

Nitrogen Cycling in a Freshwater Marsh of *Panicum hemitomon* on the Deltaic Plain of the Mississippi River

Author(s): R. D. DeLaune, C. J. Smith and M. N. Sarafyan

Source: *Journal of Ecology*, Vol. 74, No. 1 (Mar., 1986), pp. 249-256

Published by: British Ecological Society

Stable URL: <http://www.jstor.org/stable/2260361>

Accessed: 23-06-2017 14:26 UTC

REFERENCES

Linked references are available on JSTOR for this article:

http://www.jstor.org/stable/2260361?seq=1&cid=pdf-reference#references_tab_contents

You may need to log in to JSTOR to access the linked references.

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact support@jstor.org.

Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at

<http://about.jstor.org/terms>



British Ecological Society is collaborating with JSTOR to digitize, preserve and extend access to *Journal of Ecology*

NITROGEN CYCLING IN A FRESHWATER MARSH OF *PANICUM HEMITOMON* ON THE DELTAIC PLAIN OF THE MISSISSIPPI RIVER

R. D. DeLAUNE, C. J. SMITH AND M. N. SARAFYAN

*Laboratory for Wetland Soils and Sediments, Center for Wetland Resources, Louisiana
State University, Baton Rouge, Louisiana 70803-7511, U.S.A.*

SUMMARY

(1) A study was made of nitrogen cycling and the effect of added inorganic nitrogen on biomass production of *Panicum hemitomon* in the deltaic plain of the Mississippi River. Nitrogen is apparently a limiting nutrient since supplemental nitrogen increased above-ground biomass by 40%.

(2) There is apparently little loss of internal nitrogen from the system since 80% of the nitrogen added at the rate of 3 g m^{-2} was recovered in the soil–plant system at the end of the growing season.

(3) Nitrogen fixation was the principal source of nitrogen to this vast freshwater system with $6.7 \text{ g m}^{-2} \text{ year}^{-1}$ being added. These marshes are apparently serving as large nitrogen sinks, with $12 \text{ g m}^{-2} \text{ year}^{-1}$ being retained as organic nitrogen as a result of accretion as determined by ^{13}C s dating.

(4) The results suggest that these freshwater marshes may improve water quality by removing nutrients from inflowing water.

INTRODUCTION

The Gulf Coast of Louisiana is fringed by an expanse of coastal wetlands (3.6 M ha) recognized for its economic importance and natural productivity—equivalent to 41% of all coastal wetlands in the U.S.A. (Turner & Gosselink 1975). Fresh, brackish and saline marshes and associated water bodies located on the deltaic plain of the Mississippi River represent the majority of this wetland area. Barataria Basin, in which this study was conducted, is an inter-distributary basin, bounded on the east by the Mississippi River and on the west by its most recently abandoned channel, Bayou Lafourche.

Four main vegetation units can be identified within the basin which generally correlate with substratum type and salinity (Bahr & Hebrard 1976). Freshwater marsh (salinity $\approx 0.1\%$) covers 19% of the basin and is characterized by *Eleocharis* spp., *Panicum hemitomon* and *Sagittaria falcata* (Chabreck & Condrey 1979). Brackish and intermediate marshes (0.1–1%) together cover approximately 20% of the basin. The brackish marsh is vegetated largely by *Distichlis spicata*, *Spartina patens* and small amounts of *S. alterniflora*. The intermediate marsh is characterized by a dominance of *S. patens* and the absence of *S. alterniflora*. Salt marsh (1–2%) covers approximately 14% of the basin with *S. alterniflora* being the predominant species.

Numerous studies have shown that nitrogen is the limiting nutrient in salt marshes (Valiela & Teal 1974; Patrick & DeLaune 1976; Mendelssohn 1979; Buresh & Patrick 1980). To date there is little information on the nitrogen status of coastal freshwater vegetation.

The major objectives of this study were to determine the response of *Panicum hemitomon* to added nitrogen, and to measure the major nitrogen fluxes including fixation and losses from a *P. hemitomon* freshwater marsh.

