WATER QUALITY AND AQUATIC MACROINVERTEBRATES IN 3 TYPES OF REFERENCE LIMESINK WETLANDS IN SOUTHWEST GEORGIA

Juliann Battle and Stephen W. Golladay

AUTHORS: J.W. Jones Ecological Research Center, Route 2, Box 2324, Newton, GA 31770
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Abstract. In SW Georgia, three wetlands types have been classified based on vegetation and soils: marshes dominated by herbaceous vegetation, open savannas with an overstory canopy of cypress, and forested swamps composed of cypress/hardwoods. We sampled 28 relatively unimpacted limesink wetlands for water quality at eight different times during 1997-98, and sampled invertebrates using a D-frame sweep net at early, mid, and late hydroperiod times during 1997. Water quality was similar in all wetland types upon initial inundation, but later in the hydroperiod marshes and savannas still had similar water quality that differed from swamps. Swamps had higher levels of dissolved inorganic carbon, NH_4-N, NO_3-N, and PO_4-P, low dissolved oxygen levels, and darkly stained water. We identified 121 different aquatic invertebrate taxa, with 40 taxa occurring in $\geq$10% of the samples. Marshes had higher density, taxa richness, and diversity than the other wetland types. Our findings suggests that vegetation is the most important factor in determining invertebrate assemblages and that marshes have more niches and a wider variety of food sources than the other wetland types. This study will be useful in assessing and restoring wetlands in the region, although more work is needed to understand the role of fire and hydrologic variation in these wetlands.

INTRODUCTION

Non-alluvial wetlands are a common landscape feature in southeastern USA. Depressional wetlands are isolated from streams or other permanent water bodies and are seasonally inundated. They are threatened by regional development and are rapidly being removed and altered before their function and value in the landscape is fully appreciated. While perennially inundated wetlands have been extensively studied, less is known about seasonal wetlands.

For the past two years, we have been examining water quality and aquatic invertebrate assemblages in 28 reference limesink wetlands at the Ichauway Reserve in southwest Georgia. We were presented with a rare opportunity to characterize wetlands that have been minimally disturbed by humans and are located in a Reserve where upland management practices have been documented since the 1930's. Our findings will be valuable in developing guides for restoration and assessment of wetlands in southwest Georgia.

STUDY SITE

Our study site was located on Ichauway Ecological Reserve (10,500 ha), a large remnant tract of longleaf pine (*Pinus palustris*) on the Gulf Coastal Plain of southwest Georgia in a physiographic region known as the Dougherty Plain. Wetlands in this area are sites of high plant diversity (Goebel et al. 1997, Drew et al. 1998), and habitat for several rare and threatened plants and amphibians (Drew et al. 1998, Semlitsch and Bodie 1998).

Limesink wetlands are shallow, irregular-shaped depressions that are formed when underlying limestone has partially collapsed or dissolved. A typical hydroperiod occurs when wetlands fill in during late February and dry out during early July, although inundation length is ultimately dependent on climate. On the Doughtery Plain, wetlands have been classified into three types based on vegetation and soils: grass-sedge marshes, cypress savannas, and cypress-gum swamps (Goebel et al. 1997). Marshes are sandy depressions with a dense array of ground-flora dominated by panic grasses (*Panicum* spp.) and cutgrass (*Leersia hexandra*). Savannas are characterized by clayey soils, an interspersed ground-flora, and an overstory canopy of pond cypress (*Taxodium ascendens*). Swamps have organic soils, and an overstory canopy dominated by *T. ascendens*, and swamp tupelo (*Nyssa sylvatica* var. *biflora).*

METHODS

Wetlands (10 marshes, 6 savannas, and 12 swamps) were sampled for water quality on 26-27 February, 17-18 April, 4-5 June, and 15-16 December of 1997, and 28-29 January, 25-27 March, 5-6 May, and 16-17 June of 1998. In the field, temperature and dissolved oxygen (D.O.) concentrations were determined with a YSI dissolved oxygen meter, Model 50B (Yellow Springs, Ohio). Temperature and D.O. were represented as the mean of surface and bottom readings. Depth of water was measured from stationary staff gauges at each wetland. Two 500-ml water samples taken from each wetland were analyzed for water chemistry. Alkalinity and pH were determined using a Mettler DL12 tritrator and apparent color was measured with a platinum-cobalt standard scale (HACH, DR/2000 Spectrophotometer). Dissolved carbon (total, inorganic, and organic) was determined using a Shimadzu TOC-5050 analyzer. NH_4-N, NO_3-N, and PO_4-P were determined with a flow-injection colormetric assay (LaChat Instruments, Quik Chem 8000).

