Structure and Function of a Freshwater Tidal-Marsh Ecosystem

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Grant No. 1313: For a study of the structure and function of a freshwater tidal-marsh ecosystem (Hamilton Marshes, Delaware River).[1]

In 1973 we began a series of investigations of ecological characteristics of a Delaware River freshwater tidal marsh. At that time, there had been few studies of freshwater tidal marshes (McCormick, Grant, and Patrick, 1970; McCormick, 1970; McCormick and Ashbaugh, 1972; Walton and Patrick, 1973) even though they are widespread in tidal portions of eastern North American rivers. Initially our studies were centered on the floristics of the marsh vegetation. Our primary objectives were to determine which species occurred in tidally influenced freshwater marshes and how the species segregated into community types. Additionally we wanted to determine whether or not freshwater tidal marshes were as productive as estuarine brackish marshes. Based on preliminary data, Walton and Patrick (1970) had suggested that freshwater tidal marshes were efficient nutrient processors. Therefore, a second phase of our work centered on the patterns of nutrient movement through and within the marshes by analyzing seasonal patterns of selected water quality parameters, particularly nitrogen and phosphorus.

The research was conducted in the 500-hectare Hamilton Marshes (fig. 1), which are the northernmost tidal marshes in the Delaware River. In addition to the marshes, located near Trenton, New Jersey, there are lowland forests, tidally influenced shrub forests, and a few shallow impoundments (Whigham, 1974). Table 1 summarizes the coverage and production data for the major marsh vegetation types.

[1] In addition to the National Geographic Society, we extend our thanks to the Hamilton Township Environmental Commission for its financial support and to the following students whose work on the project was supported by the Society's grant: Paula Bozowski, Herbert Grover, Barie Kline, Thomas Leslie, and David West.

TABLE 1. Aerial Extent and Total Aboveground Production Estimates for Dominant Vegetation Associations of the Hamilton Marshes

Vegetation type	*Coverage*	*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
Wildrice	24	9.4	225.6
Yellow waterlily	58	7.8	452.4
TOTALS	262	X = 9.5	2491.8

*t = ton, ha= hectare.

Structurally the marsh consists of several distinct habitats, including stream banks, high marsh, and pondlike areas. The most extensive habitat is the high marsh, which is usually flooded to a depth of half a meter or less only during 3 hours of a 12-hour tide cycle. There are several recognizable community types in this habitat even though most species are widespread and occur throughout the high marsh. The most common high-marsh community consists of sweetflag *(Acorus calamus)*, arrow arum *(Peltandra virginica)*, tearthumb *(Polygonum arifolium)*, bur marigold *(Bidens laevis)*, touch-me-not *(Impatiens capensis)*, wildrice *(Zizania aquatica)*, and arrowhead *(Sagittaria latifolia)*. Phenologically, sweetflag and arrow arum dominate the marsh landscape in the early part of the growing season, but they are eventually overtopped by wildrice, which dominates in July and August, and finally by bur marigold, which dominates until the end of the growing season. Several additional species, including giant ragweed *(Ambrosia trifida)*, cattail *(Typha angustifolia* and *T. latifolia)*, and purple loosestrife *(Lythrum salicaria)*, become dominant in other high-marsh communities (Whigham et al., 1978).

Stream-bank communities are dominated by waterlily *(Nuphar advena)*, pickerelweed *(Pontederia cordata)*, waterhemp *(Acnida cannabina)*, smartweed *(Polygonum punctatum)*, and wildrice *(Zizania aquatica)*. One large marsh area (site 4B in fig. 1) is pondlike and flooded to a depth of 1 meter at high tide and drained only at low tide. Waterlily, arrow arum, wildrice, cattail, smartweed, and pickerelweed dominate in this habitat.

