameter</i>	<i>Support</i>	<i>Description</i>
$f_{1,5}$	$\{0, 1, 2, \dots\}$	From Table 1*: Average fry per female: 174 Assume a sex ratio 1:1 Then average number recruited female Fry are $0.5 * 174 = 87$
$p_{2,1}$	$\{0 < p_{2,1} < 1\}$	From Table 4*: Average survivorship (S) of ages 0 and 1 is 0.027
$p_{3,2}$	$\{0 < p_{3,2} < 1\}$	From Table 4*: Average survivorship (S) of ages 1 and 2 is 0.25 .
$p_{4,3}$	$\{0 < p_{4,3} < 1\}$	From Table 4*: Assume the survival is from age class 2 to age class 3 (Juvenile B to Spawning adult) = 0.5. From Appendix A Table 2 the proportion of instances of spawners and non spawners transitioning to Non-spawning activity is 44/122 and 7/51. Therefore, we tentatively estimate the transition probability as $51/173 = 0.3$. The transition probability is therefore estimated as $0.5 * 0.3 = 0.15$

$p_{4,4}$	$\{0 < p_{4,4} < 1\}$	From Table 4*: Assume no survival difference between Spawning and Non-spawning adults $S = 0.6824$. From Appendix A Table 2 the proportion of instances of Non-spawning adults remaining as non spawners is 0.014. There for this transition probability is estimated as $0.68 * 0.14 =$ 0.1
$p_{4,5}$	$\{0 < p_{4,5} < 1\}$	From Table 4*: Assume the adult survival 0.68. From Appendix A Table 2 the proportion of instances of spawners transitioning to Non-spawning activity is 44/122 (0.36). The transition probability is therefore estimated as $0.68 * 0.36 =$ 0.25
$p_{5,3}$	$\{0 < p_{5,3} < 1\}$	From Table 4*: Assume the survival is from age class 2 to age class 3 (Juvenile B to Spawning adult) = 0.5. From Appendix A Table 2 the proportion of instances of spawners and non spawners transitioning to spawning activity is 78/122 and 44/51. Therefore, we tentatively estimate the transition probability as $122/173 = 0.71$. The transition probability is therefore estimated as $0.5 * 0.71 =$ 0.35
$p_{5,4}$	$\{0 < p_{5,4} < 1\}$	From Table 4*: Assume the adult survival 0.68. From Appendix A Table 2 the proportion of instances of non spawners transitioning to Spawning activity is 44/51 (0.86). The transition probability is therefore estimated as $0.68 * 0.86 =$ 0.59
$p_{5,5}$	$\{0 < p_{5,5} < 1\}$	From Table 4*: Assume no survival difference between Spawning and Non-spawning adults $S=0.68$. From Appendix A Table 2 the proportion of instances of Spawning adults remaining as spawners is 0.64. There for this transition probability is estimated as $0.68 * 0.64=$ 0.44

*Table references are from the Appendix section of the 2006 Independence Lake population viability analysis report [15].

Table 3.4. Summary of parameter estimates for the stage-classified (Lefkovitch) population models of lake-dwelling Lahontan cutthroat captured at Independence and Summit Lakes, California and Nevada, USA, 1997–2005 and 2015–2017, respectively [15, 21].

<i>Parameter</i>	<i>Description</i>	<i>Independence Lake</i>	<i>Summit Lake</i>
$f_{1,5}$	Fecundity	87 ± 2.78	0.85 ± 0.027
$p_{2,1}$	Fry survival	0.03 ± 0.001	0.03 ± 0.001
$p_{3,2}$	Juvenile A survival	0.25 ± 0.008	0.25 ± 0.008
$p_{4,3}$	Juvenile B to adult NSP transition	0.15 ± 0.005	0.26 ± 0.008
$p_{4,4}$	Adult NSP to NSP transition	0.10 ± 0.003	0.53 ± 0.017
$p_{4,5}$	Adult SP to NSP transition	0.24 ± 0.008	0.28 ± 0.009
$p_{5,3}$	Juvenile B to adult SP transition	0.35 ± 0.011	0.25 ± 0.008
$p_{5,4}$	Adult NSP to SP transition	0.58 ± 0.019	0.11 ± 0.004
$p_{5,5}$	Adult SP to SP transition	0.44 ± 0.014	0.36 ± 0.012

*NSP=Non-spawning stage, SP=Spawning stage.

Table 3.5. Juvenile B (Fig. 3.2) probability rates of becoming a Spawning ($s_{5,3}$) or Non-spawning ($s_{4,3}$) adult (≥ 300 mm) for lake-dwelling Lahontan cutthroat trout at Summit Lake, Nevada, USA, 2015–2017 [21].

<i>Year</i>	$s_{5,3}$	$s_{4,3}$
2015 (n=23)	0.48	0.52
2016 (n=12)	0.67	0.33
2017 (n=34)	0.32	0.68
Mean	0.49	0.51
SE	0.18	0.18

Table 3.6. Adult (≥ 300 mm) spawner to spawner ($s_{5,5}$) and nonspawner to spawner ($s_{5,4}$) probability estimates for lake dwelling Lahontan cutthroat trout at Independence and Summit Lakes, California and Nevada, USA, 1997–2005 and 2015–2017, respectively [15, 21].

<i>Lake</i>	<i>Transition Period</i>	$s_{5,5}$	$s_{5,4}$
Independence	1997 - 2005	0.64 (n=122)	0.86 (n=51)
	2015 - 2016	0.54 (n=46)	0.13 (n=48)
Summit	2016 - 2017	0.61 (n=175)	0.22 (n=130)
	Mean	0.58	0.18
	SE	0.05	0.06

Table 3.7. Results of the sensitivity analyses of the stage–classified (Lefkovitch) population models of lake-dwelling Lahontan cutthroat captured at Independence and Summit Lakes, California and Nevada, USA, 1997–2005 and 2015–2017, respectively [15,21].

<i>Parameter</i>	<i>Description</i>	<i>Independence Lake</i>	<i>Summit Lake</i>
$f_{1,5}$	Fecundity	0.002±0.000008	0.007±0.0004
$p_{2,1}$	Fry survival	5.14±0.03	0.23±0.01
$p_{3,2}$	Juvenile A survival	0.56±0.003	0.025±0.001
$p_{4,3}$	Juvenile B to adult NSP transition	0.21±0.004	0.012±0.001
$p_{4,4}$	Adult NSP to NSP transition	0.12±0.003	0.66±0.003
$p_{4,5}$	Adult SP to NSP transition	0.30±0.01	0.29±0.002
$p_{5,3}$	Juvenile B to adult SP transition	0.31±0.011	0.013±0.001
$p_{5,4}$	Adult NSP to SP transition	0.18±0.002	0.70±0.0007
$p_{5,5}$	Adult SP to SP transition	0.43±0.007	0.31±0.00009

Values are percentages.

Table 3.8. Model selection results for survival (ϕ_A), population growth (λ), capture ($p_{CAPTURE}$), and recapture (c) rates of adult (≥ 300 mm) female lake-dwelling Lahontan cutthroat captured during the lake mark-recapture effort (n=678) at Summit Lake, Nevada, USA, 2015-2017 [21].

<i>Model</i>	AIC_c^a	ΔAIC_c^b	AIC <i>weight</i>	<i>Model</i> <i>likelihood</i>	K^c	<i>Deviance</i>
$\phi - \lambda$ (.) ^d , $p_{CAPTURE} - c$ (.,td+td ²)	6525.1697	0.0000	0.97660	1.0000	6	6513.0704
$\phi_A, \lambda, p_{CAPTURE}, c$ - (.) ^d	6532.6321	7.4624	0.02340	0.0240	4	6524.5849

^a AIC (Akaike Information Criterion) for small sample size.

^b Difference between model AIC_c and model with the lowest AIC_c .

^c No. of model parameters.

^d (.)=rate constant across sampling periods.

AIC (Akaike Information Criterion) model selection was performed, and listed above is the only model for which all of the parameters estimated correctly. Sex, fork length (fl), and trap depth (td) covariates were included with linear, quadratic, and interaction terms.

Table 3.9. Data cloning results [21].

<i>k</i>	ϕ_A	<i>Model</i>
1	0.52	Bayes: ϕ_A (.), $p_{CAPTURE}$ and c (<i>t</i>), FL, n=504
2	0.55	Bayes: ϕ_A (.), $p_{CAPTURE}$ and c (<i>t</i>), FL, n=1008
3	0.57	Bayes: ϕ_A (.), $p_{CAPTURE}$ and c (<i>t</i>), FL, n=1512
4	0.59	Bayes: ϕ_A (.), $p_{CAPTURE}$ and c (<i>t</i>), FL, n=2016
5	0.60	Bayes: ϕ_A (.), $p_{CAPTURE}$ and c (<i>t</i>), FL, n=2520
NA	0.74	MLE: ϕ_A , $p_{CAPTURE}$ and c (.), n=504

k is the number of replicate data sets. The model(s) components are female survival (ϕ_A), capture ($p_{CAPTURE}$), and recapture (c) rates, and fork length (FL). The data did not include the final two primary sampling periods (post-spawn and fall 2017). (.)=rate constant across primary periods; (*t*)=rate changes across primary periods; MLE=best model in Program Mark that estimated female survival (Table 2.14); Bayes=Bayesian model similar to MLE.

Table 3.10. Annual spawning mortality rates for lake-dwelling Lahontan cutthroat at Summit Lake, Nevada, USA, 2015–2017 [21].

<i>Year</i>	<i>Mortality</i>
2015 (n=250)	0.74
2016 (n=403)	0.48
2017 (n=423)	0.47
Mean	0.56
SE	0.15

SE=standard error.

Table 3.11. Fecundity comparison across cutthroat subspecies and systems.

<i>Fecundity</i>	<i>Species</i>	<i>System</i>	<i>Reference</i>
0.85	<i>LC</i>	Summit Lake, NV	Simmons [21]
1.5	<i>LC</i>	Summit Lake, NV	Vinyard 2000 [65]
23	<i>BC</i>	Strawberry Reservoir, UT (Indian Creek)	Knight 1997 [75]
37	<i>CC, YC,</i> & <i>HC</i>	Trappers Lake, CO (Cabin Creek)	Drummond & McKinney 1965 [74]
61	<i>BC</i>	Strawberry Reservoir, UT (Trout Creek)	Knight 1997 [75]
87	<i>LC</i>	Independence Lake, CA	Rissler et al. 2006 [15]

Estimates taken directly from study or calculated from data contained in study. Species abbreviations: LC=Lahontan cutthroat (*Oncorhynchus clarkii henshawi*), BC=Bonneville cutthroat (*Oncorhynchus clarkii utah*), CC=Colorado cutthroat (*Oncorhynchus clarkii pleuriticus*), YC=Yellowstone cutthroat (*Oncorhynchus clarkii bouvieri*), HC=hybrids of CC and YC.

Table 3.12. Juvenile survival comparison across trout species in various systems.

<i>Survival</i>	<i>Species</i>	<i>System</i>	<i>Reference</i>
0.09 ^a	BT	South Fork Walla Wall River, OR	Al-Chokhachy & Budy 2008 [133]
0.22–0.23 ^b	BT	Skiphorton Creek, OR	Bowerman & Budy 2012 [134]
0.08–0.34 ^c	LC	Gance Creek, NV	Peacock unpublished [135]
0.41–0.47 ^b	BC	Logan River, UT	Budy et al. 2007 [136]
0.03 – 0.50^c	LC	Independence Lake, CA	Rissler et al. 2006 [15]
0.44–0.69 ^d	YC	Spread Creek, WY	Uthe et al. 2016 [137]
	YC	Shields River, Montana	Uthe et al. 2016 [137]
0.0043–0.78 ^c	LT	Priest Lake, Idaho	Ng et al. 2016 [138]
0.0043–0.78 ^c	LT	Swan Lake, Montana	Cox et al. 2013 [139]

Species abbreviations: LC=Lahontan cutthroat (*Oncorhynchus clarkii henshawi*), BC=Bonneville cutthroat (*Oncorhynchus clarki utah*), YC=Yellowstone cutthroat (*Oncorhynchus clarkii bouvieri*), BT=bull trout (*Salvelinus confluentus*), LT=lake trout (*Salvelinus namaycush*).

^a2 or 3 year old: average rate for study period.

^bFirst value is 1 year old and second value is 2 year old.

^cFirst value is fry survival and the second value is 2 year old survival.

^dExcluding fry.

Table 3.13. Adult survival comparison between Lahontan cutthroat (LC, *Oncorhynchus clarkii henshawi*), Bonneville cutthroat (BC, *Oncorhynchus clarki utah*), lake trout (LT, *Salvelinus namaycush*), and bull trout (BT, *Salvelinus confluentus*) in various systems.

<i>Survival</i>	<i>Species</i>	<i>System</i>	<i>Reference</i>
0.27–0.35	LC	Gance Creek, NV	Peacock unpublished [135]
0.36	LC	Truckee River, NV	Alexiades et al. 2012 [100]
0.15–0.44	LC	Walker Lake, NV	Sedinger et al. 2012 [99]
0.51	LC	Summit Lake, NV	This study [21]
0.54	BC	Logan River, UT	Budy et al. 2007 [136]
0.68	LC	Independence Lake, CA	Rissler et al. 2006 [15]
0.20–0.70	BT	South Fork Walla Wall River, OR	Al-Chokhachy & Budy 2008 [133]
0.90	LT	Yellowstone Lake, WY	Syslo et al. 2011 [140]
0.69–0.91	LT	Experimental Lakes Area, Ontario, Canada	Mills et al. 2002 [141]
0.92	LT	Swan Lake, Montana	Cox et al. 2013 [139]

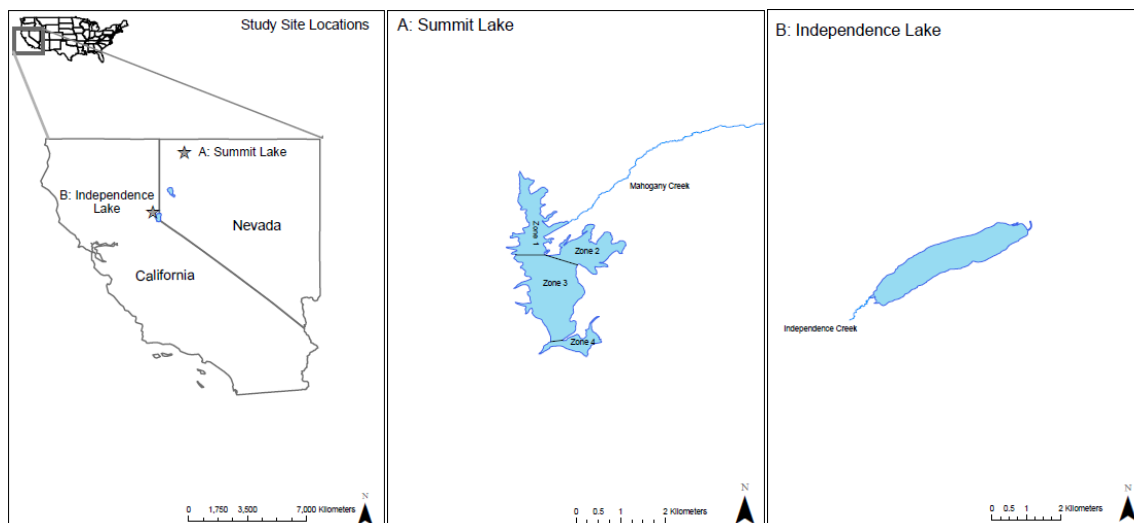


Figure 3.1. Summit Lake (Nevada, USA) and Independence Lake (California, USA), including their sole, perennial spawning tributaries, Mahogany Creek and Independence Creek (panels A and B), respectively. Panel A also displays the 4 sampling zones at Summit Lake.

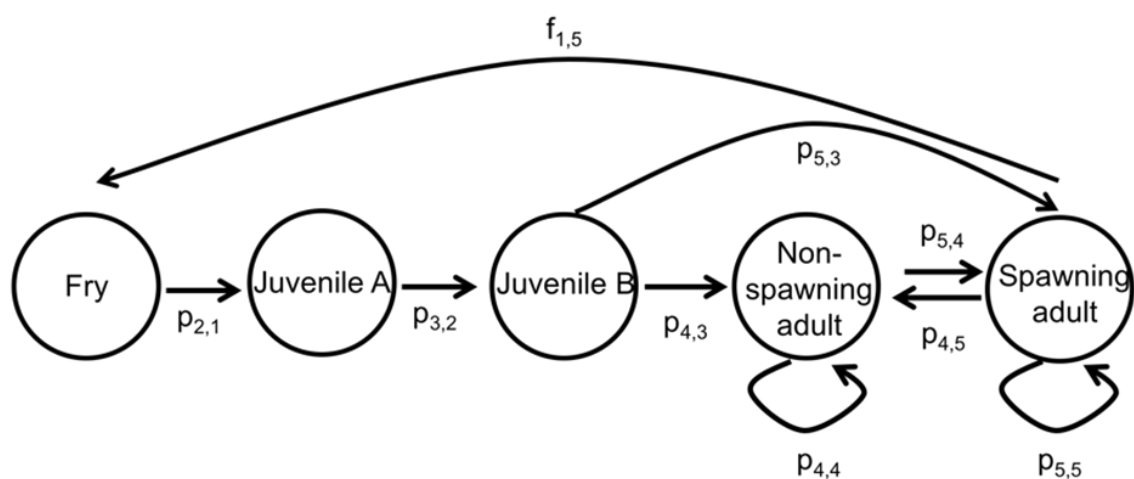


Figure 3.2. Life history model of lake dwelling Lahontan cutthroat at Independence and Summit Lakes, California and Nevada, USA, respectively. The diagram depicts the relationships and annual transition parameters ($f_{1,5} - p_{5,5}$) between the key life stages. $f_{1,5}$ is fecundity; $p_{2,1}$ and $p_{3,2}$ are the survival rates for Fry (<100 mm) and Juvenile A ($100 \text{ mm} \leq \text{Juvenile A} < 199$ mm); $p_{4,3}$ and $p_{5,3}$ are the transition rates for Juvenile B ($200 \text{ mm} \leq \text{Juvenile B} < 299$ mm) to an age 3 yr. Non-spawning or Spawning adult; $p_{4,4}$ and $p_{4,5}$ are the transition rates for Non-spawning adults (≥ 300 mm) to remain a Non-spawning or become a Spawning adult; and $p_{5,4}$ and $p_{5,5}$ are the transition rates for Spawning adults (≥ 300 mm) to remain a Spawning adult or become a Non-spawning adult, respectively. $0 < p_{2,1} - p_{5,5} < 1$ and $f_{1,5} \in \{0, 1, 2, \dots\}$.

$$\begin{bmatrix} 0 & 0 & 0 & 0 & f_{1,5} \\ p_{2,1} & 0 & 0 & 0 & 0 \\ 0 & p_{3,2} & 0 & 0 & 0 \\ 0 & 0 & p_{4,3} & p_{4,4} & p_{4,5} \\ 0 & 0 & p_{5,3} & p_{5,4} & p_{5,5} \end{bmatrix}$$

Figure 3.3. Stage-classified (Lefkovitch) population matrix model for the lake-dwelling Lahontan cutthroat populations at Independence and Summit Lakes, California and Nevada, USA, respectively. The matrix is constructed with the stages, relationships, and transition parameters from the cutthroat trout life history model (Figure 3.2). $f_{1,5}$ is fecundity; $p_{2,1}$ and $p_{3,2}$ are the survival rates for Fry (<100 mm) and Juvenile A (100 mm ≤ Juvenile A < 199 mm); $p_{4,3}$ and $p_{5,3}$ are the transition rates for Juvenile B (200 mm ≤ Juvenile B < 299 mm) to an age 3 yr. Non-spawning or Spawning adult; $p_{4,4}$ and $p_{4,5}$ are the transition rates for Non-spawning adults (≥300 mm) to remain a Non-spawning or become a Spawning adult; and $p_{5,4}$ and $p_{5,5}$ are the transition rates for Spawning adults (≥300 mm) to remain a Spawning adult or become a Non-spawning adult, respectively. $0 < p_{2,1} - p_{5,5} < 1$ and $f_{1,5} \in \{0, 1, 2, \dots\}$.

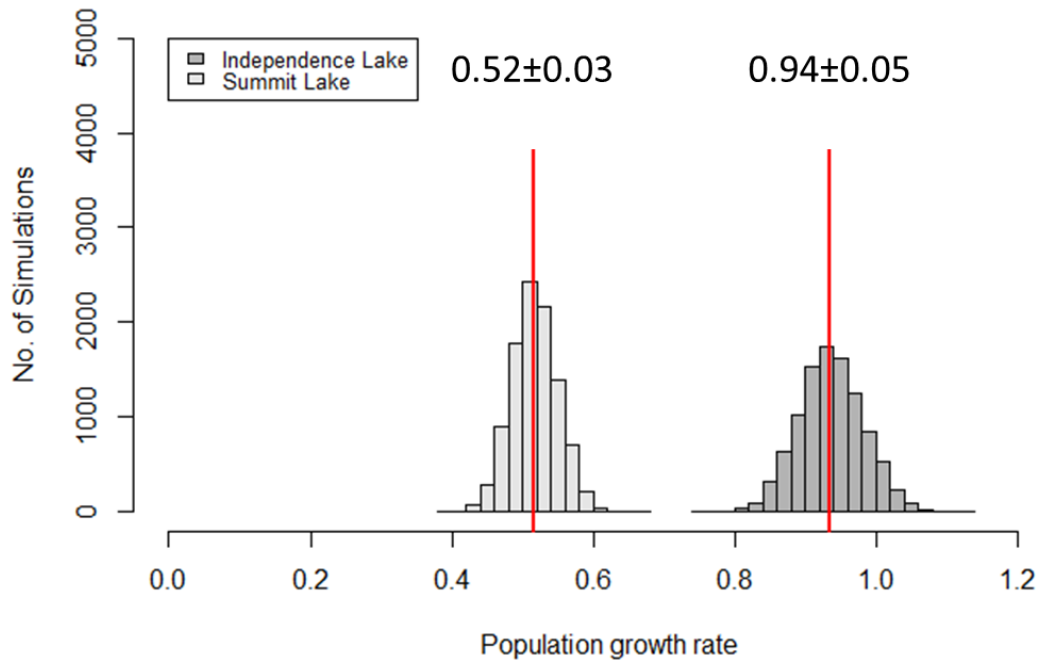


Figure 3.4. Population growth rate comparison of female lake-dwelling Lahontan cutthroat at Independence and Summit Lakes, California and Nevada, USA, 1995–2005 and 2015–2017, respectively. Each histogram was generated from a simulation that calculated the dominant eigenvalue of the stage-classified population matrix model (Figure 3.3), using the estimated parameter distributions (Table 3.4), for each population. The number of simulations and the population growth rates are located on the x and y axes, respectively. The means and standard deviations are listed below. The red vertical lines indicate the means of the histograms [15,21].

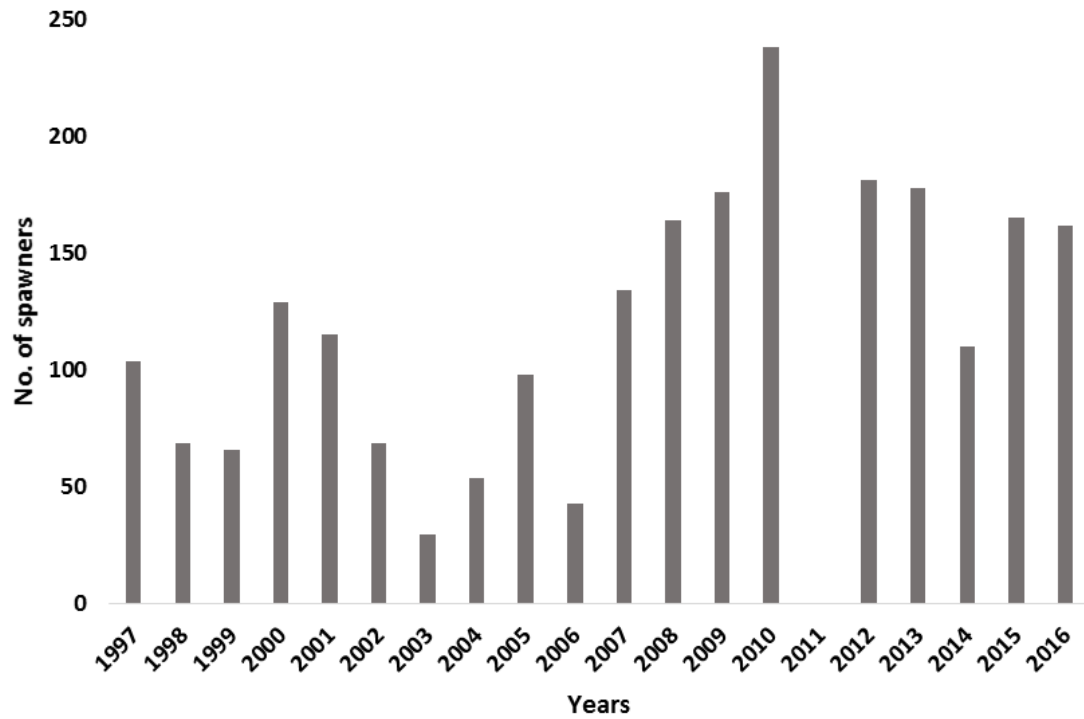


Figure 3.5. Annual number of Lahontan cutthroat spawners captured at the fish weir located in Upper Independence Creek (Independence Lake, California, USA) from 1997-2016 [15-16, email correspondence Nature Conservancy Independence Lake Preserve].

