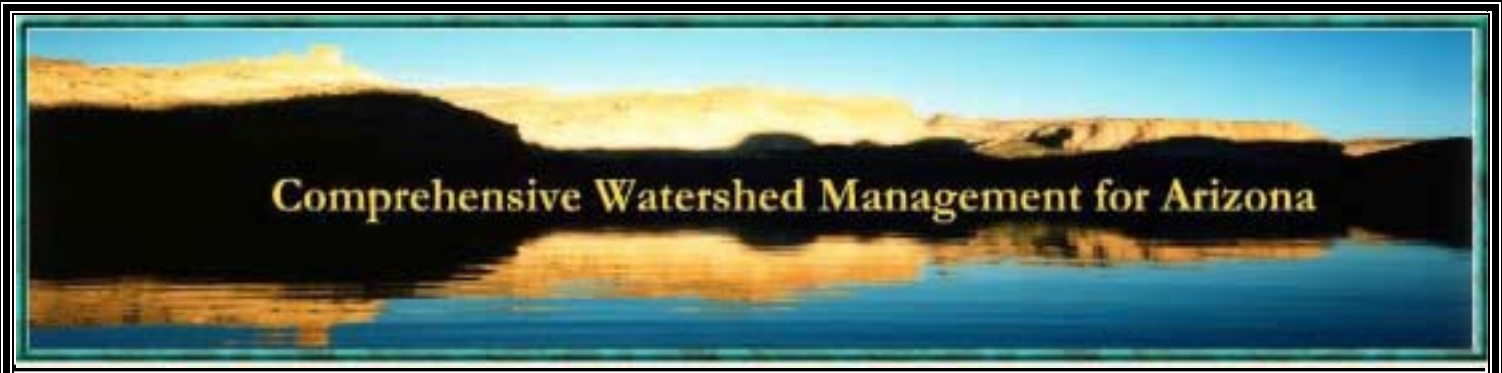


Water Quality Monitoring Report, March 2006. From the Lab of David Walker, Ph.D. University of Arizona
Environmental Research Lab, University of Arizona Ph: 520-626-2386 Fax: 520-573-0852 Email: dwalker@ag.arizona.edu

In this Issue:

Scope of Project and Name Change

For almost a decade we have been actively involved with a multitude of water quality issues in watersheds surrounding the Phoenix Metropolitan region. While we are still active in this region, our research now expands beyond these watersheds and we have on-going projects throughout the state in collaboration with a multitude of municipal, state, and federal resource agencies. This outreach and collaboration is consonant with the University of Arizona's land-grant heritage. Therefore, this newsletter, while still discussing issues in those very important watersheds surrounding the most-populated area of the state, will also discuss research we are actively performing state-wide.

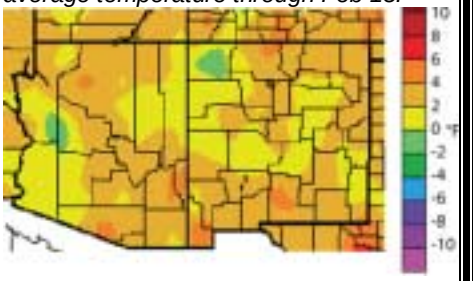
Feedback on this newsletter is always encouraged. If anyone has suggestions about content or timing (more or less frequently), or if anyone would like to be removed from (or added to) the mailing list, please let me know.

Climate and Wildfire Forecasts: The Winter that Wasn't

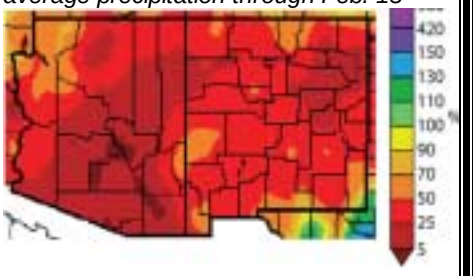
While Arizona typically has a bi-modal distribution pattern of precipitation with approximately half occurring during winter and half during summer monsoons, it is the winter precipitation that contributes to roughly 80% of stream flow. What I'm sure is painfully obvious to everyone is the extremely dry and warm winter Arizona is currently experiencing.

