COMPREHENSIVE WATERSHED MANAGEMENT FOR THE VALLEY OF THE SUN AND THE CENTRAL ARIZONA BASINS

Watershed Monitoring Report, Issue 2, September 2004 From the Lab of Dave Walker, Ph.D. University of Arizona
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Saguaro reservoir sampling

Thanks to Susan Fitch and Jennifer Hickman from ADEQ and Marc Dahlberg and Kevin Bright from AzG&F, Saguaro has been sampled on 7/14, 7/29, and 8/20. There have been no further reports of major fish kills even though, the number of potentially toxic organisms has significantly increased since July. Most of this increase in algal biomass in due to increased numbers of *Cylindrospermopsis raciborskii* and other species of potentially toxic cyanobacteria.

We have also recently found, in the riverine area, a gymnodinoid (species of *Gymnodinium*). Certain species of this genus are associated with red tides and the production of neurotoxic (*Gymnodinium breve*) and paralytic (*Gymnodinium katenatum*) shellfish poisons. Gymnodinoids, like most dinoflagellates, can often be autotrophic, heterotrophic, or both depending upon life stage and environmental condition. Dinoflagellates often behave more like animals than plants. *Pfiesteria piscicdia* is a dinoflagellate that killed scores of fish along the Carolina coast in the early 1990's. *Pfiesteria* kills by subduing with a neurotoxin and then literally "eating" the fish causing red sores.

There have been numerous red sores noticed in largemouth bass from all the Salt River Lakes. Virology and bacteriology done by Wade Cavender of AzG&F showed nothing abnormal except that 1 in 13 fish was affected with *Aeromonas hydrophila*. This species may become opportunistic under certain conditions and cause reddening around the fins but if it was a causative agent, more than 1 in 13 would have tested positive. According to Wade, the finding of *Aeromonas* on one fish doesn't explain the size, primary focus on fins, and blisters found on affected fish. Blisters on fins may be indicative of an ectoparasite but no external attachment has been noticed (per Wader Cavender AzG&F). Histology done here at the UA has shown nothing out of the ordinary. We do not believe that these sores were the primary cause of the fish kills that occurred earlier this summer but may be the result of opportunistic organisms taking advantage of already-stressed fish. The recent increase in the number of *Gymnodinium* at Saguaro makes sense if we think about the large amount of decaying fish from previous kills serving as "food" for heterotrophic organisms like *Gymnodinium.* We currently have no quantifiable reason for the red sores noticed on fish. We will be doing more investigation into the gymnodinoid as one possible cause.

The effect of water movement, including pumpback storage, on the release of toxins is unknown. As stated in previous reports, the riverine portion of the reservoirs typically contain the highest algal biomass and if large numbers of endotoxin producing species are lysed, it might lead to increases in free toxin in the water. We know from previous experience that mib and/or geosmin can be released in pulses when large amounts of taste and odor causing cyanobacteria are lysed and it seems logical that the same might be true for cyano-toxins. Unfortunately, the amount of water released hourly or daily from Mormon Flat Dam, and the amount of nightly pumpback, is unknown. Without accurate data regarding water movement and inter-reservoir transfer, trying to determine any possible cause and effect is impossible.

We have submitted samples from Saguaro to Dr. Paul Zimba of the USDA-ARS in Stoneville Mississippi. Paul is very interested in anatoxin-a producers and what is happening in the Salt River reservoirs. He has volunteered to make axenic cultures of samples submitted from Saguaro. Making uni-algal cultures is an essential first step in identifying causative organisms and their potential to produce toxins under differing environmental conditions. Without this information, prediction or prevention of future events is difficult if not impossible.

We have found cylindrospermopsin in relatively low levels (7.11 µg/L but in a concentrated zooplankton tow) in samples collected by AzG&F on 7/29 at Saguaro near Bagley Flats. It's important to note that just because the numbers of potentially toxic species of algae increase doesn't mean that conditions are favorable for toxin production or release into the water. The *only* way to quantify toxins in the water is to analyze for suspect toxins, not by merely identifying what species are present. It is possible to have very low levels of toxin-producing species but high levels of toxin in the water and vice-versa. Genes coding for toxin production have not been determined. A species produces toxin based upon environmental conditions and there is no "pre-determination" as to when, or if, any species will become toxic. There is also a poor understanding of environmental conditions necessary for toxin production.

We have found toxic levels of both microcystin and anatoxin-a in the stomachs of threadfin shad and bluegill submitted from Apache reservoir earlier in the spring. It's interesting that anatoxin-a was found at toxic levels in tissue even though, none was found in aqueous samples. Anatoxin-a is easily degraded by sunlight and alkalinity and it's half-life on the Salt River reservoirs may only be a few hours at most. Fish tissue samples of anatoxin-a may be the most useful resource for detecting this toxin on the Salt River reservoirs and elsewhere. Due to a very fast degradation rate under certain conditions, non-detects of anatoxin-a in aqueous samples may be dangerously misleading. Unfortunately, we did not have these results back during subsequent fish kills or we would have analyzed stomachs from these fish as well. The toxic levels of anatoxin-a and microcystin in fish stomachs collected during a kill at Apache is supportive evidence of cyano-toxins as the causative agent for other fish kills in the Salt River reservoirs.

So, why toxin production in the spring and early summer and why have the fish kills stopped? It's believed that toxin production evolved to prevent grazing from herbivorous zooplankton and also as an allelopathic mechanism for other species of algae. It makes sense that toxin production would be highest while the mixed assemblage of phytoplankton was on an upward growth trend. This would exclude, to a large extent, other species of non-toxin producing species. Once toxin-producing species have dominated the phytoplankton, toxin production may no longer be necessary. This is one possible scenario which does make sense upon examination of the algae data from Saguaro.

Dissolved oxygen levels at the time of the kills were more than adequate to sustain aquatic life. The DO levels in Saguaro the day of the major fish kill on 6/10 as well as the profile from Canyon taken the day before the kill on 6/9 showed no physico-chemical parameters that were suspect. Actually, DO levels in Saguaro are appreciably lower now than in June but yet, no fish have recently died.

Dissolved oxygen and ORP levels within the hypolimnion of Saguaro have significantly decreased since the summer of 2002. This same trend has been noticed on all the Salt River reservoirs. This will have long-term consequences on water quality in these reservoirs and will also help to facilitate inter-reservoir transfer of nutrients and metals. Some degradation in water quality is being noticed below Stewart Mtn. Dam and in downstream treatment plants. Per Paul Westerhoff at ASU in their newsletter, both Val Vista and Verde WTP's noticed increases in reduced Fe and Mn over a month ago. This would be consistent with what we find not only in Saguaro, but in all of the reservoirs along this chain. Keeping in mind that hypolimnetic anoxia mirrors epilimnetic algal production, the issue of increased algal growth and reducing conditions in the hypolimnion can't be separated from each other.

