ECOLOGICAL STUDIES OF THE HAMILTON MARSHES
PROGRESS REPORT FOR THE PERIOD
JUNE, 1974 - JANUARY, 1975

BY

DENNIS F. WHIGHAM AND ROBERT L. SIMPSON

BIOLOGY DEPARTMENT
RIDER COLLEGE
TRENTON, N. J.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION AND ACKNOWLEDGEMENTS

The Hamilton Marshes are an invaluable asset of the people of Hamilton Township and surrounding areas. We hope that our studies of the marshes will demonstrate their unique qualities and that the data will be used in the wise management of this resource.

This report summarizes our research for the period April, 1974 to January, 1975. This is a preliminary report but we believe that our final conclusions will not be altered after the termination of our ongoing research projects. Several studies have been completed and several continue at present. We have completed our analysis of the vegetation of the marshes as well as the primary productivity studies. A separate study of wild rice has been completed. This report also contains papers on the ecology of two other marsh species that have been studied as independent research projects by two Rider College students. Water chemistry, nutrient cycling, and mud algae studies will continue until June, 1975. Detritus and litter decomposition studies will continue until October, 1975. Incomplete results of those studies are presented in this report.

We would like to thank the many people who have encouraged us during our investigations. Mr. Gerald Hererra, Mr. Richard Klockner, and Mr. Haig Kasabach have been especially helpful in coordinating our activities with the Hamilton Township Environmental Commission and in permitting us to use the facilities of the Hamilton Township Sewage Treatment Plant as a base of many of our field operations.

Financial support for our work has been provided by the Hamilton Township Environmental Commission, the National Geographic Society, The Society of the Sigma Xi, and a Rider College Grant-in-Aid.

Special thanks go to Penelope Simpson who designed and spent long hours making the nylon bags that were used in our litter decomposition experiment. To our wives, Penny and Jan, also go our thanks for their patience during many of the long days and vacationless weekends. We would also like to thank our student assistants: Paula Bozowski, Herbert Grover, Barry Kline, Thomas Leslie, Richard McClellan, and David West.

BACKGROUND INFORMATION

The Hamilton Marshes occupy approximately 500 Hectares of tidal and nontidal land adjacent to the Delaware River near Trenton, N. J. We estimate that there are approximately 260 Hectares of tidal marshland. The marsh is bordered on the north by a highly developed section of Hamilton Township. On the western boundary is the Delaware and Raritan Canal. Except for the Canal side, the natural border of the marsh is a steep hill-side that extends almost entirely around the marsh. In most places, residental developments occur directly on the hill-sides that overlook the marshes. The marshes are impacted by a number of facilities. The most important are: DeLorenzo land fill, Hamilton Township Sewage Treatment Plant, Ocean Spray Cranberry Company, Yardville Sanitary Landfill, Yates Industrial, and Bordentown Reformatory Sewage Treatment Plant, (Walton and Patrick, 1973). In addition several, large storm-drains discharge runoff water.

Our studies were initiated in the summer of 1973. The original purpose was to quantify the interelationships of the plants and animals that are found in the marshes. In the course of our work it became apparent that the marshes were extremely valuable and ecologically interesting. Endangered birds spend several months in the marshes, there is great potential for utilization of the area for environmental education, the marshes are valuable as a sink for water during peak flow periods after heavy rainfall, and perhaps most importantly, we believed that the marshes serve a valuable function in the processing and storage of nutrients. It was obvious to us that it was necessary to document the ecological and social significance of the marshlands. As a result, our research was expanded to include important functional aspects of the marshes. This report summarizes our research to date.

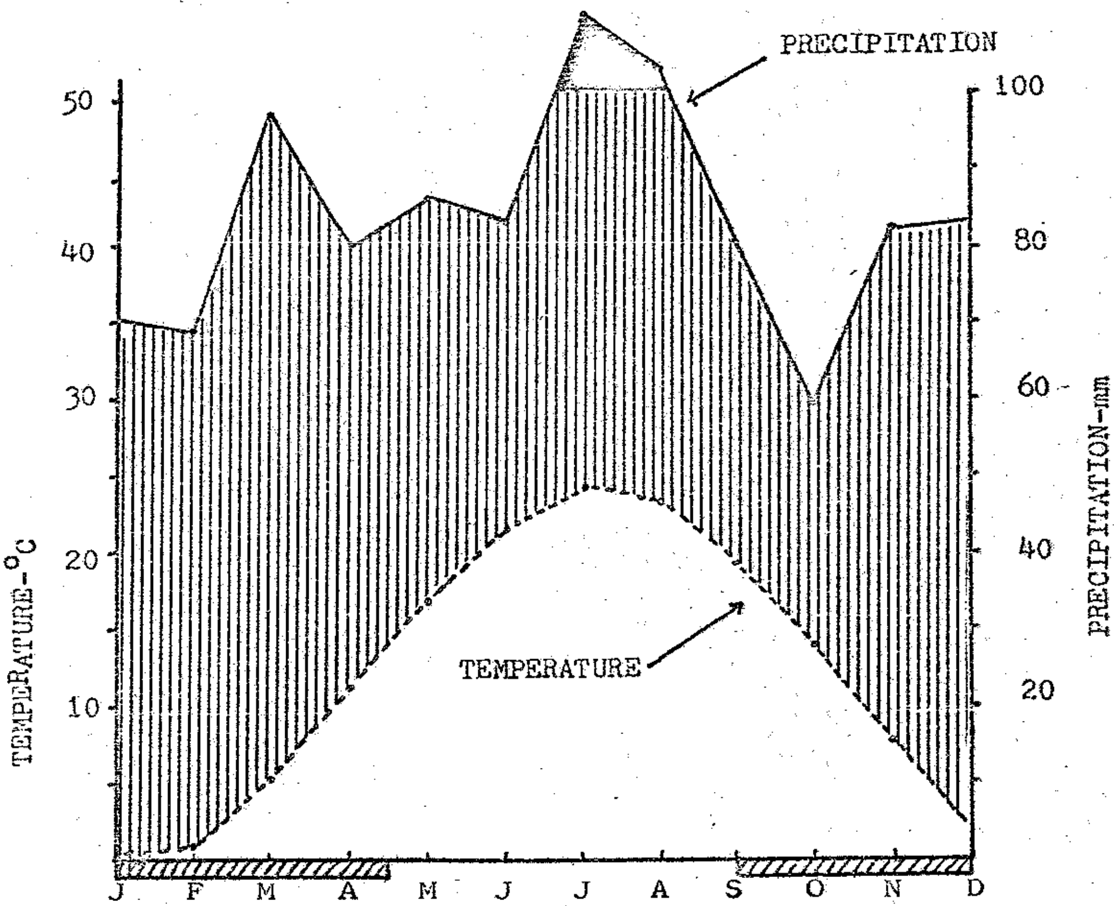
CLIMATE

Trenton has a typical temperate climate (Walter and Lieth, 1960) with a cold but not long winter (Figure 1).

Precipitation averages 1020 mm annually and it is fairly evenly distributed with a maximum in July and a minimum in October. The average temperature is 12.1°C and the growing season lasts from mid-April until late September. Within the Hamilton Marshes, water supply is always adequate and temperature, along with photoperiod, seem to be the most important factors in controlling biological activities of organisms.

