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2012 Warner Valley Fish Investigations- Warner Sucker

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PROJECT TITLE: **2012 Warner Valley Fish Investigations- Warner Suckers**

Paul D. Scheerer, Shaun Clements,

Oregon Department of Fish and Wildlife
28655 Highway 34, Corvallis, Oregon 97333

and

James T. Peterson
USGS Oregon Cooperative Fish and Wildlife Research Unit
104 Nash Hall, Oregon State University
Corvallis, OR 97331-3803

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INTRODUCTION

The Warner sucker *Catostomus warnerensis* is endemic to the Warner Valley, a subbasin of the Great Basin in southeastern Oregon and northwestern Nevada. This species was historically abundant (Snyder 1908) and its historical range includes three permanent lakes (Hart, Crump, and Pelican), several ephemeral lakes, a network of sloughs and diversion canals, and three major tributary drainages (Honey, Deep, and Twentymile creeks). Warner sucker abundance and distribution has declined over the past century and it was federally listed as threatened in 1985 due to habitat fragmentation and threats posed by the proliferation of piscivorous non-native game fishes (U.S. Fish and Wildlife Service 1985).

The Warner Valley is a northeast-southwest trending endorheic basin that extends approximately 90 km (Figure 1). The elevation of the valley floor is approximately 1,370 m and the basin is bound by fault block escarpments, the Warner Rim on the west and Hart Mountain and Poker Jim Ridge on the east. The Warner basin was formed during the middle Tertiary and late Quaternary geologic periods as a result of volcanic and tectonic activity (Baldwin 1974). Abundant precipitation during the Pleistocene Epoch resulted in the formation of Pluvial Lake Warner (Hubbs and Miller 1948). At its maximum extent approximately 11,000 years ago, the lake was approximately 100 m in depth and 1,300 km^2 in area (Snyder et al. 1964; Weide 1975).

The Warner sucker inhabits the lakes and low gradient stream reaches of the Warner Valley. The metapopulation of Warner suckers is comprised of two life history forms: lake and stream morphs. The lake suckers display a lacustrine-adfluvial pattern in which they spend most of the year in the lake and spawn in the streams. However, when upstream migration is hindered by low stream flows during drought years or by irrigation diversion dams, lake suckers may spawn in nearshore areas of the lakes (White et al. 1990). Large lake-dwelling populations of introduced fishes likely reduce sucker recruitment by preying on young suckers (U.S. Fish and Wildlife Service 1998). Periodic lake desiccation also threatens the lake suckers. The stream suckers have a fluvial life-history pattern and spawn in the three major tributary drainages (Honey, Deep, and Twentymile Creeks). Threats specific to the stream form include water withdrawals for irrigation and impacts from grazing. Stream suckers recolonized the lakes after past drying events (mid-1930's and early-1990s).

The Recovery Plan for the Threatened and Rare Native Fishes of the Warner Basin and Alkali Subbasin (U.S. Fish and Wildlife Service 1998) sets three recovery criteria for delisting the species. These criteria require that: (1) a self-sustaining metapopulation is distributed throughout the drainages of Twentymile Creek, Honey Creek, Deep Creek (below the falls), and in Pelican, Crump, and Hart Lakes; (2) passage is restored within and among these drainages so that individual populations of Warner suckers can function as a metapopulation; and (3) no threats exist that would likely threaten the survival of the species over a significant portion of its range.

To inform progress towards the first two criteria, our objectives in 2012 were to: 1) describe the abundance, current distribution, and recruitment of Warner suckers in the Warner lakes following several years of drought, 2) PIT-tag lake suckers to assess the magnitude and timing of the spring spawning migration and to evaluate the effectiveness of future passage improvements, and 3) describe movements into tributary streams during the spawning season. In addition, we documented significant mortality in the early life history of suckers in Honey Creek in 2011. To determine whether this phenomenon was a regular occurrence we also assessed summer survival/mortality of stream suckers in Honey Creek. Last, our prior research suggests that our estimates of population size may have been biased by unequal capture probabilities. To assess the extent of this bias we estimated sucker capture probabilities using repeated sampling with backpack electrofishers to estimate bias in the Lincoln-Peterson model used to collect prior abundance estimates and to determine the most appropriate effort for future sampling.

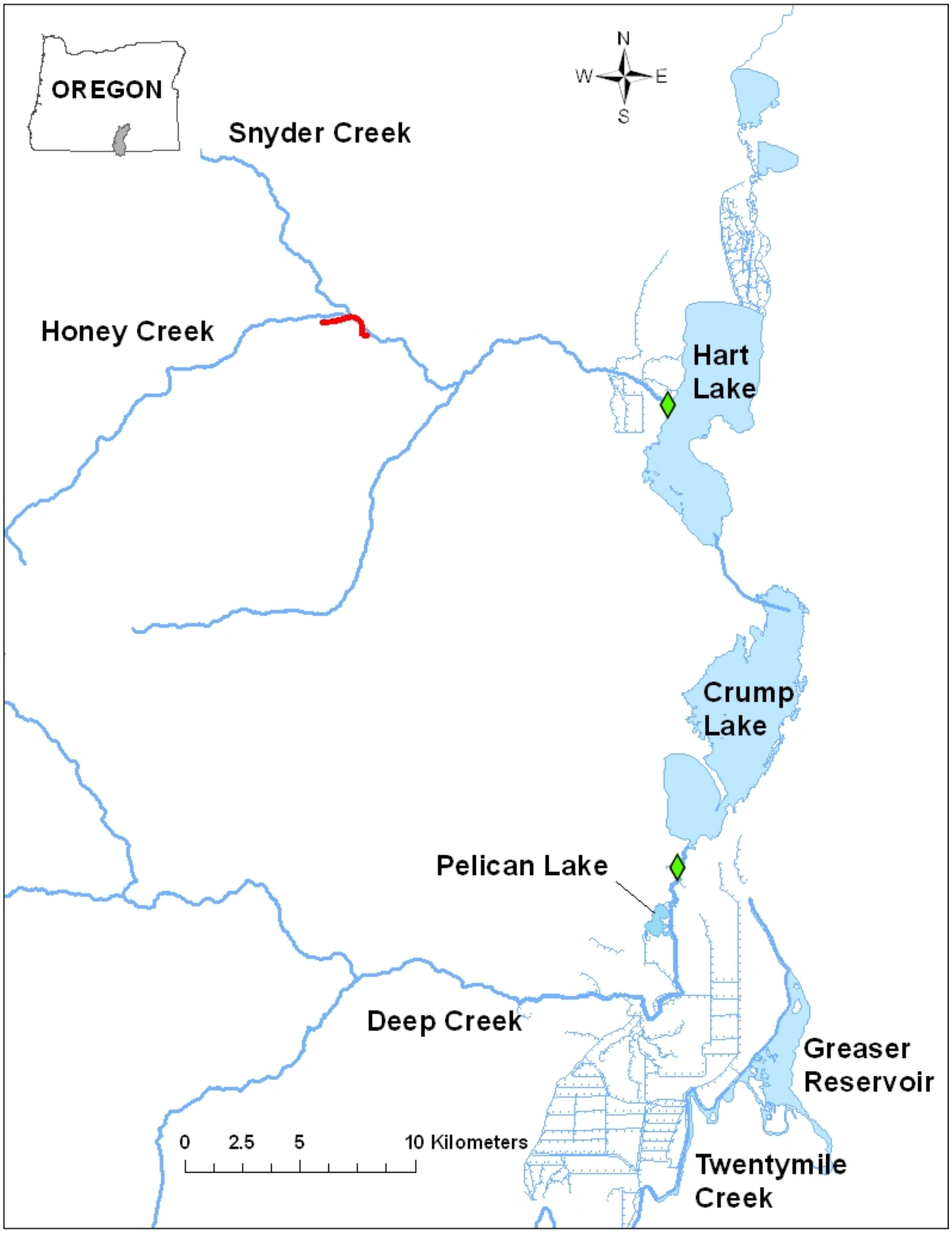

Figure 1. Map of the study area in the Warner basin, Oregon. The green diamonds represent the locations of flat-plate PIT antennas. The study area in Honey Creek is shown by the red shading. Dark blue lines represent the tributaries and light blue stippled lines represent irrigation canals.

METHODS

Distribution, Abundance, and Size Distribution of Suckers in Hart and Crump Lakes

We used trap nets to capture Warner suckers to describe their current distribution and abundance in the Warner Lakes. We sampled in Hart and Crump Lakes between 17 April and 15 June 2012 (24 nets). The trap nets (length: 3.7 m) had a wide rectangular mouth (0.9 m tall by 1.8 m wide) and narrowed to a vertical slot (0.9 m tall by 0.22 m wide), followed by four funneling hoops (0.76 m in diameter)with 0.15 m diameter fyke openings. The lead net was 15 m long by 0.9 m tall. Twenty-two of the nets had 19 mm mesh and two had 13 mm mesh. We set the nets off-shore in pairs, with their lead nets tied together and weighed them down with 3.6-4.5 kg navy anchors. We typically set nets on Mondays, checked and reset them approximately every 24 h during the week, and removed them from the water after checking them on Fridays (four overnight net sets per week). At each trap location, we recorded the time the net was set, the time the net was checked, water depth, water temperature, air temperature, current weather conditions, and trap location. We recorded the trap locations from a hand-held global positioning system (GPS).

