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AQUATIC MACROINVERTEBRATES OF THREE ACID BOGS ON CROWLEY'S RIDGE IN NORTHEAST ARKANSAS

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ABSTRACT

Qualities and quantities of parameters composing the bog systems in Northeast Arkansas are not entirely reflective of those defining bogs of the northern United States. While pH is restricting to the organisms of each bog studied (4.8-6.9), the major limiting factor is the amount of available water. Three acidophilic bogs with shallow water depths (2-30 cm) yielded a total of 75 aquatic macroinvertebrate taxa. The bog with greatest surface area supported 67 taxa and a mean numerical standing crop of 14 organisms/2 hr sampling period. The bog with the smallest surface area had 13 taxa and a mean standing crop of 2 organisms/2 hr sampling period. No clear seasonal fluctuations were observed in these bogs because the standing crops were never great, and because the amount of water available exerted the greater influence. Water levels did not always fluctuate in consort among the bogs.

INTRODUCTION

Herein, a bog is defined as a peat-covered area or peat-filled depression with a high water table and a surface mat of mosses, chiefly *Sphagnum*. The presence of an extreme limiting factor in bogs (low pH) results in a relatively simple ecosystem (McLachlan and McLachlan, 1975; Saber and Dunson, 1978). Within the spectrum of existing bog ecosystems, bogs previously studied have been relatively large and complex (Welch, 1952; Heinselman, 1963; McLachlan and Dickinson, 1977; Ramcharan and Paterson, 1978), rather than small forested bogs, such as those reported in this study. Furthermore, greater emphasis in other bog studies was placed upon the plant communities rather than on describing the aquatic macroinvertebrate communities. An absence of effective faunal sampling devices for this ecosystem type has perhaps compounded the problem.

Apparently no previous study has dealt with description of bogs in Arkansas. In fact, knowledge of their existence in this state is limited. Bogs occur sporadically along the length of Crowley's Ridge in Northeast Arkansas. Although all share certain defining characteristics (e.g., pH, vegetation), they differ in size, basin shape, water depth, pH, and soil types. These differences can be expected to influence the kinds and relative abundance of aquatic macroinvertebrates supported by each bog. The purposes of this study were to describe the existing aquatic macroinvertebrate communities within three bogs on Crowley's Ridge and to discern physicochemical relationships which may explain their present distribution and relative abundance.

STUDY SITES

The three bogs selected for study are located within Greene County, Arkansas, among the forests of Crowley's Ridge. This Ridge is generally comprised of loessial hills, with the major soil type being of the Lorine Granada Association. A secondary soil type in the study area is the Brandon Lexington Association. Both soils are deep, well to poorly drained and moderately permeable, with gentle to steep slopes developed from this loess over gravelly and sandy tertiary material. The forest of Crowley's Ridge in the vicinity of the bogs can be generally regarded as white oak-red oak-hickory with certain edaphic factors accounting for beech (*Fagus grandifolia* var. *caroliniana* Loud.) and its community associates at one extreme with shortleaf pine (*Pinus echinata* Mill.) at the other (Arkansas Department of Planning, 1974). All three of the bogs studied lie at the base of steep slopes and are adjacent to sand pits where extensive removal of material has destroyed a portion of the aquifer head which formerly furnished a constant water supply. The current water source is restricted to spring seeps located on the adjacent slopes and to limited run-off directly dependent upon rainfall. Mean annual rainfall in this region during the 1930-1980 period was 125 cm. During 1979-1980 it was 35.1 cm (U.S. Dept. Commerce, 1931-1980).

Bogs have only recently been grouped under the single term "wetlands". According to Cowardin et al. (1979), all three bogs in this study are Palustrine Systems and are contained in the Forested Wetlands class; the subclass is Broad-Leaved Deciduous. Their water regime is Saturated, water chemistry is Fresh-Acid, and soil is Organic. The bogs of this study are now in a dying state or climax condition specifically referred to as sedge-meadow.