Figure 1. Climatic diagram for Trenton, N.J. The mean annual temperature and precipitation are shown next to the climatic station name. Because the precipitation curve is always above the temperature curve, the climate is interpreted as not having a dry season. Along the abscissa are plotted the months of the year (January - December) and a shaded area which shows the number of months during which there is a chance of temperatures that fall below 0°C. Trenton has a Type VI climate according to the system of Walter and Lieth (1960). Precipitation above 100 mm per month is plotted on the scale of 1:3 (10°C:30mm ppt.).

TRENTON 12.1°C 1020 mm



SOILS

Introduction

The U.S. Department of Agriculture Soil Conservation Service (Markley, 1971) classifies all substrates within the Hamilton Marshes as tidal marsh soils. They are highly organic silt flat soils that are flooded twice daily. The Soil Conservation Service describes the soils as "brownish" with "an average thickness of about three feet". In places the soil might be as thick as 10 feet or as shallow as one foot. "Below the layers of silt are sand and gravel and, in some places, clay". Little other technical data is provided by the Soil Conservation Service, primarily because the soils are of minimal economic value.

We have collected substrate samples throughout the marsh (Figure 2 and Table 1), and have or will perform various analyses on them. To date, we have determined organic matter, nitrate nitrogen, and ammonium nitrogen for an entire set of samples. The samples will also be analyzed for phosphorous, magnesium, calcium, potassium, and sodium.

Methods

Soil cores were taken with a Weldco light duty gravity type core sampler. A preliminary study showed that the instrument provided a sample which covered most of the rooting zone of the vegetation - approximately the upper 50 cm.

Figure 2. Schematic diagram of the Hamilton Marshes. The pattern of water movement into and out of the marsh is shown at the lower right.

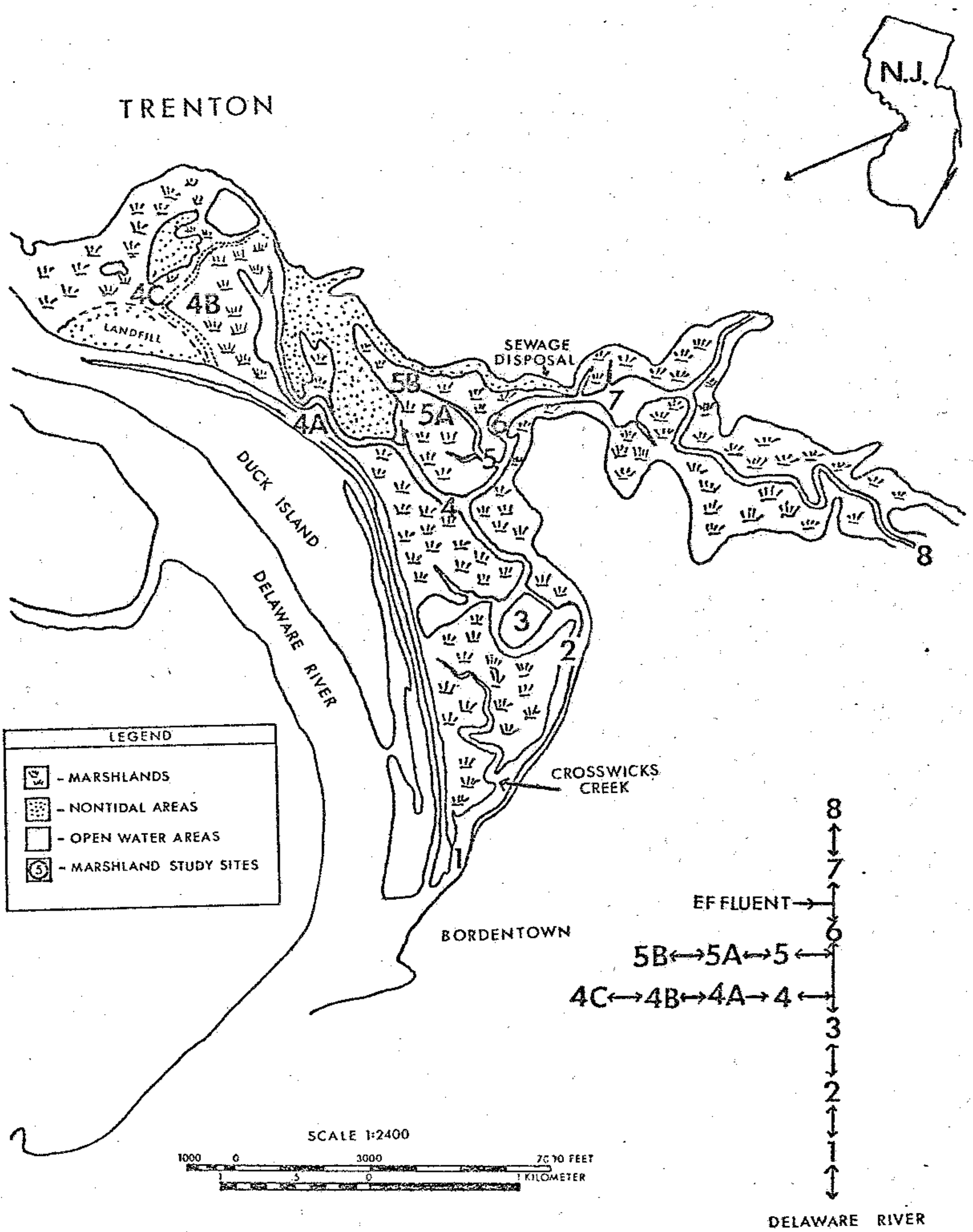

TRENTON
N.J.
4C
4B
LANDFILL
SEWAGE
DISPOSAL
5B
5A
4A
5
6
7
8
4
3
2
1
DUCK ISLAND
DELAWARE RIVER
CROSSWICKS
CREEK
BORDENTOWN
LEGEND
- MARSHLANDS
- NONTIDAL AREAS
- OPEN WATER AREAS
- MARSHLAND STUDY SITES
SCALE 1:2400
FEET
KILOMETER
EFFLUENT
5B↔5A↔5↔
4C↔4B↔4A→4↔
DELAWARE RIVER

Table 1

This table shows which experiments were performed (+) at each of the sites. See Figure 2 for the location of the sites.

EXPERIMENT

	PRIMARY PRODUCTION	WATER CHEMISTRY	DETRITUS	LITTER DECOMPOSITION	SOIL NUTRIENTS	SOIL ALGAE	WILD RICE STUDY
Site 1	-	+	-	-	-	-	-
Site 2	-	+	+	-	-	-	-
Site 3	+		-	-	+	-	-
Site 4	-	+	+	-	-	-	-
Site 4A	+	+	-	+	+	+	+
Site 4B	+	+	-	+	+	-	+
Site 4C	+	+	-	-	-	-	-
Site 5	+	+	-	+	+	+	+
Site 5A	+	+	-	+	+	+	+
Site 5B	+	-	-	-	+	+	+
Site 6	-	+	-	-	-	-	-
Site 7	+	+	+	-	+	+	+
Site 8	-	+	-	-	-	-	-

Samples were collected in the field by driving the sampler into the substrate and removing the core. Samples were collected in the major vegetation zones. The cores were returned to the laboratory and sliced into sections representing 10 centimeter depth intervals. The plugs were then air dried and ground to pass through a 2mm soil sieve. Organic matter was determined by ignition in a muffle furnace at 600°C. Nitrogen content was determined by using a microdiffusion technique (Stanford, et al, 1973). Initially samples were analyzed in duplicate but because there was very little variability between subsamples of the same soil plug, we decided to perform one analysis. In the future we will combine corresponding plugs from 3 soil cores at each sampling area. Triplicate determinations will be made on the combined plugs.