In areas adjacent to upland habitats, the open marsh is replaced by a shrub forest, which is inundated at high tide. All the herbaceous species found in

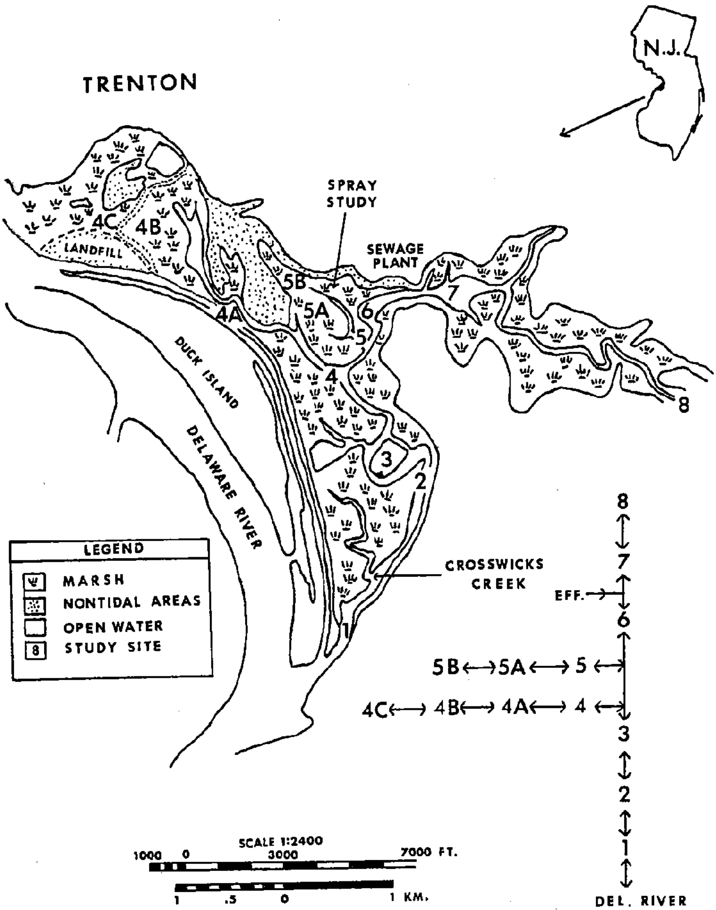

FIG. 1. Schematic diagram of the Hamilton Marshes. The pattern of water movement into and out of the marsh is shown at the lower right.

the open marsh plus several woody shrubs, the most common being arrowwood (*Viburnum dentatum*), red maple (*Acer rubrum*), alder (*Alnus serrulata*), and buttonbush (*Cephalanthus occidentalis*), occur in this transition zone.

Compared to salt marshes, the outstanding floristic characteristics of freshwater tidal marshes are high diversity and abundance, and, in some cases dominance, of annuals. The latter are virtually excluded from salt marshes, and whereas species richness is normally approximately 30 vascular plants in Delaware River salt marshes, there may be more than 60 species in freshwater

TABLE 2. Summary of Production Values for Marsh Plants

Community type (dominant)	*Aboveground net production (g/m²/yr)*	*Locale*	*Reference*
	(1) Freshwater Tidal Marshes		
Wildrice	605-1547	Pa.	McCormick, 1970
(*Zizania aquatica*)	659-1125	N.J.	Present study
	1390	N.J.	McCormick and Ashbaugh, 1972
Giant Ragweed	1211-1250	Pa.	McCormick, 1970
(*Ambrosia trifida*)	1160	N.J.	Present study
Yellow Waterlily	1166-1188	Pa.	McCormick, 1970
(*Nuphar advena*)	516	N.J.	McCormick and Ashbaugh, 1972
	775	N.J.	Present study
	245	Va.	Wass and Wright, 1969
Cattail	874-2063	Pa.	McCormick, 1970
(*Typha* sp.)	987	N.J.	McCormick and Ashbaugh, 1972
	1119-1528	N.J.	Present study
	930	Va.	Wass and Wright, 1969
Mixed	516- 897	Pa.	McCormick, 1970
(*Bidens laevis*)	756-1162	N.J.	Present study
Primrose willow (*Jussiaea repens*)	403- 583	Pa.	McCormick, 1970
Arrowhead (*Sagittaria* sp.)	628	Pa.	McCormick, 1970
Arrow arum	269	Pa.	McCormick, 1970
(*Peltandra virginica*)	500- 800	N.J.	Present study
Sweetflag (*Acorus calamus*)	712- 940	N.J.	Present study
Loosestrife	1749	Pa.	McCormick, 1970
(*Lythrum salicaria*)	2104	N.J.	Present study
Waterhemp (*Acnida cannabina*)	762	Pa.	McCormick, 1970
	(2) Salt Marshes between New York and Virginia		
Saltwater cordgrass	1332	Va.	Wass and Wright, 1969
(*Spartina alterniflora*)	445	Del.	M. H. Morgan, 1961
	300	N.J.	Good, 1965
Salt-meadow grass (*Spartina patens*)	805	Va.	Wass and Wright, 1969
Spike grass (*Fimbristylis* sp.)	360	Va.	Wass and Wright, 1969