Arizona and southwest New Mexico have currently entered into a state of extreme drought. The winter of 2005/06 is on its way to becoming the warmest and driest on record.

Water Year '05-'06 Departure from average temperature through Feb 15.



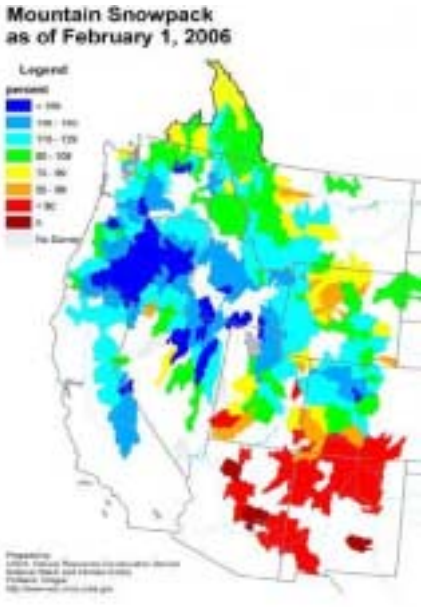
Water Year '05-'06 Departure from average precipitation through Feb. 15



While last winters precipitation brought short-term relief to ongoing-drought conditions, this winter lies in stark contrast. High pressure centered over Central/Southern Arizona blocked any early-winter/late-fall precipitation in 2005. Storm tracks were well to the north of Arizona and while this high pressure has occasionally shifted farther north, the result is the same;

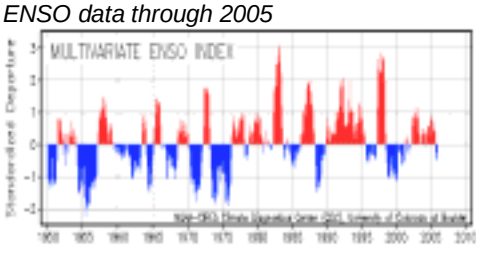
blocking any Pacific storms from entering Arizona.

What's most damning is the absence of any significant snow pack in Arizona. States to the north have benefited from high pressure systems centered over Arizona by having precipitation that would normally enter the state being funneled to the north. This bodes well for the CAP system but not so well for other rivers, streams, and reservoirs in Arizona. Riparian areas along ephemeral streams, due to years of accumulated drought conditions, will likely be hard hit this year.



Forecasts predict that conditions will likely remain the same for the next 3-6 months and while the state may receive precipitation this winter, it is unlikely to do much to alleviate current drought conditions. Forecasts also predict this to be a near-neutral to weak La Nina year.

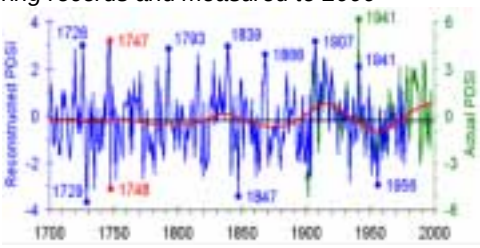
ENSO data through 2005



ENSO (El Nino, Southern Oscillation) events occur on an inter-annual basis and are important events related to short-term climate variability. Phenomenon occurring at the decadal scale, however, may be more important determinants of long-term drought conditions. Such a phenomenon is the Pacific Decadal Oscillation which we have spoken about at several previous meetings (http://ag.arizona.edu/limnology/Walker2_files/frame.htm). Negative PDO phases tend to enhance La Nina and weaken El Nino events.

Arizona has experienced wet years and dry years in the past and we will have wet and dry years in the future. The only thing constant about climate is its variability. However, one aspect that may be changing is the degree of variability between the wet and dry years. Historic Palmer Drought Severity Indices reconstructed from tree ring records indicate that the amplitude of this variability may be increasing. In other words, dry periods may become increasingly dry and wet periods increasingly wet.