Summer chlorophyll *a* levels in Saguaro have steadily increased since 2002. This correlates with the increase in hypolimnetic anoxia and reducing conditions not only in Saguaro, but in all of the other reservoirs along this chain also. We routinely sample sediments from all of the reservoirs for nutrients and metals. Iron and manganese are always found in abundance but only becomes problematic with an increase in hypolimnetic anoxia. The reduced Fe and Mn that is making it to treatment plants may also have adverse effects on the Salt River below the reservoirs if they precipitate over the benthos.

It is possible that the increased algal biomass and hypolimnetic anoxia will form a positive feedback loop. Hypolimnetic anoxia may result in increases in ammonia and phosphorous both nutrients for algal growth.

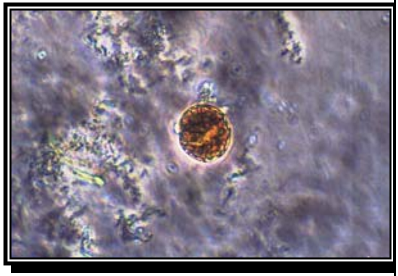
While the Salt River above Roosevelt may have long periods of acceptable or even relatively "good" water quality, it is sporadic and flashy. Low levels of metals and nutrients can enter Roosevelt for most of the year, however, substantial loading can and does occur during either monsoon rains or spring snowmelt. As explained by Cheryl Pailzote of the WMAT during the last meeting, re-vegetation of burned areas will take several more years. The increase in metals, nutrients, and carbon loading to the reservoirs that has already occurred, will probably be felt within the reservoirs and downstream areas for years to come.

Saguaro Physical Water Quality Parameters

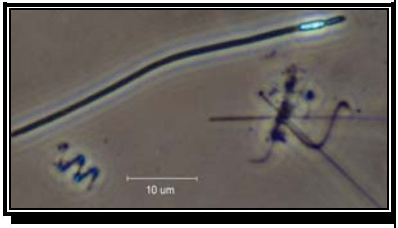
Saguaro Algae Counts from 8/20/04 (potentially toxic species in red)

Site	Division	Genus	Species	Units/mL
SRSAGA	Cyanophyta	Cylindrospermopsis	raciborskii	**6790**
SRSAGA	Cyanophyta	Anabaena	laxa	**3705**
SRSAGA	Cyanophyta	Anabaenopsis	circularis	**3516**
SRSAGA	Cyanophyta	Pseudanabaena		**3246**
SRSAGA	Chlorophyta	Carteria		**2162**
SRSAGA	Cyanophyta	Oscillatoria	agardhii	**1583**
SRSAGA	Chrysophyta	Diatoma	vulgare	**1175**
SRSAGA	Pyrrophyta	Gymnodinium		**1124**
SRSAGA	Chrysophyta	Fragilaria		**834**
SRSAGA	Cyanophyta	Microcystis		**622**
SRSAGA5	Cyanophyta	Cylindrospermopsis	raciborskii	**23477**
SRSAGA5	Cyanophyta	Anabaenopsis	circularis	**7481**
SRSAGA5	Cyanophyta	Pseudanabaena		**5106**
SRSAGA5	Chlorophyta	Carteria		**3175**
SRSAGA5	Cyanophyta	Oscillatoria	agardhii	**3060**
SRSAGA5	Chlorophyta	Scenedesmus		**2430**
SRSAGA5	Chlorophyta	Chodatella		**2307**
SRSAGA5	Chrysophyta	Stephanodiscus		**1444**
SRSAGA5	Cyanophyta	Anabaena	laxa	**1162**
SRSAGA5	Cyanophyta	Merismopedia	elegans	**769**
SRSAGB	Cyanophyta	Cylindrospermopsis	raciborskii	**38261**
SRSAGB	Pyrrophyta	Gymnodinium		**33485**
SRSAGB	Cyanophyta	Anabaenopsis	circularis	**15370**
SRSAGB	Cyanophyta	Anabaena	scheremetievi	**7108**
SRSAGB	Cyanophyta	Pseudanabaena		**3975**
SRSAGB	Cyanophyta	Microcystis		**3480**
SRSAGB	Chrysophyta	Synedra		**1614**
SRSAGB	Euglenophyta	Phacus		**1387**
SRSAGC	Pyrrophyta	Gymnodinium		**25136**
SRSAGC	Cyanophyta	Cylindrospermopsis	raciborskii	**19343**
SRSAGC	Cyanophyta	Anabaenopsis	circularis	**6495**
SRSAGC	Euglenophyta	Phacus		**2677**
SRSAGC	Chlorophyta	Trachelomonas		**1370**
SRSAGC	Chrysophyta	Navicula		**426**
SRSAGC	Chrysophyta	Pinnularia		**134**

Total units/ml Site A: 24,757
Total units/mL Site A at 5 meters: 50,411
Total units/mL Site B: 104,680
Total units/mL Site C: 55,581



Gymnodinoid from Saguaro

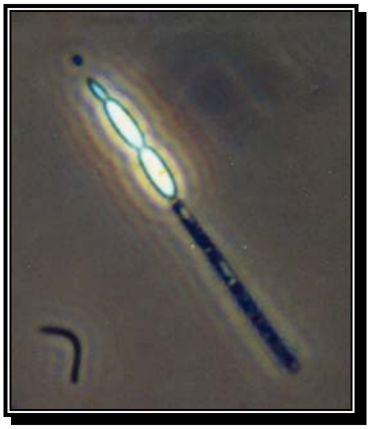


Cylindrospermopsis raciborksii

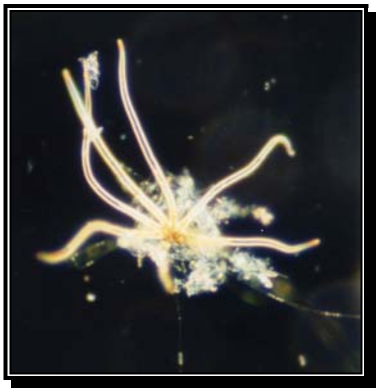
Saguaro Algae Counts from 7/29/04 (potentially toxic species in red)