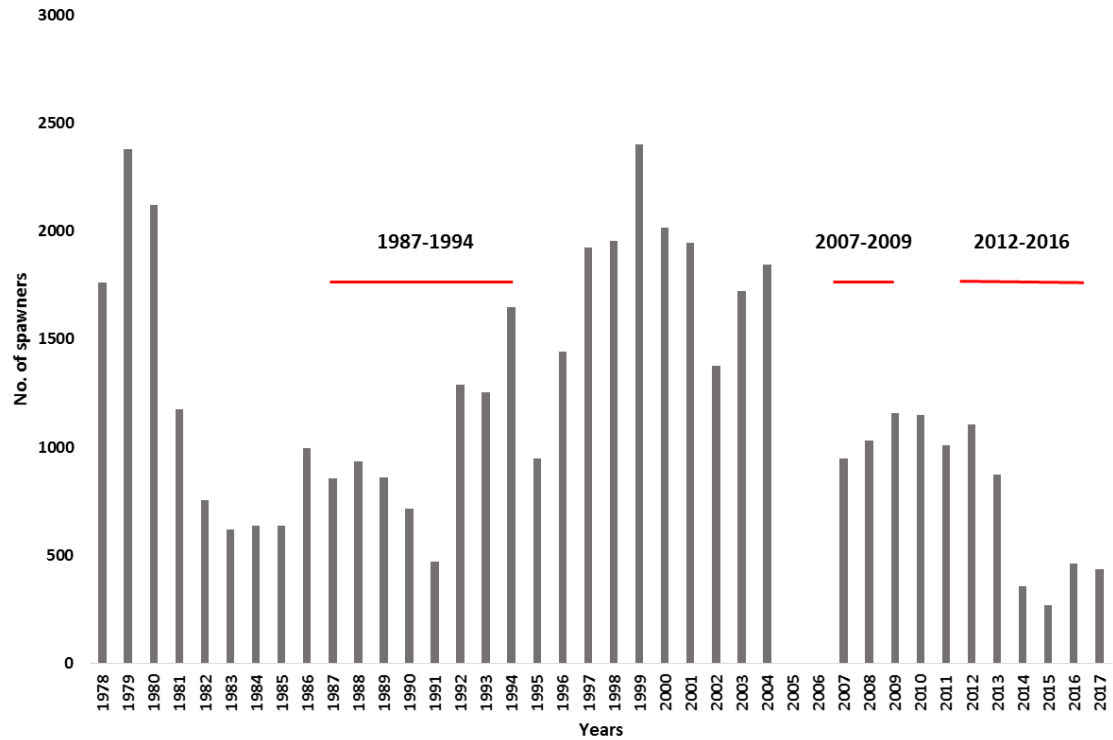


Figure 3.6. Annual number of Lahontan cutthroat spawners captured at the Summit Lake (Nevada, USA) fish weir on Mahogany Creek from 1978–2017, excluding 2004-2005. Data provided by the Summit Lake Paiute Tribe [17]. Red horizontal lines represent drought periods [26,65,70].

4.0 Chapter 4

MANAGEMENT RECOMMENDATIONS

The following management actions (some repeated from Chapter 3) are recommended to increase fecundity, survival and repeat spawning of the Summit Lake population.

- Continued reduction or elimination of tribal take during periods of low spawning runs. In addition, the standard take level should be evaluated for its impact on the population's dynamics (Chapter 3).
- Continued monitoring of the spawning run to determine interannual dynamics of the population and changes due to alterations resulting from shifts in hydroclimate regime.
- Consider maintaining creek connectivity to lake to facilitate spawning during low discharge years. Nonnative plants in the riparian vegetation, for example, may influence flows by "choking" the stream. Additional considerations for maintaining connectivity should consider long-term changes in the adaptability of the population to the regional climate. Further study may be needed connecting the genetic characteristics of this specific population to the hydroclimate.
- Consider restoration of degraded stretches of the instream and riparian corridor to improve or increase habitat for the entire spawning cycle, including fry and spawner survival. Instream remediation could include the restoration of sedimented spawning grounds to increase the quantity and quality of redds. Riparian corridor remediation, via the planting of native vegetation, should decrease terrestrial and avian predation, reduce water temperatures via shading, and increase food resources (Chapter 3).
- Consider discontinuing the practice of tagging so called "spent" spawners, fish moving downstream. Approximately 50% of postspawners tagged at the fish weir do not make it to the lake. Survival rates of spent spawners tagged at the fish weir vs. spent spawners already tagged should be compared. If tagging spent spawners is causing increased mortality, less stressful (and more cost effective) practices should be considered to increase the number of tags in the system.

- Consider the development of other revenue sources to substitute for grazing permits, and acquiring the last privately owned section of shoreline, which is exposed to grazing. These actions should create financial and physical buffers to protect and improve water quality, which should in turn reduce stressors and provide more energy for individual trout growth and reproduction (Chapter 3).

5.0.

APPENDIX

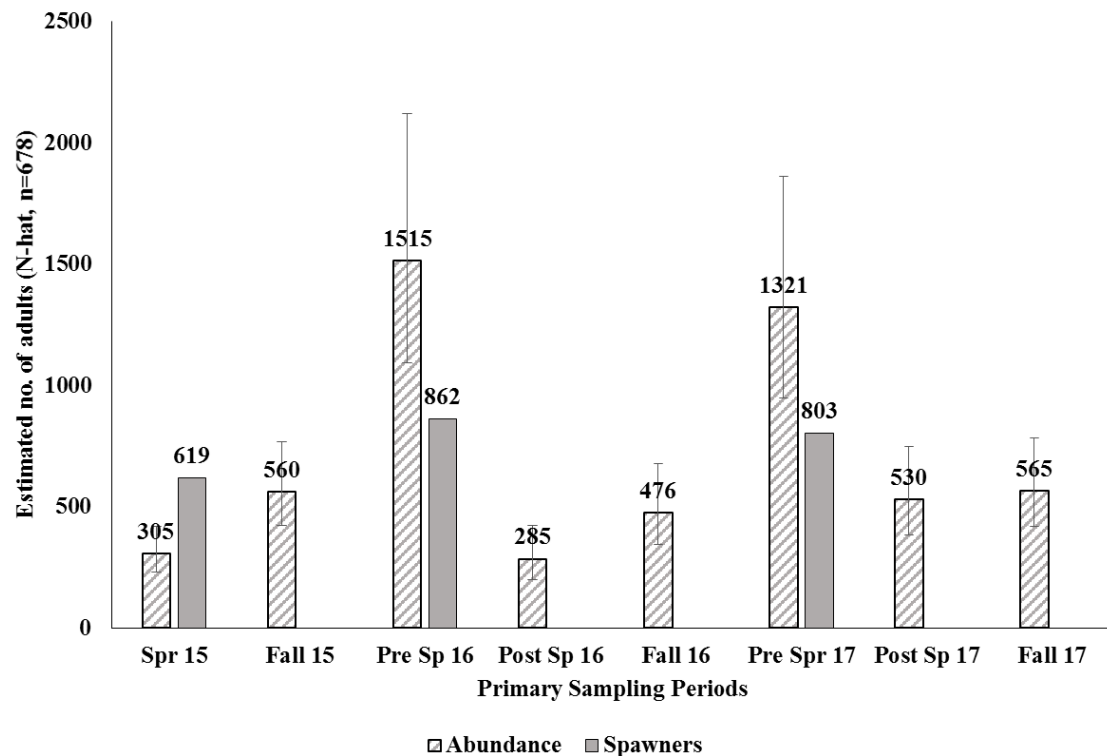
5.1 Supplemental Figures: Chapter 2-Population dynamics of threatened Lahontan cutthroat trout in Summit Lake (USA)

<i>Parameter</i>	<i>Estimate</i>	<i>Standard Error</i>	<i>95% Confidence Interval</i>	
			<i>Lower</i>	<i>Upper</i>
\hat{N}_1	305	47	231	420
\hat{N}_2	560	87	421	767
\hat{N}_3	1515	258	1093	2121
\hat{N}_4	285	55	199	421
\hat{N}_5	476	83	343	676
\hat{N}_6	1321	229	948	1861
\hat{N}_7	530	91	384	748
\hat{N}_8	565	91	418	783
φ (.)	0.77	0.03	0.71	0.82
λ (.)	1.035	0.009	1.02	1.05
$p_{CAPTURE}$ (.)	0.04	0.007	0.03	0.06
c (.)	0.03	0.004	0.02	0.04

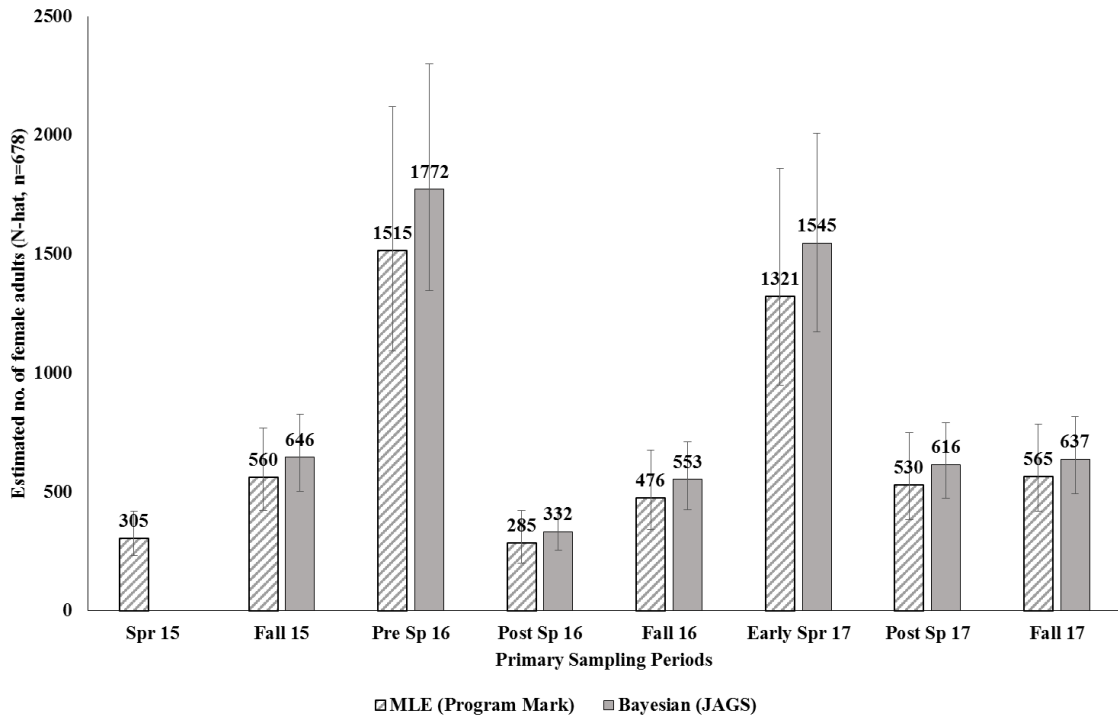
Abundance (\hat{N}_i), and survival (φ_A), population growth (λ), capture ($p_{CAPTURE}$), and recapture (c) rate estimates for the top AIC (Akaike Information Criterion) model of adult (≥ 300 mm) female lake-dwelling Lahontan cutthroat captured during the lake mark-recapture experiment (n=678) at Summit Lake, Nevada, US, 2015–2017 (Table 2.14). The numbers in the parameter names (ex. \hat{N}_1) indicate the seven primary sampling periods in chronological order, and (.) indicates the parameter is constant across the primary sampling periods.

<i>Period</i>	<i>Relative Growth Rate (%)</i>	<i>Absolute Growth Rate (mm)</i>
Spring 15–Fall 15 (n=14)	13.67 (14.62)	54.77 (53.06)
Fall 15–Spring 16 (n=59)	4.29 (5.51)	19.47 (22.33)
Spring 16–Fall 16 (n=16)	11.76 (7.26)	56.22 (33.04)
Fall 16–Spring 17 (n=20)	8.76 (10.61)	30.03 (30.73)
Annual (n=38)	16.77 (13.98)	72.90 (52.22)

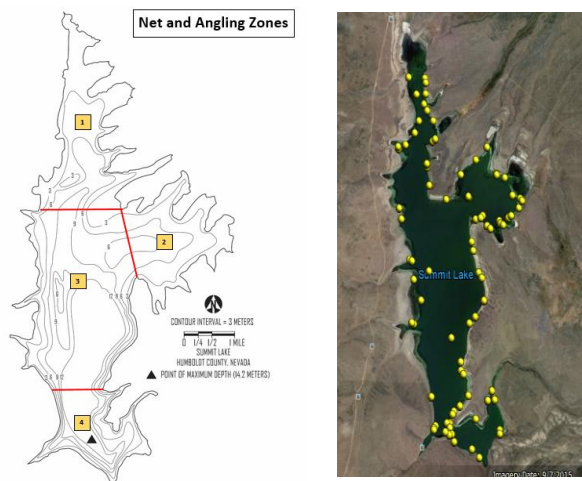
Means and standard deviations (in parenthesis) of the seasonal and annual growth rates (fork length) of lake-dwelling Lahontan cutthroat captured at Summit Lake, Nevada, US, during the lake mark recapture experiment, 2015–2017. The Annual category consists of any annual period within 2015–2017 lake sampling periods.



Comparison of the estimated annual spawning run numbers and the adult (≥ 300 mm) female abundance of lake-dwelling Lahontan cutthroat at Summit Lake, NV, US, 2015–2017. For each year, the spawning run estimates were derived from applying the proportion of tagged vs. non-tagged individuals captured at the Mahogany Creek fish trap to the number of tagged individuals detected at the PIT (Passive Integrated Transponder) detection array located near the mouth of Mahogany Creek (Table 2.6). The abundance estimates were derived from the top AIC (Akaike Information Criterion) model of the lake mark-recapture experiment ($n=678$) (Table 2.14). The spawning run and abundance estimates, and primary sampling periods, are located on the x and y axes, respectively. Only three values for the spawning run estimates because the spawning run occurs once a year during the spring. The error bars are 95% profile likelihood confidence intervals. The estimated spawning runs do not have error bars because they were derived from the proportional relationship described above.



Comparison of the MLE (Program Mark) and Bayesian (R, JAGS) adult (≥ 300 mm) female abundance estimates of lake-dwelling Lahontan cutthroat at Summit Lake, NV, US, 2015–2017. The MLE estimates were derived from the top AIC (Akaike Information Criterion) model of the lake mark-recapture ($n=678$) experiment (Table 2.14). The Bayesian estimates were derived from the same data and model (Table 2.15). The estimates and primary sampling periods are located on the x and y axes, respectively. The error bars are the 95% profile likelihood confidence intervals and 95% quantiles for the MLE and Bayesian estimates, respectively.



Sampling zones (left) and the net sets (right) from the fall 2015 sampling.

5.2 Fry trap design

The fry trap had 3 main components: two wings, a tunnel, and a holding tank. The wings were made of fine plastic mesh. One wing was attached to each side of the holding tank and extended to the shoreline on that side. The wings (and tank) covered the entire width and depth of the creek to assure that all migrating young entered the trap. The tunnel was a long plastic cylinder pipe with one end pointed upstream and the other end joined to the inside of the tank. Downstream flow entered the upstream end of the pipe end and flowed into the holding tank. The holding tank was a large square plastic box with mesh panels and holes on the sides that kept the water flowing downstream and prevented the fish inside from escape. The young entered the upstream end of the pipe and remained in the holding tank until processed.

5.3 Fyke net design and positioning

From front to back, the fyke (trap) nets were composed of a leader, throat, and hoop net. One end of the leader (4 ft high, 100 ft. long) was attached to the center front of the throat and the other end could be staked or anchored to hold it stationary. The nylon mesh leader hung vertically in the water column due to wooden floats on the top line and a lead core in the bottom line. The leader's purpose was to intercept and direct fish into the throat. The nylon mesh covered throat was an open rectangular section (4ft high x 6ft wide x 2 ft deep) framed by two consecutive rectangles of hollow metal pipe. The throat directed the fish into the hoop net. The nylon mesh covered hoop net consisted of five consecutive metal hoops with internal mesh funnels that directed the fish to a holding area (pot) in the back of the net. The fish remained in the pot until the net was pulled. During spring samplings, we staked the wing end to the shore. But during fall samplings, due to heavy nearshore vegetation, we attached an anchor to the wing end and lowered the anchor into the lake as close to the edge of the vegetation as possible. In both cases we pulled the net into the lake with the wing set perpendicular to shoreline to intercept Lahontan cutthroat.

5.4 R code for population growth rate and sensitivity analyses

```
###lambda (pop growth rate) distribution. random sample from posterior distribution for phi.
###store samples. input into phi samples into stage-structure matrix to calculate to
##adding fecundity into simulation, 12/12/17.

###libraries
library(popbio)
library(lattice)
###

###sample from independence fry survival distribution
sample <- rnorm (10000,0,1)
n<-10000

sampleif<-numeric(n)
for (i in 1:n){
  sampleif[i] <- 0.0273 + (sample[i]*0.0009)
}

##sample from Independence fecundity
sampleindfec<-numeric(n)
for (i in 1:n){
  sampleindfec[i] <- 87 + (sample[i]*2.784)
}
```

```
###sample from independence juvenileA survival distribution
sampleja<-numeric(n)
for (i in 1:n){
  sampleja[i] <- 0.2502 + (sample[i]*0.008)
}

###sample from independence juvenileB survival distribution
samplea<-numeric(n)
for (i in 1:n){
  samplea[i] <- 0.5004 + (sample[i]*0.016)
}

###sample from independence juvenile spawn transition
sampleb<-numeric(n)
for (i in 1:n){
  sampleb[i] <- 0.7 + (sample[i]*0.022)
}

###sample from independence juvenile nonspawn transition
samplec<-numeric(n)
for (i in 1:n){
  samplec[i] <- 0.3 + (sample[i]*0.001)
}

###sample from independence adult survival
sampled<-numeric(n)
for (i in 1:n){
  sampled[i] <- 0.68 + (sample[i]*0.022)
}

###sample from independence adult sp-sp transition
samplee<-numeric(n)
for (i in 1:n){
  samplee[i] <- 0.64 + (sample[i]*0.02)
}

###sample from independence adult sp-nsp transition
samplef<-numeric(n)
for (i in 1:n){
  samplef[i] <- 0.36 + (sample[i]*0.012)
}

###sample from independence adult nsp-sp transition
sampleg<-numeric(n)
for (i in 1:n){
  sampleg[i] <- 0.86 + (sample[i]*0.028)
}

###sample from independence adult nsp-nsp transition
sampleh<-numeric(n)
for (i in 1:n){
  sampleh[i] <- 0.14 + (sample[i]*0.004)
}
```

```
###sample from summit fry survival distribution
sampleif<-numeric(n)
for (i in 1:n){
  sampleif[i] <- 0.0273 + (sample[i]*0.0009)
}

###sample from summit fecundity
samplesumfec<-numeric(n)
for (i in 1:n){
  samplesumfec[i] <- 0.85 + (sample[i]*0.027)
}

###sample from summit juvenilea survival distribution
sampleja<-numeric(n)
for (i in 1:n){
  sampleja[i] <- 0.2502 + (sample[i]*0.008)
}

###sample from summit juvenileb survival distribution
samplei<-numeric(n)
for (i in 1:n){
  samplei[i] <- 0.5004 + (sample[i]*0.016)
}

###sample from summit juvenile spawn transition
samplej<-numeric(n)
for (i in 1:n){
  samplej[i] <- 0.49 + (sample[i]*0.016)
}

###sample from summit juvenile nonspawn transition
samplek<-numeric(n)
for (i in 1:n){
  samplek[i] <- 0.51 + (sample[i]*0.016)
}

###sample from summit adult survival
samplel<-numeric(n)
for (i in 1:n){
  samplel[i] <- 0.51 + (sample[i]*0.016)
}

###sample from summit adult sp-sp transition
samplem<-numeric(n)
for (i in 1:n){
  samplem[i] <- 0.58 + (sample[i]*0.019)
}

###sample from summit adult sp-nsp transition
sampleo<-numeric(n)
for (i in 1:n){
  sampleo[i] <- 0.42 + (sample[i]*0.013)
}
```

```

}

###sample from summit adult nsp-sp transition
samplep<-numeric(n)
for (i in 1:n){
  samplep[i] <- 0.18 + (sample[i]*0.006)
}

###sample from summit adult nsp-nsp transition
sampleq<-numeric(n)
for (i in 1:n){
  sampleq[i] <- 0.82 + (sample[i]*0.026)
}

###input phi posterior samples into popbio code to generate the sampling distribution of lambdas
##Independence LCT Eigenvalues
n<-10000
dlambda <-numeric(n)
for(i in 1:n){
  A<-
matrix(c(0,0,0,0,sampleindfec[i],sampleif[i],0,0,0,0,0,sampleja[i],0,0,0,0,0,(samplea[i]*samplec[i]),(sample
d[i]*sampleh[i]),(sampled[i]*samplef[i]),0,0,(samplea[i]*sampleb[i]),(sampled[i]*sampleg[i]),(sampled[i]*
samplee[i])), nrow=5, byrow=5)
  dlambda[i] <- lambda(A)
}
#dlambda
mean(dlambda)
sd(dlambda)

###input samples into popbio code to generate the sampling distribution of lambdas
##Summit LCT Eigenvalues
n<-10000
dlambda1 <-numeric(n)
for(i in 1:n){
  A2<-
matrix(c(0,0,0,0,samplesumfec[i],sampleif[i],0,0,0,0,0,sampleja[i],0,0,0,0,0,(samplei[i]*samplek[i]),(sampl
el[i]*sampleq[i]),(samplel[i]*sampleo[i]),0,0,(samplei[i]*samplej[i]),(samplel[i]*samplep[i]),(samplel[i]*s
amplem[i])), nrow=5, byrow=5)
  dlambda1[i] <- lambda(A2)
}
#dlambda1
mean(dlambda1)
sd(dlambda1)

#####sensitivity test
##Summit
n<-10000
sens1 <- numeric(n)
sens2 <- numeric(n)
sens3 <- numeric(n)
sens4 <- numeric(n)
sens5 <- numeric(n)

```

```

sens6 <- numeric(n)
sens7 <- numeric(n)
sens8 <- numeric(n)
sens9 <- numeric(n)
for(i in 1:n){
  Asens <-
matrix(c(0,0,0,0,samplesumfec[i],sampleif[i],0,0,0,0,0,sampleja[i],0,0,0,0,0,(samplei[i]*samplek[i]),(samplel[i]*sampleq[i]),(samplel[i]*sampleo[i]),0,0,(samplei[i]*samplej[i]),(samplel[i]*samplep[i]),(samplel[i]*samplem[i])), nrow=5, byrow=5)
  sens <- sensitivity(Asens)
  sens1[i] <- sens[1,5]
  sens2[i] <- sens[2,1]
  sens3[i] <- sens[3,2]
  sens4[i] <- sens[4,3]
  sens5[i] <- sens[4,4]
  sens6[i] <- sens[4,5]
  sens7[i] <- sens[5,3]
  sens8[i] <- sens[5,4]
  sens9[i] <- sens[5,5]
}
#sens1
mean(sens1)
sd(sens1)
hist(sens1)
mean(sens2)
sd(sens2)
hist(sens2)
mean(sens3)
sd(sens3)
hist(sens3)
mean(sens4)
sd(sens4)
hist(sens4)
mean(sens5)
sd(sens5)
hist(sens5)
mean(sens6)
sd(sens6)
hist(sens6)
mean(sens7)
sd(sens7)
hist(sens7)
mean(sens8)
sd(sens8)
hist(sens8)
mean(sens9)
sd(sens9)
hist(sens9)

###sensitivity test
##Independence
n<-10000
sens1a <- numeric(n)
sens2a <- numeric(n)

```

```

sens3a <- numeric(n)
sens4a <- numeric(n)
sens5a <- numeric(n)
sens6a <- numeric(n)
sens7a <- numeric(n)
sens8a <- numeric(n)
sens9a <- numeric(n)
for(i in 1:n){
  Asens1 <-
matrix(c(0,0,0,0,sampleindfec[i],sampleif[i],0,0,0,0,0,sampleja[i],0,0,0,0,0,(samplea[i]*samplec[i]),(sample
d[i]*sampleh[i]),(sampled[i]*samplef[i]),0,0,(samplea[i]*sampleb[i]),(sampled[i]*sampleg[i]),(sampled[i]*
samplee[i])), nrow=5, byrow=5)
  sensa <- sensitivity(Asens1)
  sens1a[i] <- sensa[1,5]
  sens2a[i] <- sensa[2,1]
  sens3a[i] <- sensa[3,2]
  sens4a[i] <- sensa[4,3]
  sens5a[i] <- sensa[4,4]
  sens6a[i] <- sensa[4,5]
  sens7a[i] <- sensa[5,3]
  sens8a[i] <- sensa[5,4]
  sens9a[i] <- sensa[5,5]
}
#sens1a
mean(sens1a)
sd(sens1a)
hist(sens1a)
mean(sens2a)
sd(sens2a)
hist(sens2a)
mean(sens3a)
sd(sens3a)
hist(sens3a)
mean(sens4a)
sd(sens4a)
hist(sens4a)
mean(sens5a)
sd(sens5a)
hist(sens5a)
mean(sens6a)
sd(sens6a)
hist(sens6a)
mean(sens7a)
sd(sens7a)
hist(sens7a)
mean(sens8a)
sd(sens8a)
hist(sens8a)
mean(sens9a)
sd(sens9a)
hist(sens9a)

#####

```

```

hist(dlambd, xlab="Population growth rate", ylab = "No. of Simulations", col="gray70",
main="",xlim=c(0,1.25), ylim=c(0,5000))
hist(dlambd1, add=TRUE,col="gray90")
abline(v=mean(dlambd), col="red",lwd=2)
abline(v=mean(dlambd1), col="red", lwd=2)
legend(0,5000,legend=c("Independence Lake", "Summit Lake"), fill=c("gray70","gray90"), cex=0.8)

```

5.5 R code for Bayesian survival model

```

###Bayesian Robust Design, no covariates, females only, primary intervals, and p and c constant, using
JAGS, Fall 17.