PDSI data both re-constructed from tree ring records and measured to 2000



One thing is certain this year; there is a greatly elevated risk of wildfires. Tinder-dry conditions currently exist at all elevations and the chance for fire to begin at lower elevations and spread into areas with more dense vegetation is at an all-time high. As we have stated in previous reports, all wildfires are not created equal and some will have devastating and long-term effects on watersheds and water quality (e.g., the Rodeo-Chedeski Fire) while other fires of similar size exert relatively minimal effects on watersheds and water quality (e.g. the Cave Creek Complex Fire). The degree to which any particular wildfire impacts water quality depends on several factors including the amount and type of fuel consumed which has an effect on fire temperature and degree of long-term damage to soils. We have discussed this issue in previous reports (http://ag.arizona.edu/limnology/July05report.pdf) but it's worth repeating again due to current drought conditions.

Non-native, invasive plants have the capability to carry fire quickly into areas with higher biomass and ground fuel. These same non-native plants are also those quick to become established and replace native plants after a disturbance such as wildfire. Invasive plant species, coupled with and to some extent driven by drought, will likely result in an earlier-than-average start to this years wildfire season. These same conditions may result in an increased frequency and severity of individual fires. We will continue to work closely with ADEQ monitoring any potential water quality impacts due to wildfires this season.

Roosevelt Coring

In waters without historical data, it is often impossible to predict water quality trends or increases in trophic state. Even when some data has been collected, it is usually transient or relatively short-term compared to the age of the system in question. Additionally, it is impossible to quantify detrimental effects of anthropogenic land-use activities or natural disturbances (such as wildfire) in a watershed on receiving water quality unless a substantial amount of data has been collected prior to each disturbance or activity. The subtle accumulation of non-point sources of pollution also makes determination of trends in water quality difficult to detect. Often, subtle declines in water quality go undetected until a problem becomes bad enough to warrant remedial action; actions that are often very expensive and logistically difficult to implement.

Paleolimnological techniques are often used to assess water quality trends in lakes and reservoirs over time. Incorporated in reservoir sediments is a record of the

organisms that lived in and around the lake, as well as proxy data related to processes occurring in the lake, the composition of the lake water, the conditions in its watershed, and past climatological data. The information obtained from paleolimnological studies can greatly aid resource managers in detecting problems that otherwise would have gone unnoticed.

This up-coming year, we will be working with colleagues Paul Gremillion from NAU and Owen Davis from the UA's Geosciences Department, to collect core samples from Roosevelt to analyze past response to disturbance. This work will be funded by ADEQ. We plan to collect sediment cores from the Salt River arm of Roosevelt as well as in the lacustrine zone immediately in front of Roosevelt Dam using a Wright-Livingston square rod piston corer. These cores will then be age dated using Lead-210 (^{210}Pb) and/or Cesium-137 (^{137}Cs) radionuclides. The objectives of this work are many but all pertain to quantifying long-term water quality trends in Roosevelt Reservoir and the Salt River watershed, determining how these watershed variables define water quality within the reservoir, and how aquatic biota respond to these water quality changes. While the focus of our research will be post-impoundment, local geography indicates that a pre-impoundment wetland or playa may have existed. We anticipate the cores being long enough to capture pre-impoundment environmental conditions. The extent of time that will be captured from the cores is currently unknown because this work has never been performed in Roosevelt. Paleolimnological studies in lakes often capture time frames in the thousands and sometimes tens of thousands of years before the present.

Specific objectives are given below.

Determination of watershed vegetation changes over time and how this has affected, and has been affected by, fire cycle, frequency and intensity. This information will then be correlated with other water quality variables such as % carbon, metals, nutrients, charcoal, and the biotic response via the chironomid head capsule and diatom data to observe past biotic response to watershed disturbance.

Determining the effect of anthropogenic activities within the watershed on water quality delivered to Roosevelt reservoir. The watershed immediately surrounding the reservoir has a long history of mining activity as well as complaints about the effects these mines have had on water quality within

The information obtained from this work could be used by ADEQ as an aid in determining biocriteria for reservoirs within the state. While there has been some biocriteria established for perennial, wadeable streams in Arizona, biocriteria for lacustrine environments is sorely lacking.

