Chapter 8

A Preliminary View of Water Quality Conditions of the Upper Verde River

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Introduction

Stream water temperatures are of general interest because of interactive effects among physical, biological, and chemical parameters of water chemistry (Langford 1990). Water temperature regimes dictate the types of aquatic flora and fauna present within the aquatic system, as well as influence the system's susceptibility to parasites and disease. These regimes are commonly noted in critical habitat designations as potentially limiting to native fish populations of Southwestern streams (Federal Register 2007). Temperatures that approach the upper thermal tolerances of Southwest native fishes have been noted in Arizona streams (Deacon and Minckley 1974; USDI Geological Survey 2005). Of particular interest are water temperatures for the UVR where spikedace (*Meda fulgida*) is imperiled. Recent fishery studies (Carveth and others 2006) suggest that native fishes are sensitive to annual and large temperature fluctuations. Reduced growth rates have been reported for some species (Widmer and others 2006). The relationships between desert fishes and water temperature are unclear, especially given the assumption that they should be capable of acclimating to hot and cold temperatures common to the Southwest.

State water managers rely on monitoring data to establish and validate water quality standards (Arizona Department of Environmental Quality 2002, 2007a, 2007b). Within the study area, the Arizona Department of Environmental Quality (Arizona Department of Environmental Quality 2007b) listed the headwater section of the UVR between Granite Creek and Hell Canyon as sufficiently high to support all uses attaining all uses, while the section between Perkinsville to below Camp Verde was listed as "impaired" because of sediment and turbidity. Arizona Department of Environmental Quality (2001) collected turbidity data between 1991 and 1995 to use in developing a Total Maximum Daily Load for turbidity using the "Aquatic and Wildlife Warm-water (A&Ww) Turbidity Standard" of 50 NTUs as defined in Arizona Department of Environmental Quality (1996, 2002). Anning (2003) synthesized National Water-Quality Assessment and other USDI Geological Survey monthly data for the Southwest and included the Clarkdale station located in the lower reach of the Verde River study area for the years 1981 to 1998. Aside from a few sample periods in which the A&Ww standards (Arizona Department of Environmental Quality 1996, 2002) were exceeded for pH, ammonia, total nitrogen, and total phosphorus, water quality was generally within accepted standards set by the State of Arizona (Arizona Department of Environmental Quality 1996, 2002).

In this chapter, the work of previous studies for water quality parameters, temperature, conductivity, dissolved oxygen, pH, turbidity, and total suspended solids are extended for April 2000 through April 2001 and for spring 2002. The purpose of this work was to establish a preliminary diagnosis of existing conditions for the purpose of identifying other research that could aid in identifying causal factors affecting native fishes. The data were collected using temporary monitoring stations installed in the UVR. This assessment reflects general conditions for the period of record and may not represent current conditions. Graphical contrasts of the statistical distributions of stream temperature for each station are provided.

Study Area

The UVR study area is defined as the perennial section of the river between Sullivan Dam downstream about 56 km (35 mi) to Tapco. It is described in detail in Chapter 2. Monitoring stations were established at two locations that aggregate various tributaries that contribute runoff to the main stem.

Most major historical influences, such as mining, livestock grazing, and vehicular travel, on the riparian zone have lessened over the last two decades (see Chapter 2). Grazing by livestock was modified from continuous-rotational to seasonal (winter) on most allotments in 1980, and then was entirely suspended in May 1998 (see Chapter 2. However, stray livestock graze some riparian areas intensively, as do elk. Wetland habitats are generally preferred grazing sites. Recreational impacts (e.g., off-road vehicles and camping) were also reduced through road closures, but the popularity of the river for off-road vehicles travel attracts many enthusiasts. No major fire or other off-site disturbances were noted. Potential sedimentation from rock quarries in the northern sections is possible, but not yet evident. The principal source of suspended sediments is from actively eroding paleoterraces and head cutting of tributaries adjusting to new base levels of the river (see Chapter 2).

Methods

Automated sampling stations using HydroLab* Datasondes with multi-parameter sensors were established in April 2000 at two locations on the UVR. Station 1 was located on the Prescott National Forest west boundary with the Verde River Ranch, and Station 2 was located at the Y-D Ranch in Perkinsville. Datasondes were suspended at a depth of 0.5 m (1.6 ft.), typically behind a boulder to protect sensors from large debris. Samples were taken at one-hour intervals and were obtained for continuous days where possible. Data were discounted if instrument calibrations drifted, hence making the period of record discontinuous. Data included storm- and flood-free days as determined from USDI Geological Survey Paulden flow gage records (USDI Geological Survey 2008). Additional data were collected in spring 2002 and were included in the period of record.

In addition, automated water samplers were used for determination of total suspended solids (TSS) as per Method 2540B in Clescerl and others (1998). Daily composite samples were created by collecting 50-ml aliquots every three hours. Three subsamples from each batch of 24 samples were analyzed for total organic carbon (TOC) as per Nelson and Sommers (1996). A total of 48 samples were collected in 2000. The intent was to ascertain the relative organic-inorganic fractions of about 10 to 12% of water samples.

Stations were established on or near private lands to provide security for equipment. Water quality parameters of interest included temperature, conductivity, dissolved oxygen (DO), pH, turbidity, TSS, and TOC. All data, except TOC, were summarized and graphed to display the variability for each parameter for the period of record.

Results

Temperature

Mean monthly water temperatures were virtually the same for Stations 1 and 2 (fig. 8.1). Slightly higher variability was observed at Station 1, probably owing to lesser water volume or influence from runoff emanating from high-elevation sub-watersheds. Seasonal changes in water temperature were observed, (maximum temperatures occurred in July), with a mean of 23 °C (73.4 °F) and low of 10 °C (50 °F) in January. Maximum and minimum temperatures at Stations 1 and 2 were 28.6 °C (83.5 °F) and 7.6 °C (45.7 °F), and 27.5 °C (81.5 °F) and 7.8 °C (46.0 °F), respectively. This temperature regime is consistent with the aquatic habitat criteria for native warm water fishes. Figure 8.2 illustrates and contrasts the diurnal variability in temperature across seasons. Aside from maximum and minimum values, there is great diurnal variability.