Glory Hole Bog lies in the Brandon Lexington Association soils on the western edge of Crowley's Ridge, approximately 5 km northeast of the junction of State Highways 25 and 168 in the NW¼ S23, T17N, R4E. This bog is essentially a forested mire draining into what now resembles the early stages of a swamp. Water enters the basin by rainfall runoff largely from the south and west, and leaves by an outflow channel in the north shore. The bog, with an area of 42,968 m^2, is surrounded by mat formations and peat deposits which are thoroughly protected by closely-surrounding woods and hills such that wind action would never produce major turbulence. This dense understory, combined with numerous ferns, heavily shades the water from spring through fall.

Ramer's Chapel Bog lies in the Lorine Granada Association soils at the eastern edge of Crowley's Ridge. The bog is bordered to the east by Ramer's Chapel Road, and lies 1.5 km northeast of the junction of State Highways 135 and 34 at Lafe, in S12, T18N, R5E. A climactic forest type with widely fluctuating water level, pH, and temperature is characteristic of this bog. Water flow is from direct runoff which flows in a westerly direction through the bog and terminates in a lentic environment surrounded by cultivated fields and pastures. Covering an area of 31,604 m^2, the bog has a basin composed of clay and silt with deeply stained detritus.

Bluff Springs Bog, also in the Brandon Lexington Association soil type, lies 1.5 km east of State Highway 141 at a point 6.5 km south of Beech Grove, in the NE¼, S3, T17N, R4E. Similar protection is afforded by a combination of slopes and vegetation at this site. Situated as an arm to the headwaters of a small slough, the bog, with an area of 327 m^2, is a spring seep that percolates through heavy litter and has a gravel and sand substratum. The name of the bog is derived from its location on a steep slope, one that remains moist throughout most of the year. The tree and understory vegetation is not as dense as that found within the other two bogs, yet the bog's position between steep slopes diminishes the amount of incident sunlight reaching the ferns and mosses. Also, Bluff Springs Bog does not have as continuous a *Sphagnum* mat formation as the other two bogs.

METHODS AND MATERIALS

Three sampling stations were established in Glory Hole Bog, one in Ramer's Chapel Bog, and one in Bluff Springs Bog. Since occasional drying of certain sites occurred during the sampling period, areas sampled were extended to points where any moisture or temporary pools occurred within the bog. Monthly benthic and physicochemical samples were taken from 30 September 1979 through 15 February 1981, except during July 1980. Additional random qualitative samples (sweep netting for adults) were collected from each of the bogs throughout the sampling period in order to facilitate species identification of immature forms. Soil samples, taken quarterly, were collected with a conventional hand-held corer having a 3 cm diameter. Samples were analyzed for pH, phosphorus, calcium, potassium, and total organic matter by the Soil Testing Laboratory in Marianna, Arkansas. Temperature, water pH, and water depth were measured monthly. Due to similarity in soil samples, water temperature and pH from the three sites within Glory Hole Bog, a single collecting station, Site Three, was utilized during the study.

In August and September 1979, hand-net samples were taken from all habitat types in the bogs. Examination of the samples from Glory Hole Bog revealed three distinct areas of the bog substrate with their own characteristic fauna. These areas were selected for further study. Stations sampled at the Ramer's Chapel and Bluff Springs Bogs reflected a more homogeneous pattern of macrofaunal distribution and habitat types. Location of sampling stations within each of these bogs was dictated by available moisture in the form of standing pools and seeps, some of which dried up during the sampling period.

Mud, as well as surface and bottom water samples, was collected from each station every month for the first four months of the first year and quarterly thereafter. These samples were inspected in the laboratory for benthic macrofauna. All other organisms were collected and separated from the substrate in the field.

