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INTRODUCTION

The Warner sucker (*Catostomus warnerensis*) is endemic to the Warner Valley, an endorheic subbasin of the Great Basin in southeastern Oregon and northwestern Nevada. This species was historically abundant and their 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) (U.S. Fish and Wildlife Service 1985). 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 sucker inhabits the lakes and low gradient stream reaches of the Warner Valley. Two life history forms comprise the metapopulation of Warner suckers: lake and stream morphs. The lake suckers are lacustrine adfluvial or potamodromous fish which normally spawn in the streams. However, upstream migration may be blocked by low stream flows during low water years or by irrigation diversion dams. When this happens spawning may occur in nearshore areas of the lakes (White et al. 1990). Large lake-dwelling populations of introduced fishes likely reduce recruitment by preying on young suckers (U.S. Fish and Wildlife Service 1998). The stream suckers inhabit and spawn in the three major tributary drainages (Honey, Deep, and Twentymile Creeks).

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 recovery criteria for delisting the species. These criteria require that: 1) a self-sustaining metapopulation is distributed throughout the Twentymile, Honey, and Deep Creek (below the falls) drainages, and in Pelican, Crump, and Hart Lakes, 2) passage is restored within and among the Twentymile, Honey, and Deep Creek (below the falls) drainages so that the 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.

In 2007, we conducted investigations in Warner basin tributaries to describe the current distribution of stream resident populations of Warner suckers and to quantify their abundance. Previous investigations of stream resident suckers were conducted in 1992-1994 (Tait and Mulkey 1992; 1993; Tait et al. 1995). In addition, we obtained a population estimate of Warner suckers at Summer Lake, where a self-sustaining population became established after fish salvage from Hart Lake during the 1992 drought.

METHODS

We employed the Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) sample design to draw representative sample sites from a known sample frame. EMAP employs a probabilistic sampling design that allows resource assessment over large areas based on data from representative sample locations. The design involves a spatially balanced, random sampling strategy that distributes sample locations evenly throughout the area of assessment (Overton et al. 1990; Stevens 2002; Stevens et al. 2004). The EMAP design takes into account spatial patterns of resource distribution when calculating estimates of variance to provide higher precision for a given level of sampling effort (Stevens and Olsen 2002).

Our sample frame was based on a 1:24,000 digital stream coverage. Potential Warner sucker distribution totaled 100 km (Figure 1) and was determined by consulting ODFW and BLM biologists, examining past sampling efforts and professional judgment. A total of 120 sample sites was chosen in the initial draw, including 50 sites in the Honey Creek drainage, 50 sites in the Twentymile Creek drainage, and 20 sites in the Deep Creek drainage. Additional sites were selected in each subbasin for use as replacements when sites were unsuitable (e.g., stream channel was dry or access permission was denied on private property). Each site was associated with a priority ranking that maintains the random and spatially-balanced statistical properties of the sample. Actual sampling effort was less than the target due to time constraints, but sampled sites followed the selection priority order.

Standard surveys involved estimating fish abundance at these randomly chosen sample sites using backpack electrofishing and collecting measurements to quantify site dimensions and to describe site habitat complexity. At locations where electrofishing was impractical due to conditions which make this method inefficient (high turbidity, very wide or deep channels), alternate gears (fyke nets, hoop nets, seines, and/or minnow traps) were used to determine fish presence.

Sample sites were located using UTM coordinates. Landowners were contacted to obtain permission to access sites located on private land. The field crew navigated to the site using topographic maps and GPS units that were pre-programmed with the site coordinates. Once the coordinates were located in the stream this point became the lower site boundary. If the coordinates did not fall in the stream, then the lower site boundary was assigned to the location on the stream that was nearest to the pre-assigned coordinates. The upper site boundary was determined by measuring the wetted stream channel width and measuring 30 channel widths upstream or 30 meters, whichever was greater. If 30 channel width measurements exceeded 100 meters, then the upper boundary was $\underline{\sim}$100 meters from the lower boundary. Site boundaries were occasionally modified to avoid splitting channel units (e.g., so a site boundary was not located in the middle of a pool). After the site boundaries were located, block nets were installed at the upper and lower stream boundaries to prevent fish movement into our out of the site while the depletion estimate was being obtained.

Multiple-pass depletion backpack electrofishing was used to obtain abundance (density) estimates at each site. A minimum of two passes were made, with each pass consisting of an upstream and a downstream sweep. The sampling crew electrofished upstream, starting at the downstream block net and moving to the upstream block net. The crew proceeded systematically, shocking discrete channel units and strategically working complex areas, i.e. undercuts, and woody accumulations. At the upstream block net, the crew turned and continued back towards the downstream block net, using approximately ½ to ¼ the effort used for the upstream pass. On the downstream half of the pass, the crew used a sweeping motion to 'herd' fish into the bottom block net, where the netter could collect fish off the block net. The crew recorded the electrofisher settings (pulse width, voltage, and frequency), the starting and ending times, and the water temperature. Captured fish were placed in buckets placed along the stream margins. Approximate equal sampling effort was exerted during each electrofishing pass. If the reduction in number of Warner suckers collected between the first and second passes was greater than 50 percent, then no further sampling was conducted. If the reduction in fish numbers between the two passes was less than a 50 percent, then two additional passes were completed. If a 50 percent reduction did not occur between the sum of numbers of fish captured during passes 1 and 2 and the sum of numbers of fish captured during passes 3 and 4, then the estimate failed.

