Annual assessment of June Sucker spawning population abundance and survival in Utah Lake 2008 – 2019

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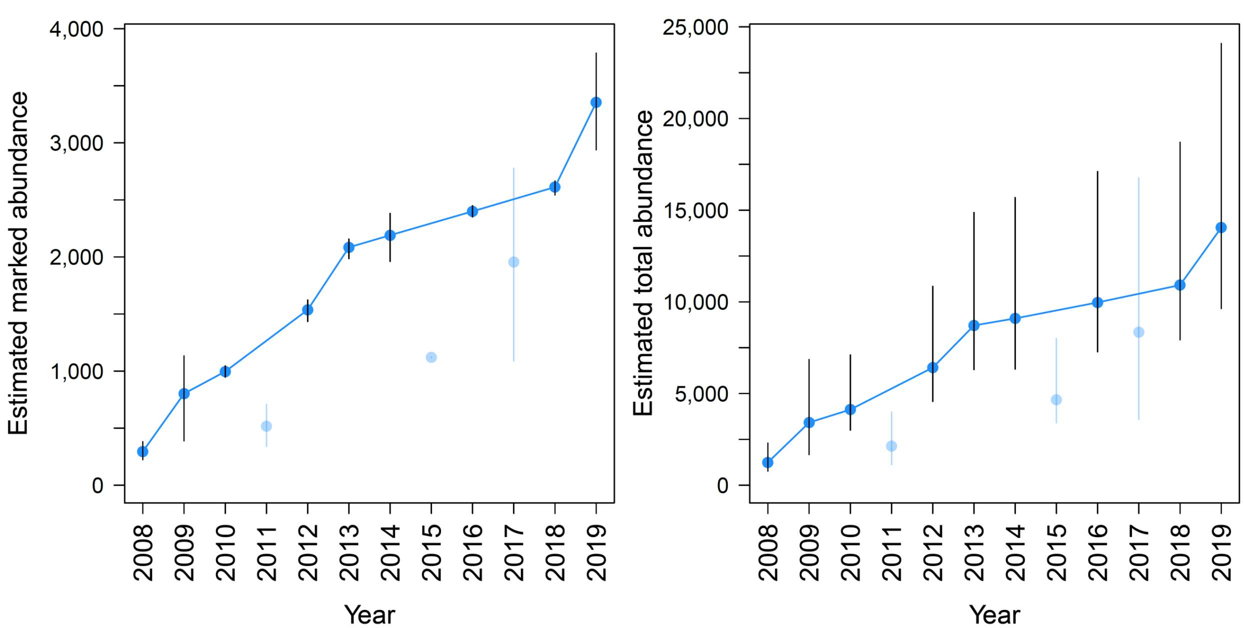
Summary

1. As a federally protected fish species in Utah Lake, UT, the June sucker (*Chasmistes liorus*) has been the focus of intense conservation and management efforts.
2. Annual PIT tag mark-recapture data were collected 2008-2019 using stationary antennae and trammel-nets to monitor the Utah Lake June sucker spawning population abundance and survival response to management actions.
3. Here, we applied a Huggins formulation of the robust-design, closed-capture model to achieve abundance and survival estimates using combined data from the three primary spawning tributaries, the Provo River, the Spanish Fork River, and Hobble Creek.
4. Estimated survival probability for PIT tagged spawning adults averaged 90% across years, with minor differences among years. Abundance estimates for PIT tagged adults showed a substantial increase from around 300 in 2008, to 3,400 individuals by 2019.
5. We developed a preliminary model to estimate total abundance (PIT tagged plus untagged) by combining an annual range of observed percentages of PIT tagged adults, with annual mark-recapture abundance estimates. Our results suggested total abundance in 2019 was around 14,000 individuals, with large confidence intervals of 9,600 to 24,000 due to high uncertainty in the percentage of PIT tagged individuals.
6. We provided a clear record of our modelling endeavors so they may be replicated, and recommend future efforts continue to refine our initial model to achieve total (PIT tagged plus untagged) annual spawning population abundance estimates.
7. Collectively, our results showed that conservation and management efforts have driven high annual survival, and a substantial increase in abundance since 2008.



