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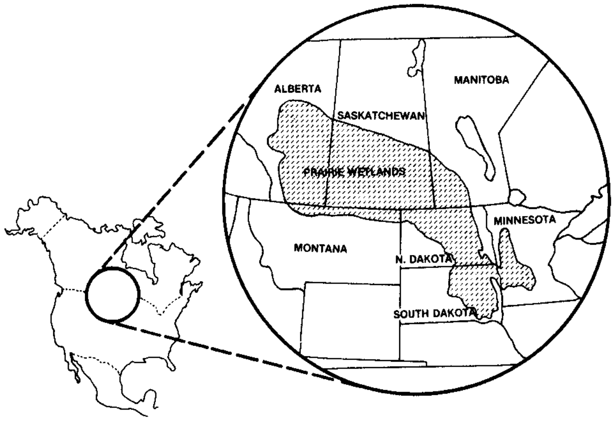

NORTH DAKOTA
RESEARCH REPORT

Soils, Microbiology and Chemistry of Prairie Wetlands: Research Methods and Annotated Bibliography

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Abstract

The broad topics of wetland soils, wetland microbiology, and wetland chemistry are briefly discussed. The author's perceptions of fruitful areas of research are enumerated, and the methods one might employ in the implementation of these research objectives are provided. A selected annotated bibliography details some of the contemporary research being pursued in these fields.

Acknowledgments

I wish to express my sincere appreciation to Dr. Jim Richardson, Mr. Donald Patterson, and Mr. Jim Knuteson of the Department of Soils, North Dakota State University for their editorial comment and advice.

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Introduction

The microbiology, chemistry, and soils of wetlands are intimately interrelated through known and unknown feedback mechanisms. These interrelationships are but one facet of wetland ecology which increasingly has been the focus of investigation by scientists in many fields. The urgency of these investigations is spawned by the unending proclivity to drain this land cover type in favor of some alternative use.

The purpose of this report is to briefly review some of the recent findings of wetland research in the disciplines of microbiology, chemistry, and soils, to enumerate research areas of potential future interest, and to suggest methods and methods development which could be employed in a study of wetlands in the Prairie Pothole Region. An annotated bibliography in these fields is also incorporated. This treatment is not meant to be comprehensive but rather introductory in scope.

Wetland Soils

Waterlogged soils or soils which are ponded are unique in a number of respects. Accretion of sediment to the surface is an important genetic process in the formation of some hydromorphic soils. Pedogenesis is also affected by restrictions upon water movement through the soil. Thus the impetus of soil horizonation differs from that of xeromorphic soil development. Physically, the pore space is occupied by water instead of air, resulting in a lower diffusion rate for gases, e.g., oxygen. This slowed oxygen diffusion rate (ODR) creates anaerobic conditions conducive for the proliferation of a population of facultative and obligate microbes. These bacteria, through the use of electron acceptors other than oxygen for their respiratory oxidations, convert many compounds/elements (e.g., manganese, iron, and sulfates) into a state of chemical reduction.

Literature Review

The ramifications of a ponded condition upon the nitrogen cycle (Fig. 1) have been partially identified through the work of Burford and Bremmer (1975), Patrick and Reddy (1976), and Edwards and Rolley (1965). Burford and Bremmer (1975) found that denitrification in soils under anaerobic conditions is controlled largely by the supply of readily decomposable organic matter, and that analysis of soils for mineralizable carbon or water soluble organic carbon provides a good index of their capacity for denitrification of nitrate. Patrick and Reddy (1976) indicate that where oxygen is absent or limiting, nitrification in flooded soils either does not occur or occurs at a lower rate, resulting in a reduced amount of nitrate available for the denitrification process. From a different perspective Edwards and Rolley (1965) found that consumption of oxygen is not affected by changing the concentration of nitrate, and there is no correlation between oxygen consumption of muds and their organic carbon counts, chemical oxidizability, dehydrogenase activity, or bacterial counts.

The sulfur cycle (Fig. 2) as it exists in freshwater wetlands, e.g., those of the Prairie Pothole Region, is understood even less. Reduction of sulfate to hydrogen sulfide requires extremely low redox (Eh) potentials (Armstrong 1975)—on the order of zero to −190 mV. Anaerobic bacteria of the genus *Desulphovibrio* have been implicated in this reduction (Starkey 1966). The odor of H_2S gas is apparent in these wetlands under certain climatic and seasonal conditions so this chemical transformation appears to be taking place. A project entitled "Dynamics of Sulfur in a Salt Marsh Ecosystem" being conducted by Woodwell et al. at the Marine Biological Laboratory in Woods Hole, Massachusetts, may go far to clarify the chemical and microbiological phenomena associated with the sulfur cycle in wetland soils.

Elements reduced under less stringent anaerobic conditions include iron and manganese. Daniels et al (1961) found that both neutral hues and greenish gray colors appear to be diagnostic for sediments with ferrous-iron content greater than .002 per cent. Collins and Buol (1970) suggest that oxygen-free environments may lead to the formation of manganese oxides with an oxidative state of two for manganese. However, significant manganese reduction does not occur until all free nitrate has disappeared (Takai and Kamura 1966) and concomitantly, the presence of manganese dioxide may delay or prevent iron reduction to the ferrous state. Figure 3 from Armstrong (1975) shows the implications of a decreasing redox (Eh) potential and oxygen level upon the oxidative state of several elements mentioned above.

The inescapable fact is that soil chemistry and soil microbiology are inextricably intertwined in a waterlogged condition. Indeed, this interrelationship is highly dynamic and dependent upon extrinsic factors such as water temperature, nutrient availability, and water chemistry. The potential for basic and applied research in this field of wetland soils is excellent.

Research Recommendations

The following are some of the areas of investigation which need to be addressed particularly in the freshwater wetlands of the Prairie Pothole Region: (1) classification of wetland soils, (2) determination of whether there is a correlation between zones of vegetation (Stewart and Kantrud 1971) and the kind of soil, and (3) examination of mineral transformations and salinity changes as a function of redox potential and water level and the implication of these phenomena in nutrient cycling.

Methods and Methods Development

The standard methods text for soils of the Prairie Pothole Region is the U.S. Soil Salinity Laboratory Handbook No. 60, *Diagnosis and Improvement of Saline and Alkali Soils* (1954). This volume addresses the subjects of Ca, Mg, K and Na exchangeable and soluble cation methods as well as sulfate and bicarbonate analysis. Redox potential (Eh) measurements are based upon polarography and use a non-attackable platinum microelectrode (Lemon and Erickson 1952). Determination of total carbon, total iron, carbonates, and other elements/compounds would depend on the research objectives.

Method development is needed to preserve the chemically reduced environment subsequent to sample extraction. Maintenance of "*in situ*" conditions is essential for accurate laboratory analysis. Several coring devices have been described (Swanson 1978; Baker et al 1977; Muckereth 1969). Modification of this hardware to accommodate the need for air-tight transport is a possibility.

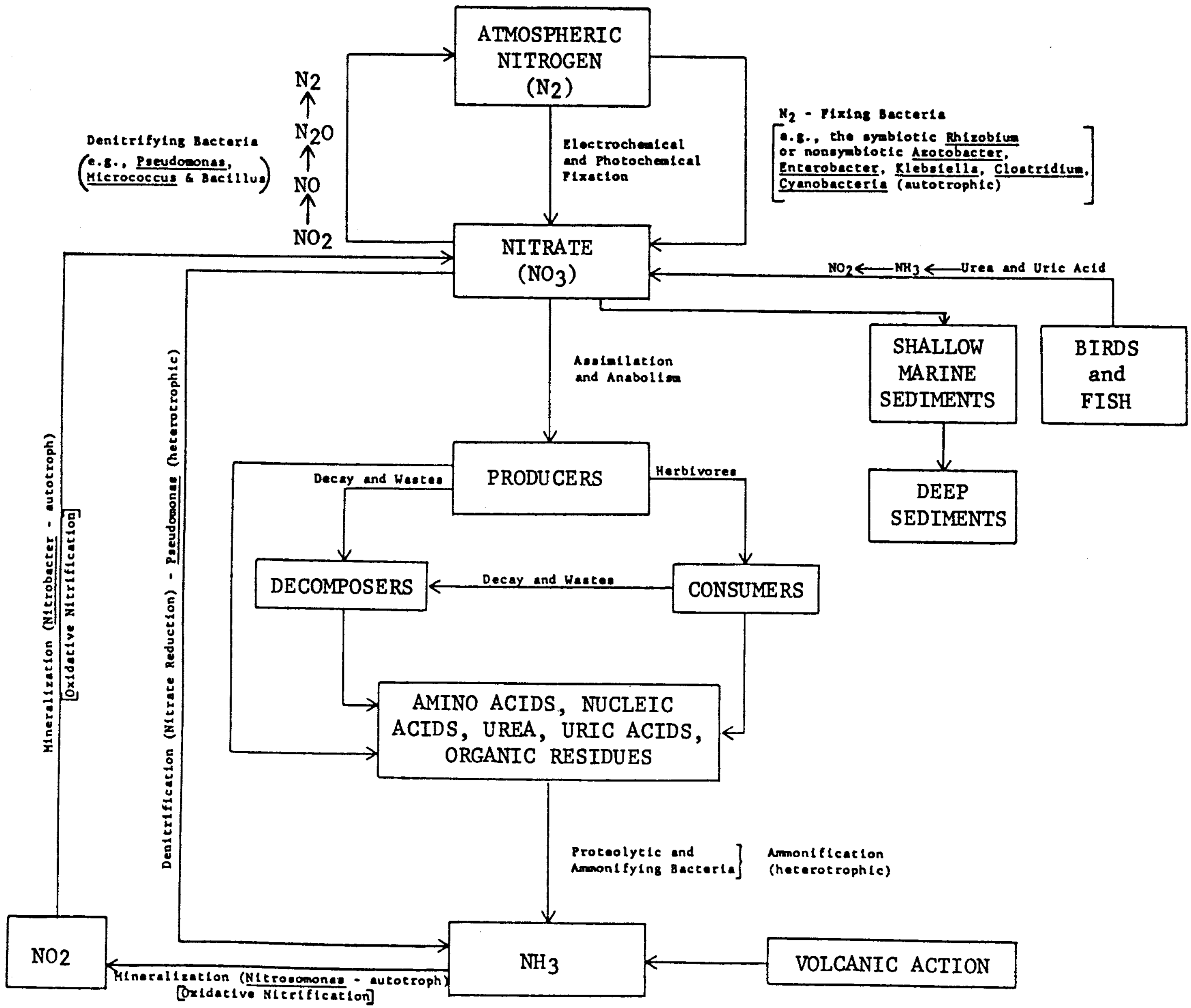

Figure 1. The Nitrogen Cycle

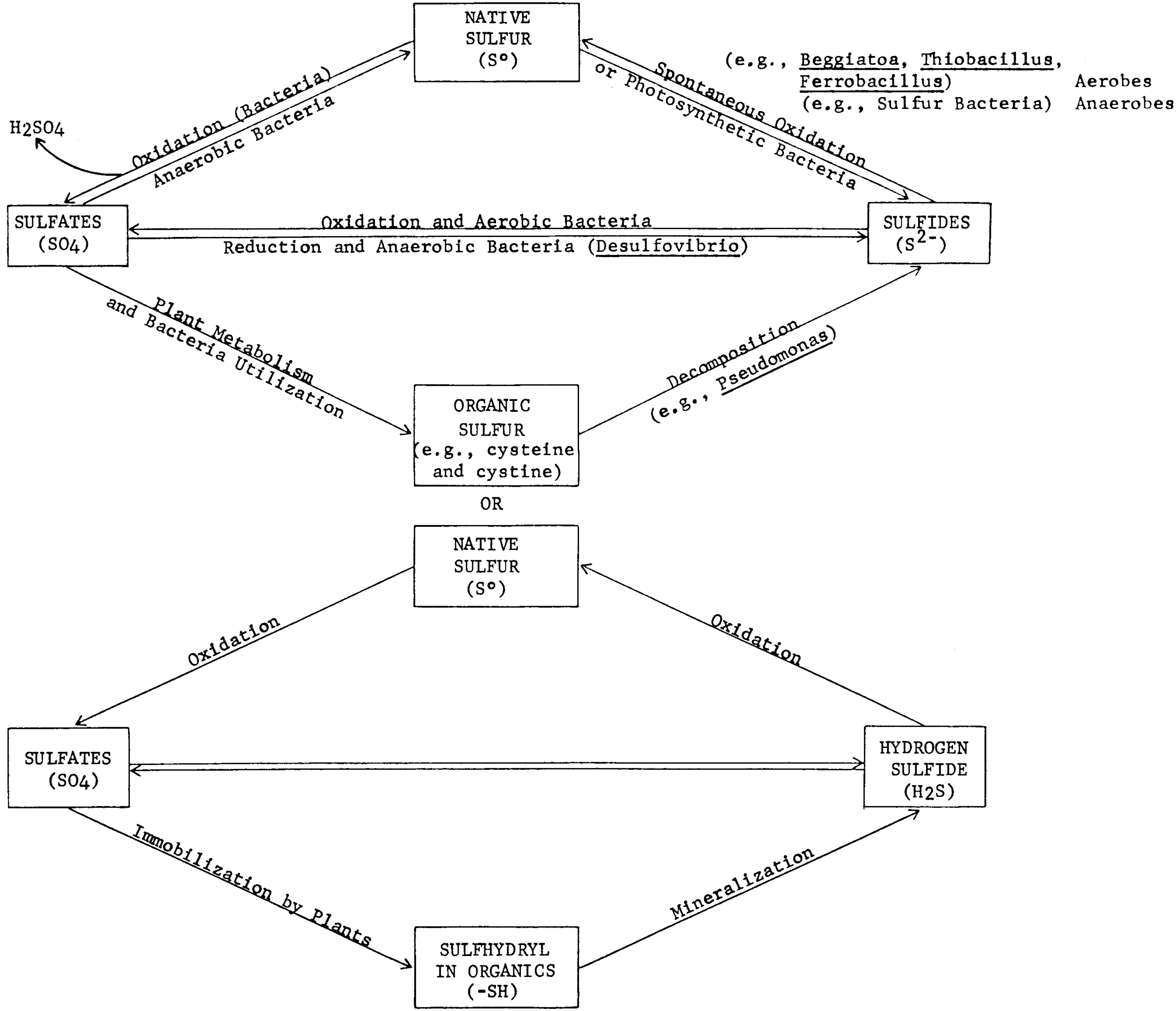

Figure 2. The Sulfur Cycle

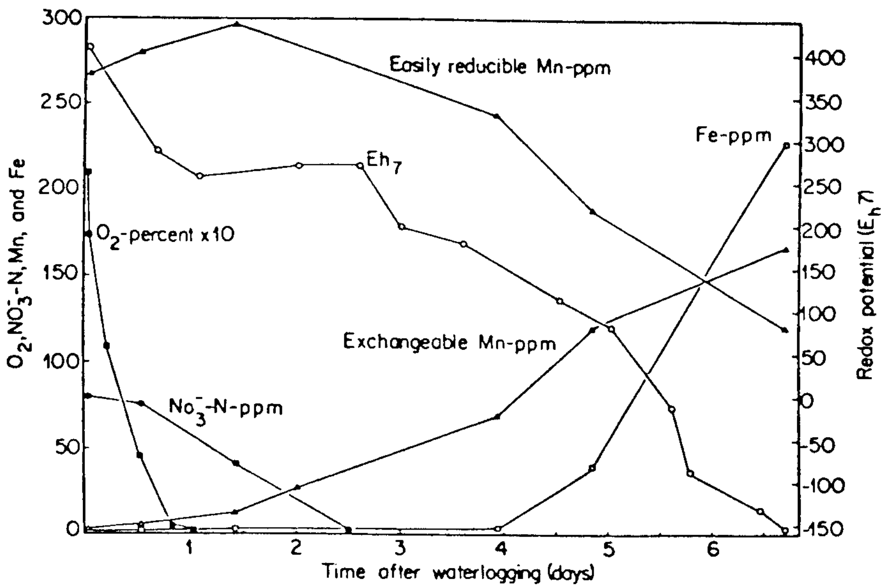

Figure 3. Changes in oxygen, nitrate, manganese, iron, and redox potential of a silty clay after waterlogging.

