8-26-1991

Draft Seagrass Bibliography Data Base

Jay R. Leverone

L. Kellie Dixon

M. Grey Valenti

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MOTE MARINE LABORATORY
... established 1955

1600 CITY ISLAND PARK
SARASOTA, FLORIDA 33577
TELEPHONE 813/388-4441

Southwest Florida
Water Management District
2379 Broad Street (U.S. 41 South) Brooksville, Florida 34609-6899
Phone (904) 796-7211 or 1-800-423-1476 SUNCOM 628-4150

August 26, 1991

Roger Johansson
c/o Andy Squires
City of Tampa Bay Studies Group
2700 Maritime Boulevard
Tampa, Florida 33605

SUBJECT: Draft Seagrass Bibliography

Dear Mr. Johansson:

The seagrass portion of the water quality assessment project has been delegated to me, an Environmental Scientist who recently joined the SWIM Department. Enclosed please find a copy of the Draft Seagrass Bibliography Data Base Report submitted by Mote Marine Laboratories. Please review and provide critical comments on this Draft including possible additional literature omitted and an objective evaluation of the technical quality of the document.

Your professional background and valued time are greatly appreciated. If you need aditional information please contact me at (813) 985-7481, ext 2203.

Sincerely,

Thomas F. Ries
Environmental Scientist
Surface Water Improvement and
Management Department

Enclosures

cc: Michael Perry, Director, SWIM Dept.

MOTE MARINE LABORATORY
1600 THOMPSON PARKWAY
SARASOTA, FLORIDA 34236
PHONE: (813) 388-4441 FAX: (813) 388-4312
"A nonprofit organization dedicated to excellence in marine sciences"

October 31, 1991

Roger Johansson, Director
Bay Studies Group
Wastewater Treatment Plant
2700 Maritime Boulevard
Tampa, FL 33605

Dear Roger:

We have received your comments and review of the SWIM Seagrass Bibliographic Data Base and are incorporating these and other suggestions into the second edition. I have been unable to locate copies of several references you cited which we would like to include in the database. Would you please furnish me with a copy (or abstract if the reference contains one) of the following publications:

1) Johansson, J.O.R. and R.R. Lewis. In press. Recent improvements in water quality and biological indicators in Hillsborough Bay, Tampa Bay, Florida, U.S.A. The Science of the Total Environment, Elsivier Publ., U.K.

2) Kenworthy, W.J., J.C. Zieman and G.W. Thayer. 1982. Evidence for the influence of seagrasses on the benthic nitrogen cycle in a coastal plain estuary near Beaufort, NC. Oecologica. 54:152-158.

3) Masini, R.J. (et al.). 1990. The effects of light and temperature on the photosynthesis of seagrasses, epiphytes and macroalgae and implications for management of the Albany harbours. (Western Australian Environmental Protection Authority, Perth) Technical Series 32. 24 pp.

4) Pearce, R.J. 1991. Management of the marine environment in Western Australia: an ecosystem approach. Mar. Poll. Bull. 23:567-572.

5) TBRPC. 1989. Chlorophyll-a target concentrations proposed for Tampa Bay Task Force on Resource-Based Water Quality Assessment, Tampa Bay Regional Planning Council. 10 pp.

We have a rapidly approaching deadline for the completion of the bibliography. Your help in expediting this request will be greatly appreciated. The efforts of yours and other reviewers should make this a very useful and workable document. Thank you sincerely for your efforts.

Respectfully yours,

Jay R. Leverone
Senior Biologist

JRL:lmf

CITY OF TAMPA
Sandra W. Freedman, Mayor
Department of Sanitary Sewers
Advanced Wastewater Treatment Plant

Mr. Thomas Ries
Southwest Florida Water Management District
7601 Highway 301 North
Tampa, FL 33637

September 19, 1991

Re: Draft Seagrass Bibliography.

Dear Tom:

My staff and I have reviewed the draft document you sent me. Below I have listed papers, which we were not able to locate in the draft and which might considered to be included. Also I received a copy of the comments Robin Lewis sent you. I agree that the papers he lists should be added and that the format of the document could be improved to include a "Listing by Author."

Additional papers:

Cambridge, M.L. and A.J. McComb. 1984. Loss of seagrass in Cockburn Sound, Western Australia. I. The time course and magnitude of seagrass decline in relation to industrial development. Aquatic Botany 20:229-243.

Cambridge, M.L., A.W. Chiffings, C. Britton, L. Moore and A.J. McComb. 1986. Loss of seagrass in Cockburn Sound, Western Australia. II. Possible causes of seagrass decline. Aquatic Botany 24:269-285.

Duarte, C.M. 1991. Seagrass depth limits. Aquatic Botany 40:363-377

Hoskin, C. M. 1983. Sediment in seagrasses near Link Port, Indian River Lagoon. Florida Scientist 46:153-161

Johansson, J.O.R. and R.R. Lewis. In press. Recent improvements in water quality and biological indicators in Hillsborough Bay, Tampa Bay, Florida, U.S.A. The Science of the Total Environment, Elsivier Publ., U.K.

Kenworthy, W.J., J.C. Zieman and G.W. Thayer. 1982. Evidence for the influence of seagrasses on the benthic nitrogen cycle in a coastal plain estuary near Beaufort, North Carolina. Oecologia 54:152-158

TAMPA
All-America City
1990
2700 Maritime Boulevard • Tampa, Florida 33605 • 813/247-3451

Masini, R.J., J. L. Cary, C.J. Simpson and A.J. McComb. 1990. The effects of light and temperature on the photosynthesis of seagrasses, epiphytes and macroalgae and implications for management of the Albany harbours. (Western Australian Environmental Protection Authority, Perth) Technical Series 32. pp. 24.

Pearce, R.J. 1991. Management of the marine environment in Western Australia: An ecosystem approach. Mar. Poll. Bull. 23:567-572.

TBRPC. 1989. Chlorophyll-a target concentrations proposed for Tampa Bay. Task Force on Resource-Based Water Quality Assessment, Tampa Bay Regional Planning Council. 10p.

Wanless, H.R. 1981. Fine-upwards sedimentary sequences generated in seagrass beds. J. Sedimentary Petrology 51:445-454

If I can be of further help or if you have any questions please call.

Sincerely,

Roger Johansson
Chief Biologist

cc. Robin Lewis

Lewis Environmental Services, Inc.

August 28, 1991

Thomas F. Ries
Environmental Scientist
SWIM Program
Southwest Florida Water Management District
2379 Broad Street
Brooksville, FL 34609-6899

Dear Tom:

I have quickly perused the draft seagrass bibliography your sent to me for review. There appears to be a number of the more widely acknowledged key Tampa Bay seagrass papers missing, including Ron Phillip's 1960 and 1962 papers (see page 127 in the attached Tampa Bay Estuarine Profile), and my 1985 Basis paper see page 124 of the Profile). The format of the bibliography could be improved with the addition of a "Listing by Author" in an alphabetical manner, in order to allow a reviewer to quickly check for papers he or she knows should be listed.

Given the above I would suggest Mote be asked to generate a second draft reflecting all the additions suggested by myself and the other reviewers, and this be circulated for additional review.

I would like to confirm that it is the SWIM program's intent to ask Mote to use the bibliography to prepare a suggested scope of work that will also be the subject of a peer review. Is this still the plan?

Sincerely yours,

Roy R. "Robin" Lewis, III
President

RRL/br

CC: Mike Perry
Roger Johansson

P.O. BOX 20005 • TAMPA, FL 33622-0005 • (813) 889-9684

DRAFT

TAMPA BAY WATER QUALITY ASSESSMENT-DETERMINATION OF ENVIRONMENTAL REQUIREMENTS OF SELECTED SPECIES

TASK 3.0

SEAGRASS BIBLIOGRAPHIC DATA BASE: A COMPILATION OF THE SCIENTIFIC LITERATURE PERTAINING TO INDIGENOUS SPECIES FROM TAMPA BAY

Submitted to:

Southwest Florida Water
Management District
SWIM Department
7601 Highway 301 North
Tampa, FL 33637

Submitted by:

Mote Marine Laboratory
1600 Thompson Parkway
Sarasota, FL 34236
(813) 388-4441

Prepared by:

Jay R. Leverone
L. Kellie Dixon
M. Grey Valenti

Kumar Mahadevan, Ph.D.
Executive Director

June 24, 1991

Mote Marine Laboratory Technical Report #219

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The authors would like to express their sincere appreciation to the many scientists who took time to respond to requests of both their time and resources during the compilation of this data base. These individuals are listed in Section IV of this report. Their warm reception and eagerness to contribute made this task an enjoyable as well as interesting experience. Gratitude is also extended to Ms. Roselyn Leon for document preparation, Ms. Jean Maguire for assistance in computer-based literature searches, Dr. Carl A. Luer for translations, Ms. Susan Lowrey for document proofing and editing and Ms. Linda Franklin for preparing the final report.

I. INTRODUCTION

The following report describes in detail the elements of a literature search performed for the Southwest Florida Water Management District (SWFWMD), Department of Surface Water Improvement and Management (SWIM). The work was performed in accordance with the agreement between the District and Mote Marine Laboratory (MML), and comprises Task 3.0 (Literature Search) of the project entitled, "Tampa Bay Water Quality Assessment- Determination of Environmental Requirements of Selected Populations."

II. BACKGROUND AND OBJECTIVES

The primary objective of this project is to establish the environmental requirements of seagrasses native to Tampa Bay. The specific question to be answered through this project is "What environmental conditions, including quality of water, are required to achieve the survivability, propagation and enhancement of the seagrass resources of Tampa Bay?" The results of this project are intended to support interim water quality targets in addition to supporting the final seagrass-based water quality criteria.

Mote Marine Laboratory has conducted a search of the scientific literature and has assembled a bibliography pertaining to seagrasses indigenous to Tampa Bay. This report addresses all elements of Task 3.0 (Literature Search) of the project. Among the elements discussed in this report are: 1)literature search design and strategy, 2) listing of search data bases and bibliographies, 3)description of the format of bibliographic abstracts. Findings from the literature search will be used to guide the development of the final plan of study and to serve as a resource document for future seagrass research in the Tampa Bay area.

III. LITERATURE SEARCH METHODOLOGY

Among the topics considered in the literature search were growth and propagation of seagrasses as related to a variety of environmental variables, including, but not limited to: photosynthetically active radiation, salinity, nutrients, sediment grain size, sediment organic content, sediment redox potential, current velocity, bioturbation, propeller dredging, thermal effects, competition for light from drift algae, competition for substrate from *Caulerpa*, and inhibition of germination from ship-induced turbulence. While the literature search focused on seagrasses indigenous to Tampa Bay, consideration was given to references with information on the effects of these variables on other species of seagrass. If it was determined that the information or methodologies would be transferable to the Tampa Bay system, the reference was included in the bibliographic data base.

The literature search strategy was comprised of four major components.

A) Seagrass textbooks, bibliographies, and proceedings from seagrass symposia and workshops were obtained and reviewed. These works included:

Proceedings of the Symposium on Subtropical-Tropical Seagrasses of the Southeastern United States. 1987. Edited by M. J. Durako, R. C. Phillips and R. R. Lewis, III. Florida Marine Research Publication Number 42. 209p.

Mahadevan, S., J. Sprinkel, D. Heatwole and D. H. Wooding. 1984. **Bibliography of Benthic Studies in the Coastal and Estuarine Areas of Florida.** Florida Sea Grant College Report 66. 576p.

Results and Recommendations of a Workshop Convened to Examine the Capability of Water Quality Criteria, Standards and Monitoring Programs to Protect Seagrasses from Deteriorating Water Transparency. 1990. Edited by W. J. Kenworthy and D. Haunert. South Florida Water Management District. 151p.

Seagrass Literature Survey. Edited by K. W. Bridges, J. C. Zieman and C. P. McRoy. U. S. Corp of Engineers Dredge Material Research Program Technical Report D-78-4. 61p.

Zieman, J. C. and R. T. Zieman. 1989. **The Ecology of the Seagrass Meadows of the West Coast of Florida: A Community Profile.** U. S. Fish and Wildlife Service Biological Report 85. 155p.

Handbook of Seagrass Biology. 1980. Edited by R. C. Phillips and C. R. McRoy, editors. Garland STPM Press. New York. 353p.

Seagrasses. 1988. Edited by R. C. Phillips and E. G. Menez. Smithsonian Contributions to the Marine Sciences Number 34. 104p.

B) Interviews were conducted and requests made of the following scientists who are currently conducting seagrass research.

Mr. Walt Avery
Bay Studies Group
Wastewater Treatment Plant
2700 Maritime Blvd.
Tampa, FL 33605

Mr. Mike Durako
Florida Marine Research Institute
100 Eighth Av. S.E.
St. Petersburg, FL 33701

Dr. David Tomasko
Florida Keys Land and Sea Trust
P.O. Box 536
Marathon, FL 33701

Dr. Clinton Dawes
Dept of Biology
University of South Florida
Tampa, FL 33620

Dr. Margeret O. Hall
Florida Marine Research Institute
100 Eighth Av. S.E.
St. Petersburg, FL 33701

Dr. Robin Lewis
Lewis Environmental Services, Inc.
5454 Jet View Cr.
P.O. Box 20005
Tampa, FL 33622-0005

Mr. Steve Sauers
Dept. Natural Resources
Coastal Zone Management
1301 Cattleman Road
Sarasota, FL 34232

Dr. Brian D. Fry
Ecosystems Center
Marine Biological Laboratory
Woods Hole, MA 02543

Dr. Warren M. Pulich, Jr.
University of Texas at Austin
Marine Science Institute
Port Aransas, TX 78373

Dr. S.L. Williams
San Diego State University
Department of Biology
San Diego, CA 92182

C) A DIALOG computer-based literature search was conducted based on the project-specific seagrass species and the environmental variables detailed above. Subject indices for the search included BIOSIS PREVIEW and AQUATIC SCIENCES AND FISHERIES ABSTRACTS and were examined from 1981 to present.

D) Searches of the weekly periodical CURRENT CONTENTS ON DISK were conducted from September 14, 1990, through June 3, 1991, to obtain the most recently published references.

IV. BIBLIOGRAPHIC FORMAT

A PC-based bibliographic database was selected to accumulate and process the acquired references. This software produced the following references, keywords, and comments listings as well as exporting the ASCII file with field contents to satisfy the magnetic flat file requirement of this task. This flat file has been selected as being that most compatible for eventual up-load to the SWIM Bibliographic Data Base (BDB) System. Software formats have been customized to reflect the required fields specified in the work order, and provisions have been made for articles, maps, books, chapters, and reports.

V. LIST OF KEYWORDS

ABUNDANCE
ACCLIMATION
ACETYLENE REDUCTION
ADAPTIVE STRATEGY
AERIAL PHOTOGRAPHY
AIR-SEA EXCHANGES
ALGAE
ALGAL DECOMPOSITION
AMINO ACIDS
AMMONIA UPTAKE
AMMONIUM
ANAEROBIC METABOLISM
AQUATIC MACROPHYTES
ATTENUATION
AXENIC CULTURE
BACTERIA
BAHAMAS
BENTHIC INVERTEBRATES
BICARBONATE
BIOGEOGRAPHY
BIOLOGY
BIOMASS
BISCAYNE NATIONAL PARK
BLUE-GREEN ALGAE
BOAT TRAFFIC
BUFFER FACTOR
CALCIUM CARBONATE PRODUCTION
CALORIC CONTENT
CARBOHYDRATES
CARBON
CARBONATE SEDIMENTS
CARBON BUDGET
CARBON DISSOLVED ORGANIC
CARBON FIXATION
CARBON ISOTOPES
CARBON METABOLISM
CARBON ORGANIC
CARBON RELEASE
CARBON UPTAKE
CAULERPA
CHEMICAL EXCHANGE
CHLOROPHYLL
CIRCULAR BEDS
CIRCULATION
CLONAL BIOLOGY
CO{-2}/PH
COLONIZATION
COLOR
COMMUNITY COMPOSITION
COMMUNITY METABOLISM
COMPETITION
CONSUMPTION
CORAL REEFS
COVERAGE
CROPPING
CULTIVATION
CULTURE
CURRENTS
CYMODOCEA
DECOMPOSITION
DEFOLIATION
DENSITY
DEPOSITION
DEPTH
DETRITUS
DIET
DIFFUSION GRADIENTS
DISTRIBUTION
DREDGING
DRIFT ALGAE
DRILLING FLUIDS
EASTERN GULF OF MEXICO
ECOLOGY
EGREGIA
EPIBIONTS
EPIFAUNA
EPIPHYTES
EQUILIBRIUM
ESTUARY
ETIOLATION
EXPORT
EXUDATES
FACILITATION
FATTY ACIDS
FLORA
FLORIDA
FLORIDA BAY
FLOWERING
FRESHWATER
FROUDE NUMBER
FRUITS
GASEOUS EXCHANGE
GENETIC DIFFERENTIATION
GEOCHEMISTRY
GEOLOGY
GLUTAMINE SYNTHETASE
GRACILARIA
GROWTH

HABITAT
HALODULE
HALOPHILA
HALOSACCION
HEAVY METALS
HETEROZOSTERA
HILLSBOROUGH BAY
HYDROGEN SULFIDE
INCOMPLETE
IRRADIANCE
ISOTOPES
ISOZYMES
LACUNAE
LEAF GROWTH
LEAF PRODUCTION
LEAF REMOVAL
LEAF ULTRASTRUCTURE
LEAF WIDTH
LIGHT
LIGHT ASSIMILATION CURVES
LIGHT COMPENSATION POINT
LIGHT COMPETITION
LIGHT LIMITATION
LIGHT TRANSMISSION
LITTORELLA
MACROALGAE
MACROFAUNAL DISTRIBUTION
MAPPING
MEIOFAUNA
MERISTEM DEPENDENCE
METABOLIC RATES
METHANOGENESIS
METHODS
MICROCOSMS
MODELS
MORPHOLOGY
MUDBANKS
NITRATE NITROGEN
NITROGEN
NITROGENASE ACTIVITY
NITROGEN CYCLE
NITROGEN FIXATION
NITROGEN UPTAKE
NORTH CAROLINA
NORTHERN GULF COAST
NUTRIENT CONTENT
NUTRIENT CYCLING
NUTRIENT ENRICHMENT
NUTRIENT LIMITATION
NUTRIENT LOADING
NUTRIENT RELEASE
NUTRIENTS
NUTRIENT UPTAKE
ORGANIC CONTENT
OSMOREGULATION
OXYGEN
PAR
PHOSPHOLIPID
PHOSPHORUS
PHOTOADAPTATION
PHOTOPERIOD
PHOTORESPIRATION
PHOTOSYNTHESIS
PHYLLOSPADIX
PHYLLOSPHERE
PHYSICAL DAMAGE
PHYTOPLANKTON
P-I CURVES
PIGMENT CONTENT
POLLINATION
POLLUTANTS
POPULATION BIOMASS
POPULATION DYNAMICS
POSIDONIA
PRESSURE
PRIMARY PRODUCTIVITY
PROTEIN
PROXIMATE CONSTITUENTS
RECIPROCAL TRANSPLANTS
REMOTE SENSING
REPRODUCTION
RESPIRATION
REVIEW
RHIZOPHYTIC ALGAE
RHIZOPLANE BACTERIA
RHIZOSPHERE
ROOT RESPIRATION METABOLISM
RUPPIA
SALINITY
SALINITY TOLERANCE
SARASOTA BAY
SATURATION-TYPE KINETICS
SCOURING
SEAGRASS
SEASONALITY
SEAWATER
SECONDARY PRODUCTION
SEDIMENT DISTRIBUTION
SEDIMENT DISTURBANCE
SEDIMENT GRAIN SIZE
SEDIMENT NUTRIENTS
SEDIMENTS
SEED GERMINATION
SEEDLINGS

SEED RESERVES
SEXUAL REPRODUCTION
SHADING
SHEAR VELOCITY
SHOOT DENSITY
STANDING CROP
STORMS
SUCCESSION
SULFIDE CHEMISTRY
SULFUR
SURVIVAL
SUSPENDED SOLIDS
SYRINGODIUM
TANNINS
TEMPERATURE
TEMPERATURE TOLERANCE
THALASSIA
THERMAL EFFECTS
THYMIDINE
TIDAL DECELERATION
TIDES
TRACE METALS
TRIBUTYLTIN
TURBIDITY
TURTLE GRAZING
ULTRAVIOLET RADIATION
UPTAKE
WATER LEVEL RECESSION
WATER QUALITY
WATER TRAPPING
ZINC
ZONATION
ZOSTERA

VI. BIBLIOGRAPHIC DATA BASE

1. **Capone, D. G. and B. F. Taylor. 1977. Nitrogen fixation (acetylene reduction) in the phyllosphere of *Thalassia testudinum*.** Marine Biology (New York). 40: 19-28.

[NITROGEN FIXATION, NUTRIENTS, PHYLLOSPHERE, THALASSIA]

<N_2 fixation (C_2H_2 reduction) associated with the leaves of the sea grass *Thalassia testudinum* was investigated at 5 sites in South Florida (Biscayne Bay) and one site in the Bahamas (Bimini Harbor). Significant activities were correlated with the occurrence of a heterocystous blue-green alga (*Calothrix* sp.) on the leaves. C_2H_2 reduction was not stimulated by organic compounds, either aerobically or anaerobically in the light or dark. Therefore, other physiological types of microbes were not important in N_2 fixation. Diurnal and seasonal variations in N_2 fixation occurred, with maximal rates during the daytime and in the late spring and early summer. N_2 fixation was negligible at four stations in Biscayne Bay. At the fifth station, near Fowey Rock, about 5 kg N ha^{-1} $year^{-1}$ was fixed. In the summer, the N_2 fixed per day (4-5 mg N m^{-2}) could provide 4 to 23% of the foliar productivity demands of *T. testudinum* at this site and the station in Bimini Harbor. N_2 fixation at the periphery of a sea grass patch near Fowey Rock, could provide 8 to 38% of the daily nitrogen requirement for leaf production, and thereby might compensate for a less effective trapping and recycling of nitrogen from dead leaves in such regions.>

2. Penuelas, J. and M. Menendez. 1990. **HCO_3^- as an exogenous carbon source for *Ruppia cirrhosa* (Petanga) grande.** Archiv fuer Hydrobiologie. 1: 89-96.

[BICARBONATE, PHOTOSYNTHESIS, RUPPIA]

<The aquatic plant *Ruppia cirrhosa* was investigated for its ability to utilize HCO_3^- and CO_2 as exogenous carbon sources for photosynthesis. In $NaHCO_3$ solutions *R. cirrhosa* increased the pH to a maximum of 9.85 corresponding to a CO_2 compensation point of 0.55 mmol m^{-3} CO_2. Measured photosynthetic rates cannot be explained only by the uptake of CO_2. Photosynthetic rates decreased at high pH but did not decline to zero until pH 11.5. Furthermore, photosynthesis was increased by higher HCO_3^- concentrations at constant CO_2 concentration. It is concluded that *Ruppia cirrhosa* has the capability to utilize HCO_3^- which helps to explain its wide distribution in alkaline saline waters.>

3. Capone, D. 1977. **$N_2(C_2H_2)$ fixation by macroalgal epiphytes.** In: Proceedings, Third International Coral Reef Symposium. 337-342. Miami: Rosenstiel School of Marine and Atmospheric Science.

[ACETYLENE REDUCTION, BLUE-GREEN ALGAE, CORAL REEFS, EPIPHYTES, MACROALGAE, NITROGEN CYCLE, NITROGEN FIXATION]

<High rates of $N_2(C_2H_2)$ fixation were associated with several macroalgae in a coral reef community at Grand Bahama Island. In all cases, the activity was light enhanced, not stimulated by organics and occurred aerobically. The activity is primarily attributed to epiphytic cyanophytes. The green algae *Microdictyon* sp. occurs on the reef proper from 5-40 m and rates of up to 2.3 ug N fixed g dry wt^{-1} h^{-1} were associated with samples in laboratory incubations.

Blue light was more effective than red light in promoting N_2 fixation, probably reflecting a depth adaptation. *Laurencia* sp., a red alga, occurred at high densities (200 g m^{-2}) in the inshore sand flats and had associated activities of up to 21 μg N fixed g dry wt^{-1} h^{-1}. N_2 fixation by epiphytes probably supplies a substantial portion of the nitrogen requirement of the reef community.>

4. Iverson, R. L. and H. F. Bittaker. 1986. **Seagrass distribution and abundance in eastern Gulf of Mexico coastal waters.** Estuarine Coastal and Shelf Science. 22: 577-602.

