WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Eutrophication in the White River watershed: Data synthesis and dynamics of planktonic communities

Principal Investigators:

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Nature, scope, and objectives of research

The overall purpose of the proposed project is to synthesize and expand existing research on water quality of the White River watershed. In the proposed study, we have two major objectives. First, we will review existing literature and ongoing studies in the watershed, synthesize results to date, and present findings to the scientific and public policy communities through the web site managed by the SMSU Bull Shoals Field Station. The second objective is to expand existing research in the region to include species composition and population dynamics of the plankton. Besides supporting the Field Station's mission of exploring regional biodiversity, research on plankton community dynamics in the White River lakes will allow a greater understanding of the causes and consequences of algal blooms both here and in other lakes undergoing eutrophication.

The White River watershed includes four reservoirs along the main channel of the White River: Beaver Lake (in Arkansas), Table Rock Lake, Lake Taneycomo, and Bull Shoals Lake (Missouri and Arkansas). Over the past 10 years, some of these lakes have exhibited the early signs of deteriorating water quality, particularly that due to nutrient loading and eutrophication. Detailed long-term research by Dr. Jack Jones and colleagues at the University of Missouri has demonstrated significant changes in transparency, nutrient levels and algal biomass in Table Rock Lake (Jones and Perkins 1999). For example, during the past 20 years, average Secchi depth (transparency) has been reduced from 4.5m to 3m, while both total phosphorus and chlorophyll-a measures increased (Jones and Perkins 1999: Fig. 2, from regression lines). The graphs also indicate an increase in within-year variability over this period, suggesting pulses of nutrients during turnover and more-frequent bloom events. As an example, the James River arm near Cape Fair experienced significant blooms of algae (especially crypotomonads, R. Rhodes, pers. obs.) during the summers of both 1998 and 1999.

Summer algae blooms have also been observed as early as 1988 in the cold-water Lake Taneycomo, especially during periods of low flushing rates (Knowlton and Jones, 1990). During summer stratification, high algal biomass leads to high rates of decomposition, consuming oxygen and ultimately leading to regions of anoxia in the bottom (hypolimnion) of lakes. One consequence of low oxygen levels is that fishes are restricted to living closer to the surface, eliminating cold-water species. Another consequence is the occurrence of fish kills downstream from dams. As an example, the hypolimnion of Bull Shoals Lake regularly becomes oxygen depleted, and releases of oxygen-poor water from the dam have caused fish kills and major impacts on the salmonid fishery in the tailwaters of the dam (Johnson et al. 1997, cited in Allee 1997). Using depth profiles of oxygen and lake volumes, Green (1996) computed hypolimnetic oxygen deficits for Beaver, Table Rock, Bull Shoals, and Norfork lakes, but was unable to detect clear trends of eutrophication from his regression models of a 20-year record. Nevertheless, there is concern that the deteriorating condition of Table Rock Lake will be repeated in Bull Shoals Lake (Wally Green, Missouri Department of Natural Resources, pers. com., October 28, 1999).

Algal production in most lakes appears to be limited by the concentration of phosphate (Wetzel 1983, Edmondson 1991). Thus excess phosphorus loading leads to accelerated eutrophication, such as was earlier demonstrated in Lake Erie and Lake Washington (Edmondson 1991). Such a trend between phosphate and eutrophication (as measured by algal biomass) is apparent from extensive surveys of lakes in Missouri (Jones and Knowlton 1993). Time series studies of Table Rock Lake and other White River lakes also reveals that enhanced algal biomass is linked to loading with excess phosphate (Jones and Perkins 1999). Nevertheless, the specific sources of this excess nutrient to the White River lakes are unknown. Point sources include wastewater treatment plants in the area and above major rivers, such as the James River. Non-point-source pollution likely contributes the majority of the nutrient load (Bruce Perkins, University of Missouri, pers. com.). Such sources include an increased density of poultry farms in Arkansas and Missouri and the application of their wastes as fertilizer to fields subject to runoff (Smith, 1999). Rapid development of Branson, areas around Table Rock Lake, and areas upstream has also lead to an increased density of septic tanks in the watershed.