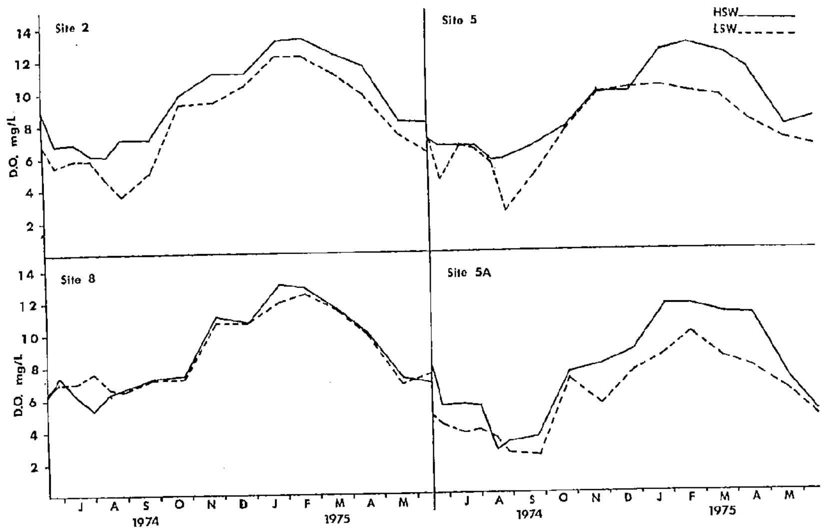

FIG. 2. Changes in dissolved oxygen (D.O.) at sites 2, 8, 5, and 5A in the Hamilton Marshes between May 1974 and July 1975. Solid lines represent high slack water (HSW) and dashed lines low slack water (LSW). Refer to figure 1 for location of sampling stations.

tidal marshes. Most likely the higher level of species richness is due to the lack of salt stress that is a normal feature in salt-marsh environments.

Table 2 shows biomass data for Delaware and Chesapeake Bay salt marshes and freshwater tidal marshes along the Delaware River from south of Philadelphia (Tinicum Marshes) to the Hamilton Marshes. It is apparent that, compared to saline marshes, a great number of community types occur in the freshwater tidal marshes. Even though the biomass data given for the freshwater marshes in table 2 represent underestimates of net production because of the seasonal changes in dominance (Whigham et al., 1978), it is obvious that freshwater tidal marshes are extremely productive and that they are probably more productive than salt marshes at the same latitude. We estimated a mean production of 950 g/m^2/yr in the Hamilton Marshes. Purple-loosestrife communities were the most productive (2100 g/m^2), while waterlily-dominated areas were the least productive (450 g/m^2).