[ABUNDANCE, DISTRIBUTION, FLORIDA, HALODULE, PAR, SALINITY, SYRINGODIUM, THALASSIA, TURBIDITY]

<The marine angiosperms *Thalassia testudinum*, *Syringodium filiforme*, and *Halodule wrightii* form two of the largest reported seagrass beds along the northwest and southern coasts of Florida where they cover about 3000 square km in the Big Bend area and about 5500 square km in Florida Bay, respectively. Most of the leaf biomass in the Big Bend area and outer Florida Bay was composed of *Thalassia testudinum* and *Syringodium filiforme* which were distributed throughout the beds but which were more abundant in shallow depths. A short-leaved form of *Halodule wrightii* grew in monotypic stands in shallow water near the inner edges of the beds, while *Halophila decipiens* and a longer-leaved variety of *H. wrightii* grew scattered throughout the beds, in monotypic stands near the outer edges of the beds, and in deeper water outside the beds. *Halophila engelmanni* was observed scattered at various depths throughout the seagrass beds and in monospecific patches in deep water outside the northern bed. *Ruppia maritima* grew primarily in brackish water around river mouths. The cross-shelf limits of the two major seagrass beds are controlled nearshore by increased water turbidity and lower salinity around river mouths and offshore by light penetration to depths which receive 10% or more of sea surface photosynthetically active radiation. Seagrasses form large beds only along low energy reaches of the coast. The Florida Bay seagrass bed contained about twice the short-shoot density of both *Thalassia testudinum* and *Syringodium filiforme*, for data averaged over all depths, and about four times the average short-shoot density of both species in shallow water compared with the Big Bend seagrass bed. The differences in average seagrass abundance between Florida Bay and the Big Bend area may be a consequence of the effects of greater seasonal solar radiation and water temperature fluctuations experienced by plants in the northern bed, which lies at the northern distribution limit for American tropical seagrasses.>

5. Capone, D. G., D. L. Taylor, and B. F. Taylor. 1977. **Nitrogen fixation (acetylene reduction) associated with macroalgae in a coral-reef community in the Bahamas.** Marine Biology (New York). 40: 29-32.

[CORAL REEFS, MACROALGAE, NITROGEN FIXATION]

<N_2 fixation (C_2H_2 reduction) was associated with several species of macroalgae on a coral reef near Grand Bahama Island. The highest rates were associated with *Microdictyon* sp. (Chlorophyceae) and *Dictyota* sp. (Phaeophyceae). Extensive mats of filamentous blue-green algae, not heterotrophic bacteria, were the N_2 fixing agents: in experiments with samples of *Microdictyon* sp., the activity was light-dependent and not stimulated by organic compounds under either aerobic or anaerobic conditions. Assays *in situ*,

at 20 m depth, and on shipboard, gave similar rates of N_2 fixation; the cyanophytes presumably have pigment adaptations to function in blue light. The maximum rate of N_2 fixation, associated with *Microdictyon* sp., was 3.8 μg N fixed g dry weight^{-1} h^{-1}. Coral-reef communities flourish in nutrient-impoverished waters, and therefore any input of nitrogen is probably important in stabilizing such ecosystems.>

6. Patriquin, D. 1973. **Estimation of growth rate, production and age of the marine angiosperm *Thalassia testudinum* König.** Caribbean Journal of Science. 13: 111-123.

[GROWTH, PRIMARY PRODUCTIVITY, THALASSIA]

<There is a linear relation between average growth rate and the average maximum leaf length of *Thalassia* stands. The ratio production-to-standing crop (wet weight including epiphytes) tends to be constant. New foliage leaves are developed at intervals of about 15 days, and by counting of leaf scars, the age, growth rate and production of underground parts can be estimated.>

7. Odum, H. T. 1957. **Primary production measurements in eleven Florida springs and a marine turtle-grass community.** Limnology and Oceanography. 2: 85-97.

[PRIMARY PRODUCTIVITY, THALASSIA]

<During July and August, 1955, primary production measurements were made in eleven Florida spring communities and a marine turtle-grass community in the Florida Keys by means of the diurnal curve method. Diurnal measurements of oxygen and carbon dioxide made at a station downstream from the main springs were used in estimating gross primary production and community photosynthetic quotients. These curves show in detail the course of production hour by hour under various conditions in whole natural communities. The primary production values obtained ranged from 0.7 g oxygen/m^2/day in a small, heavily shaded, anaerobic spring on a rainy day to 64 g oxygen/m^2/day on a sunny day in an aerobic spring where the plant beds trailed at the water surface. A comparison of the chemostatic properties in the springs studied suggests that oxygen, phosphate, nitrate, and carbon-dioxide levels are relatively unimportant in determining the magnitude of primary production in these spring communities. Light as influenced by cloud cover, trees, and water depth is the main controlling factor. Approximate efficiencies found were 0.5 to 10% (mean 4%) of the visible light energy reaching plant level. Downstream increases in planktonic chlorophyll and oxygen suggested a steady state in 7 km of longitudinal succession in Rainbow Springs River. Net production of benthic algae of 1.5 g/m^2/day was estimated in Orange Springs from the rate of bubble release into funnels placed on the bottom.>

8. Oremland, R. S. 1975. **Methane production in shallow-water, tropical marine sediments.** Applied Microbiology. 30: 602-608.

[METHANOGENESIS, SEDIMENTS, THALASSIA]

<The *in situ* production of methane was monitored in several types of tropical benthic communities. A bed of *Thalassia testudinum* located in Caesar Creek (Florida Keys) exhibited the highest methanogenic activity (initial rates = 1.81 to 1.86 μmol CH_4/m^2/h) as compared with another seagrass (*Syringodium* sp.,

0.15 to 0.33 μmol/m^2/h) and two coral reef environments (Hydro-Lab, 0.016 to 0.10 μmol/m^2/h; Curaçao, 0.14 to 0.47 μmol/m^2 per h). The results suggest that a wide variety of benthic metabolic processes (e.g., photosynthetic oxygen production) influences methane production rates.>

9. Oremland, R. S. and B. F. Taylor. 1975. **Inhibition of methanogenesis in marine sediments by acetylene and ethylene: validity of the acetylene reduction assay for anaerobic microcosms.** Applied Microbiology. 30: 707-709.

[METHANOGENESIS, SEDIMENTS]

<Methanogenesis was irreversibly inhibited in sediments by concentrations of acetylene employed in nitrogen fixation assays (1 to 20%, vol/vol). Ethylene, but not ethane, also stopped methane production, and the inhibition was reversed by gassing with hydrogen.>

10. Dawes, C. J. and J. M. Lawrence. 1983. **Proximate composition and caloric content of seagrasses.** Marine Technology Society Journal. 17: 53-58.

[CALORIC CONTENT, ORGANIC CONTENT]

<As growth and production of seagrasses are reflected in the proximate composition of their various component parts, an analysis of organic constituents of seagrasses can give insight into these processes. These analyses provide a basis for comparing intra- and interpopulation variation between different sites, seasons, and years, as well as a basis for comparing different species of seagrasses. Calculation of caloric levels and contents allows comparison between species, sites, and seasons in the absolute allocation of energy by the plant to its various parts (blades, photosynthetically inactive portion of the short shoot, rhizome, roots). Insight can also be gained with regard to differences in chemical fluctuation due to the effects of pollution and the usefulness of seagrasses as a source of biomass for energy production. The goal of this paper is to demonstrate the need for and propose a set of standardized procedures which will allow such comparisons.>

11. Fredette, T. J., R. J. Diaz, J. Van Montfrans, and R. J. Orth. 1990. **Secondary production within a seagrass bed (*Zostera marina* and *Ruppia maritima*) in lower Chesapeake Bay.** Estuaries. 13: 431-440.

[RUPPIA, SECONDARY PRODUCTION, ZOSTERA]

<Monthly sampling of a 140 ha seagrass bed in the lower Chesapeake Bay, Virginia, revealed that 13 numerically and tropically important species, representing about 20% of the total community densities over the year-long study period, accounted for the production of ca. 42 g dry wt m^{-2} yr^{-1}. This estimate is likely conservative due to our assumptions on voltinism and fixed size at maturity regardless of season for the species studied. The isopod *Erichsonella attenuata* accounted for 17.6 g dry wt m^{-2} yr^{-1} or 42% of the calculated total production, while the portunid decapod *Callinectes sapidus* and the amphipod *Gammarus mucronatus* each accounted for 7.7 g dry wt m^{-2} yr^{-1}. The 10 remaining species (4 peracarids, 4 molluscs, and 2 decapods) each produced less than 2 g dry wt m^{-2} yr^{-1}. Total seagrass-associated secondary production was estimated to equal or exceed 200 g dry wt m^{-2} yr^{-1}. By applying this estimate to the entire 140

ha grassbed, we projected that, on average, 4.8 metric tons dry wt of invertebrate standing stock and 55.9 metric tons of invertebrate production occur over the year.>

12. Durako, M. J. and M. D. Moffler. 1985. **Observations on the reproductive ecology of *Thalassia testudinum* (Hydrocharitaceae) II. Leaf width as a secondary sex character.** Aquatic Botany. 21: 265-275.

[REPRODUCTION, THALASSIA]

<Short-shoots of *Thalassia testudinum* Banks ex König were collected from 5 sites in Florida. A total of 284, 625 cm² quadrat samples, containing 6182 short-shoots was analyzed for leaf width, inflorescence number and sex (the latter if determinable). Although leaf widths and reproductive densities differed at the 5 sites, leaf width was consistently greater when reproductive structures were present, and when the number of inflorescences increased. The mean number of inflorescences per short-shoot was significantly higher for shoots bearing male inflorescences compared to female shoots. Female inflorescences were normally solitary; male short-shoots usually had 2 or 3 inflorescences. Sex ratios were male-biased for 4 of the 5 sites. Comparisons of leaf widths between the sexes indicated that leaf width constituted a secondary sex character for this species. Female short-shoots tend to have narrower leaves than male short-shoots. This relationship should also be considered when evaluating the significance of morphogeographic and stress-related variation in leaf width for this species.>

13. Durako, M. J. and M. D. Moffler. 1985. **Observations on the reproductive ecology of *Thalassia testudinum* (Hydrocharitaceae). III. Spatial and temporal variations in reproductive patterns within a seagrass bed.** Aquatic Botany. 22: 265-276.

[REPRODUCTION, THALASSIA]

<Spatial and temporal variations in the reproductive patterns of a population of *Thalassia testudinum* Banks ex König in Tampa Bay, Florida were observed from 1981 to 1983. Reproductive densities of 11.4, 20.7 and 10.0% were observed in 1981, 1982, and 1983, respectively. The significantly higher reproductive density in 1982 was due to a 3-fold increase in the temporally labile male phenotype. Sex ratios were male-biased only in 1982. In contrast, female short-shoot densities did not vary significantly during the study. Total and reproductive short-shoot densities generally decreased from the shoreward (shallower) fringe to the seaward (deeper) fringe of the bed. Spatial variations in female short-shoot densities were significant. Female short-shoots were prevalent near fringing areas of the bed, while males were predominant in the interior. This distribution pattern resulted in a negative correlation between male and female densities. The distribution and spatial separation of the sexes suggest an interaction of age with sex expression in this *Thalassia testudinum* population.>

14. Pulich, W. M., Jr. 1985. **Seasonal growth dynamics of *Ruppia maritima* L. s.l. and *Halodule wrightii* Aschers. in southern Texas and evaluation of sediment fertility status.** Aquatic Botany. 23: 53-66.

[BIOMASS, GROWTH, HALODULE, NUTRIENTS, RUPPIA, SEDIMENTS]

<Annual growth dynamics of *Ruppia maritima* L. s.l. and *Halodule wrightii* Aschers. at two southern Texas, U.S.A. coastal sites were compared using plant biomass to monitor production. While sparse *Ruppia* normally coexists with dense *Halodule* in southern Texas bays, these two sites contained extensive stands of dense *Ruppia* mixed with or adjacent to *Halodule*. Corresponding measurements of water-column salinity and temperature revealed that vigorous *Ruppia* growth correlated positively with cool spring temperatures and not with low water salinities. In contrast, *Halodule* growth increased only after warm summer temperatures were reached. Partitioning of biomass into above-ground and below-ground tissues is suggested as an important autecological factor in resource competition between the two species. *Ruppia*, with a maximum 31% below-ground biomass in mid-spring, could be out-competed by *Halodule*, with a minimum of 66% below-ground biomass, when sediment or other conditions become favorable for *Halodule* growth. Analyses of sediment interstitial water from *Ruppia* or *Halodule* grass beds showed differences in rhizosphere nutrient pools characteristic of each species. *Ruppia*-dominated beds contained up to 15 µM nitrate during spring, whereas *Halodule* beds showed only a trace (< 1 µM). *Halodule*-dominated beds showed consistently higher levels of sediment H_2S compared to *Ruppia* areas (130 µM vs. 50 µM, respectively, average autumn concentration in top 10 cm). Based on these measurable edaphic differences, growth responses to sediment fertilization with two distinct fertilizer formulations were tested: (1) Osmocote™, an ammonium nitrate-based inorganic mixture, and (2) Hyponex™, an organic mixture derived from fish meal. Contrasting responses to these two sediment fertilizers were observed. *Halodule* showed growth stimulation in early autumn by the organic fish meal only, while *Ruppia* responded to both types of fertilizer in both spring and early autumn. It is postulated that *Ruppia* normally grows on low-nutrient sediments, whereas *Halodule* prefers organic-rich sediments with substantial sulfate reduction activity.>

15. McMillan, C. 1984. **The distribution of tropical seagrasses with relation to their tolerance of high temperatures.** Aquatic Botany. 19: 369-379.

[DISTRIBUTION, TEMPERATURE]

<Tropical seagrasses that are distributed in shallow sites and are likely to be exposed to air at low tides show greater tolerance of high temperatures than those which occur in deeper sites and remain submerged. Among seven genera that occur widely in tropical oceans, *Enhalus* and *Halodule* show the greatest heat tolerance and *Syringodium* the least, with *Thalassodendron*, *Thalassia*, *Cymodocea* and *Halophila* variously intermediate. Of two sympatric *Cymodocea* species, *C. rotundata* Ehrenb. and Hempr. ex Ashers. tolerates higher temperatures than does *C. serrulata* (R.Br) Aschers. & Magnus. Within *Halodule*, narrow-leaved plants are more resistant to high temperature stresses than wide-leaved plants, and within the *Halophila ovalis* (R.Br.) Hook. *f-H. minor* (Zoll.) den Hartog complex, most small-leaved populations are more resistant to high temperatures than large-leaved populations. Although diverse leaf types may occur together within shallow seagrass beds, plants with narrow and/or small leaves predominate in sites that are most likely to be exposed to the high temperatures that may accompany low tides in the tropical oceans.>

16. Short, F. T. and M. L. Cambridge. 1984. **Male flowers of *Halophila engelmanni*: description and flowering ecology.** Aquatic Botany. 18: 413-416.

[FLOWERING, HALOPHILA]

<The male flowers of *Halophila engelmanni* Ascherson are described and illustrated from near the northern end of the species range. Flowering is discussed with emphasis on environmental factors influencing flower initiation.>

17. Fry, B. 1983. **Leaf growth in the seagrass *Syringodium filiforme* Kütz.** Aquatic Botany. 16: 361-368.

[LEAF GROWTH, SYRINGODIUM]

<Field measurements made during the summer of 1982 in the Indian River lagoon, Florida, showed that *Syringodium filiforme* Kütz. displays a consistent pattern of growth. The cylindrical leaves lengthen at initial constant rates from a basal region, slow when approaching maturity, and finally cease growing. Elongation rates of individual blades varied by a factor of 3.6, from 0.86 to 3.11 cm day^{-1}, but were usually similar within a factor of 1.5 for leaves growing on the same shoot. Leaf diameter was primarily determined by growth in the basal meristem region and varied from 0.80 to 1.47 mm during growth of an average 40 cm blade. *Syringodium* also partitions growth among leaves in a consistent manner. On an upright shoot that bears 1-3 leaves, growth is almost totally confined to the youngest leaf with a new leaf starting as the previous leaf stops. For productivity studies of *Syringodium*, monitoring growth of the youngest leaves on several leaf shoots will give accurate estimates of mean growth rates.>

18. Williams, S. L. and C. P. McRoy. 1982. **Seagrass productivity: The effect of light on carbon uptake.** Aquatic Botany. 12: 321-344.

[CARBON UPTAKE, LIGHT, PRIMARY PRODUCTIVITY]

<Productivity, as estimated by ^{14}C uptake, was determined as a function of irradiance for six North American seagrasses (*Thalassia testudinum* Banks ex. König, *Syringodium filiforme* Kütz., *Halodule wrightii* Aschers., *Halophila engelmanni* Aschers., *Phyllospadix scouleri* Hook and *Ruppia maritima* L.s.l.) from temperate, subtropical and tropical environments. Light versus productivity curves were typical of those of aquatic plants. Seagrasses achieved high rates of uptake (up to 17.31 mg C (g dry)$^{-1}$ h^{-1}) and exhibited high saturation irradiances ($\geq$ 40% surface irradiance). Within each environment half-saturation and saturation irradiances were similar, indicating no competition for light in the production systems of the various species. Between environments maximum productivity and saturation irradiances changed as a function of the differing irradiance. When rates were normalized for ambient irradiance, there were no differences in maximum rates, except for plants from Texas. In the subtropics and tropics where several species co-exist in the same seagrass bed, two types of responses occurred, corresponding to climax versus colonizer species. The difference in the responses appeared in the initial and maximum rates and in sensitivity to high irradiance. Productivity of seagrasses can be estimated, with certain limitations, from light measurements using the equations of Michaelis-Menten and Steele.>

19. Brock, M. A. 1982. **Biology of the salinity tolerant genus *Ruppia* L. in saline lakes in south Australia. II. Population ecology and reproductive biology.** Aquatic Botany. 13: 249-268.

[REPRODUCTION, RUPPIA, SALINITY]

<This paper is the second in a series reporting a study of the genus *Ruppia* in South Australia. Two of the species of *Ruppia* found in South Australia, *R. polycarpa* Mason and *R. tuberosa* Davis and Tomlinson are found primarily in temporary salt lakes and exhibit annual life cycles. A third species, *R. megacarpa* Mason is perennial and is found only in permanent waters. The differences in the life cycles and reproductive biology of these species are considered in this paper. The standing crop of the annual species was always considerable less than that of the perennial: in Little Dip Lake *R. megacarpa* communities had 410 g m^{-2} DW (grams per square metre dry weight) of total plant matter (282 g m^{-2} DW of *R. megacarpa*) in November 1977 whereas the annual population of the *R. tuberosa* community had a standing crop of 11.7 g m^{-2} DW (3.3 gm^{-2} DW of *R. tuberosa*). Although these values varied with season and salinity, depth and permanence of habitats, the difference between annuals and perennials held. Standing crop and time of seasonal maximum and minimum values showed further differences between annual and perennial life cycles: in Little Dip Lake ranges were 103 (September) to 383 (November) g m^{-2} DW for *R. megacarpa* and 1.6 (June) to 99.0 (September) g m^{-2} for *R. tuberosa*. *R. polycarpa* ranged from 4.2 (June) to 60.0 (September) g m^{-2} DW in a comparable habitat, Blue-Green Algal Pool. Partitioning of *Ruppia* into plant parts reveals differences between annual and perennial forms as well as seasonal differences within each life cycle. In the perennial, reproductive parts (flowers and seeds) always comprise only a small part of the total dry weight, whereas in the two annual species the proportion of reproductive parts (flowers, seeds and turions) is higher in all seasons. Even when vegetative growth of annuals is at its maximum the percentage of dry weight accounted for by reproductive parts is higher than at any stage in the life cycle of the perennial. Both seeds and asexual turions play a major role in propagating the annual species. The perennial spreads mainly by rhizomes. Turions are producted by both *R. polycarpa* and *R. tuberosa* in Australia. Two structural types of turions were found on *R. tuberosa* and only one of these on *R. polycarpa*. The anatomy and role of these organs in propagation are considered.>

20. Dawes, C. J. and J. M. Lawrence. 1980. **Seasonal changes in the proximate constituents of the seagrasses *Thalassia testudinum*, *Halodule wrightii*, and *Syringodium filiforme*.** Aquatic Botany. 8: 371-380.

[CALORIC CONTENT, NUTRIENTS, ORGANIC CONTENT]

<Levels of soluble carbohydrate in the rhizome of *Thalassia testudinum* Banks ex König, *Syringodium filiforme* Kützing, and *Halodule wrightii* (Aschers.) Aschers. are highest in the fall and lowest in the spring. This suggests that soluble carbohydrate is a nutrient reserve used to sustain the plants during the period of decreased productivity in the winter. Ash and dry weight levels for three plant-parts (leaf blades, photosynthetically inactive parts of short shoots, and rhizomes) were generally highest in the fall. Protein levels were highest in the summer in all plant parts in *T. testudinum* and *S. filiforme*

suggesting highest cellular activity. Calorific levels were similar for all three species, the rhizomes having the highest levels, although no seasonal pattern was evident. The organic biomass of an average-sized plant of *T. testudinum* is 8-12 times greater than that of the other two species in the fall and the short-shoot biomass may account for half of the entire plant. The rhizome of *T. testudinum* has the highest level of organic matter of the three, for most of the year. The blades of *H. wrightii* and *S. filiforme* account for the largest amount of organic material in the fall when compared with the photosynthetically inactive parts of short shoots and rhizomes of the same plant.>

21. Moffler, M. D., M. J. Durako, and W. F. Grey. 1981. **Observations on the reproductive ecology of *Thalassia testudinum* (Hydrocharitaceae)**. Aquatic Botany. 10: 183-187.

[REPRODUCTION, THALASSIA]

<A phenological inversion in *Thalassia testudinum* Banks ex König was indicated by the presence of early fruit stage in midwinter. Further observations in January 1979 detected early reproductive bud presence, and 44% of the short-shoots examined were reproductive. These observations add new information on this species' reproductive biology and indicate that caution should be applied when describing *T. testudinum* as a short- intermediate- or long-day plant.>

22. Phillips, R. C., C. McMillan, and K. W. Bridges. 1981. **Phenology and reproductive physiology of *Thalassia testudinum* from the western tropical Atlantic**. Aquatic Botany. 11: 263-277.

[REPRODUCTION, THALASSIA]

<Phenological investigations in natural seagrass beds of Texas, Florida and St. Croix, U.S. Virgin Islands, and reproductive physiology studies under controlled conditions suggest that flowering in *Thalassia testudinum* Banks ex König is related to the temperature progressions that follow winter minima. Phenological analyses did not show significant site differences that were related to latitude for any of five phenophases, but indicated that flowering may be nearly synchronous in Texas, Florida and St. Croix. Statistical analyses of one phenophase, the initial appearance of visible floral buds, and the temperatures antecedent to this phenophase indicated that flowering in St. Croix is preceded by a significantly higher temperature progression than that in Florida or in Texas. Under controlled conditions, plants of Texas were induced to flower at temperatures at or below 23°C, but plants of more tropical origin, St. Croix and Mexico, flowered less frequently and at a slightly higher temperature, 24-26°C. Plants of diverse origin produced flowers under continuous light, suggesting that photoperiod does not play a significant role in flowering phenology. The combined studies in the natural seagrass beds and in the laboratory under controlled conditions indicate that temperature responses for St. Croix plants are probably genotypically different from those of Florida and Texas.>

23. McMillan, C. 1981. **Seed reserves and seed germination for two seagrasses, *Halodule wrightii* and *Syringodium filiforme*, from the western Atlantic**. Aquatic Botany. 11: 279-296.

[HALODULE, REPRODUCTION, SALINITY, SYRINGODIUM]

<Seeds of *Halodule* and *Syringodium* from diverse sites in the western Atlantic showed low rates of germination over extended periods of time. Seeds of *Halodule* are suited to long-term dormance, possibly extending over many years, while those of *Syringodium* are oriented toward short-term dormancy. For *Halodule*, dormancy involves both seed coats and embryos, but for *Syringodium*, it probably involves only seed coats. Germination for both seagrasses occurs in a wide range of salinities: 5-50% for *Halodule*; 20-50% for *Syringodium*. One-seeded fruits of *Halodule* are produced at rhizome level and remain buried in the sediment until disturbed and constitute a seed reserve estimated at a maximum of ca. 3000 m^{-2} in both Texas and in the U.S. Virgin Islands. *Syringodium* fruits (one-seeded) are produced on inflorescences elevated above the sediment at a maximum rate of ca. 10,000 m^{-2}, but few reserves in the sediment were recorded. The dormancy of seagrass seeds permits germination over extended periods of time and allows survival in disturbed sites as well as colonization of new habitats.>

24. McMillan, C. and F. N. Moseley. 1967. **Salinity tolerances of five marine spermatophytes of Redfish Bay, Texas**. Ecology. 48: 503-506.

