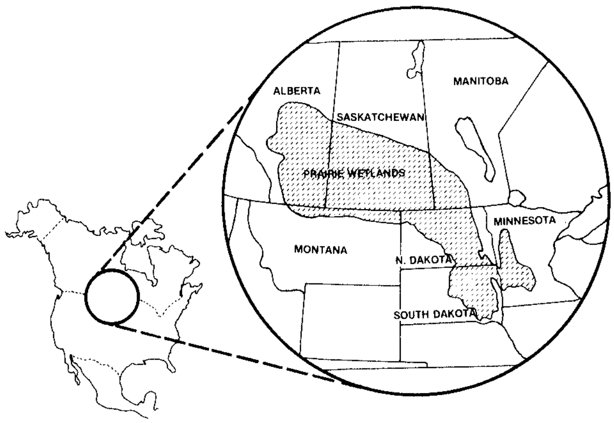
NUMBER 85
JULY, 1981




NORTH DAKOTA
RESEARCH REPORT

# Wetland Vegetation of the Prairie Pothole Region: Research Methods and Annotated Bibliography

By

Louis A. Ogaard
Department of Agricultural Economics
North Dakota State University
Fargo, North Dakota 58105

In Collaboration With

Jay A. Leitch
Donald F. Scott and William C. Nelson
Department of Agricultural Economics
North Dakota State University
Fargo, North Dakota 58105
and
Gary K. Clambey
Department of Botany
North Dakota State University
Fargo, North Dakota 58105

AGRICULTURAL EXPERIMENT STATION
NORTH DAKOTA STATE UNIVERSITY
FARGO, NORTH DAKOTA 58105

# Abstract

Analysis of freshwater vegetation is the focus of this paper. Primary production, nutrient cycling, and plant distribution are the selected topics addressed within this context. An annotated bibliography confirms the eclectic nature of this field.

# Acknowledgements

I wish to express my sincere appreciation to the following individuals for their editorial comment and advice: Drs. Harold Goetz and William Barker, North Dakota State University; Dr. Claude E. Boyd, Auburn University; Dr. J. A. Kadlec, Utah State University; and Dr. C. J. Kirby, U.S. Corps of Engineers, Vicksburg, Mississippi.

Funding for this literature review was provided by a grant from the U.S. Fish and Wildlife Service, Jamestown, North Dakota.

# Table of Contents

# List of Tables

# Introduction

A set of unique properties distinguishes wetland plants from mesophytes and xerophytes. First, they are hydrophiles, preferring a moist-to-inundated environment in which to grow and reproduce. This preference reflects an adaptation over time to oxygen deficiency, characteristic of waterlogged soils. Crawford (1978) likens aquatic vegetation to diving reptiles, birds, and mammals. He suggests that survival under flooded conditions necessitates a restricted metabolic rate in the absence of oxygen, and an exploitation of a wide range of metabolic products to aid proton disposal and avoid the dangers of cell toxicity due to the accumulation of an excessive oxygen debt. Second, hydrophytes seem to possess a much wider tolerance to high concentrations of iron and manganese than mesophytes (Armstrong 1975). These elements usually are found in a reduced chemical state in wetland sites flooded over a sustained period. Third, wetland vegetation in general is one of the most productive vegetation types in the world (Keefe 1972; Likens 1973).

Aside from these properties characteristic of nearly all hydrophytes, wetland plants of the Prairie Pothole Region must endure the climatic vagaries typical of a "continental climate." Specifically, temperature extremes range from −43 °C in the winter to 43 °C in the summer (Ramirez 1976), and yet certain species indigenous to the Northern Great Plains have been shown to grow under ice cover (Stuckey et al. 1978). The frontal storm systems of the Great Plains can transform an area under drought stress into a flooded condition in a short period of time. Water inputs of this magnitude can quickly rejuvenate wetlands which appeared dormant during drought.

The purpose of this report is to briefly review some of the current botanical research related to wetlands with a particular focus on the Prairie Pothole Region. Areas of potential research and the methods to implement this research will also be addressed. An annotated bibliography of selected articles is incorporated.

## Primary Production

Energy accumulated by plants is called primary production. The rate at which it accumulates is known as primary productivity (Smith 1966). Typically, aboveground measurements are taken and used to compare the vegetative productivity of various ecosystems. Belowground measurements are also possible but more cumbersome to take. Biomass has a tendency to shift seasonally from belowground portions (roots and rhizomes) to aboveground portions (stems and leaves) and back again.

### Literature Review

The topic of primary production in wetland ecosystems has been examined with increasing frequency over the past several years. A review of factors governing world-wide productivity in lakes is found in Brylinsky and Mann (1973). Several studies (Adams and McCracken 1974; Anderson 1978; Armstrong and Anderson 1966; Auclair et al. 1976; Bernard 1978; Boyd 1970) have described productivity for species indigenous to the Northern Great Plains. Table 1 presents the data from a few representative studies.

Aboveground species growth is dependent on both biotic and abiotic factors. Bedish (1967) found that the fastest rate and amount of growth for a hybrid cross between two species of cattail (*Typha angustifolia* and *T. latifolia*) occurred in one inch of water. Standing crops of *T. latifolia* were also positively correlated with concentrations of dilute acid-soluble phosphorus in hydrosoils and dissolved phosphorus in waters (Boyd and Hess 1970). Rice (1974) states that it is possible that *T. latifolia* is allelopathic to other emergent aquatics, resulting in virtually pure stands. Christiansen and Low (1970) showed an inverse relationship between salinity and marsh plant

Table 1. Summary of Some Recent Productivity and Standing Crop Data on Freshwater- and Brackish Water-Tolerant Plant Species.

| Species | Productivity | Standing Crop ($g/m^2$)* | Author(s) |
|---|---|---|---|
| *Carex lacustris* | 1580 $g/m^2/yr$ | 226 - 387 (BG) | Bernard (1974) |
| *Carex lacustris* | | 610 (AG) | Bernard and Bernard (1977) |
| *Carex lacustris* | 1181 $g/m^2/yr$ | | Klopatek and Stearns (1978) |
| *Carex rostrata* | 11 $g/m^2/yr$ | 114 - 852 (AG) | Bernard (1974) |
| *Carex rostrata* | | 150 - 328 (BG) | Bernard (1974) |
| *Eleocharis palustris* | | 1577 (AG) | Lindsley et al. (1977) |
| (Epiphytic algae) | 258 - 336 mg $C/m^2/day$ | | Allen (1971) |
| *Juncus effusus* | | 3760 (AG) | Lindsley et al. (1977) |
| *Phragmites communis* | 2318 $g/m^2/yr$ | | Hopkinson et al. (1978) |
| *Phragmites communis* | 551 - 1080 $g/m^2/yr$ | 524 - 942 | Mason and Bryant (1975) |
| *Sagitaria falcata* | 150 $g/m^2/yr$ | | Hopkinson et al. (1978) |
| *Sagitaria latifolia* | | 1602 (AG) | Lindsley et al. (1977) |
| *Scirpus validus* | | 2300 (AG) | Lindsley et al. (1977) |
| *Sparganium cynosuroides* | 1355 $g/m^2/yr$ | | Klopatek and Stearns (1978) |
| *Typha angustifolia* | 1445 $g/m^2/yr$ | 1118 | Mason and Bryant (1975) |
| *Typha glauca* | | 1158 (AG/BG) | Bernard and Bernard (1977) |
| *Typha glauca* | | 1040 (AG/BG) | Bernard and Bernard (1973) |
| *Typha latifolia* | | 428 - 2252 | Boyd and Hess (1970) |
| *Typha latifolia* | 3200 $g/m^2/yr$ | | Klopatek and Stearns (1978) |
| *Typha latifolia* | | 42 - 130 (inflorescence) | Boyd (1970) |
| *Zizania aquatica* | | 900 - 1400 | Good and Good (1975) |

*AG=Aboveground; BG=Belowground

germination, growth, and seed and tuber production. Anderson (1978) found that water depth, available soil potassium, available soil phosphorus, soil texture, and directional exposure were contributing factors to the dry-weight standing crop of *Potamogeton pectinatus* L.

Belowground productivity measurements are complicated by the difficulty of separating new from old growth. Nevertheless, some published data are available. Bernard and McDonald (1974) found a belowground standing crop of 387 g/m² in the winter and 226 g/m² in the summer. The dominant in this study was *Carex lacustris.* De la Cruz and Hackney (1977) report values between 970 g/m² and 1240 g/m² for belowground standing crop dominated by *Juncus roemerianus.* Root dry weight figures for a *Phragmites communis* wetland ranged from 80 g/m² to 3,600 g/m² (Fiala 1976). Whigham and Simpson (1978) found that regression equations could be used to estimate belowground biomass from aboveground biomass. Thus, the implications of seasonal and interspecific variation necessitate the need for long-term analysis of dominant and sub-dominant vegetation to attain a cogent picture of belowground productivity.

Another significant contributor to primary productivity is phytoplankton and filamentous algae. Armstrong and Anderson (1966) suggest that ultraplankters were responsible for virtually all of the productivity in Devils Lake, North Dakota. Measurements by Peterka and Reid (1968) in Lake Ashtabula, North Dakota found an average standing crop of 101 mg chlorophyll per square meter. Correll (1978) indicates that phytoplankton are the most important primary producers in estuaries, and Schindler (1978) ascribes world-wide variance of annual phytoplankton production to annual phosphorus loading.

Epiphytic and benthic algae have been studied by several researchers. Hooper-Reid and Robinson (1978a) found that cell surface area of the substrate was more directly related to productivity than was cell volume. A positive function between nutrient levels and standing crop of epiphytic algae in a *Scirpus*-dominated site was also determined by Hooper-Reid and Robinson (1978b). The examination of epiphytic algae in the primary productivity of an oligotrophic freshwater lake was conducted by Sheldon and Boylen (1975). They found that productivities of epiphytes from bottom leaves were ten-fold greater than those from top leaves. Furthermore, additions of a wide range of nutrients had no stimulatory effect on photosynthesis. Nienhuis (1978), studying benthic algae in an estuarine salt marsh, ascertained a positive correlation with the stability of the substrate, and hardly any correlation with fluctuations in soil-moisture content and salinity of the soil moisture.

### Research Recommendations

Despite a substantial number of published data on primary productivity in wetlands, there is a dearth of long-term, species-specific data for the ponds and lakes of the Prairie Pothole Region. Most studies have been conducted in the estuarine salt marshes of the southern and eastern coastal areas. Thus, the following general recommendations are made to substantiate the productivity of aquatic vegetation in this wetland ecosystem: (1) year-around measurements of above- and belowground primary productivity of macrophytes with controlled land use practice contiguous to the study sites, (2) seasonal monitoring of primary productivity of phytoplankton and other algal forms, again within a controlled land-use environment.

### Methods

A review of several methods used to measure primary productivity is found in Good et al. (1978) and Dykyjova and Kvet (1978). Advocacy for the harvest method is made by several contributing authors to the former text. Harvesting, at periodic intervals, is considered less expensive and more accurate than "gas exchange" techniques which involve the use of electronic equipment (infrared gas analyzer) and the extrapolation from short-term photosynthetic rates to annual production values (Reader 1978). The harvest method entails sampling (clipping of aboveground vegetation or coring of belowground roots and rhizomes) within randomly placed quadrats (square or circular). Clipped vegetation is dried to constant weight and production may be calculated in grams (dry weight) per unit of area (square meters) per unit of time (day or year). Drawbacks associated with this method include: (1) losses to litter, (2) grazing impacts, and (3) potential volatilization of material at high drying temperatures.

Primary productivity measurements of phytoplankton and other algal forms may be realized through light and dark bottle techniques or carbon fourteen tracer studies. The former method is based upon dissolved oxygen (DO) presence. The main precaution one must observe is the elimination of heterotrophic organisms. The latter method is a direct means to measure carbon assimilation. Care must be taken to (1) ameliorate shock associated with collection, (2) avoid creation of an artificial "micro-environment" within the bottle containing the plankters, (3) adjust for potential loss of dissolved materials from plankters, and (4) adjust for self-absorption of $C_{14}$ beta waves.

## Nutrient Cycling

The vegetative component contributes in several ways to the movement of nutrients through the wetland ecosystem. Nutrient uptake from the surrounding medium—water—or from the subtrate to which the plant is anchored is one example. Nutrient composition of plants is another. In this instance, nutrient mobility, nutrient requirements, and nutrient excess or deficiency in the water and soil are sources of inter- and intraspecific variance. Prentki et al. (1978) used an input-output model of lakeshore marsh literature to show that macrophytic translocation of nutrients is a major source of internal loading. Boyd (1978) examined data on the chemical composition of wetland plants and found that variation in composition increases in the following order: within-site intraspecific variation, between-site intraspecific variation, and interspecific variation.

Litter fall, senescence, and the process of decomposition provide release of nutrients for reuse by other aquatic organisms. Decomposition is discussed in a companion report (Ag. Expt. Stn. Research Rept. No. 84) and will not be addressed further.

### Literature Review

The subject of nutrient uptake by aquatic macrophytes has been studied in some detail. Best and Mantai (1978) ran a laboratory experiment to ascertain the location of phosphorus and nitrogen uptake in *Myriophyllum spicatum.* The authors determined that *M. spicatum* could meet its requirements for nitrogen (N) by root uptake from the sediment as well as by absorption from the water itself through stem and leaf tissue. Considerable quantities of phosphorus (P) were absorbed from the sediment via the root system and transported to the shoot regions. A synergistic relationship was suggested between these two nutrients for *M. spicatum* with nitrate absorption being limited in part by phosphorus levels in the water. Bristow and Whitcombe (1971) also found that most of the phosphate in the shoots of *Myriophyllum spicatum* and *Elodea densa* was derived from the rooted-stem base. Mayes et al. (1977), studying cadmium and lead uptake by *Elodea canadensis,* showed that differential levels of these elements in both water and sediment were reflected in plant tissue analysis, suggesting that both elements could be absorbed either from the water or sediment. Autoradiographs and radioactivity measurements provided direct evidence that $^{32}P$, $^{59}Fe$, and $^{45}Ca$ were absorbed by the roots of *Myriophyllum exalbescens* and translocated to the shoot tissues (Demarte 1974). Denney (1972) examined nutrient uptake in *Ceratophyllum demersum, Potamogeton thunbergii,* and *P. schweinfurthii* in ponds near Kampala, Uganda and concluded that uptake may occur through roots and shoots together or through roots and shoots alone. The non-specific nature of nutrient uptake precludes any general statement about the phenomenon.

Non-specificity pervades the area of plant nutrient composition as well. Adams et al. (1973) analyzed 13 macrophytic species by emission spectrometry for elemental composition. *Sparganium americanum* and *Justicia americana* exhibited significant variation between locations for seven and five ions, respectively, suggesting their utility as water quality indicators. Lathwell et al. (1973) found that *Scirpus* had a low magnesium content while *Chara* exhibited the lowest potassium content of several species examined. Tilton (1977), studying the bog plant *Larix laricina* in a bog, conifer swamp, and fen determined significant between-site differences in foliar nutrient concentrations at a single sampling time due to variations in nutrient status of the study sites. Edaphic parameters were cited as four to five times more important than community structural attributes in varying tissue element concentrations of a *Scirpus-Equisetum* wetland in southern Quebec (Auclair 1979). Elemental analysis of a *Typha glauca* community suggested seasonal fluctuations in all ions examined in the soil and all plant parts analyzed (Bayly and O'Neill 1972). Table 2 from Boyd and Walley (1972) illustrates the wide interspecific variation for boron.

The most comprehensive treatment of nutrient concentration in macrophytes is found in Dykyjova (1979). Subjects addressed in this article include: (1) general aspects of aquatic plants as accumulators of mineral elements, (2) selective absorption and the concentration factors, (3) tissue analysis and bioassays, (4) cycles of mineral elements in ecosystems, and (5) mineral accumulation by macrophytes and waste water treatment. A voluminous appendix catalogues by species and author the major, minor, and toxic elemental composition. This is truly a monographic treatment. Table 3 provides an example of the information contained therein.

**Research Recommendations**

The predominant themes throughout the literature on nutrient cycling are the interspecific and seasonal variability commensurate with this phenomenon. Additionally, to ascertain a thorough understanding of the complete process, all the points of nutrient exchange must be examined. To this end, the following research recommendations for the Prairie Pothole Region are made: (1) seasonal and interspecific plant analysis of dominant and sub-dominant vegetation should be undertaken over a sustained period (e.g., 3 years) to establish sources of variability and input, (2) conduct laboratory studies and *in situ* experiments to determine nutrient uptake sites for dominant and sub-dominant vegetation.

Table 2. Boron Concentrations in Selected Aquatic Macrophytes.

| Species | Boron (ppm dry weight) |
|---|---|
| *Eleocharis equisetoides* | 1.2 |
| *Glyceria striata* | 2.0 |
| *Panicum hemitonium* | 2.3 |
| *Scirpus americanus* | 2.7 |
| *S. validus* | 3.2 |
| *Eleocharis quadrangulata* | 3.7 |
| *Ceratophyllum demersum* | 4.3 |
| *Typha domingensis* | 4.6 |
| *Hydrochloa carolinensis* | 4.9 |
| *Typha latifolia* | 5.2 |
| *Potamogeton diversifolius* | 5.3 |
| *Hydrotrida caroliniana* | 7.6 |
| *Ultricularia inflata* | 7.6 |
| *Hydrocotyle umbellata* | 7.7 |
| *Pontederia cordata* | 7.9 |
| *Juncus effusus* | 8.1 |
| *Nuphar advena* | 8.2 |
| *Brasenia schreberi* | 10.4 |
| *Myriophyllum heterophyllum* | 10.6 |
| *Orontium aquaticum* | 10.7 |
| *Nelumbo lutea* | 10.9 |
| *Nymphaea odorata* | 11.3 |

SOURCE: 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. 88:8.

**Methods**

Elemental composition of aquatic macrophytes may be achieved through emission spectroscopy or gas chromatography. Use of compositional results for the bioassay of lakes and streams is found in Gerloff and Fishbeck (1973).

A two-compartment apparatus (Bristow and Whitcombe 1971; Frank and Hodgson 1964) can be employed for laboratory analysis of nutrient uptake sites. Field studies (Mayes et al. 1977; Demarte 1974) can be designed using radioactive tracers to ascertain sites of uptake.

## Plant Distribution

Why plants grow in certain habitats and not in others is both a synecological and autecological question. Distribution of a plant community is in turn tied to the ecological tolerances of the species which comprise that community. The concentric vegetative zonation (Stewart and Kantrud 1971) around the various wetlands of the Prairie Pothole Region provides an excellent example of plant community distribution patterns. The potential biotic and abiotic parameters which influence this pattern will be examined in the remainder of this report.

**Literature Review**

The potential sources of variable plant distribution constitute an extensive list. One such source is water chemistry. Moyle (1945) separated the aquatic flora of Minnesota on the basis of water quality tolerance and preference. These groups included a soft-water flora, hard-water flora, and an alkali- or sulphate-water flora. He found that pH was probably the most important factor in the distribution of soft-water flora. Hard-water flora flourished in waters with a total alkalinity of 90 to 250 ppm and with a sulfate ion concentration less than 50 ppm. The alkali- or sulfate-water flora was limited to waters with a total alkalinity of greater than 150 ppm, a sulfate ion concentration greater than 50 ppm, and a pH between 8.4 and 9.2. Hellquist (1980) confirmed the findings of Moyle (1945) for marshes of New England. Hutchinson (1970) studied species of the genus *Myriophyllum* and found that both *Myriophyllum spicatum* and *Myriophyllum verticillatum* extend in waters having higher calcium contents than appear to be tolerated by *M. alterniflorum.* McLoy (1976) conducted laboratory experiments on three species of duckweed and estimated lower limits, optimum and upper limits for pH at 4-5.0-10 for *Wolffia arrhiza,* 4-6.2-10 for *Lemna minor,* and 3-7.0-10 for *Spirodela oligorrhiza.*

Soil is another potential influence on plant distribution. Gray and Bunce (1972) employed association analysis and principal component analysis (PCA) in a study of the salt marshes of Morecambe Bay and determined that above certain elevations point-to-point variation in vegetation was tied to soil type, and soil chemical factors were described as dominant in the root distribution in two soils of the Nebraska Sandhills (Moore and Rhoades 1966). This positive correlation between soil factors and vegetation has been questioned by others. Walker and Coupland (1968) studied vegetation-environment relationships in the sloughs of Saskatchewan and found that soil data showed very little association with species distribution. Most variation in the vegetation was attributed, in decreasing order of importance, to disturbance, available nutrients, water regime, and salinity (Walker and Wehrhahn 1971). Dirschl and Coupland (1972), studying vegetation of the Saskatchewan River delta, determined that moisture regime, nutrient status, and pH were the most significant gradients controlling distribution of species and communities.

Salinity, alluded to above, has been identified as another major source of variability in plant distribution—particularly in the salt-water marshes of coastal areas. Stalter (1973) examined plant distribution in the marshes of the Cooper River Estuary. He concluded that

Table 3. Summary Table of Nutrient Concentrations for Selected Aquatic Macrophytes.

| Species | Author | Plant organs | Date of sampling | Biotype | N | P | K | Na | Ca | Mg | Ash |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | (% dry weight) | | | | | | |
| *Acorus calamus* L. | Bayly et Freeman 1977 | leaves | seasonal ranges (6—9) | Ottawa, Ontario flooded fresh meadow | — | — | 1.0 to 4.77 | 0.16 to 0.59 | 0.45 to 1.4 | 0.08 to 0.25 | — |
| | Bayly et Freeman 1977 | leaves | 7 (peak) | Ottawa, Ontario flooded fresh meadow | — | — | 2.6 | 0.225 | 0.80 | 0.14 | — |
| | Bayly et Freeman 1977 | scape with spadix | seasonal ranges (6—10) | Ottawa, Ontario flooded fresh meadow | — | — | 0.90 to 4.39 | 0.16 to 0.47 | 0.65 to 1.13 | 0.09 to 0.29 | — |
| | Bayly et Freeman 1977 | spadix | 7 (peak) | Ottawa, Ontario flooded fresh meadow | — | — | 2.2 | — | 0.70 | 0.14 | — |
| | Bayly et Freeman 1977 | rhizomes | seasonal ranges (5—10) | Ottawa, Ontario flooded fresh meadow | — | — | 0.50 to 1.22 | 0.12 to 0.65 | 0.25 to 0.74 | 0.13 to 0.28 | — |
| | Bayly et Freeman 1977 | rhizomes | 7 (peak) | Ottawa, Ontario flooded fresh meadow | — | — | 0.65 | 0.45 | 0.40 | 0.19 | — |
| | Bayly et Freeman 1977 | roots | seasonal ranges (5—10) | Ottawa, Ontario flooded fresh meadow | — | — | 0.75 to 2.3 | 0.15 to 0.80 | 0.30 to 0.80 | 0.11 to 0.68 | — |
| | Bayly et Freeman 1977 | roots | 7 (peak) | Ottawa, Ontario flooded fresh meadow | — | — | 1.1 | 0.70 | 5.0 | 0.40 | — |
| | Vavruska 1966 | shoots | 6 | Czechoslovakia, fertilized fishpond | 2.49 | 0.67 | 3.23 | 0.05 | 0.75 | 0.30 | 10.0 |
| | Bernatowicz 1969 | shoots | 7 | Poland, Mazuria, Warniak Lake | 1.80 | 0.03 | 0.75 | — | 0.57 | — | 6.45 |
| | Dykyjova 1973 | shoots | 6—7 | Czechoslovakia, fertilized fishponds (ranges of sites) | 1.26 to 2.92 | 0.20 to 0.35 | 1.85 to 3.67 | 0.09 to 0.24 | 0.34 to 0.85 | 0.14 to 0.21 | |
| | Dykyjova (unpublished) | shoots | 5—8 | Czechoslovakia, fertilized fishponds (seasonal ranges) | 1.26 to 3.71 | 0.23 to 0.47 | 1.85 to 3.80 | — | 0.27 to 0.85 | 0.13 to 0.25 | 11.4* to 12.9 |
| | Veber et Dykyjova (unpublished) | shoots | 8 | Czechoslovakia, ascending concentration of nutrient solutions (hydroponic cultures) | 2.62 to 3.22 | 0.50 to 0.61 | 2.52 to 4.35 | — | 0.29 to 0.56 | 0.32 to 0.58 | — |
| *Alisma plantago-aquatica* L. | Vavruska 1966 | shoots | 6 | Czechoslovakia, fertilized fishpond | 3.08 | 0.92 | 5.52 | 0.28 | 0.57 | 0.56 | 15.0 |
| *Alternanthera philoxeroides* (Mart.) Grisel. | Denton 1966 | shoots | not indicated | Georgia, Lake Seminole, arm of Flint River (polluted) | 3.04 | 0.17 | 4.56 | 0.37 | 1.43 | 0.33 | 8.39 |
| | | | | Alabama, plastic pools non-polluted | 0.85 | 0.10 | 1.39 | 0.51 | 1.17 | 0.30 | 16.11 |
| | Boyd 1969 | shoots | (4 sites) | Alabama, drainage ditch | 2.87 | 0.32 | 5.20 | 0.37 | 0.52 | 0.52 | 14.72 |
| *Batrachium aquatile* (L.) Dum. | Vavruska | whole plant | 6 | Czechoslovakia, fertilized fishpond | 1.88 | 0.49 | 2.52 | 0.39 | 4.15 | 0.70 | 20.4 |
| | Dykyjova 1978 | whole plant | 7 | Czechoslovakia, fertilized fishpond South Bohemia, Golden canal | 3.29 to 3.78 | 0.70 | 2.88 to 2.93 | 0.56 to 0.63 | 0.33 to 0.65 | 0.26 to 0.60 | — |

*May (only)

SOURCE: Dykyjova, D. 1979. Selective uptake of mineral ions and their concentration factors in aquatic higher plants. Folia Geobot. Phytotax. 14:288.

salinity limits the brackish and freshwater taxa from the more saline lower reaches of the river. Shiflet (1963) ascertained that water depth and salinity were the major influences on plant composition of Louisiana marshland ranges. He suggested that manipulation of these factors through the use of pumps and levees could change plant composition to better fit the livestock enterprises. Stewart and Kantrud (1971) emphasized that differences in species composition within vegetative zones of the Prairie Pothole Region were correlated with differences in average salinity of surface water. They indicated that distinctive associations of plants may be classified as fresh, slightly brackish, moderately brackish, brackish, subsaline, or saline.

Other factors with varying degrees of influence on plant distribution include siltation, turbidity, oxygenation, allelopathy, and competition (e.g. shading) (Stuckey 1971; McLoy 1976; Rice 1974). One or all of these parameters in concert with the primary determinants described above dictate to a major degree where plant species and communities will occur. Climatic conditions such as humidity, intensity and duration of precipitation, wind velocity with its resultant wave action, and drought may seasonally intensify the effect of one or more factors.

**Research Recommendations**

As the brief literature review above suggests, the distribution of macrophytes has been intensely studied in a wide variety of habitats. The chief determinants of vegetative zonation in the Prairie Pothole Region seem to be hydrologic regime and salinity. The following research recommendation is made to quantify the contribution and significance of these and other parameters to the pattern of vegetation characteristic of these wetlands: Select wetland classes (Stewart and Kantrud 1971) of similar hydrologic type (e.g., recharge or discharge) and ascertain the presence or absence of correlation between a wide range of variables (e.g., soil morphology, sedimentation, water quality and quantity, disturbance) with existing vegetation.

**Methods**

Frequency distribution of the dominant and subdominant plant species is determined through the use of randomly placed quadrats within each vegetative zone. Techniques to measure environmental parameters are dictated by the parameter of interest. For example, water quality can be measured using procedures in Golterman and Clymo (1969) or American Public Health Association (1975). Most soil analyses can be run by employing the methods of United States Salinity Laboratory (1954). Disturbance can be ascertained through historical accounts for the area in question. Water levels can be measured with a graduated centimeter scale.

The presence or absence of a relationship between a variable and a plant species can be acquired by using correlation/regression analysis or principal component analysis (PCA). Most statistical analysis can be handled on a computer (e.g., Statistical Analysis System) and data acquisition should be geared to such processing (e.g., data collection directly onto coding forms).

# Literature Cited


Adams, F. S., H. Cole Jr., and L. B. Massie. 1973. Elemental constitution of selected aquatic vascular plants from Pennsylvania: Submersed and floating leaved species and rooted emergent species. Environ. Pollut. 5:117-147.

Adams, M. S. and M. D. McCracken. 1974. Seasonal production of the *Myriophyllum* component of the littoral of Lake Wingra, Wisconsin. J. Ecol. 62:457-466.

Allen, H. 1971. Primary productivity, chemoorganotrophy, and nutritional interactions of epiphytic algae and bacteria on macrophytes in the littoral of a lake. Ecol. Mono. 41:97-127.