The marshes are metabolically active throughout the year (Simpson et al., 1978), as shown in figures 2 and 3. Flood-tide waters from the Delaware River are consistently higher in oxygen and lower in carbon dioxide than waters

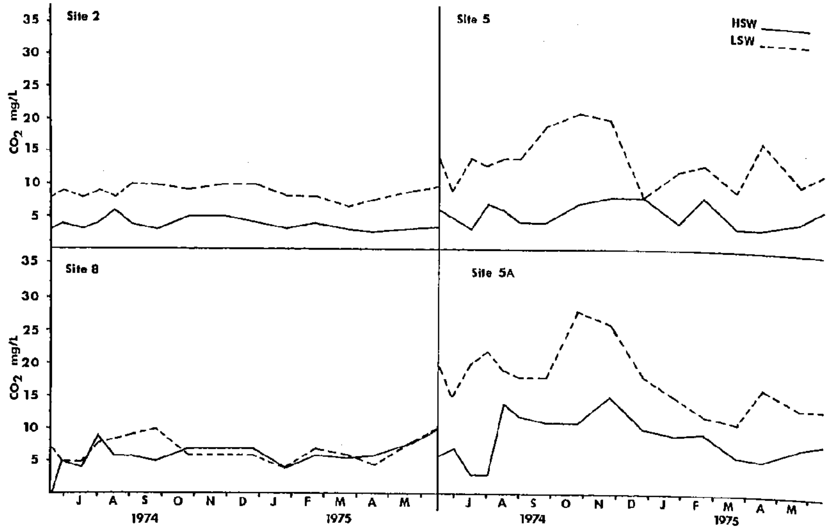

FIG. 3. Changes in carbon-dioxide content at sites 2, 8, 5, and 5A in the Hamilton Marshes between May 1974 and July 1975. Solid lines represent high slack water (HSW) and dashed lines low slack water (LSW). Refer to figure 1 for location of sampling stations.

leaving the marsh at low slack water (compare site 2 of figs. 2 and 3). The highest carbon-dioxide levels occur in October (site 5 and 5A, fig. 3), corresponding with the fall dieback of vascular plants in the marsh, suggesting that heterotrophic activity is most pronounced at that time.

High levels of productivity should be indicative of efficient nutrient utilization. Our water-quality studies (Simpson and Whigham, 1975; Simpson et al., 1978) demonstrated that nitrogen and phosphorus are assimilated by all marsh habitats during the growing season. Figures 4 and 5 demonstrate the seasonal pattern of nitrogen and phosphorus for high-marsh site 5A (fig. 1). During the summer nitrate and ammonia nitrogen and inorganic phosphate are assimilated, whereas during the winter they are exported. The pondlike areas (site 4B) were interesting because they appeared to assimilate nitrogen and phosphorus during the entire year (figs. 4, 5). Nutrient assimilation in the summer months is performed primarily by vascular plants in both habitats. In the pondlike areas filamentous algae appear to be the assimilators during the winter months. It is obvious that this riverine freshwater marsh ecosystem is capable of assimilating nutrients, especially during the summer months when eutrophication is a problem, and that they play an important role in the over-all nutrient budgets of the Delaware River (Whigham and Simpson, 1978).

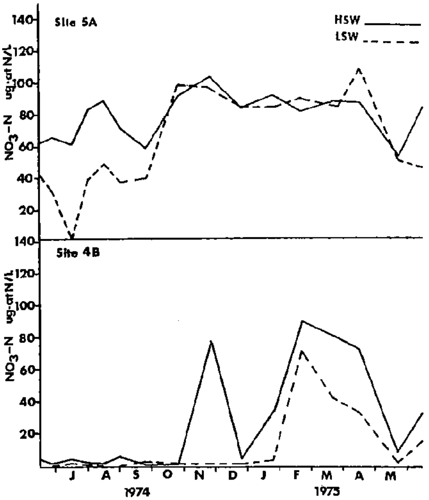

FIG. 4. Changes in nitrate nitrogen at sites 5A and 4B in the Hamilton Marshes. Refer to figure 1 for locations of sampling stations. Water samples were collected at high slack water (HSW) and low slack water (LSW) from May 1974 until July 1975.