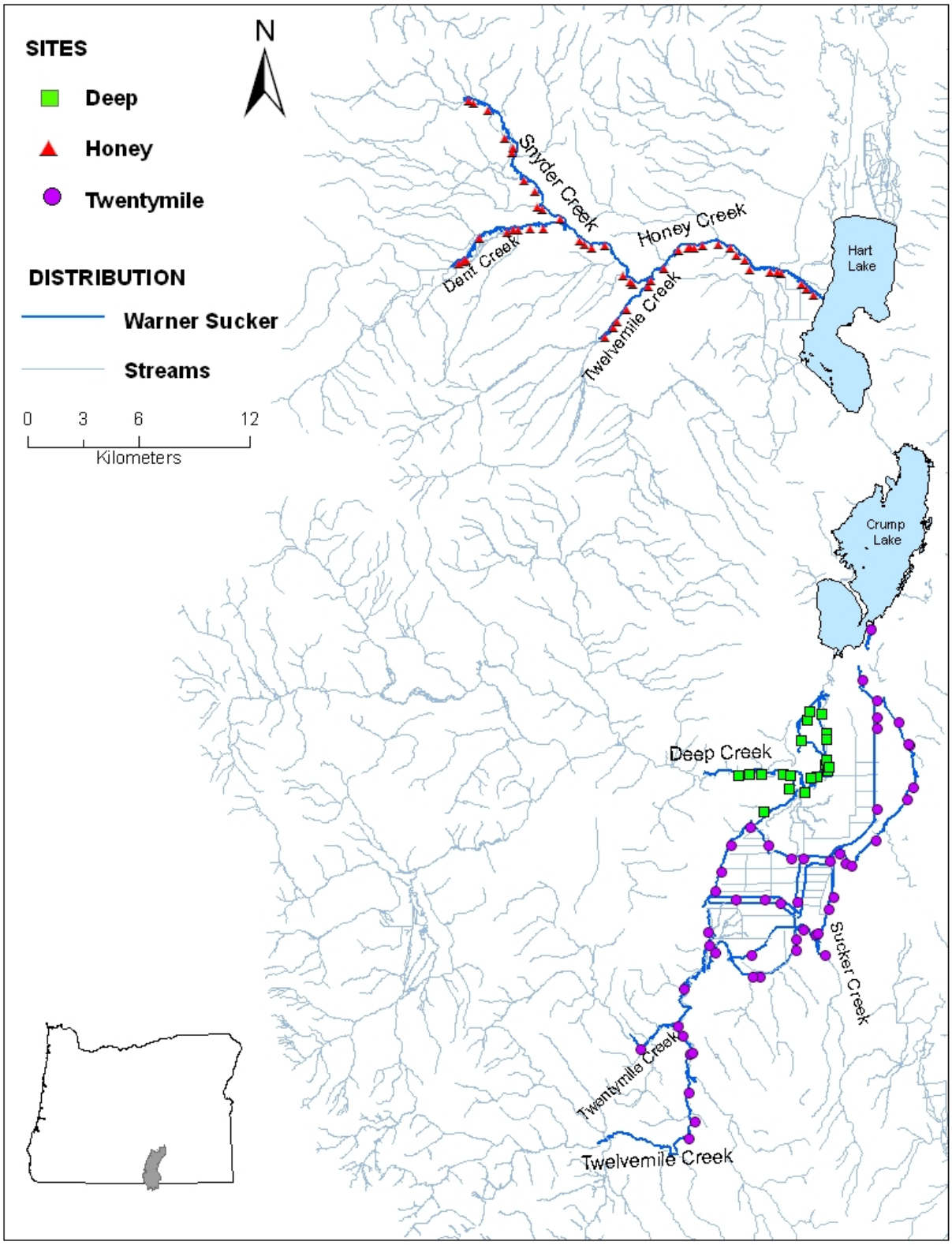

Figure 1. Sample frame and corresponding sample points for Warner Suckers in tributaries of the Warner Basin, 2007.

All captured fish were anesthetized prior to processing with buffered MS-222. Fish were then identified to species and counted. The fork length (FL) of each Warner sucker and redband trout (*Oncorhynchus mykiss)* was measured to the nearest millimeter. The fork length of a subsample of the other species collected was also measured to the nearest millimeter. Captured Warner suckers were checked for the presence of PIT tags with a hand held reader. If a tag was present, the code was recorded. If no tags were present, then a half-duplex tag was surgically implanted. A small ~0.5 cm incision was made with a scalpel in the anterior ventral side of the body cavity, and a PIT tag (23mm x 3mm) was inserted. No sutures were used. Fish smaller than 100 mm FL were not tagged. All equipment was sterilized prior to surgery and antibiotic was applied to the incision and the tag. Following processing, fish were allowed to fully recover in fresh aerated water. After all passes were completed, fish were released into the stream near the location where they were captured.

Removal estimates of population abundance at individual sampling sites were calculated using the methods described by White et al. (1982). Fish abundance was calculated from the equation: $\hat{N} = p_1^2/(p_1-p_2)$, where $\hat{N}$ is the abundance estimate, p_1 is the number of fish captured in pass 1 and p_2 is the number of fish captured in pass 2. If four passes were needed to achieve the 50 percent depletion, then p_1 was sum of the numbers of fish captured in passes 1 and 2, and p_2 was the sum of the numbers of fish captured in passes 3 and 4. Removal estimates were only calculated for fish > 59 mm, fork length. Fish density was calculated by dividing the site estimate by the site length. Estimates of population abundance within strata (population or basin) and associated precision were calculated using local neighborhood estimator methods described by Stevens and Olsen (2002). Sample probabilities used to extrapolate population totals were adjusted for the occurrence of non-target and non–response sites using the weight-modified inclusion density method described in Stevens (2002).

RESULTS

We successfully sampled 62 sites from our sample draw. We included nine additional sites that were part of a study targeting redband trout where Warner sucker data was also collected. These sites were included in the set of sites used to assess distribution and density patterns, but not included in the abundance estimate. Warner suckers were collected from 32 of the 71 sites (45%) sampled (Table 1).

