LITERATURE CITATIONS OF SALT MARSH ECOLOGY RELATIVE TO THE MARSH DIEBACK SYNDROME RESEARCH PROGRAM IN COASTAL LOUISIANA

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PREFACE

This bibliography is compiled to describe select literature relative to a resarch and remediation program developed to understand the salt marsh dieback syndrome that occurred in coastal Louisiana during 2000. As part of the “Characterization and Synthesis of Marsh DieBack” tasks under the request for proposals by the Scientific-Tecchnical Committee of the Barataria-Terrebonne National Estuary Program, a literature review was funded to assist in the initial development of conceptual models to describe the salt marsh dieback syndrome. This task was considered an important first step in conceptualization and characterization process of this research program.

This literature review does not cover all of the disciplines of salt marsh ecology. It is limited in scope to only those references that were deemed by the author to be relevant to the “Causes” tasks of this research program. Thus the review is focused on areas such as growth and ecophysiology of salt marsh vegetation, zonation and succession, and hydrology and biogeochemistry of marsh soils. The bibliography does not cover a very extensive literature on animal ecology, food webs, or functional ecology (eg. nutrient exchange) of salt marsh ecosystems. And as usual for North American scientists, this review does not include the wealth of information on salt marsh ecology from Europe, particularly references in German and French languages. We suggest several texts listed below, such as those from Chapman and Adams, that include many of these works in their references. The review focuses on journal citations and does not extensively cover book chapters and government reports and documents.

The authors encourage researchers and managers to include the following specific book citations in their literature review to assist in developing an overview of the salt marsh dieback syndrome.

Chapman, V.J. 1974. Salt Marshes and Salt Deserts of the World. Interscience Press. New York, New York, USA.

Chapman, V.J. 1977. Wet Coastal Ecosystems. Ecosystem of the World Series. Elsevier, Amsterdam, The Netherlands.

Adam, P. 1990. Saltmarsh Ecology. Cambridge University Press, Cambridge, England.

Chapter Four entitled “Coping with the environment” includes ecophysiology of salt marsh plants. Chapter Five describes the life history characteristics of salt marshes.

Seeliger, U. (editor) 1992. Coastal Plant Communities of Latin America. Academic Press, San Diego.

Four chapters (chapters 11-14) in Part III of this book are papers that describe Saltmarsh Community. Chapter 11 is on the development and organization of saltmarsh communities by A.J. Davy and C.S.B. Costa.

Mitsch, W.J. and J.G. Gosselink. 2000. Wetlands. Third Edition. Van Nostrand Reinhold Company, New York.

Chapter Nine entitled “Tidal Salt Marshes” is a review of salt marsh ecosystems. In addition, Part 2 of the book (Chapters 5-8) review wetland hydrology, biogeochemistry, biological adaptations and ecosystem development.

Keedy, P.A. 2000. Wetland Ecology. Principles and Conservation. Cambridge University Press, Cambridge, UK. 614 pp. (ISBN 0521783674, paperback).

Chapter Two entitled “Zonation and succession: shorelines as a prism” (p. 81-123) is particularly relevant to conceptualization and characterization of the salt marsh dieback syndrome.

Weinstein, M.P. and D. A. Kreeger. (editors) 2000. Concepts and Controversies in Tidal Marsh Ecology. Kluwer Academic Publishers. Boston. 875 pp. (ISBN 0792360192, hardback).

Specific references in the section of this edited book under the heading, “Sources and Patterns of Production” should be included in a review of the literature such as the following (the paper by Mendelssohn and Moris is included in the bibliography, #314):

Bertness, M. D. and S. C. Pennings. 2000. Spatial variation in process and pattern in salt marsh plant communities in eastern North America, pp. 39-58.

Ibañez, C. A. Curco, J. W. Day, Jr. and N. Prat. 2000. Structure and productivity of microtidal Mediterranean coastal marshes, p. 107-136.

Davy, A. J. 2000. Development and structure of salt marshes: community patterns in time and space, p. 137-158.

There are also sections with reviews on “Biogeochemical Processes”, “Modeling Nutrient and Energy Flux”, “Tidal Marsh Restoration: Fact or Fiction”, “Ecological Engineering of Restored Marshes”, “Measured Function of Restored Tidal Marshes”, and “Success Criteria for Tidal Marsh Restoration”.

There are several government documents that specifically describe the features of salt marsh wetlands that should also be included in any review of salt marsh ecosystems:

Bahr, L. M., Jr., R. Costanza, J. W. Day, Jr., S. E. Bayley, C. Neill, S. G. Leibowitz, J. Fruci. 1982. Ecological characterization of the Mississippi Deltaic Plain Region: a narrative with management recommendations. U. S. Fish and Wildlife Service, Division of Biological Services, Washington, D. C. FWS/OBS-82/69. 189 pp.

Boesch, D. F., ed. 1982. Proceedings of the conference on coastal erosion and wetland modification in Louisiana: causes, consequences, and options. U.S. Fish and Wildlife Service, Biological Services Program, Washington, D.C. FWS/OBS-82/59. 256 pp.

Conner, W. H., and J. W. Day, Jr., editors. 1987. The ecology of Barataria Basin, Louisiana: an estuarine profile. Biological Report 85(7.13). 165 pp.

Costanza, R. et al. 1983. Ecological models of the Mississippi deltaic plain region: data Collection and presentation. FWS/OBS-82/68. 342 pp.

Cross, R. D., and D. L. Williams, editors. 1981. Proceedings of national symposium on freshwater inflow to estuaries. FWS/OBS-81/04. 1053 pp.

Day, J. W., Jr., W. G. Smith, P. R. Wagner and W. C. Stowe. 1973. Community structure and carbon budget of a salt marsh and shallow bay estuarine system in Louisiana, Center for Wetland Resources, Louisiana State University.

Duffy, W. G., and D. Clark, editors. 1989. Marsh management in coastal Louisiana: effects and issues proceedings of a symposium. Biological Report 89(22). 378 pp.

Gosselink, J.G. 1984. The ecology of delta marshes of coastal Louisiana: a community profile. FWS/OBS-84/09, Office of Biological Services, U.S. Fish and Wildlife Service, Washington D.C., USA.

Guntenspergen, G. R., and B. A. Vairin, editors. 1998. Vulnerability of coastal wetlands in the Southeastern United States: climate change research results, 1992-97. U.S. Geological Survey, Biological Resources Division Biological Science Report USGS/BRD/BSR-1998-0002. 101pp.

Josselyn, M. 1983. Ecology of the San Francisco Bay tidal marshes: a community profile. FWS/OBS-83/23. 102 pp.

Mac, M. J., P. A. Opler, C. E. Puckett Haecker, and P. D. Doran. 1998. Regional Trends of Biological Resources – Coastal Louisiana (pp 385-436) in Status and trends of the nation’s biological resources. 2 vols. U.S. Department of the Interior, U.S. Geological Survey, Reston, Va. 964 pp.

Rozas, L. P., J. A. Nyman, C. E. Proffitt, N. N. Rabalais, D. J. Reed, and R. E. Turner. (editors). 1999. Recent research in coastal Louisiana: Natural system function and response to human influences. Louisiana Sea Grant College Program, Baton Rouge, LA.

Seliskar, D. M., and J. L. Gallagher. 1983. The ecology of tidal marshes of the Pacific Northwest coast: a community profile. FWS/OBS-82/32. 65 pp.

Turner, R. E. 1987. Relationship between canal and levee density and coastal land loss in Louisiana. Biological Report 85(14). 58 pp.

Zedler, J. B. 1982. The ecology of southern California coastal salt marshes: a community profile. FWS/OBS-81/54. 110 pp.

The following technical report/annotated bibliography provides an excellent resource on *Spartina alterniflora*:

Matthews, Geofffrey A. and Thomas J. Minello. 1994. Technology and Success in Restoration, Creation, and Enhancement of *Spartina alterniflora* Marshes in the United States. Vol. 1 – Executive Summary and Annotated Bibliography. NOAA Coastal Ocean Program Decision Analysis Series No. 2. NOAA Coastal Ocean Office, Silver Spring, MD.

Matthews, Geoffrey A., and Thomas J. Minello. 1994. Technology and Success in Restoration, Creation, and Enhancement of *Spartina alterniflora* Marshes in the United States. Vol. 2 – Inventory and Human Resource Directory. NOAA Coastal Ocean Program Decision Analysis Series No. 2. NOAA Coastal Ocean Office, Silver Spring, MD.

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This bibliography was compiled mainly through computer searches utilizing Web of Science and Cambridge Scientific Abstracts, the University of Louisiana at Lafayette on-line catalog and campus library, and the National Wetland Research Center on-line library catalog as well as NWRC library on-site search including the following database:

Buys, Judith, 2001, Spartina: Lafayette, Louisiana, U.S. Geological Survey National Wetlands Research Center Library, National Wetlands Research Center Local Area Network Procite bibliographic database. [accessed date: December 2001]

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APPENDIX – SELECTED ANNOTATIONS

1. Adams, D. A. 1963. Factors influencing vascular plant zonation in North Carolina salt marshes. ECOLOGY 44: 445-456.
   The objectives of this study were to describe the vegetation of North Carolina salt marshes, the composition of these salt marsh communities, and the environmental conditions under which they exist. Variations in the environmental conditions of these communities were determined as well as levels of tolerence for the different species. Nutrient solution experiments were conducted on *Spartina alterniflora, Distichlis spicata, Spartina patens,* and *Juncus roemerianus* to determine the responses to varous NaCl and Fe concentrations. The author concluded that *Spartina alterniflora* is restricted to the low marsh because of its moderate salinity and high iron requirements. *S. alterniflora,* grown in either low iron or fresh water becomes chlorotic. It was found that neither *S. patens* nor *D. Spicata* shows any ill effects when grown in low iron. The author also suggests that if relative sea level continues to rise, he predicts salt marsh vegetation may continue invading upland vegetation.

