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Geological Map of Mississippi
The picture is of a cross stitch of the geological map of Mississippi. Dr. Claire Babineaux created the piece. The picture was taken on March 21, 2025 at the MAS annual meeting in Biloxi, MS
Photographed by Claire Babineaux

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Assessing Impact: Challenges in Measuring High School JROTC Students' Data Literacy and Science Identity Changes within a Summer Residential Camp

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ABSTRACT

A summer residential program, leaderSTATE STEM, provided leadership, fitness, and a Science, Technology, Engineering, and Mathematics (STEM) overview for Junior Reserve Officers Training Corps (JROTC) high school students across three southern US states. The program offers 5-day residential summer camps (N=6) for over 300 students annually, with most students coming from historically marginalized groups. To evaluate the camps' effectiveness, the Test of Science Related Attitudes (TOSRA) instrument was used pre- and post-camp to ascertain changes in students' attitudes about science and society. Paired pre-post TOSRA results from 2016-2017 camps (N= 622 students) were analyzed for race, gender, and school correlations. Chi square analysis ($p = 0.05$) revealed only scattered significant improvement throughout the data. A Data Literacy Survey measured changes in students' abilities to read and interpret graphically displayed data. Paired t-tests ($p < 0.05$) documented that only one of six camps had significant results in 2016, though three of six camps exhibited significant change in 2017. Cohen's d effect sizes were small ($n = 2$) and medium ($n = 4$). Our research indicated that additional or new instruments are needed to measure the impact of short-duration residential STEM summer camps on students' science identity and data literacy. This research subsequently resulted in the use of modified assessments in both pre-pandemic and post pandemic leaderSTATE STEM camps.

Keywords: STEM, leaderSTATE, Junior Reserve Officers Training Corps, JROTC

INTRODUCTION

The low proportion of underrepresented minority (URM) and female students that enter and complete degree programs in Science, Technology, Engineering, and Mathematics (STEM) disciplines is a persistent problem in the United States. Interest and achievement gaps exist among African Americans, Hispanics, and females in the STEM fields, which limits their participation in STEM-related jobs (Olson & Riordan, 2012). Increasing the engagement of high school age URM and female students in STEM is the goal of a summer residential program, leaderSTATE STEM. This program hosts Junior Reserve Officer Training Corps (JROTC) high school students in six 5-day summer residential camps, or cycles, on Mississippi State University's campus, with multifaceted programming in leadership, fitness, and STEM, to provide an opportunity for underrepresented students to gain confidence in several areas.

With regards to STEM instruction, programming delivers geoscience-focused immersive learning experiences to target data literacy and geoliteracy, with activity development based upon the learning theory of human constructivism. The summer residential program seeks to introduce underrepresented groups to a university campus and STEM subjects and careers, inspire all students to learn STEM, and, in the process, motivate many of them to pursue STEM careers. Our research investigated the efficacy of this 5-day, university-based STEM academic leadership summer camp program on high school JROTC students' data literacy skills and their perceptions of science identity.

THEORETICAL FRAMEWORK

These residential summer camps use a constructive learning approach (McLeod, 2019; Novak, 1993) to build a deeper understanding of selected geosciences phenomena, since effective learning experiences lead to students' ability to articulate an explanation of phenomena or develop a solution to a problem. Learners' preexisting knowledge provides a foundation upon which they can construct new knowledge (McLeod, 2019). This process of building meaningful knowledge, or "subsumption" (Ausubel, 1968), occurs when new concepts are added to the learners' preexisting cognitive structure. Changing the perceptions of learners through constructivist methods creates a more internalized acceptance of new information through the process of discovery. Constructivist techniques within investigations of scientific phenomena provide learners with a more active and collaborative engagement in the process of learning (Windschitl, 2002).

Activities that ask "how" and "why" questions allow students to collaborate and construct knowledge that can challenge their preexisting suppositions, thereby promoting learning (Brooks & Brooks 1999). Additionally, it is important to involve students in the process of "doing" science and discussing the nature of science (Carey & Smith, 1993). Activities that incorporate methods of thinking in Bloom's three domains of learning (cognitive, affective, and psychomotor) also create deeper understanding of science (Bloom, 1965).

In constructivist learning, the student must be open to accepting new ideas in a manner that is internalized and recognized as personally meaningful (Mintzes et al., 2005). "Learning how to learn" as an outcome of a constructivist STEM summer camp experience would be a transferable skill with numerous future applications for learners.

Data Literacy and Geoliteracy

Scientists, and scientifically literate individuals, make sense of the world either qualitatively or quantitatively through data literacy (Bowen & Bartley, 2013). Data literacy involves understanding the meaning of data, including the ability to read graphs and charts as well as draw conclusions from data (Carlson & Johnston, 2015; Shah & Freedman, 2011). Allied with data literacy is graphicacy, the ability to understand and present information in non-textual formats including maps, charts, and graphs (Aldrich, 2000). Graphicacy is an essential skill in modern society as multimedia communication venues present a large volume of information in graphic forms (Wilmot,1999). Students who cannot read and interpret graphs are at a disadvantage in and out of school as the amount of data available in the media is large and prevalent. National and international assessments reveal that many students can identify simple data points on graphs but have difficulty identifying trends, rates of change, data anomalies, and other less obvious information (Zucker et al., 2015).

There are parallels to teaching textual literacy and teaching data literacy. Reading text, data, or graphs requires understanding the words of the text or the coding of the data set or format of the graph (Zucker et al., 2015). While several methods exist for measuring textual literacy, there is a lack of metrics available for measuring data literacy skills (Wolff & Kortuem, 2015). Direct instruction in the collection and tabulation of data, and reading, writing, and analyzing those data and their associated graphic displays is increasingly important in secondary school curricula.

Geoliteracy describes the need to build a greater awareness in the general population of our interactions with our planet (Edelson, 2011), for citizens to make informed decisions about important issues that affect natural and human systems. A geoliterate person can locate credible Earth science information (Earth Science Literacy Initiative, 2010). Activities that promote geoliteracy focus on topics that not only address important scientific content, but also transferrable skills of inquiry and collaboration necessary for evaluating the interaction of science and society.

Immersive Learning and Summer STEM Camps

Immersive learning exposes students to a variety of cross cutting skills that helps them develop the ability to be critical thinkers, collaborators, team players and leaders in other areas of study or everyday life (Dennison & Oliver, 2013). Students who engage in immersive studies use a combination of skills to learn, which reinforces connections to the area of study by making the experience more memorable (Cotton & Cotton, 2009). Immersive learning experiences draw participants based upon the motivations of each individual (Falk & Storksdieck, 2010).

Summer programs are commonly used to increase interest in STEM careers in K-12 students (Ashley et al., 2017). These informal learning environments allow students to explore STEM concepts in greater depth (Mohr-Schroeder et al., 2014). These avenues may provide a needed avenue for STEM participation; rural and small-town students have limited access to STEM coursework and extracurricular activities, which correlates with the geographic disparities observed in post-secondary STEM participation (Saw & Agger, 2021).

Challenges lie in finding and enacting effective strategies to increase students' completion of STEM degrees, and in recruiting students to STEM disciplines, especially students from historically marginalized groups. (National Research Council, 2011). Students are influenced by what they observe or experience prior to making post-secondary education choices (McCracken & Barcinas, 1991) and providing exposure through a summer STEM camp is one way to increase student's interest in STEM degree programs and careers. A particular challenge is creating an increased awareness of opportunities in geoscience STEM careers in historically marginalized populations. As of 2017, there remained a significant shortfall of students entering the geosciences, staying in the field, and entering the workforce, particularly students from underrepresented groups (Wolfe & Riggs, 2017). Furthermore, underrepresented populations, only 2% of the geoscience workforce in 1972, made negligible gains through 2016 (Friedman, 2023). Meeting the future demand for a qualified geoscience workforce will require efforts to increase recruitment, retention, and graduation of a diverse student body that is more inclusive of historically marginalized students, which include ethnic and cultural minorities, and women (Wolfe & Riggs, 2017). Quantitative studies are needed to examine the barriers that exist in increasing diversity in the geoscience workforce (Stokes et al., 2015). Due to the need for increasing the STEM workforce in the United States, all segments of the population must be encouraged to pursue careers in STEM especially within historically marginalized groups which include African Americans, Hispanics, and Native Americans (Dancy & Elon, 2010).

METHODS

Research Design

The summer residential leaderSTATE STEM program brings groups of up to 60 high school JROTC cadets, typically rising juniors, to a university campus for a one-week residential experience in personal fitness, leadership skill development, and STEM overview. These six one-week camps, or cycles, were offered annually on Mississippi State University's campus, and had the opportunity to impact up to 360 JROTC cadets each summer from three southern U.S. states (Mississippi, Louisiana, and Alabama). The camps are ambitious; beyond providing a STEM overview, fitness, and leadership, guest speakers and industry tours introduce students to career options after high school. This multifaceted approach to learning was documented to develop academic expertise and knowledge (Wai et al., 2010).

The Department of Geosciences began providing camp activities in 2016 after the earlier STEM partner stepped back from the project, less than 6 weeks before the first summer camp began. We quickly designed STEM activities to examine weather phenomena within an overarching theme of data literacy (Figure 1). Daily examination of various online weather maps and the collection, plotting, and simple analysis of selected local weather data were used to highlight the importance of data literacy. Hands-on investigations explored dew point, humidity, frontal movement, air pressure, and cloud formation. Students shared and examined their collected data, and instructor-led discussions focused on accuracy, precision, and other data literacy aspects. Because of the multifaceted nature of the camp, STEM instructional hours and activities were limited to 10-13 hours during the week, although university campus tours and guest speakers extended the STEM impact.

Figure 1 *Students present their Weather Data Analysis as part of the leaderSTATE STEM summer camp STEM activities. (Photograph by Mark Powers)*

To investigate the effect of the residential camp on the attending JROTC students, we constructed a mixed methodology research design (Caruth, 2013; Creswell, 2009) and implemented multiple assessments to evaluate the summer residential leaderSTATE STEM camp's impact on students' attitudes towards the camp experiences, their science content knowledge, and their data literacy skills. In this manuscript, we focus on the quantitative analyses of students' science content and data literacy changes over the course of the one-week camp, or cycle.

Participants

Students attend the one-week STEM residential summer camp with their colleagues. Each of the 6 cycles, or weekly camps, hosts up to 60 high school students, typically rising juniors, from similar geographic areas. The students reside in Mississippi, Alabama, and Louisiana, and all students are enrolled in the JROTC program at their high school. The majority of these JROTC students are from historically marginalized groups (Table 1), and represent the students we seek to recruit to STEM fields.

Table 1: *Demographics of residential STEM summer camp, 2016-2017*

		Gender		Race		
Year	*Cycle/ Week*	*%Male*	*%Female*	*%African American*	*%European American*	*%Other*
2016	1	30	70	98	0	2
	2	32	68	92	6	2
	3	45	55	25	68	7
	4	43	57	69	19	12
	5	48	52	63	37	0
	6	39	61	55	34	11
2016 Average		39.5	60.5	67	27.3	5.7
2017	1	31	69	93	7	0
	2	31	69	84	15	1
	3	54	46	23	64	13
	4	34	66	80	9	11
	5	43	57	66	29	5
	6	38	62	47	51	2
2017 Average		38.5	61.5	65.5	29.2	5.3

Materials

We assessed participating students' science attitudes, data literacy skills, and perceptions and attitudes towards the STEM summer residential camp. For science attitude, we used the Test of Science Related Attitudes (TOSRA) survey (Fraser, 1981). The Data Literacy Survey was specifically developed for this research.

Qualitative data were collected with student reflections and student group reports. Each student completed daily reflections in their journals on days 1-4. The reflection topics were provided by the camp leaders each evening. On the final day (day 5) of each weekly camp, student groups presented their perceptions, feedback, and analysis of the benefits of attending the residential leaderSTATE STEM summer camp. We focus on the pre- and post-camp surveys here, and not the qualitative analyses of the students' reflections and groups' presentations.

Test of Science Related Attitudes

The program's earlier STEM partner chose the TOSRA as a pre- and post-camp survey to determine students' science attitudes, and possible shifts in those attitudes because of the camp experience. We continued to use TOSRA in 2016 to detect any impact that may have resulted from Geosciences assuming the STEM partnership role.

TOSRA assesses science-related attitudes along seven dimensions: Social Implications of Science, Normality of Scientists, Attitude Towards Scientific Inquiry, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science, and Career

Interest in Science. The seven dimensions or scale categories are derived from six “schemes” associated with an attitude to science (Klopfer, 1971). Developed and validated by Barry J. Fraser and published by the Australian Council for Education Research Limited (Fraser, 1978; Fraser, 1981), the TOSRA includes 70 items measured on a 5-point Likert scale, with 10 question items corresponding to each of the seven subscales or dimensions. Students express their degree of agreement to statements as Strongly agree (SA), Agree (A), Not sure (N), Disagree (D) and Strongly disagree (SD).

Data Literacy Survey

We developed the Data Literacy Survey using the Next Generation Science Standards (NGSS) K-8 grade cluster and selected skills associated with data literacy from the 9-12 grade cluster (NGSS Lead States, 2013). The range of student grade levels and educational experiences suggested the survey should include questions at the basic level of data collection and graphic display, as well as advanced questions that were related to interpretation of graphic displays. The Data Literacy Survey was reviewed and validated by university faculty experts and secondary school practitioners during its development and prior to its administration.

The survey consists of 20 multiple choice questions and one open ended question (Appendix). Multiple-choice questions focus on data terminology, simple analysis, and identifying types of data plots. These questions correspond with multiple activities throughout summer camp that tasked students with collecting data of different types, choosing appropriate graph formats, and plotting and analyzing those resultant graphic displays. The open-ended question asked students to describe how graphically displayed data were advantageous for understanding data. Participant responses were coded and analyzed. The first author developed a categorization scheme that ranked data or graphicacy through a hierarchy of skills. Those skills, similar to those needed to develop literacy in written language, included three hierarchical skill sets as coding categories: 1) the ability to read, 2) write, and 3) analyze graphically presented data. Table 2 presents the coding categories and descriptions.

Table 2: *Coding categories and point values of hierarchical data literacy skills utilized in the Data Literacy Survey*

Coding Category	Code	Point Value	Description	Examples
No response	X	0	No response or response that did not address question	N/A
Reading data	R	1	Viewing data and finding meaning in data	“see data”; “picture”
Writing data	W	2	Understanding of how to organize raw data in a format that is sorted and displayed to enhance understanding of data; requires high level skills that Reading data	“organize data”; “show statistics”
Analyzing data	A	3	Process of extracting data and ability to evaluate and describe data; requires ability to critically apply and interpret impact of displayed data	“see change over time” “notice trends”

Data Collection: Both TOSRA and the Data Literacy Survey were administered on Day 1 (pre-camp) and again administered on Day 5 (post-camp) of each weekly cycle (N=6 annually), in years 2016 and 2017. Students arrived on the university campus around noon, and after eating lunch and moving their belongings into their dormitory rooms, they completed the pre-camp surveys. Post-camp surveys were administered after the student groups presented their final group presentations, before lunch. Students entered their TOSRA and Data Literacy Survey multiple choice responses on a Scantron. Students wrote their Data Literacy Survey open ended responses on the paper survey; we coded students' subjective responses directly from the surveys.