Summary Figure. Annual abundance estimates and 95% CI's for marked (PIT tagged), and total (PIT tagged plus untagged) June sucker spawners in Utah Lake. Transparent blue points reflect year estimates where antennae failures caused incomplete data.

Background

As a federally protected fish species in Utah Lake, UT, the June sucker (*Chasmistes liorus*) has been the focus of intense conservation and management efforts (Andersen et al. 2007). Likewise, monitoring efforts to measure the response of the Utah Lake June sucker have been intense, including efforts to monitor spawning population abundance and survival response to management implementation (Fonken 2018). June suckers have long been known to exhibit spring spawning migrations into the primary Utah Lake tributaries each year (Keleher et al. 1998, Buelow 2006), and have been most consistently found in the Provo River, Hobble Creek, and Spanish Fork tributaries over recent years (Conner and Landom 2018, Fonken 2018). Managers initiated a mark-recapture monitoring protocol in 2008, by marking suckers with passive integrated transponder tags (PIT tags), and detecting/recapturing them during the annual spring spawning migration using stationary PIT tag antennae receivers placed within the tributary habitats. The monitoring protocol proved effective at providing sound annual estimates of abundance and survival using mark-recapture model analyses, but refinement of analyses, and efforts to automate the process of accomplishing the analyses were recommended for future endeavors (Conner and Landom 2018).

Previous mark-recapture results reflected the marked (PIT tagged) spawning population abundance estimates. However, monitoring data have shown that only a small percentage of adults possessed a PIT tag (Fonken 2018), which suggests mark-recapture results substantially underestimate the total spawning population abundance. As an important component to ongoing June sucker Population Viability Analyses (Conner *in progress*), refinement of abundance estimates is most desirable. Additionally, data processing and mark-recapture modelling can be an extremely time consuming effort, and therefore hinder the process of producing important annual updates for mangers.

Here, we refined previous mark-recapture estimates of annual abundance and survival for the Utah Lake June sucker spawning population, and developed a model to extrapolate marked abundance to total abundance estimates (PIT tagged plus untagged). We accomplished all data processing, mark-recapture modelling, and output of results in both table and graph form using a free software computer program code. Our computer code automates the majority of the data processing and analysis process, which will substantially reduce the time required to update our analyses and results in the future with additional years of data.

Methods

Fish stocking, tagging, and sampling

Stocking of hatchery reared and refuge population June sucker into Utah Lake has been an integral component of conservation efforts since the mid-1990s (Andersen et al. 2007, Billman and Crowl 2007), and the majority of the spawning population is of stocking origin (Fonken 2018). All suckers were marked in some manner prior to being stocked into Utah Lake to provide origin information. However, marking with PIT tags that are compatible with the instream antennae system (134.2 kHz PIT tags) was not initiated until 2007. As June sucker are believed to live up to 40 years (Belk 1998), there are likely many stocked prior to 2007 that have survived and contribute to the spawning population, but do not have tags that can be detected by the antennae. Additionally, beginning in 2007, hatchery protocol improvements lead to extremely high production of suckers available for stocking, which drove costs for PIT tagging all individuals to unfeasible financial levels. In response, managers marked large batches of fish with an inexpensive, coded wire tag (small wire with no individual number), and smaller batches with a 134.2 kHz PIT tag prior to being stocked into Utah Lake. As a result, the stocked population of June sucker that inhabits Utah Lake is represented by a mix of individuals with tags that can be detected by the antennae system, and those that cannot, until physical capture may provide the means to give compatible tags to those individuals.

Throughout the course of each sampling year, biologists have given antennae compatible PIT tags to all physically captured June suckers found to be untagged. However, sampling specifically for mark-recapture monitoring occurred during the spring season at selected locations. June sucker physical captures and antennae recaptures were accomplished at the three primary Utah Lake spawning tributaries, the Provo River, the Spanish Fork, and Hobble Creek. Physical capture was accomplished primarily using trammel-nets that were set at the tributary mouths during the months of April through July. During low discharge years, physical capture was also accomplished, primarily in the Provo River, using hand held dip nets, and boat electrofishing was applied in the Provo River during 2018. The antennae systems were stationary within the tributary habitats and were maintained to collect potential recapture data continuously throughout the spawning season (Fonken 2018).