2. Anderson, I. C., Tobias, C. R., Neikirk, B. B., and Wetzel, R. L. 1999. Development of a process-based nitrogen mass balance model for a Virginia (USA) *Spartina alterniflora* salt marsh: Implications for net DIN flux. MARINE ECOLOGY PROGRESS SERIES 159: 13-27.
   The authors developed a process-based nitrogen mass balance model for short-term *Spartina alterniflora* in a Virginia salt marsh. Data included rates of gross mineralization, nitrification, denitrification, nitrogen fixation, above and belowground productivity, macrophyte production, and benthic microalgal production. The annual balance between sources and sinks of dissolved inorganic nitrogen (DIN) was determined for both interior *S. alterniflora* vegetated sites and unvegetated creek bank sites. The authors propose that approximately half of the DIN mineralized is immobilized into a readily remineralizable particulate organic N pool necessary for the system to maintain a steady state.

3. Bagwell, C. E., and Lovell, C. R. 2000. Microdiversity of culturable diazotrophs from the rhizoplanes of the salt marsh grasses *Spartina alterniflora* and *Juncus roemerianus*. MICROBIAL ECOLOGY 39 (2): 128-136.
   Whole genome DNA-DNA hyrbridization was used to assess the phyolgenetic relatedness of *Juncus roemerianus* and *Spartina alterniflora*. The physiological characteristics of the rhizoplane diazotroph assemblages of the two species were also examined. The authors conclude that the diazotrophs appear to be physiologically adapted for utilization of specific substrates.

4. Baldwin, A. H., and Mendelssohn, I. A. 1998. Effects of salinity and water level on coastal marshes: An experimental test of disturbance as a catalyst for vegetation change. AQUATIC BOTANY 61 (4): 255-268.
   Mesocosm experiments were utilized containing soil and vegetation from two oligohaline marsh species of different salinity tolerance, *Sagittaria lancifolia*

and *Spartina patens,* to examine the role of disturbance in vegetation change under different salinity and inundation regimes. Vegetation responses were assessed quarterly for 1 year and these responses were related to soil redox potential (Eh), sulfide concentrations, salinity and pH. Results indicate that disturbance is an important component of vegetation change in response to rising sea level.

5. Baldwin, A. H., and Mendelssohn, I. A. 1998. Response of two oligohaline marsh communities to lethal and nonlethal disturbance. OECOLOGIA 116 (4): 543-555.

   This paper describes the regeneration of vegetation by *Spartina patens* and *Sagittaria lancifolia* following three levels of disturbance: no disturbance, nonlethal disturbance, and lethal disturbance. The authors conclude that lethal and nonlethal disturbance have different effects on regeneration of vegetation that can create specific patterns in the marsh communities.

6. Benner, R., Fogel, M. L., and Sprague, E. K. 1991 Diagenesis of belowground biomass of *Spartina alterniflora* in salt marsh sediments. LIMNOLOGY AND OCEANOGRAPHY 36 (7): 1358-1374.

   During 18 months of decomposition, belowground biomass of *Spartina alterniflora* lost 55% of its organic matter. Significant losses of lignin were noted. Two phases of nitrogen loss during the decomposition study are discussed, as well as stable C isotope composition.

7. Bertness, M. D. 1991. Zonation of *Spartina patens* and *Spartina alterniflora* in a New England salt marsh. ECOLOGY 72 (1): 138-148.

   The author examines the role of interspecific competition in maintaining the zonation pattern of New England salt marshes where typically *Spartina alterniflora* monocultures dominate low marsh habitats and *Spartina patens* dominates the seaward border of high marsh habitats

8. Bertness, M. D. 1985. Fiddler crab regulation of *Spartina alterniflora* production on a New England salt marsh. ECOLOGY 66: 1042-1055.

   Manipulative field experiments were conducted on both tall and short-form *Spartina alterniflora* habitats to determine the effects of burrowing activity by *Uca pugnax*, the mud fiddler crab, on sediment oxygenation, soil drainage, and belowground decomposition rates. The author concludes that the relationship between fiddler crabs and *S. alterniflora* appears to be a facultative mutualism. While initially dependent on *S. alterniflora* in soft sediments, *U. pugnax* burrowing activity helps maintain suitable habitat for continued burrowing which ultimately increases cordgrass production and maintains tall form *S. alterniflora* stands. Fiddler crabs appear to have less of an impact on the short-form *S. alterniflora* stands because of the dense root mat associated with this habitat which hinders burrowing.

9. Bertness, M. D. 1984. Ribbed mussels and *Spartina alterniflora* production in a New England salt marsh. ECOLOGY 65 (6): 1794-1807.

   The author examines the relationship between ribbed mussels, *Geukensia demissa*, and tall form *Spartina alterniflora*. The relationship between the

two appears to represeant a facultative mutualism leading to increased marsh net primary productivity and stability.

10. Bertness, M. D., and Ellison, A. M. 1987. Determinants of pattern in a New England salt marsh plant community. ECOLOGICAL MONOGRAPHS 57 (2): 129-147.
    Zonation patterns of *Spartina alterniflora*, *Disthchlis spicata* and *Salicornia europaea* are discussed. High marsh perennials appear to be restricted to the high-marsh habitat due to harsh physical conditions in the low-marsh habitat. *S. alterniflora*, which dominates the low-marsh, is capable of vigorous growth in the high-marsh, but appears to be excluded in the high marsh by the competition of high-marsh perennials. The authors conclude that physical disturbance and interspecific competition appear to be major determinants of vegetation pattern of marsh plant communities.

11. Blum, L. K. 1993. *Spartina alterniflora* root dynamics in a Virginia marsh. MARINE ECOLOGY PROGRESS SERIES. 102 (1-2): 169-178.
    Root and rhizome decomposition and production was measured via a litter bag technique over a 2 year period in creekside and interior sediments of *Spartina alterniflora* in Virginia. Results suggest that differences in root production rather than differences in decay processes may account for differences in organic matter accumulation in high and low marsh areas.

12. Blum U., Seneca, E. D., and Stroud, L. M. 1978. Photosynthesis and respiration of *Spartina* and *Juncus* salt marshes in North Carolina: Some models. ESTUARIES 1 (4): 228-238.
    In situ gas exchange measurements were taken for *Juncus roemerianus* Scheele and short, medium, and tall height forms of *Spartina alterniflora* Loisel over a 15-month period during low tide. Preliminary models were developed for net photosynthesis, ecosystem respiration, and respiration of aboveground standing crop. These models were validated by comparing net primary productivity of aboveground standing crop calculated from model data with harvest estimates of net primary productivity for the same year. Carbon exchange and energy efficiency values were also compared to literature values.

13. Bradley, P. M., and Dunn, E. L. 1975. Effects of sulfide on the growth of three salt marsh halophytes of the southeastern United States. AMERICAN JOURNAL OF BOTANY 76 (12): 1707-1713.
    This study reports the results of a hydroponic culture experiment designed to examine the effects of in situ concentrations of sulfide on the growth and distribution of *Spartina alterniflora* and whether it plays a role in the determination of the different height forms. Additional studies were conducted on *Spartina cynosuroides* and *Borrichia frutescens* (representing a low and high tolerance species, respectively) to determine if sulfide also influences the overall distribution of these two species in the marsh. Results from culture experiments indicate that both plant height and biomass production of *S. alterniflora* were inhibited at sulfide concentrations as low as

1.0 mM strongly suggesting that sulfide may play a role in the height form determinations.

14. Bradley, P. M., and Morris, J. T. 1992. Effect of salinity on the critical nitrogen concentration of *Spartina alterniflora* Loisel. AQUATIC BOTANY 43 (2): 149-161.

The Critical Nitrogen Content (CNC) of *Spartina alterniflora* grown under varying salinity treatments was estimated, and the relationship between CNC and salinity was used to evaluate the nitrogen content of *S. alterniflora* from a variety of field sites. During a greenhouse study, nitrogen was withheld to determine the effect of salinity on critical tissue nitrogen concentrations. Results indicate decreased growth of *S. alterniflora* with increasing salinity; as well as an increase in nitrogen requirement under conditions of salinity stress; and productivity of S. alterniflora is generally limited by nitrogen throughout the salt marsh environment. It suggests that plant growth may be limited by the internal nitrogen availability, while increasing the external nitrogen content has no effect on growth.

15. Bradley, P. M., and Morris, J. T. 1991. Relative importance of ion exclusion, secretion and accumulation in *Spartina alterniflora* Loisel. JOURNAL OF EXPERIMENTAL BOTANY 42 (245): 1525-1532.

Under varying salinity treatments, the authors investigated the extent to which *Spartina alterniflora* Loisel excluded, secreted or accumulated the major seawater ions (Cl^-, SO_4^{2-}, Na^+, K^+, Mg^{2+}, and Ca^{2+}). The flux of ions from salt marsh sediments to the flood water by means of shoot secretion or stem/leaf turnover indicate that these mechanisms may be important in limiting the accumulation of salt within the root zone of *Spartina alterniflora*.