[SALINITY]

<*Thalassia testudinum* König and Sims and *Halophila engelmanni* Aschers. (Hydrocharitaceae); *Diplanthera wrightii* (Aschers.) Aschers., *Ruppia maritima* L., and *Syringodium filiforme* Kützing (Potamogetonaceae) are the major plants of the highly productive estuaries along the Texas coast. When transplanted to outdoor ponds and to controlled growth rooms, the greatest tolerance to increasing salinity was shown by *Diplanthera*. Lesser salinity tolerance was shown by *Thalassia* and *Ruppia*. Although survival was not complete under all transplant conditions for *Syringodium*, it showed least tolerance of high salinity. *Halophila* survived sporadically in the study but showed active growth at high salinity. The distributional patterns of these species in Redfish Bay are partially correlated with their salinity tolerances.>

25. Atkinson, M. J. and S. V. Smith. 1983. **C:N:P ratios of benthic marine plants**. Limnology and Oceanography. 28: 568-575.

[NUTRIENTS]

<The median C:N:P atomic ratio of benthic marine macroalgae and seagrasses is about 550:30:1. Benthic plants are much more depleted in P and less in N, relative to C, than phytoplankton. The amount of nutrients required to support a particular level of net production is much lower for benthic marine plants than it is for phytoplankton.>

26. Sauers, S. C. 1981. **Seasonal growth of seagrasses in Sarasota Bay, Florida with notes on historical changes and considerations for restoration**. In: Proceedings of the Eighth Annual Conference on Wetlands Restoration and Creation. Edited by R. H. Stovall, 22. Tampa: Hillsborough Community College.

[DISTRIBUTION, GROWTH]

<Mappings of seagrass distribution in portions of Sarasota Bay, Florida revealed significant localized declines of seagrass cover averaging 55 - 65%

since 1948. Losses were related to several factors including water quality degradation, erosion, and grazing by sea urchins. Observations on seasonal growth of *Halodule wrightii* and *Thalassia testudinum*, during 1979-1980, suggested that site-specific factors (e.g. degree of tidal inundation, temperature, drift and epiphytic algal growth, herbivore activity, and sediment stability) influence the maximum biomass attainable at a particular location. Several growth characters, including shoot and blade abundance, leaf area, flowering, and aboveground-belowground biomass were monitored and used to develop a phenological index for these seagrasses in Sarasota Bay. Comparisons of seagrass standing stock and biomass were made between Sarasota Bay and other regions of Florida, the Gulf and Atlantic coasts of southern U.S., and the Caribbean. A non-destructive means of estimating biomass from *in situ* measurement of plant parameters was introduced.>

27. City of Tampa. 1991. **Seagrass and *Caulerpa* monitoring in Hillsborough Bay: Second annual report**. Submitted to the Florida Department of Environmental Regulation, Tampa Office. Tampa: City of Tampa, Department of Sanitary Sewers, Bay Study Group.

[CAULERPA, DISTRIBUTION]

<The Bay Studies Group, in cooperation with the FDNR and the NMFS Tampa Bay Experimental Seagrass Planting Effort, has been involved in two transplantings of seagrass into Hillsborough Bay. The first transplanting effort occurred during June and July of 1987 utilizing *H. wrightii* source material from the Courtney Campbell road widening project. About 900 *H. wrightii* "bare root" units were planted in an intertidal area adjacent to western Interbay Peninsula. In addition, nearly 350 *H. wrightii* "sod blocks" were planted in seven areas of Hillsborough Bay using the Courtney Campbell source material. The second transplanting effort occurred in May 1989 and utilized source material from Port Manatee. Two 10x20 m subtidal plots were planted in Hillsborough Bay with *H. wrightii* and *Syringodium filiforme* "sod blocks." Both efforts were designed to locate areas of Hillsborough Bay suitable for seagrass transplanting, to establish a source of vegetative material, and to determine if artificially introduced seagrass could generate functional seagrass communities.>

28. Kenworthy, W. J., M. S. Fonseca, D. McIvor, and G. W. Thayer. 1987. **Hobe Sound seagrass-manatee project**. Beaufort: National Marine Fisheries Service, NOAA, Southeast Fisheries Center, Beaufort Laboratory.

[ABUNDANCE, BOAT TRAFFIC, DISTRIBUTION, LIGHT, TURBIDITY]

<An intensive field study to examine the diurnal, seasonal, and annual light regime in Hobe Sound was undertaken in conjunction with a study of seagrass distribution, abundance and growth. A submarine light sampling regime that includes weekly sampling at 24 stations located on six transects was implemented in Hobe Sound. Baseline environmental data as well as estimates of light attenuation coefficients were obtained. Results thus far indicate a seasonally improving submarine light regime with attenuation coefficients ranging between 1.0 in spring and 0.5 in summer. This range probably approximates the worst and best submarine light conditions for Hobe Sound. Two data sets showed decreased light penetration during periods of heavy boat traffic suggesting a possible cause-effect relationship between boat traffic and increased turbidity.>

29. Ballantine, D. and H. J. Humm. 1975. **Benthic algae of the Anclote estuary, I. Epiphytes of seagrass leaves.** Florida Scientist. 38: 150-162.

[ALGAE, EPIPHYTES]

<Sixty-six species of benthic algae are recorded as epiphytes on the 4 species of seagrasses that form extensive beds in the Anclote estuary near Tarpon Springs, Florida Gulf coast. Monthly field observations and collections were made at 6 representative stations from January to September, 1971. About 65% of all benthic algae that grow attached in the area occur as seagrass epiphytes. *Ceramium byssoideum* fa. *alternatum* is newly described.>

30. Sand-Jensen, K. 1990. **Epiphyte shading: Its role in resulting depth distribution of submerged aquatic macrophytes.** Folia Geobotanica et Phytotaxonomica. 25: 315-320.

[EPIPHYTES, LITTORELLA, NUTRIENT LOADING, PHYTOPLANKTON]

<The biomass of epiphytic algae increased more than the biomass of phytoplankton with increased nutrient availability (N,P,Si) in four lakes. Large epiphyte biomasses on the submerged macrophyte, *Littorella uniflora*, reduce light attenuation more than phytoplankton did. High values of shading by epiphytes correspond with a reduction in the maximum depth penetration of *Littorella* by more than 1 meter.>

31. Virnstein, R. W. 1982. **Leaf growth rate of the seagrass *Halodule wrightii* photographically measured *in situ*.** Aquatic Botany. 12: 209-218.

[GROWTH, HALODULE]

<A patch of *Halodule wrightii* Aschers. in the Indian River, Florida, was clipped near the sediment surface and a mirrored prism was set in place to photographically record subsequent regrowth of blades *in situ*. Tagging was considered not feasible. After a lag time of 1-3 days, mean blade length increased rapidly (up to 8.5 mm day^{-1}) for several days. As older blades began to mature and their growth rate slowed down, the average growth rate of all blades decreased. Within 21 days the standing stock had been completely replaced, and the clipped plot was indistinguishable from a control plot. The period of rapid growth represents a productivity of leaves of 3.0 g dry wt. m^{-2} day^{-1}. Although this value is not high compared to other seagrasses, compared to the low standing stock of only 28 g dry wt. m^{-2}, it represents an extremely high turnover rate of 11 % day^{-1} (once every 9 days).>

32. Dunton, K. H. 1990. **Production ecology of *Ruppia maritima* L. s.l. and *Halodule wrightii* Aschers. in two subtropical estuaries.** Journal of Experimental Marine Biology and Ecology. 143: 147-164.

[ESTUARY, GROWTH, HALODULE, PRIMARY PRODUCTIVITY, RUPPIA, SEAGRASS]

<Seasonal growth and production dynamics of *Ruppia maritima* L. s.l. were compared over a 3-year period in two south Texas estuaries characterized by different salinity and N regimes as a result of freshwater inputs. Measurements of shoot production in the Guadalupe Estuary (0-25% salinity) and

the Nueces Estuary (32-38% salinity) revealed no major differences in the magnitude of growth, but the plant populations differed in the seasonality of growth, the time of flowering, and the persistence of an overwintering population. During the period of rapid shoot development, from March to August, leaf elongation rates usually ranged from 2 to 4 mm day^{-1} (0.04-0.08 mg dry wt mg $shoot^{-1}$ day^{-1}), although peak growth rates of up to 8 mm day^{-1} were also recorded. In both estuaries, *R. maritima* was a strict opportunist, yearly colonizing bare areas and completing its entire growth cycle in 4 months. Overwintering populations of *R. maritima* existed at the lower nutrient and higher salinity site in Nueces Estuary but not at the high nutrient, low salinity site in Guadalupe Estuary. *Halodule wrightii* Aschers. was absent from Guadalupe Estuary, but in the Nueces Estuary, *H. wrightii* maintained large and persistent overwintering populations characterized by sustained year-round growth and larger below-ground root and rhizome fractions of total biomass (50-85%) compared to *R. maritima* (20-70%). The high nutrient regimes associated with large inputs of freshwater in the Guadalupe Estuary appear to have little beneficial effect on the growth dynamics of *R. maritima*. Instead, significant reductions in underwater light may be most important for growth. Fouling by algal epiphytes, higher riverine inflow, and local physiographic differences in wave exposure appear to be the primary factors regulating light levels and thus the proliferation and year-round persistence of *R. maritima*.>

33. Carter, V. and N. B. Rybicki. 1990. **Light attenuation and submersed macrophyte distribution in the tidal Potomac River and estuary.** Estuaries. 13: 441-452.

[AQUATIC MACROPHYTES, CHLOROPHYLL, LIGHT, SUSPENDED SOLIDS]

<Changing light availability may be responsible for the discontinuous distribution of submersed aquatic macrophytes in the freshwater tidal Potomac River. During the 1985-1986 growing seasons, light attenuation and chlorophyll *a* and suspended particulate material concentrations were measured in an unvegetated reach (B) and in two adjacent vegetated reaches (A and C). Light attenuation in reach B (the lower, fresh to oligohaline tidal river) was greater than that in reach A (the recently revegetated, upper, freshwater tidal river) in both years. Reach B light attenuation was greater than that in reach C (the vegetated, oligohaline to mesohaline transition zone of the Potomac Estuary) in 1985 and similar to that in reach C in 1986. In reach B, 5% of total below-surface light penetrated only an average of 1.3 m in 1985 and 1.0 m in 1986, compared with 1.9 m and 1.4 m in reach A in 1985 and 1986, respectively. Water column chlorophyll *a* concentration controlled light availability in reaches A and B in 1985, whereas both chlorophyll *a* and suspended particulate material concentrations were highly correlated with attenuation in both reaches in 1986. Reach C light attenuation was correlated with suspended particulate material in 1986. The relationship between attenuation coefficient and Secchi depth was K_{PAR} = 1.38/Secchi depth. The spectral distribution of light at 1 m was shifted toward the red portion of the visible spectrum compared to surface light. Blue light was virtually absent at 1.0 m in reach B during July and August 1986. Tidal range is probably an important factor in determining light availability for submersed macrophyte propagule survival at the sediment-water interface in this shallow turbid system.>

34. Williams, S. L. 1988. **Disturbance and recovery of a deep-water Caribbean seagrass bed.** Marine Ecology Progress Series. 42: 63-71.

[ABUNDANCE, LIGHT, NUTRIENTS, STORMS]

<The seagrass community in a deep-water (20m) submarine canyon on St. Croix, US Virgin Islands showed strong seasonal changes in abundances (50 to 90% of yearly maxima) of major plant species in response to predictable winter conditions of low light and storms. Major species were the seagrass *Halophila decipiens* and the green macroalga *Halimeda incrassata*. Virtual elimination of the seagrass occurred following particularly severe storms; the alga was more resistant. Seagrass and alga regained their pre-disturbance biomass or abundance within 6 to 8 mo after major storms. Addition of nutrients to the sediments had no effect on the growth or recolonization rate of the alga. The rates of recolonization of the alga and seagrass were controlled by light availability in winter. Dynamics of disturbance and recovery in this deep-water seagrass bed are very different from other Caribbean seagrass communities in shallow waters, which are more resistant to storms of similar magnitude but once disturbed take many years for recovery. The deep-water seagrass bed is an example of a tropical community that is structured by seasonal abiotic disturbances and physiological extremes, as are many temperate marine communities.>

35. Williams, S. L. 1990. **Experimental studies of Caribbean seagrass bed development.** Ecological Monographs. 60: 449-469.

[CORAL REEFS, FACILITATION, RHIZOPHYTIC ALGAE, SEDIMENT NUTRIENTS, SUCCESSION, SYRINGODIUM, THALASSIA]

<Processes important in the development of subtidal seagrass beds composed of *Thalassia testudinum*, *Syringodium filiforme*, *Halodule wrightii*, and many rhizophytic algal species were examined *in situ* for 52 mo in a coral reef lagoon on St. Croix, United States Virgin Islands. The study emphasized the early stages of development of the seagrass beds and the role played by colonizing rhizophytic algae. I tested the hypotheses that nutrient accumulation in the sediments limits seagrass recolonization, and that rhizophytic algae facilitate sediment nutrient accumulation by stabilizing the sediments and adding organic matter from rapidly decomposing thalli. Vegetation was removed from 0.25 and 1 m^2 plots in 3 m of water. Plot treatments consisted of : (1) no further manipulation, (2) adding nitrogen plus phosphorus fertilizer to the sediments, (3) removing colonizing rhizophytic algae to minimize algal effects (e.g., sediment stabilization, organic input), and (4) removing colonizing algae and adding "plastic algae" to stabilize sediments without organic input. Plant densities, sediment grain size, redox potential, inorganic nitrogen concentrations in porewaters, and ammonium production rates were measured over time in all plots, including undisturbed controls. All recolonization occurred through vegetative propagation. The sequence of plant recolonization was unaffected by the treatments, corresponding instead to life history characteristics and nutrient requirements of the species involved. Rhizophytic algae invaded the plots within a few months, followed by the seagrass *Syringodium*, then *Thalassia*. The seagrass *Halodule* was insignificant in the recolonization. Densities of rhizophytic algae and *Syringodium* declined when the density of *Thalassia* reached 200 leaf shoots/m^2. The rate increase in seagrass leaf shoot densities and biomass were greatest in the fertilized plots, supporting the nutrient limitation hypothesis. Rhizophytic algae facilitated

seagrass recolonization; seagrass densities, biomass, and porewater ammonium concentrations were lowest in plots where algae were removed. Sediment ammonium concentrations decreased when *Thalassia* became dominant. Ammonium production in the sediments increased as the plant community developed. The nitrogen required for *Syringodium* productivity was met easily by ammonium production, assuming no competition from *Thalassia*. In contrast, *Thalassia* accounted for >93% of the nitrogen required for total seagrass productivity, and ammonium production could supply up to 45% of this requirement. At the end of the experiment (52 mo), *Thalassia* density and ammonium production rates in the sediments were lower than in the surrounding undisturbed seagrass bed. The experiment provides evidence for a resource-ratio model where the rate of succession is controlled by a sediment nutrient supply that increases over time. The sequence of colonization is determined by relative rates of vegetative propagation by stolons and rhizomes across the sediment surface, which are inversely correlated with whole plant productivity and thus with requirements for nutrients. Algal colonizers tolerate low nutrients by having low productivities. The climax species *Thalassia* is competitive species effective at exploiting the sediment nutrient resource. Co-existence, rather than replacement, of species occurs, despite a relatively benign disturbance regime.>

36. McMillan, C. 1979. **Differentiation in response to chilling temperatures among populations of three marine spermatophytes, *Thalassia testudinum*, *Syringodium filiforme* and *Halodule wrightii*.** American Journal of Botany. 66: 810-819.

[CARBON UPTAKE, FATTY ACIDS, TEMPERATURE TOLERANCE]

<Upon exposure to chilling conditions, the seagrass populations of *Thalassia testudinum* Banks ex König, *Syringodium filiforme* Kütz., and *Halodule wrightii* Aschers. showed various amounts of leaf and plant damage that correlated with their origin in the Gulf of Mexico-Caribbean. Populations of more tropical origin in the southern Gulf and Caribbean showed the most chill damage and those of the northern Gulf showed the least injury from the exposure to low temperatures. Of the three seagrasses, *Halodule* showed greatest chill tolerance, *Syringodium* showed the least tolerance and *Thalassia* was intermediate. The uptake of ^{14}C by leaves following exposure to chilling temperatures showed quantitative differences that correlated with the amount of leaf damage in the various populations. No significant changes in the fatty acids in total lipid extracts were noted in the Texas seagrasses after chilling and, therefore, their resistance to low temperature damage did not relate to the changes in saturation of fatty acids. Although the growing conditions slightly altered the severity of the chilling effects, the differentiation of response to chilling among the seagrass populations is based on inherited properties.>

37. McMillan, C. 1978. **Morphogeographic variation under controlled conditions in five seagrasses, *Thalassia testudinum*, *Halodule wrightii*, *Syringodium filiforme*, *Halophila engelmannii*, and *Zostera marina*.** Aquatic Botany. 4: 169-189.

[MORPHOLOGY]

<The morphogeopraphic evidence under controlled conditions demonstrated variation in leaf width that correlated with the leaf patterns in the indigenous habitats. In *Thalassia testudinum* Banks ex König, *Halodule wrightii* Aschers.,

and *Syringodium filiforme* Kütz., the narrow-leaved variants from shallow bays in the northern Gulf of Mexico continued to produce narrow leaves in laboratory culture. Broader-leaved variants in the same three species that originated from seagrass beds associated with coral reefs in the southern Gulf of Mexico and the Caribbean continued to produce broad leaves. The turbid water and variable salinity and temperature of the shallow northern bays correlate with the presence of narrow-leaved plants, and the clear water and relatively constant salinity and temperature of the southern regions correlate with the broader-leaved populations. Although an ecotypic status for the narrow- and wide-leaved populations was suggested, the selective role of these habitat conditions needs further investigation. Clonal variation in leaf width was demonstrated within *Halodule* populations under uniform conditions. Plants of *Halophila engelmannii* Aschers. from deep seagrass beds in the Gulf of Mexico along the western coast of Florida continued to produce narrower leaves than those produced by plants from shallow Texas bays. Three collections of *Zostera marina* L. from Washington and Alaska produced leaves of significantly different widths under each of three temperature regimes. The experimental evidence suggests that the width of a seagrass leaf is dependent on its immediate environmental surroundings but that the limits of its ecoplasticity vary geographically depending on the genotype.>

38. Phillips, R. C. 1980. **Responses of transplanted and indigenous *Thalassia testudinum* Banks ex König and *Halodule wrightii* Aschers. to sediment loading and cold stress.** Marine Science (New York). 23: 79-87.

[SEDIMENTS, TEMPERATURE]

<Observations of transplanted and indigenous *Thalassia testudinum* and *Halodule wrightii* were initiated in Redfish Bay, near Port Aransas, Texas, in July 1974 and continued until July 1979. A total of 32 experimental plots were initiated (18 with *Halodule*; 14 with *Thalassia*). Twenty-three of these were planted prior to a dredging project begun in autumn 1975, 14.5 km distant from the experimental site (14 with *Halodule*; nine with *Thalassia*). The dredging project resulted in the addition of 15-25 cm sediment to the site, covering the transplants and the *Halodule* meadow. By April 1976 *Thalassia* transplants were declining and dying back. Several of these plots were being invaded by *Halodule*. Following an extremely cold winter (1976-1977) *Thalassia* transplants disappeared and only *Halodule* plots remained. All introduced sediment finally washed out of the area by December 1977. Indigenous *Halodule* and most transplants decayed to form an organic silt layer 4-6 cm deep. This study shows that *Thalassia* and *Halodule* can be debilitated by a sediment accumulation from even small dredging projects in this area. These effects are compounded when coupled with an extraordinary cold winter. *Thalassia* is much less tolerant to sediment loading and cold than is *Halodule*.>

39. Zieman, J. C. 1974. **Seasonal variation of turtle grass, *Thalassia testudinum* König, with reference to temperature and salinity effects.** Aquatic Botany. 1: 107-123.

[PRIMARY PRODUCTIVITY, SALINITY, STANDING CROP, TEMPERATURE]

<Although turtle grass, *Thalassia testudinum* König, is a tropical marine plant, studies show it undergoes seasonal fluctuation. Maximum values of productivity, standing crop, leaf length, blade density, and other biotic

variables are reached in the warmer summer months. *Thalassia* has a temperature optimum near 30°C and a salinity optimum near 30 o/oo. Significant deviations of these environmental parameters from their optima depress the biotic viability of the plant. Minimum values for the measured variables were encountered during periods of seasonally low temperatures or high temperatures coupled with lowered salinity. *Thalassia* is seen to have a slow response to environmental stress due to the stored starch reserves in the extensive robust rhizome system.>

40. McMillan, C. and R. C. Phillips. 1979. **Differentiation in habitat response among populations of new world seagrasses.** Aquatic Botany. 7: 185-196.

[HABITAT]

<Seagrass populations in diverse ecosystems show the selective influence of the local habitat conditions. The patterns of differentiation in the Gulf of Mexico and Caribbean seagrasses, *Thalassia testudinum* Banks ex König, *Syringodium filiforme* Kütz., and *Halodule wrightii* Aschers., and in the circumboreal seagrass, *Zostera marina* L., have been investigated by a variety of manipulative techniques in the laboratory and in the field. Although seagrasses may be vegetatively moved for long distances either by oceanic transport or by experimental procedures, their survival patterns reflect the selective influence of their indigenous habitat.>

41. Wiginton, J. R. and C. McMillan. 1979. **Chlorophyll composition under controlled light conditions as related to the distribution of seagrasses in Texas and the U.S. Virgin Islands.** Aquatic Botany. 6: 171-184.

[CHLOROPHYLL, LIGHT]

<Seagrasses from various depths in St. Croix, U.S. Virgin Islands, and from shallow beds in Redfish Bay, Texas, were grown in the laboratory under three light conditions. For all collections, light absorption readings of extracted pigments showed that total chlorophyll content is inversely related to reduced light over the range from 35 to 200 μM m^{-2} s^{-1}. The ratio of chlorophyll *a* to chlorophyll *b* decreases in response to reduced light for Caribbean collections of *Halodule wrightii* Aschers., *Syringodium filforme* Kütz., and *Halophila decipiens* Ostenfeld but not for *Thalassia testudinum* Banks ex König or the Texas collections of *Halodule*, *Syringodium*, *Thalassia*, and *Halophila engelmannii* Aschers. There is a correlation of the maximum depth of the St. Croix seagrasses and the ratio of chlorophyll *a* to chlorophyll *b*: *H. decipiens*, with the greatest depth range, to -42 m, has the lowest ratio; *T. testudinum*, with the least depth range, to -12 m, has the highest ratio; *H. wrightii* and *S. filiforme* have intermediate depth ranges and ratios. Although light quality and sea bottom characteristics may play roles in the ultimate depth to which a seagrass may occur, photon flux density is suggested as a primary environmental determinant.>

42. Congdon, R. A. and A. J. McComb. 1979. **Productivity of *Ruppia*: Seasonal changes and dependence on light in an Australian Estuary.** Aquatic Botany. 6: 121-132.

[LIGHT, PRIMARY PRODUCTIVITY, RUPPIA]

<*Ruppia* shows seasonal changes in biomass with peak standing crops which differ between sites and years, but which are usually at a maximum in late spring and early summer. *Ruppia* produces annually some 75-500 g dry wt. m^{-2} in the estuary, and the total annual net production for the whole estuary is of the order of 700-1900 tonnes dry wt. Mesh enclosures were used to investigate effects of shading on standing crop. Increased light attenuation significantly reduces the contribution of this species to primary production. With increased duration of shading, higher light intensities are required to sustain high standing crops. *Ruppia* may be precluded if its ambient light intensity is reduced by 80% or more for up to 100 days; a reduction by 20% for 250 days results in a significant decrease in biomass.>

43. Zimmerman, M. S. and R. J. Livingston. 1976. **Seasonality and physico-chemical ranges of benthic macrophytes from a north Florida estuary.** Marine Science (New York). 20: 33-45.