Specific Conductivity

Differences in specific conductivity were minor between Stations 1 and 2 (fig. 8.3). Both stations exhibited a similar trend through most of the year. Conductivity decreased at Station 2 in March 2001, probably in response to snowmelt runoff. This was not observed at Station 1 because there are no tributaries contributing snowmelt inflow (see watershed maps in Chapter 2). Winter precipitation in the upper headwaters (Station 1) is mostly in the form of rain, as snow rarely lasts beyond a few hours. In contrast, several tributaries that contribute to flow at Station 2 originate in the high country, where snow can last the entire season.

About a 15% increase in conductivity was observed at both stations during July. No observable difference in flow or rainfall occurred during this period so other factors could be at play. Water temperatures are noted near their highest in July, and it is possible the temperatures affected instrument calibrations for conductivity. General differences between Stations could be due to differences in location. Station 1 is located below the most spring sources for the Verde River, and baseflows derived from springs emanating from groundwater sources reportedly have different solution chemistry (Wirt and Hjalmarson 2000). Station 2 was subject to the flow and runoff influence from a vastly larger watershed, especially to those sub-watersheds from higher elevations and considerably larger drainages. The observed range of specific conductivity values are within the normal range (5 to 150 mS cm^{-1}) for potable waters (APHA-AWWA-WPCF 1989).

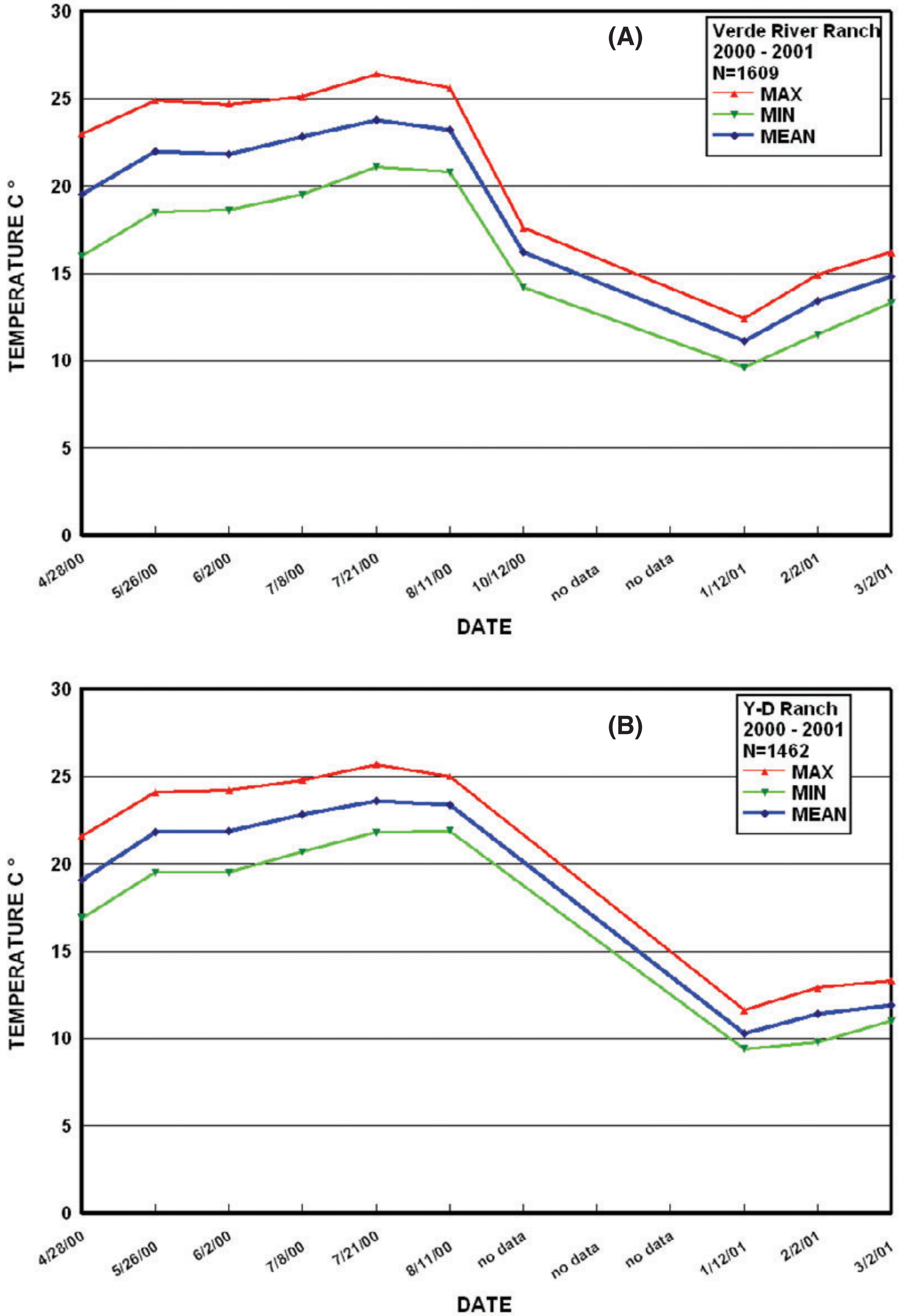


Figure 8.1—Monthly mean water temperatures at (A) the Verde River Ranch and (B) the Y-D Ranch sites, 2000 and 2001. High and low limits are equivalent to one standard deviation from the mean.