We identified all of the fish that we captured to species and counted them. We measured the fork length (FL) of each Warner sucker to the nearest 5 mm and weighed each fish on a spring balance to the nearest 10 g. We also measured the fork length, to the nearest 5 mm, of a subsample of the other species collected (i.e., we measured all fish from one net per lake per week). We determined the sex of each sucker, using a combination of the following characteristics: presence of breeding tubercles, presence of eggs or milt, anal fin morphology (Coombs et al. 1979), and spawning coloration. We checked all Warner suckers for the presence of Passive Integrated Transponder (PIT) tags with a hand held reader. If a tag was present, we recorded the tag code. If none was present, we anesthetized the fish with MS-222 (added ~2.5 ml of 20g/L MS-222 stock solution and 2.5 ml/L of 50 g/l sodium bicarbonate buffer per liter of stream water), made a small ~0.5 cm incision in the ventral cavity, and inserted a half-duplex PIT tag (23 × 3 mm) into the peritoneal cavity. We did not tag fish smaller than 100 mm FL. We disinfected all equipment prior to surgery and applied an antibiotic (iodine) to the scalpel and the tag. Following processing, we allowed the fish to recover in a net bucket placed in a shaded stream location and then released them near their capture location. We obtained information about movement by recapturing tagged suckers using trap nets and from flat-plate PIT-tag antennas that we placed at the mouth of Honey Creek between 19 April 2012 and 19 June 2012 and near the mouth of Deep Creek between 18 April and 14 June 2012 (Figure 1).

We estimated adult sucker abundance using a modified Schnabel model, where the catch (C_t), the number of marked fish at large (M_t), and the number of recaptures (R_t) were tallied by week (Ricker 1975).

Estimating Sucker Capture Probabilities in Honey Creek

In 2011, we found that abundance estimates from Lincoln-Peterson models, when compared to Huggins closed capture and Bayesian models, underestimated sucker abundance by as much as 50% due to heterogeneity in capture probabilities across size classes and between electrofishing passes (Scheerer et al. 2011). Because of a lack of data for Warner sucker, our model used sucker capture probabilities based on prior studies with eastern U.S. suckers (Price and Peterson 2010). To improve the accuracy of our model and to estimate the bias in past estimates, we conducted a capture/recapture survey in Honey Creek during two periods in 2012 (26-28 June and 31 July–2 August 2012). We sampled two adjacent 300 m reaches which were immediately upstream and downstream of the Snyder Creek confluence. We used a backpack electrofisher to capture suckers on three consecutive days during each sampling period. We did not deploy block nets during the survey. We processed suckers every 100 m and released them back to the approximate location from which they were captured. We anesthetized all suckers using MS-222, measured FL, weighed to nearest 5 g, and marked them with a different partial fin clip on each sample date (upper caudal, lower caudal, dorsal, right pectoral, and left pectoral). We scanned each sucker ≥100 mm FL for PIT tags and recorded detections of previously-installed PIT tags from prior years. During each subsequent electrofishing pass, we recorded the number of marked and unmarked suckers and which fin or fins were marked, if any. We scanned each fish for an existing PIT tag.

Following the third pass in each sampling period, we collected habitat data in each 100 m stream section including: wetted width (m), average depth (m), maximum depth (m), aquatic vegetation (as a percentage of total surface area), dominant substrate type, percent pools, and number of pools. Width, depth, substrate and aquatic vegetation measurements were taken at transects located every 100 m, starting approximately 50 m from the downstream boundary of each stream section. We calculated average depth by summing depth measurements collected at 25, 50, and 75% of the wetted width and dividing by four, to account for zero depth at the stream margins. Maximum depth was the single deepest water depth measured in each 100 m stream section. We determined the dominant substrate from seven equally-spaced points along each transect. At each point (100 mm circle), we recorded whether the majority of the substrate was fines (<0.063 mm), sand (0.063-2 mm), gravel (3-64 mm), cobble (65-256 mm), boulder (>256 mm), bedrock (native consolidated rock), or embedded. We recorded stream temperature at the beginning, middle, and end of the 600 m reach, recorded Universal Transverse Mercator (UTM) coordinates every 100 m and at each habitat transect, and recorded UTM coordinates and took photographs at the beginning of each 100 m stream segment.

Assessing Summer Survival of Suckers in Honey Creek

We used results from the repeated sampling in late-June and late-July (above) to evaluate changes in juvenile sucker abundance and size composition during the summer. We compared length-frequency distributions and abundance of juvenile suckers between sampling occasions to determine whether the juvenile sucker summer mortality that we observed in the summer of 2011 (Scheerer et al. 2011) occurs regularly and could be a life history bottleneck for this stream population. We estimated abundance using two methods and compared them to identify potential biases. First, we estimated sucker abundance for both sampling periods using a single-sample mark-recapture procedure (Ricker 1975). We also estimated abundance for the two sample periods and survival between time periods using the Robust Design (Pollock 1982) with the Huggins closed capture model in program MARK (White and Burnham 1999). The Robust Design consists of primary and secondary sampling periods. Multiple secondary samples are collected within primary sample periods to estimate abundance, with the assumption that sample sites are closed to emigration and immigration. Sites are assumed to be open between primary periods and apparent survival is estimated for these intervals. The Robust Design can also be used to estimate temporary emigration. However, we did not have a sufficient number of primary sample periods to estimate temporary emigration, so we fixed the parameter to zero. This means that the apparent survival represents both true survival and loss of individuals due to emigration. We fit several Robust Design models to evaluate the effect of body size and habitat characteristics on capture probability and apparent survival and selected the best model using Akaike's Information Criteria with small sample bias adjustment (AICc; Burnham and Anderson 2002).

RESULTS

Distribution and Abundance of Warner Suckers in the Warner Lakes

Most of the Warner suckers that we captured in the Warner Lakes were collected from locations on the west side of Hart Lake near the mouth of Honey Creek (Figure 2), and in the Crump Lake, near the mouth of Deep Creek (Figure 3), although we did not trap all parts of the lake with equal effort. This is similar to results from prior ODFW sampling (Scheerer et al. 2006; 2008; 2010). Sucker trap net catch in Hart Lake was substantially higher than recent catch since 2006, yet the 2012 CPUE was still one of the lowest on record, and a fraction of the peak CPUE's in 1990, 1996, 1999, and 2001 (Table 1).

Table 1. Warner sucker CPUE for trap nets fished in Hart and Crump Lakes, 1990-2012.

	Number of suckers		Number of trap nights		Suckers per trap night	
Year	Hart	Crump	Hart	Crump	Hart	Crump
1990	190	16	122	9	1.6	1.8
1991	103	0	175	-	0.6	-
1993	0	-	70	-	0.0	-
1994	93	3	40	15	2.3	0.2
1995	19	1	104	40	0.2	0.0
1996	835	11	252	36	3.3	0.3
1997	193	2	137	60	1.4	0.0
1998	0	0	2	2	0.0	0.0
1999	201	2	9	8	22.3	0.3
2001	176	5	63	24	2.8	0.2
2004	0	1	0	6	-	0.2
2005	0	0	9	14	0.0	0.0
2006	41	60	214	238	0.2	0.3
2008	76	27	473	258	0.2	0.1
2010	-	30	-	199	-	0.2
2012	148	37	432	276	0.4	0.1

We obtained an abundance estimate of 1,378 adult suckers (95% CI: 705-2,650) in Hart Lake (**APPENDIX A**). Precision was low due to the low number of recaptured suckers (5 out of 148 marked). We were unable to obtain an estimate in Crump Lake, as none of the suckers we marked there were recaptured in Crump Lake. Interestingly, a female sucker (230 mm) marked in the south end of Crump Lake was recaptured 15 d later near the mouth of Honey Creek in Hart Lake, a distance of ~22 km (~1.5 km/d). This is the first marked sucker that we have documented moving between the lakes since we started our surveys in 2006.