Data Analysis

We used Chi square analysis ($p = 0.05$) to investigate relationships between the paired pre-post TOSRA categories and participants' demographics of race, gender, and school. Pre-post Data Literacy Survey results were analyzed through paired *t*-tests, with Cohen's d to determine effect size ($p < 0.5$). Evaluation of the camp's impact on participants was performed at the cycle level because the ability to generalize between cycles was limited due to confounding variables related to instructional differences within the duration of programs.

RESULTS

TOSRA Survey

Chi-square analysis proceeded with the seven dimensions of the TOSRA science-related attitudes and the demographic categories of race, gender, and school. The survey results were sorted by the camp week (i.e., 6 cycles per year). Each individual camp cycle generated 21 main data categories with comparisons of three demographic categories and the seven TOSRA scale categories. Therefore, possible combinations of TOSRA categories, demographic categories, and number of cycles provided 126 separate data categories in each of the six camp cycles in 2016 and 2017.

Our analysis of pre-camp to post-camp response changes revealed scattered examples of improved student dispositions in some TOSRA scale categories, i.e., Attitude Towards Scientific Inquiry, Adoption of Scientific Attitudes, Normality of Scientists, and Enjoyment of Science Lessons. However, there was no discernible pattern of significant change throughout the dataset demographics, with significant relationships documented only sporadically between gender, race, and the students' high schools. We discuss a few of these, below. (See Powers, 2021 for a full discussion of TOSRA results.)

In 2016, a significant relationship between the TOSRA category of Attitude Towards Scientific Inquiry and race existed pre- and post-camp in cycle 2 and cycle 6, with one school making the greater gains in cycle 2 and African Americans making the greatest gains in cycle 6. Females also made significant gains in the Attitude Towards Scientific Inquiry category pre- and post-camp in cycle 5. In the TOSRA Normality of Scientists category, there was a significant relationship between schools in cycle 1 (with 3 schools exhibiting the greatest gains), while cycle 2 had a significant relationship between Normality of Scientists and race (European Americans exhibited the greatest gains). Other TOSRA categories in which 2016 significant gains were documented included Adoption of Scientific Attitude (three schools had significant pre- and post-camp change in cycle 1); in cycle 2, European Americans made greater gains in both TOSRA Social Implications of Science and Leisure Interest.

In 2017, the TOSRA Enjoyment of Science Lessons category revealed significant gains by African Americans in both cycle 1 and cycle 4, and within certain schools in cycle 3. In the category of Adoption of Scientific Attitudes, significant pre- and post-camp changes by females (cycle 1), and by certain schools (cycle 3) were observed. For TOSRA's Career Interest in Science, significant gains pre- and post-camp were made by certain schools in cycle 3, and by African Americans in cycle 4. African Americans in cycle 4 also made significant gains in TOSRA's Attitude to Scientific Inquiry. Other TOSRA categories in which 2017 significant gains were exhibited included Social Implications of Science (three schools had significant pre- and post-camp change in cycle 6) and Leisure Interest in Science (three schools demonstrated significant change pre- and post-camp in cycle 1).

Data Literacy Survey

The effects of the camp activities on the participants' data literacy skills were assessed with the paired pre- and post-camp Data Literacy Survey analysis for means, *t*-test ($p < .05$); the Data Literacy Survey has a maximum score of 23 (Appendix). Only one 2016 camp cycle had significant data literacy gains, while half of the 2017 camp cycles (N = 3) had significant gains. Cohen's d was used to appropriate effect size, with 0.2 considered as a small effect size, 0.5 a medium effect size, and 0.8 a large effect size (**Table 3**).

In 2016, only cycle 1 students demonstrated significantly better scores on their post-camp Data Literacy Survey scores; $t(46) = -2.6$, $p = 0.01$ (pre-camp survey M=16.6, SD= 2.3; post-camp survey M = 17.8. SD = 2.5), with a medium effect size (Cohen's d = 0.5). Cycle 1 JROTC cadets originate from seven public schools in an inner-city environment, with camp composition at 93-98% African American and 69-70% female. The schools are within the second majority minority city in the United States with 80% of the city's residents identifying themselves as Black or African American and 32% percent of the city's population living in poverty;78% of school students are served free or reduced meals. Therefore, cycle 1 schools represent an urban area that is generally considered to have challenges in many aspects of education, which makes data literacy improvement encouraging.

Table 3: *Cadets' Pre- and Post-Camp Data Literacy Survey responses, 2016-2017, where SD = standard deviation and* ***bold font*** *indicates significant results*

Year	Cycle/ Week	Number of Students	Pre-Camp Mean	Pre-Camp SD	Post-Camp Mean	Post-Camp SD	*p* value
2016	1	47	16.6	2.3	17.8	2.5	**0.01**
	2	56	16.5	3.0	17.2	3.2	0.01
	3	60	17.7	2.8	17.3	3.1	0.2
	4	58	16.5	3.0	17.1	2.7	0.1
	5	61	16.8	2.8	16.9	3.6	0.9
	6	46	15.5	3.1	16.2	3.6	0.1
2017	1	58	17.1	2.3	18.0	2.4	**0.02**
	2	55	16.6	2.8	17.3	2.8	**0.04**
	3	56	17.8	2.6	17.9	2.5	0.7
	4	56	16.6	2.6	17.2	2.3	0.2
	5	58	17.2	2.6	17.1	3.3	0.7
	6	45	15.6	2.6	17.0	3.3	**0.004**

Cycle 1 also exhibited a significant increase post-camp in data literacy in 2017; t (58) = -2.5, p = 0.02 (pre-camp survey M=17.1, SD= 2.3; post-camp survey M = 18.0. SD = 2.4), with a small effect size (Cohen's d = 0.38). In 2017, cycle 2 exhibited significant improvement in data literacy post-camp; t (54) = -2.1, p = 0.04; (pre-camp survey M=16.6, SD= 2.8; post-camp survey M = 17.3. SD = 2.8), also with a small effect size (Cohen's d = 0.25). Cycle 2 cadets came from schools with camp composition at 84-92 % African American and 68-69% female. The final cycle, cycle 6, had significant improvement post-camp in Data Literacy; t (44) = -3.0, p = 0.004 (pre-camp survey M=15.6, SD= 2.6; post-camp survey M = 17.0. SD = 3.3), approaching a medium effect size (Cohen's d = 0.47). These students represent inner-city schools from other large metropolitan areas, with camp composition at 47-55 % African American and 61-62% female.

DISCUSSION AND CONCLUSIONS

The overall design of the leaderSTATE STEM summer residential camp is structured to provide JROTC students, many of whom are from historically marginalized groups, an interesting, immersive on-campus leadership camp with a STEM focus. Geoscience activities were quickly developed in the 2016 camp year and further refined in 2017. STEM-related activities included classroom activities, science expert presentations, field experiences, and industry tours.

The residential summer program also includes components of personal fitness and leadership activities that promote teamwork skills; these remained consistent throughout the program. However, with the STEM, leadership, and fitness approach, the time available for any segment of the schedule can be problematic.

The TOSRA survey, implemented by the previous STEM partner, was used to evaluate potential changes in students' attitudes towards science. While some of the 2016 and 2017 cycles had sporadic significance pre- to post-camp in a few of TOSRA's seven dimensions when analyzed with student demographics (i.e., race, gender, and students' high schools), no discernable pattern within the data set emerged. The researchers also learned that the previous STEM partner combined TOSRA Likert categories; while their analyses indicated more significance among cadets pre- to post-camp, our subsequent investigation of earlier data did not support greater changes in students' attitudes in earlier camps.

It may also be unrealistic to expect a statistically significant change in scientific perspectives in the relatively short time available for STEM instruction in each camp cycle, and a short time span between pre- and post- TOSRA survey administration. Additionally, TOSRA may not be the best instrument to measure students' attitudes toward science. The survey includes 70 questions, and the administration of the pre-survey (with the Data Literacy Survey) at the beginning of the camp (mid-day Monday) and the post-survey at the end of the camp (mid-day Friday) may contribute to testing fatigue and inaccurate or "casual" responses. Additionally, the assumption was made that a test for normality was not needed because ordinal/categorical data were being evaluated. While the assumption is technically correct, it does call into question the use of a Chi-square test for such an application.

The Data Literacy Survey had more promising results in the second year of the Geoscience STEM partnership. Our analysis documented that cycle 1 inner city urban schools exhibited significance in both years. The preponderance of hands-on and other engaging and "fun" activities may have resonated with those students, contributing to the data literacy changes. After the 2016 camps, the curriculum developer revised and replaced activities in the curriculum to improve students' experiences. Those refinements likely contributed to the data literacy significance observed with three of the six camp cycles in 2017 (Figure 2).

There are numerous extraneous variables such as school, grade level, gender, and ethnicity within each camp cycle that compromise the ability to generalize across groups. There exist also nuisance variables associated with the camp environment, such as the early start to a long day of numerous activities which leads to fatigue, as well as the regimentation of the schedule, and adapting to new relationships with other students.

Figure 2 Cadets practice data collection and analysis at the summer residential STEM camps (Photograph by Mark Powers)

While statistical measures of the camps impact through survey instruments did not show a great degree of significance, qualitative observations the camps' impact on student populations suggest that the summer residential STEM camp is a worthwhile endeavor that positively affects the lives of young people from historically marginalized groups. The university instructional staff, student group counselors (university undergraduate juniors and seniors), and the high school military instructors, all reported positive changes among high school student participants. End-of-cycle discussions, or After-Action Reports (AAR), with the JROTC instructors and university program administrators, documented that the residential summer camp experience was rewarding. Students get a glimpse of university campus life, hear presentations from university STEM faculty, military representatives, and motivational speakers. Students work with students from other schools cooperatively on projects and in physical fitness challenges. Their day starts early and ends late, requiring an elevated level of stamina. To a large degree the students are upbeat and attentive and participate in hands-on activities with enthusiasm. Final camp presentations by student teams revealed that the students had huge positive takeaways from their camp experience. We did not personally encounter any JROTC student who did not want to participate in the residential STEM camp, or JROTC programming. However, we acknowledge recent concerns of force-enrollment of underrepresented student groups into high school JROTC courses (Baker et al., 2022).

Implications for Future Research

Our results indicate that additional research is needed to effectively document the summer residential STEM camps' impact. While changes were observed, the instruments did not measure the impact that high school instructors, university staff, and the STEM instructors noted.

Our research has already impacted the leaderSTATE STEM program, however. The program opted to include an additional science identity assessment in 2018 and 2019, the Draw a Scientist tool (Finson, 2002, 2003), which showed promising results. A further challenge occurred with the COVID-19 pandemic, which caused the cancellation of JROTC summer camps in 2020 and 2021; the transfer of the summer residential STEM program within the university impacted the ability to pivot quickly enough to offer the camps in 2022.

The leaderSTATE STEM program returned in summer 2023, with the Division of Access, Opportunity, and Success administering the residential summer camps. We opted to eliminate the TOSRA altogether and utilize a shorter instrument, the SIEVEA Survey, to measure the leaderSTATE STEM impact on students' science identities, their expectations of success in science, values of science, and environmental attitudes (Aghekyan, 2019). The data from 2023 and 2024 data are currently being analyzed, and undoubtedly will inform further refinement of the STEM aspects of the residential summer camps. Interviews, camp exit tickets, and/or different assessments for science attitudes and scientific skills may offer additional tools to accurately measure pre- and post-camp changes in future years.

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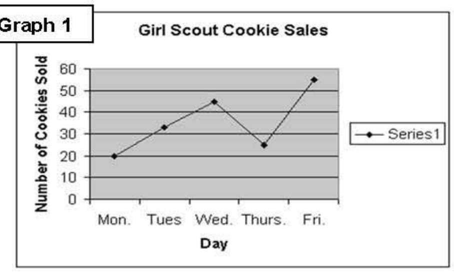
Appendix

Summer Residential Camp STEM 2016-2017 Data Literacy Survey

Data literacy survey
Birthdate dd/mm/yyyy _______/_________/_________Zip code where you live ___________________
School you are in this year _____________________________ 2016-17 grade you will be in ________

Answer

Graph 1



1. What type of graph is **graph 1**?
   A. Line C. Bar
   B. Histogram D. Scatter plot

2. On **graph 1**, on which day were the sales the best?
   A. Mon C. Wed
   B. Tue D. Thu E. Fri

3. On **graph 1**, what is the total amount of cookies sold?
   A. 55 C. 110
   B. 150 D. 177

4. Match the order of the following underlined terms with the correct parts of **graph 1**.
   Number of cookies sold, Series 1, Girl Scout cookie sales, Day
   A. x-axis, key, title, y-axis C. x-axis, y-axis, title, key
   B. y-axis, key, title, x-axis D. key, title, x-axis, y-axis

5. On **graph 1**, which day shows anomalous data? (data that seems to differ from the other data shown)
   A. Mon C. Wed
   B. Tue D. Thu E. Fri

6. An example of the term quantitative data would be
   A.The rock sample is very dense C.The rock sample has a mass of 53g.
   B.The rock sample is speckled in appearance D.The rock sample is rare and valuable

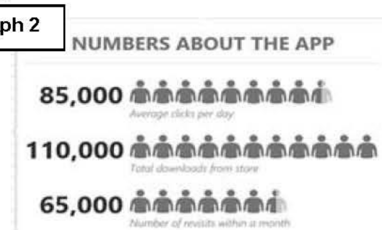
7. An example of qualitative data would be
   A. The wind is moist C.The wind direction is 120 degrees
   B. The wind temperature is 50 degrees D.The wind is blowing at 5 mph

8. What are the units of data measurement that we use in the metric system?
   A. feet, pounds, gallons C. meters, grams, liters
   B. meters, pounds, gallons D. meters, pounds, liters

9. What are some tools or instruments that can be used to collect data?
   A. Meter sticks C. Camera
   B. Microscope D. All of the above

10. In **graph 2**, how many people are represented by one symbol that looks like a person?
   A.10 C.100
   B.1,000 D. 10,000

Graph 2



In the space below, please respond to the following question; How can graphically presented data about something that you are interested in (like sports, hobbies, grades, earnings, or anything else you choose) be helpful in informing you about the thing you are interested in?

