FORM NTIS-79
REV 11-81)

U.S. DEPT. OF COMM
NAT. TECH. INF. SERV.

ACCESSION NOTICE

1. NTIS Accession No. *Allow 3 weeks for ordering*

Use when ordering or referring with prices

2. Date sent: 7/26/83

3. Report No.: A-044-MINN (1)

Title *(One per card)*: THE EFFECTS OF AGRICULTURAL RUNOFF UPON NATURAL WETLAND ECOSYSTEMS

Van Amburg, G. L.

4. Source Client Code	5. Procedure No. *(If assigned)*	6. No. copies sent
DIOWRT		

7. CONTACT Name-Number Regarding:	This Report	Planned Press Release
		0

8. NTIS DOMESTIC PRICE CODES AND CURRENT $ VALUES

PAPER COPY		MICROFICHE		COMPUTER PRODUCT	
A03	$ 8.50	A01	$ 4.50		$

INSTRUCTIONS:

1. Address card to those needing accession number and price.
2. Fill in boxes 2, 3, 4, 5 (if required), 6 and 7.
3. Staple card to front top cover of document and mail to Information Services Branch, NTIS
4. Please send 11 acceptable copies for stock to fill immediate orders and for consideration of the waiving of the registration cost.
5. NTIS will fill in boxes 1 and 8 and mail to addressee.

COMPLETION REPORT

TITLE: THE EFFECTS OF AGRICULTURAL RUNOFF UPON NATURAL WETLAND ECOSYSTEMS[1]

GRANT NO: USDI 14-34-0001-2125, A-044

PRINCIPAL INVESTIGATOR: GERALD L. VANAMBURG
BIOLOGY DEPARTMENT
CONCORDIA COLLEGE
MOORHEAD, MN 56560

September, 1983

[1]The work upon which this publication is based was supported in part by funds provided by the United States Department of the Interior as authorized under the Water Research and Development Act of 1978, P.L. 95-467.

INTRODUCTION

Wetlands are considered as an important natural resource. Over the years total wetlands area has been reduced significantly, usually by being drained and converted to another use. Inland wetlands have most often been drained and put into agricultural production (Diedrick, 1981). If not drained, inland wetlands are often considered as wastelands. However, more recently evidence has been presented to show that wetlands do provide products and services and do have real economic values (Gosselink, Odum and Pope, 1974; Jaworski et. al., 1977).

Few studies have been concerned with the interaction of the compartments of wetland ecosystems. The entire system has been treated as a black-box, with observations of inputs and outputs. Other studies have dealt with only one or two compartments of the system. It is the purpose of this research to study the major ecosystem compartments simultaneously. Such research should help to clarify how wetlands function internally.

STUDY SITES

The two small marshes chosen for this study are located in western Minnesota. One site is located in Ottertail County, Minnesota near Fergus Falls (Sec. 1 & 2, T232N. R44W) and the other in Clay County, Minnesota near Rollag (NE¼ Sec. 29, T238N, R44W). This area is located within the glaciated prairie region of the Central Lowland province. It is characterized by numerous undrained depressions resulting in a landscape dotted with prairie "pothole" wetlands of various sizes and types.

The climate of western Minnesota is typically continental. The coldest month is January, with a mean temperature of 6° to 8°F. The warmest month is July, with a mean temperature of about 71°F. The average annual temperature is 41°F to 42°F. The average frost free period is approximately 135 days. Precipitation averages increase rather abruptly moving from west to east in the region. The study sites are located within an area where the average annual precipitation varies from 19.6 in. to 24.6 in. Over 75 percent of the precipitation occurs during the growing season, from April through September. Precipitation and mean temperatures for 1981 and 1982 and the 30 year normals are given in Table 1. and 2.

The watersheds of both wetlands are small, well defined cultivated uplands. The principal crops are small grains, corn, soybeans and sunflowers. Both wetlands receive surface runoff from the watersheds. However, the Ottertail County marsh also receives inflows from a tile system which drains a part of the watershed to the west and east.

Both wetlands are classified as palustrine systems with an emergent wetland class outer zone and a central aquatic bed class (Cowardin et.al. 1979). A more complete classification and an outline map of the wetlands is given in Figures 1 and 2. Based on the classification system of

Table 1. Climatic data for the Clay County wetland. The nearest reporting station (Hawley, Minnesota) was used for mean temperatures. Detroit Lakes, Minnesota was used for the 30 year normals. Precipitation for 1981, 1982 was measured on site.

	1981		1982		30 year Normal	
	Precipitation	$\bar{x}$Temperature	Precipitation	$\bar{x}$Temperature	Precipitation	$\bar{x}$Temperature
January	0.22	11.4	1.12	-7.1	.61	4.7
February	0.48	17.5	.55	8.4	.50	8.8
March	1.14	34.5	1.61	22.9	.90	22.1
April	1.09	45.9	1.11	38.1	1.46	40.4
May	0.32	55.7	2.49	58.0	2.57	52.7
June	2.62	62.7	2.50	58.7	4.17	62.8
July	5.75	71.0	0.96	69.8	3.10	68.2
August	7.11	69.5	1.36	67.5	3.21	66.7
September	1.60	56.6	1.53	55.9	2.31	55.8
October	3.43	42.9	3.07	46.0	1.21	45.7
November	0.39	36.0	0.46	24.6	0.81	27.6
December	0.59	10.7	0.41	20.1	0.62	12.1
Annual		42.9		38.6	23.94	39.0

Table 2. Climatic data for the Otter Tail County wetland. The nearest reporting station was Fergus Falls, Minnesota (about 1 mi.) was used for all data.

	1981		1982		30 year Normal	
	Precipitation in.	Temperature °F	Precipitation in.	Temperature °F	Precipitation in.	Temperature °F
January	0.12	12.2	.54	-6.7	.77	8.2
February	0.80	19.5	.51	8.5	.60	13.4
March	0.32	33.7	1.10	23.8	1.12	26.3
April	1.38	45.7	0.61	39.4	2.60	43.5
May	0.83	55.3	2.69	58.3	2.99	56.1
June	3.53	62.7	2.40	59.8	4.68	65.7
July	5.58	70.1	2.86	70.6	3.32	71.2
August	3.14	68.1	4.10	68.4	3.05	69.9
September	0.56	57.1	2.08	56.8	2.24	59.0
October	2.69	43.7	3.95	45.4	1.42	48.2
November	0.48	36.5	0.48	25.4	0.87	29.8
December	0.30	11.6	0.26	21.0	0.90	15.1
Annual	19.73	43.0	21.58	39.2	24.56	42.2

Stewart and Kantrud (1971) the wetlands would be semipermanent ponds, slightly brackish, cover type 3 (IV-B-3). According to Shaw and Fredine (1956) both sites would be classed as Type 4 - inland deep fresh marshes.

METHODS

The wetland systems were subdivided into major compartments. Such a subdivision allows one to study each compartment separately and learn more about the interactions between the compartments. Major compartments studied were: watershed soil, watershed runoff, wetland emergent macrophytes, wetland submergent plants, wetland water and wetland sediments. The compartments were rigously sampled during the 1981 and 1982 growing seasons. The wetland emergent macrophyte and soil compartments were studied only during 1981, while the submergent plants were studied only in 1982.

Soils Compartment

Soils of the watersheds were sampled on a biweekly basis during the 1981 growing season. Cores of the upper six inches were systematically taken to include topographic and soil type variations. The samples were oven-dried at 100°C and ground to pass a 0.25 mm sieve. Ammonium and nitrate + nitrite nitrogen concentrations were determined by the MgO-Devarda alloy steam-distillation procedure (Bremner, 1965). Soil phosphorus was extracted by using 0.5N sodium bicarbonate, and analyzed by the chlorostannous-reduced molybdophosphoric blue color method in a hydrochloric acid system (Olsen et. al., 1054). Total soil nitrogen was determined by the semi micro-Kjeldahl method (Bremner, 1965), and expressed as percent nitrogen. Potassium was extracted with 1N ammonium acetate, and anlyzed by flame photometry.

Watershed Runoff

Surface runoff water was collected from the Clay County wetland watershed at three locations where drainage waters entered the basin. Small catchment devices were constructed from plastic wading pools and placed in low areas where surface runoff entered the wetland basin. A hole was drilled into the lower part of the catchment where a hose was attached leading to a five gallon reservoir container. Runoff water was taken for analysis from the container after each significant runoff event. Runoff samples were filtered and analyzed for conductivity, pH, ammonia, nitrate nitrogen, nitrite nitrogen, total phosphorus, orthophosphate and potassium. Conductivity was measured with a YSI model 33 conductivity meter. The pH was measured by the glass electrode method. Ammonia was analyzed for by the Nessler method,nitrate by the cadmium reduction method and nitrite by diazotization (APHA, 1975). Total phosphorus was determined by persulfate digestion of the sample followed by the colorimetric ascorbic acid method. Orthorposphate was determined directly using the ascorbic acid method (APHA, 1975). Potassium was analyzed for byflame photometry.

Emergent macrophytes

The emergent wetland zone at both study sites (Figs. 1 and 2) was studied during the 1981 growing season. The emergent zone consisted of almost pure stands of *Typha latifolia*, *T. angustifolia* and *T. glauca*. No other species were encountered in the sample plots except in minute quantities. Three 50 x 50 cm quadrats were harvested at biweekly intervals throughout the growing season in represenative *Typha* stands. Above and below ground biomass was harvested. The roots and rhizomes were removed from the quadrat area by cutting around the quadrat perimeter with

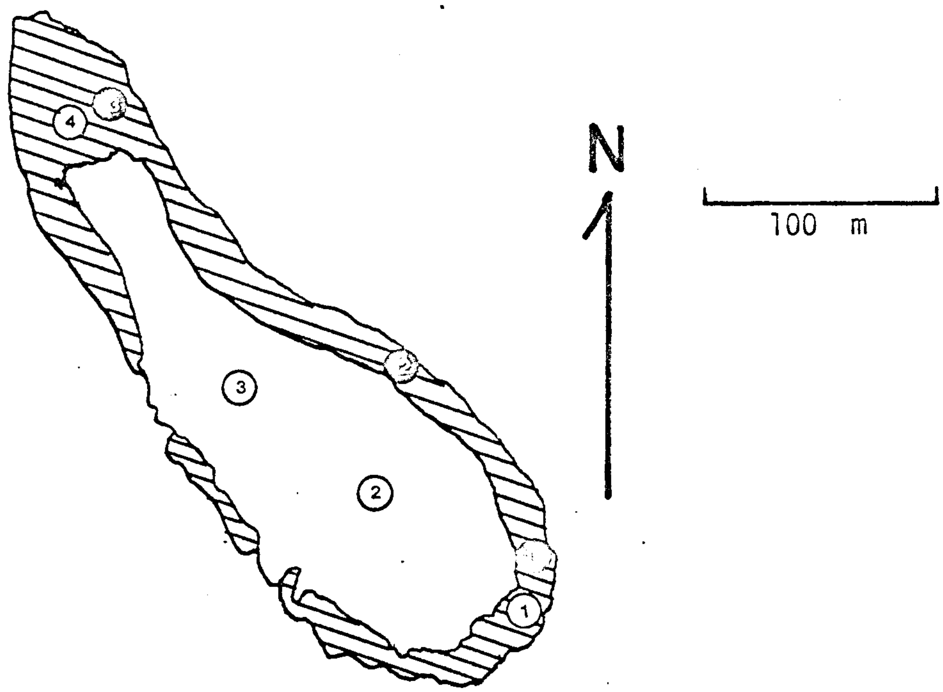


Fig. 1. Outline map of the Clay county wetland. The numbers identify sampling locations.