No standard aquatic-macroinvertebrate sampling devices were found to be suitable for this study because in most areas of the bogs the water areas were too shallow or too narrow, or the mud and vegetation too thick. As a result, the monthly samples were each made as a combination of three different collecting techniques. Benthic organisms were collected using a Turtox Indestructable Dip Net™ where water depth and substrate were suitable. Manual picking through leaf samples collected by hand, and sand sifting or "panning" the substrate using a tea strainer with a mesh size of 49 squares/cm, proved to be the two most-useful sampling techniques. Since quantification could not be made on a unit-area basis, this was accomplished using a common time factor, specifically two hours per station.

After washing and sorting in the field, specimens were preserved and stored in 70% ethanol. On every visit, random samples were collected at each station from leaf detritus, substrate, and surface water of the bog proper. All specimens were catalogued and housed in the Arkansas State University aquatic macroinvertebrate collection.

RESULTS

A total of 75 aquatic macroinvertebrate taxa was found in the three bogs. Of these, 67 taxa were found at Glory Hole Bog; 24 taxa at Ramer's Chapel Bog; and 13 taxa at Bluff Springs Bog. Only five taxa were common to all three bogs; Oligochaeta, *Caecidotea recovitzai*, *Tipula*, Chironomidae, and *Tabanus*. Nineteen taxa were restricted to two of the three bogs; Glory Hole and Ramer's Chapel exhibited 13 taxa in common, while Glory Hole and Bluff Springs Bogs exhibited six taxa in common. Forty-one taxa were found only in Glory Hole Bog, six only in Ramer's Chapel Bog, and two only in Bluff Springs Bog (Table).

Table. Aquatic macroinvertebrates of three acid bogs, Greene County, Arkansas, 9 September 1979 through 15 February 1981, expressed as total numbers collected.

Taxa	Glory Hole Bog Site 1	Glory Hole Bog Site 2	Glory Hole Bog Site 3	Ramer's Chapel	Bluff Springs
NEMATOMORPHA	1		1		1
CLITELLATA					
Oligochaeta	8	7	10	10	6
HYDRACARINA			3		
GASTROPODA		1			
PELECYPODA					
Heterodonta					
Sphaeriidae					
Pisidium casertanum (Poli)	7		7		
CRUSTACEA					
Isopoda					
Asellidae					
Caecidotea forbesi (Fleming)			1		
Caecidotea recovitzai (Williams)	58	10	24	3	5
Amphipoda					
Gammaridae					
Gammarus pseudolimnaeus Bousfield	15				
Synurella bifurca (Hay)	29	3	5		2
Crangonyx sp. nr. *gracilis* Smith	20	20	1		
Decapoda					
Astacidae					
Cambarus (*Lacunicambarus*) *diogenes* Girard*	2	1	7		2
Procambarus (*Ortmannicus*) *acutus acutus* (Girard)		10			
INSECTA					
Collembola					
Isotomidae					
Isotomurus palustris (Muller)	30	12	2	10	
Hemiptera					
Belostomatidae					
Belostoma lutarium (Stahl)			1	1	
Gelastocoridae					
Gelastocoris oculatus oculatus (Fabr.)				1	
Gerridae					
Gerris marginatus Say	2	2	4		
Limnogonus canaliculatus (Say)				1	
Hydrometridae					
Hydrometra martini Kirkaldy		7	8	3	
Nepidae					
Nepa apiculata Uhler	2		8		
Ranatra australis Hungerford			1		
Notonectidae					
Notonecta irrorata Uhler				1	
Notonecta undulata Say			4	3	
Veliidae					
Microvelia albonotata Champ.		7			
Microvelia americana (Uhler)		3	1	9	
Ephemeroptera					
Leptophlebiidae					
Leptophlebia			2		
Odonata					
Calopterygidae					
Calopteryx maculata (Beauvois)			3		
Coenagrionidae					
Ischnura		1	1	1	
Petaluridae					
Tachopteryx thoreyi (Hagen)		1			2
Cordulegastridae					
Cordulegaster maculata Selys		9	7		
Cordulegaster obliquus Say	5	41	3		
Gomphidae					
Dromogomphus spoliatus Hagen	8	6	1		
Aeshnidae					
Anax junius Drury			1		
Boyeria vinosa Say	1				
Gomphaeschna furcillata Say		1	2		
Corduliidae					
Somatochlora linearis Hagen	1	3	1		
Libellulidae					
Erythemis simplicicollis Say	1		1		
Erythrodiplax umbrata Linnaeus	1				
Ladona deplanata Rambur	1				
Libellula cyanea Fabricius	1		6		
Libellula flavida Rambur	1				
Libellula semifasciata Burmeister	1				
Libellula vibrans Fabricius			7	1	
Pachydiplax longipennis Burmeister		4	21	3	
Plathemis lydia Drury	1				
Sympetrum vicinum Hagen	1				
Megaloptera					
Sialidae					
Sialis	14	27	18		
Corydalidae					
Chauliodes pectinicornis (Linnaeus)	4				4