[AQUATIC MACROPHYTES, COLOR, DEPTH, SALINITY, SEASONALITY, TEMPERATURE, TURBIDITY]

<Samples were taken for 15 months in Apalachee Bay, north Florida to determine the seasonality of the various species of benthic macrophytes. A total of 39 species was collected. Quantitatively the flora was dominated by the seagrass, *Thalassia testudinum*, and the green alga, *Halimeda incrassata*. The phylum Rhodophyta had the largest representation with 17 species. The flora was warm temperate with many eurythermal tropical species. One species *Polysiphonia harveyi*, was shown to have a disjunct distribution and a temperate origin. Environmental limits (temperature, salinity, etc.) for each species were presented. Most species appeared to be eurythermal, which was considered an adaptation of tropical species for existence in a warm temperate region. Both euryhaline and stenohaline species coexist in Apalachee Bay. Species distribution in response to factors such as turbidity, color, and depth was discussed.>

44. Harlin, M. M. and B. Thorne-Miller. 1981. **Nutrient enrichment of seagrass beds in a Rhode Island coastal lagoon.** Marine Biology (New York). 65: 221-229.

[NUTRIENTS]

<Seagrass and algal beds showed a variety of responses when the water column was treated with low level additions of ammonium, nitrate and phosphate. The nutrients were added separately to 3 uniform seagrass beds of a temperature coastal lagoon during 1979 and 1980. (1) Ammonium caused the production of dense mats of free-floating green algae *Enteromorpha plumosa* and *Ulva lactuca*. It also stimulated growth in both the leaf and root-rhizome fractions of *Zostera marina*. This growth response in *Z. marina* was greater in the area where current reached 12 $cm \cdot s^{-1}$ than in the area with little or no current. The concentration of nitrogen in the tissue did not change. In contrast, where current was lacking, *Z. marina* growth increase with ammonium was small, but the concentration of nitrogen in the tissue doubled over that in control plots. The growth of *Ruppia maritima* was inversely related to the growth of green algae in the same plots. The red alga *Gracilaria tikvahiae* did not grow better in ammonium, but its tissue reddened. (2) Nitrate additions enhanced the growth of the green seaweeds *Enteromorpha* spp. and *U. Lactuca*, but not *Z. marina* or *R. maritima*. *G.*

tikvahiae, when fertilized in isolation from other plants, showed a marginal response to this nutrient, and the tissue always reddened. (3) Phosphate enhanced growth in *Z. marina* and *R. maritima* exposed to moderate current. *G. tikvahiae* growing alone showed a small growth response to phosphate. The phosphate made no difference in the growth of the green seaweeds. (4) None of the nutrient supplements noticeably altered the species composition of either epiphytic or planktonic algae associated with the beds, although we did detect small increases in their numbers. The rapid and dense growth of green algae in nitrogen-enriched water probably limited growth of adjacent seagrasses and red algae. Because these seaweeds did not use the phosphate, it became available to other plant components. The overall floral response to nutrient addition in seagrass communities depends, therefore, upon the particular nutrient supplied, the ability of alternate species in the area to compete for that nutrient and the velocity of current in the specific area.>

45. Walsh, G. E. and T. E. Grow. 1972. **Composition of *Thalassia testudinum* and *Ruppia maritima*.** Quarterly Journal of the Florida Academy of Sciences. 35: 97-108.

[CALORIC CONTENT, NUTRIENTS]

<Little is known at present about the nutritive value of aquatic plants, especially in relation to annual variations in their chemical constituents. Turtle grass (*Thalassia testudinum*) and widgeon grass (*Ruppia maritima*) are common in the inshore waters of Florida (Phillips, 1960). They are important constituents of estuarine nursery grounds for marine animals and many forms of plant and animal life are associated with them (Hudson et al., 1970). The seagrasses are eaten by fishes, turtles, and other aquatic animals (Randall, 1965), and birds (Olney, 1968). Detritus derived from seagrasses is eaten by small marine animals (Menzies and Rowe, 1969; Fenchel, 1970). Also, *T. Testudinum* and its epiphytes are important in biogeochemical cycles in estuarine areas (Parker, 1966). Both *T. Testudinum* and *R. maritima* have been used successfully in preliminary experiments as fertilizers for tomatoes (van Breedveld, 1966) and as feed supplements for Sheep (Bauersfeld et al., 1969). Because of the importance of *T. testudinum* and *R. maritima* to estuarine ecosystems, we investigated seasonal distributions of protein, carbohydrate, trace elements, and energy content of their leaves and rhizomes. Also, the potential nutritive value of the seagrasses was evaluated.>

46. McMahan, C. A. 1968. **Biomass and salinity tolerance of shoalgrass and manateegrass in lower Laguna Madre, Texas.** Journal of Wildlife Management. 32: 501-506.

[BIOMASS, HALODULE, SALINITY TOLERANCE, SYRINGODIUM]

<Three different shoalgrass (*Diplanthera wrightii*) stands and a manateegrass (*Syringodium filforme*) community in Lower Laguna Madre, Texas, were sampled for their plant biomass. The winter standing crop of all (wet) shoalgrass herbage and roots is estimated to be 317,345 tons, a yield of 4,656 lb/acre. The standing crop of (wet) manateegrass is estimated to be 48,214 tons, a yield of 5,795 lb/acre. Manateegrass is not seasonal in abundance. Shoalgrass sprigs planted in culture vessels lived in salinities ranging from 9.0 to 52.5 parts per thousand (ppt), but died in salinities of 3.5 ppt and 70.0 ppt, or more. Manateegrass rhizomes planted in culture vessels survived best in a

salinity of 35.0 ppt, while those planted in a vessel containing 52.5 ppt died. Shoalgrass is an important food of waterfowl wintering in Lower Laguna Madre, and provides spawning and nursery grounds for fish and shrimp. Manateegrass appears to be of minimal value to fish and waterfowl. If the usual salinity of Laguna Madre is permanently decreased by construction of fish passes from the Gulf of Mexico, or by drainages from river diversion projects, the shoalgrass biomass is likely to be reduced and the production promoted of manateegrass or other marine spermatophytes intolerant of hypersaline water.>

47. Patriquin, D. G. 1972. **The origin of nitrogen and phosphorus for growth of the marine angiosperm *Thalassia testudinum*.** Marine Biology (New York). 15: 35-46.

[NUTRIENTS, THALASSIA]

<How are high rates of production by *Thalassia testudinum* König maintained in notably nutrient-poor tropical waters? Yield-nutrient supply correlations indicate that a significant proportion of the phosphorus, and virtually all nitrogen for leaf growth are taken-up from the sediments, and that growth is generally limited by availability of nitrogen. Considerations of supply and demand suggest that the sediments could not be a primary source of phosphate, but the sediments may act as a "storage bank" for phosphate taken up from the sea water by *T. testudinum*. It is believed that inorganic nitrogen in the root layer is derived from fixation of gaseous nitrogen by anaerobic bacteria. Maintenance of anaerobic conditions in the root layer appears to be essential for good growth of *T. testudinum*, and it is suggested that such conditions facilitate nitrogen fixation.>

48. Patriquin, D. and R. Knowles. 1972. **Nitrogen fixation in the rhizosphere of marine angiosperms.** Marine Biology (New York). 16: 49-58.

[ACETYLENE REDUCTION, NITROGEN FIXATION]

<High rates of acetylene reduction were observed in systems containing excised rhizomes of the Caribbean marine angiosperms *Thalassia testudinum*, *Syringodium filiforme* and *Diplanthera wrightii*, and the temperate marine angiosperm *Zostera marina*. For 4 plant and plant-sediment systems the ratio of acetylene reduced/N_2 fixed varied from 2.6 to 4.6. For *T. testudinum* the estimated rates of nitrogen fixation are in agreement with estimated requirements of the plant for nitrogen. For a typical *T. testudinum* stand, N_2 fixation is estimated to be 100 to 500 kg N/hectare per year. Numbers of N_2-fixing bacteria in the rhizosphere sediments were roughly 50 to 300 times more abundant than those in the non-rhizosphere sediments, and in both types of sediments were of the same orders as the estimated numbers of heterotrophic aeroles.>

49. McMillan, C. 1984. **The condensed tannins (proanthocyanidins) in seagrasses.** Aquatic Botany. 20: 351-357.

[TANNINS]

<In a survey of 29 species in the 12 seagrass genera, those in the Potamogetonaceae that characteristically have tannin cells in the leaves (Posidonioideae: *Posidonia*; Cymodoceoideae: *Halodule*, *Syringodium*, *Cymodocea*, *Thalassodendron*, *Amphibolis*) contained compounds with the R_f values and color

reactions typical of condensed tannins. Species in the Potamogetonaceae that are not characterized by tannin cells in the leaves (Zosteroideae: *Zostera*, *Phyllospadix*, *Heterozostera* contained compounds with the R_f values associated with condensed tannins but without the typical staining reactions. Two of the three genera in the Hydrocharitaceae (*Enhalus*, *Thalassia*) are characterized by tannin cells in the leaves and contain compounds with the R_f values of condensed tannins but only some of the typical staining reactions. The third genus, *Halophila*, lacks tannin cells in the leaves but contains compounds with the R_f values of condensed tannins but without the typical staining reactions. The role of condensed tannins as feeding deterrents because of their protein-binding properties has been well established for many land plants, but their role in seagrass biology has not been assessed fully.>

50. Thorhaug, A. and M. A. Roessler. 1977. **Seagrass community dynamics in a subtropical estuarine lagoon**. Aquaculture. 12: 253-277.

[DISTRIBUTION, PRIMARY PRODUCTIVITY, STANDING CROP]

<The temporal and spatial distribution of major plant and animal species were investigated for 4 years in south Biscayne Bay including Card Sound, Florida, a subtropical estuarine lagoon. This was part of a larger study including chemical, physical and geological investigations. The major species of plants were *Thalassia testudinum* Banks ex König, turtle grass, Laurencia poitei (Lamour.) Howe, a red macroalga and the green algae *Penicillus capitatus* Lamarck and *Halimeda incrassata* (Ellis) Lamour. Standing crop and production of plant material taken bi-weekly is given in detail for 16 stations in Card Sound for the 4-year period and for eight stations in Biscayne Bay for a 1-year period. The major animal species were not equally distributed; in the near-shore *Thallassia* community, species of *Pagurus*, *Neopanope*, *Hippolyte*, *Cerithium*, *Bulla*, *Prunum* and *Modulus* were dominant. In mid-bay, where patchy *Thalassia* plus green algae occurred, *Thor* and *Chondrilla* were the dominant animals. Near the fringing islands, where tidal flow caused more oceanic conditions, the community was dominated by sponges, urchins and corals. This highlights the structural differences in what is now termed the "*Thalassia* community". Comparisons with other known *Thalassia* communities are made.>

51. Vincente, V. P., J. A. Arroyo-Aguilù, and J. A. Rivera. 1980. ***Thalassia* as a food source: Importance and potential in the marine and terrestrial environments**. Journal of Agriculture of University of Puerto Rico. 64: 107-120.

[NUTRIENT CONTENT, THALASSIA]

<The chemical composition of *Thalassia* leaves is described. Of the leaf-dry matter, 40.6% consists of soluble nutrients: crude protein, lipids, soluble carbohydrates and ash. Crude protein content was 17% (R = 15.8-18.1%). Essential nutritive minerals were found in considerable quantities: Calcium, 1.32% (R = 1.21-1.47%); phosphorus, 0.21% (R = .19-23%); potassium, 3.0% (R = 2.47%-3.30%) and magnesium, 1.26% (R = 1.09%-1.38%). The cell wall or neutral-detergent fiber fraction was 59.4% (R = 46.1-64.6%), of which 19.1% consisted of hemicellulose. The lignin content varied from 22.9% ($KMnO_4$) to 9.1% (H_2SO_4) depending on whether $KMnO_4$ or H_2SO_4 was used as an oxidizing agent. The importance of *Thalassia* leaves as a food source for the seagrass community is described by five major food chains hereby proposed: the large herbivore, the

fish herbivore, the gastropod herbivore, the urchin herbivore and the detrital food chains. The potential value of *Thalassia* as a food source for domestic animals is evaluated on the basis of comparison with forage crops.>

52. Dawes, C. J., K. Bird, M. Durako, R. Goddard, R. Hoffman, and R. McIntosh. 1979. **Chemical fluctuations due to seasonal and cropping effects on an algal-seagrass community**. Aquatic Botany. 6: 79-86.

[CALORIC CONTENT, NUTRIENT CONTENT]
<Benthic algae as well as blades and short shoots of *Thalassia testudinum* Banks ex König (turtle grass) were collected from caged plots in February, May, and October off Tarpon Springs, Florida in 1 m of water. The study was designed to determine chemical changes in algal and seagrass components from a seasonal and regrowth standpoint. *Thalassia* blades had ash levels of 30-40% while the algae had levels of 60-70%, both components showing highest ash levels in the fall. Ash levels were lower in plots where all plants were cut off at the surface and in plots where all plants were cropped to 5 cm above the substrate. Protein levels ranged from 3 to 12% for turtle grass and 2 to 5% for algae with highest levels in the spring and regrowth plots. Soluble carbohydrate levels were 3-12% for turtle grass and 6-10% for the algae with highest levels in the late spring and fall. Calculated energy levels were constant over the year (1.75 to 1.80 x 10^4 l/g organic wt.) for both *Thalassia* and the algal components. The study demonstrated that the algal component was energetically equal in importance to turtle grass.>

53. Conover, J. T. 1958. **Seasonal growth of benthic marine plants as related to environmental factors in an estuary**. Publications of the Institute of Marine Science University of Texas. 5: 97-147.

[CURRENTS, LIGHT, MACROALGAE, SEDIMENTS, STANDING CROP, TEMPERATURE]
<A study was made of the standing crops of 70 taxa of benthic marine plants and some physical, chemical, and biotic agents in a tidal estuary. Seasonal comparisons were made between plant growth and environmental factors from 1952 to 1954. The standing crop of benthic marine plants was in excess of 4.0 kg wet weight per square meter during July and August and less than 1.5 kg in January. Temperature and illumination were variously associated with the maximum seasonal growth of those benthic plants studied. Some species, including *Cladophora gracilis F. tenuis*, *Enteromorpha linza*. *E. plumosa*, *Stilophora rhizoides*, and *Ulva lactuca* var. *latissima*, grew best under conditions of high insolation (over 500 gram calories per square centimeter per day) at moderate water temperatures (18° to 20°C.). Others, including *Agardhiella tenera*, *Enteromorpha compressa*, *Gracilaria verrucosa*, *Ruppia maritima* and *Zostera marina*, showed increased growth under diminished light intensities (less than 400 gram calories per square centimeter per day) at high water temperatures (over 24° C.). The low calculated seasonal yield of one group, including *Enteromorpha clathrata*, *E. intestinalis*, *Ecotocarpus siliculosus*, *Gracilaria verrucosa*, *Polysiphonia novae-angliae*, *Punctaria plantaginea*, and *Scytosiphon lomentaria* was related to low concentrations of inorganic phosphate (less than 0.4 microgram atoms/liter P) in the spring (April and May) and nitrate (less than 0.2 microgram atoms/liter N) in the fall (October). Forty-seven of the 70 taxa flourished in the tidal and brackish areas of the estuary. Sixteen of the 70, including *Chondrus cripus*, *Corallina officinalis*, *Enteromorpha linza*, *Gelidium crinale*, *Nemalion multifidum*,

Petalonia fascia, *Polysiphonia nigrescens*, *P. novae-angliae*, *Punctaria plantagineae*, *Sargassum filipendula* and *Ulva lactuca* var. *rigida* were found only in normal sea water at the mouth of estuary. The occurrence of some species, including *Ceramium rubrum* var. *proliferum*, *Ectocarpus siliculosus*, *Gracilaria verrucosa*, *Spyridia filamentosa* and *Stilophora rhizoides*, in the brackish water sloughs in January and February and their absence in low salinity water in March and April, suggested some relationship with either rising temperatures or changes in water density. Six species of *Vaucheria*, found only in the marshland between neap and spring high water levels, were observed to fruit in winter and early spring but attained best vegetative growth in mid-summer. Fruiting periods of all six species were associated with spring tides. A large portion of the benthic plant populations of the major basin of the estuary was observed to receive large additions of algal sporelings which first became established on coarse beach sediments and after some growth were wave-transported onto the silt-laden basin floor. These plants were still attached to small shells or pebbles. The effects of sedimentation, tidal currents, storm and hurricane winds, ice, and freezing are described. The aperiodic occurrences of some species in the area from 1952 through 1956 remain unexplained.>

54. Buesa, R. J. 1974. **Population and biological data on turtle grass (*Thalassia testudinum* König, 1985) on the northwestern Cuban shelf.** Aquaculture. 4:.207-226.

[BIOMASS, CHLOROPHYLL, LIGHT, PHOTOSYNTHESIS, RESPIRATION, TEMPERATURE, THALASSIA]

<Research carried out on the Northwestern Cuban shelf from 1970 on turtle grass (*Thalassia testudinum*) has covered different population and biological aspects of the species. Data on population biomass, photosynthesis as a function of light quantity and quality, respiration as a function of temperature, chlorophyll *a* content, photosynthetic and respiratory quotients, leaf emergence and growth, population production and turnover rates with approximations to natural loss rates are given in this paper. Factors which limit depth distribution of the species are discussed, as well as results of harvesting experiments which indicate that *Thalassia* can be safely harvested at least four times a year in Cuba.>

55. Burkholder, P. R., L. M. Burkholder, and J. A. Rivero. 1959. **Some chemical constituents of turtle grass, *Thalassia testudinum*.** Bulletin of the Torrey Botanical Club. 86: 88-93.

[PRIMARY PRODUCTIVITY, PROXIMATE CONSTITUENTS, THALASSIA]

<Primary biological productivity in the coastal waters of Puerto Rico is based upon the synthetic processes of phytoplankton, benthic algae, mangroves, corals and the turtle grass, *Thalassia testudinum*. A considerable portion of the total production of organic matter in this region appears to be contributed by the large beds of *Thalassia*, widely scattered at depths of less than five meters, over well-illuminated, shallow bays, channels, and inner margins of coral reefs. These studies have been initiated in order to find out more about the magnitude, chemical composition, and possible value of *Thalassia* to the marine life of tropical regions. Some simple comparisons of proximate analyses are made between *Thalassia*, and other primary crops of grasses from Georgia, and phytoplankton from Long Island Sound.>

56. Greenway, M. 1974. **The effects of cropping on the growth of *Thalassia testudinum* (König) in Jamaica.** Aquaculture. 4: 199-206.

[GROWTH, PRIMARY PRODUCTIVITY, THALASSIA]

<A study of blade growth in *Thalassia testudinum* has been carried out in order to evaluate the production potential of this seagrass in Jamaica. Summer and winter values of day length and water temperature differ by 2 h and 2.5°C respectively, and monthly variation in the growth rates of *Thalassia* shoots is small. The annual production rate is high compared with plants growing at more northerly latitudes and the shoots may be harvested up to six times a year.>

57. Livingston, R. J. 1984. **The relationship of physical factors and biological response in coastal seagrass meadows.** Estuaries. 7: 377-390.

[DISTRIBUTION, PRIMARY PRODUCTIVITY]

<Continuous, long-term studies of coastal grassbed assemblages in the N.E. Gulf of Mexico indicate complex relationships between physical controlling factors and biological response. Such seagrass systems are physically unstable over short periods. Seasonal ranges of temperature, salinity, and natural water quality conditions are considerable with periodic, recurrent "catastrophic" events such as floods and cold winters. These factors control the distribution and productivity of the seagrasses and algae which constitute the habitat and organic substrate for diverse assemblages of organisms. In addition, the benthic plants mediate predator-prey relationships and competitive interactions. Despite the physical instability, timed sequences of distinct ontogenetic feeding populations are generally stable from year to year as are other population and community characteristics. Thus, physical processes determine overall habitat conditions and productivity cycles whereas biological processes such as predation and competition define specific community relationships. However, seemingly minor changes in the physical environment due to anthropogenous activities can lead to major reorganization of the biological system; the observed biological stability of the seagrass beds can be ephemeral if important habitat features are altered in a way that exceeds the adaptive response of the system. Concepts are discussed which relate observed sequences of ontogenetic feeding units to food web patterns and geographic differences of population-niche relationships from one estuary to another.>

58. Grady, J. R. 1981. **Properties of sea grass and sand flat sediments from the intertidal zone of St. Andrew Bay, Florida.** Estuaries. 4: 335-344.

[ORGANIC CONTENT, SEDIMENT GRAIN SIZE]

<Organic and carbonate carbon and textural properties of the substrates underlying *Halodule wrightii* and *Thalassia testudinum* sea grass beds in the intertidal zone of St. Andrew Bay, Florida were compared to adjacent unvegetated sand flats by physiographic divisions within the bay and to the subtidal slopes of the bay. Sea grass and sand flat sediments were principally fine-grained quartz sands. The mean particle-size of the sea grass sediments were finer-grained than those of the sand flats only in the west arm and lagoon of the bay. Size-frequency distributions of the sea grass sediments were generally

slightly more negatively skewed and more leptokurtic than those of the sand flats. The sea grass sediments were less well sorted than were the sand flat sediments. The average organic and carbonate carbon contents of the sea grass beds were 1.9-fold greater than that of the sand flats but much less than that of the subtidal sea grass meadows. In the areas of pollution, sea grasses were absent; near this area *Halodule wrightii* was the dominant sea grass.>

59. Hough, R. A. 1974. **Photorespiration and productivity in submersed aquatic vascular plants.** Limnology and Oceanography. 19: 912-927.

[AQUATIC MACROPHYTES, PHOTORESPIRATION]

<A ^{14}C assay for photorespiration (the light-induced uptake of oxygen and release of carbon dioxide resulting from glycolate metabolism) was developed for use with submersed aquatic plants. Laboratory studies with axenic cultures of *Najas flexilis* (Willd.) Rostk. and Schmidt indicated that respired carbon dioxide is refixed extensively in the light and that the ^{14}C assay is a measure of net, rather than gross, photorespiration. Analyses of leaf anatomy and early ^{14}C fixation products of photosynthesis indicated that *N. flexilis* is a C_3 plant with Calvin-Benson cycle photosynthesis and glycolate metabolism. Respiration in light in axenic *N. flexlis* increased with increasing dissolved oxygen concentration, which indicated the presence and enhancement of photorespiration and that net photosynthesis would decrease with increasing oxygen concentration. *In situ* experiments with *N. flexilis* and *Scirpus subterminalis* demonstrated variations in photorespiration and dark respiration within a 1-day photosynthetic period and seasonally.>

60. Humm, H. J. 1964. **Epiphytes of the sea grass, *Thalassia testudinum* in Florida.** Bulletin of Marine Science of the Gulf and Caribbean. 14: 306-341.

[EPIPHYTES, SHADING, THALASSIA]

<One hundred and thirteen species of algae are reported occurring as epiphytes on the seagrass, *Thalassia testudinum*, 92 of which have been recorded from the south Florida area, 20 to 25 per cent of the total algal flora. Two groups of epiphytes are recognized, the year-round species and the seasonal annuals. Among the former are calcareous Corallinaceae which contribute significantly to the sediments of sea grass beds; among the latter is a group of large plants which may become sufficiently abundant during winter and spring to shade the *Thalassia* significantly. Each species listed is annotated, and a key to the species known to occur as epiphytes on *Thalassia* in south Florida is provided. *Stictyosiphon subsimplex* and *Polysiphonia harveyi* are newly reported for Florida; *Griffithsea barbata* is newly reported for the Bahamas.>

61. Pomeroy, L. R. 1960. **Primary productivity of Boca Ciega Bay, Florida.** Bulletin of Marine Science of the Gulf and Caribbean. 10: 1-9.

[PRIMARY PRODUCTIVITY, THALASSIA]

<The relative importance of turtle grass, phytoplankton, and the benthic microflora as primary producers was determined in Boca Ciega Bay, Florida. In water less than two meters in depth, which makes up 75 per cent of the bay, the three are about equally important. In deeper water only

phytoplankton is significant. The methods used and the estimation of community production are discussed.>

62. Kelly, J. R., S. N. Levine, L. A. Buttel, K. A. Carr, D. T. Rudnick, and R. D. Morton. 1990. **The effects of tributyltin within a *Thalassia* seagrass ecosystem.** Estuaries. 13: 301-310.