MATERIALS AND METHODS

Study site

The experimental site was a *Panicum hemitomon* freshwater marsh bordering Lac des Allemandes, a 65 km² freshwater lake (90°33'N, 29°48'W) in the northern part of Barataria Basin located along the deltaic plain of the Mississippi River. *P. hemitomon* is the predominant freshwater plant in these marshes, a large percentage of which are floating marsh or flotant and contain a mat of roots and plant remains overlying an unconsolidated peat layer 0–35 cm thick, underlain by 1–5 m of organic ooze which grades with depth to clay (Kolb & Van Lopik 1966). Floating marshes form a large part of Louisiana's 1.6 M ha of coastal marsh. According to O'Neil (1949) 617 500 ha are fresh floating marsh dominated by *P. hemitomon*. The study site contains less than 1 m of organic ooze but is classified as flotant because the surface responds to increases in water level.

Response to added nitrogen

Nitrogen (as 1 M (NH₄)₂SO₄ solution) was applied in four equal instalments to total 0, 3 and 10 g m⁻², to each of four 0.25 m² circular plots for each treatment. The plots were enclosed by metal retainers inserted 21 cm below the surface. The retainers were 43 cm in height and coated with epoxy paint to resist corrosion. The ammonium-sulphate solutions were injected 20 cm below the surface at fifteen random locations within each plot. The 3 g m⁻² (100 µg g⁻¹ dry sediment) treatment was labelled with ¹⁵N at 618.7 atom percentage. The nitrogen treatments were given on 22 March, 14 June, 1 July and 26 July 1983.

On 26 September 1983, near the end of the first growing season, the *P. hemitomon* was sampled. The plants were clipped approximately 3 cm above the surface and analysed for total N by the macro-Kjeldahl method (Bremner 1965). Two (10 cm diameter × 45 cm depth) soil cores were removed from the plots which received ¹⁵N. The atom percentage ¹⁵N content of the plant nitrogen and soil nitrogen was determined on a mass spectrometer.

Acetylene-reduction measurements

Nitrogen fixation was measured by the acetylene-reduction method. The soil profile was sampled ten times during the year. A sample in a sealed glass container was incubated under an atmosphere containing 10% acetylene and 90% air (Mague & Burris 1973; Hanson 1977; Bohloul & Wiebe 1978). Soil samples were incubated in the dark in the laboratory under controlled conditions (21–24 °C). The effect of different gas phases on acetylene reduction rates was investigated in preliminary experiments in which the soil samples were incubated under atmospheres of 90% air and 10% acetylene and 90% N₂ and 10% acetylene. The air-acetylene incubation yielded the highest rates after incubation periods of 20 h (Casselmann & Patrick 1981). Gas samples (0.25 ml) were withdrawn with a hypodermic needle and syringe after 20 h of incubation. The acetylene-reduction estimates were corrected for any ethylene production by the sediment. The gas samples were analysed for ethylene with a gas chromatograph equipped with a flame ionization

detector and a 1.83 m stainless-steel column with Porapak N packing, 80–100 mesh. The temperature settings were: column 55 °C, interface 150 °C. Retention times were 32 s for ethylene and 72 s for acetylene. After the assay, the samples were weighed before and after drying at 70 °C.

Soil extractable ammonium

Extractable ammonium analyses were performed on subsamples of the material collected for acetylene-reduction measurements. Each sample (≈ 10 g dry soil) was extracted with 100 ml of 2N KCl by mechanically shaking for 1 h. The soil solution was then filtered through Whatman No. 1 filter paper and refrigerated for a maximum of 1 week until the ammonium analysis could be made. Ammonium N in the filtrate was determined by nesslerization after 5 min steam distillation with 0.3 g MgO (Environmental Protection Agency 1979).

Nitrogen accumulation

The ^{137}Cs dating method has recently been used to document vertical accretion rates in Louisiana's rapidly accreting salt marshes (DeLaune, Patrick & Buresh 1978). In this study a core was taken from the marsh adjacent to the plot receiving added nitrogen. The ^{137}Cs activity in each core was determined from oven-dried, 3 cm thick sections of the profile using a lithium-drifted-germanium detector and multichannel analyser. Accretion rates were calculated from the peak ^{137}Cs concentrations found in the profile. These concentrations can be correlated to 1963, the year of peak ^{137}Cs fallout (from nuclear testing) and 1954, the first year of significant ^{137}Cs fallout (Pennington, Cambray & Fisher 1973). There is little mobility of ^{137}Cs in sediment as it is rapidly absorbed. The rates obtained are similar to that determined by artificial marker horizon (DeLaune, Baumann & Gosselink 1983). Total nitrogen content in the section was determined using a macro-Kjeldahl technique. Using the measured accretion rate ($0.90 \text{ cm year}^{-1}$) and the mean nitrogen content of the profile, the annual amount of nitrogen removed from the system mainly as organic nitrogen in the form of peat was determined.