Data processing and analyses

Initial June sucker PIT tag capture and recapture data were extracted from the Microsoft Access® June sucker database and provided to us by the Utah Division of Wildlife in a Microsoft Excel® spreadsheet. Minor reformatting to standardize variables, such as sample location names or sampling methods, within the PIT tag data set was necessary to support data manipulation and analyses (see Landom & Conner 2020, supplemental information). All data processing, mark-recapture modelling, and tables or graphs of results were accomplished using the R Statistical Computing Environment (R Core Team 2017). Mark-recapture models were accomplished using the `RMark' package (Laake 2013), and we wrote additional code to output graphs of results in pdf form, and to output a Microsoft Excel® spreadsheet containing results. The R code we accomplished provides the framework for duplication of all analyses and results provided heir in, even following the addition of multiple years of data, with minimal time and effort (see Landom & Conner 2020, supplemental information).

Based on our previous assessments of Utah Lake June sucker spawning population PIT tag data (Conner 2017, Conner and Landom 2018), we applied a Huggins formulation of the robust-design model to estimate annual abundance and survival, using combined data from the Provo River, the Spanish Fork River, and Hobble Creek. As robust-design models require a closed-capture time period, and capture sessions within that time period, we defined May and June as the closed-capture period because the majority of encounters occurred during these months, and we defined capture sessions as the first and second half of each month within the closed-capture period (4 total capture sessions). Therefore, only encounters that occurred at the Provo River, the Spanish Fork River, and Hobble Creek, and happened during the month of May or the month of June were included in our analyses. We also applied a previous capture individual covariate, to account for the fact that individuals who already possessed a PIT tag, such as those that were stocked with a 134.2 kHz PIT tag prior to being encountered during the spawning run, had an extremely high capture probability on the antennae systems, which was shown to drive low-biased abundance estimates in previous analyses (Conner and Landom 2018). We also excluded encounters for initial tagging years, such as when untagged fish were captured and given their first PIT tag, but included all encounters for those fish in subsequent years. The exclusion of initial tagging encounters was necessary to avoid double counting of untagged fish when applying our preliminary total abundance model.

We applied a robust approach to estimating survival and abundance parameters, by developing a suite of *a priori* models that *could* best describe the mark-recapture relationships, running all possible combinations of *a priori* models, and model averaging the results (Cooch and White 2019). The *a priori* models defined potential relationships such as survival varying from year to year, the probability of movement from an “observable” to “unobservable” state (Kendall 2019) varying from year to year, and the probability that capture and recapture probabilities varied among all years and capture session combinations. After running all possible combinations of *a priori* models, we applied the model-weights (relative importance of each model) to generate model-averaged parameter estimates. Our approach accounts for model selection uncertainty (Cooch and White 2019), and is particularly fitting for automating mark-recapture analyses, which is a goal for this study, as model-averaging will account for potential changes in relationships due to the addition of new data.

We developed a preliminary model to estimate total abundance (PIT tagged plus untagged) by combining an annual range of observed percentages of PIT tagged adults, with our annual mark-recapture abundance estimates. The range of percent PIT tagged was acquired from physical capture sampling of adults within the tributary habitats (primarily the Provo River) during the spawning run across the years 2008-2018. We applied a bootstrap sampling computer simulation (1000 simulations), to estimate total abundances for each year, by applying all possible percent PIT tagged scenarios that fell within the observed range, to each annual mark-recapture abundance estimate and the error around that estimate. The primary assumption of our preliminary total abundance model, is that the *true* percent PIT tagged for each year falls somewhere within the range we simulated.