16. Bradley, P. M., and Morris J. T. 1991. The influence of salinity on the kinetics of NH_4^+ uptake in *Spartina alterniflora*. OECOLOGIA 85 (3): 375-380.

A laboratory culture experiment was used to determine the effects of short and long-term exposure to a range in concentration of sea salts on the kinetics of NH_4^+ uptake by *Spartina alterniflora*. This study demonstrates that constant long-term exposure to salinity within the 5-50 g/L range competitively inhibits the uptake of NH_4^+ in *S. alterniflora*. High salinity and/or rapid increases in salinity appear to be toxic to the plants. Results are consistent with a conceptual model describing changes in the kinetics of NH_4^+ uptake of *S. alterniflora* as a function of environmental gradients in the salt marsh.

17. Bradley, P. M., and Morris, J. T. 1990. Influence of oxygen and sulfide concentration on nitrogen uptake kinetics in *Spartina alterniflora*. ECOLOGY 71 (1): 282-287.

A laboratory culture experiment was conducted to measure the kinetics of nitrogen uptake by *Spartina alterniflora* as a function of rhizosphere sulfide and oxygen concentration. The study indicates that nitrogen is one edaphic factor that limits the growth of *S. alterniflora*, however nitrogen uptake and nitrogen limitation are functions of sulfide and oxygen concentration and possibly other variables such as salinity.

18. Breteler, R. J., Valiela I., et al. 1981. Bioavailability of mercury in several North eastern U.S. *Spartina* ecosystems. ESTUARINE COASTAL AND SHELF SCIENCE 12: 155-166.

This study focuses on the measurement of mercury concentrations in sediments, marsh grasses, mussels and fiddler crabs in salt marsh plots treated with mercury-containing commercial sludge fertilizer and in clean and industrially contaminated marshes. Results indicate that mercury accumulated in the roots of *Spartina alterniflora* rather than above ground tissues or rhizomes.

19. Brewer, J. S., and Bertness, M. D. 1996. Disturbance and intraspecific variation in the clonal morphology of salt marsh perennials. OIKOS 77 (1): 107-116.

Wrack burial disturbance and intraspecific variation in clonal morphology of *Distichlis spicata* and *Spartina patens* were examined. The authors conclude that intraspecific variation in clonal morphology of marsh perennials can be strongly affected by disturbance and that disturbance effects can be site and species specific.

20. Brewer, J. S., Rand, T, Levine, J. M., and Bertness, M. D. 1998. Biomass allocation, clonal dispersal, and competitive success in three salt marsh plants. OIKOS 82 (2): 347-353.

A greenhouse study was conducted to determine biomass allocation, clonal dispersal, and competitive success of *Distichlis spicata, Spartina patens*, and *Juncus gerardi*.

21. Bricker-Urso, S., Nixon, S. W., Cochran, J. K., Hirschberg, D. J., and Hunt, C. 1989. Accretion rates and sediment accumulation in Rhode Island salt marshes. ESTUARIES 12 (4): 300-317.

^{210}Pb analyses were completed and accretion rates were determined using constant flux and constant activity models to low Spartina alterniflora sediment cores to test the assumption that accretion rates are approximately equal to rates of sea-level rise in a Rhode Island salt marsh.

22. Broome, S. W., Seneca E. D., and Woodhouse W. W. 1986. Long-term growth and development of transplants of the salt marsh grass *Spartina alterniflora*. ESTUARIES 9 (1): 63-74.

The role of transplant spacings on the establishment of *Spartina alterniflora* in a North Carolina salt marsh was investigated and annual biomass of the transplanted marsh was compared to a natural marsh. 45, 60 and 90 cm spacings were evaluated. The 45 and 60 cm spacings were more successful on marginal sites near the lower elevation limits of S. alterniflora, while the 90 cm spacing was adequate under favorable growing conditions. Annual above and belowground rates of transplanted and nearby natural marshes were compared over 10 years. The transplanted marsh was persistent and self-sustaining. It was effective in reducing shoreline erosion and was comparable to a natural marsh under similar environmental conditions.

23. Broome, S.W., Seneca, E. D., and Woodhouse W. W. 1983. The effects of source, rate and placement of nitrogen and phosphorus fertilizers on growth of *Spartina alterniflora* transplants in North Carolina. ESTUARIES 6 (3): 212-226.

Establishment, growth, and tissue nutrient concentrations of *Spartina alterniflora* were evaluated to determine the effects on rate of N and P fertilizer, type of fertilizer material, and application method. N and P were growth-limiting factors at the test site. During the second growing season, residual evidence of the fertilizer was evident, but top-dressing of N and P was necessary to maintain a vigorous stand.

24. Broome, S. W., Woodhouse, W. W., and Seneca, E. D. 1974. Propagation of smooth cordgrass, *Spartina alterniflora*, from seed in North Carolina. CHESAPEAKE SCIENCE 15(4): 214-221.

This paper discusses direct seeding of *Spartina alterniflora*, which is an effective method of establishing new stands of *Spartina* on dredge spoil in protected areas. The authors discuss the process of harvesting the seeds, storage, and direct seeding. The success of seeding versus transplants is also discussed.

25. Burdick, D. M., Mendelssohn, I. A., and McKee, K. L. 1989. Live standing crop and metabolism of the marsh grass *Spartina* patens as related to edaphic factors in a brackish, mixed marsh community in Louisiana. ESTUARIES 12 (3): 195-204.

The authors examined the soil-plant relationships of three zones (creek edge, levee berm, and inland) of a brackish marsh co-dominated by *Spartina patens* and *Spartina alterniflora*. Soil physiochemical factors (soil moisture, redox potential, interstitial pH, salinity, ammonium, and sulfide concentrations) were compared to physiological indicators of *Spartina patens*.

26. Burger, J. and Shisler, J. 1983. Succession and productivity on perturbed and natural *Spartina* salt marsh areas in New Jersey. ESTUARIES 6 (1): 50-56.

The authors examined vegetation growth on dredge spoil placed on a *Spartina patens* and *Spartina alterniflora* marsh in New Jersey, two years after the spoil deposition. In areas of spoil deposition matching elevation of the marsh, percent cover by year one was 60 to 90% and 100% by year two. In areas where spoil was thicker, succession was extremely slow with only about 5% cover by the end of year one. Because *Spartina* colonizes primarily by rhizome growth, this slow recovery was attributed to the plants' inability to penetrate the thick spoil layer.

27. Burke, D. J., Weis J. S., and Weis, P. 2000. Release of metals by the leaves of the salt marsh grasses *Spartina alterniflora* and *Phragmites australis*. ESTUARINE COASTAL AND SHELF SCIENCE 51 (2): 153-159.

The purpose of this study was to examine differential release of metals by *Spartina alterniflora* and *Phragmites australis*. The authors conclude that via excretion and leaf deposition, *S. alterniflora* can release larger quantities of metals into the marsh environment than *P. australis*.

28. Carlson, P. R. and Forrest, J. 1982. Uptake of dissolved sulfide by *Spartina alterniflora*- Evidence from natural sulfur isotope abundance ratios. SCIENCE 216: 633-635.

The purpose of this study was to determine whether sulfide was taken up and incorporated by *Spartina alterniflora* in a natural marsh. To accomplish this, the isotopic composition of plant sulfur was compared to the isotopic composition of sulfate and sulfide in marsh pore waters. Results strongly indicate that sulfide had been oxidized within the plants because most of the plant sulfur derived from pore water sulfide was recovered as sulfate.

29. Cavalieri, A. J. 1983. Proline and glycinebetaine accumulation by *Spartina alterniflora* Loisel in response to NaCl and nitrogen in a controlled environment. OECOLOGIA 57 (1-2): 20-24.

Controlled environment growth chambers and hydroponic solutions were utilized to determine the effects of nitrogen and salinity on the growth of roots and shoots and accumulation of glycinebetaine and proline in *Spartina alterniflora* Loisel.

30. Chalmers, A. G. 1979. The effects of fertilization on nitrogen distribution in a *Spartina alterniflora* salt marsh. ESTUARINE AND COASTAL MARINE SCIENCE 8: 327-337.

The purpose of this study was to determine the effects of sewage sludge on the nitrogen cycle, specifically the effects on distribution of various forms of nitrogen in the soil of a short *Spartina alterniflora* marsh. In a year-long study, plant biomass and g N m^{-2} were increased substantially following the application of sewage sludge. At the end of the study, only about half of the added nitrogen could be accounted for, with the probable mechanism for loss being tidal exchange. Salinities in the sludge-amended areas were higher than unfertilized areas possibly due to transpiration. The authors discuss this increase in salinity on nitrogen utilization.

31. Chambers, R. M., Harvey, J. W., and Odum, W. E. 1992. Ammonium and phosphate dynamics in a Virginia salt marsh. ESTUARIES 15 (3): 349-359.

Experimental chambers in a short *Spartina alterniflora* marsh zone in a Virginia marsh were used to partition the tidal flux of dissolved nutrients at the marsh surface and in the water column. The authors hypothesize that the primary source of nutrients was organic matter mineralization in surface sediments that released nutrients into the flooding water column. Surface release and assimilation in the water column of both phosphate and ammonium were discussed.