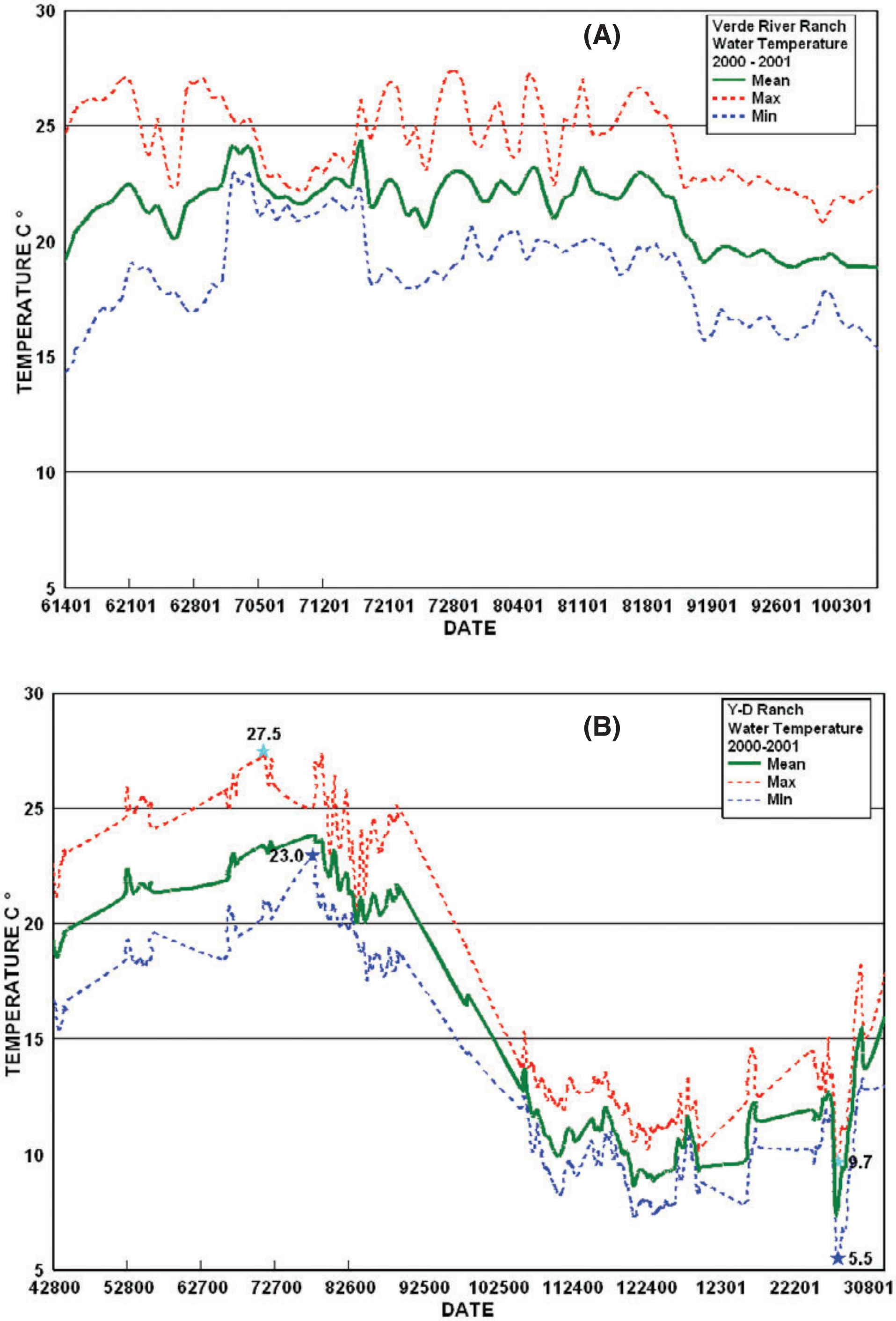


Figure 8.2—Comparison in diurnal variability in temperature between (A) the Verde River Ranch site (07/21/00 to 02/23/01) and (B) the Y-D Ranch site (04/28/00 to 03/08/01).