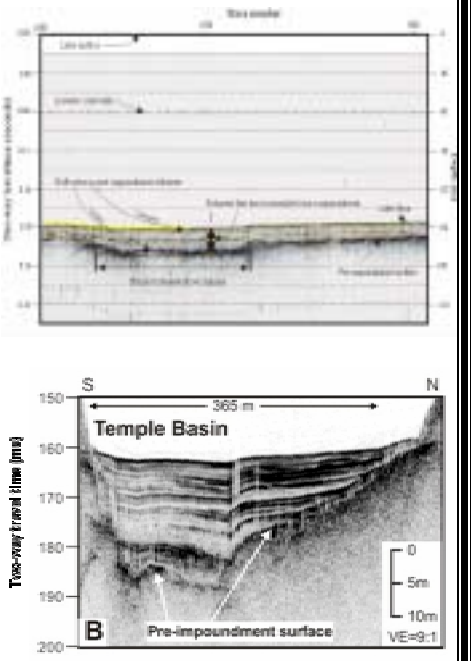
While we are focusing on the post-impoundment time period (especially in regard to anthropogenic activities), we may be able to assess long-term climatic trends depending on the length of the core obtained.

Side-scanning sonar and seismic profiling are powerful tools for mapping the shape and stratigraphy of ocean and lake sediments. These instruments, linked with spatial analysis software, are capable of providing highly accurate maps of bathymetry, sediment thickness, and sediment deposition characteristics.

Sediment maps are themselves of interest for such applications as assessing depletion in reservoir capacity and characteristics of sediment redistribution under conditions of changing lake level. This sediment survey, however, has the additional capability to direct our siting of locations for sediment coring. It is essential to select coring locations carefully and to understand the depositional context of each core. Therefore, we will collect one core in each of the tributary river arms of the lake and a third core in the deepest part of the lacustrine basin. Seismic profiling will permit us to select riverine sites at which sediment has been deposited in undisturbed strata.

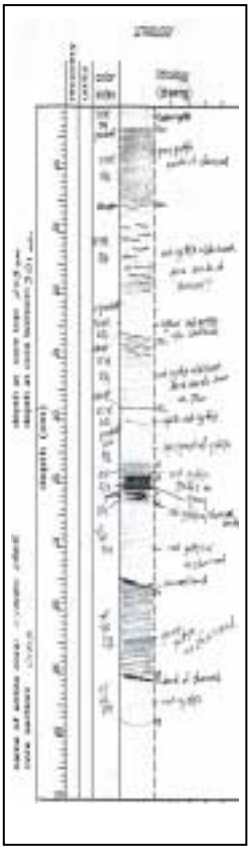
An important objective for the lacustrine core is to capture the pre-impoundment playa-like lake that likely existed in the Salt River riparian area. Because organic material bears distinct seismic signatures, we expect to map with accuracy the extent of riparian organic matter buried beneath Roosevelt sediments. This will enable us to position our coring platform at a suitable location for collecting not only the post-impoundment sediment, but the pre-impoundment playa sediments. The buried playa sediment may contain a well-preserved record of pre-impoundment water quality and watershed conditions.

Typical seismic-profiler images of reservoir sediment, from Lake Mead, Nevada, Arizona (reproduced from Twichell et al., 1999).

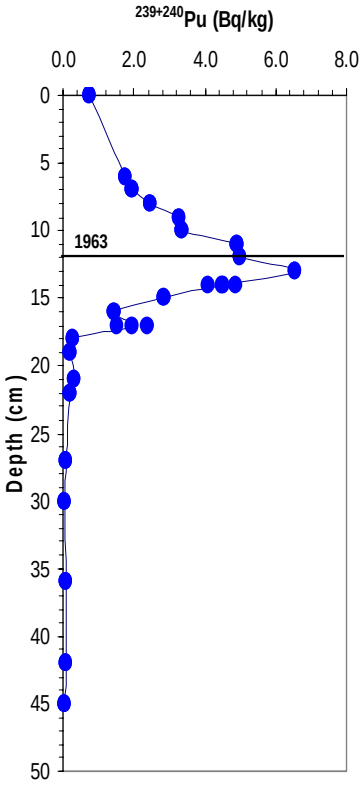


Based on the acoustic data, we will select three coring sites. This methodology has successfully been used by Dr. Gremillion to collect sediment cores representing the entire depositional histories of Lyman and Alamo Lakes in Arizona, resulting in a 4.5 meters of sediment core for Lyman Lake and 5 meters of core in Alamo Lake.

