PRELIMINARY ANALYSIS OF MSEA LAKE WATER QUALITY

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INTRODUCTION

Water erosion removes 1.5 to 2 billion tons of U. S. topsoil each year and is a significant problem nationally. The Mississippi River alone carries 331 million tons of soil to the Gulf of Mexico annually (Brown 1984). Fowler and Heady (1981) reported that in stream suspended sediments are, by volume, the largest pollutants in the United States. Much of the worldwide decline in aquatic habitats over the course of the past century can be attributed to draining and clearing of land for agriculture. It is estimated that 60% of the approximately 3 billion tons of sediment per year deposited in the waterways originates from agricultural lands. In addition, these sediments are often accompanied by other contaminants such as pesticides and nutrients. Delta lakes, long known for their productivity and recreational value (Cooper et al. 1984) have not escaped the detrimental effects of soil erosion. Their popularity as recreational resources has decreased as water quality and fisheries have declined (Coleman 1969). Cooper and Knight (1978) have attributed these declines, in part, to soil erosion and sedimentation. Detrimental impacts on stream and lake water quality due to erosion and sedimentation have been well documented (Knight et al. 1994; Waters 1995).

Oxbow lakes are remnants of meandering floodplain rivers that have been cut off and physically isolated from their respective main river channels. Because of this isolated condition, changes begin to occur in the physical and chemical characteristics of the lake basin and in the floral and faunal assemblages. Over time, as allochthonous organic materials derived from previous connections with the floodplain river ecosystem are processed and energetically depleted, isolated oxbow lakes in agricultural regions tend to become less heterotrophic and more autotrophic, becoming closed entities within themselves, functioning similarly to farm ponds and other small impoundments.

If suspended sediment concentrations are low enough to provide suitable light penetration, oxbow lakes provide conditions conducive to photosynthesis, primarily via phytoplankton, and may support a sustainable sport fishery. However, agricultural practices often result in soil erosion that can lead to increased turbidity in the oxbow lakes and subsequent inhibition of photosynthesis. Turbidity in oxbow lakes can be persistent in areas having soils with high clay content. Although nutrients such as phosphorus are commonly associated with delta soils and isolated oxbow lakes tend to load nutrients, these systems may become energy starved and very unproductive due to lack of light penetration.

Best management practices designed to reduce sediment-laden runoff should reduce suspended sediment concentrations in the receiving waters of oxbow lakes. Although some reduction in nutrient in-flow may be realized, most oxbow lakes should be eutrophic enough to boost primary productivity and, consequently, support a sustainable fishery. Research is needed to examine the impact of these management practices on the water quality and productivity of oxbow lakes receiving runoff from these managed watersheds.

The Mississippi Delta MSEA (Management Systems Evaluation Area) is a competitive agricultural systems-based research project designed to address the problems associated with these non-point source pollutants. The Mississippi Delta MSEA is unique among MSEA projects both because of its location in the Mississippi River alluvial plain and its strong ecological research component. Experimental design of the Mississippi Delta MSEA calls for the development of comprehensive land and cultural treatments targeted to reduce sediment and associated pollutants entering watershed oxbow lakes. Major objectives of the MSEA project are: 1) to develop and evaluate alternative and innovative farming systems for improved water quality/ecology in the Mississippi Delta; 2) to increase the knowledge to design and evaluate economical environmentally-sound best management practices (BMPs) as components of farming systems; and 3) to increase awareness and adoption by farmers/landowners of alternative farming systems to reduce adverse agricultural impacts on water resources and ecological processes.

To evaluate the efficacy of a management strategy such as the one proposed for the Mississippi Delta MSEA Project, a thorough understanding of pre-project conditions and ecological processes is required.

This study examines and documents pre-management water quality conditions on three oxbow lakes prior to the implementation of Best Management Practices.