```

```

###set working directory
setwd("~/UNR/Masters/Summit/Project DB/Data/Prad RD GOF/Files for Bayesain 3D capture history
array/Fall 17 Capture Histories-Mark-Bayesian/Females")
###

```

```

###Load packages
library(R2jags)
library(coda)
library(abind)
library(fda)
###

```

```

#####First time capture for primary and sub periods
###first time capture for primaries
lctcap <- read.csv("SummitPrimaryg.csv", header=TRUE)
uniqueNames <- unique(lctcap$PIT)
nan <- length(uniqueNames)
CHList <- list()
firsts <- numeric(nan)
for(i in 1:nan){
  eval(parse(text=sprintf("CHList$PIT%s <- subset(lctcap,PIT==uniqueNames[i])",uniqueNames[i])))
}
for(ind in 1:nan){
  df <- CHList[[ind]]
  for(obs in 1:nrow(df)){ # loop through by observation..
    thisObs <- df[obs,]
    thisPeriod <- which(1==thisObs)

    if(obs==1){ # if this is the first capture
      firsts[ind] <- thisPeriod # record period of first capture
    }
  }
}

```

```

###first time sub capture for each primary
firstpc<-read.csv("firstsubp-c.csv",header=TRUE)
firstpc1<-as.matrix(firstpc)
first<-read.csv("firstsubc.csv",header=TRUE)
first1<-as.matrix(first)
subfirst<-as.numeric(first1[,2])

```

```

firsts2 <- firsts-1
###

###number of subs for each primary
prim <- c(8,6,2,4,4,2,4,5)
nss <- array(prim, dim=c(8))
###

###interval periods inbetween each primary period
int <- c(2,2,1,2,2,1,2)
###

###3d capture history array
summitsub1a <-read.csv("SummitSub1d.csv",header=TRUE)
summitsub2a <-read.csv("SummitSub2d.csv",header=TRUE)
summitsub3a <-read.csv("SummitSub3d.csv",header=TRUE)
summitsub4a <-read.csv("SummitSub4d.csv",header=TRUE)
summitsub5a <-read.csv("SummitSub5d.csv",header=TRUE)
summitsub6a <-read.csv("SummitSub6d.csv",header=TRUE)
summitsub7a <-read.csv("SummitSub7d.csv",header=TRUE)
summitsub8a <-read.csv("SummitSub8d.csv",header=TRUE)

summitsub1c <- as.matrix(summitsub1a)
summitsub2c <- as.matrix(summitsub2a)
summitsub3c <- as.matrix(summitsub3a)
summitsub4c <- as.matrix(summitsub4a)
summitsub5c <- as.matrix(summitsub5a)
summitsub6c <- as.matrix(summitsub6a)
summitsub7c <- as.matrix(summitsub7a)
summitsub8c <- as.matrix(summitsub8a)

caphist <-
abind(summitsub1c,summitsub2c,summitsub3c,summitsub4c,summitsub5c,summitsub6c,summitsub7c,su
mmitsub8c, along=3)

###2D primary period capture history

primcap <- read.csv("SummitPrimaryh.csv",header = TRUE)
ch2 <- as.matrix(primcap,dim=c(678,8))
ch2d <-as.array(ch2)

###Covariate data
#cov.data <- read.csv("Fall17caphistfemalescovs.csv",header = TRUE)
#fleff <- as.vector(cov.data$FL)
#trapeff <- as.vector(cov.data$Trap)

###

sink("SummitRobustDesign4.text")
cat("
  model{

#####

```

```

##Robust Design (CJS) Model
#####

#####
##Survival
#####

for(i in 1:nan){
  phi[i] <- phi0
}

#####
##Latent variable: alive or dead
#####

for(i in 1:nan){
  for(t in 1:(pfirst[i]-1)){
    alive[i,t] ~ dbern(1)
  }
}

for (i in 1:nan){
  alive[i,pfirst[i]] ~ dbern(1)
  for (t in (pfirst[i]+1):np){
    transition[i,t] <- pow(phi[i],int[t-1])
    alive.prob[i,t] <- alive[i,(t-1)]*transition[i,t]
    alive[i,t] ~ dbern(alive.prob[i,t])
  }
}

#####
##OBSERVATION MODEL (actual data likelihood)
#####
# use the year/season of first capture to help refine p estimates. p and c constant.

for(i in 1:nan){
  for(t in 1:np){
    p[i,t] <- p0
    c[i,t] <- c0
  }
}

for(i in 1:nan){
  for(j in (subfirst[i]+1):nss[pfirst[i]]){
    c1[i,pfirst[i],j] <- c[i,pfirst[i]]
    muy[i,pfirst[i],j] <- alive[i,pfirst[i]]*c1[i,pfirst[i],j]
    y[i,pfirst[i],j] ~ dbern(muy[i,pfirst[i],j])
  }
}

for(i in 1:nan){
  for(t in (pfirst[i]+1):np){
    for(j in 1:nss[t]){
      p1[i,t,j] <- ((1 - step(j - firstpc1[i,t]-1))*p[i,t]) + (step(j - firstpc1[i,t]-1)*c[i,t])
    }
  }
}

```

```

    muy[i,t,j] <- alive[i,t]*p1[i,t,j]
    y[i,t,j] ~ dbern(muy[i,t,j])
  }
}

#####
##Derived Quantities: N; CALCULATE ABUNDANCE USING HORVITZ-THOMPSON
ESTIMATOR
#####

for(i in 1:nan){
  for (t in 1:np){
    p.prim.ncap[i,t,1] <- (1 - p[i,t]) #formula for never capturing an individual
    for(j in 2:nss[t]){
      p.prim.ncap[i,t,j] <- p.prim.ncap[i,t,j-1]*(1 - p[i,t])
    }
    pcap[i,t] <- 1 - p.prim.ncap[i,t,nss[t]] # pcap refers to the prob of being captured at least once for
entire 3-day period
    inv.p[i,t] <- 1/pcap[i,t] #for H-T estimator
  }
}

for(t in 2:np){
  N[t] <- inprod(inv.p[1:nan,t],ch2d[1:nan,t])
}

#####
##Model Priors
#####

phi0~dunif(.6,.95)    #survival
p0~dunif(.01,.1)     #capture
c0~dunif(.01,.1)     #recapture

}

")

sink()

###model data - in list form
rd.data.for.bugs<-list(
  nan = nan,
  np = 8,
  nss = as.vector(nss),
  pfirst = as.vector(firsts2),
  firstpc1 = firstpc1,
  subfirst = subfirst,
  y = caphist,
  ch2d = ch2d,
  #fleff = fleff,
  int = int

```

```

)

###
#Z <- array(1,dim=c(504,7))

###Initial parameter values
rd.init.vals.for.bugs <- function(){
  rd.init.list <- list(
    phi0=runif(1,.60,.95),
    p0=runif(1,.01,.1),
    c0=runif(1,.01,.1)
    #FLEff=runif(1,0,.1)
    #alive=Z
  )
  return(rd.init.list)
}

###Parameters
rd.params.to.store <- c("phi0","p0","c0","N")
###

rd.jags.fit <-
jags(data=rd.data.for.bugs,inits=rd.init.vals.for.bugs,parameters.to.save=rd.params.to.store,n.iter=25000,
odel.file="SummitRobustDesign4.text",n.chains = 3,n.burnin = 5000)

rd.jagsfit.mcmc <- as.mcmc(rd.jags.fit) # convert to "MCMC" object (coda package)

summary(rd.jagsfit.mcmc)

gelman.diag(rd.jagsfit.mcmc)

plot(rd.jagsfit.mcmc["phi0"])

plot(rd.jagsfit.mcmc["p0"])

plot(rd.jagsfit.mcmc["c0"])

plot(rd.jagsfit.mcmc["N"])

densityplot(rd.jagsfit.mcmc)

DIC <- rd.jags.fit$BUGSoutput$DIC
DIC

#####End of model

```

5.6 Trap net set data

<i>GPS coordinates** or Location</i>	<i>Zone</i>	<i>Mesh size (inches)</i>	<i>Trap Depth (ft)</i>	<i>Set Date/Time</i>	<i>Pull Date/Time</i>
HeatherGpsGarminWaypoint 16	*	*	5	3/4/2015 17:15	3/5/2015 18:20
Near boat dock	1	*	5	3/10/2015 11:00	3/10/2015 13:50
By boat dock	1	*	5	3/11/2015 10:00	3/11/2015 14:30

Boat dock	1	*	5	3/12/2015 9:30	3/12/2015 12:00
West of boat dock	1	*	5	3/18/2015 10:27	3/18/2015 15:50
Across Mahogany Bay from dock	1	*	*	3/19/2015 10:20	3/19/2015 14:30
East of boat dock	1	*	5	3/27/2015 10:00	3/27/2015 15:05
20 m left of dock	1	*	5	3/28/2015 9:05	3/28/2015 12:45
11T0327561 4599307	1	*	*	3/28/2015 16:15	3/29/2015 9:00
East of boat dock	1	*	5	4/3/2015 12:10	4/3/2015 15:00
11T0328541 4598195	2	*	*	4/4/2015 10:40	4/4/2015 15:16
*	2	*	8	4/6/2015 16:15	4/7/2015 9:45
*	2	*	11	4/7/2015 10:48	4/8/2015 13:15
*	2	*	10	4/9/2015 7:50	4/9/2015 12:30
11T0328546 4598195	2	*	*	4/10/2015 13:25	4/11/2015 9:30
*	1	*	*	4/10/2015 13:40	4/11/2015 11:00
11T0327596 4599154	1	*	*	4/11/2015 14:30	4/12/2015 9:25
11T0328546 4598195	2	*	*	4/11/2015 14:50	4/12/2015 10:50
Mahogany Bay "Boat Dock 2015"	1	*	10	4/15/2015 14:37	4/15/2015 16:10
11T0327670 4599202	1	*	4	4/17/2015 15:00	4/18/2015 9:00
11T0328535 4598158	2	*	6	4/17/2015 15:20	4/18/2015 10:15
11T0328533 4598157	2	*	*	4/18/2015 14:54	4/19/2015 8:45
11T0327249 4598860	1	*	*	4/18/2015 15:42	4/19/2015 9:50
11T0327582 4596285	4	*	8	4/19/2015 9:39	4/19/2015 14:20
11T0327577 4599530	1	*	5	4/19/2015 10:37	4/19/2015 15:10
11T0327577 4599530	1	*	5	4/20/2015 6:45	4/20/2015 14:15
11T0327182 4598577	1	*	8	4/20/2015 7:00	4/20/2015 14:44
11T0327577 4599530	1	*	5	4/20/2015 14:15	4/21/2015 8:40
11T0327178 4598579	1	*	8	4/20/2015 14:44	4/21/2015 9:20
11T0327577 4599530	1	*	8	4/21/2015 9:11	4/21/2015 13:55
11T0327861 4596358	4	*	25	4/21/2015 9:40	4/21/2015 14:35
11T0327861 4596358	4	*	25	4/21/2015 14:35	4/22/2015 9:15
11T0328224 4596224	4	*	23	4/22/2015 9:05	4/22/2015 14:00
11T0327861 4596358	4	*	25	4/22/2015 9:15	4/22/2015 14:30
11T0328224 4596224	4	*	23	4/22/2015 14:00	4/23/2015 14:25
11T0327861 4596358	4	*	25	4/22/2015 14:30	4/23/2015 14:58
11T0327891 4598311	2	*	4	4/25/2015 9:10	4/26/2015 8:10
11T0328060 4596751	4	*	6	4/25/2015 9:38	4/26/2015 9:45
11T0327992 4598464	2	*	4	4/27/2015 14:00	4/28/2015 14:50
11T0327656 4598354	2	*	6	4/28/2015 14:40	4/29/2015 13:49
11T0327992 4598464	2	*	4	4/28/2015 14:50	4/29/2015 14:16
11T0328207 4598189	2	*	8	4/29/2015 13:30	4/30/2015 13:40
11T0327656 4598354	2	*	6	4/29/2015 13:50	4/30/2015 13:38
11T0328520 4598589	2	*	5	4/29/2015 15:00	4/30/2015 14:30
11T0328470 4596400	4	*	4	5/1/2015 15:46	5/2/2015 8:30

11T0327363 4599421	1	*	6	5/1/2015 16:04	5/2/2015 9:30
11T0327860 4596487	4	*	11	5/2/2015 9:10	5/3/2015 8:00
11T0327449 4599110	1	*	7	5/2/2015 10:15	5/3/2015 9:50
11T0327640 4598732	1	*	8	5/2/2015 10:49	5/3/2015 9:00
11T0328060 4596882	4	*	10	5/3/2015 8:52	5/4/2015 7:35
11T0328060 4596882	3	*	10	5/3/2015 8:52	5/4/2015 7:35
11T0327237 4598802	1	*	8	5/3/2015 10:34	5/4/2015 8:05
11T0327604 4599167	1	*	7	5/9/2015 9:00	5/10/2015 8:00
11T0327238 4598800	1	*	7	5/9/2015 9:15	5/10/2015 10:07
11T0327287 4597743	3	*	7	5/9/2015 9:30	5/10/2015 10:40
11T0327365 4599428	1	*	5	5/10/2015 9:59	5/11/2015 8:00
11T0328689 4598307	2	*	7	5/10/2015 10:30	5/11/2015 6:50
11T0327318 4597240	3	*	5	5/10/2015 11:10	5/11/2015 7:20
11T0327583 4599515	1	*	4	5/15/2015 11:38	5/16/2015 10:30
11T0328117 4598006	3	*	7	5/17/2015 9:02	5/18/2015 7:45
11T0328455 4598121	2	*	7	5/17/2015 9:15	5/18/2015 8:10
11T0327370 4599416	1	*	5	5/17/2015 9:35	5/18/2015 9:02
11T0327370 4597297	3	*	8	5/18/2015 8:00	5/19/2015 8:38
11T0328537 4598602	2	*	6	5/18/2015 8:45	5/19/2015 9:00
11T0327578 4599525	1	*	4	5/18/2015 9:45	5/19/2015 9:40
11T0327249 4598860	1	*	*	5/19/2015 9:21	5/20/2015 11:28
11T0327596 4599154	1	*	8	5/19/2015 9:29	5/20/2015 9:40
11T0327368 4599421	1	*	5	5/19/2015 10:27	5/20/2015 10:25
11T0327718 4599262	1	*	3	5/20/2015 9:20	5/21/2015 7:57
11T0327379 4599245	1	*	*	5/20/2015 10:14	5/21/2015 8:40
11T0327564 4599416	1	*	7	5/20/2015 11:13	5/21/2015 8:16
11T0327635 4598740	1	*	*	5/20/2015 11:38	5/21/2015 9:00
11T0328503 4598194	2	*	*	10/5/2015 17:00	10/6/2015 10:34
11T0327824 4596424	4	*	*	10/5/2015 17:15	10/6/2015 11:30
11T0328503 4598194	2	*	*	10/6/2015 10:40	10/6/2015 17:35
11T0327824 4596424	4	*	*	10/6/2015 11:40	10/7/2015 10:30
11T0327589 4598865	1	*	*	10/6/2015 16:52	10/7/2015 9:35
11T0328160 4597564	3	*	*	10/6/2015 17:00	10/7/2015 10:20
11T0327574 4597416	3	*	*	10/6/2015 17:13	10/7/2015 10:40
11T0328503 4598194	2	*	*	10/6/2015 17:40	10/7/2015 11:25
11T0327544 4599147	1	*	*	10/7/2015 10:30	10/8/2015 8:15
11T0327507 4597278	3	*	*	10/7/2015 11:15	10/8/2015 9:15
11T0328278 4596213	4	*	*	10/7/2015 11:50	10/8/2015 8:15
11T0328426 4598192	2	*	*	10/7/2015 12:12	10/8/2015 9:10
11T0328000 4597131	3	*	*	10/7/2015 12:15	10/8/2015 8:57
11T0327576 4598953	1	*	*	10/13/2015 15:10	10/14/2015 8:50
11T0327295 4598557	1	*	*	10/13/2015 15:25	10/14/2015 9:40

11T0328143 4598279	2	*	*	10/13/2015 15:36	10/14/2015 10:06
11T0327984 4596767	4	*	*	10/13/2015 16:08	10/14/2015 11:15
11T0327777 4596486	4	*	*	10/13/2015 16:20	10/14/2015 12:15
11T0327521 4599083	1	*	*	10/14/2015 9:30	10/15/2015 9:30
11T0327578 4598497	1	*	*	10/14/2015 9:55	10/15/2015 10:35
11T0328533 4598276	2	*	*	10/14/2015 10:45	10/15/2015 8:35
11T0328366 4596772	4	*	*	10/14/2015 11:58	10/15/2015 12:20
11T0328357 4596633	4	*	*	10/14/2015 12:48	10/15/2015 11:37
11T0328270 4598654	2	*	*	10/15/2015 8:27	10/16/2015 8:00
11T0328144 4598243	2	*	*	10/15/2015 9:19	10/16/2015 8:55
11T0327491 4599175	1	*	*	10/15/2015 10:25	10/16/2015 9:47
11T0327476 4598842	1	*	*	10/15/2015 11:25	10/16/2015 14:30
11T0328393 4596571	4	*	*	10/15/2015 12:55	10/16/2015 16:15
11T0328370 4596500	4	*	*	10/15/2015 14:06	10/16/2015 15:35
11T0328482 4598210	2	*	8	10/16/2015 8:51	10/17/2015 8:50
11T0328205 4597555	3	*	11	10/16/2015 9:35	10/17/2015 10:57
11T0327622 4597503	3	*	6	10/16/2015 10:45	10/17/2015 10:10
11T0327593 4599019	1	*	10	10/16/2015 15:05	10/17/2015 14:41
11T0328318 4596402	4	*	27	10/16/2015 16:04	10/17/2015 11:50
11T0327563 4598445	1	*	20	10/16/2015 17:07	10/17/2015 15:35
11T0327649 4598938	1	*	8	10/17/2015 9:56	10/18/2015 11:15
11T0327460 4597825	1	*	16	10/17/2015 10:23	10/18/2015 12:30
11T0328052 4597256	3	*	16	10/17/2015 11:36	10/18/2015 9:35
11T0327868 4596428	4	*	31	10/17/2015 12:15	10/18/2015 8:09
11T0327516 4598916	1	*	13	10/17/2015 15:26	10/18/2015 8:55
11T0328150 4598460	2	*	11	10/17/2015 16:18	10/18/2015 10:21
11T0328342 4596650	4	*	16	10/18/2015 8:40	10/19/2015 8:08
11T0328120 4597758	3	*	23	10/18/2015 9:29	10/19/2015 8:45
11T0327938 4596884	3	*	17	10/18/2015 9:52	10/19/2015 8:30
11T0328306 4598179	2	*	9	10/18/2015 11:04	10/19/2015 9:10
11T0327589 4598720	1	*	10	10/18/2015 12:20	10/19/2015 10:45
11T0327656 4598899	1	*	8	10/18/2015 13:00	10/19/2015 10:00
11T0328089 4596283	4	*	15	10/19/2015 8:15	10/20/2015 8:10
11T0328204 4597499	3	*	19	10/19/2015 8:40	10/20/2015 10:00
11T0328562 4598269	2	*	7	10/19/2015 9:00	10/19/2015 15:30
11T0328426 4598183	2	*	8	10/19/2015 9:40	10/20/2015 11:00
11T0327513 4599130	1	*	9	10/19/2015 10:00	10/20/2015 13:50
11T0328134 4596430	4	*	14	10/19/2015 14:30	10/20/2015 9:00
11T0328143 4598467	2	*	12	10/19/2015 16:15	10/20/2015 13:00
11T0328390 4596403	4	*	9	10/20/2015 8:48	10/21/2015 9:00
11T0328002 4596677	4	*	7	10/20/2015 9:38	10/21/2015 10:15
11T0327768 4596521	4	*	34	10/20/2015 10:42	10/21/2015 10:25

11T0328466 4598437	2	*	6	10/20/2015 11:52	10/21/2015 11:35
11T0327538 4597084	3	*	9	10/20/2015 13:30	10/21/2015 13:30
11T0327488 4599213	1	*	7	10/20/2015 14:25	10/21/2015 14:35
11T0328363 4596667	4	*	16	10/21/2015 10:02	10/21/2015 16:00
11T0327748 4596430	4	*	19	10/21/2015 11:00	10/22/2015 8:00
11T0328496 4598202	2	*	8	10/21/2015 12:23	10/22/2015 9:05
11T0327523 4599240	1	*	7	10/21/2015 16:26	10/22/2015 9:45
11T0328417 4596429	4	*	9	10/26/2015 14:25	10/27/2015 8:20
11T0327932 4596418	4	*	30	10/26/2015 14:37	10/27/2015 9:13
11T0327623 4596319	4	*	10	10/26/2015 15:02	10/27/2015 9:45
11T0327601 4597087	3	*	14	10/26/2015 15:43	10/27/2015 10:35
11T0328494 4598414	2	*	6	10/26/2015 16:00	10/27/2015 13:10
11T0327521 4599200	1	*	7	10/26/2015 16:15	10/27/2015 11:25
11T0328270 4596377	4	*	14	10/27/2015 9:04	10/28/2015 8:05
11T0328040 4598047	3	*	11	10/27/2015 9:32	10/28/2015 8:55
11T0327416 4598039	3	*	12	10/27/2015 10:23	10/28/2015 9:25
11T0327670 4598914	1	*	7	10/27/2015 11:05	10/28/2015 10:15
11T0327985 4596861	3	*	11	10/27/2015 12:10	10/28/2015 11:15
11T0328401 4598200	2	*	9	10/27/2015 13:25	10/28/2015 11:30
11T0328047 4596446	4	*	6	10/28/2015 8:43	10/28/2015 13:00
11T0328370 4598505	2	*	7	10/28/2015 9:19	10/28/2015 13:25
11T0328359 4596577	4	*	20	11/2/2015 16:05	11/3/2015 10:17
11T0328006 4596720	4	*	10	11/2/2015 16:18	11/3/2015 11:15
11T0327607 4597258	3	*	6	11/2/2015 16:30	11/3/2015 11:50
11T0328334 4598166	2	*	9	11/2/2015 16:45	11/3/2015 13:20
11T0327491 4599227	1	*	7	11/2/2015 17:00	11/3/2015 13:50
11T0328571 4598269	2	*	6	11/3/2015 10:00	11/4/2015 9:10
11T0328280 4596242	4	*	22	11/3/2015 11:05	11/4/2015 10:05
11T0328200 4597484	3	*	15	11/3/2015 11:35	11/4/2015 10:45
11T0327814 4597456	3	*	30	11/3/2015 12:18	11/4/2015 11:35
11T0328409 4598188	2	*	8	11/3/2015 13:35	11/4/2015 9:45
11T0327532 4599118	1	*	8	11/3/2015 14:00	11/4/2015 12:25
11T0328571 4598269	2	*	6	11/4/2015 9:15	11/5/2015 9:00
11T0328479 4598373	2	*	8	11/4/2015 9:50	11/5/2015 9:35
11T0328402 4596429	4	*	13	11/4/2015 10:35	11/5/2015 10:24
11T0328203 4597608	3	*	23	11/4/2015 11:25	11/5/2015 11:45
11T0327786 4596514	4	*	32	11/4/2015 12:00	11/5/2015 13:10
11T0327520 4598412	1	*	21	11/4/2015 12:40	11/5/2015 14:00
11T0327468 4597809	3	*	15	11/5/2015 9:21	11/6/2015 9:02
11T0328555 4598357	2	*	6	11/5/2015 10:10	11/5/2015 14:45
11T0328177 4596418	4	*	12	11/5/2015 11:36	11/5/2015 15:10
11T0327547 4597294	3	*	14	11/5/2015 12:02	11/6/2015 9:45

11T0327903 4598228	2	*	20	11/5/2015 13:42	11/6/2015 11:10
11T0327268 4598562	1	*	11	11/5/2015 14:30	11/6/2015 13:00
11T0328411 4598321	2	*	9	11/5/2015 14:57	11/6/2015 12:10
11T0328347 4596643	4	*	18	11/5/2015 15:33	11/6/2015 10:26
11T0327492 4599284	1	*	6	11/6/2015 9:30	11/7/2015 9:05
11T0327702 4596826	4	*	33	11/6/2015 10:20	11/7/2015 9:38
11T0328330 4596391	4	*	24	11/6/2015 10:55	11/7/2015 10:16
11T0328114 4598287	2	*	14	11/6/2015 11:51	11/7/2015 11:15
11T0328502 4598232	2	*	8	11/6/2015 12:45	11/7/2015 12:17
11T0327535 4598879	1	*	12	11/6/2015 13:19	11/7/2015 12:45
11T0327781 4598287	2	*	8	11/7/2015 9:25	11/8/2015 8:55
11T0328006 4597138	3	*	32	11/7/2015 10:05	11/8/2015 9:50
11T0328092 4596413	4	*	29	11/7/2015 10:50	11/8/2015 11:25
11T0327848 4596430	4	*	27	11/7/2015 12:00	11/8/2015 12:21
11T0328299 4598210	2	*	9	11/7/2015 12:30	11/8/2015 14:05
11T0327449 4598725	1	*	18	11/7/2015 13:44	11/8/2015 15:10
11T0328028 4598293	2	*	11	11/8/2015 9:41	11/9/2015 8:58
11T0327589 4598316	3	*	9	11/8/2015 10:42	11/9/2015 9:05
11T0328166 4596319	4	*	31	11/8/2015 12:12	11/9/2015 9:26
11T0327586 4597859	3	*	15	11/8/2015 12:39	11/9/2015 10:10
11T0328411 4598429	2	*	8	11/8/2015 14:53	11/9/2015 10:55
11T0327532 4599182	1	*	9	11/8/2015 15:55	11/9/2015 11:25
11T0328119 4597532	3	.5 in	32	4/5/2016 12:26	4/6/2016 16:17
11T0327526 4599300	1	.5 in	6	4/5/2016 12:51	4/6/2016 9:40
11T0328452 4598175	2	1 in	8	4/5/2016 13:08	4/6/2016 14:50
11T0327520 4597076	3	1 in	4	4/5/2016 13:30	4/6/2016 16:49
11T0328440 4596420	4	.5 in	6	4/5/2016 13:49	4/6/2016 17:30
11T0327502 4599114	1	.5 in	5	4/6/2016 14:43	4/7/2016 8:45
11T0328692 4598333	2	1 in	4	4/6/2016 16:07	4/7/2016 9:50
11T0327559 4597753	3	.5 in	8	4/6/2016 16:40	4/7/2016 11:00
11T0328064 4596799	3	1 in	6	4/6/2016 17:21	4/7/2016 15:13
11T0327984 4596445	4	.5 in	6	4/6/2016 18:41	4/7/2016 16:00
11T0327376 4598679	1	.5 in	6	4/7/2016 9:36	4/8/2016 8:41
11T0327570 4598840	1	1 in	10	4/7/2016 10:47	4/7/2016 13:20
11T0328311 4596613	4	1 in	8	4/7/2016 15:51	4/8/2016 9:22
11T0327712 4598907	1	1 in	6	4/11/2016 10:30	4/11/2016 15:17
11T0327585 4599191	1	1 in	7	4/11/2016 16:37	4/12/2016 9:20
11T0327704 4598200	3	.5 in	16	4/11/2016 17:07	4/12/2016 10:50
11T0328535 4598551	2	1 in	4	4/11/2016 17:22	4/12/2016 11:30
11T0327464 4597280	3	.5 in	11	4/11/2016 17:38	4/12/2016 14:27
11T0328249 4596428	4	.5 in	4	4/11/2016 17:53	4/12/2016 14:50
11T0327351 4598805	1	1 in	8	4/12/2016 10:43	4/13/2016 8:50