American Public Health Association. 1975. Standard methods for the examination of water and wastewater. Fourteenth Edition, New York. 1193 p.

Anderson, M. G. 1978. Distribution and production of sago pondweed (*Potamogeton pectinatus* L.) on a northern prairie marsh. Ecology 59:154-160.

Armstrong, R. and D. W. Anderson. 1966. Primary productivity measurements at Devils Lake, North Dakota. Proc. N. D. Acad. Sci. 20:136-149.

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

Auclair, A. N. D. 1979. Factors affecting tissue nutrient concentrations in a *Scirpus-Equisetum* wetland. Ecology 60:337-348.

Auclair, A. N. D., A. Bouchard, and J. Pajaczkowski. 1976. Plant standing crop and productivity relations in a *Scirpus-Equisetum* wetland. Ecology 57:941-952.

Bayly, I. L. and T. A. O'Neill. 1972. Seasonal ionic fluctuations in a *Typha glauca* community. Ecology 53:714-719.

Bedish, J. W. 1967. Cattail moisture requirements and their significance to marsh management. Am. Midl. Nat. 78:288-300.

Bernard, J. M. 1978. Life history of primary production in sedge wetlands. Pages 39-51 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), Freshwater wetlands: ecological processes and management potential. Academic Press, New York.

Bernard, J. M. 1974. Seasonal changes in standing crop and primary production in a sedge wetland and an adjacent dry old field in central Minnesota. Ecology 55:350-359.

Bernard, J. M. and F. A. Bernard. 1977. Winter standing crop and nutrient contents in five central New York wetlands. Bull. Torrey Bot. Club 104:57-59.

Bernard, J. M. and J. G. McDonald, Jr. 1974. Primary production and life history of *Carex lacustris*. Can. J. Bot. 52:117-123.

Best, M. D. and K. E. Mantai. 1978. Growth of *Myriophyllum:* Sediment or lake water as the source of nitrogen and phosphorus. Ecology 59:1075-1080.

Boyd, C. E. 1978. Chemical composition of wetland plants. Pages 155-167 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

Boyd, C. E. 1970. Production, mineral accumulation and pigment concentrations in *Typha latifolia* and *Scirpus americanus*. Ecology 51:285-290.

Boyd, C. E. and L. W. Hess. 1970. Factors influencing shoot production and mineral nutrient levels in *Typha latifolia*. Ecology 51:296-300.

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.

Bristow, J. M. and M. Whitcombe. 1971. The role of roots in the nutrition of aquatic vascular plants. Am. J. Bot. 58:8-13.

Brylinsky, M. and K. H. Mann. 1973. An analysis of factors governing productivity in lakes and reservoirs. Limnol. Oceanogr. 18:1-14.

Christiansen, J. E. and J. B. Low. 1970. Water requirements of waterfowl marshlands in northern Utah. Utah Division of Fish and Game, Logan. 108 p.

Correll, D. L. 1978. Estuarine productivity. BioScience 28:646-650.

Crawford, R. M. M. 1978. Biochemical and ecological similarities in marsh plants and diving animals. Naturwissenschaften 65:194-201.

De la Cruz, A. A. and C. T. Hackney. 1977. Energy value, elemental composition and productivity of belowground biomass of a *Juncus* tidal marsh. Ecology 58:1165-1170.

Demarte, J. A. 1974. Studies on absorption of $^{32}$P, $^{59}$Fe, and $^{45}$Ca by water milfoil (*Myriophyllum exalbescens* Fernald). Ecology 55:188-194.

Denney, P. 1972. Sites of nutrient absorption in aquatic macrophytes. J. Ecol. 60:819-829.

Dirschl, H. J. and R. T. Coupland. 1972. Vegetation patterns and site relationships in the Saskatchewan River Delta. Can. J. Bot. 50:647-675.

Dykyjova, D. 1979. Selective uptake of mineral ions and their concentration factors in aquatic higher plants. Folia Geobot. Phytotax. 14:267-325.

Dykyjova, D. and J. Kvet (eds.). 1978. Ecological studies, analysis and synthesis, Vol. 28. Pond littoral ecosystems: structure and functioning. Springer-Verlag, New York. 464 p.

Fiala, K. 1976. Underground organs of *Phragmites communis,* their growth, biomass, and net production. Folia Geobot. Phytotax. 11:225-259.

Frank, P. A. and R. H. Hodgson. 1964. A technique for studying absorption and translocation in submersed plants. Weeds 12:80-82.

Gerloff, G. C. and K. A. Fishbeck. 1973. Plant content of elements as a bioassay of nutrient availability in lakes and streams. Bioassay Techniques and Environmental Chemistry, Ann Arbor.

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

Good, R. E. and N. F. Good. 1975. Vegetation and production of the Woodbury Creek-Hessian Run freshwater tidal marshes. Bartonia 43:38-45.

Good, R. E., D. F. Whigham, and R. L. Simpson (eds.). 1978. Freshwater wetlands: ecological processes and management potential. Academic Press, New York.

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.

Hellquist, C. B. 1980. Correlation of alkalinity and the distribution of *Potamogeton* in New England. Rhodora 82:331-344.

Hooper-Reid, N. M. and G. G. C. Robinson. 1978a. Seasonal dynamics of epiphytic algal growth in a marsh pond: Productivity, standing crop, and community composition. Can. J. Bot. 56:2434-2440.

Hooper-Reid, N. M. and G. G. C. Robinson. 1978b. Seasonal dynamics of epiphytic algal growth in a marsh pond: Composition, metabolism, and nutrient availability. Can. J. Bot. 56:2441-2448.

Hopkinson, C. S., J. G. Gosselink, and R. T. Parrondo. 1978. Aboveground production of seven marsh plant species in coastal Louisiana. Ecology 59:760-769.

Hutchinson, G. E. 1970. The chemical ecology of three species of *Myriophyllum* (Angiospermae, Haloragaceae). Limnol. Oceanogr. 15:1-5.

Keefe, C. W. 1972. Marsh production: a summary of the literature. Contrib. Mar. Sci. 16:163-181.

Klopatek, J. M. and F. W. Stearns. 1978. Primary productivity of emergent macrophytes in a Wisconsin freshwater marsh ecosystem. Am. Midl. Nat. 100:320-332.

Lathwell, D. J., D. R. Bouldin, and E. A. Goyette. 1973. Growth and chemical composition of aquatic plants in twenty artificial wildlife marshes. N. Y. Fish and Game J. 20:108-146.

Likens, G. E. 1973. Primary production: freshwater ecosystems. Human Ecology 1:347-356.

Lindsley, D., T. Schuck, and F. Stearns. 1977. Primary productivity and mineral regimes in a northern Wisconsin marsh. Pages 38-52 *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.

Mason, C. F. and R. J. Bryant. 1975. Production, nutrient content, and decomposition of *Phragmites communis* Trin. and *Typha angustifolia* L. J. Ecol. 63:71-96.

Mayes, R. A., A. W. McIntosh, and V. L. Anderson. 1977. Uptake of cadmium and lead by a rooted aquatic macrophyte (*Elodea canadensis*). Ecology 58:1176-1180.

McLoy, C. L. 1976. The effect of pH on the population growth of three species of duckweed: *Spirodela oligorrhiza, Lemna minor* and *Wolfia arrhiza*. Freshwater Biol. 6:125-136.

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.

Moyle, J. B. 1945. Some chemical factors influencing the distribution of aquatic plants in Minnesota. Am. Midl. Nat. 34:402-420.

Nienhuis, P. H. 1978. Dynamics of benthic algal vegetation and environment in Dutch estuarine salt marshes, studied by means of permanent quadrats. Vegetatio 38:103-112.

Peterka, J. J. and L. A. Reid. 1968. Primary production and chemical and physical characteristics of Lake Ashtabula, North Dakota. Proc. N. D. Acad. Sci. 22:138-156.

Prentki, R. T., T. D. Gustafson, and M. S. Adams. 1978. Nutrient movements in lakeshore marshes. Pages 169-194 *in* R. E. Good, D. F. Whigham and R. L. Simpson (eds.), Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

Ramirez, J. M. 1976. Meteorological and air quality aspects of a proposed coal gasification plant in Dunn County, North Dakota. Department of Soils, North Dakota State University, Fargo.

Reader, R. J. 1978. Primary production in northern bog marshes. Pages 53-62 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), Freshwater wetlands: ecological processes and management potential. Academic Press, New York.

Rice, E. L. 1974. Allelopathy. Academic Press, New York. 353 p.

Schindler, D. W. 1978. Factors regulating phytoplankton production and standing crop in the world's freshwaters. Limnol. Oceanogr. 23:478-486.

Sheldon, R. B. and C. W. Boylen. 1975. Factors affecting the contribution by epiphytic algae to the primary productivity of an oligotrophic freshwater lake. Appl. Microbiol. 30:657-667.

Shiflet, T. N. 1963. Major ecological factors controlling plant communities in Louisiana marshes. J. Range Manage. 16:231-235.

Smith, R. L. 1966. Ecology and field biology. Harper and Row, New York. 686 p.

Stewart, R. E. and H. A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. U. S. Fish and Wildlife Service Resource Publ. 92, Washington, D. C. 57 p.

Stalter, R. 1973. Factors influencing the distribution of vegetation of the Cooper River estuary. Castanea 38:18-24.

Stuckey, R. L. 1971. Changes of vascular aquatic flowering plants during 70 years in Put-in-Bay Harbor, Lake Erie, Ohio. Ohio J. Sci. 71:321-342.

Stuckey, R. L., J. R. Wehrmeister, and R. J. Bartolotta. 1978. Submersed aquatic vascular plants in ice-covered ponds of central Ohio. Rhodora 80:575-580.

Tilton, D. L. 1977. Nitrogen dynamics in a northern freshwater wetland. Bull. Ecol. Soc. Amer. 58:19.

United States Salinity Laboratory. 1954. Diagnosis and improvement of saline and alkali soils. U. S. Department of Agriculture Handbook No. 60, Washington, D. C. 160 p.

Walker, B. H. and R. T. Coupland. 1968. An analysis of vegetation-environment relationships in Saskatchewan sloughs. Can. J. Bot. 46:509-522.

Walker, B. H. and C. F. Wehrhahn. 1971. Relationships between derived vegetation gradients and measured environmental variables in Saskatchewan wetlands. Ecology 52:85-95.

Whigham, D. F. and R. L. Simpson. 1978. The relationship between aboveground and belowground biomass of freshwater tidal wetland macrophytes. Aquat. Bot. 5:355-364.

# Annotated Bibliography

Adams, F. S., H. Cole, Jr., and L. B. Massie. 1973. Elemental constitution of selected aquatic vascular plants from Pennsylvania: Submersed and floating leaved species and rooted emergent species. Environ. Pollut. 5:117-147.

Thirty species of submersed and floating leaved aquatic vascular plants and 15 rooted emergents were collected and analyzed by emission spectrometry for element constitution of 11 potentially-polluting ions including: P, K, Ca, Mg, Mn, Fe, Cu, B, Al, Zn, and Na. Plant species included *Elodea canadensis, Potamogeton crispus, Vallisneria americana, Myriophyllum exalbescens, Nuphar variegatum, Potamogeton illinoensis, Ceratophyllum demersum, Eleocharis acicularis,* and *Elodea nuttallii.* Rooted emergents included *Typha latifolia, Sparganium americanum, Sagittaria latifolia,* and *Justicia americana.*

These species were characterized according to intraspecific variation in element constitution, significant statistical variation for each ion within each species between locations and species potential for monitoring nutrient pollution.

*Sparganium americanum* and *Justicia americana* exhibited significant variation between locations for seven and five ions, respectively. Use of these plants to monitor water pollution trends is a much cheaper means than the establishment of automated monitoring systems.

Adams, M. S. and M. D. McCracken. 1974. Seasonal production of the *Myriophyllum* component of the littoral of Lake Wingra, Wisconsin. J. Ecol. 62:457-466.

The littoral of Lake Wingra is occupied by a plant community dominated by the submergent macrophyte *Myriophyllum spicatum* L. This study reports the seasonal pattern of ash-free biomass production, photosynthetic capacity (mg C fixed/g/h) of terminal portions of stems, productivity (mg C fixed/$m^2$/day) of stem tips, and calculations of mean and maximum productivity of the *Myriophyllum* component of the littoral zone community.

Depth-integrated maximum seasonal productivity on the date of maximum photosynthetic capacity during 1971 was 10.8 g C/day/$m^2$ littoral, or 3.35 g C/day/$m^2$ lake. This is 4.70t carbon/day/total/lake, or 10.70t ash-free dry weight. Total annual production by macrophytes was 117 g C/$m^2$ lake surface, higher than that of several other lakes which were compared.

Allen, H. 1971. Primary productivity, chemoorganotrophy, and nutritional interactions of epiphytic algae and bacteria on macrophytes in the littoral of a lake. Ecol. Mono. 41:97-127.

Epiphytic algal and bacterial *in situ* community metabolism and physiological nutritional relationships of macrophyte-epiphyte systems were investigated in the littoral zone of a small temperate lake from April, 1968 through May, 1969. Annual primary productivity, chemoorganotrophy of dissolved organic compounds, and field and laboratory studies of macrophyte-epiphyte interactions were monitored by carbon 14 techniques. The mean daily productivity of epiphytic algae was higher per unit macrophyte surface area of emergent plants (336 mg C/$m^2$/day) than on submerged plants (258 mg C/$m^2$/day). Mean daily productivity per unit area of the littoral zone, for all of the macrophytic surface area colonized, was 195 and 1,807 mg C/$m^2$/day in the *Scirpus acutus* and *Najas flexilis-Chara* spp. dominated sites, respectively.

Macrophyte-epiphyte metabolism may be an important source of dissolved organic materials and extracellular metabolites and thus may help to sustain high levels of primary productivity and chemoorganotrophy in lakes.

Anderson, M. G. 1978. Distribution and production of sago pondweed (*Potamogeton pectinatus* L.) on a northern prairie marsh. Ecology 59:154-160.

Physical and chemical parameters of soils and water, measured on 140 sites in the Delta Marsh, Manitoba, were compared with presence and dry-weight standing crop of *Potamogetan pectinatus* L. on those sites. Multiple regression analysis suggested that water depth, available soil K, available soil P, soil texture, and directional exposure were important factors affecting growth on colonized sites. Within the euphotic zone of the Delta Marsh, sago pondweed distribution was probably most affected by prevailing winds through their influence on soil distribution and turbulence. (author).

Anderson, R. R. 1969. Temperature and rooted aquatic plants. Chesapeake Sci. 10:157-164.

The author used a Gilson differential respirometer to investigate respiratory variation in leaves of *Potamogeton* at 25°, 30°, 35°, 40°, and 45°C. Plants growing in heated and nonheated water were compared. The data indicate the *P. perfoliatus* is capable of physiological adjustment to higher temperatures as the leaf matures, since only older leaves tended to respire less at the elevated temperatures. Death of plant material occurred at 45°C.

Armstrong, R. and D. W. Anderson. 1966. Primary productivity measurements at Devils Lake, North Dakota. Proc. N.D. Acad. Sci. 20:136-149.

This is a study of the primary productivity of Devils Lake in northeastern North Dakota. The rate of carbon fixation at the level of primary producers is influenced by the morphometry of the lake and the geology and hydrology of the drainage basin. It is the best available assessment of the actual fertility of the lake, and provides the best estimate of the rate at which matter moves through biogeochemical cycles.

Standing crops of littoral species (*Ruppia maritima, Enteromorpha prolifera,* and *Cladophora* sp.) were measured by harvesting a swath 18 cm. wide extending from the shoreline outward to the depth at which no more plants were found. Harvested plants were air-dried for four months in a warm room and then weighed.

Mean gross photoplankton productivity during the 175-day study period was 0.80 g $C/m^2$/day. Photosynthesis under the ice is negligible. Circumstantial evidence is presented which suggests that ultra plankters are responsible for virtually all of the productivity in Devils Lake. The total annual production of 1720 kg C/ha qualifies Devils Lake as a highly productive or eutrophic lake.

Auclair, A. N. D. 1979. Factors affecting tissue nutrient concentrations in a *Scirpus-Equisetum* wetland. Ecology 60:337-348.

The influence of community and edaphic variables on tissue nutrient concentration was assessed for six species occupying a *Scirpus-Equisetum* emergent aquatic wetland in southern Quebec, Canada. Potassium and nitrogen (12.0-23.5 mg/g) had by far the highest tissue concentrations, followed by Ca > Na > P > Mg. Micronutrient concentrations (Fe > Mn > Zn > Cu) ranged from .003-.532 mg/g. Macronutrients were 1.3-6 times and micronutrients 2-20 times as great as reported in *Carex, Fagus,* and *Quereus* dominated ecosystems.

Edaphic parameters were four to five times more important than community structural attributes in varying tissue element concentrations. Soil potassium concentration was the foremost or second most important parameter in 9 of 12 elements tested by multiple regression. It was concentrated in plant tissue 79-fold over levels measured in the soil. Among soil elements, potassium had the highest correlation with tissue P, K, Ca, and Mg concentration. Soil calcium had the highest correlation with tissue nitrogen and the micronutrients Cu, Fe, and Mn. The concentration of any soil element, however, never explained more than 64 percent of the variation of any tissue element.

Auclair, A. N. D., A. Bouchard, and J. Pajaczkowski. 1976. Plant standing crop and productivity relations in a *Scirpus-Equisetum* wetland. Ecology 57:941-952.

Plant standing crop and productivity relations were examined for an extensive marsh complex in southern Quebec, Canada. Forty-five 1-$m^2$ plots were sampled for dry weight shoot biomass, species composition, structure (species density, diversity, height), and soil parameters, including nutrient concentrations (Ca, K, Mg, Na, N, P) pH, organic matter, and water depth.

Seasonal productivity showed a strong bimodal pattern with peaks in late July (12.90 $g/m^2 \cdot day^{-1}$) and mid-September (4.73 $g/m^{-2} \cdot day^{-1}$). Two-thirds of annual litter production was lost by export. Complete decomposition of remaining litter occurred within the next growing season.

Among edaphic parameters, soil K had the highest correlation (r=.49) with standing crop while soil N had the highest correlation with shoot net primary productivity (r=0.39). Soil P correlated negatively with all production and soil nutrient parameters except soil Mg levels.

Shoot NPP and standing crop correlated negatively with all measures of species diversity.

Barker, W. T. and G. Larson. 1976. Aquatic plant communities. *In* Wildlife, biological, and vegetation resources of the Dunn County coal gasification project study area. An Interim Report, Departments of Botany and Zoology, North Dakota State University, Fargo.

Plant communities associated with sloughs in and adjacent to a proposed mining site in Dunn County, North Dakota were analyzed. Development of these plant communities is chiefly influenced by basin morphometry. Detailed descriptions of these plant communities are presented, using the classification system of Stewart and Kantrud (1971).

Bayly, I. L. and T. A. O'Neill. 1972. Seasonal ionic fluctuations in a *Typha glauca* community. Ecology 53:714-719.

Calcium, magnesium, potassium, sodium, iron, and phosphorus concentrations were measured in rhizomes, leaves, and floral stalks of a *Typha glauca* community during the growth season of 1968. Leaf-length and plant-organ moisture contents were also determined and used as indicators of physiological aging. Seasonal fluctuation was found in all ions examined in the soil and all plant parts analyzed. The ions studied were grouped into three categories with reference to apparent seasonal fluctuations of ionic concentrations. Concentration changes of calcium and possibly magnesium in plant tissue were inversely related to apparent changes in substrate concentration. Changes in concentration of potassium and phosphorus in floral stalks and leaves were inversely related to apparent changes in ion concentration in the rhizome, although not related to changes in the substrates. Changes in concentration of sodium and iron in all plant parts sampled were directly related, but no relationship was detected between the apparent changes in concentration in plant tissue and those in the substrates.

Beal, E. O. and P. H. Monson. 1954. Marsh and aquatic angiosperms of Iowa. State Univ. Iowa Stud. Nat. Hist. 19:1-95.

The flora of Iowa, composed of about 1900 species of vascular plants, is commonly divided into two ecological associations, the true prairie and oak-hickory forest. Within these associations many plant communities exist, including the flora of lakes, ponds, streams, and adjacent swampy or boggy areas. The selection of species for this volume has been made on the basis of limited field work by the authors, personal communication with interested botanists, habitat information on herbarium sheets, and comparative examination of several similar works from adjacent states.

Bedford, B. 1977. Seasonally displaced water temperatures as a factor affecting depletion of stored carbohydrates in *Typha latifolia.* Pages 83-98 *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.

The community dynamics of a sedge meadow and shallow marsh receiving thermal discharge from the cooling lake of an electric generating station were studied for three years. Significant alterations in shoot emergence patterns, extensive plant mortality, and shifts in community composition toward a greater number of annual and hydrophytic species occurred within two years of station operations. It was hypothesized that this response pattern was generated principally by increased and seasonally displaced water temperatures. To test this hypothesis, two techniques were employed: (1) measures of change in the concentration of TNC available to the plants as energy reserves for shoot production and plant growth, (2) measures of associated changes in shoot density and height.

Common cattail, *Typha latifolia,* exhibited both positive and negative responses to altered thermal regimes. Minimal temperature elevations resulted in early spring growth and rapid increases in shoot density. Winter groundwater temperatures comparable to summer temperature patterns resulted in population decrease due to the exhaustion of overwintering carbohydrate reserves available in *Typha* rhizomes for spring shoot production and growth. Results of data suggest the critical nature of the timing of thermal stress, in addition to the magnitude. (author).

Bedish, J. W. 1967. Cattail moisture requirements and their significance to marsh management. Am. Midl. Nat. 78:288-300.

A hybrid cattail resulting from a natural cross of *Typha latifolia* and *Typha angustifolia* was studied under greenhouse and field conditions in an attempt to determine optimum soil moisture and water depth for germination, growth, and vegetative reproduction.

The fastest rate and amount of growth was recorded for plants in 1 inch of water. Plants in saturated soil and 6 inches of water grew nearly as well as in 1 inch of water. Vegetative reproduction was similar in saturated soil and in soil flooded with 1 inch of water and 6 inches of water.

Criteria to evaluate field experiments were: (1) survival of rootstocks and production of plants in relation to soil moisture conditions and grazing by muskrats, (2) growth rate of plants in different soil moisture conditions, (3) production of new rhizome shoots.

Beeftink, W. G., M. C. Daane, W. DeMunck, and J. Nieuwenhuize. 1978. Aspects of population dynamics in *Halimione portulacoides* communities. Vegetatio 36:31-42.

Studies on sample plots in *Halimione portulacoides* communities show that environmental disturbances, either natural or induced by man, start a sequence of partly overlapping density maxima in *Suaeda maritima, Aster tripotium* and *Puccinellia maritima* successively, before the original *Halimione* community totally recovers. Minor environmental impacts induce a longer time-log period of the *Suaeda* density maximum, suggesting threshold values of these impacts for the species to maintain minimal population densities or to become locally extinct. This sequence of interim species starting after an environmental disturbance suggests also a gradient character in various biological attributes, for instance in lifetime, propagation, nutrient and genetic plasticity strategies.

Bernard, J. M. 1978. Life history of primary production in sedge wetlands. Pages 39-51 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.). Freshwater Wetlands: Ecological processes and management potential. Academic Press, New York.

Methods: Permanent quadrats of 50 X 50 cm were established and all living shoots within were measured for length and tagged with a number. Shoots outside the quadrat similar in length to shoots within are harvested, dried, and weighed, and regressions of shoot weight versus shoot length were determined. The standing crop of tagged shoots within the quadrat is then determined on the basis of their length measurements. The same measurements and analyses were performed on each subsequent sampling data. When new shoots emerged within the permanent quadrat, they also are tagged with a number and measured; those emerging during the same sampling period were treated as a cohort.

Life histories of species have a profound influence on their production processes, and the author believes that year-around studies with due attention to life histories are essential to the accurate calculation of primary productivity in ecosystems.

Bernard, J. M. 1974. Seasonal changes in standing crop and primary production in a sedge wetland and an adjacent dry old field in central Minnesota. Ecology 55:350-359.

Seasonal changes in above- and belowground standing crop and primary production in a *Carex rostrata* wetland and an adjacent dry *Poa pratensis* old field were determined. Aboveground, the *Carex rostrata* standing crop of green material varied from a minimum of 114 $g/m^2$ frozen in the winter ice to a high of 852 $g/m^2$ in late August. Maximum daily production averaged about 11 $g/m^2$ day from mid-June to mid-July. Belowground standing crop then increased at a rate averaging about 1 $g/m^2$ day.

Methods: Employed the "ladder quadrat" of Pearsall and Gorham (1956). Determined aboveground and belowground standing crop by the harvest method.

Bernard, J. M. and F. A. Bernard. 1977. Winter standing crop and nutrient contents in five central New York wetlands. Bull. Torrey Bot. Club. 104:57-59.

Winter biomass and nutrient contents were determined for five central New York wetlands. The sites dominated by *Carex lacustris* and *C. rostrata* were characterized by having a relatively large aboveground standing crop and a corresponding high nutrient content in those tissues. The sites dominated by *Carex lanuginosa*, *Sparganium eurycarpum*, and *Typha glauca* had small aboveground, but massive belowground, standing crops. Nutrient supply in these species was concentrated in belowground tissues. All species had large winter biomass values ranging from 610 g/m² in *Carex lacustris* to 1,158 g/m² in *Typha glauca*.

Methods: One ladder quadrat of five 25 X 25 cm plots was harvested in the case of sedge species and 50 X 50 cm plots of the other two species. Each sample was dug to a depth of approximately 30 cm. These samples were taken to a laboratory and carefully washed.

Bernard, J. M. and F. A. Bernard. 1973. Winter biomass in *Typha glauca* Godr. and *Sparganium eurycarpum* Engelm. Bull. Torry. Bot. Club. 100:125-127.

In central Minnesota, winter biomass was determined for *Typha glauca* and *Sparganium eurycarpum* after all the current year's growth had dried. *Typha* had 1040 g/m² of living material of which 954 g/m² were roots and rhizomes and 86 g/m² were new shoots. The old shoots, which had just died, weighed 946 g/m². *Sparganium* had 682 g/m² total living material consisting of 656 g/m² roots and rhizomes and 26 g/m² new shoots. The old dead shoots weighed 543 g/m². Annual belowground rhizome production is here estimated to be 371 g/m²/year in *Typha* and 225 g/m²/year/year in *Sparganium*.

Authors employed five ladder quadrats, each 50 X 50 cm for vegetative sampling.

Bernard, J. M. and J. G. McDonald, Jr. 1974. Primary production and life history of *Carex lacustris*. Can. J. Bot. 52:117-123.

Seasonal changes in aboveground and belowground standing crop and primary production in a *Carex lacustris* wetland were determined and related to the basic life history of this species. There was a seasonal minimum of 180 g/m² green material aboveground frozen in ice in winter and a maximum of 1037 g/m² in summer (early August). Seasonal aboveground production based on quadrat data and based on the difference between maximum and minimum standing crop is estimated to be 857 g/m² per year, maximum daily production 15 g/m² per day. A second estimate, also based on quadrat data but taking into account the very high shoot mortality during the growing season, was determined. Seasonal aboveground production then is 1580 g/m² per year, maximum daily production is 20.3 g/m² per day. Belowground standing crop ws 387 g/m² in winter, but then declined to an average summer low of 226 g/m². Belowground standing crop increased during autumn and, by October 7, a value equal to the previous winter's value was reached.

Methods: Three sets of "ladder" quadrats were used to sample aboveground standing crop. Each quadrat was 25 X 25 cm and five were placed in a linear series. Belowground material was collected by digging up all material between 0 and 30 cm depth.

Bernard, J. M. and B. A. Solsky. 1977. Nutrient cycling in a *Carex lacustris* wetland. Can. J. Bot. 55:630-638.

Seasonal changes in aboveground and belowground life history of *Carex lacustris* were determined and used to study primary production and nutrient cycling in an ecosystem. Seasonal aboveground production was estimated to be about 964 g/m² per year, with a peak rate of 20.9 g/m² per day reached in late July. Belowground production was estimated to be 208 g/m² per year for a total production estimate of 1,173 g/m² per year.

Nitrogen, phosphorus, and potassium began the season with high percentage concentrations in green overwintering shoots but the percentages declined to only about one-third of the original at death in December. Calcium and magnesium did not show any important translocation patterns during the year. The yearly budget of uptake and loss of nutrients during a year was estimated to be 15.9 g/m² N, 1.9 g/m² P, 16.6 g/m² K, 2.9 g/m² Ca, and 1.5 g/m² Mg.

Bernatowicz, S., S. Leszcynski, and S. Tyczynska. 1976. The influence of transpiration by emergent plants on water balance in lakes. Aquat. Bot. 2:275-288.