SOURCE: Armstrong, W. 1975. Waterlogged soils. Page 191 *in* J. R. Etherington, Environment and Plant Ecology, John Wiley and Sons, New York.

Wetland Microbiology

Central to the functioning of the wetland ecosystem is the decomposition of plant and animal tissue into component nutrients. The mineralization allows reuse of this nutrient pool primarily by autotrophic organisms—plants. The so-called "nutrient cycle" is completed. Nitrogen fixation, the process whereby nitrogen is transformed into forms usable by plants, is the other primary ecological task performed by bacteria. The earlier discussion concerning the role of bacteria in the chemical transformations in waterlogged soil suggests other equally significant contributions by this group.

The nuances of variable water chemistry, soil depth, length of inundation, and "mixing" through wave action contribute to a highly dynamic environment. Bacterial populations in wetland soils and water will fluctuate both in numbers and composition depending on a wide range of biotic and abiotic factors. This dynamism is a source of obfuscation when attempts are made to unravel the interrelationships between elemental transformations and bacteria.

Literature Review

Decomposition is a two step process. First there is hydrolytic breakdown of large organic polymers, the major parts of plant and animal tissue, into compounds of low molecular weight. Secondly, nonhydrolytic breakdown occurs resulting in small organic molecules (mineralization) (Sorokin and Kadota 1972).

Allen (1971) found that epiphytic algal and bacterial relationships with macrophytes may be an important source of dissolved organic materials and extracellular metabolites and thus may help to sustain high levels of primary productivity and chemo-organotrophy in lakes. In this same vein, bacteria were assessed as important contributors to the cycling of carbon in the Pamlico River estuary (Crawford et al 1974), and carbon metabolism seemed to be positively influenced in *Spartina alterniflora* by the presence of bacteria (Fallon and Pfaender 1976).

Rates of decomposition have been examined in several recent studies. Carpenter and Adams (1979) found that laboratory estimates of decay rates lagged "*in situ*" experiments. This discrepancy was explained as possibly slow establishment of detrital microflora, lower nitrogen availability in the laboratory, or absence of animals. Temperature is also an important element in decay. Godshalk and Wetzel (1978) observed that at high temperatures (25° C), dissolved organic matter was decomposed even under anaerobic conditions. Actual rates of decomposition have been ascertained for a variety of plant species including *Phragmites communis* and *Typha angustifolia* (Mason and Bryant 1975).

The study of nitrogen fixation by both algae (Carpenter et al 1978) and bacteria (Teal et al 1979) has been conducted primarily in salt water environments. Tjempkema and Evans (1976) did attempt to quantify the nitrogen fixed in a freshwater wetland dominated by *Juncus balticus*. They found that high rates of N_2 fixation may be associated with many of the plants growing in wet soils.

Microbial mobilization of calcium and magnesium was examined recently under anaerobic and aerobic conditions (Silverman and Munoz 1980). Findings included a drop in pH accompanied by several-fold increases in Ca and Mg under both sets of conditions. The authors speculated that these changes may be attributed to microbial production of a variety of organic metabolites from glucose (an amendment) which may be responsible for the release of Ca and Mg from exchange sites.

Research Recommendations

The paucity of knowledge concerning bacteriological function in the wetlands of the Prairie Pothole Region dictates the need for the following research: (1) measurement of nitrogen fixation in several classes (Stewart and Kantrud 1971) of wetlands, (2) implication of seasonal variation with decomposition rate, (3) identification of microbial populations primarily responsible for decomposition, and (4) elucidation of biological pathways in the process of chemical reduction in soils.

A grasp of these questions would be an important first step in understanding the roles of bacteria in this unique group of wetlands.

Methods

Nitrogen fixation is nearly always measured indirectly in the field with the acetylene-reduction technique of Hardy et al (1968). The theory behind this method is that the reduction of acetylene, like the reduction of nitrogen, requires ATP and a reducing agent such as dithionite or reduced ferredoxin. As the enzyme system is purified for N_2 fixation, it is also purified for C_2H_2 reduction in parallel fashion. Sorokin and Kadota (1972) in their methods text entitled *Microbial Production and Decomposition in Fresh Waters* recommend periodic control tests of $^{15}N_2$ to check results, and they also suggest the use of direct measurements in the laboratory through NH_3 formation or $^{15}N_2$ fixation.

The most popular method to determine decomposition rates is with nylon "litterbags." Plant material is placed in these "flow-through" bags and left on the bottom of the wetland being examined. Dry weight loss is measured over time to ascertain rate.

Identification of bacteria involved in chemical reduction could be realized through techniques described in a variety of methods texts (Sorokin and Kadota 1972; Rodina 1972; American Public Health Association 1975; Parkinson et al. 1971). Details of these procedures are beyond the scope of this report. Selection of which methods to use will depend on the parameter to be measured, the accuracy required, and the availability of testing equipment.

Wetland Chemistry

The distinction between wetland chemistry and wetland bacteriology is artificial because at any given point in time the character of one reflects the influence of the other. The water chemistry is influenced not only by bacterial populations but also by a myriad of other inputs such as animal and plant products, sediment and hydrologic inputs from the surrounding watershed, and benthic perturbations. Water chemistry is but one subset of wetland chemistry. Soil chemistry and nutrient composition of plants are other obvious examples. The implications of these chemistry subsets are described earlier in this paper or in one of the companion publications (Ag. Research Rpt. No. 85).

The chemical ties between all segments of the wetland ecosystem make delineation of cause-and-effect relationships extremely difficult. As implied before, what appears to be a serene, unobtrusive wetland is in fact a chemically dynamic entity reflecting the biotic and abiotic inputs at a point in time. A description of "normalcy" will have to be qualified with a characterization of certain key inputs for any meaningful comparison with other aquatic environments.

Literature Review

Wetlands of the Prairie Pothole Region are ice-covered during the winter. Barcia and Mathias (1979) found that mean rates of dissolved oxygen depletion ranged from 0.22 to 0.34 g/m²/day for ice-covered non-stratified lakes and 0.32 - 0.42 g/m²/day for stratified ones. Winter kill risk was estimated through a knowledge of initial dissolved oxygen storage of the lake, the oxygen depletion rate, and the critical time required to reach winter anoxia. Ice has also been cited as a potential source of phosphate for spring growth (Bozniak and Kennedy 1968).

Nutrient dynamics has been a subject of investigation outside the Prairie Pothole Region. Gaudet (1979) studied a papyrus swamp associated with Lake Naivasha, Kenya and found that dissolved nutrients were effectively extracted from tropical river systems but later exported as organic particulate matter or adsorbed to particles which are carried into the lake by through-flow. Pellenbarg and Church (1979) examined trace metal cycling in a salt marsh and report that these metals cycle by net import on the surface microlayer and net export in the dissolved and seston components during maximum monthly tides. Results of these two studies are not totally applicable to the Prairie Pothole Region since many freshwater wetlands are "closed" hydrologically, i.e., runoff and ground water may be inputs but no hydrologic output exists other than evapotranspiration.

The influence of nutrients upon phytoplankton production in Lake Ashtabula, North Dakota was investigated by Peterka and Reid (1968). Their conclusion was that nutrients were not a limiting factor in the photosynthetic process.

Research Recommendations

Measurements of certain selected chemical elements over time is a gauge of the dynamic nature of wetland chemistry. Such an exercise does not address the more fundamental question of why this dynamic situation exists and what key variables impinge upon the chemical milieu. To broach this problem, the following research is proposed: (1) analysis of the chemical constituents from "*in situ*" soil samples and correlation of identified bacterial populations with the production of these constituents, (2) artificially create a wetland and then control the inputs while measuring for a battery of chemical elements.

Methods

The difficulty of maintaining "*in situ*" conditions in soil samples has already been discussed and is not an insurmountable problem. Certain bacterial genera are associated with known chemical reactions (e.g., *Desulphovibrio* and sulfate reduction). Thus, through careful identification and quantification of bacterial populations and concomitant chemical analysis, a basic picture of soil chemistry should emerge. Again, the chemicals to be measured will be dictated by what one might expect to find.

Two methods texts which could be employed, depending on the constraints of equipment, data accuracy, and parameter measured, are American Public Health Association (1975) and Golterman and Clymo (1969). The latter, while not as comprehensive as the former, is structured on the basis of the constraints described above. Thus, a "Level I" analysis can be made in the field using inexpensive techniques. A "Level III" requires state-of-the-art laboratory equipment.

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Soils

Armstrong, W. 1975. Waterlogged soils. Pages 181-218 *in* J. R. Etherington (ed.), Environment and Plant Ecology, J. Wiley and Sons, New York.

This chapter in Etherington's book (1975) provides an excellent description of the phenomena—biotic and abiotic—characteristic of wetland soils. Subtitles include (1) physiochemical characteristics of wet soils; (2) adaptations to the wetland environment; and (3) wetland tolerance in woody species. Physiochemical characteristics include gas exchange mechanisms, oxidation-reduction potential, soil nitrogen, manganese and iron, sulfate:sulfide, phosphorus, organic products of anaerobic metabolism, soil pH, and specific conductance. Adaptations discussed include exclusion of soil toxins, the provision of air-space tissue and its functional significance, anaerobic metabolism, xeromorphy, and other less pervasive features.

Armstrong, W. and O. J. Boatman. 1967. Some field observations relating the growth of bog plants to conditions of soil aeration. J. Ecol. 55:101-110.

The aeration of a flushed and stagnant soil regime in a Sutherland Valley bog was studied by means of oxygen diffusion measurements. Oxygen diffusion values were higher in the flush, with oxygen present to a depth of 16-18 cm., whereas oxygen was not detected below 6 cm. in the stagnant soil. The growth and chemical composition of *Molina caerula* growing in the habitat were recorded. *Molina* was vigorous in the flush but stunted where conditions were stagnant. Evidence is presented which supports the proposition that distribution of *Molina* is related to redox conditions of the soil.

Authors conclude that the potential oxidizing activity of roots may play a significant role in plant distribution in waterlogged soils.

Baker, J. H., L. A. Pugh III, and K. T. Kimball. 1977. A simple hand corer for shallow water sampling. Chesapeake Sci. 18:232-236.

A simple, inexpensive 2" hand corer has been developed for efficiently sampling most types of shallow water sediments. The cover consists of a Lexan plastic core tube, 1½"-check valve unit, and polyvinyl chloride tube handle.

The 2" hand corer consistently collected higher mean densities or organisms than did the Mackin Corer, resulting in more precise estimates of the mean densities of the collected taxa. Undisturbed sediment samples for pesticide, oil and grease, and heavy metals analysis also were collected.

Black, C. A. 1965. Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties. American Society of Agronomy Inc., Madison, Wisconsin.

This text is the standard methods source for soil analysis of most areas of the United States. General areas covered include physical measurement, soil mineral analysis, chemical analysis, and soil microbiology.

Boyd, C. E. 1970. Influence of organic matter on some characteristics of aquatic soils. Hydrobiologia. 36:17-21.

Analysis of hydrosoils from 29 Alabama impoundments revealed that relationships between soil organic matter and organic nitrogen, organic sulfur and cation exchange capacity were similar to those for agricultural soils. Therefore, much of the data for agricultural soil organic matter should be applicable to studies of hydrosoils.

Breeman, N. V. and W. G. Wielemaker. 1974. Buffer intensities and equilibrium pH of minerals and soils: I. The contribution of minerals and aqueous carbonate to pH buffering. Soil Sci. Soc. Am. Proc. 38:55-60.

Thermodynamic equilibrium considerations were used to calculate pH buffer intensities for a number of aqueous systems involving 16 common soil and rock minerals (viz. gibbsite, kaolinite, allophane, hematite, limonitic iron oxide, quartz, amorphous silica, calcite, siderite, hydrated magnetic + amorphous Fe $(OH)_3$, microcline, albite, anorthite, Mg-montmorilonite, two illites, and Mg-chlorite), gaseous Co_2 and 26 dissolved species. The calculation of buffer intensities is outlined for simple oxides and carbonates and for silicate minerals during congruent and incongruent dissolution (graphical differentiation). Silicate minerals, carbonates, and gibbsite provide strong buffering upon addition of strong acid under slightly alkaline to slightly acid conditions. Carbon dioxide at constant partial pressure is far more effective than any of the minerals considered in counteracting the effect of an increase in alkalinity.

Brupbacher, R. H., W. P. Bonner, and J. E. Sedberry, Jr. 1968. Analytical methods and procedures used in the soil testing laboratory. Agricultural Experiment Station Bulletin No. 632, Louisiana State University, Baton Rouge. 15 p.

This bulletin describes the procedures currently in use at the Soil Testing Laboratory at Louisiana State University. Contents include: general laboratory determinations, soil sample preparation, determination of soil reaction (pH), determination of the lime requirements of soils, determination of calcium, magnesium, potassium and sodium of soils, determination of phosphorus and determination of water-soluble salts.

Burford, J. R. and J. M. Bremmer. 1975. Relationships between the denitrification capacities of soils and total, water-soluble and readily decomposable soil organic matter. Soil Biol. Biochem. 7:389-394.

The relationships between the denitrification capacities of 17 surface soils and the amount of total organic carbon, mineralizable carbon, and water-soluble organic carbon in these soils were investigated. The soils used differed markedly in pH, texture, and organic-matter content. Denitrification capacity was assessed by determining the N evolved as N_2 and N_2O on anaerobic incubation of nitrate-treated soil at 20°C for seven days, and mineralizable carbon was assessed by determining the C evolved as CO_2 on aerobic incubation of soil at 20°C for seven days. The denitrification capacities of the soils studied were significantly correlated with total organic carbon and very highly correlated with water-soluble organic carbon or mineralizable carbon. The amount of nitrate N lost on anaerobic incubation of nitrate-treated soils for seven days was very closely related to the amount of N evolved as N_2 and N_2O.

The work indicates that denitrification in soils under anaerobic conditions is controlled largely by the supply of readily decomposable organic matter and that analysis of soils for mineralizable carbon or water-soluble organic carbon provides a good index of their capacity for denitification of nitrate.

Chapman, S. B. 1971. A simple conductimetric soil respirometer for field use. Oikos. 22:348-353.

This paper describes a simple soil respirometer suitable for use in the field. The principle of absorption of CO_2 by KOH is employed. Conductimetric determination of the CO_2 absorbed in the electrolyte is substituted for titrimetric methods. Details of calibration and performance characteristics of the apparatus are described.

Cole, N. H. A. 1973. Soil conditions, zonation and species diversity in a seasonally flooded tropical grass-herb swamp in Sierra Leone. J. Ecol. 61:831-847.

Five vegetation zones were distinguished in a tropical grass-herb swamp in Sierra Leone. The different zones showed characteristic seasonal trends in soil moisture, pH and water-table depths, related to flooding in the wet season and desiccation in the dry season. The summation of the duration of these two adverse extremes of soil moisture was used to express the unsuitability of the habitats for plant growth; this factor was inversely related to the species diversity. The "habitat unsuitability" also altered the normal continuous growing season of the humid tropics. There were present wet season ephemerals, dry season therophytes, dormant herbaceous perennials and deciduous shrubs. The general significance of these findings is discussed in relation to transition from species-richness to single-species dominance in the tropics.

Collins, J. F. and S. W. Buol. 1970. Effects of fluctuations in the Eh-pH environment on iron and/or manganese equilibria. Soil Sci. 110:111-118.

The physico-chemical behavior of iron and manganese was examined in terms of pH and Eh (oxidation-reduction potential) on the assumption that these parameters afford two basic controls which significantly contribute to the genesis of manganese-rich and/or ferromanganiferous accumulations in soils. The validity of stability field diagrams (Eh-pH diagrams) for certain specified species of both elements was proven by a number of carefully controlled experiments. In all mono-elemental systems the observed occurrences and measurements coincided closely with theoretically-predicted conditions.

In oxygen-free environments, high Eh values may be obtained in acidification of manganese precipitates with HCl, a nonoxidizing acid. Such a reaction in oxygen-poor or oxygen-free soil environments may lead to the formation of manganese oxides having an "x" value in MnOx of 2 or nearly so, e.g., manganese dioxide and its equivalents.

Coultas, C. L. and E. R. Gross. 1978. Tidal marsh soils of Florida's middle Gulf Coast (USA). Soil Crop Sci. Soc. FLA Proc. 37:121-125.