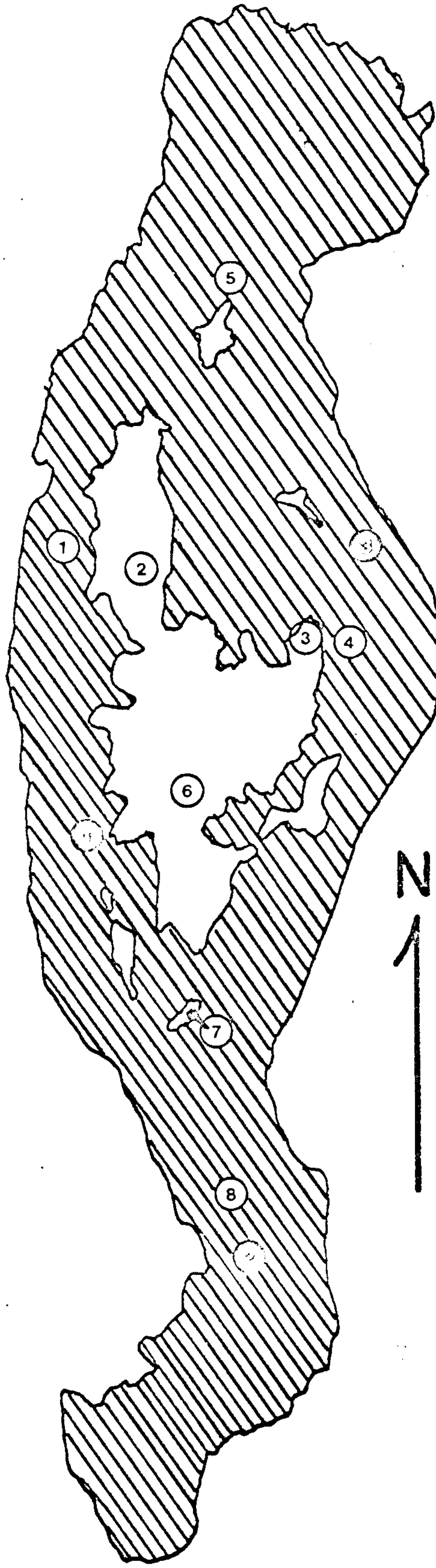
SYSTEM Palustrine, CLASS Emergent Wetland, SUBCLASS Persistant, WATER REGIME Semipermanently Flooded, WATER CHEMISTRY Oligo-saline-Alkaline, SOIL Organic. The dominant plant is _Typha latifolia_.

SYSTEM Palustrine, CLASS Aquatic Bed, SUBCLASS Rooted Vascular, WATER REGIME Permanently Flooded, WATER CHEMISTRY Oligosaline-Alkaline, SOIL Organic. The dominant plant is _Potamogeton pectinatus_.

Water and sediment sample sites.

Emergent macrophyte harvest plots and decomposition bag sites.

Fig. 2. Outline map of the Otter Tail county wetland. The numbers identify sampling locations.



SYSTEM Palustrine, CLASS Emergent wetland, SUBCLASS Persistant, WATER REGIME Semipermanently Flooded, WATER CHEMISTRY Oligosaline-Alkaline, SOIL Organic. The dominant plant is _Typha latifolia_.

SYSTEM Palustrine, CLASS Aquatic Bed, SUBCLASS Rooted Vascular, WATER REGIME Permanently flooded, WATER CHEMISTRY Oligosaline-Alkaline, SOIL Organic. The dominant plants are _Potamogeton berchtoldii_ and _Ceratophyllum demersum_.

○ Water and sediment sample sites.

◯ Emergent macrophyte harvest plots and decomposition bag sites.

a long machete and removing material to a depth where no more was encountered. The roots and rhizomes were washed on the site, with only living material retained. All samples were placed in ice and transported to the laboratory where they were oven-dried at 70°C and weighed. The weighed samples gave an estimate of the above and below ground standing crop biomass for each sampling date.

The first two sampling dates (May 6 and 20) roots and rhizomes were not segregated. However, for all subsequent sampling dates the roots and rhizomes from each plot were separated after drying and being weighed. The resulting three sample types, above ground biomass, roots and rhizomes, were then ground in a Wiley mill to pass a 40-mesh screen. The ground samples were analyzed for total nitrogen, phosphorus and potassium. Total nitrogen was determined by the semimicro-Kjeldahl procedure (Bremner, 1965). Phosphorus was determined by the molybdenum blue method of Fiske and Subbarow (Chapman and Pratt, 1961). Potassium determinations were made from the same ashed samples as the phosphorus by flame photometry.

Root and rhizome samples were analyzed for total nonstructural carbohydrate (TNC) content. The method of TNC extraction was similar to Smith (1969). However, purified diastase (Fisher Chemical Co.) was used as the enzyme. It was necessary to dialyze the enzyme solution, using tap water, for a period of four days to remove interfering reducing substance. TNC concentrations within the extracts were determined by a photometric adaptation of the Somogyi method (Nelson, 1944), and expressed on a glucose equivalent basis of mg/g plant material.

Decomposition of *Typha* litter was followed for a period of one year (October 1981 to November 1982) using the litter bag technique. Standing dead biomass of the current years growth was collected from random plots in October 1982. Only the leaves were retained for the study. The leaves were cut into 15 cm segments, thoroughly mixed and oven-dried at 70°C. The dried leaves were placed in 15 x 20 cm bags constructed of nylon cloth with a one mm mesh. Chamie and Richardson (1978) have reported that such a mesh size minimized loss by fragmentation while permitting access to most decomposer organisms. Each bag contained 10 to 15 gm of leaves. The bags were sewn closed with nylon thread, weighed to the nearest mg and permanently labeled. The bags were placed at three locations within each marsh, each location having 22 bags. Litter bag sites were adjacent to the harvest plots. After two or three days the material became waterlogged and the bags remained at the sediment-water interface. Two litter bags from each site were collected on 11 dates through November 1, 1982. The bags were rinsed in distilled water, dried at 70°C and weighed to the nearest mg to determine weight loss. The contents of each bag was ground to pass a 40-mesh screen and analyzed for total nitrogen, phosphorus and potassium. Methods of analysis were identical to the other plant material.

Submergent plants

Submergent vegetation of the aquatic bed zone in each wetland was sampled at biweekly intervals throughout the 1982 growing season to determine biomass and chemical composition. Six transect lines 30 m long and 5 m apart were permanently marked in the aquatic bed zone of each wetland. Ten quadrat positions were systematically assigned at 3 m intervals along the lines. On each sampling date one quadrat position on each line was randomly chosen for harvest. A 30 m tape was stretched between the end poles and used to identify the correct quadrat position. A 50 x 50 cm quadrat, constructed from 6mm x 15cm plexiglass was used. All plant material above and below the sediment was removed from the quadrats. This was facilitated by cutting around the inside margin of the plot with a machete. The plant material from each plot was placed in a plastic bag on ice and transported to the laboratory. Plant material was sorted by species, with like species from each plot within each wetland being combined. Below sediment biomass was combined into one sample due to problems of species identification. Sorted plant material was dried at 70°C and weighed to determine above sediment standing crop by species and total below sediment standing crop.

The dried plant material was ground to pass a 40-mesh screen and analyzed for total nitrogen, phosphorus and potassium. Methods of chemical analyses were the same as those previously noted for emergent plants.

Sediment compartment

Sites for sediment sampling were systematically assigned within each wetland to ensure a spread throughout the basins and inclusion of both wetland emergent and aquatic bed zones (Figs. 1 and 2). The Otter Tail County wetland contained eight such sites, due to size, while the Clay County wetland had four. Sampling sites within each wetland were equally divided between the emergent and aquatic bed zones.

Sediment sampling occurred on a biweekly basis throughout May to November in 1981 and 1982. A plexiglass pipe 6cm in diameter and 5 ft. long was used. One end was bevel-sharpened for penetration and the other contained a removable rubber stopper. After the pipe was pushed into the sediment the rubber stopper was used to create a suction to hold the sample during withdrawal. Three sediment cores approximately 10cm deep were taken from each sampling site and pooled to make one sample. Samples were placed on ice in sealed whirlpak bags and transported to the laboratory. At the laboratory the wet samples were transferred to soil tins and dried at 100°C. Dried samples were pulverized with a mortar and pestle and stored in sealed plastic bags until analyzed. Total nitrogen, ammonium, nitrate + nitrite, bicarbonate extractable phosphorus and potassium were determined in all sediment samples by the same methods used for soils. Organic phosphorus was measured by the ignition method (Jackson, 1958). Organic carbon was determined on a limited number of samples: one sample from each sampling site for four months in 1981. Organic carbon was determined by the Walkley-Black method (Allison, 1965). Two deep cores of the sediment were taken at each wetland. At the Clay County wetland sediment cores were taken to 185cm. At the Otter Tail wetland it was possible to extract sediment cores to 360 cm. The cores were visually and physically examined and described. Subsamples of each core were arbitrarily taken at 10 cm and each 25 cm thereafter. Subsamples from the same depth were combined, dried, pulverized and analyzed as all other sediment samples.

Sediment samples treated in the traditional manner before chemical analyses, i.e. oven-dried, were very wet and required about three to four days at 100°C for complete drying. An experiment was conducted to compare the recovery of N, P and K from traditional oven-dried sediments with two alternative treatments. Alternative treatments were: (1) analysis of fresh sediment samples placed on ice (not frozen), (2) analysis of fresh frozen sediment and (3) analysis of fresh frozen, freeze-dried sediment. Numerous sediment cores, 10 cm deep, were taken, combined in a plastic pail and thoroughly mixed. Subsamples from this sediment mix were placed in whirl-pak plastic bags and treated as noted above. Liquid-nitrogen was used to freeze samples on site. The entire process took about 30 minutes. Samples were transported to the laboratory where the fresh samples were immediately analyzed. Approximately four hrs. elasped from sampling to analysis of the fresh sediment. Oven-dried and freeze-dried sediments required four days to dry. Analysis of all samples were run in triplicate and restricted to total N, ammonium-nitrogen, nitrate + nitrite - nitrogen, bicarbonate extractable phosphorus and potassium.

<u>Wetland water</u>

Water samples were collected biweekly from the same wetland locations as the sediments (Figs. 1 and 2). The same plexiglass pipe used to collect sediments was also used to collect water samples. The pipe was lowered horizontally into the water and filled. The water was then poured into 300 ml BOD bottles. Two bottles were collected at each site. Conductivity and temperature measurements were taken at the same time. The collected water was placed on ice and transported to the laboratory where the pH was recorded. The water samples were then filtered and refrigerated until analyzed. Analysis was usually completed within a few hours. Ammonia-nitrogen, NO_3-N, NO_2- N, orthophosphate, total phosphorus and potassium was determined for all samples. Methods of analysis were the same as those used for runoff water.

RESULTS AND DISCUSSION

In many wetlands typical of the glaciated prairie region the movement of nutrients and other chemicals into the basin is greatly affected by the physical and chemical features of the watershed. The nutrient status of the Otter Tail and Clay County wetlands is given in Tables 3 and 4. The nutrient status of the watersheds seem to be within the normal range for most soils. The concentration of those nutrients measured is probably typical for the soils of the region. Ammonium-nitrogen was much higher in the soils than is usually reported. Reasons for this are not apparent.