From measurements taken over a period of 3 years of the helophytes *Phragmites australis* (Cav.) Trin. ex Stued, *Typha angustifolia* L., *T. latifolia* L., and *Schoenoplectua lacustris* (L.) Palla, the transpiration coefficients have been calculated. Mean coefficients were as follows: on land, *P. australis* was 391.0, *S. lacustris* was 690.6, *T. angustifolia* was 499.8, and *T. latifolia* was 421.9. *In* a lake, *P. australis* was 320.0, *S. lacustris* was 592.7, *T. angustifolia* was 460.6, and *T. latifolia* was 384.1. Transpiration was calculated with the formula: $T_2 = \xi [(B.K.)/A]$ where B = dry weight of a grain plant species per unit area (g/m²), K = transpiration coefficient of that species, and A = area occupied by that species (m²).

Best, M. D. and K. E. Mantai. 1978. Growth of *Myriophyllum:* Sediment or lake water as the source of nitrogen and phosphorus. Ecology. 59:1075-1080.

A series of laboratory culture experiments was designed to investigate uptake of phosphorus and nitrogen by roots and shoots of *Myriophyllum spicatum* in a number of lake water/substrate and nutrient medium/substrate environments. The plants were compared with respect to biomass, physical dimensions, and total P and N in the plant tissues.

It appears that *Myriophyllum spicatum* can meet its requirements for N by root uptake from the sediment as well as by absorption from the water itself through stem and leaf tissue. It was also seen that

*Myriophyllum* can absorb considerable quantities of P from the sediment via the root system and transport it to the shoot regions of the plant.

A synergistic relationship between P and N was noted; P in the water clearly affected the ability of *Myriophyllum* plants to take up nitrate from the water. These data suggest that the limiting concentration of nitrate for *Myriophyllum* might vary considerably, depending in part on the phosphate concentration.

Birch, P. B., R. S. Barnes, and D. E. Spyridakis. 1980. Recent sedimentation and its relationship with primary productivity in four western Washington lakes. Limnol. Oceanogr. 25:240-247.

Studies of sedimentation processes in four western Washington lakes reveal up to sixfold variations in sedimentation rates over the past 130 years of settlement in the region. These variations in sedimentation can be linked with known changes in land use in the watersheds, especially logging, which appears to have accelerated erosion.

Contemporary deposition of phosphorus into profundal sediments is positively correlated with phytoplankton productivity in the four lakes. If a similar relationship existed in the past when sedimentation rates of phosphorus were different, then increases in primary productivity from twofold to fourfold could have occurred in three of the lakes since about 1840.

Boyd, C. E. 1978. Chemical composition of wetland plants. Pages 155-167 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

Examination of data on the chemical composition of wetland plants reveals that variation in composition increases in the following order: within-site intraspecific variation, between-site intraspecific variation, and interspecific variation. Furthermore, chemical composition changes as some species mature and variation in chemical composition occurs between different plant structures. No average composition for an individual species or ecological grouping of species based on data from the literature would be reliable. Therefore, actual measurements should be made in studies requiring data on chemical composition. Energy content values are more constant than chemical parameters.

Boyd, C. E. 1970a. Losses of mineral nutrients during decomposition of *Typha latifolia*. Arch. Hydrobiol. 66:511-517.

Dry matter and mineral nutrient losses from *Typha latifolia*, as determined by the fiberglass bag technique, were much greater for shoots submerged in water than for shoots suspended in air. Mineral regeneration time from plant tissues decaying in water is apparently much shorter than for typical terrestrial plant decomposition.

Methods: Weight loss of decomposing material confined to fine mesh nylon bags placed on wetland bottoms represents either true decomposition or the release of soluble organic compounds, dissolved inorganic nutrients, or fairly small detritus and is a meaningful measure of the degradation of macrophytes.

Boyd, C. E. 1970b. Production, mineral accumulation, and pigment concentrations in *Typha latifolia* and *Scirpus americanus*. Ecology 51:285-290.

Shoot productivity was measured for *Typha latifolia* and *Scirpus americanus*. For *Typha*, flowering was first observed on May 16. Standing crops of inflorescences (spikes cut just beneath the seed heads) were 42 $g/m^2$ on May 29 and 130 $g/m^2$ on June 18. Inflorescence and fruit formation amounted to 16.7 and 125.7 percent of net dry matter production for periods late in the summer. For *Scirpus*, flowering first noted on May 1. Inflorescences were small and no attempt was made to estimate the percentage of the total production that went into reproductive structures.

Levels of ash, nitrogen, phosphorus, sulfur, and potassium declined in both species as the plants aged. *Typha* seed heads contained the following percentages of nutrients: .81 N, .23 P, 0.10 S, 0.25 Ca, 0.22 Mg, 2.41 K, and 0.07 Na. Nutrient accrual in seed heads amounted to 30.1, 39.0, and 36.8 percent of the total quantities of nitrogen, phosphorus, and magnesium, respectively, per square meter.

Boyd, C. E. 1970c. Amino acid, protein, and caloric content of vascular aquatic macrophytes. Ecology. 51:902-906.

The percentage of each amino acid in the total protein was remarkably similar in 11 species of vascular aquatic plants, as well as in the same species from different sites and the same species at different stages of maturity. Total protein concentrations in the various samples differed greatly. However, such differences may have great importance in food webs. Caloric values for all samples were relatively uniform.

Boyd, C. E. 1969. The nutrient value of three species of water weeds. Econ. Bot. 23:123-127.

This paper provides the results of an evaluation of the chemical composition of water hyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes*), and *Hydrilla* sp. Samples were collected from sites in southern Florida. These were taken from a variety of environmental situations. Plants were harvested and killed by heating at 105 °C for 30 minutes. Temperature was then reduced to 50 °C and plants were dried for 72 hours. Total available carbon (TAC) was determined by the Weinmann method.

Boyd, C. E. 1968. Freshwater plants: a potential source of protein. Econ. Bot. 22:359-368.

This study was the preliminary phase of a program to determine the food value of aquatic plants. Data

were obtained on the chemical composition of dried plants to evaluate their potential as roughages. Extractability of leaf protein was determined for several species.

Aquatic plants contain large amounts of moisture and would have to be at least partially dried prior to use as roughage. For protein extraction, the high moisture content is desirable since extraction is generally facilitated by the addition of water. Exploratory research to assess the food value of the native aquatic flora should be initiated in nations that presently have severe protein shortages.

Boyd, C. E. and L. W. Hess. 1970. Factors influencing shoot production and mineral nutrient levels in *Typha latifolia*. Ecology 51:296-300.

Shoot standing crops for *Typha latifolia* ranged from 428 to 2,252 g dry wt./m$^2$. Standing crops were positively correlated with concentrations of dilute acid soluble phosphorus in hydrosoils and dissolved phosphorus in the waters. Except for a weak correlation for dissolved calcium, additional site fertility parameters were not correlated with standing crop.

Tissue concentrations of most nutrients were positively correlated with nitrogen content. Despite variations in tissue levels of nutrients, standing crop was the decisive factor determining quantities of nutrients per unit area of stand.

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 mg 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.

Bozniak, E. G. and L. L. Kennedy. 1968. Periodicity and ecology of the phytoplankton in an oligotrophic and eutrophic lake. Can. J. Bot. 46:1259-1271.

An oligotrophic and a eutrophic lake in Alberta were comparatively investigated for 14 months to elucidate relationships between the physiochemical environment and the species composition, seasonal succession, vertical distribution, and seasonal cycles of their phytoplankton. Increases in the numbers of *Anabaena flos-aquae* accompanied decreases in the numbers of several green algae, viz, *Pediastrum* and *Scenedesmus* spp., suggesting antagonistic effects. Three groups of vertical distribution patterns of phytoplankton occurred in both lakes. Ice may be of heretofore unrealized ecological significance as a phosphate reservoir for the spring aquatic community.

Brewster, D. A. and J. R. Caldwell. 1974. Wetland habitat changes in Saskatchewan, Canada, 1975. Naturalist 25:18-21.

Factors influencing wetland drainage in Canada included the drought in the 1930's, the Prairie Farm Rehabilitation Administration which assisted farmers in constructing "back flood" irrigation projects for the production of livestock forage, and more recently the flooding of farm land, the increased costs of farming operations, and higher prices for both grain and livestock.

Problems faced by wildlife managers include: (1) the calculation of the amount of habitat required to sustain present populations, (2) determination of what is available, and (3) prediction of the annual rate of loss. When wildlife managers have adequate data they will be in a better position to request additional funds to preserve wetlands as the situation warrants.

Bristow, J. M. and M. Whitcombe. 1971. The role of roots in the nutrition of aquatic vascular plants. Am. J. Bot. 58:8-13.

Rooted stems of three aquatic species were cultured in a two-compartment apparatus which allowed the upper and lower portions of the stem to be kept in different nutrient solutions. $P^{32}$ was supplied to either the upper or lower compartment. The results showed that most of the phosphate in these shoots was not absorbed from the ambient medium but was derived from the rooted stem base in the lower compartment. These results give a very different but probably more accurate picture of phosphate absorption in rooted aquatic vascular plants than short-term experiments, in which phosphate is readily taken up from the ambient medium by leaves of *Myriophyllum spicatum* and *Elodea densa*. Evidence is presented that normal growth of axillary shoots occurs even when all mineral ions have to be obtained by translocation from the lower compartment.

Brodie, P. F. 1978. Alternative sampling device for aquatic organisms. J. Fish. Res. Board Can. 35:901-902.

Problems of obtaining quantitative samples of aquatic organisms (primarily phytoplankton) via conventional devices are discussed in this paper, and an alternative sampler based on the presumed mechanics of cetacean feeding is proposed. A polyethylene tube mounted on a light frame that minimizes the bow wave envelops a column of water

and permits its filtration. The design of this sampler resulted from morphological studies of rorquals (baleen whales with highly expandable throat pouches) and the presumed mechanics of their feeding apparatus when engulfing highly concentrated prey.

Brylinsky, M. and K. H. Mann. 1973. An analysis of factors governing productivity in lakes and reservoirs. Limnol. Oceanogr. 18:1-14.

Data collected as part of the International Biological Program from 43 lakes and 12 reservoirs, distributed from the tropics to the arctic, were subjected to statistical analysis to establish which factors were important in controlling production and how they were related. In the whole body of data, variables related to solar energy input had a greater influence on production than variables related to nutrient concentration; in lakes within a narrow range of latitude, nutrient-related variables assumed greater importance. Morphological factors had little influence on productivity per unit area in either case. Chlorophyll a concentration was a good indicator of nutrient conditions and when combined with an energy-related variable constituted a good estimator of primary production.

There was a strong correlation between photosynthetic efficiency and phytoplankton production, a phenomenon which implied that highly productive lakes made more efficient use of solar energy. Energy transfer efficiencies were close to the idea of 90 percent energy loss at each trophic level.

Carignan, R. and J. Kalff. 1979. Quantification of the sediment phosphorus available to aquatic macrophytes. J. Fish. Res. Board Can. 36:1002-1005.

The specific activity of phosphorus taken up by three species of submergent macrophytes grown in partitioned containers and rooted in $^{32}P$-labeled sediments was shown to be identical to the specific activity of the sediment mobile phosphorus measured by two techniques. Therefore, the mobile phosphorus, as determined by isotopic dilution, represents the total pool of sediment phosphorus available to macrophytes. The ability to measure and specifically label this pool will allow the testing of hypotheses concerning the role of macrophytes in phosphorus cycling.

Carlson, R. A. and J. B. Moyle. 1968. Key to the common aquatic plants of Minnesota. Min. Dept. Cons., Div. Game and Fish, Spec. Publ. 53.

This volume is a key to the aquatic plants of Minnesota. Illustrations and a list of common species are provided.

Carpenter, S. R. and M. S. Adams. 1979. Effects of nutrients and temperature on decomposition of *Myriophyllum spicatum* L. in a hard-water eutrophic lake. Limnol. Oceanogr. 24:520-528.

Temperature, phosphorus, and nitrogen were investigated as possible factors influencing decay of *Myriophyllum spicatum* shoots. In laboratory experiments, nitrogen enrichment significantly increased decay rates while phosphorus enrichment did not. Similar increases in decay rate per unit of added nitrogen occurred whether nitrogen was provided as nitrate or was present as additional tissue nitrogen. Exponential decay coefficients depended on temperature with a $Q_{10}$ of about 3.

Prediction of decay rates during litter bag experiments were based on laboratory responses of decay rate to temperature and initial nitrogen concentration of the shoots. Predictions underestimated decay rates. Possible explanation for the discrepancies include slow establishment of the detrital microflora, lower nitrogen availability, and absence of animals in the laboratory incubations.

Cattaneo, A. and J. Kalff. 1980. The relative contribution of aquatic macrophytes and their epiphytes to the production of macrophyte beds. Limnol. Oceanogr. 25:280-289.

The epiphyte contribution to the total production of lake Memphremagog macrophyte beds changed in a predictable fashion with the season, the morphology of the macrophytes, the depth of the bed, and the trophy of the water. In the mesotrophic portion of the lake, epiphytes fixed more carbon than the macrophytes only at the beginning and end of the growing season, whereas under more eutrophic conditions they did so even during summer.

Christiansen, J. E. and J. B. Low. 1970. Water requirements of waterfowl marshlands in northern Utah. Utah Division of Fish and Game, Logan. 108 p.

The use of water by marshlands of northern Utah, as indicated by calculation of evapotranspiration from inflow-outflow data, varies from about 4 in. in April to 9 in. in June for a 7-month total of about 41 in. These determinations were correlated with climatic data to determine the monthly coefficient K according to the Blaney-Criddle formula, which was used to estimate consumptive use. Values for K from the Blaney-Criddle formula varied from 0.90 for April to 1.20 for June.

Conductance measurements at all waterfowl refuges near Great Salt Lake indicated that the water available varied in quality from excellent to poor (6 mmhos).

Salt tolerance studies of important marsh plants showed that germination, growth, and seed and tuber production decreased as salinity increased. Fresh water produced the best growth in all plants except sago pondweed tubers, which showed greatest growth in slightly saline conditions (3,000 p.p.m.).

Relationships were developed for estimating monthly water requirements based on considerations of evapotranspiration, quality of water, and precipitation.

Cooksey, K. E. and B. Cooksey. 1978. Growth-influencing substances in sediment extracts from a subtropical wetland: Investigation using a diatom bioassay. J. Phycol. 14:347-352.

A biological assay using *Amphora coffeaeformis* var. *perpusilla* (Grunow) Cleve. and *A. coffeaeformis* (Agardh) Kützing was used to investigate the changes in the properties of soluble organic carbon in sediments taken from a coastal wetland. During January to May, sediment extracts became increasingly inhibitory to diatom growth. After the onset of the spring rains, the inhibitory properties of the extracts disappeared. Substances capable of promoting mixotrophic growth and heterotrophic growth were found in extracts taken in July to December. These positive responses took place at the time of mangrove (*Rhizophora mangle* L.) leaf-fall.

Correll, D. L. 1978. Estuarine productivity. Bioscience. 28:646-650.

Author addresses the questions: (1) Which biota enable estuaries to maintain high productivity? (2) What are the mechanisms by which an estuary is able to maintain the environmental conditions favorable to high productivity?

The most important primary producers in estuaries seem to be phytoplankton, and submerged vascular plants take an important but secondary role. Periphyton and benthic thalloid algae provide significant amounts of productivity in shallow water areas.

Estuaries maintain high productivity by maintaining high nutrient levels in bottom sediments and water column. This is done by nutrient/plankton trapping via the "salt wedge" countercurrent and the nutrient-modulating actions of tidal marshes, bottom sediments, and submerged vascular plants.

Crawford, R. M. M. 1978. Biochemical and ecological similarities in marsh plants and diving animals. Naturwissenschaften 65:194-201.

Higher plants which can survive flooding have certain ecological and biochemical similarities with diving reptiles, birds, and mammals. To survive in the wetland or aquatic habitat, species of terrestrial origin have to restrict their metabolic rate in the absence of $O_2$ and exploit a wide range of metabolic products to aid proton disposal and avoid the dangers of cell toxicity due to the accumulation of an excessive oxygen debt.

Dabbs, D. L. 1971. A study of *Scirpus acutus* and *Scirpus validus* in the Saskatchewan River delta. Can. J. Bot. 49:143-153.

This study of *Scirpus* populations in the Saskatchewan River Delta was conducted to examine morphological and ecological characters of the *Scirpus acutus* Muhl. and *S. validus* Vahl complex and to determine whether or not they should be differentiated as species. Two morphologically and ecologically distinct groups emerged; their hybrids were sterile or nearly so. The features of panicle ray length and floral scale length: achene length ratio were found to be diagnostic morphological criteria for separating the *Scirpus* examined into two sets of distinct populations. These two sets of populations differed ecologically in terms of water depth tolerances: S. *acutus* type tolerates between 60 and 150 cm, whereas *S. validus* type occurs only at depths less than 65 cm. It was concluded that in the geographic area in which they were studied, those two separate populations would best be regarded as separate species.

Dale, H. M. and T. J. Gillespie. 1977. The influence of submersed aquatic plants on temperature gradients in shallow water bodies. Can. J. Bot. 55:2216-2225.

In Lake Opinicon, Frontenac County, Ontario, the temperature gradient at midday from 10 cm below the water surface to soil, in clear weather in August, was found to be 10 °C/m in shallow water where there was a large macrophyte biomass and only .2 °C/m in deeper water with fewer plants. There was a direct correlation between the log of the biomass per cubic meter and steepness of the gradient.

The biomass of aquatic macrophytes growing in a heated greenhouse in tubs with a capacity of 1 $m^3$ increased from early January to the end of February. With increased biomass, the temperature gradient became larger. The size of the gradient correlated with the incoming radiation. Temperature gradients within large populations of the pondweed *Potamogeton richardsonii* were enhanced by low temperatures near the bottom.

The gradients produced by a population of *P. richardsonii* with tips 17 cm from surface were from 5.2 to 3.4 °C/m but showed less correlation with radiation when the wind velocity was above threshold value. No gradient was produced in tubs of water without plants.

Davis, A. M. 1979. Wetland succession, fire, and the pollen record: A midwestern example. Am. Midl. Nat. 102:86-94.

The pollen record from the upperfill in Tamarack Creek, Wisconsin, documents succession in a non-acid wetland environment subject to a high frequency of fire. Interpretation of changes in local and extralocal communities was aided by reconstruction of the fire history at the site. Variations in the regional vegetation were difficult to determine. The mosaic character of the prairie-deciduous forest ecotone in this area appeared to have remained largely unchanged throughout the record.

Davis, C. B. and A. G. van der Valk. 1978. Litter decomposition in prairie glacial marshes. Pages 99-113 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.). Freshwater wetlands: Ecological processes and management potential. Academic Press. New York.

Questions: Nutrient turnover rates; nutrient immobilization in shoot-to-rhizome translocation; what effect of extreme cold on breakdown of litter and release of nutrients?

Methods: Changes in shoot density were determined from weekly counts made on 3 1 X 1 m permanent quadrats located in homogeneous stands. Standing litter sampled by harvesting ten 1 x 1 m quadrats of each species. Quadrats were located at 10-15 m intervals along transect lines located in each stand sampled. Culms were clipped at substrate level. The rate of decomposition of fallen litter was measured by deploying nylon mesh bags containing leaf and culm material on the bottom of the marsh. Fresh standing litter was collected immediately after the first killing frosts. The litter for each species was thoroughly mixed and oven dried to constant weight of 80°C. Fifty grams oven dry weight of fresh *T. glauca* were placed in 3-mm nylon mesh bags in Goose Lake study. Thirty-six bags of each species were distributed randomly in 3 adjacent 2 X 2m quadrats, 12 bags per quadrat. Bags were anchored with nylon cord. One bag from each quadrat was collected at each sampling time. At collection time, each sample dried to constant weight, ground in 40-mesh Wiley Mill. Mineral analysis: total N by semimicrokjeldahl procedures, and P, K, Na, Ca, Mg, Al, and Fe by multispectral analysis.

Models shown for nutrient cycling.

Day, F. P. Jr. 1979. Litter accumulation in four plant communities in the Dismal Swamp, Virginia. Am. Midl. Nat. 102:281-289.

Marshes and swamps are reported to exhibit the largest accumulation of litter among world ecosystems. The objective of this study was to quantify litter accumulations in four plant communities in the Great Dismal Swamp, Virginia. The four communities differed by species composition and extent of flooding. Woody litter ranged from a minimum of 8428 kg/ha in the mixed hardwood community to a maximum of 50,147 kg/ha in the Atlantic White Cedar (*Chamaecyparis thyoides* (L) BSP.) community. The ranking of communities based on quantity of 01 leaf litter in December was reversed with 4028 kg/ha in the cedar community and 5484 kg/ha in the mixed hardwood community. Intermediate values were obtained for the red maple-gum (*Acer rubrum* L. - *Nyssa* spp.) and cypress (*Taxodium distichum* (L.) Richard) communities. Leaf litter pools decreased from December to August in all four communities. The general trend for community totals and most species was leaf biomass > maximum leaf litter standing pools > peak leaf fall. The dynamics of the Dismal Swamp litter layer are only partially defined presently, but a study of decomposition rates and litter fall is in progress and should clarify the picture.

De la Cruz, A. A. 1978. Primary production processes: Summary and recommendations. Pages 79-86 *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 primary production. Chapters reviewed were (1) primary production in freshwater tidal wetlands (Whigham *et al.* 1978), (2) primary production of prairie glacial marshes (van der Valk and Davis 1978b), (3) life history aspects of primary production in sedge wetlands (Bernard and Gorham 1978), (4) primary production in northern bog marshes (Reader 1978), and (5) the role of hydrology in freshwater wetland ecosystems (Gosselink and Turner 1978).

The author suggests several parameters which must be addressed in future productivity studies. These include: (1) geographical location and hydrologic regime, (2) soil regime, (3) community type and stand history, (4) life history, and (5) extrinsic factors.

De la Cruz, A. A. and C. T. Hackney. 1977. Energy value, elemental composition and productivity of belowground biomass of a *Juncus* tidal marsh. Ecology 58:1165-1170.

Belowground standing crop of a *Juncus roemerianus* marsh in Mississippi ranged from 9.7 to 12.4 kg dry wt/m$^2$ with the peak biomass occurring in April. Annual productivity estimated from expected maximum minus expected minimum biomass fitted into a periodic regression model was 1.36 kg/m$^2$. Ninety-four per cent of the productivity was within the top 20 cm, indicating that the bulk of the materials found beyond this depth consisted of dead tissues. Energy, carbon, hydrogen, nitrogen, and phosphorus contents of belowground materials did not vary significantly during the year, but patterns of differences in samples taken from different depths were evident.

Methods: Core samples were collected using a stratified random sampling scheme from an area of *J. roemerianus* marsh which appeared to be uniform. Core sampling device was 10 cm. in diameter and 50 cm. long. Annual productivity was estimated by fitting a general periodic regression curve.

Demarte, J. A. 1974. Studies on absorption of $^{32}$P, $^{59}$Fe, $^{45}$Ca by water milfoil (*Myriophyllum exalbescens* Fernald). Ecology 55:188-194.

A method was developed for determining uptake and translocation of mineral elements by intact submersed aquatic vascular plants in laboratory and field studies. Autoradiographs and radioactivity measurements provided direct evidence that $^{32}$P, $^{59}$Fe, and $^{45}$Ca were absorbed by the roots of *Myriophyllum exalbescens* and translocated to the shoot tissues. Similar evidence was obtained from absorption of $^{32}$P by the shoots and translocation to the roots. Data from experiments designed to compare the effect of substrate type (sand or muck) and the presence or absence of light showed no significant difference in the amounts of $^{32}$P absorbed by roots. Translocation of $^{59}$Fe from root to shoot tissues occurred mainly when plants were rooted in muck. $^{45}$Ca translocation from roots to shoots was greatest for plants rooted in sand and maintained in the light.

$^{32}$P absorbed by the roots of *Myriophyllum* was translocated to the shoots system and released to the surrounding water. Experimental evidence showed that injury to submersed hydrophytes can result in additional release of phosphate to the water. The rate of release is increased as a result of physical damage to the shoot. This provides an additional pathway for the cycling of phosphorus in freshwater environments.

Denney, P. 1972. Sites of nutrient absorption in aquatic macrophytes. J. Ecol. 60:819-829.

Six taxa of floating-leaved and submerged-leaved water plants were planted in artificial ponds in Kampala, Uganda. The subtratum was divided into nutrient-rich mud and nutrient-poor sand sections, but the waters were monogeneously mesotrophic. The plants were harvested from 8 to 15 weeks after planting. Growth rates in mg dry weight plant $^{-1}$ day $^{-1}$ were calculated for roots and shoots.

The growth rate of the totally submerged rootless species, *Ceratophyllum demersum,* was least affected by substratum whilst the floating-leaved, rooted species, *Potamogeton thunbergii,* showed a four-fold increase on mud. This was reflected in ratios of growth rates of root/shoot of the rooted taxa. The rates were higher when plants were grown in washed sand, but *P. schweinfurthii,* a submerged species, showed only a small increase whereas *P. thunbergii* had a nine-fold greater root/shoot growth rate ratio on sand than on mud.

It is concluded that nutrients may enter through roots and shoots, but in some circumstances entry may be through roots or shoots alone.

DeVlaming, V. and V. W. Proctor. 1968. Dispersal of aquatic organisms: Viability of seeds recovered from the droppings of captive killdeer and mallard ducks. Am. J. Bot. 55:20-26.

Seeds of aquatic and semiaquatic angiosperms were fed to two representative waterbirds: killdeer (*Charadrius vociferus*) and mallard ducks (*Anas platyrhynchos*). The viability and maximum period of retention for seeds recovered from the droppings were determined. Results indicate that resistance of the seeds to avian digestive processes depends both upon the nature of the seed coat and the species of bird through which they pass. Periods of maximum retention, greater in killdeer than in mallard ducks, were much longer than had previously been supposed. Plants with highly resistant seeds are for the most part of wide geographic distribution suggesting that the extensive range of many aquatic plants can be accredited, at least in part, to their adaptation to interval transport by birds.

Dirschl, H. J. and R. T. Coupland. 1972. Vegetation patterns and site relationships in the Saskatchewan River Delta. Can. J. Bot. 50:647-675.

This 5-year study attempted to order the landscape pattern of the flood plain complex in the Saskatchewan River Delta. The approach involved a stepwise progression, from traditional, subjective classification of the vegetation and mapping by air photo interpretations to objective classification using association analysis, and final verifications by stand and species ordinations through principal component analysis (PCA). The application of PCA to these landscape units showed moisture regime, nutrient status, and pH to be the most significant gradients controlling distribution of species and communities.

The major environmental gradients which directly affect the composition and distribution of ten community-types are pH and nutrient status of the hydroedaphic complex.

Disrud, D. T. 1968. Wetland vegetation of the Turtle Mountains of North Dakota. Ph.D. Thesis, Department of Botany, North Dakota State University, Fargo. 197 p.

The objectives of this study, carried out during the summer of 1967, were to define and characterize wetland vegetation of the Turtle Mountains. Species composition as well as frequency, density, and dominance of species occurring in quadrats were recorded in 50 stands from which importance values and indices of similarity, homogeneity, diversity, and community dominance were calculated.

A total of 136 species in 84 genera and 39 families were encountered with eight families accounting for two-thirds of the species. These families are, in order of decreasing importance, Graminieae, Compositae, Cyperaceae, Juncaceae, Polygonaceae, Potamogetonaceae, Ranunculaceae, and Labiatae.

The greatest number of species was observed in the wet meadow class, with lesser numbers in emergent, submerged, upland border, and floating classes. No single species occurred in all 50 stands but several showed high presence values, led by *Carex atherodes* (94%), *Typha latifolia* (88%), and *Scholochloa festucacea* (86%).

Dix, R. L. and F. E. Smeins. 1967. The prairie, meadow, and marsh vegetation of Nelson County, North Dakota. Can. J. Bot. 45:21-58.

The objectives of the study were to determine the general phytosociological structure of the native prairies, meadows, and marshes of Nelson County, North Dakota; to establish relationships between the structure and factors of the physical environment; and to evaluate the relationships between the vegetation of Nelson County and the True and Mixed prairies.

The drainage regime proved to be the most important single environmental factor in determining the vegetation. Species composition of each stand was determined by the frequency method; each stand was sampled by using 30 quadrats of the size 0.5m X 0.5m placed at predetermined paced distances along several transects laid out so that all parts of the stand were represented.

It is concluded from this study that Nelson County should be considered to be within the geographical area of the True Prairie.

Dokulil, M. 1975. Planktonic primary and bacterial productivity in shallow waters within a large *Phragmites* community (Beusielersee; Austria). Verh. Internat. Verein, Limnol. 19:1295-1304.