Site	Division	Genus	Species	**Units/mL**
SRSAGA	Cyanophyta	Cylindrospermopsis	raciborskii	**2579**
SRSAGA	Cyanophyta	Anabaenopsis	circularis	**854**
SRSAGA	Cyanophyta	Anabaena	laxa	**612**
SRSAGA	Cyanophyta	Aphanizomenon	flos-aquae	**552**
SRSAGA	Cyanophyta	Oscillatoria	agardhii	**448**
SRSAGA	Chlorophyta	Carteria		**427**
SRSAGA	Cyanophyta	Pseudanabaena		**360**
SRSAGA	Chlorophyta	Chlamydomonas		**311**
SRSAGA	Chrysophyta	Nitzchia		**153**
SRSAGA	Chrysophyta	Stephanodiscus		**122**
SRSAGA	Cyanophyta	Microcystis		**83**
SRSAGB	Cyanophyta	Cylindrospermopsis	raciborskii	**6888**
SRSAGB	Cyanophyta	Anabaena	laxa	**3887**
SRSAGB	Cyanophyta	Microcystis		**3064**
SRSAGB	Cyanophyta	Aphanizomenon	flos-aquae	**2983**
SRSAGB	Cyanophyta	Anabaenopsis	circularis	**1637**
SRSAGB	Chlorophyta	Carteria		**860**
SRSAGB	Chlorophyta	Scenedesmus		**818**
SRSAGB	Pyrrophyta	Gymnodinium		**769**
SRSAGB	Euglenophyta	Phacus		**583**
SRSAGB	Cyanophyta	Oscillatoria	agardhii	**300**
SRSAGB	Chlorophyta	Closterium		**264**
SRSAGB	Chrysophyta	Fragilaria		**228**
SRSAGB	Cyanophyta	Merismopedia	elegans	**207**
SRSAGB	Chrysophyta	Gomphonema		**162**
SRSAGB	Chrysophyta	Nitzchia		**119**
SRSAGC	Cyanophyta	Cylindrospermopsis	raciborskii	**3449**
SRSAGC	Cyanophyta	Microcystis		**1840**
SRSAGC	Pyrrophyta	Gymnodinium		**1477**
SRSAGC	Cyanophyta	Anabaenopsis	circularis	**1083**
SRSAGC	Cyanophyta	Pseudanabaena		**824**
SRSAGC	Chlorophyta	Chlamydomonas		**411**
SRSAGC	Cyanophyta	Anabaena	laxa	**333**
SRSAGC	Cyanophyta	Aphanizomenon	flos-aquae	**164**
SRSAGC	Chrysophyta	Fragilaria		**162**
SRSAGC	Chrysophyta	Gomphonema		**159**
SRSAGC	Chlorophyta	Chodatella		**137**
SRSAGC	Cyanophyta	Merismopedia	elegans	**134**
SRSAGC	Chlorophyta	Coelastrum		**117**
SRSAGC	Chrysophyta	Fragilaria		**103**

Total units/ml Site A: 6501
Total units/mL Site B: 22,769
Total units/mL Site C: 10,477



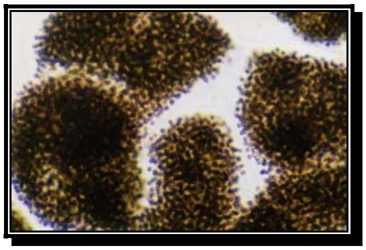
C. raciborskii with 2 heterocysts and a terminal akinete.



Freshwater hydra from Apache.

Saguaro Algae Counts from 7/14/04 (potentially toxic species in red)

Site	Division	Genus	Species	Units/mL
SRSAGA	Cyanophyta	Aphanizomenon	flos-aquae	**1687**
SRSAGA	Chlorophyta	Chlamydomonas		**1862**
SRSAGA	Cyanophyta	Cylindrospermopsis	raciborskii	**1180**
SRSAGA	Cyanophyta	Anabaenopsis	circularis	**412**
SRSAGA	Cyanophyta	Anabaena	laxa	**167**
SRSAGA	Chlorophyta	Carteria		**134**
SRSAGA	Chrysophyta	Diploneis		**127**
SRSAGA	Cyanophyta	Oscillatoria	aghardii	**83**
SRSAGA	Cyanophyta	Gloeocapsa		**81**
SRSAGA	Chrysophyta	Synedra		**65**
SRSAGB	Cyanophyta	Aphanizomenon	flos-aquae	**4130**
SRSAGB	Cyanophyta	Cylindrospermopsis	raciborskii	**2051**
SRSAGB	Cyanophyta	Anabaena	laxa	**2063**
SRSAGB	Cyanophyta	Anabaena	torulosa	**1409**
SRSAGB	Cyanophyta	Anabaenopsis	circularis	**1183**
SRSAGB	Chlorophyta	Carteria		**740**
SRSAGB	Cyanophyta	Oscillatoria	agardhii	**581**
SRSAGB	Cyanophyta	Anabaena	variabilis	**264**
SRSAGB	Chlorophyta	Scenedesmus		**259**
SRSAGB	Chlorophyta	Coelastrum		**220**
SRSAGB	Chlorophyta	Chlamydomonas		**174**
SRSAGB	Chrysophyta	Synedra		**158**
SRSAGB	Chlorophyta	Lepocinclus		**110**
SRSAGB	Chlorophyta	Cosmarium		**71**
SRSAGB	Chrysophyta	Navicula		**38**
SRSAGC	Cyanophyta	Aphanizomenon	flos-aquae	**3588**
SRSAGC	Chlorophyta	Chlamydomonas		**2140**
SRSAGC	Cyanophyta	Anabaenopsis	circularis	**1387**
SRSAGC	Cyanophyta	Cylindrospermopsis	raciborskii	**808**
SRSAGC	Cyanophyta	Anabaena	variabilis	**725**
SRSAGC	Chlorophyta	Carteria		**439**
SRSAGC	Cyanophyta	Anabaena	laxa	**427**
SRSAGC	Cyanophyta	Oscillatoria	agardhii	**416**
SRSAGC	Chlorophyta	Scenedesmus		**386**
SRSAGC	Chlorophyta	Coelastrum		**347**
SRSAGC	Chrysophyta	Melosira		**265**
SRSAGC	Cyanophyta	Gloeocapsa		**248**
SRSAGC	Chrysophyta	Diploneis		**200**
SRSAGC	Euglenophyta	Thoracomonas		**162**



