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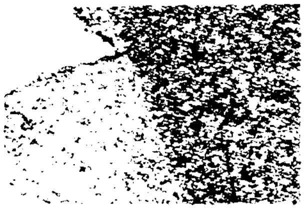

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INFLUENCES OF SUBMERSED AQUATIC MACROPHYTES ON ZONATION OF SEDIMENT ACCRETION AND COMPOSITION, EAU GALLE RESERVOIR, WISCONSIN

by

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Sediment accretion and composition were examined in vegetated and nonvegetated regions across all depths in Eau Galle Reservoir, Wisconsin. Within riverine areas, delta formation was observed. In the lacustrine area of the reservoir (i.e., nonriverine), both sediment accretion and moisture content decreased while sediment density increased, along a gradient of decreasing depth between 9 and 2.5 m. However, accretion again increased at shallower depths (<2.5 m) occupied by submersed macrophytes.

Based on differences in sediment accretion and composition, four zones of sediment accretion were distinguished in the lacustrine area: an accumulation zone (>6 m), a transport zone (3.5 to 6 m), an erosional zone (2.5 to 3.5 m), and a vegetated littoral zone (<2.5 m). Low-density sediments with relatively high organic matter and nutrient concentrations were found in both the littoral and accumulation zones, while high-density sediments with low organic matter and nutrient concentrations were found in the erosional zone.

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Dispersion of sediment from pans placed in the littoral zone was greatest during vernal mixing, when macrophyte biomass was low. Sediment dispersion decreased substantially as macrophytes grew, and remained low during autumnal overturn, when macrophyte standing crop was near peak biomass. Sediment dispersion was high throughout the study in the nonvegetated erosional zone.

Marked differences in sediment composition between the littoral and erosional zones, and the occurrence of high rates of sediment accretion in the littoral zone, suggest that submersed macrophytes have been influential both in reducing sediment erosion and promoting sediment accretion in the shallow regions of Eau Galle Reservoir.

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Accretion
Littoral zone
Macrophytes
Profundal zone
Sediment composition
Sediment erosion
Sediment focusing
Zones of sediment accretion

Preface

The work reported herein was conducted as part of the Aquatic Plant Control Research Program (APCRP). The APCRP is sponsored by the Headquarters, US Army Corps of Engineers (HQUSACE), and is assigned to the US Army Engineer Waterways Experiment Station (WES) under the purview of the Environmental Laboratory (EL). Funding was provided under Department of the Army Appropriation No. 96X3122, Construction General. The APCRP is managed under the Environmental Resources Research and Assistance Programs (ERRAP), Mr. J. L. Decell, Manager. Mr. Robert C. Gunkel was Assistant Manager, ERRAP, for the APCRP. Technical Monitor during this study was Mr. James W. Wolcott, HQUSACE.

The study was conducted and the report prepared by Mr. William F. James and Dr. John W. Barko of the Aquatic Processes and Effects Group (APEG) of the EL. Mr. Patrick Bradley, Ms. Bambi Fulton, Ms. Yvonne Hartz, Mr. Robert Kuta, Ms. Karne Mueller, Ms. Bobby Nelson, and Mr. Roger Olewinski of the APEG assisted in collection of sediment cores. Ms. Gail Bird and Mr. Harry Eakin of the APEG provided chemical analyses of the sediment core sections. Technical reviews of the report were provided by Drs. Douglas Gunnison, Thomas L. Hart, and William D. Taylor and Ms. Dwilette G. McFarland of the APEG. Additional anonymous technical reviews were provided by individuals assigned by Dr. Robert G. Wetzel, North American Editor, for the journal *Archiv für Hydrobiologie*. The report was edited for publication by Ms. Jessica S. Ruff of the WES Information Technology Laboratory.

The investigation was conducted under the general supervision of Dr. John Harrison, Chief, EL, and Mr. Donald L. Robey, Chief, Ecosystem Research and Simulation Division, and under the direct supervision of Dr. Thomas L. Hart, Chief, APEG.

COL Larry B. Fulton, EN, was the Commander and Director of WES. Dr. Robert W. Whalin was Technical Director.

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Contents

INFLUENCES OF SUBMERSED AQUATIC MACROPHYTES ON ZONATION OF SEDIMENT ACCRETION AND COMPOSITION EAU GALLE RESERVOIR, WISCONSIN

Introduction

1. It has long been known that sediment accretion is not uniformly distributed within a lake basin. Accretion is often greater in deeper areas than in shallow areas of lakes due to basin morphometry and other factors that influence the distribution of sediment (Håkanson 1977; Evans and Rigler 1980, 1983; Hilton 1985). Focusing of sediment into deep basins (Likens and Davis 1975) and variations in the physical and chemical composition of surficial sediment (Kamp-Nielson and Hargrave 1978) have been attributed to differences in water movement between shallow, high-energy regions and deeper, low-energy regions of lakes that create erosional and depositional environments (Håkanson 1977).

2. Little is known about sediment accretion and composition patterns in areas of lakes extensively colonized by aquatic macrophytes. Sedimentation of macrophyte and periphyton remains (Godshalk and Wetzel 1984, Moeller and Wetzel 1988) and interception of suspended sediment by macrophytes (Wetzel 1979, Gregg and Rose 1982, Madson and Warncke 1983) may result in greater accretion of sediment than would be expected in shallow, potentially erosional environments.