Runoff from the watershed into the wetland has an immediate effect upon the wetland chemistry. Results of the analyses of surface runoff and drainage tile water entering the wetlands are show in Tables 5, 6, 7 and 8. Both the ammonia and nitrate forms of nitrogen contributed significantly to the nitrogen entering the wetlands. However, organic nitrogen was not determined. Nitrate-nitrogen was usually the greatest contributor of runoff nitrogen. Occasionally NH_3-nitrogen was higher than the NO_3-nitrogen. Nitrite-nitrogen was a minor component of runoff nitrogen. There are some noticeable differences in the chemical composition of runoff between sites. This is to be expected considering that the sites were collecting from fields with different crops and management programs. Unfortunately the amount of runoff into the wetlands could not be measured. Measuring nonpoint inputs, such as surface runoff into a wetland would be very expensive. However, such data would be very valuable in evaluating impacts upon the wetland as well as in studying the functional features of wetlands.

Table 3. Biweekly averages ($\bar{x} \pm SD$) of the chemical parameters of the watershed soil at the Clay County wetland.

DATE	NH_4 (ppm)	NO_3 (ppm)	PO_4 (ppm)	Total N (%)	K (meg/100g)
4-17-81	35.9 (8.6)	29.4 (8.4)	18.7(2.5)	0.186(0.035)	0.383(0.025)
5-6-81	46.9 (6.3)	39.2 (6.4)	29.2(3.0)	0.190(0.043)	0.427(0.076)
5-20-81	70.6(13.0)	48.1 (2.7)	28.5(6.5)	0.182(0.046)	0.417(0.051)
6-3-81	45.73(3.3)	66.9(11.6)	27.3(2.1)	0.186(0.038)	0.400(0.036)
6-15-81	54.0 (2.4)	48.7(16.4)	32.8(4.0)	0.197(0.040)	0.377(0.029)
7-1-81	54.6 (8.6)	51.1(27.0)	32.8(3.1)	0.181(0.017)	0.390(0.017)
7-16-81	40.4 (5.4)	19.9 (3.1)	25.2(6.5)	0.168(0.028)	0.383(0.025)
7-28-81	88.4(11.9)	19.7 (7.2)	68.1(9.8)	0.188(0.029)	0.417(0.012)
8-11-81	89.1(14.9)	23.4(15.9)	68.4(1.4)	0.162(0.033)	0.470(0.035)

Table 4. Biweekly averages ($\bar{x} \pm SD$) of the chemical parameters of the watershed soil at the Otter Tail county wetlands.

DATE	NH_4 (ppm)	NO_3 (ppm)	PO_4 (ppm)	Total N (%)	K (meg/100g)
5-6-81	61.0 (9.2)	55.7(21.2)	37.3 (9.2)	0.242(0.084)	0.632(0.178)
5-20-81	99.5(29.3)	74.8(33.1)	37.3 (6.5)	0.279(0.041)	0.665(0.141)
6-3-81	45.7 (3.3)	66.9(11.6)	40.1(20.1)	0.186(0.037)	0.400(0.036)
6-15-81	61.4 (3.3)	58.6(20.8)	37.1 (9.0)	0.279(0.050)	0.710(0.200)
6-30-81	68.5(10.4)	51.0(7.6)	34.5 (3.5)	0.251(0.040)	0.685(0.175)
7-15-81	62.9 (9.7)	23.0(4.3)	41.5 (8.3)	0.285(0.033)	0.657(0.140)
7-29-81	140.5(28.6)	16.1(1.8)	72.4 (5.9)	0.305(0.069)	0.742(0.208)
8-13-81	114.5(30.5)	11.4(5.8)	63.8 (2.7)	0.292(0.083)	0.767(0.182)

Table 5. Water chemistry of drainage tile water from the watershed entering the Otter Tail County wetland during 1981.

Site	Date	Conductivity (mmho)	pH	NH_3	NO_2	NO_3 (ppm)	PO_4	TOTAL-P	K
2	8-06		7.21	0.26	0.028	0.195	0.48	0.44	10.6
3			7.27	0.16	0.119	0.125	0.47	0.42	10.4
2	8-13		7.28	0.55	0.003	0.025	0.61	0.84	9.4
3			7.25	0.55	0.003	0.017	0.58	0.80	9.2
2	8-26	550	6.90	0.14	0.035	0.425	0.29	0.90	18.0
3		550	6.90	0.54	0.006	0.059	0.65	0.74	11.0

Table 6. Surface runoff water chemistry at the Clay County wetland during 1981.

Site	Date	Conductivity (mmho)	pH	NH_3	NO_2	NO_3 (ppm)	PO_4	TOTAL-P	K
2	6-10	180	7.16	0.32	0.068	0.463	0.11	0.34	3.2
2	6-15	100	7.27	0.25	0.067	0.293	0.07	0.15	2.1
2	6-25	63	7.87	0.35	0.009	0.064	0.06	0.23	2.5
2	7-01	190	7.74	0.17	0.030	0.263	0.21	0.22	5.3
2	7-08	230	8.95	0.32	0.025	1.600	0.16	0.17	4.1
1	7-16	130	9.16	0.24	0.002	0.053	0.25	0.27	19.0
2	7-16	160	9.35	0.07	0.041	0.370	0.19	0.20	8.2
1	7-28	185	8.72	0.35	0.004	0.051	0.28	0.29	11.0
2		200	8.99	0.15	0.035	0.178	0.27	0.38	7.5
3		180	9.12	0.19	0.041	0.241	0.21	0.30	5.5
1	8-06		8.01	0.77	0.018	1.900	0.37	0.57	23.0
2			7.85	0.34	0.042	3.300	0.25	0.90	6.2
3			8.02	0.33	0.022	1.800	0.25	0.62	3.6
2	8-11		8.40	0.10	0.014	0.307	0.06	0.17	4.8
1	8-26	170	7.35	0.40	0.067	0.214	0.39	0.53	32.0
2		130	7.40	0.43	0.059	0.312	0.19	0.30	6.0
3		90	7.60	0.37	0.011	0.490	0.18	0.44	4.0
2	9-07			0.31	0.060	0.309	0.29	0.41	7.0
2	10-14	150	6.51	0.31	0.099	0.619	0.11	0.24	5.0
2	10-31	120	7.40	0.24	0.023	0.400	0.12	0.25	5.0

Table 7. Water chemistry of drainage tile water from the watershed entering the Otter Tail County wetland during 1982.

Site	Date	Conductivity (mmho)	pH	NH_3 (ppm)	NO_2 (ppm)	NO_3 (ppm)	PO_4 (ppm)	TOTAL-P (ppm)	K (ppm)
2	4-21	225	7.80	0.13	0.011	0.057	0.32	0.46	12.0
3		180	7.78	0.14	0.009	0.060	0.26	0.42	12.0
2	5-14	450	8.19	0.23	0.002	0.025	0.29	0.46	15.0
3		420	7.68	0.28	0.004	0.032	0.25	0.37	13.0
2	6-10	375	7.90	0.52	0.004	0.029	0.13	0.29	10.0
3		370	7.23	0.51	0.002	0.025	0.17	0.32	9.0
4	7-20	850	7.30	0.17	0.008		0.05	0.15	5.5
4	8-18	800	7.43	1.63	0.006	8.100	0.18	0.85	6.0
4	9-6	810	7.41	0.13	0.005	16.600	0.15	0.21	4.5
4	9-14	900	7.60	0.21	0.005	9.900	0.11	0.21	4.0

Table 8. Surface runoff chemistry at the Clay County wetland during 1982.

Site	Date	Conductivity (mmho)	pH	NH_3	NO_2	NO_3 (ppm)	PO_4	TOTAL-P	K
1	4-21	150	7.83	0.52	0.107	0.260	0.56	0.81	10.0
2		170	7.71	0.14	0.059	0.133	0.06	0.24	13.0
2	5-26	170	7.80	0.54	0.048	0.171	0.12	0.26	4.0
2	6-10	220	7.35	0.74	0.131	0.290	0.14	0.26	11.0
1	6-30	140	8.90	0.03	0.005	2.000	0.25	0.34	23.0
2		260	7.31	0.83	0.263	4.000	0.05	0.29	3.6
1	7-13	195	8.08	0.68	0.164	0.782	0.21	0.43	6.6
2		250	7.82	0.88	0.002	0.025	0.07	0.31	14.0
2	7-20	180	7.38	1.23	0.115	0.513	0.02	0.08	11.0
2	8-10	275	8.00	0.43	0.022	0.095	0.29	0.61	33.0
2	8-17	360	7.80	0.51	1.300	5.100	0.82	1.06	59.0
2	9-14	450	7.73	0.23	0.002	0.032	0.26	0.38	60.0
2	9-27	315	7.40	0.16	0.052	0.305	0.14	0.22	41.0
1	10-28	290	7.50	0.02	0.009	0.056	0.21	0.29	1.1
2		320	7.58		0.017	0.459	0.20	0.27	22.0

Above ground and below ground biomass production of Typha is plotted in Figures 3 and 4. The curves for both wetlands are very similar. Above ground biomass reached a maximum in mid-July. The Clay County site had a higher peak standing biomass (988 g/m^2) than the Otter Tail County (650 g/m^2). The values are comparable to those reported by Boyd (1970, 1971) in South Carolina, although peak biomass occurred in mid-June in that study. Klopatek and Stearns (1978) reported a standing crop of 1494 g/m^2 in Wisconsin, however the harvest was conducted in September and included the entire seasons total above ground production. Above ground biomass declined from mid-July until dormancy.

Below ground biomass curves show an initial decline which corresponds with the initiation of shoot growth (Figs. 3 and 4). However, early in June below ground biomass abruptly increased. This is likely due to the numerous adventitious buds that form at the basal portion of the Typha shoots (Linde, et. al. 1976). Below ground biomass declined from the early to late June peak (depending upon the site) until late summer. During late summer and early fall the root/rhizome biomass increased to the level recorded for early spring.

The nitrogen concentration of the shoot and rhizome tissues shows an initial increase until 15 June, after which the nitrogen concentration decreases (Figs. 5 and 6). Shoot nitrogen continues to decrease, the lowest values obtained in mid-October. Boyd (1970) attributed this pattern in shoots to a rapid uptake in early spring for storage, and translocation later in the season when conditions are optimum for growth. Shoot nitrogen peaked in South Carolina cattails on 18 June at 2.4% as compared to a 15 June peak of 2.62% in this study. The low nitrogen con-

Fig. 3. Aboveground and belowground standing crop biomass of *Typha* spp. at the Otter Tail county wetland.