11T0327509 4598551	1	.5 in	21	4/12/2016 11:15	4/13/2016 9:25
11T0328368 4598119	2	1 in	8	4/12/2016 12:21	4/13/2016 10:21
11T0327596 4596992	3	.5 in	6	4/12/2016 14:41	4/13/2016 11:10
11T0328365 4596626	4	.5 in	13	4/12/2016 15:07	4/13/2016 11:55
11T0327563 4598650	1	1 in	13	4/13/2016 9:20	4/14/2016 9:07
11T0328052 4597264	3	.5 in	16	4/13/2016 10:11	4/14/2016 11:38
11T0328519 4598224	2	1 in	8	4/13/2016 11:00	4/14/2016 15:00
11T0327460 4597900	3	.5 in	5	4/13/2016 11:43	4/14/2016 16:00
11T0328093 4596513	4	.5 in	4	4/13/2016 12:37	4/14/2016 12:30
11T0327434 4599214	1	1 in	6	4/14/2016 11:18	4/15/2016 8:30
11T0327899 4596401	4	.5 in	28	4/14/2016 12:16	4/15/2016 9:30
11T0327556 4599165	1	1 in	9	5/31/2016 16:05	6/1/2016 10:42
11T0327825 4596403	4	.5 in	10	5/31/2016 16:27	6/1/2016 15:03
11T0328432 4598162	2	1 in	8	5/31/2016 17:11	6/1/2016 11:45
11T0328494 4598530	2	.5 in.	5	5/31/2016 17:27	6/1/2016 12:25
11T0327460 4597295	3	.5 in	12	5/31/2016 17:56	6/1/2016 14:23
11T0328167 4596509	4	.5 in	4	6/1/2016 11:01	6/2/2016 10:03
11T0327346 4598813	1	1 in	7	6/1/2016 11:33	6/2/2016 8:40
11T0328158 4597354	3	*	13	6/1/2016 11:40	6/2/2016 13:00
11T0328241 4598206	2	1 in	9	6/1/2016 12:17	6/2/2016 10:33
11T0328671 4598352	2	.5 in	5	6/1/2016 13:07	6/2/2016 11:02
11T0327623 4598465	1	*	7	6/1/2016 13:55	6/2/2016 11:00
11T0327280 4598271	3	.5 in	4	6/1/2016 14:00	6/2/2016 11:30
11T0327574 4599352	1	.5 in	6	6/1/2016 14:23	6/2/2016 9:30
11T0327995 4596979	3	.5 in	12	6/1/2016 14:54	6/2/2016 13:08
11T0328125 4596262	4	0.5	9	6/1/2016 15:44	6/2/2016 10:36
11T0327658 4598843	1	.5 in	9	6/2/2016 10:00	6/3/2016 9:15
11T0328438 4596419	4	.5 in	5	6/2/2016 10:28	6/3/2016 8:45
11T0328288 4598793	2	.5 in	5	6/2/2016 12:00	6/3/2016 10:15
11T0327432 4597823	3	.5 in	14	6/2/2016 12:10	6/3/2016 9:16
11T0327594 4598651	1	1 in	12	6/6/2016 16:45	6/7/2016 7:35
*	1	.5 in	6	6/6/2016 16:57	6/7/2016 8:15
11T0328535 4598188	2	1 in	7	6/6/2016 17:24	6/7/2016 9:03
11T0328582 4598379	2	*	4	6/6/2016 17:48	6/7/2016 9:32
11T0328395 4598563	2	.5 in	4	6/6/2016 17:59	6/7/2016 9:58
11T0328380 4596666	4	.5 in	19	6/6/2016 18:20	6/7/2016 9:05
11T0328082 4596701	4	.5 in	5	6/6/2016 18:25	6/7/2016 10:38
11T0327873 4596473	4	.5 in	32	6/6/2016 18:30	6/7/2016 10:15
11T0327406 4597833	3	.5 in	10	6/6/2016 18:57	6/7/2016 11:28
11T0327664 4599020	1	1 in	8	6/7/2016 8:10	6/8/2016 7:15
11T0327666 4596692	4	old net	15	6/7/2016 8:43	6/8/2016 9:12
11T0327451 4598916	1	*	8	6/7/2016 8:44	6/8/2016 7:53

11T0328330 4598096	2	1 in	7	6/7/2016 9:22	6/8/2016 8:20
11T0328568 4598206	2	.5 in	5	6/7/2016 9:51	6/8/2016 8:42
11T0328438 4596388	4	.5 in	7	6/7/2016 10:00	6/8/2016 10:20
11T0328079 4598359	2	.5 in	6	6/7/2016 10:14	6/8/2016 9:12
11T0327998 4596907	3	.5 in	10	6/7/2016 11:01	6/8/2016 11:40
11T0327921 4596571	4	.5 in	12	6/7/2016 11:05	6/8/2016 10:09
11T0327454 4597666	3	.5 in	4	6/7/2016 11:43	6/8/2016 11:40
11T0327573 4599255	1	1 in	7	6/8/2016 7:40	6/9/2016 7:16
11T0328219 4598188	2	1 in	9	6/8/2016 8:32	6/9/2016 7:28
11T0328302 4596660	4	.5 in	*	6/8/2016 11:14	6/9/2016 8:20
11T0328114 4597984	3	*	6	6/8/2016 11:56	6/9/2016 7:55
11T0327564 4599391	1	1 in	4	6/13/2016 14:00	6/14/2016 6:41
11T0327375 4599400	1	1 in	5	6/13/2016 14:13	6/14/2016 7:13
11T0327925 4596323	4	.5 in	27	6/13/2016 14:26	6/14/2016 7:12
11T0328025 4596877	4	.5 in	13	6/13/2016 14:50	6/14/2016 7:46
11T0328291 4598120	2	.5 in	8	6/13/2016 15:01	6/14/2016 7:48
11T0328257 4597490	3	.5 in	10	6/13/2016 15:17	6/14/2016 9:00
11T0328445 4598138	2	.5 in	8	6/13/2016 15:19	6/14/2016 8:30
11T0328531 4598192	2	.5 in.	7	6/13/2016 15:33	6/14/2016 8:57
11T0327698 4596432	4	.5 in	15	6/13/2016 15:43	6/14/2016 8:34
11T0328132 4597909	3	*	7	6/13/2016 16:15	6/14/2016 9:36
11T0327593 4599109	1	1 in	8	6/14/2016 7:05	6/15/2016 6:41
11T0328349 4596741	4	.5 in	16	6/14/2016 7:30	6/15/2016 7:30
11T0327594 4598645	1	1 in	10	6/14/2016 7:38	6/15/2016 7:05
11T0328693 4598333	2	.5 in	5	6/14/2016 8:01	6/15/2016 7:43
11T0327987 4596616	4	.5 in	7	6/14/2016 8:30	6/15/2016 7:58
11T0327820 4598344	2	.5 in	6	6/14/2016 8:47	6/15/2016 8:32
11T0327436 4597305	3	.5 in	10	6/14/2016 8:50	6/15/2016 8:15
11T0328160 4598683	2	.5 in	9	6/14/2016 9:14	6/15/2016 9:04
11T0327307 4598178	3	.5 in	13	6/14/2016 9:30	6/15/2016 9:30
11T0328196 4597724	3	.5 in	10	6/14/2016 9:45	6/15/2016 9:05
11T0327266 4598779	1	1 in	7	6/15/2016 6:55	6/16/2016 6:34
11T0328208 4596194	4	.5 in	12	6/15/2016 7:50	6/16/2016 7:00
11T0327887 4597178	3	.5 in	38	6/15/2016 8:55	6/16/2016 7:30
11T0328075 4598370	2	.5 in	9	6/15/2016 9:39	6/16/2016 6:58
11T0327689 4598863	1	.5 in	9	6/20/2016 14:30	6/21/2016 7:20
11T0327261 4598798	1	1 in	7	6/20/2016 14:40	6/21/2016 7:55
11T0327898 4596385	4	.5 in	22	6/20/2016 14:57	6/21/2016 8:30
11T0328473 4598127	2	1 in	6	6/20/2016 15:00	6/21/2016 8:23
11T0327987 4598557	2	.5 in	6	6/20/2016 15:15	6/21/2016 9:02
11T0327695 4596421	4	.5 in	7	6/20/2016 15:22	6/21/2016 8:06
11T0328295 4598121	2	.5 in	8	6/20/2016 15:45	6/21/2016 9:45

11T0328091 4597300	3	.5 in	14	6/20/2016 15:47	6/21/2016 7:23
11T0327905 4596547	4	old net	8	6/20/2016 16:26	6/21/2016 7:45
11T0327627 4597737	3	.5 in	21	6/20/2016 16:45	6/21/2016 6:47
11T0327539 4597492	3	.5 in	10	6/21/2016 7:14	6/22/2016 7:05
11T0328232 4597679	3	.5 in	19	6/21/2016 7:37	6/22/2016 6:40
11T0327596 4598622	1	.5 in	9	6/21/2016 7:50	6/22/2016 7:51
11T0328377 4596676	4	old net	14	6/21/2016 7:57	6/22/2016 9:00
11T0327499 4599020	1	1 in	11	6/21/2016 8:17	6/22/2016 8:20
11T0328655 4598272	2	1 in	5	6/21/2016 8:55	6/22/2016 8:56
11T0328401 4598555	2	.5 in	7	6/21/2016 9:30	6/22/2016 9:23
11T0328160 4598176	2	.5 in	9	6/21/2016 10:06	6/22/2016 10:10
11T0327715 4596452	4	.5 in	23	6/21/2016 10:07	6/22/2016 8:09
11T0327843 4596475	4	.5 in	29	6/21/2016 10:26	6/22/2016 8:03
11T0327868 4596380	4	.5 in	28	6/22/2016 8:32	6/23/2016 8:00
11T0327876 4596436	4	.5 in	27	6/22/2016 8:47	6/23/2016 8:20
11T0328533 4598190	2	.5 in	*	6/22/2016 10:05	6/23/2016 7:22
11T0327468 4599251	1	.5 in	*	6/22/2016 10:40	6/23/2016 6:50
11T0328393 4598412	2	.5 in	7	10/17/2016 18:04	10/18/2016 15:00
11T0327508 4599052	1	.5 in	7	10/17/2016 18:19	10/18/2016 15:38
11T0328425 4596442	4	.5 in	7	10/18/2016 14:15	10/19/2016 10:20
11T0327937 4596408	4	1 in	29	10/18/2016 14:28	10/19/2016 11:07
11T0327595 4597075	3	.5 in	11	10/18/2016 14:42	10/19/2016 11:45
11T0328247 4598267	2	.5 in	8	10/18/2016 15:27	10/19/2016 13:50
11T0327622 4598970	1	.5 in	8	10/18/2016 16:22	10/19/2016 15:30
11T0328335 4596590	4	.5 in	14	10/19/2016 10:58	10/20/2016 10:45
11T0328045 4596339	4	1 in	28	10/19/2016 11:33	10/20/2016 11:05
11T0328231 4597527	3	.5 in	13	10/19/2016 12:40	10/20/2016 12:03
11T0328171 4598396	2	.5 in	11	10/19/2016 14:43	10/20/2016 14:00
11T0327509 4599092	1	.5 in	7	10/19/2016 16:24	10/20/2016 14:49
11T0328252 4596387	4	.5 in	11	10/20/2016 10:58	10/21/2016 11:09
11T0327821 4596512	4	1 in	22	10/20/2016 11:52	10/21/2016 12:15
11T0327778 4598288	3	.5 in	8	10/20/2016 12:45	10/21/2016 13:15
11T0328190 4598573	2	.5 in	9	10/20/2016 14:36	10/21/2016 16:35
11T0327545 4598671	1	.5 in	18	10/20/2016 15:30	10/21/2016 15:51
11T0328327 4596324	4	.5 in	22	10/21/2016 12:00	10/22/2016 11:24
11T0327768 4596457	4	1 in.	24	10/21/2016 13:04	10/22/2016 13:03
11T0327577 4597758	3	.5 in	6	10/21/2016 14:40	10/22/2016 14:01
11T0327614 4598871	1	1 in	9	10/21/2016 15:10	10/22/2016 8:00
11T0327526 4599053	1	.5 in	9	10/21/2016 15:20	10/22/2016 8:40
11T0327284 4598472	1	*	13	10/21/2016 15:42	10/22/2016 9:14
11T0328307 4598198	2	*	8	10/21/2016 15:50	10/22/2016 9:35
11T0328189 4598409	2	.5 in	11	10/21/2016 16:00	10/22/2016 9:44

11T0327911 4596638	4	*	28	10/21/2016 16:27	10/22/2016 11:08
*	3	.5 in	22	10/21/2016 17:21	10/22/2016 12:28
11T0327622 4598982	1	1 in	8	10/22/2016 8:35	10/23/2016 7:40
11T0328441 4598370	2	.5 in	8	10/22/2016 10:57	10/23/2016 8:10
11T0327710 4596629	4	.5 in.	21	10/22/2016 11:24	10/23/2016 10:05
11T0328251 4596227	4	.5 in	25	10/22/2016 12:30	10/23/2016 9:45
11T0328091 4597862	3	.5 in	9	10/22/2016 12:55	10/23/2016 12:15
11T0327555 4598654	1	1 in	13	10/22/2016 13:27	10/23/2016 11:07
11T0328155 4598268	2	.5 in	*	10/22/2016 14:26	10/23/2016 13:20
11T0327925 4598282	3	.5 in.	14	10/23/2016 13:06	10/24/2016 7:30
11T0328050 4598218	3	.5 in	12	10/23/2016 14:00	10/24/2016 7:55
11T0330623 4601296	4	.5 in	23	11/1/2016 10:27	11/2/2016 9:37
11T0328142 4597748	3	.5 in	17	11/1/2016 10:41	11/2/2016 10:00
11T0328327 4598241	2	.5 in	8	11/1/2016 11:04	11/2/2016 10:23
11T0327524 4597953	3	.5 in	20	11/1/2016 11:09	11/2/2016 11:15
11T0327556 4598610	1	.5 in	11	11/1/2016 11:27	11/2/2016 12:05
11T0328401 4596565	4	.5 in	13	11/2/2016 9:47	11/3/2016 9:07
11T0328036 4597092	3	.5 in	15	11/2/2016 10:12	11/3/2016 9:50
11T0328136 4598529	2	.5 in	10	11/2/2016 11:01	11/3/2016 10:32
11T0327576 4597328	3	.5 in	15	11/2/2016 11:56	11/3/2016 11:23
11T0327294 4598542	1	.5 in	13	11/2/2016 12:18	11/3/2016 11:47
11T0328125 4596468	4	.5 in	18	11/3/2016 9:40	11/4/2016 8:53
11T0328060 4597953	3	.5 in	8	11/3/2016 10:21	11/4/2016 9:35
11T0328390 4598277	2	.5 in	8	11/3/2016 11:09	11/4/2016 10:20
11T0327672 4598275	3	.5 in	6	11/3/2016 11:35	11/4/2016 11:13
11T0327557 4599031	1	.5 in	9	11/3/2016 12:24	11/4/2016 11:35
11T0327800 4596771	4	.5 in	33	11/4/2016 9:24	11/5/2016 8:52
11T0328106 4597340	3	.5 in	18	11/4/2016 10:10	11/5/2016 9:31
11T0328251 4598505	2	.5 in	7	11/4/2016 11:00	11/5/2016 10:15
11T0327476 4597829	3	.5 in	16	11/4/2016 11:23	11/5/2016 9:54
11T0327590 4598876	1	.5 in	9	11/4/2016 12:11	11/5/2016 11:15
11T0328044 4596830	4	.5 in	12	11/5/2016 9:23	11/6/2016 8:05
11T0327626 4597043	3	.5 in	11	11/5/2016 9:45	11/6/2016 8:42
11T0328042 4598069	3	.5 in	8	11/5/2016 10:07	11/6/2016 10:52
11T0328185 4598291	2	.5 in	7	11/5/2016 11:01	11/6/2016 9:56
11T0327444 4598755	1	.5 in	15	11/5/2016 11:41	11/6/2016 9:26
11T0328393 4598455	2	.5 in	6	11/6/2016 10:43	11/7/2016 7:14
11T0327982 4598288	2	.5 in	10	11/6/2016 11:30	11/7/2016 7:24
11T0327742 4598902	1	.5 in	5	3/29/2017 10:46	3/29/2017 14:30
11T0328305 4598152	2	.5 in	8	3/29/2017 10:55	3/29/2017 14:25
11T0327995 4596620	4	old net	8	4/1/2017 15:50	4/2/2017 8:25
11T0328035 4597001	3	.5 in	18	4/1/2017 16:07	4/2/2017 9:40

11T0327415 4597581	3	.5 in	4	4/1/2017 16:26	4/2/2017 10:10
11T0328445 4598141	2	1 in	8	4/1/2017 16:55	4/2/2017 11:40
11T0327366 4599424	1	1 in	4	4/1/2017 17:11	4/2/2017 12:45
11T0328427 4596616	4	.5 in	12	4/2/2017 9:27	4/3/2017 9:30
11T0327903 4596343	4	.5 in	17	4/2/2017 9:56	4/3/2017 9:04
11T0327442 4597708	3	.5 in	2	4/2/2017 11:10	4/3/2017 10:45
11T0328671 4598291	2	1 in	5	4/2/2017 12:39	4/3/2017 12:45
11T0327590 4599157	1	1 in	8	4/2/2017 15:34	4/3/2017 14:30
11T0327950 4596451	4	.5 in	32	4/3/2017 9:23	4/4/2017 8:10
11T0327415 4597840	3	.5 in	15	4/3/2017 10:23	4/4/2017 8:38
11T0328534 4598187	2	.5 in	8	4/3/2017 11:29	4/4/2017 9:15
11T0328416 4598559	2	1 in.	7	4/3/2017 14:12	4/4/2017 10:00
11T0327358 4598846	1	1 in	7	4/3/2017 15:05	4/4/2017 11:05
11T0328445 4596395	4	.5 in	7	4/4/2017 8:30	4/5/2017 8:05
11T0327590 4596926	3	.5 in	5	4/4/2017 9:05	4/5/2017 9:30
11T0328074 4598370	2	.5 in	6	4/4/2017 9:50	4/5/2017 11:45
11T0327560 4599420	1	1 in	5	4/4/2017 10:56	4/5/2017 13:00
11T0327268 4598785	1	1 in	6	4/4/2017 11:53	4/5/2017 13:15
11T0327690 4596362	4	.5 in	9	4/5/2017 9:26	4/6/2017 7:25
11T0328228 4598224	2	.5 in	5	4/5/2017 10:44	4/6/2017 10:02
11T0328446 4598132	2	.5 in	7	4/5/2017 11:00	4/6/2017 10:48
11T0328303 4596549	4	.5 in	7	4/5/2017 11:30	4/6/2017 8:15
11T0327573 4598627	1	.5 in	8	4/5/2017 11:45	4/6/2017 9:21
11T0327558 4599143	1	.5 in	8	4/5/2017 11:57	4/6/2017 8:45
11T0327482 4599121	1	.5 in	8	4/5/2017 12:15	4/6/2017 8:24
11T0328105 4598018	3	.5 in	4	4/5/2017 12:20	4/6/2017 8:40
11T0328247 4594534	3	.5 in	9	4/5/2017 15:48	4/6/2017 9:15
11T0328060 4593752	3	.5 in	12	4/5/2017 16:09	4/6/2017 9:55
11T0327910 4596453	4	.5 in	30	6/12/2017 14:25	6/13/2017 7:58
11T0328425 4596619	4	.5 in	11	6/12/2017 14:49	6/13/2017 8:22
11T0327372 4597827	3	.5 in	14	6/12/2017 15:21	6/13/2017 8:39
11T0328546 4598200	2	1 in	10	6/12/2017 15:33	6/13/2017 9:00
11T0327569 4599441	1	1 in	6	6/12/2017 15:48	6/13/2017 9:22
11T0328074 4597174	3	.5 in	18	6/13/2017 8:14	6/14/2017 7:50
11T0327999 4596610	4	.5 in	7	6/13/2017 8:33	6/14/2017 8:05
11T0328175 4597785	3	.5 in	10	6/13/2017 8:53	6/14/2017 8:36
11T0328679 4598299	2	1 in	7	6/13/2017 9:15	6/14/2017 9:00
11T0327711 4598872	1	1 in	6	6/13/2017 10:02	6/14/2017 9:45
11T0327743 4596352	4	.5 in	8	6/14/2017 8:00	6/15/2017 7:40
11T0327452 4597181	3	.5 in	4	6/14/2017 8:27	6/15/2017 8:23
11T0328305 4598107	2	.5 in	9	6/14/2017 8:53	6/15/2017 9:10
11T0328718 4598568	2	1 in	3	6/14/2017 9:38	6/15/2017 9:24

11T0327366 4599408	1	1 in	5	6/14/2017 9:57	6/15/2017 9:55
11T0327640 4596387	4	.5 in	18	6/15/2017 8:17	6/16/2017 8:00
11T0327408 4597622	3	.5 in	4	6/15/2017 9:02	6/16/2017 7:37
11T0328458 4598101	2	.5 in	7	6/15/2017 9:19	6/16/2017 7:13
11T0327598 4598628	1	1 in	12	6/15/2017 9:50	6/16/2017 6:43
11T0327282 4598691	1	1 in	4	6/15/2017 10:07	6/16/2017 6:26
11T0328307 4596690	4	.5 in	14	6/19/2017 15:03	6/20/2017 8:08
11T0327585 4599147	1	.5 in	10	6/19/2017 15:16	6/20/2017 8:10
11T0327598 4599246	1	.5 in	7	6/19/2017 15:26	6/20/2017 8:53
11T0328401 4596363	4	1 in	19	6/19/2017 15:26	6/20/2017 8:22
11T0327917 4596325	4	.5 in	31	6/19/2017 15:41	6/20/2017 9:00
11T0327687 4598857	1	.5 in	11	6/19/2017 15:45	6/20/2017 9:13
11T0328053 4597036	3	.5 in	17	6/19/2017 16:02	6/20/2017 9:35
11T0328383 4598595	2	.5 in	4	6/19/2017 16:10	6/20/2017 9:55
11T0327592 4596884	3	1 in	4	6/19/2017 16:13	6/20/2017 10:02
11T0328539 4598186	2	old net	10	6/19/2017 16:30	6/20/2017 10:16
11T0328299 4596546	4	.5 in	6	6/20/2017 8:18	6/21/2017 8:34
11T0327369 4599280	1	.5 in	5	6/20/2017 8:42	6/21/2017 9:55
11T0328189 4596202	4	1 in	20	6/20/2017 9:00	6/21/2017 9:25
11T0327575 4599528	1	.5 in	5	6/20/2017 9:05	6/21/2017 10:23
11T0327660 4596687	3	.5 in	16	6/20/2017 9:26	6/21/2017 10:43
11T0328082 4597220	3	.5 in	4	6/20/2017 9:39	6/21/2017 11:55
11T0328601 4598209	2	.5 in	9	6/20/2017 9:45	6/21/2017 8:05
11T0328077 4598659	2	.5 in	4	6/20/2017 10:10	6/21/2017 9:10
11T0328071 4597237	3	1 in	20	6/20/2017 10:15	6/21/2017 11:15
11T0328466 4598124	2	old net	8	6/20/2017 10:35	6/21/2017 8:26
11T0328730 4598364	2	.5 in	5	6/21/2017 8:19	6/22/2017 9:30
11T0328183 4596425	4	.5 in	24	6/21/2017 8:52	6/22/2017 7:45
11T0327924 4598493	2	old net	4	6/21/2017 9:00	6/22/2017 10:17
11T0327614 4598435	1	.5 in	12	6/21/2017 9:42	6/22/2017 7:56
11T0327635 4598541	1	.5 in	11	6/21/2017 10:16	6/22/2017 8:38
11T0327696 4596438	4	1 in	19	6/21/2017 10:27	6/22/2017 8:50
11T0327596 4598796	1	.5 in	8	6/21/2017 10:45	6/22/2017 9:01
11T0327725 4596355	4	.5 in	10	6/21/2017 10:52	6/22/2017 8:15
11T0328006 4597179	3	1 in	17	6/21/2017 11:17	6/22/2017 9:33
11T0327527 4597055	3	.5 in	11	6/21/2017 12:25	6/22/2017 10:30
11T0328414 4596536	4	.5 in	25	6/22/2017 8:05	6/23/2017 7:44
11T0327209 4598494	1	.5 in	8	6/22/2017 8:30	6/23/2017 6:38
11T0328308 4596251	4	.5 in	25	6/22/2017 8:35	6/23/2017 7:50
11T0327641 4599063	1	.5 in	11	6/22/2017 8:57	6/23/2017 6:17
11T0328318 4598174	2	.5 in	12	6/22/2017 9:20	6/23/2017 7:00
11T0328720 4598569	2	.5 in	3	6/22/2017 10:13	6/23/2017 7:08

11T0328148 4597777	3	.5 in	19	6/22/2017 10:43	6/23/2017 8:30
11T0327436 4597717	3	old net	4	6/22/2017 11:06	6/23/2017 8:55
11T0328691 4598320	2	.5 in	7	6/26/2017 3:20	6/27/2017 8:53
11T0327587 4599153	1	.5 in	11	6/26/2017 14:29	6/27/2017 7:35
11T0327531 4599010	1	.5 in	13	6/26/2017 14:46	6/27/2017 8:05
11T0327978 4596296	4	old net	13	6/26/2017 14:56	6/27/2017 7:43
11T0327878 4598290	2	.5 in	15	6/26/2017 15:09	6/27/2017 9:19
11T0328353 4596316	4	.5 in	22	6/26/2017 15:15	6/27/2017 7:59
11T0328022 4596864	3	.5 in	15	6/26/2017 15:30	6/27/2017 8:20
11T0328254 4597591	3	.5 in	23	6/26/2017 15:46	6/27/2017 8:37
11T0327772 4596376	4	old net	24	6/27/2017 7:51	6/28/2017 7:40
11T0327269 4598531	1	.5 in	14	6/27/2017 7:57	6/28/2017 8:00
11T0328128 4596226	4	.5 in	10	6/27/2017 8:15	6/28/2017 8:00
11T0327443 4597290	3	.5 in	12	6/27/2017 8:33	6/28/2017 9:39
11T0327565 4598678	1	.5 in	17	6/27/2017 8:44	6/28/2017 8:30
11T0328109 4597850	3	.5 in	14	6/27/2017 8:45	6/28/2017 9:36
11T0328317 4598182	2	.5 in	12	6/27/2017 9:07	6/28/2017 9:00
11T0328261 4598501	2	.5 in	12	6/27/2017 9:38	6/28/2017 9:49
11T0327871 4596455	4	old net	35	6/28/2017 7:53	6/29/2017 7:08
11T0328298 4596187	4	.5 in	16	6/28/2017 8:13	6/29/2017 7:29
11T0327392 4598648	1	.5 in	16	6/28/2017 8:32	6/29/2017 10:15
11T0327525 4599068	1	.5 in	12	6/28/2017 8:45	6/29/2017 9:56
11T0328148 4597365	3	.5 in	25	6/28/2017 9:24	6/29/2017 8:10
11T0328145 4598337	2	.5 in	17	6/28/2017 9:44	6/29/2017 9:01
11T0327448 4597856	3	.5 in	22	6/28/2017 10:07	6/29/2017 8:39
11T0328063 4598529	2	.5 in	14	6/28/2017 10:57	6/29/2017 9:21
11T0328021 4596781	4	old net	22	6/29/2017 7:22	6/30/2017 9:14
11T0328368 4596377	4	.5 in	26	6/29/2017 8:02	6/30/2017 8:41
11T0327661 4596883	3	.5 in	26	6/29/2017 8:33	6/30/2017 9:30
11T0327582 4597527	3	.5 in	11	6/29/2017 8:53	6/30/2017 9:50
11T0328370 4598463	2	.5 in	11	6/29/2017 9:12	6/30/2017 10:13
11T0328432 4598232	2	.5 in	11	6/29/2017 9:46	6/30/2017 10:35
11T0327618 4598938	1	.5 in	13	6/29/2017 10:05	6/30/2017 10:53
11T0327558 4598429	1	.5 in	21	6/29/2017 10:32	6/30/2017 11:11
11T0326263 4596397	4	.5 in	19	6/30/2017 9:25	7/1/2017 8:34
11T0328066 4597240	3	.5 in	18	6/30/2017 9:40	7/1/2017 8:52
11T0328149 4598222	2	.5 in	17	6/30/2017 10:26	7/1/2017 9:38
11T0327384 4598797	1	.5 in	16	6/30/2017 11:12	7/1/2017 10:12
11T0328374 4596622	4	.5 in	24	7/1/2017 8:49	7/2/2017 7:42
11T0328257 4597574	3	.5 in	16	7/1/2017 9:33	7/2/2017 7:57
11T0328086 4598309	2	.5 in	17	7/1/2017 10:01	7/2/2017 8:36
11T0327593 4598836	1	.5 in	13	7/1/2017 10:18	7/2/2017 9:00