3. Macrophytes may also play a role in reducing the erosion of sediment by redirecting water currents (Fonseca et al. 1982). In addition, sediment accretion in the littoral zone needs to be considered as a potentially important mechanism in replenishing nutrient pools depleted by rooted submersed macrophytes (Carignan 1985; Barko et al. 1988; Barko, Gunnison, and Carpenter, in press) and possibly expanding the sediment surface area colonizable by aquatic macrophytes (Carpenter 1981, 1983).

4. This study examined the distribution and composition of sediment in vegetated as well as nonvegetated regions; specific zones of erosion and accumulation in Eau Galle Reservoir, Wisconsin, were identified. The study results indicate that submersed macrophytes have altered the sediment accretion and composition patterns in shallow regions of this reservoir.

Materials and Methods

Study site

5. Eau Galle Reservoir is a small (0.6-km^2) US Army Corps of Engineers impoundment located in west-central Wisconsin. Initially flooded in 1969, the reservoir has mean and maximum depths of 3.2 and 9 m, respectively. Over 60 percent of the reservoir is less than 4 m deep (Figure 1). The deep central area of the reservoir was created as a borrow pit from which the dam was constructed. The bottom slopes most steeply at the dam face and around the central basin of the reservoir between the 4- and 6-m depth contours.

6. Mostly submersed littoral vegetation is distributed irregularly around the perimeter of the reservoir (Figure 2), with densities reaching 500 g dry mass m^{-2} in some areas (Filbin and Barko 1985). *Ceratophyllum demersum* L. and *Potamogeton* spp. are the dominant species. Plant densities are greatest near the mouths of streams, in bays, and along the northern and eastern shorelines. Submersed macrophytes do not grow along the dam face due to the steep slope and submerged riprap (large cobbles). Elsewhere, submersed macrophytes are restricted by light to depths less than about 2.5 m (Barko, unpublished data). Mean Secchi depth is 1.26 m, based on 8 years of measurements (Barko et al. 1990).

7. The reservoir receives high external and internal phosphorus loads and exhibits excessive phytoplankton growth, moderate alkalinity (range = 1.8 to 4.2 meq ℓ^{-1}), and hypolimnetic anoxia in summer (Barko et al. 1990). The Eau Galle River drains a predominantly agricultural watershed (166 km^2) and provides 80 to 90 percent of the reservoir's gaged water income. The reservoir overturns in spring and autumn, stratifies during the summer and winter, and is covered by ice from November until April.

Evaluation of spatial patterns of sediment accretion and composition

8. Sediment cores were collected under the ice in 1987 and 1988 at 50-m intervals along transects that either radiated from the center of the reservoir to the shoreline or ran perpendicular to the western shoreline near the mouth of the Eau Galle River (Figure 1). Additional cores were collected at closer intervals (25 m or less) along relatively steep depth gradients and in vegetated areas of the reservoir. In total, 150 sediment cores were collected from the reservoir during the two periods of ice cover.

9. A Wildco KB Sediment Core Sampler (Wildco Wildlife Supply Company), fitted with a plastic core liner (5.08-cm inside diameter, 50.8- or 91.4-cm length), was used to collect samples. Each core sample was sectioned at 5-cm intervals until preimpoundment soil was encountered. This material (distinctly different from the aquatic sediment) consisted of hard clays, sands, pebbles, and roots and was characterized as having a moisture content of less than about 30 percent.

10. Each core section above the preimpoundment soil was weighed immediately for moisture content determination, and then dried to a constant weight at 105° C (Håkanson 1977). Sediment density was calculated as the dry mass divided by the volume of each core section. Average sediment accretion rates were calculated as the dry mass of sediment accreted above preimpoundment soil divided by the cross-sectional area of the core liner and the reservoir age (18 years).

11. Concentrations of organic matter in each core section were determined by loss on ignition at 550° C (American Public Health Association (APHA) 1985). Analyses of total nitrogen (N) and phosphorus (P) concentrations in core sections were performed colorimetrically using Technicon Auto-Analyzer II procedures (APHA 1985) following digestion with sulfuric acid, potassium sulfate, and red mercuric oxide (Plumb 1981). Concentrations of total iron, total manganese, and total calcium were determined by atomic absorption spectrophotometry after digestion with nitric acid (Plumb 1981). Sediment elemental concentrations were calculated as the sum (over core sections) of elemental mass divided by the sum (over core sections) of dry mass of accreted sediment for each sediment core. Statistical analyses were performed using the Statistical Analysis System (SAS 1985).

Evaluation of sediment erosion

12. A related study was conducted in 1988 to examine seasonal variations in the dispersion of sediment at a shallow (1-m) vegetated site and a deeper (3-m) nonvegetated site. Bulk quantities of sediment (characterized as having a moisture content of >75 percent and a sediment density <0.30 g ml^{-1}) were collected with a ponar sediment sampler from a shallow vegetated area of the reservoir. The sediment was screened (7- by 7-mm mesh) of large debris and homogenized by manual stirring. A known mass of wet sediment was placed into 15 sediment dispersion pans measuring 6 by 23 by 32 cm. These pans were filled to within 1.5 cm of the top. Six of the pans were dried immediately at

105° C to a constant weight to determine a dry mass conversion factor. Three pans filled with fresh wet sediment were deployed at each station.

13. The pans were secured to a metal tubing frame that held the pans approximately 5 cm above the sediment to prevent contamination from disturbance of the bottom sediments during pan placement. Each sediment-filled pan was sealed with a lid before deployment, then carefully placed onto the frame using SCUBA. Lids were removed 15 min after deployment to allow settling of any sediment disturbed during the placement process.