This paper presents that part of an International Biome Program (IBP) primary production study which was carried out within the reed belt on Neusiedlersee. Bacterial biomass, converted from total counts on Millipore-filters, is high in winter and early spring (3.2-7.4 mg C $m^{-3}$) and decreases after ice break until the end of August (0.5 mg C $m^{-3}$). Phytoplankton productivity increases rapidly after ice-break and reaches a peak in early May. Dark-carbon-uptake, as a measure of heterotrophic production, is generally highest in winter and autumn.

The most effective plant in energy utilization of the community is *Phragmites communis* (3 per cent of PhAR), followed by *Utricularia vulgaris* (0.7 per cent PhAR). Both plants are important to bacterial production. Energy conversion by phytoplankton is low (0.16 per cent PhAR) resulting in low productivity (Max. 20 mg C $m^{-2}d^{-1}$).

Drake, B. G. 1976. Seasonal changes in reflectance of standing crop biomass in three salt marsh communities. Plant Physiol. 58:696-699.

Reflectance of red (656-705 nm) and infrared (776-826 nm) solar radiation and standing crop biomass were measured in three salt marsh communities at intervals of approximately 2 weeks between February and August, 1974. Red reflectance declined at the onset of greening in each community and was correlated with standing crop of green biomass. Infrared reflectance increased substantially in the shrub community but less in the grass and sedge communities. The inverse of red reflectance was found to be a reliable predictor of green biomass in sedge and grass communities, but not in a shrub community.

-Reflectance was measured with a portable, battery-operated radiometer (Tektronics J-16) equipped with two silicon photodiodes and interference filters (orion).

Dubay, C. I. and G. M. Simmons, Jr. 1979. The contribution of macrophytes to the metalimnetic oxygen maximum in a montane, oligotrophic lake. Am. Midl. Nat. 101:108-117.

Mountain Lake, Virginia exhibits a strong metalimnetic oxygen maximum during summer thermal stratification. Dense beds of rooted macrophytes, primarily *Nitella flexilis,* grow around the circumference of the lake to a depth of 11 m. There was no correlation between the positive heterograde oxygen curve and limnetic phytoplankton density or estimates of primary productivity. The strongest association existed between the metalimnetic oxygen maximum and standing crop dry weights of the microphyte community. All transects across the macrophyte beds indicated the greatest standing crop to be between depths of 6-10 m. Variation in total standing crop between transects is attributed to slope angle of the basin, substrate and direction of slope, in order of importance.

Macrophyte sampling was accomplished with a hand-operated 15.2 $cm^2$ Ekman dredge.

Dykyjova, D. 1979. Selective uptake of mineral ions and their concentration factors in aquatic higher plants. Folia Geobot. Phytotax. 14:267-325.

A comparative review of the elementary chemical composition of aquatic vascular plants is presented together with the author's own results. Attention is focused on the specific genotypic, onthogenetic, and between-organs variability of the selective uptake and accumulation of mineral ions in macrophytes in relation to trophic conditions of habitat. The concentration factors and atomic ratios are also considered. Numerical tables presenting comparative data are arranged alphabetically according to plant species, with indications of geographical situation, phenology, part of plant tissues analyzed, nutrient status in biotopes and appropriate bibliography.

Dykyjova, D. 1971. Production, vertical structure and light profiles in littoral stands of reed-bed species. Hidrobiologia (Buchar.) 12:361-376.

Primary data are acquired about the production characteristics of natural reed swamp communities, but not all the reasons for their high productive capacity are discerned. It appears that the efficiency coefficient of solar energy conversion may be higher than theoretically forecast.

Dykyjova, D. and S. P. Pribil. 1975. Energy content in the biomass of emergent macrophytes and their ecological efficiency. Arch. Hydrobiol. 75:90-108.

In order to estimate the ecological efficiency of solar energy conversion in the highly productive reed-swamp communities, the energy contents were determined in the dominant species in this study. The calculation of the net efficiency of solar energy conversion in the production processes taking place in the community was accomplished by relating the energy content of aboveground dry biomass per 1 $m^2$ to the sum of total incident global radiation (measured by a Kipp-Zonen solarimeter) from the beginning of growing season to the harvest data:

$$n = \frac{\text{kcal organic matter/m}^2\text{/days X 100}}{\text{kcal total global radiation/m}^2\text{/days}}$$

The variation of the energy content in higher aquatic plants is relatively low so that the net conversion efficiency for the total growing season is most closely correlated with the total amount of biomass produced.

Eleuterius, L. N. 1972. The marshes of Mississippi. Castanea. 37:153-168.

Mississippi marshes were sampled in this study during 1968 and 1969 by live transect and list count quadrats, and the composition of vascular plants throughout the salinity gradient was determined in three estuarine systems. Profile diagrams were prepared to illustrate lateral zonation of the plant communities. Marsh acreage, measured by planimeter from survey maps, was determined. Organic production of the vascular marsh plants in Mississippi was estimated.

*Juncus roemerianus* dominates these marshes. There is a two-way penetration of plant species into the estuarine marsh; those which extend downward from freshwater into the *J. roemerianus* dominated region and those which extend from the more saline *J. roemerianus* dominated areas into marsh areas of less salinity. Dry weight determinations for freshwater marshes was approximately 400 $g/m^2$ and in the best *J. roemerianus* marsh areas, approximately 2 $kg/m^2$ was determined.

Eleuterius, L. N. and S. McDaniel. 1978. The salt marsh flora of Mississippi. Castanea, 43:86-95.

Vascular plants found in the tidal marshes of Mississippi were collected over an eight-year period, with an intense investigation from 1973 to 1976. A list of plants totalling 173 species, representing 53 families, is presented. The general distribution is indicated for each species. The purpose of this effort was to fulfill the need for a relatively complete list of local salt marsh vascular plants.

Fiala, K. 1976. Underground organs of *Phragmites communis,* their growth, biomass, and net production. Folia Geobot. Phytotax. 11:225-259.

This paper sums up the knowledge obtained from the study of growth periodicity in the underground organs of *Phragmites communis* Trin. and from the analyses of different *Phragmites* stands in three regions of Czechoslovakia. A period of intense growth of *Phragmites* rhizomes was recorded in summer. Spring (end of April and beginning of May) and autumn (mainly September) seem to be the periods of most active root growth. During July and August, accumulation of reserve material takes place both in new and old rhizomes. In the stands investigated, the biomass of *Phragmites* rhizomes varied from 2 $kg/m^2$ to 5 $kg/m^2$, and root dry weight from 0.08 $kg/m^2$ to 3.6 $kg/m^2$. The ratio of underground to total aboveground dry weight was highly variable (1.0 to 9.9). The estimated annual net rhizome production of *Phragmites,* in two different stands, was 30 per cent (Sakvicky fishpond) and 60 per cent (Nesyt fishpond) of the seasonal maximum aboveground biomass.

Fiala, K. 1971. Comparison of seasonal changes in the growth of underground organs of *Typha latifolia* L. and *Typha angustifolia* L. Hydrobiologia (Buchar.) 12:235-240.

An inseparable part of the growth of plants is the growth of their underground parts and the accumulation of reserves. The relative share of the aerial parts in total biomass seems to increase during the first part of the growing season. The relative share of the underground organs in total biomass seems to increase earlier in *Typha angustifolia* than *T. latifolia.*

The general seasonal pattern of growth is of specific nature so that it can be only modified but not completely changed by the environment.

Flemer, D. A., D. R. Heinle, C. W. Keefe, D. H. Hamilton, and M. Johnson. 1978. Standing crops of marsh vegetation of two tributaries of Chesapeake Bay. Estuaries 1:157-163.

A comparative study of the standing crop of marsh vegetation was made of the Patuxent River and Parker Creek, two tributaries of Chesapeake Bay. Maximum values of biomass occurred in the tidal freshwater and slightly brackish water region of Parker Creek. Biomass values for the Patuxent River and Parker Creek averaged about 1417 and 895 $g\ m^{-2}$ dry weight, respectively. Estimates of total annual marsh production based on the maximum standing crop was 27 X $10^3$ and 519 metric tons, respectively, for the Patuxent River and Parker Creek.

Methods: A sample consisted of all the standing live and dead plant material clipped within about 2 cm of the substrate from a $0.5m^2$ area cut by means of a pole with a rotating arm and plumb line that inscribed the area. Total net weights of living and dead materials were taken within 24 hours. Subsamples were taken and these were oven-dried for at least 48 hours at 60° to 70°C to a constant weight.

Flowers, M. G. 1973. Vegetation zonation in two successional brackish marshes of the Chesapeake Bay. Chesapeake Sci. 14:197-200.

Vascular plant zonation and successional stages were studied in two brackish marshes of Calvert County, Maryland. Transect surveys show a general zonation *Spartina alterniflora* → *Scirpus olneyi* → upland vegetation in the stable marsh → and a *Spartina alterniflora* → *Scirpus robustus* → *Typha angustifolia* → upland vegetation succession in the developing marsh. Elevation of the marsh relative to mean high water was the most obvious factor influencing the plant distribution.

Forrest, G. I. and R. A. H. Smith. 1975. The productivity of a range of blanket-bog types in the Northern Pennines. J. Ecol. 63:173-202.

Total and component net production of seven blanket bog sites in the northern Pennines, representing a range of variation in floristic composition were estimated.

Between-year variation was relatively small in comparison to that between sites. The sites with the highest production were those which had recently been burned. For the remaining sites, assumed to be in a steady state situation, there was a trend of decreasing production with increasing wetness, reflecting decreasing contribution of *Calluna* and *Eriophorum vaginatum* only partly replaced by increased *Sphagnum* growth on the wetter sites.

Mean production per growing season for the four Calluneto-Eriophoretum sites was 1.98 $gm^{-2}$ - $day^{-1}$. The total production of the 1215 ha of blanket bog within the Moor House National Nature Reserve was estimated as 7.67 X $10^6$ kg $yr.^{-1}$.

Forsberg, C. 1959. Quantitative sampling of subaquatic vegetation. Oikos 10:233-240.

A new sampling device is described by the author for sampling of subsequent meadows consisting of, for instance, *Chara, Ceratophyllum*, or *Myriophyllum*.

Investigations on *Myriophyllum verticillatum* and *Nitella mucronata* in Osby Lake, Djursholm, showed that the maximum values of the oven-dry weight were 240 and 310 g/m$^2$, respectively. The highest productivity data were 2.8 g/m$^2$/day for *M. verticillatum* and 2.5 for *N. mucronata.* In the autumn the data are negative: *M. verticillatum* $-1.3$ and *N. mucronata* $-0.9$ g/m$^2$/day. Then decomposition and dissimilation are greater than assimilation.

Frank, P. A. and R. H. Hodgson. 1964. A technique for studying absorption and translocation in submersed plants. Weeds 12:80-82.

An effective technique was developed for partitioning the environment of intact submersed aquatic plants. The technique facilitates absorption and translocation studies by permitting application of radioactive herbicides to selected portions of the plants. Root and shoot treatments of *Potamogeton pectinatus* L. for 24 to 96 hours with $C^{14}$ labeled 2, 3, 6-trichloro-phenylacetic acid (fenac) showed no leakage across the partitioned system. Little or no basipetal translocation of the herbicide was observed. Limited acropetal translocation occurred and this was reduced by removal of tubers prior to herbicide application.

The apparatus used in partitioning the plant and water medium consists of a 4-ounce lightproof glass bottle, no. 12 rubber stopper, polyethylene funnel with a 3-inch glass tubing. Article shows a picture of this apparatus.

Fulton, G. W. 1979. Wetland vegetation in southwestern N.D. M.S. Thesis, Department of Botany, North Dakota State University, Fargo. 1970 p.

The purpose of this study was to determine the present status of wetland plant communities of southwestern North Dakota. The species composition, zonation, aboveground biomass, and water chemistry of man-made impoundments were found to be similar to descriptions of natural wetlands in the glaciated regions. The number of species in each zone decreased from 55 in the wet meadow to 20 in the shallow marsh, 8 in the deep marsh emergents, and 8 submerged. Species with the highest per cent frequency occurrence at the sites sampled included: *Hordeum jubatum* (100 per cent), *Eleocharis palustris* (100 per cent), *Scirpus americanus* (86 per cent), *S. acutus* (86 per cent), *Potamogeton pectinatus* (86 per cent), *Typha latifolia* (79 per cent), *Myriophyllum spicatum* (67 per cent), *Scirpus validus* (60 per cent), and *Spartina pectinata* (53 per cent). Mean aboveground biomass of the zones was 306 g/m$^2$ wet meadow, 525 g/m$^2$ shallow marsh, 968 g/m$^2$ deep marsh emergents, and 551 g/m$^2$ in submergents. Mean density of the zones was 541 stems/m$^2$ wet meadow, 688 stems/m$^2$ shallow marsh, and 171 stems/m$^2$ in deep marsh emergents. Density was not a good indicator of biomass.

Gabriel, B. C. and A. A. de la Cruz. 1974. Species composition, standing stock, and net primary production of a salt marsh community in Mississippi. Chesapeake Sci. 15:72-77.

Square meter quadrat samples harvested monthly during 1971 and 1972 provided data on the species composition, standing stock, and net primary aerial production of a salt marsh community in St. Louis Bay Estuary, Mississippi. Although a total of 34 species of marsh plants were identified, *Juncus roemerianus, Spartina cynosuroides, Scirpus americanus*, and *Distichlis spicata* were found to be the most dominant in all the quadrats sampled. Maximum biomass of alive, dead, and partially decayed plants were observed in July, August, and January, respectively. Community annual net production estimated by harvest method was 1051 g dry wt. m$^{-2}$ or 5012 ash-free kcal m$^{-2}$. Total biomass obtained by reharvesting previously clipped quadrats in various ages of regrowth revealed a seasonal pattern of growth rate with a maximum during late summer and a productivity estimation of 1108 g dry wt. m$^{-2}$ or 5541 ash-free kcal m$^{-2}$.

Gallagher, J. L. and F. C. Daiber. 1974. Primary production of edaphic algal communities in a Delaware salt marsh. Limnol. Oceanogr. 19:390-395.

Gross primary production of edaphic algae was estimated for five areas in a high salinity tidal marsh near Lewes, Delaware. Salt pan and bare bank (free of angiosperms) algal production did not vary significantly from one part of the year to another. Annual cycles of light, temperature, and salinity were measured. Gross algal production was about a third of the angiosperm net production. Since much of the algal production occurs when angiosperms are dominant, it complements the pattern of angiosperm energy fixation.

The annual gross production by the marsh algae was about 80 g C m$^{-2}$ or 160 g m$^{-2}$ of ash-free dry weight. Much of this production occurs when the grasses are dormant.

Gallagher, J. L. and F. G. Plumley. 1979. Underground biomass profiles and productivity in Atlantic coastal marshes. Am. J. Bot. 66:156-161.

An aluminum coring device was used to collect underground soil samples which were subsequently washed free of mineral and microorganic matter by using a 1 mm sieve and water. The samples were dried at 60 °C, ground to pass a 40-mesh sieve, and analyzed for carbon content with a Leco WR12 Carbon Determinator. Nitrogen was measured by the Kjeldahl method and P, K, Mg, Ca, Mn, and Fe assayed by spark emission spectrometry (Jones and Warner, 1969).

Student's t-tests were done according to methods outlined by Yamane (1967).

Garbisch, E. W. Jr., and L. B. Coleman. 1978. Tidal freshwater marsh establishment in upper Chesapeake Bay: *Pontederia cordata* and *Peltandra virginia.* Pages 285-298 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

The effects of tidal elevation, substrate type, and fertilization on the establishment of *Peltandra virginia* and *Pontederia cordata* by seeding and transplanting seedling stock has been determined at a freshwater location in the Upper Chesapeake Bay, MD.

Germination percentages ranged from 93 per cent to 5 per cent for *Peltandra virginia* and from 20 per cent to 5 per cent for *Pontederia cordata* with the higher percentages occurring at the high tidal elevations. The percentages of seedlings that survived the study period averaged $\simeq$ 30 per cent for both species, but the surviving seedlings developed poorly.

Seeding does not appear feasible for the establishment of *Pontederia cordata* in areas subject to significant wave exposure.

Gessner, R. V. 1978. *Spartina alterniflora* seed fungi. Can. J. Bot. 56:2942-2947.

The filamentous fungi occurring on *Spartina alternifolia* seeds attached to inflorescences, on marsh sediments, and submerged in estuarine waters were studied. Seed-borne fungi commonly found on grain crops and graminiculous Ascomycetes were found on the seeds attached to the panicles. After 2 months on the marsh surface or in the adjacent sound and tidal creek, additional species, including marine fungi, were observed on the seeds. After 5-7 months marine fungi and graminiculous Ascomycetes were the only fungi found by direct observations, although seed-borne species could still be isolated by incubation methods. The seeds were completely degraded or barely recognizable after 11 months on the marsh sediments or seawater. *Claviceps purpurea* parasitized the seed heads at all the marsh areas sampled. *Ceriosporopsis halima, Corollospora maritima, Cirrenalia macrocephala, Halosphaeria hamata,* and *Trichocladium achrasporum,* primarily known as "wood-inhabiting" marine fungi, occur on submerged *Spartina alternifolia* seeds, suggesting that these fungi are general decomposers of plant debris in marine habitats.

Gloser, J. 1978. Net photosynthesis and dark respiration of reed estimated by gas-exchange measurements. Pages 227-234 *in* D. Dykyjova and J. Kvet (eds.) Pond Littoral Ecosystems: Structure and Functioning. Volume 28, Springer-Verlag, New York.

Gasometric measurements of net photosynthesis and dark respiration were performed with the aim of assessing some basic data necessary for mathematical modeling of canopy photosynthesis and primary production in *Phragmites communis* stands. The intention was not only to find absolute values of these processes in different organs, but especially to define the dependence of both photosynthesis and respiration on the principal abiotic variables.

The authors found that $CO_2$ exchange characteristics were related to both leaf area and leaf weight as well as to individual leaf laminae. Within the leaf canopy, the air composition was highly dependent on the diurnal changes of $CO_2$ concentration in the above-canopy layer of air.

Godshalk, G. L. and R. G. Wetzel. 1978. Decomposition of aquatic angiosperms. II. Dissolved components. Aquat. Bot. 5:281-300.

The decomposition of dissolved organic matter (DOM) released from freshwater vascular macrophytes was investigated over a 180 day period under controlled conditions of temperature and $O_2$ (10° and 25°C; anaerobic and aerobic). Plant species studied were *Scirpus acutus, Nuphar variegatum, Myriophyllum heterophyllum, Najas flexilis* and *Scirpus subterminalis.* The concentration of dissolved organic C (DOC) released by autolysis and by bacterial metabolism were analyzed in total.

Under aerobic conditions, small and large MW fractions showed consistent losses in total C at both temperatures. At high temp., DOM was decomposed even under anaerobic conditions.

Goldman, C. R. 1968. Aquatic primary production. Amer. Zool. 8:31-42.

The ecosystem concept has been particularly useful and extensively employed in the study of aquatic primary productivity. The flow of energy through the system is an attractive area of investigation when it involves some process, but has a more restricted value when units of biomass are simply converted to calories. Although we are able to measure primary productivity in terms of the carbon fixed, we are not yet able to measure the actual change in the oxidative state of the newly fixed carbon. The fate of photosynthate as food for higher trophic levels is, therefore, dependent upon a considerable array of biological and environmental variables. Primary productivity is considered in terms of its evolution from measures of standing crop and yield, which have been gradually replaced by measures of rate of carbon uptake or oxygen production, or by measure of nutrient loss, or by change of $CO_2$ in the environment. Light and nutrients are important in limiting primary productivity, and are contributing factors to the great variability which one may encounter within a given lake. Only with a sounder understanding of productivity at the base of the food-chain can we have any real hope of controlling the productivity of aquatic environments for the benefit of man.

Good, R. E. and N. F. Good 1975. Vegetation and production of the Woodbury Creek-Hessian Run freshwater tidal marshes. Bartonia 43:38-45.

The Woodbury Creek-Hessian Run marshes in Gloucester County, New Jersey were the site of this study. These marshes are dominated by extensive stands of wild rice, with peak aboveground standing crop exceeding 1400 g/m$^2$ and peak belowground standing crop approximately 900 g/m$^2$. Peak aboveground standing crops for other community types are considerably lower than wild rice, but belowground standing crop perennial species with rhizomes (*Nuphar, Peltandra, Typha*) exceed those of wild rice. Caloric values varied little, regardless of species or plant part, with most figures in the range of 4300 ± 300 calories/g ashfree dry weight.

Gorham, E. 1974. The relationship between standing crop in sedge meadows and summer temperatures. J. Ecol. 62:487-491.

The standing crops of sedge meadows in northern and middle latitudes are shown to be strongly correlated with summer temperatures in this study. Aboveground dry biomass in late summer ranged from about 200 g/m$^2$ in subarctic and montane sites to almost 1500 g/m$^2$ in a lowland mid-latitude site.

The correlation coefficient for aboveground biomass and monthly mean temperature was 0.84, significant at 1 percent level.

Gorham, E. and J. M. Bernard. 1975. Midsummer standing crops of wetland sedge meadows along a transect from forest to prairie. J. Minn. Acad. Sci. 41:15-17.

Midsummer standing crops of wetland sedges were measured along a transect from forest to prairie in northwestern Minnesota. The eight forest stands, all but one on waterlogged fibrous peats, were dominated by *Carex lacustris* (four stands), *C. lasiocarpa* (2), *C. rostrata* (1), and *C. atherodes* (1). They exhibited aboveground standing crops ranging from 425 to 738 g dry wt/m$^2$, with a mean of 606 g/m$^2$. The five prairie stands on well-drained silty peats were all dominated by *Carex atherodes*, and their standing crops ranged from 679 to 1248 g dry wt/m$^2$, with a mean of 941 g/m$^2$. (authors).

Gossett, D. R. and W. E. Norris, Jr. 1971. Relationship between nutrient availability and content of nitrogen and phosphorous in tissues of the aquatic macrophytes, *Eichornia crassipes* (Mart) Solms. Hydrobiol. 38:15-28.

Samples of *Eichornia crassipes* (Mart.) Solms were collected from the New Braunfels to Gonzales reach of the Guadalupe River, Texas. Plants were also cultured in the laboratory in media containing varying amounts of nitrate and phosphate. The nitrogen and phosphorous content of the blades, floats, and roots of the plants were determined and the values were compared with the nitrogen and phosphorous content of the water in which they were growing. The data show a positive correlation between the nitrogen and phosphorous content of the water hyacinth tissues and the nitrogen and phosphorous content of the environment. Values obtained on plants cultures in the laboratory suggest that luxury nitrogen and phosphorous may be stored in the floats.

Results reported in this paper support the suggestion that the technique of tissue analysis has potential for assaying the nutrient status of lakes and streams.

Goulder, R. 1969. Interactions between the rates of production of a freshwater macrophyte and phytoplankton in a pond. Oikos 20:300-309.

In a gravel pit in N. E. England the annual production (for 1967) of phytoplankton (1100 g carbon/m$^2$) was measured with the $^{14}C$ technique, and the gross production of the macrophyte *Ceratophyllum demersum* (600 g carbon/m$^2$) with the diurnal oxygen method. Over the year the two communities were complementary, and high productivity by the macrophyte in summer succeeded high productivity by phytoplankton in spring. A second pond, in which macrophytes were scarce, contained more phytoplankton in summer but on an annual basis its phytoplankton production (500 g carbon/m$^2$) was less than in the first pond. *Ceratophyllum* was found to cause greater shading of the phytoplankton beneath it than *Potamogeton natans*. Some observations were made on the vertical distribution of chlorophyll and phytoplankton productivity.

Goulder, R. and D. J. Boatman. 1971. Evidence that nitrogen supply influences the distribution of a freshwater macrophyte, *Ceratophyllum demersum*. J. Ecol. 59:783-791.

*Ceratophyllum demersum* appears to be a nitrophilos plant which requires high inorganic nitrogen levels in the surrounding water at least for part of the year. Two ponds were examined—one with little nitrogen and one with a rich supply. That with a rich supply supported a population of *Ceratophyllum* while the one with poor nitrogen content did not. Controlled experiments in the laboratory confirmed the influence of nitrogen as a significant growth factor.

Grittenger, T. F. 1977. Patterned vegetation in Cedarburg Bog, Wisconsin. Pages 359-363 *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.

Aerial observations of Cedarburg Bog reveal a mosaic of patterns reflecting vegetational differences. The most unique of these patterns is the string bog or "strangmoor." It is unusual to find this type of patterned vegetation this far south. The string bog consists of slightly elevated peaty ridges and islands with cedar, tamarack, bog birch, leatherleaf and other woody species, alternating with relatively flat areas supporting sedges and other nonwoody species. This string bog, like others, is found on a slightly sloping surface; the patterns lie at right angles to the slope. Apparently this orientation indicates the importance of water flow in pattern formation.

Gucinski, H. 1978. A note on the relation of size to ecological value of some wetlands. Estuaries 1:151-156.

Marshes located on the Mayo Peninsula between the South and Rhode Rivers, Maryland, were measured to determine acreage per tract, total upland and seaward edge lengths. For these marshes, 54 per cent of the total area is associated with tracts of less than five acres. Of total upland edge length, 68 per cent is along tracts less than five acres, while 72 per cent of seaward edge length is associated with these smaller tracts. Comparison of edge length to area ratios shows that tracts of one acre or less have significantly higher edge length than tracts of five acres or more. While this should be extrapolated to other geographic regions with care, the findings suggest that regulatory agencies revise wetland management principles to include greater protection and enhanced survival of small tracts.

Gunnison, D. 1978. Mineral cycling in salt marsh-estuarine ecosystems: Ecosystem structure, function, and general compartmental model describing mineral cycles. U.S. Army Eng. Wat. Exp. Stn. Tech. Rpt. D-78-3-DMRP, Vicksburg, Mississippi. 93 p.

The objective of this study was to gather as much of the existing information as possible on mineral cycling in marsh-estuarine ecosystems. A compartmental model outlining pathways of mineral cycling within the marsh-estuarine ecosystem was developed. Approaches used in the study included literature surveys and discussions with authorities in marsh-estuarine ecology.

The proximity of oxidizing and reducing environments within marsh-estuarine ecosystems permits the nitrogen and sulfur biogeochemical cycles to exist in complete forms. The intimacy of oxidizing-reducing zones permits oxidation of ammonium to nitrate, followed by anaerobic production of molecular nitrogen. Reduction of sulfate to sulfur and sulfide also require anaerobic conditions.

Hackney, C. T. and A. A. de la Cruz. 1980. *In situ* decomposition of roots and rhizomes and two tidal marsh plants. Ecology 61:226-231.

In situ decomposition of roots and rhizomes of the marsh plants *Juncus roemerianus* and *Spartina cynosuroides* was investigated using litter bags. The decomposition rate was greatest in the top 10 cm (20% mass loss/yr) of the marsh soil. There was no apparent decomposition below 20 cm depth. Belowground tissues of *S. cynosuroides* decomposed faster than those of *J. roemerianus* during the first 4 mo. The rhizome decomposition rate of 27%/yr. (mass loss) was faster than the 16%/yr. of the roots of *J. roemerianus.* There was no difference between the decomposition rate of mixed root and rhizome materials between experiments initiated in winter and those started in the spring. This indicates a relatively constant decomposition rate during the year in the 0-10 cm soil zone. There was no apparent trend in the hydrogen, carbon, phosphorus, nitrogen, or caloric content changes of the decomposing roots and rhizomes during the study.

Haines, E. B. 1977. The origins of detritus in Georgia salt marsh estuaries. Oikos 29:254-260.

The current view that estuarine food chains are in large part supported by influx of plant detritus from bordering tidal wetlands may not be correct for all cases. In Georgia estuarine ecosystems, salt marshes dominated by the cordgrass, *Spartina alterniflora* Loisel., are thought to be the major source of particulate detritus in the estuarine waters. However, I present three lines of evidence which suggest that *Spartina* detritus may not form a significant fraction of the organic seston in Georgia estuaries: 1) For *Spartina* salt marshes, attempts to document the net loss of plant material to the estuary have yielded contradictory results, 2) the stable carbon isotopic composition of organic seston in Georgia coastal waters does not match the isotopic composition of *Spartina* carbon; however, the seston $^{13}C^{12}C$ ratios are compatible with phytoplankton or terrestrial detritus sources, 3) estimates of potential input of organic materials to Georgia estuaries of 770 g $m^{-2}$ $yr^{-1}$ by phytoplankton of 600 g $m^{-2}$ $yr^{-1}$ by terrestrial plant matter are of the same magnitude as the hypothetical detritus input of 780 to 1660 g $m^{-2}$ $yr^{-1}$ from the *Spartina* salt marshes. A revision of the concepts about the role of salt marshes in estuarine production may be in order.

Haller, W. T., D. L. Sutton, and W. C. Barlowe. 1974. Effects of salinity on growth of several aquatic macrophytes. Ecology 55:891-894.