Table 1. Frame length, length of stream sampled, and numbers of sites by outcome category (sites sampled, sites where suckers were collected, sites with dry channels, and sites with denied access).

	Frame	Sampled	Number of Sites			
Drainage	(km)	(km)	Sampled	with Suckers	Dry	Denied Access
Deep Creek	19.0	0.7	9	2	9	18
Honey Creek	37.4	2.9	38	17	3	18
Twentymile Creek	44.0	2.0	24	13	16	11
Total	100.4	5.6	71	32	28	47

We found the 2007 Warner sucker distribution was discontinuous in most of the Warner basin tributaries (Figure 2). Suckers generally were evenly distributed in the Twentymile drainage upstream of the irrigation diversion canal matrix, but rare in the canals themselves. Suckers also showed a fairly even distribution in lower Honey Creek and in the reach upstream of the Twelvemile Creek confluence (first major tributary entering from the south), but were rare in the canyon (downstream of Twelvemile Creek). Because of denied access to large portions of Snyder and Deep Creeks, our ability to comprehensively assess the current distribution and status of Warner suckers in these areas was limited.

Densities of suckers (fish per kilometer) in the basin were typically low but highly variable (Figure 3). Sucker densities tended to be highest in the Twentymile Creek drainage, intermediate in the Honey Creek drainage, and lowest in the Deep Creek drainage; however because of inter-site variability none of these differences were statistically significant.

Warner suckers ranged in size from 22mm to 330mm FL ($\bar{x}$=87.5; 95% CI= $\pm$ 13%; n=662). Most of the suckers (85%) were less than 100mm FL and only a few (2%) were larger than 200mm FL (Figure 4). Based on aging conducted by Coombs et al. (1979), most of the suckers we collected were one year old fish (2006 year-class). It is uncertain whether the scarcity of suckers less than 30mm in our sample was due to low reproductive success in 2007 or our inability to reliably identify or effectively sample small suckers using backpack electrofishing. Juvenile suckers <60mm were collected from only 9 of the 32 sites (28%) where suckers were captured. Juvenile suckers <60mm were more common in the Honey Creek drainage (6 sites) than in the Twentymile Creek (2 sites) and Deep Creek (1 site) drainages (Figure 5).

We obtained populations estimates for Warner suckers $\geq$60 mm FL in each of the three major tributary basins and for the entire drainage (excluding lakes). The basin estimate totaled approximately 6,800 suckers (Table 2). Most of these fish occurred in Honey Creek followed by Twentymile Creek. The large number of sites where no suckers were collected, combined with the few sites where relatively large numbers of suckers were collected, resulted in the broad confidence intervals around our estimates. Further, removing the portion of the sample frame and associated samples located within the matrix of irrigation canals in the lower portions of Deep and Twentymile Creeks did not applicably improve the precision of our estimates. Power analysis indicates that under the high degree of variation encountered in 2007 a sample size of approximately 600 sites would be necessary to reduce confidence limits to within $\pm$ 20%.

Other native fish species that we collected during our surveys included redband trout (*Oncorhynchus mykiss*), speckled dace (*Rhinichthys osculus*), tui chub (Siphateles bicolor), and Pit roach (*Lavinia symmetricus mitrulus*). Nonnative fishes that we collected included white crappie (*Pomoxis annularis*), largemouth bass (*Micropterus salmoides*), brown bullhead *(Ameiurus nebulosus)*, and brook trout (*Salvelinus fontinalis*) (Figures 6 and 7). Results from the 2007 ODFW surveys targeting redband trout are summarized on our web site which is located at: http://oregonstate.edu/dept/ODFW/NativeFish/GreatBasinRedband2007.htm.