11T0328273 4596330	4	.5 in	27	7/1/2017 10:48	7/2/2017 10:01
11T0327779 4596424	4	.5 in	23	7/1/2017 10:58	7/2/2017 10:17
11T0327769 4596656	3	.5 in	38	7/1/2017 11:27	7/2/2017 10:43
11T0328009 4597183	3	.5 in	37	7/1/2017 11:37	7/2/2017 11:01
11T0328013 4597209	4	.5 in	35	7/2/2017 10:10	7/3/2017 6:44
11T0327807 4596482	4	.5 in	30	7/2/2017 10:30	7/3/2017 6:30
11T0327735 4596932	3	.5 in	39	7/2/2017 10:50	7/3/2017 7:01
11T0327719 4597218	3	.5 in	34	7/2/2017 11:09	7/3/2017 7:18
11T0327596 4598988	1	.5 in	11	10/10/2017 14:50	10/11/2017 8:40

*Data not collected or recorded

**GPS coordinates are North American Datum of 1983 (NAD 83)

5.7 Trap net capture data

<i>PIT Tag #</i>	<i>Sex</i>	<i>FL (mm)</i>	<i>Weight (kg)</i>	<i>New Tag (Y/N)</i>	<i>Pull Date/Time</i>
989001003072260	F	275	0.27	Y	4/7/2015 9:45
989001003072258	F	590	2.75	Y	4/7/2015 9:45
989001003072258	F	595	2.69	N	4/26/2015 9:45
989001003072215	F	600	3.35	Y	4/8/2015 13:15
989001003072208	F	610	2.74	Y	4/8/2015 13:15
989001003072289	M	565	1.95	Y	4/8/2015 13:15
989001003072278	M	500	1.48	Y	4/8/2015 13:15
989001003072273	F	585	2.28	Y	4/8/2015 13:15
989001003072230	M	550	1.98	Y	4/8/2015 13:15
989001003072230	M	578	2.49	N	4/14/2016 16:00
989001003072219	F	535	1.65	Y	4/8/2015 13:15
989001003072222	F	370	0.67	Y	4/8/2015 13:15
989001003072201	M	610	2.64	Y	4/8/2015 13:15
989001003072201	M	615	*	N	4/30/2015 14:30
989001003072226	F	600	2.76	Y	4/8/2015 13:15
989001003072242	F	585	2.37	Y	4/8/2015 13:15
989001003072242	F	595	2.33	N	4/26/2015 9:45
989001003072206	F	470	1.26	Y	4/8/2015 13:15
989001003072206	F	539	1.63	N	10/8/2015 8:15
989001003072206	F	545	1.56	N	4/11/2016 15:17
989001003072280	M	550	2.15	Y	4/8/2015 13:15
989001003072280	M	555	2.01	N	4/23/2015 14:58
989001003072280	M	555	1.96	N	5/10/2015 8:00
989001003072221	F	480	1.32	Y	4/8/2015 13:15
989001003072251	F	595	2.3	Y	4/8/2015 13:15
989001003072251	F	595	2.28	N	4/19/2015 15:10

989001003072243	F	665	1.24	Y	4/9/2015 12:30
989001003072207	M	645	1.95	Y	4/9/2015 12:30
989001003072207	M	546	1.77	N	5/3/2015 9:50
989001003072272	U	480	1.55	Y	4/11/2015 11:00
989001003072233	U	563	1.94	Y	4/11/2015 11:00
900118001564189	M	628	2.51	N	4/11/2015 11:00
900118001564189	M	620	2.73	Y	3/11/2015 14:30
900118001564189	M	630	2.67	N	3/27/2015 15:05
900118001563799	M	536	1.73	N	4/11/2015 11:00
900118001563799	M	535	1.84	Y	3/28/2015 12:45
989001003072267	M	554	1.83	Y	4/11/2015 9:30
989001003072267	M	552	1.92	N	4/28/2015 14:50
989001003072270	U	570	2.05	Y	4/11/2015 9:30
989001003072247	M	478	1.31	Y	4/11/2015 9:30
989001003072205	M	614	2.78	Y	4/12/2015 10:50
989001003072205	M	615	2.55	N	5/18/2015 8:10
989001003072205	M	615	2.56	N	5/11/2015 8:00
900118001564337	U	525	1.47	N	4/12/2015 9:25
900118001564337	F	528	1.58	N	3/10/2015 13:50
989001003072292	U	432	0.95	Y	4/12/2015 9:25
900118001562811	U	610	2.65	N	4/12/2015 9:25
989001003072295	U	678	3.5	Y	4/12/2015 9:25
989001003072295	F	670	*	N	4/30/2015 14:30
900118001564935	M	618	2.54	N	4/12/2015 9:25
900118001564935	M	615	2.64	Y	3/28/2015 12:45
989001003072229	M	448	0.97	Y	4/12/2015 9:25
989001003072211	F	529	1.79	Y	4/12/2015 9:25
900118001563536	M	620	3.04	Y	3/5/2015 18:20
900118001563536	M	620	3.01	N	4/15/2015 16:10
900118001563536	M	624	2.84	N	4/30/2015 13:40
900118001562616	F	470	1.14	Y	3/5/2015 18:20
900118001564372	F	546	*	Y	3/5/2015 18:20
900118001519531	F	560	*	Y	3/5/2015 18:20
900118001564853	M	505	*	Y	3/5/2015 18:20
900118001564668	M	633	2.61	Y	3/10/2015 13:50
900118001564668	M	636	2.45	N	3/27/2015 15:05
900118001564667	F	595	2.45	Y	3/10/2015 13:50
900118001564878	F	633	2.98	Y	3/10/2015 13:50
900118001564878	U	632	2.8	N	3/28/2015 12:45
900118001563994	F	466	1.24	Y	3/10/2015 13:50
900118001564713	F	509	1.53	Y	3/10/2015 13:50
900118001564713	U	510	1.53	N	3/27/2015 15:05

900118001564942	M	360	0.64	Y	3/10/2015 13:50
900118001565402	F	485	1.49	Y	3/10/2015 13:50
900118001564754	M	630	2.77	Y	3/11/2015 14:30
900118001564754	M	641	2.59	N	3/28/2015 12:45
900118001564754	M	645	2.47	N	4/30/2015 13:40
*	M	730	*		3/11/2015 14:30
900118001564670	F	564	2.27	Y	3/11/2015 14:30
900118001564670	U	566	2.12	N	3/28/2015 12:45
900118001512701	M	515	1.51	Y	3/11/2015 14:30
900118001512701	M	515	1.41	N	4/15/2015 16:10
900118001512701	M	522	*	N	4/30/2015 14:30
900118001563019	M	660	3.56	Y	3/11/2015 14:30
900118001563019	M	670	3.45	N	3/27/2015 15:05
900118001564025	F	583	2.25	Y	3/11/2015 14:30
900118001564025	F	585	2.1	N	4/15/2015 16:10
900118001564029	F	510	1.44	Y	3/11/2015 14:30
900118001564029	U	515	1.42	N	3/27/2015 15:05
900118001564517	F	582	2.6	Y	3/11/2015 14:30
900118001564517	F	579	2.22	N	5/4/2015 8:05
900118001563195	F	660	3.39	Y	3/18/2015 15:50
900118001564454	F	555	2.05	Y	3/18/2015 15:50
900118001564934	M	610	2.79	Y	3/18/2015 15:50
900118001562590	M	455	1.05	Y	3/18/2015 15:50
900118001564560	F	515	1.59	Y	3/18/2015 15:50
900118001564560	U	516	1.62	N	3/27/2015 15:05
900118001564469	F	495	1.53	Y	3/18/2015 15:50
900118001563718	F	470	1.33	Y	3/18/2015 15:50
900118001563718	F	480	1.22	N	4/30/2015 13:40
900118001564171	F	510	1.64	Y	3/18/2015 15:50
900118001562713	M	444	0.94	Y	3/18/2015 15:50
900118001562713	M	441	0.93	N	3/27/2015 15:05
900118001565122	M	505	1.56	Y	3/18/2015 15:50
900118001564715	F	490	1.35	Y	3/18/2015 15:50
900118001563332	F	620	2.87	Y	3/18/2015 15:50
900118001512539	F	500	1.42	Y	3/18/2015 15:50
900118001512539	F	500	*	N	4/30/2015 14:30
900118001562889	F	480	1.42	Y	3/18/2015 15:50
900118001564435	M	520	1.75	Y	3/18/2015 15:50
900118001563492	F	466	1.36	Y	3/18/2015 15:50
900118001564475	F	495	1.55	Y	3/18/2015 15:50
900118001562695	F	465	1.44	Y	3/18/2015 15:50
900118001563316	F	565	2.03	Y	3/18/2015 15:50

900118001564937	M	596	2.76	Y	3/18/2015 15:50
900118001564505	M	514	1.67	Y	3/18/2015 15:50
900118001563321	M	490	1.35	Y	3/18/2015 15:50
900118001562700	F	579	2.08	N	3/27/2015 15:05
900118001562700	F	564	2.13	N	4/3/2015 15:00
900118001564255	M	595	2.52	Y	3/27/2015 15:05
900118001564255	M	600	2.33	N	4/20/2015 14:15
900118001565335	U	580	2.31	Y	3/27/2015 15:05
900118001565335	U	575	2.25	N	4/3/2015 15:00
900118001565032	U	553	2.02	Y	3/27/2015 15:05
900118001565032	F	548	*	N	4/30/2015 14:30
900118001565154	U	594	2.17	Y	3/27/2015 15:05
900118001565154	F	590	2.04	N	4/30/2015 14:30
900118001564156	U	486	1.36	Y	3/27/2015 15:05
900118001564156	F	490	1.37	N	4/29/2015 14:16
900118001564156	F	490	1.29	N	5/16/2015 10:30
900118001564816	M	597	2.54	Y	3/27/2015 15:05
900118001564275	U	561	2.24	Y	3/27/2015 15:05
900118001565017	U	543	1.75	Y	3/27/2015 15:05
900118001565017	F	540	1.59	N	5/10/2015 8:00
900118001565217	F	629	2.99	Y	3/27/2015 15:05
900118001563418	F	620	2.7	Y	3/27/2015 15:05
900118001562798	M	566	2.04	Y	3/27/2015 15:05
900118001564912	U	505	1.33	Y	3/27/2015 15:05
900118001565322	U	505	1.48	Y	3/27/2015 15:05
900118001565322	F	533	1.72	N	10/18/2015 12:30
900118001564981	M	555	2.09	Y	3/27/2015 15:05
900118001564981	M	560	2.05	N	3/28/2015 12:45
900118001562880	U	609	2.75	Y	3/27/2015 15:05
900118001563657	U	515	1.72	Y	3/27/2015 15:05
900118001512985	U	623	2.65	Y	3/27/2015 15:05
900118001512985	U	622	2.58	N	4/3/2015 15:00
900118001512985	F	625	2.5	N	4/18/2015 9:00
900118001564927	U	625	2.99	Y	3/27/2015 15:05
900118001562848	U	529	1.36	Y	3/27/2015 15:05
900118001564636	M	457	0.99	Y	3/27/2015 15:05
900118001563797	U	527	1.71	Y	3/27/2015 15:05
900118001564173	M	615	3.0	Y	3/27/2015 15:05
900118001565084	U	467	1.12	Y	3/27/2015 15:05
900118001564841	M	662	3.49	Y	3/27/2015 15:05
900118001564988	U	552	2.04	Y	3/27/2015 15:05
900118001562501	M	480	1.2	Y	3/27/2015 15:05

900118001564273	U	535	1.98	Y	3/27/2015 15:05
900118001564273	M	541	2.12	N	4/30/2015 13:40
900118001563147	U	595	2.31	Y	3/27/2015 15:05
900118001564408	U	435	0.92	Y	3/28/2015 12:45
900118001564804	M	477	1.28	Y	3/28/2015 12:45
900118001562482	U	508	1.44	Y	3/28/2015 12:45
900118001564499	M	536	1.89	Y	3/28/2015 12:45
900118001564443	U	437	1.1	Y	3/28/2015 12:45
900118001565184	U	528	1.69	Y	3/28/2015 12:45
900118001565184	U	524	1.9	N	4/3/2015 15:00
900118001565184	F	520	1.7	N	4/15/2015 16:10
900118001562961	U	525	1.8	Y	3/28/2015 12:45
900118001563727	U	475	1.28	Y	3/28/2015 12:45
900118001563727	U	465	1.33	N	4/3/2015 15:00
900118001565079	U	462	1.16	Y	3/28/2015 12:45
900118001565079	F	500	1.49	N	10/15/2015 10:35
900118001564858	U	476	1.03	Y	3/28/2015 12:45
900118001564507	U	586	2.33	Y	3/28/2015 12:45
900118001564507	F	625	2.76	N	10/19/2016 11:07
900118001564734	M	490	1.21	Y	3/28/2015 12:45
900118001562886	F	604	2.69	Y	3/28/2015 12:45
900118001562583	M	554	2.15	Y	3/28/2015 12:45
900118001564773	M	488	1.17	Y	3/28/2015 12:45
900118001563331	U	590	2.48	Y	3/28/2015 12:45
900118001563331	F	592	*	N	4/30/2015 14:30
900118001563331	F	590	2.35	N	5/10/2015 8:00
900118001563359	U	545	1.91	Y	3/28/2015 12:45
900118001563401	M	596	2.26	Y	3/28/2015 12:45
900118001565259	U	484	1.17	Y	3/28/2015 12:45
900118001564233	U	534	1.7	Y	3/28/2015 12:45
900118001564136	U	508	1.67	Y	3/28/2015 12:45
900118001565280	U	465	1.13	Y	3/28/2015 12:45
900118001565280	F	511	1.44	N	10/17/2015 14:41
900118001563991	F	564	1.94	Y	3/28/2015 12:45
900118001563314	U	526	1.63	Y	3/28/2015 12:45
900118001564276	U	472	1.33	Y	3/28/2015 12:45
900118001563153	U	526	1.66	Y	3/28/2015 12:45
900118001564340	M	571	2.4	Y	3/28/2015 12:45
900118001563059	M	584	2.37	Y	3/28/2015 12:45
900118001563059	M	590	2.57	N	4/26/2015 8:10
900118001563059	M	590	*	N	4/30/2015 14:30
900118001564520	U	440	0.98	Y	3/28/2015 12:45

900118001564470	M	507	1.72	Y	3/28/2015 12:45
900118001564470	M	500	1.7	N	4/15/2015 16:10
900118001564792	U	526	1.77	Y	3/28/2015 12:45
900118001564788	U	499	1.49	Y	3/28/2015 12:45
900118001564558	U	514	1.5	Y	3/28/2015 12:45
900118001564558	F	515	1.51	N	4/28/2015 14:50
900118001564790	M	558	2.04	Y	3/28/2015 12:45
900118001564790	M	556	1.95	N	4/18/2015 9:00
900118001564790	M	560	1.97	N	4/21/2015 8:40
900118001565172	M	475	1.1	Y	3/28/2015 12:45
900118001564295	M	618	2.42	Y	3/29/2015 9:00
900118001565162	U	518	1.51	N	3/29/2015 9:00
900118001565162	F	515	1.41	N	5/19/2015 9:40
900118001562521	U	460	1.11	Y	3/29/2015 9:00
900118001564875	M	438	0.85	Y	3/29/2015 9:00
900118001564809	U	514	1.7	Y	3/29/2015 9:00
900118001565169	M	654	3.18	Y	3/29/2015 9:00
900118001564114	U	514	1.48	Y	3/29/2015 9:00
900118001564114	F	520	1.43	N	4/28/2015 14:50
900118001562849	U	581	2.35	Y	3/29/2015 9:00
900118001562849	F	581	2.25	N	4/30/2015 13:38
900118001565171	M	485	1.21	Y	3/29/2015 9:00
900118001564602	M	561	1.92	Y	3/29/2015 9:00
900118001564775	U	544	2.04	Y	4/3/2015 15:00
900118001565212	M	565	2.47	Y	4/3/2015 15:00
900118001565212	M	595	2.65	N	4/14/2016 9:07
900118001564857	U	629	2.85	Y	4/3/2015 15:00
900118001563500	U	577	2.33	Y	4/3/2015 15:00
900118001563500	F	585	2.22	N	4/18/2015 10:15
900118001563141	M	350	0.6	Y	4/3/2015 15:00
900118001565198	U	591	2.32	Y	4/3/2015 15:00
900118001564871	M	415	0.95	Y	4/3/2015 15:00
900118001564915	M	635	3.03	Y	4/3/2015 15:00
900118001564915	M	637	3.01	N	4/18/2015 10:15
900118001564915	M	635	3.01	N	4/23/2015 14:25
900118001564915	M	638	2.8	N	5/2/2015 8:30
900118001564915	M	639	2.8	N	5/3/2015 9:50
900118001564915	M	635	2.67	N	5/19/2015 9:40
900118001564915	M	637	2.77	N	5/11/2015 8:00
900118001565316	F	590	2.22	Y	4/3/2015 15:00
900118001565385	U	655	3.2	Y	4/3/2015 15:00
989001003072266	U	481	1.37	Y	4/4/2015 15:16

989001003072266	F	485	1.27	N	5/2/2015 9:30
989001003072266	F	493	1.24	N	5/4/2015 8:05
989001003072266	F	488	1.26	N	5/11/2015 8:00
989001003072209	U	408	0.82	Y	4/4/2015 15:16
989001003072238	U	453	1.21	Y	4/4/2015 15:16
989001003072238	M	581	2.34	N	11/5/2015 10:24
989001003072238	M	584	2.22	N	4/12/2016 9:20
989001003072244	U	475	1.2	Y	4/4/2015 15:16
989001003072212	M	670	3.34	Y	4/4/2015 15:16
989001003072212	M	665	3.33	N	4/22/2015 14:30
989001003072212	M	665	3.57	N	10/15/2015 9:30
989001003072212	M	680	3.53	N	4/5/2017 8:05
989001003072255	U	590	2.54	Y	4/4/2015 15:16
989001003072204	F	565	2.09	Y	4/15/2015 16:10
989001003072277	F	430	0.96	Y	4/15/2015 16:10
989001003072297	F	555	1.9	Y	4/15/2015 16:10
989001003072231	F	560	2.11	Y	4/15/2015 16:10
989001003072231	F	572	2.0	N	5/10/2015 8:00
989001003072236	F	530	1.75	Y	4/15/2015 16:10
989001003072202	M	640	3.64	Y	4/15/2015 16:10
989001003072298	F	530	1.79	Y	4/15/2015 16:10
989001003072296	M	540	2.01	Y	4/15/2015 16:10
989001003072232	F	465	1.23	Y	4/15/2015 16:10
989001003072232	F	470	1.11	N	5/10/2015 8:00
989001003072240	F	595	2.34	Y	4/15/2015 16:10
989001003072216	F	610	2.68	Y	4/15/2015 16:10
989001003072257	F	447	1.02	Y	4/18/2015 9:00
989001003072248	F	481	1.33	Y	4/18/2015 9:00
989001003072283	F	549	1.87	Y	4/18/2015 9:00
989001003072203	F	605	2.45	Y	4/18/2015 9:00
989001003072223	F	604	2.39	Y	4/18/2015 9:00
989001003072299	F	578	2.25	Y	4/18/2015 9:00
989001003072261	M	637	2.62	Y	4/18/2015 9:00
989001003072261	M	642	2.58	N	5/3/2015 9:00
989001003072217	F	458	1.12	Y	4/18/2015 9:00
989001003072217	F	465	*	N	4/30/2015 14:30
989001003072218	F	510	1.64	Y	4/19/2015 8:45
989001003072218	M	590	2.38	N	11/5/2015 10:24
989001003072287	U	245	0.18	Y	4/19/2015 9:50
989001003072225	M	580	2.25	Y	4/19/2015 15:10
989001003072253	M	605	2.27	Y	4/19/2015 15:10
989001003072253	M	604	*	N	4/30/2015 14:30

989001003072253	M	600	2.14	N	5/10/2015 8:00
989001003072220	F	533	1.83	Y	4/19/2015 15:10
989001003072246	F	498	1.36	Y	4/19/2015 14:20
989001003072256	M	615	2.87	Y	4/19/2015 14:20
989001003072265	M	680	4.13	Y	4/20/2015 14:44
989001003072265	M	682	3.96	N	5/20/2015 10:25
989001003072213	M	340	0.42	Y	4/20/2015 14:15
989001003072237	F	585	2.68	Y	4/20/2015 14:15
989001003072252	M	590	2.38	Y	4/20/2015 14:15
989001003072252	M	586	2.33	N	4/29/2015 14:16
989001003072252	M	588	2.26	N	5/3/2015 9:50
989001003072252	M	582	2.16	N	5/20/2015 9:40
989001003072252	M	591	2.16	N	5/21/2015 8:40
989001003072252	M	580	2.2	N	5/16/2015 10:30
989001003072281	M	688	3.25	Y	4/21/2015 8:40
989001003072281	M	690	3.13	N	5/10/2015 8:00
989001003072284	M	484	1.25	Y	4/21/2015 8:40
989001003072263	F	565	2.01	Y	4/21/2015 8:40
989001003072269	M	630	2.88	Y	4/21/2015 14:35
989001003072291	M	620	2.29	Y	4/21/2015 14:35
989001003072291	M	618	2.14	N	6/2/2016 9:30
989001003072245	M	530	1.6	Y	4/21/2015 14:35
989001003072245	M	530	*	N	4/30/2015 14:30
989001003072249	F	605	2.61	Y	4/21/2015 14:35
989001003072249	F	605	2.51	N	5/10/2015 8:00
989001003072274	M	710	3.85	Y	4/21/2015 13:55
989001003072227	M	590	2.38	Y	4/22/2015 9:15
989001003072227	M	591	2.47	N	4/30/2015 13:40
989001003072228	F	550	1.9	Y	4/22/2015 9:15
989001003072259	M	620	3.17	Y	4/22/2015 9:15
989001003072250	M	633	3.14	N	4/22/2015 14:00
900118001564336	F	520	1.59	N	4/22/2015 14:00
900118001564336	F	501	1.56	N	10/7/2015 10:20
989001003072264	F	576	2.2	Y	4/22/2015 14:00
989001003072286	F	480	2.23	Y	4/22/2015 14:00
989001003072286	F	585	2.19	N	5/11/2015 8:00
900118001563087	F	565	2.17	N	4/23/2015 14:25
989001003072271	F	590	2.75	Y	4/23/2015 14:25
989001003072271	F	585	2.78	N	4/30/2015 13:40
989001003072234	U	365	0.59	Y	4/23/2015 14:25
989001003072239	F	600	2.33	Y	4/23/2015 14:58
989001003072239	F	595	2.31	N	5/11/2015 8:00

989001003072288	U	350	0.5	Y	4/23/2015 14:58
989001003072288	U	486	1.33	N	10/7/2015 10:30
989001003072288	M	490	1.33	N	10/21/2015 9:00
989001003072288	M	510	1.45	N	4/11/2016 15:17
989001003072300	F	525	1.88	Y	4/26/2015 9:45
989001003072241	M	630	3.23	Y	4/26/2015 9:45
989001003072290	U	325	0.43	Y	4/26/2015 9:45
989001003072282	U	430	1.08	Y	4/26/2015 9:45
989001003072282	F	525	1.66	N	4/11/2016 15:17
989001003072268	M	530	1.81	Y	4/26/2015 9:45
989001003072268	F	527	1.73	N	5/20/2015 10:25
989001003072214	M	545	1.7	Y	4/26/2015 9:45
900118001565288	F	574	2.19	N	4/28/2015 14:50
989001003072262	F	485	1.23	Y	4/28/2015 14:50
989001003072294	M	545	1.81	Y	4/28/2015 14:50
989001003072254	M	675	3.38	Y	4/28/2015 14:50
989001003072276	F	578	2	Y	4/28/2015 14:50
989001003072276	F	611	2.36	N	4/14/2016 15:00
989001003072224	M	571	1.92	Y	4/28/2015 14:50
989001003072285	F	530	1.79	Y	4/28/2015 14:50
989001003072285	F	634	1.71	N	5/11/2015 8:00
989001003072275	U	566	2.19	Y	4/28/2015 14:50
989001003072130	F	622	3	Y	4/30/2015 13:38
900118001563747	F	645	3.51	N	4/29/2015 13:49
900118001562678	U	600	2.34	N	4/29/2015 14:16
989001003072210	M	336	0.43	Y	4/29/2015 14:16
989001003072116	M	638	3.01	Y	4/29/2015 14:16
989001003072116	M	640	*	N	4/30/2015 14:30
989001003072148	M	309	0.31	Y	4/29/2015 14:16
989001003072129	M	462	1.03	Y	4/29/2015 14:16
989001003072129	M	465	0.97	N	5/10/2015 8:00
989001003072129	M	429	1.41	N	4/7/2016 9:50
989001003072132	M	564	2	Y	4/29/2015 14:16
989001003072125	M	571	2.01	Y	4/29/2015 14:16
989001003072125	M	592	2.4	N	4/6/2016 17:30
989001003072125	M	590	2.37	N	4/13/2016 11:55
989001003072115	F	580	2.13	Y	4/30/2015 13:40
989001003072115	U	584	2.08	N	10/17/2015 15:35
989001003072101	M	642	3.4	Y	4/30/2015 13:40
989001003072110	F	436	1.08	Y	4/30/2015 13:40
989001003072145	F	611	2.67	Y	4/30/2015 13:40
989001003072104	F	495	1.5	Y	4/30/2015 13:40