Results and discussion

Model selection, and survival estimates

The top mark-recapture model was heavily weighted over all other possible models, and included a parameter for movement of individuals into an unobservable state, that varied among sample years (Table 1.). Further exploration suggested our results may have driven by incomplete data rather than true movement. For instance, extremely high tributary flows led to antennae failures during the years 2011 and 2017 (Fonken 2018), and electronic malfunctions resulted in antenna data loss in 2015 (Seegert 2015). The disturbances in data collection drove an artificial annual movement relationship within the mark-recapture models. As a result, the model-averaged survival probability confidence intervals were confounded during some years (Figure 1). However, model-averaged survival estimates were high for PIT tagged spawning adults, averaging 90% across years, with minor differences among years (Figure 1).

Mark-recapture, and total abundance

As our mark-recapture assessments are based on spawning adult June suckers, which are on average larger in body size than the full range of body sizes captured within the Utah Lake habitat (Figure 2), we applied PIT tag percentages from spawner data only, to support our total abundance model. The percent of adults captured within the tributary habitats that possessed a 134.2 kHz PIT tag ranged from 13.5% to 33% across the sampling years 2008-2018 (Figure 2). Model-averaged mark-recapture abundance estimates for PIT tagged adults showed a clear trend of increasing abundance from around 300 in 2008, to 3,400 individuals by 2019 (Figure 3). The loss of data in 2011, 2015, and 2017, drove an artificial dip in abundance estimates for those years specifically, but did not affect estimates for years when data collection was fully functional. Our total abundance model results showed the same increasing trend from 2008 through 2019 as our mark-recapture abundance results (Figure 3). However, the total abundance estimate for 2019 was around 14,000 individuals, with large confidence intervals of 9,600 to 24,000 individuals, due to high uncertainty in the percentage of PIT tagged individuals (Figure 3).

Table 1. Model selection results from PIT tag mark-recapture analysis for the June sucker spawning population in Utah Lake. Analysis used a Huggins closed-capture robust model in RMark.

model	npar	AICc	DeltaAICc	weight	Deviance
S(~-1 + time)Gamma''(~-1 + time)Gamma'(~-1 + time)p(~-1 + session:time + prevcap:pint + c:beforelast:session:time + prevcap:pint + c)c()	106	82508.99	0.00	0.637025107	82296.1
S(~-1 + time)Gamma''(~-1 + time)Gamma'(~1)p(~-1 + session:time + prevcap:pint + c:beforelast:session:time + prevcap:pint + c)c()	97	82510.11	1.12	0.362974863	82315.4
S(~-1 + time)Gamma''(~-1 + time)Gamma'()p(~-1 + session:time + prevcap:pint + c:beforelast:session:time + prevcap:pint + c)c()	96	82543.06	34.07	2.54902E-08	82350.3
S(~-1 + time)Gamma''(~-1 + time)Gamma'(~1)p(~-1 + session:time + prevcap + c:beforelast:session:time + c:prevcap)c()	97	82546.27	37.28	5.11585E-09	82351.5
S(~-1 + time)Gamma''(~1)Gamma'(~1)p(~-1 + session:time + prevcap:pint + c:beforelast:session:time + prevcap:pint + c)c()	86	82567.36	58.37	1.34768E-13	82394.8
S(~-1 + time)Gamma''(~-1 + time)Gamma'()p(~-1 + session:time + prevcap + c:beforelast:session:time + c:prevcap)c()	96	82671.17	162.18	0	82478.5
S(~-1 + time)Gamma''(~1)Gamma'(~1)p(~-1 + session:time + prevcap + c:beforelast:session:time + c:prevcap)c()	86	82686.94	177.96	0	82514.4
S(~-1 + time)Gamma''(~-1 + time)Gamma'(~-1 + time)p(~-1 + session:time + prevcap + c:beforelast:session:time + c:prevcap)c()	106	82817.94	308.95	0	82605.1
S(~-1 + time)Gamma''(~1)Gamma'(~1)p(~-1 + session:time + prevcap + c:prevcap)c()	62	83247.33	738.34	0	83123.0
S(~-1 + time)Gamma''(~-1 + time)Gamma'()p(~-1 + session:time + prevcap + c:prevcap)c()	72	83254.95	745.96	0	83110.5
S(~-1 + time)Gamma''(~-1 + time)Gamma'(~1)p(~-1 + session:time + prevcap + c:prevcap)c()	73	83263.82	754.83	0	83117.4
S(~-1 + time)Gamma''(~-1 + time)Gamma'(~-1 + time)p(~-1 + session:time + prevcap + c:prevcap)c()	82	83279.51	770.52	0	83115.0