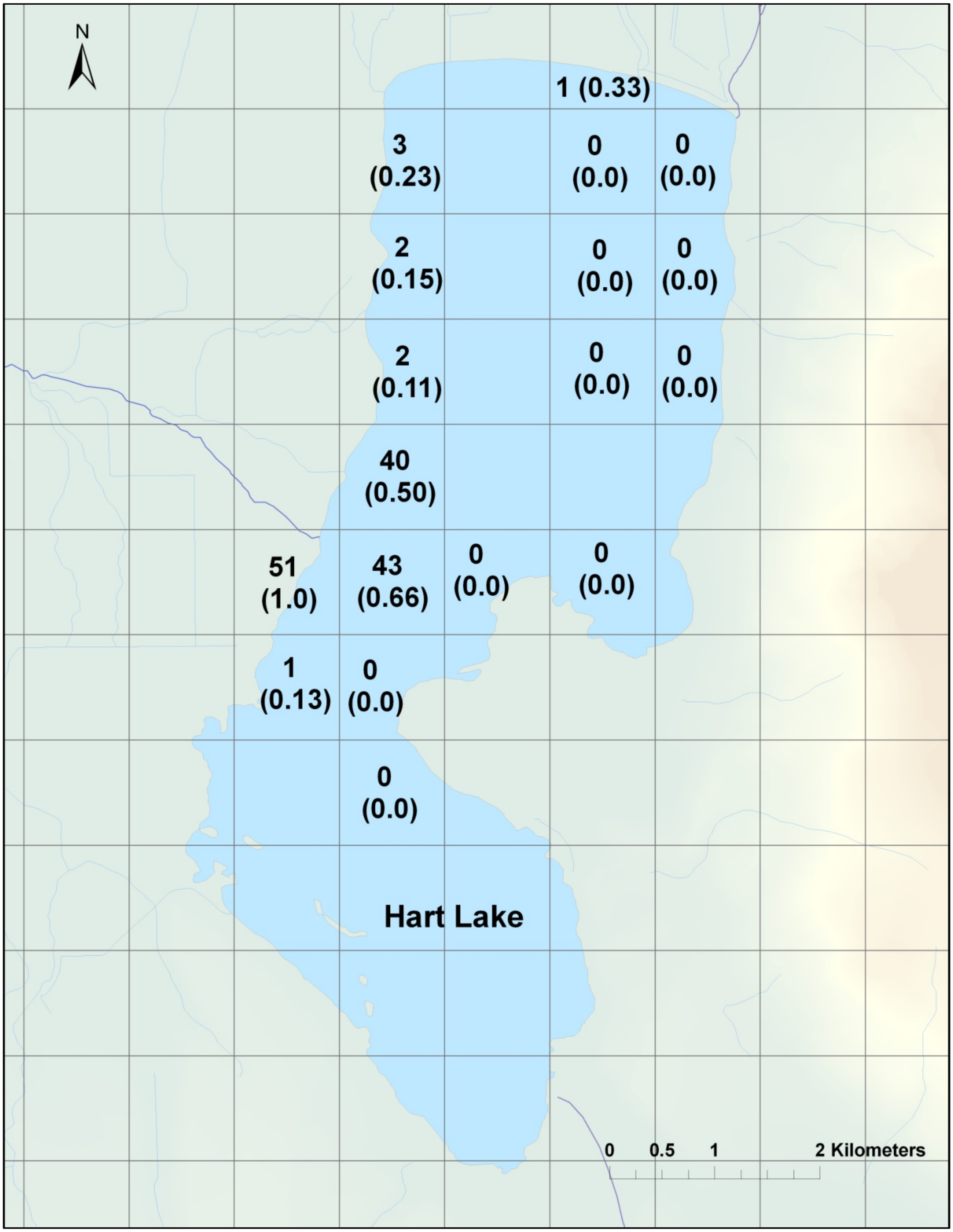

Figure 2. Trap net catch of Warner suckers in Hart Lake, spring 2012. Numbers in parentheses represent the catch-per-unit-of-effort (suckers per trap night). Grids with no numbers were not trapped.

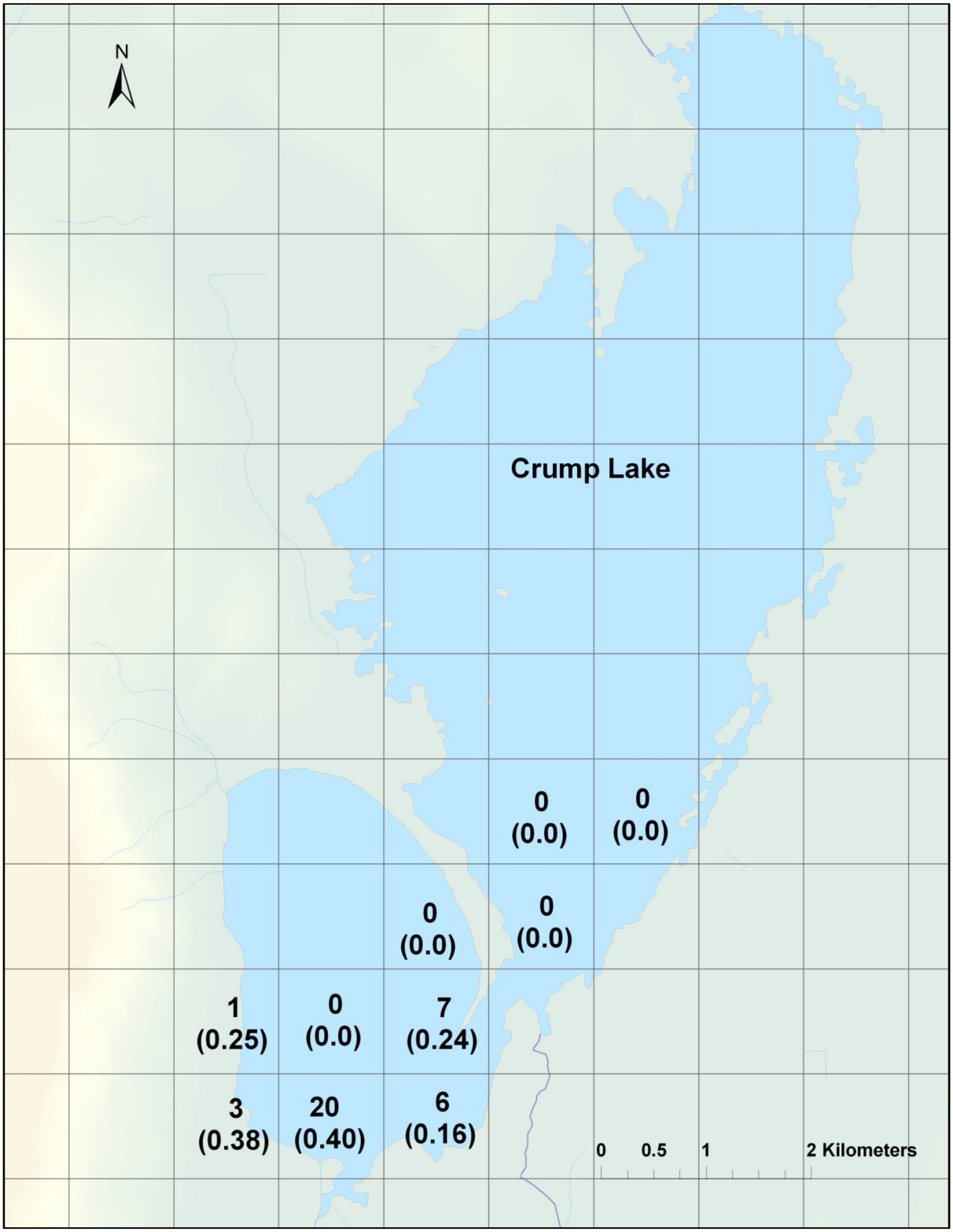

Figure 3. Trap net catch of Warner suckers in Crump Lake, spring 2012. Numbers in parentheses represent the catch-per-unit-of-effort (suckers per trap night). Grids with no numbers were not trapped.

Sucker Recruitment in the Warner Lakes

From 1994 through 2010, the average length of suckers captured in the lakes increased steadily, suggesting minimal recruitment during this period (Figure 2). However, in 2012, this trend reversed, as we captured a substantially larger proportion of smaller, presumably younger suckers (<250 mm FL), compared to prior years (Figures 2 and 3). In 2012, the average length of lake suckers was significantly smaller than in 2006 and 2008 (Table 2), and was substantially,

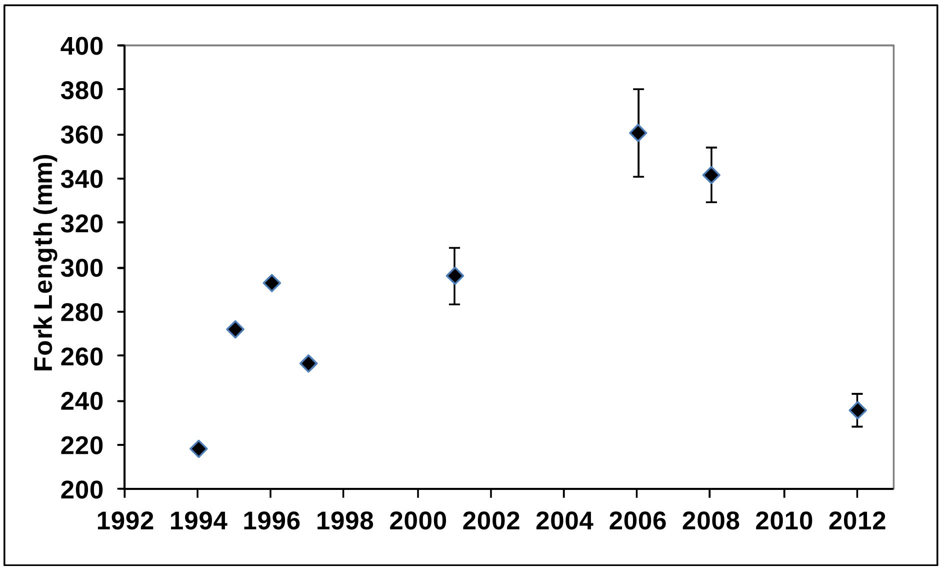

Figure 2. Mean lengths of suckers captured in trap nets from Hart Lake, 1994-2012. The vertical bars represent 95% confidence limits. No sampling occurred in years with missing data and no confidence limits were available for data prior to 2001.

Table 2. Mean length (FL) of Warner suckers captured in 2006, 2008, 2010, and 2012 from Crump and Hart Lakes. Differences in mean length between years are significant ($\alpha<0.05$) when 95% confidence limits do not overlap. Note: Hart Lake was too shallow to sample in 2010.