MATERIALS AND METHODS

Study Site

Thighman and Beasley Lakes near Indianola, Mississippi, in Sunflower County and Deep Hollow Lake near Greenwood, Mississippi, in Leflore County, are the three oxbow lake study sites. Thighman Lake has a watershed of approximately 1,900 acres and a surface area of 25 acres. Crop production is conventional cotton, rice, soybeans, and corn. In addition to runoff from these crops, Thighman Lake receives water discharged from catfish ponds. Beasley Lake is a 40 acre oxbow located in a 1,000 acre watershed. The watershed is primarily in conventional tillage cotton. It also contains a large wooded riparian zone. This watershed will be protected with such structural practices as slotted board risers, slotted pipes, grass filter strips, and riparian zones. Deep Hollow Lake has a surface area of 20 acres and a watershed size of 40 acres. This watershed is farmed in cotton and soybeans. Deep Hollow watershed will receive both structural and cultural management practices to reduce sediments and other non-point pollutants including: no-till cotton and soybeans with winter cover crop, hooded pesticide sprayers and weed sensor technology, slotted board risers, slotted pipes, grass filter strips, and riparian zones.

Data Collection

Three sampling sites on each of the three lakes were selected for water quality monitoring. Yellow Springs Instruments automated water quality monitoring equipment was used to obtain hour measurements of temperature, pH, dissolved oxygen, and conductivity. Surface water quality was sampled biweekly for total, suspended, and dissolved solids, total phosphorus, filterable ortho-phosphate, ammonium nitrogen and nitrate nitrogen, chlorophyll, coliform and enterococci bacterial counts, and secchi visibility.

Analytical and chemical methods were based on procedures from APHA (1992). Calculation of means and statistical analysis was completed using SAS statistical software (SAS Institute, Inc. 1996). All parameters were tested for differences at the 5% level of significance.

RESULTS AND DISCUSSION

Mean physical and chemical water quality data for the three MSEA Lakes prior to establishment of erosion and pollution control structures and management practices may be found in Tables 1 and 2. No statistically significant differences were found between the three MSEA lakes in any parameter except for conductivity, dissolved solids, and nitrate. Thighman Lake had significantly higher conductivity and concentrations of dissolved solids and nitrate than either Deep Hollow or Beasley Lakes.

General Water Quality

Analyses of water quality prior to the implementation of management practices indicate lakes that were stressed and ecologically damaged due to excessive inflowing sediment. Mean total water column sediment concentrations ranged from 487 mg/L to 334mg/L with maximum values reaching 2,365 mg/L for Beasley Lake, 1,094 mg/L for Thighman Lake and 804 mg/L for Deep Hollow Lake. High suspended solid concentrations on Thighman and Beasley Lakes corresponded to lower concentrations of chlorophyll and lower Secchi visibility. Deep Hollow Lake had the highest mean concentration of chlorophyll at 24.42 mg/L as well as the lowest mean concentration of suspended sediment (269 mg/L). Temperature, conductivity, and pH values fell within ranges expected for the oxbow lakes in the Mississippi Delta. While all three lakes experienced occasional periods of low dissolved oxygen concentrations, average annual dissolved oxygen concentrations were adequate to maintain warm water fisheries.

Nitrogen

Atmospheric nitrogen is highly soluble in fresh water and only rarely a limiting factor in lake or pond productivity. All steps in the nitrogen cycle may occur in fresh water and are typically controlled by biological processes. Boyd (1979) reported that ammonium nitrogen and nitrate nitrogen concentration of unfertilized woodland ponds to be 0.052 mg/L and 0.075 mg/L, respectively, while catfish ponds had concentrations of 0.50 mg/L ammonium nitrogen and 0.25 mg/L nitrate nirogen. Although the MSEA lakes exceeded these values, they never exceeded the 1 mg/L at pH 7 and 30°C standard for ammonium nor the 0.02 mg/L standard for the highly toxic unionized form. MSEA lakes were also well below the 10 mg/L USEPA (1987) standard for water and fish ingestion. MSEA lakes had nitrate nitrogen concentrations that compared similarly to those values reported for Yazoo Basin lakes in 1969 (Table 3).