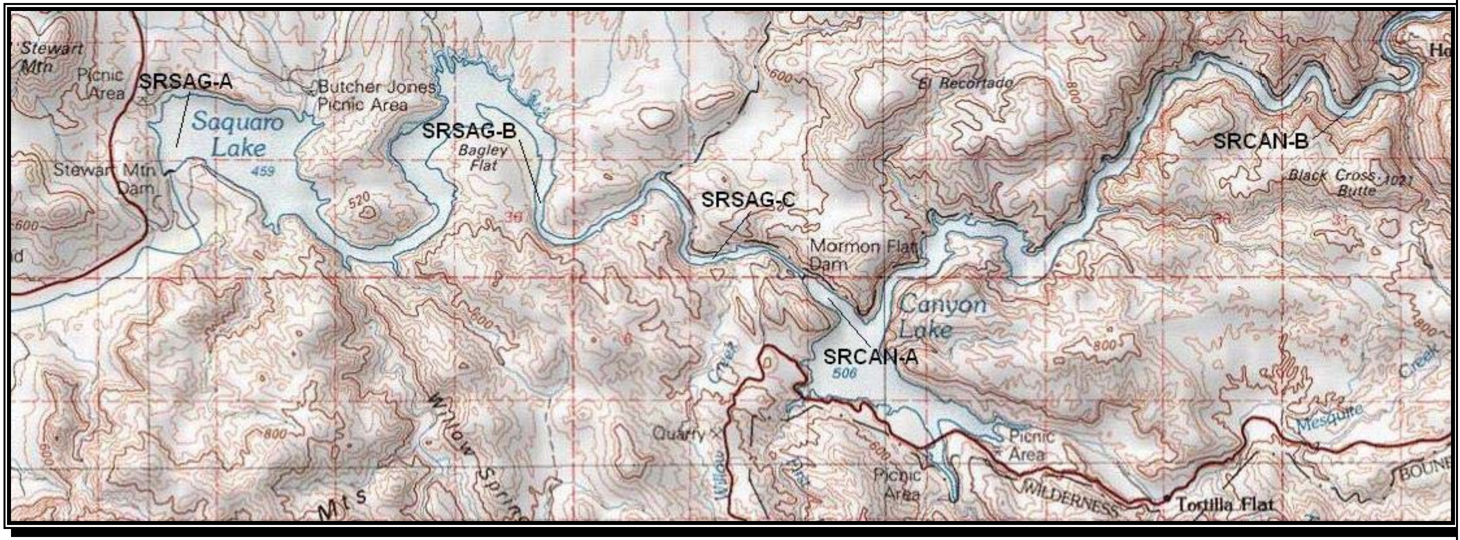
Microcystis colonies

Anabaenopsis circularis

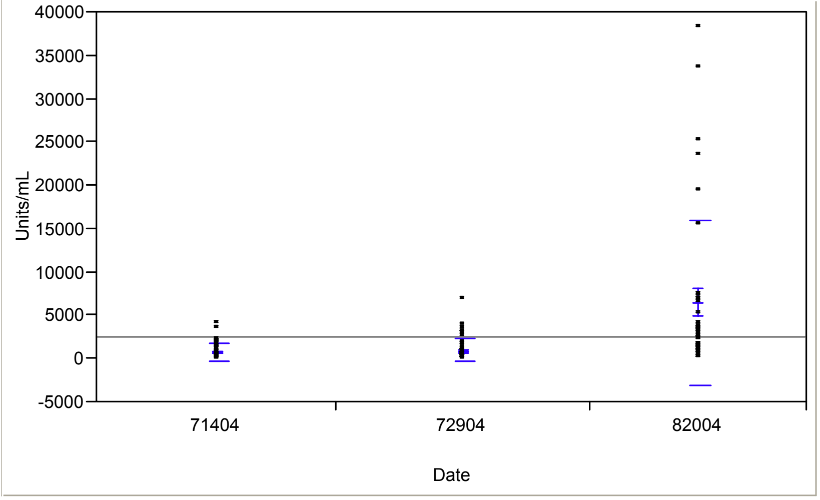
Total units/ml Site A: 5498
Total units/mL Site B: 9321
Total units/mL Site C: 7950

Saguaro Lake Fish Kill, 6/10/04. ***Photos courtesy of Dave Rigo, AzG&F Dept. and www.azbasszone.com***

Saguaro and Canyon Reservoir Sampling Sites



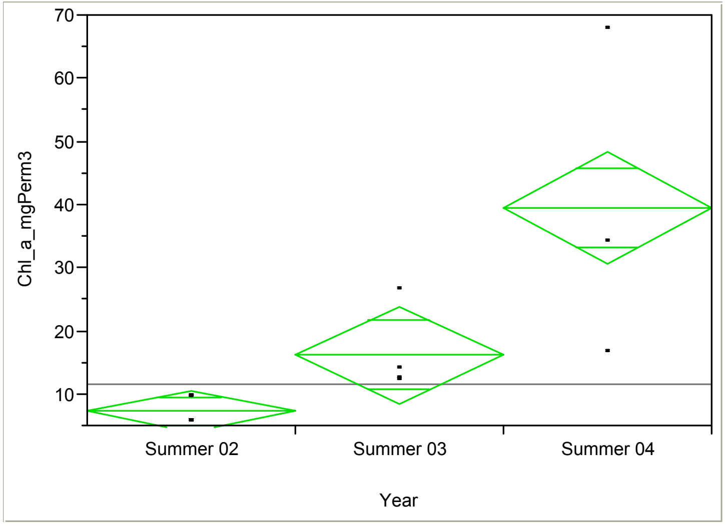
Saguaro Mean Algae Counts by Date



Means

Level	Number	Mean
71404	40	771.90
72904	42	947.14
82004	36	6543.03

Chlorophyll *a* levels (mg/m3) in Saguaro for the summers of 2002, 2003, and 2004.



Physicochemical Data from SRSAG-A on 8/20/04

Depth (m)	Time (HHMMSS)	Temp (degrees C)	SpCond (µs/cm2)	pH	DO (% sat.)	DO (mg/L)	ORP (mV)
0.1	103552	28.19	2198	8.5	104.1	6.62	115
0.5	103635	27.91	2196	8.51	101.7	6.51	118
1	103707	27.82	2196	8.51	101.1	6.48	120
2	103800	27.73	2195	8.49	104	6.67	124
3	103855	27.55	2193	8.42	92.5	5.95	129
4	103941	27.46	2194	8.4	87.9	5.67	132
5	104057	26.86	2179	7.7	25.5	1.66	147
4.5	104219	27.41	2196	8.44	92.1	5.94	136
5.5	104317	25.84	2173	7.34	5	0.34	148
6.1	104413	25.6	2178	7.33	3.8	0.25	119
7	104629	25.08	2175	7.27	3.2	0.22	-87
8	104719	24.75	2176	7.3	3.2	0.22	-119
8.9	104759	24.54	2172	7.3	3.2	0.22	-140
10	104858	24.36	2176	7.28	3.1	0.21	-185
12	105003	24.04	2168	7.3	3.1	0.21	-218
14	105100	23.84	2151	7.31	3.1	0.21	-231
16	105158	23.69	2143	7.31	3.2	0.22	-216
18	105241	23.61	2138	7.31	3.1	0.22	-230
20	105343	23.53	2128	7.31	3	0.21	-195
22	105430	23.43	2124	7.31	3.1	0.22	-183
24	105550	23.35	2123	7.32	3.2	0.22	-217
26.1	105705	23.25	2123	7.32	3.2	0.22	-263
28	105756	23.14	2124	7.32	3.2	0.22	-283
29.9	105855	23.02	2125	7.3	3.2	0.22	-300

Physicochemical Data from SRSAG-B on 8/20/04

Depth (m)	Time (HHMMSS)	Temp (degrees C)	SpCond (µs/cm2)	pH	DO (% sat)	DO (mg/L)	ORP (mV)
0	121427	28.73	2142	8.66	135.7	8.56	56
0.5	121511	27.9	2137	8.69	142.3	9.11	57
0.9	121557	27.82	2134	8.68	144.6	9.27	58
2	121654	27.27	2139	8.6	132.8	8.59	63
3	121748	26.94	2131	8.44	110	7.16	69
4	121947	26.57	2128	8.23	89.5	5.87	77
5	122039	26.18	2115	8.06	77.7	5.13	82
6	122152	25.52	2114	7.83	56.6	3.78	90
7	122255	25.34	2110	7.78	51	3.41	91
8	122349	24.81	2104	7.66	46	3.11	94
9	122445	24.35	2100	7.66	42.7	2.92	95