____

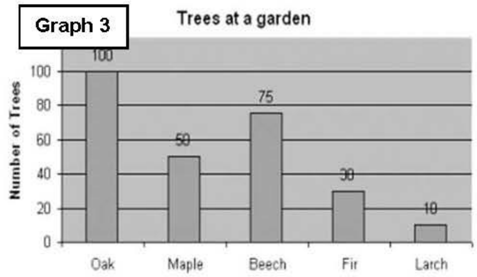
____

____

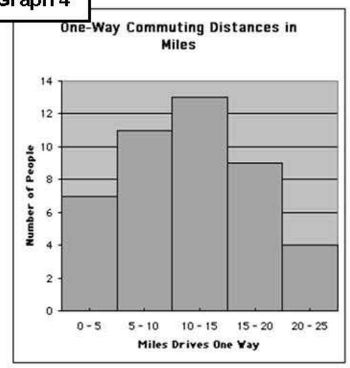
____

____

Graph 3



Graph 4



11. What type of graph is **graph 3**?
   A. Histogram C. Line graph
   B. Bar graph D. Pie graph

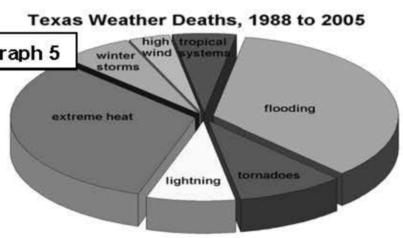
12. What type of graph is **graph 4**?
   A. Histogram C. Line graph
   B. Bar graph D. Pie graph

13. What type of graph is best for showing change over time?
   A. Histogram C. Line graph
   B. Bar graph D. Pie graph

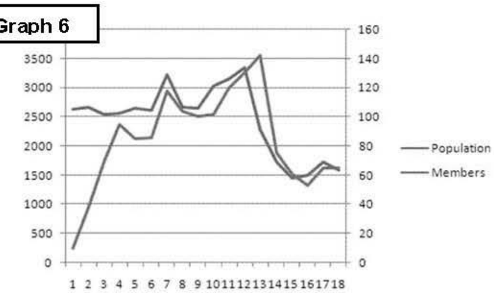
14. What type of graph would be best for showing data about a number of categories such as preference (favorite choice) for a particular brand of car?
   A. Histogram C. Line graph
   B. Bar graph D. Pie graph

15. What is the importance of showing data graphically?
   A. Shows data in a visual way to show trends. C. Changes data to fit an intended purpose
   B. Makes data better D. Hides bad data results

Graph 5



Graph 6



16. What type of graph is **graph 5**?
   A. Histogram C, Line graph
   B. Bar graph D. Pie graph

17. What was the <u>second</u> highest cause of death due to weather from 1988-2005 on **graph 5**?
   A. Flooding C. Extreme heat
   B. Tornadoes D. Lightning

18. **Graph 6** has one y axis on the left and another one on the right. Which one is probably for members?
   A. Left
   B. Right

19. When was the <u>ratio</u> of members to the population the lowest/smallest on **graph 6**?
   A. Day 1 C. Day 4
   B. Day 7 D. Day 16

20. When was the ratio of members to the population the highest on **graph 6**?
   A. Day 7 C. Day 15
   B. Day 13 D. Day 17

Taphonomy And Carcass Fall Stage Analysis of a Late Cretaceous Mosasaur Specimen, Oktibbeha County, Mississippi, USA

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ABSTRACT

The taphonomy and paleoecology of a well preserved *Mosasaurus* sp. (DSM 10716) is reported from Oktibbeha County, Mississippi, USA. The mosasaur is assigned to the Prairie Bluff Chalk Formation using published foraminiferal zonation for the Late Cretaceous of the United States Gulf Coast. A possible species identification of *Mosasaurus hoffmanni* is given using published literature on common *Mosasaurus* species for the study area. DSM 10716 (13 cranial, 28 post cranial elements) has well preserved trace fossils including feeding scavenges and the remains of encrusting bivalves. The trace fossils are compared for similarities between modern whale-falls and ancient carcass-falls. Based on trace fossils present on DSM 10716, evidence for a mobile scavenger stage, a possible enrichment opportunist stage, and a reef stage is established. No chemosynthetic organisms are documented to suggest the existence of a sulfophilic stage.

Key words: mosasaur, whale fall stages, Cretaceous Mississippi, Mississippi Embayment

INTRODUCTION

As Late Cretaceous apex predators, mosasaurs (Squamata: Mosasauridae) exploited and dominated niches left open by the extinction of the ichthyosaurs and the decline of the plesiosaurs (Russell, 1967; Bell, 1997). With high eustatic sea levels and warm temperatures, mosasaurs were cosmopolitan in their distribution, as their fossils have been found on every continent. Their habitat included the Mississippi Embayment, a shallow, epicontinental sea that covered much of Mississippi and Alabama during the Late Cretaceous (Russell, 1967; Russell, 1970). This embayment was home to a rich diversity of mosasaurs that has been documented extensively within the state of Alabama (Russell, 1967; Russell, 1970; Kiernan, 2002).

Gibbes (1850) first reported the presence of mosasaur fossils within the southeastern United States. Research in the region intensified during the "bone wars" of Cope and Marsh in the latter half of the nineteenth century. Many of the early mosasaur discoveries resulted from this feud, including the discovery of the type materials of *Platecarpus tympaniticus* Cope, 1869 near Columbus, Mississippi and *Clidastes propython* Cope, 1869 near Uniontown, Alabama (Kiernan, 2002). Major mosasaur research and recovery did not begin in earnest in the Selma Group until the mid-1940s, in the Mooreville Chalk of central Alabama (Zangerl, 1948; Russell, 1970; Kiernan, 2002).

Mosasaur research within the embayment has not been conducted at the same level in Mississippi as it has in Alabama (Derstler, 1988). There are fewer surface exposures of Cretaceous strata in Mississippi and therefore fewer well-preserved mosasaurs have been recovered from the state than in Alabama (Kiernan, 2002). However, an excellently preserved mosasaur specimen, with approximately half of the skull recovered, was recently collected from Oktibbeha County, Mississippi, and accessioned in the Dunn-Seiler Museum collections at Mississippi State, Mississippi (DSM 10716).

This research examines the well-preserved mosasaur from Mississippi (DSM 10716) for paleoecological similarities to documented modern and ancient carcass falls. Modern whale carcass research may provide an understanding of mosasaur taphonomy that occurred in the deep sea. Studies demonstrated that during decomposition, whale carcasses follow a faunal succession represented as stages, based mainly on the amount of nutrients available near the carcass. These stages are the mobile scavenger stage, the enrichment opportunist stage, and the sulfophilic or chemosynthetic stage (Smith et al., 2015). Additionally, Smith and Baco (2003) hypothesized a fourth stage that they named the reef stage, which exists only in the fossil record.

Geological setting

The geology of Northeast Mississippi is similar to that of Alabama, with the Selma Group being exposed through the eastern part of the state and containing a similar faunal assemblage (Derstler, 1988). The strata exposed in Mississippi, however, were considered by some researchers to be of a lower quality for vertebrate research because in addition to fewer exposed accessible outcrops, the sediments in formations are more clastic and exhibit a more solid matrix than the lower formations found in Alabama (Kiernan, 2002). Late Cretaceous depositional environments in Mississippi were inferred from studies done in Alabama (Kiernan, 2002), so the need exists for additional Mississippi mosasaur research.

In Oktibbeha County, Mississippi, there are three exposed formations of Cretaceous strata: the Demopolis Chalk, Ripley Formation, and Prairie Bluff Chalk (Figure 1). The Prairie Bluff Formation, the uppermost formation in the Selma Group, represents the youngest Cretaceous formation in Oktibbeha County. The Prairie Bluff unconformably overlies the Ripley Formation in much of northeast Mississippi (Stephenson, 1937). The Prairie Bluff Formation is mainly composed of carbonate sediments and a glauconitic sand-rich chalk at its base, transitioning to a fine-grained marl then to a dirty chalk for most of its exposures in the study area (Stephenson and Monroe, 1940).

The depositional environment of the Prairie Bluff Formation was described as offshore continental shelf, based on the distribution of biofacies (Sohl and Koch, 1986). Using ostracod assemblages, Puckett (1992) assigned a middle to outer neritic depositional environment for the Prairie Bluff Formation. Oil and gas explorations demonstrated that the Prairie Bluff shelf is gently dipping without a shelf break (Larina et al., 2016). Puckett (1991) designated a depth of approximately 60m to the sea that occupied the Mississippi Embayment during the Maastrichtian in the northern Gulf Coastal Plain.

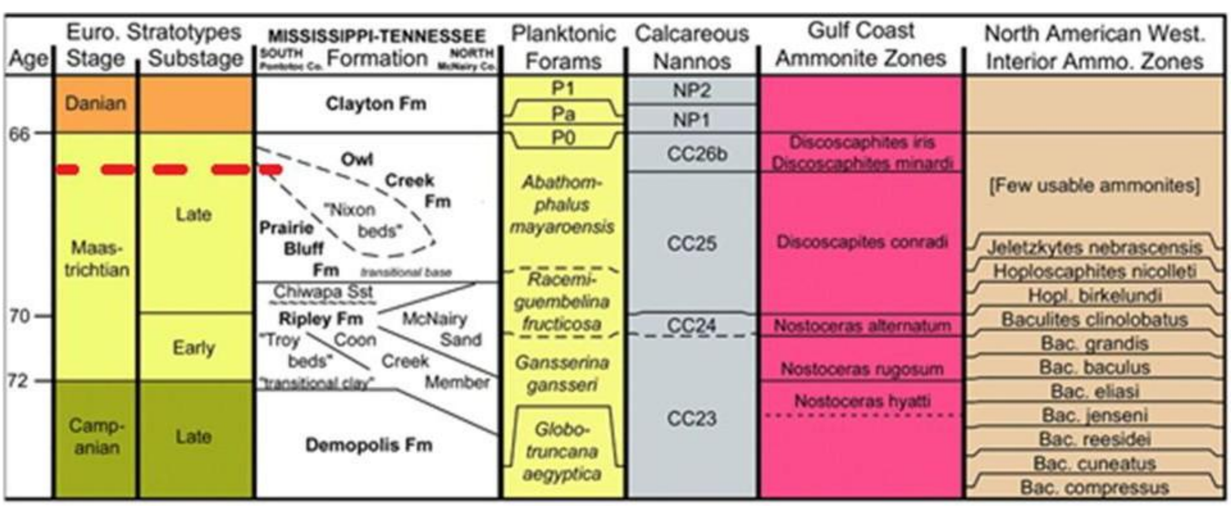

Figure 1. Mississippi Cretaceous Stratigraphic Column. The Upper Series of the Gulf Coastal plain includes the Selma Group Chalk from Campanian to Maastrichtian age. Modified from Farke and Phillips (2017). Red line indicates approximate stratigraphic location of DSM 10716.

Puckett (2005) also updated the foraminiferal biostratigraphy described by Smith (1975), and described the *Gansserina gansseri* Bolli, 1951 Interval Zone as occurring through much of Prairie Bluff Formation in Mississippi. This interval zone is used as a replacement for the *Abathomphalus mayaroensis* Bolli, Loeblich, and Tappan, 1957 Zone (Brönnimann, 1952) for Gulf Coast stratigraphy. The *G. gansseri* Interval Zone contains several highly evolved planktonic foraminifera that are characteristic of the Maastrichtian, including several species of *Rugoglobigerina*, *Contusotruncana patelliformis* Gandolfi, 1955, and *Racemiguembelina powelli* Smith and Pessagno, 1973 (Puckett, 2005).

MATERIALS AND METHODS

Research specimen

A partial mosasaur skeleton of the genus *Mosasaurus* was recovered in 2017, eroding from a creek bed on private property near Oktoc, Oktibbeha County, Mississippi (DSM 10716) (Figures 2,3). Location information is available upon considered written request to the Dunn-Seiler Museum, Mississippi State University.

Amateur collectors recovered large portions of the mosasaur and prepared the fossil by removing the matrix and reassembling connected fragments of bone. Regrettably, they also removed several encrusting bivalves and matrix attached to the skeleton and did not retain this material.

DSM 10716 was almost completely disarticulated at the time of recovery. A total of 31 nearly complete elements were recovered. Bone counts for complete or nearly complete skeletal elements present in DSM 10716 are recorded in Table 1; additional incomplete skeletal fragments that were recovered are not included. Included elements are the surangular, parietal, coracoid, numerous rib fragments, teeth and tooth roots, maxillary fragments, vertebral fragments, and numerous unidentifiable bone fragments.

Table 1. *Complete or nearly complete skeletal element counts recovered for DSM 10716. A total of 13 bones recovered are cranial elements and 28 are post cranial, with 23 of those being vertebrae.*

Skeletal Element	Number of Bones Present
Jugal	1
Coronoid	2
Splenial	1
Quadrate	1
Palatine	2
Squamosal	1
Surangular	1
Pterygoid	1
Maxilla	1
Dentary	2
Radius	1
Phalange	1
Complete Ribs	2
Vertebrae	23

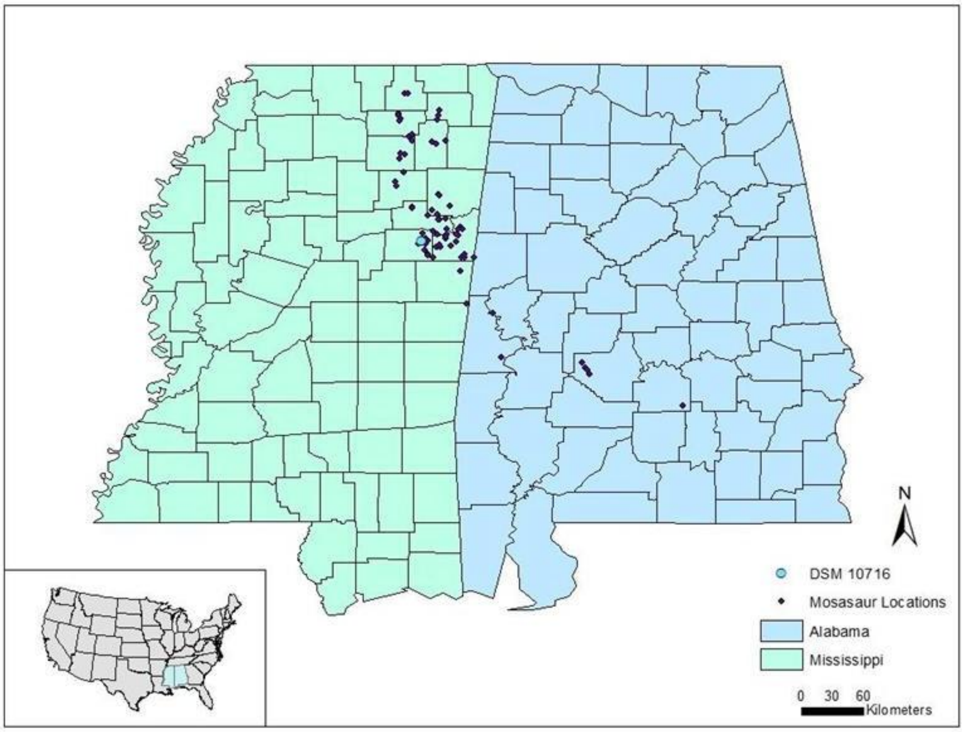

Figure 2. Location of DSM 10716. DSM is illustrated (blue dot) relative to other occurrences of mosasaur fossils in both the Dunn-Seiler Museum and Mississippi Museum of Natural Science collections.