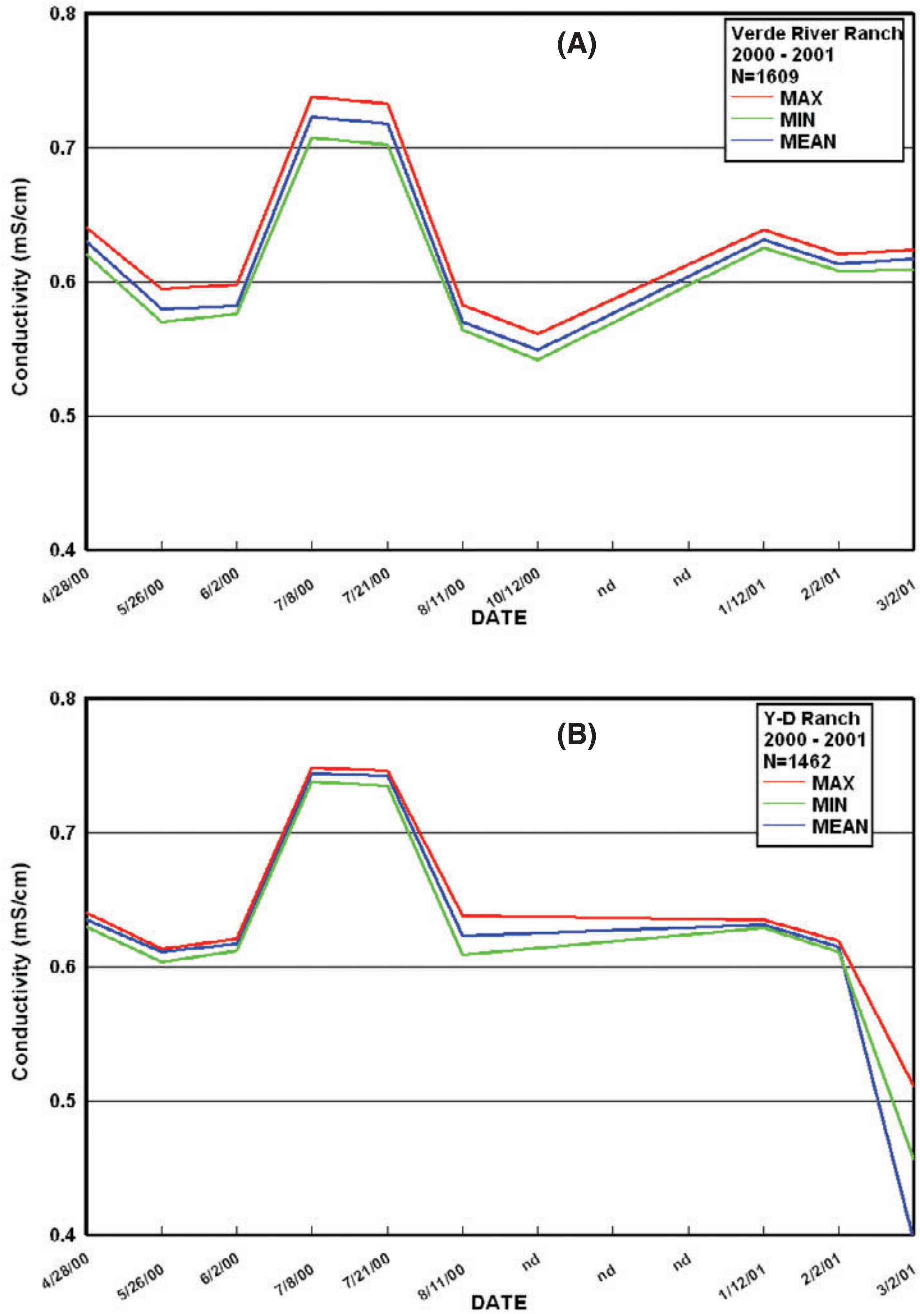


Figure 8.3—Contrasts in mean specific conductivity for (A) the Verde River Ranch and (B) the Y-D Ranch. High and low limits are equivalent to one standard deviation from the mean.

Dissolved Oxygen

Mean DO (fig. 8.4) saturation at Station 1 was above 90% (the suggested standard; Arizona Department of Environmental Quality 1996, 2002) in all cases, except for in early July when it dropped to a mean of 86% (± 26%). Mean DO (fig. 8.4) saturation at Station 2 was above 90% saturation for most of the year, except for brief periods in August and March, which coincided with the onset of macroinvertebrate production and algae algal blooms. The annual mean for both Stations combined was 97.2% ± 19%.

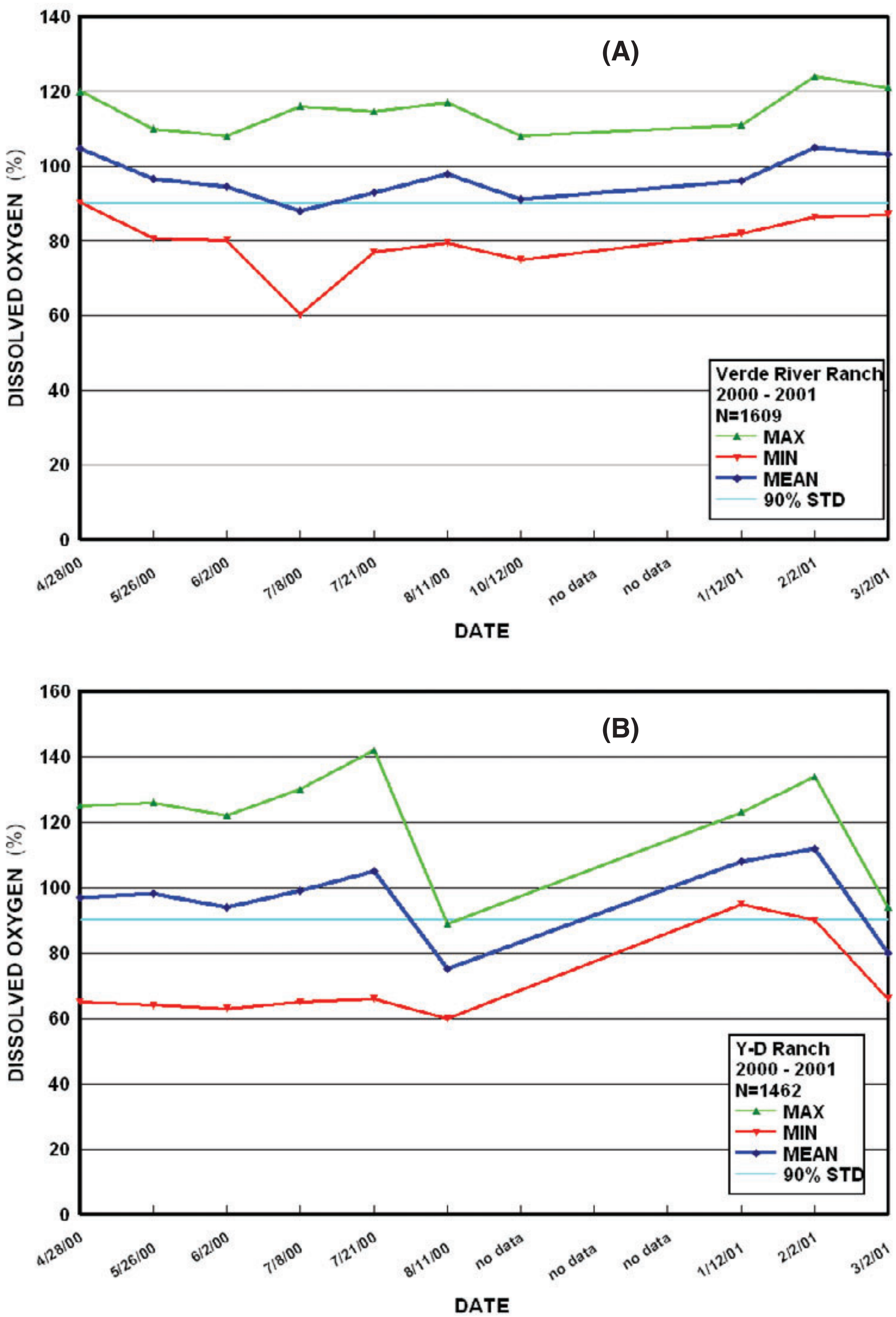


Figure 8.4—Contrasts in mean percent dissolved oxygen at (A) the Verde River Ranch and (B) the Y-D Ranch. High and low limits are equivalent to one standard deviation from the mean.

pH

Mean pH values for Station 1 were generally stable between April and late summer (fig. 8.5). An increase of 0.5 standard units was noted during the winter months, returning to pre-existing conditions in the spring. Mean pH levels at Station 2 were slightly lower than at Station 1 (7.7 and 8.1, respectively) (fig. 8.5). These levels are consistent with standards for warmwater streams (Arizona Department of Environmental Quality 1996, 2002) and do not pose a risk to water quality or aquatic habitats for native fauna.