Sediment cores are useful only if the quality of the depositional record can be assessed. Cores collected from highly disturbed environments, for example, do not yield a systematic, chronological sequence of sediments. Sedimentation in reservoirs can be subject to highly dynamic conditions, particularly in arid lands where hydrologic events may be large in magnitude. Dr. Gremillion has discovered in these reservoirs that the large-magnitude hydrologic events deliver such massive pulses of sediment that these inputs tend to form distinct sediment strata that protect underlying sediment from disturbance. An example of the distinct stratigraphy observed in Arizona reservoirs is shown below which is the lithologic description of part of the core Dr. Gremillion collected from Lyman Lake.



Of the analyses we will perform on the Roosevelt Lake cores, several are dedicated to determining the quality of the depositional record captured and the chronology of the sediment sequences. Other analyses will yield information on past water quality and watershed processes. Visual assessment of lithology, photographic grayscale analysis, and magnetic susceptibility will be used to assess how well the sediments were deposited in an orderly sequence. Lead-210 and Cesium-137 analyses will provide both chronological data and information on depositional quality. In particular, the shape of the plutonium peak, an artifact of above-ground nuclear testing from the mid-1950s to early-1960s, will provide an assessment of the quality of the sediment record. The figure below, for example, shows a well-defined curve for plutonium, an analog for ^{137}Cs, in Upper Lake Mary, Arizona sediments.



After we have completed coring Roosevelt, similar work may be performed in other reservoirs both surrounding the Valley and throughout the state.

Algal Toxins in the Salt River Reservoirs

We will be expanding our scope of research and monitoring effort this spring and summer on all of the Salt River reservoirs in collaboration with ADEQ and AzG&F. We are very fortunate to be collaborating with Dr. Paul Zimba from the USDA and Dr. JoAnn Burkholder from NCSU.

Frequent fish kills in both 2004 and 2005 have prompted obvious concern as to the cause. While the finding by AzG&F last year of *Prymnesium parvum*, a type of algae that produces an ichthyotoxin, certainly makes this species suspect, little is known about the environmental requirements for it to produce prymnesin, its toxin, in levels high enough to kill fish. Additionally, we have been monitoring algal and cyano-toxins in all the reservoirs surrounding the Valley since 2000 and do know that others are also present. The synergistic effect of several toxins acting as a stressor on fish, wildlife, or humans, is poorly understood.

Starting this spring, we intend to isolate and purify axenically suspect algal toxin producers from the Salt River reservoirs. We will sample from established areas, as well as other areas suspect of harboring potentially toxic species of algae, within Roosevelt, Apache, Canyon, and Saguaro reservoirs. We will sample whole water samples from within the photic zone of each reservoir. We will concentrate samples using a specially-made 5.0 µm plankton net and water will be filtered through the net using a peristaltic pump and flowmeter rather than towed through the water.

Samples will be sent to Dr. Burkholder at NCSU for uni-algal culture. Once it has been determined that the cells have been isolated axenically, we will distinguish the uniqueness of each isolate by performing REP-PCR techniques like those described by Lyra et al. (2001). Those having identical REP-PCR fingerprints and similar morphology will be grouped together and a single representative isolate will be chosen for characterization with respect to toxin production. Lypholized cultures of each unique isolate will be sent to the laboratory of Dr. Paul Zimba for pigment and toxin analyses. Toxin analyses will include anatoxin-a, cylindrospermopsin, microcystin,

bioactive peptides, and prymnesin. Additional tests will be conducted to verify toxin production in response to environmental stimuli such as photoperiod, temperature, grazing pressure (by zooplankton), varying nutrient levels, and introduction of other algal species to check for any allelopathic mechanism.