Figure 3. Skeletal elements recovered from DSM 10716 including (from right to left) a partial skull, pectoral elements, ribs, and 18 vertebrae. (Photograph by Amy Moe-Hoffman)

We photographed and described the skeletal elements in detail and analyzed the donated macrofossils that the collectors recovered with the skeleton, and the associated microfossils. The United States Geological Survey (USGS) microfossil processing procedures were used (Poore et al., 1994).

Taphonomical Investigation

Surface features on the bones were analyzed to determine the possible origins of the pathological features. These features include larger sharp-edged scratches, circular marks, encrusted bivalves, and very small, fine scratches. These surface features were photographed and documented. The photographs and descriptions were compared to literature of common surface features of ancient and modern carcass falls to determine possible origins. Typical methods for analyzing shark bites include measuring the spacing of teeth and their serrations (if present), compared to the spacing of the trace fossil (Schwimmer et al., 1997; Ehret and Harrell, 2018). The preparation scars were not included in this study but were identified so as not to be included in trace fossil counts.

Species identification

The identification of the mosasaur in this study was determined using literature on mosasaurs that have been previously documented from the Mississippi Embayment. All available diagnostic elements were analyzed: dentary, maxilla, pterygoid, and quadrates. These elements were then compared to those described by Russell (1967), Lingham-Soliar (1995), Lingham-Soliar (2000), Konishi et al. (2014), Ikejiri and Lucas (2015), and Street and Caldwell (2017) to diagnose various species within the genus *Mosasaurus* common to the late Maastrichtian; this provided the criteria for species identification of DSM 10716. The species and abundances of microfossil species were compared to Smith (1975) and Puckett (2005) to determine a relative late Maastrichtian, biostratigraphic age for DSM 10716.

Carcass Succession Investigation

The numbers, types, and locations of trace fossils and encrusting organisms were recorded and compared with modern whale carcass fall successions described by Danise et al. (2014) and Smith et al. (2015). The features of DSM 10716 were compared to those listed by Danise et al. (2014) and Smith et al. (2015) to determine a position in the succession. Although species of organisms differ from modern whale falls, the types of traces present are similar between both ancient carcass falls and modern whale falls (Danise et. al, 2014).

Determining DSM 10716's position in a succession is more difficult because DSM 10716 is a fossilized carcass fall. However, there are distinctive characteristics of fossil falls for stages: mobile, enrichment opportunistic, sulfophile, and reef. The mobile scavenger stage is indicated by the presence of sharp-edged grooves and crushing puncture marks, likely the result of scavenging from large fish and reptiles (Smith et al., 2015). The sharp-edged grooves are typically V-shaped and vary in depth. These are presumed to be the traces of large fish pulling at flesh (Danise et al., 2014). Crushing puncture wounds are circular in shape with crushed bone surrounding the hole (Njau and Blumenschine, 2006).

The enrichment opportunist phase, which often overlaps heavily with the mobile scavenger stage (Hilario et al., 2015), is difficult to determine in the fossil record. However, evidence that does exist shows a decreasing abundance of invertebrates moving away from the carcass site. This implies that these fossiliferous animals were directly feeding on the nutrients in the surrounding sediment (Smith et al., 2015).

The sulfophilic stage is typified by microborings and sulfides. This stage is uncommon in Mesozoic carcass falls, likely because the annelid worm *Osedax* had not evolved until the Late Cretaceous (Danise and Higgs, 2015). Because this relatively complete mosasaur fossil is unique in the Dunn-Seiler Museum collection, thin sections for microboring were not obtained.

The reef stage hypothesized by Danise et al. (2014) is typified by large numbers of encrusting suspension feeders and algal mats. The presence of algal mats on the skeleton is supported by evidence in the fossil record showing traces of mat grazing animals feeding on the surface of the bones. The presence of trace fossils such as *Gnathichnus pentax* Bromley, 1975 (the result of regular echinoid grazing) and of encrusting suspension feeders would indicate that the carcass was in a reef stage (Danise et al., 2014). Bryan (1992) described irregular echinoid spines found in association with a specimen of *Mosasaurus hoffmanni* (formerly *Mosasaurus maximus* Cope, 1869), proposing that they were feeding on the nutrients resulting from the decaying mosasaur.

The fossils found on the bone surface and those that were donated with the sample were identified to the best possible taxonomic level. The identifications were made using Stephenson (1955) and Sohl (1977) as well as personal correspondence with paleontologists who specialize in certain taxonomic groups. The life habits of these organisms were used to determine the probable nature of the ecosystem in the immediate vicinity of the mosasaur carcass.

RESULTS

Many of the complete skeletal fragments exhibit preparation damage on their surfaces. These include shallow scrape marks that resulted from tools used to remove the sediment on the fossils, grey casting used to repair fragmented bones, and remains of bivalves that had been ground off. The unrepaired fragments of several bones are free of any preparation damage and therefore preserve excellent examples of traces of probable scavenging. The rib fragments in particular preserve instances of sharp, narrow grooves. It is difficult to discern any traces on fragments of maxilla and unidentified fragments because they are highly fragmented.

In this study, fine scratches are defined as those that measure less than 1 mm in length and are roughly 0.2 mm deep on the fossil. These are best viewed under a microscope and are typically overlapping one another. Traces left by fish and sharks are described as deep, sharp-edged scratches in the bone, usually a few cm in length. Evidence of encrusting bivalves remain as obscured attachment points incompletely ground off by the collectors. Pits are typically circular, roughly 1 cm deep, and are usually surrounded by crushed and cracked bone. They do not show evidence of healing, indicating the damage happened after the death of the individual.

Of the 18 non-vertebral bones, 13 had fine scratches measuring up to 1 mm in length that were not preparation artifacts. Artifacts include scratches that vary in depth and thickness but are superficial to the bone, resulting from the removal of the outer layer of rock, leaving discolorations on the surface of the fossil. These typically are lighter in color than the surrounding undamaged bone. Three non-vertebral bones have deep circular pitting, six have encrusting bivalves, and four have scratches over 2 cm in length that are likely the result of scavenging. Additionally, the scapula has a broad shallow pit and probable traces of shark scavenging. Sixteen of the bones possess preparation artifacts on them.

Surface mark analysis and stage comparisons

Sharp-edged scratches are typically V-shaped and are most common on the ribs and rib fragments. Circular marks are usually shallow pits, sometimes with fractured bone around the hole and sometimes found on dissolved bones; linear pits were found on the left squamosal and scapula, while pits of uncertain origin were found on the radius. The small scratches, typically less than 1 mm in length, are the most common surface marks in this specimen and were often found on cranial bones and vertebrae.

Evidence for mobile scavengers on DSM 10716 is present as sharp edged, narrow, V-shaped grooves (Figure 4), and by more U-shaped grooves with notable traces of serration.

Figure 4. Typical sharp-edged scratch found on a complete rib of DSM 10716 inside red square. Scale bar is 8 cm. (Photograph by Joseph Moffitt)

DISCUSSION

Stratigraphic position of DSM 10716

Foraminiferal analysis revealed *Globotruncana gansarri* Bolli, 1951, *Rugoglobigerina rugosa* Plummer, 1927, *Guembelitria cretacea* Cushman, 1933, *Racemiguembelina powelli* Smith and Pessagno, 1973, *Globugeruba* sp., and *Rotaliid* sp. This foraminiferal assemblage is consistent with foraminifera found in the Middle Maastrichtian and is indicative of the *G. gansarri* zone that is commonly represented in Mississippi as the Prairie Bluff Formation, the youngest Cretaceous strata exposed in Mississippi (Puckett, 2005).

Identification of DSM 10716 genus

All diagnostic elements can vary within the Mosasauridae (Russell, 1967). Based on the shape of the quadrate, the number of teeth in the maxilla/dentary/pterygoid (e.g., 14 teeth in the maxilla, 14-15 teeth in dentary), and the structure of the jugal (i.e., vertical arm approximately 90 degrees to the horizontal arm, vertical arm that flattens distally, horizontal arm gently concave upward), DSM 10716 is assigned to *Mosasaurus hoffmanni* Mantell, 1829. This identification fits well with the biogeographic and stratigraphic range previously reported for the taxon (Lingham-Soliar, 1995; Mulder, 1999; Harrell and Martin, 2015; Street and Caldwell, 2017).

Taphonomy and analysis of mosasaur carcass fall succession

Common trace fossils from the Late Cretaceous include shark bite marks, echinoid grazing, and bivalve borings. Echinoid grazing traces are shallower marks on the bone than shark scavenge marks. Matias et al. (2015) described and photographed common echinoid trace patterns on Cenozoic whale fossils. Important characteristics include size, orientation, and any repeating patterns of the traces. Bivalve borings are common sources of pitting on Cretaceous marine vertebrate fossils. Defining characteristics of bivalve borings are the shape of the opening to the bore, and evidence of dissolved bone material (Belaústegui et al., 2012; Kelly and Bromley, 1984).

The information obtained from the study of recent whale carcasses is integral to understanding the pre-burial fate of large marine vertebrates in the fossil record. Whale falls follow a general faunal succession through the mobile scavenger stage, the enrichment opportunist stage, and the sulfophilic or chemosynthetic stage (Smith et al., 2015). The succession is based on the level of decomposition of the whale and the availability of nutrients at the carcass. Bathymetry and dissolved oxygen affect the length of stages (Smith et al., 2015), with succession at shallower depths occurring more rapidly than at deeper depths (Dahlgren et al., 2006).

The first, mobile scavenger stage can last for several months to a year depending on bathymetry and dissolved oxygen in the water (Smith et al., 2015). The enrichment opportunist stage typically has no clear beginning, lasting months to years (Hilario et al., 2015). The sulfophilic, or chemosynthetic stage, often overlaps the previous stage with no discernable start, and is the longest of the succession, usually lasting several years to several decades depending on the size of the whale and the water depth (Hilario et al., 2015). This stage only ends when the whale bones have either been fully dissolved or have been buried (Danise et al., 2014).

Smith and Baco (2003) hypothesized a fourth stage, the reef stage, which occurs after all organic matter has been exhausted, and remaining minerals provide a hard substrate for suspension and filter feeders. Studies using cow carcasses dropped into the deep-sea show that there is an overlap between the enrichment opportunists, the sulfophilic, and the reef stages (Hilario et al. 2015), with almost complete overlap of the sulfophilic stage and the reef stage if there is a hard substrate for suspension feeders to anchor upon.

Using a shallow ichthyosaur carcass fall environment, Danise et al. (2014) attempted to establish evidence for similar stages to whale falls. While they found evidence for a mobile scavenger stage in the form of shark and fish bite traces, little evidence existed to support a sulfophilic stage, which they hypothesized was likely due to the shallow waters in which the animal was buried being poorly suited for such chemosynthetic organisms. The ichthyosaur bones also had been heavily eroded by a boring organism whose identity could not be determined. Unlike modern whale falls, however, there appears to be a well-preserved reef stage on the fossil. The fossil was covered in encrusting bivalves such as oysters, serpulid polychaetes, and mussels. Danise et al. (2014) concluded that the ichthyosaur in their study had followed a succession of mobile scavenger stage, enrichment opportunist stage, mat grazer stage, and finally a well-defined reef stage.

The chemosynthetic bivalves that are known to inhabit modern whale falls did not exist until the Paleogene; however, there are other chemosynthetic bivalve families that evolved in the Jurassic (Taylor and Glover, 2010). Because of this, scientists have been probing for similarities in taphonomy between other Mesozoic marine fossils and modern sulfophilic stage whale falls. Using a plesiosaur fossil, Kaim et al. (2008) detected iron sulfides in the vertebrae thin sections that could be evidence for anaerobic sulfate reduction of bone lipids, and microborings that could have resulted from sulfur oxidizing bacteria. The fossils were also covered by a micrograzing gastropod typical of chemosynthetic communities. The authors concluded that the plesiosaur would have supported a chemosynthetic community in common with local methane seeps and hot vents of the Late Cretaceous, and that chemosynthetic organisms on carcass falls developed prior to Cenozoic whale falls.

Talevi and Brezina (2019) investigated bioerosion structures on a mosasaur from Antarctica but did not document the taphonomy of a fall ecosystem. In the bones, they found microborings through existing blood vessel cavities, but were unable to determine the origin of the traces as the fossil would have been deposited in the photic zone with little evidence for chemosynthetic organisms.

DSM 10716 most likely would have spent some time bloated and floating in the water column prior to resting on the sea floor, when it is easiest for scavengers to remove parts of the carcass. This is supported by the incomplete skeleton, which is missing limb material, and ribs. These bones could easily become removed while the animal was still floating based on ichthyosaur skeletons (Dick, 2015).

The sharp-edged V-shaped grooves resemble those left by scavenging fish (Bianucci et al., 2010; Danise et al., 2014). The small size of these dental traces would make it unlikely that they were from predation on a live animal. There were no fish teeth recovered from the vicinity of the specimen.

Grooves with serration (Figure 5) resemble those of the shark genus *Squalicorax* (Schwimmer et al., 1997; Shimada and Cicimurri, 2005). Serrations of *Squalicoax* sp. tooth collected from a separate site align with the scores within the surface scratches on the scapula (Figure 6).

Other traces on bones that would indicate mobile scavengers consist of what are believed to be traces from puncture wounds (Figure 7). These are semi-circular holes in bones surrounded by crushed bone (Kauffman 2004; Einarsson et al., 2010). These traces are the possible result of large scavenging animals biting into the bones of the dead mosasaur. The trace makers for these puncture wounds could be mosasaurs, crocodiles, or large fish.

Figure 5. Overlapping crescent shaped grooves on a scapula. Serrations are present within the grooves. Scale bar is 8 cm. (Photograph by Joseph Moffitt)

Figure 6. *Squalicorax* tooth placed in a scratch on the recovered scapula with serrations on the tooth lined up with scores within the scratch mark. (Photograph by Joseph Moffitt)

Figure 7. Typical possible puncture wound on a rib fragment inside red square. Scale bar is 10 mm. (Photograph by Joseph Moffitt)

DSM 10716 displays evidence for prolonged reef and microbial mat feeding stages. These stages are uncommon in modern whale falls due to extensive structural reduction of the carcass by the worm *Osedax*. They are, however, much more common in ancient carcass falls (Danise et al., 2014; Dick, 2015). There is an abundance of encrusting bivalve attachment points on DSM 10716. A total of 16 bivalves were found encrusting DSM 10716 9 (Figure 8). Sasikumar et al. (2007) found that modern oysters grow at a rate of approximately 7.56 cm in their first year. Based on this growth rate for oysters, DSM 10716 would most likely have been exposed for at least a year prior to burial. The number and size of these attachment points would indicate that the bones had been exposed on the sea floor for an extended time, possibly up to several years, prior to the final burial of DSM 10716 halting the reef stage.