Tidal marsh soils of Citrus and Levy Counties are predominantly Sulfaquents and Psammaquents. Sulfaquents are higher in organic matter and clay. Small areas of Fluvaquents occur in a high position in the marsh. All soils are highly base-saturated with reactions ranging from medium acid to mildly alkaline. All soils are saline and nearly saturated with moisture. The predominant clays are kaolinite-meta halloysite and montmorillonite.

These soils support a dense stand of *Juncus roemerianus* Scheele. A radio-carbon date indicates the marsh area is aggrading at a rate of 3.3 cm. per 100 years.

Dale, H. M. 1965. Influence of soil on weed vegetation on a drained river millpond. II. Can. J. Bot. 43:557-561.

After 7 months under 2 to 4 ft. of water, a river bed when redrained developed the same four communities as on a previous occasion. These were again associated with specific substrates, soil textures, and quantity of organic matter was most significant. Stands of one community covered larger areas at the expense of the other three types. This community, favored at the expense of the other three, was the one richest in species, and the one which had been associated the first year with the substratum with the highest content of organic matter as well as of potassium and magnesium. A superior seed source, a more suitable growing season, and changes in the organic content of the seed bed would all contribute to this expansion.

Daniels, R. B., G. H. Simonson, and R. L. Handy. 1961. Ferrous iron content and color of sediments. Soil Sci. 91:378-382.

During investigations of entrenched streams in western Iowa, sediments in place with fresh colors of greenish gray (5G4 5/1, i.e., Munsell colors of moist soil) were found to change color, upon exposure to air, to olive brown or dark grayish brown (2.5Y 4/4 to 10YR 4/2) or to a mixture of these colors. Sediments with colors other than greenish gray, however, did not change upon such exposure. The shifting of the matrix color to browner hues of certain sediments upon exposure to air can be attributed to a change in the state of oxidation of the iron. To check the inferences drawn from the field observations, 51 samples of sediment were collected for laboratory analysis for ferrous iron, free iron, and organic carbon.

Results suggest that both neutral hues and greenish-gray colors appear to be diagnostic sediments with ferrous-iron contents greater than .002 per cent. Only samples with neutral hues and greenish-gray colors closely fit a current definition of a gleyed horizon.

Denning, J. L., F. D. Hole, and J. Bouma. 1977. Effects of *Formica cinerea* on a wetland soil on west Blue

Mound, Wisconsin. Pages 276-287 *in* C. B. Dewitt and E. Soloway (eds.), Wetlands Ecology, Values, and Impacts: Proceedings of the Waubesa Conference on Wetlands, Institute for Environmental Studies, University of Wisconsin—Madison.

Influence of activity of the ant, *Formica cinerea*, on the profile of a clayey wetland soil (Typic Haplaquall) was studied by comparing a profile at a mound site with an adjacent intermound profile in a wet meadow 2.6 ha in area in the midst of an oak (*Quercus* sp.) forest. By construction of a mound with a network of channels the ants have changed the saturated hydraulic conductivity of the soil from that of a normal clay soil to that of a gravel. Crusting during a rainstorm partially seals over the mound, thus giving additional protection of the nest from flooding from above. The soil of the mound contained less organic matter, but more available phosphorus, potassium, calcium, and magnesium than did the intermound soil.

Edwards, D. 1969. Some effect of siltation upon macrophytic vegetation in rivers. Hydrobiologia 34:29-37.

Although no intensive studies have apparently been made of the ecological effects of siltation upon the aquatic macrophyte vegetation of South African rivers, data available from extensive surveys in different parts of the country generally indicate a relationship resulting in a decline or retrogression of aquatic vegetation. This apparent decline in the autotrophic element of the river ecosystems is of considerable national concern for the future maintenance of ecologically stable and productive river ecosystems, as well as for their aesthetic character.

Edwards, R. W. and H. L. J. Rolley. 1965. Oxygen consumption of river muds. J. Ecol. 53:1-19.

The oxygen consumption of several river sediments was determined at 10°, 15°, and 20° using a polarographic respirometer. Oxygen consumption was independent of sediment depth at depths greater than about 2 cm. The relation between oxygen consumption and oxygen concentration in the overlying water could generally be described by $y=a_3C^b$, where y is oxygen consumption and C is oxygen concentration, a_3 and b being constants. Oxygen consumption increased during March and April and was probably associated with the growth of epibenthic algae. Further evidence is given of the importance of substrate in determining the oxygen consumption of some invertebrates and of the indirect effect of *Chironomous* larvae on mud metabolism.

It is concluded that the consumption of oxygen was not affected by changing the concentration of nitrate, cores with high rates of oxygen consumption had high rates of nitrate consumption, and nitrate consumption was related to its concentration. There is no correlation between oxygen consumption of muds and their organic carbon content, chemical oxidizability, dehydrogenase activity or bacterial counts.

Farnham, R. S. and H. R. Finney. 1965. Classification and properties of organic soils. Advan. Agron. 17:115-162.

Certain physical and chemical properties of organic soils that seem most meaningful as criteria in classification are considered. These properties include bulk density, fiber characteristics, pH ash content, and degree of decomposition.

A classification system for organic soils, along with details of the diagnostic criteria for the horizons, bases of the system, and its utilization are presented. The fact that the system is an approximation and that certain refinements of the various criteria and taxa are needed should be emphasized.

Gallagher, J. L. 1974. Sampling macroorganic matter profiles in salt marsh plant root zones. Soil Sci. Soc. Proc. 38:154-155.

A device for sampling the root zones of marsh plants and a method for processing the resulting cores are described in this paper. Using these techniques, five stands of marsh plants were sampled and their macroorganic matter profiles compared. The least total macroorganic matter was found in the high vigor *Spartina alterniflora* Loisel. and *Distichlis spicata* (L.) Greene root zones. Within *S. alterniflora* stands, the macroorganic matter in the soil profile increased as vigor of the aerial portions decreased. *Juncus roemerianus* Scheele and short form *S. alterniflora* profiles were similar in shape and had the highest macroorganic matter content.

Halder, M. and L. N. Mandal. 1979. Influence of soil moisture regimes and organic matter application on the extractable Zn and Cu content in rice soils. Plant and Soil 53:203-213.

A laboratory incubation experiment was conducted to study the influence of three moisture regimes, "viz" (i) waterlogged (W_1), (ii) alternate waterlogged and saturated (W_2) and (iii) continuous saturated (W_3) and two levels of organic matter application, "viz" (i) O (T_1) and (ii) 0.5 per cent of the soil (T_2) in all their possible combinations on the extractable (N NH_4OAC, pH 7.0) zinc and copper in three lowland alluvial rice-growing soils of West Bengal (India). The results showed that the extractable zinc and copper content in soils recorded marked decrease in incubation under all the moisture regimes, but the same was most prominent under the continuous saturated moisture regime (W_3), followed by water-logged (W_1) and alternate waterlogged and saturated (W_2) moisture regimes. Application of organic matter brought about further decrease in the content of these elements. Organic matter application combined with saturated moisture regime brought about the greatest decrease both in zinc and copper content. The microbiological immobilization and the antagonistic effect of increased concentration of extractable iron, manganese and phosphorus have been suggested as the possible reasons for the observed decrease of the content of extractable zinc and copper.

Harms, W. R. 1973. Some effects of soil type and water regime on growth of tupelo seedlings. Ecology. 54:188-193.

Two-year old swamp tupelo (*Nyssa sylvatica* var. *biflora* (Walt.) Sarg.) and water tupelo (*N. aquatica*

L.) grown in large tanks in a silty loam soil from a river swamp or a sandy loam soil from a nonalluvial headwater swamp were subjected to continuous flooding at depths of 20 cm. above the soil surface with moving water, 20 cm. above the soil surface with stagnant water, or at the soil surface with moving water. Height growth of water tupelo averaged 1.8 times greater and dry weight, two to three times greater, in the more fertile soil from the river swamp than in soil from the head water swamp. Soil type had no effect on growth of swamp tupelo. Growth and dry weight of both tupelos were poorest in the regime with stagnant water, which also had the highest CO_2 and lowest O_2 contents. Swamp tupelo grew 50 cm. more in height in the surface-flooded regime with moving water than in either deep-flooded regime. Water tupelo in both regimes with moving water grew 37 cm. taller than those in the stagnant regime.

Iri, H., I. Maruta, I. Takahashi, and M. Kubota. 1957. The variation of ferrous iron content and soil profiles under flooded condition of rice field. (Part 1). Soil and Plant Food 3:36-47.

Iron changes its form from ferric state to ferrous state in accordance with the development of reduction. One of the factors causing the reduction state of soil is the activity of various kinds of bacteria consuming oxygen contained in water, soil itself, and even oxides in soil. The activity of bacteria may be accelerated by temperature rise. This could explain why the variation of ferrous iron content resembled the variation of atmospheric temperature in the furrow horizons. The Eh value variation was larger on the furrow horizons and smaller on the lower horizons.

Soil profile observations indicated that the yellowish-brown soil color was changed into greenish-gray and iron mottlings disappeared in August only on the furrow horizons. Iron mottlings on the lower horizons showed no appreciable changes.

It may be concluded that there exist vertically oxidation or reduction-oxidation-reduction horizons at sample site A (a better drained site) and reduction (partly oxidation)-reduction horizons at site B (poorer drained site).

Jeffery, J. W. O. 1961. Measuring the state of reduction of a waterlogged soil. J. Soil Sci. 12:317-325.

Eh and pH measurements and the term $r_{Eh}=Eh+3 \text{ X } 2.3RT/FpH$ have been tested under simulated field conditions and errors assigned to them. The author considers that, while Eh measurements in the field may be used to differentiate between reduced and oxidized soils, their error is too large for them to supply more precise information about the state of reduction of a waterlogged soil; he also considers that there is little point in adjusting these measurements for pH change.

It is proposed that an estimation of the concentrations of the two states of iron in a waterlogged soil should be used as the basis of a field method for measuring the soil's state of reduction.

The results give some support for the argument that the equation:

$$Eh=K-k \log c_{fc}^{++} - 3 \text{ X } 2.3 \frac{RT}{F} pH$$ is applicable

to waterlogged soils.

Jorgensen, S. E., L. Kamp-Nielsen, and O. S. Jacobsen. 1975. A submodel for anaerobic and mud-water exchange of phosphate. Ecol. Model. 1:133-146.

A submodel for anaerobic mud-water exchange of phosphate is obtained from experiments in a laboratory. Phosphorus in the sediment can be divided into exchangeable and nonexchangeable phosphorus. The exchangeable phosphorus is decomposed in accordance with a first-order reaction. The phosphorus moves, after the decomposing process, from the interstitial water to the water phase, in accordance with a diffusion expression. The yearly increase of the sediment was determined by means of lead concentration as a function of the depth.

Kar, S., S. B. Varode, T. K. Subramangam, and B. P. Ghildyal. 1976. Soil physical conditions affecting rice root growth: bulk density and submerged soil temperature regime effects. Agron. J. 68:23-26.

Information is lacking on the performance of the rice plant due to variations in temperature regimes in association with other soil physical properties. This investigation, carried out under controlled greenhouse conditions, evaluated the influence of temperature and mechanical impedence of soil, as well as of their interaction, on root and shoot growth of rice (*Oryza sativa* L. "Taichung Native 1").

Multiple regression analysis indicated that the number of degenerated roots increased with the increase in submerged soil temperature regime, but decreased with the increase in bulk density of the lateritic sandy loam soil. The multiple correlation coefficient between these three variables was significant at 1 per cent level ($r=0.79$).

With increase in bulk density from low to medium, the dry weight of shoot and root, and the number of roots at the base significantly increased at 27° to 15 °C and 42° to 30 °C, but decreased at 37° to 25 °C in all the three soil textures studied. However, when the bulk density was increased from medium to high levels, the shoot and root growth parameter decreased under all temperature regimes.

Lee, G. B. 1977. Wetland soils of the Upper Midwest. Pages 12-23 *in* C. B. Dewitt and E. Soloway (eds.). Wetlands ecology, values, and impacts: proceedings of the Waubesa Conference on Wetlands, Institute for Environmental Studies, University of Wisconsin—Madison.

Pedologists can predict with some certainty how most wetland soils, and the ecosystems of which they are a part will respond when a wetland soil is disturbed in a particular way. Nevertheless, a great deal of research needs to be done before an adequate understanding of these soils is achieved. Preferably such pedological research should be done cooperatively with hydrologists, ecologists, and perhaps other scientists so that the relatively narrow, disciplinary foci of each may combine with the others to provide a much broader overall understanding of wetland soils, and the total wetland ecosystem of which they are a part.

Loach, K. 1966. Relations between soil nutrients and vegetation in wet-heaths. I. Soil nutrient content and moisture conditions. J. Ecol. 54:597-608.

The nutrient content of soils from three adjacent and closely related plant communities in Bramshill Forest, northeast Hampshire, was determined. *Molinia caerula* was most abundant in the site with richest nutrient supply and greatest water-table depth and fluctuation. Soil analyses nevertheless suggested that the Molinietum topsoil was phosphorus deficient in comparison with many other soils. Nutrients were concentrated in the surface horizons of the Molinietum, a feature which may result from the activity of the deep rooted *Molinia* plant itself. *Molinia* tussocks had total nitrogen and phosphorus content 8-10 times greater than that held in the standing crop in August, but exchangeable potassium was only half of the potassium content of the crop.

Tree growth was greatest in the most nutrient rich site (the Molinietum) and least in the most nutrient deficient (the valley bog).

Loach, K. 1968. Relations between soil nutrients and vegetation in wet-heaths. II. Nutrient uptake by the major species in the field and in controlled conditions. J. Ecol. 56:117-127.

Seedlings or tillers of *Molinia caerula, Calluna vulgaris,* and *Erica tetralix* were planted at widely-spaced intervals in cleared plots of three sites, representative of the different facies of wet-heath. At harvest, yields and nutrient contents were lowest in the valley bog site. In the Molinietum site, the heath species grew well when competition from *Molinia* was eliminated and had slightly higher nutrient contents than plants grown in the central associes of wet-heath. A glasshouse experiment confirmed that the Molinietum soil had the highest, and the valley bog the lowest nutrient status. Growth in all soils was improved by phosphorus additions and to a lesser extent by nitrogen and potassium.

It was concluded that although differences in the nutrient status of the sites may play a contributory role in influencing the composition of the natural plant cover, other factors such as inter-specific competition and soil aeration are important.

Lytle, S. A. 1968. The morphological characteristics and relief relationships of representative soils in Louisiana. Agricultural Experiment Station Bulletin No. 631, Louisiana State University, Baton Rouge. 23 p.

This bulletin describes the color, texture, structure, consistence, thickness, and arrangement of the various soil layers in the soil profiles, i.e., the morphological characteristics of representative Louisiana soils. Relief is depicted as "normal," "subnormal," "excessive," and "flat or concave." A color map shows the general soil areas within the state. Coastal marshlands are comprised of marsh peats, mucks, clays, and Harris with swamp peats, mucks, and clays.

Macfadyen, A. 1970. Soil metabolism in relation to ecosystem energy flow and to primary and secondary production. Pages 167-172 *in* Unesco (ed.). Methods of Study in Soil Ecology, Unesco, Paris, France.

The metabolic activity of soil is the sum total of that of all the constituent soil-inhabiting organisms. A computation of this metabolic activity has usually been achieved by subtracting the energy consumed by herbivores from net primary production. A check on the accuracy of this method can be made in the field by covering soil *in situ* with a bell jar or other open-ended container and measuring carbon dioxide output. The factors which impinge on this CO_2 output include: (1) respiration from plant roots; (2) transient effects due to changes in atmospheric pressure; and (3) metabolic activity of the soil organisms, as modified by temperature and other physical factors.

The author concludes that if the activities of soil decomposers are to be accurately measured within the context of the ecosystem, investigators must either measure their true activity in the field or determine corrections from which such data can be derived.

McKaegue, J. A., J. E. Brydon and N. M. Miles. 1971. Differentiation of forms of extractable iron and aluminum in soils. Soil Sci. Soc. Am. Proc. 35:33-38.