Growth rates of 10 aquatic macrophytes in various salinities under greenhouse conditions varied widely. Salt concentrations of 1.66% and 2.50% were toxic to *Pistia stratiotes* L. and *Eichornia crassipes* (Mart.) Solms, respectively. Salinities of 16.65% or higher were toxic to *Lemna minor* L., but growth of *Lemna* was increased by salt concentrations of 0.83%, 1.66%, 2.50%, and 3.33% as compared to other *Lemna* plants grown in fertilized pondwater. Other species studied, *Hydrilla verticillata* Royle, *Myriophyllum spicatum, Najas quadalupensis* (Spreng.) Magnus, *Vallisneria americana* Michx., *Azolla caroliniana* Willd., and *Salvinia rotundifolia* Willd., gradually declined in growth as salinity increased. Transpiration of the emersed growth form of *Myriophyllum basiliense* Camb. decreased with increasing levels of salinity, but root growth was stimulated by salt concentrations of 0.83%-3.33%, presumably a response of the plant to overcome an internal water deficit resulting from the saline solutions.

Hannan, H. H. and T. C. Dorris. 1970. Succession of a macrophyte community in a constant temperature river. Limnol. Oceanogr. 15:442-453.

The relationship of community metabolism to community structure in a 567-m stretch of the spring-fed San Marcos River, Texas, was studied during a period of autotrophic succession after a dredging operation. In general, plant biomass increased throughout the study period. Species diversity of submerged macrophytes increased sharply in the immature community, but there was a general decrease in diversity in the older community. Light intensity limited gross photosynthesis. An inverse relationship existed between photosynthetic efficiency and light intensity. The observed 29:1 ratio of plant surface area to streambed may be about optimum for maximum use of solar energy by the plant community. As succession developed in the ecosystem with increase in species and biomass, ecological stability increased until only autotrophic conditions existed even under low light intensity.

Solar input was determined from continuous pyrheliometer measurements. Light intensity measured with a foot-candle meter.

Hansen, D. J., P. Doyanandan, P. B. Kaufmann, and J. P. Brotherson. 1976. Ecological adaptations of salt marsh grass *Distichlis spicata* (Gramineae), and environmental factors affecting its growth and distribution. Amer. J. Bot. 63:635-650.

Salt grass is an important pioneer plant in early stages of succession. In salt marshes of southern Utah, salt grass contributes to a hummock-building process that favors localized removal of salts by capillary action and evaporation. This process provides a narrow strip of soil that is favorable for the rooting of extended rhizomes. In laboratory experiments, maximum growth for *Distichlis spicata*, a perennial salt marsh grass, was obtained at 15,000 ppm soluble salts in nutrient solution cultures. Comparable concentrations of salts occurred in soils of the habitat from which plants were taken.

Stomata on exposed ridges of vascular bundles, where desiccation is greatest, usually are covered by four epidermal cells. In contrast, stomata found in the grooves between vascular bundles tend to be uncovered. The salt gland is composed of a large basal cell and a cap cell and actively excretes (in a diurnal rhythm) excess sodium, potassium, and chloride ions. A mechanism for salt excretion from this gland is postulated. The silica-containing trichomes on the leaves may play a role in cooling the leaf under conditions of high solar radiation and also serve to protect from herbivores.

Hardisky, M. A. and R. J. Reimold. 1977. Salt-marsh plant geratology. Science 198:612-614.

Measurements of individual culms of several salt-marsh plants demonstrated seasonal community change in terms of height increments and live and dead leaves. Tissue production and its ultimate transition from live to dead components and culm mortality all suggest a continuum of geratologic processes contributing to the estuarine ecosystem.

Methods: Each culm was measured from soil level to the tip of its tallest vegetative component to determine its height to the nearest centimeter. Live leaves, defined as any leaf with green color, were counted, as well as dead leaves. Each sample site represented a unique climatic regime. Change in number of live leaves, dead leaves, and culm height was determined after eight weeks of measurements by subtracting the initial datum from the final datum of any one interval. Annual leaf production is the sum of the initial numbers of leaves and the leaf production for each interval.

Harmen, W. N. 1974. Phenology and physiognomy of the hydrophyte community of Otsego Lake, N.Y. Rhodora 76:497-508.

During the summer of 1969 it was noted that the zoobenthos and zoomeroplankton populations underwent drastic fluctuations that correlated with the phenology of aquatic macrophytes and the seasonal changes in the physiognomy of the plant community. This study was initiated to more accurately determine the composition of the flora at various times during the year so that one could quantitatively ascertain its effects on the associated fauna.

The phenology and physiognomy of four sites along a 500 m long transect are described. (author).

Harris, S. W. and W. H. Marshall. 1963. Ecology of water-level manipulations on a northern marsh. Ecology 44:331-343.

A study of vegetation changes associated with marsh drawdowns at Agassiz National Wildlife Refuge, Minnesota, revealed that the development of five types of vegetation on mud flats during the first year was influenced by seed availability, soil type and moisture, season and duration of drawdown, and the amount of stranded algal debris. The more an area combined early season drawdown, rich soil types, slow rates of mud flat drainage, and small amounts of stranded algae, the greater was the development of emergent aquatics. In the second year, most areas developed greater amounts of upland and shoreline weeds and fewer emergents. Upon reflooding, mud flat and shoreline annuals were eliminated and marshes of cattails, soft-stem bulrush, sedges, spike-rush, willows, and aquatic annuals developed in the first year. Spike-rush and soft-stem bulrush were destroyed by flooding with over 15 inches of water in three years and any continuously flooded area in four-five years. Sago made outstanding growth and seed production in the first year of flooding.

Haslam, S. M. 1970. The performance of *Phragmites communis* Trin. in relation to water supply. Ann. Bot. 34:867-877.

Water table is one of the factors controlling the distribution and performance of *Phragmites communis* Trin. Dense stands normally lose more water through evapotranspiration than is supplied by rain. However, *Phragmites* grows in a wide range of regimes, and is limited, in Britain, more by nutrient status than by water depth at its wetter limit, and more by competition than by water shortage at its drier limit.

Rhizome level and level of bud initiation are affected by water table, but performance of aerial shoots need not be affected by this, in the ordinary water regimes. Soil aeration, in the range found in East Anglia, does not affect performance, but if cut (or broken) reed is flooded, thus impeding aeration, performance decreases. Once a seasonal pattern of water-level fluctuations is established, departure from this (causing drying in a season the stand is normally flooded) disturbs the growth cycle and lowers the yield.

Haslam, S. M. 1970. The development of the annual population of *Phragmites communis* Trin. Ann. Bot. 34:571-591.

This study showed that each year, a young population of shoots of *Phragmites communis* Trin. shows a positively skew height/number curve. In a dominant stand, the mode moves to the right during development, and the final growth curve is negatively skewed. The width of the emergent bud determines its potential number of nodes, and its potential for flowering.

The first cause of serious harm to young shoots is frost. Frost typically kills the early, potentially large, shoots, and gives a shorter and denser final population. Internal competition is serious only after the end of the emergence period, and as small and late-emerging shoots are affected most, there is little effect on performance or flowering.

Haynes, R. R. 1980. Aquatic and marsh plants of Alabama. Castanea 45:31-50.

The families of the Alismatidae occurring in Alabama include Alismataceae, Hydrocharitaceae, Juncaginaceae, Najadaceae, Potamogetonaceae, and Zannichelliaceae. A key to the taxa and, for each of the species, county dot distribution maps and characteristics are presented in this article.

Hellquist, C. B. 1980. Correlation of alkalinity and the distribution of *Potamogeton* in New England. Rhodora 82:331-344.

The ranges of the alkalinities for New England taxa were found to compare favorably with those of Moyle (1945) from Minnesota. Certain New England taxa tolerated alkalinity ranges as low as, or lower than their Minnesota counterparts, especially *Potamogeton robbinsii, P. zosteriformis, P. friesii, P. obtusifolius,* and *P. natans. Potamogeton nodosus* and *P. crispus* occurred at much lower alkalinites than previously reported.

The results from this study are statistically determined and in some cases offer excellent information to help further the knowledge of *Potamogeton* distribution.

Hodkinson, I. D. 1975. Dry weight loss and chemical changes in vascular plant litter of terrestrial origin, occurring in a beaver pond ecosystem. J. Ecol. 63:131-142.

Rates of breakdown for five terrestrial litter types in an abandoned beaver pond followed the sequence *Salix* sp. leaves > *Deschampsia cespitosa* leaves and stems > *Juncus tracyi* leaves and stems > *Pinus contorta* needles > *Picea glauca* bark. Dry weight loss for all litter types showed a very close fit to Olson's (1963) negative exponential decay model but breakdown rates (k values of Olson) were low in comparison to those recorded for other aquatic systems. It is suggested that K values for litter in streams may be high due to physical fragmentation of litter by the current.

In *Salix, Pinus* and *Picea* bark, significant nitrogen enrichment occurred but phosphorous was released slowly whereas in *Juncus* and *Deschampsia* nitrogen enrichment did not occur and phosphorous was released rapidly. Phosphorus immobilization appears to be linked to nitrogen enrichment.

Potassium was rapidly leached from all litter types until a critical carbon/potassium ratio of between 500:1 and 1000:1 was reached, beyond which it became relatively immobile.

Hooper-Reid, N. M. and G. G. C. Robinson. 1978a. Seasonal dynamics of epiphytic algal growth in a marsh pond: Productivity, standing crop, and community composition. Can. J. Bot. 56:2434-2440.

The seasonal growth of epiphytic algae colonizing artificial cellulose acetate substrates positioned in a stand of *Scirpus acutus* Muhl. and in a zone of *Potamogeton pectinatus* L. in a marsh pond was quantified in terms of $^{14}C$ photosynthetic uptake, cell volume, cell surface area, dry weight, and chlorophyll a, protein, carbohydrate, and lipid content. Standing crop and productivity increased at both sites in September and October, after generally low summer growth with the exception of the occurrence of heterocystous blue-green algae at the *Potamogeton* site in July. Factor analysis of interrelationships among the various parameters suggested that cell surface area was more directly related to productivity and various standing-crop parameters than was cell volume.

Hooper-Reid, N. M. and G. G. C. Robinson. 1978b. Seasonal dynamics of epiphytic algal growth in a marsh pond: Composition, metabolism, and nutrient availability. Can. J. Bot. 56:2441-2448.

Seasonal growth and succession of epiphytic algae on artificial substrates in a marsh pond were related to nutrient levels (N, P, and Si) and to various physiological indicators of nutrient availability, including chlorophyll content, protein to carbohydrate and lipid ratio, Si debt, storage phosphate levels, alkaline phosphatase activity, and nitrogenase activity. Lowstanding crops in June and early July coincided with indications of deficiency in terms of chlorophyll a content and protein to carbohydrate and lipid ratios at chosen *Scirpus* and *Potamogeton* sites. Low available N may have been limiting growth. In July and August, when available N, P, and Si were low, there was evidence of Si limitation of diatom growth at both sides. Growth of heterocystous, $N_2$-fixing, blue-green algae and high alkaline phosphatase activity occurred in July at the *Potamogeton* site. Increased standing crop of epiphytic algae in September and October at the *Scirpus* site coincided with higher nutrient levels and an absence of deficiency symptoms. A delay in the standing crop increase at the *Potamogeton* site correlated with low nutrient levels and various physiological deficiency symptoms.

Hopkinson, C. S., J. G. Gosselink, and R. T. Parrondo. 1978. Aboveground production of seven marsh plant species in coastal Louisiana. Ecology 59:760-769.

Results of a 2-year evaluation of aboveground production of 7 plant species commonly found in Louisiana's coastal marshes show a generally higher level of production compared to other studies. In five of the seven species significant growth occurred throughout the year. Calculated annual production in grams per square meter for each species was: *Distichlis spicata*-3237; *Juncus roemerianus*-3416; *Phragmites communis*-2318; *Sagittaria falcata*-1501; *Spartina alterniflora*-3658, *Spartina cynosuroides*-1355; and *Spartina patens*-6043. Sampling variability, expressed as the ratio of the standard error to the mean X 100 averaged between 8 and 18 for different species. Instantaneous loss rates (mg X $g^{-1}$ X $day^{-1}$) of dead vegetation from the marsh, averaged over the year, ranged from 4.7 for *P. communis* to 25.2 for *S. falcata.*

Hough, R. A. and R. G. Wetzel. 1978. Photorespiration and $CO_2$ compensation point in *Najas flexilis.* Limnol. Oceanogr. 23:719-724.

The response of net photosynthesis, light:dark respiration ratio, and $O_2$ compensation point to oxygen manipulation and to inhibitors of glycolate metabolism confirms earlier evidence that photorespiration occurs in *Najas flexilis* and can influence its productivity. Estimates of the $CO_2$ compensation point are similar to those for several other submerged angiosperms which cannot reduce total aqueous $CO_2$ concentration much below air equilibrium levels.

Howard, L. D. and I. A. Worley. 1977. Phytosociological, hydrological, and other ecological features at Colchester Bog, Vermont. Pages 52-117 *in* Proc. Lake Champlain Basin Environmental Conference, Miner Center, Chazy, New York.

This paper reports the highlights of a major phytosociological study at Colchester Bog. The authors found that classic hydrosere "bog" succession is not a major factor in the present patterns of vegetation. Environmental changes cause localized changes in the structure of vegetation zones and the location of their boundaries. The principal determinant of vegetative patterns was the hydrological gradient which extends southward from Malletts Bay.

Hunter, R. D. 1976. Changes in carbon and nitrogen content during decomposition of three macrophytes in freshwater and marine environments. Hydrobiologia 51:119-128.

Three species of aquatic plants were analyzed for their ash, organic carbon, and nitrogen content both fresh and after decomposition using the mesh bag method. *Chara contraria* A. Br. ex Kutz in a small freshwater pond and *Lemna minor* L. in a shallow swamp were examined over a 70 day period of *in situ* decomposition. *Fucus vesiculosus* L. was examined over a 63 day period of decomposition in a rocky shore and a salt marsh environment.

During decomposition, *Chara* showed a decrease in carbon and an increase in nitrogen content while *Lemna* increased in carbon and decreased in nitrogen all on an ash-free weight basis. *Fucus* decomposing in the salt marsh showed no significant change in carbon but increased in nitrogen content while that at the rocky shore decreased in carbon and increased in nitrogen content. Consistent and significant differences in the C:N ratio of decomposing *Fucus* at the two marine sites may be attributable to the nature of the decomposer organisms that inhabit these environments.

This study suggests that intial differences in nutritional value of aquatic macrophytes diminish during decomposition and that the ultimate C:N ratio attained may be more dependent on the nature of the decomposer organisms present than on the nature of the organic material undergoing decomposition.

Hutchinson, G. E. 1970. The chemical ecology of three species of *Myriophyllum* (Angiospermae, Haloragaceae). Limnol. Oceanogr. 15:1-5.

Analysis of the data published by Lohommar indicates that *Myriophyllum alterniflorum* occurs in moderately acid, neutral, or slightly alkaline waters. Both *Myriophyllum spicatum* and *Myriophyllum verticillatum* extend into waters having higher calcium contents than appear to be tolerated by *M. alterniflorum. Myriophyllum verticillatum* tends to occur in waters having a lower pH than many inhabited by *M. spicatum.* The difference is highly significant and may be correlated with *M. spicatum* being able, and *M. verticillatum* not being able, to use the bicarbonate ion as a source of carbon in photosynthesis. In northern Sweden, in a region the lakes of which did not contain *M. verticillatum,* the softwater part of its niche may be occupied by *M. spicatum.* Examination of various other genera containing two or more species fails to show any other clear-cut cases of pH limitation in the alkaline waters studied by Lohammar; usually the more calciphil species seem to require and thrive at high calcium concentrations. It is, however, possible that in very soft water, low pH may be limiting.

Jefferies, R. L. and N. Perkins. 1977. The effects on the vegetation of the additions of inorganic nutrients to salt marsh soils at Stiffkey, Norfolk. J. Ecol. 65:867-882.

Regular additions of mineral salts were made in this study over a 4- or 5-year period to sites in an upper marsh at Stiffkey, Norfolk, in order to examine the effects of these salts on the composition of the vegetation and determine whether the upper marsh was deficient in nitrogen for plant growth. The relatively poor response of species to the additions of nutrients reflects their adaptation to the presence of summer drought and hypersaline conditions in this upper marsh.

Experimental design and statistical methods: at each site the experimental plot was laid out in the form of a Latin square of 5 X 5 m with 25 subplots of 50 X 50 cm. Analysis of variance (arcsine transformed) was employed to compare control plots with experimental plots.

Jeglum, J. K. 1971. Plant indicators of pH and water level in peatlands at Candle Lake, Saskatchewan. Can. J. Bot. 49:1661-1676.

Vegetational measurements: herbs, 20 to 30 0.5 X 0.5 m quadrats.
tree density-linestrip method (Lindsey, 1955).
bryophyte and lichen species were recorded as present in a quadrat if the species covered 25 per cent or more of quadrat area →dominance frequency (Loucks, 1962)

Stand pH index = [§ (species in class X Class #)]§ species

↑
based on pH

This formula yielded the highest correlation coefficient significant at 1 per cent level, and the lowest standard error of estimate.

Jervis, R. A. 1969. Primary production in the freshwater marsh ecosystem of Troy Meadows, New Jersey. Bull. Torrey Bot. Club. 96:209-231.

Primary production was studied in four freshwater marsh communities in New Jersey's Troy Meadows. These communities included: an open aquatic system of emergent and floating plants, a cattail community, a swale of sedge tussocks and associated herbaceous tussock colonists, and a sedge-shrub thicket. The seasonal course of production varied among species and among communities. The estimated average (9.5 $g/m^2/day$) and maximum (20.94 $g/m^2/day$ during early summer) productivities were among the highest reported for natural vegetation. Soil colloids and the groundwater nutrient level were high, and it is suggested that these variables, along with the abundance of soil moisture and of unusually well-adapted flora, are the major factors contributing to the high marsh productivity.

Kadlec, J. A. and W. A. Wentz. 1974. State-of-the-art survey and evaluation of marsh plant establishment techniques: induced and natural; Volume I, report of research. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. 266 p.

Knowledge of marsh and aquatic plant establishment was assessed by reviewing the literature and contacting agencies and individuals likely to have relevant information. In freshwater areas, the factors that affect plant establishment include water levels or depths, substrate water quality, turbidity, and currents and wave action. Aquatic and marsh plants propagate naturally by both seeds and vegetative parts. The propagules are dispersed by wind, water, animals, and man. Seeding appears to be the least expensive procedure to establish marsh plants, but environmental conditions must be favorable or success will be low. Transplants usually provide faster establishment and are hardier than seedlings. The basic problems encountered in the establishment of aquatic and marsh plants are physically unsuitable substrates, nutrient deficiencies, polluted sediments, excessive wind or current action, excessive turbidity, unfavorable patterns of water level fluctuations, and unfavorable water depths.

Keddy, P. A. 1976. Lakes as islands: the distributional ecology of two aquatic plants, *Lemna minor* L. and *L. trisulca* L. Ecology 57:353-359.

Groups of lakes can be considered archipelagos, and island biogeographic theory can be used to explain the distribution of aquatics within them. Two species of duckweed, *Lemna minor* and *Lemna trisulca*, were studied as examples. Both are found in southern Ontario, but *L. minor* occurs much more frequently than *L. trisulca*. It is this difference the experiments were designed to explain.

Colonization capability of each species was defined as its ability to: (1) withstand desiccation, (2) quickly populate a new habitat, and (3) inhibit the other species competitively. Wherever *L. minor* and *L. trisulca* are still colonizing recently deglaciated habitats, superior colonization capability alone can explain the more frequent occurrence of *L. minor*.

Southern Ontario lakes may already have reached equilibrium, where the rate of species colonization is balanced by the rate of species extinction. Increases in summer pH above eight occur, and as both species die above this point, pH could be the major cause of mortality. The observed frequencies of occurrence could, therefore, be the result of a balance between different rates of colonization and approximately equal rates of extinction.

Kirby, C. J. and J. G. Gosselink. 1976. Primary production in a Louisiana gulf coast *Spartina alterniflora* marsh. Ecology 57:1052-1059.

Live and dead aboveground biomass of *Spartina alterniflora* Loisel in a Louisiana salt marsh was determined monthly over an annual cycle. Litterbags were used to determine loss rates of particulate vegetation from the marsh surface. Net aboveground primary production estimates ranged from 750 to 2,600 $g/m^2/year$, depending on how data were handled. Analysis of these results suggested that true net production was probably much closer to the higher estimate than to the lowest.

Klopatek, J. M. 1978. Nutrient dynamics of freshwater riverine marshes and the role of emergent macrophytes. Pages 195-216 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.). Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

A key feature of the marsh separating it from terrestrial ecosystems is its inundated and anaerobic soils which show statistically significant ($P < .01$) seasonal variations in available P and K and exchangeable Ca and Mg. Regression analyses revealed nutrient uptake by the macrophytes was significantly correlated ($r^2 = .98$, $P < .01$) with total

soil N and available P. Models of the flow of nutrients in a *Scirpus fluviatilis* stand are depicted. The effects of a marsh drawdown on the nutrient cycle and nutrient dynamics of *Salix interior*, a typical riverine marsh shrub, are also discussed.

The macrophytes are visualized as nutrient pumps, taking in nutrients from the soil and immobilizing them (at least temporarily) in below- and aboveground structures. To assess the effects of the marsh on water quality, a quantified hydrology is required along with frequent sampling to establish total elemental concentrations in the soil. (author).

Klopatek, J. M. and F. W. Stearns. 1978. Primary productivity of emergent macrophytes in a Wisconsin freshwater marsh ecosystem. Am. Midl. Nat. 100:320-332.

In 1972, primary production of various emergent macrophytes was examined in Theresa Marsh, a shallow, semi-managed impoundment in southeastern Wisconsin. Dominant macrophytes included *Typha latifolia*, *Scirpus fluviatilis*, *Carex lacustris*, *Phalaris arundinacea* and a shrub, *Salix interior*. Seasonal patterns of production as well as total production varied greatly among species. With estimates for litter loss and belowground production, annual net primary production ranged from 1181 g/m²/year for *Carex lacustris* to nearly 3200 g/m²/year for *Typha latifolia*. Peak standing crop values were generally among the highest reported. Average productivities during the growing season, however, were relatively low, ranging from 6.31 to 10.52 g/m²/day for aboveground standing crops. Primary production was also estimated for transient species that occurred on mud flats following a marsh drawdown. The high primary production within the marsh appears to be based on high nutrient levels as indicated by the marsh water and soil chemistry.

Korinkova, J. 1971. Quantitative relations between submerged macrophytes and populations of invertebrates in a carp pond. Hidrobiologia (Burchar.) 12:377-382.

For investigating relations between plants and animals demonstrated in this paper the number of individuals and weight of animals per 100 g of airdried plant or per 1m² of plant surface were used as the most appropriate measures.

The maximum biomass of the plants was 270 g/m² of *Elodea*, 180 g/m² of *Batrachium*, and 120 g/m² of *Potamogeton*.

Annual means of animal quantities of the three plant species show that there is no clear relationship between population densities of animals and the degree of leaf dissection.

Krapu, G. L. and H. F. Duebbert. 1974. A biological survey of Kraft Slough. The Prairie Naturalist. 6:33-55.

An inventory of the biota of Kraft Slough suggests the marsh is in a relatively pristine condition and supports an unusually diverse avifauna and flora. The marsh and adjoining lands to be inundated by the proposed reservoir provide breeding habitat for 70 species of birds, including several that are uncommon to rare elsewhere in southeastern North Dakota. The site is particularly significant because it supports breeding populations of several species of colonial nesting marsh birds, giant Canada geese, and three species of diving ducks. Ecological factors contributing to high avian productivity are discussed.

Krull, J. N. 1969. Factors affecting plant die-offs in shallow water areas. Am. Midl. Nat. 82:293-294.

Many areas are managed for wildlife with specific objectives in mind. At times, a combination of ecological factors reduces the effectiveness of the management program. An unusual submerged aquatic plant die-off in a shallow-water area in central New York is attributed to a series of both biological and nonbiological events.

Kvet, J. 1971. Growth analysis approach to the production ecology of reedswamp plant communities. Hidrobiologia (Buchar.) 12:15-40.

The concepts of growth analysis, including the analysis of the development of vertical canopy structure, can be fruitfully used in production ecological investigations of reedswamp plant communities. Several circumstances, especially the large variation encountered in most natural reedswamp stands and the difficulties connected with the assessment of changes in rhizome and root biomass, complicate the application of this approach.

The seasonal maximum of total shoot biomass and the maximum values of its components (stems, leaf laminae, inflorescences, etc.) are a useful relative measure of stand production.

Study of the vertical structure of a stand's canopy in combination with measurements of the interception of incoming solar radiation enables one to identify the principal photosynthetically active zones in the canopy. The vertical distribution of biomass within the stand also characterizes the architecture of the stand and describes the utilization of the dry matter produced for various purposes at different times.

All described relationships seem to stand out most clearly if there is a defined and regularly occurring period of rest imposed on a stand either by the environment (frost, drought, etc.) or by an internal physiological rhythm or by both.

Larson, G. 1979. The aquatic and wetland vascular plants of North Dakota. Ph.D. Dissertation, Department of Botany, North Dakota State University, Fargo. 453 p.

A taxonomic treatment of the aquatic and wetland vascular plants of North Dakota is provided as a means of identifying the vascular plants encountered in wetland habitats of the state. The treatment includes diagnostic keys, plant descriptions and statements of range, habitat preferences and flowering/fruiting periods to accommodate the identification of wetland plant species.

Three hundred and ninety species, 152 genera, and 62 families of vascular plants are included. These include 48 species newly recorded for North Dakota since the 1963 publication of Steven's *Handbook for North Dakota Plants.*

Lathwell, D. J., D. R. Bouldin, and E. A. Goyette. 1973. Growth and chemical composition of aquatic plants in twenty artificial wildlife marshes. N.Y. Fish and Game J. 20:108-146.

Measurements of the standing crop of aquatic plants were made in 20 artificial marshes in the summers of 1968, 1969, and 1970, some 10 years subsequent to construction of the marshes. The dominant plants found in the marshes belonged to the genera *Scirpus* and *Chara. Scirpus* dominated the shallow marshes and made up about three-fourths of the total plant material in the one-foot marshes. *Chara* dominated the deeper marshes and made up nearly two-thirds of the total vegetation in the three-foot marshes. Aboveground standing crops ranged from about 800 grams per square meter in the shallow marshes to about 300 grams per square meter in the deepest marshes. The calcium content of *Chara* was 20 per cent in contrast to 0.5 per cent for *Scirpus. Scirpus* was notable for its low magnesium content, while the potassium content in *Chara* was substantially lower than that of any other species. The manganese and iron content of the submergent species was highly variable but in general was higher than that of the emergent species.

Likens, G. E. and F. H. Bormann. 1974. Linkages between terrestrial and aquatic ecosystems. Bioscience. 24:447-456.

The terrestrial-output/aquatic-input link between ecosystems is crucial to management of aquatic ecosystems. Management "solutions" that consider rivers or lakes as entities, in isolation from their watersheds and airsheds, are sheer folly. New strategies to control and recycle outputs from terrestrial ecosystems are imperative. This certainly should include the possibility of disposal and recycling of land wastes on land, instead of the current practice of dumping these materials into water. A knowledge of the land-water interactions, properly conceived and evaluated, could provide some of the much needed basis for intelligent management of these resources.

Lind, C. T. and G. Cottam. 1969. The submerged aquatics of University Bay: a study in eutrophication. Am. Midl. Nat. 81:353-369.

The submerged aquatic plants of University Bay, Lake Mendota, Dane Co., Wisconsin, were sampled using the line intercept method. Twenty-one lines, perpendicular to the shoreline and extending into the bay to the depth at which growth of submerged aquatic plants ceased, were sampled. All plants intercepting the line were recorded within consecutive half-meter segments of the line. The data were used to construct a contour map of the vegetated portions of the bay and to delimit the plant communities. Six plant communities were found. Data on plant height and standing crop were obtained from quadrat samples taken at biweekly intervals from four regions within the bay. The data were compared with studies made in 1922. Marked changes in quantitative composition have occurred since 1922, with the most marked difference being the great increase in *Myriophyllum exalbescens* and the complete disappearance of such species as *Potamogeton amplifolius* and *Potamogeton illionoensis.*

Lindsley, D., T. Schuck, and F. W. Stearns. 1977. Primary productivity and mineral regimes in a northern Wisconsin marsh. Pages 38-52 *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.