Physicochemical Data from SRSAG-C on 8/20/04

Depth (m)	Time (HHMMSS)	Temp (degrees C)	SpCond (µs/cm2)	pH	DO (% sat)	DO (mg/L)	ORP (mV)
0	132943	23.33	2084	7.56	38.1	2.65	81
0.9	133016	23.33	2085	7.56	37.6	2.61	81
2.2	133210	23.3	2084	7.55	36.6	2.55	82
3.4	133314	23.29	2084	7.56	35.5	2.47	82

Physicochemical Data from SRSAG-A on 7/29/04 (from Jenny Hickman, ADEQ)

Depth (m)	Time (MMHHSS)	Temp (degrees C)	SpCond (µs/cm2)	pH	DO (% sat)	DO (mg/L)	ORP (mV)
0.098	8:02:11	28.31	2208	8.5	114.5	8.86	133
1.03	8:03:05	28.28	2205	8.56	116.2	9	147
2.043	8:03:54	28.23	2203	8.59	115.8	8.97	158

3.04	8:04:44	28.19	2204	8.6	114.4	8.87	167
4.017	8:06:24	28.13	2203	8.61	113.1	8.78	184
4.953	8:07:35	26.01	2165	8.36	71	5.72	204
6.039	8:08:24	25.11	2161	8.23	54.7	4.49	215
7.075	8:09:38	24.53	2162	8.06	39.4	3.27	228
8.165	8:10:35	24.21	2164	7.97	38.7	3.22	236
8.146	8:11:32	24.16	2160	7.9	39.1	3.26	242
9.028	8:12:24	23.98	2155	7.84	38	3.18	246
10.051	8:13:23	23.8	2161	7.8	32.5	2.73	251
15.082	8:14:58	23.19	2147	7.72	34.4	2.92	234
20.083	8:15:55	22.72	2112	7.69	34.1	2.92	242
25.197	8:16:52	22.47	2114	7.65	31.8	2.74	248

Physicochemical Data from SRSAG-B on 7/29/04 (from Jenny Hickman, ADEQ)

Depth (m)	Time (HHMMSS)	Temp (degrees C)	SpCond (µs/cm2)	pH	DO (% sat)	DO (mg/L)	ORP (mV)
0.077	11:45:06	29.53	2187	8.43	123.3	9.34	211
1.098	11:45:56	29.3	2181	8.42	121.4	9.24	267
2.014	11:46:58	28.83	2175	8.43	119.2	9.14	300
3.469	11:47:42	27.67	2155	8.34	104.7	8.2	318
4.328	11:48:30	25.1	2102	8.04	61.8	5.07	344
5.704	11:49:07	24.44	2090	7.93	52.7	4.37	353
6.402	11:50:03	24.18	2089	7.86	47	3.92	360
11.171	11:51:20	22.86	2072	7.82	40.7	3.48	362

Physicochemical Data from SRSAG-C on 7/29/04 (from Jenny Hickman, ADEQ)

Depth	Time (HHMMSS)	Temp (degrees C)	SpCond (µs/cm2)	pH	DO (% sat)	DO (mg/L)	ORP (mV)
0.147	10:46:55	26.32	2126	7.75	88.9	7.13	276
1.001	10:48:51	25.87	2124	7.82	79.4	6.42	338
2.044	10:49:59	25.49	2118	7.88	73	5.94	346
8.433	10:51:25	25.18	2115	7.93	64.1	5.25	348
5.075	10:52:16	25.38	2117	7.98	66.5	5.42	344
3.205	10:52:56	25.45	2119	8.03	68.5	5.58	340

Physicochemical Data from SRSAG-A on 7/14/04 (from Kevin Bright, AzG&F)

Depth (m)	Temp (degrees C)	SpCond (µs/cm2)	pH	DO (mg/L)	DO (% sat)	ORP (mV)
0.1	28.20	2315	8.6	9.4	129	332
1	28.10	2313	8.6	9.4	129	330
2	28.07	2311	8.5	9.5	129	329
3	27.98	2310	8.5	9.4	128	328
4	26.42	2272	8.4	9.8	129	330
5	24.46	2260	8.2	8.1	104	335
6	24.00	2258	7.9	5.8	74	340
7	23.85	2260	7.8	5.2	66	341
8	23.63	2259	7.6	4.0	51	344
9	23.35	2258	7.5	2.3	29	347
10	23.15	2255	7.4	0.7	9	347
12	22.79	2252	7.4	0.3	3	315
14	22.50	2243	7.4	0.6	8	316
16	22.32	2234	7.4	0.9	11	317
18	22.26	2235	7.4	1.1	13	318
20	22.13	2226	7.4	1.4	17	318
22	22.11	2224	7.4	1.4	18	318
24	22.02	2220	7.4	1.5	19	318
26	21.97	2217	7.4	1.6	20	318
28	21.89	2222	7.4	1.0	12	319
30	21.86	2225	7.4	0.8	9	319

Physicochemical Data from SRSAG-B on 7/14/04 (from Kevin Bright, AzG&F)

Depth (m)	Temp (degrees C)	Sp. Cond. (µs/cm2)	pH	DO (mg/L)	DO (% sat.)	ORP (mV)
0	28.79	2285	8.5	9.4	130	334
1	28.69	2285	8.5	9.4	130	328
2	27.88	2276	8.5	9.0	122	327
3	26.50	2252	8.3	7.5	100	328
4	24.81	2227	8.0	6.1	78	332
5	24.01	2214	7.9	5.4	68	334
6	23.33	2204	7.8	4.8	59	335
7	22.99	2198	7.8	4.4	55	336
8	22.72	2196	7.7	4.2	52	336
9	22.46	2191	7.7	4.1	50	336
10	22.04	2182	7.7	3.7	46	336
11	21.66	2177	7.7	3.4	42	295

Physicochemical Data from SRSAG-C on 7/14/04 (from Kevin Bright, AzG&F)

Depth (m)	Temp (degrees C)	SpCond (µs/cm2)	pH	DO (mg/L)	DO (%sat)	ORP (mV)
0.1	26.62	2247	8.2	7.8	104	354
1	25.95	2242	8.2	7.6	99	347
2	25.85	2246	8.2	7.5	98	344
3	25.80	2244	8.2	7.1	94	341
4	25.74	2243	8.2	7.0	92	339
5	25.71	2242	8.2	6.9	90	332
6	25.71	2241	8.2	6.9	90	331
7	25.67	2242	8.2	6.8	88	371
8	25.67	2242	8.2	6.7	87	366
9	25.65	2243	8.2	6.5	85	363
10	25.64	2243	8.2	6.6	86	360