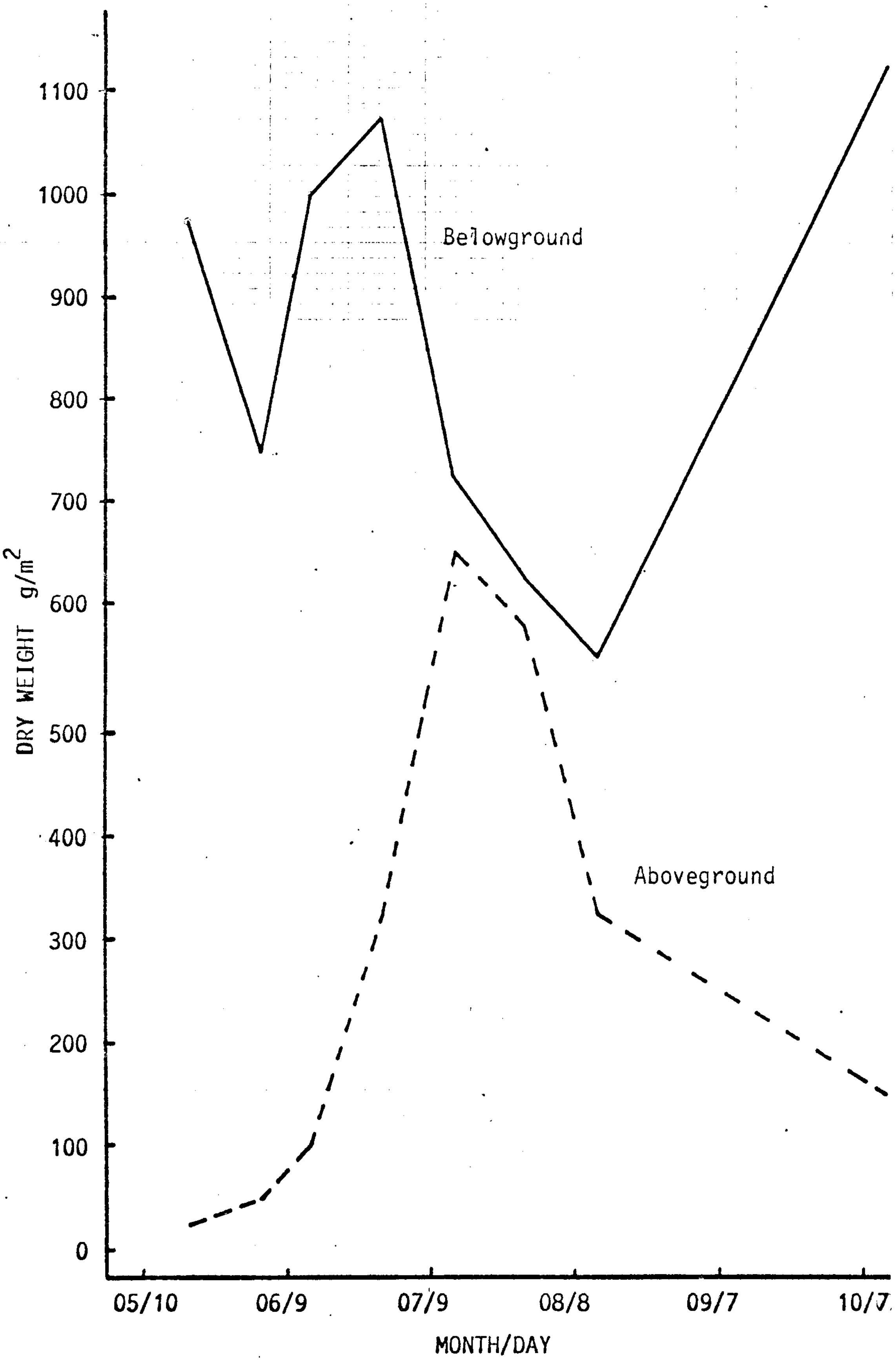


Fig. 4. Aboveground and belowground standing crop biomass of *Typha* spp. at the Clay county wetland.

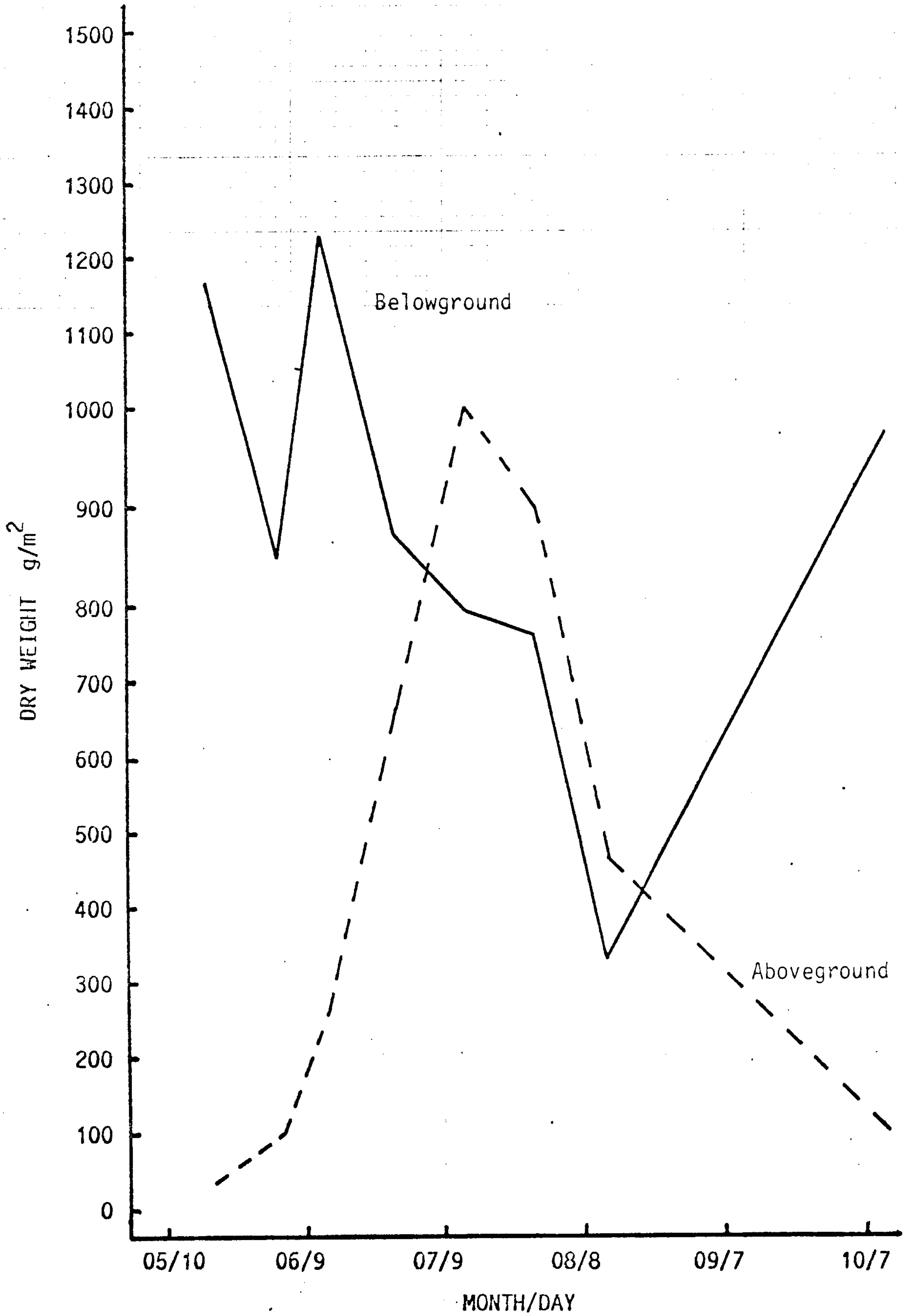


Fig. 5. Total nitrogen concentration of _Typha_ spp. shoot, rhizome and root tissue at the Otter Tail county wetland.

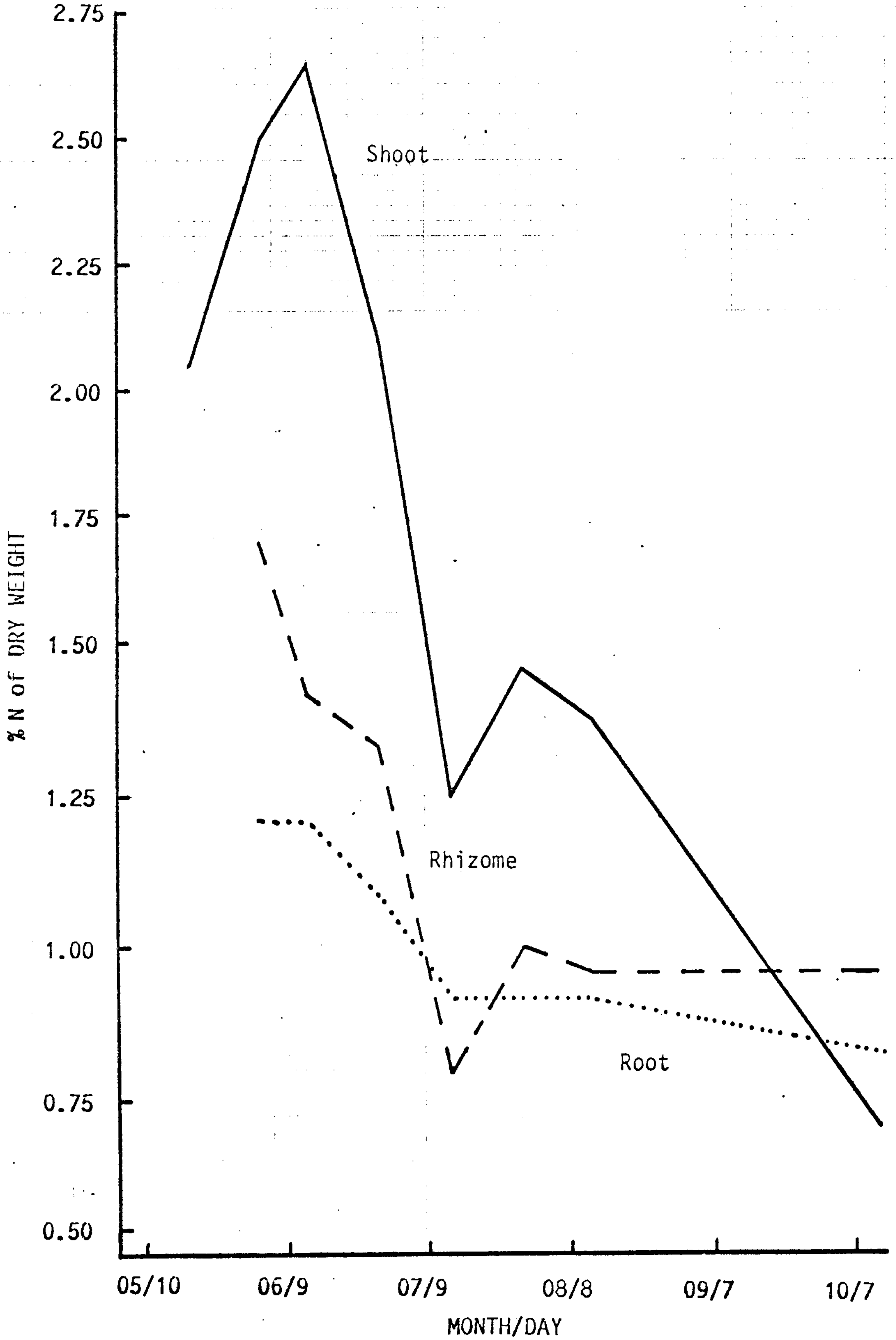
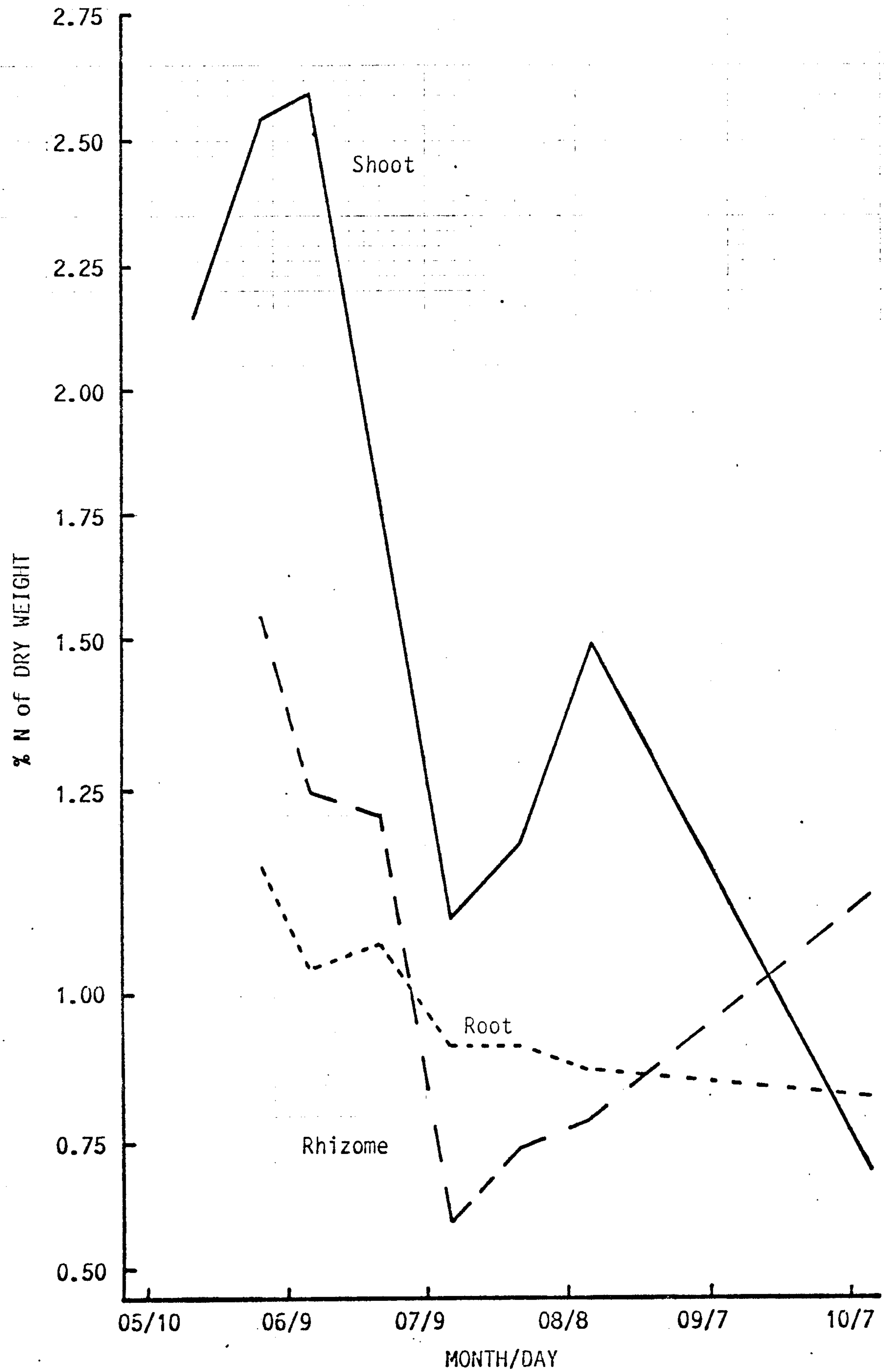