The approximate differentiation of crystalline and amorphous iron oxide in soils by extraction methods can be extended to a distinction between organic-complexed and amorphous inorganic Fe. Data for synthetic Fe-Fulvic acid complexes, X-amorphous hydrous Fe oxide, crystalline Fe oxides and soils show that the Fe extracted by 0.1M $Na_4P_2O_7$ is largely organic Fe. The difference between oxalate- and pyrophosphate-extractable Fe gives a measure of amorphous inorganic Fe, and dithionite-minus oxalate-extractable Fe provides an estimate of more or less crystalline Fe-oxides. These extractants are less useful in distinguishing forms of Al in soils.

Spodic horizons contained much more pyrophosphate-extractable Fe and Al than other soil materials. A criterion for spodic horizons could be based upon pyrophosphate-extractable Al, Fe, and possible C. The rusty mottles of several Aquepts and Aqualfs and some placic horizons low in organic matter contained goethite as well as amorphous inorganic Fe. Hematite occurred in some reddish-brown parent materials having a high ratio of dithionite- to oxalate-extractable Fe, but mottles formed in these soils contained secondary goethite.

McLeese, R. L. and E. P. Whitside. 1977. Ecological effects of highway construction upon Michigan woodlots and wetlands: Soil relationships. J. Environ. Qual. 6:467-471.

Ecological effects of recent highway construction on soils, hydrology, vegetation, and wildlife in Michigan was the subject of this paper. Five woodland and five wetland areas representative of common situations encountered in highway location and planning studies were selected for analysis. Wetland areas were the most sensitive to highway construction activities. Natural soil drainage conditions and circulation patterns were easily disrupted at these sites. Methods for predicting potential soil loss and potential changes in natural soil drainage conditions due to construction activities are suggested. A soil map can be useful in predicting construction impact on the associated hydrology, plants, and animals in the area.

Moore, A. W. and H. F. Rhoades. 1966. Soil conditions and root distribution in two wet meadows of the Nebraska Sandhills. Agron. J. 58:563-566.

Root distribution and properties of two meadow soils in the Nebraska Sandhills were studied. Profile 1 was alkaline while profile 2 was acidic. Both sites carried some legumes but late-maturing grasses predominated at site 1 and early-maturing grasses at site 2. Soil moisture was related to water-table level. Soil temperatures at the 4-inch depth remained between 60° and 75°F for most of the growing season. Soil aeration was good throughout the growing season, the oxygen content to a depth of 2 to 3 feet rarely falling below 15 per cent.

The broad pattern of root distribution in both soils consisted of a heavy concentration of roots near the surface and a rapid decline with depth. The total weight of roots to a depth of approximately 4 feet was 5.5 and 7.3 tons per acre for Soils 1 and 2 respectively. One-half of two-thirds of the roots were found in the surface 2 inches. This broad pattern may be attributed to the influence of a high, fluctuating water table.

Soil chemical properties appeared to be the dominant factors resulting in differences in root distribution between the two soils. Grass root penetration virtually ceased on reaching sand low in nutrients.

Moravec, J. 1969. Succession of plant communities and soil development. Folia Geobot. and Phytotax. 4:133-164.

Changes of plant communities (or biotic communities) are classified according to their causes. The term succession is restricted in Clements' original sense to gradual directional replacement changes of phytocenoses (or biocenoses) caused by their reaction upon the environment, including soil development, and a classification of succession is proposed. Gradual changes of communities caused by external factors are termed adaptive changes. The connection between succession and soil development as a unified process as well as the concept of climax as its result are discussed. A brief historical survey of the theory of succession as well as soil development is presented and definitions of some successional terms are proposed.

Muckereth, F. H. 1969. A short core sampler for subaqueous deposits. Limnol. Oceanogr. 14:145-151.

The author describes a core sampler designed to obtain a core 1 m long and 5 cm diameter with the inclusion of a few centimeters of water above the sediment surface so that the position of the sediment-water interface can be determined with accuracy. A diagram and discussion of sampler use are provided.

Owens, D. W., R. B. Daniels, and G. B. Brauen. 1977. Lacustrine sediments in the Allegheny Plateau of Erie County, New York: their characteristics, distribution, and land use problems. J. Soil and Water Conserv. 32:93-97.

Temporary glacial lakes developed in many Allegheny Plateau river valleys 12,000 to 13,000 years ago when glacial ice dammed the north-flowing streams. The lakes were only 1 to 2 miles wide and 5 to 10 miles long, but more than 100 feet of illitic lacustrine silts and clays were deposited in some of the valleys before the lakes were drained. Erosion since the glacial ice melted has cut into the glacial, glaciofluvial, and lacustrine sediments in the narrow valleys, resulting in extremely complex but predictable soil patterns. A thorough knowledge of the glacial geology of the area is needed to map the areas underlain by lacustrine sediments because most soils are formed in the sand and gravel of the glaciofluvial cap. Many of the areas underlain by lacustrine sediments would be missed if only the surficial soil properties were used.

Palmisano, A. W. and R. H. Chabreck. 1972. The relationship of plant communities and soils of the Louisiana coastal marshes. La. Ass. Agron. Proc. 13:72-101.

This study deals with a survey of the entire coastal marsh area of Louisiana from Saline Lake on the west to the Chandeleur Islands on the east. Included in the area is approximately 3.9 million acres of marshland and 4.0 million acres of bays and sounds. Soil, water, and vegetative composition samples were collected in the marshland area in an effort to determine the basic ecological factors influencing the distribution of marsh plants in coastal Louisiana.

Plant distribution was closely related to water salinity and total salts in the soil. Both factors decrease inland, resulting in a zonation of plant communities generally paralleling the shoreline.

Plant species diversity was greatest in the fresh marsh communities as the water salinity and total salts in the soil increased. Of the 118 species encountered during the survey, only 17 were recorded in the saline vegetative type; but in the fresh type, 93 species were recorded.

Organic soils were best developed in fresh marshes. Major factors affecting the organic content of marsh soils included the rate of sediment deposition, biomass production, oxidation rates of organic material, physical loss of organic material as a result of storm surges and normal tidal action, marsh fires, and grazing by herbivorous animals. Phosphorus concentrations were especially low in fresh marshes containing over 50 per cent organic matter.

Parkinson, D., T. R. C. Gray, and S. T. Williams. 1971. Methods for studying the ecology of soil microorganisms. Blackwell Scientific Publications, Oxford, England. 116 p.

This handbook attempts to survey methods which are in use in soil microbiological laboratories—methods which microbial ecologists have found useful. Complete standardization of methodology in studies of soil microbial ecology is not desirable and methods must be chosen and modified which attempt to provide data relevant to the soils and organisms being studied.

Patrick, W. H. Jr. and R. A. Khalid. 1974. Phosphate release and sorption by soils and sediments: effect of aerobic and anaerobic conditions. Science 186:53-55.

Anaerobic soils released more phosphate to soil solutions low in soluble phosphate and sorbed more phosphate from soil solutions high in soluble phosphate than did aerobic soils. The difference in behavior of phosphate under aerobic and anaerobic conditions is attributed to the change brought about in ferric oxyhydroxide by soil reduction. The probably greater surface area of the gel-like reduced ferrous compounds in an anaerobic soil results in more soil phosphate being solubilized where solution phosphate is low and more solution phosphate being sorbed where solution phosphate is high.

Patrick, W. H. Jr. and K. R. Reddy. 1976. Nitrification-denitrification reactions in flooded soils and water bottoms: dependence on oxygen supply and ammonium diffusion. J. Environ. Qual. 5:469-472.

Ammonium nitrogen in a flooded soil or water bottom exposed to oxygen from the water column undergoes sequential nitrification and denitrification. Oxygen moving through the overlying water column causes the development of an aerobic surface layer of soil or sediment. Ammonium in this aerobic surface layer is nitrified and the resulting ammonium concentration gradient across the aerobic layer and the underlying anaerobic layer causes ammonium in the anaerobic layer to diffuse upward into the aerobic layer where it undergoes nitrification. Nitrate produced in the aerobic layer then diffuses downward into the anaerobic layer where it is denitrified to N_2 and N_2O. Nitrate derived from ammonium nitrogen in the aerobic layer appears as an intermediate product in the nitrification-denitrification reaction.

A laboratory experiment utilizing ^{15}N as a tracer showed that approximately one-half of the nitrogen involved in the nitrification-denitrification process was ammonium originally present in the surface aerobic soil or water bottom layer with the remainder diffusing up from the underlying anaerobic layer. Where oxygen was absent or limiting, nitrification either did not occur or occurred at a lower rate, resulting in a reduced amount of nitrate available for the denitrification process.

Patrick, W. H. and F. T. Turner. 1968. Effect of redox potential on manganese transformation in waterlogged soil. Nature 220:476-478.

Manganese reduction from insoluble oxidized forms to slightly soluble reduced forms occurs readily when an aerated soil is waterlogged. Together with the disappearance of oxygen and nitrate, an increase in the manganese ion in the soil solution and on the cation exchange complex is one of the first measurable effects of reducing conditions caused by waterlogging. This report deals with the distribution of various forms of manganese in waterlogged soils, and the effects of the oxidation-reduction or redox potential on these transformations.

The most striking effect of waterlogging on manganese transformation was the conversion of easily reducible manganic compounds to the exchangeable manganous form. The intensity of reduction at which oxidized forms of manganese were reduced in waterlogged soils was investigated, using the redox potential as an index of reduction intensity.

Phillipson, J. (ed.) 1970. Methods of study in soil ecology. United Nations Educational, Scientific, and Cultural Organization. Paris, France. 303 p.

This book presents the results of a symposium on methods of study in soil ecology organized jointly by UNESCO and the IBP and held in Paris, France in November, 1967. General headings include: (1) general problems in soil ecology, (2) structural aspects of soil ecosystems, (3) functional aspects of soil ecosystems, (4) methods for the study of production by soil microorganisms, (5) methods for the study of productions by macrophytes, (6) soil respiration, (7) methods for the study of production by the soil mesofauna, (8) methods for the study of production by arthropods of the macrofauna, (9) methods for the study of production by root-fluid feeders and nematodes, (10) methods for the study of production by earthworms, enchytraeids and molluscs, and (11) soil ecology in the next decade.

Reed, D. M., J. H. Riemer, and J. A. Schwarzmeier. 1977. Some observations on the relationship of floodplain siltation to reed-canary grass abundance. Pages 99-107 *in* C. B. Dewitt and E. Soloway (eds.), Wetlands Ecology, Values, and Impacts: Proceedings of the Waubesa Conference on Wetlands, Institute for Environmental Studies, University of Wisconsin—Madison.

Observations of reed-canary grass (*Phalaris arundinacea* L.) abundance patterns in relation to various types of wetland degradation may hold potential for improving floodplain planning and management. Observations in the Pewaukee and Fox (Illinois) River floodplains in Waukesha County, Wisconsin suggest indicator relationships between reed-canary grass dominated marshes/meadows and one more of the following conditions: (1) floodplain landfills, (2) former floodplain pastures, (3) adjacent upland uses which accelerate runoff, and (4) strong silt deposition in floodplains. Hummock spatial relationships and wetland floor elevations were studied in relation to reed-canary grass abundance at a Fox River site: these data suggested a significant loss of annual floodwater capacity because of heavier silt decomposition in reed-canary grass portions. If studies from engineering, ecological, and soils perspectives can refine and further document any indicator relationships, one should have a valuable new tool for monitoring the quality and function of floodplains and possibly even determining suitable widths of upland buffers.

Richardson, J. L. and F. D. Hole. 1979. Mottling and iron distribution in a Glossoboralf-Haplaquoll hydrosequence on a glacial moraine in northwestern Wisconsin. Soil Sci. Soc. Am. J. 43:552-558.

Distribution of iron oxide and forms of mottling and cutans under various moisture regimes were studied in a Woodfordian glacial moraine landscape. Hydrosequence members were observed and sampled along two transects in adjacent first-order drainage basins. Considerable iron had been translocated out of the A horizon and either into the B horizon or out of the solum in all pedons studied. Mottle development followed an expected systematic sequence from none at well-drainage sites, where unsaturated movement of water predominates; to considerable at somewhat poorly drained sites, where saturated flow occurs frequently and where the dry-wet cycle is characteristic; to few at very poorly drained sites where gleying has been favored by stagnant water conditions in wet seasons. Changes in distribution of iron extractable by aqua regia, dithionite and oxalate characterized the degree of crystallinity of iron compounds in the sequence. Iron-oxides were most crystalline at well-drained sites, where they tended to concentrate in the clay fraction. Iron oxides were concentrated in sand-size concretions at somewhat poorly drained sites.

Rozema, J., H. J. M. Nelissen, M. Vander Kroft, and W. H. O. Ernst. 1977. Nitrogen mineralization in sandy salt marsh soils of the Netherlands. Pflanzenernaehr Bodenkd. 140:707-718.

The seasonal variation of ammonification and nitrification of an alkaline salt marsh soil were studied. Ammonium nitrogen is almost absent and the nitrate values remain very low due to the low organic matter content of the soil. Seasonal variation of the soil nitrate content and incubation tests may partly be explained by varying temperature, although many factors seem to interfere. Microbial population of the soil seems to be adapted to medium saline conditions. Mineral nitrogen content of the soil probably does not contribute to the zonation of the vegetation. It is suggested that the low soil nitrogen status limits the rate of vegetation development.

Ryan, J. A. 1972. Effect of phosphate and chloride salts on ammonification of waterlogged soils. Soil Sci. Soc. Am. Proc. 36:195-197.

A survey of 15 different soils types indicated ammonification under waterlogged conditions was usually decreased by addition of KH_2PO_4, although occasional increases were observed. Ammonification in the Pembroke soil was studied in more detail with varying concentrations of KH_2PO_4, NaH_2PO_4, KCl and NaCl and between 1 and 35 days of incubation. In general, as the salt concentration increased, there was a significant interaction between salt treatments and incubation periods, reflecting the tendency of ammonification to be decreased more at intermediate incubations than at longer incubations. Potassium salts generally depressed ammonification more than did Na salts, especially in the phosphate series. Of the anions, the depression was greater with Cl salts than with P salts for most short-term incubations, but the reverse was true for the 35-day incubation. The critical concentration for the salts in this study was about 2.5×10^{-2} M.

Ryan, J. A. and J. C. Sims. 1974. Effect of phosphate and chloride salts on microbial activity in flooded soil. Soil Sci. 118:95-101.

Samples (5g) of Pembroke soil were incubated at 40°C in 12.5 ml of salt solution for varying time periods up to 35 days in order to determine salt effects on biological and chemical changes in flooded soil.

For all salts, carbon dioxide evolution increased with time of incubation and generally decreased with concentration of salt at the 7-day incubation. However, at longer incubations, P salts stimulated CO_2 evolution while Cl salts had little effect. Although theoretically possible, NH_4 precipitated with P as ammonium taranakites in these soil systems was rejected, since added NH_4 was recovered from sterile soil systems. The data suggest that P salts increase microbial activity, resulting in greater amounts of N being immobilized in microbial tissue.

Sindu, M. A. and A. H. Cornfield. 1967. Comparative effects of varying levels of chlorides and sulphates of sodium, potassium, calcium, and magnesium on ammonification and nitrification during incubation of soil. Plant Soil 27:468-472.

The effect of chlorides and sulphates of sodium, potassium, calcium, and magnesium, added at 0.1 per cent to 2.0 per cent sodium chloride-equivalent (soil basis), on nitrogen mineralization and nitrification was between 0.5 per cent and 1.0 per cent of the added salts. Nitrogen mineralization was reduced only where 1-2 per cent of salts were added. In the sulphate series, nitrogen mineralization and nitrification were reduced to a fair extent only by the 2 per cent level of sodium sulphate, the other sulphates having little or no effect on these processes. At some levels, the sulphates and chlorides of all cations, except sodium, resulted in a small but significant increase in nitrogen mineralization.

Sommers, L. E. and D. W. Nelson. 1972. Determination of total phosphorus in soils: a rapid perchloric acid digestion procedure. Soil Sci. Soc. Am. Proc. 36:902-904.

Extraction and colorimetric methods were evaluated for determining total P in soils. A procedure involving simultaneous digestion of 60 soil samples with perchloric acid and determination of extracted orthophosphate with an ascorbic acid method was evaluated. Analysis of diverse soils indicated that the proposed and conventional $HClO_4$ digestion procedures yielded essentially the same total P values; however, both $HClO_4$ methods underestimated total P by 1-6% when compared to Na_2CO_3 fusion. A comparison of colorimetric orthophosphate procedures indicated the method of Murphy and Riley (1962) was suitable for determination of orthophosphate following either $HClO_4$ digestion or Na_2CO_3 fusion. Determination of total P in soils by tube $HClO_4$ digestion and estimation of extracted P by the method of Murphy and Riley (1962) enables rapid and precise estimation of total P in a wide range of soils.