32. Chambers, R. M., Mozdzer, T. J., and Ambrose, J. C. 1998. Effects of salinity and sulfide on the distribution of *Phragmites australis* and *Spartina alterniflora* in a tidal salt marsh AQUATIC 62 (3): 161-169.

The effects of short-term response of *Phragmites australis* and *Spartina alterniflora* to root immersion in solutions of different salinity and sulfide concentrations was examined under laboratory conditions. Results indicate that increased sulfide in the rhizosphere reduces Phragmites' ability to take up nutrients, thus restricting species distribution in the salt marsh, while Spartina is much better adapted to sulfidic soil conditions.

33. Christian, R.R., Hansen, J. A., Hodson, R. E., and Wiebe, W. J. 1983. Relationships of soil, plant, and microbial characteristics in silt-clay and sand, tall-form *Spartina alterniflora* marshes. ESTUARIES 6(1): 43-49.

Two tall-form *Spartina alterniflora* marshes on Sapelo Island, Georgia were compared with reference to soil texture, plant growth, and anaerobic microbial activity. One marsh soil type was composed of typical silt-clay-sized particles, while the other marsh consisted of >90% sand-sized particles. The two soil types supported similar biomass, but the plants in the silt-clay soil were taller and more robust than the sand soil.

34. Craft, C., Reader, J., Sacco, J. N., and Broome, S. W. 1999. Twenty-five years of ecosystem development of constructed *Spartina alterniflora* (Loisel) marshes. ECOLOGICAL APPLICATIONS 9(4): 1405-1419.

During a 25 year period, two constructed Spartina alterniflora marshes and paired natural S. alterniflora marshes in North Carolina were periodically monitoried to determine community structure (macrophyte aboveground biomass, macro-organic matter, benthic invertebrates) and ecosystem processes (soil development, organic C, N, and P concentrations). The authors conclude that different ecological attributes develop at different rates with primary producers achieving equivalence during the first 5 years and benthic infauna 5-10 years later. Levels of soil nutrients accumulated in the constructed marshes similar to natural marsh levels may require more time.

35. Dai, T., and Wiegert, R. G. 1996. Ramet population dynamics and net aerial primary productivity of *Spartina alterniflora*. ECOLOGY 77 (1): 276-288.
Net aerial primary productivity (NAPP) and ramet dynamics were compared among the tall, short and short with nitrogen fertilization forms of *Spartina alterniflora* at Sapelo Island, Georgia. The four objectives of the study were to: 1) compare demographic characteristics of the three forms; 2) use plant demographic information to estimate longevity of stems and leaves; 3) use a non-destructive method to estimate net aboveground primary productivity; and 4) test the hypothesis that the leaves of short *S. alterniflora* should have longer longevity or lower turnover than those of the tall form.

36. de la Cruz, A. A. 1974. Primary productivity of coastal marshes in Mississippi. GULF RESEARCH REPORTS 4: 351- 356.
Annual net primary productivity for nine species common to the Mississippi Gulf Coast were studied via the harvest method (*Sagittaria lancifolia, Phragmites communis, Juncus roemerianus, Scirpus robustus, Spartina cynosuroides, Spartina patens, Spartina alternilfora* short form, *Spartina alterniflora* tall form, and *Dishichlis spicata*). Generally, annual net primary productivity for Mississippi marshes was slightly higher than for Atlantic marshes.

37. DeLaune, R. D., Buresh, R. J., and Patrick, W. H. 1979. Relationship of soil properties to standing crop biomass of *Spartina alterniflora* in a Louisiana marsh. ESTUARINE AND COASTAL MARINE SCIENCE 8 (5): 477-487.
This study measured the variation in chemical and physical soil properties and aboveground plant biomass with distance inland from a stream to examine the relationship between soil properties and total standing crop biomass of *Spartina alterniflora*. Plants were taller with denser stands streamside versus inland, and soil density decreased with increasing distance inland. Neither extractable P, K, Mg, Ca, Na, or total soil N expressed on a dry weight soil basis was significantly related to plant growth, but when converted to soil volume expression ($\mu g\ cm^{-3}$) was positively correlated with growth of *S. alterniflora*.

38. DeLaune, R. D., Nyman, J. A., and Patrick, W. H. 1994. Peat collapse, ponding and wetland loss in a rapidly submerging coastal marsh. JOURNAL OF COASTAL RESEARCH 10 (4): 1021-1030.
The purpose of this study was to test the hypothesis that plant mortality and the resultant structural collapse of the living root network caused marsh surface elevation to decrease thus causing pond initiation and wetland loss. Elevation of 20 marsh hummocks of living *Spartina alterniflora* was monitored between April 1990 and April 1992. Results of ^{137}Cs inventory in soil collected before and after the study indicated peat collapse rather than erosion caused the elevation decrease.

39. DeLaune, R. D., Smith, C. J., and Patrick, W. H. 1983. Relationship of marsh elevation, redox potential, and sulfide to *Spartina alterniflora* productivity. SOIL SCIENCE SOCIETY OF AMERICAN JOURNAL 47 (5): 930-935.
The purpose of this study was to identify the relationships of inorganic NH_4^+-N, redox potential, and sulfide concentration to the productivity of *S. alterniflora* in Louisiana salt marshes. The study site was located in Barataria Bay, Louisiana and represented the two height forms of *S. alterniflora* most commonly found, located along a transect from a tidal stream (tall form) to the nonvegetated inland depression (short form). Results suggest that the short height form of S. alterniflora found in inland areas of Louisiana Gulf Coast marshes

is caused by toxic sulfide concentrations, a result of slightly lower elevation and subsequently lower sediment redox potential than the adjacent streamside marsh.

40. DeLaune, R. D., Smith, C. J., and Tolley, M. D. 1984. The effect of sediment redox potential on nitrogen uptake, anaerobic root respiration and growth of *Spartina alterniflora* Loisel. AQUATIC BOTANY 18 (3): 223-230.

    This study's focus was to determine the effects of sediment redox potential on nitrogen uptake, anaerobic root respiration, and growth of *S. alterniflora*. Seedlings were obtained from a site in Barataria Basin, Louisiana, the plants were grown under controlled redox potential-pH conditions (the plants were transferred to desiccator bases containing pre-incubated soil suspensions and grown for 20 days). Results from this study indicate that redox potential alone does not have any affect on the growth and NH_4^+ assimilation by *S. alterniflora*.

41. deSouza, M. P., and Yoch, D. C. 1997. *Spartina alterniflora* dieback recovery correlates with increased acetylene reduction activity in salt marsh sediments. ESTUARINE COASTAL AND SHELF SCIENCE 45 (4): 547-555.

    Four different diebacks of *Spartina alterniflora* in Cooper River estuary were studied and all four sites showed low rates of acetylene reduction activity (ADA) relative to control plots populated by healthy *S. alterniflora*. One of the four dieback sites recovered and the recolonization of the barren area with healthy plants correlated with a return of sediment ARA, but this recovered ARA could not be correlated to any of the porewater parameters measured or with any sediment characteristics.

42. Drifmeyer, J. E., and Redd, B. 1981. Geographic variability in trace element levels in *Spartina alterniflora*. ESTUARINE COASTAL AND SHELF SCIENCE 13: 709-716.

    The purpose of this study was to determine the variation in trace element composition (Mn, Fe, Cu, Zn, and Ni) in live *Spartina alterniflora* from six marshes along a salinity gradient of the York River estuary. Samples were also taken from areas over a large extent of the plant's geographic range (the Atlantic coast from Maine to Georgia, with specific emphasis on the Mid-Atlantic areas of Virginia and North Carolina). This allowed the investigation of two scales of geographic variability: within a given estuary and between several different estuaries.

43. Dunstan, W. M., Windom, H. L., et al. 1975. The role of *Spartina alterniflora* in the flow of lead, cadmium and copper through the salt marsh ecosystem. <u>Mineral cycling in southeastern ecosystems.</u> F. G. Howell, J. B. Gentry and M. H. Smith. Washington, D. C., U. S. Energy Research and Development Administration.

    The objective of this study was to examine the significance of the heavy metals cadmium, lead and copper on *Spartina alterniflora* production and assess the importance of *Spartina* in controlling their flux within the marsh system and ultimately to the coastal marine environment. A rough budget for these metals was constructed from measurements of the input of these metals from southeastern river systems, from which the role of *Spartina* in the cycle of these heavy metals is estimated.

44. Eleuterius, L. N., and Caldwell, J. D. 1985. Soil characteristics of *Spartina alterniflora*, *Spartina patens*, *Juncus roemerianus*, *Scirpus olneyi*, and *Distichlis spicata* populations at one locality in Mississippi. GULF RESEARCH REPORTS 8(1): 27-33.

    Soil characteristics from five adjacent monotypic zones (*Spartina alterniflora, Spartina patens, Juncus roemerianus, Scirpus olneyi,* and *Distichlis spicata*) were determined. Soil pH, organic matter, N, P, K, S, Zn, Ca, and Mg concentrations were based on seasonal composite soil samples. Soil water samples were analyzed to determine water content, salinity, PO_4, and NH_3. Results depict the complex patterns in the physical and chemical soil characteristics among salt marsh plant species with soil characteristics being highly variable within and among a population.

45. Fallon, R. D., and Pfaender, F. K. 1976. Production and fractionation of $^{14}CO_2$ labeled smooth cordgrass, *Spartina alterniflora*. CHESAPEAKE SCIENCE 17(4): 292-295.