Fig. 6. Total nitrogen concentration of *Typha* spp. shoot, rhizome and root tissue at the Clay county wetland.



tent of the shoots in late summer and early fall are probably due to senescence, with nitrogen being translocated or lost from the plant as it ages.

Nitrogen concentration in the rhizomes and roots was less than the shoot, but displayed a similar pattern of decrease until mid-July. In the latter part of the growing season rhizome nitrogen increased while root nitrogen was generally stable.

Changes in phosphorus concentrations of the shoot rhizomes and roots were very similar in pattern to those of nitrogen (Figs. 7 and 8). The shoot increased in phosphorus concentration until mid-June, then steadily declined until the last sampling date in October. Phosphorus concentration of the roots and rhizomes remained relatively steady throughout the season.

Potassium concentrations in Typha tissues are shown in Figgures 9 and 10. Shoot concentration increased early in the growing season, reaching a peak in mid-June. The concentration of potassium in the shoot declined from mid-June throughout the growing season. Potassium content of the rhizomes and roots show more flucuation than the shoot. After mid-August both rhizomes and roots show a trend of increasing potassium concentration.

Total nonstructural carbohydrate (TNC) measurements are estimates of the carbohydrate energy readily available to the plant (Smith, 1969). TNC concentration was much higher in the rhizomes than in roots (Fig. 11). Both roots and rhizomes declined in the TNC concentration until mid-July. After this low, TNC concentration began increasing and continued to increase into the fall. Linde et.al. (1976) reported a similar trend

Fig. 7. Phosphorus concentration of Typha spp. shoot, rhizome and root tissue at the Otter Tail county wetland.

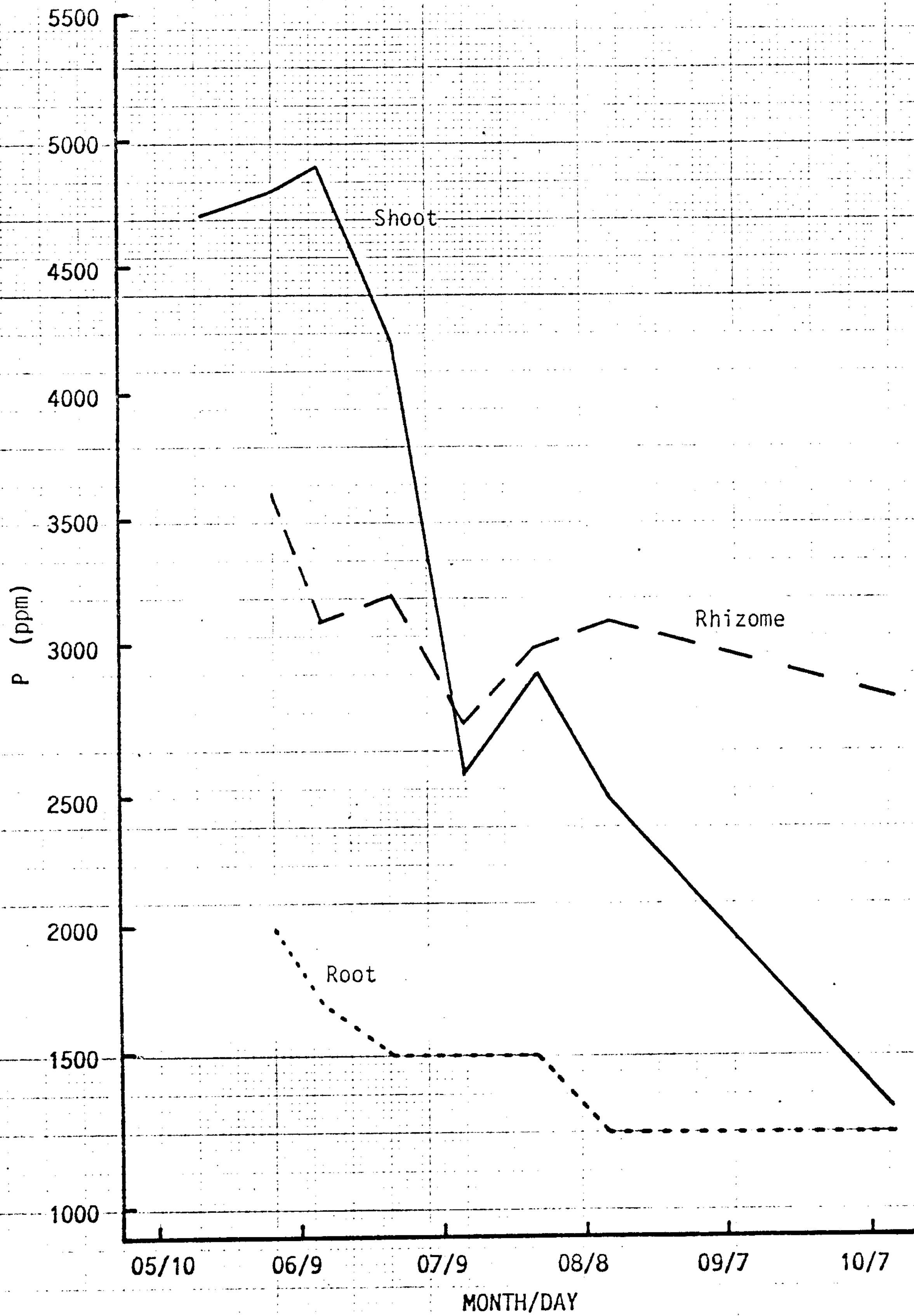


Fig. 8. Phosphorus concentration of *Typha* spp. shoot, rhizome and root tissue at the Clay county wetland.

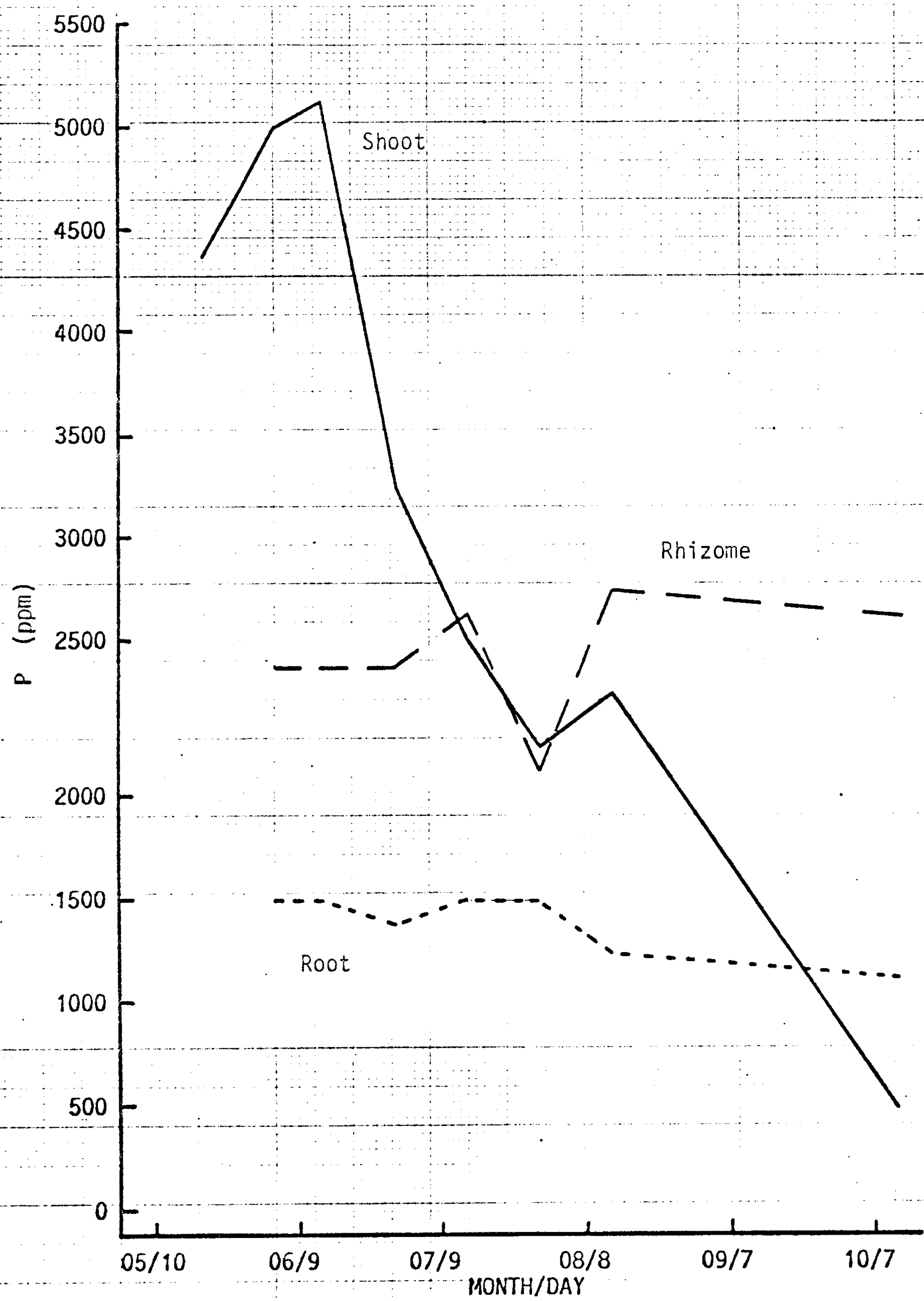


Fig. 9. Potassium concentration of *Typha* spp. shoot, rhizome and root tissue at the Otter Tail county wetland.