Model notation:
time=across years (May and June closed-capture periods)
Gamma''=(movement) probability that the animal *was* present, but not encountered, and survived to the next year
Gamma'=(movement) probability that the animal *was not* present, and therefore not encountered, yet survived to the next year
session=capture sessions within closed-capture periods, 2 in May and 2 in June
prevcap=individual covariate for fish that already had a PIT tag
p=capture probability
c=recapture probability
pint=initial capture probability
beforelast=probability that capture probability, and recapture probability are equal on the final capture session within each year

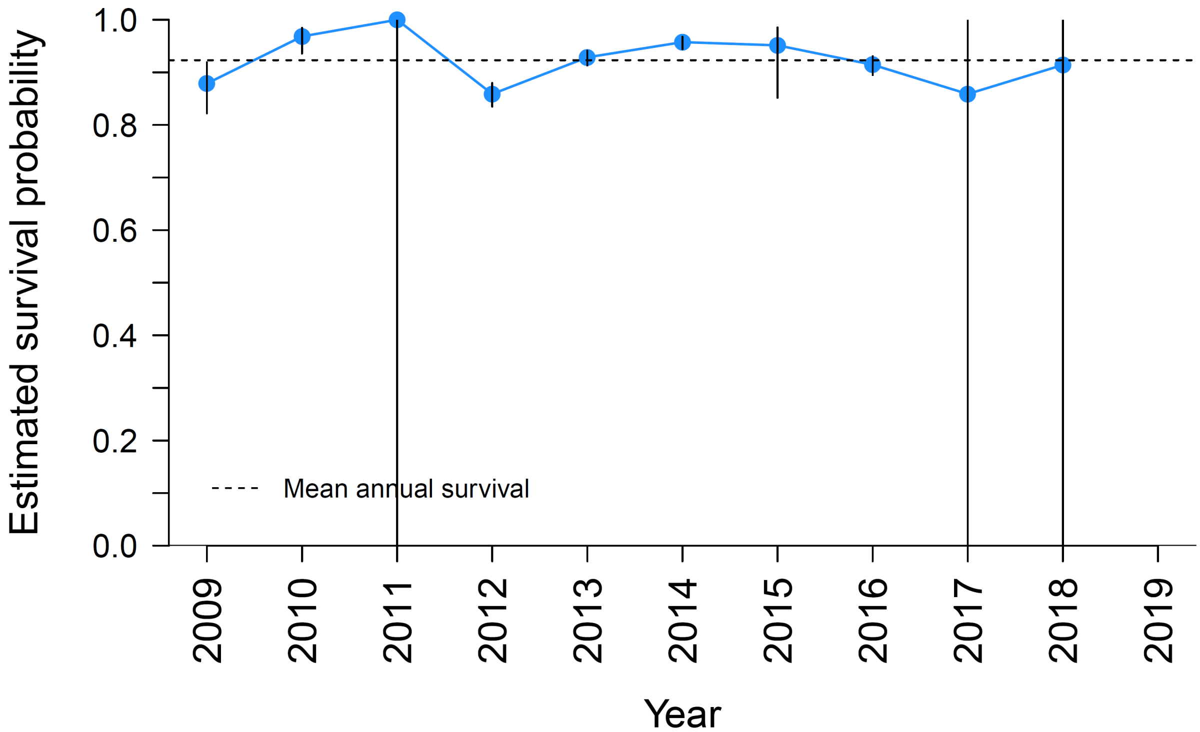


Figure 1. Estimates of annual survival and 95% confidence intervals for the June sucker spawning population in Utah Lake achieved using a Huggins formulation of the closed-capture robust model. Final sampling year estimates are mathematically biased and therefore not depicted.