The authors developed a simple growth chamber technique for use of labeling *Spartina alterniflora* with ^{14}C. After a 1-week pulse of $^{14}CO_2$, useful levels of activity in the plant material were achieved. The authors recommend use of this simple, low cost chamber for plant biochemistry experiments and for the production of labeled detritus and plant fractions.

46. Ford, M. A., Cahoon, D. R., and Lynch, J. C. 1999. Restoring marsh elevation in a rapidly subsiding salt marsh by thin-layer deposition of dredged material. ECOLOGICAL ENGINEERING 12 (3-4): 189-205.

The purpose of this study was to evaluate the impact of spray dredging (thin-layer deposition of dredged material on a coastal marsh by means of high-pressure spray dredging technology) on vegetated marsh and adjacent shallow-water habitat (previously vegetated marsh that deteriorated to open water). A 0.5-ha *Spartina alterniflora* dominated marsh in coastal Louisiana was chosen as the study site. Thin layer deposition of dredged material appeared effective in restoring and maintaining marsh elevation after 1.5 years, but the open water sediments are vulnerable and must first stabilize vegetative colonization because erosion may lower elevations to a level where emergent vegetation can no longer endure.

47. Furbish, C. E., and Albano, M. 1994. Selective herbivory and plant community structure in a mid-Atlantic salt marsh. ECOLOGY 75 (4): 1015-1022.

The purpose of this study was to determine if physicochemical environmental conditions (tidal inundation and amplitude, surface and subsurface salinity, and subsurface redox potential) created the potential for a competitive relationship between *Spartina alterniflora* and *Distichlis spicata*. The authors also examined preferential grazing pressure, if any, in the salt marsh via field measurements of grazed plants. Observations of feral horse feeding behavior and examination of feral horse feces for grass epidermal fragments was also completed. An exclosure experiment was also implemented to simulate preferential grazing. Results indicate a competitive relationship between the grasses under suboptimal conditions of either species. Selective herbivory was likely a factor impacting *S. alterniflora* in favor of *D. spicata*.

48. Gallagher, J. L. and Howarth, R. W. 1987. Seasonal differences in *Spartina* recoverable underground reserves in the Great Sippewissett marsh in Massachusetts. ESTUARINE COASTAL AND SHELF SCIENCE 25: 313-319.

Cores taken from stands of three growth forms of *Spartina alterniflora* and one of *Spartina patens* and recoverable underground reserves (RUR) were collected. Collections were coordinated around spring growth and following senescence in the fall. For *S. alterniflora*, reserves were very low in summer, but were restored by fall, while *Spartina patens* RUR remained high during the summer.

49. Gallagher, J. L., Reimold, R. J., Linthurst, R. A., and Pfeiffer, W. J. 1980. Aerial production, mortality, and mineral accumulation export dynamics in *Spartina alterniflora* and *Juncus roemerianus* plant stands in a Georgia salt marsh. ECOLOGY 61 (2): 303-312.

An objective of this study was to compare the aboveground primary productivity of creek bank and high marsh *Spartina alterniflora* with *Juncus roemarianus*. Spartina (tall creek bank and short high marsh) and Juncus stands were measured at 4-wk intervals for 1 year and 8-wk intervals for a 2nd year. Net primary production estimates were then compared using the Wiegert and Evans (1964) method with the Smalley (1959) methods. The seasonal amplitudes in the amounts of N, P, K, Ca, and Mg in the living tissue were also measured and discussed.

50. Gallagher, J. L., Somers, G. F., Grant, D. M., and Seliskar, D. M. 1988. Persistent differences in 2 forms of *Spartina alterniflora* – A common garden experiment. ECOLOGY 69 (4): 1005-1008.

A nine-year study was conducted monitoring the growth of tall and short form *Spartina alterniflora* plants transplanted from a Delaware marsh to common garden plots. At the end of nine years, plant biomass, culm height, density and diameter and flowering frequency

remained distinct for the two forms. The authors suggest some genetic control of the morphology and physiology of the two growth forms because they had been living in the same environment for nine years, and had retained many morphological and physiological differences.

51. Gerard, V. A. 1999. Positive interactions between cordgrass, *Spartina alterniflora*, and the brown alga, *Ascophyllum nodosum* ecad scorpioides, in a mid-Atlantic coast salt marsh. JOURNAL OF EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY 239 (1): 157-164.
The purpose of this study was to determine the interactions between *Spartina alterniflora* and the brown alga, *Ascophyllum nodosum*. This was done by the experimental removal of each species. Both *S. alterniflora* and *A. nodosum* appear to benefit from their coexistence in the low marsh. The absence of *A. nodosum* throughout the growing season caused a significant reduction in plant biomass at the end of the season in comparison to the control treatment. *A. nodosum* exhibited slower growth and greater dehydration when held in the *Spartina*-removed plots versus the control plots and most *A. nodosum* was lost from the *Spartina*-removed plots during the following fall.

52. Giurgevich, J. R., and Dunn, E. L. 1981. A comparative analysis of the CO_2 and water vapor responses of two *Spartina* species from Georgia coastal marshes. ESTUARINE COASTAL AND SHELF SCIENCE 12 (5): 561-568.
The purpose of this study was to examine CO_2 and water vapor exchange patterns of *Spartina cynosuroides* and *Spartina alterniflora* along the coast of Georgia. Comparisons regarding photosynthetic response are made among the two species and results indicate that both species efficiently utilize the high light/high temperature regimes of the southeastern U.S. marshes.

53. Gleason, M. L. and Zieman, J. C. 1981. Influence of tidal inundation on internal oxygen-supply of *Spartina alterniflora* and *Spartina patens*. ESTUARINE COASTAL AND SHELF SCIENCE 13 (1): 47-57.
This study examines the fluctuations of internal oxygen content of *Spartina alterniflora* (both controlled laboratory and natural environments) and *Spartina patens* (controlled laboratory experiments only). Oxygen concentrations during tidal submergence and emergence, as well as light and dark conditions are discussed. Findings suggest that *Spartina patens* may have a lesser ability to supply oxygen to belowground organs during flooding, possibly explaining *S. patens'* inability to colonize the regularly flooded marsh habitat of *S. alterniflora*.

54. Halvorson, W. L. and Singer, A. C. 1974. Growth responses of *Spartina patens* and *Spartina alterniflora* analyzed by means of a 2-dimensional factorial design. AMERICAN MIDLAND NATURALIST 91 (2): 444-449.
A greenhouse experiment was conducted to compare growth of *Spartina patens* and *Spartina alterniflora* under identical controlled conditions and environmental factors. Varying levels of iron and nitrogen and levels of salinity were used to relate conditions found to occur in the natural marsh. Results indicate *S. patens* grew better under low iron levels, while *S. alterniflora's* growth was only slightly enhanced under low iron conditions and growth of both species was reduced more due to salinity than lack of nitrogen.

55. Hopkinson, C. S., Jr, and Schubauer, J. P. 1984. Static and dynamic aspects of nitrogen cycling in the salt marsh graminoid *Spartina alterniflora*. ECOLOGY 65: 961-969.
The purpose of this study was to examine quantitatively the nitrogen cycle in *Spartina alterniflora* and assess the importance of this plant to the overall nitrogen cycle of a salt marsh ecosystem. The authors conclude that the high degree of nitrogen conservation in *Spartina*, low leachability, and retraction from senescent tissue are consistent with the notion that primary productivity in salt marshes is nitrogen limited.

56. Howarth, R. W., and Teal, J. M. 1979. Sulfate reduction in a New England salt marsh. LIMNOLOGY AND OCEANOGRAPHY 24: 999-1013.
Radiotracer technique was used to measure sulfate reduction rates for *Spartina alterniflora*. The stable pyrite (FeS_2) is a major end product of sulfate reduction in the marsh peat, while

iron monosulfide (FeS) is not. Pyrite acts as a temporary store of reduced sulfur, with seasonal concentration changes.

57. Howes, B. L., Dacey, J. W. H., and Teal, J. M. 1985. Annual carbon mineralization and belowground production of *Spartina alterniflora* in a New England salt marsh. ECOLOGY 66 (2): 595-605.
    Belowground decomposition for short *Spartina alterniflora* stands was estimated by measuring CO_2 production. Two independent techniques to measure CO_2 production were used. The results of the two techniques were similar with total annual CO_2 production ranging between 67 and 70 mol m^{-2} yr^{-1}.

58. Hwang, Y. H., and Morris, J. T. 1994. Whole plant gas exchange responses of *Spartina alterniflora* (Poaceae) to a range of constant and transient salinities. AMERICAN JOURNAL OF BOTANY 81 (6): 659-665.
    Whole-plant gas exchange was measured, including photosynthesis, leaf conductance, and respiration using a two-chamber system to determine *Spartina alterniflora's* response to long-term and transient salinity treatments in the range of 5 to 40 ppt. Results indicate that *S. alterniflora* adapts to constant salinity through, fixed, salinity-dependent structural modifications (i.e. stomatal density).