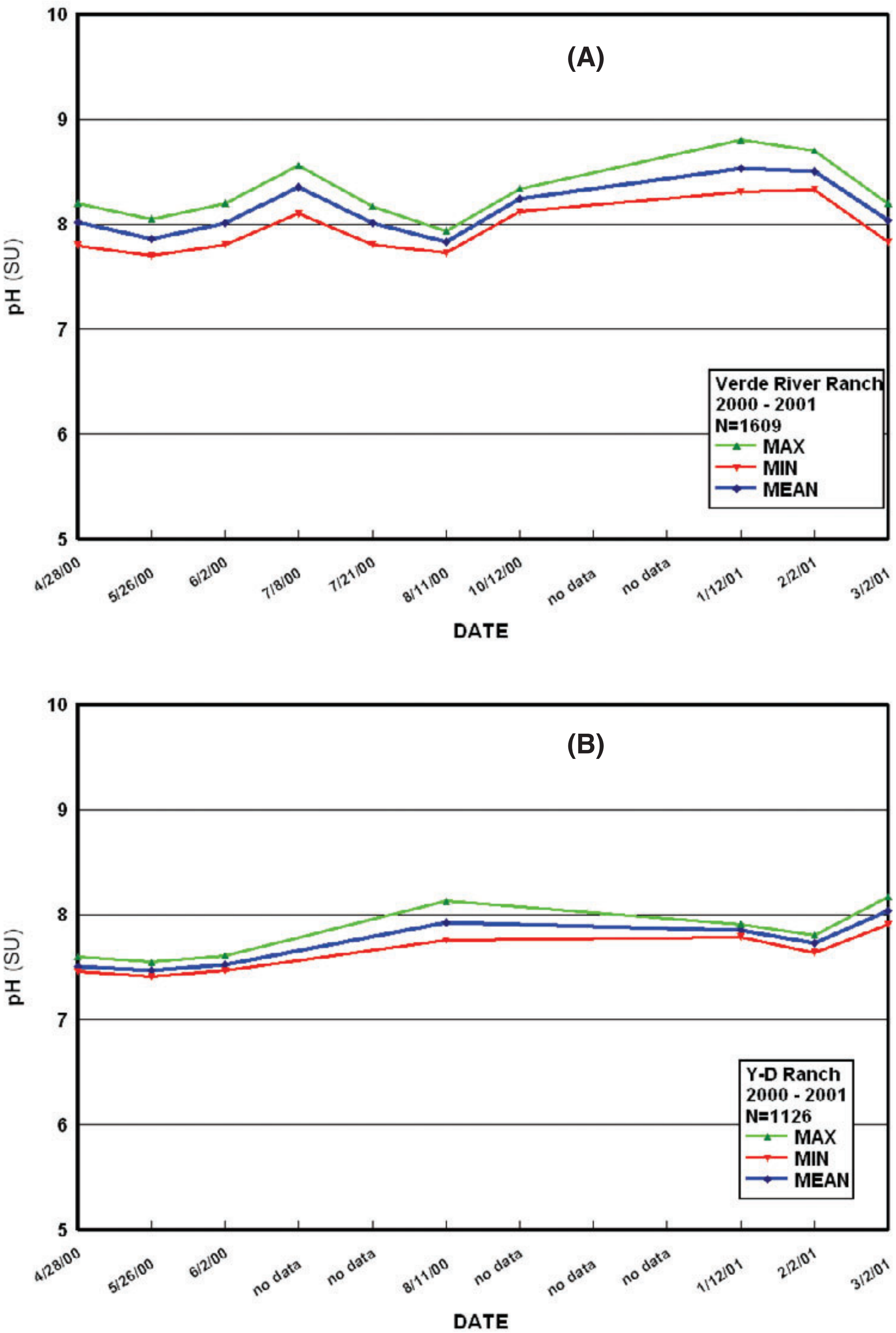


Figure 8.5—Contrast in mean pH values between (A) the Verde Ranch and the (B) Y-D Ranch. High and low limits are equivalent to one standard deviation from the mean.

Turbidity

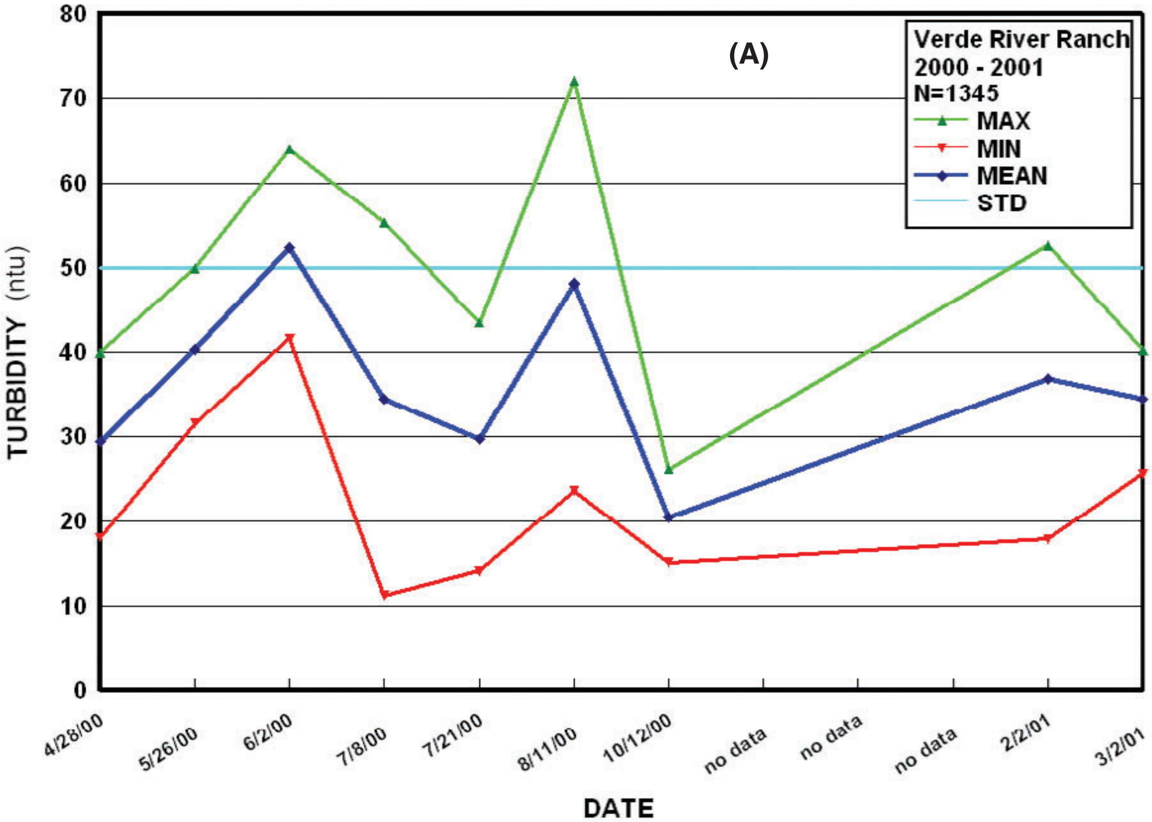
Turbidity levels fluctuated across time at both stations (fig. 8.6). Mean turbidity at Station 1 was below the 50 NTU standard (Arizona Department of Environmental Quality 1996, 2002) for all times except for June when mean turbidity reached 53 NTU ± 11. Mean annual turbidity for Station 1 was 35 NTU ± 17. Turbidity levels at Station 2 were always below the 50 NTU standard. Mean annual turbidity for Station 2 was 38 NTU ± 35. Turbidity proved to be unreliable estimates of suspended solids because of sensor fouling by detritus, diatoms, benthos, and algae. The effect of phytoplankton on turbidity sensors was most evident in the spring when various algae also became prevalent. Distinct patterns are evident between Stations and are attributed to actual water clarity. Station 1 was in a location with relatively little human disturbance but it was subject to biological growth owing to water clarity, especially algae. Station 2 was in a location where human disturbance occurred nearby as well as at a campground 1.6 km (1 mi) away. Crayfish and beaver were also abundant at Station 2 but were lacking at Station 1. The presence of these animals could account for additional differences either at specific times/seasons or in general.