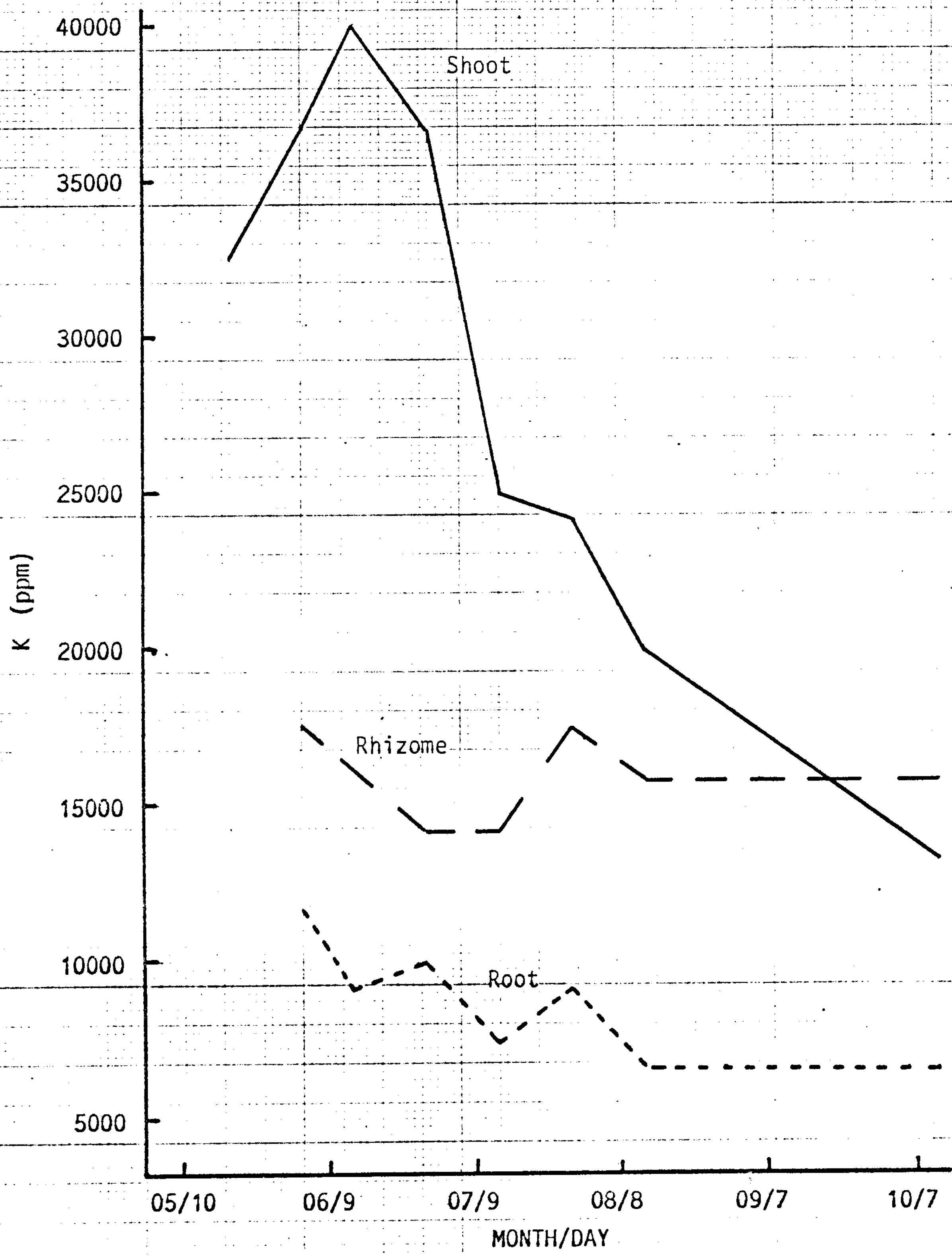


Fig. 10. Potassium concentration of *Typha* spp. shoot, rhizome and root tissue at the Clay county wetland.

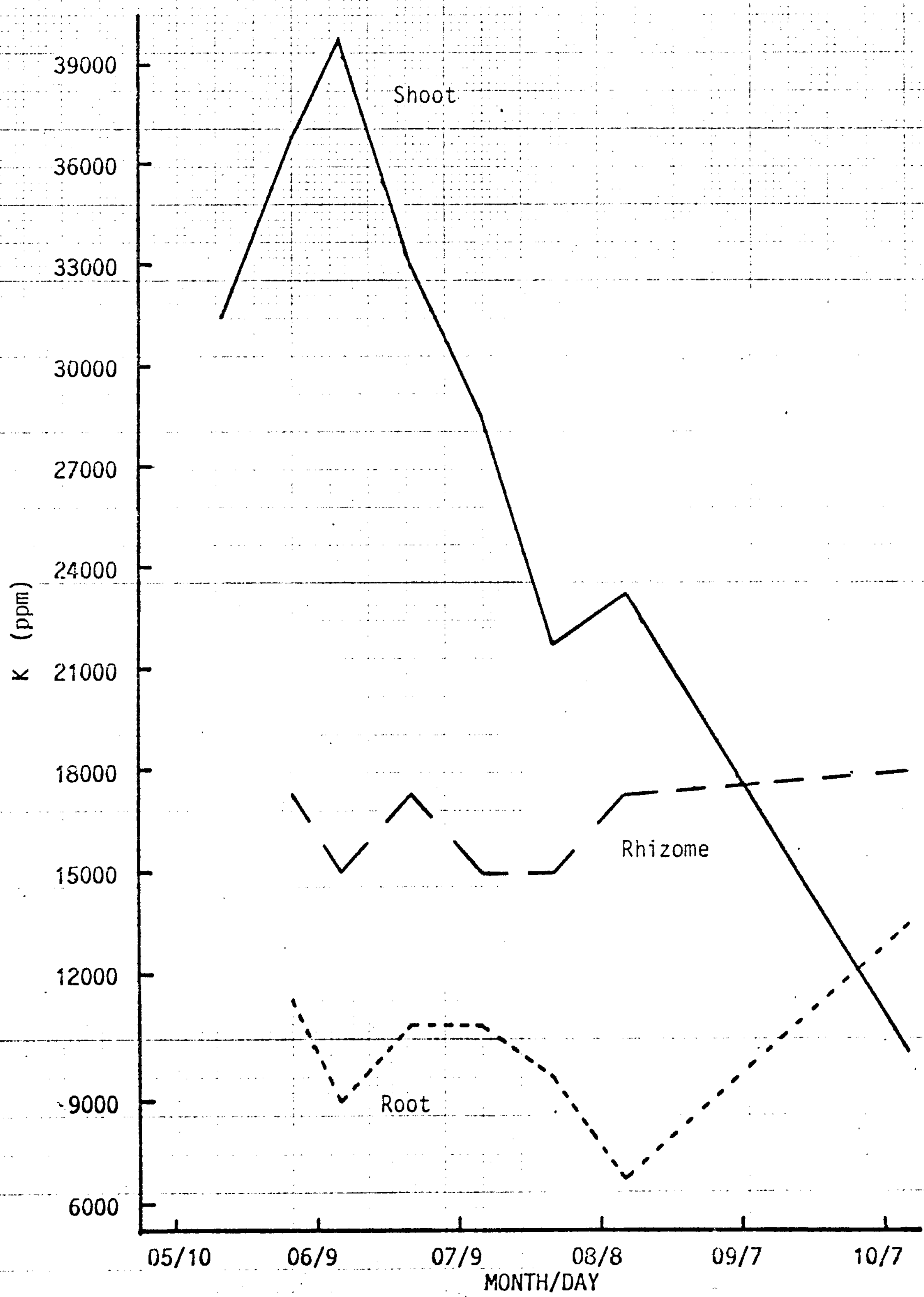
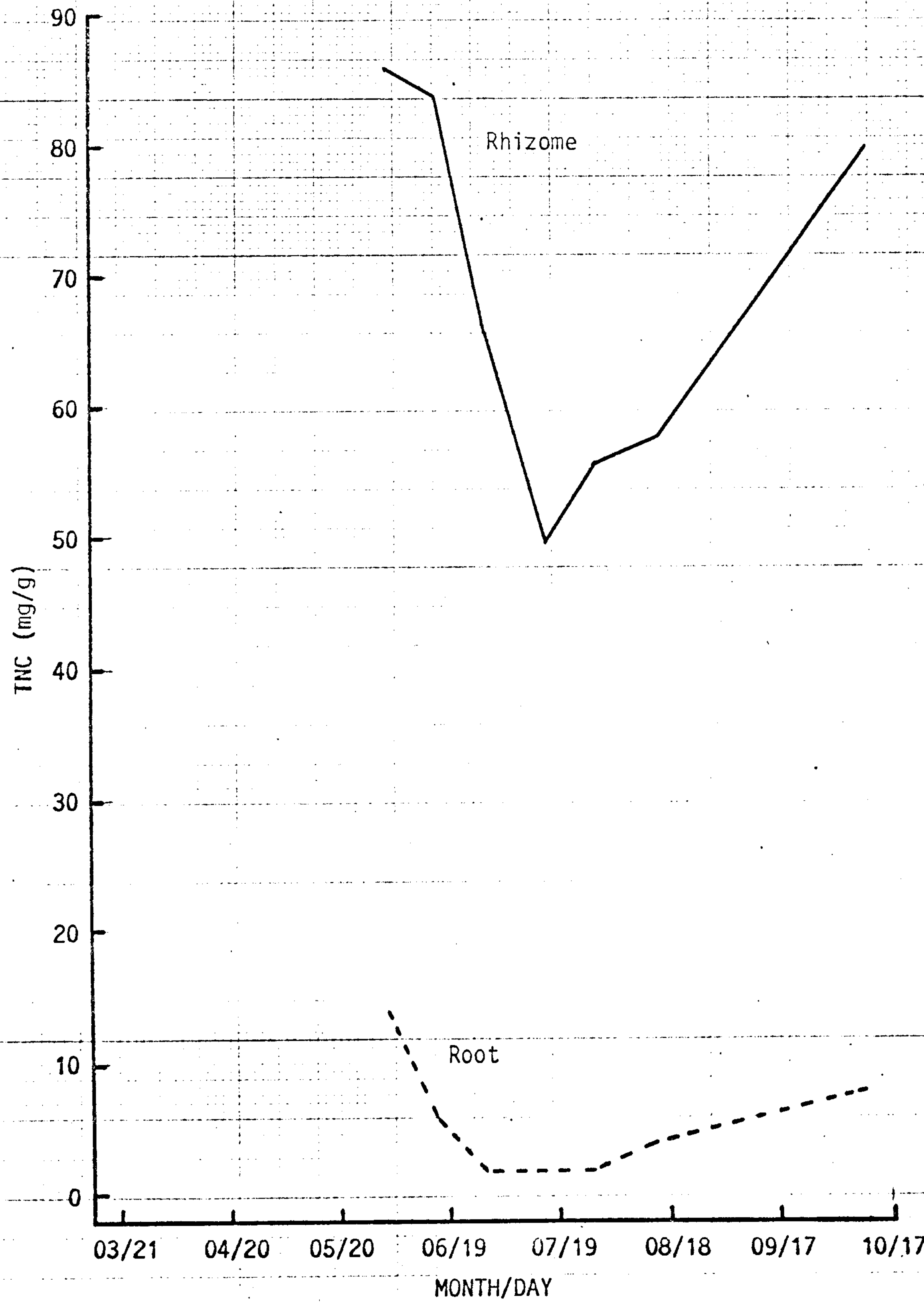


Fig. 11. Total nonstructural carbohydrate concentration (glucose equivalent) of Typha spp. rhizome and root tissue throughout the growing season. Mean values of samples from the Otter Tail and Clay county wetlands.



for cattails. However, the low point in TNC concentration in their study occurred on June 20.