989001003072160	M	355	0.59	Y	4/30/2015 13:40
989001003072160	M	419	0.88	N	10/21/2015 9:00
989001003072173	F	575	2.26	Y	4/30/2015 13:40
989001003072146	M	591	2.22	Y	4/30/2015 13:40
989001003072156	M	630	*	Y	4/30/2015 14:30
989001003072200	U	326	*	Y	4/30/2015 14:30
989001003072128	F	535	*	Y	4/30/2015 14:30
989001003072166	F	565	*	Y	4/30/2015 14:30
989001003072122	F	465	*	Y	4/30/2015 14:30
989001003072168	F	550	*	Y	4/30/2015 14:30
989001003072135	M	550	*	Y	4/30/2015 14:30
989001003072164	F	530	*	Y	4/30/2015 14:30
989001003072175	F	540	*	Y	4/30/2015 14:30
989001003072175	F	540	1.76	N	5/21/2015 8:40
989001003072138	U	420	*	Y	4/30/2015 14:30
989001003072138	F	525	1.52	N	4/11/2016 15:17
989001003072199	M	705	*	Y	4/30/2015 14:30
989001003072162	M	580	*	Y	4/30/2015 14:30
989001003072147	M	281	*	Y	4/30/2015 14:30
989001003072189	F	500	*	Y	4/30/2015 14:30
989001003072197	M	502	*	Y	4/30/2015 14:30
989001003072194	F	630	*	Y	4/30/2015 14:30
989001003072103	M	573	*	Y	4/30/2015 14:30
989001003072103	M	665	3.61	N	5/20/2015 9:40
989001003072103	M	670	3.66	N	5/10/2015 8:00
989001003072103	M	679	3.83	N	10/16/2015 16:15
989001003072103	M	679	3.8	N	11/8/2015 11:25
900118001564554	F	560	*	N	4/30/2015 14:30
989001003072195	F	415	*	Y	4/30/2015 14:30
989001003072118	M	605	*	Y	4/30/2015 14:30
989001003072118	M	610	2.58	N	6/1/2016 11:45
989001003072118	M	610	2.44	N	6/15/2016 7:43
989001003072191	F	576	*	Y	4/30/2015 14:30
989001003072165	U	353	0.51	Y	5/2/2015 9:30
989001003072165	M	454	*	N	6/29/2017 8:10
989001003072107	F	614	*	Y	5/2/2015 9:30
989001003072159	F	532	*	Y	5/2/2015 9:30
989001003072157	M	596	*	Y	5/2/2015 9:30
989001003072177	F	542	*	Y	5/2/2015 9:30
989001003072185	M	604	2.49	Y	5/2/2015 8:30
989001003072185	M	601	2.41	N	5/21/2015 9:00
989001003072188	F	590	2.35	Y	5/3/2015 8:00

989001003072188	F	600	2.52	N	4/14/2016 9:07
989001003072170	F	569	2.58	Y	5/3/2015 9:50
989001003072143	M	660	3.53	Y	5/3/2015 9:50
989001003072154	M	448	0.98	Y	5/3/2015 9:00
989001003072117	M	676	3.81	Y	5/3/2015 9:00
989001003072109	U	270	0.19	Y	5/4/2015 8:05
989001003072180	M	327	0.37	Y	5/4/2015 8:05
989001003072153	M	525	1.84	Y	5/4/2015 8:05
989001003072124	F	517	1.36	Y	5/4/2015 8:05
989001003072137	F	642	2.91	Y	5/19/2015 9:40
989001003072181	M	449	0.96	Y	5/19/2015 9:40
989001003072142	F	464	1.27	Y	5/19/2015 9:40
989001003072105	U	271	0.24	Y	5/19/2015 9:40
989001003072105	F	525	1.53	N	11/5/2016 10:15
989001003072113	F	559	1.92	Y	5/19/2015 9:40
989001003072112	F	472	1.12	Y	5/18/2015 8:10
989001003072131	M	372	0.54	Y	5/18/2015 9:02
989001003072169	F	570	1.73	Y	5/18/2015 9:02
989001003072120	M	731	4.51	Y	5/18/2015 9:02
989001003072120	M	723	4.21	N	6/8/2016 10:09
989001003072121	U	147	0.09	Y	5/18/2015 9:02
989001003072167	F	608	2.51	N	5/20/2015 9:40
989001003072167	F	605	2.45	Y	5/10/2015 8:00
989001003072334	F	583	2.53	Y	5/20/2015 9:40
989001003072139	M	559	1.83	N	5/20/2015 9:40
989001003072139	M	555	1.85	Y	5/16/2015 10:30
989001003072133	F	500	1.27	N	5/20/2015 9:40
989001003072133	F	501	1.26	Y	5/11/2015 8:00
989001003072307	F	461	1.06	Y	5/20/2015 9:40
989001003072353	F	610	2.59	Y	5/20/2015 9:40
989001003072359	U	147	*	Y	5/20/2015 10:25
989001003072309	U	133	*	Y	5/20/2015 10:25
989001003072400	U	325	0.36	Y	5/20/2015 10:25
989001003072400	F	457	1.1	N	11/9/2015 11:25
989001003072400	F	468	1.18	N	4/7/2016 9:50
989001003072400	F	572	2.01	N	4/5/2017 13:00
989001003072301	U	128	*	Y	5/20/2015 10:25
989001003072149	M	555	1.64	Y	5/10/2015 8:00
989001003072198	F	573	2.1	Y	5/10/2015 8:00
989001003072123	F	618	2.59	Y	5/10/2015 8:00
989001003072123	F	615	2.54	N	5/16/2015 10:30
989001003072172	F	555	1.86	Y	5/10/2015 8:00

989001003072163	M	500	1.34	Y	5/10/2015 8:00
989001003072119	F	501	1.35	Y	5/10/2015 8:00
989001003072119	F	495	1.37	N	5/16/2015 10:30
989001003072102	F	590	2.32	Y	5/10/2015 8:00
989001003072179	F	610	2.67	Y	5/10/2015 8:00
989001003072152	M	648	3.02	Y	5/10/2015 8:00
989001003072127	M	411	0.7	Y	5/10/2015 8:00
989001003072192	M	335	0.4	Y	5/10/2015 8:00
989001003072183	F	617	2.84	Y	5/10/2015 8:00
989001003072178	F	625	2.53	Y	5/10/2015 8:00
989001003072182	M	456	1.08	Y	5/10/2015 8:00
989001003072193	M	610	2.39	Y	5/10/2015 8:00
989001003072136	M	335	0.38	Y	5/10/2015 8:00
989001003072187	F	440	0.88	Y	5/10/2015 8:00
989001003072141	F	505	1.46	Y	5/10/2015 8:00
989001003072151	F	525	1.51	Y	5/10/2015 8:00
989001003072161	M	565	2.19	Y	5/10/2015 8:00
989001003072174	U	305	0.3	Y	5/10/2015 10:40
989001003072106	M	625	2.94	Y	5/11/2015 8:00
989001003072140	M	581	2.18	Y	5/11/2015 8:00
989001003072114	F	447	0.93	Y	5/11/2015 8:00
989001003072155	F	457	1.13	Y	5/11/2015 8:00
989001003072158	M	455	1.04	Y	5/11/2015 8:00
989001003072308	M	675	3.07	Y	5/21/2015 9:00
989001003072306	F	529	1.55	Y	5/21/2015 9:00
989001003072316	U	243	0.14	Y	5/21/2015 8:16
989001003072358	F	525	1.26	Y	5/21/2015 8:16
989001003072358	F	550	1.7	N	10/6/2015 11:30
989001003072196	M	610	2.58	Y	5/16/2015 10:30
989001003072279	M	550	2.12	N	5/16/2015 10:30
989001003072111	F	405	0.69	Y	5/16/2015 10:30
989001003072150	F	595	2.8	Y	5/16/2015 10:30
989001003072186	F	410	0.67	Y	5/16/2015 10:30
989001003072144	F	570	2.42	Y	5/16/2015 10:30
989001003072144	F	*	*	N	10/27/2015 11:25
989001003072190	F	555	1.71	Y	5/16/2015 10:30
989001003072171	U	195	0.07	Y	5/16/2015 10:30
989001003072126	F	280	0.23	Y	5/16/2015 10:30
989001003072184	F	580	2.16	Y	5/16/2015 10:30
989001003072134	M	455	1.42	Y	5/16/2015 10:30
989001003072176	M	655	3.14	Y	5/16/2015 10:30
989001003072527	F	580	2.08	Y	10/6/2015 10:34

989001003072567	F	410	0.89	Y	10/6/2015 10:34
989001003072349	F	552	2.01	Y	10/6/2015 10:34
989001003072382	U	315	0.37	Y	10/6/2015 11:30
989001003072310	F	447	1.06	Y	10/6/2015 17:35
989001003072310	F	464	1.07	N	4/6/2016 14:50
989001003072396	M	585	3.04	Y	10/6/2015 17:35
989001003072396	M	595	2.74	N	4/13/2016 10:21
989001003072363	F	536	2.04	Y	10/6/2015 17:35
989001003072363	M	541	1.97	N	10/22/2015 9:45
989001003072363	M	546	2	N	11/9/2015 10:55
989001003072325	F	475	1.32	Y	10/6/2015 17:35
989001003072325	F	545	1.95	N	6/7/2016 9:03
989001003072325	M	596	2.6	N	11/4/2016 10:20
989001003072384	F	495	1.44	Y	10/6/2015 17:35
989001003072372	M	415	0.92	Y	10/6/2015 17:35
989001003072372	M	415	0.81	N	10/7/2015 11:25
989001003072372	M	415	0.8	N	10/28/2015 8:05
989001003072507	U	393	0.69	Y	10/7/2015 9:35
989001003072507	F	394	0.7	N	10/16/2015 14:30
989001003072336	F	420	0.9	Y	10/7/2015 9:35
989001003072336	F	450	1.07	N	4/6/2016 9:40
989001003072352	M	545	1.85	Y	10/7/2015 9:35
989001003072467	F	393	0.75	Y	10/7/2015 10:20
989001003072490	F	357	0.58	Y	10/7/2015 10:30
989001003072424	F	537	1.85	Y	10/7/2015 10:30
989001003072477	F	530	1.6	Y	10/7/2015 10:30
989001003072477	F	535	1.66	N	11/7/2015 12:45
989001003072520	F	554	2.12	Y	10/7/2015 10:40
989001003072374	F	400	0.85	Y	10/7/2015 11:25
989001003072411	F	450	1.05	Y	10/7/2015 11:25
989001003072410	M	417	0.85	Y	10/7/2015 11:25
989001003072405	F	464	1.15	Y	10/7/2015 11:25
989001003072489	F	484	1.46	Y	10/7/2015 11:25
989001003072501	M	539	1.75	Y	10/8/2015 8:15
989001003072501	M	539	1.68	N	10/21/2015 9:00
989001003072501	M	540	1.72	N	11/6/2015 12:10
989001003072368	F	607	2.49	Y	10/8/2015 8:15
989001003072368	F	618	2.48	N	4/11/2016 15:17
989001003072330	M	568	2.66	Y	10/8/2015 8:15
989001003072330	M	590	2.61	N	4/6/2016 9:40
989001003072350	F	478	1.4	Y	10/8/2015 8:15
989001003072528	F	593	2.33	Y	10/8/2015 8:15

989001003072479	F	425	0.92	Y	10/8/2015 8:15
989001003072315	F	437	1.02	Y	10/8/2015 9:10
989001003072514	M	481	1.33	Y	10/8/2015 9:10
989001003072514	M	483	1.3	N	10/16/2015 8:55
989001003072566	F	427	0.79	Y	10/8/2015 9:10
989001003072439	F	450	1.07	Y	10/8/2015 9:10
989001003072421	M	521	1.59	Y	10/8/2015 9:15
989001003072421	M	520	1.52	N	10/14/2015 11:15
989001003072571	M	425	0.97	Y	10/14/2015 8:50
989001003072571	M	435	1.06	N	11/5/2015 10:24
989001003072588	M	455	1.18	Y	10/14/2015 8:50
989001003072588	M	480	1.35	N	4/6/2016 14:50
989001003072517	F	80	0.61	Y	10/14/2015 10:06
989001003072517	M	529	1.47	N	10/19/2016 15:30
989001003072515	M	475	1.29	Y	10/14/2015 10:06
989001003072337	M	611	2.69	Y	10/14/2015 11:15
989001003072337	M	631	2.31	N	6/8/2016 7:15
989001003072498	F	530	2.0	Y	10/14/2015 11:15
989001003072498	F	535	1.99	N	10/19/2015 15:30
989001003072586	M	575	2.22	Y	10/14/2015 12:15
989001003072586	M	580	2.24	N	11/3/2015 10:17
989001003072586	M	591	2.1	N	4/14/2016 9:07
989001003072470	F	541	2.05	Y	10/14/2015 12:15
989001003072546	M	435	1.02	Y	10/14/2015 12:15
989001003072590	F	505	1.48	Y	10/15/2015 9:30
989001003072506	F	449	1.03	Y	10/15/2015 9:30
989001003072577	M	560	2.41	Y	10/15/2015 9:30
989001003072577	M	577	2.32	N	4/14/2016 9:07
989001003072530	F	540	1.88	Y	10/15/2015 9:30
989001003072530	F	458	2.02	N	4/12/2016 11:30
989001003072600	F	412	0.72	Y	10/15/2015 9:30
989001003072600	F	478	1.23	N	6/8/2016 10:20
989001003072422	F	560	2.28	Y	10/15/2015 10:35
989001003072442	M	585	2.14	Y	10/15/2015 10:35
989001003072442	M	606	2.01	N	4/12/2016 9:20
989001003072419	F	535	1.73	Y	10/15/2015 10:35
989001003072419	F	541	1.8	N	11/8/2015 14:05
989001003072593	F	490	1.45	Y	10/15/2015 8:35
989001003072593	F	547	1.96	N	10/24/2016 7:30
989001003072595	M	455	1.22	Y	10/15/2015 8:35
989001003072346	M	484	1.34	Y	10/15/2015 8:35
989001003072632	F	470	1.35	Y	10/15/2015 12:20

989001003072632	F	493	1.32	N	4/6/2016 14:50
989001003072458	M	465	1.28	Y	10/15/2015 11:37
989001003072623	M	470	1.28	Y	10/15/2015 11:37
989001003072623	M	491	1.28	N	4/6/2016 9:40
989001003072607	F	430	0.87	Y	10/15/2015 11:37
989001003072651	F	460	1.16	Y	10/15/2015 11:37
989001003072651	F	472	1.27	N	11/9/2015 9:26
989001003072625	F	510	1.46	Y	10/15/2015 11:37
989001003072625	F	510	1.47	N	11/3/2015 11:50
989001003072675	F	550	1.88	Y	10/15/2015 11:37
989001003072606	F	457	0.94	Y	10/16/2015 8:00
989001003072606	F	464	1.2	N	11/7/2015 11:15
989001003072606	M	582	2.26	N	11/5/2016 10:15
989001003072604	U	198	0.09	Y	10/16/2015 8:55
989001003072615	F	504	1.57	Y	10/16/2015 9:47
989001003072615	F	509	1.61	N	10/27/2015 8:20
989001003072615	F	525	1.59	N	4/12/2016 9:20
989001003072602	F	406	0.75	Y	10/16/2015 9:47
989001003072621	F	440	1.11	Y	10/16/2015 9:47
989001003072621	F	440	1.04	N	10/21/2015 14:35
989001003072621	F	460	1.13	N	4/7/2016 9:50
989001003072618	M	610	2.54	Y	10/16/2015 9:47
989001003072618	M	620	2.44	N	4/6/2016 17:30
989001003072614	F	414	0.78	Y	10/16/2015 14:30
989001003072631	M	543	2.09	Y	10/16/2015 14:30
989001003072656	M	522	1.61	Y	10/16/2015 14:30
989001003072661	M	595	2.15	Y	10/16/2015 16:15
989001003072661	M	595	2.16	N	10/21/2015 14:35
989001003072661	M	614	2.06	N	4/6/2016 9:40
989001003072613	F	514	1.59	Y	10/16/2015 16:15
989001003072613	F	510	1.5	N	4/7/2016 8:45
989001003072608	F	441	0.89	Y	10/16/2015 16:15
989001003072639	U	299	0.31	Y	10/16/2015 15:35
989001003072639	M	508	1.47	N	10/21/2016 11:09
989001003072617	F	415	0.78	Y	10/16/2015 15:35
989001003072636	F	409	0.78	Y	10/16/2015 15:35
989001003072601	F	510	1.61	Y	10/16/2015 15:35
989001003072601	F	563	2.13	N	7/2/2017 7:57
989001003072699	U	485	1.38	Y	10/17/2015 8:50
989001003072624	U	184	0.06	Y	10/17/2015 10:57
989001003072658	U	163	*	Y	10/17/2015 10:57
989001003072630	F	475	1.2	Y	10/17/2015 10:57

989001003072630	F	485	1.16	N	4/6/2016 9:40
989001003072630	F	485	1.14	N	4/11/2016 15:17
989001003072620	F	374	0.53	Y	10/17/2015 10:57
989001003072652	U	165	0.05	Y	10/17/2015 14:41
989001003072635	F	563	2.26	Y	10/17/2015 14:41
989001003072663	F	455	1.18	Y	10/17/2015 14:41
989001003072642	F	483	1.4	Y	10/17/2015 14:41
989001003072642	F	493	1.48	N	11/8/2015 8:55
989001003072642	F	528	1.67	N	4/5/2017 13:00
989001003072669	F	449	1.02	Y	10/17/2015 11:50
989001003072669	F	472	1.22	N	4/14/2016 15:00
989001003072669	F	501	1.36	N	6/9/2016 7:55
989001003072669	M	580	2.1	N	3/29/2017 14:30
989001003072665	F	469	1.22	Y	10/17/2015 15:35
989001003072665	F	483	1.32	N	4/11/2016 15:17
989001003072644	F	438	0.88	Y	10/17/2015 15:35
989001003072644	F	487	1.37	N	6/1/2016 15:03
989001003072644	F	496	1.3	N	6/8/2016 10:20
989001003072644	F	494	1.29	N	6/21/2016 8:23
989001003072644	M	559	1.78	N	4/3/2017 12:45
989001003072683	F	454	1.08	Y	10/17/2015 15:35
989001003072683	F	468	1.03	N	4/11/2016 15:17
989001003072653	F	418	0.94	Y	10/17/2015 15:35
989001003072653	F	559	1.97	N	4/5/2017 13:00
989001003072633	F	430	0.9	Y	10/17/2015 15:35
989001003072672	U	279	0.26	Y	10/17/2015 15:35
989001003072685	F	449	1.07	Y	10/18/2015 11:15
989001003072647	U	196	0.06	Y	10/18/2015 12:30
989001003072647	F	434	0.89	N	6/15/2017 9:24
989001003072671	U	161	0.05	Y	10/18/2015 12:30
989001003072680	F	567	2.11	Y	10/18/2015 12:30
989001003072680	F	580	2.11	N	4/12/2016 9:20
989001003072605	U	196	0.07	Y	10/18/2015 8:09
989001003072629	F	515	1.67	Y	10/18/2015 8:55
989001003072678	F	455	1.12	Y	10/18/2015 10:21
989001003072659	M	586	2.63	Y	10/18/2015 10:21
989001003072694	U	278	0.26	Y	10/27/2015 8:20
989001003072694	F	504	1.42	N	4/2/2017 12:45
989001003072691	M	382	0.62	Y	10/27/2015 8:20
989001003072499	M	503	1.57	Y	10/27/2015 8:20
989001003072434	F	314	0.33	Y	10/27/2015 8:20
989001003072500	F	422	0.84	Y	10/27/2015 8:20

989001003072494	F	436	0.94	Y	10/27/2015 8:20
989001003072494	F	507	1.54	N	4/3/2017 12:45
989001003072475	M	595	2.25	Y	10/27/2015 10:35
989001003072461	U	178	0.06	Y	10/27/2015 11:25
989001003072423	F	285	0.27	Y	10/28/2015 8:05
989001003072468	M	339	0.48	Y	10/28/2015 8:05
989001003072440	M	448	0.99	Y	10/28/2015 8:05
989001003072459	F	391	0.68	Y	10/28/2015 8:05
989001003072476	F	426	0.78	Y	10/28/2015 8:05
989001003072484	M	369	0.61	Y	10/28/2015 9:25
989001003072493	M	447	1.12	Y	10/28/2015 10:15
989001003072464	F	550	1.91	Y	10/28/2015 10:15
989001003072462	F	580	2.43	Y	10/28/2015 10:15
989001003072485	F	409	0.8	Y	10/28/2015 11:30
989001003072404	F	450	0.96	Y	10/28/2015 13:00
989001003072404	F	460	0.97	N	4/6/2016 14:50
989001003072643	M	487	1.42	Y	10/19/2015 9:10
989001003072641	M	524	1.75	Y	10/19/2015 15:30
989001003072668	F	459	1.12	Y	10/19/2015 15:30
989001003072668	F	474	1.08	N	4/14/2016 16:00
989001003072610	M	424	0.88	Y	10/19/2015 15:30
989001003072645	M	436	1.03	Y	10/19/2015 15:30
989001003072649	F	563	2.08	Y	10/19/2015 15:30
989001003072649	F	601	2.19	N	4/3/2017 12:45
989001003072650	M	430	0.92	Y	10/20/2015 8:10
989001003072650	M	441	0.96	N	4/6/2016 9:40
989001003072626	F	309	0.32	Y	10/20/2015 11:00
989001003072626	F	395	0.79	N	6/15/2016 7:43
989001003072622	F	548	2.02	Y	10/20/2015 11:00
989001003072603	M	595	2.6	Y	10/20/2015 11:00
989001003072603	M	609	2.45	N	4/14/2016 16:00
989001003072681	M	427	0.9	Y	10/20/2015 11:00
989001003072662	M	478	1.33	Y	10/20/2015 11:00
989001003072695	F	436	1.07	Y	10/20/2015 11:00
989001003072695	F	437	1.04	N	10/21/2015 11:35
989001003072698	F	519	1.58	Y	10/20/2015 11:00
989001003072611	M	528	1.58	Y	10/20/2015 13:50
989001003072611	M	536	1.59	N	4/6/2016 17:30
989001003072684	F	495	1.47	Y	10/20/2015 13:50
989001003072684	F	620	2.73	N	10/22/2016 8:00
989001003072619	F	477	1.33	Y	10/20/2015 13:50
989001003072619	F	545	2.02	N	10/20/2016 14:00

989001003072660	F	439	0.95	Y	10/20/2015 9:00
989001003072660	F	465	1.14	N	4/7/2016 15:13
989001003072654	F	444	1.02	Y	10/20/2015 13:00
989001003072654	F	464	1.14	N	4/12/2016 11:30
989001003072674	F	529	1.69	Y	10/21/2015 9:00
989001003072609	F	570	2.01	Y	10/21/2015 9:00
989001003072609	F	574	2.04	N	4/13/2016 11:10
989001003072609	F	565	1.93	N	6/1/2016 15:03
989001003072634	M	438	1.05	Y	10/21/2015 9:00
989001003072634	M	450	1.01	N	4/6/2016 9:40
989001003072627	M	473	1.17	Y	10/21/2015 9:00
989001003072676	F	497	1.63	Y	10/21/2015 9:00
989001003072682	M	537	2.0	Y	10/21/2015 9:00
989001003072677	M	418	0.75	Y	10/21/2015 9:00
989001003072646	U	239	0.17	Y	10/21/2015 10:25
989001003072648	U	257	0.18	Y	10/21/2015 10:25
989001003072657	F	435	0.97	Y	10/21/2015 11:35
989001003072612	M	525	1.74	Y	10/21/2015 11:35
989001003072679	F	550	2.17	Y	10/21/2015 11:35
989001003072655	M	410	0.87	Y	10/21/2015 11:35
989001003072640	F	559	2.05	Y	10/21/2015 11:35
989001003072696	M	545	1.91	Y	10/21/2015 11:35
989001003072689	F	439	1.01	Y	10/21/2015 13:30
989001003072689	F	470	1.27	N	11/3/2016 9:50
989001003072700	F	460	1.18	Y	10/21/2015 13:30
989001003072690	M	452	1.14	Y	10/21/2015 13:30
989001003072664	M	522	1.98	Y	10/21/2015 13:30
989001003072670	M	556	1.87	Y	10/21/2015 13:30
989001003072638	M	450	1.18	Y	10/21/2015 13:30
989001003072688	M	444	0.99	Y	10/21/2015 13:30
989001003072687	F	383	0.64	Y	10/21/2015 14:35
989001003072687	F	401	0.83	N	4/7/2016 8:45
989001003072687	M	546	1.83	N	4/3/2017 12:45
989001003072666	F	573	2.2	Y	10/21/2015 14:35
989001003072666	F	581	2.11	N	4/15/2016 8:30
989001003072686	F	423	1.02	Y	10/21/2015 14:35
989001003072686	F	435	1.06	N	11/7/2015 10:16
989001003072637	F	541	1.99	Y	10/21/2015 14:35
989001003072637	F	542	1.97	N	10/22/2015 9:45
989001003072637	M	645	3.17	N	10/19/2016 10:20
989001003072637	M	640	3.04	N	11/3/2016 10:32
989001003072692	F	452	1.18	Y	10/21/2015 14:35

989001003072693	M	522	1.66	Y	10/21/2015 14:35
989001003072628	M	617	2.65	Y	10/21/2015 14:35
989001003072697	F	438	1.09	Y	10/22/2015 8:00
989001003072616	M	515	1.58	Y	10/22/2015 9:05
989001003072673	M	536	1.88	Y	10/22/2015 9:45
989001003072667	F	600	2.36	Y	10/22/2015 9:45
989001003072482	M	452	1.03	Y	11/3/2015 10:17
989001003072432	M	522	1.43	Y	11/3/2015 10:17
989001003072432	M	529	1.43	N	4/12/2016 11:30
989001003072417	F	442	0.98	Y	11/4/2015 9:10
989001003072444	F	375	0.56	Y	11/4/2015 10:45
989001003072444	F	394	0.69	N	4/14/2016 15:00
989001003072480	U	250	0.15	Y	11/4/2015 10:45
989001003072428	M	475	1.29	Y	11/4/2015 10:45
989001003072406	F	478	1.33	Y	11/4/2015 10:45
989001003072406	M	617	2.53	N	4/2/2017 10:10
989001003072406	M	615	2.51	N	4/5/2017 9:30
989001003072456	U	272	0.25	Y	11/4/2015 10:05
989001003072431	F	545	1.94	Y	11/4/2015 11:35
989001003072431	F	550	1.86	N	4/6/2016 17:30
989001003072437	F	510	1.37	Y	11/4/2015 12:25
989001003072463	F	433	0.96	Y	11/5/2015 10:24
989001003072402	M	618	2.88	Y	11/5/2015 10:24
989001003072466	M	525	1.78	Y	11/5/2015 10:24
989001003072429	F	575	2.18	Y	11/5/2015 10:24
989001003072429	F	580	2.08	N	4/11/2016 15:17
989001003072558	M	462	1.15	Y	11/5/2015 10:24
989001003072473	U	305	0.12	Y	11/5/2015 9:35
989001003072436	M	434	1.02	Y	11/5/2015 9:35
989001003072497	M	505	1.72	Y	11/5/2015 9:35
989001003072516	F	398	0.76	Y	11/5/2015 13:10
989001003072516	F	542	1.72	N	4/2/2017 10:10
989001003072594	F	494	1.63	Y	11/5/2015 14:00
989001003072584	F	391	0.65	Y	11/5/2015 14:00
989001003072589	M	492	1.53	Y	11/6/2015 9:45
989001003072549	F	539	1.99	Y	11/6/2015 11:10
989001003072548	F	521	1.95	Y	11/6/2015 11:10
989001003072556	F	568	2.43	Y	11/6/2015 11:10
989001003072550	F	625	2.93	Y	11/6/2015 11:10
989001003072550	F	624	2.37	N	6/2/2016 11:02
989001003072511	F	538	1.85	Y	11/6/2015 12:10
989001003072518	U	238	0.15	Y	11/6/2015 12:10