McNaughton Marsh, located on the Wisconsin River in north central Wisconsin, was underlaid by sands of the Vilas/Crivitz series. During the 1974 growing season primary production of five species of emergent aquatics was determined monthly. Net primary production was found to approximate values reported from much more eutrophic sites elsewhere in North America. Daily productivity aboveground, from the beginning of growth to the time of peak biomass, was as follows: *Sagittaria latifolia* 4.39 $g/m^2$, *Eleocharis palustris* 4.32 $g/m^2$, *Juncus effusus* 10.3 $g/m^2$, *Sparganium eurycarpum* 8.8 $g/m^2$ and *Scirpus validus* 6.3 $g/m^2$. Mineral nutrient concentrations in McNaughton Marsh plants were comparable to those reported elsewhere, despite the low levels of available minerals in these sandy soils. The nature of the substrate was important in nutrient uptake. Plants growing in McNaughton Marsh appeared to "skim off" nutrients from the substrate as rapidly as they were received from river flow and run-off. The degree to which the river nutrient load can be increased without altering the functioning of the marsh system must be resolved by further research.

Major, J. 1971. *Carex* for the ecologist. Ecology. 52:539.

This paper is a one-page review of the genus *Carex*; specifically a book review of *Carices* of the Rocky Mountains, by F. J. Hermann. One hundred and sixty-five species are keyed, described, illustrated in excellent black and white drawing, and their ecologies, distribution, and forage values are given, according to the reviewer.

Mall, R. E. 1969. Soil-water-salt relationships of waterfowl food plants in Suisun Marsh of California. Wildl. Bull. No. 1, California Dept. Fish and Game. 59 p.

Plant food use and selection indices were developed for waterfowl wintering in California's 54,500 acre Suisan Marsh. Alkali bulrush (*Scirpus robustus*) was the most used and selected plant food, with brass buttons (*Cotula coronopifolia*) ranking second.

Seven soil and water factors were monitored for two growing seasons within specific vegetative stands to assess their influence on plant distribution. Length of soil submergence was the most important factor influencing plant distribution and competitive ability. Soil salinity ranked second. Multiple regression curves showing the functional relationship between these factors and competitive ability were developed for six plant species.

The relationship between alkali bulrush seed yield and monthly soil salinity levels was determined. Soil salinities during May were critical to September seed yield. Optimal levels were between 7 and 14 per cent. No seed production resulted when May salinity exceeded 24 per cent.

Mann, G. 1974. The prairie pothole region. Naturalist. 25(4):2-7.

This is a "popularized" description of the prairie pothole region. The article attempts to answer in layman terms such questions as what makes this region so important to waterfowl and why the public can look optimistically on the region's possibilities for the future. The author makes a plea for "ecological engineering" within the region and an attempt to keep the land uses of the prairie zones within their natural long-term limitations of topographic, soil, climatic, and biological characteristics.

Marchant, C. J. and P. J. Goodman. 1969a. *Spartina maritima* (Curtis) Fernald. J. Ecol. 57:287-291.

This paper is a taxonomic treatment of the species *Spartina maritima.* Article includes a detailed description, geographical distribution, habitat, communities in which it is found, gregariousness, effect of frost, drought, etc., morphology, phenology, floral biology, and animal feeders and parasites. Distribution work limited to the country of Great Britain.

Marchant, C. J. and P. J. Goodman. 1969b. *Spartina alterniflora* Loisel. J. Ecol. 57:291-295.

This is a taxonomic treatment of *Spartina alterniflora.* Article includes a detailed description, geographical distribution in Great Britain, habitat, communities in which it is found, gregariousness, effect of frost, drought, etc., morphology, phenology, floral biology, and animal feeders and parasites.

Marchant, C. J. and P. J. Goodman. 1969c. *Spartina glabra* Muhl. J. Ecol. 57:295-297.

This is a taxonomic treatment of *Spartina glabra.* Article includes a detailed description, geographical distribution in Great Britain, habitat, communities in which it is found, gregariousness, effect of frost, drought, etc., morphology, phenology, floral biology, and animal feeders and parasites.

Mason, C. F. and R. J. Bryant. 1975. Production, nutrient content, and decomposition of *Phragmites communis* Trin. and *Typha angustifolia* L. J. Ecol. 63:71-96.

The growth, production, decomposition, and nutrient content of shoots of *Phragmites communis* and *Typha angustifolia* were studied in Norfolk, England. The peak shoot density of *Phragmites* was 127/$m^2$ in 1972 and 72/$m^2$ in 1973. *Typha* shoots reached a maximum density of 100/$m^2$ in 1973. Peak standing crop of *Phragmites* was 942 g.dry wt./$m^2$ in 1972 and 524 g/$m^2$ in 1973, and that of *Typha* 1119 g/$m^2$ in 1973. The net productivity was estimated as 1080 g/$m^2$ and 551 g/$m^2$ for *Phragmites* in 1972 and 1973 and 1445 g/$m^2$ for *Typha* in 1973. In terms of decomposition, *Phragmites* broke down at a faster rate than *Typha.* Bacteria present on the surface of decomposing *Typha* leaves in water had a density of 4.5 X $10^6$/$cm^2$, the majority of which were pectolytic. Yellow *Cytophaga, Erwinia* sp. and *Pseudomonas* spp. were identified. The possible role of reedswamp vegetation as a "regulator" of nutrient inflow into lakes is discussed.

Mayes, R. A., A. W. McIntosh, and V. L. Anderson. 1977. Uptake of cadmium and lead by a rooted aquatic macrophyte (*Elodea canadensis*). Ecology 58:1176-1180.

The role of roots in the uptake of nonessential trace metals by aquatic macrophytes was investigated using *Elodea canadensis.* Plants were grown in two lakes in which metal concentrations in the water differed. Specimens in each lake were anchored in either control sediment or a sediment contaminated with Cd and Pb.

Plants grown in the same water but in sediment from different sources had significantly different concentrations of the two metals. *Elodea* samples rooted in sediments from the same source but grown in water with different levels of metals also accumulated significantly different amounts of Cd and Pb. Thus the importance of both sediment and the surrounding water as sources of metals for aquatic plants was demonstrated. Samples grown in water and sediment containing low levels of metals had minimal concentrations of 0.32/*ug*/g Cd and 5.2 *ug*/g Pb, while plants grown in metal-contaminated water and sediment accumulated up to 32.33 *ug* Cd/g and 160.9 *ug* Pb/g.

McCombie, A. M. and I. Wile. 1971. Ecology of aquatic vascular plants in southern Ontario impoundments. Weed Sci. 19:225-228.

Aquatic plants and physical-chemical data were collected during 1969 from 19 ponds and lakes. The fertility of these waters, as indicated by specific conductance, appeared to be a function of watershed area over the range 0 to 100 hectares. For watersheds greater than 100 hectares, differences in soil type and farming intensity were major causes of variability. *Chara* was found at specific conductances from 96 to 445 micromhos/sq. cm. (at 18° C) but was most abundant between 218 and 300. *Chara* also grew best in the upper half of the transparency range at Secchi disc readings varying from 2.4 to 5.8 m. *Elodea canadensis* Michx. flourished at specific conductances of 224 to 300 micromhos/sq. cm. and at transparencies from 2.7 to 5.8 m. Largeleaf pondweed (*Potamogeton amplifolius* Tuckerm.) was found only in the least fertile impoundment whereas curly leaf pondweed (*P. crispus* L.) occurred only in the most fertile impoundment. Sago pondweed (*P. pectinatus* L.) occurred at specific conductances of 200 to 349 mmho/sq. cm. but was most prolific from 229 upward. This species also favored extensive shallow areas subject to a continuous summer flow.

McCormick, J. 1978. Ecology and the regulation of freshwater wetlands. Pages 341-355 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.). Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

The present state of wetland regulation is primitive, being derived more from common sense than from science. Future wetland regulation to be fully effective and rational must be conducted in conformity with ecologically based, long-range planning with the focus on the wetland system as a dynamic resource. To achieve this goal, the author suggests that it is imperative that wetland ecologists, consultants, planners, and regulators work toward standardization of methodology for obtaining, presenting, and evaluating data, thus permitting more direct comparison of data and reduction of variation in data produced by different groups.

McGahee, C. F. and G. J. Davis. 1971. Photosynthesis and respiration in *Myriophyllum spicatum* L. Limnol. Oceanogr. 16:826-829.

After about 20 hours at low light intensity in the laboratory, photosynthesis was depressed in *Myriophyllum spicatum* tips at a salinity of 32 per cent, but respiration was not affected. Neither photosynthesis nor respiration was depressed at salinities of 16 per cent or less. When the plants were maintained on 10-14 hour light-dark cycles at moderate light intensities, after 48 hours and up to 10 days, photosynthesis was depressed at salinities of 16 per cent below that of plants in Albemarle Sound water, although respiration remained high. The depression of photosynthesis at high salinity and its effect on the P:R ratio are assumed to play a part in controlling natural distribution of *M. spicatum* in estuaries.

McLoy, C. L. 1976. The effect of pH on the population growth of three species of duckweed: *Spirodela oligorrhiza, Lemna minor* and *Wolffia arrhiza*. Freshwater Biol. 6:125-136.

Three species of duckweed, *Spirodela oligorrhiza, Lemna minor* and *Wolffia arrhiza* were grown under aseptic conditions on both buffered and unbuffered solutions of Jacob's media. Media with manually regulated pH levels were also used.

Growth on unbuffered media was initially rapid but eventually inhibited, probably by increased pH levels. On buffered media growth was poor and effects of buffers could not be separated out. These media gave inadequate pictures of the species' responses to changes in pH.

Growth was most successful on media with regulated pH where sustained logarithmic population increases were achieved. *Spirodela* and *Lemna* rates were symmetrical about an almost neutral, optimal pH, declining fairly rapidly away from the optimum. *Wolffia* had an optimum at pH 5 and growth declined with increasing pH. All three species had optimal at or below the neutral point.

The range of tolerance of duckweeds was broader than had previously been suspected. Estimated lower limits, optimum and upper limits for each species were: *Wolffia*, pH 4-5.0-10, *Lemna* pH 4-6.2-10, *Spirodela* pH 3-7.0-10.

Rates of population growth were similar for all species. In decreasing order they are: *Wolffia, Lemna, Spirodela.* In biomass units, *Lemna* grew more than six and *Spirodela* seventeen times faster than *Wolffia*.

Mendelssohn, I. A. 1979. Nitrogen metabolism in the height forms of *Spartina alterniflora* in North Carolina. Ecology 60:574-584.

Selected aspects of the nitrogen nutrition of salt marsh cordgrass, *Spartina alternifolia*, were investigated in Oak Island Marsh, North Carolina. Nitrate was of minor importance as a nitrogen source for *Spartina* in this marsh as indicated by low soil interstitial water nitrate concentrations and low plant tissue nitrate concentrations and nitrate reductase activities. However, *Spartina* did have the capability of assimilating nitrate nitrogen when available. Interstitial water and plant tissue ammonium concentrations were 1-2 orders of magnitude greater than for nitrate, which strongly indicated that ammonium was the dominant inorganic nitrogen source. Leaf and root nitrogen constituents and nitrogen metabolism measured via glutamate dehydrogenase activity indicated that the nitrogen status of the short height form of *Spartina* was deficient relative to that of the tall form. (author).

Mendelssohn, I. A. and K. L. Marcellus. 1976. Angiosperm production of three Virginia marshes in various salinity and soil nutrient regimes. Chesapeake Sci. 17:15-23.

The net aerial angiosperm productivity, salinity, and soil nutrient composition of three Virginia marshes were determined. Oligohaline Ware Creek Marsh and mesohaline Carter Creek Marsh were most productive, 563 and 572 $g/m^2/yr$., respectively, while euhaline Wachapreague Marsh was least productive, 362 $g/m^2/yr$. Species in Carter and Ware Creek Marshes were clustered into associations based on salinity tolerance. Nitrogen and phosphorous concentrations of *Spartina alterniflora* tissue were high in the spring and decreased as the growing season continued. Soil nutrient concentrations were variable, and trends during the growing season were not discernible. No significant correlations were found between soil and plant nutrient concentrations. Although the empirical data suggest that high soil salinity and low soil nitrogen and phosphorus concentrations limited primary productivity in Wachapreague Marsh, a multiple regres-

sion of standing crop on these parameters did not delineate any as the primary factors limiting salt marsh production.

Merezhko, A. I. 1973. Role of higher aquatic plants in the self-purification of lakes and streams. Hydrobio. J. 9:103-109.

The studies analyzed in this paper demonstrate the various aspects of the life processes of higher aquatic plants associated with the self-purification of lakes and rivers. Their filtration, absorption, and accumulation functions, mineralization and oxidation of organic matter functions, and their role in the detoxification of noxious substances was discussed.

The author suggests that the mechanism by which aquatic plants take up individual elements, the dynamics of the latter in plant tissues and organs throughout the year, and the intensity of uptake need to be examined.

Miller, P. C. and W. A. Stoner. 1976. A model of stand photosynthesis for the wet meadow tundra at Barrow, Alaska. Ecology 57:411-430.

A model of radiation, air temperature, and vapor density in the vegetation canopy, plant water relations, and photosynthesis, developed in the primary production research program of the U.S. Tundra Biome, IBP, is described and results for the years 1970 through 1973 presented. The model calculates daily courses of direct and diffuse solar radiation; infrared radiation; wind, air temperature and humidity; leaf temperatures; convectional and transpirational exchange by leaves, stems, and dead material; leaf water content, leaf water potential; leaf resistance to water loss; internal resistance to $CO_2$ diffusion; and net photosynthesis.

Photosynthesis seems adjusted to maximize carbon gain under the most frequent conditions but not under all conditions or extreme conditions.

Mitchell, R. S. 1976. Submergence experiments on nine species of semi-aquatic *Polygonum*. Amer. J. Bot. 63:1158-1165.

Cloning experiments were carried out in growth chambers to determine responses of members of the genus *Polygonum* (sect. Persicaria) to aquatic submergence. By using both external morphology and anatomical modifications, comparisons were made among 23 populations with respect to their preadaptations after a rise in water level. Varieties of *P. amphibium* L. responded quite differently to submergence, offering more evidence to the theory that there is a cline of phenotypic plasticity in the species which corresponds roughly with the gradient in morphology. Other than *P. amphibium*, the species most well adapted to aquatic conditions was *P. densiflorum* Meisn., a member of the *P. punctatum* Ell. complex. Populations of *P. hydropiperoides* Michx. showed a dichotomy of response which appeared to correlate with the habitats in which they were collected. A few species of *Polygonum* did not survive well after inundation, but most were capable of underwater growth, and were at least half as well adapted to aquatic conditions as was the most plastic variety, *P. amphibium* var. *stipulaceum* Colem.

Mooring, M. J., A. W. Cooper, and E. D. Seneca. 1971. Seed germination and evidence for height ecophenes in *Spartina alterniflora* from North Carolina. Am. J. Bot. 58:48-55.

This study was conducted to determine germination response to temperature and salinity and seedling response to salinity by three height forms of the salt marsh grass *Spartina alternifolia* Loisel. Germination tests showed that seeds cannot withstand drying at moderate temperature, as viability was lost within seeds stored dry at 72°F. Viability is retained at least 8 months when seeds are stored in sea water at 43°F. Germination response was good in a 65-95°F alternating diurnal thermoperiod but was poor in a 72°F constant thermoperiod. Germination response to salinity was an inverse curvilinear relationship with germination inhibition at high salinities apparently due to osmotic effects. A logarithmic curve best described seedling growth response to various NaCl levels. On the basis of these germination and seedling responses, the height forms of *S. alterniflora* in North Carolina salt marshes are best described as ecophenes.

Moyle, J. B. 1945. Some chemical factors influencing the distribution of aquatic plants in Minnesota. Am. Midl. Nat. 34:402-420.

Based on the results of this study, Minnesota aquatic flora can be separated on the basis of water quality tolerance and preference into three major groups: The soft-water flora, the hard-water flora, and the alkali- or sulphate-water flora. Within these groups, subgroups can be constructed on the basis of the chemical tolerance of the individual species. Although the soft-water flora is most characteristic of waters with a total alkalinity below 40 ppm, a number of species range into harder waters in situations where the pH remains low. This suggests that pH is a more important factor in limiting the distribution of this group of plants than the dissolved mineral content of the water. The hard-water flora consists of a large and varied group of aquatic plants that are most typical of waters with a total alkalinity of 90 to 250 ppm and with a sulphate ion concentration less than 50 ppm. The alkali- or sulphate-water flora is largely limited to Minnesota waters with a total alkalinity greater than 150 ppm, a sulphate ion concentration greater than 50 ppm, and a pH between 8.4 and 9.2.

The type of bottom soil and the physical nature of the body of water greatly influence the local distribution of a species within its range of chemical tolerance.

Nichols, D. S. and D. R. Keener. 1976a. Nitrogen nutrition of *Myriophyllum spicatum:* Variation of plant tissue nitrogen concentration with season and site in Lake Wingra. Freshwater Biol. 6:137-144.

Samples of water, sediment and *Myriophyllum spicatum* were collected from four weedbed sites in Lake Wingra, a small hypereutrophic hard-water lake in Madison, Wisconsin, several times during the 1972 and 1973 growing seasons, and analyzed for various forms of N. The concentrations of inorganic N in the lake water were quite similar at all sites. The differences in the total N content of the *Myriophyllum* tissue from site to site directly related to the levels of available sediment N, indicating a dependence upon the sediment as a N source. *Myriophyllum* tissue N concentrations (ash and moisture-free basis) were highest in spring, decreased steadily during the summer, and increased again in the fall. *Myriophyllum* apparently grows very little during the winter, but continues to accumulate N. The death and decay of a considerable portion of the *Myriophyllum* in the fall contributes insignificant amounts of N directly to the lake water. Nitrogen does not appear to be limiting *Myriophyllum spicatum* growth in Lake Wingra.

Nichols, D. S. and D. R. Kenner. 1976b. 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* is 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/l of $NG_4$-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 taken up by the roots were subsequently released to the water through the foliage.

Nicholson, S. A. and D. G. Best. 1974. Root:shoot and leaf area relationships of macrophyte communities in Chautagua Lake, New York. Bull. Torrey Bot. Club. 101:96-100.

Root:shoot, leaf:shoot, and leaf surface area:weight ratios were consistent in *Vallisneria americana* and *Potamogeton richardsonii* from Chautauga in all except the smallest individuals. Root:shoot ratio increased across the aquatic hydrosere, i.e., from submergent to floating leaf to emergent communities, but leaf area index (LAI) varied little. LAI in most undisturbed native communities ranged between 5-7 $m^2/m^2$ but disturbed communities dominated by the alien *Potamogeton crispus* had LAI's of 11 $m^2/m^2$ or more. Since these communities are very unstable and characterized by explosive growth, decreased life span, and spontaneous dieoff, and since *P. crispus* is an introduced species, the high LAI's may be maladjusted to local conditions. A community exhibiting high LAI's soon suffers excessive shading and spontaneous dieoffs.

Nienhuis, P. H. 1978. Dynamics of benthic algal vegetation and environment in Dutch estuarine salt marshes, studied by means of permanent quadrats. Vegetatio 38:103-112.

Knowledge of the spatial structure of benthic algal vegetation in salt marshes, consisting of about 100 species of blue-green, green, brown, and red algae, formed the basis of a detailed study into the dynamics of the algal mat.

The temporal changes in algal vegetation and concomitant processes in their environment were studied in 27 permanent quadrats (PQ's), plotted in tidal salt marshes and along brackish inland waters in the SW Netherlands.

From the Spearman rank-correlation between vegetational and environmental parameters it appeared that in semi-terrestrial land, terrestrial environments, the average number of algal species in a relevé and the average similarity between the species composition of successive relevés obtained from one PQ have a significant positive correlation with the stability of the substrate, and hardly any correlation with fluctuations in soil-moisture content and salinity of the soil moisture and with the maximum cover percentage of the phanerogams.

Nixon, S. W. and C. A. Oviatt. 1973. Ecology of a New England salt marsh. Ecol. Mono. 43:463-498.

Measurements of the abundance of major populations, their metabolism, and the seasonal patterns of total system metabolism throughout the year were used to develop energy-flow diagrams for a New England salt-marsh embayment. The annual ecological energy budget for the embayment indicates that consumption exceeds production, so that the system must depend on inputs of organic detritus from marsh grasses. Gross production ranged from almost zero in winter to about 5 g $O_2/m^2$/day in summer. Production of aboveground emergent grasses on the marsh equalled 840 $g/m^2$ for tall *Spartina alterniflora,* 432 $g/m^2$ for short *S. alterniflora,* and 430 $g/m^2$ for *S. patens.* These values are similar to those for New York marshes, but substantially lower than southern marsh types.

A simulation model based on the laboratory and field metabolism and biomass measurements of parts of the embayment system was developed to predict diurnal patterns of dissolved oxygen in the marsh. The model was verified with field measurements of diurnal oxygen curves. The model indicated the importance of the timing of high tides in determining the oxygen levels.

Oborn, E. T. 1964. Intracellular and extracellular concentration of manganese and other elements by aquatic organisms. U.S. Geological Survey Water-Supply Paper 1667-C, Washington, D.C.

Examinations of mineral concentrations or deposits accumulated on the inside walls of plant-culture tanks used in a greenhouse study show how the amount of the mineral deposited is related to the aquatic-plant species growing in the tanks.

A bacterium tentatively identified as *Bacterium precipitatum* Kalin commonly grows symbiotically on sago pondweed. This bacterium is responsible for deposition of a mineral, mainly calcite, on the plant-body surface of the pondweed; this deposit may amount to more than 1.2 per cent of the fresh weight of the plant.

Water-submersed lake-bottom soil had four times as much manganese as adjacent farm-land soil. The manganese concentration in aquatic plants may be more than 30 times that found in comparable parts of land plants.

Microscopic study of plant sections shows that mineral deposition patterns associated with the growth of pond scum, stonewort, and pondweed range widely. In addition to the inanimate phenomena of water-body area, depth, and evaporation, the growth processes of the different aquatic-organism species and species associated are significant in the determination of the amount and type of mineral accumulations.

Oborn, E. T. 1960. Iron content of selected water and land plants. U.S. Geological Survey Water-Supply Paper 1459-G, Washington, D.C.

Plant roots contain a higher proportion of iron than the leaves and stems. The iron content of leaves is a function of the amount of chlorophyll present, which varies seasonally in any given species.

The iron content of lichens and water plants, on a dry basis, averaged 5.16 and 4.99 milligrams per gram of dry matter, respectively; whereas the iron content of land plants on the same basis averaged only 0.30 milligrams. The relative absence of woody tissue in the lichens and water plants probably is the reason for the difference. Soil-rooted water plants are effective in removing iron from submerged soils, and the water-rooted types also seem to be effective in removing iron from the water. The iron content of the soil-rooted types is about three to seven times as great as that of the water-rooted type. The iron content for plants growing in rock, soil, and water environments agrees in general with published data.

Oborn, E. T. and J. D. Hem. 1962. Some effects of the larger types of aquatic vegetation on iron content of water. U.S. Geological Survey Water-Supply Paper 1459-1, Washington, D.C.

Complex antagonistic factors affecting solution of iron in natural water were investigated by correlating data from field and laboratory studies of aquatic plants.

A gradual accumulation of iron in the bottom mud of the Federal Center Lake seemed to result from additive effects of oxygen entry into lake water from the air and from photosynthesis of the water plants growing in the lake. Both greenhouse and lake water with submerged soil-rooted plants had highest concentrations of iron in solution when growth was most conspicuous. Water-hyacinth leaves shade the water surface and do not permit exchange of oxygen at the air-water interface of the water body. As a result, dissolved oxygen and Eh remained high, and iron in water continued low throughout the growing season of water-hyacinth.

Water percolating through soil may dissolve 10 or more times the amount of iron normally present at a lake bottom.

Odum, W. E. and M. A. Heywood. 1978. Decomposition of intertidal freshwater marsh plants. Pages 89-97 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.). Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

Methods: Decomposition rates were estimated using nylon bags with 2-mm mesh. 40 g. of air-dried, green plant leaves were placed in each bog. Four replicates were removed at intervals, the plant material washed thoroughly, ovendried at 105 °C for 48 hours, weighed, and ground in a Wiley mill to 20-mesh size. Replicate 1-g samples were ashed in a muffle furnace at 550 °C for 12 hours.

Total N determined by Kjeldahl technique and by the indol phenol blue method for ammonia using a Technicon Autoanalyzer I. Organic carbon was assumed to be equal to 45 per cent of ash-free dry weight. Analysis of variance was to test the data for significance.

Summary: Freshwater marsh plants are readily attacked by detritovores, facilitated by low lignin and cellulose contents. DOM pathway important: dead plant → DOM → bacteria → consumer. (authors).

Olson, J. S. 1963. Energy storage and the balance of producers and decomposers in ecological systems. Ecology 44:322-331.

While some fraction of the solar energy fixed by producing plants is released by respiration of these plants and of animals, much of it is stored in dead organic matter until released by decomposing organisms, at rates which vary greatly from place to place. The general differential equation for the rate of change in energy storage is illustrated by models for build-up and decomposition of organic matter, particularly for litter in deciduous or evergreen forests. Since it takes a period of about 3/k years before storage has attained 95 per cent of its steady-state level and since decomposition rates (k) within mineral soils may range from near .001 to .0001, many ecosystems continue to show a positive net community production for centuries—perhaps long after changes in numbers and biomass of some species are reduced to minor fluctuations around a "climax" composition. On the other hand, the slow change in soil conditions may in some cases facilitate the introduction of new species after some delay during succession.

Olson, R. A. 1979. Ecology of wetland vegetation on selected strip mine ponds and stockdams in the northern Great Plains. Ph.D. Dissertation, Department of Botany, North Dakota State University, Fargo.

Wetland plant communities of strip mine ponds and stockdams were studied through intense field sampling from early July to late August during 1976, 1977, and 1978 on five geographical study areas in the Northern Great Plains. Floristically, stockdams are richer, with 106 vascular plant species identified in 28 families during 1976-78, compared to 76 species in 20 families from strip mine ponds. The largest percentage of species are wet meadow forms, the smallest percentage floating and suspended. Communities of strip mine ponds are distributed in narrow concentric bands around pond margins compared to wider complex mosaic patterns on stockdams. Correlation matrices indicate that mean water depth in wetland communities is inversely related to mean density, number of species, and species diversity in both impoundment types. As a group, stockdams exhibit stronger species composition similarity compared to strip mine ponds. The magnitude of summer drawdown and basin slope are major factors determining wetland community attributes.

Ondok, J. P. 1971. Horizontal structures of some macrophyte stands and its production aspects. Hidrobiologia (Buchar.) 12:47-55.

The main purpose of this paper was to show how useful the methods of descriptive plant sociology may be in investigations of production ecology. Three quantitative parameters are usually used for determining the distribution of plants: density, cover, and frequency. Only density was employed in this study because of the difficulty in determining, e.g., cover.

Ondok, J. P. and J. Kvet. 1978. Selection of sampling areas in assessment of production. Pages 163-174 *in* D. Dykyjova and J. Kvet (eds.). Pond littoral ecosystems. Springer-Verlag, New York.

Authors examine various methods for estimating above- and belowground biomass/production. Both destructive and indirect methods are addressed.

O'Neill, E. J. 1972. Alkali bulrush seed germination and culture. J. Wildl. Manage. 36:649-652.

Several hundred acres of alkali bulrush (*Scirpus paludosus*) were successfully seeded and propagated near Tulelake, California, after a technique was developed for breaking the seed dormancy, employing use of sodium hypochlorite, water, transparent plastic sheeting, and direct sunshine for several days. The pregermination process presents a method that can accommodate large amounts of seed for bulk aerial or broadcasting seeding in situations similar to shallow, flooded rice fields or wet shoreline units.

Owens, M., M. A. Learner, and P. J. Maris. 1967. Determination of the biomass of aquatic plants using an optical method. J. Ecol. 55:671-676.

A method, based on that proposed by Westlake (1964), of determining the quantitative distribution of aquatic plants from underwater light distributions is described.

Vertical attenuation coefficients for several species of aquatic plants have been determined in the field and compared with those obtained using laboratory procedures. An example is given of the application of this method to determine the effect of a herbicide on the biomass of *Elodea canadensis* present in a small lake.

Patriquin, D. G. and C. Keddy. 1978. Nitrogenase activity (acetylene reduction) in a Nova Scotian salt marsh: its association with angiosperms and the influence of some edaphic factors. Aquat. Bot. 4:227-244.

Excised roots of 33 species of angiosperms from a coastal marsh in Nova Scotia were assayed for nitrogenase activity by the acetylene-reduction technique. Two nodulated species and 13 species without nodules exhibited acetylene-reducing activities in excess of 100 umoles $C_2H_4$/g/h. *In situ* acetylene reduction assays confirmed the existence of moderate levels of nitrogenase activity in the intact systems. In the driest areas, only nodulated plants exhibited high nitrogenase activity. There was an inverse correlation of nitrogenase activity in roots with the concentration of ammonium in the groundwater.