Results

Table 2 shows the results of the organic matter determinations. With one exception, there is no significant trend in organic matter from the top of the soil to the 50 cm level and there is only a slight decrease in organic matter from the top to the bottom of the profile. The exception is at Site 4A where there is a sharp decrease in organic matter between 20 and 30 cm. We attribute this to the fact that the nearby stream probably flowed over that site at one time and that it has since changed course and a soil has been built upon the old stream bed.

The amount of organic matter in the soils of the marsh is much

Table 2. Organic matter analysis of marsh soils. Refer to Figure 2 for locations of the sampling sites. All values are means (%) ± 1 standard error.

Table 2

ORGANIC MATTER CONTENT OF MARSH SOILS

Site Number		7	7	7
Dominant Vegetation		Yellow Water lily	Arrow arum	Sweet flag
Number of samples		1	1	1
Soil Horizon	0-10 cm	13.2	21.1	30.0
	10-20 cm	13.8	16.2	X
	20-30 cm	14.3	16.1	34.2
	30-40 cm	14.7	15.4	23.8
	40-50 cm	14.6	12.4	21.2
MEAN ± 1 $S.E._{\bar{X}}$:		14.1 ± .6	18.7 ± 6.6	27.3 ± 5.9

Site Number		5	5	5
Dominant Vegetation		Yellow Water lily	Arrow arum	Reed Canary grass
Number of samples		4	2	3
Soil Horizon	0-10 cm	13.4 ± 2.0	15.2 ± .9	18.1 ± 4.1
	10-20 cm	13.3 ± 2.3	15.8 ± .5	17.9 ± 1.0
	20-30 cm	16.1 ± 3.7	16.8 ± 0.	15.8 ± 2.5
	30-40 cm	12.4 ± 1.2	16.3 ± .5	14.1 ± 2.1
	40-50 cm	12.0 ± 2.0	12.5 ± .8	12.8 ± 1.6
MEAN ± 1 $S.E._{\bar{X}}$:		13.4 ± 2.6	15.3 ± 1.6	15.8 ± 3.0

		5A	5A	5A
Site Number		5A	5A	5A
Dominant Vegetation		Yellow Water lily	Arrow arum	Sweet flag
Number of samples		3	2	3
Soil Horizon	0-10 cm	20.4 ± 1.6	21.4 ± 1.0	28.6
	10-20 cm	20.7 ± 1.1	22.3 ± 2.5	24.5 ± 2.0
	20-30 cm	20.3 ± 2.4	20.1 ± .7	36.6 ± .2
	30-40 cm	19.7 ± 6.6	18.7 ± 5.5	23.4 ± .4
	40-50 cm	15.3 ± 7.7	21.2 ± 1.9	22.3 ± .2
MEAN ± 1 S.E.$_{\bar{X}}$:		19.3 ± 4.5	20.7 ± 2.5	26.8 ± 5.8

Site Number		5B	5B
Dominant Vegetation		Arrow arum	Cattail and Sweet flag
Number of samples		3	4
Soil Horizon	0-10 cm	21.7 ± 5.9	46.5 ± 5.1
	10-20 cm	26.5 ± 2.5	44.5 ±10.1
	20-30 cm	29.2 ± 9.1	45.7 ± 7.2
	30-40 cm	37.8 ± 3.3	41.8 ±13.0
	40-50 cm	39.1 ± 5.6	19.3 ± 4.7
MEAN ± 1 S.E.$_{\bar{X}}$:		30.6 ± 7.8	39.6 ±12.6

Site Number		4A	4A	4A
Dominant Vegetation		Loosestrife	Arrow arum	Cattail
Number of samples		2	3	3
Soil Horizon	0-10 cm	25.3 ± 4.5	20.3 ± 2.9	23.3 ± 3.3
	10-20 cm	22.3 ± 5.8	15.5 ± 3.5	27.9 ± 2.5
	20-30 cm.	15.7 ± 5.4	7.8 ± 1.3	22.5 ± 1.5
	30-40 cm	8.4 ± 1.4	4.5 ± .6	12.4 ± 3.6
	40-50 cm	5.0 ± .2	4.2 ± .5	6.1 ± 1.1
MEAN ± 1 $S.E._{\bar{X}}$:		15.3 ± 9.0	10.5 ± 6.8	18.4 ± 8.6

higher than most upland forest or agriculture soils but not as high as one finds in peat dominated soils. The fact that there is little differentiation from the top of the substrate to a depth of 50 cm implies that the conditions of deposition have not changed drastically for a long period of time, probably since sections of the marsh were diked. Our experience has been that most of the movement of inorganic sediment takes place in or near the channels. During the summer there is a net increase in the amount of material in the channels, probably due to the presence of vegetation which acts as a trap, and that during the winter months much of the accumulated sediment is washed away.

There are significant differences between the amounts of organic matter at different habitats. Areas dominated by yellow water lily, mostly in and along stream channels, have lower amounts of organic matter (Table 2). This is probably due to the scouring effects of tidal waters. High marsh areas have higher amounts of organic matter. Except for Site 4A, most of the arrow arum areas have between 10-15% organic matter. There are locations in the marsh where the substrate is extremely soft and walking is very precarious. Under those circumstances we have measured the greatest amounts of organic matter. Site 5B is an example of this situation. Sweet flag and cattail dominate the area and the organic matter is as high as 30-40%. One section of Site 5A is dominated by sweet flag and the amount of organic matter is greater at that location also (Table 2).

Total inorganic nitrogen (nitrate and ammonium) of soils in the Hamilton Marshes is not appreciably different from surface organic layers of many soils. There is, however, a significant difference in the relative amounts of nitrate nitrogen (NO_3^-) and ammonium (NH_4^+) nitrogen. The inorganic forms of nitrogen in most soils are ammonium, nitrate, and nitrite (American Society of Agronomy, 1965). Under most conditions, nitrite is present in very small amounts compared to the other forms and the quantity is usually assumed to be negligible. Ammonium is primarily formed as a result of the breakdown of organic matter. Under aerobic conditions (with oxygen present in the soil) NH_4^+ is usually short-lived and is oxidized to nitrate nitrogen, with nitrite as an intermediate in the process. As a result, most soils contain more nitrate than ammonium. Under anaerobic (lack of oxygen) conditions, the ratio is changed. Because there is little oxygen and because of low pH there is usually little nitrification in anaerobic soils. As a result, ammonium accumulates and it is more abundant than nitrate. Such is the case in the Hamilton Marshes. Table 3 shows our summary statistics for inorganic nitrogen in the marsh soils. There are no significant differences between sites. Values ranged from 19.7 ± 2.2 ppm to 29.5 ± 6.6 ppm. Within sites, differences do occur. In areas where the substrate is very

Table 3

Summary statistics for ammonium and nitrate nitrogen. All values are ppm ± 1 standard error.