Figure 8. Figure illustrating typical attachment points of a bivalves on a vertebra after the rest of the bivalve had been removed during collection. Attachment points are within the red square. Scale bar is 10 cm. (Photograph by Joseph Moffitt)

The reef stage most likely overlapped with a microbial mat feeding stage. This stage is unique to ancient carcass falls (Danise et al., 2014). Associated with DSM 10716 were small regular echinoid spines (Figure 9). There were also overlapping small, radial scratches on the surface of several bones that may be analogous traces of *Gnathichnus pentax* Bromley, 1975 (Figure 10). These small traces, along with the physical presence of echinoid spines, indicate that DSM 10716 was still supporting a microbial mat feeding stage at the time of final burial.

No evidence was found of a sulfophilic stage. Due to the uncertain usefulness of the procedure and rarity of exceptionally preserved mosasaur fossils in the university collection, thin sections were not made to investigate the possible existence of microborings, which may (or may not) be an indicator of sulfophilic microbes (Kaim et al., 2008; Talevi and Brezina, 2019). There was no evidence for chemosynthetic macroinvertebrates found in association with DSM 10716 making it unlikely that there would be bone lipid reduction occurring. However, there is preservation bias against these organisms and the primary evidence would have been presence of organically produced sulfides in the surrounding sediment. Modern whale fall chemosynthetic macroinvertebrates evolved in the late Paleogene, concomitant with whales; however, bivalve families known to have chemosynthetic members such as Lucinidae and Nucinellidae would have existed as early as the Jurassic Period (Taylor and Glover, 2010). Therefore, there could have possibly been chemosynthetic organisms had a favorable environment been present.

The absence of a sulfophilic or chemosynthetic stage could be because the mosasaur died on a shallow shelf environment, or that it was too small of an organism to support this stage (Danise et al., 2014; Puckett, 1991; Smith and Baco, 2003). This shallow water, moderate energy environment (as supported through the disarticulation of the fossil) would more easily support photosynthetic organisms, rather than chemosynthetic ones (Danise et al., 2014).

Figure 9. A regular echinoid spine found on the right coronoid of DSM 10716. Echinoid spine is in the red box. Boxes on scale bar are 1 cm. (Photograph by Joseph Moffitt)

Figure 10 Upper image is of fine scratches in a circular, overlapping pattern on DSM 10716 inside red square. Scale bar is in mm. (Photograph by Joseph Moffitt). Lower image is of *G. pentax* on an ichthyosaur fossil, scale bar in lower image is 0.2 cm. Modified from Danise et al., 2014.

Concluding thoughts

Strata and microfossil biostratigraphy indicate a Maastrichtian age for a relatively well preserved *Mosasaurus hoffmanni* (DSM 10716) recovered in Oktibbeha County, Mississippi. Analysis of the mosasaur bones' surfaces indicate that DSM 10716 would have experienced an ecological succession similar to modern day whale falls prior to final burial.

A probable mobile scavenger stage had existed, demonstrated through shark and fish scavenging marks. Associated macroinvertebrate fossils found at the site support an enrichment opportunist stage as the mosasaur decomposed. Several bivalves were encrusted on the fossil at the time of recovery, suggesting a reef stage existed prior to final burial of the bones. There is possible evidence for a mat feeder stage, with several regular echinoid spines recovered and possible echinoid grazing trace fossils on several bones. There was no evidence for a sulfophilic stage, possibly due to the shallow sea in which the skeleton was deposited.

Although Mississippi recovered far fewer fossil mosasaur specimens than Alabama, the DSM 10716 specimen contradicts the general assumption that Mississippi strata yield poor mosasaur fossils. This research contributes to carcass fall succession in the fossil record, and our data indicate the succession of a Late Cretaceous mosasaur fall within the Mississippi Embayment follow the mobile scavenger, enrichment opportunistic, and reef stages. Additional taphonomic analysis of mosasaur specimens from the southeastern United States will determine whether the DSM 10716 specimen's carcass taphonomic succession was typical for mosasaurs in the area.

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Variations in Chloride, Phosphorus, Nitrogen, and Alkalinity in Yazoo River Basin, Mississippi

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ABSTRACT

The Yazoo River Basin (YRB), also known as the Alluvial Plain of Mississippi or the Mississippi's Delta region, is a geographically low area in the northwest part of the State of Mississippi. The area has fertile soil that makes it a major agricultural area in the state. The YRB is bounded on the eastern side by the steeply dipping Bluff Hills and on the western side by the Mississippi River. Major south-flowing rivers such as the Big Sunflower River, the Tallahatchie River, and the Yazoo River flow in this region. These rivers merge just north of the city of Vicksburg and drain into the Mississippi River. The United States Geological Survey in Mississippi conducted a major investigation on physical and chemical composition of the rivers and bayous in this region. Water samples were analyzed by the Mississippi Department of Environmental Quality. This study uses the chloride, phosphorus, nitrogen, and alkalinity measurements to determine the effect of natural processes and anthropogenic activities on river water composition in the YRB.

Concentrations of chloride, total phosphorus, total nitrogen, and alkalinity show two trends in the YRB. One trend includes a southward decrease in concentrations of all four components from high values at the location where the Little Tallahatchie River enters the YRB. This trend is attributed to contributions from recreational activities south of Sardis Lake as well as input from the adjacent municipal areas. A second trend shows westward increase in concentrations of these components from low values along the Bluff Hills. This trend is most likely related to natural dissolution of rocks of the Bluff Hills by groundwater. As such, this study demonstrates that concentrations of chloride, total phosphorus, total nitrogen, and alkalinity in the YRB cannot be solely attributed to agricultural activities as has been previously thought. Recreational, municipal, and industrial activities as well as input from natural processes such as dissolution of rocks by groundwater have contributed to river water composition in the YRB.

Keywords:Yazoon River Basin (YRB), Mississippi Delta, water samples, anthropogenic activities

INTRODUCTION

Maintaining water quality is everyone's responsibility. Since reservoirs of water on Earth will not change with time, understanding variables that control physical, chemical, and biological characteristics of waters are critical to ecological integrity (Karr and Dudley, 1981; Biswas and Tortajada, 2011). Water quality should be comprehensively managed and monitored to ensure the diversity and the composition of the habitat (Karr and Dudley, 1981). Only by understanding all sources and sinks of pollutants can one manage water quality and retain the integrity of an ecosystem. As such, this investigation conducts a critical examination of water quality in the Yazoo River Basin (YRB) to understand all sources that contributed pollutant to this region.

Ever since the recognition of a low oxygen zone (hypoxia) in the coastal waters of the Gulf of Mexico, composition of solutes carried by rivers and their effects on flora and fauna have become a top environmental quality issue (see Rabalais and Turner, 2019, Rabalais and Baustian, 2020 for reviews). For example, high concentrations of phosphorus occur because of agricultural runoff, as well as from urban lawn products and discharge from septic or sewage systems (United States Environmental Protection Agency, 2023). Phosphorus is essential to plant life, so elevated levels of phosphorus can cause uncontrolled growth and algal blooms that induce hypoxia by overconsuming oxygen (eutrophication). Natural wetlands act as sinks that store phosphorus in minerals, sediments, and in aqueous form. However, as climate changes, phosphorus is being released back into the water system. Since it occurs in such small quantities, minor changes in concentration may have extensive consequences. In the YRB, phosphorus levels are elevated about four to five times higher than the criteria set by the EPA. Phosphorus levels were correlated with mean monthly discharge in seasonal patterns that can likely be attributed to farming practices (Shields, et al., 2009).

Like phosphorus, nitrogen levels have been steadily increasing over time and contributing to hypoxia and eutrophication. For example, in the Delta region of Mississippi, nitrogen concentrations peak in the spring time when agriculture and crop fertilization are in full swing; concentrations do not display seasonal patterns in the Bluff Hills (Shields, et al., 2009). Furthermore, increasing deforestation to make room for agricultural lands intensifies the effect of nitrogen runoff by eliminating both terrestrial plant life and wetlands that act as nitrogen sinks. Studies show that forest area is indirectly proportional to both nitrate and phosphate loads, and that increasing forestation can decrease nitrate and phosphate loads (Ouyang et al., 2015). Another consequence of an increased nitrogen load is that nitrogen cycles extensively before it exits the water column; one atom of nitrogen is recycled nearly four times over in the Gulf of Mexico before it can exit (Rabalais et al., 1999). As a result, an input of 0.95 million metric tons of nitrogen from the Mississippi River can yield an output of over 20 million metric tons of organic carbon annually, which further depletes the aqueous oxygen (Goolsby et al., 1999). This cycle is self-perpetuating, as hypoxia leads to a release in phosphorus from sediment and phosphates.

Alkalinity, measured as calcium carbonate ($CaCO_3$), acts as a buffer against acidic conditions in rivers and bayous. However, elevated alkalinity can be detrimental to plant life, as it restricts water supply to the roots and induces phosphorus deficiency. In the Yazoo River (fed by the Little Tallahatchie from Sardis Lake), alkalinity is measured at 110.6 units—this is nearly 36 times greater than the EPA criteria (3.08 units) for Mississippi Water Quality (Acholonu, et al., 2011). Interestingly, the excessively high phosphorus levels compensate for the high alkalinity, allowing the plants to survive and flourish in conditions that would be otherwise fatal.

Table 1. Values for discharge, alkalinity, chloride, nitrate and phosphorous

Some authors have suggested that the YRB contributes disproportionate amounts of nutrients to the Mississippi River (Kleiss et al., 2000). On this basis, the United States Geological Survey in Mississippi investigated river waters in the Yazoo River Basin (Hicks and Stocks, 2010). These investigators analyzed many physical and chemical variables in waters from rivers and bayous in this region (Hicks and Stocks, 2010).

We have used spatial concentration of chloride, total phosphorus, total nitrogen, and alkalinity of river water in YRB (Table 1) from data provided by Hicks and Stocks (2010) to distinguish contributions from farming, municipal, recreational, and natural processes to the YRB. Nitrogen and phosphorus are primarily derived from the use of fertilizers in farming and municipal lawns (Shield et al. 2009). Chloride is mainly found in disinfectant, which points to municipal, industrial, and recreational inputs (Fish et al., 2020). Alkalinity has a predominantly natural source, as it is chiefly derived from dissolution of rocks due to chemical weathering (Raymond and Cole, 2003).

Table 1. Values for discharge, chloride, total phosphorus, total nitrogen, and alkalinity in 29 river water samples from Yazoo River Basin, Mississippi. The locations of the samples are shown in Figure 1 (Data from Hicks and Stocks, 2010).

Sample Location	Discharge (Ft^3/S)	Alkalinity As $CaCO_3$	Chloride (mg/L as Cl)	Nitrate (mg/L as N)	Phosphoruos (mg/L as P)
9	ND	501	121	19.9	4.66
10	11	48	4.9	0.37	0.08
11	21	31.3	9.2	1.03	0.09
12	E 0.4	61.7	9.4	0.55	0.12
17	10	231	64.9	1.18	0.76
23	16	186	47.2	1.01	0.31
25	5.9	55.4	5.3	0.33	0.06
27	ND	121	11	0.81	0.12
29	4.6	20.1	14.7	0.87	0.1
30	3.1	199	16	1.53	0.33
31	17	167	14.8	0.75	0.12
33	55	134	38.2	2.36	0.3
34	54	133	38.3	2.04	0.33
35	24	143	55.7	0.57	0.17
36	31	114	42.6	4.3	0.76
37	6.4	47.4	5.6	0.4	0.09
38	35	21.4	9.9	0.76	0.07
39	20	26.4	4.1	0.36	0.04
40	180	124	37.4	1.92	0.26
41	158	133	33.8	2.39	0.31
42	127	145	34.6	2.17	0.34
43	19	124	23.7	1.25	0.23
44	0.74	82.2	3.6	0.45	0.04
47	121	95.4	15.4	0.94	0.14
49	269	110	22.7	1.3	0.14
50	207	136	22	1.23	0.18
51	205	115	21.8	0.88	0.15
52	55	79.8	7	1.99	0.07
54	ND	43.9	2.9	1.24	0.07

E = Estimated. ND = No data

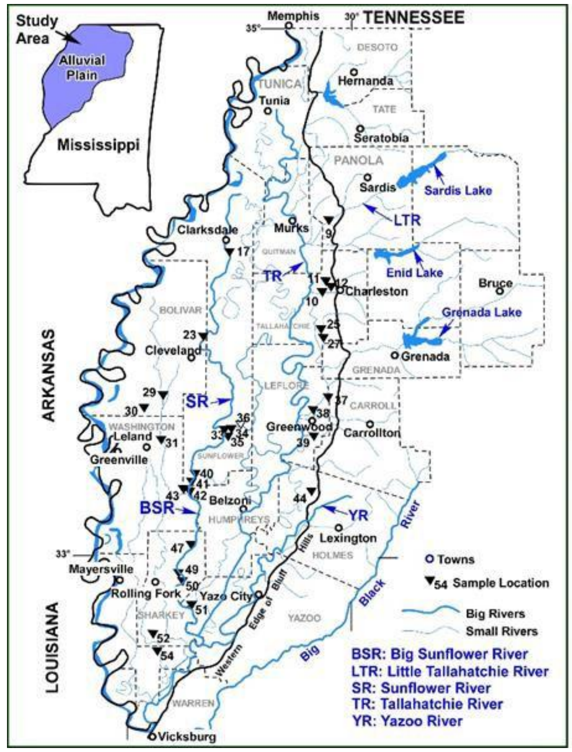


Figure 1. The map of the YRB shows locations where river waters were sampled, locations of rivers, lakes, and towns in the area (Modified from Hicks and Stocks, 2010). Pleases see Table 1 for the river water composition at each location.

Study Area

The YRB, also known as the Alluvial Plain of Mississippi or the Mississippi's Delta region, is a geographic area with low elevations in northwest part of the State (Fig. 1). The YRB encompasses a drainage area of approximately 35,000 km^2. It includes 30% of the Mississippi’s land and 25% of the state's population (Parajuli and Kim, 2012). Within the YRB boundary, there are four main reservoirs: the Sardis Lake, Enid Lake, Grenada Lake, and Arkabutla Lake (Fig. 1).