The concern over deteriorating water quality of the White River lakes and potential impacts on the large tourism industry of the area led to a recent conference (The White River Basin Water Quality Forum, Branson, October 27, 1999), at which a Memorandum of Agreement was signed between the Missouri Department of Natural Resources, the Arkansas Department of Environmental Quality, and the Arkansas Soil and Water Conservation Commission. In addition, the federal government has recently allocated $5.5 million to improving phosphorus removal at sewage treatment facilities of small towns and of determining ways for controlling non-point-source releases of phosphorus (Springfield News Leader, October 16, 1999).

There is clearly a need for solid baseline environmental data against which future changes in the White River lakes can be measured. Currently, multiple agencies and organizations have ongoing studies in these lakes. The U.S. Army Corps of Engineers samples near the dams of Beaver, Table Rock, and Bull Shoals lakes. Numerous other groups sample Table Rock Lake. The Missouri Department of Natural Resources samples the James River arm of the lake, near Bois d’Arc (D. Leyland, pers. com.). The University of Missouri samples eight sites on the lake at least once a month (Dr. Jack Jones, pers. com.). The primary emphasis of all these studies is to examine nutrient loading and effects on algal biomass and water clarity. In addition, volunteers with the Lakes of Missouri program sample some sites on Table Rock, Taneycomo, and Bull Shoals (F. Pope, University of Missouri, pers. com.), contributing useful information on water clarity. Other groups are studying land use and streams draining into the lakes. Using Geographic Information Systems, the Missouri Department of Natural Resources has mapped land use in the watershed (DNR 1999). The Missouri Department of Conservation is currently mapping the location of sampling sites in the drainage by volunteers with the Missouri Stream Team (R. Schulz, MDC, pers. com.).

Since so many different agencies are involved, coordination among studies is difficult. There is thus a need for thorough synthesis of existing information on past studies and ongoing studies of these lakes. Furthermore, since the algae include a wide variety of taxa having large physiological differences (Van den Hoek et al. 1995), the composition of algal blooms is important for explaining their effects (Steidinger et al. 1998). There is

thus a need to examine the composition of algae which dominate during bloom periods. Zooplankton are important grazers of algae and it is well known that during periods of high zooplankton abundance, water has a high clarity (called the "clear water phase"; Edmondson 1991, Lampert and Sommer 1997). The zooplankton subsequently serve as food for larval fish. Food chain effects ("top-down effects") sometimes provide an additional explanation for the clarity of lakes (Edmondson 1991).

The objectives of the current study are to synthesize existing water quality data on the White River watershed and to initiate biomonitoring research at the Bull Shoals Field Station.

Methods, procedures, and objectives of research

In the current study, we will first conduct a thorough literature review of past studies and ongoing studies within the White River watershed, synthesize this information, and place the information in a database accessible through an internet web site. Second, we will establish a water quality monitoring program at the Bull Shoals Field Station, collecting limnological data, nutrient and chlorophyll samples, and samples of algae and zooplankton. Southwest Missouri State University has recently established the Bull Shoals Field Station (http://www.cnas.smsu.edu/bullshoals/Default.htm) as a site for research on southwest Missouri ecosystems. The location of the Field Station, overlooking the western end of Bull Shoals Lake and ca. 15 miles from Branson, gives the University a prime location for monitoring water quality of the White River watershed. A number of working hypotheses (below) guide our water quality monitoring and focus primarily on eutrophication.

<u>Literature and data synthesis</u>. In support of the new Field Station, we have recently begun a literature review focused on studies conducted in the upper White River watershed and of the Ozarks region as a whole. In the proposed study, we will exhaustively search refereed literature, Master's and Ph.D. theses, government reports, and other articles and books. The search will include visits to area academic libraries and agency headquarters,

as well as internet-based searches. Complete citations and abstracts from each item of literature will be listed in a dynamic database, using Microsoft Access. The database will be imported into the web site for the Bull Shoals Field Station (URL above). The web site, in turn, will be cross linked with other web sites of interest (e.g., U.S. Geological Survey and Missouri Department of Conservation). This proposed web site will provide an information base to support research by users of the Bull Shoals Field Station, as well as others needing information about the White River drainage. We expect a wide variety of users to be served by this site, including researchers, teachers, planners, business owners, and government officials.

We will also search, through personal communications and internet searches, for detailed information on existing sampling programs. These data will be presented via maps and tables. Development of this data base will allow better coordination of existing programs and can later be incorporated into a Geographic Information System.