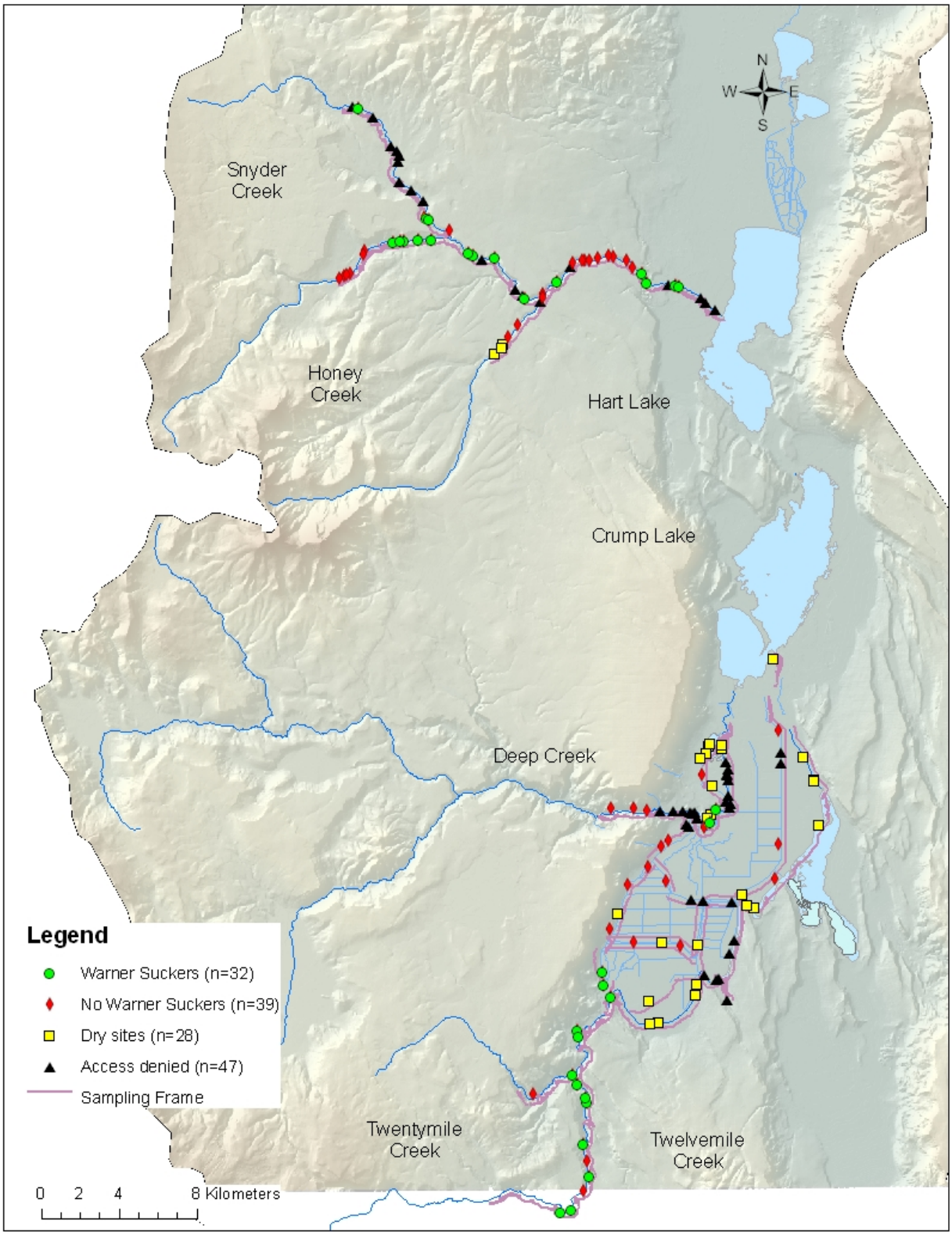

Figure 2. Map showing the sites where we collected Warner suckers, sites where no Warner suckers were collected, sites with dry channels, and sites where access was denied.

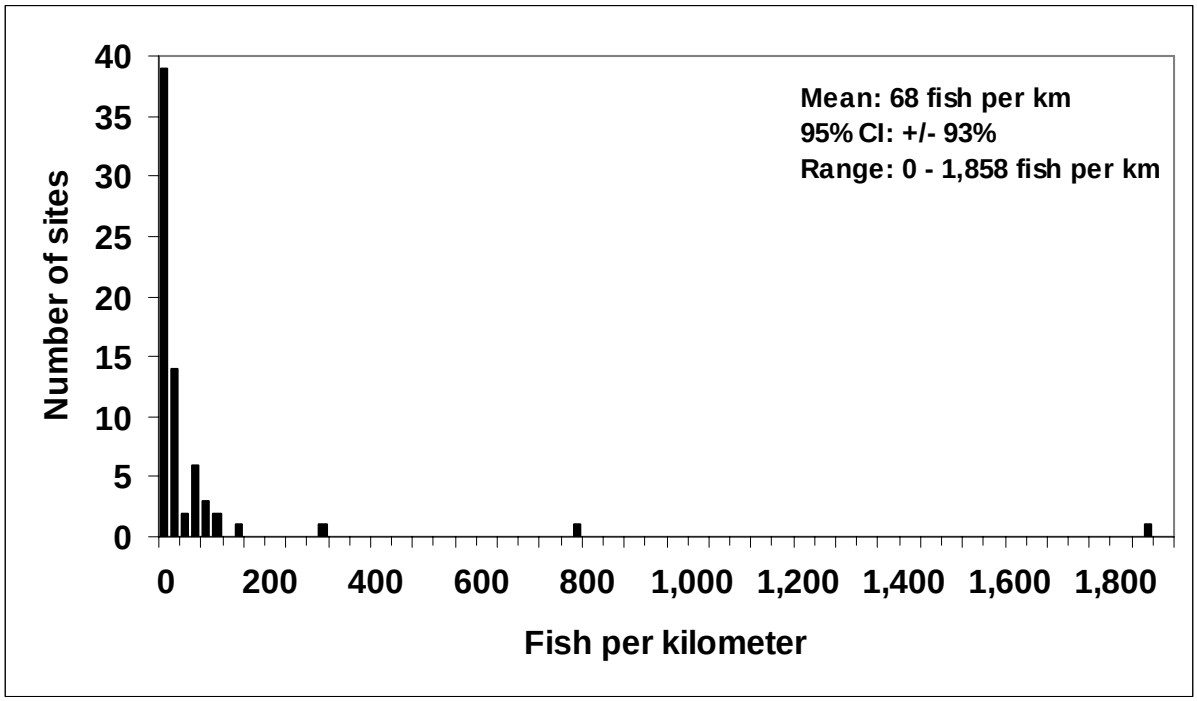

Figure 3. Histogram showing the frequency distribution of densities of Warner suckers ≥ 60 mm fork length estimated at 71 sites sampled in Warner basin tributaries, 2007.