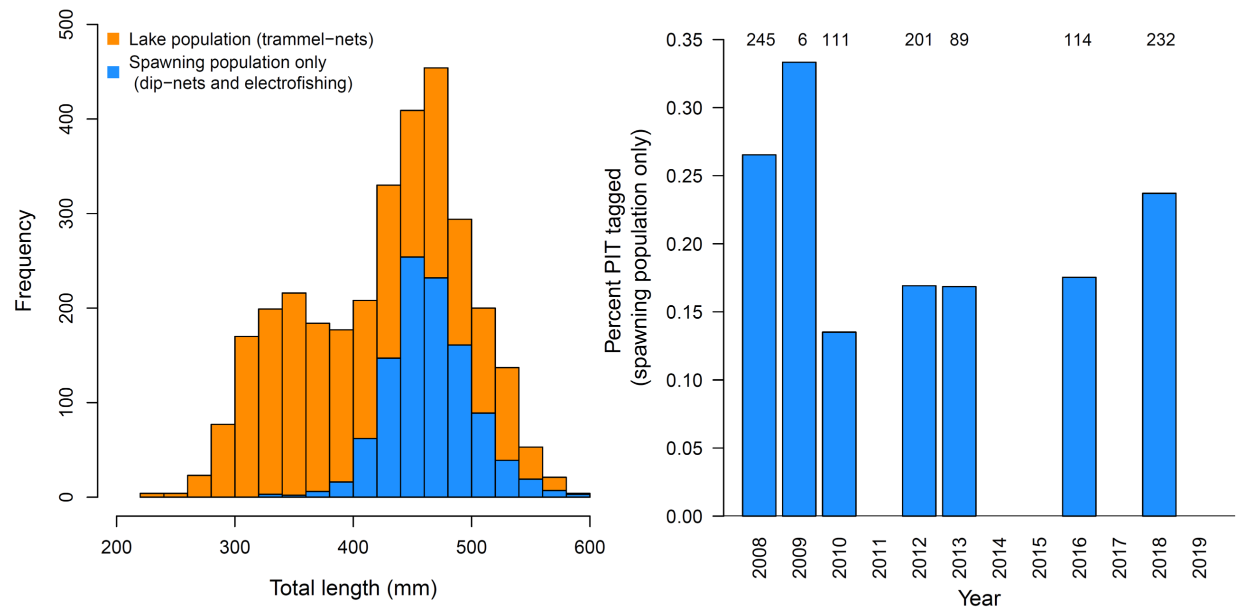


Figure 2. Length frequency comparison (left panel) between June suckers captured in the lake habitat of Utah Lake 2008-2019, and those captured within the tributary habitat (primarily the Provo River) during the spawning run 2008-2018. The percentage of adults captured (right panel) within the tributary habitat (primarily the Provo River) that possessed a 134.2 kHz PIT tag 2008-2018 (total sample size depicted above each year).