	Dominant Vegetation						
	Arrow-arum	Yellow water lily	Sweet flag	Cattail	Loosestrife	Other	Site Average
Site 7	40.2 ± 20	15.7 ± 3.9	29.8 ± 6.0	X	X	X	28.6 ± 7.1
Site 5	20.9 ± 1.7	14.6 ± 2.5	X	X	X	17.9 ± 2.5	20.6 ± 1.5
	17.7 ± 3.5	25.0 ± 12.5				24.1 ± 5.2	
						24.3 ± 12.5	
Site 5A	32.0 ± 3.9	11.1 ± 1.6	43.2 ± 25.8	X	X	X	27.8 ± 4.4
	24.8 ± 11.6	14.7 ± 2.2	40.0 ± 8.4				
		17.8 ± 1.3	38.7 ± 10.2				
Site 5B	12.2 ± 3.8	X	46.3 ± 8.7	34.6 ± 2.2	X	X	29.5 ± 6.6
	16.8 ± 3.8			49.6 ± 2.8			
	17.2 ± 1.8						
Site 4A	11.3 ± 9.9	X	X	28.3 ± 5.7	21.6 ± 7.2	X	19.7 ± 2.2
	14.9 ± 6.7			23.2 ± 6.8	15.9 ± 7.8		
				28.0 ± 13.3			
Average for Vegetation Type	20.8 ± 2.9	16.5 ± 1.9	39.6 ± 2.8	31.7 ± 4.9	18.8 ± 2.8	22.1 ± 3.6	

soft and highly organic, the soil is waterlogged (sweet flag and cattail areas at Sites 5A and 5B) and there is significantly more nitrogen, especially ammonium. Habitats dominated by yellow water lily are somewhat lower in nitrogen (16.5 ± 1.9 ppm) and as stated, they are also lower in organic matter. Table 4 shows detailed ammonium and nitrate data for the study sites.

Table 4. Ammonium and nitrate data for marsh soils. Refer to Figure 2 for locations of the sample sites. All values are means (ppm) $\pm$ 1 standard error.

Table 4

AMMONIUM AND NITRATE CONTENT (p.p.m.) OF MARSH SOILS ± 1 STANDARD ERROR

Site Number		7	7	7
Dominant Vegetation		Arrow arum	Yellow water lily	Sweet flag
Number of samples		1	1	1
Soil Horizon	0-10 cm	X	9.5 ± .8	36.3 ± 4.9
	10-20 cm	37.2 ± 5.5	12.4 ± .9	18.8 ± 2.3
	20-30 cm	33.8 ± 4.8	17.0 ± 1.6	24.2 ± 2.1
	30-40 cm	14.2 ± 1.1	15.5 ± 1.3	28.8 ± 6.2
	40-50 cm	52.3 ± 11.8	18.3 ± 1.3	28.7 ± 2.8
		40.2 ± 20.0	15.7 ± 3.9	29.8 ± 6.0

Site Number		5	5	5	5
Dominant Vegetation		Arrow arum	Arrow arum	Yellow water lily	Yellow water lily
Number of samples		1	2	1	2
Soil Horizon	0-10 cm	18.5 ± 2.4	11.1 ± 2.3	11.6 ± 1.6	36.2 ± 5.0
	10-20 cm	18.2 ± 2.5	12.1 ± 2.7	10.2 ± 1.2	25.4 ± 2.8
	20-30 cm	17.1 ± 2.3	17.2 ± 2.3	10.7 ± 1.3	15.7 ± 2.8
	30-40 cm	18.0 ± 2.0	17.4 ± 1.9	14.3 ± 1.5	11.4 ± .9
	40-50 cm	20.1 ± 3.6	18.5 ± 3.3	15.8 ± 1.7	X
		20.9 ± 1.7	17.7 ± 3.5	14.6 ± 2.5	25.0 ± 12.5

Site Number		5	5	5	5A
Dominant Vegetation		Reed canary grass	Reed canary	Reed canary	Arrow arum
Number of samples		1	2	3	1
Soil Horizon	0-10 cm	15.1 ± 1.8	10.2 ± 1.9	18.1 ± 1.8	29.7 ± 4.6
	10-20 cm	16.3 ± 2.7	24.9 ± 2.9	27.5 ± 3.5	31.9 ± 5.7
	20-30 cm	16.7 ± 1.8	26.2 ± 4.5	21.7 X	26.6 ± 3.9
	30-40 cm	13.2 ± 1.0	15.4 ± 1.6	17.0 ± 1.5	25.2 ± 3.9
	40-50 cm	19.3 ± 1.5	X	24.8 ± 2.8	24.9 ± 3.4
		17.9 ± 2.5	24.3 ± 12.7	24.1 ± 5.2	32.0 ± 3.9

Site Number		5A	5A	5A	5A
Dominant Vegetation		Arrow arum	Sweet flag	Sweet flag	Sweet flag
Number of samples		2	1	2	3
Soil Horizon	0-10 cm	21.9 ± 2.3	21.5 ± 2.0	28.6 ± 3.7	35.1 ± 5.6
	10-20 cm	21.5 ± 1.9	30.5 ± 10.3	32.6 ± 4.3	34.4 ± 5.1
	20-30 cm	11.0 ± .7	53.2 ± 13.2	41.8 ± 7.5	24.3 ± 3.6
	30-40 cm	34.6 ± 5.4	37.7 ± 5.2	23.8 ± 2.3	34.7 ± 5.6
	40-50 cm	X	53.5 ± 10.5	41.5 ± 7.3	42.8 ± 8.8
		24.8 ± 11.6	43.2 ± 25.8	38.7 ± 10.2	40 ± 8.4

Site Number		5A	5A	5A
Dominant Vegetation		Yellow water lily	Yellow water lily	Yellow water lily
Number of samples		1	2	3
Soil Horizon	0-10 cm	9.8 ± 1.6	10.5 ± 3.0	14.7 ± 2.2
	10-20 cm	13.6 ± 2.1	7.8 ± 2.0	14.5 ± 2.2
	20-30 cm	14.0 ± 2.7	8.7 ± 1.7	15.0 ± 2.2
	30-40 cm	11.4 ± 1.7	8.3 ± 1.6	16.1 ± 2.2
	40-50 cm	13.1 ± 3.1	9.6 ± 2.3	17.2 ± 2.6
		14.7 ± 2.2	11.1 ± 1.6	17.8 ± 1.3

Site Number		5B	5B	5B
Dominant Vegetation		Arrow arum	Arrow arum	Arrow arum
Number of samples		1	2	3
Soil Horizon	0-10 cm	14.8 ± 2.7	16.5 ± 3.0	13.8 ± 2.0
	10-20 cm	11.3 ± 2.3	12.6 ± 2.5	16.2 ± 2.7
	20-30 cm	11.0 ± 2.2	17.2 ± 3.1	12.2 ± 2.7
	30-40 cm	6.3 ± 1.4	15.2 ± 3.0	16.7 ± 2.3
	40-50 cm	7.7 ± 1.6	8.8 ± 2.1	15.3 ± 2.6
		12.2 ± 3.8	16.8 ± 3.8	17.2 ± 1.8