Sorenson, L. H. 1974. Rate of decomposition of organic matter in soils as influenced by repeated air drying-rewetting and repeated additions of organic material. Soil Biol. Biochem. 6:287-292.

Repeated air drying and rewetting of three soils followed by incubation at 20°C resulted in an increase in the rate of decomposition of a fraction at ^{14}C labeled organic matter in soils. The labeled organic matter originated from labeled glucose, cellulose and straw, respectively, metabolized in the soils during previous incubation ranging from 1.5 to 8 years.

Air drying and rewetting every 30th day over an incubation period of 160-500 days caused an

increase in the evolution of labeled CO_2 ranging from 16 to 121 per cent as compared to controls kept moist continuously. The effect of the treatment was least in the soil which had been incubated with the labeled material for the longest time.

Additions of unlabeled, decomposable organic material also increased the rate of decomposition of the labeled organic matter. Three additions of organic material during the period of incubation resulted totally in an increase over the controls ranging from 36 to 146 per cent.

Starkey, R. L. 1966. Oxidation and reduction of sulfur compounds in soils. Soil Sci. 101:297-306.

Sulfur undergoes many chemical changes in soil, and microorganisms are involved in the principal transformations. A great diversity of reactions is possible because S occurs in various states of oxidation.

Most inorganic S in aerobic soils is sulfate, but there is frequently considerable sulfide in anaerobic soils. Their transformation and that of organic S compounds produce elemental S, thiosulfate, polythionates, thiocyanate, and sulfite. All of these can be reduced by microorganisms.

The S transformations affect soil color, soil reaction, and availability of plant nutrient elements. The completely reduced substance hydrogen sulfide is a microbial product with a very important effect on soils. Under inundated conditions, S accumulates as sulfides and anaerobic bacteria develop. The state of iron in soils is particularly affected by the S transformations.

Ungar, I. A. 1970. Species-soil relationships on sulfate dominated soils of South Dakota. Am. Mid. Nat. 83:343-357.

Species-soil relationships were studied at Stink and Bitter Lakes in South Dakota. The effect of high salt concentrations on species distributions was established. The sulfate dominated soils of Nebraska, with an index similarity equalling 90.0 per cent. The succulents invading the salt pan appear to represent a cyclical invasion stage which disappears during periods of drouth, and which is not necessarily a primary stage of succession.

Vamos, R. 1964. The release of hydrogen sulfide from mud. J. Soil. Sci. 15:103-109.

Damage due to H_2S in some acidic, heavy paddy soils and peaty fishponds is usually preceded by falls in temperature and atmospheric pressure. The O_2 content of the water layer increases with the fall in the temperature and as the redox-level sinks in the mud, the superficial layer of the mud is oxidized and H_2SO_4 is formed which releases H_2S from the sulphide in its environment. The decrease of atmospheric pressure lifts the gases including H_2S from the hollows of the mud into the water layer and thence into the atmosphere. The gases carry colloidial particles and render the water turbid. The released H_2S may result in root-rot and deficiency diseases in the rice plants, and algae bloom and fish death in the ponds.

Van Cleemput, O., W. H. Patrick, Jr., and R. C. McIlhenny. 1975. Formation of chemical and biological denitrification end products in flooded soil at controlled pH and redox potential. Soil Biol. Biochem. 7:329-332.

The formation of denitrification products was studied in a waterlogged soil which was treated with and without mercuric chloride. Before the addition of the sterilant and NO_3H and pH was controlled at 4.5, 6, and 8 and the redox potential at 0 and +400 mV in stirred suspensions. Denitrification products N_2, N_2O were determined. Added NO_3-N was almost completely converted to N_2 at O mV and pH 6 and 8. At pH 4.5 and O mV, a substantial amount of N_2 was formed. At +400 mV, the N_2 production of N_2O was very important; it decreased at pH 6 and became minimal at pH 8. In oxidizing conditions only at pH 4.5 could N_2O be detected. In the presence of $HgCl_2$, no N_2O could be detected, and the N_2 gas production was not completely blocked.

Van Licrop, W. and A. F. MacKenzie. 1974. Carbonate determination in organic soils. Can. J. Soil Sci. 54:457-462.

The acid neutralization method and manometric procedures, using several acid-reducing agent combinations, were compared to determine their suitability for carbonate determination in organic soils. The soil-acid reaction observed with the acid neutralization procedure was significantly influenced by the acid concentration and soil type. Mean soil-acid reactions were 0.394 and 0.412 meq/g with the 0.3 and 0.6 M HCl, respectively. Moreover, it ranged from 0.023 to 0.694 meq/g soil for different soil types. The comparison of manometric procedures that were made used different acid-reducing agent combinations of HCl, CCl_3COOH, $HClO_4$, and $SnCl_2$ and $FeCl_2$. Of these, the $HClO_4-SnCl_2$ combination gave the lowest mean blank reading and standard deviation that remained stable (0.05 ± 0.009 ml). Though the perchloric acid alone was adequate for calcitic determinations, using the $SnCl_2$ reducing agent with longer reaction times was recommended.

Williams, J. D. H. and A. E. Pashley. 1979. Lightweight Corer designed for sampling very soft sediments. J. Fish. Res. Board. Can. 36:241-246.

An underwater corer has been developed capable of taking 10-cm diam. cores up to 1 m. long from unconsolidated, fine-grained fluvial and lacustrine sediments including organic rich (gyttja-like) deposits. The corer is lightweight and compact for transport and hand operation from float planes and small boats. It is of the piston type and has a sphincter valve for core retention. A miniature optical sensor triggers the corer when the sediment-water interface is penetrated. The corer is compatible with a system to subdivide the cores by vertical extrusion.

Wooten, J. W. 1973. Edaphic factors in species and ecotypic differentiation of *Sagittaria.* J. Ecol. 61:151-156.

Soil from populations of four ecotypes of two varieties within the *Sagittaria graminea complex,* a third variety of this complex, and populations of *S. cristata* and *S. platyphylla* were analyzed. Values for pH, CaO, MgO, P_2O_5 and K_2O were established, and tests for significance of the data made. Significant soil nutrient levels were established that were characteristic for and served to delimit each taxon. Two of the four ecotypes were found to be specific to certain soils. Edaphic adaptation appears to be of importance in this group of plants and may be of significance in other hydrophytes.

Worcester, B. K., L. J. Brun, and E. J. Doering. 1975. Classification and management of saline seeps in western North Dakota. N.D. Farm Res. 33(1):3-7.

Saline seeps observed in western North Dakota can be classified into one of several general categories based on different geologic conditions. Present management practices lead to the formation of saline seeps and their growth. Suggestions are given for modification of these practices which may have a beneficial effect on control and abatement of seeps.

Microbiology

Berger, P. S., J. Rho, and H. B. Gunner. 1979. Bacterial suppression of *Chlorella* by hydroxylamine production. Water Res. 13(3):267-274.

Algal growth has been shown to be stimulated or repressed by bacteria, depending upon species and environmental factors. Several investigators have found that low molecular weight compounds liberated by bacteria suppress algal growth, but seldom have been identified.

Interactions between *Arthrobacter* and *Chlorella* were studied in Petri dishes containing PCA. Pour plates of *Chlorella* were prepared, incubated at 26 °C in the dark for one day, then streaked once with the bacterial culture and reincubated in the dark. Algal colonies appeared within 3-4 days.

Hydroxylamine is produced by *Arthrobacter* sp. Q1 and this does not inhibit the alga.

Carpenter, E. J., C. D. Van Raalte, and I. Valiela. 1978. Nitrogen fixation by algae in a Massachusetts salt marsh. Limnol. Oceanogr. 23:318-327.

Over a three-year period, N_2 fixation on the surface of a Cape Cod salt marsh was highest in summer, with overall rates of about 10-20 mg N/m²/d. This average, coupled with N_2 fixation in the rhizosphere (Ca. 80 mg N/M²/d), compared favorably with the highest N_2 fixation rates measured anywhere. There were significant variations from one marsh habitat to another; the blue-green algae met had the highest rate of N_2 fixation per unit area (100-200 mg N/cm²/h) but due to its large area, the low marsh with short *Spartina* contributed the greatest amount of fixed N. Nitrogen is fixed on the marsh surface primarily by blue-green algae.

Chamie, J. P. M. and C. J. Richardson. 1978. Decomposition in northern wetlands. Pages 115-130 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

Much longer studies using more accurate methods must be developed before northern wetland decomposition processes can be more fully understood.

Methods: Large representative areas were chosen in each of the two communities. Sixteen 6 X 6 m plots were systematically placed approximately 6-10 m from one another. Plots were marked using metal conduit and heavy twine to prevent disturbance. All plots were numbered, then divided into 20 subplots (1 X 1m) which were systematically numbered and randomly selected for analyses. All experiments utilized full factorial, completely crossed designs.

Litterbag technique was employed for decomposition measurements. All samples were first air dried to constant weight, then oven dried (85 °C) to constant weight. A regression equation relating air dry to oven dry weight was calculated from representative samples.

Total nitrogen was determined using semimicro Kjeldahl procedure. Total P was done utilizing spectrophotometry following wet acid digestion of the ground samples (pechloric and nitric acid system). Na, Mg, K, and Ca were determined by atomic absorption spectrophotometry (Perkins-Elmer 1973).

Statistical analysis: two-way analysis of variance utilizing factorial program. Simple and complex contrasts determined using a posterior, multiple comparison test.

Christian, R. R., K. Bancroft, and W. J. Wiebe. 1978. Resistance of the microbial community within salt marsh soils to selected perturbations. Ecology 59:1200-1210.

The response of the soil microbial community in a short *Spartina alternifolia* salt marsh to selected, long-term perturbations was examined. The state of the microbial community was monitored by adenosine triphosphate and total adenylate concentrations, community adenylate energy charge ratio and anaerobic uptake of ^{14}C-glucose by mud slurries. The overall responses of the various parameters were consistent with the hypothesis that the soil microbial community is relatively unlinked to plant growth. This "unlinking" appears reponsible for the observed resistance to change by the microbial community in the face of perturbations to the marsh system. Two mechanisms of resistance were postulated. First, while the microbial community resides in a large reservoir of organic matter, most of this organic matter may be relatively refactory. Hence, the microorganisms would be nutrient limited by the slow transformation of this material. Such a large resource pool with a long turnover time would promote resistance to perturbations. Second, the microbial community would be resistant to changes in nutrient status if in fact it were limited by physico-chemical, spatial constraints rather than nutrients. While neither hypothesis could be totally rejected, the results of this study give greater support to the second hypothesis.

Christian, R. R. and W. J. Wiebe. 1978. Anaerobic microbial community metabolism in *Spartina alterniflora* soils. Limnol. Oceanogr. 23:328-336.

The anaerobic uptake of ^{14}C glucose was used as an index of potential microbial activity in the soils of a *Spartina alterniflora* salt marsh. The turnover times of glucose were consistently faster in soils where tall *S. alterniflora* grew along a creekbank than in the high marsh soils where *S. alterniflora* productivity was lower; this difference was magnified with increased depth. The distribution of label, followed through CO_2, particulate, and ether-soluble fractions indicated rapid recycling in the soil of the tall *S. alterniflora* marsh. In an experiment designed to assess the effects of tidal inundation on the activity of the microbial community in the tall *S. alterniflora* marsh soils, no consistent changes in glucose uptake or ATP concentration were evident after two months of restricting water movement. No direct link of tidal inundation with the microbial community was observed.

Crawford, C. C., J. E. Hobbie, and K. L. Webb. 1974. The utilization of dissolved free amino acids by estuarine microorganisms. Ecology 55:551-563.

The importance of bacteria in the cycling of carbon in the Pamlico River estuary was studied by measuring the rates of uptake of organic compounds. There was considerable variation in the heterotrophic activity over time and distance, probably caused by patchiness in distribution of plankton and dissolved compounds in the water. Mutual inhibition was found between the similar amino acid pairs glutamic acid and aspartic acid, threonine and serine, glycine and alanine, and leucine and alanine. The dissolved free amino acids (DFAA) were present in the water at concentrations of from 10 to 30 *ug* C/1; over half of this was ornithine, glycine, and serine. The production of particulate material was calculated by correcting total uptake figures for each amino acid by its characteristic respiration percentage. Over 60 per cent of the particulate production from amino acids was by uptake of alanine, leucine, valine, serine, glycine, aspartic acid, and glutamic acid. Such particulate production averaged 0.79 *ug*. C/1. hr. for the year and ranged from 0.06 to 2.37 *ug* C/1. hr.; this is about 10 per cent of the rate of production by algae during the summer months. This amount of particulate organic material is a significant contribution to this estuarine food chain.

David, K. A. V., S. K. Apte, A. Banerji, and J. Thomas. 1980. Acetylene reduction assay for nitrogenase activity: gas chromatographic determination of ethylene per sample in less than one minute. Appl. Environ. Micro. 39:1078-1080.

Ammoniacal silver nitrate (10 mg/ml) was added to terminate acetylene reduction assays used to measure nitrogenase activity. Silver nitrate quantitatively precipitated acetylene as the carbide salt, but did not affect the ethylene formed. The vials containing ethylene can be analyzed gas chromatographically at the rate of about 13 samples in 10 min.

Durbin, K. J. and I. Watanabe. 1980. Sulfate-reducing bacteria and nitrogen fixation in flooded rice soil. Soil Biol. Biochem. 12:11-14.

Acetylene reduction and ^{15}N studies showed that the addition of sulfate to flooded soil with rice straw enhanced N_2 fixation. The extent of the enhancement was dependent on the sulfate concentration. Sulfate also increased the population of SO_4^{2-} reducing bacteria and was completely reduced to sulfide by those microorganisms. Purified cultures of soil isolates were capable of C_2H_2 reduction. Based on this evidence, SO_4^{2-} reducing bacteria were considered responsible for the increase in N_2 fixation but only 1-2 mg N_2 were fixed /g SO_4^{2-} reduced. We conclude that the contribution of SO_4^{2-} reducing bacteria to the total N_2 fixation in flooded soil is unimportant.

Erkenbrecher, C. W. Jr. and L. H. Stevenson. 1978. The transport of microbial biomass and suspended material in a higher-marsh creek. Can. J. Microbiol. 24:839-846.

The transport of microbial biomass and suspended material in a high-marsh creek was investigated during four 40-h tidal studies throughout the year. Although considerable differences were noted between successive tidal cycles, overall the creek was found to be an exporting system and transported a mean concentration of ATP (−33g), chlorophyll a (−68g), particulate organic carbon (−31 kg), total suspended material (−344 kg), and fixed suspended material (−195 kg) during each tidal cycle. This net outward flux of materials was associated with a net flow of water out of the creek, while the net import of aerobic, heterotrophic bacteria (43 X 10^{12}) and volatile suspended material (238 kg) was generally due to a higher mean concentration of these materials per unit volume of water during the flooding tide. Also the latter generally were associated with increased amounts of suspended material suggesting an association between bacteria and suspended matter.

Fallon, R. D. and F. K. Pfaender. 1976. Carbon metabolism in model microbial systems from a temperate salt marsh. Appl. Environ. Micro. 31:959-968.

The metabolism of a saltwater leachate of ^{14}C-labeled *Spartina alterniflora* was examined in laboratory systems using mixed, salt marsh microbial communities and, by addition of appropriate antibiotics, communities with bacteria or eukaryotes inhibited. Label uptake was more rapid in the systems with bacteria alone and with the mixed microbial community than with fungi alone. Mineralization of the added label was more extensive in the mixed and bacterial systems, whereas the fungi appear more efficient at converting the label into particulate biomass. Particulate biomass production efficiencies ranged from a high of 0.82 for the fungal system to 0.21 in the mixed community, with the bacterial system giving an intermediate value of 0.54. The presence of protozoa and microcrustaceans in the mixed system appears to account for an increase in the mineralization of the label assimilated. Additional experiments with whole labeled *Spartina*, a leachate from *Spartina*, and the *Spartina* after leaching revealed that the seawater-soluble portions of the plant were attacked most rapidly by the microbial community.