59. Khalid, R. A., Patrick, W. H., and Gambrell, R. P. 1978. Effect of dissolved oxygen on chemical transformations of heavy-metals, phosphorus, and nitrogen in an estuarine sediment. ESTUARINE AND COASTAL MARINE SCIENCE 6 (1): 21-35.
    Under laboratory conditions, the authors examined the various levels of dissolved O_2 on the transformation of Fe, Mn, Zn, Cu, Pb, Cd, Nh_4^+-N and P in Barataria Bay, Louisiana sediments. They also differentiated metal ions associated with Mn oxides from those associated with Fe oxides in the sediment-water system. The authors attempted to simulate dredging and dredged material disposal conditions. The study also estimates changes in the natural estuarine environment where seasonal variation in pH, oxidation-reduction conditions, and other physicochemical properties typically occur.

60. King, G. M. 1988. Patterns of sulfate reduction and the sulfur cycle in a South Carolina salt marsh. LIMNOLOGY AND OCEANOGRAPHY 33 (3): 376-390.
    This paper examines rates of sulfate reduction and the magnitude of various sediment parameters related to the sulfur cycle, measured quarterly over three years at tall and short form *Spartina alterniflora* sites in South Carolina.

61. King, G. M., Klug, M. J., Wiegert, R. G., and Chalmers, A. G. 1982. Relation of soil-water movement and sulfide concentration to *Spartina alterniflora* production in a Georgia salt marsh. SCIENCE 218 (4567): 61-63.
    This study proposes that the variations in plant height and productivity of *Spartina alterniflora* (short and tall forms) are controlled by the dynamic association among tidal water movement, dissolved iron and sulfide concentrations in marsh soils, and bacterial sulfate reduction. The authors propose that sulfide is the major factor limiting *S. alterniflora* production at the plant level, while at the ecosystem level the major limiting factor is the interchange among soil water movement and sulfide and iron concentrations. Conclusions are that the variations in *S. alterniflora* plant production within salt marshes of the southeastern Atlantic and Gulf coasts appear to be a result of water movement and iron input.

62. King, G. M., and Weibe, W. J. 1980. Regulation of sulfate concentrations and methanogenesis in salt marsh soils. ESTUARINE AND COASTAL MARINE SCIENCES 10: 215-223.
    The purpose of this study was to investigate the interaction of water movement, sulfate concentration, and methanogenesis. By restricting water movement through soils of the tall

form *Spartina alterniflora*, interstitial sulfate concentrations decreased by a factor of 2-5 over a period of two months. Accompanying this decrease in sulfate was a marked increase in *in vitro* methane production. The authors conclude that sulfate depletion may occur in microzones within the soil, and *in situ* differences between methanogenesis in the tall and short form *Spartina* regions are suggested to be the result of this sulfate depletion.

63. Kirby, C. J. and Gosselink, J. G. 1976. Primary production in a Louisiana gulf coast *Spartina alterniflora* marsh. ECOLOGY 57 (5): 1052-1059.
    This paper reports the results of net primary production of *Spartina alterniflora* Loisel in a Louisiana salt marsh determined monthly over an annual cycle. Estimates for net primary production ranged from 750 to 2,600 g m^{-2} yr^{-1} and analysis of these results indicate that true net production was probably closer to the highest estimate than the lowest.

64. Koch, M. S., and Mendelssohn, I. A. 1989. Sulphide as a soil phytotoxin: Differential responses in two marsh species. JOURNAL OF ECOLOGY 77 (2): 565-578.
    A glass house study was conducted to determine if sulphide addition affects the growth of *S. alterniflora*. A comparative study was also set up to determine if *Panicum hemitomon* Schult. was more susceptible to sulphide additions.

65. Koch, M. S., Mendelssohn, I. A., McKee, K. L. 1990. Mechanism for the hydrogen sulfide induced growth limitation in wetland macrophytes. LIMNOLOGY AND OCEANOGRAPHY 35 (2): 399-408.
    This study compares the effects of aeration, hypoxia, and hypoxia plus sulfide on root ADH activity, root energy status, nitrogen uptake, and leaf growth of *Spartina alterniflora* (a salt marsh species that is regularly exposed to high sulfide concentrations) and *Panicum hemitomon* (a fresh water species that is rarely in contact with high sulfide levels). Results indicate that H_2S has a growth limiting effect on plants inhabiting waterlogged soil environments. The data suggest that H_2S can hinder ADH activity, limiting an important alternate anoxic course, resulting in the inability to produce ATP and maintain the energy status of the root cells. This can result in limitations of nutrient uptake (i.e. N uptake), which is an energy dependent metabolic function. The authors conclude that "wetland plants exposed to strongly reducing soil conditions where sulfide accumulates may exhibit reduced growth and even die-back because of the suppression of anoxic, as well as aerobic, energy production".

66. Linthurst, R. A., and Seneca, E. D. 1980. The effects of standing water and drainage potential on the *Spartina alterniflora* substrate complex in a North Carolina salt marsh. ESTUARINE AND COASTAL MARINE SCIENCE 11 (1): 41-52.
    The objectives of this study were to examine the effects of various standing water depths (elevation) and drainage potential differences on the nature of the substrate and on the growth of *Spartina alterniflora*. A 1-year field investigation was completed to determine the impact that drainage and standing water have on the growth of *S. alterniflora* and on the levels of selected substrate variables.

67. Livingstone, D. C., and Patriquin, D. G. 1981. Belowground growth of *Spartina alterniflora* Loisel- Habitat, functional biomass and non-structural carbohydrates. ESTUARINE COASTAL AND SHELF SCIENCE 12 (5): 579-587.
    The purpose of this study was to examine aboveground/belowground biomass ratios and estimated net belowground production for stands of *Spartina alterniflora* of increasing plant density and age of a recently colonized sandbar in Nova Scotia. The relationship of non-structural carbohydrate (NSC) content to plant growth during a growing season was also examined. Three distinct phases of growth are discussed.

68. Mendelssohn, I. A. 1979. Nitrogen metabolism in the height forms of *Spartina alterniflora* in North Carolina. ECOLOGY 60 (3): 574-584.

The purpose of this study was to explore nitrogen limitation of *Spartina alterniflora* by monitoring the inorganic nitrogen metabolism and concentrations of various nitrogen constituents in the tall, medium, and short forms of this species. Low soil interstitial water nitrate concentrations and low plant tissue nitrate concentrations and reductase activities indicate that nitrate was of minor importance as a nitrogen source for this *Spartina* marsh. Results indicated that ammonium, with interstitial water and plant tissue concentrations of magnitude 1-2 orders greater than nitrate, was the dominant inorganic nitrogen source.

69. Mendelssohn, I. A., and McKee, K. L. 1988. *Spartina alterniflora* dieback in Louisiana- time course investigation of soil waterlogging effects. JOURAL OF ECOLOGY 76 (2): 509-521.
A time course experiment was conducted to identify factors involved in the growth reduction and dieback of *Spartina alterniflora* in a Louisiana marsh. Sequence and timing of various changes in soil and plant parameters were determined after the reciprocal transplantation of swards (intact soil substrate plus associated vegetation) of streamside *Spartina* marsh into the more waterlogged inland/dieback transition zone and vice versa. Results indicate that reciprocal transplantation demonstrated that inland sites in Louisiana marshes caused reduced soil conditions and sulphide accumulation in streamside soil that was previously low in sulphide. When inland swards were transplanted to the more oxidized streamside zone, the detrimental conditions were ameliorated resulting in increased plant growth. The authors conclude that soil reduction, sulphide concentration, and root anaerobic metabolism may all interact to affect growth of *Spartina* more than one single factor. This study supports the hypothesis that increased soil reduction and increased sulphide concentrations are major factors limiting the growth of *Spartina* and may be a cause of dieback, but more investigations are necessary to determine the specific effects of sulphide and the interaction of root anaerobic metabolism.

70. Mendelssohn, I. A., McKee, K. L., and Postek, M. T. 1982. Sublethal stresses controlling *Spartina alterniflora* productivity, pp. 223-42.. In B. Gopal, R. E. Turner, R. G. Wetzel, and D. F. Whigham, (eds), Wetlands: Ecology and Management, National Institute of Ecology, Jaipur, India.
This paper reviews and presents experimental data concerning the importance of tidal inundation, salnity, soil waterlogging, ion toxicity, and nutrient deficiencies in determining the height forms (tall versus short) of *Spartina alterniflora*. Review of the literature was completed for *S. alterniflora* productivity covering topics including salinity, plant nutrients, light and temperature, soil waterlogging, root oxygen deficiency, soil phytotoxins, tidal energy subsidy, mineral content of marsh substrates, and ecotypic differentiation.

71. Mendelssohn, I. A., and Postek, M. T. 1982. Elemental analysis of deposits on the roots of *Spartina alterniflora* Loissel. AMERICAN JOURNAL OF BOTANY 69 (6): 904-912.
The objectives of this study were to evaluate the extent to which the rhizosphere of *Spartina alterniflora* is important in precipitating iron and manganese and to determine any difference in intensity of precipitation as a function of location (inland versus streamside). Elemental analysis of the roots of streamside versus inland plants resulted in approximately 50 times more iron found in streamside roots than inland roots suggesting a better developed oxidized rhizosphere for the streamside *Spartina* plants, thus providing a more favorable environment for nutrient uptake to proceed.

72. Mendelssohn, I. A., and Seneca, E. D. 1980. The influence of soil drainage on the growth of salt marsh cordgrass *Spartina alterniflora* in North Carolina. ESTUARINE AND COASTAL MARINE SCIENCE 11 (1): 27-40.
The objectives of this study were to define the differences in soil drainage among the different height forms of *Spartina alterniflora* in Oak Island Marsh, North Carolina, as well as the effect of soil drainage on *Spartina* growth. A greenhouse study was utilized to determine the effect of three levels of soil-water drainage on the growth of the three height forms of *Spartina* (tall, medium, and short forms). Results from field manipulations and greenhouse studies (simulated marsh conditions and high nutrient growth conditions) are discussed.