			Confidence limits (95%)	
Location	Year	Mean length (mm)	Lower	Upper
Crump Lake	2006	310	292	328
	2008	250	238	263
	2010	268	244	291
	2012	223	198	247
Hart Lake	2006	361	341	380
	2008	342	314	370
	2012	236	228	244
Both Lakes	2006	334	320	348
	2008	319	305	333
	2012	234	226	242

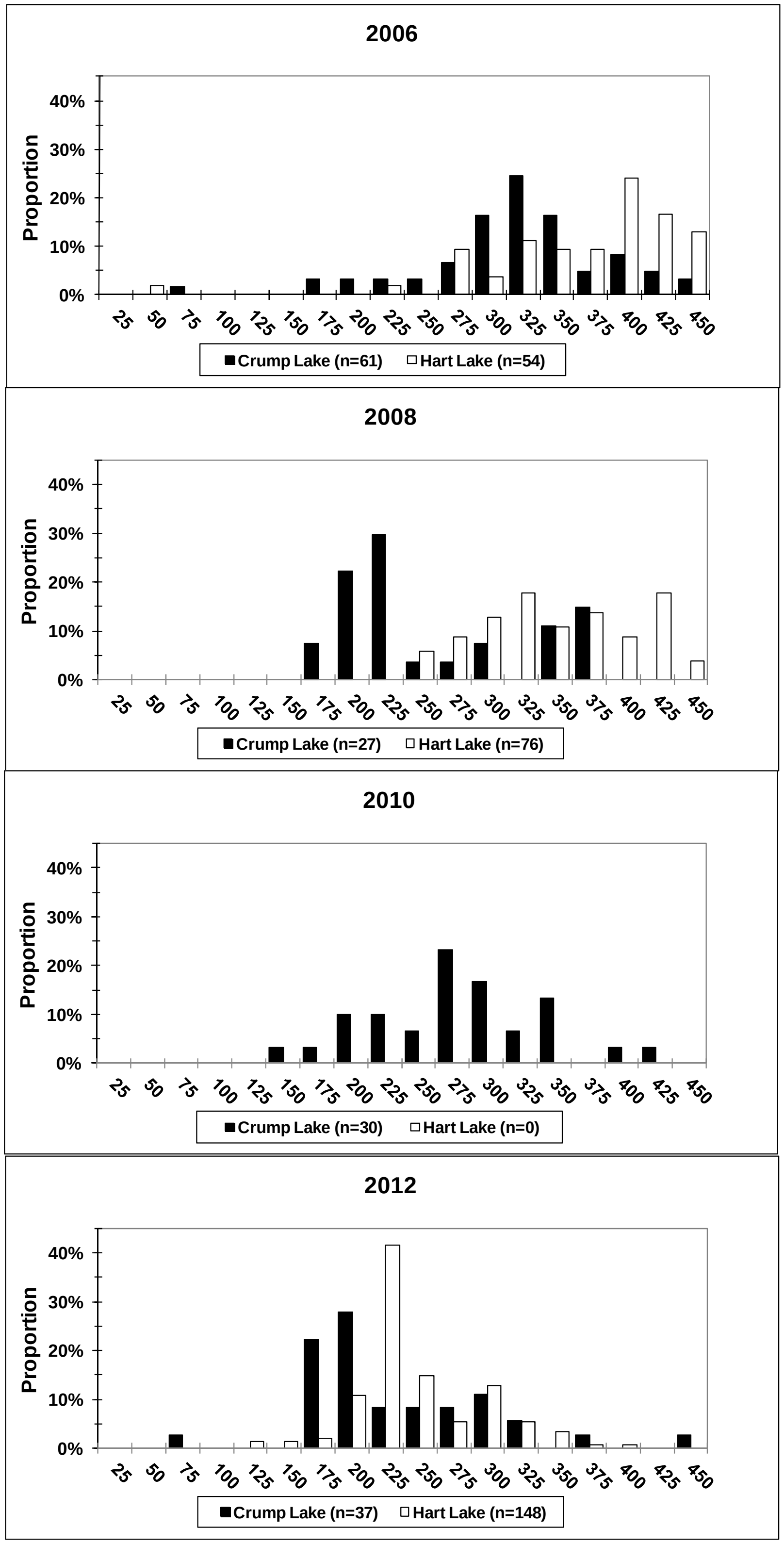

Figure 3. Length-frequency histograms for Warner suckers captured in trap nets in Hart and Crump Lakes, 2006-2012. Note: Hart Lake was too shallow to sample in 2010.

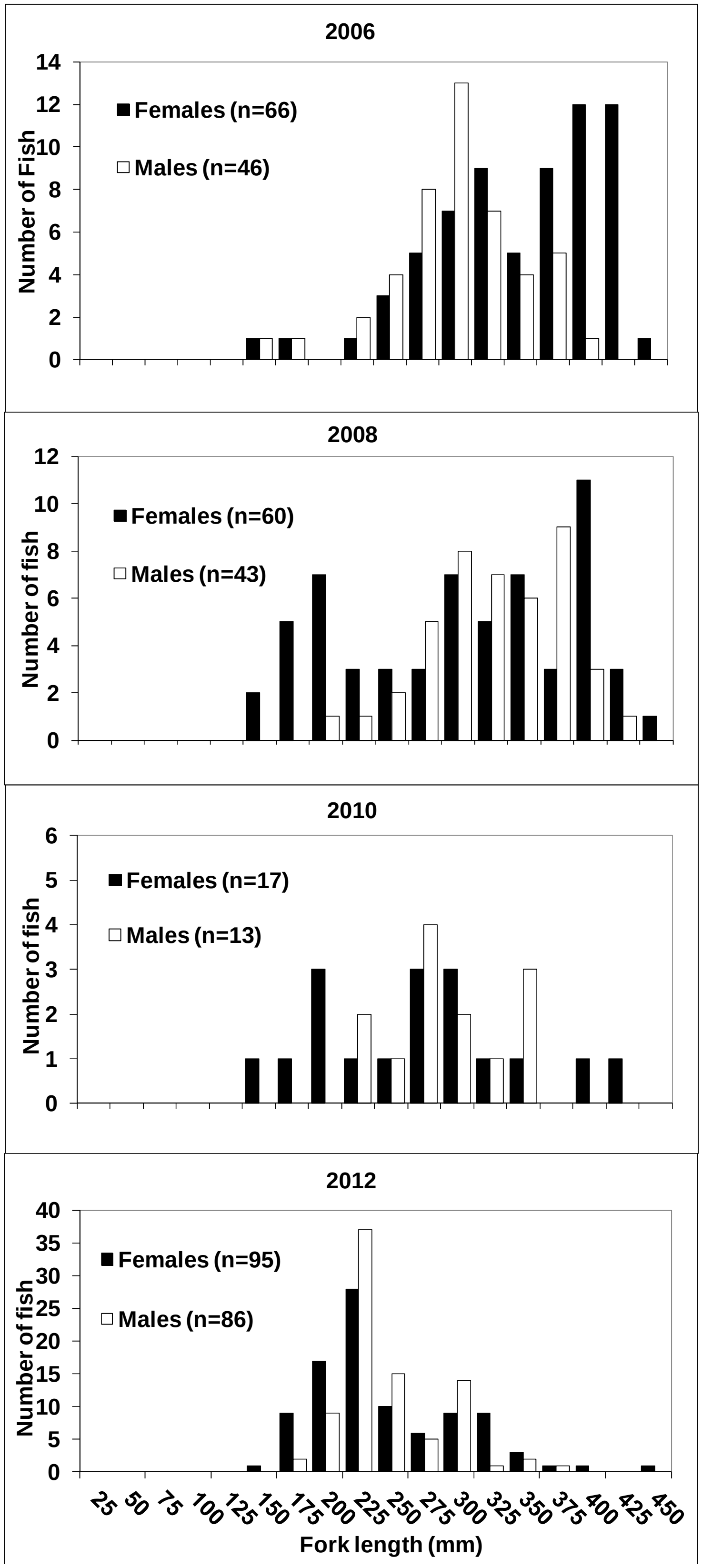

Figure 4. Length-frequency histograms for male and female suckers from the Warner Lakes, 2006-2012.

yet not significantly smaller than in 2010. Because we captured many tui chub, bullheads, and crappies between 100-175 mm (**APPENDIX B**), but captured very few suckers smaller than 175 mm in our trap nets, this suggests that the paucity of suckers in our trap nets was not a result of gear selectivity. Rather, it suggests that suckers may be more vulnerable to predation than these other fishes and that vulnerability does not end until they reach ~175 mm.

Sucker Size Distributions

We found no difference in mean lengths of suckers from Hart Lake ($\bar{x}$ = 236.1 mm; 95% CI: 228.5-243.6 mm) and Crump Lake ($\bar{x}$ = 222.8; 95% CI: 199.2-246.4 mm), nor between males ($\bar{x}$ = 136.3; 95% CI: 228-245) and females ($\bar{x}$ = 236.2; 95% CI: 225-248) in the lakes, although females were more common in the smaller length categories (<u><</u>200 mm) (Figure 4). We found strong log weight:log length relationships for both male and female Warner suckers (Figure 5). Differences in the slopes of the log-weight log-length relationships for male and female suckers in Hart and Crump Lakes where not significant ($p > 0.05$).