[THALASSIA, TRIBUTYLTIN]

<Flow-through seagrass core microcosms were used to examine responses of species and processes to a logarithmic gradient of dosing with ^{14}C-labeled tributyltin-cloride (TBT-Cl). Experiments involved delivery of TBT-Cl to the water column of replicate cores of a treatment (n=16) once per week; one-half of the cores were sacrificed after 3 wk of dosing, the others were dosed for 6 wk. Initial water column concentrations for the three treatments average 0.205, 2.23, and 22.21 μg l$_{1}$, expressed as TBT cation, but these concentrations dropped rapidly. Retained ^{14}C tracer, an estimate of total organotin species, was distributed to sediments, plants, and other biological tissues, all of whose tracer concentrations increased with time. Measures to indicate responses of both autotrophic and heterotrophic organisms were made; in general, treatment effects were demonstrable statistically only at the highest dose level. Accumulation of chlorophyll and biomass on glass slides was highest when suspended for the entire experiment in the water of the highest treatment; this unexpected result was perhaps an indirect effect related to reduced grazing activity in the microcosms. The highest dose of TBT-Cl resulted in virtual population mortality of a few macrobenthic species and decreased loss of plant material in litter bags, both demonstrated within the first 3 wk of dosing. Reduced litter loss was coincident with mortality of an amphipod (*Cymadusa Compta*) capable of shredding plant material, and a causal relation between the two effects is plausible. Thus, if concentrated to similar levels in a *Thalassia* bed, TBT may have direct species-level effects and process-level effects, potentially causing ecosystem change via disruption of a species-process linkage influential in seagrass detrital food web dynamics.>

63. Bauersfeld, P., R. R. Kifer, N. W. Durrant, and J. E. Sykes. 1969. **Nutrient content of turtle grass (*Thalassia testudinum*).** Proceedings of the International Seaweed Symposium. 6: 637-645.

[NUTRIENTS, THALASSIA]

<Turtle grass (*Thalassia testudinum*) grows abundantly in the euphotic zone off the southern coast of the United States. The plant has flat, narrow leaves originating from a rhizome system. Yields of dry matter from the entire plant have been reported as ranging from 2.9 to 30 tons per acre. Although the leaf portion constitutes only 23 percent of the total plant, the potential commercial harvest is substantial. Data were collected on the chemical composition (proximate composition, mineral spectrum, and carbohydrate and amino acid content) of both the leaves and the rhizomes. An experiment was conducted to determine if changes in chemical content occurred following washing of the plants in fresh water for varying periods of time. 15 minutes washing resulted in (1) a 61-percent increase in available protein, (2) a 50-percent reduction in ash, and (3) and 11-percent reduction in sodium chloride equivalent. Two feeding trials were conducted to determine the feasibility of using the grass in sheep rations. The first trial indicated that turtle grass could not promote

normal growth in sheep when used as the sole food. The second trial indicated that a ration of turtle gras replacing 20 percent of the alfalfa in a sheep diet produced a significant increase in rate of gain when compared with a control diet containing 50 percent alfalfa and 50 percent corn.>

64. Fourqurean, J. W. and J. C. Zieman. 1991. **Photosynthesis, respiration and whole plant carbon budget of the seagrass *Thalassia testudinum*.** Marine Ecology Progress Series. 69: 161-170.

[CARBON BUDGET, PHOTOSYNTHESIS, RESPIRATION, THALASSIA]

<The photosynthesis versus irradiance (P/I) response of the seagrass *Thalassia Testudinum* from Florida Bay, USA, was measured using the oxygen evolution of intact short shoots enclosed in sealed chambers, and found to have a light-saturated P/I behavior. All 4 of the commonly used mathematical formulations of the P/I curve were of equal utility in describing the data. When fit to the data using a least-squares fitting procedure, they produced nearly identical lines explaining 90% of the variance in the data. The estimates of the P/I model parameters α and P_{max} produced by the 4 different formulations varied widely, however, so parameter values generated using one model cannot be used in other models. Green photosynthetic leaves account for only 15.0% of the total biomass of Florida Bay *T. testudinum.* The remaining 85% is apportioned into belowground short shoots, rhizomes and roots. Leaves had higher respiration rates (7.4 $\mu g\ O_2\ g^{-1}\ min^{-1}$) than the belowground structures (0.9 to 4.6 $\mu g\ O_2\ g^{-1}\ min^{-1}$), and accounted for 42.6% of total plant respiration. The P/I curve and respiration data were used to build a daily carbon budget for Florida Bay *T. testudinum*. Estimated carbon fixation rates agreed closely with previously collected field ^{14}C uptake measurements. Under average summer light conditions, the budget was positive as deep as 4 m, suggesting that plants can survive at this depth. H_{sat} was 0 h at depths greater than 3 m, however.>

65. Taylor, J. L., C. H. Saloman, and K. W. Prest Jr. 1973. **Harvest and regrowth of turtle grass (*Thalassia testudinum*) in Tampa Bay, Florida.** Fishery Bulletin. 71: 145-148.

[GROWTH, THALASSIA]

<A comparison of leaf growth and new leaf production in plots of cut and uncut turtle grass, *Thalassia testudinum*, indicated that plants suffered no damage when harvested twice during a 6-month growing season in Boca Ciega Bay (Tampa Bay), Florida. In deeper or warmer waters where the growing season is protracted, three or more cuttings per year may prove practical.>

66. Sauers, S. C. 1980. **Seasonal growth cycles and natural history of two seagrasses (*Halodule wrightii* Aschers. and *Thalassia testudinum* König) in Sarasota Bay, Florida.** Chap. A-1. In: Environmental status of Sarasota Bay: Selected studies. Mote Marine Laboratory Technical Report. Edited by W. J. Tiffany III, 1-78. Sarasota: Mote Marine Laboratory.

[GROWTH, MAPPING, SARASOTA BAY]

<A review of several aspects of the seasonal variation and life histories of *Halodule* and *Thalassia* in Sarasota Bay, as determined during this study, is presented in the Executive Summary section. Prior to the start of this

project, several investigators (den Hartog, 1977; McRoy, 1966; Phillips, 1978) published recommendations detailing the kinds of seagrass research which they felt needed to be done. Among these research recommendations were: (1) autecology of dominant seagrasses; (2) standing stock, productivity, and decomposition in the course of the year at different tide levels, latitudes, seasons, light intensity and water temperatures; (3) continuous monitoring of the abiotic environment; (4) comparisons with similar communities in other areas; and (5) nutrient and heavy metal cycling between seagrasses, the sediments, and water masses. The thrust of this study was to address these perceived needs for information regarding seagrasses and it is felt that much has been accomplished toward this end, including the laying of a broad data base which will supplement future assessments in Sarasota Bay. Mapping and documentation of area changes in seagrass cover throughout Sarasota Bay should be, and hopefully will be, continued. In addition, techniques for assessing seagrass cover and standing crop at a wide variety of sites by non-destructive means can be developed using the existing data base. Linear and exponential regression models can now be developed for estimating aboveground biomass from leaf area or for estimating belowground biomass from either shoot density or aboveground biomass. A battery of relatively simple techniques could be assembled for monitoring short and long term changes in seagrass populations with Sarasota Bay.>

67. Odum, M. A. 1985. **Shading effects of epiphytes on leaves of turtle grass, *Thalassia testudinum* Banks ex König**. Master of Arts Thesis, The University of Texas at Austin, Austin, TX.

[EPIPHYTES, SHADING, THALASSIA]

<Shading effects of epiphytic algae and associated material on underlying *Thalassia testudinum* leaves were studied with field experiments and laboratory analyses. Absorption spectra of pigment extracts from seagrass leaves of different ages and thus different degrees of overgrowth of epiphytes were compared to each other. As with terrestrial plants whose shade adaptations have been studied, changes in pigment quantity and ratios of particular pigments may reflect responses by seagrass leaves to different light environments. Instead of adapting to shading by enhancing the capability of pigments to capture sunlight, *Thalassia* leaves appeared to become senescent with increasing epiphyte abundance. Shading screens were placed in a seagrass meadow to determine effects of shading all surfaces of leaves to the same extent as those leaves most heavily epiphytized. Productivity (leaf elongation and sprouting) of shaded leaves was lower than for unshaded leaves. Leaf density decreased gradually until no leaves were present beneath the shading screens approximately eight months later, in April, 1985. During this period, control plats showed no decline in leaf density initially; during the winter a decrease in leaf growth occurred followed by a resurgence in growth in the spring. Although epiphytes may cover older portions of seagrass leaves to the extent that net photosynthesis ceases in the underlying leaf, epiphytes do not cover enough of the exposed leaves to cause an overall decline of the *Thalassia testudinum* population under current field conditions.>

68. Wiginton, J. R. 1978. **Pigment composition under controlled light intensities as related to the distribution of five seagrasses in Texas and in the Virgin Islands**. Master of Arts Thesis, The University of Texas at Austin.

[CHLOROPHYLL, IRRADIANCE, LIGHT]

<Five Caribbean and Gulf of Mexico seagrasses from various depths in St. Croix, U.S. Virgin Islands, and from shallow beds in Texas were grown in the laboratory under three light irradiances. For all collections, light absorption readings of extracted pigments showed that total chlorophyll content is inversely related to lowered light intensity, 200 to 35 microeinsteins per square meter per second. Caribbean collections of *Halodule wrightii* Aschers., *Syringodium filiforme* Kütz., and *Halophila decipiens* Ostenfeld significantly decreased their chlorophyll *a* to chlorophyll *b* ratios in response to the lowered light intensities, but *Thalassia testudinum* Banks ex König., and the Texas collections of *Halodule*, *Syringodium*, *Thalassia*, and *Halophila engelmannii* Aschers. did not. The maximum depth of the St. Croix seagrasses is related to pigment ratios: *H. decipiens*, with the greatest depth range, to -42 m, has the lowest chlorophyll a/b ratio; *T. testudinum*, with the least depth range, to -12 m, has the highest chlorophyll a/b ratio. Although light quality may play a role in the ultimate depth to which a seagrass may occur, light intensity is suggested as the primary environmental determinant.>

69. City of Tampa. 1988. **An ongoing survey of *Halodule wrightii*, *Ruppia maritima* and the alga, *Caulerpa prolifera*, in Hillsborough Bay, Florida: Initial assessment and design.** Tampa: City of Tampa, Department of Sanitary Sewers, Bay Study Group.

[CAULERPA, COVERAGE, DISTRIBUTION, HALODULE, HILLSBOROUGH BAY, RUPPIA]

<General observations of the seagrasses *Halodule wrightii* and *Ruppia maritima* and the attached alga, *Caulerpa prolifera*, in Hillsborough Bay include: 1) about 57% of nearly 2,000 m^2 of *H. wrightii* occurs in The Kitchen. The remainder of *H. wrightii* is located in Big Bend's turning basin and the intertidal areas of Fish Hook Spoil, southern and eastern Interbay Peninsula, and southeastern Davis Island. Seasonal and geographical differences were noted for *H. wrightii* blade persistence. These differences make standardization of seasonal seagrass mapping projects imperative. Vertical and oblique aerial photographs taken during late summer during low tide appear to yield the best information for assessment of seagrass coverage. In an area adjacent to Hillsborough Bay, a mapping effort utilizing vertical aerial photographs documented a substantial increase of *H. wrightii* coverage between Apollo Beach and Simmons Park from 1983 to 1986. Intertidal and subtidal areas of southeastern Interbay Peninsula, Ballast Point, Davis Island and the Pendola Point - Archie Creek tidal flat have *C. prolifera* coverage. From April 1986 to December 1986, *C. prolifera* coverage of the southeastern Interbay peninsula increased from 2.5 hectares to about 200 hectares. During the same time period, *C. prolifera* coverage at Ballast Point increased from 2.8 hectares to about 10 hectares. At Davis Island, *C. prolifera* covered 1.5 hectares in December 1986. *C. prolifera* between Pendola Point and Archie Creek increased from 0.9 hectares in March 1986 to 65 hectares in January 1988. By April 1987, approximately 2.2 hectares of *R. maritima* were located and identified in Hillsborough Bay. Approximately half of the *R. maritima* was located in The Kitchen and about a third in McKay Bay. Scattered areas of *R. maritima* were found along Interbay Peninsula, Pendola Point and in the Davis Island yacht basin.>

70. Fry, F. 1984. **^{13}C/^{12}C ratios and the trophic importance of algae in Florida *Syringodium filiforme* seagrass meadows.** Marine Biology (New York). 79: 11-19.

[CARBON ISOTOPES, ISOTOPES, SYRINGODIUM]

<Over 380 stable carbon isotope (δ^{13}C) analyses made during 1981-82 showed that *Syringodium filiforme* Kütz. seagrass meadows in the Indian River lagoon of eastern Florida have food webs based on algal rather than seagrass carbon. Seagrasses averaging approximately -8% were isotopically distinct from algae epiphytic on seagrass blades (x =-19.3%) and particulate organic matter in the water column (x =-21.6%). δ^{13}C values of most fauna ranged between -16 and -22%, as would be expected if food web carbon were derived solely from algal sources. These results counter the idea that seagrass detritus is the dominant carbon source in seagrass ecosystems. Two factors that may contribute to the low apparent importance of seagrass in the study area are high algal productivities that equal or exceed *S. filforme* productivity and the high rates of seagrass leaf export from meadows.>

71. Hammer, L. 1972. **Temperatur-Toleranz tropischer Meeresalgen und mariner Phanerogamen.** Mitteilungen aus dem Instituto Colombo-Aleman de Investigaciones Cientificas 'Punta de Betin'. 6: 53-64.

[PHOTOSYNTHESIS, RESPIRATION, TEMPERATURE]

<Marine tropical algae and two marine tropical phanerogams were exposed for 12 hours to either elevated or lowered temperatures. After exposure the photosynthetic or respiratory rates were measured at ambient temperature. All algae investigated show temperature resistance between 34 and 36°C. 38°C could not be tolerated neither from the algae nor the phanerograms. Temperature tolerance in the two marine vascular plants *Thalassia testudinum* and *Halophila decipiens*, was found to be between 32.5 and 34°C. As a general rule the photosyntetic system is less resistant to elevated temperatures than the respiratory apparatus. Lowered temperatures of 8-10°C were tolerated without damage by the algae *Chaetomorpha media*, *Grateloupia cuneifolia*, *G. filicina* and *Padina vickersiae*, as well as the phanerogams *Thalassia testudinum* and *Halophila decipiens*.>

72. Fry, B. and R. W. Virnstein. 1988. **Leaf production and export of the seagrass *Syringodium filiforme* Kütz. in Indian River lagoon, Florida.** Aquatic Botany. 30: 261-266.

[EXPORT, LEAF PRODUCTION, SYRINGODIUM]

<Regrowth and *in situ*-marking techniques were used to estimate leaf production of *Syringodium filiforme* Kütz. in Indian River Lagoon during 1981 and 1982. Productivity varied with season from 0.5 (winter) to 4.0 (summer) g dry weight m^{2} day^{1} in 1981 and averaged 1.8 g dry weight m^{2} day^{1} during May-August 1982. Seagrass export, estimated by collecting floating leaves over 1-2 weeks from field enclosures, averaged 47% of total production in the 1982 summer growing season. Such high rates of export, relative to productivity, characterize the extensive *Syringodium* meadows in Indian River Lagoon of Florida.>

73. Anderson, R. R. 1969. **Temperature and rooted aquatic plants.** Chesapeake Science. 10: 157-164.

[AQUATIC MACROPHYTES, PHOTOSYNTHESIS, RESPIRATION, TEMPERATURE]

<In relation to the disappearance of a *Ruppia maritima* population near the effluent of an electrical generating station on the Patuxent River, Maryland, a broad study of temperature effects on respiration and photosynthesis of aquatic plants was begun. A Gilson differential respirometer was used to investigate respiratory variation in leaves of *Potamogeton perfoliatus* at 25, 30, 35, 40, and 45°C. This species grows with *Ruppia maritima*, appears to be more tolerant of high temperatures and plant material was readily available. Plants growing in heated and non-heated water were compared. The data indicate that *P. perfoliatus* is capable of physiological adjustment to higher temperatures as the leaf matures, since only older leaves tended to respire less at the elevated temperatures. Death of plant material occurred at 45°C.>

74. Durako, M. J. 1988. **Turtle grass, (*Thalassia testudinum* Banks ex König) - a seagrass.** Biotechnology in Agriculture and Forestry. 6: 504-520.

[CULTURE, DISTRIBUTION, THALASSIA]

<The importance of seagrasses is reviewed. The habitat values of seagrasses includes having high growth and production rates. The leaves support large numbers of epiphytic organisms with biomass approaching that of the seagrasses themselves. Although few organisms feed directly on them, seagrasses produce large quantities of detritus which serves as a major food source for many species. Seagrasses bind sediments and prevent erosion, in turn providing a quiescent environment in which a great variety of organisms can grow. They provide organic matter which encourages sulfate reduction and an active sulfur cycle, and also act as nutrient sinks and sources.>

75. Durako, M. J., R. A. Medlyn, and M. D. Moffler. 1982. **Particulate matter resuspension via metabolically produced gas bubbles from benthic estuarine microalgae communities.** Limnology and Oceanography. 27: 752-756.

[SEDIMENTS, SUSPENDED SOLIDS, THALASSIA]

<Gas bubbles originating from interstitial and epibenthic organisms in *Thalassia testudinum* culture and field systems were observed to rise and resuspend adsorbed particulate matter. In culture, 307.9 ml of gas were evolved and 0.97 g dry wt of particulate matter was resuspended$\cdot m^{-2} \cdot 24\ h^{-1}$. *In situ* studies in Tampa Bay, Florida, yielded similar values for gas production, but higher particulate loads. Chromatographic analyses of the bubbles indicated that the major component was photosynthetically produced oxygen. The resuspended particulate matter was 70-96% inorganic; the organic fraction consisted of living organisms and detrital material. This phenomenon may be important in the sediment kinetics and nutrient cycles of estuarine systems.>

76. Durako, M. J. and M. D. Moffler. 1985. **Spatial influences on temporal variations in leaf growth and chemical composition of *Thalassia testudinum* Banks ex König in Tampa Bay, Florida.** Gulf Research Reports. 8: 43-49.

[GROWTH, ORGANIC CONTENT, THALASSIA]

<The importance of spatial influences on seasonal fluctuations in *Thalassia testudinum* leaf blade lengths and chemical constituents was demonstrated. Differences between samples from fringe and mid-bed for several constituents were significant and, if not accounted for, could affect the measurement of apparent seasonal cycles. Fringe-shoots, reflecting the influence of more intense grazing activity, had shorter leaf blade lengths, lower dry weights and carbohydrate levels, and higher protein levels than mid-bed shoots. Mid-bed rhizomes and roots had highest protein and ash levels reflecting possible sediment influence. Percent ash and protein in the rhizomes, and percent carbohydrate in the roots exhibited seasonal fluctuations, but the levels were different between fringe and mid-bed samples. Protein levels were greatest in shoots and roots, while carbohydrate levels were highest in rhizomes, illustrating the respective partitioning of biosynthetic and storage functions. The spatial differences seem to reflect gradients in biological and chemical interactions, and they may play an important role in trophic interactions in seagrass systems.>

77. Durako, M. J. and M. D. Moffler. 1987. **Factors affecting the reproductive ecology of *Thalassia testudinum* (Hydrocharitaceae).** Aquatic Botany. 27: 79-95.

[REPRODUCTION, THALASSIA]

<Morpho-anatomical studies of short-shoots of *Thalassia testudinum* Banks ex König collected in Tampa Bay, Florida from February 1979 to October 1980 (n = 5394) demonstrated the presence of sexually reproductive short-shoots during all months, except August and September. Mean inflorescence lengths (MIL) indicated that little inflorescence development occurs during autumn and winter (MIL 0.2-1.0 mm); MIL's in 1979 increased rapidly during April (19.47 mm ± 17.04 mm SD) and May (74.10 mm ± 27.11 mm SD), peaking in June (110.17 mm ± 8.88 mm SD). Large standard deviations reflect the presence of early stage inflorescences throughout the reproductive season. This suggests possible genetic diversity and aseasonality for floral induction. Quantitative *in situ* observations from 1981 to 1985 detected significant temporal and spatial variations in reproductive patterns. Annual variations in flowering (anthesis) may be explained by the influence of environmental factors, such as water temperature and salinity, on inflorescence development and survival. Spatial patchiness in reproductive effort, negative correlations between male and female short-shoot distributions and sex-related differences in the number of leaf scars short-shoot^{-1} may reflect clonal variation and/or a possible interaction of ramet age with sex expression in this species.>

78. Durako, M. J. and M. D. Moffler. 1987. **Nutritional studies of the submerged marine angiosperm *Thalassia testudinum*. I. Growth responses of axenic seedlings to nitrogen enrichment.** American Journal of Botany. 74: 234-240.

[NITROGEN, NUTRIENTS, THALASSIA]

<Algae-and bacteria-free seedling cultures of the seagrass *Thalassia testudinum* Banks ex König were utilized to evaluate effects of nutrient enrichment on growth and chemical composition. Seedlings cultured in media based

on both synthetic seawater and *NH*-15 medium amended with inorganic nitrogen (NH_4) and organic nitrogen (glutamine, glutamate, urea and yeast extract) exhibited no growth enhancement relative to controls in the growth parameters measured. General decreases in green leaf areas and leaf widths after one month coupled with relatively high C:N ratios after 3 months in culture suggest utilization and depletion of stored reserves with little or no assimilation of exogenous nutrients. These observations coupled with previous results in non-axenic seedling cultures indicate microbial associations may play a critical role in the nutrient physiology of this species.>

79. Moffler, M. D. and M. J. Durako. 1984. **Axenic culture of *Thalassia testudinum* Banks ex König (Hydrocharitaceae)**. American Journal of Botany. 71: 1455-1460.

[AXENIC CULTURE, THALASSIA]

<Cultures of *Thalassia testudinum* were established and maintained in the absence of other detectable organisms. Axenic cultures were initiated using surface sterilized seeds which were aseptically dissected from surface sterilized fruits. Seedlings were cultured in 75-ml(25-mm x 200-mm) culture tubes containing 30 ml of rooting substrate and 40 ml of chemically defined seawater media. Seedlings and culture media were analyzed for microbial contamination after 42 days of culture utilizing standard marine bacterial/fungal isolating procedures and by light and scanning electron microscopy. Axenic seagrass cultures allow physiological studies such as nutrient assimilation kinetics, rhizosphere and phyllosphere microbial interactions through mono- and poly-axenic seagrass-microbial cultures.>

80. Fry, B. D. 1977. **Stable carbon isotope ratios - a tool for tracing food chains**. Master of Arts Thesis, The University of Texas at Austin.

[CARBON ISOTOPES, DETRITUS, DIET]

<In natural communities where it is not known what animals are eating, animal carbon isotope ratios may provide an index to animal diet. In marine seagrass communities, plants do not segregate into discrete groups, yet one can make some calculations about minimum and maximum influences of different plants on animal $\delta^{13}C$ values. Surveying fish, shrimp, mollusks and polychaete worms in offshore and local seagrass areas showed that offshore organisms have carbon isotope ratios of -16% to -20%, while those in seagrass areas have carbon isotope ratios of -8% to -16%. This difference is attributed to the available diet in both places. Carbon isotope ratios may prove useful in delineating the mutual influences of these two carbon reservoirs on each other. Mangrove areas may be a third area with distinctive $\delta^{13}C$ values. Plant variability was confined to a range of 3.9% or less for nine species examined. Some plant species had narrow ranges while others had wider ranges. The reasons for this are unknown. Some initial observations indicate that detrital seagrasses have carbon isotope ratios similar to living seagrasses.>

81. Oremland, R. S. 1976. **Studies on the methane cycle in tropical marine sediments**. Doctor of Philosophy Thesis, University of Miami.

[METHANOGENESIS, SEDIMENTS, THALASSIA]

<Gas bubbles in the sediments and gases in the internal spaces of the rhizomes of *T. testudinum* contained O_2, N_2 and CH_4. CH_4 was a minor component and its concentration varied diurnally between a minimum of 1 nmoles cm^{-3} at midday in the rhizome gases to a maximum of 33 nmoles cm^{-3} in the sediment bubbles. The percentage composition of the major components, O_2 and N_2, varied from 2.3% O_2 + 94% N_2 (sediment bubbles, early morning) to 30% O_2 + 69% N_2 (rhizome gases, mid-afternoon). The variations probably reflected changes in O_2 content of the gases caused by diurnal variations in photosynthetic and oxidative activities in the seagrasses and sediments. It is concluded that there is a net transfer of O_2 from *T. testudinum*, via its rhizome system, to the sediments.>

82. Capone, D. G. 1978. **Dinitrogen fixation in subtropical seagrass and macroalgal communities**. Doctor of Philosophy Thesis, University of Miami, Coral Gables, FL.

