CLIP/RIB: An Analysis of Caddo Lake Water Quality 1998-2005
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Long-term monitoring of water quality at Caddo Lake has been carried out from 1998-2005. Five sites were sampled in the middle of the each month: Caddo Lake State Park boat ramp (riverine), Clinton Lake (wetland), Turtle Shell (wetland), mouth of Harrison Bayou (wetland), and midlake (lake). Field data were taken with a pre-calibrated YSI multiparameter water quality sonde, a standard secchi disc, and thermometer. Water samples were taken at the surface (0.3 meters) for chemical analysis at the ETBU laboratory. Bacteria levels were determined using the membrane filtration technique for fecal coliform from 1998-2001, but the procedure was then changed to the Idexx most-probable number method for *Escherichia coli*. The purpose of this analysis is to: (1) examine long-term trends in the water quality parameters during the time period and (2) look for correlations among the parameters.

Long-Term Trends

Rainfall, Lake Level, and Inflow

Annual rainfall was highly variable with a range of 30.42 inches to maximums of 66.31 inches in 2004 in 57.30 inches in 2001. Rainfall variability led to varying levels of inflow into the lake as well as lake level. The highest inflow (1,843,774 dsf) was in 2001 and the lowest (403,527) in 2005. The USACE website reports a daily lake level at the spillway near Mooringsport, Louisiana. The annual mean lake level was highest (170.17 feet) in 2001, while the lowest level was reported in 2005 at 168.49 feet which is the only year in which the lake level mean was below the spillway level. Thus, the year 2005 had the lowest rainfall total, lowest inflow, and the lowest annual lake level mean.

Dissolved Oxygen

Dissolved oxygen (DO) levels in the lake as a whole continue to meet State of Texas standards for the segment, except in the wetland areas. DO levels at midlake had a mean of 8.5 mg/l over the time period, while the three wetland sites had a mean of 5.30 mg/l. As part of the Clean Rivers Program, 24 hour DO samples have been taken between since March 2002 at Big Cypress-Marshall Intake, Carter Lake, Clinton Lake, Turtle Shell, Harrison Bayou, and midlake. These samples suggest that the riverine and lake sites meet the State of Texas water quality standards but that much of the wetland habitat at Caddo Lake is anoxic during the summer months. The summer months typically have no or low flow into the lake and high temperatures, both factors are conducive to low DO values. The low DO values usually begin in May or June and lasts until at least August. I do not have sufficient DO data in September or October to know when higher DO values are reached. This pattern has been seen at Carter Lake, Clinton Lake, and Harrison Bayou and to a lesser extent at Turtle Shell. This pattern of low DO in the wetland area constricts the lake area in which fish and other animals can live during the summer months. The 24 hr DO samples at Big Cypress-Marshall Intake and at midlake indicate no low DO problems at those sites.

pH

Caddo Lake is an acidic lake which is typical of east Texas water bodies. The mean pH during this time period was 6.30 with the lowest mean pH found in the river (6.15) and the wetland sites (6.18), and the highest mean pH found at the lake site (6.66). This trend is expected because the inflow water is acidic while photosynthesis in the open areas of the lake drive the pH upward. The lowest mean pH values for all sites combined were found during 2000 and 2001. However, the lowest annual pH at a site type was 5.79 at the river site during 1999. Since, 2001, pH values at all site-types have increased.

Chemicals

Alkalinity is a measure of the buffering capacity of water to resist changes in pH. Alkalinity at Caddo Lake is generally low with an overall mean of 17.7 mg/l compared to other water bodies in east Texas. Alkalinity is highest at the wetland sites and lowest at the riverine site. Alkalinity was lowest in 2000 and highest in 2005 which indicates a slight upward trend in alkalinity since 2000.

Sulfate concentrations at Caddo Lake were fairly stable during the time period with an overall mean of 13.8 mg/l. The site-type with highest mean and largest variability was the riverine site at the state park. The peak years for sulfate concentrations in the river were 1999, 2002, and 2004. The highest annual rainfall occurred during 2004 while 2002 had the second highest inflow.