989001003072562	F	447	1.07	Y	11/6/2015 10:26
989001003072562	F	442	0.86	N	6/16/2016 6:34
989001003072542	F	390	0.73	Y	11/7/2015 10:16
989001003072542	F	407	0.83	N	4/15/2016 8:30
989001003072585	M	526	1.72	Y	11/7/2015 9:38
989001003072585	M	530	1.67	N	4/12/2016 9:20
989001003072579	M	443	1.25	Y	11/7/2015 9:38
989001003072544	U	184	0.11	Y	11/7/2015 11:15
989001003072598	F	468	1.3	Y	11/7/2015 12:45
989001003072598	F	494	1.48	N	4/12/2016 11:30
989001003072598	M	633	2.97	N	11/6/2016 10:52
989001003072525	F	455	1.12	Y	11/7/2015 12:45
989001003072525	M	604	2.79	N	4/2/2017 12:45
989001003072559	F	410	0.85	Y	11/7/2015 12:45
989001003072574	F	484	1.55	Y	11/7/2015 12:45
989001003072574	F	561	2.5	N	6/22/2016 8:20
989001003072522	F	475	1.2	Y	11/7/2015 12:45
989001003072557	M	569	1.96	Y	11/7/2015 12:45
989001003072557	M	570	1.83	N	4/6/2016 9:40
989001003072561	M	466	1.23	Y	11/7/2015 12:45
989001003072596	M	447	1.06	Y	11/7/2015 12:45
989001003072537	M	469	1.23	Y	11/7/2015 12:45
989001003072573	F	542	1.93	Y	11/7/2015 12:45
989001003072597	M	532	1.84	Y	11/8/2015 8:55
989001003072581	U	197	0.09	Y	11/8/2015 8:55
989001003072552	F	452	1.11	Y	11/8/2015 11:25
989001003072552	F	450	0.88	N	6/1/2016 15:03
989001003072580	M	461	1.26	Y	11/8/2015 11:25
989001003072580	M	468	1.24	N	4/6/2016 9:40
989001003072575	M	574	2.16	Y	11/8/2015 11:25
989001003072575	M	577	2.06	N	4/6/2016 17:30
989001003072587	M	455	1.04	Y	11/8/2015 11:25
989001003072554	F	447	1.09	Y	11/8/2015 9:50
989001003072513	F	429	0.88	Y	11/8/2015 9:50
989001003072519	U	262	0.15	Y	11/8/2015 9:50
989001003072539	F	350	0.52	Y	11/8/2015 9:50
989001003072541	M	575	2.16	Y	11/8/2015 14:05
989001003072541	M	583	2.11	N	4/7/2016 9:50
989001003072540	M	414	0.82	Y	11/8/2015 14:05
989001003072540	M	424	0.85	N	4/6/2016 9:40
989001003072502	F	558	2.0	Y	11/8/2015 14:05
989001003072592	F	476	1.21	Y	11/8/2015 15:10

989001003072592	M	615	2.58	N	4/5/2017 13:00
989001003072505	F	496	1.34	Y	11/8/2015 15:10
989001003072526	M	490	1.34	Y	11/8/2015 15:10
989001003072512	F	511	1.32	Y	11/8/2015 15:10
989001003072560	U	193	0.31	Y	11/9/2015 9:26
989001003072533	U	313	0.42	Y	11/9/2015 9:26
989001003072547	F	358	0.51	Y	11/9/2015 9:26
989001003072583	F	423	0.94	Y	11/9/2015 10:10
989001003072583	F	434	0.89	N	4/12/2016 9:20
989001003072535	F	458	1.05	Y	11/9/2015 10:10
989001003072535	M	574	2.23	N	4/11/2016 15:17
989001003072599	F	477	1.21	Y	4/6/2016 9:40
989001003072553	M	573	2.26	Y	4/6/2016 9:40
989001003072524	F	460	1.17	Y	4/6/2016 9:40
989001003072569	F	456	1.08	Y	4/6/2016 9:40
989001003072578	M	467	2.02	Y	4/6/2016 9:40
989001003072578	M	565	1.92	N	4/11/2016 15:17
989001003072510	F	457	1.13	Y	4/6/2016 9:40
989001003072521	F	400	0.82	Y	4/6/2016 9:40
989001003072504	F	474	1.08	Y	4/6/2016 9:40
989001003072538	M	612	2.36	Y	4/6/2016 9:40
989001003072551	M	605	2.3	Y	4/6/2016 9:40
989001003072551	M	604	2.22	N	4/15/2016 8:30
989001003072565	F	557	1.97	Y	4/6/2016 9:40
989001003072508	M	439	1.07	Y	4/6/2016 9:40
989001003072701	M	496	1.4	Y	4/6/2016 9:40
989001003072714	F	465	1.1	Y	4/6/2016 9:40
989001003072760	F	434	0.9	Y	4/6/2016 9:40
989001003072752	F	441	0.99	Y	4/6/2016 9:40
989001003072707	M	465	1.02	Y	4/6/2016 9:40
989001003072707	M	430	0.58	N	6/28/2017 8:00
989001003072738	M	430	0.82	Y	4/6/2016 9:40
989001003072789	M	509	1.48	Y	4/6/2016 9:40
989001003072708	F	477	1.3	Y	4/6/2016 9:40
989001003072786	F	569	2.11	Y	4/6/2016 9:40
989001003072742	F	428	0.81	Y	4/6/2016 9:40
989001003072746	F	441	0.92	Y	4/7/2016 9:50
989001003072720	F	461	1.01	Y	4/7/2016 9:50
989001003072778	F	421	0.98	Y	4/7/2016 9:50
989001003072779	F	429	0.92	Y	4/7/2016 9:50
989001003072733	F	481	1.22	Y	4/7/2016 9:50
989001003072743	F	448	1.08	Y	4/7/2016 9:50

989001003072767	M	613	2.53	Y	4/7/2016 9:50
989001003072744	F	422	0.95	Y	4/7/2016 9:50
989001003072795	F	393	0.71	Y	4/7/2016 9:50
989001003072704	M	550	1.41	Y	4/6/2016 14:50
989001003072749	F	426	0.33	Y	4/6/2016 14:50
989001003072749	F	455	1.06	N	6/2/2016 11:02
989001003072706	F	580	2.14	Y	4/6/2016 14:50
989001003072706	F	575	2.08	N	4/12/2016 11:30
989001003072792	M	428	0.87	Y	4/6/2016 14:50
989001003072721	F	459	1.15	Y	4/6/2016 14:50
989001003072717	F	389	0.77	Y	4/6/2016 14:50
989001003072717	F	390	0.77	N	4/7/2016 11:00
989001003072717	F	458	1.24	N	10/19/2016 11:45
989001003072756	F	370	0.57	Y	4/6/2016 14:50
989001003072705	F	470	1.11	Y	4/6/2016 14:50
989001003072763	F	481	1.29	Y	4/6/2016 14:50
989001003072763	M	620	2.56	N	4/5/2017 8:05
989001003072771	F	387	0.69	Y	4/6/2016 14:50
989001003072770	F	600	2.57	Y	4/6/2016 14:50
989001003072770	F	610	2.46	N	4/6/2017 10:48
989001003072793	M	498	1.47	Y	4/6/2016 16:49
989001003072783	U	490	1.32	Y	4/6/2016 16:49
989001003072718	F	530	1.81	Y	4/6/2016 17:30
989001003072740	F	332	0.42	Y	4/6/2016 17:30
989001003072740	F	339	0.46	N	6/22/2016 7:05
989001003072740	F	432	0.9	N	4/5/2017 8:05
989001003072787	F	444	1.09	Y	4/6/2016 17:30
989001003072759	M	579	2.19	Y	4/6/2016 17:30
989001003072759	M	580	2.15	N	4/13/2016 10:21
989001003072791	F	450	1.14	Y	4/6/2016 17:30
989001003072791	F	465	0.83	N	6/15/2016 7:05
989001003072791	F	486	1.33	N	4/2/2017 12:45
989001003072732	M	480	1.36	Y	4/6/2016 17:30
989001003072768	F	453	1.0	Y	4/6/2016 17:30
989001003072768	F	512	1.59	N	11/5/2016 10:15
989001003072768	F	513	1.38	N	4/3/2017 14:30
989001003072799	F	470	1.08	Y	4/6/2016 17:30
989001003072753	F	409	0.96	Y	4/6/2016 17:30
989001003072737	M	677	3.69	Y	4/6/2016 17:30
989001003072745	F	425	0.92	Y	4/7/2016 8:45
989001003072725	F	440	1.1	Y	4/7/2016 8:45
989001003072773	F	424	0.87	Y	4/7/2016 8:45

989001003072796	F	509	1.45	Y	4/7/2016 8:45
989001003072797	F	414	0.76	Y	4/7/2016 8:45
989001003072794	U	302	0.34	Y	4/7/2016 8:45
989001003072772	F	610	2.82	Y	4/7/2016 15:13
989001003072781	F	464	1.34	Y	4/7/2016 11:00
989001003072790	U	272	0.23	Y	4/8/2016 8:41
989001003072715	F	416	0.9	Y	4/8/2016 8:41
989001003072758	F	491	1.29	Y	4/8/2016 8:41
989001003072723	M	659	3.45	Y	4/7/2016 13:20
989001003072719	F	529	1.65	Y	4/7/2016 13:20
989001003072719	F	530	1.64	N	10/21/2016 15:51
989001003072729	M	531	1.76	Y	4/7/2016 13:20
989001003072762	M	337	0.88	Y	4/7/2016 13:20
989001003072735	F	430	0.89	Y	4/7/2016 13:20
989001003072769	F	455	1.13	Y	4/7/2016 13:20
989001003072741	U	316	0.4	Y	4/7/2016 13:20
989001003072785	F	489	1.3	Y	4/7/2016 13:20
989001003072874	U	124	*	Y	4/15/2016 9:30
989001003072868	F	467	1.13	Y	4/12/2016 11:30
989001003072868	F	510	1.54	N	10/20/2016 12:03
989001003072868	F	521	1.23	N	6/22/2017 7:56
989001003072884	M	502	1.37	Y	4/12/2016 11:30
989001003072862	M	551	1.72	Y	4/12/2016 11:30
989001003072894	U	279	0.24	Y	4/12/2016 11:30
989001003072848	F	404	0.78	Y	4/12/2016 11:30
989001003072858	F	468	1.13	Y	4/13/2016 11:55
989001003072897	M	464	1.09	Y	4/13/2016 11:55
989001003072816	U	198	0.08	Y	4/13/2016 11:10
989001003072856	M	627	2.72	Y	4/13/2016 8:50
989001003072881	F	500	1.49	Y	4/13/2016 9:25
989001003072881	F	530	1.9	N	10/19/2016 10:20
989001003072808	F	444	1.09	Y	4/13/2016 10:21
989001003072804	M	526	1.76	Y	4/13/2016 10:21
989001003072832	F	455	1.07	Y	4/14/2016 16:00
989001003072807	M	449	1.15	Y	4/14/2016 16:00
989001003072860	F	451	1.61	Y	4/14/2016 16:00
989001003072845	F	506	1.45	Y	4/14/2016 16:00
989001003072888	F	581	2.15	Y	4/14/2016 15:00
989001003072888	F	584	2.14	N	4/2/2017 11:40
989001003072877	F	265	0.22	Y	4/14/2016 15:00
989001003072873	F	385	0.75	Y	4/14/2016 15:00
989001003072851	F	484	1.4	Y	4/14/2016 15:00

989001003072867	F	575	1.91	Y	4/14/2016 15:00
989001003072853	F	446	1.01	Y	4/14/2016 15:00
989001003072871	F	330	0.46	Y	4/14/2016 15:00
989001003072836	F	430	0.96	Y	4/14/2016 15:00
989001003072820	M	475	1.28	Y	4/14/2016 11:38
989001003072811	F	423	0.88	Y	4/14/2016 9:07
989001003072899	M	287	0.26	Y	4/14/2016 9:07
989001003072822	M	517	1.62	Y	4/14/2016 9:07
989001003072870	F	575	2.19	Y	4/14/2016 9:07
989001003072896	F	503	1.44	Y	4/14/2016 9:07
989001003072864	F	561	2.14	Y	4/14/2016 9:07
989001003072895	F	510	1.51	Y	4/14/2016 9:07
989001003072863	M	502	1.37	Y	4/14/2016 9:07
989001003072889	M	539	1.99	Y	4/14/2016 9:07
989001003072837	U	240	0.14	Y	4/14/2016 9:07
989001003072880	U	238	0.12	Y	4/14/2016 9:07
989001003072841	F	484	1.3	Y	4/14/2016 9:07
989001003072841	M	610	2.39	N	4/5/2017 8:05
989001003072883	F	309	1.34	Y	4/14/2016 9:07
989001003072817	M	359	0.53	Y	4/14/2016 9:07
989001003072835	M	501	1.38	Y	4/14/2016 9:07
989001003072855	F	444	0.98	Y	4/14/2016 9:07
989001003072842	M	577	2.02	Y	4/14/2016 9:07
989001003072891	F	406	0.68	Y	4/14/2016 9:07
989001003072828	F	449	0.87	Y	4/14/2016 9:07
989001003072828	F	445	0.88	N	4/15/2016 8:30
989001003072818	F	434	0.9	Y	4/14/2016 9:07
989001003072869	F	622	2.77	Y	4/14/2016 9:07
989001003072838	F	450	0.99	Y	4/14/2016 9:07
989001003072859	M	466	1.1	Y	4/14/2016 9:07
989001003072882	M	585	2.45	Y	4/15/2016 8:30
989001003072823	F	410	0.83	Y	4/15/2016 8:30
989001003072830	M	470	1.19	Y	4/15/2016 8:30
989001003072821	F	550	1.83	Y	4/15/2016 8:30
989001003072813	F	540	1.77	Y	4/15/2016 8:30
989001003072813	M	557	1.96	N	11/6/2016 9:56
989001003072833	F	408	0.82	Y	4/15/2016 8:30
989001003072734	F	496	1.34	Y	4/12/2016 9:20
989001003072709	M	513	1.39	Y	4/12/2016 9:20
989001003072748	F	434	0.93	Y	4/12/2016 9:20
989001003072748	F	431	0.75	N	6/15/2016 7:43
989001003072755	M	496	1.49	Y	4/12/2016 9:20

989001003072730	U	616	2.65	Y	4/12/2016 9:20
989001003072751	F	439	0.9	Y	4/12/2016 9:20
989001003072784	F	484	1.3	Y	4/12/2016 9:20
989001003072776	M	480	1.2	Y	4/12/2016 9:20
989001003072782	F	395	0.74	Y	4/12/2016 9:20
989001003072782	F	460	1.19	N	4/2/2017 12:45
989001003072898	F	547	1.85	Y	4/12/2016 9:20
989001003072824	F	467	1.19	Y	4/12/2016 9:20
989001003072824	F	517	1.72	N	4/2/2017 12:45
989001003072825	F	585	1.96	Y	4/12/2016 9:20
989001003072754	F	486	1.4	Y	4/12/2016 9:20
989001003072892	M	621	2.74	Y	4/12/2016 9:20
989001003072765	M	396	0.77	Y	4/11/2016 15:17
989001003072728	M	565	1.85	Y	4/11/2016 15:17
989001003072712	M	520	1.62	Y	4/11/2016 15:17
989001003072731	M	465	1.11	Y	4/11/2016 15:17
989001003072757	M	272	0.23	Y	4/11/2016 15:17
989001003072702	M	500	1.25	Y	4/11/2016 15:17
989001003072775	M	448	0.96	Y	4/11/2016 15:17
989001003072798	F	459	1.12	Y	4/11/2016 15:17
989001003072774	F	444	1.75	Y	4/11/2016 15:17
989001003072774	F	565	2.08	N	10/19/2016 13:50
989001003072739	F	527	1.82	Y	4/11/2016 15:17
989001003072727	F	448	1.01	Y	4/11/2016 15:17
989001003072711	F	525	1.51	Y	4/11/2016 15:17
989001003072722	M	320	0.37	Y	4/11/2016 15:17
989001003072713	F	540	1.75	Y	4/11/2016 15:17
989001003072788	M	631	3.0	Y	4/11/2016 15:17
989001003072777	F	481	1.33	Y	4/11/2016 15:17
989001003072777	F	475	1.31	N	4/14/2016 9:07
989001003072777	F	525	1.79	N	11/4/2016 10:20
989001003072777	F	530	1.77	N	4/4/2017 10:00
989001003072800	M	468	1.14	Y	4/11/2016 15:17
989001003072764	F	520	1.59	Y	4/11/2016 15:17
989001003072716	F	555	1.91	Y	4/11/2016 15:17
989001003072750	M	648	2.89	Y	4/11/2016 15:17
989001003072766	F	468	1.16	Y	4/11/2016 15:17
989001003072766	F	529	1.3	N	6/15/2017 9:24
989001003072726	F	554	2.12	Y	4/11/2016 15:17
989001003072747	F	513	1.68	Y	4/11/2016 15:17
989001003072703	M	595	2.59	Y	4/11/2016 15:17
989001003072761	M	523	1.65	Y	4/11/2016 15:17

989001003072710	M	511	1.47	Y	4/11/2016 15:17
989001003072724	F	579	1.98	Y	4/11/2016 15:17
989001003072724	F	569	1.51	N	6/8/2016 10:09
989001003072736	M	585	1.95	Y	4/11/2016 15:17
989001003072780	M	586	2.15	Y	4/11/2016 15:17
989001003072939	M	430	0.81	Y	6/1/2016 10:42
989001003072939	M	431	0.8	N	6/3/2016 9:15
989001003072916	F	462	1.28	Y	6/1/2016 12:25
989001003072931	F	505	1.73	Y	6/1/2016 12:25
989001003072931	F	505	1.69	N	6/7/2016 9:05
989001003072931	F	512	1.64	N	6/21/2016 8:06
989001003073083	F	434	1.12	Y	6/2/2016 8:40
989001003073009	F	532	1.46	Y	6/2/2016 11:02
989001003072927	F	555	2.14	Y	6/2/2016 13:08
989001003072927	F	565	2.17	N	6/15/2016 7:43
989001003072945	F	395	0.75	Y	6/2/2016 10:36
989001003072945	F	385	0.75	N	6/8/2016 10:09
989001003072945	F	480	1.34	N	4/2/2017 12:45
989001003073041	F	504	1.74	Y	6/2/2016 13:00
989001003073041	F	558	2.35	N	11/2/2016 10:23
989001003073080	F	487	1.12	Y	6/2/2016 13:00
989001003072933	F	340	0.54	Y	6/2/2016 11:30
989001003073097	U	105	*	Y	6/3/2016 9:15
989001003073064	M	524	1.61	Y	6/3/2016 9:15
989001003073021	F	515	1.49	Y	6/3/2016 9:15
989001003073071	M	472	1.05	Y	6/3/2016 9:15
989001003072922	F	465	1.29	Y	6/3/2016 8:45
989001003072922	F	535	2.01	N	10/20/2016 12:03
989001003072922	F	538	1.41	N	6/30/2017 10:35
989001003072925	F	467	1.25	Y	6/3/2016 8:45
989001003072925	M	544	1.73	N	4/2/2017 12:45
989001003073089	F	333	0.46	Y	6/7/2016 7:35
989001003073095	F	496	1.72	Y	6/7/2016 7:35
989001003073095	F	570	1.81	N	6/15/2017 8:23
989001003072904	F	480	1.23	Y	6/7/2016 9:05
989001003072930	F	489	1.26	Y	6/7/2016 9:05
989001003072930	F	495	1.32	N	6/21/2016 9:02
989001003073038	U	108	*	Y	6/8/2016 8:42
989001003073084	F	442	1.1	Y	6/8/2016 10:09
989001003073058	F	425	0.99	Y	6/8/2016 10:09
989001003073058	F	499	1.38	N	4/6/2017 10:02
989001003073098	F	495	1.6	Y	6/8/2016 10:09

*	U	117	*	N	6/8/2016 10:09
989001003072918	F	451	1.19	Y	6/8/2016 9:12
989001003072968	F	485	1.35	Y	6/8/2016 9:12
989001003072935	F	513	1.74	Y	6/8/2016 10:20
989001003072935	M	580	2.52	N	10/19/2016 10:20
989001003072935	M	603	2.49	N	4/5/2017 13:00
989001003072905	F	460	1.24	Y	6/8/2016 11:40
989001003073024	F	590	1.97	Y	6/9/2016 8:20
989001003073027	F	371	0.7	Y	6/14/2016 7:46
989001003072990	F	384	0.69	Y	6/15/2016 7:05
989001003072953	F	410	0.83	Y	6/15/2016 7:43
989001003072937	F	540	1.88	Y	6/15/2016 7:43
989001003073043	U	130	*	Y	6/16/2016 7:00
989001003073026	U	441	1.11	Y	6/15/2016 9:30
989001003073003	F	522	1.75	Y	6/15/2016 9:30
989001003073003	M	570	2.13	N	11/3/2016 10:32
*	U	100	*	N	6/21/2016 8:30
989001003072908	F	515	1.65	Y	6/21/2016 8:06
989001003072908	M	575	2.29	N	10/21/2016 11:09
989001003072965	F	424	0.86	Y	6/22/2016 7:05
989001003072965	F	493	1.33	N	4/2/2017 12:45
989001005493361	F	453	0.77	N	6/22/2016 7:05
989001003072902	U	124	*	Y	6/22/2016 6:40
989001003072929	F	386	0.73	Y	6/22/2016 9:00
989001003073090	F	457	1.3	Y	6/22/2016 8:20
989001003073069	F	469	1.18	Y	6/22/2016 8:20
989001003073020	F	495	1.58	Y	6/22/2016 9:23
989001003072926	U	135	*	Y	6/23/2016 8:00
989001003072943	U	145	*	Y	6/23/2016 8:20
989001003072915	F	419	0.94	Y	6/23/2016 6:50
989001003072992	F	586	2.09	Y	6/23/2016 6:50
989001003072992	F	610	2.79	N	10/19/2016 13:50
989001003072941	F	500	1.49	Y	6/23/2016 6:50
*	U	109	*	N	6/23/2016 8:00
*	U	111	*	N	6/23/2016 8:20
989001003072108	F	555	2.01	Y	5/11/2015 7:20
989001003072957	F	470	1.39	Y	10/18/2016 15:38
989001003072923	F	620	3.25	Y	10/18/2016 15:38
989001003072940	U	200	0.1	Y	10/19/2016 11:45
989001003072958	F	527	1.91	Y	10/19/2016 11:45
989001003072958	F	545	1.87	N	4/5/2017 11:45
989001003072971	F	360	0.57	Y	10/19/2016 13:50

989001003072970	M	465	1.31	Y	10/19/2016 13:50
989001003072984	U	268	0.34	Y	10/19/2016 13:50
989001003072984	M	307	0.24	N	6/21/2017 9:25
989001003072947	F	405	0.6	Y	10/19/2016 13:50
989001003072966	U	213	*	Y	10/19/2016 15:30
989001003072969	F	590	1.98	Y	10/19/2016 15:30
989001003072980	M	555	1.75	Y	10/19/2016 15:30
989001003072964	M	570	2.32	Y	10/19/2016 15:30
989001003072961	F	480	1.35	Y	10/19/2016 15:30
989001003073029	F	428	1.02	Y	10/20/2016 11:05
989001003073074	U	213	0.11	Y	10/20/2016 11:05
989001003072803	F	590	2.47	N	10/20/2016 11:05
989001003073039	F	545	1.83	Y	10/20/2016 12:03
989001003073046	U	295	0.31	Y	10/20/2016 12:03
989001003073044	M	432	1.06	Y	10/20/2016 12:03
989001003073050	F	480	1.52	Y	10/20/2016 12:03
989001003073050	F	503	1.4	N	4/5/2017 13:00
989001003073008	M	540	1.7	Y	10/20/2016 14:49
989001003073042	F	400	0.78	Y	10/21/2016 11:09
989001003073006	M	562	2.15	Y	10/21/2016 11:09
989001003073030	F	405	0.9	Y	10/21/2016 11:09
989001003073030	F	423	0.86	N	4/2/2017 12:45
989001003073082	F	411	0.85	Y	10/21/2016 11:09
989001003073099	U	245	0.18	Y	10/21/2016 12:15
989001003073099	F	335	0.46	N	6/20/2017 8:10
989001003073091	U	234	0.12	Y	10/21/2016 12:15
989001003073062	U	210	0.1	Y	10/21/2016 13:15
989001003073073	U	237	0.14	Y	10/21/2016 13:15
989001003073093	U	256	0.2	Y	10/21/2016 13:15
989001003073093	U	250	*	N	10/23/2016 12:15
989001003073093	U	282	0.22	N	4/5/2017 13:00
989001003073078	U	175	0.03	Y	10/21/2016 13:15
989001003073055	U	255	0.18	Y	10/21/2016 13:15
989001003073040	U	295	0.31	Y	10/21/2016 13:15
989001003073035	F	470	1.3	Y	10/21/2016 13:15
989001003073035	F	485	1.06	N	6/16/2017 7:37
989001003073045	U	200	0.09	Y	10/21/2016 13:15
989001003073049	F	475	1.31	Y	10/21/2016 13:15
989001003073049	F	490	1.31	N	4/5/2017 8:05
989001003073031	F	462	1.35	Y	10/21/2016 13:15
989001003073019	F	555	1.86	Y	10/21/2016 13:15
989001003073037	M	554	2.5	Y	10/21/2016 16:35