It is impossible to determine if a species is capable of producing toxin through genetic fingerprinting alone. More than likely, the production of toxin is determined by as-of-yet poorly understood environmental factors such as light and nutrients levels, degree of herbivory and grazing pressure, etc. Indeed, we often find a species of algae that produces toxin erratically and likely in response to some un-quantified environmental stimuli. Additionally, overall numbers may not be as important as these environmental factors in toxin production. Overall biomass or numbers of potentially toxic species are often mis-leading in regard to the amount of toxin actually being produced.

This will be the most comprehensive work to date looking at algal toxins in the Salt River reservoirs. Hopefully, this work will provide a solid foundation in answering questions about toxicity in these reservoirs; questions that have previously been addressed largely through anecdotal evidence.

Endocrine Disrupting Compounds and Pharmaceuticals

While much research has focused on identification, fate, transport, and degradation of endocrine disrupting compounds and pharmaceuticals, very little is known about their biological effect. Several endocrine-disrupting compounds (EDC's) are known to have non-monotonic dose-response curves where a greater effect is actually observed at a lower dose. One of the pervasive questions in examining the effect of EDC's should be if a compound, or suite of compounds, is degraded in the environment through biological or mechanical action, what physiological effect does the remaining fraction have on biota? It is important to determine fate, transport, and degradation of individual and suites of compounds but with only a very limited understanding of their biological effect, understanding how these compounds move through the environment may be putting the cart before the horse.

In the arid southwest, effluent dominated waters (EDW's) are becoming increasingly prevalent. Due to the finite nature of water in the area, this trend is expected to increase dramatically over the next few years to decades. These areas will naturally become increasingly important as habitat for native fish and wildlife species some of which are threatened with extinction due to water withdraws from critical habitat. The importance of EDW's as both habitat for native species and as a future potential drinking water source is no longer in question, yet, very little research has been done on waterbodies solely within the state designated as "aquatic and wildlife, effluent dependent" and even less research has been done on the biological effect of contaminants in this treated wastewater.

The Santa Cruz River below Roger Road WWTP. Unlike several areas of the country where dilution in EDW's occurs, in arid regions these systems are often 100% treated effluent for major portions of the year.

While there have been several studies examining the effect of endocrine-disrupting compounds and pharmaceuticals found in wastewater on wildlife, primarily fish, most of these studies have been performed either *in situ* or examining the effect(s) of only a small group of relatively short-lived, powerful, compounds known to cause endocrine-disruption. While these studies certainly all have merit and have set the groundwork for successive studies, most do not have any grounds for comparison (controls or replicates) needed to quantify an effect. Additionally, most work to date has focused on feminization of male fish. While feminization of males is an important finding, from an ecological standpoint, androgenization of females would be even more damning at the population level.

For over a year and a half we have been exposing bonytail chub (*Gila elegans*) to water collected from the Santa Cruz River below Roger Road WWTP. This was a controlled laboratory study examining the effect of fish exposed to differing dosages of treated wastewater compared to fish in control tanks filled with tap water treated by carbon filtration and reverse osmosis. Wastewater analytes were sent to USGS and passive infrared transducers were surgically implanted in fish so that we could monitor individuals over time, dose, and treatment. Blood samples were pulled without sacrificing any individual fish and sent to Dr. Tim Gross at the USGS Florida-Caribbean Science Center for plasma hormone analysis of 17β-estradiol, 11-ketotestosterone, testosterone, and the egg protein vitellogenin. Randomly selected fish were chosen at the end of each dose for histopathological analyses to check for stage of sexual maturation and any abnormalities.

This research did have replication and all tanks were 100% re-circulating with make-up water added only for evaporative losses. All tanks had the same passive filtration systems (sand filters and reverse-flow bio-reactors filled with specially graded sand) that basically consisted of providing surface area for nitrifying bacteria since accumulating ammonia/ammonium levels would have quickly killed all of the fish in a re-circulating system. Since it is known that several of the

more powerful pharmaceuticals known to cause endocrine disruption are easily degraded in the environment, this experiment examined the long-term, chronic effect of environmentally-persistent compounds on plasma hormone levels in fish. It is also generally believed that bonytail chub are a relatively pollution-tolerant species. The new EPA Aquatic Life Ambient Water Quality Criteria for Nonylphenol examined this contaminants effect on bonytail chub (and a host of other aquatic species) and came to the conclusion that bonytail chub were relatively resistant to this contaminants effect when compared to other species. Photo-period and water temperature were kept the same throughout the experiment to minimize any environmental influences on fluctuating hormone levels. So, all in all, this experiment is an accurate and fair assessment of the effect of treated wastewater on endocrine disruption in fish.