Water transparency

Water transparency has been measured using two methods: the traditional secchi disc depth and turbidity using a Hach Turbidimeter. All three habitat-types at Caddo Lake indicate turbid water with secchi depths of less than 1 m. The secchi depth during this time period has remained fairly constant with small trend in more turbid water over time. The lake has the most turbid water with a secchi depth of 0.79 m, while the wetland sites have the least turbid water with a secchi depth of 0.85 m. This difference is probably attributed to the effect of wind in creating turbulence in the water column. Wind velocities in the open lake are always higher than those that occur in the riverine and wetland areas. Turbidity as measured by the turbidimeter correlate well with those of the secchi disc. There is a slight upward trend in the data over time indicating slightly more turbid water.

Water transparency is affected by many factors including water color and suspended solids. True color is mainly dependent on the color created by dissolved substances in the water, while apparent color is due to both dissolved and suspended substances. Caddo Lake has a high color compared to other lakes in the region. Over this time period, true color (79 CU) represents 63.2% of the apparent color (125 cU). Apparent color is always highest at the riverine site which indicates higher amounts of suspended solids found coming into the lake.

Nutrients

I use Hach tests for determining nitrate and phosphorus levels in water. These tests are relatively inexpensive but do not have low detection limits and probably have some chemical interferences associated with them. My nitrate levels are higher than what we commonly find when Ana-Lab does the quarterly CRP lab analysis for us. Nonetheless, I believe the tests that I use provide valuable information on trends. Nitrate levels were highest in 2001 which was the second highest rainfall year and the highest inflow year during this time period. This suggests that nitrates are associated with inflow, but other factors such as internal re-cycling must be considered. Nitrate levels in the three site-types are similar with the concentrations in the river usually slightly higher. Total phosphorus levels are what I consider to be high at Caddo Lake. All site-types have similar means over the time period with the wetland sites having a slightly higher mean. There appears to be an increasing trend in total phosphorus over time with the highest levels found during the past three years of monitoring. Similar to nitrates, phosphorus is entering by inflow into the lake and by internal re-cycling. Reactive phosphate does not follow the same trend of increasing concentration. The highest reactive phosphate level was reached in 2002, which was the second highest inflow year during the time period.

Bacteria

The indicator test from 1998- 2001 was the fecal coliform membrane filtration test. Since then, I have been using the TCEQ approved Idexx test for *E. coli*. Bacteria levels tend to low at Caddo Lake and there seems to be no increasing or decreasing trend over time. The site with the highest levels is the state park site where there are a lot of human activities, businesses, and housing. The open water site at midlake has had few months when bacteria are even detected. The wetland sites are the most variable sites for bacteria with some months being high and others non-detectable. This might be due to wildlife using those areas to varying degrees through the year. I comprehensive, systematic bacterial monitoring program has never been carried out in the riverine portion of Caddo Lake. Perhaps it would be good idea to do this in the near future.

Water Quality Index

WQIs were generally in the “good” category at all sites and remained fairly stable with only the wetland WQI improving over the time period. Only during a few months did the WQI fall into the “medium” category. This occurred during the summer months when dissolved oxygen was at its lowest.

Correlations

I thought it would be a good approach to look at bivariate correlations among some of the water quality parameters, especially those that correlate with lake elevation, flow, rainfall amounts in the past 5 days, rainfall amounts during the previous months, whether water is going over the dam on the sampling day, and lake inflow on the sampling day.

The first correlations examined were for dissolved oxygen. DO had a high positive correlation with elevation and flow over the dam, but was not statistically correlated with rain or inflow. In order to understand these trends, I examined the correlations at each site-type independently of each other. DO is correlated with inflow at the riverine site, with elevation, inflow, rain in the previous month, and inflow at the wetland sites, and is not correlated with any of the variables at the lake site.