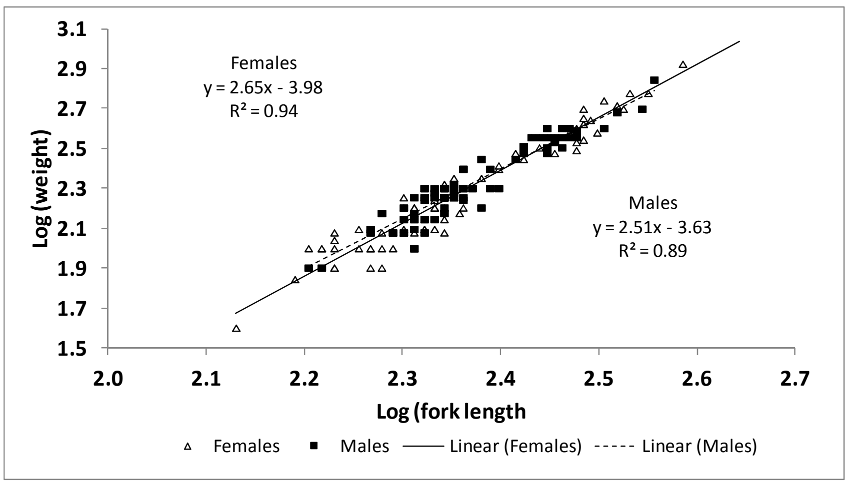

Figure 5. Relationship of log weight (g) to log fork length (mm) for adult Warner suckers collected in 2012 from Hart and Crump Lakes.

Fish Assemblages in the Warner Lakes

Since 2006, trap net catch has been dominated by nonnative fishes (71-90%), including white crappie *Pomoxis annularis* (31-67%), brown bullhead *Ameiurus nebulosus* (4-30%), *and* black crappie *P.nigromaculatus* (13-20%) (Table 3). Native tui chub *Gila bicolor* (9-35%) were the most common native fish captured. Warner suckers were one of the least common fish captured (0.3-1.0%). In 2012, only ten percent of the fish we captured were native and tui chub made up the lowest proportion of the total catch since 2001.

Changes in species composition have occurred since sampling began in 1990 (Figure 6). Prior to the lakes drying in 1992, the catch was dominated by nonnative fishes, with white crappie being the most abundant. For several years following the drought, native fishes dominated the catch, with tui chub being the most abundant. Since 1997, nonnative fish have dominated the catch. Bullheads were the most

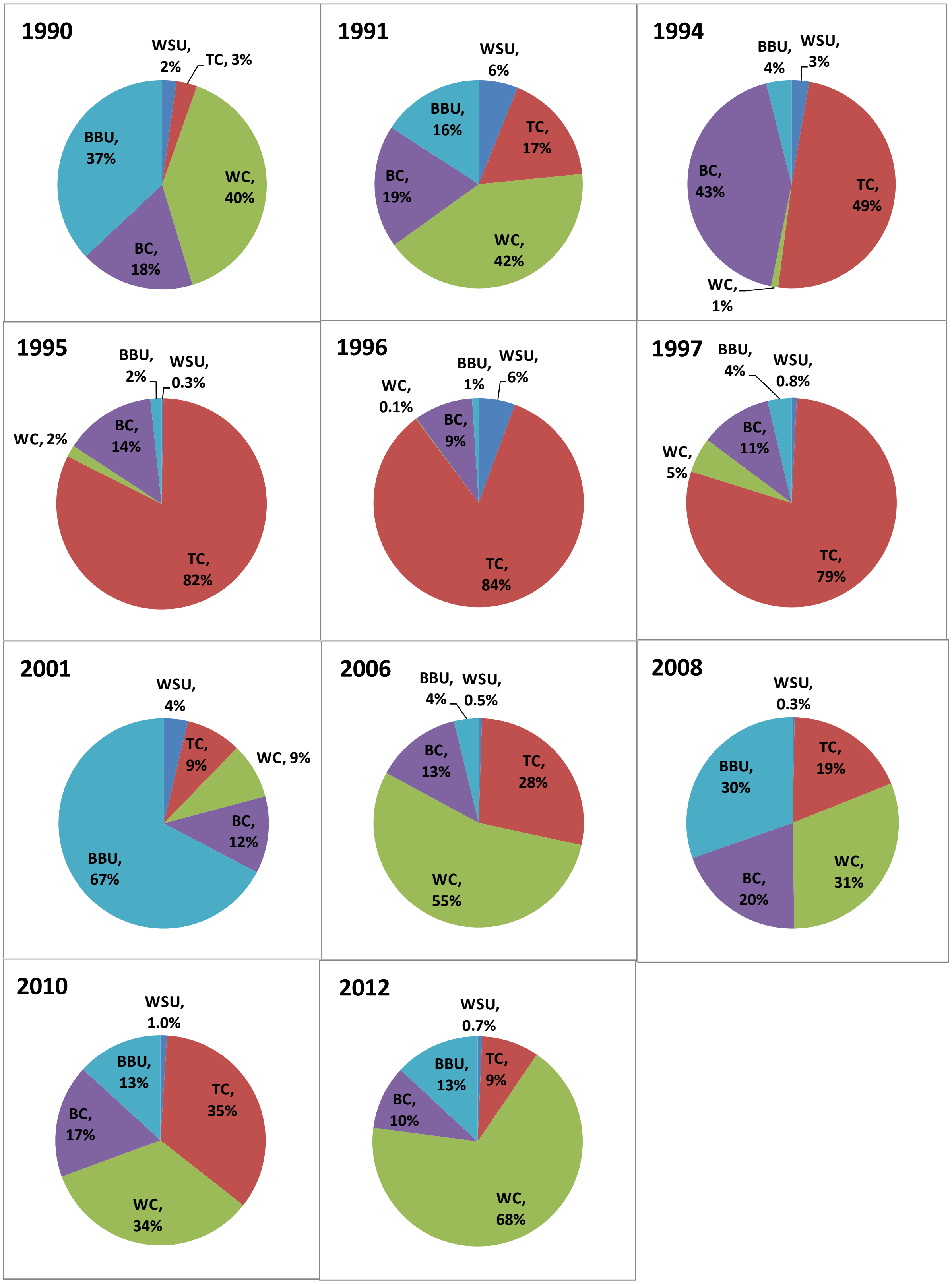

Figure 6. Proportional catch from trap nets fished in Hart and Crump Lakes, 1990-2012. Fish codes: WSU- Warner sucker, TC- tui chub, BBU- brown bullhead, WC- white crappie, and BC- black crappie.

abundant species in the 2001 catch, whereas white crappie have been the most abundant species since 2006 (with the exception of 2008). In 2012, we also noted a shift in the size distribution of brown bullheads, white crappies, and tui chub following the drought towards smaller individuals (indicating recent recruitment) accompanied by the apparent mortality of larger individuals (Figure 7).

Table 3. Proportions of native and nonnative fishes in the trap net catch from the Warner Lakes, 1990-2012. Also included is the total catch of all species, total trap net effort, and catch-per-unit-of-effort (CPUE).

Species	1990	1991	1993	1994	1995	1996	1997	2001	2006	2008	2010	2012
Warner sucker	2.2%	6.1%	0.0%	2.7%	0.3%	5.6%	0.8%	3.7%	0.5%	0.3%	1.0%	0.8%
Redband trout	0.0%	0.0%	0.0%	0.0%	0.2%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tui chub	3.2%	17.3%	0.4%	49.0%	82.0%	83.9%	79.0%	8.4%	28.2%	18.6%	34.6%	9.0%
White crappie	39.9%	41.6%	0.0%	1.1%	1.8%	0.1%	5.4%	8.5%	54.7%	30.8%	33.8%	67.1%
Black crappie	17.7%	19.1%	0.2%	42.6%	14.0%	9.1%	11.1%	11.7%	12.9%	19.8%	17.4%	9.8%
Brown bullhead	37.0%	15.8%	0.0%	3.9%	1.7%	1.0%	3.7%	66.5%	3.6%	30.3%	13.2%	13.2%
Largemouth bass	0.1%	0.1%	0.0%	0.8%	0.0%	0.0%	0.0%	1.2%	0.0%	0.2%	0.0%	0.0%
Natives	5.4%	23.4%	70.8%	51.7%	82.5%	89.8%	79.8%	12.1%	28.7%	18.9%	35.6%	9.8%
Nonnatives	94.7%	76.6%	29.2%	48.4%	17.5%	10.2%	20.2%	87.9%	71.2%	81.1%	64.4%	90.2%
Total catch	9,578	1,675	41	3,590	6,532	15,234	24,936	4,890	20,835	29,861	3,086	25,220
Trap nights	131	175	95	89	144	288	197	87	452	731	199	708
CPUE	73.0	9.6	0.7	65.2	45.4	52.9	126.6	56.2	44.7	40.8	15.3	35.6