Inorganic nitrogen in the adjacent lake

Water was taken seasonally from the lake bordering the marsh and filtered before determining its inorganic nitrogen concentration. Nitrate was determined by the cadmium-reduction method and ammonium by the phenol-hypochlorite method (Strickland & Parsons 1972).

RESULTS

Effects of added nitrogen on plant biomass

The yield of above-ground plant material is shown in Table 1. Added nitrogen at 10 g m^{-2} caused a statistically significant ($P < 0.05$, analysis of variance) biomass increase of 550 g m^{-2} over the control. There was no significant increase for the 3 g N m^{-2} application.

Even though a response to added nitrogen was observed, these highly organic marsh soils apparently mineralized significant amounts of N for plant growth as demonstrated by the amount of above-ground biomass produced in the control plots. To produce 1320 g m^{-2} containing 6.7 mg N g^{-1} of plant and assuming no turnover during the growing season, requires 8.87 g N m^{-2} for the above-ground production alone.

TABLE 1. Above-ground yield and nitrogen content of plants of *Panicum hemitomon* in a freshwater marsh on the deltaic plain of the Mississippi, Louisiana, U.S.A., in September 1983.

Nitrogen added (g m ⁻²)	Plant dry weight (g m ⁻²)	Nitrogen in plant tissue (mg g ⁻¹)	Increase in biomass (%)
0	1320 ± 120 ^a	6.7	—
3	1404 ± 95 ^a	6.8	0
10	1876 ± 170 ^b	7.0	40

Values are means ± 1 S.D., *n* = 4. Values followed by different superscripts are significantly different at *P* = 0.05.

Recovery of added N

The recovery of added labelled nitrogen is shown in Table 2. Approximately 80% was recovered in the above-ground plant material and the soil plus roots. In the above-ground plant portion 18% of the added labelled nitrogen was recovered and 62% was recovered in the soil.

TABLE 2. Recovery of (¹⁵NH₄)₂SO₄ added at 3 g m⁻² to plants of *Panicum hemitomon* in a freshwater marsh on the deltaic plain of the Mississippi, Louisiana, U.S.A., at the end of 1983 growing season. Roots were examined to a depth of 45 cm.

	Excess ¹⁵ N (mg plot ⁻¹)		Recovery (%)		Total
	Soil + roots	Plant	Soil + roots	Plant	
Replicates	161	44	44	12	57
	223	65	62	18	80
	293	68	80	19	99
	217	79	60	22	82
Mean ± 1 S.D.			62 ± 14.7	18 ± 4.2	80 ± 17

Nitrogen fixation

Nitrogen fixation (acetylene reduction) was greatest during the summer (Fig. 1). The highest rates were found in upper portion of the profile which represent the rooting zone

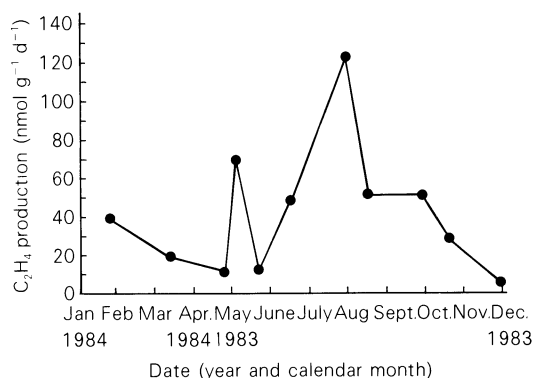


FIG. 1. Seasonal changes in the production rate of ethylene in fresh soil (to a depth of 42 cm) of a freshwater marsh on the deltaic plain of the Mississippi, Louisiana, U.S.A. Note that sampling commenced in May 1983 and that the horizontal axis has been transposed to depict the seasonal changes for a year commencing in January.