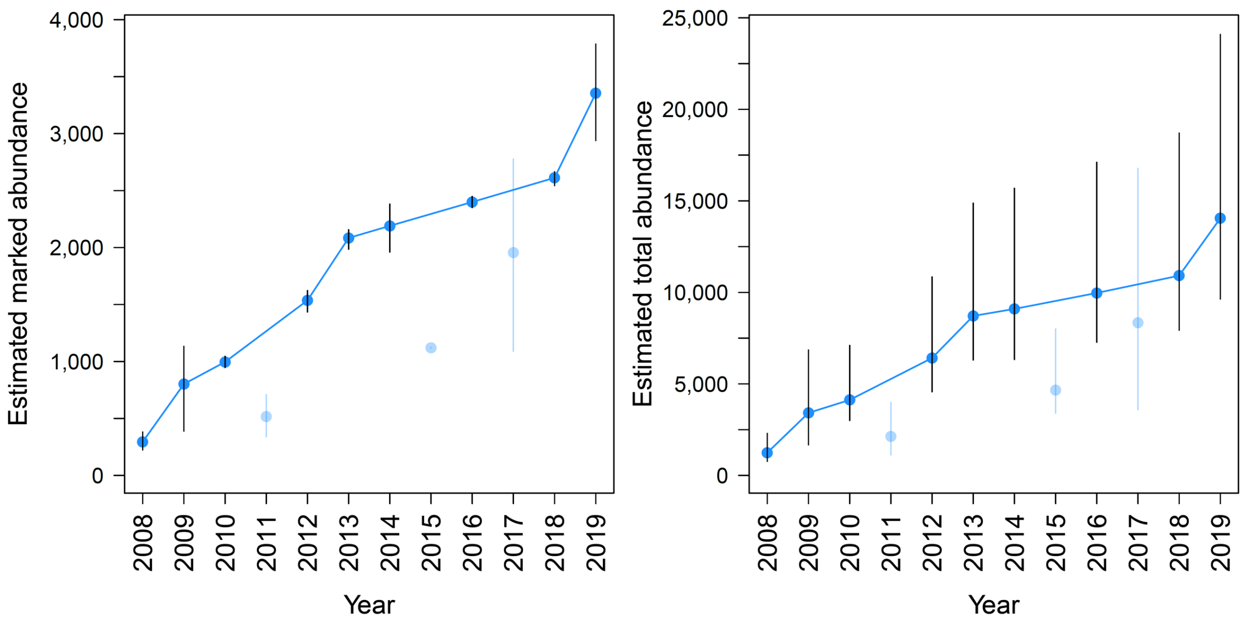


Figure 3. Model-averaged annual abundance estimates (left panel) and 95% confidence intervals for marked (PIT tagged) individuals of the June sucker spawning population in Utah Lake, achieved using a Huggins formulation of the closed-capture robust model. Total (PIT tagged plus untagged) annual abundance estimates (right panel) and 95% confidence intervals for the June sucker spawning population in Utah Lake, achieved by applying computer bootstrap simulations of the range of observed annual PIT tagged adult percentages (13%-33%), to the mark-recapture abundance estimates (left panel). Transparent blue points reflect year estimates where antennae failures caused incomplete data.

Recommendations and conclusions

1. The process of formatting data exported directly from the June sucker database so that it is compatible with the computer code we have written is not automated. Although we, partially because of institutional knowledge and extensive experience in formatting data in general, do not find the tasks of formatting this data to be arduous, we do believe the formatting steps required could be reduced with additional work. We suggest working directly with the database manager on the data extraction, and/or adding some additional data formatting computer code, could prove beneficial toward improving automation of future work related to this project.
2. Important mark-recapture data were lost throughout the course of this study due to antennae failure, either caused by high discharge or electronic issues. However, the June Sucker Recovery Program has recently installed high quality antennae systems that are unlikely to be damaged by high water or experience electronic failures. Therefore, we do not anticipate future mark-recapture data loss to be an issue of concern.
3. We consider our total abundance model (PIT tagged plus untagged) to be preliminary. Our total abundance model is based on mark-recapture abundance estimates, which are mathematically robust, and a range of percentages of adults that are actually PIT tagged, which is highly uncertain. Although we believe our total abundance model is mathematically sound, a potential shortcoming of our approach is the assumption of similar percentages across years. We recommend continued refinement of our total abundance modelling approach be incorporated into future extensions of this study, with a particular mathematical emphasis on achieving percent PIT tagged estimates for adult spawners within each year individually.
4. Collectively, our results showed that conservation and management efforts have been successful at achieving high annual survival, and a substantial increase in abundance since 2008. We recognize managers still have many research questions regarding June sucker mark-recapture data, such as survival by stocking origin (e.g., hatchery vs. grow-out ponds), survival by body size, or our observed and currently unexplained documented movements of individual adult suckers among tributaries, both within and among spawning years (Conner and Landom 2018). We recommend pursuing such research questions as the results may prove valuable toward informing management decisions. However, the goal of this project was to provide managers with the June sucker spawning population abundance and survival estimates in Utah Lake, estimates that reflect the cumulative results of previous management decisions.