Phosphorus

Phosphorus plays a major role in biological metabolism and is typically the limiting factor in lake productivity and eutrophication (Hutchinson 1957; Lee 1970). Phosphate fertilizers are routinely added to ponds to increase primary productivity and fish growth (Mortimer 1954; Hickling 1962). Excessive amounts of phosphorus, however, may result in massive phytoplankton blooms and corresponding oxygen depletion. Boyd (1976) reported that fertilized farm ponds in Alabama averaged 0.17mg/L total phosphorus and 0.02 mg/L ortho-phosphate. USEPA (1987) stated that lake or reservoir waters should not exceed .025 mg/L total phosphorus in order to prevent nuisance growth of plants and eutrophication. Total phosphorus in the three MSEA lakes ranged from an average of 0.442 to 0.525 mg/L. Although these values are rather high, they are not unexpected given the relatively high phosphorus content of Mississippi Delta soils.

Sediment and chlorophyll

Few studies have been conducted to determine the effects of clay turbidity on warmwater fishes. Wallen (1951) found that concentrations of suspended sediments as high as 100,000 mg/L were required for gills and opercular cavities to become clogged. However, stress related behaviors could be induced at concentrations as low as 20,000 mg/L. Wedemeyer et al. (1976) reported that concentrations of 80-100mg/L are considered to be the maximum that most species of fish can tolerate on a continual basis without causing gill damage. Long term exposures (several months) to concentrations of 200-300 mg/L have caused bacterial tail and fin rot in salmonids, as well as pathological changes in gill structure (Herbert and Merkins 1961). While high concentrations of suspended solids rarely cause direct fish mortality, relatively low concentrations can affect lake productivity (Murphy 1962). Waters (1995) detailed the sources, effects, and control of sediment in streams and provided a summary of research on the effects of sediments on aquatic organisms.

Suspended and total solids concentrations were sufficiently high to consider the MSEA lakes sediment stressed systems. Suspended sediment concentrations exceed water quality standards established for Alaskan water reported by Lloyd (1987). The MSEA lakes also had suspended solids concentrations that were 84.2 % higher than that of Morris Pond, a 1.09 ha farm pond located in the hill lands of central Mississippi (Cooper and Knight 1990). Annual mean suspended solids concentration was 55.0 mg/L for Morris Pond, compared to 381 mg/L, 402 mg/L, and 269 mg/L, respectively, for Thighman, Beasley, and Deep Hollow. When compared to historical turbidity data (Table 3) collected from Yazoo Basin lakes from 1969, the three MSEA lakes exceeded estimated suspended solids concentrations of all lakes with the single exception of Arkabutla Reservoir (USCOE 1975). It should be noted that this data was collected prior to the increase of intensive cultivation of soybeans in the Mississippi Delta that occurred in the 1970s and based on sediment-turbidity models developed by Sigler et al. (1984).

Secchi visibility was exceptionally low, averaging less than 17 cm and further supporting the contention that the MSEA lakes were sediment stressed. Cooper and Bacon (1980) reported that primary productivity was adversely affected when suspended sediments exceeded 100mg/L. At this concentration of suspended sediments, chlorophyll concentration was reduced to less than 20 mg/L. Cooper et al. (1995) demonstrated that when suspended sediments were reduced through diversion of sediment laden runoff, chlorophyll concentration doubled. Cooper and Bacon (1980) reported mean annual suspended sediment concentrations of 117, 198, and 262 for the years 1977, 1978, and 1979 which were lower than the means for the three MSEA lakes. Chlorophyll concentrations were also impacted by high suspended sediments in the MSEA oxbows ranging form 9.89 to 24.42 mg/L.