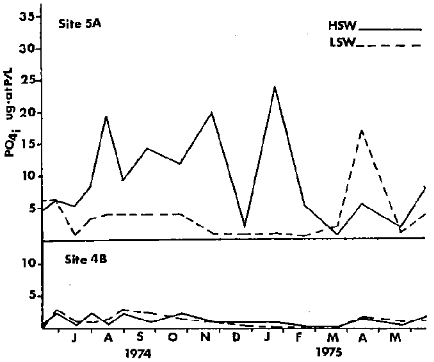

FIG. 5. Changes in inorganic phosphate at sites 5A and 4B in the Hamilton Marshes. Refer to figure 1 for locations of sampling stations. Water samples were collected at high slack water (HSW) and low slack water (LSW) from May 1974 until July 1975.

REFERENCES

GOOD, RALPH E.
1965. Salt marsh vegetation, Cape May, N.J. Bull. New Jersey Acad. Sci., vol. 10, pp. 1-11.

MCCORMICK, JACK
1970. The natural features of Tinicum Marsh, with particular emphasis on the vegetation. Pp. 1-104 *in* "Two Studies of Tinicum Marsh, Delaware and Philadelphia Counties, Pa.," J. F. McCormick, R. R. Grant, Jr., and R. Patrick, eds. Conservation Foundation, Washington, D. C.

McCormick, Jack, and Ashbaugh, T.
1972. Vegetation of a section of Oldmans Creek tidal marsh and related areas in Salem and Gloucester Counties, New Jersey. Bull. New Jersey Acad. Sci., vol. 17, pp. 31-37.

McCormick, Jack; Grant, R. R., Jr.; and Patrick, R.
1970. Two studies of Tinicum Marsh, Delaware and Philadelphia Counties, Pa., 123 pp. Conservation Foundation, Washington, D. C.

Simpson, Robert L., and Whigham, Dennis F.
1976. Seasonal distribution of selected water chemical parameters in a Delaware River freshwater tidal marsh. American Society of Limnology and Oceanography, Savannah, Georgia. (Abstract.)

Simpson, Robert L.; Whigham, Dennis F.; and Walker, R.
1978. Seasonal patterns of nutrient movement in a freshwater tidal marsh. Pp. 242-258 *in* "Freshwater Wetlands: Ecological Process and Potential," R. E. Good, D. F. Whigham, and R. L. Simpson, eds. Academic Press, New York.

Walton, T., and Patrick, R.
1973. Delaware River estuarine marsh survey. *In* "Delaware Estuary System: Environmental Impacts and Socio-economic Effects," 177 pp. A report prepared for the National Science Foundation (RAAN). Academy of Natural Sciences of Philadelphia.

Wass, Marvin L., and Wright, Thomas D.
1969. Coastal wetlands of Virginia. Interim report to the Governor and General Assembly. Virginia Inst. Mar. Sci. Spec. Rpt. in Appl. Mar. Sci. and Ocean Eng., no. 10, 154 pp.

Whigham, Dennis F.
1974. Preliminary ecological studies of the Hamilton Marshes: Progress report for the period ending January 1974, 66 pp. Rider College, Lawrenceville, New Jersey.

Whigham, Dennis F.; McCormick, Jack; Good, Ralph E.; and Simpson, Robert L.
1978. Biomass and primary production in freshwater tidal wetlands of the Middle Atlantic Coast. Pp. 1-20 *in* "Freshwater Wetlands: Ecological Process and Management Potential," R. E. Good, D. F. Whigham, and R. L. Simpson, eds. Academic Press, New York.

Whigham, Dennis F., and Simpson, Robert L.
1975. Ecological studies of the Hamilton Marshes: Progress report for the period June, 1974-January, 1975, 185 pp. Rider College, Lawrenceville, New Jersey.
1976. The potential use of freshwater tidal marshes in the management of water quality in the Delaware River. Pp. 173-186 *in* "Biological Control of Water," Joachim Tourbier and Robert W. Pierson, Jr., eds. University of Pennsylvania Press.
1978. Nitrogen and phosphorus movement in a freshwater tidal wetland receiving sewage effluent. Pp. 2089-2203 *in* "Coastal 78: Symposium on Technical, Environmental, Socioeconomic, and Regulatory Aspects of Coastal Zone Management." American Society of Civil Engineers, Minneapolis, Minnesota.

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