[MACROALGAE, NITROGEN FIXATION, THALASSIA]

<Nitrogen fixation was investigated in communities of the seagrass, *Thalassia testudinum*, and associated with the macroalgae *Microdictyon* sp. and *Laurencia* sp. Nitrogen fixation in the phyllosphere of *Thalassia* was highly variable both spatially and temporally. High rates of light stimulated foliar N_2 fixation were noted at several sites and correlated with the presence of a heterocystous cyanobacterium, *Calothrix* sp. Seasonal and diurnal variations were observed in phyllosphere N_2 fixation. At those sites exhibiting highest nitrogenase activity, rates in the summer were about 0.8 μmoles C_2H_4 g dry wt^{-1} h^{-1} for samples of leaves and epiphytes assayed under *in situ* conditions of light and temperature. Average input of nitrogen during summer months was calculated to be about 3-4 mg N m^{-2} day^{-1} at several stations. In *Thalassia* communities, rhizosphere N_2 fixation was of the greatest quantitative significance, being 2-3 times as great (on an areal basis) as phyllosphere fixation and about 10-fold greater than activity in non-rhizosphere sediments. Seasonal and diurnal fluctuations were also noted in rhizosphere activity. Maximum rates of rhizosphere fixation were about 0.7 nmoles C_2H_4 g dry wt^{-1} h^{-1} for samples of roots, rhizomes and sediments incubated anaerobically. During summer periods, nitrogen input by rhizosphere sediments ranged from 8-13 mg N m^{-2} day^{-1}. Rhizosphere N_2 fixation could supply up to 50% of the net nitrogen requirement for *Thalassia* production, calculated from measurements of leaf growth, and up to 25% of the nitrogen demand calculated from $^{14}CO_2$ uptake by the plant, when it was assumed that *Thalassia* was highly (66-75%) efficient in recovering nitrogen from senescing leaves. This assumption was based on the observed decrease in nitrogen content during leaf aging. The nitrogen input by foliar epiphytes, although smaller than rhizosphere fixation, is probably important in promoting the development of the epifloral community of *Thalassia* leaves. N_2 fixation associated with several benthic macroalgae was also mediated by cyanobacteria. Activities up to 2 μmoles C_2H_4 g dry wt^{-1} h^{-1} (25 mg N m^{-2} day^{-1}) for *Laurencia* sp. could supply a large fraction (one-fifth) of the total nitrogen requirement of this association.>

83. Jones, J. A. 1968. **Primary productivity by the tropical marine turtle grass, *Thalassia testudinum* König, and its epiphytes**. Doctor of Philosophy Thesis, University of Miami, Coral Gables, FL.

[PRIMARY PRODUCTIVITY, THALASSIA]

<Methods were developed to measure the primary productivity of aquatic spermatophytes. These involved the polarographic determination of the change in concentration of dissolved oxygen within chambers holding individual plants or small portions of the plant community. The methods have been tested on *Thalassia* over a one-year period under suitable natural environmental conditions. Those factors emerging as most important in the primary productivity by *Thalassia* were its standing crop (V), irradiance (I), and possible temperature (T). Temperature played a prime role in determining the respiration rate of the plant, while standing crop was of secondary importance in this. For *Thalassia*, maximum gross production per unit weight (W) was about 1.0 ml $O_2/g \cdot hr$ under favorable conditions. Mean respiration rate was about -0.15 ml $O_2/g \cdot hr$. (Maximum net production per unit area (A) was about 700 ml $O_2/m^2 \cdot hr$ for standing crop densities greater than 830 g/m^2). At standing crops less that 300 g/m^2, the sedimentary microflora became the predominating producer. (Mean respiration rates were about -100 ml $O_2/m^2 \cdot hr$, dependent upon temperature and standing crop.) Total annual production of a *Thalassia* community was about 1700 L O_2/m^2 (net) under ideal conditions. An additional 1300 L O_2/m^2 were consumed by respiration. Taking advantage of commonly used assumptions, this net production would have been equivalent to a carbon fixation of 900 g C/m^2, which could be related to a live tissue production of 18 kg/m^2. Those factors appearing most important to production by the epiphytes of *Thalassia* were their standing crop and species composition. Maximum rates of production per unit weight (W) reached 0.65 ml $O_2/g \cdot hr$, and respiration rates ranged between -0.1 and -0.3 ml $O_2/g \cdot hr$, depending upon the species composition of the flora. Using several assumptions relating W to A, it was estimated that one-fourth to one-third of the metabolism of a *Thalassia* community may be accounted for by the epiphytes.>

84. Zieman, J. C., Jr. 1968. **A study of the growth and decomposition of the seagrass *Thalassia testudinum*.** Master of Science Thesis, University of Miami, Coral Gables, FL.

[DECOMPOSITION, GROWTH, THALASSIA]

<This work was begun with the recognition that the sea grass community is a great contributor to the estuarine food chain. The purpose of this study was mainly to perfect techniques which could be used to study the role of sea grass communities both qualitatively and quantitatively. The techniques have been presented. The data and conclusions given with the techniques can best be considered as preliminary. They are proof that the techniques are feasible; however, the main work remains to be done. This is the application of these techniques to study fully the importance of the grass beds to the entire estuarine ecosystem, and not simply two stations. The following is a summary of the techniques presented and the data which they have yielded thus far: 1) A technique for studying the comparative blade dynamics of a *Thalassia* community was shown, and results were presented for 2 stations. 2) The patterns of the new blades compare well in both communities. A marked decline in the new blades produced was noted in May, and this is believed by observation to be linked with the output of flowers or fruit. 3) The net change in numbers of the blades in the two communities was given. The patterns for both communities compare well. 4) Average growth rates for the communities were shown. Station SK-3 had a substantially higher growth rate. 5) A technique was given that measured the amount of leaf material produced. By this means it was shown that station SK-3 produced 6 gms dry weight/m^2/day vs. about 4.5 gms d wt./m^2/day produced for SK-2.

6) The growth pattern of blades on a branch was demonstrated. The respective growth rates of the individual blades on the branch were given. 7) The length of time required for a branch to put out a new blade was determined to be 14-16 days. 8) The increase of blade width with increasing distance from the rhizome meristem was shown. 9) A correlation between the average growth rate of the community and the average blade width of the community was shown. 10) It was shown that most of the blade growth was basal, but that elongation continues some distance from the blade meristem. 11) A description of the decomposition of undisturbed blades of *Thalassia* was given. Later the decomposition of blades which had been previously dried was compared with this. 12) The decay rates of *Thalassia* was given. *Thalassia* which had been dried prior to decomposition was compared with blades which had not been dried. It was shown that predrying has a distinct effect on the decay rates and accelerates them. 13) It was shown that *Thalassia* has a faster decay rate than *Spartina*. This is important since a faster decay rate means that the material is then made available to detritus feeders at a faster rate.>

85. Levine, I. A. 1980. **Biomass and colonization of the benthic marine flora of lower Tampa Bay**. Master of Science Thesis, University of South Florida, Tampa, FL.

[COLONIZATION, MACROALGAE, SALINITY, SEAGRASS, TEMPERATURE]

<A study of biomass and the colonization of artificial substrata by benthic marine plants was conducted from September 18, 1978 to October 31, 1979. Salinity ranged from a minimum of 18 o/oo in January to a maximum of 33.4 o/oo in July. Water temperature measured at the sampling stations ranged from 12°C in January to 29°C in July. Water temperature off Egmont Key ranged from 14°C in January to 31°C in July, August, and September. Mean annual nutrient concentrations for ammonia, nitrate, nitrite, and phosphate were 1.80 µg atom/l, and 9.39 µg atom/l respectively. These values are one order of magnitude greater, except nitrate which was enriched by 88%, than the values reported from the Anclote study (Moore, 1976). Mean blade tissue biomass was calculated to be 82.56 grams dry weight per square meter. Total seagrass biomass per square meter was determined to be 359 grams. This figure was compared with the 225 grams dry per square meter reported from the Anclote Anchorage. Mean epilithic algal biomass was calculated to be 300 grams dry per square meter. Density (blades per square meter) of seagrass leaves are 960 for *Thalassia*, 2,864 for *Syringodium*, and 13,632 for *Halodule*. Summer density ranges from the Anclote Anchorage were reported as 100-900 for *Thalassia*, 800-2500 for *Syringodium*, and 5000-9000 for *Halodule*. Forty-eight species of benthic algae were found colonizing the artificial substrata. This was 48% of all species known along the margins of the Skyway. Thirty-nine species or 32% of benthic algae known from the Anclote Anchorage were found colonizing artificial substrata. In comparison with the Anclote Anchorage, temperature and salinity range differences are insignificant. Nutrient enrichment of lower Tampa Bay, of one order of magnitude greater than Anclote may be responsible for the higher values of biomass and density. Rapid colonization of the artificial substrata by the benthic algae would minimize effects of planned construction if suitable habitat is made available to colonize and the water quality is not drastically altered. With high biomass and density values and rapid colonization of new substrates, lower Tampa Bay appears to be a healthy stabilized estuary with a flourishing benthic marine flora.>

86. Rogers, S. W. 1977. **Sediments of a seagrass bed in Anclote Anchorage, Tarpon Springs, Florida.** Master of Science Thesis, University of South Florida, Tampa, FL.

[CARBON ORGANIC, SEDIMENT GRAIN SIZE]

<During the summer of 1972 the area within Anclote Anchorage Tarpon Springs, Florida was sampled to obtain seagrass and sediment data. At every sampling station each species of seagrass was measured for biomass (g dry wt/m^2). The sediment was vertically subsectioned according to visual differences and each section was analyzed for grain-size distribution, % inorganic carbon and % total carbon. Each seagrass species' percentage by weight and the total seagrass biomass at each station were computed. Sediment characters (% "silt and clay", % sand, % gravel, median phi diameter, mean phi diameter, sorting, % organic carbon and % $CaCO_3$) were also calculated. Seagrasses were found at all stations sampled between water depths of 0.15 m and 1.37 m. Total biomass figures ranged from 0.0 to 547.1 g/m^2. *Thalassia* obtained a maximum density of 533.0 g/m^2, *Syringodium*: 234.6 g/m^2 and *Diplanthera*: 535.2 g/m^2. Substrate types varied from slightly gravelly, muddy sand to sand to slightly gravelly sand to gravelly sand. The range of sand percentages was from 76.1% to 99.3%, "silt and clay" 0.7% to 16.7% and gravel 0.0% to 20.4%. Median phi diameter varied from 2.1 to 2.7 and mean phi diameter from 1.6 to 3.3. The sediments displayed very good to poor sorting. Total carbon values ranged from 0.16% to 6.76% (the organic component 0.07% to 3.49% and the inorganic fraction 0.04% to 4.75%). Using correlation coefficients significant associations (at a 90% confidence level) of the analyzed parameters were determined. Sediment trapping and binding effects of seagrasses may be causing a positive correlation between % "silt and clay" and the values of *Syringodium*, *Thalassia* and total seagrass biomass. A negative association of *Diplanthera* and total seagrass biomass with median phi diameter may indicate that coarse sand sediments in the Anchorage provide an optimum base for the growth of *Diplanthera* and other seagrasses. A positive correlation of *Syringodium* biomass with organic, inorganic and total carbon may be due to trapping, and *in situ* generation of "silt and clay" which has a high carbon content. *Diplanthera* beds may not present a suitable environment for calcareous faunal communities as indicated by a negative correlation of *Diplanthera* density with inorganic and total carbon. The high tolerance of *Diplanthera* to more extreme or variable physical conditions and effect of light availability are probably indicated by the negative association of *Diplanthera* dominance and density (as well as total seagrass biomass) with water depth. A positive association of % "silt and clay" and % gravel with water depth is probably due to increased deposition and *in situ* generation of these components, and less erosion with depth in the anchorage. Inorganic and total carbon show a positive correlation with % gravel because almost all gravel is composed of $CaCO_3$ shell fragments. Areas of high $CaCO_3$ in the Anchorage are a result of a variety of factors including storm and river associated deposition, and *in situ* benthic and epiphytic faunal activity. Littoral sand areas in the Anchorage are moderately well to very well sorted, fine sand with less than 0.1% gravel, less than 2% "silt and clay" and less than 1% carbon. Mottling occurs in some sediments found less than 0.20 m below MLW level. This is probably a result of accumulations of dark, decomposed, organic material. The outer seagrass area west of Rabbit Key may be experiencing increased siltation from periodic channel dredging, but a decrease in influence of river currents. The area near the Anclote River

distributary's eastern bank may be undergoing increased effects from the Anclote River. Seagrass beds off Bailey's Bluff may be supporting larger populations of calcareous epiphytic and benthic fauna, yet these beds may be sparser than those in the recent past. Generally, the Anclote Anchorage is a recently stable area of uniform fine quartz sand with geographically localized substrates containing large amounts of gravel and "silt and clay". Abundant seagrass and benthic fauna populations have been associated with these sediments.>

87. Moore, S. J. 1976. **Growth of *Syringodium filiforme* in thermally stressed and unstressed areas of the Anclote River estuary, Tarpon Springs, Florida.** Master of Science Thesis, University of South Florida, Tampa, FL.

[GROWTH, NUTRIENTS, SALINITY, SYRINGODIUM, THERMAL EFFECTS]

<Growth rates of *Syringodium filiforme* were determined for the first time in two areas of the Anclote estuary. One area was under the direct influence of the thermal plume of the Anclote power plant; the other was well away from the thermal plume. A new procedure was developed for marking *Syringodium* leaves using a needle and thread technique. Growth rates in millimeters at the experimental station were higher than those of the control station during the cooler months of the year. During the warmer part of the year, growth at the control station was higher than at the experimental station. There was a significant reduction in the density of erect branches of *Syringodium* at the experimental station during the summer of 1975. No such reduction was observed at the control station. Leaf growth was highest from April 15 to June 16, lowest from November 1 to January 31, and intermediate from June 16 to September 15 during 1974-1975. Water temperature at the experimental station was usually 2.0 to 3.0°C higher, with a maximum of 5.0°C higher, than at the control station. The highest temperature at the experimental station was 34.0°C; at the control station, 31.4°C. Both occurred on June 16, 1975. The salinity difference between the two stations was less than 1% at any given time. Light attenuation at the experimental station was generally higher than at the control station. Nutrient concentrations of ammonia, nitrite, nitrate and ortho phosphate were generally higher at the experimental station than at the control station. Sedimentation at the experimental station was notably higher and is believed to have been damaging to *Syringodium*. During the summer of 1975, a bluegreen alga, *Microcoleus lyngbyaceus*, formed a heavy growth over the seagrass beds at the experimental station but not at the control station.>

88. Holsing, N. W. 1974. **The measurement of gaseous exchange in thermally stressed and unstressed *Diplanthera wrightii* communities using a modified flow-through system.** Master of Arts Thesis, University of South Florida, Tampa, FL.

[GASEOUS EXCHANGE, HALODULE, TEMPERATURE]

<The gaseous exchange of thermally stressed and unstressed *Diplanthera* communities was measured using a modified flow-through system. No significant difference between the gaseous exchange of the *Diplanthera* communities was found although the communities differed in seagrass biomass and blade length and in the total number of genera of infauna. The flow-through system permits the sampled population to remain in constant contact with its environment and essentially undisturbed and therefore, should increase the accuracy of the oxygen

estimates. The syringe sampling method used in conjunction with the flow-through system, appears to work well and with minor modifications in the fixing technique precision may be increased.>

89. Gilbert, S. S. 1976. **Seasonal variation in standing crop of benthic vegetation in the north Indian River**. Master of Science Thesis, Florida Institute of Technology, Melbourne, FL.

[BIOMASS, PRIMARY PRODUCTIVITY, SEDIMENT NUTRIENTS, STANDING CROP]

<Undisturbed seagrass beds in the North Indian River, Titusville, Florida were studied to determine seasonal changes and zonation. Seasonal variation in standing crop was measured monthly by a 25 core sample grid in a 5000 m^2 quadrat for one year. Maximum biomass for the dominant seagrasses was in late summer, and minimum biomass occurred in mid to late winter. Organic carbon in the sediments, as well as population rises in benthic deposit feeders, followed the annual decay cycle of the seagrasses. An estimate of net productivity for the dominant species, *Syringodium filiforme*, showed an annual production of 50-190 g C/m^2. Major zonation patterns were investigated by transectional analysis. *Diplanthera wrightii* dominated from shore to a depth of 50 cm. *Syringodium* dominated from 50 cm to its depth limit of 2.6 m. Competitive interaction and light penetration appear to define the depth limits. Seasonal fluctuations in environmental parameters were examined, and relationships with macrophytic cycles revealed. Of the parameters that may influence production, the correlation with water temperature was highly significant. Standing crop biomass, in turn, has its effect on the environment and benthic community, notably influencing factors such as dissolved oxygen levels, water transparency, and species diversity.>

90. Trocine, R. P. 1978. **Effects of ultraviolet-B radiation on the photosynthesis of seagrasses**. Master of Science in Biological Sciences Thesis, Florida Institute of Technology, Melbourne, FL.

[PHOTOSYNTHESIS, ULTRAVIOLET RADIATION]

<In this study the effects of ultraviolet-B radiation on the photosynthesis of the seagrasses *Halophila engelmannii*, *Halodule wrightii*, and *Syringodium filiforme* were studied. The intrinsic tolerance of each seagrass to UV-B was examined, the presence and effectiveness of photorepair mechanisms in reversing UV-B induced photosynthetic damage, and the role of epiphytic growth as a shielding layer from UV-B was studied. *Halophila* was found to possess the lowest tolerance for UV-B in terms of percent inhibition of photosynthesis, followed by *Syringodium*, and finally *Halodule*. Evidence of a photorepair mechanism effective against UV-B was found in both *Halophila* and *Halodule*, but only in *Halodule* was the mechanism effective in attenuating photosynthetic inhibition in the presence of UV-B dose rates and dosages above ambient conditions. *Syringodium* apparently relies on a thick epidermal cell layer to reduce photosynthetic inhibition due to UV-B. The presence of epiphytes on leaf surfaces was found in all cases to reduce the degree of photosynthetic inhibition as compared to samples with this growth removed. Of major importance during this project was the observation that UV-A, at least in *Halophila engelmannii*, was capable of inhibiting photosynthesis as a function of photosynthetically active radiation (PAR) present. Data from these experiments has raised the question

as to whether UV-A or UV-B is of greater environmental consequence in shallow aquatic and estuarine systems.>

91. Tomasko, D. A. and B. E. Lapointe. 1990. **Productivity and biomass of *Thalassia testudinum* as related to water column nutrient availability and epiphyte levels; field observations and experimental studies.** Marathon: Florida Keys Land and Sea Trust.

[EPIPHYTES, NUTRIENTS, THALASSIA]

<*Thalassia testudinum* meadows from 0.5 m and 2.0 m (MLW) depths were studied at nine sites in the Florida Keys and western Caribbean. Two meadows, one offshore of a populated island with over 2000 septic tanks, and one offshore of a large bird rookery, were similar in having elevated levels of water column nutrients (DIN and SRP), greater epiphyte levels, low shoot densities, low leaf area indices, and low biomass. Increased blade turnover time is partially responsible for increased epiphyte levels offshore of the populated island, but epiphyte communities developed faster on seagrass blades there vs. a paired site offshore of an uninhabited island. Experimental aquarium studies approximated the observed phenomena from the field studies; elevated water column nutrients produced increased epiphyte levels, and decreased blade turnover rates. Reduced irradiance moderated the effect of nutrient enrichment on epiphyte levels. Elevated levels of water column nutrients, by stimulating epiphyte growth, reduced rhizome growth rates. This could be related to the observed lower shoot density of *Thalassia testudinum* meadows near sources of water column nutrients.>

92. Durako, M. J. and M. D. Moffler. 1984. **Qualitative assessment of five artificial growth media on growth and survival of *Thalassia testudinum* (Hydrocharitaceae) seedlings.** In: Proceedings of the Eleventh Annual Conference on Wetlands Restoration and Creation. Edited by F. J. Webb Jr., 73-91. Plant City: Hillsborough Community College Environmental Studies Center.

[GROWTH, SEEDLINGS, SURVIVAL, THALASSIA]

<Growth and survival of turtle grass, *Thalassia testudinum* Banks ex König, seedlings from five Florida sites were monitored in four commercially available growth media (Jiffy-7™ peat pellets, Rootcubes™, Horticubes™ and Plant Plugs™) and a control medium of shell hash (aragonite). After six months in culture, survival was highest (40%) in Rootcubes and the control, but efficacy (growth x % survival) was highest for seedlings in Plant Plugs. Cost effectiveness (efficacy/cost per planting unit) was highest for Horticubes, followed by Rootcubes, Jiffy-7 peat pellets and Plant Plugs. A preliminary field transplanting experiment was performed using *Thalassia* seedlings collected during the summer of 1982, cultured in peat pellets in the laboratory over the winter of 1982/83, and transplanted during the spring and summer of 1983. Observations after seven months, indicated that planting the units in a *Halodule wrightii* bed, a "compressed successional" approach, resulted in higher survival than planting in bare sediments. In addition, survival of transplants that were anchored with steel staples was no greater than unanchored transplants. The variability of these results suggests that site, planting design and logistic considerations are all important in deciding what growth medium and anchoring system should be employed in a particular seagrass restoration project.>

93. Libes, M. 1986. **Productivity-irradiance relationship of *Posidonia oceanica* and its epiphytes.** Aquatic Botany. 26: 285-306.

[EPIPHYTES, IRRADIANCE, PRIMARY PRODUCTIVITY]

<The photosynthetic response to light of the marine phanerogam *Posidonia oceanica* (L.) Delile and its epiphytes from the Bay of Port-Cros (France) was determined monthly from March 1981 to July 1982. A ^{14}C technique was developed *in situ* for entire plants of *P. oceanica*. Their epiphytes were then removed in the laboratory after incubation. The productivity increased with light to an asymptotic value at which the system was light saturated. During summer photoinhibition was observed. In spite of a high variability, epiphytic productivity was twice that of *P. oceanica*. The productivity-irradiance relationship showed both circadian and seasonal variations. During the year, productivity-irradiance curves of *P. oceanica* and its epiphytes followed the sun-shade model for photosynthetic adaptation. The photosynthetic efficiency was highest in winter and decreased towards summer. During the day photosynthetic efficiency was highest in the morning and decreased towards sunset. Factors which may regulate these variations in efficiency are discussed.>

94. Neverauskas, V. P. 1988. **Response of a *Posidonia* community to prolonged reduction in light.** Aquatic Botany. 31: 361-366.

[ATTENUATION, EPIPHYTES, SHOOT DENSITY]

<An *in situ* shading experiment, using 50% shadecloth, was conducted in seagrass meadows dominated by *Posidonia sinuosa* Cambridge et Kuo and *Posidonia angustifolia* Cambridge et Kuo. The experiment ran for 12 months, samples being taken at 3-monthly intervals. Eight variables described the response of the *Posidonia* community to the reduction in light. There was no change in shoot density for the first 6 months but standing crop and leaf density decreased, apparently owing to the abscission of some of the older leaves. The weight of epiphytes on the seagrass leaves also decreased. Over the next 6 months the community rapidly declined but the amount of epiphytes on the leaves of the seagrass did not change.>

95. Pirc, H. 1986. **Seasonal aspects of photosynthesis in *Posidonia oceanica*: influence of depth, temperature and light intensity.** Aquatic Botany. 26: 203-212.

[DEPTH, IRRADIANCE, PHOTOSYNTHESIS, TEMPERATURE]

<Photosynthetic rates of *Posidonia oceanica* (L.) Delile from 5, 15, and 30 m depths were determined in the laboratory at three light intensities in September and November 1981 and May 1982. Highest photosynthetic rates were measured in plants from the 5 m depth. The seasonal maxima for all plants were reached in spring. With the exception of November, plants from the 15 m depth always had the lowest photosynthetic rates, and light saturation in these plants was achieved at lower irradiances than in those from 5 and 30 m. In general, the productivity pattern remained unchanged even after cultivation for one or two months in the laboratory under equal light and temperature conditions. During the beginning of the new growing season in autumn, higher cultivation temperatures increased photosynthetic rates. The same treatment in spring decreased photosynthetic rates due to earlier leaf senescence enhanced by higher

water temperatures. The productivity pattern of *Posidonia oceanica* growing at different depths is well correlated to ambient light and temperature conditions and seems to be genetically fixed.>

96. Dennison, W. C. and R. S. Alberte. 1985. **Role of daily light period in the depth distribution of *Zostera marina* (eelgrass).** Marine Ecology Progress Series. 25: 51-61.