14. Three additional sediment-filled pans were subjected to the same deployment procedure, then dried to a constant weight at 105° C to determine a correction factor for potential sediment loss from pans during placement and retrieval. Less than 3 percent was lost from any single pan during all deployment periods. Pans were resealed with lids before retrieval (2- to 3-week deployment interval) to prevent loss of material. Apparent sediment dispersion was calculated as the percent sediment lost from pans divided by the area of the pans and days of deployment.

Results

Zonation of sediment accretion and composition

15. Pronounced variations in sediment accretion rates were observed within the reservoir (Figure 2). Accretion was maximal at the mouth of the Eau Galle River (e.g., areas 2D and 3D) and the streams (e.g., areas 8C and 11G) where river delta formation occurs. Accretion was also high (7 to 22 kg m^{-2} $year^{-1}$) in the deep central area of the reservoir. Steep accretion gradients (0.5 to 12 kg m^{-2} $year^{-1}$) were observed between the 3.5- and 6-m depth contours. Accretion minima (0.4 to 2 kg m^{-2} $year^{-1}$) were observed just beyond the maximum depth of submersed macrophyte colonization (e.g., areas 2C, 6D, 8E, and 3J), and at intermediate depths located near the western shoreline (e.g., 5F) and the dam (e.g., 7J).

16. In most vegetated areas of the reservoir, accretion was higher than in nearby nonvegetated areas (0.7 to 5 kg m^{-2} $year^{-1}$). Lower accretion was observed along the exposed northern and eastern shorelines where wave action is often vigorous (e.g., areas 2A, 1C, 7C, and 9E). Sediment accretion in the lacustrine area (i.e., excluding riverine areas) of the reservoir was directly

related overall to depth (Figure 3a). Accretion decreased to a minimum near the 2.5-m depth, and then increased in the vegetated region.

17. To examine sediment accretion patterns in a depth-weighted fashion, accretion rates were divided by depth to normalize for differences in the volume of water and, thus, mass of particles that can potentially settle to the sediment surface. Depth-weighted accretion exhibited a pattern similar to unweighted accretion (Figure 3b). However, many vegetated sites exhibited depth-weighted rates that were greater than those observed in the deepest area of the reservoir.

18. Moisture content of the surficial sediment (0 to 5 cm) was high in the deepest areas of the lake, declined with decreasing depth to a minimum near the 2.5-m depth, then increased within vegetated sites (Figure 3c). In general, moisture content in the vegetated region was lowest near shoreline areas and near the outer edge of the macrophyte beds. At intermediate vegetated depths (1 to 2 m), moisture content was similar to values observed in the deep central basin. Density of the surficial sediment was inversely related to moisture content for all sediment cores ($r^2 = -0.85$; $p < 0.05$), and therefore exhibited a trend opposite to that of moisture content (Figure 3d).

19. In nonvegetated areas of the reservoir, sediment accretion and the physical composition of sediment (i.e., moisture content and density) were highly correlated with depth (Table 1, Figure 3). In contrast, vegetated areas showed no significant relationships ($p > 0.05$) between accretion or physical sediment composition and depth (Figure 3). Thus, when all lacustrine sites (vegetated and nonvegetated) were combined, the coefficients were much weaker (Table 2), particularly for physical sediment composition and depth-weighted accretion versus depth.

20. Moisture content from Eau Galle Reservoir (Figure 3c) was used in conjunction with Håkanson's (1977) relationships between moisture content and energy environments to identify three regions of sediment accretion in the nonvegetated lacustrine areas of this reservoir. Håkanson (1977) used a moisture content of >75 percent to distinguish regions of sediment accumulation from transport and a moisture content of <50 percent to identify regions of sediment erosion.

21. Using regression analysis of depth versus moisture content (depth = percent moisture content (0.1169) - 2.4409; $p < 0.0001$; $r^2 = 0.52$), the regions of sediment accretion were identified as follows: an accumulation zone (moisture content >75 percent), located between the 6- and 9-m depths; a

transport zone (moisture content 50 to 75 percent, located between the 3.5- and 6-m depths; and an erosional zone (moisture content <50 percent) located at depths between 2.5 and 3.5 m within nonvegetated areas. Because of the unique physical and chemical characteristics of vegetated sediment (see below), a fourth zone of lacustrine sediment accretion was identified--the littoral zone, comprising all sites occupied by submersed macrophytes (0 to 2.5 m).

22. Mean values of sediment accretion, thickness (after 18 years of impoundment), and composition indicated that the littoral zone exhibited patterns differing greatly from those to be expected on the basis of depth alone (Table 3). Accretion, thickness, and depth-weighted accretion rates were significantly higher in the littoral zone than in the erosional zone. Relatively high moisture content, low sediment density, and high organic matter content paralleled high sediment accretion in the littoral zone. In contrast, low moisture content, high sediment density, and low organic matter content of erosional zone sediments reflected the action of erosional forces. In general, elemental concentrations (with the exception of iron) were higher in the littoral than in the erosional zone, and comparable to values measured in the transport zone. In particular, sediment calcium concentrations in the littoral zone were significantly greater than elsewhere in the reservoir.

Sediment erosion in reservoir shallows

23. Marked differences in the dispersion of sediment, measured from pans, were observed between the littoral (1-m) and erosional (3-m) zones (Figure 4). Sediment dispersion was generally much greater in the erosional zone than in the littoral zone throughout the investigation. Sediment dispersion in the erosional zone was high during vernal overturn in May, then declined in late June and early July, during stratification. In the littoral zone, dispersion was greatest in May, coinciding with both vernal overturn and a period of low macrophyte biomass. Dispersion decreased substantially in the littoral zone during the summer, coincident with an increase in macrophyte biomass. In particular, sediment gains, rather than losses, in the dispersion pans were observed in the littoral zone during July.