Physicochemical Data from SRSAG-A on 6/10/04 (from Kevin Bright, AzG&F)

Depth (m)	Temp (degrees C)	Sp.Cond (µS/cm2)	pH	DO (mg/L)	DO (% sat.)	ORP (mV)
0.5	25.26	2298	8.7	9.3	123	306
1.4	25.21	2295	8.7	9.1	120	305
2.1	24.75	2293	8.7	9.3	121	305
2.9	24.62	2291	8.7	9.2	120	305
4.4	24.42	2285	8.6	8.7	113	306
5.1	23.24	2261	8.5	7.8	99	310
8	22.01	2244	8.0	2.7	34	326
10	21.42	2236	7.8	1.4	17	329
15	20.78	2233	7.6	1.1	13	332
20.9	19.88	2222	7.6	1.8	22	332
30	18.78	2221	7.5	0.7	8	334

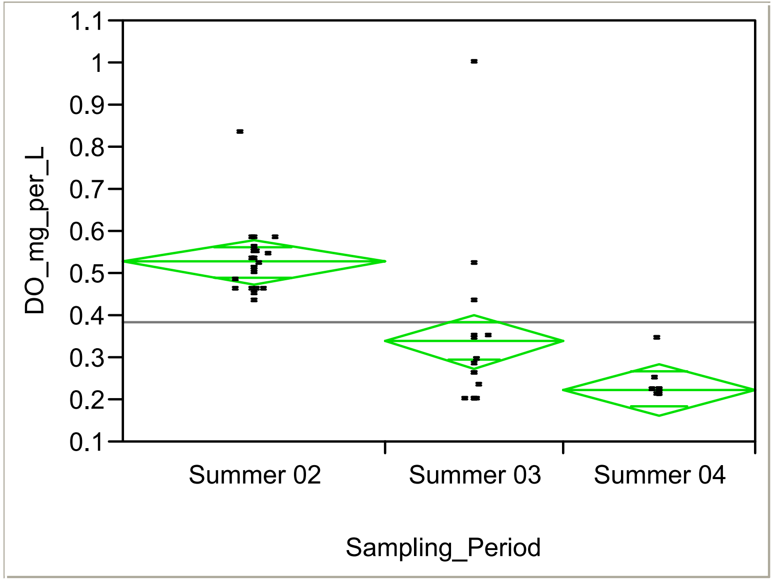
Physicochemical Data from SRSAG-B on 6/10/04 (from Kevin Bright, AzG&F)

Depth (m)	Temp (degrees C)	Sp.Cond (µS/cm2)	pH	DO (mg/L)	DO (% Sat.)	ORP (mV)
0	26.50	2292	8.5	8.2	110	340
1	25.90	2292	8.6	8.5	114	336
2	25.60	2285	8.6	8.7	115	332
3	25.09	2280	8.5	8.3	107	331
5	24.24	2276	8.4	7.1	91	333
7	23.11	2262	8.1	6.3	79	331
11	21.17	2246	8.0	4.7	58	337

Physicochemical Data from SRCAN-A on 6/9/04

Depth (m)	Time (MMHHSS)	Temp (degrees C)	SpCond (µS/cm2)	pH	DO(% sat)	DO (mg/L)	ORP (mV)
0.1	101819	23.21	2303	8.53	107	7.46	153
0.5	101906	23.17	2302	8.55	108	7.53	145
0.9	101937	23.05	2302	8.56	108.6	7.59	142
1.9	102018	22.6	2298	8.47	100	7.05	142
3	102104	22.03	2295	8.36	93.4	6.66	144
4	102142	21.8	2295	8.31	87.5	6.26	145
5	102221	21.59	2294	8.25	81.3	5.84	146
6	102255	21.19	2295	8.11	74.5	5.39	149
7	102335	20.55	2291	7.92	61.4	4.5	154
7.9	102705	20.34	2289	7.83	55.9	4.11	153
8.9	102752	20.27	2287	7.81	54.9	4.05	154
10.8	102835	20.16	2285	7.77	52.6	3.89	155
11.8	102919	20.13	2288	7.77	51.5	3.81	155
13.1	103049	19.93	2287	7.72	48.8	3.63	155
13.9	103135	19.84	2287	7.7	47.6	3.54	156
15	103221	19.79	2287	7.7	47.1	3.51	159
16	103301	19.75	2288	7.7	46.7	3.48	156
17	103340	19.73	2287	7.69	47	3.5	157
18.8	103659	19.52	2284	7.65	44.9	3.36	157
19.7	104943	19.65	2287	7.69	46.5	3.47	137
21.1	105223	19.53	2286	7.66	45.8	3.42	142
22	105315	19.49	2288	7.64	42.8	3.21	144
23.3	105414	19.45	2288	7.65	42.8	3.21	145
22.2	105449	19.5	2291	7.67	43.4	3.25	146
25.2	105545	19.41	2290	7.65	42.8	3.21	147
25.8	105629	19.39	2286	7.63	42	3.15	149
27	105734	19.33	2286	7.62	41.3	3.11	151
27.9	105811	19.29	2287	7.62	41.6	3.13	149
29.3	105853	19.12	2289	7.64	41.8	3.15	150
29.9	105939	19.09	2289	7.63	42.1	3.18	150
31.1	110048	19.1	2289	7.64	42.1	3.18	151
31.9	110153	19.05	2290	7.63	42.5	3.21	151
33.3	110301	19.04	2291	7.63	41.8	3.16	109
34	110348	19.01	2291	7.63	41.6	3.15	116

Hypolimnetic DO levels in Saguaro for the summers of 2002, 2003, and 2004.



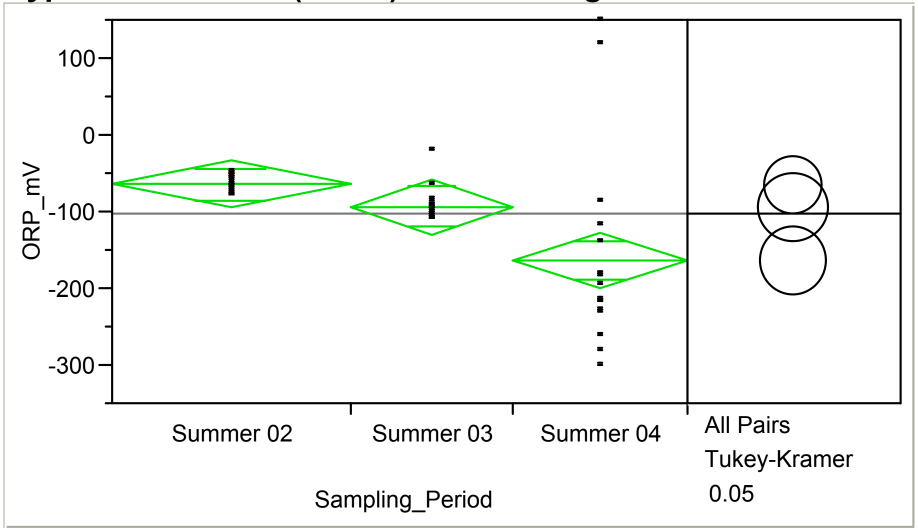
Summary of Fit

Mean of Response	0.384151
Observations (or Sum Wgts)	53

Means

Level	Mean	Std Error	Lower 95%	Upper 95%
Summer 02	0.528182	0.02595	0.47607	0.58030
Summer 03	0.340667	0.03142	0.27755	0.40378
Summer 04	0.226875	0.03043	0.16576	0.28799

Hypolimnetic ORP (in mV) levels in Saguaro for the summers of 2002, 2003, and 2004.