Macroinvertebrates were collected from the wetlands in April, June, and December 1997 using a 500-µm mesh D-frame sweep net. Samples were taken over a 1-m distance at three locations and then preserved with 70% EtOH. Invertebrates retained in a 1-mm mesh sieve were identified to the lowest taxonomic level possible, usually genus (Merritt and Cummins 1996). Invertebrate data were expressed as number per m^2. Multivariate analysis (nonmetric multidimensional scaling) was used to determine the relationships between taxa and wetland types (PC-ORD for Windows, Version 3.04, McCune and Mefford 1997).

RESULTS

Upon initial inundation, all the wetland types had similar physical and chemical characteristics: very clear water, relatively high pH, and low NH_4-N and dissolved organic carbon concentrations. A few months after the initial flooding, wetland types could be distinguished by water quality. In general, marshes and savannas maintained similar habitat attributes throughout the hydroperiod (Table 1). In contrast, swamps had higher levels of PO_4-P, benthic organic matter (BOM), and inorganic carbon than the other two wetland types. As water levels receded, NH_4-N and organic carbon levels increased in the swamps and the water became darkly stained.

There were 121 taxa recorded for the three dates that invertebrates were sampled. Forty taxa occurred in ≥10% of the samples. Marshes had the highest density and taxa richness while swamps had the lowest (Table 2). The most taxonomically rich orders were Coleoptera (beetles) with 37 taxa, and Hemiptera (true bugs) with 21 taxa. The most abundant taxa were chironomids, calanoida, amphipods (*Crangonyx* sp.), and isopopods (*Caecidotea* sp.).

Multivariate analysis indicated that during the early hydroperiod, marshes were characterized by zooplankton (Ostracoda, Calanoida, and Sididae) and later described by predators (chironomids, Cyclopoida, *Bezzia* sp., *Buenoa* sp., *Enallagma* sp., *Palmacorixa* sp., and *Oxyethira* sp.). Savannas during the early hydroperiod were strongly characterized by Cyclopoida and later were typified by amphipods and isopods. Cyclopoida, amphipods, and isopods characterized the swamps during the early hydroperiod, but were not prevalent at later timepoints.

DISCUSSION

Water quality

Palik et al. (submitted) classified the ecosystems on Ichauway Reserve based primarily on soil and geomorphic variables and secondarily on vegetation. They determined that swamps were readily distinguishable from marshes and savannas based on soil texture. Marshes and savannas had similar soil characteristics but differed largely in vegetation type (Palik et al. submitted). Upon initial inundation, wetland types had similar water quality and we concluded that these initial conditions were a reflection of precipitation. Over time water quality was modified by contact with soils and vegetation, and marshes and savannas had very different water characteristics than swamps, mainly altered organic carbon and nutrient concentrations.

Marsh and savanna wetlands had similar water quality characteristics even though they have very different plant communities. In marshes, dense aquatic macrophytes and lack of a overstory canopy resulted in higher D.O. levels and water temperature than savanna wetlands.

Savannas are probably the most nutrient limited wetland type, indicated by low levels of NH_4-N and PO_4-P; this nutrient limitation may be a limiting factor

Table 1. Averages of habitat variables measured for three limsink wetland types over 8 sampling dates in 1997-1998.

Habitat variables	Marshes	Savannas	Swamps
Dissovled oxygen (mg/L)	5.0	4.6	2.8
Temperature (C°)	18.9	17.7	15.8
Total diss. carbon (ppm)	18.3	14.7	22.0
Inorganic carbon (ppm)	2.0	1.7	2.6
Organic carbon (ppm)	16.3	13.0	19.4
NO_3-N (μg/L)	2.4	2.9	4.8
PO_4-P (μg/L)	2.4	1.3	3.0
NH_4-N (μg/L)	19.8	13.8	24.6
pH	5.9	5.5	5.5
Alkalinity	10.4	5.7	10.5
Apparent color (PtCo)	118	103	212
BOM (g/sample)	39	46	136
% organic matter in BOM	90.4	92.8	95.0

for plant growth. Watt and Golladay (1999) have suggested that catchment area has an effect on nutrient subsidies and productivity in swamp wetlands. The small basin size of savannas in this study suggests there is little surface runoff introducing nutrients.