Table (continued).

Taxa	Site 1	Glory Hole Bog Site 2	Site 3	Ramer's Chapel	Bluff Springs
Trichoptera					
Phryganeidae					
Ptilostomis	1		5		
Coleoptera					
Dytiscidae					
Agabus disintegratus (Crotch)		2	1		
Celina angustata Aube				1	
Coptotomus interrogatus obscurus Sharp					1
Ilybius incarinatus Zimmermann					1
Dytiscus hybridus Aube			5		
Hydroporus clypealis Sharp			1		
Hydroporus undulatus undulatus Say			1		
Laccophilus proximus proximus Say			2		
Thermonectus basillaris (Harris)			7	1	
Haliplidae					
Haliplus triopsis Say			2		
Hydrophilidae					
Berosus			1		
Cymbiodyta vindicata Fall	1		1		
Enochrus ochraceus Melsheimer				1	
Helochares				1	
Hydrophilus triangularis Say			1		
Tropisternus lateralis nimbatus (Say)			14	1	
Helodidae					
Microcara			2		
Diptera					
Tipulidae					
Helius flavipes (Macquart)			1		
Tipula	2		4	1	5
Pedicia			1		1
Pseudolimnophila			2		
Ptychopteridae					
Ptychoptera quadrifasciata Say	1	2	3	1	
Bittacomorpha clavipes (Fabricius)	10	7	20	43	
Chironomidae	6	2	22	2	5
Tabanidae					
Chrysops	3			1	
Tabanus			1	3	2
Syrphidae					
Eristalis			1		
Total organisms	295	188	255	103	35
Total taxa	30	25	53	24	13

*Closer to subspecies *ludovicianus* Faxon than *diogenes* Girard (Hobbs, pers. comm.). The specimens are housed in the Smithsonian Institution collection.

Mean numerical standing crop for Glory Hole Bog was 14 organisms/2 hrs, 18% of which were odonates. Amphipods and dipterans were next in abundance with 17% and 14% of the total numbers, respectively. Standing crop for Ramer's Chapel Bog was 6 organisms/2 hrs, less than half that of Glory Hole Bog. Dipterans and hemipterans comprised 51% and 18% of the standing crop, respectively. Mean standing crop for Bluff Springs Bog was 2 organisms/2 hrs, one-third that of Ramer's Chapel Bog. Dipteran larvae comprised 35% of the standing crop.

Glory Hole Bog exhibited the largest standing crop during the March, 1980 sampling period with 27 organisms/2 hrs. Ramer's Chapel Bog exhibited its largest standing crop during August, 1980 with 22 organisms/2 hrs. Bluff Springs Bog's largest standing crop of 10 organisms/2 hrs occurred during May, 1980.