Summary of Fit

Mean of Response	-101.679
Observations (or Sum Wgts)	53

Analysis of Variance

Source	DF	F Ratio	Prob > F
Sampling_Period	2	9.0003	0.0005
Error	50		
C. Total	52		

Means for Oneway Anova

Level	Mean	Std Error	Lower 95%	Upper 95%
Summer 02	-63.409	15.288	-94.12	-32.70
Summer 03	-92.933	18.515	-130.12	-55.75
Summer 04	-162.500	17.927	-198.51	-126.49

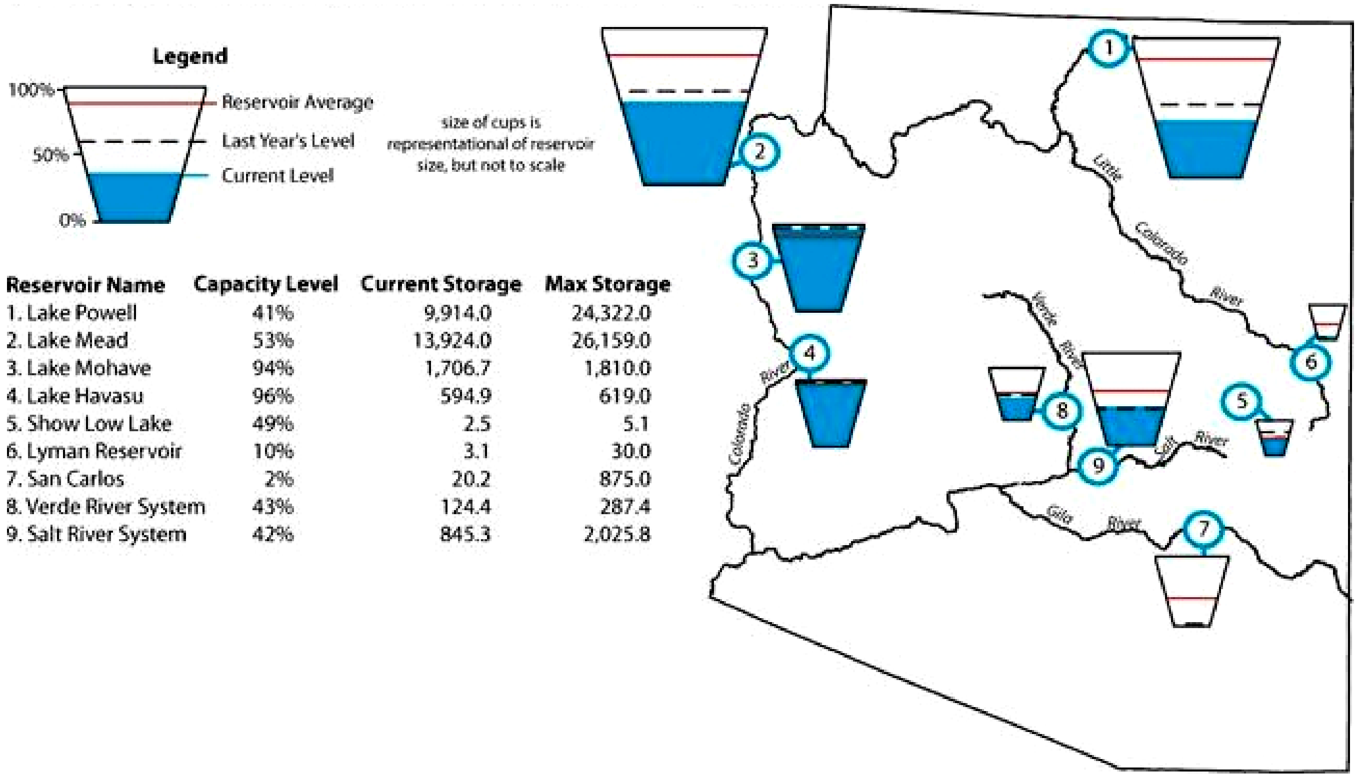
Climate and Drought

Changes in the upper air flow that was very beneficial to the Northwestern U.S. (i.e. stormy and wet) unfortunately meant that the Arizona monsoon came to an abrupt halt. The monsoon season, overall, was sub-par to mediocre at best and brought little relief to the ongoing drought. The high pressure system that normally develops over the Four Corners region causing warm, wet air to enter the state was routinely knocked out of place by storms tracking in from the northwest. The only good news is that this translated into lower than expected sediment, nutrient, and metal loading from burned areas in the Rodeo-Chedeski Fire into the Salt River, Roosevelt, and downstream reservoirs and from the Willow Fire into Verde River drainages going into Horseshoe and Bartlett reservoirs. This situation may change with winter rains or spring snowmelt but this precipitation is not nearly as erosive as monsoonal rains.

Much of the moisture that constitutes the Arizona monsoon, moved into far eastern New Mexico over the summer and as a result, this area is no longer considered to be in a short-term drought. There is still what appears to be, the onset of a weak El Nino in the Pacific which may persist over the next several months. Most climate predictions are anticipating a slightly increased probability of wetter-than-average conditions in Arizona this winter. Hopefully, this will bring some relief from long-term drought. However, El Nino's only increase the *probability* of precipitation and generally not viewed by climatologists as a means to end drought.

Reservoirs on the Upper Colorado River continue to decline. Lake Powell is at its lowest level since May 1970 (less than 10 million acre feet) and Lake Mead is at its lowest level since June 1964 (less than 14 million acre feet). This may have consequences on water quality entering the state. Obviously, the drought will have impacts on dilution and flushing which may impact pollutants, such as perchlorate. However, cleanup efforts at the source may mitigate any potential increase of perchlorate through decreased dilution and flushing. Other potential water quality concerns associated with the Colorado River and drought are increases in algal biomass and salinity. Increases in algal biomass may translate into higher DOC and THM precursors in the years to come if the drought persists

Arizona reservoir levels as of July 2004 (from the UofA's Institute for the Study of Planet Earth, Climate Assessment for the Southwest project, http://www.ispe.arizona.edu/climas/index.shtml)



Reservoir Name	Capacity Level	Current Storage	Max Storage
1. Lake Powell	41%	9,914.0	24,322.0
2. Lake Mead	53%	13,924.0	26,159.0
3. Lake Mohave	94%	1,706.7	1,810.0
4. Lake Havasu	96%	594.9	619.0
5. Show Low Lake	49%	2.5	5.1
6. Lyman Reservoir	10%	3.1	30.0
7. San Carlos	2%	20.2	875.0
8. Verde River System	43%	124.4	287.4
9. Salt River System	42%	845.3	2,025.8

Other Watershed/Water Quality-Related Projects

Quantifying Potential Endocrine Disruption in Effluent Dominated and Effluent Dependent Waters Within Arizona: Fish as Habitat Assessment Biomarkers

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 massive 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 dependant.