Swamps were typified by high BOM standing stocks and dissolved carbon levels, indicating that these wetlands are a heterotrophic system driven by the decomposition of organic matter. The dense canopy of trees in these wetlands not only blocks out sunlight, causing lower water temperatures, but also provides an annual influx of carbon in the form of leaves and wood. This deciduous material leaches and decays, releasing tannins that stain the water black and increases levels of dissolved organic carbon and nutrients. The differences in water chemistry between swamp and savanna wetlands can be attributed to the larger amounts of litterfall and wood inputs in swamp sites.

Macroinvertebrates

We recorded a total number of taxa (121) that is within the range reported by other studies of southern seasonal wetlands. Previous studies have recorded from 27 to 243 taxa (Sklar 1985, McClure 1994, Leslie et al. 1997, Leeper and Taylor 1998). Based on studies in the Carolina bays (e.g., McClure 1994, Leeper and Taylor 1998) it has been suggested that wetlands in the southeastern Coastal Plain support higher invertebrate diversity than other regions (range of 115-243).

Densities of invertebrates we found are on the lower end of the range reported by other studies in southern seasonal wetlands (Haack 1984, Leslie et al. 1997, Golladay et al. 1999). Haack (1984) reported macroinvertebrate densities as low as 442 individuals/m^2 for a Florida cypress slough while others reported densities in southern wetlands >4000 individuals/m^2 (Leslie et al. 1997, Golladay et al. 1999).

In our study, marshes had higher densities and taxa richness than savannas or swamps, which indicates that the dense ground flora serves as an abundant food source and habitat for invertebrates, particularly to invertebrates capable of clinging to emergent vegetation. Trophic diversity of invertebrates is higher in marshes because detritus, as well as algae, are available food sources allowing for detritivory and herbivory by invertebrates. In addition, aquatic vegetation in these sites provides high daily D.O. levels, which is advantageous for most invertebrates.

During early inundation, the invertebrate fauna in all the wetland types was characterized by zooplankton. Zooplankton are planktonic and feed on particles suspended in the water. These filter-feeding taxa most likely have a quick emergence after the dry period so they have the benefit of reproducing before experiencing a heavy mortality by predators. In addition to zooplankton, savanna and swamp wetlands were characterized by detritivores. Watt and Golladay (1999) reported high total litterfall inputs (410 to 582 g m^{-2} yr^{-1}) in swamps, which indicated that there is an abundant food source for detritivores. In the mid- and late hydroperiod, detritivores were no longer dominant in swamp sites, suggesting that these invertebrates could not tolerate late season low D.O. concentrations.

Future interests

All the wetland types are in close proximity on the landscape, yet they each have distinctly different vegetation and soils. Furthermore, no wetlands appear to be in a state of transition, although there are different ages of tree stands in savanna and swamp wetlands. Further research is needed to examine the role of fire (in the uplands and wetlands) and hydrology in these wetlands, as well as location on the landscape. Goebel et al. (1997) found that many limesink wetlands occur in the uplands of the Dougherty Plain and occupy a relatively high topographic position. A topographic

Table 2. Macroinvertebrate density/m^2 and taxa richness for each wetland type as an average of three months.

Wetland type	Density/m^2 (±SD)	Range of taxa richness
Marshes	1057 (± 1195)	9-17
Savannas	765 (± 1030)	7-28
Swamps	546 (± 560)	4-19

gradient may determine separation of wetland types with swamps occurring in drainage areas of low elevation and marshes occurring on high sand ridges (Blood, unpublished). Fire may be instrumental in increasing soil nutrient availability. Marshes in the past may have experienced more frequent and/or intense fires than swamps because soils in swamp wetlands usually are damp except for periods of drought. Present management practices largely exclude fire from entering the wetlands although uplands are burned with a 1-3 year return interval, most likely providing a pulse of nutrient inputs into a wetland with the first rainfall following the burn.

Findings of this study can be used in developing reference criterion for water quality and macroinvertebrate assemblages in undisturbed wetlands in southwest GA. Plans for future research include a comparison of these sites to impacted and restored wetlands to determine if the invertebrate assemblages we found are a valid gauge of a relatively pristine system.

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