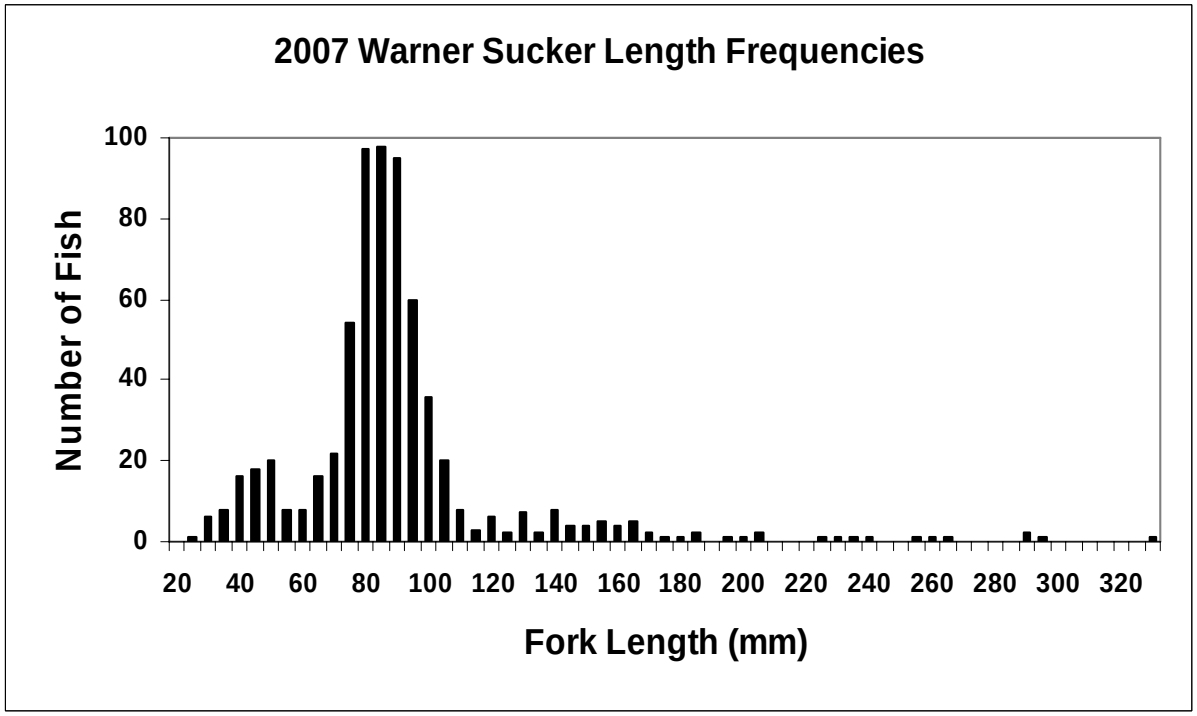

Figure 4. Length frequency distribution of suckers collected from Warner basin tributaries in 2007.

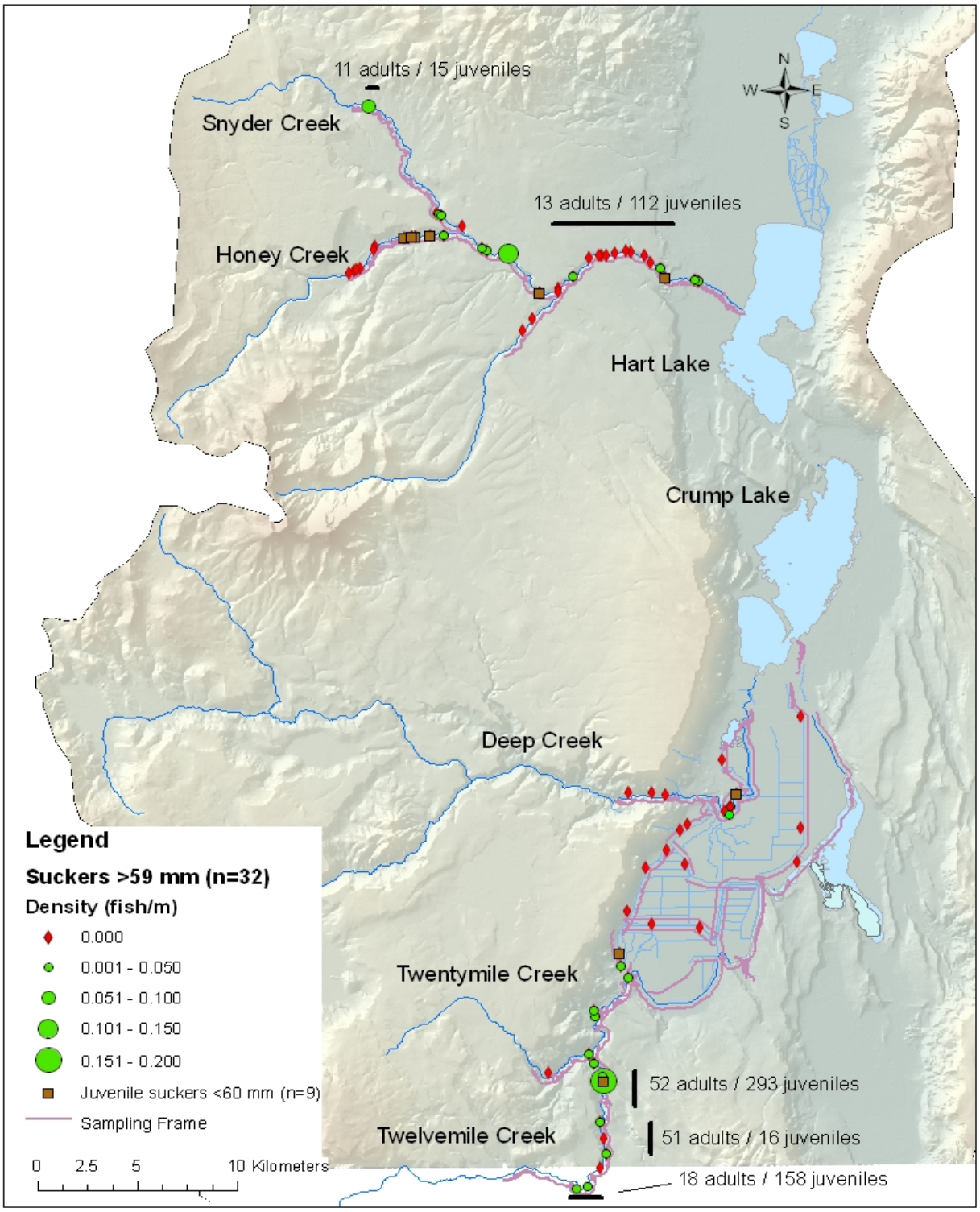

Figure 5. Map showing the documented Warner sucker distributions from 1994 and 2007 surveys and sites where juvenile Warner suckers (≤60 mm) were collected in 2007. Fish densities listed are for 2007 surveys. All sites with juvenile suckers also contained adults. The reaches surveyed in 1994 are marked with bold lines adjacent to the stream. Numbers of fish observed in 1994 are listed next to these bold lines.