24. During the period of autumnal overturn (September), the littoral and erosional zones exhibited opposing patterns of sediment dispersion. In the erosional zone, sediment losses increased to a maximum during overturn. In the littoral zone, however, sediment gains, rather than losses, occurred

during this period. Macrophyte biomass was maximal in September, suggesting that it influenced sediment dispersion in the littoral zone at the time.

Discussion

25. In Eau Galle Reservoir, measurements of both sediment accretion and composition indicate the existence of distinct zones of erosion, transport, and accumulation positioned along a gradient in water depth in nonvegetated lacustrine regions. Accretion of sediment has been minor in relatively shallow areas (<3.5 m), except in the presence of vegetation (littoral zone) and near the mouths of tributaries (riverine zone).

26. As in this investigation, others have generally found a linear decrease in accretion with decreasing depth (e.g., Evans and Rigler 1980, 1983). However, with vegetated sites included (littoral zone) in our correlation analyses, relationships between accretion and depth became weaker (Table 2), due to greater accretion occurring at shallow depths occupied by submersed macrophytes. Accretion minima occurred in erosional areas just beyond the macrophyte beds, where sediment composition was markedly different than that in the littoral zone. Lower rates of sediment loss from the littoral zone, as compared to the erosional zone, are suggested by both the higher moisture content and lower sediment density of littoral deposits, indicating sediment accumulation in this area.

27. To explain the marked differences in sediment accretion and composition observed in the shallow regions of Eau Galle Reservoir, possible mechanisms of erosion and sediment retention need to be considered. Håkanson (1977) suggested that slope plays an important role in the erosion of sediment. However, there was no significant correlation between slope and accretion, nor were there significant differences in slope at different depths in the shallow regions of Eau Galle Reservoir. Slope was <10 percent at all stations less than 4 m, suggesting that slumping or sliding (Hilton, Lishman, and Allen 1986) played a minor role as an erosional mechanism.

28. Hilton, Lishman, and Allen (1986) identified several possible mechanisms for erosion of sediment. Of these, intermittent complete mixing (during periods of overturn) and wind-driven epilimnetic mixing/metalimnetic migration (during the stratified period) appear to be the most plausible mechanisms of erosion in Eau Galle Reservoir.

29. Gaugush (1984) and James, Kennedy, and Gaugush (1990) have shown that the reservoir exhibits frequent periods of thermal instability and extensive mixing due to the passage of cold fronts and high wind power during the summer. During these periods, the thermocline has been shown to migrate from the 2.5-m depth to as deep as the 6-m depth. Resuspended metalimnetic shelf sediments could be transported to deeper areas as a result of these wind-driven circulation patterns and possibly by the stress-drop jet (Bryson and Bunge 1956), which is a rapid current reversal occurring at the thermocline when high wind power ceases. Expansion of the epilimnion and mixing during overturn in spring and autumn may similarly cause resuspension and transport of metalimnetic sediments. However, these mixing processes do not adequately explain the nearly complete erosion of sediments at intermediate, nonvegetated depths with much less erosion at shallow, vegetated depths.

30. The presence of submersed macrophytes appears to be very important in explaining the different sediment accretion and composition patterns observed in the shallow areas of Eau Galle Reservoir. Submersed macrophytes can reduce erosion and promote accretion by reducing and/or redirecting water circulation patterns (Fonseca et al. 1982; Gregg and Rose 1982; Madson and Warncke 1983). As in Eau Galle Reservoir, Moeller and Wetzel (1988) reported that sediment accretion rates were high within the littoral region and declined to a minimum just beyond submersed macrophyte beds, before increasing again in the deeper profundal region. In contrast, very little sediment accretion has been shown to occur at shallow depths in lakes where aquatic vegetation is sparse (Davis and Ford 1982, Moeller and Wetzel 1988). These differing patterns strongly suggest that submersed macrophytes influence sediment accretion.

31. Indirect evidence for the effects of submersed macrophytes on sediment erosion in Eau Galle Reservoir was provided by sediment dispersion pans. In the littoral zone, it was observed that apparent sediment dispersion was high during vernal overturn, when macrophyte biomass was visibly low, suggesting sediment transport to deeper areas. During summer stratification and autumnal overturn, however, sediment dispersion was markedly reduced in the littoral zone, when macrophytes were near or at peak biomass. In contrast, sediment dispersion was high in the erosional zone throughout the study, particularly during vernal and autumnal overturn.

32. We do not know with certainty the origin of sediment gains in pans or the extent of sediment removal from specific regions of the reservoir based

on dispersion pan measurements. However, qualitatively different patterns of sediment dispersion from pans between the littoral and erosional zones were consistent with sediment compositional differences nearby, indicating that macrophytes have reduced erosion of sediment from the littoral zone. The ability of macrophytes to overcome sediment erosion may be a very important factor in net sediment accumulation in the littoral zone.

33. Differences in sediment composition between the littoral and erosional zones suggest that submersed macrophytes have been influential in modifying the sedimentary environment of the littoral zone in Eau Galle Reservoir. The preimpoundment soils of this reservoir were composed primarily of gravelly, sandy subsoils that were uniformly distributed throughout both shallow and deep regions, as a result of the removal of top soils during reservoir construction (US Army Engineer District, St. Paul 1976). Through time, however, enhanced accretion of organic matter, nitrogen, and phosphorus has occurred in the littoral zone relative to the erosional zone. In addition, concentrations of calcium were greatest in the littoral zone relative to other zones, suggesting that metabolic activities of macrophytes may have induced calcium carbonate precipitation (e.g., Otsuki and Wetzel 1972; Murphy, Hall, and Yesaki 1983) in this moderately alkaline reservoir.