Site Number		5B	5B	5B	4A
Dominant Vegetation		Cattail	Cattail	Sweet flag	Arrow arum
Number of samples		1	2	1	1
Soil Horizon	0-10 cm	30.7 ± 5.6		37.5 ± 8.7	20.7 ± 3.0
	10-20 cm	30.7 ± 5.6	43.0 ± 9.0	36.8 ± 6.7	13.3 ± 2.0
	20-30 cm	29.7 ± 4.6	42.0 ± 9.9	32.2 ± 4.8	9.1 ± 2.0
	30-40 cm	27.4 ± 4.3	38.1 ± 8.2	38.3 ± 5.9	X
	40-50 cm	X ± 4.9	40.4 ± 7.8	52.8 ± 7.8	5.8 ± 1.1
		34.6 ± 2.2	49.6 ± 2.8	46.3 ± 8.7	11.3 ± 9.9

Site Number		4A	4A	4A	4A
Dominant Vegetation		Arrow arum	Cattail	Cattail	Cattail
Number of samples		2	1	2	3
Soil Horizon	0-10 cm	X	X	41.8 ± 3.5	23.9 ± 3.6
	10-20 cm	12.7 ± 1.3	25.0 ± 3.7	24.3 ± 4.0	24.8 ± 4.0
	20-30 cm	19.1 ± 1.7	25.0 ± 4.2	22.3 ± 2.8	X
	30-40 cm	17.6 ± 1.4	16.2 ± 2.9	11.5 ± 1.8	17.2 ± 2.4
	40-50 cm	5.4 ± 9.0	14.3 ± 1.6	X	11.5 ± 5.9
		14.9 ± 6.7	23.2 ± 6.8	28.0 ± 13.3	28.3 ± 5.7

Site Number		4A	4A
Dominant Vegetation		Loosestrife	Loosestrife
Number of samples		1	2
Soil Horizon	0-10 cm	X	24.5 ± 6.2
	10-20 cm	21.2 ± 4.2	20.2 ± 2.9
	20-30 cm	17.0 ± 1.0	16.1 ± 2.7
	30-40 cm	10.5 ± 2.5	11.5 ± 2.2
	40-50 cm	6.5 ± .5	X
		15.9 ± 7.8	21.6 ± 7.2

VEGETATION

Research in 1974 focused on the open marsh areas because we did not have sufficient personnel to continue our investigations of the forests and shrub forests that were described in our previous work (Whigham, 1974). We are hopeful that we will be able to examine the ecological significance of the shrub forests at a later date.

A. VEGETATION ANALYSIS

1. Introduction

A considerable volume of vegetation data was collected in 1974. We have found a considerable number of discrepencies between our interpretation of vegetation patterns and the manner in which vegetation patterns are portrayed on the New Jersey Wetland Maps (N.J.D.E.P., 1972). We have described these dissimilarities to officials of the New Jersey Department of Environmental Protection and they have expressed concern about the discrepancies. They are presently working with the contract company that produced the maps in order to determine why the discrepancies exist and to correct them if necessary. We believe that this is another valuable contribution of our work.

2. Results

Vegetation of the forests, shrub forests, and open marsh areas was analyzed in 1973 (Whigham, 1974). Our interpretation of the vegetation patterns has been modified since our first report.

We interpret the marshes as being divided into four habitats: (1) streams and stream banks - included in this category are drainage channels that connect streams to high marsh areas, (2) high marsh areas, (3) sections of the marsh that are pond-like at high tide and drained at low tide, and (4) areas that are continuously covered by water. Several vegetation types exist in each habitat (Table 5). There is much overlap between the vegetation types and it is difficult to delineate between them.

High marsh areas (vegetation types 6,7,9,10) cover approximately 137 hectares (Table 6). Compared to those vegetation types, others occupy a much smaller area. Vegetation types dominated by yellow water lily occupy approximately 58 hectares. Cattail and wild rice vegetation types occupy 19 and 24 hectares respectively. The remaining vegetation types are minor components in terms of their aerial coverage.

Table 5. Our interpretation of major habitates and associated vegetation typé in the Hamilton Marshes. Refer to Figure 2 for site locations. Dominant species are underlined.

HABITAT TYPE (see Figure 2 for site location)	VEGETATION TYPE
I. Stream channels (Site 5A)	1. Yellow water lily, wild rice, wild celery, arrowhead, water millfoil
Stream banks (exposed at low tide) (Site 5, 5A, 7)	2. Yellow water lily, water hemp, arrowhead, pickerelweed, water smartweed, wild rice
Drainage channels that connect streams to high marsh areas (Sites 4A, 5, 5A, 7)	3. Yellow water lily, wild rice, pickerelweed, water smartweed, water hemp
II. High marsh areas (Sites 3, 4A, 5, 5A, 7)	4. Cattail (3 species), arrow arum, sweet flag, touch-me-not, tearthumbs, marsh mallow
	5. Swamp loosestrife, arrow arum, tearthumbs, touch-me-not, marsh mallow
	6. Sweet flag, arrow arum, tearthumbs, touch-me-not
	7. Bur marigold, arrow arum, tearthumbs, arrowhead, water hemp, touch-me-not
	8. Giant ragweed, arrow arum, touch-me-not, tearthumbs
	9. Reed canary grass
	10. Wild rice, bur marigold, sweet flag, arrow arum
III. Pond-like environments that are water covered at high tide and exposed at low tide (Site 4B)	11. Yellow water lily, pickerelweed, water smartweed, arrowhead, wild rice, swamp loosestrife
	12. Arrow arum, wild rice, arrowhead, water smartweed
	13. Swamp loosestrife, arrow arum, yellow water lily, marsh mallow
	14. Cattail, arrow arum, water smartweed

IV. Ponds that are continuously water covered (Site 4C)	15. Marsh mallow, swamp loosestrife, arrow arum, yellow water lily
	16. Yellow water lily, pickerelweed, Elodea, pondweeds, water smartweed
	17. Swamp loosestrife, yellow water lily, arrow arum, water smartweed, marsh mallow
	18. Marsh mallow, yellow water lily, arrow arum, water smartweed, swamp loosestrife

Table 6: Aerial extent and total aboveground production estimates for dominant vegetation associations of the Hamilton Marshes.

VEGETATION TYPE	COVERAGE (HA)	ANNUAL ABOVEGROUND PRODUCTION (T/HA)	TOTAL PRODUCTION (T)
Mixed	137	9.1	1246.7
Cattail	19	13.2	250.8
Giant Ragweed	3	11.6	34.8
Arrow arum	11	6.5	71.5
Spiked Loosestrife	10	21.0	210.0
Wild Rice	24	9.4	225.6
Yellow Water Lily	58	7.8	452.4
TOTAL	262	$\overline{X}$ = 9.5	2491.8

B. PRIMARY PRODUCTIVITY

1. Introduction

Using the vegetation scheme given in Table 5, we designed a stratified random sampling procedure to study primary production of marsh vegetation throughout the 1974 growing season. Figure 2 and Table 1 show and list the locations of our sample areas. Within each vegetation type, all vascular plants in three $\frac{1}{4}m^2$ quadrats were harvested. The sampling breakdown was a follows:

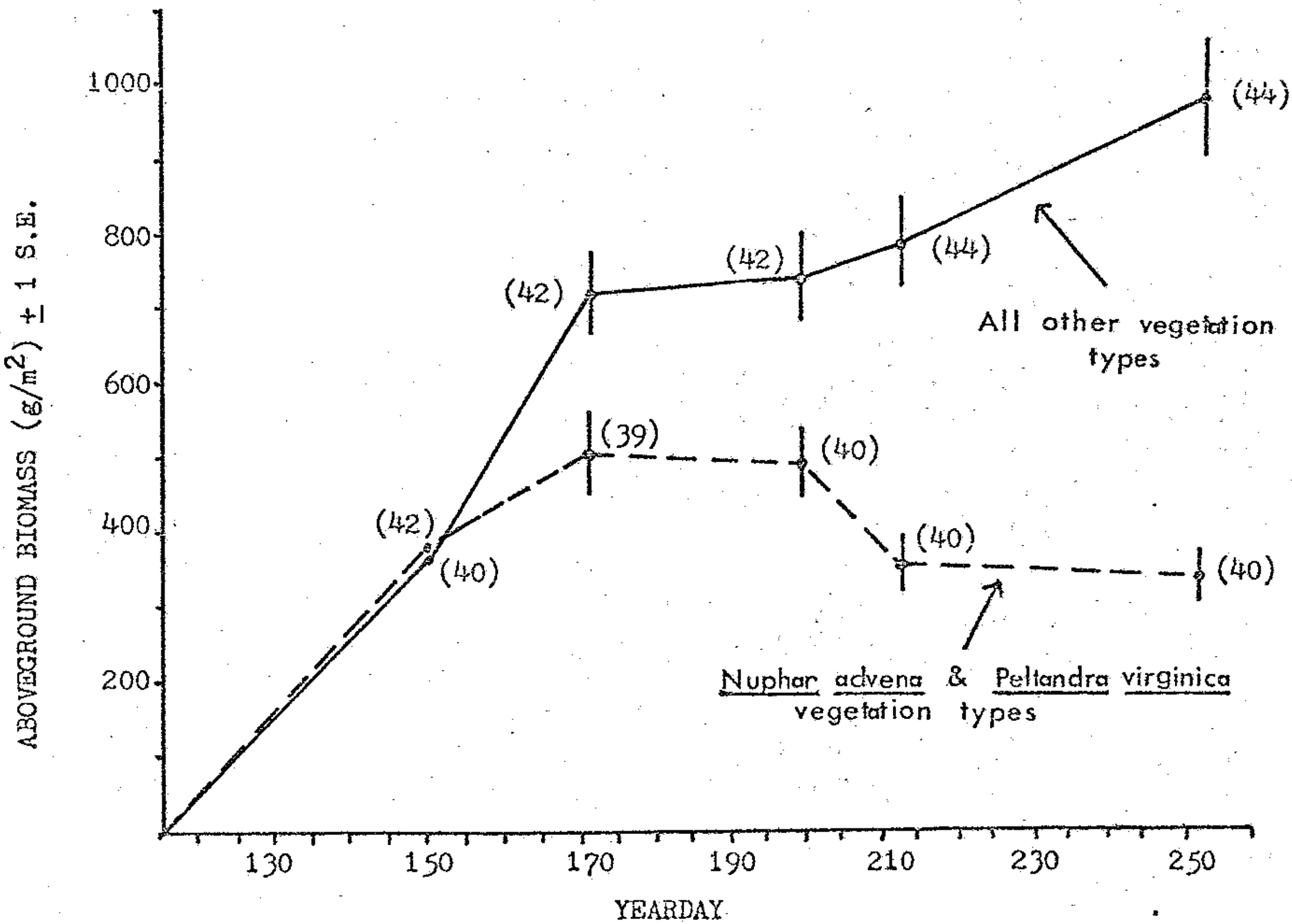
	Vegetation types sampled (from Table 5)	Total number of quadrats samples per sampling date	Total number of samples collected during growing season
Site 7	2,10,6	9	54
Site 5	2, 7,9	9	54
Site 5A	3,10,6,7	12	72
Site 5B	4, 6,7	12	72
Site 4C	16	3	18
Site 4B	12,11	9	54
Site 4A	4, 5,10	12	72
Site 3	2, 6, 7, 4	12	72
			468

All samples were returned to the laboratory where they were washed, separated by species, and dried at 105°C.

2. Results

Seasonal primary production patterns of the entire marsh are shown in Figure 3. The data have been separated into two categories: (1) sites dominated by arrow arum and/or yellow water lily, and (2) all other sites. This separation was necessary because of a bimodal production patterns for both arrow arum and yellow water lily. Having no internal dormancy mechanisms, both species grow during the winter whenever temperatures are above

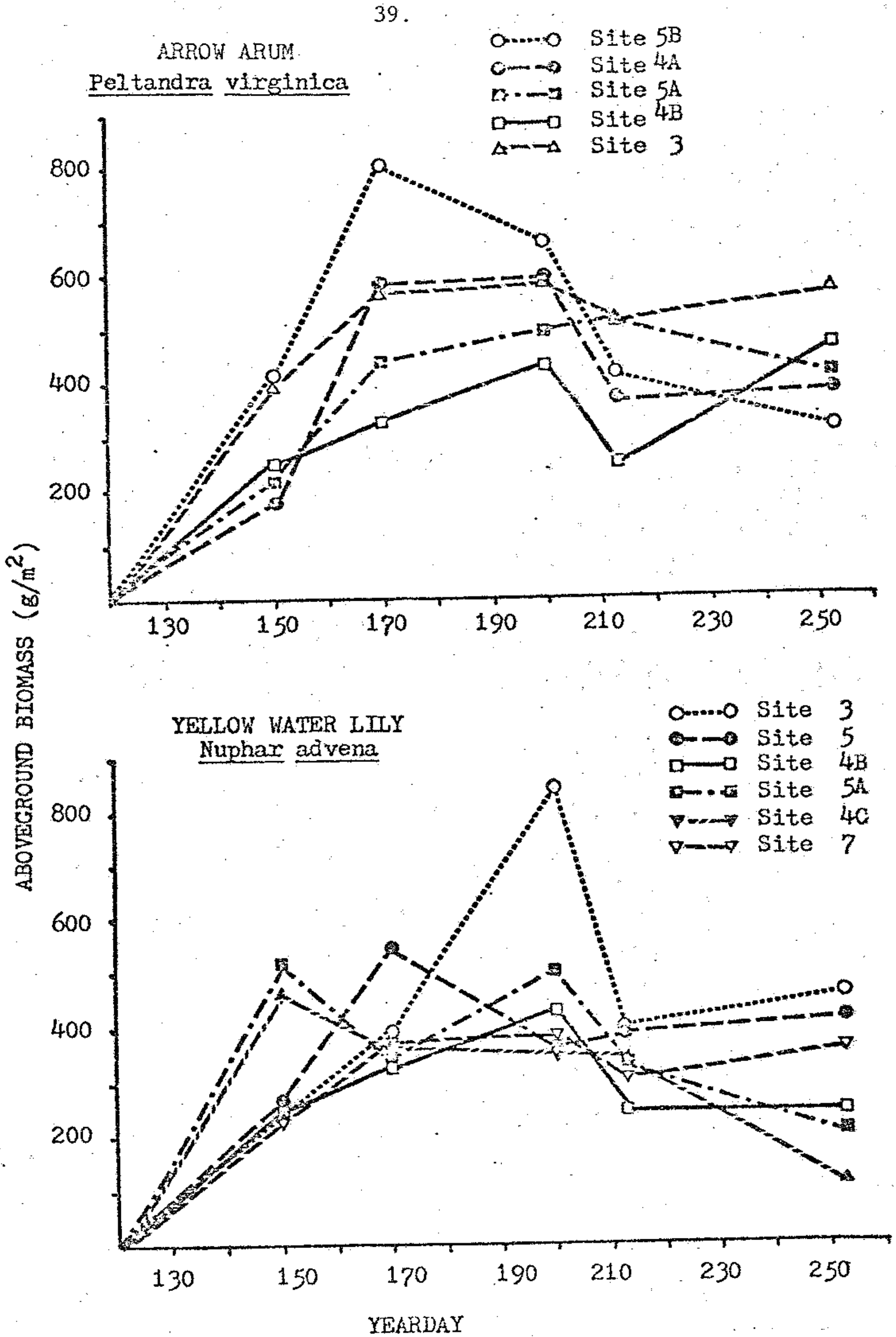
Figure 3. Aboveground primary production for all study sites. As described in the text, data were divided into two categories: (1) vegetation types dominated by <u>Nuphar advena</u> and <u>Peltandra virginica,</u> (2) all other vegetation types. Numbers in parenthesis represent sample size ($g/m^2 \times 10^{-2} = t/Ha$)