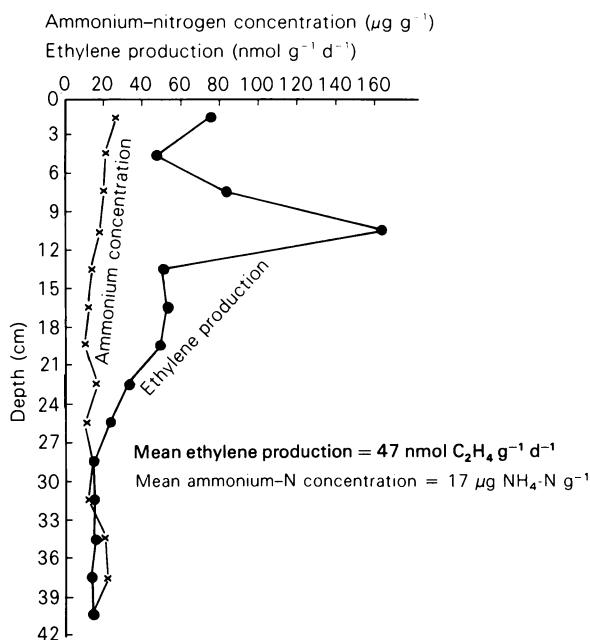


FIG. 2. Annual mean (●) ethylene production ($\text{nmol g}^{-1} \text{ day}^{-1}$) and (x) ammonium-N concentration ($\mu\text{g g}^{-1}$) in a fresh soil profile of a freshwater marsh on the deltaic plain of the Mississippi, Louisiana, U.S.A.

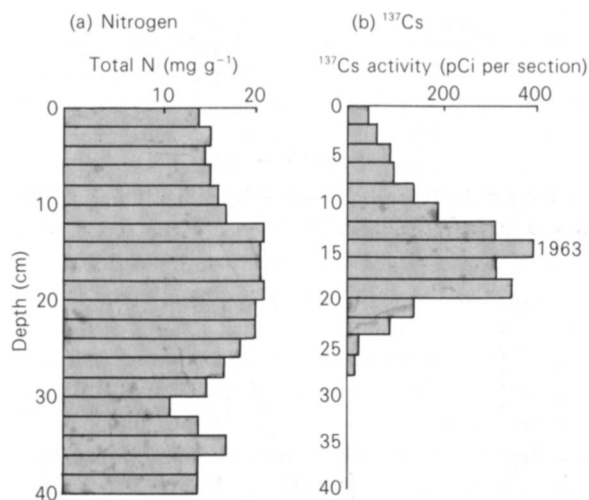


FIG. 3. Total (a) soil nitrogen and (b) ^{137}Cs profile distribution in a fresh soil profile of a freshwater marsh on the deltaic plain of the Mississippi, Louisiana, U.S.A.

(Fig. 2). The yearly mean rate throughout the profile (42 cm depth) was $46.8 \text{ n moles C}_2\text{H}_4 \text{ g sediment}^{-1} \text{ d}^{-1}$.

Using the conversion factor of 3 moles of acetylene reduced for each mole of dinitrogen gas fixed (Hauck & Bremner 1976), the equivalent of $159 \mu\text{g N g}^{-1} \text{ year}^{-1}$ would be fixed in

the soil profile. Taking into account the bulk density of the fresh soil (0.10 g cm^{-3}), the fixation rate is equivalent of $6.7 \text{ g N m}^{-2} \text{ year}^{-1}$ to a depth of 42 cm.

Nitrogen sinks

Sediment is accumulating (De Laune, Baumann & Grosselink 1983), as determined by ^{137}Cs dating, at $0.75 \text{ cm year}^{-1}$ (Fig. 3). The mean nitrogen content of the profile was $16 \text{ mg N g sediment}$. Calculations using accretion rate, bulk density and total N content of the sediment showed that the marshes are accumulating $12 \text{ g N m}^{-2} \text{ year}^{-1}$. Thus a large portion of the nitrogen incorporated in the vegetation is accumulating, mainly as organic nitrogen, in the accreted sediments.

DISCUSSION

The biomass increase following the addition of 10 g N m^{-2} shows that nitrogen is limiting in this marsh, while the 80% retention rate of labelled N in the plant and soil system indicates an efficient use of the added nitrogen. This recovery rate can be compared with that of a salt marsh at the lower end of the basin in which 28% of added nitrogen was recovered in the above-ground plant portion and 65% in the soil (Buresh & Patrick 1981). A somewhat lower proportion of the added nitrogen was accounted for in this study. DeLaune, Smith & Patrick (1983) recovered 93% of added labelled nitrogen from a salt marsh as compared to the 80% total recovery reported in this study. The lower recovery would be expected since freshwater marsh, especially floatant, had very low bulk density with little inorganic clay to adsorb the added $\text{NH}_4^+\text{-N}$ rapidly.