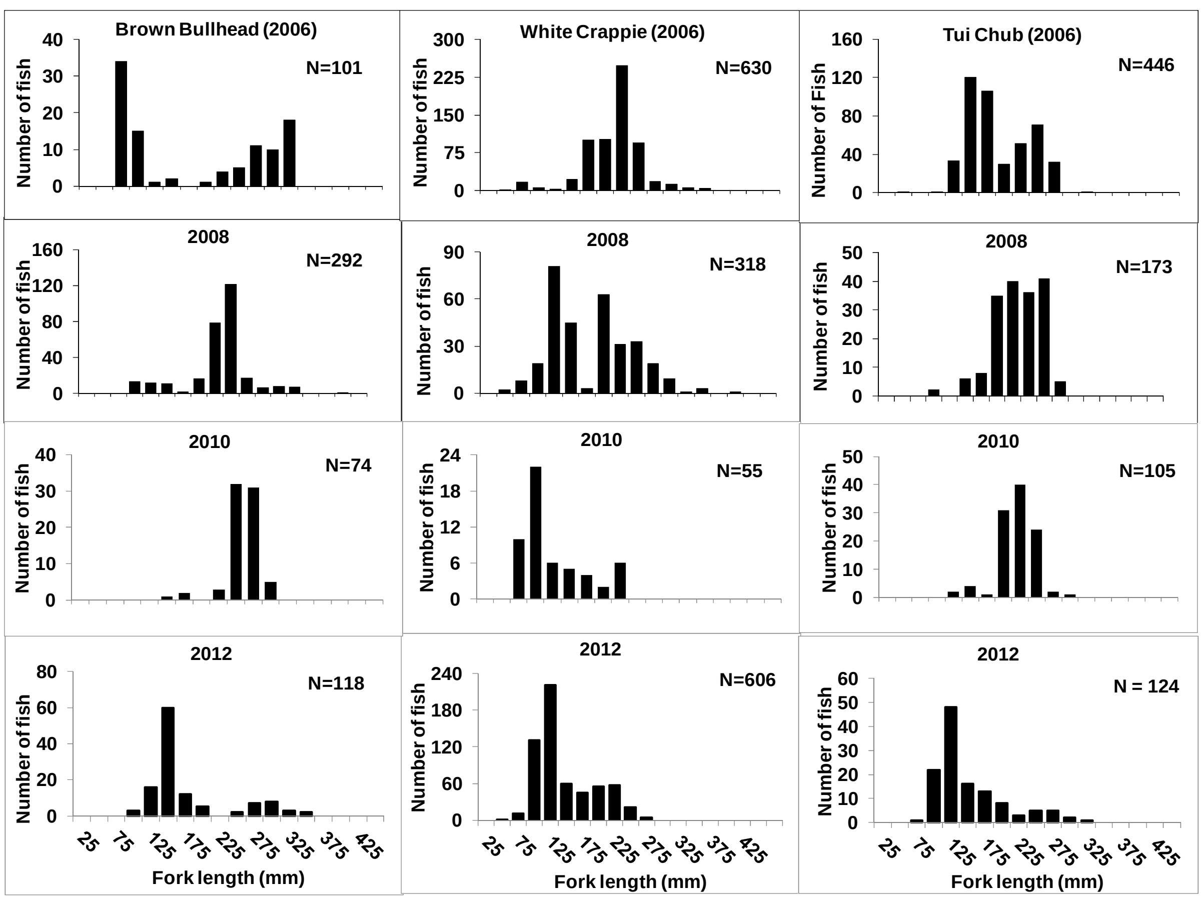

Figure 7. Length-frequency histograms for brown bullheads, white crappies, and tui chub in the Warner Lakes, 2006-2012.

Sex Ratios and Size at Sexual Maturation

We determined the sex of 187 Warner suckers from the Warner Lakes in 2012. The female to male ratio was 1.1 to 1, which was slightly less than the ratios of 1.4 to 1 in 2006 and 2008, and 1.3 to 1 in 2010 (Scheerer et al. 2006; 2008; 2010). In 2012, we noted suckers in spawning condition in the lakes from late-May through mid-June. We captured spawned-out females starting in mid-June. The smallest mature male and female suckers that we captured in the lakes in 2012 were 165 mm and 160 mm FL, respectively. All lake suckers larger than 214 mm were mature.

Seasonal Movements into Tributary Streams

We PIT tagged 177 suckers in the Warner Lakes and tracked their movements across fixed PIT antennas installed at the mouths of Honey and Deep Creeks. We detected a total of 66 unique suckers at the Honey Creek antenna and four unique suckers at the Deep Creek antenna, representing 46% of the 143 fish marked in Hart Lake and 12% of the 34 suckers marked in Crump Lake, respectively. When we expand the proportion of marked fish entering Honey Creek by the abundance of suckers in Hart Lake, we estimate that approximately 636 suckers (95% CI: 325-1,223) entered the creek, presumably to spawn. We did not detect any fish that we marked in Hart Lake at the Deep Creek antenna nor any fish marked in Crump Lake at the Honey Creek antenna. The majority of the sucker movement into Honey Creek occurred between 7 May and 4 June (Figure 8). During this time period the Honey Creek discharge averaged 41.7 cfs (range 19-58 cfs) and temperatures averaged 13.4 ^{o}C (range 9.4-15.9^{o}C. All sucker movement we detected occurred between 30 April and 18 June. During this broader time period, discharge averaged 39.9 cfs (range 9-87 cfs) and temperatures averaged 13.2 ^{o}C (range 9.4-18.6^{o}C). Note that discharge is measured at the stream gage, which is located several kilometers upstream. There are eight irrigation diversions between the gage and the mouth of Honey Creek, so actual discharge at the mouth of Honey Creek was substantially lower. At flows below 60 cfs, irrigators operate on a rotation schedule and all 60 cfs is withdrawn, leaving only irrigation return flow in the creek (B. Mayer, Oregon Water Resources, personal communication).

Avian Predation

From 2010 through 2012, researchers studying avian predation on fishes in the Warner Basin detected a total of 69 PIT tags and two radio tags in predatory bird nests on Pelican and Tern Islands. Because the island nesting sites are often used by different bird species in different years (e.g., Caspian tern *Hydroprogne caspia*, double-crested cormorant *Phalacrocorax auritus*, white pelican *Pelecanus onocrotalus*, great blue heron *Ardea herodias*, or great egret *Ardea alba*), it was impossible to determine which species was responsible for the predation. The recovered tags were from suckers tagged between 1997 and 2012 and include those marked in Hart and Crump Lakes (n=42) and in the Twentymile Creek drainage (n=34) (Table 11). These suckers ranged in size from 102 to 420 mm.

The proportion of tagged suckers that we documented were consumed in a given year ranged from 0.0 to 60% (Table 11), indicating that the impact of bird predation on Warner suckers can be substantial. For example, when we multiplied the proportion of suckers marked in the Twentymile Creek drainage whose tags were recovered in 2010 (5.9%) by the 2009 abundance estimate of suckers (4,612; *95% CI*: 3,820-5,567) in that subbasin, then adjusted for an estimated mean on-colony detection efficiency of 66% (based on detection of 98 seeded tags) and a 71% off-colony deposition rate (estimated from PIT-tagged fish fed to Caspian terns;

Allen Evans, Real Time Research, personal communication), we estimated approximately 584 (95% CI: 484-705) suckers were consumed by avian predators.