Land use in the YRB includes cropland (41%), forest (30%), wetland (12%), pastureland (10%), urban (4%), and water (3%) (Parajuli and Kim, 2012). As a major agricultural area in the state of Mississippi, the YRB contributes about 3% water discharge to the Mississippi River. This suggests that it is responsible for high percentage of nitrogen and phosphorus input to the Gulf of Mexico (Alexander et al., 2007).

The YRB is a very distinct location on the geological map of Mississippi because it is entirely covered by recent sediments, masking older rocks that constitute the geology of the state (Fig. 2). The YRB is a fertile ecoregion bounded by the Mississippi River and the Bluff Hills, encompassing approximately 13,400 square miles (Hicks and Stocks, 2010). About half of the YRB is lowlands, colloquially referred to as the Delta, and the other half consists of upland regions that form the Bluff Hills (Fig. 2). Nearly all the land in the YRB is used for agriculture, meaning that changes in water quality may cause far-reaching consequences, regarding both crop production and wildlife. Furthermore, many rivers in the YRB flow into the Mississippi River and/or drain into the Gulf of Mexico.

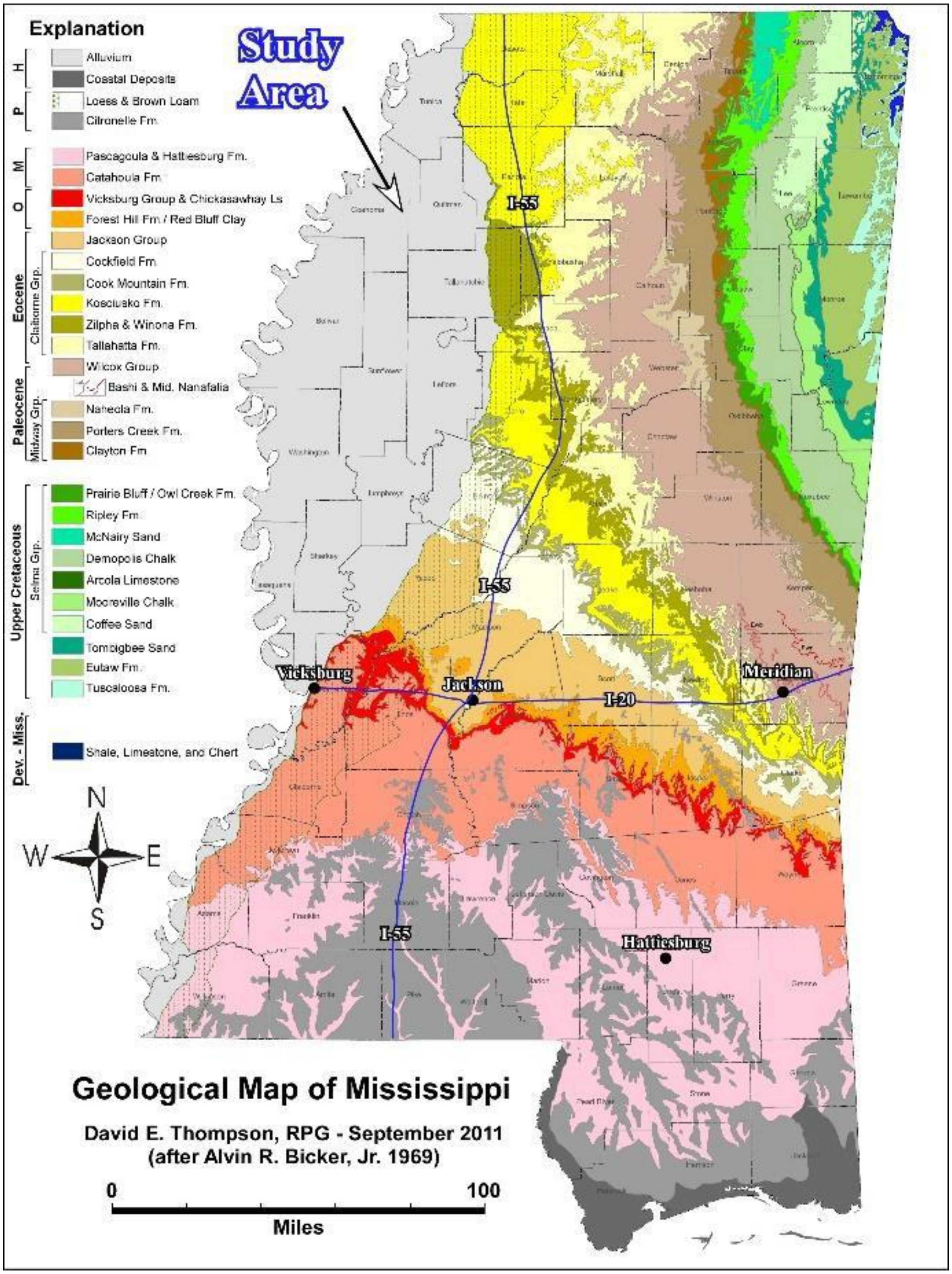


Figure 2 . Geographical Map of Mississippi. The geological map shows lithologic units exposed in the state of Mississippi (modified after Thompson, 2011). The study area is the oval-shaped area in the northwest part of the state. This area is also called the Yazoo River Basin (YRB) or the Mississippi's Delta region. The YRB bounded by the Bluff Hill to East and the Mississippi River to the west. The YRB itself is characterized by low elevations and significant river sediments.

MATERIALS AND METHODS

Data used in this investigation were collected by the U.S. Geological Survey (USGS) in collaboration with the U.S. Environmental Protection Agency (EPA) as a part of their study of water quality in the YRB ecoregion of northwest Mississippi (Hicks and Stocks, 2010). River water samples were collected during a roughly one-month period from September 10 to October 3 of the year 2007.

Waters were sampled based on standard procedure provided by the EPA (Hicks and Stocks, 2010). Physical and chemical variables analyzed include turbidity, dissolved oxygen, pH, specific conductance, temperature, alkalinity, chloride, total suspended solids, ammonia, total nitrogen, nitrite plus nitrate, orthophosphate, total phosphorus, total organic carbon, chemical oxygen demand, chlorophyll *a*, and suspended sediments (Hicks and Stocks, 2010). Samples were collected by either wading into the stream, using cabled samplers from atop a bridge, or from a boat (Hicks and Stocks, 2010). At sites with significant water flow, no less than five 1-liter bottles were filled from equal width and discharge transects; all samples were used for onsite processing. At sites with no flow, samples were collected by placing containers directly into the stream at mid-depth. All sampling equipment consisted of clean, nonstick materials to prevent contamination of samples (Hicks and Stocks, 2010). Samples filtered on-site with a low vacuum pump. All lab analyses were carried out at the Mississippi Department of Environmental Quality (MDEQ) laboratory in Pearl, Mississippi, within 48 hours of sample collection. Suspended sediment analysis done at the USGS sediment laboratory in Baton Rouge, Louisiana (Hicks and Stocks, 2010).

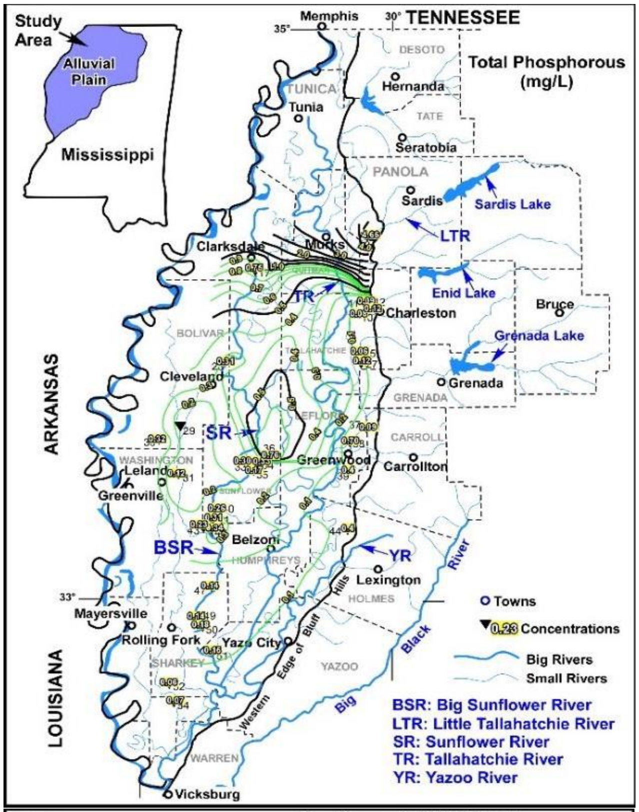
The present investigation uses analysis of water samples taken from rivers in the YRB reported by Hicks and Stocks (2010). Locations where each water sample was collected is shown in Figure 2. Discharge from these rivers varies from less than 1 ft^3/s (0.03 m^3/s) to 269 ft^3/s (7.6 m^3/s) (Table 1). We chose variations in chloride, total phosphorus, total nitrogen, and alkalinity in river waters to determine the source(s) of their input to the YRB. The reasons for choosing these four variables were indicated in the introduction section of this report.

RESULTS

River discharge, chloride, total phosphorus, total nitrogen, and alkalinity from 29 river water compositions from the YRB are shown in Table 1 and plotted in Figures. 3, 4, 5, 6. Chloride concentrations vary from 121 mg/L to 4 mg/L (Fig. 3). Total phosphorus values change from 4.6 mg/L to 0.07 mg/L (Fig. 4). Total nitrogen changes from 19.9 mg/L to 0.36 mg/L (Fig. 5). Alkalinity is measured as total $CaCO_3$ and varies from 501 to 21 (Fig. 6).

Note that, chloride, total phosphorus, total nitrogen, and alkalinity show very high values at the location where the Little Tallahatchie River enters the YRB (Figs. 3, 4, 5, 6). The lowest values for the four components occur at the southernmost part of the YRB and at the foothill of the Bluff Hill (Figs. 3, 4, 5, 6). The average river water concentrations for these components, without the Little Tallahatchie River water sample, are 22.03 mg/L, 0.21 mg/L, 1.25 mg/L, and 104.93, respectively. Concentrations of these components for the Little Tallahatchie River are 121 mg/L, 4.66 mg/L, 19.9 mg/L, and 501, respectively. That is, concentration of chloride, total phosphorus, total nitrogen, and alkalinity of the Little Tallahatchie River water sample is 5.5, 32.3, 15.9, and 4.8 times higher, respectively, than average concentrations of these components of other river waters in the YRB.

The data shows two trends in concentration of components we studied (Figs. 3, 4, 5, 6). The first is southward decrease from a high value at the mouth of the Little Tallahatchie River (Figs. 3, 4, 5, 6) which originates from Lake Sardis (Fig. 1). The second trend is a westward increase in concentrations from lowest values along the Bluff Hills (Figs. 3, 4, 5, 6).



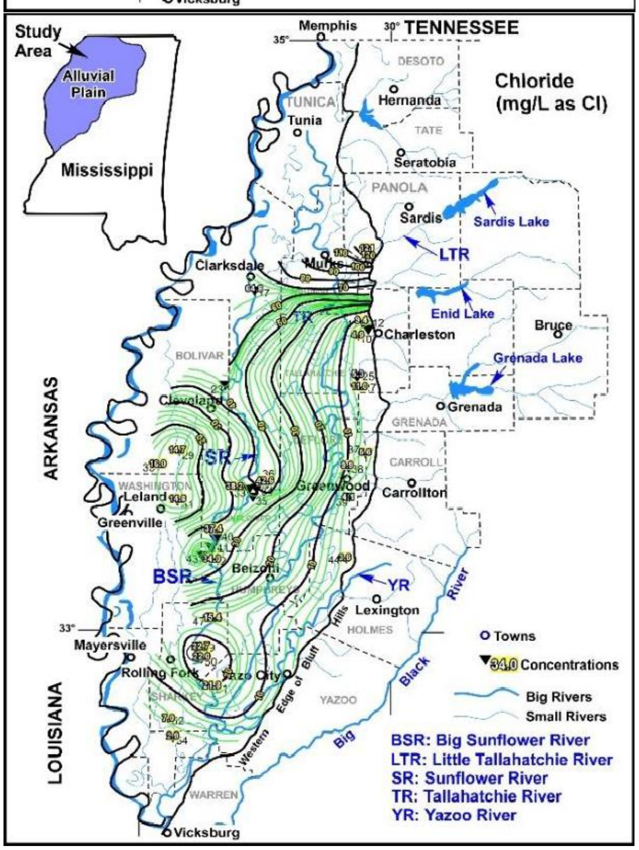


Figure 3. The map shows variations in chloride concentration of river water samples in the YRB, Mississippi. The highest concentrations occur at the mouth of the Little Tallahatchie River and decrease southward from that location. In addition, low concentrations of chloride occur along the edge of the Bluff and increase westward from that location. The contour interval is 0.2 mg/L for the green contours and 10 mg/L for black contour lines.

Figure 4. The map shows variations of total phosphorus concentration of river water samples in the YRB, Mississippi. Like chloride concentration, the highest values of occur at the mouth of the Little Tallahatchie River. Phosphorus concentrations decrease southward from that location. In addition, the low concentrations of phosphorus occur along the edge of the Bluff Hills and increase westward from that location. Contour interval is 0.1 mg/L for green contours and 0.5 mg/L for black contour lines.

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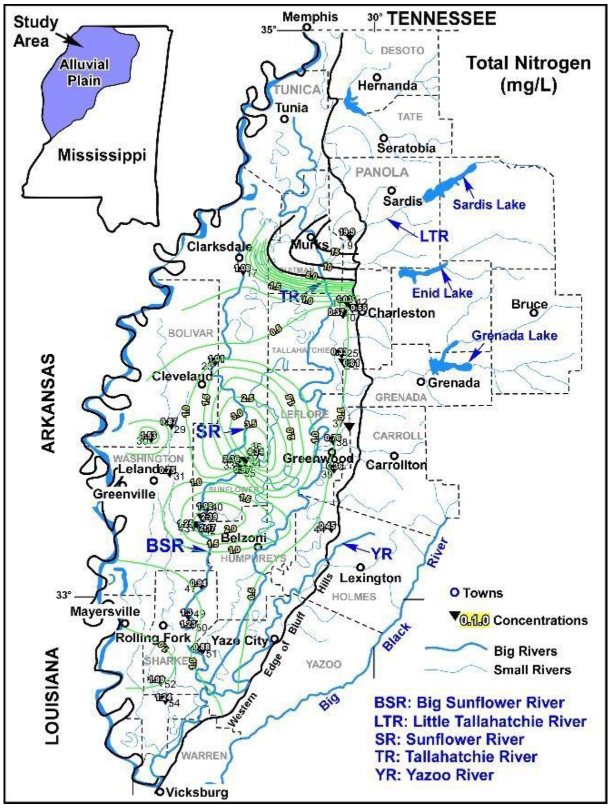

Figure 5. The map shows variations of total nitrogen concentration in river water samples in the YRB, Mississippi. Like chloride and phosphorous concentrations, the highest value of total nitrogen occurs at the mouth of the Little Tallahatchie River and decreases southward from that location. In addition, low concentrations of nitrogen occur along the edge of the Bluff Hills and increase westward from that location. Contour interval is 0.5 mg/L for the green contours and 5 mg/L for black contour lines.