Conclusions and Recommendations

34. In this investigation, direct comparisons of accretion and sediment dispersion could not be made between vegetated and unvegetated regions located at the same depth, because submersed macrophytes occupied nearly the entire colonizable area of Eau Galle Reservoir between the 0- and 2.5-m depths. Despite this limitation, however, it is apparent from core data that the submersed macrophyte community of this reservoir has significantly increased rates of sediment accretion in areas otherwise subject to erosional forces. It is recommended that, in future studies, quantitative seasonal measures of sediment accretion and dispersion be attempted at several depths in both vegetated and unvegetated regions to elucidate the seasonal patterns of sediment transport and accretion influenced by aquatic macrophytes.

35. Accretion and retention of sediment and associated nutrients have important implications for nutrient cycling and macrophyte growth in the littoral zone of aquatic systems. Accretion of predominantly fine-grained sediment with a high nutrient content can be expected to stimulate macrophyte

production rates, as potential nutritional deficiencies (due to plant uptake) are overcome. Sedimentation results in reduced reservoir volume, thereby contributing to the expansion of reservoir shallows with a concomitant increase in the area of the littoral zone. These processes collectively contribute to increased areal distribution of aquatic macrophytes, and may also result in shifts in macrophyte community composition as floating-leaved and emergent forms of vegetation assume dominance. In addition to exacerbating aquatic macrophyte problems, increased rates of sediment accretion can also be expected to contribute to elevated rates of lake and reservoir aging.

36. To minimize problems associated with sediment accretion in littoral zones, it is recommended that "in-lake" and watershed disturbances that may contribute to sediment suspension and transport be avoided. Such practice may be impractical in most reservoirs, because they focus inputs from typically large watersheds that are difficult to manage. Macrophyte control activities that result in localized sediment disturbance and resuspension, such as dredging, drawdown, underwater rototilling, and some forms of harvesting, may need to be evaluated as to their effects on patterns of sediment accretion in the littoral zone.

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Table 1

Pearson Correlation Coefficients (r) for Sediment Accretion Rates and Physical Characteristics at Nonvegetated Lacustrine Sites

Variable	Accretion	Weighted Accretion	Moisture Content	Sediment Density
Depth	0.90*	0.74*	0.72*	-0.60*
Accretion		0.94*	0.73*	-0.62*
Weighted accretion			0.75*	-0.66*
Moisture content				-0.92*

Note: Asterisks indicate significant correlations at the 5-percent level or less.

Table 2

Pearson Correlation Coefficients (r) for Sediment Accretion Rates and Physical Characteristics, Vegetated and Nonvegetated Lacustrine Sites

Variable	Accretion	Weighted Accretion	Moisture Content	Sediment Density
Depth	0.86*	-0.09	0.35*	-0.28*
Accretion		0.32*	0.47*	-0.39*
Weighted accretion			-0.21*	-0.19*
Moisture content				-0.92*

Note: Asterisks indicate significant correlations at the 5-percent level or less.

Table 3

Mean (±1 Standard Error) Sediment Accretion Rates, Sediment Thickness, and Physical and Chemical Properties of Sediments of Eau Galle Reservoir

	Zone of Accretion			
Variable	Littoral	Erosional	Transport	Accumulation
Accretion, kg m^{-2} $year^{-1}$	2.35(0.15) c*	0.85(0.13) d	3.59(0.44) b	12.68(0.52) a
Depth-weighted accretion kg m^{-3} $year^{-1}$	1.82(0.15) a	0.36(0.06) c	0.92(0.09) b	1.71(0.06) a
Sediment thickness, cm	8.6(0.6) c	2.4(0.4) d	14.2(1.7) b	43.8(1.8) a
Moisture content, percent	63.8(2.2) b	46.8(2.7) c	66.7(1.3) b	75.7(0.6) a
Sediment density, g/ml	0.41(0.04) b	0.78(0.09) a	0.36(0.02) b	0.23(0.01) c
Organic matter, mg/g	75.8(4.4) b	45.8(4.9) c	91.4(14.0) ab	101.4(1.6) a
Nitrogen, mg/g	13.5(1.0) ab	6.8(0.9) c	11.4(0.6) b	16.0(0.5) a
Phosphorus, mg/g	3.6(0.2) b	2.2(0.2) c	3.9(0.2) b	6.0(0.2) a
Iron, mg/g	23.5(1.3) b	25.2(3.0) b	38.3(4.0) b	35.6(3.5) a
Manganese, mg/g	2.6(0.1) b	1.8(0.2) c	2.6(0.1) b	3.7(0.1) a
Calcium, mg/g	220.1(11.5) a	168.3(18.4) b	167.7(9.8) b	102.7(7.2) c
	N = 55	16	29	32

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* Different letters indicate significant differences at the 5-percent level or less based on Duncan's Multiple Range Analysis.