1000
800
600
400
200
ABOVEGROUND BIOMASS (g/m2) ± 1 S.E.
(42)
(40)
(42)
(39)
(42)
(40)
(44)
(40)
(44)
(40)
All other vegetation types
Nuphar advena & Peltandra virginica vegetation types
130
150
170
190
210
230
250
YEARDAY

freezing for several consecutive days. Initial growth is very rapid and both species assume aspect dominance throughout the marshes by May 30 (Figure 4).

Average daily aboveground production rates were 4.6-11.4 g/m^2 for arrow arum and 6.4-14.7 g/m^2 for yellow water lily during the period April 25 - May 30. For the period May 30 - June 20 daily aboveground production values were 7.9 - 16 g/m^2 for arrow arum. During the remainder of June and into July, the standing crop of both species remained fairly constant. Peak biomass was measured on either the June 20th or July 19th sampling periods. By mid-July, leaves of both species began to die and as a result the aboveground standing crop began to decrease on subsequent sampling dates. The decrease would have been more pronounced except that other species (mostly pickerelweed and arrowhead) were still growing and accounted for much of the biomass. Site 4C (Figure 4) is the best example of this die-off phenomenon. The area sampled is in a pond where the water level fluctuates very little during each tide cycle. Yellow water lily was the dominant species and it accounted for almost 100% of the cover. Other species in the area were submerged aquatics (water millifoil, waterweed, and pondweeds). Peak aboveground biomass at Site 4C was 460 g/m^2 (Figure 4). The standing crop remained fairly constant until late July when the yellow water lily dieback began. Many leaves died naturally while others were consumed by sucking insects. McCormick

Figure 4. Aboveground primary production of yellow water lily (*Nuphar advena*) and arrow arum (*Peltandra Virginica*) dominated marsh sites. ($g/m^2 \times 10^{-2} = T/Ha$) Refer to Figure 2 for site locations.



ARROW ARUM
Peltandra virginica
Site 5B
Site 4A
Site 5A
Site 4B
Site 3
800
600
400
200
130
150
170
190
210
230
250
ABOVEGROUND BIOMASS (g/m^2)
YELLOW WATER LILY
Nuphar advena
Site 3
Site 5
Site 4B
Site 5A
Site 4C
Site 7
YEARDAY

cited a similar die-off phenomenon in Oldmans Creek, a freshwater tidal marsh in Salem County, New Jersey (McCormick, 1972). In most populations there was renewed growth during September that lasted until the first heavy frosts. In one area where yellow water lily was completely gone after the dieback in late July, we measured new aboveground growth of 101.6, 278.4, and 366.0 g/m^2. Arrow arum also went through a die-off period in July. The die back began shortly after other plants began to overtop the arrow arum. Because arrow arum grows best during the high light regime of the early part of the growing season, it is most probable that the species was unable to maintain a positive photosynthesis to respiration ratio under the low light conditions that were present when the arrow arum was overlapped. Once the taller plants began to senesce, thus permitting higher amounts of solar radiation to reach the surface of the marsh, arrow arum produced a new crop of leaves. In some areas arrow arum assumed aspect dominance again. In the case of yellow water lily, the die-off didn't appear to be caused by low light conditions. If late season growth is considered, the total aboveground yearly production would be estimated at 700-800 g/m^2 for yellow water lily and arrow arum. This is an underestimate of total primary production for both species since a portion of the yearly net production is translocated to the underground stem where it is stored, used for maintenance, or used in vegetative propogation. A detailed presentation of the data used in Figure 4 is given in Table 7 .

Table 7

Aboveground biomass for Yellow Water lily and Arrow arum. All values are means (g/m^2) of 3 quadrats ± 1, S.E. X = no sample. Refer to Figure 2 for site locations.

Yellow Water lily

Site	7	5	5A	4C	4B	3
May 30	222 ± 128	266 ± 117	521 ± 74	460 ± 57	248 ± 14	X
June 29	362 ± 25	548 ± 147	346 ± 37	346 ± 47	323 ± 29	391 ± 70
July 19	380 ± 29	358 ± 32	501 ± 83	337 ± 32	427 ± 13	840 ± 283
August 1	305 ± 11	390 ± 67	332 ± 59	251 ± 55	242 ± 34	387 ± 44
September 10	361 ± 146	419 ± 134	201 ± 36	107 ± 39	244 ± 119	458 ± 145