SUMMARY

Since changes in lake water quality are being used as one measure of management success of the Mississippi Delta MSEA project, a thorough understanding of pre project conditions and ecological processes is required. This study examined and documented pre-management water quality conditions on three oxbow lakes prior to the implementation of Best Management Practices. Analyses of water quality prior to the implementation of management practices indicate lakes that were stressed and ecologically damaged due to excessive in-flowing sediment. Mean total suspended sediment concentrations for the three MSEA lakes exceeded concentrations estimated for regional lakes in 1969, as well as levels acceptable for fish growth and health. Because all MSEA lakes had low concentrations of chlorophyll despite relatively high concentrations of phosphorus, it is reasonable to assume that high suspended solid concentrations likely suppressed phytoplankton production. This conclusion is further supported by the fact that Deep Hollow Lake had the highest mean concentration of chlorophyll of the three lakes, as well as the lowest mean concentration of suspended sediment. If suspended sediment concentrations can be reduced in these oxbow lakes, conditions favorable for phytoplankton production should prevail. Increases in phytoplankton production will result in increased chlorophyll concentrations and higher concentrations of dissolved oxygen, leading to improved secondary productivity. Land and farm management practices designed to control erosion and reduce transport of soil, organic matter, and agricultural chemicals should improve water quality and, therefore, ecological conditions.

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Table 1. Physical Data from MSEA Lakes Before implementation of Best Management Practices in September 1996.

Lake	Temp C	Conductivity mS/cm	Dissolved Oxygen mg/L	pH	Secchi cm	Total mg/L	Solids Dissolved mg/L	Suspended mg/L
T	29.80 (2.44)	0.309 (0.127)	5.06) (2.17)	7.21 (0.39)	11.5 (8.52)	487 (256)	119 (52)	381 (273)
B	25.61 (12.98)	0.072 (0.017)	6.38 (3.74)	7.00 (0.37)	16.6 (16.87)	458 (430)	59 (23)	402 (434)
DH	24.42 (6.52)	67.89 (46.21)	4.04 (1.59)	6.68 (0.75)	13.2 (9.37)	334 (224)	55 (22)	269 (237)

T= Thighman, B= Beasley, DH = Deep Hollow

Table 2. Chemical Data from MSEA Lakes Before implementation of Best Management Practices in September 1996.

Lake	Filterable ortho-PO_4 Mg/L	Total Phosphorus Mg/L	Coliform Count	Enterococci Count	NH_4 Mg/L	NO_3 Mg/L	Chlorophyll Mg/L
T	0.018 (0.021)	0.422 (0.218)	4593 (5416)	27 (43)	0.169 (0.144)	1.157 (0.917)	9.89 (6.07)
B	0.033 (0.018)	0.484 (0.301)	86 (86)	7 (16)	0.126 (0.067)	0.620 (0.617)	16.56 (26.71)
DH	0.035 (0.062)	0.525 (0.256)	863 (958)	0 (0)	0.189 (0.144)	0.393 (0.375)	24.42 (34.70)

T= Thighman, B= Beasley, DH = Deep Hollow

Table 3 Mean water quality data from Yazoo Basin Lakes collected in 1969.[1]

Lake	Turbidity JTU	Suspended[2] Solids mg/L	NO3 mg/L	PO4 mg/L
Alligator Lake	25	25	0.43	0.54
Eagle Lake	25	25	0.11	0.08
Thompson Lake	25	25	0.00	0.00
Bear lake	25	25	0.39	0.02
Buzzard Bayou	109	115	0.00	0.66
Fish Lake	25	25	0.15	0.48
Old Orchard Lake	25	25	0.00	0.04
McIntyre Lake	42	45	0.55	0.42
Mathews Brake	25	25	0.29	0.05
Roebuck Lake	25	25	0.15	0.50
Twin Lake	222	240	1.08	0.73
Four Mile Lake	184	197	1.20	0.54
Sky lake	60	62	1.13	1.43
Goose Lake	25	25	0.00	0.08
Moon Lake	25	25	0.46	0.14
Lake Washington	77	80	0.00	0.44
Arkabutla Lake	280	305		
Sardis Lake	103	110		
Enid Lake	78	82		
Grenada lake	120	127		

[1] Source: USCOE 1975.

[2] Suspended sediment concentrations estimated from JTU data based on models published by Sigler et al. 1984.