989001003073079	U	305	0.4	Y	10/21/2016 16:35
989001003073079	M	410	0.96	N	6/28/2017 9:49
989001003073059	U	250	0.19	Y	10/21/2016 15:51
989001003073059	M	293	0.25	N	4/5/2017 9:30
989001003073096	F	390	0.74	Y	10/21/2016 15:51
989001003073096	F	476	1.36	N	6/22/2017 10:17
989001003073054	F	505	1.65	Y	10/21/2016 15:51
989001003073004	U	204	0.1	Y	10/22/2016 11:24
989001003073005	F	297	0.33	Y	10/22/2016 11:24
989001005493832	F	402	0.74	Y	10/22/2016 8:00
989001005493832	M	425	0.88	N	4/3/2017 12:45
989001005493871	F	497	1.35	Y	10/22/2016 8:00
989001005493897	F	489	1.41	Y	10/22/2016 8:00
989001005493897	F	504	1.66	N	4/2/2017 12:45
989001005493862	F	539	1.8	Y	10/22/2016 8:40
989001005493862	F	*	*	N	10/23/2016 11:07
989001005493850	F	454	1.1	Y	10/23/2016 7:40
989001005493850	M	473	1.12	N	4/3/2017 14:30
989001003073016	U	271	0.26	Y	10/23/2016 10:05
989001003073016	F	287	0.28	N	11/4/2016 9:35
989001003073016	F	371	0.6	N	6/16/2017 7:37
989001003073022	F	485	1.27	Y	10/24/2016 7:30
989001003073022	F	494	1.15	N	6/20/2017 9:13
989001003073092	U	200	*	Y	10/23/2016 12:15
989001003073057	U	205	*	Y	10/23/2016 12:15
989001003073068	U	256	*	Y	10/23/2016 12:15
989001003073056	U	310	*	Y	10/23/2016 12:15
989001003073048	U	360	*	Y	10/23/2016 12:15
989001003073070	M	554	2.18	Y	10/23/2016 11:07
989001003073085	F	520	1.63	Y	10/23/2016 11:07
989001003073052	U	247	0.19	Y	10/23/2016 13:20
989001003073011	U	259	0.22	Y	10/23/2016 13:20
989001003073012	U	360	0.54	Y	10/23/2016 13:20
989001003073012	F	447	1.05	N	6/28/2017 9:00
989001003073002	F	445	1.29	Y	10/23/2016 13:20
989001003073002	F	465	1.41	N	4/3/2017 12:45
989001003073061	U	230	0.16	Y	10/24/2016 7:55
989001003073017	F	437	1.06	Y	10/24/2016 7:55
989001003073036	F	253	0.18	Y	11/2/2016 10:23
989001003073081	F	465	1.4	Y	11/2/2016 10:23
989001003073076	F	505	1.53	Y	11/2/2016 10:23
989001003073015	U	226	0.13	Y	11/2/2016 11:15

989001003073100	M	560	2.1	Y	11/3/2016 9:07
989001003073023	U	280	0.26	Y	11/3/2016 9:50
989001003073063	F	353	0.46	Y	11/3/2016 10:32
989001003073063	F	421	0.85	N	6/21/2017 11:15
989001003073060	F	530	1.76	Y	11/3/2016 10:32
989001003073051	F	520	1.64	Y	11/3/2016 10:32
989001003073010	F	500	1.47	Y	11/3/2016 11:47
989001003073013	F	422	0.84	Y	11/3/2016 11:47
989001003073013	F	479	1.22	N	6/27/2017 8:05
989001003073014	U	250	0.2	Y	11/3/2016 11:47
989001003073053	F	345	0.43	Y	11/4/2016 8:53
989001003073028	F	375	0.64	Y	11/4/2016 8:53
989001003073007	F	439	1.06	Y	11/4/2016 9:35
989001003073072	F	395	0.82	Y	11/4/2016 9:35
989001003073088	U	233	0.13	Y	11/4/2016 9:35
989001003073065	U	210	0.1	Y	11/4/2016 9:35
989001003073032	M	552	2.04	Y	11/4/2016 10:20
989001003073067	M	520	1.74	Y	11/4/2016 10:20
989001003073077	F	475	1.2	Y	11/4/2016 10:20
989001003073077	F	468	0.82	N	6/30/2017 9:50
989001003073075	M	495	1.44	Y	11/4/2016 10:20
989001005493840	F	424	0.94	Y	11/4/2016 10:20
989001005493840	M	447	1.1	N	3/29/2017 14:30
989001005493908	M	485	1.52	Y	11/4/2016 11:35
989001005493908	M	508	1.39	N	4/2/2017 10:10
989001005493893	F	578	2.2	Y	11/4/2016 11:35
989001005493890	U	220	0.12	Y	11/5/2016 8:52
989001005493837	F	385	0.65	Y	11/5/2016 10:15
989001005493852	M	577	1.89	Y	11/5/2016 10:15
989001005493852	M	582	1.83	N	4/5/2017 13:00
989001005493888	F	553	1.84	Y	11/5/2016 10:15
989001005493857	U	298	0.36	Y	11/5/2016 10:15
989001005493894	U	271	0.26	Y	11/5/2016 10:15
989001005493884	F	465	1.42	Y	11/5/2016 10:15
989001005493896	F	544	1.88	Y	11/5/2016 10:15
989001005493845	M	481	1.33	Y	11/5/2016 10:15
989001005493861	F	495	1.39	Y	11/5/2016 11:15
989001005493861	F	501	1.37	N	4/6/2017 10:02
989001005493419	M	472	1.05	Y	11/6/2016 10:52
989001005493386	F	462	1.1	Y	11/6/2016 10:52
989001005493918	U	290	0.29	Y	11/6/2016 10:52
989001005493900	M	425	0.94	Y	11/6/2016 10:52

989001005493912	F	315	0.4	Y	11/6/2016 10:52
989001005493885	F	460	1.19	Y	11/6/2016 10:52
989001005493914	M	392	0.87	Y	11/6/2016 10:52
989001005493909	M	590	2.26	Y	11/6/2016 9:56
989001005493886	F	495	1.52	Y	11/6/2016 9:56
989001005493886	F	503	1.4	N	4/3/2017 10:45
989001005493889	M	532	1.7	Y	11/6/2016 9:56
989001005493416	F	485	1.49	Y	11/6/2016 9:56
989001005493397	F	380	0.66	Y	11/6/2016 9:56
989001005493394	F	440	1.0	Y	11/6/2016 9:56
989001005493394	F	446	0.9	N	4/5/2017 13:00
989001005493330	U	194	0.08	Y	11/6/2016 8:05
989001005493905	U	180	0.06	Y	11/6/2016 8:05
989001005493869	U	238	0.14	Y	11/6/2016 8:05
989001005493922	F	472	1.26	Y	11/6/2016 8:42
989001005493922	F	485	1.32	N	4/2/2017 12:45
989001005493887	U	230	0.17	Y	11/6/2016 8:42
989001005493420	F	560	2.06	Y	11/6/2016 9:26
989001005493919	U	223	0.12	Y	11/7/2016 7:24
989001003072887	F	463	1.29	N	11/4/2016 10:20
989001005493358	F	374	0.62	N	11/4/2016 9:35
989001005493245	U	278	0.23	Y	3/29/2017 14:30
989001005493275	F	480	1.24	Y	3/29/2017 14:30
989001005493306	F	563	2.14	Y	4/2/2017 10:10
989001005493299	M	496	1.28	Y	4/2/2017 10:10
989001005493273	M	320	*	Y	4/2/2017 10:10
989001005493247	F	483	1.23	Y	4/2/2017 11:40
989001005493277	U	300	0.23	Y	4/2/2017 11:40
989001005493240	U	379	0.66	Y	4/2/2017 11:40
989001005493322	M	562	1.8	Y	4/2/2017 11:40
989001005493322	M	563	2.01	N	4/5/2017 13:00
989001005493298	M	409	0.11	Y	4/2/2017 12:45
989001005493298	M	409	0.64	N	4/6/2017 10:02
989001005493300	F	536	1.81	Y	4/2/2017 12:45
989001005493263	F	580	2.36	Y	4/2/2017 12:45
989001005493286	F	431	1.1	Y	4/2/2017 12:45
989001005493292	F	590	2.19	Y	4/2/2017 12:45
989001005493315	F	510	1.5	Y	4/2/2017 12:45
989001005493283	M	417	0.77	Y	4/2/2017 12:45
989001005493269	U	373	0.56	Y	4/2/2017 12:45
989001005493260	F	420	0.85	Y	4/2/2017 12:45
989001005493268	F	435	1.07	Y	4/2/2017 12:45

989001005493272	F	495	1.4	Y	4/2/2017 12:45
989001005493287	U	324	0.34	Y	4/2/2017 12:45
989001005493255	F	388	0.52	Y	4/2/2017 12:45
989001005493259	F	505	1.38	Y	4/2/2017 12:45
989001005493253	U	391	0.64	Y	4/2/2017 12:45
989001005493253	F	450	1.19	N	6/16/2017 6:43
989001005493238	M	579	2.39	Y	4/2/2017 12:45
989001005493290	M	443	0.99	Y	4/2/2017 12:45
989001005493294	F	446	1.03	Y	4/2/2017 12:45
989001005493293	F	524	1.93	Y	4/2/2017 12:45
989001005493242	F	391	0.8	Y	4/2/2017 12:45
989001005493289	F	500	1.42	Y	4/2/2017 12:45
989001005493323	M	565	1.94	Y	4/2/2017 12:45
989001005493241	F	475	1.46	Y	4/2/2017 12:45
989001005493241	F	475	1.39	N	4/4/2017 11:05
989001005493226	M	330	0.41	Y	4/2/2017 12:45
989001005493251	F	485	1.14	Y	4/2/2017 12:45
989001005493309	F	388	0.69	Y	4/2/2017 12:45
989001005493254	F	494	1.26	Y	4/2/2017 12:45
989001005493266	F	437	0.93	Y	4/2/2017 12:45
989001005493256	F	452	1.05	Y	4/2/2017 12:45
989001005493316	F	415	0.79	Y	4/2/2017 12:45
989001005493316	F	420	0.71	N	6/22/2017 7:56
989001005493313	M	598	2.14	Y	4/2/2017 12:45
989001005493227	F	446	1.07	Y	4/2/2017 12:45
989001005493408	F	498	1.14	Y	4/2/2017 12:45
989001005493374	M	418	0.91	Y	4/2/2017 12:45
989001005493409	F	476	1.2	Y	4/2/2017 12:45
989001005493279	U	246	0.13	Y	4/3/2017 9:30
989001005493249	U	237	0.16	Y	4/3/2017 9:30
989001005493305	F	381	0.63	Y	4/3/2017 9:30
989001005493317	M	578	2.16	Y	4/3/2017 10:45
989001005493261	M	276	0.12	Y	4/3/2017 10:45
989001005493295	M	560	1.82	Y	4/3/2017 10:45
989001005493282	U	294	0.3	Y	4/3/2017 12:45
989001005493282	F	361	0.54	N	6/20/2017 9:13
989001005493274	F	439	1.07	Y	4/3/2017 12:45
989001005493301	M	584	2.2	Y	4/3/2017 12:45
989001005493262	F	333	0.43	Y	4/3/2017 12:45
989001005493237	U	279	0.25	Y	4/3/2017 12:45
989001005493229	U	352	0.49	Y	4/3/2017 12:45
989001005493244	M	330	0.36	Y	4/3/2017 12:45

989001005493244	M	324	0.35	N	4/5/2017 8:05
989001005493232	M	377	0.62	Y	4/3/2017 12:45
989001005493308	F	461	1.09	Y	4/3/2017 12:45
989001005493308	F	460	0.91	N	6/21/2017 9:25
989001005493314	F	420	0.8	Y	4/3/2017 12:45
989001005493248	M	582	1.9	Y	4/3/2017 12:45
989001005493318	F	425	0.88	Y	4/3/2017 12:45
989001005493303	F	433	0.89	Y	4/3/2017 12:45
989001005493224	F	463	1.2	Y	4/4/2017 9:15
989001005493243	F	607	2.45	Y	4/4/2017 10:00
989001005493284	F	463	1.11	Y	4/4/2017 10:00
989001005493285	M	284	0.27	Y	4/4/2017 10:00
989001005493285	M	288	0.28	N	4/5/2017 9:30
989001005493246	F	442	1.02	Y	4/4/2017 11:05
989001005493311	U	243	0.16	Y	4/4/2017 11:05
989001005493311	F	320	0.26	N	6/28/2017 9:36
989001005493265	U	273	0.26	Y	4/4/2017 11:05
989001005493250	U	272	0.16	Y	4/4/2017 11:05
989001005493870	F	504	1.23	Y	4/5/2017 13:00
989001005493851	M	485	1.27	Y	4/5/2017 13:00
989001005493898	M	378	0.52	Y	4/5/2017 13:00
989001005493902	F	522	1.59	Y	4/5/2017 13:00
989001005493847	M	476	1.09	Y	4/5/2017 13:00
989001005493828	M	526	1.76	Y	4/5/2017 13:00
989001005493906	F	512	1.41	Y	4/5/2017 13:00
989001005493911	M	472	1.07	Y	4/5/2017 13:00
989001005493899	M	436	0.79	Y	4/5/2017 13:00
989001005493834	U	404	0.85	Y	4/5/2017 13:00
989001005493831	M	296	0.24	Y	4/5/2017 13:00
989001005493849	M	466	1.02	Y	4/5/2017 13:00
989001005493848	M	631	2.85	Y	4/5/2017 13:00
989001005493904	F	503	1.41	Y	4/5/2017 13:00
989001005493842	F	417	0.82	Y	4/5/2017 13:00
989001005493855	M	586	2.36	Y	4/5/2017 13:00
989001005493824	F	563	2.07	Y	4/5/2017 13:00
989001005493920	F	518	1.47	Y	4/5/2017 13:00
989001005493854	F	490	1.27	Y	4/5/2017 13:00
989001005493858	F	526	1.49	Y	4/5/2017 13:00
989001005493881	F	594	2.09	Y	4/5/2017 13:00
989001005493843	M	442	0.81	Y	4/5/2017 13:00
989001005493856	F	492	1.27	Y	4/5/2017 13:00
989001005493856	F	486	1.13	N	6/21/2017 9:25

989001005493903	F	640	2.88	Y	4/5/2017 13:00
989001005493836	F	519	1.67	Y	4/5/2017 13:00
989001005493872	M	495	1.46	Y	4/5/2017 13:00
989001005493873	M	526	1.58	Y	4/5/2017 13:00
989001005493864	M	522	1.5	Y	4/5/2017 13:00
989001005493252	F	507	1.42	Y	4/5/2017 13:00
989001005493270	F	532	1.77	Y	4/5/2017 13:00
989001005493296	F	515	1.48	Y	4/5/2017 13:00
989001005493302	F	424	0.71	Y	4/5/2017 13:00
989001005493320	M	535	1.46	Y	4/5/2017 13:00
989001005493236	M	495	1.02	Y	4/5/2017 13:00
989001003072819	F	465	1.02	Y	4/5/2017 13:00
989001005493291	F	412	0.77	Y	4/5/2017 8:05
989001005493278	F	540	2.02	Y	4/5/2017 8:05
989001005493312	M	302	0.29	Y	4/5/2017 8:05
989001005493264	M	527	1.51	Y	4/5/2017 8:05
989001005493235	F	560	2.14	Y	4/5/2017 8:05
989001005493297	F	460	1.11	Y	4/5/2017 8:05
989001005493280	U	292	0.25	Y	4/5/2017 8:05
989001003072455	F	362	0.61	Y	4/5/2017 8:05
989001005493258	M	599	2.35	Y	4/5/2017 9:30
989001005493267	M	365	0.55	Y	4/5/2017 9:30
989001005493231	U	262	0.2	Y	4/5/2017 9:30
989001005493234	F	361	0.6	Y	4/5/2017 9:30
989001005493239	F	445	1.09	Y	4/5/2017 9:30
989001005493228	M	621	3.02	Y	4/5/2017 9:30
989001005493319	F	430	0.98	Y	4/5/2017 9:30
989001005493233	U	306	0.28	Y	4/5/2017 9:30
989001005493310	U	559	2.12	Y	4/5/2017 9:30
989001005493230	F	318	0.43	Y	4/5/2017 9:30
989001005493271	F	475	1.25	Y	4/5/2017 11:45
989001005493288	F	338	0.43	Y	4/5/2017 13:15
989001005493257	F	427	0.89	Y	4/5/2017 13:15
989001005493225	F	396	0.69	Y	4/5/2017 13:15
989001005493901	U	271	0.22	Y	4/6/2017 10:02
989001005493910	F	421	0.87	Y	4/6/2017 10:02
989001005493825	F	351	0.57	Y	4/6/2017 10:02
989001005493838	F	376	0.65	Y	4/6/2017 10:02
989001005493879	M	479	1.37	Y	4/6/2017 10:02
989001005493860	F	521	1.58	Y	4/6/2017 10:02
989001005493883	U	279	0.16	Y	4/6/2017 9:21
989001005493882	M	466	1.21	Y	4/6/2017 9:21

989001005493895	F	284	0.25	Y	4/6/2017 9:21
989001005493496	F	414	0.8	Y	4/6/2017 9:21
989001003072814	F	620	3.06	Y	4/6/2017 9:21
989001005493921	F	324	0.41	Y	4/6/2017 8:45
989001005493839	F	414	0.84	Y	4/6/2017 8:45
989001005493865	F	373	0.58	Y	4/6/2017 8:45
989001005493508	U	269	0.19	Y	4/6/2017 9:15
989001005493474	U	243	0.17	Y	4/6/2017 9:15
989001005493449	U	233	0.13	Y	4/6/2017 9:15
989001005493479	U	199	*	Y	4/6/2017 7:25
989001005493493	F	434	0.67	Y	4/6/2017 7:25
989001005493511	F	386	0.41	Y	4/6/2017 7:25
989001005493485	F	460	1.08	Y	4/6/2017 7:25
989001005493515	F	421	0.7	Y	4/6/2017 7:25
989001005493505	F	436	*	Y	4/6/2017 7:25
989001005493446	M	275	0.24	Y	4/6/2017 8:40
989001005493514	U	278	0.19	Y	4/6/2017 8:40
989001005494093	M	519	1.28	Y	6/13/2017 9:22
989001005494032	F	502	1.62	Y	6/14/2017 9:00
989001005494068	F	388	0.66	Y	6/14/2017 9:00
989001005493428	F	475	1.12	Y	6/14/2017 9:00
989001005494069	U	343	0.47	Y	6/14/2017 9:00
989001005494078	U	168	0.05	Y	6/15/2017 7:40
989001005494056	F	293	0.27	Y	6/15/2017 7:40
989001005494113	F	444	1.03	Y	6/15/2017 7:40
989001005494031	F	530	1.65	Y	6/15/2017 8:23
989001005494031	F	540	1.68	N	6/21/2017 9:25
989001005494041	F	371	0.61	Y	6/15/2017 8:23
989001005494104	F	480	1.27	Y	6/15/2017 8:23
*	U	129	*	N	6/15/2017 8:23
989001005494089	F	476	1.41	Y	6/16/2017 8:00
989001005494040	F	470	1.16	Y	6/16/2017 8:00
989001005494088	F	519	1.68	Y	6/16/2017 7:37
989001005494091	F	438	0.82	Y	6/16/2017 6:43
989001005494036	F	435	1.09	Y	6/16/2017 6:43
989001005494043	F	529	1.53	Y	6/16/2017 6:43
989001005494038	F	374	0.67	Y	6/16/2017 6:26
989001005494100	F	537	1.76	Y	6/16/2017 6:26
989001005494100	F	536	1.78	N	6/21/2017 8:26
989001005493738	F	489	1.51	Y	6/20/2017 8:10
989001005494053	F	483	1.56	Y	6/20/2017 8:22
989001005494057	F	517	1.59	Y	6/20/2017 8:22

*	U	85	*	N	6/20/2017 9:00
*	F	529	1.65	N	6/21/2017 11:15
*	U	95	*	N	6/27/2017 8:05
*	U	107	0.02	N	6/28/2017 9:36
*	U	86	*	N	6/28/2017 9:36
*	U	109	0.01	N	6/28/2017 9:36
*	U	118	0.01	N	6/28/2017 9:36
*	U	92	*	N	6/28/2017 8:00
*	U	95	*	N	6/28/2017 9:00
*	U	120	0.01	N	6/30/2017 8:41
*	U	102	*	N	6/30/2017 11:11
*	U	95	*	N	7/1/2017 8:52
*	U	104	*	N	7/1/2017 8:52
*	U	98	*	N	7/2/2017 7:57
*	U	111	*	N	7/2/2017 9:00
*	U	123	*	N	7/2/2017 8:36
989001005494106	F	490	1.47	Y	6/21/2017 9:25
989001005494103	F	403	0.88	Y	6/21/2017 9:25
989001005494092	F	433	0.95	Y	6/21/2017 9:25
989001005494081	F	483	1.39	Y	6/21/2017 9:25
989001005494034	F	460	1.26	Y	6/21/2017 9:25
989001005494042	M	425	0.72	Y	6/21/2017 9:25
989001005494039	F	553	2.11	Y	6/21/2017 11:15
989001005494061	F	544	1.96	Y	6/21/2017 11:15
989001005494102	F	319	0.39	Y	6/21/2017 11:15
989001005494117	F	539	2.23	Y	6/21/2017 11:15
989001005494084	F	448	1.05	Y	6/21/2017 11:15
989001005494077	F	413	0.81	Y	6/21/2017 11:15
989001005493407	M	476	1.09	Y	6/21/2017 9:25
989001005493790	F	337	0.44	Y	6/22/2017 9:30
989001005493728	F	470	1.27	Y	6/22/2017 9:30
989001005493728	F	476	1.27	N	7/2/2017 9:00
989001005493778	U	394	0.71	Y	6/22/2017 9:30
989001005493742	F	350	0.56	Y	6/22/2017 9:30
989001005493752	F	473	1.2	Y	6/22/2017 10:17
989001005493804	U	151	0.02	Y	6/22/2017 10:17
989001005494044	F	468	1.22	Y	6/22/2017 8:50
989001005494049	F	356	0.52	Y	6/22/2017 8:20
989001005494118	F	555	0.78	Y	6/22/2017 9:33
989001005494108	F	490	0.93	Y	6/22/2017 9:33
989001005494070	F	423	0.94	Y	6/22/2017 9:33
989001005494028	F	388	0.72	Y	6/22/2017 9:33

989001005494028	F	389	0.72	N	6/28/2017 9:49
989001005494074	U	195	0.08	Y	6/22/2017 9:33
989001005494076	F	457	1.2	Y	6/22/2017 9:33
989001005494029	F	312	0.34	Y	6/22/2017 9:33
989001005494051	F	386	0.68	Y	6/22/2017 9:33
989001005494071	F	396	0.76	Y	6/22/2017 9:33
989001003072801	F	511	1.27	Y	6/22/2017 9:33
989001005493810	M	340	0.43	Y	6/23/2017 6:17
989001005493800	F	490	1.5	Y	6/23/2017 7:08
989001005494090	F	295	0.26	Y	6/23/2017 7:50
989001005494095	F	381	0.68	Y	6/23/2017 8:30
989001005493783	F	419	0.88	Y	6/27/2017 8:05
989001005493766	U	115	0.05	Y	6/27/2017 8:05
989001005493787	F	397	0.78	Y	6/27/2017 9:19
989001005494115	F	352	0.4	Y	6/28/2017 9:36
989001005494122	F	349	0.37	Y	6/28/2017 9:36
989001005494119	U	162	0.04	Y	6/28/2017 9:36
989001005493792	F	390	0.75	Y	6/28/2017 8:00
989001005493751	F	350	0.53	Y	6/28/2017 8:00
989001005493802	U	113	*	Y	6/28/2017 8:00
989001005493796	F	493	1.3	Y	6/28/2017 9:00
989001005493809	F	472	1.25	Y	6/28/2017 9:00
989001005493809	F	474	1.23	N	6/29/2017 9:21
989001005493817	F	324	0.38	Y	6/28/2017 9:00
989001005493805	F	364	0.67	Y	6/28/2017 9:49
989001005493788	F	299	0.33	Y	6/28/2017 9:49
989001005493793	F	422	1.07	Y	6/28/2017 9:49
989001005493731	F	470	1.26	Y	6/28/2017 9:49
989001005493729	F	554	2.08	Y	6/28/2017 9:49
989001005493803	U	138	0.03	Y	6/28/2017 9:49
989001005493486	F	473	1.07	Y	6/28/2017 9:49
989001005493775	F	433	1.11	Y	6/29/2017 10:15
989001005493791	F	435	0.9	Y	6/29/2017 7:29
989001005493771	M	325	0.27	Y	6/29/2017 7:29
989001005494037	F	462	1.09	Y	6/30/2017 10:53
989001005494064	U	135	0.03	Y	7/1/2017 8:52
989001005494067	F	475	0.95	Y	7/1/2017 8:52
989001005494060	F	330	0.38	Y	7/1/2017 8:52
989001005494101	F	355	0.53	Y	7/1/2017 8:52
989001005494052	F	358	0.49	Y	7/1/2017 9:38
989001005494058	F	370	0.77	Y	7/2/2017 7:57
989001005494085	F	473	1.24	Y	7/2/2017 7:57

989001005493454	F	550	1.21	Y	7/2/2017 10:17
989001005494050	F	426	0.91	Y	10/11/2017 8:40
989001005494062	F	380	0.67	Y	10/11/2017 8:40

*Data not collected or recorded, or PIT tag not inserted

5.8 Hook and line data

<i>Location</i>	<i>Start Date/Time</i>	<i>End Date/Time</i>
S. lake by paleo, snow creek bay	3/5/2015 15:30	3/5/2015 17:15
S. end before paleo channel	3/18/2015 11:15	3/18/2015 12:15
Snow creek bay	3/19/2015 10:45	3/19/2015 11:45
Snow creek bay	3/19/2015 15:16	3/19/2015 16:33
Snow creek bay	3/27/2015 13:29	3/27/2015 14:10
Snow creek bay	4/4/2015 14:05	4/4/2015 15:02
N41 30.939 W119 03.365***	4/11/2015 15:00	4/11/2015 15:40
11T0327291 4598810**	5/9/2015 10:00	5/9/2015 11:15
*	3/27/2015 11:00	3/27/2015 11:50
11T0328035 4597147**	6/30/2017	6/30/2017

*Data not collected or recorded

**GPS coordinates are North American Datum of 1983 (NAD 83)

*****GPS coordinates are latitude and longitude

5.9 Hook and line capture data

<i>PIT</i>	<i>Sex</i>	<i>FL (mm)</i>	<i>Weight (kg)</i>	<i>New Tag</i>	<i>Location</i>	<i>Date/Time</i>
900118001564725	M	640	*	Y	S. lake by paleo, snow creek bay	3/5/2015 17:15
989001003072279	M	552	2.12	Y	Snow Creek Bay	4/4/2015 15:02
989001003072235	M	479	1.3	Y	Snow Creek Bay	4/4/2015 15:02
989001003072250	M	633	3.22	Y	Snow Creek Bay	4/4/2015 15:02
900118001562678	U	595	2.45	Y	Snow Creek Bay	3/27/2015 14:10
989001005494120	F	501	1.59	Y	GPS: 11T0328035 4597147	6/30/2017

*Data not collected or recorded