In the treatment which received 10.0 g m^{-2} of ammonium nitrogen, the increase in above-ground plant biomass above the control accounted for 3.9 g m^{-2} , or 39% of the nitrogen added. However, using non-labelled nitrogen, it was not possible to determine the true distribution and loss of the added nitrogen within the system.

The annual rate at which nitrogen is being added to the system through fixation is intermediate between the rates of 15 g m^{-2} for a streamside and 4.5 g m^{-2} for an inland (*Spartina alterniflora*) salt marsh at the lower end of the Basin (Casselman & Patrick 1981). However, nitrogen fixation is the most likely source of nitrogen for the freshwater marsh, since it does not receive the organic-rich sediment which is the principal source of nitrogen for the salt marsh nearest the coast (Smith & Patrick 1982).

The results presented in this paper suggest that there are nitrogen sources other than fixation available to these highly organic marshes. In contrast to the salt marshes nearer the coast, where sediment input is the primary source of nitrogen (DeLaune, Reddy & Patrick 1981), in these freshwaters the substratum consists of nearly pure organic material with little or no input of inorganic sediment. It is apparent that there is a very efficient internal nitrogen cycle since Smith & Patrick (1982) reported very little gaseous loss ($55 \text{ mg N m}^{-2} \text{ year}^{-1}$) via denitrification. In addition, in the present study 80% of the added nitrogen was recovered. The deficit between nitrogen accumulation and input via fixation assumes that nitrogen input from rainfall is insignificant; in coastal marshes it is reported to be of the order of $0.5 \text{ g m}^{-2} \text{ year}^{-1}$ (Nixon 1980). Thus, the likely source of nitrogen in these marshes is the through-flowing water; in the water bodies adjacent to the study area the water contained, on average, $0.10 \text{ mg NH}_4^+\text{-N litre}^{-1}$ and $0.13 \text{ g NO}_3^-\text{-N litre}^{-1}$. Stow, DeLaune & Partick (1984) have also reported significant amounts of

inorganic nitrogen in the water bodies of the freshwater region of Barataria Basin. This would suggest that inflowing water is an important nutrient source and that these marshes have the capacity to 'improve' the water quality of adjacent lakes and water bodies.

ACKNOWLEDGMENTS

This research was supported by the National Science Foundation and Louisiana Sea Grant Programme, a part of the National Sea Grant Programme maintained by National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