There were notable differences in turbidity and water clarity observed for several years between the warm and cool seasons. During the summer water color approximated a gray-green in contrast to a clear color in the winter. Likewise high turbidity was most evident at locations where cattails abound and in pools and glides. Riffle areas tended to clarify turbid conditions.

TSS and TOC

Estimates of TSS are depicted in fig. 8.7. Greater variability was observed at Station 2. The data illustrate that suspended solids are relatively low and do not constitute an impairment to water quality. In this study, estimations of suspended solids are preferable to turbidity estimates because of the unknown effect of fouling of the turbidity sensor (see the “Turbidity” section). Hence, no correlation between TSS and turbidity was attempted. It is highly likely that the higher TSS for Station 2 at the Y-D Ranch was due to recreational disturbances from campgrounds and recreational vehicle travel on the floodplain and stream. These activities are common about 1 mile upstream of Station 2. It seems unlikely that livestock grazing contributed to the differences between Stations as both had grazing occurring above the collection site. However, livestock grazing at Station 2 was seasonal, while grazing was year-long at Station 1.

Analysis of 48 sediment samples from the TSS samples revealed that nearly 92% ± 4.6 of TSS was due to organic matter across all seasons. Organic fractions were highest during the growing season (96% ± 3.8)—May through September—and lowest during the fall-winter period 81% ± 5.7. There is an obvious change in turbidity and water color between these seasons, with turbid water evident during the summer. This is likely due to the activity of macroinvertebrates (shredders) during late spring and summer. No estimates of TOC were taken during flooding.



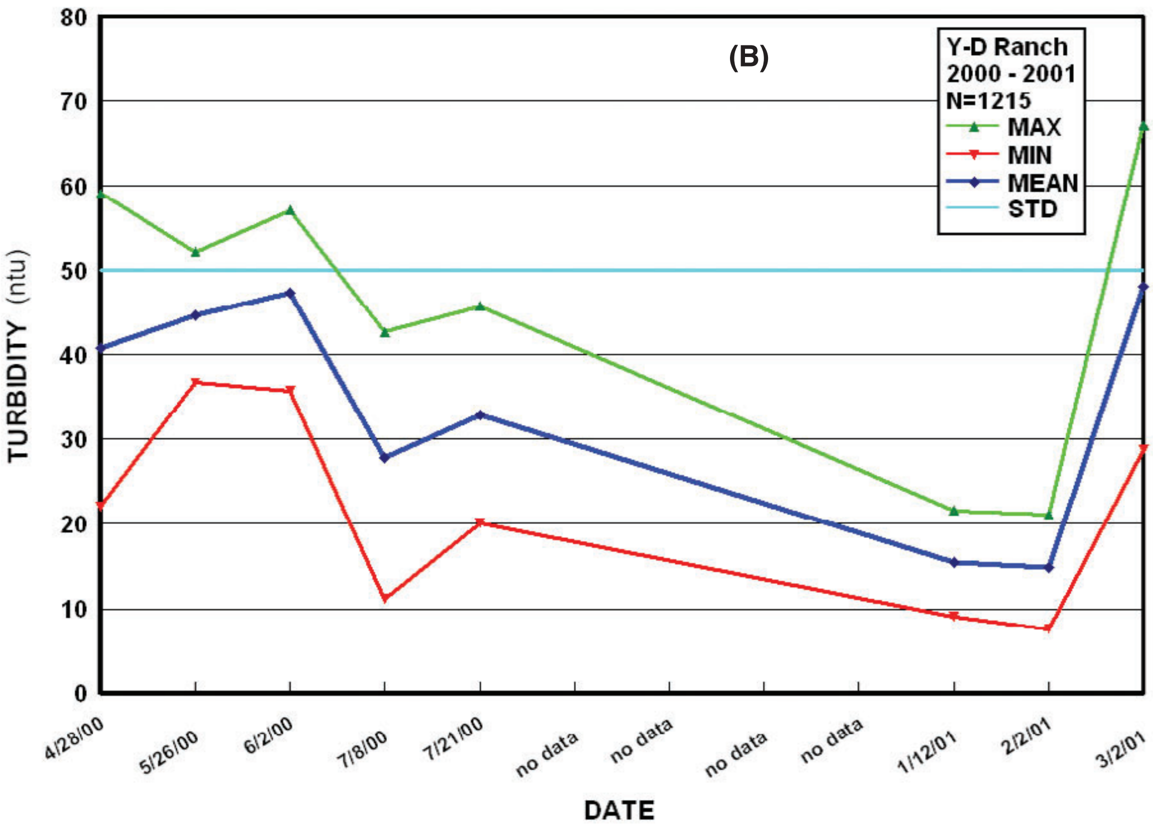


Figure 8.6—Contrast in mean turbidity values at (A) Verde Ranch and (B) Y-D Ranch. High and low limits are equivalent to one standard deviation from the mean.