73. Morris, J. T. 1980. The nitrogen uptake kinetics of *Spartina alterniflora* in culture. ECOLOGY 61 (5): 1114-1121.

An experiment was designed to measure the capacity of *Spartina alterniflora* to absorb nitrogen. Rates on nitrogen uptake were measured using intact plants growing outdoors in solution cultures. A Michaelis-Menten model was an accurate predictor of nitrogen uptake kinetics and was fit to the observed uptake rates thus providing a measure of the efficiency of nitrogen utilization.

74. Morris, J. T., and Dacey, J. W. H. 1984. Effects of O_2 on ammonium uptake and root respiration by *Spartina alterniflora*. AMERICAN JOURNAL OF BOTANY 71 (7): 979-985.

A greenhouse study was used to look at the relationship between O_2 concentration in the rhizosphere and NH_4^+ uptake rate by *Spartina alterniflora*. Plants were collected from Great Sippewissett Marsh in Falmouth, Massachussetts and transplanted to sand cultures in the greenhouse. Results suggest that the growth effects of nitrogen availability and sediment aeration are related. The authors investigated the importance of O_2 diffusion through the stems by measuring NH_4^+ uptake and root respiration by using a CH_4 tracer and varying the O_2 concentration in the leaf chamber. Results suggest that the external supply of O_2 to the roots is a significant determinant of *Spartina* productivity in sediments that are usually anoxic. Also, internal diffusion of O_2 appears to be important to the metabolism of roots in an anoxic environment. The diffusion rate of the CH_4 tracer gas from leaves to roots of individual plants indicated significant variations in anaerobic rates of NH_4^+ uptake and root respiration from plant to plant.

75. Morris, J. T., and Haskin, B. 1990. A 5-yr record of aerial primary production and stand characteristics of *Spartina alterniflora*. ECOLOGY 71 (6): 2209-2217.

The purpose of this study was to document and explain the interannual variability in aboveground primary productivity over a 5-year period of salt marsh sites dominated by *Spartina alterniflora* in North Inlet, South Carolina. A non-destructive census method to measure plant growth was used. Mean seal level and/or rainfall appear to be important determinants of annual production, and have an effect on sediment salinity. Results also indicate that equivalent aboveground productivity was maintained in sites differing in their allocation of photosynthate between stem growth and asexual reproduction.

76. Naidoo, G., McKee, K. L., and Mendelssohn, I. A. 1992. Anatomical and metabolic responses to waterlogging and salinity in *Spartina alterniflora* and *S. patens* (Poaceae). AMERICAN JOURNAL OF BOTANY 79 (7): 765-770.

This study examined the effects of salinity and flooding tolerance stressors on *Spartina alterniflora* (salt marsh species dominant in the low marsh) and *Spartina patens* (usually occurring in brackish marshes, middle and upper reaches of salt marshes, and adjacent sandy beaches). A 2x2x2 factorial experiment with six replicates was conducted with the two species, two salinity levels, and drained or flooded regime. Results indicate that greater ADH activities and observations of root growth indicate that the effects of hypoxia appear greater on *S. patens* than *S. alterniflora*. *S. alterniflora* appears to be more tolerant of reducing soil conditions and increased salinity than *S. patens* and these differences in responses to waterlogging and salinity tolerance may explain the differences in salt marsh distribution between these two species.

77. Nyman, J. A., and DeLaune, R. D. 1991. CO_2 Emission and Soil Eh responses to different hydrological conditions in fresh, brackish, and saline marsh soils. LIMNOLOGY AND OCEANOGRAPHY 36 (7): 1406-1414.

The purpose of this study was to compare the effects of hydrological conditions on CO_2 emissions among fresh, brackish, and saline marshes of the Mississippi River Deltaic Plain, as well as examine the effects of hydrological conditions of soil Eh. The fresh marsh site was dominated by *Panicum hemitomon*, the brackish site by *Spartina patens*, and the saline site by *Spartina alterniflora*. Results exclude the possibility that reported differences in field measurements of CO_2 emission among fresh, brackish, and saline marsh soils relate to different hydrological conditions in the marsh types. Results also indicate that fundamental differences in decomposition processes and soil Eh exist among the different marsh types and these differences may be attributed to the different species of emergent vegetation occupying these different marsh types.

78. Otte, M. L., and Morris, J. T. 1994. Dimethylsulphoniopropionate (DMSP) in *Spartina alterniflora* Loisel. AQUATIC BOTANY 48 (3-4): 239-259.
A greenhouse study was utilized to determine the effect of sulphate on DMSP in *Spartina alterniflora* Loisel. The effect of nitrogen supply on DMSP was also examined. Results indicate that DMSP concentrations were not correlated with either salinity or sulphide concentrations in soil pore water suggesting that DMSP is neither a compatible osmolyte nor involoved in sulphide detoxification. Data suggests that nitrogen does play a key role in determining DMSP concentrations.

79. Padgett, D. E., and Brown, J. L. 1999. Effects of drainage and soil organic content on growth of *Spartina alterniflora* (Poaceae) in an artificial salt marsh mesocosm. AMERICAN JOURNAL OF BOTANY 86 (5): 697-702.
A mesocosm study was established to determine the effect of soil drainage depth and organic content on growth and rhizome proliferation of *Spartina alterniflora*. Results presented are from the first year of the long-term study. The authors propose a mathematical model for predicting the mass of photosynthetically significant leaf tissue without cutting and drying the leaves.

80. Parrondo, R. T., Gosselink, J. G., and Hopkinson, C. S. 1981. Influence of salinity on the absorption of rubidium by *Spartina alterniflora* and *Distichlis spicata*. BOTANICAL GAZETTE 142 (3): 402-407.
This paper examines the effects of NaCl, $CaCl_2$, and $MgCl_2$ on the absorption of rubidium (Rb) by isolated, excised roots and intact seedlings of *Spartina alterniflora*, and of NaCl on Rb absorption by *Distichlis spicata*. The rate of Rb absorption was reduced for both species when external NaCl solution concentrations equaled or exceeded 10 mM NaCl.

81. Parrondo, R. T., Gosselink, J. G., and Hopkinson, C. S. 1978. Effects of salinity and drainage on growth of three salt marsh grasses. BOTANICAL GAZETTE 139 (1): 102-107.
Two experiments were conducted: 1) Seedlings of *Spartina alterniflora, Spartina cynosuroides*, and *Distichlis spicata* were grown in a controlled environment in a nutrient solution containing varying concentrations of NaCl; and 2) seedlings of *S. alterniflora* and *S. cynosuroides* were grown in a greenhouse under constantly flooded or drained substrate. *D. spicata* was the most tolerant of high salinity than the two *Spartina* species. Roots of *S. alterniflora* grew better under flooded conditions than drained, while *S. cynosuroides* was significantly better in drained than flooded sediment. Findings were compared with field observations and the importance of salinity and flooding in determining plant distribution is discussed.

82. Pellenbarg, R. E. 1984. On *Spartina alterniflora* litter and the trace metal biogeochemistry of a salt marsh. ESTUARINE COASTAL AND SHELF SCIENCE 18 (3): 331-346.
The aqueous surface mircrolayer retained on fallen *Spartina alterniflora* litter was studied in spatial and seasonal contexts to determine the concentrations of the trace metals copper, nickel, zinc, manganese, and iron. The author also identifies two distinct chemical and physical types of microlayer in the salt marsh and discusses the biogeochemical significance of both microlayer types.

83. Pellenbarg, R. E., and Church, T. M. 1979. The estuarine surface microlayer and trace metal cycling in a salt marsh. SCIENCE 203 (9): 1010-1012.
The authors of this study examine the tidal budgets of trace metals copper, zinc, and iron carried as dissolved, particulate, and microlayer components fluxing in and out of a *Spartina alternifora* salt marsh with the tides. Water, seston, and surface microlayer samples were taken periodically over both ebbing and flooding tidal cycles over the spring, summer and fall

of 1975. Results indicate that trace metals cycle in this Delaware salt marsh by net import on the surface microlayer and net export in the dissolved and seston components during maximum monthly tide.

84. Pezeshki, S. R., and DeLaune, R. D. 1988. Carbon assimilation in contrasting streamside and inland *Spartina alterniflora* salt marsh. VEGETATION 76 (1-2): 55-61.
This paper compares stomatal conductance, photosynthetic rates, and above-ground biomass of *Spartina alternflora* growing on streamside (tall form) and inland marshes (short form) during the growing season in Barataria Bay, Louisiana. Average photosynthetic rates were significantly lower for inland plants, as well as lower leaf dry weight, leaf area index, and standing crop biomass. The differences betweeen the stream side and inland sites were attributed to a more stressed environment in the inland marsh including a combination of factors such as greater soil waterlogging, increased anaerobic root respiration, plant toxins (sulfide), and restricted nutrient uptake.