Pearsall, W. H. and E. Gorham. 1956. Production ecology I. Standing crops of natural vegetation. Oikos 7:193-201.

The basis of the method used to measure standing crops of natural vegetation was to estimate the dry weight of this standing crop in a quadrat of known area. Quadrat size was 625 sq. cm. (1/16 sq. m.). Samples were taken from five contiguous quadrats, taken in linear series as would be the holes of a ladder. This "ladder series" gave the authors insight into the "pattern" of the plant community as well as increasing the so-called edge effect. Sites were chosen in which there had been no grazing.

The similarity in range of the results for different species from widely diverse soil types suggests that the authors were dealing with a quantity which is determined in the first place by some general factor such as the annual amount of photosynthesis—a function of the light climate in the first place, and possibly also in the second place by the effects of temperature and soil conditions on leaf growth.

Peterka, J. J. and L. A. Reid. 1968. Primary production and chemical and physical characteristics of Lake Ashtabula, North Dakota. Proc. N.D. Acad. Sci. 22:138-156.

This paper describes the chemical and physical characteristics of the water of Lake Ashtabula, a reservoir on the Sheyenne River, North Dakota, and attempts to relate these to the standing crops and production rates of phytoplankton.

Phytoplankton standing crop and production rate data indicated that this lake is very productive. The average phytoplankton standing crop was 101 mg chlorophyll a/m². This figure is about 3 times that reported for five Wisconsin lakes (McConnell and

Sigler 1959). The average gross photosynthesis from May to December, 1966 was 2.2 g C/m² per day or 4.4 g dry organic matter/m² per day. Since multiple regression analysis did not indicate any significant relationships of productivity with various macronutrients, particularly nitrogen and phosphorous, it is suggested that nutrients did not limit photosynthesis.

Pip, E. 1979. Survey of the ecology of submerged aquatic macrophytes in central Canada. Aquat. Bot. 7:339-357.

A total of 305 sites were examined in southern Manitoba and adjacent regions for submerged macrophytes in relation to water body and substrate type, and eight water chemistry parameters. Decreasing numbers of macrophyte taxa showed significant t-test results for the hydrochemical parameters in the following order: total alkalinity, total filtrable residue, pH, dissolved organic matter, combined nitrate and nitrite, molbdenum blue phosphorus, chloride, and sulfate. Most macrophytes tended to occur at sites where certain other species were also present. Chi-square tests revealed 287 significant correlations between pairs of plants, of which 278 were positive and nine were negative. Net hydrochemical preferences were assessed for each plant pair by comparing the significant positive and negative affinities for the eight parameters; one-third of the significant Chi-square correlations did not coincide with the apparent net preferences of the respective plants. The most common species did not form the greatest number nor the most highly significant positive correlations with other plants. The similarities between pairs of plants were compared in terms of the significant positive correlations shown by each plant for other species. The major plant groupings that emerged appeared to reflect the habitats in which they most often occurred.

Polisini, J. M. and C. E. Boyd. 1972. Relationships between cell-wall fractions, nitrogen, and standing crop in aquatic macrophytes. Ecology 53:484-488.

Shoot samples of 21 species of aquatic macrophytes were separated into cell-wall and noncell-wall fractions by digestion in a neutral-detergent solution. This method is useful for estimating the digestibility of plant production by native herbivores. Nitrogen content was also used as an indication of nutritive quality. Amounts of noncell-wall material and nitrogen in the dry matter decreased as shoot standing crops of the different species increased. Dry matter standing crops, caloric equivalents, and other conventions of reporting plant production are often of limited use in ascertaining the value of different plant species within an ecosystem to other trophic levels. Interpretation of primary production data should in many cases consider nutritive value. Fundamental differences in biochemical synthesis have a pronounced effect upon the utilization of primary production.

Prentki, R. T., T. D. Gustafson, and M. S. Adams. 1978. Nutrient movements in lakeshore marshes. Pages 169-194 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.). Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

Seasonal phosphorus allocation in *Typha latifolia* L. was investigated by analysis of above- and belowground parts in a lakeshore marsh. Maximum total P stocks of 4.3 and 2.2-2.5 g P/m² were found in summer and winter, respectively. Over an entire summer, 40 per cent of the 3.2 g P/m² accumulated aboveground was reallocated from belowground plant parts. However, only 23 per cent of this amount returned to belowground in the fall.

Analysis of lakeshore marsh literature via an input-output model suggests that macrophytic translocation of nutrients is an important source of internal loading. In those marshes without major surface water inputs, seasonal accumulation and abandonment of nutrients above the soil interface is likely to be the dominant term in nutrient budgets. Methods: Used partial harvest technique aboveground and excavation belowground.

Prophet, C. W. and B. A. Carrillo. 1979. Gross primary productivity in a small Kansas lake, based on continuous *in situ* recordings, 24 Marsh-31, 1977. Southwest. Nat. 24:667-676.

Daily gross primary productivity was recorded continuously in Gladfelter Pond from 14 March through 31 June, 1977, except for two brief interruptions. Daily gross production averaged 2.57 g C/m² day (± SD 1.46) during this study. Daily primary productivity exceeded community respiration 21 per cent of the 86 days during which values were recorded. Gross productivity was more highly correlated with surface solar radiation on clear days, r= 0.85, than on partly cloudy to overcast days, r = 0.39.

Reader, R. J. 1978. Primary production in northern bog marshes. Pages 53-62 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

Methods: Both "gas-exchange" and "harvest" methods have been utilized to measure bog marsh primary productivity. Gas exchange techniques have been employed only for the estimation of primary productivity by single populations rather than total ecosystems.

The harvest method offers several advantages over gas exchange for the estimation of total ecosystem primary productivity. A pair of clippers is the only piece of equipment needed to apply the harvest technique while several pieces of relatively expensive equipment (e.g., infrared gas analyzer), are required to monitor photosynthetic rates using gas exchange techniques. It is also very difficult to extrapolate accurately from short-term, small scale gas exchange measurements to long-term production values.

$$\text{Total belowground productivity} = \frac{\text{belowground standing crop}}{\text{aboveground standing crop}} \; \text{total aboveground productivity}$$

Reader, R. J. and J. M. Stewart. 1972. The relationship between net primary production and accumulation for a peatland in southeastern Manitoba. Ecology 53:1024-1037.

Two functional attributes of an ecosystem, net primary production and subsequent dry matter accumulation, were examined in four peatland types (lagg, bog, muskeg, and bog forest) located in southeastern Manitoba. A preliminary peat accumulation budget was constructed by relating the amount of litter present after a single year of decomposition to the initial litter income and annual net primary production. Annual litter "income" in the four vegetation zones ranged from 489 $gm/m^2$ to 1,750 $gm/m^2$, which represented 69 per cent to 90 per cent of the calculated net primary production. Decomposition losses in the following year amounted to approximately one quarter of the original income. An average annual accumulation rate of 26 $gm/m^2$/year to 51 $gm/m^2$/year was calculated from radiocarbon-dated peat cores, thus suggesting that less than 10 per cent of the annual net primary production will remain as peat.

Rich, P. H., R. G. Wetzel, and N. Van Thuy. 1971. Distribution, production, and role of aquatic macrophytes in a southern Michigan marl lake. Freshwat. Biol. 1:3-21.

The low diversity but relatively high quantitative importance of macrophytes in marl lakes is attributed to an adverse dissolved inorganic and organic chemical milieu which inhibits phytoplanktonic production and allows only certain adapted macrophytes to develop strongly (e.g., *Scirpus subterminalis* Torr.). The phenomenon of perennial biomass levels throughout the year is believed to be much more common than previously expected and has likely resulted from adaptations of submersed macrophytes to ameliorated conditions of water and temperatures relative to the terrestrial situation in winter.

Richardson, C. J., D. L. Tilton, J. A. Kadlec, J. P. M. Chamie, and W. A. Wentz. 1978. Nutrient dynamics of northern wetland ecosystems. Pages 217-241 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

Methods: Water samples were collected at 45 locations. All samples were filtered through 0.45 *u*m pore membrane filters. Chemical analysis of rainfall included dry fall contributions. An auto analyzer was used to analyze for $NO_3-$, $NH_4+$, and $PO_4$. Nitrate ($NO_3- + NO_2-$) was analyzed with the cadmium reductions reaction and is reported as $NO_3--N$ and the Berthelot reaction was used to analyze for $NH_4-N$. After persulfate digestion, P was analyzed using the molybdate reaction.

Plant samples were harvested monthly for biomass and nutrient analysis by species. Wet ashing ($HClO_4 + HNO_3$) was carried out. Total N was determined using semimicro Kjeldahl digestion. Phosphorus was determined colorimetrically utilizing the molybdate-vanadate technique.

Soil analysis included bulk density, per cent $H_2O$ content, ash and organic content. Wet samples were transferred immediately to polyethylene bags to avoid excessive air contact. Analysis of N and P were determined via the ammonia-salicylate complex and phosphomolybdenum complex. CEC, exchangeable cations, $NH_4-N$, $NO_3-N$, and available P were made using weat peat soils.

Ripley, B. D. 1978. Spectral analysis and the analysis of pattern in plant communities. J. Ecol. 66:965-982.

Spectral analysis is a relatively untried method for the analysis of data from a line of contiguous quadrats. Conventional block-size analyses are shown to be related to square waves. In spectral analysis square waves are replaced by sine waves.

These methods and Mead's test are compared with conventional methods, using artificial and filed data. Spectral analysis performed reliably and gave a good indication of the type of departure from a random pattern. Mead's test proved sensitive but hard to interpret, often contradicting other methods.

It is argued that standardization should not be used with methods based on variances.

Routledge, R. E. 1979. Diversity indices: which ones are admissible? J. Theor. Biol. 76:503-515.

Many indices have been proposed for measuring diversity. If we demand that any index satisfy a few basic properties, including that it contains hierarchical components, that only the subset ($N_a$ for a > o) of Hill's family need be considered. (This subject includes indices related to the Shannon-Wiener index, $H^1 = \log N_1$, and Simpson's index of concentration, $h = 1/N_2$). Ecological components can also be defined for any of these indices. Only $N_2$, however, can be used consistently to define local diversity and segregation components. These observations suggest that $N_2$ is the best, single measure of diversity and that the only other index worth considering is $N_1$.

Schindler, D. W. 1978. Factors regulating phytoplankton production and standing crop in the world's freshwaters. Limnol. Oceanogr. 23:478-486.

A regression analysis of global data for freshwater phytoplankton production, chlorophyll, and various nutrient parameters revealed the following: A high proportion of the variance in both annual phytoplankton production and mean annual chlorophyll could be explained by annual phosphorus input (loading), once a simple correction for water renewal time was applied. Good relationships were also found between phosphorus loading and mean total phosphorus concentration, and between total P concentration, and chlorophyll. The slope of the regression of total P on P loading for stratified lakes was not significantly different from that for unstratified lakes, suggesting that the effect of stratification on phosphorus concentration is insignificant compared to external sources of the element. Nutrient input, which was unavailable in previous analyses, appears to be an important factor in controlling freshwater production. There is some evidence for a correlation between latitude and nutrient input, and it is possible that this may explain the good correlation between latitude and production observed by earlier investigators.

Schwintzer, C. R. 1978. Vegetation and nutrient status of northern Michigan fens. Can. J. Bot. 56:3044-3051.

The vegetation, selected characteristics of shallow groundwater, and depth to water were examined in five fens in northern lower Michigan. The field layer was the dominant stratum in all five fens and contained a total of 85 vascular species with a mean density of 30 vascular species per stand. *Carex lasiocarpa* was the most prevalent dominant plant and attained a frequency-presence index (FPI) of 8,000 of a possible 10,000 and a mean importance value of 33 of a possible 200. The vegetation was relatively homogeneous as indicated by a homogeneity index of 58 per cent.

The shallow groundwaters were minerotrophic with pH values from 5.7 to 7.0 and calcium concentrations of 11.0 to 75.0 mg/l. Four of the fens were on floating mats and had relatively stable water levels while the fifth was on a grounded mat and was subject to substantial water level fluctuation.

Three previously described alkaline lake-edge kettle hole "bog" communities were found to be similar to the fens in species composition and water chemistry.

Schwintzer, C. R. 1977. Vegetation changes and water levels in a small Michigan bog. Pages 326-336 *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.

Bryant's Bog consists of two concentric zones, a free floating and a grounded mat surrounding a central pool. Quantitative descriptions of the vegetation are available for several years since 1917. The vegetation changed from the *Chamaedaphne* association of 1917 to the high bog-shrub association in the 1920's. The two zones differed in species composition, biomass, and extent of tree mortality. Water levels are the most probable cause of the tree mortality and differences in the two zones.

Schwintzer, C. R. and G. Williams. 1974. Vegetation changes in a small Michigan bog from 1971 to 1972. Am. Midl. Nat. 92:447-459.

Quantitative descriptions of the vegetation and maps of the pool of Bryant's Bog are available for several years since 1917. The vegetation advanced into the bog pod in an irregular manner at an average rate of 2.1 cm/year. In 1972 the pool was 76 per cent of its extent in 1926. The vegetation changed in a successional series from *Chamaedaphne* association of 1917 to the high bog-shrub association in the dry years of the 1920's to a bog forest which was well established in the late 1960's. It regressed in the early 1970's when many of the trees died and the *Chamaedaphne* association appeared to be reestablished. The most probable cause of tree mortality was flooding caused by exceptionally high water levels due to natural weather cycles. Tree mortality was also found in Hoop Lake Bog, which, like Bryant's Bog, lacks aboveground drainage—while none occurred in bogs with aboveground drainage.

Seddon, B. 1972. Aquatic macrophytes as limnological indicators. Freshwater Biol. 2:107-130.

Species of submersed and floating-leaved aquatic macrophytes have been placed in a series based on their patterns of occurrence in an ordination of floral lists. Two chemical parameters from lake water analyses are correlated with the species assemblage in individual lakes and trophic categories are defined on the quantitative chemical characteristics of lake waters. Restriction toward eutrophic conditions is considered as an obligate relationship reflecting physiological demands. Some dystrophic and oligotrophic species are shown to have wide tolerance and are thought to be excluded from sites of higher trophic status by competition rather than physiological limitation.

Sefton, D. F. 1977. Productivity and biomass of vascular hydrophytes on the upper Mississippi. Pages 53-61 *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.

The biomass of vascular hydrophytes in Navigation Pool 8 of the upper Mississippi River was determined in order to provide basic data on the productivity, frequency, and distribution of these plants. Two 0.25 $m^2$ quadrats constituted a sample at a given site. All vegetation, including underground parts, was removed from these quadrats. The vegetation in each sample was washed, separated into component species, frozen, dried, and weighed. Oven-dry weight of each species per 0.5 $m^2$ was recorded.

Submergent *Ceratophyllum demersum* was the most frequently occurring species, while the greatest portion of the total biomass of Pool 8 consisted of emergent *Sagittaria latifolia*. An average summer crop of 181.70 $g/m^2$ for the littoral zone of Pool 8 was comparable to that for hard water lakes in Wisconsin.

Maximum productivity rates were coincident with flowering and fruit development in *Nelumbo pentapetela*, *Sagittaria latifolia*, and *Vallisneria americana*. The submergent *Vallisneria* community was less productive than floating-leaved *Nelumbo*, while emergent *Sagittaria latifolia* was the most productive of all.

Sharma, K. P. and B. Gopal. 1977. Studies on stand structure and primary production in *Typha* spp. Int. J. Ecol. Environ. Sci. 3:45-55.

This paper reports data on the stand structure and net primary production in *Typha angustata* Bory and Chaub. and *T. elephantina* Roxb.—two widespread weeds of marshes and shallow waters around Jaipur (India). The stands show a 2-tier structure with *Typha* species being the dominant constituent.

The biomass distribution shows considerable variation among different stands of *T. angustata* and within *T. elephantina* stand. The underground/aboveground biomass ratio ranges from 1.56 in the submerged zone to 3.97 in the dry zone of *T. elephantina* stand.

The aboveground net primary production has been estimated from the trough-peak biomass differences, and the underground production has been computed from the aboveground/underground biomass ratios. It is observed that the total primary production respectively is as high as or more than that for other temperate species of *Typha* or for the terrestrial communities in India.

Shearer, L. A., B. J. Jahn, and L. Lenz. 1969. Deterioration of duck foods when flooded. J. Wildl. Manage. 33:1012-1015.

Eighteen kinds of seeds readily eaten by waterfowl were submerged in flooded fields to determine the percentage of deterioration. Samples were placed in nylon mesh bags and placed under for 30-, 60-, and 90-day periods. Tests were conducted to correspond with the normal period of flooding practiced by most owners of managed duck hunting fields in the State of Washington. Seeds showed varying degrees in rate of percentage of deterioration. Peas (*Pisum arvense*), lentils (*Lens culinaris*), and soybeans (*Glycine soja max*) showed the greatest deterioration, while saltmarsh bulrush (*Scirpus robustus*), smartweed (*Polygonum lapathifolium*), and safflower (*Carthamus tinctorius*) showed the least.

Sixteen of the waterfowl foods were then fed to wild mallards, (*Anas platyrhynchos*), to determine palatability of the fermented seeds. Based on small field tests, fermented agricultural grains are readily accepted as food by mallards.

Sheldon, R. B. and C. W. Boylen. 1977. Maximum depth inhabited by aquatic vascular plants. Am. Midl. Nat. 97:248-254.

*In situ* observations of submerged, rooted aquatic plants by a diver equipped with SCUBA have shown that the maximum depth distribution of a number of submerged species in a clear freshwater lake (Lake George, New York) is greater than previously reported. Maximum depth for any species was 12 m for *Elodea canadensis.* Water clarity is sufficient to allow 10 per cent of the light intensity hitting the surface during mid-summer to penetrate to this depth. The number of submergent species drops linearly from 38 to 1 m to one at 12 m. Data are presented for the maximum depth of occurrence for 28 vascular macrophyte species, and population densities of these species at their preferred and maximum growth depths compared. The effect of several environmental parameters on depth inhabited by rooted aquatics is discussed.

Sheldon, R. B. and C. W. Boylen. 1975. Factors affecting the contribution by epiphytic algae to the primary productivity of an oligotrophic freshwater lake. Appl. Microbiol. 30:657-667.

A diatom-dominated population of epiphytic algae was studied in an oligotrophic lake to determine the factors which limit epiphyte growth and to measure their contribution to primary productivity. Algae were collected from plants growing at four sites in Lake George, NY during the spring, summer, and fall of 1974. Samples were taken from 3 m, corresponding to the depth at which macrophytes were most productive. Algae exhibited an optimum temperature for $H^{14}CO_3$ uptake at 30 °C, although the summer littoral lake temperature ranged from 18 to 25 °C. Light saturation occurred at an intensity of 8,608 lux, approximating the environmental intensity at the depth from which algae were taken. Epiphytes exhibited their maximum photosynthetic capacity of 0.6 mg of carbon fixed/$m^2$ of macrophyte surface area per h in the afternoon in mid-August. Epiphyte population densities followed the seasonal growth patterns of the macrophytes, with maximal leaf colonization remaining essentially constant relative to the leaf position on the plant. Productivities of epiphytes from bottom leaves were 10-fold greater than those of epiphytes from top leaves. Addition of $PO_4^{-3}$, $NO_3$, $NH_3$, Si, and $SO_4^{-2}$ had no stimulatory effect on photosynthesis. Addition of $HCO_3$ stimulated photosynthesis greater than 30 per cent, suggesting that carbon may be a limiting nutrient for epiphytic algae in Lake George.

Shiflet, T. N. 1963. Major ecological factors controlling plant communities in Louisiana marshes. J. Range Manage. 16:231-235.

Results of this study indicate that water depth and salinity exert major influences on plant composition on Louisiana marshland ranges. The author suggests that manipulation of these factors by use of pumps and levees can change plant composition to better fit the livestock enterprise. The giant-cutgrass community can be converted to longtom by lowering water level, preventing salt water intrusion, and mowing.

Simpson, R. L., D. F. Whigham, and R. Walker. 1978. Seasonal patterns of nutrient movement in a freshwater tidal marsh. Pages 243-257 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.). Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

Methods: Water samples were analyzed for DO using the azide modification of the Winkler method, $CO_2$ by titration, $NO_3-N$, $NO_2-N$, $NH_3-N$, $PO_4-P$ by Stickland and Parsons (1968) and total P following Menzel and Corwin (1965).

Results: Inorganic N and $PO_4-P$ were accumulated in the marsh during summer with emergent vegetation appearing to play an important role in the uptake and retention of nutrients. Most N and P is leached after death of vascular plants with up to 80 per cent of the total N and even more P lost within one month. It appears that habitats of freshwater tidal marshes may be sinks for inorganic N and $PO_4$—P during the vascular plant growing season and that certain habitats may continually function as sinks.

Smith, A. L. 1973. Life cycle of the marsh grass, *Scolochloa festucacea*. Can. J. Bot. 51:1661-1668.

This paper describes the life cycle of *Scolochloa festucacea*, a dominant species in potholes subjected to regular burning or mowing throughout the Drift Prairie and Missouri Couteu of the Northern Great Plains. Vernal growth is initiated at extremely low temperatures; some plants grow in water at the freezing point. Flowers develop in June if the pothole is inundated in the spring. Mature caryopses drop in July, but do not germinate until the next year. Tillers and new rhizomes are produced in August, followed by senescence in late September-early October.

Spence, D. H. N., R. M. Campbell, and J. Chrystal. 1971. Productivity of submerged freshwater macrophytes. Hidrobiologia (Buchar.) 12:169-176.

This paper is concerned with estimates of the biomass and rates of carbon fixation of submerged macrophytes and some of the factors which affect them. The contribution of submerged macrophytes in the productivity of a freshwater ecosystem can be estimated from a knowledge of their biomass and rates of carbon fixation. Results suggest that their rate of fixation of carbon may be limited by a lack of nutrients.

Spence, D. H. N. and J. Chrystal. 1970a. Photosynthesis and zonation of freshwater macrophytes. II. Adaptability of species to deep and shallow water. New Phytol. 69:217-227.

Comparison was made of the photosynthetic response of leaves produced in a glasshouse in unscreened (sun) and screened (shade) conditions, from two species rooted in significantly different depths of water; the shallow-water *Potamogeton polygonifolius*, a "sun" species of the deep-water and *P. obtusifolius*, a "shade" species. Their rates of net $O_2$ production at various irradiances and of $O_2$ uptake were estimated, and chlorophyll content (a + b), specific leaf area (SLA: $cm^2$ leaf area per mg leaf dry weight) and leaf thickness were measured.

From facts described in this paper, the authors conclude that a higher net photochemical capacity/unit area of shade leaves and shade species of *Potamogeton* in low irradiances (C. 1 per cent summer daylight) is achieved by lowered respiration rate/unit area which itself may result from reduction in leaf weight/unit area. The authors suggest that the limitation of net photosynthesis in shade species at higher irradiances is a function in a species like *P. obtusifolius* of its inability to reduce SLA, thicken its leaves and hence increase its capacity to absorb light.

Spence, D. H. N. and J. Chrystal. 1970b. Photosynthesis and zonation of freshwater macrophytes. I. Depth distribution and shade tolerance. New Phytol. 69:205-215.

The mean, range, and standard deviation are given of the depths of water above the soil surface in which a number of *Potamogeton* species occur in Scottish lochs. Sun leaves of these species were produced in unscreened containers in a glass-house and their rates of net $O_2$ production were measured at irradiances of from 1.34 to 7.08 cal/cm²/hour in a Warburg apparatus, using Warburg buffer no. 11 as bathing solution. Using only leaves of species of which the rates appeared to be unaffected by buffer solution during the short experiments, it was shown that the shade tolerance of these leaves was correlated with the natural depth distribution of the species. This valid contrast in inherent photosynthetic response between some deep water species (e.g., *P. praelongus, P. obtusifolius*) and some of shallow water (e.g., *P. polygonifolius*) indicates that light may be as important as substrate or competition in controlling the zonation of freshwater macrophytes.

Stalter, R. 1973. Factors influencing the distribution of vegetation of the Cooper River estuary. Castanea 38:18-24.

The marshes of the Cooper River Estuary were categorized as three units: salt marsh, brackish marsh, and freshwater marsh. The vegetation of these marshes was sampled by means of the line intercept method during July, 1971. A surveyor's transit was used to determine the evaluation range of each species above the species occupying the lowest portion of the marsh for 23 stations. Soil samples were taken and analyzed for chlorinity and salinity. Zonation of vegetation was most pronounced and distinct in salt marshes and less pronounced and less distinct in saline areas. Salinity limits the brackish and freshwater taxa from the more saline lower reaches of the river. Several taxa occupying the lowest zone of the three marshes were well adapted to long periods of submergence.

Stearns, F. W. 1978. Management potential: Summary and recommendations. Pages 357-363 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.). Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

Wetlands may be managed for a variety of reasons: (1) maintain water quality, (2) reduce erosion, (3) protect from floods, (4) provide an unsubsized system which can process airborne pollutants, (5) maintain gene pool of marsh plants and to provide examples of communities complete and capable of functioning as unsubsidized support systems, (6) provide aesthetic and psychological support for human beings, (7) produce wildlife, (8) control insect populations, (9) provide needs of fish for spawning and the production of food organisms, (10) provide food, fiber, and fodder, (11) expedite scientific inquiry. Management may assist in furthering knowledge of marshes.

Sampling vegetation and environments to provide data for management decisions can be greatly improved, especially with the introduction of system modeling and the use of conceptual models in communication of research results.

Stewart, R. E. and H. A. Kantrud. 1972. Vegetation of prairie potholes, North Dakota, in relation to quality of water and other environmental factors. U.S. Geol. Surv. Prof. paper 585-D.

Measurements of specific conductance provide an adequate indication of the average salinity of surface waters in natural ponds and lakes of the northern prairie region. The principal salts represented were sulfates and chlorides of sodium and magnesium. In less saline waters, carbonate and bicarbonate salts of calcium and potassium were of greater importance.

A major environmental factor controlling the establishment of marsh and aquatic vegetation is the permanence of surface water. Permanence is a measure of the extent to which surface water persists at a given site.

Salinity of surface waters was closely correlated with differences in species composition of plant communities found in the principal vegetational types. Land-use practices of varying degrees of intensity also had a secondary influence on species composition.

Characteristic species of wetland vegetational types occupied the central deeper parts of pond and lake basins or occurred as concentric peripheral bands.

Stuckey, R. L. 1971. Changes of vascular aquatic flowering plants during 70 years in Put-in-Bay Harbor, Lake Erie, Ohio. Ohio J. Sci. 71:321-342.

Based on a survey of 1898, 40 species of vascular aquatic flowering plants were reported for Put-in-Bay Harbor in western Lake Erie. Studies of this flora at various times since then have revealed a loss of species from this harbor to the extent that today 20 species of the original 40, or 50 per cent of the flora, have disappeared. Only three of the original 40 can be considered to be common or abundant today in the harbor. Possible reasons for these changes, such as increase in water temperature, decrease in oxygen, increase in turbidity, and man's influence on the harbor by dredging, building retaining walls, increasing use of motor boats, dumping of domestic sewage, and runoff from agricultural land are all considered as possible factors that have, independently and interrelatedly, in part or in total, been responsible for this 50 per cent loss in species composition. Species of turbid, warm, poorly oxygenated waters, whose distributions are primarily widespread and whose ecological tolerances are apparently wide, have survived.

Stuckey, R. L., J. R. Wehrmeister, and R. J. Bartolotta. 1978. Submersed aquatic vascular plants in ice-covered ponds of central Ohio. Rhodora 80:575-580.

This paper confirms the perennial growth habits of six species of submersed aquatic vascular plants as whole, intact leaf plants. Observations were made on these plants in small, shallow, man-made ponds during the severe winter of 1976-1977, when ambient air temperatures remained below freezing continuously from 28 December to 2 February. The species studied were *Najas guadalupenis, Potamogeton crispus, Ceratophyllum demersum, Elodea canadensis, Myriophyllum spicatum,* and *Ranunculus longirostris.* The plants had stems with cauline leaves and, with the exception of *Ceratophyllum demersum,* these leaves or leaf segments were smaller in width than usually occurs in the summer foliage.

Swanson, G. A. and P. F. Springer. 1972. Wigeongrass balls on alkali lakes. The Prairie Naturalist. 4:52-54.

The alkali lakes of North Dakota are the remnants of what were once fresh lakes formed during the stagnation and subsequent retreat of glaciers that covered most of the eastern and northern portions of the state. A high evaporation-precipitation ratio that eventually followed the glacial period, in conjunction with nonirrigated surface drainage, contributed to the formation of large, shallow, evaporation basins which concentrated dissolved salts that were supplied by surface runoff and groundwater.