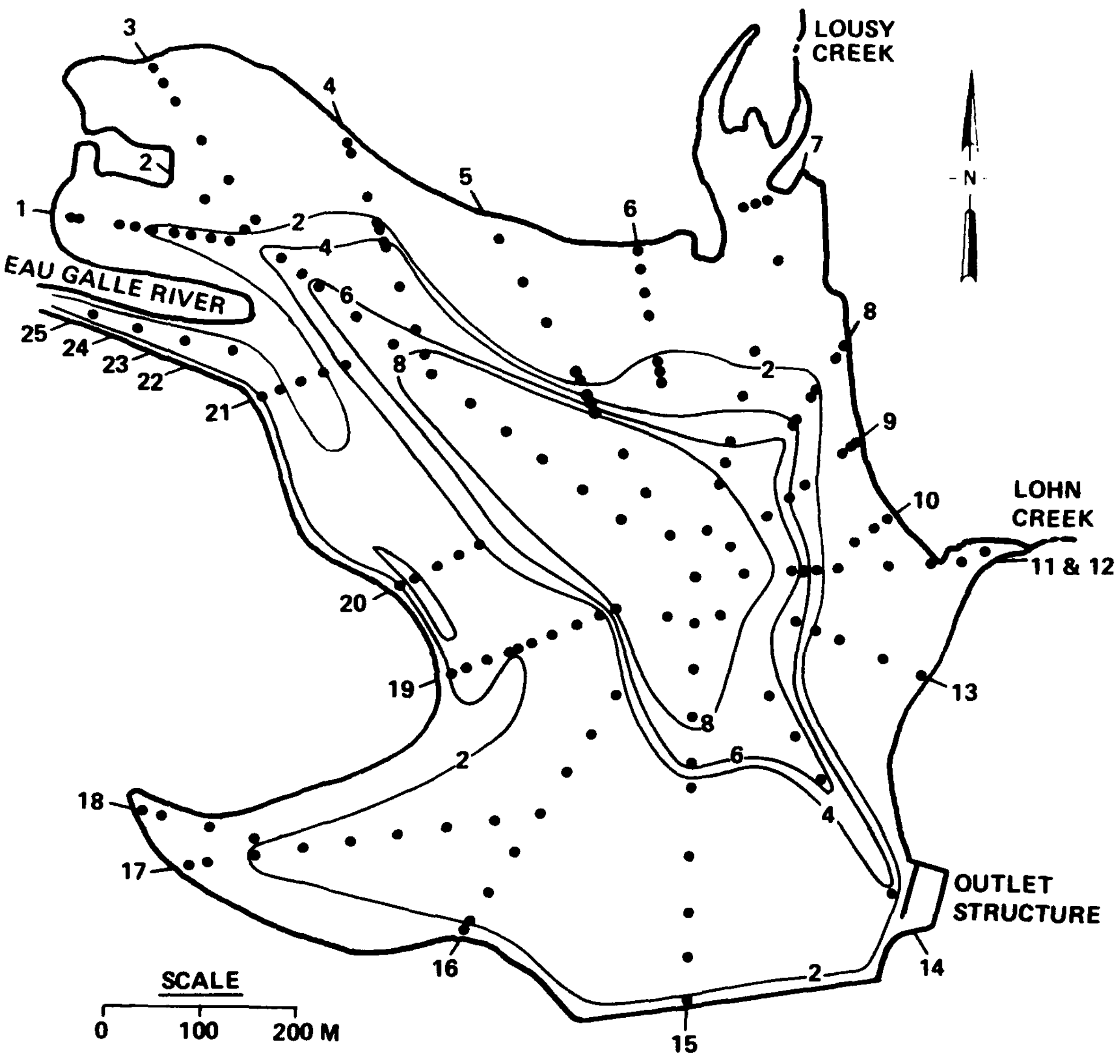


Figure 1. Morphometric map of Eau Galle Reservoir with transect and sampling locations. Contour lines represent depth (meters)