Fourteen of the 67 taxa found in Glory Hole Bog were common to all three sampling sites within the bog. Sites One and Three held the largest standing crops with a mean of 17 and 15 organisms/2 hrs, respectively. Site One was dominated by *Caecidotea* spp. which comprised 31% of the standing crop. *Cordulegaster* spp. contributed the largest standing crop at Site Two with 28%. Site Three was dominated by *Caecidotea recovitzai* with 10% of the standing crop.

All three bogs are characterized by shallow, acidic waters which are heavily stained throughout the year. During the study period, pH values were normally comparable between bogs and ranged from a low of 4.83 in Ramer's Chapel Bog to a high of 6.95 in Bluff Springs Bog. Mean water depth was always greatest in Glory Hole Bog which had a mean of 10.4 cm. Water depth in Ramer's Chapel Bog, with a mean of 3.6 cm, was always intermediate and was less than one-half that of Glory Hole Bog. During more than one-half of the study period, Bluff Springs Bog was composed of saturated detritus and mud with no standing water. During these periods when water was present, the maximum standing water depth was 2 cm.

The essential nutrients measured (phosphorus, potassium, and calcium) existed in low or moderate concentrations that were similar in all bogs. Percent organic matter was consistently greater in Glory Hole Bog (mean = 3.7%) than in Ramer's Chapel or Bluff Springs Bog, the latter two being comparable in this respect (mean = 2.4%) (Farris, 1981).

DISCUSSION

The three bogs in this study were found to be of the acidophilic forested type. The dense deciduous forests in which they are located are the major source of acids, which are derived from the natural process of organic matter degradation. Jewel and Brown (1929) provided the first evidence that the acid is not produced in bog lakes as such, nor is it brought in with ground water from deeper strata. Rather, it is leached from the decaying vegetation of the lake margin. Vanderpool (1982) found that soil pH within the deciduous forest immediately surrounding three bogs on Crowley's Ridge was higher than that of the bog soils proper.

The second major limiting factor in the bogs of this study is the amount of water available. This has not been a major consideration in other bogs (McLachlan and McLachlan, 1975; Ramcharan and Paterson, 1978), primarily because of their larger size. In the present study the bogs were quite small, ranging from 327-43,000 m^2 in area, making them more susceptible to environmental alteration. Their aquifers have been disturbed by sand and gravel mining, which has reduced the amount of water available to them. Finally, this study was conducted during the second worst drought and the second hottest summer in Arkansas' history. These combined events greatly restricted the area and diversity of the microhabitats available to the aquatic macroinvertebrates.

Because of higher water and air temperatures, an extended growing season, and restricted peat formation, the turnover of organic matter is apparently more rapid in these study bogs than is characteristic of bogs located farther north. The percent organic matter was comparable among all three bogs. Fluctuations in percent organic matter most-clearly paralleled the amount of standing water available and percentages decreased as water levels dropped.

Essential elements often linked to dystrophic conditions within bogs were not limiting factors in this study. Phosphorus is normally a limiting factor in aquatic systems, often being present in amounts of less than 1 ppm (Reid and Wood, 1976). Available phosphorus in typical acid dome bogs is on the order of 16 ppm (Small, 1972). Phosphorus values in this study ranged from 2-22 ppm. The availability of a slight current during wetted periods and the presence of a greater amount of calcium than is usually found in bogs could also contribute to a more rapid turnover of organic material. Because northern bog waters percolate through *Sphagnum* muskegs far from mineral soils, they often carry limited supplies of calcium and they seldom exhibit calcium values in the range of 250-500 ppm as found in the three bogs reported in this investigation. The importance of calcium shortage in bringing about dystrophy has been documented by Hasler et al. (1951), and Cole (1975).

When compared with the diversity and abundance of aquatic macroinvertebrates reported for swamps, lakes and streams of northeast Arkansas (Cather and Harp, 1975; Latimer, 1975; Harp and Harp, 1980), these parameters in the three bogs are certainly restricted. The bogs contain an abundance of organic materials as a food base and feature a variety of microhabitats. Nevertheless, the combined effects of low pH, drastic fluctuation in water level and extreme shading by the associated deciduous forests result in a distinctive but sparse aquatic macroinvertebrate community.