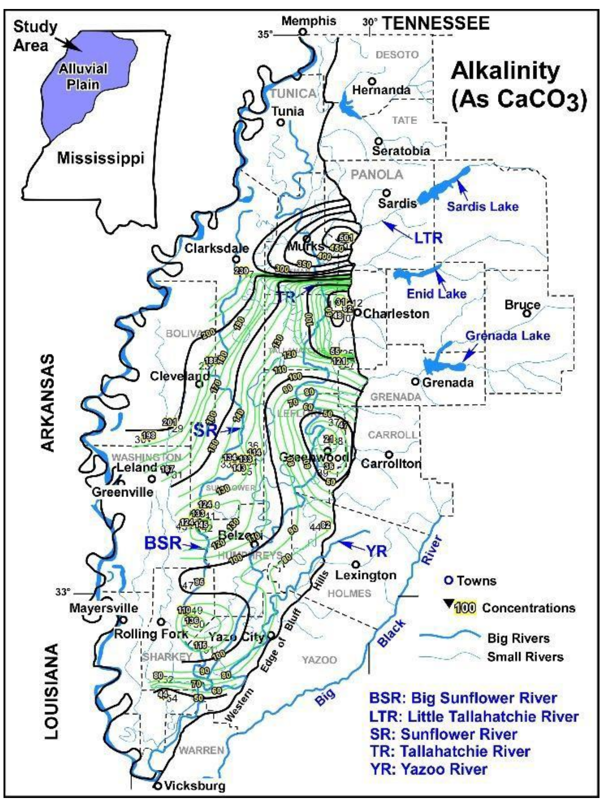

Figure 6. The map shows variations of alkalinity of river water samples in YRB, Mississippi. Similar to chloride, phosphorous, and total nitrogen concentrations, the highest value of total alkalinity occurs at the mouth of the Little Tallahatchie River and decreases southward from that location. In addition, low values of alkalinity occur along the edge of the bluff and increase westward from that location. Contour interval is 10 for green contours and 50 for black contour lines.

DISCUSSION

Variations in concentrations of chloride, total phosphorus, total nitrogen, and alkalinity indicate two systematic trends in the YRB (Fig. 7). One trend includes a southward decrease in concentration of all four components from a high value at the Little Tallahatchie River (Figs. 2, 3, 4, 5). The Little Tallahatchie River originates from the Lower Lake, which is small body of water, south of Sardis Lake. The Lower Lake is designated as a recreational area. In addition, this river also flows adjacent to the town of Batesville. It is very likely that high observed values of chloride, total phosphorus, total nitrogen, and alkalinity of the Little Tallahatchie River is related to recreational, industrial, and municipal activities around and along the river. In fact, chloride could not have been introduced by agricultural activities. Chloride-related compounds are mainly used as disinfectant (Fish et al., 2020) and therefore point to recreational, industrial, and municipal input.

A second trend shows westward increases in concentrations of the aforementioned four compounds from low values along the Bluff Hills (Fig. 7). The Bluff Hills consists primarily of Tertiary strata that are overlain by about 50 feet of loess, a fine-grained sedimentary rock that was deposited by wind (Dockery and Thompson, 2016). It is very likely that this westward trends in concentrations of these compounds are related to dissolution of loess deposits as groundwater flows toward the YRB. In fact, alkalinity has a predominantly natural source because it is chiefly derived from dissolution rocks by chemical weathering (Raymond and Cole, 2003).

This investigation shows agricultural activity may not be the only contributor of chloride, total phosphorus, total nitrogen, and alkalinity in river waters of the YRB, as previously concluded (Shields et al., 2009). Recreational, industrial, and municipal activities appear to be other sources of contribution of these compounds to the YRB. In addition, contributions from natural processes such as dissolution of rocks of the Bluff Hills also affected the concentration of these compounds in the YRB.

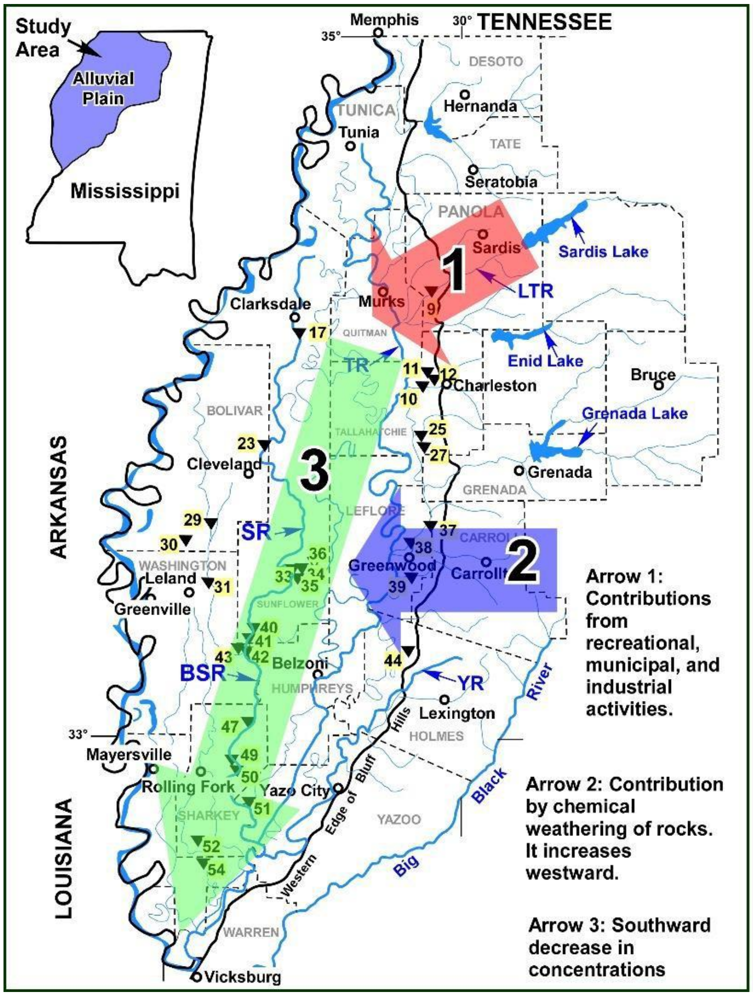

Figure 7. The map shows trends in chloride, phosphorous, and total nitrogen concentrations in the YRB. Arrow 1 indicates contribution from recreational activity adjacent to Sardis Lake. Arrow 2 shows westward increase in concentrations of these four components from low values along the Bluff Hills. Arrow 3 shows southward decrease from a high value at the mouth of the Little Tallahatchie River.

CONCLUSIONS

The study analyzed concentrations of chloride, total phosphorus, total nitrogen, and alkalinity in the river waters of the YRB. Our results show that agriculture may not be the sole contributor to river water composition in the YRB as was previously concluded (Shields et al., 2009). Two other contributing sources to the YRB solutes are shown by this study. The first is recreational activity associated with Sardis Lake, as well as municipal and industrial inputs along the river, none of which were not considered in previous studies. The second is contributions from dissolution of rocks of the Bluff Hills by natural processes such as chemical weathering, which also was not evaluated before. The findings of this investigation indicate that the study of the quality of natural waters needs a holistic approach to define all possible sources of pollution into the system. Considering the important findings of this study, similar detailed analyses of natural water composition are needed for the state of Mississippi to clearly define all sources of pollution.

ACKNOWLEDGEMENTS

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A Review of Human Parasitic and Mycotic Infections in Mississippi (1989-1993). – A Retrospective Study

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ABSTRACT

Human parasitism is a perennial problem in developing countries of the world and several developed countries including the United States of America. However, there appears to be a belief that it is a thing of the past in the State of Mississippi. This review was conducted to highlight the existence and prevalence of human parasitic and mycotic infections in the State of Mississippi during the period of 1989-1993 and encourage such studies in the future. It is also to encourage the resumption of reporting their occurrence in the State of Mississippi as is done for other microbial and viral infections. The data were obtained from the Mississippi State Public Health Diagnostic Laboratory records for human parasitic and fungal infections covering the period 1989-1993 and analyzed. The overall occurrence of protozoans was 8.6%, helminths, 2.0% and mycotic infections, 35.0%. These results show that human parasitism and mycotic infections were still prevalent in Mississippi at the period reviewed. Necessary steps should be taken to reactivate studies and reporting of the occurrence of human parasitic and fungal infections in Mississippi especially with respect to trichomoniasis. Well-planned prospective study on human parasitism needs to be conducted and is highly recommended. This is more so essential as more immigrants from different parts of the world where human parasites are abundant, are settling in the State Mississippi.

Key Words: Review, Human parasitic and mycotic infections, Mississippi, Retrospective study

INTRODUCTION

Parasitic infection has not been well reported in the State of Mississippi. There appears to be a belief that human parasitism is not prevalent in the State and for that matter, in the US. It is for this reason that Gildner (2023) reported on parasites thriving in the US, despite what many Americans think. Cantey et al.(2021) also reported on Neglected Parasitic Infections: What Family Physicians Need to Know. This situation is more evident when parasitological diagnosis in the Mississippi Public Health Diagnostic Laboratory is waning or practically nonexistent. Crawford and Vermund (1987) referring to the 1978 compilation of data by CDC said: “These figures are not true incidence or prevalence rates because the denominator is all stool specimens submitted, not all individuals at risk for parasitic infections.” So, the recorded figures may be lower than the actual prevalence in endemic areas (Chart 1).

The treatment quality of human parasitism in the U.S was briefly discussed by Roberts and Janovy, Jr. (1996). They wrote: “The notion held by the average person that humans in the United States are free of worms is largely an illusion- an illusion created by the fact that the topic is rarely discussed because of our attitudes that worms are not the sort of thing that refined people talk about, the apparent reluctance of the media to disseminate such information, and the fact that poor people are the ones most seriously affected.”

Studies on human parasitism and mycosis do not need to be discontinued in the State of Mississippi as it appears to have been done.

So this study was conducted to highlight the existence and prevalence of human parasitic and mycotic infections in the State of Mississippi with the goal to document or record their state-wide patterns and distribution during 1989-1993 period; to serve as a reference to other related studies, and to encourage the resumption of human parasitic and fungal investigations and the reporting of their occurrence in the State of Mississippi.

Literature review demonstrated a minimal work that was done on human parasitism in the State of Mississippi within the period covered by this study and beyond.

Revisiting and the review of such database has at least 2-fold importance: 1) Preventive measures of the occurrence in the State of Mississippi and public awareness, 2) wide-spread distribution during the period of migration of people from different parts of the world settling in the State of Mississippi.

Chart 1. Representative data from MS State Department of Health

Provisional Reportable Disease Statistics*

May 2021

****Monthly statistics are provisional**. Disease totals may change depending on additional reporting from healthcare providers and public health investigation. These numbers do **not** reflect the final case counts.*

		Public Health District									State Totals*			
		I	II	III	IV	V	VI	VII	VIII	IX	May 2021	May 2020	YTD 2021	YTD 2020
Sexually Transmitted Diseases	Primary & Secondary Syphilis	10	3	1	4	11	6	0	5	4	**44**	43	282	283
	Early Latent Syphilis	0	1	0	6	18	1	0	1	2	**29**	78	337	481
	Gonorrhea	70	82	55	75	184	59	39	81	88	**733**	996	4673	5076
	Chlamydia	154	142	104	111	323	82	74	125	158	**1273**	1539	8190	9193
	HIV Disease	0	1	1	1	3	1	0	2	0	**9**	19	121	185
Myco-bacterial Diseases	Pulmonary Tuberculosis (TB)	2	1	0	2	2	0	0	0	2	**9**	4	16	15
	Extrapulmonary TB	1	0	1	0	0	0	0	0	1	**3**	1	4	1
	Mycobacteria Other Than TB	3	8	0	3	1	2	3	1	8	**29**	26	124	145
Vaccine Preventable Diseases	Diphtheria	0	0	0	0	0	0	0	0	0	**0**	0	0	0
	Pertussis	0	0	0	0	0	0	0	2	1	**3**	0	6	8
	Tetanus	0	0	0	0	0	0	0	0	1	**1**	0	2	0
	Poliomyelitis	0	0	0	0	0	0	0	0	0	**0**	0	0	0
	Measles	0	0	0	0	0	0	0	0	0	**0**	0	0	0
	Mumps	0	0	0	0	0	0	0	0	0	**0**	0	0	1
	Hepatitis B (acute)	0	0	0	0	1	0	0	0	0	**1**	3	6	26
	Invasive *H. influenzae* disease	0	0	0	0	1	0	0	1	0	**2**	4	13	21
	Invasive Meningococcal disease	0	0	0	0	0	0	0	0	0	**0**	0	0	0
Enteric Diseases	Hepatitis A (acute)	0	0	0	0	10	6	0	3	6	**25**	23	156	148
	Salmonellosis	3	18	3	2	15	7	6	10	5	**69**	49	238	192
	Shigellosis	0	0	0	0	0	0	1	0	1	**2**	6	15	31
	Campylobacteriosis	9	6	1	2	6	2	1	4	4	**35**	43	167	141
	E. coli O157:H7/STEC/HUS	0	0	0	0	0	0	0	0	0	**0**	3	3	18
Zoonotic Diseases	Animal Rabies (bats)	0	0	0	0	0	0	0	0	0	**0**	0	0	1
	Lyme disease	0	0	0	0	0	0	0	0	0	**0**	0	0	0
	Rocky Mountain spotted fever	0	0	0	0	0	0	0	1	0	**1**	1	5	10
	West Nile virus	0	0	0	0	0	0	0	0	0	**0**	2	0	2

*Totals include reports from Department of Corrections and those not reported from a specific District.

This chart shows:

1. *Under Sexually Transmitted Diseases, Trichomoniasis is not included*
2. *Under Enteric Diseases, gastrointestinal parasites are not included*

Ref. This chart is reproduced from the monthly publication of the Mississippi State Department of Health with permission

MATERIALS AND METHODS

The Mississippi State Public Health Laboratory diagnostic records for human parasitic and fungal infections covering the period 1989-1993 were obtained, collated, tabulated and analyzed.

The stool specimens that the laboratory diagnosed were submitted by clinics and health centers from different counties of the State.

The samples were processed according to standard methods, tabulated and included in the laboratory's annual reports.

RESULTS

The overall occurrence of protozoans was 8.6%, helminths, 2.0% and mycotic infections, 35.0 %. These include 6 genera of protozoans, 6 of helminths and 3 of mycotic flora.

The results show that human parasitism was occurring at the time covered by this study and that mycotic infections were not uncommon. Intestinal parasites and dermatophytes recorded, are indicated in Tables 1-3 and Figures 1-3.