Acknowledgements

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Literature cited

Andersen, M. E., C. J. Keleher, J. E. Rasmussen, E. S. Hansen, P. D. Thompson, D. W. Spears, M. D. Routledge, and T. N. Hedrick. 2007. Status of June sucker in Utah Lake and refuges. American Fisheries Society Symposium **53**:39-58.

Belk, M. C. 1998. Age and growth of June sucker (*Chasmistes liorus*) from otoliths. Great Basin Naturalist **58**:390-392.

Billman, E. J., and T. A. Crowl. 2007. Population dynamics of a June sucker refuge population. Transactions of the American Fisheries Society **136**:959-965.

Buelow, K. A. 2006. Movement behavior and habitat selection of the endangered June sucker (Chasmistes liorus) in Utah Lake, Utah. M.S. thesis. Utah State University, Logan, Utah.

Conner, M. 2017. Estimation of population size, survival, and rate of population change for the spawning population of June Suckers in Utah Lake using mark-recounter data. Department of Wildland Resources, Utah State University.

Conner, M., and K. Landom. 2018. Population size, survival, and population growth rate, and evaluation of monitoring efforts for the spawning population of June suckers in Utah Lake 2008-2016. Utah State University, Department of Wildland Resources and Ecology Center.

Cooch, E. G., and G. C. White. 2019. Program Mark: A Gentle Introduction. 19 edition.

Fonken, D. 2018. Monitoring trends in Utah Lake sucker populations: 2018 Report to the June Sucker Recovery Program. Utah Division of Wildlife Resources, Springville, UT.

Keleher, C. J., L. D. Lentsch, and C. W. Thompson. 1998. Evaluation of flow requirements for June Sucker (*Chasmistes liorus*) in the Provo River: an empirical approach., Utah Division of Wildlife Resources, Salt Lake City, Utah.

Kendall, W. L. 2019. The 'robust design'. Pages 15-01 - 15-48 *in* E. Cooch and G. C. White, editors. Program MARK: A Gentle Introduction.

Laake, J. L. 2013. RMark: An R Interface for Analysis of Capture-Recapture Data with MARK. AFSC Processed Rep 2013-01, Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

Landom, K., and M. Conner. 2020. June Sucker spawning population mark-recapture model supplemental information. Ecology Center and Watershed Sciences Department, and Department of Wildland Resources, Utah State University.

R Core Team. 2017. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Seegert, S. 2015. Monitoring trends in Utah Lake sucker populations. Utah Division of Wildlife Resources, Springville, Utah.

Appendix

Table 2. Model-averaged annual abundance estimates from PIT tag mark-recapture analysis for the June sucker spawning population in Utah Lake, using a Huggins closed-capture robust model in RMark.

Estimate	se	lcl	ucl	year
295	39.62	223	381	2008
802	183.45	389	1132	2009
996	25.17	947	1045	2010
517	94.86	340	709	2011
1536	50.89	1435	1623	2012
2084	45.62	1986	2156	2013
2190	119.87	1961	2381	2014
1120	0.93	1118	1122	2015
2400	24.89	2351	2448	2016
1956	551.16	1089	2777	2017
2612	31.83	2544	2666	2018
3354	221.41	2939	3786	2019

Table 3. Model-averaged annual survival estimates from PIT tag mark-recapture analysis for the June sucker spawning population in Utah Lake, using a Huggins closed-capture robust model in RMark.

Estimate	lcl	ucl	year
0.88	0.82	0.92	2009
0.97	0.94	0.98	2010
1.00	0.00	1.00	2011
0.86	0.83	0.88	2012
0.93	0.91	0.94	2013
0.96	0.94	0.97	2014
0.95	0.85	0.99	2015
0.91	0.89	0.93	2016
0.86	0.00	1.00	2017
0.91	0.00	1.00	2018
0.90	0.00	1.00	2019