85. Reed, D. J., and Cahoon, D. R. 1992. The relationship between marsh surface topography, hydroperiod, and growth of *Spartina alterniflora* in a deteriorating Louisiana salt marsh. JOURNAL OF COASTAL RESEARCH 8 (1): 77-87.
Field surveys, tide gauge records, and plant growth measurements were used too determine the relationships between marsh elevation, flooding frequency and duration, and vegetative growth in a *Spartina alterniflora* marsh in coastal Louisiana over two growing seasons. Data suggest more flooded areas of the marsh are deteriorating and the authors anticipate plant die-back will occur in this area resulting in more wetland loss.

86. Reimold, R. J. 1972. The movement of phosphorus through the salt marsh cordgrass, *Spartina alterniflora* Loisel. LIMNOLOGY AND OCEANOGRAPHY 17: 606-611.
This article describes a pathway for the flux of Phosphorus to the sediment to *Spartina alterniflora* to the estuarine waters. *Spartina* acts as a nutrient pump, translocating measurable amounts of phosphorus from the sediment to the leaves then, with tidal inundation, phosphorus is released in the water during each tidal cycle.

87. Shea, M. L., Warren, R. S., and Niering, W. A. 1975. Biochemical and transplantation studies of growth form of *Spartina alterniflora* on Connecticut salt marshes. ECOLOGY 56 (2): 461-466.
Using electrophoretic comparisons of total soluble proteins and selected enzymes as well as reciprocal field transplants, the authors attempted to clarify the ecotype versus ecophene status of the tall and short-forms of *Spartina alterniflora*. Results indicate that the two forms are genetically indistinguishable and the variations between the two forms reflect physiological responses to different environmental differences.

88. Smart, R. M., and Barko, J. W. 1980. Nitrogen nutrition and salinity tolerance of *Distichlis spicata* and *Spartina alterniflora*. ECOLOGY 61 (3): 630-638.
A greenhouse experiment was conducted to determine the critical concentrations of nitrogen and phosphorus for the salt marsh plants *Distichlis spicata* and *Spartina alterniflora*. These experimental values were then used to assess the limiting nutrient status of plants grown on freshwater, brackish, and marine sediments. The authors also discuss the effect of salinity stress on plant growth in *Spartina* marshes in relation to nitrogen limitation.

89. Smart, R. M., and Barko, J. W. 1978. Influence of sediment salinity and nutrients on physiological ecology of selected salt marsh plants. ESTUARINE AND COASTAL MARINE SCIENCE 7 (5): 487-495.
A greenhouse experiment was conducted to investigate the influence of salinity and nutrients on the physiological ecology of *Spartina alterniflora, S. foliosa, S. patens, and Distichlis spicata*. A specific objective of this study was to determine important sediment characteristics to the establishment of salt marsh vegetation and relate differences in plant growth to sediment

characteristics. This paper specifically examines the nutrient concentrations and salt tolerance mechanisms present in the selected species.

90. Smith, K. F., Good, R. E., Good, N. F. 1979. Production dynamics for above and belowground components of a New Jersey *Spartina alterniflora* tidal marsh. ESTUARINE AND COASTAL MARINE SCIENCE 9: 189-201.
During a 14 month period, above and belowground portions of short form *Spartina alterniflora* were analyzed for changes in biomass, caloric content, and chemical composition. The authors conclude that S. alterniflora, short form, has a more dynamic belowground component than aboveground.

91. Squiers, E. R., and Good, R. E. 1974. Seasonal changes in the productivity, caloric content and chemical composition of a population of salt marsh cordgrass (*Spartina alterniflora).* CHESAPEAKE SCIENCE 15: 63-71.
The purpose of this study was to determine the seasonal changes in productivity, caloric values and the chemical composition of a population of *Spartina alterniflora* in a New Jersey marsh. For samples of both short and tall form *S. alterniflora*, aboveground biomass of living and dead grass was determined via the harvest method. Subsamples were analyzed for nitrogen free extract, ether extract, crude fiber, crude protein, nitrogen, ash and caloric equivalents.

92. Stalter, R., and Batson, W.T. 1969. Transplantation of salt marsh vegetation, Georgetown, South Carolina. ECOLOGY 50 (6): 1087-1089.
This study examines the tolerance, survival, and growth rate of salt marsh species to the varying conditions of the marsh when these species are moved to new zones with atypical habitats. Four marsh zones were identified and thirty plants of each dominant species in a specific zone were transplanted to the other three zones, while 30 plants of each dominant species in each zone were dug up and replanted in that same zone to serve as controls. Results indicate that *Salicornia virginica*, *L. carolinianum*, *S. alterniflora* (dwarf and tall forms), *B. frutescens*, and to a lesser degree *S. patens* have the ability to survive and may thrive when moved to a zone previously unoccupied by that species. Data also suggest that the dwarf *S. alterniflora* is truly inherently dwarf, and the tall form is inherently tall with more saline conditions inhibiting the tall form, but the transplanted tall plants were still taller than the smaller dwarf plants adjacent to them.

93. Sullivan, M. J., and Daiber, F. C. 1974. Response in production of cord grass *Spartina alterniflora* to inorganic nitrogen and phosphorus fertilizer. CHESEPEAKE SCIENCE 15 (2): 121-123.
During the 1972 growing season, fertilization of a *Spartina alterniflora* marsh with inorganic nitrogen and phosphorus was conducted. The authors concluded that in this specific study, nitrogen supplies are limiting production of dwarf form *S. alterniflora*, and suggest that the introduction of additional sources of inorganic nitrogen into a marsh that is deficient in nitrogen would most likely increase its productivity.

94. Teal, J. M. 1962. Energy flow in the salt marsh ecosystems of Georgia. ECOLOGY 43: 614-624.
This paper describes the energy flow (trophic level production) of a Georgia salt marsh. 5 regions are described: creek bank, streamside, levee marsh, short-*Spartina* marsh and *Salicornia* marsh. Aerial photographs were used to measure the relative areas of these marsh types.

95. Turner, R. E. 1993. Carbon, nitrogen, and phosphorus leaching rates from *Spartina alterniflora* salt marshes. MARINE ECOLOGY PROGRESS SERIES 92 (1-2): 135-140
Annual carbon, nitrogen and phorphorus leachate rates were estimated for live *Spartina alterniflora* in a Louisiana salt marsh. Leachates appear to be a significant, yet underappreciated nutrient and carbon source for saltt marsh food webs.

96. Turner, R. E. and Gosselink, J. G. 1975. A note on standing crops of *Spartina alterniflora* in Texas and Florida. MARINE SCIENCE 19: 113-118.

This paper examines a late summer survey of eight *Spartina alterniflora* marshes in Texas and Florida. Comparisons of live and dead biomass, grass height and slope of regression between Gulf Coast and Atlantic marshes are discussed.

97. Vernberg, J. F. 1993. Salt marsh processes: A review. ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY 12: 2167-2195.

This paper summarizes the functional processes of salt marshes. Topics discussed include physical, chemical and geological factors; biotic factors; material cycling, biogeochemical cycling, and nutrients; long-term changes; and interaction with adjacent ecosystems.

98. Warren, R. S., and Niering, W. A. 1993. Vegetation change on a northeast tidal marsh: Interaction of sea-level rise and marsh accretion. ECOLOGY 74 (1): 96-103.

This paper documents the vegetation changes that have occurred over the last 40 years on the Wequetequock-Pawcatuck marshes in New England. The authors present a model in which the difference between rates of marsh accretion and sea level rise is an important factor influencing vegetation change and species distribution within the tidal wetlands of this system.

99. Webb, E. C., Mendelssohn, I. A., and Wilsey, B. J. 1995. Causes for vegetation dieback in a Louisiana salt marsh: A bioassay approach. AQUATIC BOTANY 51 (3-4): 281-289.

A manipulative field experiment was conducted to examine factors causing vegetation dieback in Louisiana. Four native salt marsh plant species with different salinity and flooding tolerances were placed at two elevations in a deteriorating marsh (ambient elevation and 20 cm above the marsh surface). Results indicated that for this particular system, excessive submergence rather than salinity was the primary factor controlling dieback in this marsh.

100. White, D. A., Trapani, J. M., Thien, L. B., and Weiss, T. E. 1978. Productivity and decomposition of the dominant salt marsh plants in Louisiana. ECOLOGY 59 (4): 751-759.

This paper discusses the net primary production and decomposition of *Distichlis spicata, Spartina patens, Juncus roemarianus,* and *Spartina alterniflora*.

101. White, D. S., and Howes, B. L. 1994. Translocation, remineralization, and turnover of nitrogen in the roots and rhizomes of *Spartina alterniflora* (Gramineae). AMERICAN JOURNAL OF BOTANY 81 (10): 1225-1234.

The authors used ^{15}N to determine turnover of belowground biomass in short form *Spartina alterniflora*. Field lysimeters monitored long-term loss of ^{15}N from intact live roots and rhizomes. Internal recycling of ^{15}N through translocation was also measured in hydrologically controlled laboratory lysimeters maintained under field conditions.

102. Wolaver, T. G., and Zieman, J. 1984. The role of tall and medium *Spartina alterniflora* zones in the processing of nutrients in tidal water. ESTUARINE COASTAL AND SHELF SCIENCE 19: 1-13.

The purpose of this study was to determine, via a nitrogen and phosphorus nutrient exchange study, if the tall and medium forms of *Spartina alterniflora* act as a sink for nutrients with respect to tidal inundation and to evaluate the contribution of this possible nutrient source to plant productivity. Both low and high marsh functions were discussed.

KEYWORDS

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