Of the 82 counties in the State of Mississippi, Union County had the highest reported hookworm infection (84.0%), strongyloidiasis (32.0%), trichuriasis (24.0%) and ascariasis (9.6%). Hancock County had the highest enterobiasis (96.0%). Desoto had the highest giardiasis (40.0%). Clarke and Marion had the highest *Trichophyton* infection (100% each). Stones, George, Sunflower, Clay, Hancock and Pearl River had the highest candidiasis (100% each) followed by Oktibbeha (86.8%) but the sample sizes examined and reported were minimal. (The respective counties mentioned are indicated in Figure 4).

TABLE 1. PREVALENCE OF PROTOZOAN INFECTIONS 1989-1993

YEAR NO. EXAM NUMBER INFECTED AND PERCENTAGE

		Giardia Intestinalis	*Entamoeba hartmanni*	*Entamoeba coli*	*Endolimax nana*	Iodamoeba buetschili	*Blastocystis hominis*
Year	Total	+/(%)	+/(%)	+/(%)	+/(%)	+/(%)	+/(%)
7/89- 6/90	5671	275(4.8)	10(0.)	141(2.5)	78(1.4)	9(0.2)	9(0.5)
7/90- 6/91	5038	273(5.4)	4(0.1)	80(1.6)	46(1.6)	1(0.02)	29(0.6)
7/91- 6/92	4796	223(4.6)	13(0.3)	113(2.4)	96(2.4)	13(0.3)	10(0.2)
7/92- 6/93	3865	131(3.4)	4(0.1)	42(1.1)	32(1.0)	6(0.08)	77(0.4)
TOTAL	19370	902(4.7)	31(0.2)	376(2.0)	252(1.3)	29(0.15)	126(3.4)

TABLE 2. PREVALENCE OF HELMINTHIASIS
1989-1993

YEAR NO. EXAM NUMBER INFECTED AND PERCENTAGE

Year	Total	Clonorchis +/(%)	Hookworm +/(%)	Ascaris +/(%)	Trich +/(%)	Enterobius +/(%)	Strongyloides +/(%)
7/89- 6/90	5671	2(0.04)	29(0.5)	33(0.6)	13(0.23)	26(0.46)	12(0.2)
7/90- 6/91	5038	0.0	38(0.8)	55(1.1)	9(0.2)	20 (0.4)	22 (0.4)
7/91- 6/92	4796	0.0	40(0.83)	21(0.44)	38(0.8)	21(0.44)	9 (0.2)
7/92- 6/93	3865	0.0	3 (0.08)	11(0.3)	5(0.13)	10(0.3)	3(0.8)
TOTAL	19370	2(0.01)	110(0.6)	120(0.6)	65(0.34)	77(0.4)	46(0.24)

TABLE 3. PREVALENCE OF FUNGAL INFECTIONS
1989-1993

YEAR NO. EXAM NUMBER INFECTED/PERCENTAGE

Year	Total	Trichophyton +/(%)	Microsporum +/(%)	C. albicans +/(%)	Other Candida +/(%)
7/89- 6/90	1492	18(1.2)	0.0	323(21.6)	146(9.8)
7/90- 6/91	1518	42(2.8)	0.0	263(17.3)	135(8.9)
7/91- 6/92	1349	43(3.2)	0.0	308(22.8)	146(10.8)
7/92- 6/93	1102	32(3.0)	2(0.2)	290(26.3)	139(12.6)
TOTAL	5461	135(2.5)	2(0.04)	1184(21.7)	566(10.4)

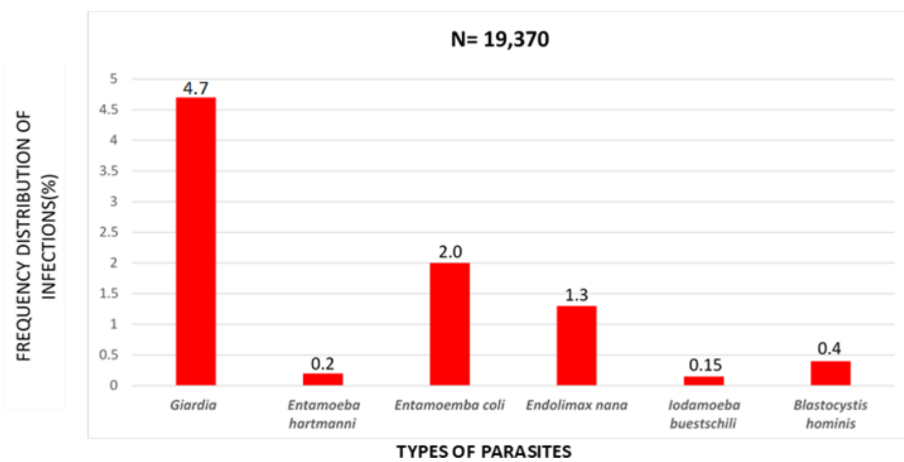

Figure 1. Frequency distribution of 6 different Protozoans 1989-1993

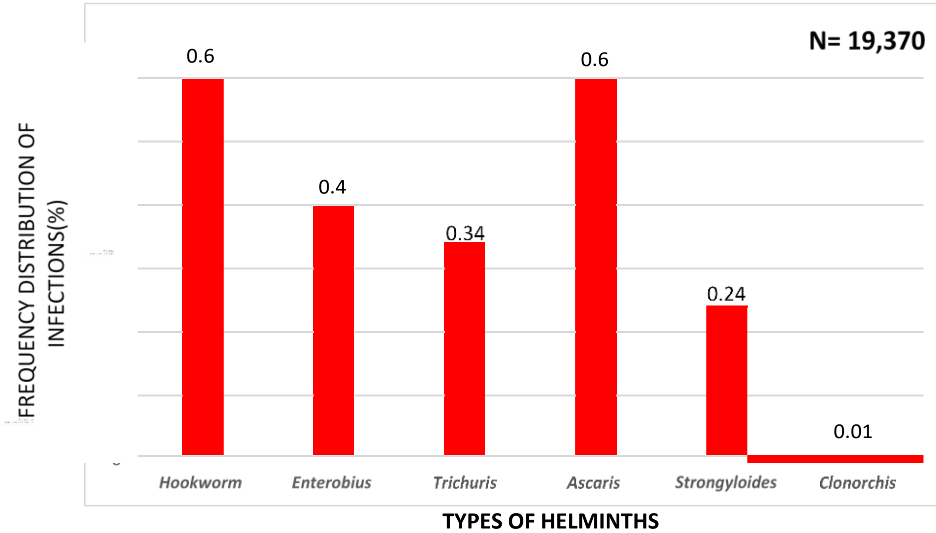

Figure 2. Frequency distribution of Helminths 1989-1993

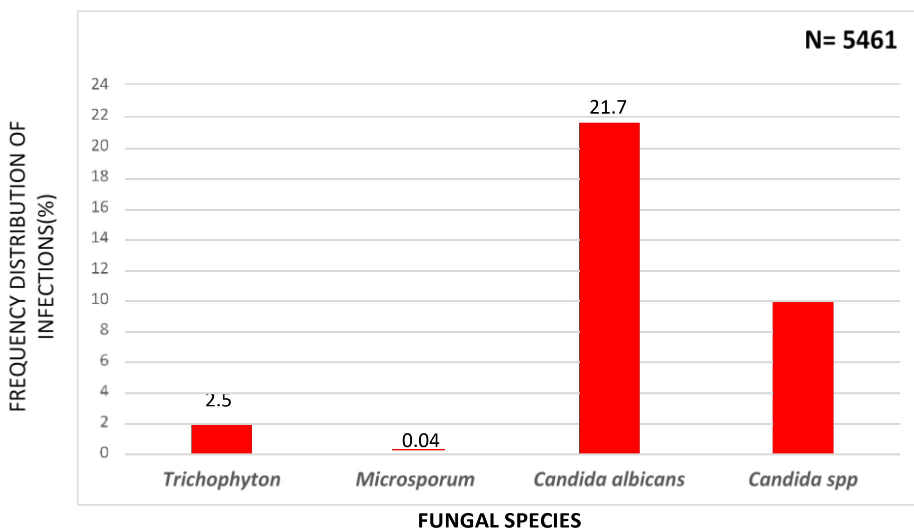

Figure 3. Frequency distribution of Fungal Infections 1989-1993

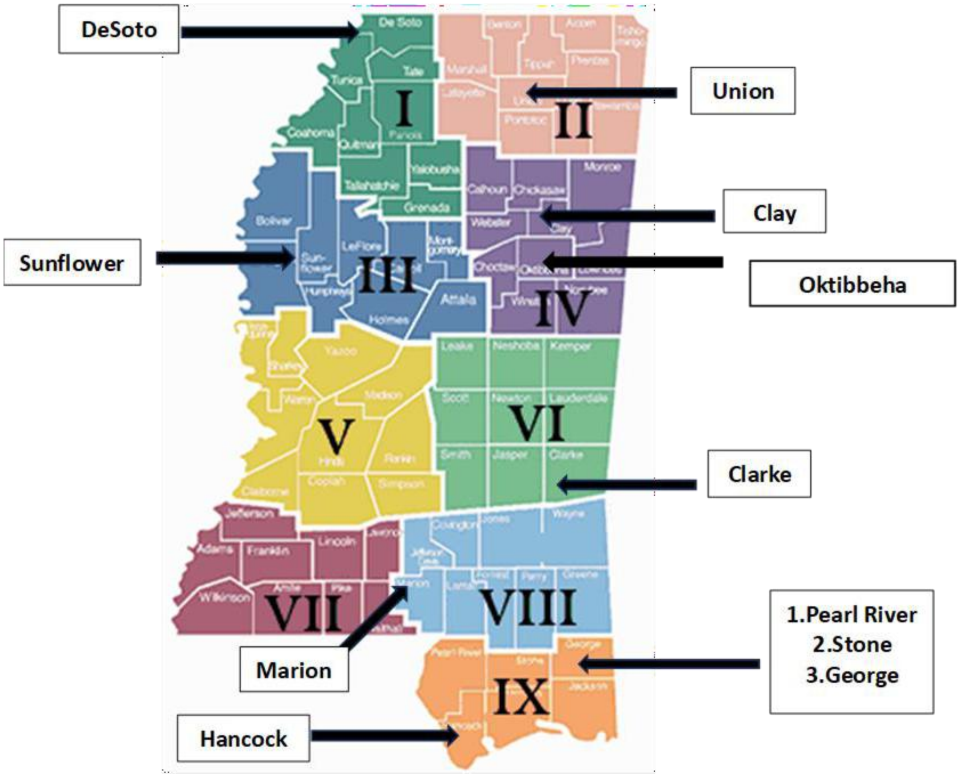

Figure 4. Map of Mississippi showing Public Health Divisions & Counties
(Arrows show Counties in each Public Health Division mentioned in the Results.)

DISCUSSION

This study covering the period 1989-1993, shows that human parasitism was still a public health problem in the State of Mississippi at the time of the study and that mycosis (dermatophytosis and candidiasis) was widespread and uncontrolled.

In this review 60 (73.3%) out of the 82 counties in the State of Mississippi had one or more parasitic and/or fungal infections reported. Such infections, although widespread in the State, were more prevalent in the southern region.

For several years the recording and reporting of state-wide prevalence of parasitic infections has dwindled or is non-existent. Necessary steps should be taken to reactivate or do more studies and reporting of human parasitic and fungal infections in Mississippi.

The results presented here indicate that a well-planned prospective study on human intestinal parasitosis, especially in rural and suburban areas need to be conducted and is recommended. This is supported by Gildner (2023) who said: "Though national infection rates remain unclear because of the absence of large-scale studies, our primary work in 2019, found that 38% of children sampled in a predominantly Black Mississippi Delta community had intestinal parasitic infections".

Amin (2002) reported on the seasonal prevalence of intestinal parasites in the United State during the year 2000. This study covered patients in 48 states (which included Mississippi) and District of Colombia. The reported percentages of infections are relatively high and very revealing. Thirty two percent (32%) of 2896 tested patients were infected with 18 species of intestinal parasites in the year 2000 in 48 states and the District of Colombia. These support the recommendation for a prospective study and when done will give a better representation of the prevalence of human gastrointestinal parasitosis in the State and reveal the extent to which this poses a public health problem.

This is more necessary as there is an influx of immigrants from different parts of the world where parasitic infections are endemic, especially Mexico, coming into the State of Mississippi to settle.

It needs to be observed that trichomoniasis is grossly omitted under Sexually Transmitted Diseases (STDs) in the Reportable Diseases chart published by the Public Health Department of Mississippi monthly (See Chart 1). When inquiry was made about this at the Department of Public Health Diagnostic Laboratory, the author was informed that the prevalence of the disease was so frequent or common that the laboratory did not want to be involved with it. Acholonu (1998) reported on the situation of trichomoniasis in Mississippi and USA in general. He noted that, Tidwell et al. (1994) reported trichomoniasis positivity rate of 31% out of 302 patients attending the University of Mississippi Medical Center in Jackson, MS and undergoing pelvic examination.

Acholonu and Walker (1998), reported on trichomoniasis surveillance in Mississippi and observed, among other things, that 14.0% of 150 vaginal swabs and 13.2% of Pap smears were positive. As reported by Firger. (2014) in a CBS news broadcast on health titled: CDC warns of common parasites plaguing millions in U.S, trichomoniasis was included as one of 5 most common parasitic infections in the U.S. It was also reported that approximately 11% of people in the United Statra are infected with it.

A review of the pathology of trichomoniasis reveals the following: Trichomoniasis may cause "intense inflammation with itching and a copious white discharge (leukorrhea). In men there may be an irritating urethritis or prostatitis (Roberts and Janovy Jr., 1996). Sogbetun and Osoba (1974) reported azoospermia in a patient with numerous *T. vaginalis* in his seminal fluid. Alausa and Osoba (1978) reported male infertility and occurrence of oligospermia and azoospermia in two patients respectively suffering from chronic trichomonal urethritis. Cotch et al., (1991&1997), associated trichomoniasis with salpingitis, Pelvic Inflammatory Disease (PID), ectopic pregnancy, infertility in both men and women and an increased incidence of adverse pregnancy outcomes such as low birth weight, or preterm delivery. According to Mackell and Voge (1976), a possible relationship between this infection and cervical carcinoma has been suggested. These pathological conditions reported by several authors, give a compelling reason why trichomoniasis should be included as one of the reportable diseases under Sexually Transmitted Diseases(STDs) in the Mississippi Provisional Reportable Disease Statistics published monthly.

Human parasitic and mycotic infections deserve recognition as ones of public health importance in the State of Mississippi and ones that require further investigation.

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Bold, H.C., C.J. Alexopoulos, and T. Delevoryas. 1980. Morpholgy of plants and fungi, 4th ed. Harper and Row, New York. 819 pp

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