[BIOMASS, CHLOROPHYLL, GROWTH, IRRADIANCE, LIGHT, PHOTOSYNTHESIS, ZOSTERA]

<Photosynthesis, biomass and growth characteristics of the temperate seagrass, *Zostera marina* L. (eelgrass), were examined in a meadow in Great Harbor, Woods Hole, Massachusetts during June and August, 1982. Underwater lamps and light shading screens were placed at shallow (1.3 m) and deep (5.5 m) stations to lengthen and shorten daily light periods. The portion of the day (H_{sat}) that light intensities saturated *Z. marina* photosynthesis was lengthened by 4 to 6 h and shortened by 3 to 5 h. Photosynthesis vs irradiance relations, leaf chlorophyll content, photosynthetic unit size and density, shoot size, specific leaf area, leaf biomass, and production rates were determined at the end of 30 d experiments. Cellular photosynthetic adjustment (photosynthesis vs irradiance relationships, chlorophyll and photosynthetic unit characteristics) to the H_{sat} manipulations occurred only in June, however biomass and growth adjustments occurred both in June and August. Photosynthesis and respiration rates, and H_{sat} regimes, were used to calculate daily leaf carbon balances. Daily carbon balance was an accurate predictor of plant survival. Plant responses to manipulations indicate that growth is light limited for eelgrass growing near the deep edge of the meadow, and that these plants appear to be living near the minimum light regime for growth and survival (H_{sat} = 6 to 8 h). Maximum depth distribution of this species appears to be controlled principally by daily light periods.>

97. Dennison, W. C. and R. S. Alberte. 1982. **Photosynthetic responses of *Zostera marina* L. (eelgrass) to *in situ* manipulations of light intensity.** Oecologia (Berlin). 55: 137-144.

[IRRADIANCE, PHOTOSYNTHESIS, ZOSTERA]

<Photosynthetic responses of the temperate seagrass, *Zostera marina* L., were examined by manipulations of photon flux density in an eelgrass bed in Great Harbor, Woods Hole, MA during August 1981. Sun reflectors and light shading screens were placed at shallow (1.3 m) and deep (5.5 m) stations in the eelgrass bed to increase (+35% to +40%) and decrease (-55%) ambient photon flux densities. The portion of the day that light intensities exceeding the light compensation point for *Z. marina* (H_{comp}) and the light saturation point (H_{sat}) were determined to assess the impact of the reflectors and shades. The H_{comp} and H_{sat} periods at the deep station shading screen were most strongly affected; H_{comp} was reduced by 11% and H_{sat} was reduced by 52%. Light-saturated photosynthetic rates, dark respiration rates, leaf chlorophyll content, chlorophyll a/b, PSU_{O_2} size, PSU density, leaf area, specific leaf area, leaf turnover times and leaf production rates were determined at the end of three sets of 1- to 2-week experiments. None of the measured parameters were affected by the photon flux density manipulations at the shallow station; however, at the deep station leaf production rates were significantly reduced under the shading screen and chlorophyll a/b ratios were higher at the reflector. These results indicate that adjustment to short-term

changes in light regime in *Z. marina* is largely by leaf production rates. Further, the most dramatic changes in the periods of compensating or saturating photon flux densities had the greatest impact on the measured photosynthetic responses.>

98. Mazzella, L. and R. S. Alberte. 1986. **Light adaptation and the role of autotrophic epiphytes in primary production of the temperate seagrass, *Zostera marina* L.** Journal of Experimental Marine Biology and Ecology. 100: 165-180.

[EPIPHYTES, PHOTOADAPTATION, PHOTOSYNTHESIS, PIGMENT CONTENT, PRIMARY PRODUCTIVITY, SEAGRASS, ZOSTERA]

<Photosynthetic features of *Zostera marina* L. and its autotrophic epiphyte community were investigated in a population inhabiting a shallow (1.3 m depth) water meadow in Great Harbor, Woods Hole, MA (U.S.A.). Photosynthesis versus irradiance (P-I) relationships were measured with respect to leaf age determined by the leaf position in the shoot bundle and by location of the tissue along the leaf axis. Therefore both age and light intensity gradients along the leaf axis were considered. The maximum photosynthesis (P_{max}) per dm^2 typically increased nearly two-fold along the leaf axis from leaf bases to apices. Photosynthetic rate on a chlorophyll (Chl) basis did not increase as dramatically along the leaf axis, and rates were usually lowest in tissues with the highest Chl content. The P-I relationships of leaves of differnt ages did not reveal photoinhibition even at light intensities > 1400 $\mu E\ m^{-2}\ s^{-1}$. Furthermore, no photoinhibition was observed in tissues from leaf blade bases, which never experienced high light levels (> 500 $\mu E\ m^{-2}\ s^{-1}$) *in situ* in Great Harbor. The initial slopes of the P-I curves and light compensation and saturation values varied along the leaf axis in relation to *in situ* light intensity gradients and in relation to leaf or tissue age. It appeared that leaf and/or tissue age was more important than light environment in determining P-I responses. The contribution of the autotrophic epiphyte community on *Z. marina* leaves to total photosynthesis per dm^2 was between 27 and 50%, and between 10 and 44% per mg chlorophyll. These levels of epiphyte photosynthesis can double the primary production of *Z. marina* leaves. No detrimental effects of epiphyte cover were realized in leaf maximal photosynthesis or P-I relationships. Non-epiphytized leaves and leaves from which epiphytes were removed showed essentially identical photosynthetic features. Light intensity and age gradients along the leaf axis control both the photosynthetic performance of the leaves and epiphyte biomass and photosynthesis.>

99. Dennison, W. C. and R. S. Alberte. 1986. **Photoadaptation and growth of *Zostera marina* L. (eelgrass) transplants along a depth gradient.** Journal of Experimental Marine Biology and Ecology. 98: 265-282.

[GENETIC DIFFERENTIATION, PHOTOADAPTATION, PHOTOSYNTHESIS, RECIPROCAL TRANSPLANTS, ZOSTERA]

<Photosynthetic and growth responses were assessed in *Zostera marina* L. transplants within and beyond the natural extent of an eelgrass meadow in Great Harbor, Woods Hole, MA. Transplant survival and rapid growth inshore of the shallow edge of the meadow (0.5 and 0.8 m water depth) indicated a periodic disturbance factor maintaining the shallow edge of the meadow. Transplant mortality, reduced growth, and a negative carbon balance of eelgrass transplanted

offshore the deep edge of the meadow (7 and 10 m) supported the hypothesis of light-limited eelgrass growth in the deep regions of the Great Harbor meadow. Photoadaptive responses occurred along the water depth gradient, and both photosynthesis and growth responses were used to assess the genetic vs. phenotypic components of eelgrass response to the water depth gradient. Reciprocal transplants between shallow (1.3 m) and deep (5.5 m) areas within the eelgrass meadow indicated photosynthetic and growth responses were primarily a result of growth habitat rather than genetic differentiation within the eelgrass meadow.>

100. McPherson, B. F. and R. L. Miller. 1987. **The vertical attenuation of light in Charlotte Harbor, a shallow, subtropical estuary, south-western Florida.** Estuarine Coastal and Shelf Science. 25: 721-737.

[AQUATIC MACROPHYTES, ATTENUATION, FLORIDA, LIGHT TRANSMISSION, ORGANIC CONTENT, SUSPENDED SOLIDS]

<The relative contribution of different components to the attenuation of photosynthetically active radiation was determined in the Charlotte Harbor estuarine system based on laboratory and *in situ* measurements. Agreement between laboratory and *in situ* measurements of the attenuation coefficient (k_t) was good ($r^2 = 0.92$). For all *in situ* measurements ($n = 100$), suspended, non-chlorophyll matter accounted for an average of 72% of k_t, dissolved matter accounted for 21%, suspended chlorophyll for 4%, and water for the remaining 3%. For individual determinations, suspended non-chlorophyll matter, dissolved matter, suspended chlorophyll, and water, each accounted for as much as 99%, 79%, 21%, and 18% of k_t. Attenuation by suspended matter was greatest near the mouth of the northern tidal rivers and was variable over the rest of the estuarine system. Attenuation by dissolved matter was greatest in the brackish tidal rivers and decreased with increasing salinity. Attenuation due to dissolved matter was positively correlated with water color. The source of the color was basin runoff. Wavelength transmittance changed along the salinity gradient. Maximum transmittance shifted from 500 to 600 nm in gulf waters to 650 to 700 nm in colored, brackish waters. Dissolved matter was primarily responsible for the large attenuation at short wavelengths (400-500nm).>

101. Dennison, W. C. 1987. **Effects of light on seagrass photosynthesis, growth and depth distribution.** Aquatic Botany. 27: 15-26.

[DEPTH, GROWTH, LIGHT, PHOTOSYNTHESIS, ZOSTERA]

<The relationships between light regime, photosynthesis, growth and depth distribution of a temperate seagrass, *Zostera marina* L. (eelgrass), were investigated in a subtidal eelgrass meadow near Woods Hole, MA. The seasonal light patterns in which the quantum irradiance exceeded the light compensation point (H_{comp}) and light saturation point (H_{sat}) for eelgrass photosynthesis were determined. Along with photosynthesis and respiration rates, these patterns were used to predict carbon balances monthly throughout the year. Gross photosynthesis peaked in late-summer, but net photosynthesis peaked in spring (May), due to high respiration rates at summer temperatures. Predictions of net photosynthesis correlated with *in situ* growth rates at the study site and with reports from other locations. The maximum depth limit for eelgrass was related to the depth distribution of H_{comp}, and a minimum annual average H_{comp} (12.3 h) for

survival was determined. Maximum depth limits for eelgrass were predicted for various light extinction coefficients and a relationship between Secchi disc depth and the maximum depth limit for survival was established. The Secchi disc depth averaged over the year approximates the light compensation depth for eelgrass. This relationship may be applicable to other sites and other seagrass species.>

102. Kendrick, G. A., D. I. Walker, and A. J. McComb. 1988. **Changes in distribution of macro-algal epiphytes on stems of the seagrass *Amphibolis antarctica* along a salinity gradient in Shark Bay, Western Australia.** Phycologia. 27: 201-208.

[EPIPHYTES, SALINITY]

<Sixty-six species of macro-algal epiphytes were recorded on the seagrass *Amphibolis antarctica* from 34 locations along a permanent hypersalinity gradient (38-60 o/oo) in Shark Bay, Western Australia. Fifty percent of the species are endemic to southern temperate Australia. Species richness of epiphytic communities was negatively correlated with salinity ($r = 0.84$; $P < 0.001$). Diversity (H_o) was less strongly correlated ($r = 0.63$; $P = 0.003$), as the evenness of the epiphytic communities had little to no correlation with salinity. The largest amount of total variation in epiphyte community structure from principal components analysis was significantly correlated with salinity. Cluster analysis of epiphytic species gave three major groups: species that have high relative abundances in areas of salinity greater than 50 o/oo but occur throughout the salinity range; species that only occur in areas with salinities less than 50 o/oo; and species that show no relationship between their relative abundances and salinity.>

103. Buesa, R. J. 1975. **Population biomass and metabolic rates of marine angiosperms on the northwestern Cuban shelf.** Aquatic Botany. 1: 11-23.

[METABOLIC RATES, POPULATION BIOMASS]

<Data on population biomass of turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), and two species of the genus *Halophila* (*H. decipiens* and *H. engelmanni*) from the northwestern Cuban shelf, as well as on metabolic rates of these and *Halodule beaudettei*, are given in this paper. Special attention was paid to photosynthesis as a function of light quantity and quality for *Thalassia* and *Syringodium*. Total population photosynthesis and respiration on daily and yearly bases, as well as bottom characteristics and their role as superficial distribution limiting factors, are also presented.>

104. Williams, S. L. 1987. **Competition between the seagrasses *Thalassia testudinum* and *Syringodium filiforme* in a Caribbean lagoon.** Marine Ecology Progress Series. 35: 91-98.

[COMPETITION, LIGHT, SEDIMENT NUTRIENTS]

<In typical Caribbean seagrass beds, several seagrass species co-occur and may compete for resources. The decline in *Syringodium filiforme* as *Thalassia testudinum* becomes abundant during successional development of Caribbean seagrass beds suggests that competition occurs between these seagrasses. The hypothesis that *T. testudinum* out competes *S. filiforme* for light and sediment nutrients

was tested *in situ* within a shallow seagrass bed in St. Croix, U.S. Virgin Islands. Exploitative competition with *T. testudinum* for primarily sediment nutrients but also light limited the leaf shoot density of *S. filiforme* but had little effect on leaf growth. Removal of the *T. testudinum* leaf canopy increased light above the saturation level of photosynthesis by *S. filiforme* and leaf shoot density and belowground biomass of *S. filiforme* doubled within 9 mo compared to control areas. The *T. testudinum* canopy protected *S. filiforme* leaves from breaking. Fertilization of the sediments with nitrogen and phosphorus increased leaf shoot density and belowground biomass of *S. filiforme*, an effect enhanced by *T. testudinum* canopy removal. Belowground competition for nutrients limited the areal aboveground productivity of *S. filiforme* more than exploitation of light by *T. testudinum*. Increased shoot density of *S. filiforme* resulting from greater rhizome density, rhizome branching, and leaf pairs per node contributed more to enhanced aboveground productivity with additional light or nutrients than increases in leaf growth.>

105. Jagels, R. 1973. **Studies of a marine grass, *Thalassia testudinum*. I. Ultrastructure of the osmoregulatory leaf cells.** American Journal of Botany. 60: 1003-1009.

[OSMOREGULATION, THALASSIA]

<*Thalassia testudinum* (Turtle Grass), a marine monocot which grows completely submerged, differs from intertidal and other halophytic angiosperms in that it has no specialized salt-secretory glands. Osmoregulation appears to be accomplished by the epidermal leaf cells which have highly invaginated plasmalemmas with numerous mitochondria situated in the interdigitations. The ultrastructure and proposed mode of secretion are similar to that of the salt-marsh monocot *Spartina*, but differ from that found in dicots. Evidence is presented to show why monocots are the only angiosperms which have adapted to a completely marine environment.>

106. Jagels, R. 1983. **Further evidence for osmoregulation in epidermal leaf cells of seagrasses.** American Journal of Botany. 70: 327-333.

[LEAF ULTRASTRUCTURE, OSMOREGULATION]

<A comparison of the epidermal leaf cell ultrastructure of three seagrasses, *Thalassia testudinum* (tropical, high salinity), *Zostera marina* (North temperate, moderate salinity), and *Ruppia maritima* (North temperate, brackish) provides confirmation for the theory that an invaginated plasmalemma-mitochondrial transport system is developed at least in part as a response to salt concentration. Cytochemical localization of presumed Cl^- ion provides further evidence for the presence of a salt secretion or exclusion mechanism. Immature epidermal leaf cells communicate with each other and with mesophyll cells through numerous plasmodesmata, but during cell maturation these cytoplasmic connections are lost and the apoplastic transport system develops to replace the symplastic one. The two North temperate region seagrasses contain cytoplasmic lipids which are absent in the tropical species. *Thalassia* and *Zostera* have chloroplasts which lack starch, but stain densely for polysaccharides with thiocarbohydrazide. The polysaccharide staining is essentially negative in the chloroplasts of *Ruppia*, but mesophyll chloroplasts of this brackish water species contain starch. These and other cytological findings are compared with other seagrasses.>

107. Jagels, R. and A. Barnabas. 1989. **Variation in leaf ultrastructure of *Ruppia maritima* L. along a salinity gradient.** Aquatic Botany. 33: 207-221.

[LEAF ULTRASTRUCTURE, RUPPIA, SALINITY]

<Distinct differences in leaf ultrastructure were found in *Ruppia maritima* L. growing in waters of low vs. high salinities. Leaf epidermal cells of low-salinity plants, compared with those of high-salinity plants, were characterized by: larger central vacuoles; fewer chloroplasts; reduced plasmalemma area (owing to less extensive plasmalemma invaginations); fewer mitochondria; thinner walls; reduced extracytoplasmic volume; symplastic connections with mesophyll cells (which are absent in high-salinity plants). Histochemically, cell walls of high-salinity plants show a stronger acidity gradient based on staining for sulphated and acidic mucopolysaccharides. This may indicate a pH driven anion exchange mechanism in the wall.>

108. Bulthuis, D. A. 1987. **Effects of temperature on photosynthesis and growth of seagrasses.** Aquatic Botany. 27: 27-40.

[GROWTH, PHOTOSYNTHESIS, TEMPERATURE]

<The effects of temperature on the photosynthesis and growth of seagrasses may be summarized by considering the ways in which temperature alters the characteristics of the photosynthesis-irradiance (P-I) curve of seagrasses. Within the limits of physiological tolerance (ca. 5-30°C) temperature has little effect on the initial slope of the P-I curve. At 35-40°C the photosynthetic capacity of seagrasses is reduced. Within the limits of physiological tolerance, the rate of photosynthesis at light saturation, the dark respiration rate and the light compensation point more than double as temperature increases. The optimum temperature for photosynthesis decreases from 25-35°C at light saturation to as low as 5°C as irradiance decreases. As a result of these effects of temperature on the P-I curve, growth of seagrasses in high (saturating) light environments increases with temperature, whereas growth of seagrasses in low (near the light compensation point) light environments decreases as temperature increases.>

109. Carlson, P. R. and J. G. Acker. 1985. **Effects of *in situ* shading on *Thalassia testudinum*: preliminary experiments.** In: Proceedings of the Twelfth Annual Conference on Wetlands Restoration and Creation. Edited by F. J. Webb, 64-73. Tampa: Hillsborough Community College.

[BIOLOGY, FLORA, GEOLOGY, HYDROGEN SULFIDE, SEAGRASS, SEDIMENTS, SHADING, THALASSIA]

<Three 0.92 m^2 plots of turtle grass, *Thalassia testudinum* Banks ex König were shaded for 68 days during the summer of 1984 to determine the effects of light stress on turtle grass growth and sediment chemistry. The shaded plots, receiving only 25% of incident sunlight, were randomly interspersed with three control plots in a homogeneous turtle grass bed near the mouth of Tampa Bay, Florida. No significant treatment effects were observed in pore water sulfide concentrations, pH, or redox potentials. The total leaf area per short-shoot, the density of short-shoots, leaf blade length, leaf blade width, and turnover

times for short shoot biomass all declined dramatically in the shaded *Thalassia* plants. We suggest that these parameters may be used in appropriate circumstances as indicators of light stress in *Thalassia*.>

110. Zimmerman, R. C., J. L. Reguzzoni, Wyllie-Echeverria, M. Josselyn, and R. S. Alberte. 1991. **Assessment of environmental suitability for growth of *Zostera marina* L. (eelgrass) in San Francisco Bay.** Aquatic Botany. 39: 353-366.

[LIGHT, PHOTOSYNTHESIS, TURBIDITY, ZOSTERA]

<The relationship between turbidity and light availability, and its subsequent effect on the depth distribution of *Zostera marina* L. (eelgrass) in San Francisco Bay was explored. The average daily period of irradiance-saturated photosynthesis (H_{sat}) required for the maintenance of whole plant carbon balance and growth, based on measured rates of photosynthesis and respiration as well as data available in the literature, were estimated to be between 3 and 5 h. Estimates of average H_{sat} availability in the field were determined from laboratory measurements of the phytosynthesis vs. irradance (P vs. I) response and from field observations of light attenuation measured at five sites in San Francisco Bay. Although plants were found to be low-light adapted with regard to their P vs. I response, they were limited to depths shallower than -2 m mean lower low water (MLLW) at all sites. The -2 m depth limit corresponded fairly well to predicted H_{sat} requirements at two sites where turbidity was relatively low and constant, but depth limits of eelgrass were less than 1.5 m at three sites subjected to extremely turbid and variable light environments, much shallower than predicted from calculations of mean daily carbon requirements and H_{sat} availability. Thus, in addition to the mean light environment, periods of extreme light attenuation that last from days to weeks may be important in controlling eelgrass growth and productivity in highly turbid and dynamic estuaries such as San Francisco Bay.>

111. Zimmerman, R. C., R. D. Smith, and R. S. Alberte. 1989. **Thermal acclimation and whole-plant carbon balance in *Zostera marina* L. (eelgrass).** Journal of Experimental Marine Biology and Ecology. 130: 93-109.

[CARBON BUDGET, OXYGEN, PHOTOSYNTHESIS, RESPIRATION, SEAGRASS, TEMPERATURE]

<Thermal acclimation in eelgrass *Zostera Marina* L. was investigated in laboratory experiments after growing plants at 10 and 20°C for 21 days under a 12:12 L:D regime. Metabolic rates showed significant shifts in short-term response to temperature in leaves and roots. Growth rates, tissue carbohydrate concentrations and metabolic rates measured at the two growth temperatures were statistically identical, indicating that thermal acclimation was essentially complete at these temperatures. When measured at PO_2 values high enough to achieve capacity rates of respiration, thermal responses of respiration (Q_{10}) were lower than previously reported while the thermal response of photosynthesis (measured at PO_2 below air saturation) was similar to previous reports. Daily carbon budgets constructed from metabolic rate data indicated that H_{sat} periods required for photosynthesis to balance carbon demand can vary from 3 to > 12 h, depending on the ratios of net photosynthesis:respiration (P_{net}:R) and shoot:root. Since *Z. marina* shows evidence of thermal acclimation, seasonal changes in ambient temperature may not significantly affect H_{sat} requirements and whole-plant

carbon balance. Rapid mortality at high temperatures during summer may result instead from thermal disruption of metabolism while internal carbon reserves may be important in meeting carbon demand during winter periods of low light availability, particularly among high-latitude populations.>

112. Goldsborough, W. J. and W. M. Kemp. 1988. **Light responses of a submersed macrophyte: implications for survival in turbid tidal waters.** Ecology. 69: 1775-1786.

[ACCLIMATION, AQUATIC MACROPHYTES, ESTUARY, ETIOLATION, IRRADIANCE, LIGHT, PHOTOADAPTATION, PHOTOSYNTHESIS, PIGMENT CONTENT, SEAGRASS, SHADING, TURBIDITY]
<Responses and acclimation of the submersed vascular plant *Potamogeton perfoliatus* L. to changes in total irradiance were investigated by growing replicate plant populations under neutral density screens to create three treatment levels (11, 32, and 100% of ambient). Changes in the relationship between photosynthesis and irradiance (P-I) were monitored during a 17-d treatment period and a 16-d "recovery" period, as were concentrations of photosynthetic pigments and several morphological features. Both initial slope of P-I relations and leaf chl *a* content increased significantly within 3 d after the beginning of shade treatment. These responses, which represent mechanisms of increasing photosynthetic efficiency at low irradiance, were also reversed within 3 d after treatment removal. Significant morphological responses to and recovery from shade were evident within 10 d, including: elongation of stems, thinning of lower leaves, and canopy formation at the water surface. Preliminary calculations indicate that both photosynthetic and morphological acclimations to shade conferred substantial improvements in *P. perfoliatus* production at experimentally reduced irradiance compared to pretreatment conditions. Significant decreases in plant stem density, biomass, and reproduction, as well as increases in mortality, were observed for plants at low (but not medium) growth irradiance. The inability of populations treated at low irradiance to exhibit any recovery (i.e., post treatment increases) in these variables after 16 d of full ambient light suggests that 11% of ambient irradiance was below the minimum level needed for survival of this plant. Time scales for significant shade acclimation responses were comparable to the temporal scales of changes in light climate for aquatic ecosystems such as Chesapeake Bay. It is argued that, although stem elongation is a beneficial response to shade for *P. perfoliatus* in turbid lakes, it may be nonadaptive in turbulent tidal waters because of increased susceptibility to fragmentation.>

113. Bulthuis, D. A. 1983. **Effects of *in situ* light reduction on density and growth of the seagrass *Heterozostera tasmanica* (Martens ex Aschers.) den Hartog in Western Port, Victoria, Australia.** Journal of Experimental Marine Biology and Ecology. 67: 91-103.