REFERENCES

- Bahr, L. M. & Hebrard, J. J. (1976).** *Barataria Basin: Biological Characterization*. Sea Grant Publication No. LSU-T-76-055, Center for Wetland Resources, Louisiana State University, Baton Rouge, Louisiana.
- Bohlool, B. B. & Wiebe, W. J. (1978).** Nitrogen-fixing communities in an intertidal ecosystem. *Canadian Journal of Microbiology*, **24**, 932–938.
- Bremner, J. M. (1965).** Inorganic forms of nitrogen. *Methods of Soil Analysis, Vol. 2* (Ed. by C. A. Black), pp. 1179–1237. American Society of Agronomy, Madison, Wisconsin.
- Buresh, R. J. & Patrick, W. H. Jr (1980).** Nitrogen and phosphorus distribution and utilization by *Spartina alterniflora* in a Louisiana Gulf Coast salt marsh. *Estuaries*, **3**, 111–121.
- Buresh, R. J. & Patrick, W. H. Jr (1981).** Influence of *Spartina alterniflora* on nitrogen loss from a marsh soil. *Soil Science Society of America Journal*, **45**, 660–661.
- Casselman, M. E. & Patrick, W. H. Jr (1981).** Nitrogen fixation in a Gulf Coast salt marsh. *Soil Science Society of America Journal*, **45**, 51–56.
- Chabreck, R. H. & Condrey, R. E. (1979).** *Common Vascular Plants of the Louisiana Marsh*. Sea Grant Publication No. LSU-T-79-003. Center for Wetland Resources, Louisiana State University, Baton Rouge, Louisiana.
- DeLaune, R. D., Baumann, R. H. & Grosselink, J. G. (1983).** Relationships among vertical accretion, coastal submergence, and erosion in a Louisiana Gulf Coast marsh. *Journal of Sedimentary Petrology*, **53**, 147–157.
- DeLaune, R. D., Patrick, W. H. Jr & Buresh, R. J. (1978).** Sedimentation rates determined by ^{137}Cs dating in a rapidly accreting salt marsh. *Nature, London*, **275**, 532–533.
- DeLaune, R. D., Reddy, C. N. & Patrick, W. H. Jr (1981).** Accumulation of plant nutrients and heavy metals through sedimentation processes and accretion in a Louisiana salt marsh. *Estuaries*, **4**, 328–334.
- DeLaune, R. D., Smith, C. J. & Patrick, W. H. Jr (1983).** Nitrogen losses from a Louisiana Gulf Coast salt marsh. *Estuarine and Coastal Shelf Science*, **17**, 133–141.
- Environmental Protection Agency (1979).** *Methods for Chemical Analysis of Water and Wastes*. U.S. Government Printing Office, Washington.
- Hanson, R. B. (1977).** Comparison of nitrogen fixation activity in tall and short *Spartina alterniflora* salt marsh soils. *Applied and Environmental Microbiology*, **33**, 596–602.
- Hauck, R. D. & Bremner, J. M. (1976).** Use of tracers for soil and fertilizer nitrogen research. *Advancements in Agronomy*, **28**, 219–266.
- Kolb, C. R. & Van Lopik, J. R. (1966).** Depositional environments of the Mississippi River deltaic plain—southeastern Louisiana. *Deltas in Their Geologic Framework* (Ed. by M. L. Shirley), pp. 17–61. Houston Geological Society, Houston, Texas.
- Mague, T. H. & Burris, R. H. (1973).** Biological nitrogen fixation in the Great Lakes. *BioScience*, **23**, 236–239.
- Mendelssohn, I. A. (1979).** Nitrogen metabolism in the height forms of *Spartina alterniflora* in North Carolina. *Ecology*, **60**, 574–584.
- Nixon, S. W. (1980).** Between coastal marshes and coastal waters—a review of twenty years of speculation and research on the role of salt marshes in estuarine productivity and water chemistry. *Estuarine and Wetlands Processes* (Ed. by P. Hamilton & K. Macdonald), pp. 437–525. Plenum Press, New York.
- O'Neil, T. (1949).** *The Muskrat in Louisiana's Coastal Marshes*. Louisiana Wildlife and Fisheries Commission, New Orleans.
- Patrick, W. H. Jr & DeLaune, R. D. (1976).** Nitrogen and phosphorus utilization by *Spartina alterniflora* in a salt marsh in Barataria Bay, Louisiana. *Estuarine and Coastal Marine Science*, **4**, 59–64.

- Pennington, W., Cambray, R. S. & Fisher, E. H. (1973).** Observations on lake sediments using fallout ^{137}Cs as a tracer. *Nature, London*, **242**, 324–326.
- Smith, C. J. & Patrick, W. H. Jr (1982).** Carbon and nitrogen cycling in *Spartina alterniflora* salt marsh. *The Cycling of Carbon, Nitrogen, Sulfur, and Phosphorus in Terrestrial and Aquatic Ecosystems* (Ed. by J. R. Freney & I. E. Galbally), pp. 97–104. Springer, Berlin.
- Stow, C. A., DeLaune, R. D. & Patrick, W. H. Jr (1984).** Nutrient fluxes in a eutrophic coastal Louisiana freshwater lake. *Environmental Management*, **9**, 243–252.
- Strickland, J. D. H. & Parsons, T. R. (1972).** A manual of sea water analysis. *Bulletin of Fisheries Resources Board of Canada*, **167**.
- Turner, R. E. & Gosselink, J. G. (1975).** A note on standing crops of *Spartina alterniflora* in Texas and Florida. *Contributions in Marine Science*, **19**, 113–118.
- Valiela, I. & Teal, J. M. (1974).** Nutrient limitation in salt marsh vegetation. *Ecology of Halophytes* (Ed. by R. J. Reimold & W. H. Queen), pp. 547–563. Academic Press, New York.

(Received 11 December 1984)