Pulling blood samples from bonytail chub. Fish were lightly anesthetized for this event. Our survival ratio following drawing blood was anywhere from 98 - 100%

We have found significantly lower 17β-estradiol levels in female fish at every dose. This likely has severely detrimental impacts at the population level. While we have also found feminization of male fish (as measured by plasma sex hormone levels), the combination of endocrine-disruption/impairment in both genders is especially damning. Especially interesting is the fact that we, as anticipated, have found only very small quantities of environmentally-persistent, yet typical, wastewater compounds.

While this research quantified hormonal impairment in fish, it also raises more questions. What are even longer-term effects? What are the impacts on subsequent (F2 and longer) generations? Is this effect plastic and, if so, what treatment technologies could be used to mitigate these effects? Would water from a recharge monitoring well have similar effects? The list of questions will almost assuredly be longer than the list of answers for some time to come. It is, however, a beginning.

We will be presenting the results of this work at the National Groundwater Associations' 5th International Conference on Pharmaceuticals and Endocrine Disrupting Chemicals in Water on March 13th. This work was supported by State of Arizona funding, through the Technology and Research Initiative.

Experimental setup at ERL.

Restoring Backwaters Along the Lower Colorado River for Native Fish Species

We are currently working with both the USF&WS and the USBOR examining backwaters along the Lower Colorado River regarding their potential to serve as habitat for native fish species.

Backwater lakes and wetlands in river floodplains are highly valued riparian environments capable of supporting high levels of biodiversity and productivity. Riparian zones have a long history of disturbance and loss due to human activities especially in the arid Southwest. Historically, backwater wetlands were continually created and destroyed as a normal consequence of flooding, scouring, sedimentation, and shifts in channel location. Modern efforts to constrain river flows to narrow, levied channels have cut off some backwaters from regular inflows and have prevented formation of new backwaters. Additionally, backwaters along the Lower Colorado River are now at the mercy of upstream impoundments and dams. Previous studies on backwaters in the arid Southwest indicate that the longevity, productivity, and habitat quality of floodplain wetlands are greatly affected by the degree of hydraulic connection to the adjacent river. Backwaters that receive little input from the river tend to become hyper-eutrophic, hyper-saline, overgrown with rooted vegetation, and subject to prolonged periods of low dissolved oxygen levels. Backwaters that receive frequent, high volume inputs from the river are subject to scour, loss of nutrients and organic matter, and frequent water level fluctuations that inhibit development of littoral zone vegetation. Backwaters with intermediate inputs from the river had the highest levels of productivity and diversity.

Several native species of fish are believed to have fairly high tolerances for a wide range of water quality conditions; however, it makes little sense to meet the minimum requirements for survival with no added margin of safety. Making an area habitable for a species requires a simultaneous analysis of the species in question and the area to be evaluated. Determination of "habitability" requires analysis of both biotic and abiotic variables and how one affects, and is affected by, the other. It is within this framework that we will analyze backwaters, recommend management and remediation measures to alleviate limitations to potential as habitat, and then study these effects after this remediation has occurred to determine their efficacy.

This study takes place on Imperial National Wildlife Refuge and is

funded by the Bureau of Reclamation. It is only through forward-thinking individuals at both the USBOR and USF&WS that this work is made possible.

Other Projects

We are currently involved with several other projects throughout the state (I have to save something for future newsletters!). The previously mentioned projects are just the few for which current data or updates are available.

Other current projects include monitoring and clean sampling for mercury in Arizona lakes and reservoirs, ambient monitoring for ADEQ, urban lake issues, and examining biological criteria for water right issues.