Saltwater wigeongrass (*Ruppia maritima*) is one of the most salt-tolerant of the submerged aquatic plant species found in North Dakota and is also a common plant in inland lakes high in dissolved salts in other parts of the country. The rather stiff peduncles that support wigeongrass seeds are washed together and molded into round balls as they are rolled up and down the sand beach by wave action.

Szczepanski, A. 1977. Limiting factors and productivity of macrophytes. Folia Geobot. Phytotax. 12:1-7.

This paper summarizes the present state of knowledge on submerged and emergent macrophyte productivity as related to both natural and man-induced environmental factors. Particular attention is paid to the light and $CO_2$ regimes, mineral nutrient supply, and competitive relationships. All these factors are subject to marked changes with the present large-scale eutrophication of waters. Pronounced alterations in the structure of macrophyte vegetation over large areas represent a predictable outcome of these changes. The role of macrophytes in aquatic ecosystems, especially in temperate lakes, is also discussed.

Teal, J. M. 1962. Energy flow in the salt marsh ecosystem of Georgia. Ecology 43:614-624.

The producers, primarily *Spartina alternifolia,* are the most important consumers of energy, followed by the bacteria which degrade about 1/7 as much energy as the producers. The animals, both primary and secondary consumers, are a poor third, degrading only 1/7 as much energy as the bacteria.

The tides are of supreme importance in controlling the environment of the salt marshes. They limit the number of species that can occupy the system and so make it simple enough to be studied in the detail reported within this paper. They are responsible for the high production of *Spartina* as witnessed by the luxuriant growth along the tidal creeks as compared

with that on the short *Spartina* areas. At the same time the tides remove 45 per cent of the production before the marsh consumers have a chance to use it and in so doing permit the estuaries to support an abundance of animals.

Tilton, D. L. 1977. Seasonal growth and foliar nutrients of *Larix laricina* in three wetland ecosystems in Minnesota. Can. J. Bot. 55:1291-1298.

Levels of N, P, Ca, Mg, K, Al, Fe, Mn, and B were determined in foliage from tamarack (*Larix laricina* (DuRoi) K. Koch) in a bog, conifer swamp, and few from budbreak to leaf abscission. Elongation of needles and lateral shoots as well as dry and ash weight of needles were determined. Expansion of needles and shoots ceased at similar dates for all sites, but trees in the fen had significantly longer needles and lateral shoots.

On August 13, foliar concentrations of N, Ca, and Mg were higher in the fen than in the conifer swamp or bog, while concentrations of Al, Fe, An, Mn, and B were higher in the bog than the other two sites. Phosphorus concentrations in foliage were similar on this data in the fen and conifer swamp but were lower in the bog site. Despite significant between-site variation for certain foliar elements, two patterns of seasonal variation in nutrient concentrations were discerned. Significant between-site differences in the amounts and rates of needle and shoot elongation, foliar nutrient concentrations at a single sampling time, and patterns of certain foliar elements were associated with variations in nutrient status and moisture-aeration conditions of the study sites.

Titus, J. E. and M. S. Adams. 1979. Comparative carbohydrate storage and utilization patterns in the submersed macrophytes, *Myriophyllum spicatum* and *Vallisneria americana*. Am. Midl. Nat. 102:263-272.

A prolonged dormant period for *Vallisneria americana* is one of the conspicuous differences between it and *Myriophyllum spicatum*, another submersed macrophyte with which it co-occurs in the littoral zones of lakes of Madison, Wisconsin. To test the hypothesis that ample storage of total nonstructure carbohydrates (TNC) by *V. americana* could support a growth flush to compensate for its shorter growing season, plant tissues were collected over two annual cycles, and analyzed for TNC. Both species exhibited marked seasonal patterns in per cent TNC in above- and below-sediment plant parts. Mean TNC values in *M. spicatum* tissues ranged from 1.6-19.0 per cent for roots and 2.0-20.0 per cent for shoots. The low values were associated with the spring growth flush. Analysis of variance revealed significant differences in these TNC storage and utilization patterns for roots and shoots, plants collected at different sites and plants collected at different times. *Vallisneria americana* tissues ranged from 4 per cent to 28 per cent TNC during the growing season, while winter bud TNC values were ca. 45 per cent. By virtue of low winter biomass, however, the total reserves in the *Vallisneria* community were inadequate to permit compensation for a late start in the spring, prompting us to reject our hypothesis.

Titus, J. E., R. A. Goldstein, M. S. Adams, J. B. Mankin, R. V. O'Neill, P. R. Wirler, H. H. S. Lingart, and R. S. Booth. 1975. A production model for *Myriophyllum spicatum* L. Ecology 56:1129-1138.

The mathematical model WEED was derived to study the productivity of the submerged macrophyte *Myriophyllum spicatum* in the littoral of Lake Wingra, Madison, Wisconsin. The model coordinates four biomass compartments with selected physiological processes evaluated for a stratified meter-squared water column. Light and temperature are the primary environmental forcing functions. The model considers growth form (depth distribution of biomass), total biomass/meter-squared, the depth profile of photosynthesis and macrophyte contributions to dissolved and particulate organic matter pools in the water column.

The model output was tested against field data for seasonal patterns of standing crop, depth distribution of biomass and depth profile of photosynthesis for a rooting depth of 150 cm. WEED has permitted the simulation of macrophyte growth response to changes in environmental conditions and has outlined areas of needed research.

Toetz, D. W. 1974. Uptake and translocation of ammonia by freshwater hydrophytes. Ecology 55:199-201.

The roots of two species of freshwater hydrophytes (*Elodea densa* and *Scirpus* sp.) are capable of absorbing $^{15}NH_4$ and translocating labeled N to apical tissues under laboratory conditions.

Turner, R. E. 1976. Geographic variation in salt marsh macrophyte production: a review. Contrib. Mar. Sci. 20:47-68.

A review of salt marsh macrophyte production measurements supports the conclusion of a north-south gradient parallels solar energy inputs at a 0.20-0.35% net conversion efficiency. There is considerable variation within and among marshes. Methods previously employed to measure salt marsh macrophyte production have generally underestimated the actual net aboveground production because of an inability to account for the turnover of live material between sampling periods. Turnover apparently increases with decreasing latitude and may be equal to annual changes in standing live biomass. The effect of other factors influencing production are discussed and a detailed review presented.

Valiela, I. and J. M. Teal. 1978. Nutrient dynamics: summary and recommendations. Pages 259-263 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

To solve problems of nutrient inputs and outputs, one needs increased emphasis on hydrology. Investigators must obtain precipitation data as well as data on flow rates of both surface and groundwater. Once flow rates are known and nutrient concentrations are determined, it will be possible to calculate inputs and outputs.

Microbial activity is particularly important when considering N and S. Rates of N fixation should be measured because both blue-green algae and bacteria associated with roots of aquatic plants can be significant contributors to the N budgets of a wetland.

To understand internal cycling, it is necessary to measure rates of nutrient exchange. One needs measurements of gross uptake rates of nutrients by plants and microorganisms.

A third area that seems neglected is the role of animals in nutrient cycling. Muskrats, mice, snails, amphipods, midges, and other insects are abundant and may be involved in the production of particulate matter and maintaining the stability of sediments. Excretion of $NH_4$ by animals must influence nutrients in water.

Finally, need experiments to understand limits and thresholds of nutrients.

Valiela, I., J. M. Teal, and N. Y. Persson. 1976. Production and dynamics of experimentally enriched salt marsh vegetation: belowground biomass. Limnol. Oceanogr. 21:245-252.

Root growth increased during the early growing season in *Spartina alterniflora* salt marsh plots. While fertilization with nitrogenous fertilizer did not affect initial growth, a marked decrease in root biomass followed the spring peak, particularly where nutrient doses were highest. A sharp reduction in roots occurred in enriched areas covered by *Spartina patens,* although, as with *S. alterniflora,* aboveground biomass increased. Roots disappeared during autumn, leaving rhizomes as the only part of the plants to overwinter. The maximum standing crop for roots was 0-2 cm deep, for rhizomes 2-5 cm. Net annual underground production was calculated from annual increments in dead matter belowground. Total production, underground, and aboveground, exceeds that of any marine vegetation, ranging from 3,900 to 6,600 g/m²/year in *S. alterniflora* areas and 3,200 to 6,200 g/m²/year in *S. patens* areas. Fertilization increased production particularly aboveground where dead plant parts are subject to export.

Valiela, I., J. M. Teal, and W. Sass. 1975. Production and dynamics of salt marsh vegetation and the effect of experimental treatment with sewage sludge. I. Biomass, production, and species composition. J. Applied Ecol. 12:973-981.

Fertilization with a 10-6-4 sewage sludge fertilizer increased the total peak standing crops of salt marsh vegetation, in spite of the presence of considerable amounts of heavy metals and chlorinated hydrocarbons in the sludge. The increases in biomass over a three-year period are believed to be due to the nitrogen additions. *Spartina alterniflora,* which was the dominant species in low marsh areas, progressively excluded *Salicornia* spp. from the fertilized plots. In high marsh areas, fertilization initially increased the standing crop of *Distichlis spicata* but was later replaced by *Spartina patens.*

The production achieved by the most heavily fertilized plots are among the highest recorded for marsh plants (1.32 kg/m²). Fertilization treatments have converted low marsh vegetation, consisting mainly of dwarf form *S. alternifolia,* into a sward approaching the biomass and morphology of tall form. The authors conclude the so-called "forms" are a response to nitrogen supply.

Van, T. K., W. T. Haller, and G. Bowes. 1976. Comparison of the photosynthetic characteristics of three submersed aquatic plants. Plant Physiol. 58:761-768.

Light- and $CO_2$-saturated photosynthetic rates of the submersed aquatic plants *Hydrilla verticillata, Ceratophyllum demersum,* and *Myriophyllum spicatum* were 50 to 60 *u*mol $O_2$/mg Chl: hr. at 30 °C. At air levels of $CO_2$, the rates were less than 5 per cent of those achieved by terrestrial $C_3$ plants. The low photosynthetic rates correlated with low activities of the carboxylation enzymes. In each species, ribulose, 1,5-diphosphate carboxylase was the predominant carboxylation enzyme. Optimum temperatures for the photosynthesis of *Hydrilla, Myriophyllum,* and *Ceratophyllum* were 36.5°, 35.0°, and 28.5° C, respectively.

*Hydrilla* and *Ceratophyllum* had $CO_2$ compensation points of 44 and 41 *ul*/l, respectively, whereas the value for *Myriophyllum* was 19. Relatively high $CO_2$ compensation points under 1 per cent $O_2$ indicated that some "dark" respiration occurred in the light. The inhibition of photosynthesis by $O_2$ was less than with terrestrial $C_3$ plants.

Field measurements in a *Hydrilla* mat indicated that in the afternoon, free $CO_2$ dropped to zero, and $O_2$ rose to over 200 per cent air saturation. The low light requirement of *Hydrilla* probably provides a competitive advantage under these field conditions.

Van der Valk, A. G. 1975. Floristic composition and structure of fen communities in northwest Iowa. Proc. Iowa. Acad. Sci. 82:113-118.

Iowa fens have three distinct, concentric vegetation zones: a border zone, a sedge mat zone, and a discharge zone where ground water supplying the fens comes to the surface. *Calamagrostis inexpansa, Viola nephrophylla, Scirpus americanus* and *Carex* spp. are the dominants in the border zone. The composition of this zone is quite variable both within and between the fens. The sedge mat is composed primarily of *Rhynchospora capillacea.* Other species normally found in this zone are *Lobelia kalmii, Muhlenbergia racemosa, Parnassia glauca, Triglochin maritima* and *Scirpus americanus.* Although all of the species in this zone are also found in the other zones, this zone is readily distinguishable because of the low stature of the vegetation. The discharge zone is dominated usually by *Carex* spp. of *Calamagrostis inexpansa,* except at one fen where *Phragmites communis* and *Helianthus grosseserratus* are the dominants. The sedge mat zone on the average has fewer species per quadrat (5.8 versus 6.0 and 8.6), lower Shanon-Weiner Index (0.58 versus 0.42 and 0.32) than the discharge and border zones, respectively.

Van der Valk, A. G. and L. C. Bliss. 1971. Hydrarch succession and net primary production of oxbow lakes in central Alberta. Can. J. Bot. 49:1177-1199.

The plant communities in a series of 15 oxbow lakes were examined to determine their successional sequence and productivity. Twelve communities were recognized as a result of analyses carried out on the phytosociological data. Water chemistry and water level fluctuations caused by periodic flooding are the major factors controlling plant distribution and succession.

The maximum aboveground standing crop of communities followed a definite pattern with succession: from submerged (ca. 200/g/m$^2$), through floating-leaved (ca. 210 g/m$^2$), to the emergent community (ca. 465 g/m$^2$). There is a stepwise increase in annual production, which declines in the meadow community (ca. 325 g/m$^2$).

Leaf area index (LAI) does not change with succession: it remains between three and four in all the stages examined. Chlorophyll follows a pattern similar to standing crop, except that submerged communities contain more chlorophyll than floating-leaved: submerged (0.24-0.92 g/m$^2$), floating-leaved (0.29-0.80 g/m$^2$), emergents (0.62-2.13 g/m$^2$), and meadow (0.54-1.42 g/m$^2$).

Van der Valk, A. G. and C. B. Davis. 1978a. The role of seed banks in the vegetation dynamics of prairie glacial marshes. Ecology 59:322-335.

The authors examined the seed banks and vegetation of two marshes in north-central Iowa. Objectives were: (1) to assess the size and species composition of the seed banks within and among different existing vegetation in a prairie marsh, (2) to examine the fate of seedlings produced by seeds that had germinated during a drawdown, normal water levels and predrawdown levels, (3) to elucidate the role and significance of seed banks in the vegetation cycle of prairie marshes.

Three types of species were present in these seed banks: emergent species (e.g., *Typha, Scirpus*) which germinate on mud flats, submersed and free-floating species (e.g., *Lemna, Spirodela*) whose dormant seeds/turions can survive on exposed flats for a year, and mud-flat species (*Bidens, Cyperus*) which are ephemeral whose seeds can only germinate on exposed mud flats during periods of no standing water.

Van der Valk, A. G. and C. B. Davis. 1978b. Primary production of prairie glacial marshes. Pages 21-37 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.), Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

Methods: Eagle Lake: stratified random sampling scheme. All samples harvested in 1975 and 1976. At each sampling point a 1 X 1 m quadrat was clipped at ground level and sorted by species. These samples were oven dried at 80 °C. In 1975, 350 quadrats were harvested and in 1976, 322 quadrats.

Belowground biomass samples were collected by using 50 X 50 cm quadrats. All the soil in the root and rhizome zone was removed from the quadrats. In the lab, the samples were washed free of soil, and dead and live material was separated on the basis of appearance.

Maximum standing crop can equal net primary production only if the maximum shoot density and average maximum shoot weight occurred simultaneously. If they are out of synchrony, then the maximum standing crop will always underestimate net primary production.

Van der Valk, A. G. and C. B. Davis. 1976. Changes in composition, structure, and production of plant communities along a perturbed wetland coenocline. Vegetatio 32:87-96.

Comparisons of a wetland coeconocline before and after a drought-caused drawdown and the refilling of the basin to a higher-than-normal water level revealed that there was little difference in the aboveground standing crop or in the floristic composition of the submersed, emergent, or meadow zones along the coenocline. However, the position of many species along the coenocline shifted in response to these perturbations. *Sagittaria latifolia, Carex* spp., *Potamogeton* sp. *aff. pusillus* all were found two to four m closer to shore. *Glyceria grandis* is normally found only in the meadow zone; but after the drawdown, it was found along the whole length of the coenocline. The drawdown also nearly eliminated *Ceratophyllum demersum* from the coenocline. Species richness as a result of these perturbations increased in the submersed (3.3 to 5.9) and emergent (3.6 to 4.3) zones, but decreased in the meadow zone (7.6 to 6.0). The Simpson's index in all three zones was not appreciably influenced by the perturbations. The average Simpson's indices for the meadow, emergent and submersed zones were 0.4, 0.7, and 0.5 respectively.

Vollenweider, R. A. (ed.). 1969. A manual on methods measuring primary production in aquatic environments. IBP Handbook No. 12, Blackwell Scientific Publications, Ltd., Oxford.

The basic idea behind this text was to produce a simple outline of techniques already established for primary productivity studies. Much emphasis has been given to a critical review of techniques, rather than to a set of standard procedures to be used in all situations. Primary production studies are concerned with (a) the evaluation of the capacity of an ecosystem to build up, at the expense of external energy, both radiant and chemical, primary organic compounds of high chemical potentials for further transformation and flow to higher system levels; (b) the composition, properties, and fate of the structural elements of the system which act as carriers of the primary production process.

Walker, B. H. and R. T. Coupland. 1970. Herbaceous wetland vegetation in the aspen grove grassland regions of Saskatchewan. Can. J. Bot. 48:1861-1878.

Wetland vegetation in an aspen grove and grassland regions of Sakatchewan was examined with respect to vegetation types and environmental control of species distribution. Species frequency and presence and a number of environmental gradients were measured in 246 stands. Association analysis of the vegetation data resulted in 27 vegetation groups, distinct on the basis of species present. Owing to overriding effects of disturbance, nine of these groups show close similarities to one or more of the others on the basis of dominant species. Water regime, salinity, and disturbance are the three major gradients influencing species distribution. Combinations of these three gradients comprise 23 environmental categories into which the vegetation groups fall. The occurrence of different vegetation groups in the same habitat type is due partly to environmental factors other than those considered in this study and partly to succession.

Walker, B. H. and R. T. Coupland. 1968. An analysis of vegetation-environment relationships in Saskatchewan sloughs. Can. J. Bot. 46:509-522.

This study examined the relationships between the distribution of herbaceous species and some of the major environmental factors in sloughs. Frequency distribution of species was studied in 64 stands. Environmental data, collected in 40 of these, included weekly readings of water level, fort-nightly readings of pH and total dissolved solids in water, and texture and organic matter content of topsoil and subsoil. The soil data showed very little association with species distribution. Plotting the frequency distribution of the leading dominant species over the environmental arrangement of stands showed most of the species to be strongly affected by the water regime and somewhat less affected by salinity. A few were restricted to a very narrow range of one of these factors, while others flourished in all segments of the environment. The relationships suggested by this analysis are largely in agreement with those suggested by the vegetation analysis alone.

Walker, B. H. and C. F. Wehrhahn. 1971. Relationships between derived vegetation gradients and measured environmental variables in Saskatchewan wetlands. Ecology 52:85-95.

Thirty-four relatively undisturbed stands of vegetation in shallow marsh, non- to slightly saline wetlands in south-central Saskatchewan were examined with respect to environmental influence on species distribution. Four environmental gradients account for the bulk of variation in the vegetation. They are, in decreasing order of importance, disturbance (despite the fact that all stands are relatively undisturbed), available nutrients, water regime, and salinity. The greatest variation in the data from these stands as a whole is in their salinity, but this is not reflected in the vegetation. The correlation between water regime and available nutrients is negative. The method of application of principal components analysis used in this study is a valuable aid in the interpretation of data. It provides estimates of the proportions of (1) the variance associated with each principal component and (2) the total variation in the vegetation data that can be assigned to variation in the environmental measurements.

Walsh, G. F. 1971. Energy budgets of four ponds in northwestern Florida. Ecology 52:298-304.

The annual energy budgets of four small ponds in northwestern Florida were calculated from the amounts of 1) solar radiation, 2) atmospheric long-wave radiation, 3) back radiation, 4) evaporative energy, 5) conducted energy, and 6) sensible heat which entered or was lost from the water. Long-wave radiation constituted between 62.1 and 63.9% of the total incoming radiative energy and 80.8 to 85.0% of the total energy loss. Evaporative loss was between 14.6 and 18.3% of the total. Between 370,498 and 631,970 kcal/m$^2$/yr were stored. Atmospheric radiation counteracts a portion of the radiative loss from water, thus reducing loss of stored solar energy.

Ward, R. L. 1970. Distribution of the *Scirpus validus* complex in North Dakota. The Prairie Naturalist 2:63-64.

This paper is a brief synopsis of the taxonomic treatment of the *Scirpus validus* complex in North Dakota. Based on the collections of the author in 1967, 1968, and 1969, he concludes that probably *Scirpus validus* occurs in every county in North Dakota. *Scirpus acutus* was identified for all but 12 counties, and *Scirpus heterochaetus* was collected in 10 counties. *S. heterochaetus* was most often found in water ranging from 3 to 8 feet in depth.

Weber, J. A. and L. D. Nooden. 1976. Environmental and hormonal control of turion germination in *Myriophyllum verticillatum*. Am. J. Bot. 63:936-944.

Germination, or outgrowth, of *Myriophyllum verticillatum* turions involves a series of visible changes starting with reflexing of leaves followed by extension and curving of the axis, and then by root formation. Before abcission, turions grow out in response to long days (16 hour) but not short days (8 hour). After abcission, turions show maximal dormancy which can be fully broken by a cold treatment (4 °C). Turions are heterogenous in degree of dormancy and ability to respond to less complete dormancy-breaking treatments, e.g., long days at 20 °C. Cytokinins ($10^{-6}$ M) break dormancy of noncold-treated turions whereas gibberilic acid ($GA_3$) is ineffective except at high concentrations ($10^{-3}$M). Continuous treatment with cytokinins causes abnormal development after germination. $GA_3$, on the other hand, induces apparently normal development even at high concentration. Indoleacetic acid (IAA) induces outgrowth only at high concentrations ($10^{-3}$ - $10^{-4}$ M), but these concentrations also produce abnormal development. Abscisic acid (ABA, $10^{-5}$ M) retards outgrowth of cold-treated turions and can completely suppress it in noncold-treated turions. The activity of ABA-like substances in turions remains about the same before and during germination, whereas other (unidentified) acidic inhibitors decrease markedly. The cytokinin activity changes in a complex pattern.

Weselow, D. V. and R. T. Brown. 1971. Plant distribution within a heron rookery. Am. Midl. Nat. 86:57-64.

An island rookery of approximately 8000 Ardeidaean birds in west-central Minnesota was mapped and divided into three areas of use: heavy, light, and none. Quadrats, 1m on a side, were used to sample these three areas for floristic composition, soil nutrients, and pH, light regime and great blue heron nest composition.

The results support previous work on oceanic rookeries showing a reduction in plant density in areas of high avian activity. The distribution of 21 plant species discussed, with relation to the three areas of activity, is limited neither by the summer light intensity nor the concentration of nutrients measured during the winter.

Wetzel, R. G. and D. L. McGregor. 1968. Axenic culture and nutritional studies of aquatic macrophytes. Am. Midl. Nat. 80:52-64.

Studies were undertaken on nutritional factors regulating growth of aquatic macrophytes in calcareous lakes.

Rates of germination of *Najas flexilis* were inhibited by low light intensities and were increased markedly by exposure to mild heat treatments in darkness. Light quality, intensity, and duration have significant effects on the germination of *Chara*. Low light intensities in the visible spectral range provide more favorable conditions for germination.

Germination of *Najas* was similar in both aerated liquid media and in agar of low redox gradients. Indirect evidence of chemoorganotrophic growth by *Chara* in the absence of light was found in the early stages of growth following germination.

Rates of photosynthesis of axenic hydrophytes under varying nutrient concentrations were determined by rates of $^{14}C$ bicarbonate uptake and radioassay of organic carbon in gas-phase. Photosynthetic rates of *Najas flexilis* were greatly reduced by $Ca^{++}$ levels about 20 mg/l. Vitamin B-12 but not other water soluble vitamins stimulated growth of *Najas*. Similar photosynthetic responses have been found among phytoplanktonic algae of marl lakes.

Whigham, D. F., J. McCormick, R. E. Good, and R. L. Simpson. 1978. Biomass and primary production in freshwater tidal wetlands of the middle Atlantic Coast. Pages 3-20 *in* R. E. Good, D. F. Whigham, and R. L. Simpson (eds.). Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

Methods: In freshwater tidal wetlands, obtaining estimates of actual net production is difficult because of phenological changes in the wetland communities, heterogeneity in community composition, and the difficulty in obtaining estimates of leaf mortality, plant mortality, and belowground production.

Measurement of peak aboveground standing crop was not a good estimator of annual production. Peak aboveground standing crop must be viewed as only a rough estimate of a single parameter, aboveground production.

Suggest that investigators use multiple harvest techniques when measuring primary production within freshwater tidal wetlands. Future studies should include estimates of belowground biomass, leaf mortality and herbivory.

Whigham, D. F. and R. L. Simpson. 1978. The relationship between aboveground and belowground biomass of freshwater tidal wetland macrophytes. Aquat. Bot. 5:355-364.

Aboveground and belowground biomass relationships of 15 annual and perennial freshwater tidal wetland macrophytes were examined. The data showed that regression equations may be used with confidence to estimate belowground biomass from aboveground biomass for most species. The linear regression model was suitable except for one species which had a large belowground component and for which the exponential model was more appropriate. Belowground:aboveground biomass ratios were significantly different for the eight annual species examined. At peak biomass, all annuals allocated less than one-third of the total net annual production into belowground structures. They exhibited distinct seasonal patterns of biomass allocation with more biomass incorporated into belowground components during the early part of the growing season. Perennial species exhibited four patterns of biomass allocation with *Peltandra virginica* (L.) Kunth having a significantly greater mean belowground:aboveground biomass ratio than other perennials. Factors that may control allocation patterns include depth of rooting and life history strategies.

Whigham, D. and R. Simpson. 1977. Growth, mortality, and biomass partitioning in freshwater tidal wetland populations of wild rice (*Zizania aquatica* var. *aquatica*). Bull. Torrey. Bot. Club 104:347-351.

Wild rice is a common annual in Delaware River tidal wetlands. Net production was as high as 20.9 g/m$^2$/day and varied seasonally. The lowest production rates occurred during the seedling phenophase and the highest followed seedling establishment. On a percentage basis, more biomass was allocated into root production during the seedling phenophase. Population mortality was constant between May and early August.

White, D. A., T. E. Weiss, J. M. Trapani, and L. B. Thien. 1978. Productivity and decomposition of the dominant salt marsh plants in Louisiana. Ecology 59:751-759.

Net primary production and decomposition of the four dominant salt marsh plants found in Louisiana were determined. Live and dead standing crops were calculated by the harvest method over an annual cycle. Litterbags were used to estimate loss rates of vegetation from the marsh. Peak standing crops were: 1164 $g/m^2$ for *Distichlis spicata*, 2194 $g/m^2$ for *Spartina patens*, 1959 $g/m^2$ for *Juncus roemerianus*, and 1473 $g/m^2$ for *Spartina alterniflora*. It is estimated that these four species of Louisiana marshland plants produce 146 X $10^6$ metric tons/year of plant material. This accounts for approximately one-half of 17,050 $km^2$ of marshes in the states. In general, production was higher for this Louisiana marsh than reported in Atlantic Coast marshes. Also, decomposition rates were considerably higher. *Spartina alterniflora* decomposed most rapidly with 100 per cent removal in seven months: 24 per cent/year for *D. spicata*, 36 per cent/year for *S. patens*, and 20 per cent/year for *J. roemerianus*. In addition, a belowground standing crop analysis was undertaken on new *S. alterniflora* roots.

White, J. and J. L. Harper. 1970. Correlated changes in plant size and number in plant populations. J. Ecol. 58:467-485.

The 3/2 power law which relates the number of surviving plants in a population undergoing self-thinning to their mean dry weight has been confirmed in this study and extended to several species. Root and shoot components of plant yield appear to follow the same law. Stands of the same species starting growth simultaneously at different densities are shown to follow a common thinning line, the stands of highest density thinning first.

A possible alternative derivation of the law is recorded based on distance to nearest neighbor measurements. The assumption sometimes made that the smallest plants in a population are the first to thin, leaving the larger ones to grow more rapidly, is shown to be valid, by measurements of individual plant weight over a series of harvests.

Williams, G. 1970. Investigations in the white waterlilies (Nymphaea) of Michigan. Mich. Bot. 9:72-86.

Taxonomic problems associated with the separation of *Nymphaea odorata* Ait. and *N. tuberosa* are discussed for lakes in Michigan. Good review.

Williams, R. B. and M. B. Murdock. 1972. Compartmental analysis of the production of *Juncus roemerianus* in a North Carolina salt marsh. Chesapeake Sci. 13:69-79.

Data obtained near Cape Lookout, North Carolina, during 1965 to 1968 on standing crop, growth rate, and longevity of aboveground portions of needlerush, *Juncus roemerianus*, were synthesized into a three-compartment linear mathematical model. Analysis of field observations yielded average standing crops for live, dying, and dead *Juncus* of 344, 504, and 1,604 g dry wt. $m^{-2}$. The model, defined by equations in this article, duplicated the average standing crops and annual production and yielded seasonal cycles in the standing crops of the three compartments which explained much of the variation observed in these during the field work.

# Author Index for Bibliography