The second correlations examined were for pH, alkalinity, and sulfate. There is a highly significant inverse relationship between pH and alkalinity and all of the water level indicators. Thus, as more water comes into the lake through inflow and rain, the lower the pH and alkalinity is. Sulfate has a significant, positive (direct) correlation with elevation and flow over the dam; the other indicators have a positive correlation but they are not statistically significant. When the site-types are analyzed separately, there are some important trends. At the riverine site, pH and alkalinity were highly negatively correlated with lake elevation, flow over the dam, rain in the past 5 days, and lake inflow. Thus, it appears that rain events are causing the pH of the river to drop. Sulfate was positively correlated with only flow over the dam. The wetland sites and lake site had similar correlation patterns for all three parameters.

The third set of correlations was for the parameters related to water transparency. Turbidity as measured with the turbidimeter and the secchi disc had statistically significant positive correlations with the water level variables. Thus, as rain and inflow increases, turbidity increases. Interestingly, total solids and suspended solids had a statistically negative correlation with the water level indicators which is the opposite to what I would predict. However, when the correlations for true and apparent color are examined, I found that they exhibit a statistical positive correlation. Thus, it appears that as rain and inflow increases, turbidity also increases and that increase primarily is due to increase in water color. This conclusion is supported when the data for each site-type are analyzed separately. At the riverine site, turbidity and secchi depth are highly negatively correlated with most of the water level indicators. Suspended solids were positively correlated with lake elevation and rain in the previous five days. Both true color and apparent color are highly correlated with all of the water level indicators. The wetland sites had fewer correlations than the riverine site, and the lake site has even fewer correlations. This pattern suggests that the lake inflow brings in highly turbid and colored water and that the wetland areas lower the turbidity levels.

My guess is that this trend is exacerbated when Little Cypress and Black Cypress flows increase while Big Cypress flows remain the same. The transparency in water released from Lake O' the Pines reservoir is fairly clear compared to the typical turbidity of Little Cypress and Black Cypress. More study needs to be done on sediment (suspended solids) transport into Caddo Lake because many nutrients and bacteria can attach to and be transported by these particles. Also, additional sediment input into Caddo will fill in the shallow areas of the lake more quickly.

The fourth set of correlations was for the nutrient parameters. Ammonia is statistically significantly correlated with lake elevation, flow over the dam, and the amount of rain in the 5 previous days. Nitrate concentrations were not correlated with statistically with any of the water level variables. Surprisingly, total phosphorus was negatively correlated with most of the water level variables, which is contrary to what I thought would be true. When the site-type are analyzed separately, only a few parameters correlate with water level indicators. At the riverine site, only ammonia positively correlated with lake elevation and flow over the dam. Total phosphorus did not correlate with any of the water level indicators. At the wetland sites, there was only nitrate-nitrogen correlated with lake elevation. At the lake site, ammonia was positively correlated with lake elevation, flow, and rain during the previous month. Total phosphorus has a negative correlation with lake elevation. In summary, the understanding of nutrient dynamics is complex. There are only a few correlations of nutrients with lake level indicators which suggests that other factors are at work, such as plant decomposition, algal uptake, and release and sequestration of nutrients by the sediment.

The fifth set of correlations was for *E coli*. There were statistically significant correlations with *E coli* and lake elevation, amount of rain in the previous month, and the inflow on the sampling day. When the three site-types are analyzed separately, all three have positive correlations with lake elevation. This indicates that the levels of *E coli* in the lake can at least partially be explained by water level.

The last set of correlations was for the water quality index (WQI). There were statistically significant positive correlations with lake elevation and flow, however there was a statistically significant negative correlation with rain in the previous five days. When the three site-types are analyzed separately, the riverine site had highly negatively significant correlations with lake elevation, flow over the dam, rain during the past 5 days, and rain during the past month. This indicates that a high flow into the river lowers the WQI of the river. However, this trend was not seen at the wetland sites or the lake site.