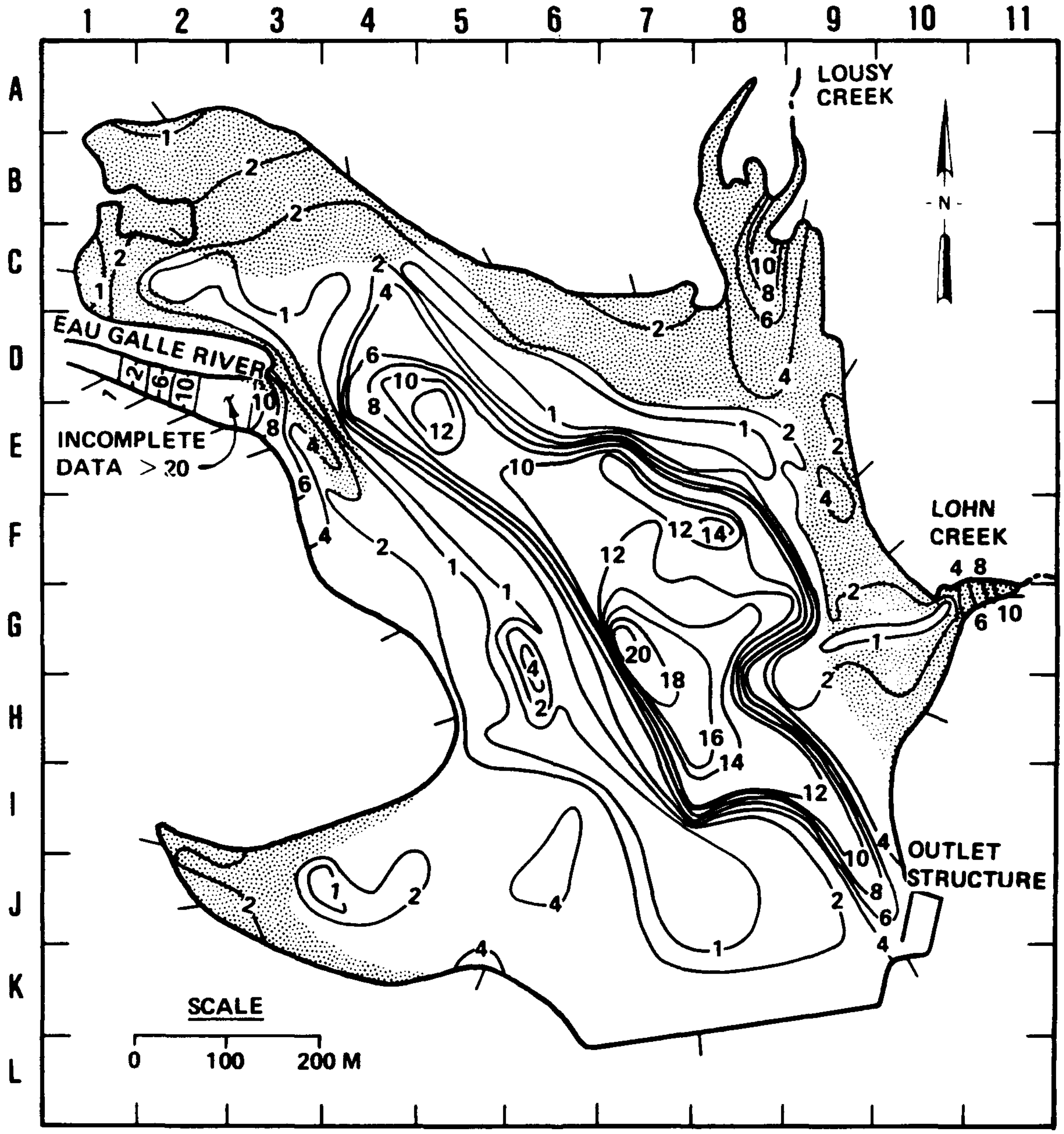


Figure 2. Contour map of spatial variations in sediment accretion rates (kg m^{-2} year $^{-1}$). Shaded area represents regions inhabited by macrophytes