Finlayson, M. and A. J. McComb. 1978. Nitrogen fixation in wetlands of southwestern Australia. Search 9(3):98-99.

This paper, according to the authors, provides formal evidence that nitrogen fixation is carried out in western Australia wetlands by organisms related to those known to fix nitrogen in other regions. Nitrogen-fixing ability was assayed by the reduction of acetylene to ethylene.

Fixation was detected in blue-green algal mats, lake water, epiphytes on aquatic plants, sediment, and rhizosphere, and the nodules of wetland legumes.

The authors suggest that the challenge now is to quantify the contribution which the organisms concerned make to the nitrogen budgets of wetland ecosystems.

Gallagher, J. L. 1978. Decomposition processes: Summary and recommendations. Pages 145-151 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

This is a summary chapter dealing with decomposition. Chapters reviewed include: (1) decomposition of intertidal freshwater marsh plants (Odum and Heywood, 1978), (2) litter decomposition in prairie glacial marshes (Davis and Van der Valk, 1978), (3) decomposition in northern wetlands (Chamie and Richardson, 1978), and (4) decomposition in the littoral zone of lakes (Godshalk and Wetzel, 1978).

The author concludes that much more descriptive work must be done before a clear picture of decomposition aspects of freshwater marsh dynamics emerges.

Godshalk, G. L. and R. G. Wetzel. 1978. Decomposition in the littoral zone of lakes. Pages 131-143 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

Methods: Senescent plants of five freshwater species of aquatic angiosperms were collected at the end of the growing season, washed free of sediments and lyophilized. Replicated samples of dried plant material were put in one-liter flasks of synthetic lake water (Wetzel Medium 5), inoculated with natural sediment containing no coarse organic matter and incubated up to 180 days under anaerobic and aerobic conditions at 10 °C and 25 °C. Samples were taken after 2, 4, 10, 24, 50, 90, and 180 days of decomposition and contents filtered (0.22 *u*m Millipore GS membrane filters). Dissolved organic compounds (<.02 *u*m) were fractionated by Amicron membrane ultra-filtration. Each fraction was examined for total dissolved organic carbon, analyzed for dissolved C and N content, and analyzed by infrared spectrophotometry. Microbial activity of identical fresh detritus at each time interval was assessed by determining dehydrogenase activity and ATP content.

Different species do decompose at different rates. The nutritive value of detrital vegetation to consumers is influenced by the qualitative species-specific characteristics of the decaying macrophytes.

Harrits, S. M. and R. S. Hanson. 1980. Stratification of aerobic methane-oxidizing organisms in Lake Mendota, Madison, Wisconsin. Limnol. Oceanogr. 25:412-421.

The microflora responsible for methane oxidation are stratified in a narrow band in the thermocline of Lake Mendota where dissolved oxygen is low during summer. Oxygen sensitivity of growth of these organisms or of methane oxidation cannot account for their absence from the epilimnion because oxygen does not inhibit either process under *in situ* conditions at concentrations exceeding those measured in natural samples. The dissolved inorganic nitrogen content of samples where methane oxidation rates were highest was >1 mg. liter $^{-1}$ in summer 1977. The authors could not obtain evidence of *in situ* nitrogen fixation although enrichment cultures grew on nitrogen-free media and fixed $^{15}N_2$. Nitrite was present at the position in the water column of maximum methane oxidation; this suggests that methanotrophic bacteria co-oxidized ammonia. The distribution of methanotrophs in the lake indicated that their position in the water column at each time of year was determined by the concentration profiles of oxygen and methane. Methane oxidation in summer depletes the methane in the epilimnion and the absence of oxygen in the hypolimnion precludes growth of the organisms there. At other times of year the rates of oxidation of methane seem to be determined by the concentration of methane in the water. The rate of oxidation of methane by a sample was increased by additional methane when the *in situ* concentration was <5 *u*M.

Hook, L. A. 1977. Distribution of myxobacters in aquatic habitats of an alkaline bog. Appl. Environ. Microbiol. 34:333-335.

Ten species of myxobacteria were identified from samples from an alkaline bog and adjacent soils. The frequency of occurrence and the diversity of species were highest at the margin of the bog and were lowest in the center and bottom of the bog lake.

Samples were obtained from aquatic habitats on eight dates. For comparison, terrestrial regions were chosen, each represented by a composite of 10 subsample sites that circumscribe the bog lake study area. The pH of the water at each sampling site was determined in the field with a Corning model 6 portable pH meter. The dissolved oxygen and temperature were measured *in situ* with a 4SI model 51A dissolved-oxygen meter.

Species identified included *Myxoccus fulvus, M. disciformis, M. stipitatus, M. coralloides, Polyangium sorediatum, Archangium gephyra, Myxococcus xanthus, Melittangium lichenicola,* and *Polyangium cellulosum.*

James, L. S., E. L. Robinson, C. O. Emeh, P. V. Krishn - Amurti, and G. S. Ghuman. 1977. Effects of nutrient concentration on microbial productivity in a Savannah (Georgia) salt marsh. Sci. Biol. J. 3:315-328.

Seasonal influences on the productivity and distribution of heterotrophic bacteria in a Savannah salt marsh were studied. Variations in the concentrations of mineral and inorganic elements in water and

sediment samples were also determined. Results indicated that methanogensis and denitrification were under stringent environmental influences, while sulfate reduction and nitrification were affected primarily by the composition of sediments. All sediments and water samples were positive for *Staphylococcus aureus, Escherichia coli, Nocardia* spp. and nontyphoid salmonellae. *Pseudomonas aeruginosa* was recovered from four sampling sites, *Chlostridium perfringens* from three sites, and *Bacillus fastidiosus* and *Desulfovibrio* from only one site. Bacterial counts increased in proportion to the total solids of water samples.

Jones, K. 1974. Nitrogen fixation in a salt marsh. J. Ecol. 62:553-566.

Nitrogen fixation occurs in all zones of the salt marsh. Blue-green algae in pools and on the banks of creeks fix nitrogen throughout the year whenever the temperature and light intensity permit. Bare areas in the lower marsh become progressively colonized with blue-green algae during the year, and maximum rates of nitrogen fixation are found in late summer and early autumn. Small, but consistent, levels of nitrogen fixation by bacteria are found in many parts of the marsh but at levels below those for blue-green algae. Nitrogen fixation is stimulated in the rhizosphere of *Puccinellia maritima*. The products of bacterial and algal nitrogen fixation are rapidly utilized by higher plants in the salt marsh.

Author employed acetylene reduction technique as a measure of nitrogen fixation.

Kaplan, W., I. Valiela, and J. M. Teal. 1979. Denitrification in a salt marsh ecosystem. Limnol. Oceanogr. 24:726-734.

The rate of denitrification measured throughout the year in various habitats of a New England salt marsh was correlated to temperature and was highest in the wettest habitats. Over 60 per cent of denitrification took place in the muddy creek bottoms. Annual denitrification exceeds nitrogen fixation. An amount of nitrate similar to the quantity consumed by denitrifiers is supplied by the flow of groundwater into the marsh and by nitrifiers within the marsh itself.

King, G. M. and M. J. Klug. 1980. Sulfhydrolase activity in sediments of Wintergreen Lake, Kalamazoo County, Michigan. Appl. Environ. Micro. 39:950-956.

The hydrolysis of p-nitrophenyl sulfate, p-nitrocatechol sulfate, and ^{35}S) sodium dodecyl sulfate was examined in anoxic sediments of Wintergreen Lake, Michigan. Significant levels of sulfhydrolase activity were observed in littoral, transition, and profundal sediment samples. Rates of sulfate formation suggest that the sulfhydrolase system would represent a major source of sulfate within these sediments. Sulfate formed by ester sulfate hydrolysis can support dissimilatory sulfate reduction as shown by the incorporation of ^{35}S from labeled sodium dodecyl sulfate into $H_2{}^{35}S$. Sulfhydrolase activity varied with sediment depth, was greatest in the littoral zone, and was sensitive to the presence of oxygen. Estimations of ester sulfate concentrations in sediments revealed large quantities of ester sulfate (30 per cent of total sulfur). Both total sulfur and ester sulfate concentrations varied with the sediment type and were two to three orders of magnitude greater than the inorganic sulfur concentration.

Latter, P. M., J. B. Cragg, and O. W. Heal. 1967. Comparative studies on the microbiology of four moorland soils in the northern Pennines. J. Ecol. 55:445-464.

The microbiology of four soils in the Moor House National Nature Reserve, Westmorland, England (*Festuca-Agrostis* grassland on limestone, *Juncus squarrosus* moor, mixed *Calluna-Eriophorum* moor and an area of bare eroded peat) was studied using a variety of methods. A general decrease in the variety of fungi and in their ability to colonize fresh substrates and to decompose cellulose was observed in the above mentioned series. Numbers of bacteria estimated by direct counts were: limestone grassland 16-79 X 10^8/cm^3; *Juncus* moor 18-39 X 10^8/cm^3; mixed moor 14-35 X 10^8/cm^3; bare peat 1-9 X 10^8/cm^3. Estimated by dilution culture counts, numbers decreased from 13 X 10^6/cm^3 in the limestone grassland to 8 X 10^3/cm^3 in the bare peat.

The studies establish the existence of an activity gradient with its highest values in the grassland site and its lowest in bare peat. This gradient can be related to a change from mineral-rich, relatively basic and well-drained conditions to mineral poor, acid, waterlogged conditions.

Lopez, G. R., J. S. Levinton, and B. Slobodkin. 1977. The effect of grazing by the detritovore *Orchestia grillus* on *Spartina* litter and its associated microbial community. Oecologia (Berl) 30:111-128.

Orchestia grillus efficiently feeds upon microorganisms attached to ingested *Spartina alterniflora* litter but does not ingest litter itself. Microorganisms respond to *Orchestia* grazing with increased metabolic activity reflected in accelerated decomposition of the nitrogen fraction of litter and increased microbial biomass. Increased microbial activity may be partly a function of ammonia excretion and higher diffusion rate due to animal movement, but mainly it is a direct response to grazing. Microbial biomass increases with grazing because the pool of available nitrogen becomes larger. A model postulating interactions between *Orchestia*, *Spartina* litter and attached microorganisms is presented.

Oborn, E. T. and J. D. Hem. 1961. Microbiologic factors in the solution and transport of iron. U.S. Geological Survey Water-Supply Paper 1459-H, Washington, D. C.

Amounts of iron dissolved by distilled water from soil, sand, and mixtures of organic matter with soil and sand were determined before and after 2 weeks of incubation at temperatures from 35° to 100°F. Amounts of iron present in solution were from about 1 to 8 ppm after incubation at 72° or 100°F. After incubation at 35° or before incubation, only a few tenths of a ppm or less were present. Amounts of iron in solution were generally much larger when organic matter was mixed with the soil than when

soil or sand alone was used. The amounts of iron brought into solution sometimes exceeded the amount available in the organic matter added. The organic matter consisted of pulverized dried plant leaves and stems, mostly aquatic species, and manures of three species of herbivorous animals.

The increase in amount of iron leached from soils after incubation is related to microbiologic activity. Organic complexes of iron aid in retaining in solution the iron made available by the microbiota. By helping to bring iron into solution, microbiota influence the iron content of surface and ground water in many areas.

Paerl, H. W. 1978. Microbial organic carbon recovery in aquatic ecosystems. Limnol. Oceanogr. 23:927-935.

Aquatic heterotrophic microorganisms were examined as producers of particulate matter in addition to their traditionally defined roles as mineralizers. Dialysis experiments illustrated the significance of microbial scavenging of dissolved organic carbon (DOC) in particulate organic carbon (POC) formation. Since microbial respiration of single assimilated DOC compounds can range between 10 and 60 per cent, a majority of nonrespired substrates may at times go into synthesis of structural carbon, much in a size range available to grazers. Dialysis bag experiments demonstrated the relationships between ambient DOC supplied and POC formation. Autoradiographs and scanning electron micrographs showed some natural planktonic assemblages responsible for conversion of DOC to POC, leading to the formation of particulate matter.

Rodina, A. G. 1972. Methods in aquatic microbiology. University Park Press, Baltimore, Maryland. 461.

This book has been translated from Russian. The general headings include: (1) sampling for microbiological investigations, (2) methods of microscopy, (3) methods of culturing microorganisms, (4) isolating pure cultures and identifying bacterial species, (5) quantitative determination of microorganisms in water and sediment, (6) methods of studying microorganisms involved, (7) methods of studying microorganisms of the nitrogen cycle, (8) methods of studying the sulfur cycle, (9) methods of studying transformations of phosphorous compounds by microorganisms, (10) methods of culturing iron bacteria, (11) culturing pigmented and luminous microorganisms and streptomycetes: methods of isolating streptomycetes, (12) submerged slide culture, (13) methods of bacteriological analysis of water in public health, (14) radioactive tracer methods, and (15) determining pH and oxidation-reduction potential.

Sorokin, Y. I. and H. Kadota. 1972. Microbial production and decomposition in freshwaters. IBP Handbook No. 23, Blackwell Scientific Publications, Oxford. 112 p.

This handbook was the sixth issued by the Production in Freshwaters (PF) group of the IBP. It is an attempt to bring together the main methods of microbial assessment. General headings include: (1) introduction, (2) measurement of biological N_2 fixation with $^{15}N_2$ and acetylene: R. H. Burris, (3) measurement of microbial activity in relation to decomposition of organic matter, (4) determination of microbial numbers and biomass, (5) estimation of production rate and *in situ* activity of autotrophic and heterotrophic microorganisms, and (6) evaluation of the trophic role of microorganisms.

Silverman, M. P. and E. F. Munoz. 1980. Microbial mobilization of calcium and magnesium in waterlogged soils. J. Environ. Qual. 9:9-12.

Microbial mobilization of Ca and Mg was studied in 12 California soils amended with 0.5 per cent glucose solution and incubated in air and anaerobically for two weeks under waterlogged conditions in the laboratory. Incubation in air resulted in a decrease of one to two units in the pH of soil solutions relative to control soils incubated without glucose. This was accompanied by 2.4- to 29.4-fold increases in the Ca content and 0.7- to 41-fold increases in the Mg content of soil solutions. A similar decrease in pH was observed under anaerobic incubation as well as 2.7- to 15.3-fold increases in the Ca content and 1.5- to 47-fold increases in the Mg content of soil solutions.

The changes under anaerobic and air incubation conditions may be attributed to microbial production of a variety of organic metabolites from glucose which may be reponsible for the release of Ca and Mg from exchange sites and other mineral reservoirs. These metabolic products probably are relatively stable under anaerobic incubation but become susceptible to subsequent biodegradation in the presence of air.

Suberkropp, K. and M. J. Klug. 1976. Fungi and bacteria associated with leaves during processing in a woodland stream. Ecology 57:707-719.

Autumn-shed leaves of white oak (*Quercus alba*) and pignut hickory (*Carya glabra*) were fastened together and incubated in a third order hard water stream in southwestern Michigan. At biweekly intervals, leaves were removed and the microbial populations assessed. Direct counts of bacteria increased logarithmically with time, but viable counts were generally lower. *Flexibacter, Achromobacter, Flavobacteria, Pseudomonas,* and *Cytophaga* were isolated from leaves. No apparent bacteria succession was detected. The mycoflora was assessed in five ways, including direct examination and incubations ranging from environment simulating to particle platings on nutrient medium. Aquatic hyphomycetes, particularly *Alatospora acuminata, Flagellospora curvula,* and *Tetracladium marchalianum* were the dominant members of the mycoflora. The successional pattern of these fungi on both leaf species was discussed. It was concluded that the aquatic hyphomycetes are actively growing and completing their life cycle in this environment and that the terrestrial fungi are normally present mainly in a dormant state, growing and sporulating only in greatly enriched conditions.

Taft, C. E. 1978. A mounting medium for freshwater plankton. Trans. Am. Microsc. Soc. 97:263-264.

A mounting medium of glucose can be used for making permanent phytoplankton and zooplankton slides. An inexpensive method that precludes the use of extensive time and equipment is described. Preparations are usable a decade or more later.

Teal, J. M., I. Valiela, and D. Berlo. 1979. Nitrogen fixation by rhizosphere and free-living bacteria in salt marsh sediments. Limnol. Oceanogr. 24:126-132.