Significant amounts of nutrients are incorporated into the biomass of any ecosystem. The release of the nutrients for potential reuse is accomplished by a complex process simply referred to as decomposition. Numerous studies have described some of the changes that take place as plant litter decomposes (Brinson et. al. 1981; Davis and van der Valk, 1978). The loss in dry weight of litter over a one-year period is shown in Figure 12. Approximately a 10% loss in dry weight occurred within 22 days. Boyd (1970) and Kulshreshtha and Gopal (1982) have reported that these early losses are due to the leaching of nutrients and dissolved organic matter. Approximately 34% of the dry weight was lost after one year. Nitrogen showed a slight initial decrease, but then increased rather steadily throughout the study (Fig. 13). Increases in nitrogen have been explained as immobilization of dissolved nitrogen by microorganisms. Phosphorus concentration in the litter rapidly declined, reaching a low point after seven months (Fig. 14). Phosphorus increased from the seventh month until the end of the study. Potassium concentration decreased very rapidly and remained present at a relatively low concentration (Fig. 15).

The two wetlands differed in dominant submergent macrophyte composition. The Clay County wetland was dominated by a single species. Potamogeton pectinatus. Peak standing crop biomass of P. pectinatus was 264 g/m^2 on August 10. The Otter Tail County wetland had Cerotophyllum demersum and Potamogeton berchtoldii as condominant species.

Fig. 12. Percent weight loss of *Typha* spp. litter over a one year period. Mean values of 12 litter bags for each date from the Otter Tail and Clay county wetlands.

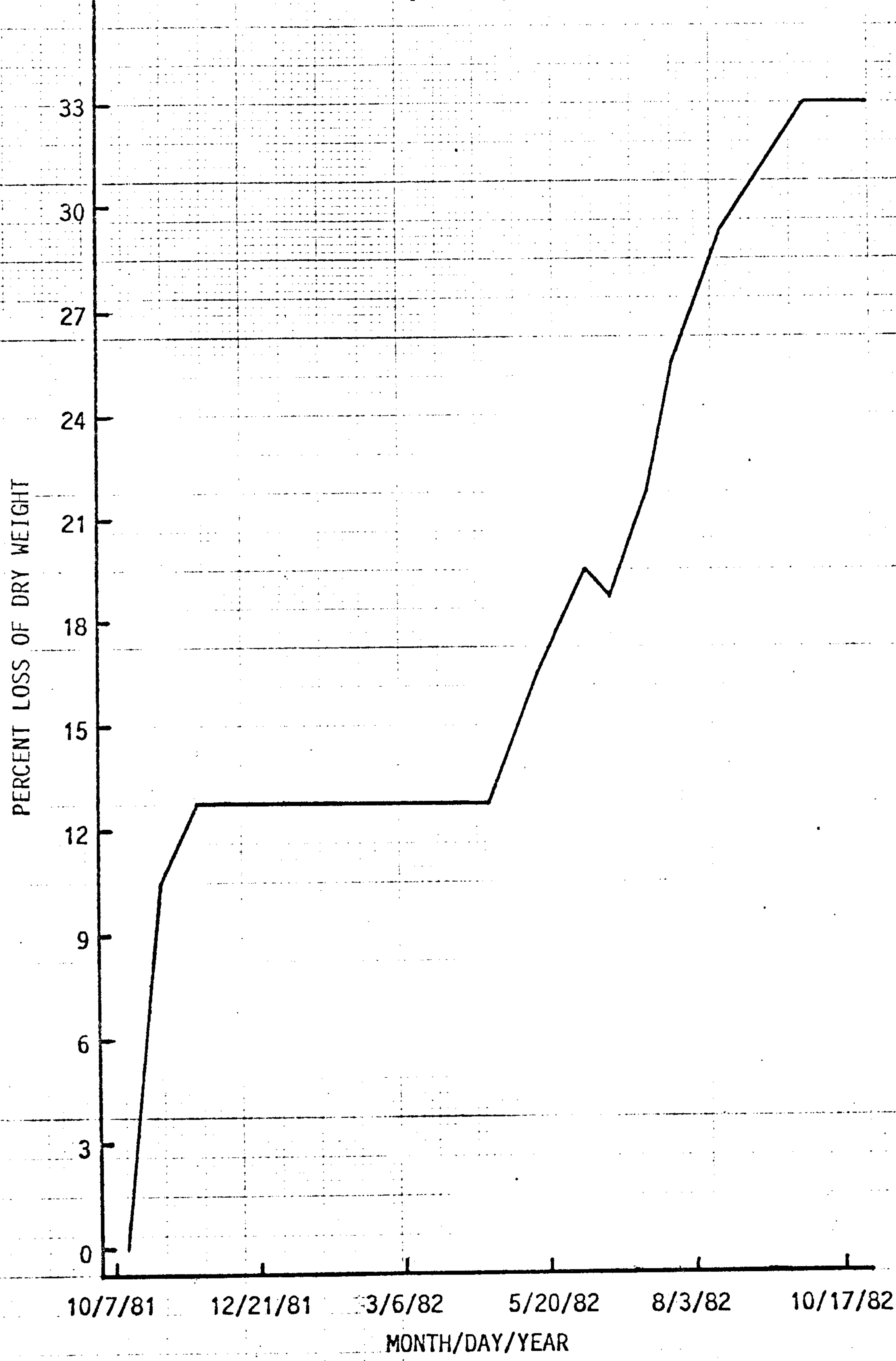


Fig. 13. Nitrogen concentration of decomposing _Typha_ spp. leaves. Mean values of 12 litter bags for each date from the Otter Tail and Clay county wetlands.

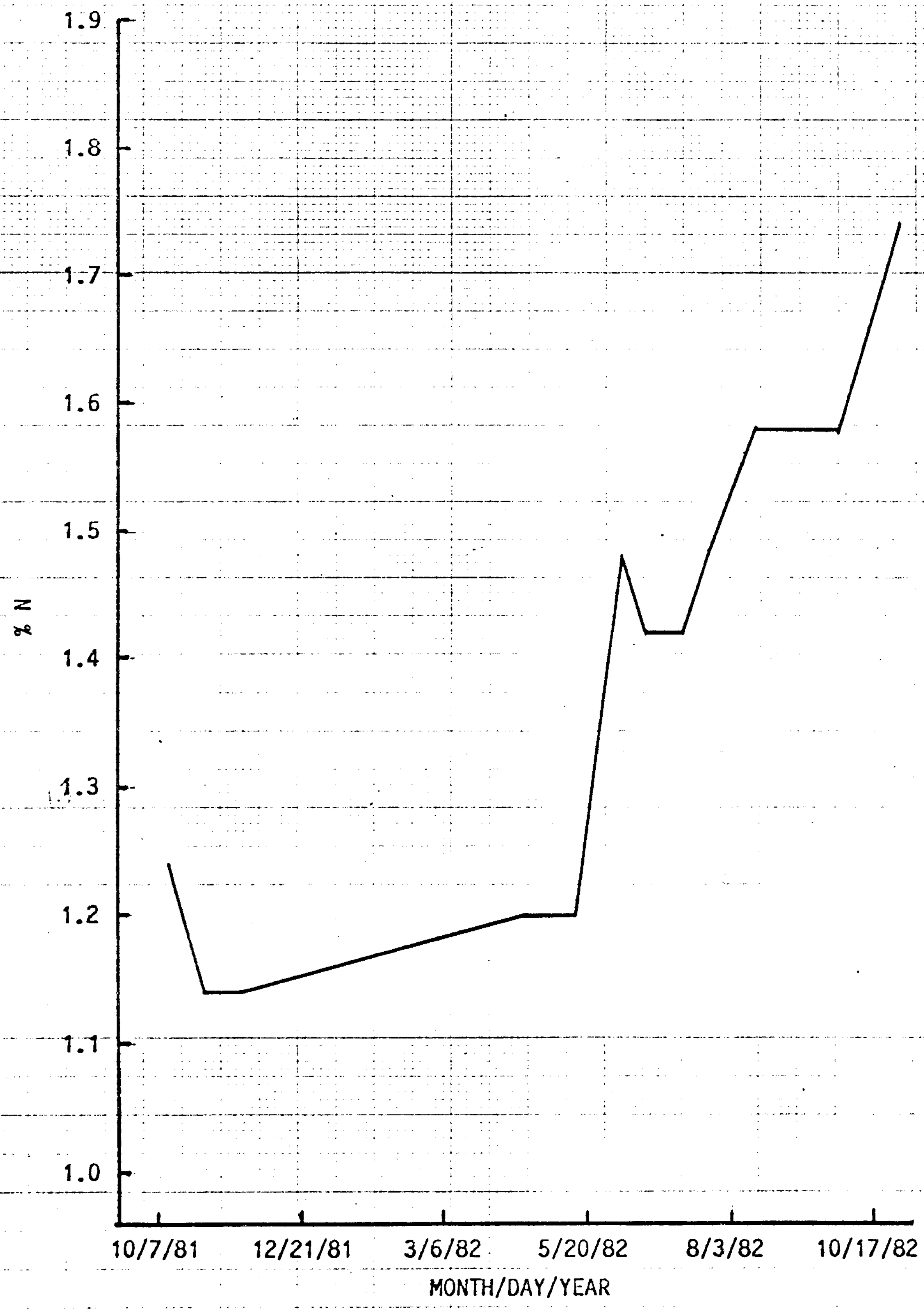


Fig. 14. Phosphorus concentration of decomposing *Typha* spp. leaves. Mean values of 12 litter bags for each date from the Otter Tail and Clay county wetlands.