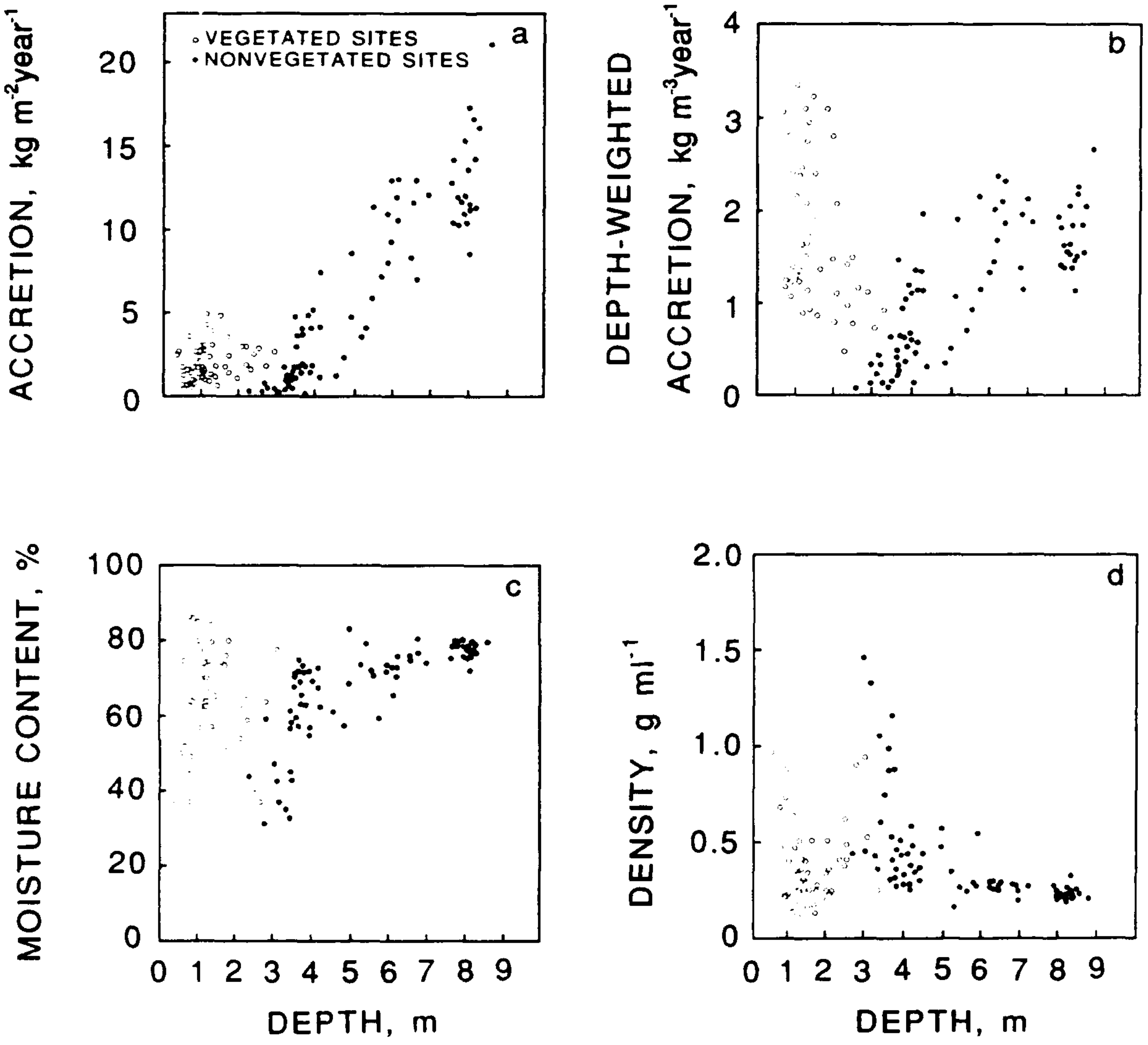
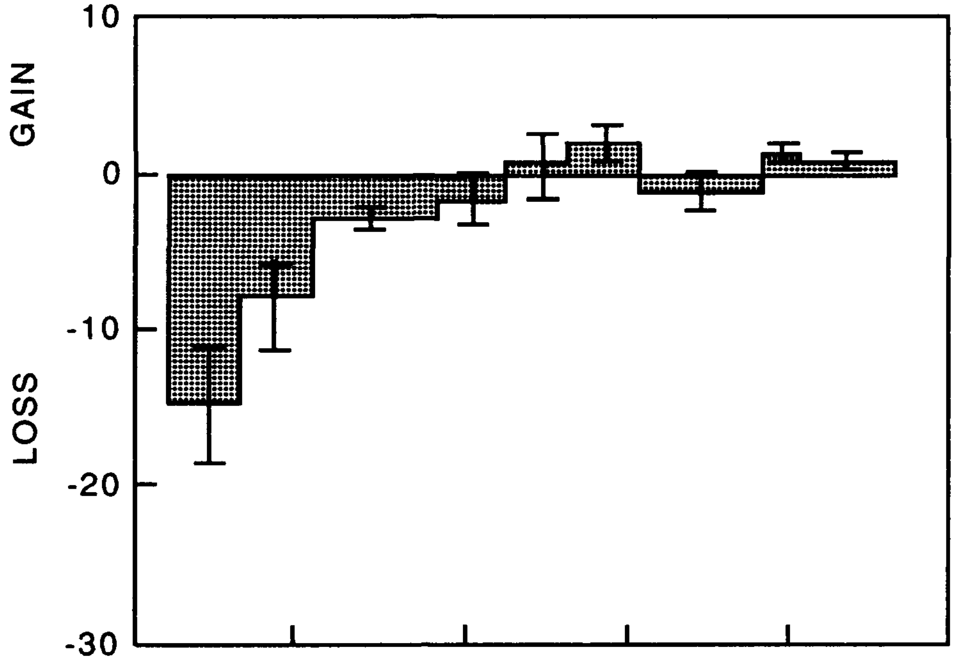
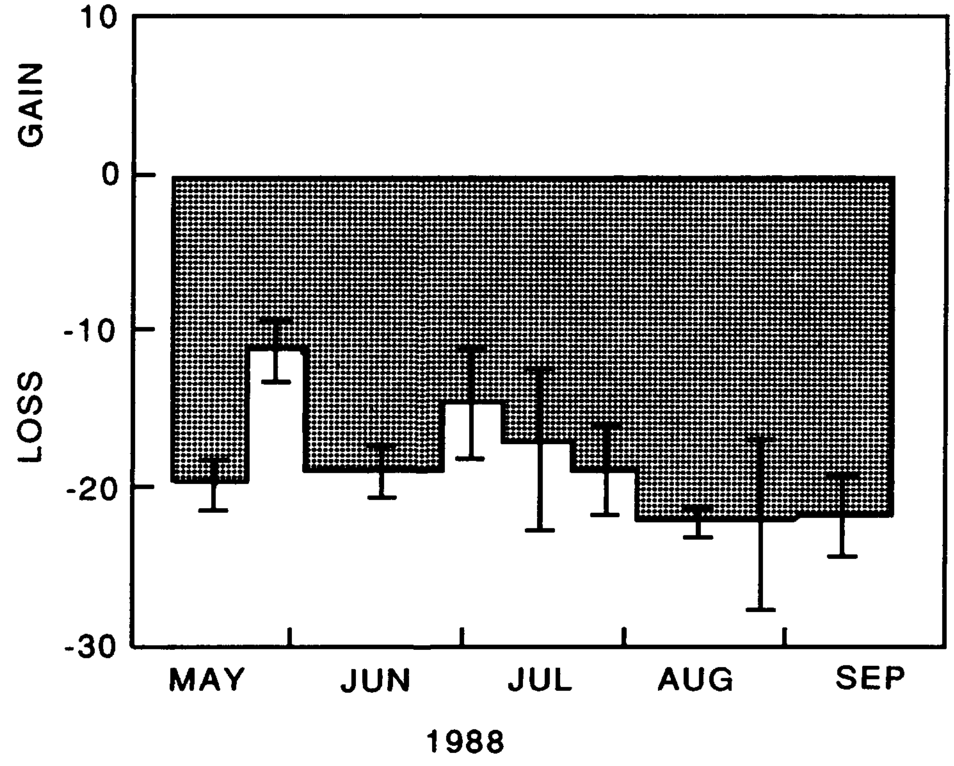


Figure 3. Variations in (a) sediment accretion rates, (b) depth-weighted sediment accretion rates, (c) moisture content of the surficial sediments, and (d) density of the surficial sediments with depth



a. Littoral zone



b. Erosional zone

Figure 4. Means (n = 3) and standard errors for dispersion of sediment from pans placed at 1-m vegetated site and 3-m nonvegetated site