Table 2. Estimates of Warner sucker population abundance (fish ≥60mm) in streams in the Warner basin, summer 2007.

Stream	Frame (km)	Sampled (m)	N	Estimate	Relative 95% Confidence Interval
Deep Creek	19.0	0.7	8	150	192%
Honey Creek	37.4	2.9	33	2,202	81%
Twentymile Creek	44.0	2.0	20	4,746	164%
Entire basin	100.4	5.6	61	6,852	92%

We obtained a mark-recapture population estimate of the adult Warner suckers at ODFW's Summer Lake Wildlife Area. This population resulted from natural production of adult suckers that were moved to the refuge when the Warner Lakes desiccated during the 1992 drought. The population estimate was 142 fish (95% CI: 91-218) in the ditch that extends from the well head to the gated culvert. An additional 3 suckers were collected from the ~400 meter sinuous channel located downstream of the ditch. No suckers were collected from the wetland that the sinuous channel empties into. The lake downstream of the wetland was not sampled. The length-frequency distribution of the Summer Lake suckers is shown in Figure 8. Missing were suckers representing the smaller size (age) class(es).

During our Warner basin population studies, we PIT tagged 60 Warner suckers (≥100 mm FL) which will be allow us to conduct future assessments of sucker movements and growth. No suckers PIT-tagged in previous years were captured in 2007. In addition, we collected fin clips from 179 Warner Suckers for future genetic investigations, including 63 fish from Honey Creek, 45 fish from Twentymile Creek, 26 fish from Deep Creek, and 45 fish from the Summer Lake Wildlife Area.

DISCUSSION

The Warner sucker was federally listed as threatened in 1985. Reasons cited for the listing include watershed degradation, irrigation diversion practices, and predation and competition from introduced fishes (U.S. Fish and Wildlife Service 1998). Warner suckers inhabit both the streams and lakes in the basin. In most years Hart and Crump Lakes hold water year round, however during droughts the suckers inhabiting the lakes are lost when the lakes desiccate (White et al. 1991; Allen et al. 1994). Stream suckers recolonize the lakes following desiccation (Allen et al. 1994). Irrigation dams and diversions limit movements and genetic exchange between lake and stream suckers (and redband trout) by blocking both the upstream spawning migrations from the lakes into the streams and the downstream migration of young fish into the lakes. When young fish enter the lakes, they face a gauntlet of introduced fishes which both prey upon and compete with them. These conditions have gone relatively unchanged in the 22 years since listing.

In 2006, we found that the lake populations of Warner suckers were depressed (Scheerer et al. 2006). The results of our 2007 stream investigations indicate that the sucker populations in Warner basin tributaries have patchy distributions. At locations where suckers were collected, densities were typically low. These data may be, in part, due to the drought