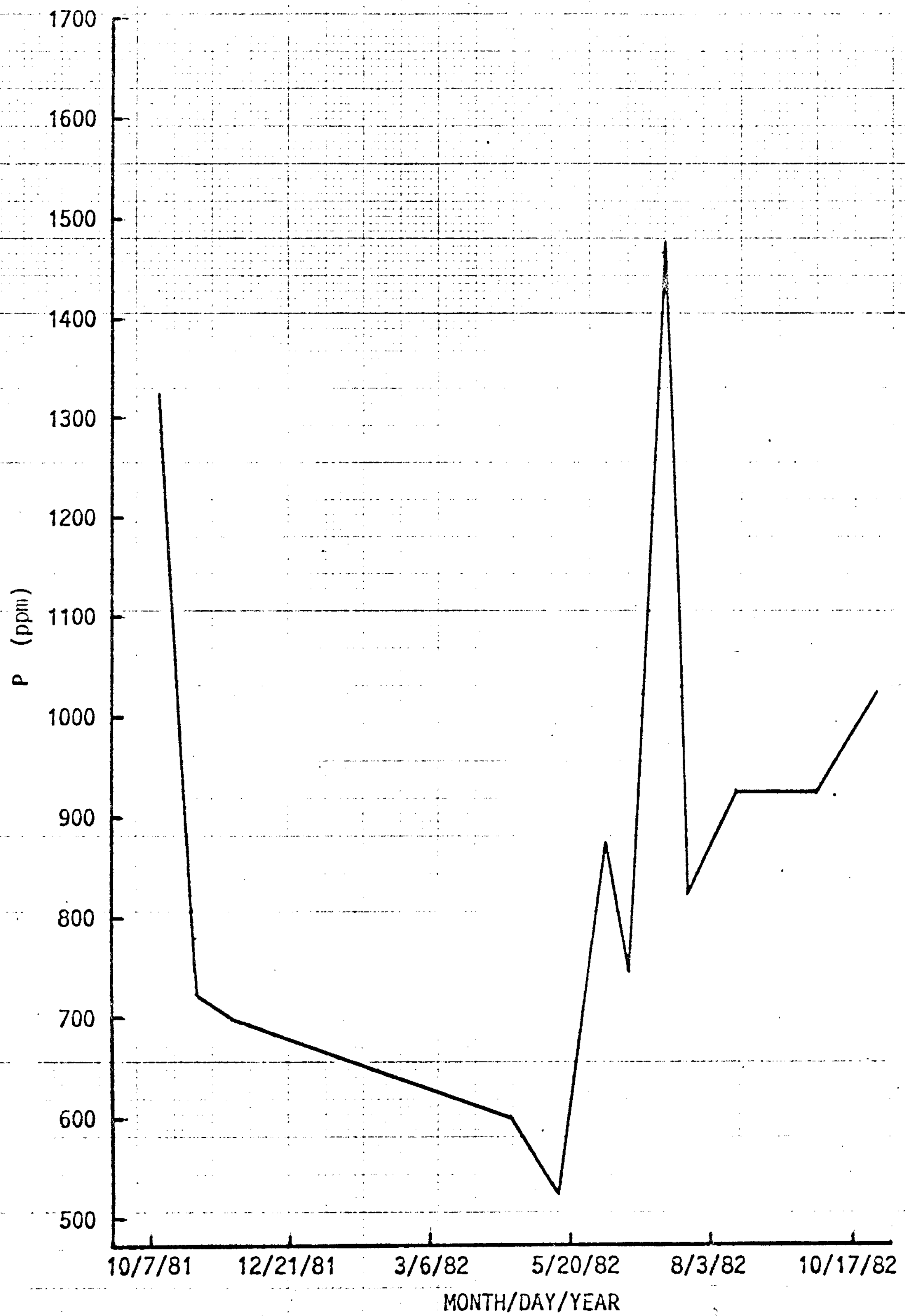
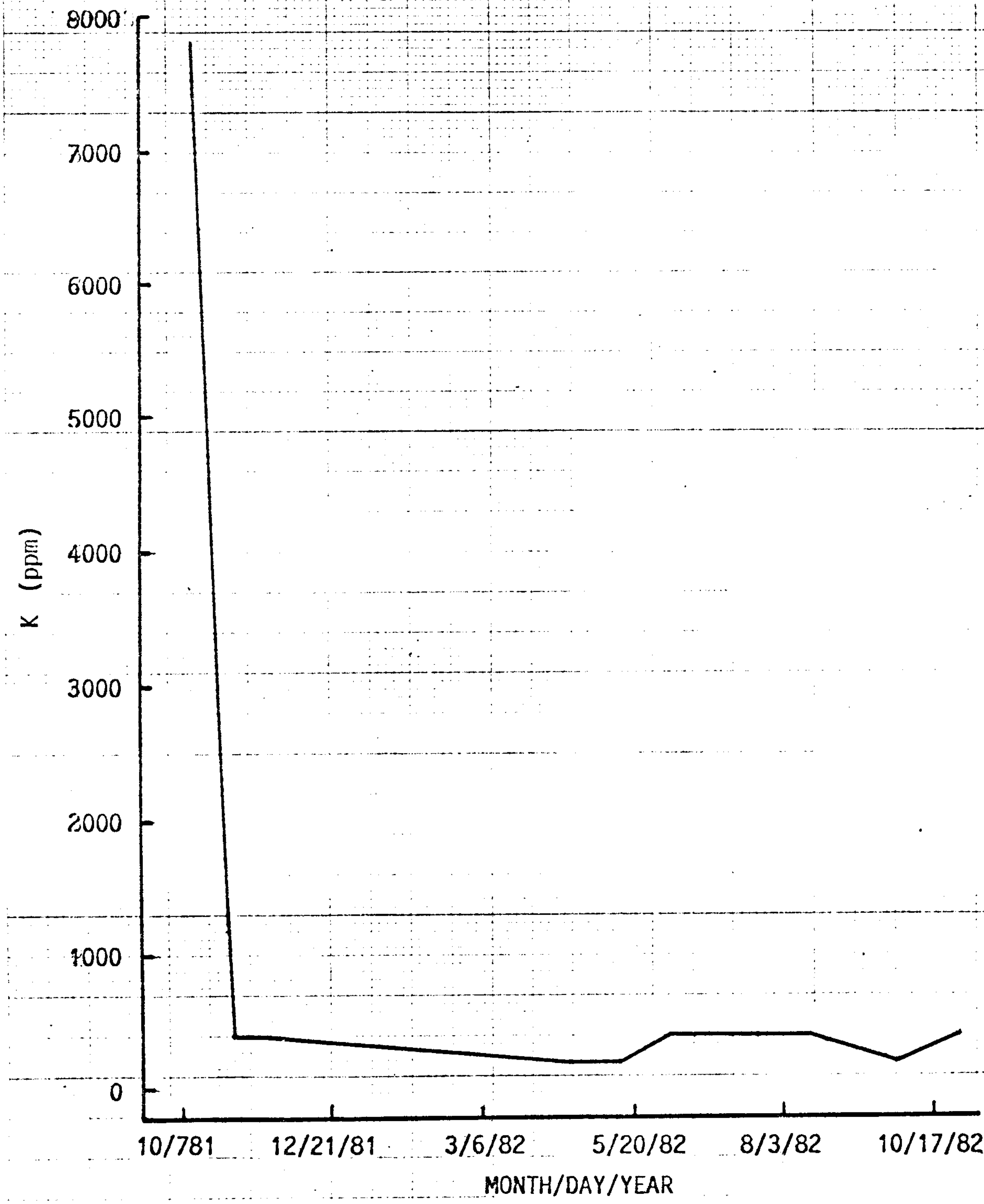


Fig. 15. Potassium concentration of decomposing *Typha* spp. leaves. Mean values of 12 litter bags for each date from the Otter Tail and Clay county wetlands.



P. berchtoldii reached the peak standing crop of 128 g/m² on June 30. *C. demersum* peaked at 127 g/m² on July 28.

Although chemical analyses of the submergent macrophytes, sediments and water have been completed, a complete statistical analysis is unfinished. These results, together with a more complete discussion will be presented in later papers.

LITERATURE CITED

Allison, L. E. 1965. Organic carbon, p. 1367-1378. In C. A. Black et. al. [ed.] Methods of soil analysis, part 2, chemical and microbiological properties. Monogr. 9, Amer. Soc. Agron, Madison, Wisconsin.

APHA. 1975. Standard methods for the examination of water and wastewater, 14th ed. American Public Health Association, Washington, D.C.

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

Boyd, C. E. 1970b. Losses of mineral nutrients during decomposition of *Typha latidolia*. Archiv. Hydrobiol. 66:511-517.

Boyd, C. E. 1971. Further studies on productivity, nutrient and pigment relationships in *Typha latifolia* populations. Bull. Torrey Bot. Club 98:144-150.

Bremner, J. M. 1965. Inorganic forms of nitrogen, p. 1179-1237. In C. A. Black et. al. [ed.] Methods of soil analysis, part 2, chemical and microbiological properties. Monogr. 9, Amer. Soc. Agron., Madison, Wisconsin.

Brinson, M. M., A. E. Lugo and S. Brown. 1981. Primary productivity, decomposition and consumer activity in freshwater wetlands. Ann. Rev. Ecol. Syst. 12:123-161.

Chapman, H.D. and P. F. Pratt. 1961. Methods of analysis for soils, plants and water. Univ. of California, Div. of Agric. Sci., Publ. 4034.

Cowardin, L. M., V. Carter, F.C. Golet and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Department of Interior, Fish and Wildl. Serv., FWS/OBS-79/31.

Davis, C. B. and A. G. van der Valk. 1978. Litter decomposition in prairie glacial marshes, p. 99-113. In R. E. Good et. al. [ed.] Freshwater wetlands--ecological processes and management potential. Academic Press, New York.

Diedrick, R. T. 1981. The agricultural value of wet soils in the upper midwest, p. 97-106. In B. Richardson [ed.] Selected proceedings of the midwest conference on wetland values and management. Minnesota Water Planning Board.

Gosselink, J. G., E. P. Odum and R. M. Pope. 1974. The value of the tidal marsh. Center for Wetland Resources Publ. No. LSU-SG-74-03, Louisiana State University, Baton Rouge, LA. 30 p.

Jackson, M. L. 1958. Soil chemical analysis. Prentice Hall, Inc., Englewood Cliffs, New Jersey.

Jaworski, W. C. N. Raphael, D. L. Tilton and R. H. Kadlec. 1977. Wetlands value study; annotated bibliography. Michigan Department of Natural Resources, Lansing, Michigan.

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

Kulshreshtha, M. and B. Gopal. 1982. Decomposition of freshwater wetland vegetation. II. Aboveground organs of emergent macrophytes, p. 279-292. In B. Gopal et. al. [ed.] Wetlands ecology and management. Proc. First International Wetlands Conf., New Delhi, India, 1980. International Scientific Pub., Jaipur, India.

Linde, A. F., T. Janisch and D. Smith. 1976. Cattail--the significance of its growth, phenology and carbohydrate storage to its control and management. Wisconsin Dept. of Natural Resources, Tech. Bull. No. 94, Madison, Wisconsin.

Nelson, N. 1944. A photometric adaptation of the Somogyi method for the determination of glucose. Jour. Biol. Chem. 153:375-380.

Olsen, S. R., C. V. Cole, F. S. Watanabe and L. A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U. S. Dept. Agric. Circ. 939.

Shaw, S. P. and C. G. Fredine. 1956. Wetlands of the United States. U. S. Fish Wildl. Serv., Circ. 39. 67 p.

Smith, D. 1969. Removing and analyzing total nonstructural carbohydrates from plant tissue. Univ. of Wisconsin, College of Agric. and Life Sci., Res. Rpt. 41.

Stewart, R. E. and H. A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. U. S. Fish Wildl. Serv., Resour. Publ. 92. 57 p.