We plan to incorporate the database and web-based methods developed by the NSF-supported Long Term Ecological Research program (http://lternet.edu/) and the Organization for Biological Field Stations (http://www.obfs.org/).

<u>Water quality monitoring</u>. We will collect field data and samples from Bull Shoals Lake on a similar sampling schedule to that of our University of Missouri collaborators working on Table Rock Lake (every 3 weeks during May-October, monthly November-April; total ca. 15 sample dates). Such coordination will allow us to examine the timing of events at the two lakes. Furthermore, the University of Missouri group will provide us with free samples of algae and zooplankton from Table Rock Lake (Dr. Jack Jones, pers. com.), which we can then compare with Bull Shoals Lake.

Physical measurements. Our routine collections from Bull Shoals Lake will occur at two pelagic sites in the main channel of Bull Shoals Lake. Site 1 will be in the western end of the lake, near the Bull Shoals Field Station, in Taney County, Missouri. This site is riverine in character and has a maximum depth of ca. 20 m. Site 2 will be in eastern end of the lake, near the dam, in Marion County, Arkansas. This site is lacustrine in character and has a maximum depth of ca. 40 m. Limnological measurements at each site and on each sampling date will include Secchi depth (transparency) and a depth profile of temperature and dissolved oxygen, using a YSI digital oxygen meter. The depth profile will extend every meter from the surface to the bottom or to 30 m.

Based upon prior knowledge of lake and reservoir systems in general (Lampert and Sommer 1997) and prior data on the higher fertility of Table Rock Lake (Jones and Knowlton 1993), we can make the following predictions.

1. A clear water phase will occur during late spring in each lake.

2. Secchi transparency will tend to be greater in Bull Shoals than Table Rock and transparency at lacustrine sites will be greater than in riverine sites.

3. The annual range of variation in Secchi transparency will be greater in Table Rock than in Bull Shoals Lake.

Water chemistry. Samples for water chemistry parameters will be taken by grab samples from ca. 0.5 m depth. Four 1-L samples will be collected and composited. From this pooled sample, 125-mL subsamples will be taken for total nitrogen and total phosphorus. Chlorophyll-a and total suspended solids samples will be collected by filtering 250-mL and 1-L subsamples, respectively, through glass fiber filters, dessicated, and transported on ice. These samples will then be stored frozen, prior to shipping for analysis by the laboratory of Dr. Jack Jones (University of Missouri). Contracting their analyses of these samples will ensure that analyses from the two lakes are comparable.

Based upon knowledge of lakes in general (Wetzel 1983, Lampert and Sommer 1997) and prior research from lakes in this region of the country (Jones and Knowlton 1993), we can make the following predictions:

4. Algal biomass (as chlorophyll-a) will show a strong positive correlation with total phosphorus concentration.

5. Secchi transparency will show a weak negative correlation with algal biomass.

Plankton analysis. Samples for algae (phytoplankton) will be collected on each date using a Kemmerer water bottle from multiple depths, composited, and then preserved with Lugol's iodine (Edmondson 1959). Zooplankton will be sampled by vertical tows, from 10 m depth to the surface, using a calibrated 80 μm-mesh Wisconsin net. The zooplankton will be anaesthesized with cold CO_2, then preserved with cold buffered sugar formalin (Prepas 1978). Besides these samples from Bull Shoals Lake, the University of Missouri group will provide us numerous samples of algae and zooplankton from Table Rock Lake. They will visit eight sites in Table Rock Lake on a routine basis and do at least one longitudinal survey along the James River and Long Creek arms of the lake. Thus, over all dates, approximately 170 total collections of algae and zooplankton will be made (30 in Bull Shoals, 140 in Table Rock). These collections will cover dates and areas which should show transitions between good and poor water quality, so we expect to find considerable variation in plankton community composition and dynamics.

Algae and zooplankton samples will be analyzed at the highest practical magnification.

Subsamples of algae will be identified to species and counted at 400X using the Utermohl technique and a Leitz inverted microscope. Zooplankton will be identified at 25-100X, classified to species (cladocerans) or genera (copepods and rotifers) and subsamples counted by standard techniques.