The five taxa common to all three bogs are detritivores which are often abundant in most aquatic ecosystems where organic detritus is available. They are also adapted to a broad range of environmental conditions including dissolved oxygen and pH (Reid and Wood, 1976; Hiltunen and Klemm, 1980). The abundance of aquatic oligochaetes in these bogs is illustrative in that their greatest abundance is associated with organically-rich substrates (Latimer, 1975).

The ecology of *Caecidotea* spp. in North America is not well known. However, in most of Europe this genus is characteristically present within given sections of organically-polluted rivers (Williams, 1976). Its tolerance to a wide range of water depths and substrata is exhibited in this study where it was collected in all three bogs throughout most of the sampling period.

The diversity and relative abundance of the aquatic macroinvertebrates were greatest in Glory Hole Bog, intermediate in Ramer's Chapel Bog, and least in Bluff Springs Bog. This sequence follows that of bog size, but the strongest influence is exerted by the amount of water available, which entails water depth as well as surface area. Bluff Springs Bog, with 0.7% of the area of Glory Hole Bog, had 19% as many taxa (13 vs. 67). All these taxa were able to function in the wetted organic debris and mud in the absence of standing water.

Among those taxa found only in Glory Hole Bog were the following. *Pisidium* is often the only molluscan representative found in bog lakes (Welch, 1952). *Procambarus* is found in sluggish to moderately flowing streams and lentic habitats (Hobbs, 1976). However, in this study, *Procambarus* was present only in the sandy troughs of Glory Hole Bog. *Nepa* and *Ranatra*, two sluggish-swimming predators, are definitely restricted to dense pondweed masses and heavy, submerged leaf litter. These hemipterans were also noted by Lindeman (1941) as bog forms. *Sialis* larvae are common predators in many streams and ponds and are adapted for survival during periods of low prey density in that they can live up to two months without food and then develop rapidly when food becomes abundant (Azam and Anderson, 1969). Further, they have a wide tolerance range for pH (2.8-8.3) (Tarter and Woodrum, 1972).

Those species found only within Ramer's Chapel Bog (*Limnoporus, Gelastocoris, Notonecta irrorata, Helochares, Enochrus,* and *Celina*) are all invading forms that may, or may not, be consistently present in the bog during drying conditions. One obvious difference in the macroinvertebrate communities of Ramer's Chapel Bog is the absence of amphipods. As a group, amphipods are cold stenotherms, strongly thigmotactic, and react negatively to light (Pennak, 1978). Consequently, daytime is spent beneath vegetation or hidden between debris and stones. In addition, amphipods are most often found in unpolluted clear waters, a condition never present in Ramer's Chapel Bog. Their presence and relative abundance in Glory Hole and Bluff Springs Bogs were sporadic, depending mainly upon the amount of water present during sampling.

Taxa found only in Bluff Springs Bog fail to reflect any distinctive physicochemical characteristics. Rather, the absence of taxa and the presence of such forms as *Tachopteryx* seem to reflect the dried nature of this bog. These bog odonates are known to burrow in substrate adjacent to shores (Needham and Westfall, 1955), and can withstand periods of drought and other adverse environmental conditions. This was the only odonate taken at Bluff Springs bog. The amphipod *Synurella* was found in this bog. Pennak (1978) stated that although amphipods are not generally adapted for withstanding drought, *Crangonyx gracilis* and *Synurella bifurca* are inhabitants of temporary as well as permanent ponds and streams. It has been suggested that these species tide over unfavorable conditions by burrowing into the substrate. This was verified in both Glory Hole and Bluff Springs Bogs during drying conditions when only mud was present.