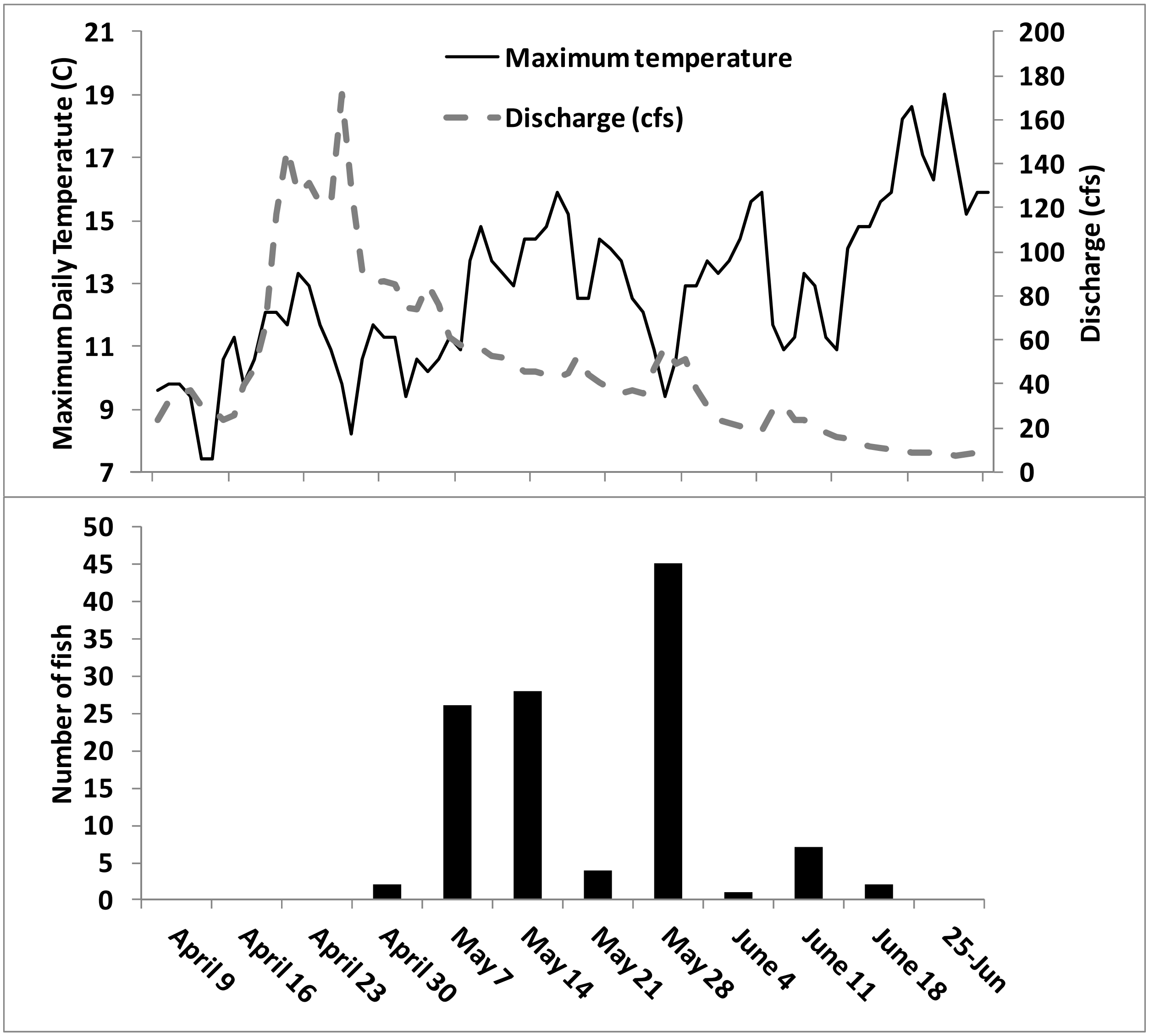

Figure 8. Maximum daily temperature and stream discharge in Honey Creek (top) and number of PIT-tagged fish entering the mouth of Honey Creek (bottom) during the spring, 2012. Note, the stream gage is located several kilometers upstream of the mouth of Honey Creek and there are eight diversions between the gage and the mouth, thus discharge at the mouth of the creek is substantially less than the reading on the gage.

Table 11. Numbers and percentages of Warner suckers tagged in the Warner basin that we documented were consumed by avian predators. Fish were tagged between 1997 and 2012. All totals were for PIT tags, except for those listed in 2010 for Twentymile Creek, which were radio tagged suckers consumed by double crested cormorants.

Year	Location tagged	Number of tags recovered	Total number tagged	Proportion
1997	Hart Lake	1	131	0.8%
2001	Hart Lake	1	177	0.6%
2006	Hart Lake	5	54	9.3%
2006	Crump Lake	5	60	8.3%
2007	Twentymile Creek	0	27	0.0%
2007	Honey Creek	0	33	0.0%
2008	Hart Lake	4	74	5.4%
2008	Crump Lake	4	27	14.8%
2008	Twentymile Creek	2	28	7.1%
2009	Twentymile Creek	25	421	5.9%
2010	Twentymile Creek	7	30	23.3%
2010	Crump Lake	18	30	60.0%
2011	Honey Creek	0	372	0.0%
2012	Hart Lake	1	148	0.7%
2012	Crump Lake	3	37	8.1%
		76	1649	4.6%

Estimating Sucker Capture Probabilities and Summer Survival in Honey Creek

The Warner sucker capture probabilities ranged from 6 to 11%. Capture probabilities varied by fish size and increased by 13% for every 1 cm increase in fish length. Sucker capture probabilities did not vary between sampling periods. Warner sucker capture probabilities were approximately half of those estimated for eastern suckers (Price and Peterson 2010); probabilities that we used to obtain our 2011 abundance estimate (Scheerer et al. 2011). In 2011, Lincoln-Peterson model bias was approximately 50%, compared to the Huggins closed-capture model (Scheerer et al. 2011). In 2012, the Lincoln-Peterson model underestimated abundance, for the 600 m stream segment that we sampled, by 30%, compared to the Huggins closed-capture model.

In the summer of 2011, we noted a reduction in the number of suckers ≤60 mm of greater than 50% over approximately 30 d period. This was especially notable downstream of Snyder Creek confluence where we witnessed both high turbidity and dying aquatic vegetation in August. In the summer of 2012, we observed no apparent reduction in the number of suckers ≤60 mm during the summer (Figure 8). We estimated 71% sucker apparent survival between the late-June to the late-July sampling periods. However, we were unable to separate mortality from emigration in the model as discussed earlier, thus the estimate includes both.

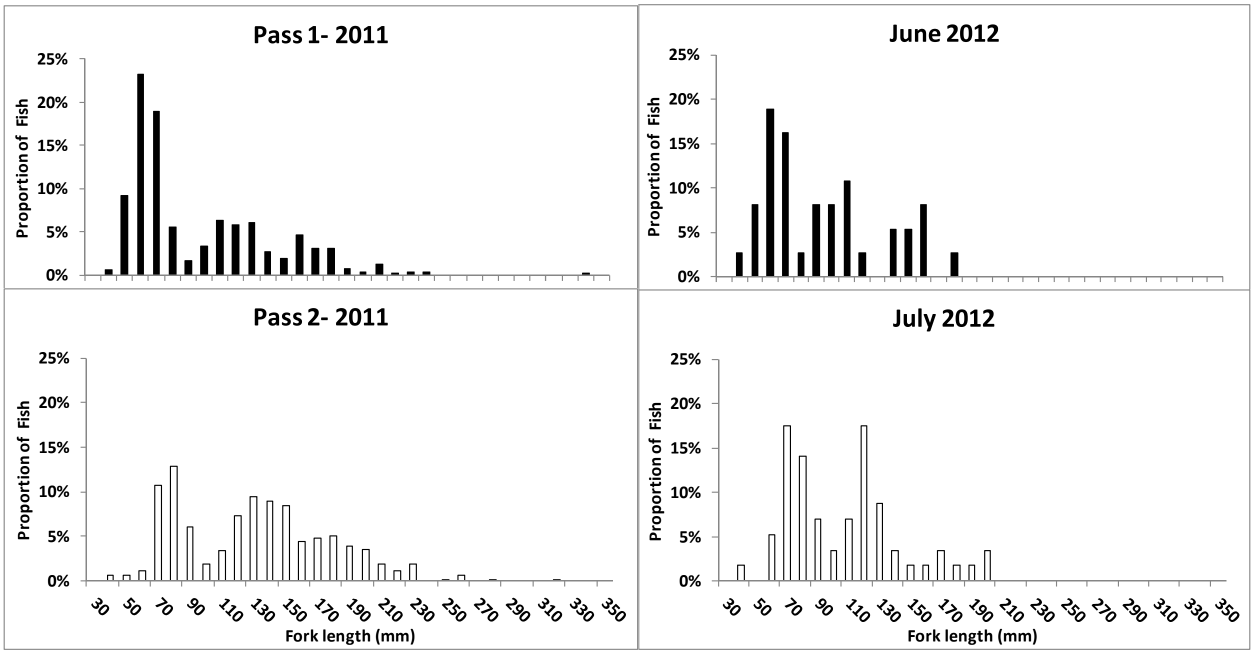

Figure 8. Length-frequency histograms for Warner suckers collected from Honey Creek during pass 1 (13 July- 9 August) and pass 2 (15 August- 14 September) in 2011 and in late-June and late-July, 2012. Note: some shift in the size distributions (peaks) during the summer is a result of growth.

DISCUSSION

The Warner sucker was federally listed as threatened in 1985. Factors implicated in the listing included watershed degradation, irrigation diversion practices, and predation and competition from introduced fishes (U.S. Fish and Wildlife Service 1998). There has been only minor progress towards recovery in the nearly three decades since listing. Habitat fragmentation, resulting from impassable irrigation dams and diversions and the proliferation of nonnative fishes in the lakes, limits movement and genetic exchange between lake and stream suckers by impeding both the upstream spawning migrations from the lakes into the streams and the downstream migration of fish into the lakes. Nonnative fishes limit recruitment in the lakes and lake suckers are periodically lost when the lakes desiccate. Stream suckers recolonize the lakes following desiccation (Allen et al. 1994) and are considered to be the stronghold for the metapopulation.

Previous investigations indicate that the Warner sucker populations in Crump and Hart Lakes are depressed compared to levels in the mid-1990's (Allen et al. 1994; Allen et al. 1995; Allen et al. 1996; Scheerer et al. 2006; 2008; 2011). During the recent drought, indices of abundance (CPUE) in Hart and Crump Lakes were some of the lowest on record and, compared to peak sucker catches in the 1990s, recent CPUE's have declined more than 90%. In 2012, the CPUE doubled in Hart Lake, compared to estimates from 2006-2010, and we estimated 1,378 adult suckers in Hart Lake, although precision was somewhat low (95% CI: 705-2,650).

From 2006 through 2010, we found no evidence of substantial recruitment of suckers into the lake populations. The sucker size distributions were dominated by large, presumably older aged fish. We documented an increase in the average sucker length in Hart Lake from 1993, following complete lake desiccation, through 2010 (Scheerer et al. 2010). In 2011, the lakes refilled following high winter flow events (peak flows of over 3,000 cfs and 500 cfs in the Twentymile and Honey Creek subbasins, respectively). Periodic winter and early spring high flow events may act to flush suckers downstream into the lakes and may be the current mechanism by which recruitment into the lakes occurs. In 2012 we found our first recent evidence of substantial sucker recruitment into the lakes. The 2012 sucker catch increased in Hart Lake, and the proportion of suckers smaller than 150 mm increased substantially in both lakes. Unfortunately, the abundance and proportion of nonnatives in the catch did not decline following partial lake desiccation (2007-2010), as it did following complete lake desiccation in 1992 (Allen et al. 1994). However, we noted a shift in the length frequency distributions of nonnative fishes towards smaller sizes, with apparent mortality of larger size classes between 2010 and 2012. This reduction should temporarily reduce predation pressure on lake suckers and may enhance the survival of the recent sucker recruits. Suppression of nonnatives in the lakes may be a management tool that managers can use to enhance lake sucker recruitment and early survival.