The species composition of these plankton will be compared among sites and dates. Limited literature exist on species composition. Previous work on Bull Shoals Lake has reported algae to genera (Allee 1997) and zooplankton to species (Damico 1973, Allee

1997). A recent survey by our group provided a species list for the summer zooplankton community from all the lakes in the White River drainage (Havel and Eisenbacher, unpublished). Typically, zooplankton communities change in composition with the seasons (Lampert and Sommer 1997), so the proposed study will likely detect numerous species not previously reported.

Plankton will be further analyzed with several descriptive and graphic measures. Species diversity and percent composition of the major groups of algae will be calculated. Since cell size is highly variable, percent composition will instead be based upon biovolume, using published estimates of cell and colony volumes (Kirschtel 1992 and Kirschtel 1996). Total algal biovolume will later be compared to chlorophyll-a estimates, which should be closely correlated with algal biomass. Abundance of total zooplankton, particularly of the most-important grazers (e.g., *Daphnia*) will be compared with algal biomass and periods of dominance by blue-green algae.

Based upon prior understanding of lakes in general (Lampert and Sommer 1997) and personal observations on plankton of this region, we can make the following predictions:

> 6. Total algal abundance and biomass will each show strong variation over time.
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> 7. Algal composition during summer blooms will be dominated by dinoflagellates and blue-green algae.
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> 8. During algal blooms, zooplankton will be dominated by copepods and during clear water periods zooplankton will be dominated by cladocerans.
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> 9. During algal blooms, taxonomic diversity of zooplankton will be less than during clear water periods.

Related research (<u>see</u> Nature, scope, and objectives above)

Relevance of the project

<u>Relevance to Missouri needs and international significance</u>. The upper White River region, near Branson, Missouri, has experienced significant growth in the past 10 years, with development of a $1.5 billion tourism industry, including entertainment at area shows and amusement parks. Over 6 million tourists are attracted each year to area lakes, which are widely known to have good fishing and high water clarity (e.g., <u>see</u> Jones and Knowlton 1993). The recent decline in water quality (Jones and Perkins 1999) threatens this tourist industry, as well as the natural ecology of this system.

During 1999, an algae bloom in the James River arm of Table Rock Lake lasted several months (D. Leyland, Missouri Department of Natural Resources, pers. com.). This bloom was readily visible to casual observers and attracted considerable media attention. Algae blooms are generally known to be responsible for taste and odor problems for public water supplies (Van den Hoek et al. 1995, Youngsteadt and Gumucio 1994). In addition, some fish kills are linked to algae blooms. For example, fish kills in Stockton Lake, Missouri, and in Indian Lake, Florida, were linked to blooms of the algal dinoflagellate *Gymnodinium* (Fields and Rhodes 1991, Steidinger et al. 1998). Fish kills of a greater magnitude, together with human health effects, have been reported for another dinoflagellate (*Pfiesteria*), which lives in estuaries on the east coast (Burkholder 1999). A fish kill occurred in Table Rock Lake during the summer of 1999, though this event was likely from bacterial infections following parasitism by protozoans (W. Anderson, Missouri Department of Conservation, pers. com.). Numerous other fish kills have been noted in White River area lakes and streams (Baylis and Vitello 1999).

Future research and funding. The proposed study is linked to the mission of the SMSU Bull Shoals Field Station. The Field Station receives an operations budget from the University and we are soliciting funding from the National Science Foundation for facilities improvement. Scientific work at the Field Station will be supported from external grants. Besides providing useful information for ongoing studies of the White River drainage, the proposed grant will help make the Field Station attractive to outside investigators and future funding from the National Science Foundation. To extend research on the White River drainage, we intend to solicit funding from the U.S. Environmental Protection Agency, through the “319 grant” program through the Missouri Department of Natural Resources. Since a sizable fraction of the nutrient loading apparently comes from non-point sources, including area agriculture, we also intend to pursue funding opportunities through the U.S. Department of Agriculture. Finally, an exotic species of the zooplankter *Daphnia* has recently invaded area lakes, where it dominates during late summer (Havel et al. 1995). This discovery spurred recent grants from the National Science Foundation. A future grant proposal may examine the role of these important grazers in controlling blue-green algae growth.

Student involvement. The proposed project will employ one 12-month graduate research assistant and a part-time student worker. (See Training potential above.)

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