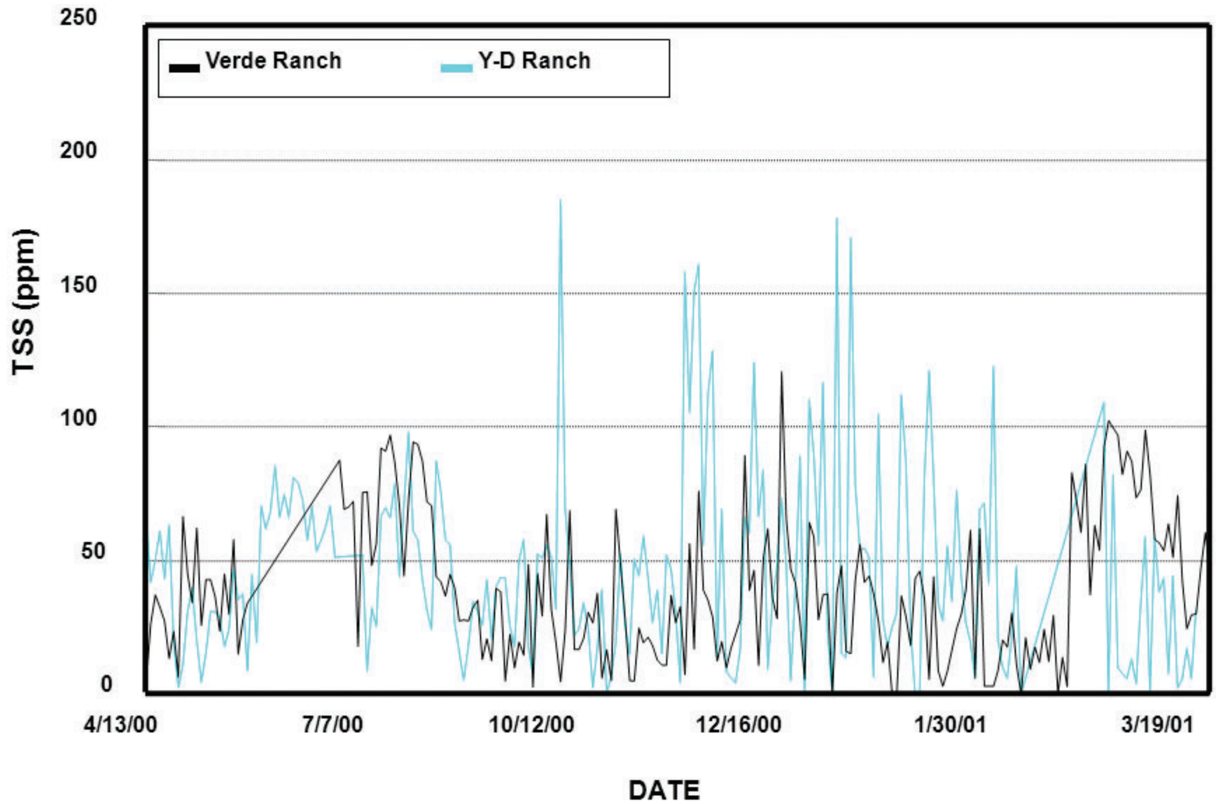


Figure 8.7—Contrast of TSS for the Verde River Ranch and the Y-D Ranch. Data are for non-flood days.

Discussion

Temperature

The temperature regimes identified in this study are consistent with results from other streams in Arizona (Barber and Minckley 1966; Barber and others 1970) and New Mexico (Propst and others 1986) for native warmwater fishes. Emphasis herein is placed on spikedace (*Meda fulgida*) because of its threatened status and its interest to management agencies, but the data apply to other important native fishes of the Verde River, including roundtail chub (*Gila robusta*), Sonora sucker (*Catostomus insignis*), speckled dace (*Rhinichthys osculus*), and longfin dace (*Agosia chrysogaster*). All these fishes are close associates of desert streams in Arizona and New Mexico. However, temperature regimes, including thermal maxima, can vary by several factors, including species, time of year, flow conditions, and local habitat conditions.

Barber and others (1970) reported habitat temperatures of occupied spikedace habitat to vary with time of year. In May, water temperatures at Aravaipa Creek, a stream system much like the Verde River, were uniformly 19 °C (66.2 °F). Summer water temperatures remained at no more than 27 °C (80.6 °F). On the Gila River, similar to the Verde River, in southern New Mexico in the Forks area in the Cliff-Gila Valley, summer temperatures reached a mean of 19.3 °C (66.7 °F) between June and November (Propst and others 1986). Winter water temperatures on Aravaipa Creek ranged between 20.6 °C (69.1 °F) in November down to 8.9 °C

(48.0 °F) in December (Barber and Minckley 1966). Rinne and others (2002) noted stream temperatures on the Verde River can exceed 30 °C daily and suggested some fish may survive temperatures near 35 °C but also noted that fish in the wild can move to cooler habitats and avoid temperature extremes.

These diurnal extremes are common on the Verde River, as evidenced in fig. 8.2. This variability is important and likely more common when considering habitat suitability for aquatic species. How this variability is apt to change with respect to major changes in vegetation (see Chapter 6) and channel conditions (see Chapter 5) is unknown but it is an important management consideration for warmwater fauna, especially TES species.