The rates of nitrogen fixation by rhizosphere and free-living bacteria are highest near the surface of a variety of salt marsh sediments and in the warm part of each year. The highest rates were found in vegetated habitats, reaching up to about 500 ng N. cm^{-2}. h^{-1}. Bacterial N_2 fixation for the entire marsh is more than 10 times larger than algal fixation and less than a third of the N required to support growth of the vegetation.

Tjepkema, J. D. and H. J. Evans. 1976. Nitrogen fixation associated with *Juncus balticus* and other plants of Oregon wetlands. Soil Biol. Biochem. 00:505-509.

High rates of N_2 fixation were associated with *Juncus balticus* Wildl., and five other species of plants growing in wetlands. Intact plants in soil cores of 15.3 cm. dia. were assayed, using C_2H_2 reduction method. There was a lag of about a day before high activity was observed, but linear rates of C_2H_4 evolution then occurred for at least 2 days. Higher rates were found when the cores were assayed in N_2 rather than air, and O_2 was not required for N_2 fixation. At the soil temperature of about 15 °C, the rates in N_2 extrapolated to a N_2-fixation rate of about 0.8 kgN/ha/d. The reason for the lag in activity was not clear, but it was not due to the time required for C_2H_2 diffusion into and C_2H_4 diffusion out of the cores. Our results suggest that high rates of N_2 fixation may be associated with many plants growing in wet soils.

Van Raalte, C. D. and I. Valiela. 1978. Nitrogen fixation by algae in a Massachusetts salt marsh. Limnol. Oceanogr. 23:318-327.

Over a three-year period, N_2 fixation on the surface of a Cape Cod salt marsh was highest in summer, with overall rates of about 10-20 mg N $m^{-2}d^{-1}$, compared favorably with N_2 fixation in the rhizosphere (ca. 80 mg N $m^{-2}d^{-1}$), compared favorably with the highest N_2 fixation rates measured anywhere. There were significant variations from one marsh habitat to another; the blue-green algal mat had the highest rate of N_2 fixation per unit area (100-200 ng N $cm^{-2}h^{-1}$), but due to its large area, the low marsh with short *Spartina* contributed the greatest amount of fixed N. Nitrogen is fixed on the marsh surface primarily by blue-green algae.

Ward, D. M. and G. J. Olson. 1980. Terminal processes in the anaerobic degradation of algal-bacterial mat in a high-sulfate hot spring. App. Environ. Micro. 40:67-74.

The algal-bacterial mat of a high-sulfate hot spring (Bath Lake) provided an environment in which to compare terminal processes involved in anaerobic decomposition. Sulfate reduction was found to dominate methane production, as indicated by comparison of initial electron flow through the two processes, rapid conversion of (2-^{14}C) acetate to $^{14}CO_2$ and not to $^{14}CH_4$, and the lack of rapid reduction of $NaH^{14}CO_3$ to $^{14}CH_4$. Sulfate reduction was the dominant process at all depth intervals, but a marked decrease of sulfate reduction and sulfate-reducing bacteria was observed with depth. Concurrent methanogenesis was indicated by the presence of viable methanogenic bacteria and very low but detectable rates of methane production. A marked increase in methane production was observed after sulfate depletion despite high concentrations of sulfide (1.25 mM), indicating that methanogenesis was not inhibited by sulfide in the natural environment. Although a sulfate minimum and sulfide maximum occurred in the region of maximal sulfate reduction, the absence of sulfate depletion in interstitial water suggests that methanogenesis is always severely limited in Bath Lake sediments. Low initial methanogenesis was not due to anaerobic methane oxidation.

Zachary, A. 1978. An ecological study of bacteriophages of *Vibrio natriegens*. Can. J. Microbiol. 24(3):321-324.

Effects of temperature and anaerobic conditions on the replication of two bacteriophages, nt-1 and nt-6, of the estuarine bacterium *Vibrio natriegens* were studied. Reduction in temperature resulted in longer latent periods and reduced burst sizes for both phages. Replication under anaerobic conditions resulted in longer latent periods; however, phage nt-6 had a reduced burst size, whereas phage nt-1 had an increased burst size, resulting in a rate of phage production nearly equal to that observed under aerobic conditions. Therefore the distribution of phages in marsh areas could be influenced by temperature and anaerobiosis.

Chemistry

American Public Health Association. 1975. Standard methods for the examination of water and wastewater. 14th edition, New York, New York. 1193 pages.

This is the accepted methods text for chemical and microbiological analysis of water by the American Public Health Association (APHA). General headings include: (1) physical and chemical examination of natural and treated waters in the absence of gross pollution, (2) methods for the examination of water and wastewater for radioactivity, (3) physical and chemical examination of wastewater, treatment plant effluents, and polluted waters, (4) physical and chemical examination of industrial wastewaters, (5) physical and chemical examination of sludge and bottom sediments in wastewater treatment process and in polluted rivers, lakes, and estuaries, (6) bioassay methods for the evaluation of acute toxicity of industrial wastewaters and other substances to fish, (7) routine bacteriologic examination of water to determine its sanitary quality, (8) methods for detection and isolation of iron and sulfur bacteria, and (9) biologic examination of water, wastewater sludge, and bottom materials.

Aomine, S. 1962. A review of research on redox potentials of paddy soils in Japan. Soil Sci. 94:6-13.

The redox potential of the plowed layer (A_p horizon) of paddy soils rapidly drops to below 0.30 volts at pH 6 after waterlogging on the whole mass, reducing nitrate, manganese dioxide, ferric iron, and sulfate to nitrogen gas, manganous manganese, ferrous iron, and sulfide, respectively, and forming certain gases and organic acids. In some degraded soils, rice plants have physiological diseases owing to reduced products, such as hydrogen sulfide. Reduced-surface soils easily recover the oxidized condition (above Eh_6 + 0.30 volts) by drainage. Thus, the redox potential of the plowed layer of paddy soils is susceptible to waterlogging and drainage.

The redox potential of the B horizon of the soils is only slightly affected by waterlogging and drainage, persisting in the oxidized condition throughout the year. This persistence of the oxidized layer under the reduced layer is one of the characteristics of a well-drained paddy soil.

Waterlogged soils develop a very thin oxidized layer a few mm thick at the surface, and, in general, they include oxidized portions even in the reduced layer. Such heterogeneity of the redox potential, that is the coexistence of the oxidized and reduced portions, causes nitrogen to be lost from the soils, but it is favorable to the healthy growth of rice plants.

Avnimelech, Y. 1971. Nitrate transformation in peat. Soil Sci. 111:113-118.

Nitrate accumulation and denitrification in peat from the Hula Valley, Israel were studied.

Nitrates are accumulated in the peat as one of the end products of the decomposition of organic matter. Nitrate production is affected by the moisture content of the peat, reaching an optimum at about field capacity. Its rate is roughly doubled between 24° and 36°C. The rate of nitrate accumulation at field capacity is 7 and 17 *ug* NO_3 per gram soil per day at 24° and 36°C, respectively. These values were used for the calculation of oxygen consumption by the decomposition process. The average oxygen consumption for the temperature range mentioned above was 2.28 mmole O_2 per kg soil per day.

Such high oxygen consumption favors anaerobic conditions in the subsoil layers. Under these conditions, a rapid process of denitrification occurs. The rate of the process depends on temperature, nitrate, concentration, and on the interaction between them. The reaction appears to be a first order one. The existence of two different denitrification mechanisms is indicated by the presence of two groups of rate constants and different changes in these due to temperature variations.

Barica, J. and J.A. Mathias. 1979. Oxygen depletion and winterkill risk in small prairie lakes under extended ice cover. J. Fish. Res. Board Can. 36:980-986.

Mean rates of dissolved oxygen depletion in 10 shallow eutrophic prairie lakes (area 2.3-27.3 ha, mean depth 1.6-4.2m) ranged from 0.22 to 0.34 $g/m^2.d^{-1}$ for nonstratified lakes and 0.32-0.42 $g/m^2.d^{-1}$ for stratified ones. An average rate for all lakes was 0.29 ± 0.06 $g/m^2.d^{-1}$. The rates correlated with the lake depth.

Winterkill risk is estimated through a knowledge of the initial dissolved oxygen storage of the lake, the oxygen depletion rate, and the critical time required to reach winter anoxia. If bathymetric data for the lake are not available, determine the intial D.O. storage of water column at the deepest site of the lake by measuring D.O. at 1-m intervals and compute the mean value for $1.m^2$. This will tend to underestimate storage by overestimating the bottom layers and yield a conservative winterkill prediction.

Boyd, C. E. and W. W. Walley. 1972. Studies of the biogeochemistry of boron. I. Concentrations in surface waters, rainfall, and aquatic plants. Am. Midl. Nat. 88:1-14.

Boron concentrations in streams, swamps, ponds, and reservoirs of the southeastern United States were usually below 100 ppb. Levels of boron in rainfall varied greatly between different periods of precipitation, but the highest concentrations were observed during winter. However, most rainfall samples contained less than 10 ppb. boron. The annual input of boron in rainfall at two Mississippi sites and one station in South Carolina ranged from 62.7 to 74.2 g/ha.

Boron levels in 22 species of aquatic macrophytes from a reservoir ranged from 1.2 to 11.3 ppm dry weight. The plant populations accrued from 0.5 to 6.8 boron per m^2. Boron uptake studies on *Typha latifolia* populations indicated a maximum rate of uptake during early spring growth. Boron concentrations in *T. latifolia* and *Juncus effusus* samples from different sites varied considerably. There was no significant correlation between concentrations of boron in soils and in plant tissues. Standing crops of *T. latifolia* increased with increasing levels of soil boron.

Cammen, L. M. 1975. Accumulation rate and turnover time of organic carbon in a salt marsh sediment. Limnol. and Oceanogr. 20:1012-1015.

Concentrations of organic carbon (excluding below ground plant material) decreased logarithmically with depth in the sediment of a *Spartina alterniflora* marsh near Drum Inlet, N.C. A similar decrease was measured in nearby areas of unvegetated dredge spoil and in dredge spoil planted with *Spartina*. Both spoil areas accumulated organic carbon, but the annual rate was higher where *Spartina* was present (range, 80.3-96.8 g C/m^2). The organic carbon in the top 13 cm of the natural marsh sediment had a turnover time, based on this rate of accumulation, of 3.7 to 4.5 years.

Crisp, D. T. 1966. Input and output of minerals for an area of Pennine moorland: the importance of precipitation, drainage, peat erosion, and animals. J. Appl. Ecol. 3:327-348.

An outline balance sheet for water and the elements of sodium, potassium, calcium, phosphorus, and nitrogen was constructed for a stream catchment of 83 ha within the Moor House National Nature Reserve. The catchment surface comprised 11-20 per cent eroding peat, 80-85 per cent blanket bog vegetation and a little grassland. The input in precipitation was measured and the outputs in solution in stream water, in eroding peat, as downstream-drift of invertebrates and by sale of sheep and wool were estimated.

About 80 per cent of the input water left the catchment via the stream.

Only peat erosion and elements in solution in the stream water were significant sources of output of the five elements. For all five of the total output was greater than the input, but for three metals this may reflect additional input by solution of mineral deposits within the catchment. Such additional input of phosphorus, potassium, and nitrogen is unlikely. The outputs of phosphorus in solution in the stream water were much less than the inputs, but both elements were lost from the catchment as eroding peat in large enough quantities to give a total output greater than the input. The estimated net annual losses of phosphorus and nitrogen in all forms were 0.17-0.40 and 9.48 kg/ha/year, respectively.

Evans, R. D. and F. H. Rigler, 1980. Measurement of whole lake sediment accumulation and phosphorus retention using lead-210 dating. Can. J. Fish. Aquat. Sci. 37:817-822.

Lead-210 dating was used to measure rates of sediment accumulation in 15 cores from Bob Lake, Ontario. The rate of accumulation was highly correlated with sample depth. This relation allowed the calculation of accumulation of sediments over the whole lake area. Phosphorus (P) retention was calculated from mean concentration of P in the sediments and the whole lake accumulation of sediment. Retention of P calculated in this way was similar to retention calculated from previously measured input and output of P.

Galloway, J. N. and E. B. Cowling. 1978. The effects of precipitation on aquatic and terrestrial ecosystems: a proposed precipitation chemistry network. J. Air Pollut. Control Assoc. 28:229-235.

The major purpose of this paper is to describe the changing chemistry of precipitation and its effects on terrestrial and aquatic ecosystems. The concept of sensitive areas is discussed, together with the need to identify them on a regional basis. The changing chemistry of precipitation emphasizes the need for a network of precipitation measuring stations in the U.S. and Canada to provide information about changes in the deposition of beneficial nutrient elements as well as potentially injurious substances. Such information is needed to permit prudent management of anthropogenic emissions of atmospheric trace constituents and the aquatic and terrestrial ecosystems in which these emissions and their transformation products are deposited.

Gaudet, J. J. 1979. Seasonal changes in nutrients in a tropical swamp: north swamp, Lake Naivasha, Kenya. J. Ecol. 67:953-981.

North Swamp, a papyrus swamp at the north end of Lake Naivasha, Kenya, was assayed monthly during 1975-76 for dissolved (0.45-*u*m-filtered) nutrients: NO_2-N, NH_3-N, NH_3-N, organic N, total P, PO_4-P, SO_4-S, Fe, Mn, O_2, pH, conductivity and organic matter. Sediment traps under the floating papyrus mat were used to obtain an estimate of the rate of sedimentation inside the swamp.

All of the dissolved nutrients (N, P, S, Fe, and Mn) generally showed a common pattern in vertical profiles through the swamp, with minimum values at the swamp surface and maximum values on the bottom. The prevailing pH, O_2, and redox potentials in the swamp indicate that at the surface, much of the iron would be present as ferric-Fe, while ferrous-Fe predominates on the bottom. The annual output of organic N is much larger than the total input from the river, suggesting that nitrogen is fixed in appreciable quantities.

It is concluded that papyrus swamps effectively extract dissolved nutrients from tropical river systems, but such nutrients are later exported as organic particulate matter or adsorbed to particles which are carried into the lake by through-flow.

Golterman, H. L. and R. S. Clymo. 1969. Methods for chemical analysis of freshwaters. IBP Handbook No. 8. Blackwell Scientific Publications, Oxford. 166 p.

This handbook, authored by members of the Production Freshwater (PF) group of the IBP, deals with the chemical ingredients which make biological production possible. General headings include: (1) introduction, (2) sample taking and storage, (3) conductivity, pH, oxidation-reduction potential, alkalinity, total CO_2, acidity, (4) major elements; Ca^{2+}, Mg^{2+}, Na^+, K^+, Fe^{2+} and Fe^{3+}, Cl^-, SO_4^{2-}, S^{2-}, CO_3^{2-}, and HCO_{3-}, (5) minor elements; N-, P-, and Si compounds, (6) trace elements; B, Co, Cu, Fe, Mn, Mo, V, Zn, (7) organic substances, (8) dissolved gases; O_2, N_2, CO_2, H_2, CH_4, (9) electrochemical properties of water, and (10) bibliography, makers' addresses.

Gorham, E. 1953. Chemical studies on the soils and vegetation of waterlogged habitats in the English Lake District. J. Ecol. 41:345-360.

This study was made of the nutrient status of some waterlogged soils and their plants in the English Lake District. In passing from relatively inorganic lake muds through semi-aquatic soils to raised bog peats, the amount of soils acids increases, base saturation declines, and humus nitrogen also falls. These changes are reflected in the nutrient status of the plants, those from underwater sites being highest in minerals and nitrogen and those from raised bogs lowest in both these constituents.

Gray, A. J. and R. G. H. Bunce. 1972. The ecology of Morecambe Bay VI. Soils and vegetation of the salt marshes: A multivariate approach. J. Appl. Ecol. 9:221-234.

Data from 168 samples of soils and vegetation on the salt marshes of Morecambe Bay were examined by a combination of association-analysis and principal component analysis. The major trend of variation was provided by the contrast between the vege-

tation of calcareous nutrient-poor sands with that of comparatively fertile organic silty soils, reflecting the complex of factors associated with pedogenesis. A second component of variation, contrasting soil sodium content, reflected the factors related to tidal submergence.

Whereas areas of continuous vegetation may be limited by tidal factors to elevations about 4.5 m A. O. D., point-to-point variation in the vegetation above this level reflects the interaction of such factors with local variation in soil type.