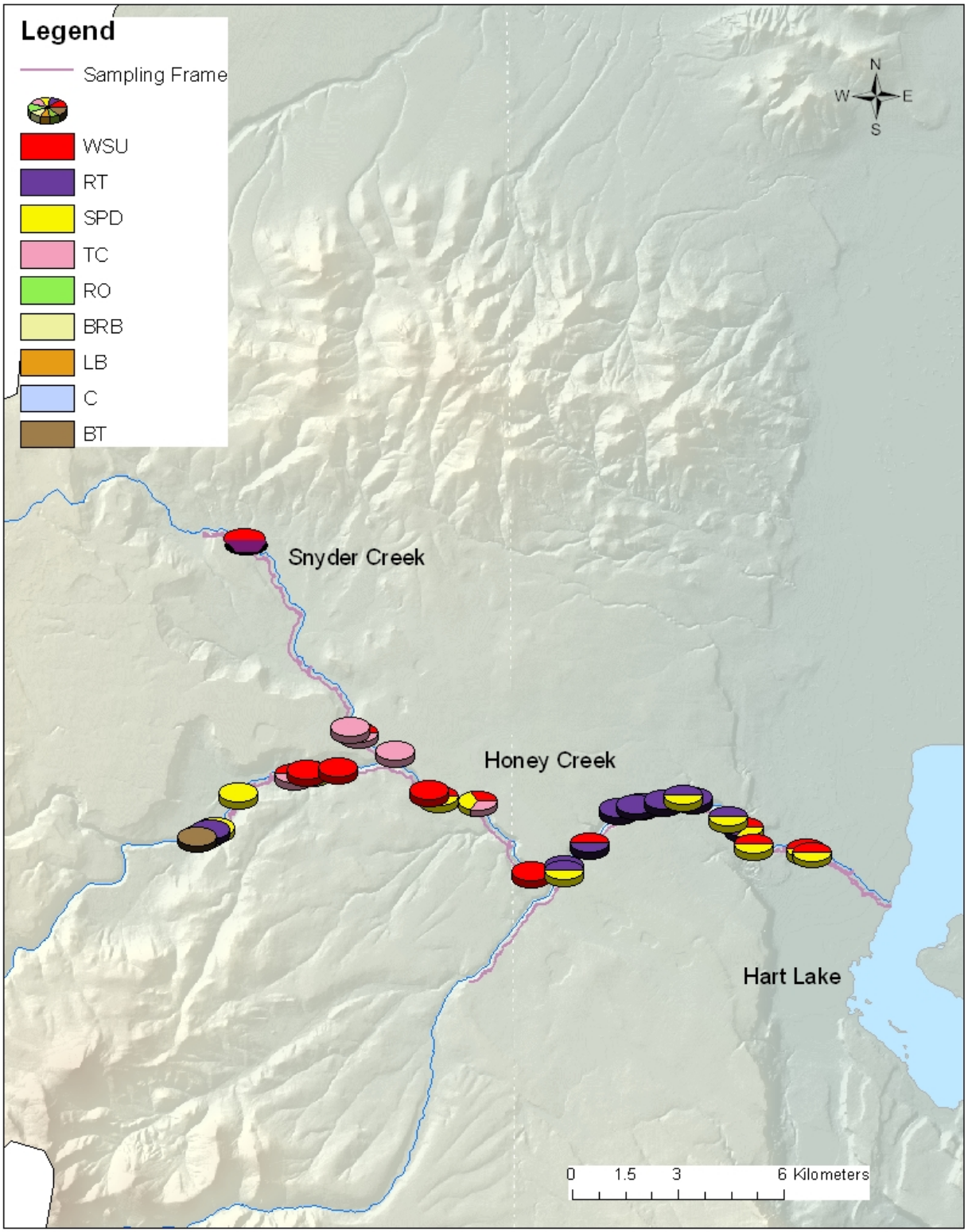

Figure 6. Map showing the distribution of all fish species collected in the Warner basin surveys in the Honey Creek drainage, 2007. Species codes: WSU- Warner sucker, RT- redband trout, SPD- speckled dace, TC- tui chub, RO- Pit roach, BRB- brown bullhead, LB- largemouth bass, C- white crappie, and BT- brook trout.

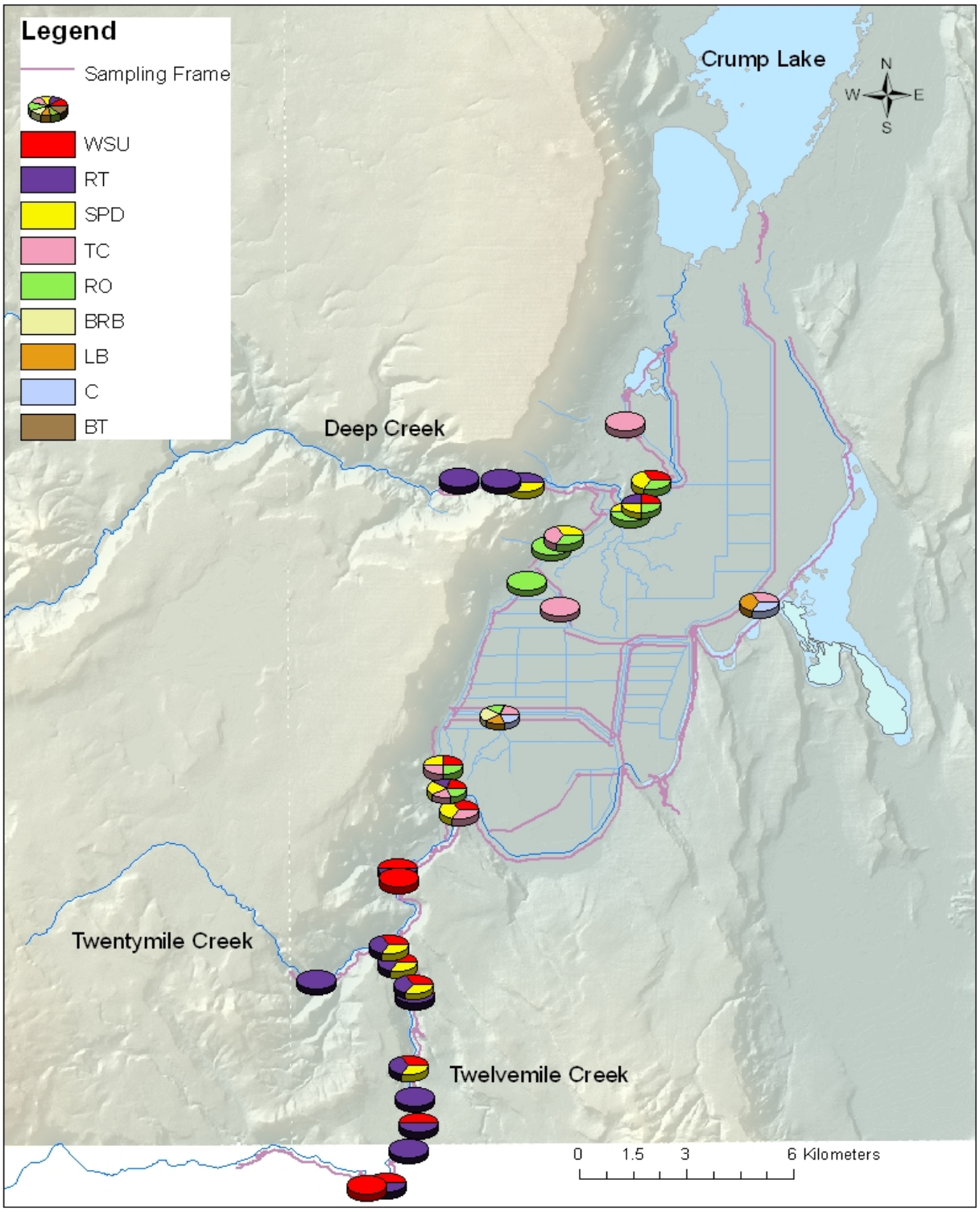

Figure 7. Map showing the distribution of all fish species collected in the Warner basin surveys in the Deep and Twentymile Creek drainages, 2007. Each species present is represented by an equal proportion of the pie. Species codes: WSU- Warner sucker, RT- redband trout, SPD- speckled dace, TC- tui chub, RO- Pit roach, BRB- brown bullhead, LB- largemouth bass, C- white crappie, and BT- brook trout.