Carveth and others (2006) performed laboratory studies on temperature tolerances of spikedace from Aravaipa Creek and determined that no spikedace survived exposure of 30 days at 34 or 36 °C (93.2 or 96.8 °F) and that 50% mortality occurred after 30 days at 32.1 °C (89.8 °F). In addition, growth rate was slowed at 32 °C (89.6 °F) as well as at lower test temperatures of 10 °C and 4 °C (50 and 39.2 °F). The authors further observed multiple behavioral and physiological changes, indicating that fish became stressed at 30, 32, and 33 °C (86, 89.6, and 91.4 °F) treatments. The study concluded that temperature tolerance in the wild may be lower due to the influence of additional stressors, including disease, predation, competition, or poor water quality. Temperatures in the UVR during the monitoring never reached 30° C, much less the high temperatures tested in the University of Arizona study. Low temperatures briefly dipped below 10 °C (50 °F). The study concluded that 100% survival of spikedace at 30 °C (86 °F) in the experiment suggests that little juvenile or adult mortality would occur due to thermal stress if peak water temperatures remained at or below that level (Carveth and others 2006), accounting for genetic constraints that may be present among the various subspecies across the Gila River Basin, the Verde River included.

Carveth and others (2006) further compared the upper thermal tolerances of native and nonnative fish species of Arizona. Among the species acclimated to 25 °C (77 °F), desert pupfish (*Cyprinodon macularius*), western mosquitofish (*Gambusia affinis*), and Gila topminnow (P*oeciliopsis occidentalis*) were most tolerant to high temperature. The smaller native fishes—speckled dace (*Rhinichthys osculus*), spikedace (*Meda fulgid*a), and loach minnow (*R. cobitis*)—were least tolerant. Many native species demonstrated a limited ability to extend their upper temperature tolerances via acclimation. The Carveth and others (2006) study suggested that several native species may be sensitive to increasing annual and or large daily temperature fluctuations in Arizona's streams and rivers. Hence, the current changes in habitat conditions (see Chapters 2, 5, and 6) are increasingly important when defining management strategies, especially when their basis is limited or outdated. Although Southwest United States native fishes were previously believed to be tolerant to high temperature due to their evolution in desert environments, this may not be the case for some fishes.

Dissolved Oxygen

Warm water that is typically found in Southwest desert rivers and lakes contains decreased levels of DO, which can adversely affect aquatic animals such as fishes and amphibians not adapted to lower oxygen levels (Laws 2000). DO concentrations in the UVR were within the acceptable standards set by Arizona Department of Environmental Quality (1996, 2002) for warmwater streams. However, besides temperature, the high percentage of sampled organic matter is of concern with respect to potential decreased DO concentration. The UVR harbors a diverse aquatic plant flora; some such as cattails (*Typha* spp.), inhabit large areas of instream habitat (see Chapters 2 and 6). These dense stands of cattails, located primarily in the upper reaches, and associated herbaceous vegetation produce large amounts of detritus, which becomes part of the suspended load. Growth of these plants commences with the increase in ambient temperatures of spring and summer, as well as other growth of phytoplankton, macroinvertebrates, etc. These combined conditions produce a major change in water turbidity seasonally that is evidenced by a crystalline-clear to a murky gray-green appearance. In addition, the UVR in 1979 was a very different system compared to today. Channel habitat consisted mostly of wide and long riffles—a stark contrast to the more common pool-glide habitat present today (see Chapter 2). It's uncertain what the effects are of the combinations of temperature, organic loading, suspended silts/clays from eroding terraces, and changes in channel substrates and habitat (see Chapters 2 and 5) on productivity of the aquatic system. As noted elsewhere, these changes in vegetation and channel conditions are a recent condition. In some respects, one would expect primary and secondary production to increase, but this is not evident from fish population surveys conducted over the last 20 years.

Conductivity and pH

The data show nothing remarkable about conductivity or pH aside from some temporal anomalies that are difficult to explain. Specific conductivity and pH levels are consistent with standards for warmwater streams (Arizona Department of Environmental Quality 1996, 2002) and do not pose a risk to water quality or aquatic habitats for native fauna. Differences in specific conductivity between sampling locations is best attributed to differences in the size and origin of runoff for the lower location.

Turbidity and Total Dissolved Solids

Turbidity is a temporal problem on the UVR, most likely resulting from the abundant aquatic plant growth in the channel during the growing season. Estimates of organic matter content in water samples averaged 92% ± 4.6 across the sampling period in 2000 and accounted for increased concentrations of TSS. However, none of these was remarkable with respect to exceeding water quality standards (Arizona Department of Environmental Quality 1996, 2002). Today, better turbidity sensors are available to record this parameter across a continuous record.

Management Implications

Water quality data collected in this study were intended to provide land managers with a diagnostic reference about current conditions; the data were not intended for extrapolating cause-and-effect relationships of upland and riparian management activities. They are too limited in extent, duration, and flow range sampling to do so. At best, one can say that the water quality of the sampled reaches of the UVR is within the range of variability of warmwater standards for the Southwest and does not raise any particular concerns other than those discussed for organic loading. Sampling occurred under grazed and ungrazed conditions, which are inseparable, and no adverse effects can be attributed to such.

Since aquatic habitat conditions continue to change relative to 1979, it is recommended that a more extensive assessment of aquatic habitat suitability and availability be conducted before any major change in fish management occurs. This assessment should be conducted periodically—every three to five years—to establish trends and identify potential risk factors that could impair restoration efforts for riparian-aquatic habitats or aquatic fauna. Although there were no remarkable diagnostics for the parameters examined, recent studies have implicated the presence of chemical cocktails, e.g., pharmaceuticals, in aquatic fauna population studies (some conducted in Arizona rivers [Environmental Protection Agency 2009]). The concern has alarmed Environmental Protection Agency (2009) such that officials now include monitoring of “pharmaceutical and personal care products” as part of its National Rivers and Streams Assessment. This new concern is relevant to the UVR because of the potential for chemical contamination from the rural area above the dam. The rural area above Sullivan dam was once a sparsely populated community, until recently as the area is presently occupied by many homes, agricultural industries and other commercial business. A diagnostic approach to exclude chemical constituents is important to add to the status of knowledge of the UVR.

Summary and Conclusions

Water quality data collected on the UVR were not comprehensive or continuous and involved only two sites that were chosen for their ease of access and security, not for any scientific concern. However, the preliminary data collected for two stations on the UVR during the period April 2000 through March 2001 suggest that all parameters (temperature, DO, pH, conductivity, turbidity, and TSS) are consistent with warmwater standards for the Southwest. They are also well within the normal range of conditions for native fishes such as the spikedace.