It is common for stream suckers to migrate upstream in large aggregations to spawn. Thousands of white suckers (*C. commersoni)* in the Midwestern U.S (Scott and Crossman 1979) and Sacramento suckers (*C. occidentalis)* in California (Wydoski and Whitney 2003) have been observed ascending suitable spawning streams during the spawning season and large schools of largescale suckers *C. macrocheilus* have been observed along river margins during the spawning season in the northwestern US (Wydoski and Whitney 2003). We documented a mass movement of PIT-tagged suckers across the upper PIT antenna on Twentymile Creek in June 2010, apparently to spawn (Scheerer et al. 2011). When we expanded the number of fish captured by the total number of fish we tagged, we estimate that approximately 469 adult suckers, or 40% of the 2009 adult population, crossed the antenna during June. In 2012, we documented a similar large aggregation of suckers entering Honey Creek, with nearly half of the fish we PIT-tagged in Hart Lake entering the creek (>600 fish). The latter results are encouraging, as we documented the continued existence/expression of the migratory life history form of lake suckers in the Warner basin, a life history form that we feared may no longer exist.

In 2011, we compared abundance estimation models and found the Lincoln-Peterson model, which we had been using to estimate stream sucker abundance, underestimated sucker abundance by over 50%, compared to the Bayesian modeling approach. Because we had not yet obtained capture probability estimates for Warner suckers in 2011, we used estimates obtained for suckers in the eastern U.S. (Scheerer et. al. 2011; Price and Peterson 2010) in the 2011 Bayesian model. In 2012, we obtained estimates of Warner sucker specific capture probabilities. We found these probabilities were lower than those estimated for eastern suckers. We also found that sucker capture probabilities varied by fish size, i.e., for every 1 cm increase in fish length capture probability increased by 13%, but did not vary by sampling occasion. When we calculated sucker abundance for the sampled stream reach in 2012, the Lincoln-Peterson model underestimated abundance of suckers by 30%. We plan to use this multiple-occasion sampling approach to estimate sucker capture probabilities and obtain an abundance estimate in lower Honey Creek in 2013.

In 2011, we noted a substantial reduction in the number (presumed mortality) of juvenile suckers captured in Honey Creek between successive electrofishing passes, which were conducted approximately one month apart. Tait and Mulkey (1993) reported a similar reduction in counts of juvenile suckers between June and August in 1992. The potential loss of a year-class was of concern, as it may represent a substantial barrier to recovery. In 2012, we used repeated sampling and length frequency analysis to evaluate whether there was an annual bottleneck to survival of juvenile suckers in Honey Creek. Using the Robust Design in program MARK, we estimated 71% sucker survival from late-June through late-July 2012 and did not observe any notable change in the sucker size distribution over this period, which would have indicated differential survival by size. This suggests that stream conditions in 2012 may have been better than those in 2011 and 1992, and that summer mortality of juvenile suckers may be a periodic, rather than annual, occurrence.

The Warner Valley is home to large populations of avian predators, including double crested cormorants, great blue herons, white pelicans, California gulls, ring-billed gulls, and Caspian terns (Roby et al. 2010). We have documented direct avian predation on Warner suckers, including radio-tagged suckers that were consumed by cormorants and PIT tags collected from predatory bird nesting islands (Scheerer et al. 2011). A varying proportion (0-60%) of the tagged suckers that we marked in a given year was consumed. This indicates that in some years and habitats, the impact of bird predation on Warner suckers can be substantial. For example, we estimated approximately 584 suckers that we marked in 2009 in the Twentymile Creek subbasin were consumed between 2009 and 2012. White et al. (1990; 1991) and Coombs et al. (1979) also noted evidence of bird predation on Warner suckers. During the drought in the late-1980s and early-1990s, sucker mortality due to bird predation increased as the lake levels dropped (White et al. 1990).

During prior investigations (Tait and Mulkey 1993, Scheerer et al. 2008; Richardson et al. 2009), biologists noted high incidences of external parasites, lesions and deformities in Warner suckers. In 2012, the U.S. Fish and Wildlife Service Fish Health Center conducted a fish health investigation, collecting samples of fish from Honey Creek and Summer Lake Wildlife Area (WMA), and found the fish were relatively pathogen free, with no viruses or bacteria detected and relatively low levels of opportunistic parasites (*Lernaea sp*. on the skin, Microsporidium spores and nematodes under the skin, Myxobolus spores in the brain, and digenic trematodes in gall bladder) (Ken Lujan, USFWS, personal communication).

DeHaan and VonBargen (2011) recently completed a survey of the genetic diversity in tributary populations of Warner suckers. They found that Warner suckers exhibited a relatively high level of genetic variation among the different tributaries (Twelvemile, Deep, Honey, and Snyder Creeks) and tests of allele frequency heterogeneity suggested that each tributary contained a genetically independent spawning population. They also found no differences in the levels of genetic variation between populations, suggesting that no population currently faces an increased risk of threats from reduced genetic diversity. These results, combined with the high levels of genetic variation documented among populations, as indicated by pairwise F_{ST} estimates, suggests that recent gene flow among Warner sucker populations is relatively low. This is not surprising considering the many passage barriers that exist in the basin. In 2012, they analyzed suckers from the Warner lakes and used genetic assignment tools to assign unknown origin fish from Hart and Crump lakes to their tributary of origin to help infer individual movement patterns. Genetic assignment tests revealed that Crump Lake suckers, collected between 2006 and 2012, originated from Deep Creek (90 of 92 fish or 98%). These tests also revealed that Hart Lake suckers, collected during this same time frame, originated from both Deep Creek (144 of 232 fish or 62%) and Honey Creek (88 of 232 fish or 38%). Suckers collected from Hart Lake during the drought years (2006 and 2008) were mostly of Deep Creek origin (68 of 87 fish or 78%), however suckers collected in 2012 had similar proportions originating from Deep (76 of 145 fish or 52%) and Honey Creek (48%). It is also notable, when they evaluated the origin of Summer Lake suckers, using similar assignment tests, and removed Summer Lake as a potential source of origin, that all suckers were assigned to Deep Creek. Although this test is not truly valid, because this population originated from suckers introduced in 1992 and has diverged substantially over the past 20+ years (it is now considered a genetically independent population), it further suggests that Deep Creek is a major source of lake recruitment, especially during drought years. It is notable that no suckers from the lakes or Summer Lake WMA were assigned to the Twentymile Creek population. Apparently, suckers are at least occasionally recruiting into the lake populations from Deep Creek, the lower extent of which has no substantial migration barriers, and Honey Creek (during wet years), but there is no evidence that they are able to migrate through the complex of irrigation canals in lower Twentymile Creek and recruit into the lakes.

From prior investigations, we found suckers were abundant and widely distributed in the tributaries (Scheerer et al. 2007, 2011; Richardson et al. 2009), but connectivity between the lakes and other tributaries was restricted by unscreened and mostly un-laddered irrigation diversions. The numerous diversion dams and unscreened irrigation canals act to fragment the habitat of Warner suckers in the basin and are a major obstacle to meeting recovery criteria. The stream populations are the stronghold for suckers in the Warner basin and after suckers arrive in the lakes, it is unlikely that they are able to successfully mix with stream suckers and function as a true metapopulation. Therefore, our future management focus in the basin is to work with private landowners to install and evaluate passage improvement projects. A recent increase in landowner interest in partnering to improve stream passage is encouraging. Several projects have been recently completed and two more are planned for 2013 (Dyke Diversion on Twentymile Creek and Rookery Diversion on lower Honey Creek). It is crucial that we enlist and engage the support of the landowners, whose livelihoods depend on the limited water in the desert, to recover this species that not only bears the name of the valley where they live, but also represents the strong survival spirit that is essential for both to thrive in the desert environment.

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APPENDIX A. Modified Schnabel population estimate for Warner suckers in Hart Lake, 2012.

Week of:	Catch (C_t)	Recaps (R_t)	Number marked (less removals)	Marked fish at large (M_t)	C_tM_t	M_tR_t	$C_tM_t^2$	$R_t^2C_t$
17-Apr	0	0	0	0	0	0	0	0.0
24-Apr	2	0	2	0	0	0	0	0.0
1-May	11	0	11	2	22	0	44	0.0
8-May	44	0	43	13	572	0	7436	0.0
15-May	50	1	50	56	2800	56	156800	50.0
22-May	7	0	6	106	742	0	78652	0.0
29-May	13	1	11	112	1456	112	163072	13.0
5-Jun	14	2	13	123	1722	246	211806	56.0
12-Jun	7	1	2	136	952	136	129472	7.0
	148	5	138	548	8266	550	747282	126

Schnabel:	N = sum(CtMt)/sum(Rt)	95% Poisson Confidence Intervals
	1,378	**705** **2,650**

3406 Cherry Ave. NE
Salem, Oregon 97303