Determination of endocrine disruption within EDW's or other waterbodies has often been nebulous with no range of values between "good" and "bad". This has often been due to low sample sizes covering relatively small geographic regions within the arid or semi-arid western U.S.; municipalities, utilities, and regulatory agencies need a comprehensive framework, with data obtained wholly within the state, upon which sound managerial decisions regarding endocrine disruption, and overall ecosystem health, within EDW's can be formulated. With EDW's becoming increasingly important components of the landscape, the need to understand how they may differ from "natural" aquatic ecosystems also becomes increasingly important. Endocrine disruption may play an important role in determining nutrient and energy cycling within EDW's.

Endocrine disrupting compounds may reduce the reproductive potential of fish populations by causing intersex, decreased gonad size, and altered sex ratio. Intersex is a condition where both male and female gonadal tissue is present in the same male gonad and is a condition commonly found in fish exposed to sewage effluent

Discharge from municipal sewage treatment plants (STP's) may serve as primary pathways in which endocrine disrupting compounds are introduced into the aquatic environment (Desbrow *et al.* 1998, Ternes *et al*. 1999). Water discharged from STP's are generally believed to be higher in some of the more conventional pollutants such as organic and inorganic nutrients and currently, nothing is known of how these conventional pollutants will interact with synthetic organic pollutants many of which can cause endocrine disruption. Organisms most prone to these endocrine disrupting compounds are long-lived aquatic species such as fish. In the arid Southwestern U.S., these effluent-dependant or effluent-dominated waters (EDW's) are expected to increase in number and size as municipalities and their treatment plants are forced to handle larger amounts of sewage as population centers also increase in size. These EDW's will, over time, become hydrologically linked to other surface waters of the state and this places an increased importance in understanding these systems and their potential effects on wildlife and human health.

For this project, we are analyzing cold (*Onchorynchus apache,* Apache trout) and warmwater (*Gila elegans,* bonytail chub) native fish grown in captivity using water from 2 EDW's the PI's are currently investigating for another project; effluent from the Roger Road WWTP as it empties into the Santa Cruz River near Tucson and water from the Rio de Flag WWTP as it empites into the Rio de Flag in Flagstaff.

Fish are being housed in one of four, 650 gallon re-circulating tanks at the Environmental Research Laboratory. Two of the tanks are filled with split samples of water collected from one of the two EDW's ("treatment" tanks) previously mentioned while the remaining 2 tanks are filled with tap water treated by reverse osmosis with salts added to maintain osmo-regulation ("control" tanks). The water from each tank will be analyzed by Dana Kolpin at the USGS for a suite of compounds known to cause endocrine disruption in vertebrates. Fish have been implanted with PIT tags to identify individuals. Next month, we will randomly select tagged fish from each tank, withdraw blood, and analyze for 17β estradiol, 11-ketotestorone, and the egg protein vitellogenin. Blood samples will be sent to Dr. Timothy Gross at the USGS Florida Caribbean Science Center.

In addition to analysis of sex hormones and the egg protein vitellogenin, samples of male and female gonads will be taken after blood has been sampled, Testes will be cut longitudinally and ovaries transversely. Samples will be sectioned to 5 µm for histological evaluation. Gonads of female fish will be classified according to four stages of sexual maturation (stage 0,1,2,3 and 4), based on evaluation of histological slides. Male gonads will be classified according to three stages of sexual maturation (stage 1,2, and 3).

The results of this work will enable municipalities and resource managers to gain insight into the effect of EDW's on aquatic communities and human health.

This work is supported by the University of Arizona, Technology and Research Initiative Fund (TRIF), Water Sustainability Program

Aquaculture facility for housing fish exposed to water collected from selected effluent dependent streams.

Bonytail Chub *(Gila elegans)*

Apache trout (*Onchorynchus apache)*

Biocriteria Assessment of EDW's within Arizona.

This work, funded by USEPA and ADEQ, is nearing completion and the final report due later this month.

This project examines aquatic communities of EDW's within the state so that determinations can be made regarding goal attainment of "aquatic and wildlife, effluent dependent". This involves examining aquatic macro-invertebrates within several EDW's and correlating community diversity, similarity, and pollution tolerance with several chemical and geophysical parameters. Each EDW was sampled during the summer and winter months and spatial variation was accounted for by sampling downstream of outfalls to a "recovery area" as determined by physicochemical parameters. This involved much traveling within the state as well as a high degree of taxonomic expertise in identifying and quantifying macro-invertebrates, algae, terrestrial and aquatic plants, etc. Geomorphological variables were determined through a Rosgen level III analysis of each EDW.

We are working on the data analyses and expect to have the finalized report submitted within the next few weeks.

Taking geomorphological measurements along Rio de Flag

Ancillary Projects

We also have an ongoing project with the Department of Interior, National Park Service examining aquatic communities in ephemeral streams in Arizona. During substantial periods of the year, these streams form disconnected pools and often go completely dry. In such systems, the hyporheos may play a very important role as refugia for aquatic organisms attempting to avoid dessication. In this project, we are sampling from the hyporheic zone using colonization pots placed in the thalweg of the streams as well as piezometers placed out of channel.

This assessment is being done to determine how pumping of groundwater for domestic use may affect aquatic communities adapted to drying of the stream bed for extended periods.

The result of this work may be used in water rights issues within the state.

We are also assisting both the US Bureau of Reclamation and Fish and Wildlife Service in determing whether certain backwaters along the lower Colorado River can be used as habitat by native species of fish. This involves examining water quality as well as morphometric measurements of selected backwaters and determining what restoration techniques, if any, are feasible to improve these species chance of survival and reproduction.

This project has just started and we are in the data gathering and preliminary analysis phase.

Upcoming Watershed Meeting at ADEQ.

We are planning to have the next meeting sometime in early to mid October. We will be discussing several agenda items as they pertain to each watershed from algal toxins to perchlorate, eutrophication, tastes and odors, drought, runoff from wildfires, and several others. This meeting will include several guest speakers. I will email an announcement to the list within the next few weeks, which will include a rough agenda. Any interested municipality or agency is welcome to attend. If you know of someone that is not on the mailing list and would like to be, please don't hesitate to let me know.