Within Glory Hole Bog the sapling sites differed as to substratum, water, depth, current, and macroinvertebrates collected. Site One was composed of extremely heavy detritus upon fine, darkly stained silt. Water depth never rose above 6 cm and a current was virtually absent. Among the 32 taxa at this site, common lentic water forms such as *Caecidotea* dominated numerically, followed by amphipods, *Sialis,* and *Bittacomorpha.* These species quickly drop in number at Site Two which is composed of sandy troughs with a slow current present during much of the sampling period. *Cordulegaster* is the numerically dominant taxon here. This effective predator is adapted for burrowing in the sandy substrate by the presence of short, stout legs and tarsal claws. The relative sterility of sand substrates is reflected in the fact that the lowest number of taxa and the lowest standing crops within Glory Hole Bog were at this site. At Site Three, a beaver dam along the north shore is causing a transition of the bog toward a swamp condition. Water depths range from 15-30 cm. Greater water depth and surface area at this site is utilized by a more diverse macroinvertebrate community, particularly by the highly predatory Hemiptera and Coleoptera. The diversity of microhabitats available within Site Three is clearly reflected in that 53 of the 67 taxa found in Glory Hole Bog were here (Table).

A recommendation to preserve one or more of Arkansas' bogs is strongly indicated by this study. First, bogs in this state are characteristically small, and therefore more subject to damage or alteration due to sand and gravel mining, timbering, or other land uses. Second, they constitute relatively simple ecosystems, thus facilitating the study of the interrelationships of organisms which populate them. Finally, these bogs support a number of species found infrequently and in small numbers within Arkansas. In many instances, they are found only in bogs.

Previous to this study, only three specimens of *Nepa apiculata* had been collected in Arkansas, one each from three different sites. Ten specimens were collected from Glory Hole Bog. One adult specimen of *Gomphaeschna furcillata* had been previously collected from Arkansas. Virtually nothing is known of its biology. Three naiads were collected from thig bog. One adult *Tachopteryx* had been previously collected from northwest Arkansas. Its collection from Glory Hole and Bluff Springs Bogs represent the first naiads taken in this state, as well as the second and third sites for this species. *Erythrodiplax umbrata* has been colected once previously in Arkansas, *Libellula semifasciata* from three scattered Arkansas sites, *L. flavida* from seven sites, *Cordulegaster maculata* and *obliqua* from four and seven sites, respectively (Harp and Rickett, 1977). All these species were collected in Glory Hole Bog.

The presence of so many species in Glory Hole Bog that are rare in the state makes it a prime candidate for preservation. Its relatively large size and its location enhance the probability that preservation efforts would be successful.

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LITERATURE CITED

ARKANSAS DEPARTMENT OF PLANNING. 1974. Arkansas Natural Area Plan. Little Rock, Arkansas. 248p.

AZAM, K. M., and N. H. ANDERSON. 1969. Life history and habits of *Sialis rotunda* and *S. californica* in western Oregon. Ann. Ent. Soc. Am. 62:549-558.

CATHER, M. R., and G. L. HARP. 1975. The aquatic macroinvertebrate fauna of an ozark and a deltaic stream. Proc. Ark. Acad. Sci. 29:30-35.

COLE, G. A. 1975. Textbook of Limnology. C. V. Mosby Co., St. Louis. 283p.

COWARDIN, L. M., V. CARTER, F. C. GOLET, and E. T. LAROE. 1979. Classifications of wetlands and deepwater habitats of the United States. Biol. Serv. Prog., FWS/OBS-79-31. 103p.

FARRIS, J. L. 1981. Aquatic macroinvertebrates of three acid bogs on Crowley's Ridge in northeast Arkansas. Unpub. M.S. Thesis, Arkansas State Univ. 58p.

HARP, G. L., and P. A. HARP. 1980. Aquatic macroinvertebrates of Wapanocca National Wildlife Refuge. Proc. Ark. Acad. Sci. 34:115-117.