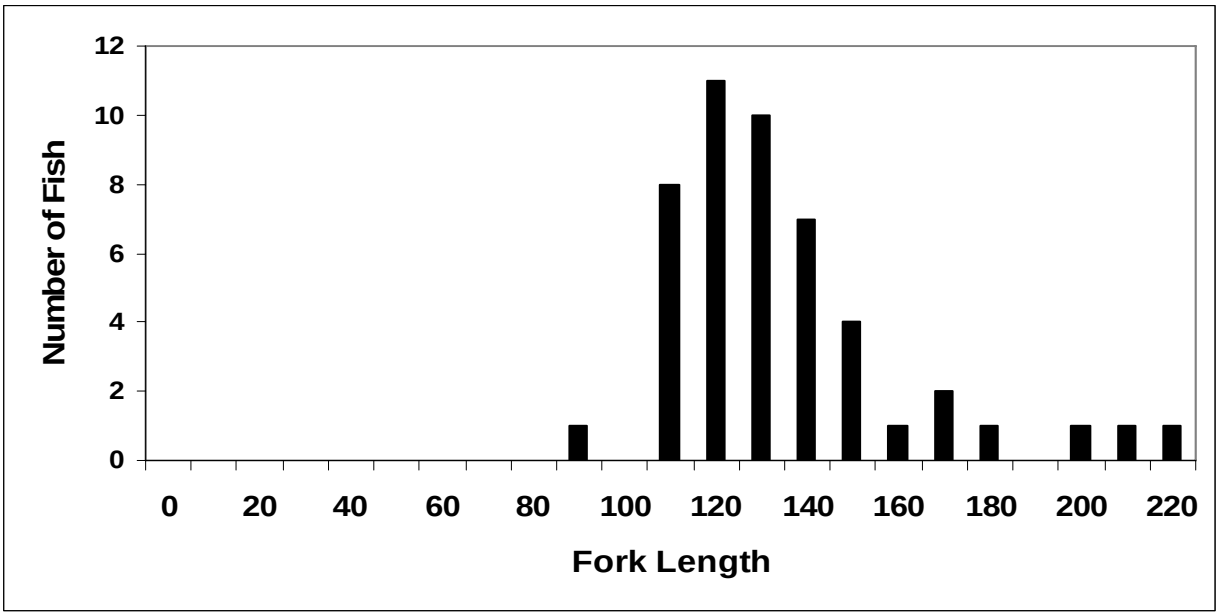

Figure 8. Length-frequency histogram for Warner suckers in the modified ditch at the Summer Lake Wildlife Area, 2007.

conditions that existed in the Warner basin in the summer of 2007. However, our survey results were similar to results from previous stream population assessments of Warner suckers, last obtained in 1994 (Tait et al. 1995). Both surveys found sucker distribution to be patchy and densities to be relatively low (Figure 5). Both surveys documented relatively high sucker numbers in lower Twelvemile Creek. Different methods were employed in 1994 (snorkel surveys) than in 2007 (multiple-pass electrofishing), thus actual density estimates are not directly comparable.

Our surveys were more comprehensive than the previous surveys, which enabled us to better describe current sucker distribution and to identify additional areas of relatively high sucker abundance. Our surveys documented a broader distribution of Warner suckers (adults and juveniles) in both the Honey and Twentymile Creek drainages than the 1994 surveys. In addition, we documented both adult and juvenile suckers in lower Deep Creek (not part of 1994 sampling frame). In 2006, we noted the movement of adult suckers that were radio tagged in Crump Lake into lower Deep Creek during the spawning period (Scheerer et al. 2006). These data suggest that lower Deep Creek may serve as an important sucker spawning and rearing habitat. Because access was denied to large portions of lower Deep Creek and lower Honey Creek, we were limited in our ability to assess the actual distribution of suckers in these areas. In 2007, ODFW also conducted population surveys for redband trout in the Warner basin. The redband sampling frame included the upper portions of these same drainages. No Warner suckers were collected at any of the redband sampling sites outside (upstream) of the Warner sucker sampling frame.

Because of the patchy distribution of sucker in the streams (large proportion of sites with zero suckers) and the presence of a few sites with high sucker densities, our population and basin abundance estimates had low levels of precision. In the future, we plan to modify our sampling protocol to include less intensive sampling at each site (single pass electrofishing without blocknets vs. multiple pass electrofishing with blocknets) but more extensive sampling within the drainages. This more extensive sampling effort should allow us to better locate those

rare pockets of relatively high sucker abundance in the streams. After areas of high sucker density are located, we will focus the intensity of our surveys in the vicinity of those areas. This should improve the precision of our estimates, which will allow us to better assess trends in population abundance over time.

The presence of numerous impassable diversion dams and unscreened irrigation canals is a major obstacle to meeting recovery criteria. These dams and canals act to fragment the habitat of Warner suckers in the basin. In 2008, we plan to begin to identify whether certain irrigation diversions impede upstream migration of lake suckers and redband trout by tracking seasonal movements of radio tagged suckers. This information will allow managers to prioritize restoration funding that can be used to assist local landowners in restoring passage both upstream and downstream of irrigation diversions. We will also track movements of radio tagged suckers during the spawning season to identify spawning grounds and to obtain a population estimate of suckers in the Warner Lakes, focusing most of our efforts in Hart Lake (since Crump Lake nearly dried completely in the fall of 2007).

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