Arrow Arum

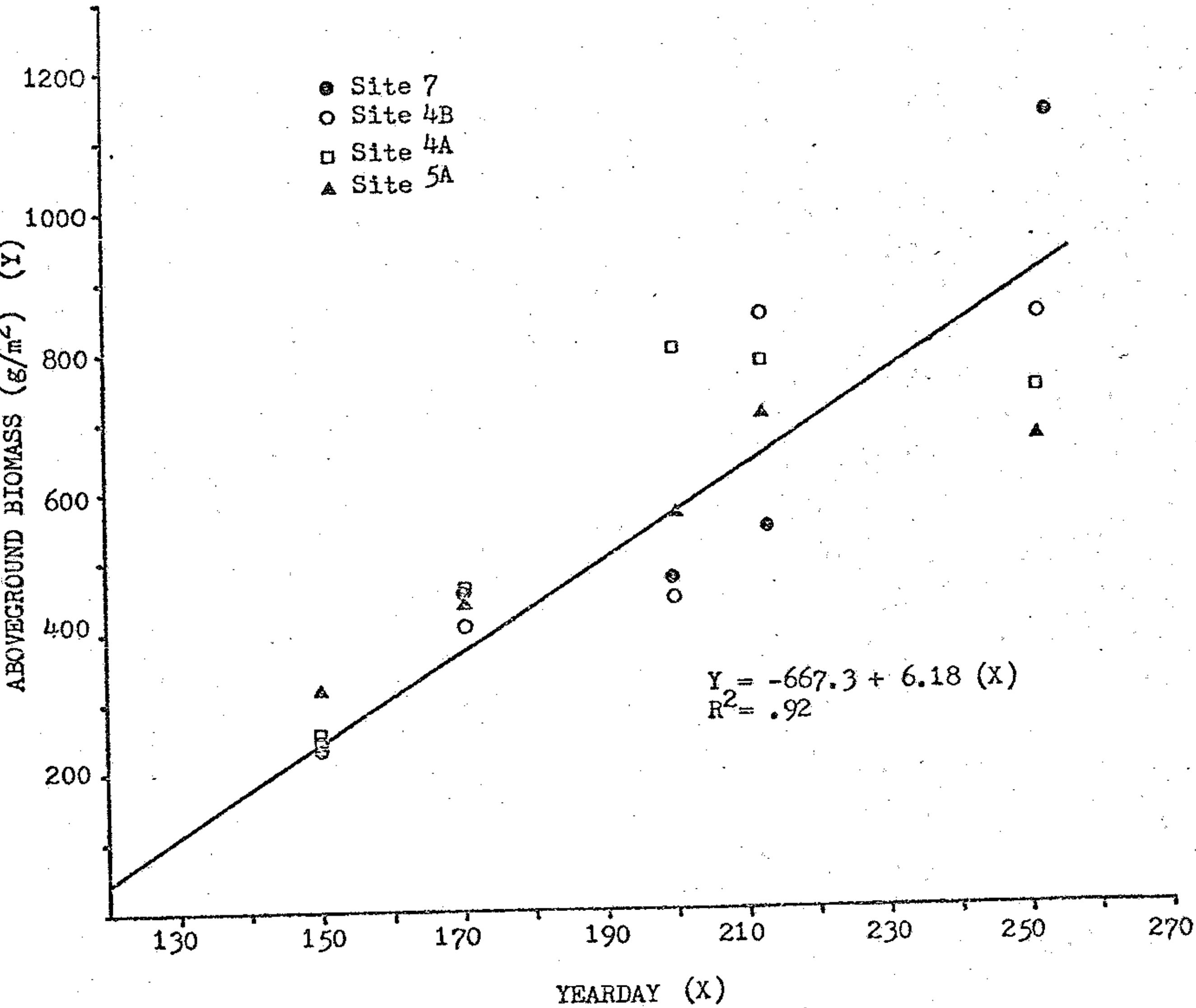
Site	5A	5B	4B	4A	3
May 30	270 ± 71	401 ± 44	248 ± 14	180 ± 53	389 ± 78
June 29	434 ± 79	802 ± 22	323 ± 29	588 ± 87	562 ± 112
July 19	490 ± 20	676 ± 234	427 ± 13	593 ± 32	576 ± 36
August 1	504 ± 235	410 ± 104	242 ± 34	365 ± 64	508 ± 23
September 10	403 ± 57	304 ± 130	468 ± 74	X	562 ± 112

In areas not dominated by yellow water lily or arrow arum, there was a continual increase in aboveground biomass throughout the growing season. Peak biomass averaged 980 g/m^2 in early September (Figure 3). The patterns of aboveground biomass accumulation were different for each community type due to differences in plant size and patterns of seasonal primary production.

Areas dominated by wild rice showed a linear increase in biomass throughout the growing season (Figure 5 and Table 8). Peak biomass varied between 659 and 1125 g/m^2 and daily production rates in those communities were between 4.8 - 8.6 g/m^2 per day. These values only account for aboveground biomass. Wild rice has a root:shoot ratio that averages .25. Adding 25% to the aboveground total production biomass, we estimated that the total production was between 800-1400 g/m^2. These values are comparable to the data obtained during the study of wild rice that is discussed in pgs. 124-144 of this report.

In areas dominated by annual species (primarily bur marigold, touch-me-not, and tearthumbs) primary productivity patterns were similar to those found in wild rice dominated areas. Peak aboveground biomass was 756-1162 g/m^2 (Figure 6 and Table 8). This corresponds to an average daily production rate of between 5.8 and 8.9 g/m^2.

Figure 5. Aboveground primary production of wild rice (<u>Zizania aquatica</u>) dominated marsh sites. Refer to Figure 2 for site locations. ($g/m^2 \times 10^{-2} = T/Ha$)



Site 7
Site 4B
Site 4A
Site 5A
ABOVEGROUND BIOMASS (g/m2) (Y)
1200
1000
800
600
400
200
130
150
170
190
210
230
250
270
YEARDAY (X)
Y = -667.3 + 6.18 (X)
R2= .92

Table 8. Aboveground production data for dominant vegetation types in the Hamilton Marshes. See Table 5 for a listing of species found in each vegetation type. ($g/m^2 \times 10^{-2} = T/HA$)

Table 4

I. Aboveground production in wild rice (Zizania aquatica) areas. Values are means (g/m^2) of 3 replicate samples ± 1, S.E. See Figure 2 for site locations.

	Site 7	5A	4B	4A
May 30	222 ± 77	310 ± 24	290 ± 123	223 ± 72
June	450 ± 72	442 ± 101	401 ± 45	451 ± 53
July	463 ± 75	561 ± 172	441 ± 31	796 ± 161
August	540 ± 39	700 ± 44	841 ± 67	774 ± 79
September	1125 ± 218	659 ± 74	835 ± 224	729 ± 94

II. Aboveground production in mixed vegetation mostly bur marigold (Bidens laevis) areas. Values are means of 3 replicate samples ± 1, S.E. See Figure 2 for site locations.

	Site 1	2A	2B
May	240 ± 41	203 ± 108	324 ± 12
June	579 ± 117	432 ± 65	547 ± 132
July	629 ± 168	492 ± 53	581 ± 43
August	635 ± 91	X	X
September	1160 ± 289	756 ± 86	1162 ± 332

III. Aboveground production in Sweet flag (*Acorus calamus*) areas. Values are means of 3 replicate samples ± 1, S.E. See Figure 2 for site locations.

	Site 5A	Site 5	Site 5	Site 3
May	450 ± 110	334 ± 68	328 ± 44	501
June	452 ± 36	624 ± 120	764 ± 272	712 ± 258
July	439 ± 96	739 ± 81	633 ± 234	580 ± 156
August	722 ± 41	711 ± 175	830 ± 81	478 ± 67
September	596 ± 72	946 ± 300	896 ± 89	418 ± 38

IV. Aboveground production in Cattail (*T. latifolia*, *T. angustifolia*, and *T. glauca*) areas. Values are means of 3 replicate samples ± 1, S.E. See Figure 2 for site locations.

	Site 5B	Site 4A	Site 3
May	505 ± 42	379 ± 47	X
June	939 ± 257	1119 ± 32	1528 ± 103
July	1189 ± 357	936 ± 176	1502 ± 250
August	932 ± 234	900 ± 88	1212 ± 25
September	975 ± 161	963 ± 78	1489 ± 239

V. Aboveground production in Swamp loosestrife (*Lythrum salicaria*) areas. Values are means of 3 replicate samples ± 1, S.E. See Figure 2 for site locations.

	Site
	4A
May	419 ± 147
June	1059 ± 300
July	1014 ± 82
August	1505*
September	2104 ± 104

* No sample was collected due to fantastic bee population working on *Lythrum* flowers. The value was estimated by regression analysis of biomass against yearday (r^2 = .99).