HARP, G. L., and J. D. RICKETT. 1977. The dragonflies (Anisoptera) of Arkansas. Proc. Ark. Acad. Sci. 31:50-54.

HASLER, A. D., O. M. BRYNILDSON, and W. T. HELM. 1951. Improving conditions for fish in brown-water bog lakes by alkalization. J. Wildl. Manage. 15:347-352.

HEINSELMAN, M. L. 1963. Forest sites, bog processes, and peatland types in the Glacial Lake Agassiz Region Minnesota. Ecol. Monogr. 33(4):327-374.

HILTUNEN, J. K., and D. J. KLEMM. 1980. A guide to the Naididae (Annelida: Clitellata: Oligochaeta) of North America. Water Pollution Control Research Series EPA-600/4-80-0. U.S. Environmental Protection Agency, Cincinnati, Ohio. 48p.

HOBBS, H. H. 1976. Crayfishes (Astacidae) of North and Middle America. Water Pollution Control Research Series 18050 ELDO5/72. U.S. Environmental Protection Agency, Cincinnati, Ohio. 173p.

JEWEL, M. E., and H. W. BROWN. 1929. Studies on northern Michigan Bog Lakes. Ecology 10:427-473.

LATIMER, C. J. 1975. The effects of channelization on the benthic macroinvertebrates of Cache River and Bayou DeView. Unpub. M.S. Thesis, Arkansas State Univ. 64p.

LINDEMAN, R. L. 1941. Seasonal food-cycle dynamics in a senescent lake. Amer. Midl. Nat. 26(3):636-673.

MCLACHLAN, A. J., and S. M. McLACHLAN. 1975. The physical environment and bottom fauna of a bog lake. Arch. Hydrobiol. 76(2):198-217.

McLACHLAN, A. J., and C. H. DICKINSON. 1977. Micro-organisms as a factor in the distribution of *Chironomus lugubris* Zetterstedt in a bog lake. Arch. Hydrobiol. 80:133-146.

NEEDHAM, J. G., and M. J. WESTFALL, JR. 1955. A manual of the dragonflies of North America. (Anisoptera). Univ. California Press, Berkeley. 622p.

PENNAK, R. W. 1978. Freshwater invertebrates of the United States. Wiley Interscience Co., N.Y. 769p.

RAMCHARAN, V., and C. G. PATERSON. 1978. A partial analysis of ecological segregation in the chironomid community of a bog lake. Hydrobiol. 58:129-135.

REID, G. K. and R. D. WOOD. 1976. Ecology of inland waters and estuaries. D. Van Nostrand Co., N.Y. 485p.

SABER, P. A., and W. A. DUNSON. 1978. Toxicity of bog water to embryonic and larval anuran amphibians. J. Exp. Zool. 204:33-42.

SMALL, E. 1972. Ecological significance of four critical elements in plants of raised *Sphagnum* peat bogs. Ecology 53:498-503.

TARTER, D. C., and J. E. WOODRUM. 1972. Low pH tolerance of the larvae of the alderfly, *Sialis aequalis* Banks, under controlled conditions. Proc. W. Va. Acad. Sci. 44(1):85-88.

U.S. DEPARTMENT OF COMMERCE NATIONAL CLIMATIC CENTER. 1931-1980. Climatological data. Wash., D.C.

VANDERPOOL, S. S. 1982. Comparative study of vascular plants from selected bogs of Crowley's Ridge, Arkansas. Unpub. M.S. Thesis, Arkansas State Univ. in prep.

WELCH, P. S. 1952. Limnology. McGraw-Hill Book Co., Inc., N.Y. 538p.

WILLIAMS, W. D. 1976. Freshwater isopods (Asellidae) of North America. Water Pollution Control Research Series 18050 ELDO5/72. U.S. Environmental Protection Agency, Cincinnati, Ohio. 45p.