Hardy, R. W. F., R. D. Holsten, E. K. Jackson, and R. C. Burns. 1968. The acetylene-ethylene assay for N_2 fixation: laboratory and field evaluation. Plant Physiol. 43:1185-1207.

The methodology, characteristics, and application of the sensitive C_2H_2-C_2H_4 assay for N_2 fixation by nitrogenase preparations and bacterial cultures in the laboratory and by legumes and free-living bacteria *in situ* is presented in this comprehensive report. This assay is based on the N_2ase-catalyzed reduction of C_2H_2 to C_2H_4, gas chromatographic isolation of C_2H_4, and quantitative measurement with a H_2-flame analyzer. As little as 1 *uu* mole C_2H_4 can be detected, providing a sensitivity 10^3-fold greater than is possible with ^{15}N analysis.

A simple, rapid, and effective procedure utilizing syringe-type assay chambers is described for the analysis of C_2H_2-reducing activity in the field. Assay values reflected the degree of nodulation of soybean plants and indicated a calculated seasonal N_2 fixation rate of 30 to 33 kg N_2 fixed per acre, in good agreement with literature estimates based on Kjeldahl analyses. The validity of measuring N_2 fixation in terms of C_2H_2 reduction was established through extensive comparisons of these activities using defined systems, including purified N_2ase preparations and pure cultures of N_2-fixing bacteria.

With this assay it now becomes possible and practicable to conduct comprehensive surveys of N_2 fixation, to make detailed comparisons among different N_2-fixing symbionts, and to rapidly evaluate the effects of cultural practices and environmental factors on N_2 fixation.

Hem, J. D. 1970. Study and interpretation of the chemical characteristics of natural water. U.S. Geological Survey Water-Supply Paper 1473, Washington, D.C. 363 p.

The chemical composition of natural water is derived from many different sources of solutes, including gases and aerosols from the atmosphere, weathering and erosion of rocks and soil, solution or precipitation reactions occurring below the land surface, and cultural effects resulting from activities of man.

The ways in which solutes are taken up or precipitated and the amounts present in solution are influenced by many environmental factors, especially climate, structure and position of rock strata, and biochemical effects associated with life cycles of plants and animals, both microscopic and macroscopic.

Chemical analyses may be grouped and statistically evaluated by averages, frequency distributions, or ion correlations to summarize large volumes of data.

Fundamental knowledge of processes that control natural water composition is required for rational management of water quality.

Hem, J. D. 1965. Reduction and complexing of manganese by gallic acids. U.S. Geological Survey Water-Supply Paper 1667-D, Washington, D.C.

Tannic (digallic) and gallic acids form 1:1 complexes with Mn^{+2} in dilute solution. The stability constant of digallic complex was determined to be $10^{3.9}$ by spectrophotometric studies. Water solutions of tannic and gallic acid can bring 100 parts per million or more of manganese into solution from solid manganese dioxide reagent. The reducing and complexing reactions are most rapid at pH's below 5. The manganese brought into solution was oxidized very slowly at pH's as high as 9.8.

Hem, J. D. 1964. Deposition and solution of manganese oxides. U.S. Geological Survey Water-Supply Paper 1667-B, Washington, D.C.

Manganese is essential for plant growth and some aquatic species contain considerable amounts. Manganese oxide deposits, generally mixed with iron oxide, occur in streambeds and in lakes in some areas. Manganese oxide is an important constituent of desert varnish.

Feldspathic sand removes manganese from dilute solutions by cation exchange, and above pH 7.0 the sand acts as a catalyst in the oxidation of manganous ions by aerated water. The catalytic effect was strongest in sand whose exchange positions had been saturated with manganese and which had been thoroughly dried. Manganese was a little more strongly absorbed than calcium.

Manganese oxide coprecipitated with ferric hydroxide in aerated solutions above pH 6.5. Mixed deposits of iron and manganese oxides can form in freshwater environments at pH and redox potential where manganese oxide would not be precipitated alone if the ferrous iron activity in solution is maintained at a very low value.

Hem, J. D. 1963. Chemical equilibria and rates of manganese oxidation. U.S. Geological Survey Water-Supply Paper 1667-A, Washington, D.C.

The relationships between manganese in solution, Eh, pH, and the activities of bicarbonate and sulfate ions are shown by means of seven stability-field diagrams. The behavior of manganese in laboratory experiments is in general agreement with predictions of the diagrams.

Bicarbonate species in equilibrium with manganese carbonate may control manganese solubility in some systems. Increased bicarbonate activity decreases manganese solubility. Relationships between manganese and sulfate activities are related to solution of manganese sulfide with oxidation of the sulfur.

Manganese forms soluble complexes with bicarbonate and sulfate. The association constant for $MnHCO_{3+}$ ion was determined to be 63. The solubility of manganese in natural water, especially that which contains large amounts of bicarbonate or sulfate, is influenced by complexing.

The rate at which divalent manganese is oxidized and precipitated from aerated solutions is sharply increased by increasing the pH. The rate is diminished when sulfate and bicarbonate ions are present. Experimental data suggest that the reaction may be first order with respect to manganese concentration initially, but the rate increases as the reaction proceeds, probably because of autocatalysis.

Manganese coprecipitates with ferric hydroxide when the pH is greater than 6.7.

Hem, J. D. 1960a. Restraints on dissolved ferrous iron imposed by bicarbonate redox potential, and pH. U.S. Geological Survey Water-Supply Paper 1459-B, Washington, D.C.

Chemical equilibrium involving carbon dioxide, bicarbonate, carbonate, and pH influences the amount of ferrous iron in much natural water. Values of pH computed from assumed equilibrium involving calcite or siderite approximate measured values of pH in 13 of 20 samples of ground water from different geologic terrains; thus, some degree of equilibrium probably existed. Failure to reach equilibrium may result from absence of the minerals in the aquifer, unrepresentative analytical data, lack of reaction time, or chemical complexing.

At equilibrium, pH and iron content provide a basis for estimating the Eh (redox potential) of ground water. If much bicarbonate is present, the amount of iron dissolved may not change with change in Eh. The measured Eh (0.28 v) of water from a pumped water-table well was 0.18 v higher than the computed value. This difference was probably due to the effect of oxygen from the atmosphere on the measurement.

Hem, J. D. 1960b. Some chemical relationships among sulfur species and dissolved ferrous iron. U.S. Geological Survey Water-Supply Paper 1459-C, Washington, D.C.

Sulfur species most likely to occur in natural waters are HS^{-2}, H_2S, HSO_4^{-2}, and SO_4^{-2}; and free sulfur (S) may be a stable form. The stability fields for these five species are shown on an Eh-pH diagram. Reactions involving oxidation or reduction of sulfur are slow but may be speeded by biochemical influences.

If equilibrium is established, natural water containing a few hundred ppm of SO_4^{-2} and HCO_3^{-1} could contain over 10 ppm of iron only if pH is less than about 6.1 over a rather wide Eh range.

Oxidation of pyrite evidently can be an important source of iron in ground water. The changes in Eh with depth below the water table and the fluctuation of the water table may result in stratification of iron content in ground water and in erratic changes in iron content of water from wells; they may cause iron deposits to form in aquifers and wells. Such deposits could reduce the capacity of wells to yield water and might interfere with ground water movement.

Hem, J. D. 1960c. Complexes of ferrous iron with tannic acid. U.S. Geological Survey Water-Supply Paper 1459-D, Washington, D.C.

Solutions of tannic (digallic) acid at concentration of 5 or 50 ppm reduce dissolved ferric iron to the ferrous state when the pH is less than 4. In solutions with a pH of 4 or more, a black material containing ferric iron and tannic acid is precipitated. In a solution containing 500 ppm of tannic acid, and ferrous complex forms at a pH of more than 5. This complex is oxidized at a slow rate, and some ferrous iron remains in solution after a month of storage in contact with air. Uncomplexed ferrous iron is oxidized and precipitated from solution in a few hours or less at pH levels of more than 5.

The approximate value of the first dissociation constant for tannic acid is between 1×10^{-5} and 1×10^{-6}. The stability constant for the ferrous complex is comparable in magnitude to that of the pink bipyridine complex used in the determination of iron.

Hem, J. D. and W. H. Cropper. 1959. Survey of ferrous-ferric chemical equilibria and redox potentials. U.S. Geological Survey Water-Supply Paper 1459-A, Washington, D.C. 31 p.

Amounts of iron in solution in natural water at equilibrium are related to the pH and Eh of the solution. Important ionic species present include Fe^{+++}, $FeOH^{++}$, $Fe(OH)_{2}^{+}$, Fe^{++}, and $FeOH^{+}$. The amounts of iron that theoretically could be present in solution are mostly below 0.01 ppm if pH is between 5 and 8, and Eh values from 0.30 to 0.50. The content of Fe could exceed 100 ppm at pH 5 and Eh 0.30.

Solutions containing 12 to 24 ppm of iron in various proportions of Fe^{++} to Fe^{+++} were unstable when exposed to air. Changes in the Eh values of these solutions indicate that equilibrium is not reached in such mixtures at the end of a week when the initial pH is 3.6 to 4.1.

A natural ground water containing 16 ppm of ferrous iron when collected, and 9 artificial solutions containing from about 12 to about 26 ppm of ferrous iron at pH 5.8 to 6.7, lost iron by oxidation and precipitation of ferric hydroxide at a rate governed by the diffusion of oxygen through water.

Hem, J. D. and M. W. Skougstad. 1960. Coprecipitation effects in solutions containing ferrous, ferric, and cupric ions. U.S. Geological Survey Water-Supply Paper 1459-E, Washington, D.C.

Precipitates of ferric hydroxide that form when solutions containing ferrous iron are raised in pH or Eh may remove other ions from solution by coprecipitation. Solutions containing from 1 to 10 ppm of iron and about 0.5 ppm of copper were adjusted to pH values ranging from 3.8 to 8.5 by adding sodium carbonate or sodium bicarbonate. More copper was lost from solutions whose pH was 5.5 or more than would have been expected had iron been absent. Stable or metastable colloidal suspensions of ferric

hydroxide have a positive zeta potential and do not adsorb copper; but when the zeta potential decreases or becomes negative as a result of a change (increase) in the pH of the solution, copper is adsorbed by the ferric hydroxide precipitate.

Iron precipitating from water samples after they have been collected may remove dissolved copper. Samples from which iron has precipitated can be acidified at the time of analysis to return all the copper to solution. Precipitation of iron can be prevented by lowering the pH of the sample to 4.5 or less at the time of collection if the amount of copper originally dissolved is to be determined.

Nichols, D. S. and D. R. Keeney. 1976. Nitrogen nutrition of *Myriophyllum spicatum:* uptake and translocation of ^{15}N by shoots and roots. Freshwater Biol. 6:145-154.

Intact *Myriophyllum spicatum* plants were grown in compartmentalized containers in a growth room so that the roots were separated from the shoots by a watertight partition. Nitrogen ^{15}N was added to the water or sediment to trace the uptake of inorganic N by the plant shoots or roots. *Myriophyllum spicatum* was capable of taking up inorganic N through both roots and shoots. Plant N requirements can apparently be met by root uptake alone. However, when about 0.1 mg/1 of NH_4-N were present in the water, foliar uptake supplied more N to the plants than did root uptake. Foliar uptake of NH_4-N was found to be several times faster than that of NO_3-N when both forms of N were present in the water. Only about 1 per cent of the N taken up by the roots was subsequently released to the water through the foliage.

Pellenbarg, R. E. and T. M. Church. 1979. The estuarine surface microlayer and trace metal cycling in a salt marsh. Science 203:1010-1012.

The aqueous surface microlayer in a Delaware salt marsh carries an average of 10 per cent of the copper, 19 per cent of the zinc, and 23 per cent of the iron relative to the total metal flux including the dissolved and seston components. Such trace metals cycle in the salt marsh by net import on the surface microlayer and net export in the dissolved and seston components during maximum monthly tides.

Shoesmith, J. A., V. A. Adomaitis, and G. A. Swanson. 1968. Aspects of the determination of the pH of marsh waters. Proc. N. D. Acad. Sci. 22:135-138.

A mechanically operated color comparator-indicator dye kit is of sufficient accuracy and low cost to warrant its adoption instead of indicator papers or electrical meters for the determination of the pH of alkaline marsh waters in the field. It also has the advantage of being easy to carry and capable of withstanding rough handling or adverse field conditions.

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

The concentrations of N, P, Mn and Al in plants of two ombrotrophic bogs, and four adjacent environments were examined. The current year's foliage of the evergreen bog species, as contrasted with the older leaves, invariably possessed higher concentrations of N and P and lower concentrations of Al and Mn within the bog species. The composition of the current year's foliage of the evergreen was not significantly different for any of the elements from that of the deciduous species. Foliage of the bog species was lower in content of N and P than the foliage of plants of other habitats and reflects the paucity of available N and P in the bog substrate. Broadleaved evergeen leaves of bog plants appear to manufacture more photosynthate per acquired unit of N or P than do deciduous leaves, primarily because of their longevity. The high occurrence of evergreenness in infertile environments may, therefore, reflect a decreased need to acquire N and P from a substrate deficient in these elements. Mn and Al contents were comparable in the bog plants to plants of other habitats, despite potentially toxic levels of these elements in acid bogs. Apparently many bog plants selectively exclude Mn and Al.

Syers, J. K., R. F. Harris, and D. E. Armstrong. 1973. Phosphate chemistry in lake sediments. J. Environ. Qual. 2:1-14.

The amounts and forms of inorganic and organic phosphate (P) in lake sediments are discussed in relation to sediment composition and properties. The ability of noncalcareous and calcareous sediments to sorb and desorb added P in the laboratory and in the lake environment is interpreted in terms of the amounts and reactivities of sediment components involved in the sorption of P; emphasis is placed on the role of an Fe-rich gel complex. Factors controlling the chemical mobility and biological availability of sediment inorganic and organic P are considered. Whether sediments act as a P source or sink is determined by sediment composition and limnological conditions. The factors involved in the interchange of P between the sediment interstitial water and the overlying water column are reviewed. The role of P in lake eutrophication is discussed briefly.

Tuschall, J. R. Jr. and P. L. Brezonik. 1980. Characterization of organic nitrogen in natural waters: its molecular size, protein content, and interactions with heavy metals. Limnol. Oceanogr. 25:495-504.

The nitrogenous organic matter from two freshwater lakes and from the filtrate of a unialgal culture of *Anabaena* sp. was characterized chemically and evaluated for metal complexation ability. Proteinaceous matter was isolated from acidified samples by cellulose cation exchange columns and eluted with a basis salt solution. Isolated proteinaceous matter accounted for 14-34% of the original dissolved organic nitrogen. Gel permeation chromatography and ultrafiltration methods used to separate dissolved organic nitrogen into various size fractions yielded differing results, but most of the organic nitrogen had apparent molecular weights between 10,000 and 50,000 daltons. The copper-complexing capacity of the proteinaceous matter was determined by differential pulse anodic stripping voltammetry. Conditional stability constants which represent the mixed stability of all nonlabile ligands in the sample, ranged from 1.6×10^6 to 1.3×10^7 for the three samples.

Wendt, R. C. and R. B. Corey. 1980. Phosphorus variations in surface runoff from agricultural lands as a function on land use. J. Environ. Qual. 9:130-136.

Phosphorus (P) carried in surface runoff from agricultural lands can be a major source of algal-available P in surface waters. The available P may include both dissolved and some fraction of sediment-bound forms. In this study the effects of land use, time of year, and application of animal manure on several forms of P in runoff from farmed and forested lands were investigated. Simulated rain was used to generate runoff. Losses of dissolved molybdate-reactive P(DMRP), the majority of which is dissolved orthophosphate, were greatest from established or newly-seeded alfalfa fields (*Medicago sativa* L.) in the fall after the foliage had been killed by frost. Greatest total P losses were from corn and seed bed areas due to greater sediment losses. Phosphorus potentially available to algae was estimated by extraction with hydroxy-aluminum resin. Amounts extracted were equal to DMRP plus an average of 17 and 34% of the remaining total P for samples with and without apparent sediment, respectively. Greatest losses were associated with highest sediment loads. Surface-applied manure on corn and alfalfa increased P concentrations in runoff but, due to increased infiltration, did not significantly increase P losses. Loss of P from forest land was less than from crop land.

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