[ATTENUATION, DENSITY, GROWTH]
<Neutral density screens were used to reduce the level of irradiance available to an intertidal population of *Heterozostera tasmanica* (Martens ex Aschers.) den Hartog in Western Port, Victoria, Australia. When irradiance was reduced to 9 and 2% of control (ambient) levels, death of all leaf clusters of *H. tasmanica* resulted within 2 to 10 months. Reduction of irradiance to 35 to 25% of control levels resulted in a 25-50% decrease in leaf cluster density for the duration of the experiment (14 months). As irradiance level decreased, leaf

length increased (leaf length at 9% irradiance was twice leaf length in control areas) while leaf growth rate and leaf width remained the same. It is suggested that leaf growth rate per leaf cluster remains the same under reduced irradiance because of the decreased likelihood of self-shading by surviving leaf clusters and increased surface area per leaf cluster. Density decreased more rapidly during summer than during winter at reduced light levels. This response may be due to an increase in the plant's light compensation point because of increased respiration at summer temperatures. Information on the lower limits of vertical distribution of *H. tasmanica* in Western Port and Port Phillip Bay, Victoria together with the experimental irradiance reduction data suggests that *H. tasmanica* requires a minimum of ≈5% of surface irradiance for survival.>

114. Ott, J. A. 1979. **Persistence of a seasonal growth rhythm in *Posidonia oceanica* (L.) Delile under constant conditions of temperature and illumination.** Marine Biology Letters. 1: 99-104.

[ADAPTIVE STRATEGY, CULTIVATION, GROWTH, POSIDONIA, TEMPERATURE]

<In the Mediterranean seagrass *Posidonia oceanica* (L.) Delile the pronounced seasonal growth rhythm of the natural population persisted for 2 yr in the laboratory under constant conditions of illumination, day length and temperature. Decay of leaf tips was not correlated with epiphyte cover as it appears to be in natural populations. The adaptive significance of this independence of the growth rhythm from an external 'Zeitgeber' is seen in the possibilities of damping the influence of short time fluctuations of environmental variables, elimination of term lags in reaction to seasonal changes and the possibilities for a productivity pattern that allows *Posidonia* to successfully compete for nutrients with phytoplankton and annual epiphytes which are more directly bound to the regular seasonal pattern of environment.>

115. Lapointe, B. E., K. R. Tenore, and C. J. Dawes. 1984. **Interactions between light and temperature on the physiological ecology of *Gracilaria tikvahiae* (Gigartinales: Rhodophyta).** Marine Biology (New York). 80: 161-170.

[LIGHT, LIGHT COMPETITION, PHOTOSYNTHESIS, RESPIRATION, TEMPERATURE]

<Main effects and interactions of light and temperature on rates of growth (μ). net photosynthesis (P_n), and dark respiration (R) of the red seaweed *Gracilaria tikvahiae* were investigated in outdoor, nutrient-replete continuous-flow seawater culture chambers. Below 15°C. *G. tikvahiae* did not grow and between 15° and 30°C both main effects and interactions of light and temperature on μ and P_n were significant, which explains the occurrence of this alga as a summer annual in its northern range. Temperature interacted with light (I) through its influence on the μ vs I curve, *a*. the light saturation intensity, I_k. and maximum growth rate μ_{max}, were all significantly lower at 15°C compared to 20°, 25°, or 30°C. Maximum values of μ_{max}, the P_n:R ratio and the net photosynthesis:gross photosynthesis ratio (P_n:P_g) all occurred at 25°C, suggesting that this is the best temperature for growth of *G. tikvahiae*. Values for P_{max} increased up to 30°C, indicating that the temperature for maximum growth and net photosynthesis are not the same for *G. takvahiae*. Significant photoinhibition of growth and photosynthesis at full incident sunlight (I_o) occurred at 15°C but not at 20°, 25°, or 30°C. Steele's equation fit the 15°C μ vs I data best, whereas the hyperbolic tangent function fit the 20°, 25°, and 30°C data best. Main

effects and interaction of light intensity and temperature on rates of R were also significant ($P<0.001$). R was highly intercorrelated with μ and P_s ($0.86 \leq r \leq 0.94$), indicating that R in *G. tikvahiae* is primarily regulated by growth rate and not temperature *per se*. Environmental factors that regulate growth, such as light intensity, exert a great influence on R in *G. tikvahiae*.>

116. Lindeboom, H. J. and A. J. J. Sandee. 1989. **Production and consumption of tropical seagrass fields in eastern Indonesia measured with bell jars and microelectrodes.** Netherlands Journal of Sea Research. 23: 181-190.

[CONSUMPTION, PRIMARY PRODUCTIVITY]

<During the Indonesian-Dutch Snellius-II Expedition the production and consumption of tropical seagrass species were measured with bell jars at four sampling stations in eastern Indonesia. Applying a conversion factor of 0.29, the amount of carbon fixed and mineralized was calculated from the recorded oxygen evolution. The gross production of the different seagrass communities was found to be between 1230 and 4700 mg C m^{-2} d^{-1}. The consumption lay between 860 and 3860 mg C m^{-2} d^{-1}. From these data a relatively low net production of 60 to 1060 mg C m^{-2} d^{-1} could be calculated. At one sampling station incubations were carried out at different depths in a sloping *Halodule uninervis* (Forssk.) Aschers meadow, which indicated that seagrasses above a depth of about 2 m may become subject to photoinhibition. A linear correlation between biomass and measured production was found for *Thalassia hemprichii* (Ehrenb.) Aschers. Above a biomass of 100 g DW m^{-2} the production per unit of biomass decreased due to shelf shading. Using microelectrodes the oxygen production of epiphytes was found to be 230 mg C m^{-2} leaf surface d^{-1} at 1900 μE m^{-2} s^{-1} assuming an epiphyte coverage of 40%. This indicated that up to 36% of the primary production in a seagrass community may be attributed to epiphytes. The seagrass fields in Indonesia were found to be healthy ecosystems with a high primary production, but organisms within the communities use the abundance of organic matter very efficiently, creating net production rates of 100 to 300 mg C m^{-2} d^{-1} which are similar to barren areas.>

117. Bulthuis, D. A. 1983. **Effects of temperature on the photosynthesis-irradiance curve of the Australian seagrass, *Heterozostera tasmanica*.** Marine Biology Letters. 4: 47-57.

[HETEROZOSTERA, LIGHT, LIGHT COMPENSATION POINT, PHOTOSYNTHESIS, SEAGRASS, TEMPERATURE]

<Photosynthesis-irradiance curves were determined for leaves of the seagrass, *Heterozostera tasmanica*, from Western Port, Victoria, Australia at 8 temperatures from 5 to 40°C. At light saturation the rate of photosynthesis increased with temperature to a maximum at 30°C (temperature optimum) and then decreased sharply. At lower light intensities the temperature optimum decreased. The initial slope of the photosynthesis-irradiance curve was similar at temperatures from 5 to 30°C but was reduced at 35°C. The irradiance at light saturation and at the light compensation point increased linearly with temperature from 5 to 30°C and 5 to 35°C, respectively. The increased compensation irradiance at higher temperatures implies that *H. tasmanica* has a greater light requirement during summer and is more susceptible to short-term decreases in irradiance levels during summer than during winter.>

118. Cooper, L. W. and M. J. DeNiro. 1989. **Stable carbon isotope variability in the seagrass *Posidonia oceanica*: evidence for light intensity effects.** Marine Ecology Progress Series. 50: 225-229.

[CARBON ISOTOPES]

<Stable carbon isotope ratios were determined for leaves of the seagrass *Posidonia oceanica* (L.) Delile collected over a 38 m depth gradient at Bay of Calvi, Corsica. Although variability in $\delta^{13}C$ values among individual leaves at specific depths was as high as 6 o/oo, there was an overall trend towards less discrimination against ^{13}C at the shallowest water levels. The mean $\delta^{13}C$ value of leaves at 5 m was -11.0 o/oo and declined to a minimum mean of -16.4 o/oo at 35 m. Isotopic variability in individual leaves divided into thirds was consistent with this trend, except in those leaf sections nearest to the meristem, whose $\delta^{13}C$ values did not vary with depth. A variety of explanations for these observations were considered, including the effects of light intensity, temperature, pressure, relative water motion, seasonal variability in biochemical fractionation, isotopic variability in the dissolved inorganic carbon pool, and differential use of bicarbonate and dissolved carbon dioxide on the carbon isotopic composition of *P. oceanica*. Differences in light intensity and consequently photosynthetic rate are most likely to influence discrimination against ^{13}C and thus account for the observations reported here.>

119. Pulich, W. M., Jr. 1989. **Effects of rhizosphere macronutrients and sulfide levels on the growth physiology of *Halodule wrightii* Aschers. and *Ruppia maritima* L. s.l.** Journal of Experimental Marine Biology and Ecology. 127: 69-80.

[HALODULE, NUTRIENT CONTENT, RHIZOSPHERE, RUPPIA, SEAGRASS]

<Correlations were found between seasonal shoot production rates, tissue N and P contents, and stable S isotope ratios for co-occurring *Halodule wrightii* Aschers. and *Ruppia maritima* L.s.l. plants at a typical estuarine field site. *Halodule* growth rates correlated positively with elemental composition of root tissue while *Ruppia* growth correlated positively with leaf tissue elemental concentrations. Based on these field observations, controlled laboratory studies were conducted to compare growth responses of *Halodule* and *Ruppia* to selected sediment nutrient regimes. *Ruppia* grew readily on sediments enriched with low-to-moderate levels of inorganic nutrients (e.g., NO_3^- or NH_4^+ and PO_4^{3-}). In contrast, these inorganic nutrients were ineffective in supporting *Halodule* growth and sediment enrichment with organic N was specifically required for vigorous growth. Nitrate added to organic-enriched sediments was inhibitory to *Halodule* growth, most likely through its suppressive effect on SO_4^{2-} reduction activity. These data provide experimental evidence that differential responses to sediment sulfate reduction are involved in the competition between *Halodule* and *Ruppia* under polyhaline estuarine regimes.>

120. Smith, R. D., A. M. Pregnal, and R. S. Alberte. 1988. **Effects of anaerobiosis on root metabolism of *Zostera marina* (eelgrass): implications for survival in reducing sediments.** Marine Biology (New York). 98: 131-141.

[ANAEROBIC METABOLISM, SEDIMENTS, ZOSTERA]

<The temperate seagrass *Zostera marina* L. typically grows in highly reducing sediments. Photosynthesis-mediated O_2 supplied to below-ground tissues sustains aerobic respiration during photosynthetic periods. Roots, however, experience daily periods of anoxia and/or hypoxia at night and under conditions that reduce photosynthesis. Rhizosphere cores of *Z. marina* were collected in August 1984 from Great Harbor, Massachusetts. We examined short-term anaerobic metabolism of (U-^{14}C) sucrose in excised roots and roots of intact plants. Under anaerobic conditions roots showed appreciable labeling of CO_2, ethanol and lactate, and slight labeling of alanine and other metabolites. Over 95% of the ^{14}C-ethanol was recovered in the root exudate. Release of other metabolites from the roots was minimal. Ethanol was also released from hypoxic/anoxic roots of intact plants and none of this ethanol was transported to the shoot under any experimental conditions. Loss of ethanol from roots prevented tissue levels of this phytotoxin from increasing during anaerobiosis despite increased synthesis of ethanol. Anaerobic metabolism of (U-^{14}C) glutamate in excised roots led to appreciable labelling of *γ*-aminobutyrate, which was known to accumulate in eelgrass roots. Roots recovered to fully aerobic metabolism within 4 h after re-establishment of aerobic conditions. The contributions of these root metabolic responses to the ability of *Z. marina* to grow in reducing marine sediments are related to light-regulated interactions of shoots and roots that likely dictate depth penetration, distribution and ecological success of eelgrass.>

121. Marmelstein, A. D., P. W. Morgan, and W. E. Pequegnat. 1968. **Photoperiodism and related ecology in *Thalassia testudinum*.** Botanical Gazette. 129: 63-67.

[PHOTOPERIOD, THALASSIA]

<A study was conducted to determine, through ecological observations and experimental manipulation, whether the marine angiosperm *Thalassia testudinum* König and Sims is responsive to photoperiod. The field observations, made in St. Andrew Bay on the northwestern Gulf Coast of Florida and in Biscayne Bay on the southern Atlantic Coast of Florida, revealed that : (1) *Thalassia* bloomed in St. Andrew Bay, which extended its previously described flowering range considerably northward; (2) flowering was seasonal and limited in many cases to discrete areas within a grass flat; and (3) natural flowering in *Thalassia* was apparently influenced to some extent by photoperiod, as indicated by its seasonal nature and response to water depth and clarity. Laboratory culture of *Thalassia* at 6- 12- 18- and 24-hr photoperiods resulted in the following observations: (1) vegetative growth in *Thalassia* was highly responsive to photoperiod and was favored by intermediate daylengths; (2) flowering was also favored by intermediate daylengths; (3) the flowering response of *Thalassia* to photoperiod appeared to be one of expression rather than induction; and (4) there was an apparent requirement for a minimum daylength as well as a minimum nightlength. These observations led to a tentative classification of *Thalassia* as an "intermediate-day plant" with respect to flowering and vegetative growth.>

122. Bridges, K. W. and C. McMillan. 1986. **The distribution of seagrasses of Yap, Micronesia, with relation to low tide conditions.** Aquatic Botany. 24: 403-407.

[DISTRIBUTION, TIDES]

<On the shallow coral shelves of Yap, the distribution of *Cymodocea rotundata* Ehrenb. & Aschers., *Thalassia hemprichii* (Ehrenb.) Aschers. and *Enhalus acoroides* (L.) Royle reflects their tolerance of low tide conditions that include mid-day water temperatures exceeding 40°C and water salinity during heavy rains to 2 o/oo. The restriction of *Cymodocea serrulata* (R.Br.) Aschers. & Magnus and *Syringodium isoetifolium* (Aschers.) Dandy to deeper sites reflects less tolerance to low tide conditions.>

123. Kerr, E. A. and S. Strother. 1985. **Effects of irradiance, temperature and salinity on photosynthesis of *Zostera muelleri*.** Aquatic Botany. 23: 177-183.

[IRRADIANCE, PHOTOSYNTHESIS, SALINITY, TEMPERATURE, ZOSTERA]

<Physiological and biochemical knowledge of the Australian seagrass *Zostera muelleri* Irmisch ex Aschers. is scanty. Harvested samples of *Z. muelleri* have been used in physiological experiments to examine the effects of irradiance, temperature and salinity on apparent photosynthesis. Photosynthesis is significantly decreased by decreases in salinity and also by extremes of temperature. However, apparent photosynthesis is still maintained at a salinity 15% that of normal seawater and at temperatures of 3 and 30°C, consistent with the ecological role of *Z. muelleri* as an intertidal species.>

124. Orth, R. J. and K. A. Moore. 1988. **Distribution of *Zostera marina* L. and *Ruppia maritima* L. sensu lato along depth gradients in the lower Chesapeake Bay, U.S.A.** Aquatic Botany. 32: 291-305.

[DEPTH, DISTRIBUTION, RUPPIA, ZOSTERA]

<Seventeen transects in areas containing beds of submerged aquatic vegetation in the lower Chesapeake Bay were selected for analysis of the depth distribution of *Ruppia maritima* L. sensu lato and *Zostera marina* L. during a 6-week period (25 July-12 September 1978). Transects studied ranged in length from 130 to 1100 m with estimates of percent cover made on 785 plots. Mean importance value (relative frequency + relative cover) for *Z. marina* was 96.0 (range of 0-200) while for *R. maritima* it was 94.9 (0-184.4). Average cover across the beds ranged from 0 to 51.7% for *Z. marina* and 0-79.2% for *R. maritima*, with average transect biomass up to 72.9 and 55.4 g dry weight m^{-2} for the two species, respectively. Comparison of individual transects showed a consistent pattern of zonation where *R. maritima* occupied the nearshore, shallower area which graded to a mixed zone of *R. maritima* and *Z. marina* at intermediate depths. At the deepest part of the beds, *Z. marina* was the only species found. Transects along the western shore sites were characterized by lower percent cover with more open areas in the beds when compared with the eastern shore sites. Depth distributions of *R. maritima* and *Z. marina* on the eastern shore were +20 to -100 cm and -30 to 150 cm (mean low water (MLW), respectively, while on the western shore they were +10 to -80 cm and +10 to -110 cm, respectively. The greater depth penetration of the two species along the eastern shore transect sites may reflect a greater influence of clearer, oceanic water compared with the more turbid, riverine influence along the western shore sites. Results demonstrate that both optimum and maximum depth limits for a species can vary considerably within a particular region and suggest the potential for marked variability over time.>

125. Hall, M. O., D. A. Tomasko, and F. X. Courtney. 1989. **Demographic, morphological and physiological responses of *Thalassia testudinum* to *in situ* light reduction.** In: Abstracts, Tenth Biennial International Estuarine Research Conference. Edited by J. Reynolds, S. Zedler, and A. Whelan, 31. San Diego: Estuarine Research Federation.

[GROWTH, LIGHT, SURVIVAL, THALASSIA]

<Reduction in the amount of light reaching seagrass blades is widely considered the major reason for seagrass decline in coastal and estuarine waters. A field study examining the effects of decreased light on the growth and survival of *Thalassia testudinum* (turtle grass) was begun in February 1989. Neutral density screens are being used to reduce the available irradiance by approximately 45% to a both a shallow (0.6m) and deep (2m) *T. testudinum* bed in Tampa Bay, Florida. Demographic, morphological and physiological responses of turtle grass to decreased light availability will be determined every three months for at least one year.>

126. Mazzella, L., D. Mauzerall, and R. S. Alberte. 1979. **Photosynthetic light adaptation features of *Zostera marina* L.** (eelgrass). Biological Bulletin (Woods Hole). 159: 500.

[CHLOROPHYLL, IRRADIANCE, PHOTOSYNTHESIS, ZOSTERA]

<The light adaptation features of photosynthesis in *Zostera marina* L. were studied in plants collected in a Woods Hole tidal bed. Our previous studies on *Zostera* showed a gradient in leaf pigmentation and photosynthetic activity along the leaf axes. Therefore, we sought to characterize in the laboratory the photosynthetic characteristics of *Zostera* leaves developed *in situ* under a range of light environments. Photon flux densities measured at the collection site (July, 1980) showed a gradient from the level of tips of submerged plants to the bottom (2 m) (830-250 and 400-70 μE m^{-2} sec^{-1} on cloudless and cloudy days, respectively). The maximal photosynthetic rates per unit area, measured as CO_2-dependent O_2 evolution, increased almost two-fold (3.0-5.6 μMol O_2 dm^{-3} min^{-1} from the leaf bases to the tips. However, when rates were expressed on a chlorophyll (Chl) basis, leaf bases had higher rates than tips (4.0 μMol O_2 mg Chl^{-1} min^{-1}). The differences in Chl and area rates can be attributed to the fact that there is a 40% increase in Chl per dm^2 in leaf tips compared with bases. Light saturation of photosynthesis occurred 100 and 150 μE m^{-2} sec^{-1} for all leaf types examined. Initial slopes of the photosynthetic light saturation curves, defined as photosynthetic efficiency, increased from leaf bases to tips when rates were expressed per unit area. Photosynthetic activities of young, old epiphytized, old non-epiphytized, and old leaves with epiphytes removed were compared along the leaf axes. In almost all cases photosynthetic activity increased from the bases to the tips. It is clear that epiphytes contribute a significant portion of the total leaf photosynthesis per unit area. Photosynthesis measured as $^{14}CO_2$-fixation rates paralleled the O_2 evolution rates described above. Such studies provide a molecular and biochemical framework for further investigations aimed at defining the adaptive physiology of a highly productive coastal marine species.>

127. Fonseca, M. S. and W. J. Kenworthy. 1987. **Effects of current on photosynthesis and distribution of seagrasses.** Aquatic Botany. 27: 59-78.

[CURRENTS, LEAF PRODUCTION, LIGHT, ZOSTERA]

<Studies of the effect of current on seagrass physiology and distribution are few, and the influence of current may be severely underestimated. Current flow may enhance nutrient uptake at the leaf surface of seagrasses by reducing the diffusion boundary layer, modifying the scale of turbulence within the canopy and presenting more nutrients to the leaf. Preliminary laboratory studies suggest that currents between 2 and 50 cm s^{-1} affect leaf production of *Zostera marina* L. under light-saturated conditions. Canopy modification of flow structure and light capture efficiency by the deflected canopy should be examined as strategies that could help explain species distribution under different current regimes. Current velocity (together with wave action) creates hydraulic regimes that influence seagrass and seedling distribution. Currents and waves have been correlated with meadow configuration, relief and blowout formation and migration, as well as the distribution of seagrass detritus.>

128. Jensen, P. R. and R. A. Gibson. 1986. **Primary production in three subtropical seagrass communities: A comparison of four autotrophic components.** Biological Sciences Curriculum Study Bulletin. 49: 129-141.

[ALGAE, BIOMASS, EPIPHYTES, NUTRIENTS, PRIMARY PRODUCTIVITY]

<A one-year study was conducted in which seagrass communities in Tampa Bay, the Indian River Lagoon, and the Little Bahama Bank were monitored quarterly for primary production, standing stock biomass, and nutrient concentrations. Primary production rates were measured *in situ* for the following four community autotrophic components: seagrasses, their associated epiphytic flora, phytoplankton and microbenthic algae. Photosynthetic rates were compared both within and between locations to determine the relative significance of the primary producers, and the contribution by each to areal, i.e., community production (mg C m^{-3} h^{-1}). In general, all species of seagrasses, their associated epiphytic flora and microbenthic algae produced at similar rates at all locations. The Indian River Lagoon had phytoplankton primary production rates that were greater than both seagrass and microbenthic algal production rates. Phytoplankton in Tampa Bay had primary production rates greater than all other community photosynthetic components, and primary production rates by all photosynthetic components in the nutrient-deplete Bahama Banks were similar. Therefore, the majority of the community primary production, i.e., the production base, in Tampa Bay and the Indian River Lagoon is contributed by phytoplankton. These areas are characterized by anthropogenic perturbations and associated high nutrient concentrations. Historical data indicate that phytoplankton, turtle grass and microbenthic algae were, at one time, equally productive in Tampa Bay. Increased phytoplankton production has reduced the relative importance of seagrasses and microbenthic algae to community production in this area. It is suggested that the relative contributions by the components of the photosynthetic community are affected by nutrient availability. Nutrient enrichment may induce a shift in the production base from benthic plants to phytoplankton. A shift

of this type may be interpreted as an ecological indicator of either eutrophication or environmental stress in a coastal marine environment.>

129. Howard, R. K. and F. T. Short. 1986. **Seagrass growth and survivorship under the influence of epiphyte grazers.** Aquatic Botany. 24: 287-302.

[EPIPHYTES, GROWTH, HALODULE]

<Substantial reduction of epiphyte biomass by grazing epifauna is widespread in seagrass systems, and a hypothesized effect is enhanced vigour of the host seagrasses. Effects of epiphyte grazing on seagrass growth and biomass were tested using cultures of the sub-tropical seagrass *Halodule wrightii* Aschers. established with and without the epiphyte-grazing fauna of local seagrass beds of the Indian River Lagoon, Florida, U.S.A. In the absence of grazing epifauna, a rapid build-up of epiphytes on seagrass leaves occurred and, initially, leaf defoliation was high. After 2 months there was a reduction in growth rate of *Halodule* in the ungrazed treatment relative to the grazed treatment. Leaf biomass-to-length ratios and shoot biomass were also lower. After 3 months, above- and below-ground biomass and shoot density of ungrazed seagrass were significantly lower, and a substantial drop in productivity had occurred. Results suggest that the suppression of epiphyte biomass by grazing epifauna may be an important factor in the maintenance of growth, productivity and depth distribution of seagrasses, particularly in light-stressed and nutrient-stressed situations.>

130. Zieman, J. C., J. W. Fourqurean, and R. L. Iverson. 1989. **Distribution, abundance and productivity of seagrasses and macroalgae in Florida Bay.** Bulletin of Marine Science. 44: 292-311.

[ABUNDANCE, DISTRIBUTION, MACROALGAE, PRIMARY PRODUCTIVITY, SEAGRASS]

<The distribution, abundance, and productivity of submerged macrophytes were measured in Florida Bay to determine the total productivity and seagrass habitat distribution throughout the region. *Thalassia testudinum* was widely distributed and was the dominant macrophyte species in the 1,660 km^2 of seagrass beds contained in the bay. *Halodule wrightii* was also common, but had standing crop significantly less than *Thalassia* at all sample locations. *Syringodium filiforme* grew mainly in areas with strong oceanic influence, especially along the south and west margins of the bay. Macroalgae were a small percentage of the total macrophyte biomass. Gradients in environmental and biological variables extended from southwest to northeast Florida Bay. Water clarity, water exchange, and sediment depth were all greatest in the south and west portion of the bay and decreased towards the northeast corner of the bay. The seagrass standing crop varied from between 50 and 125 g dw m^{-2} in the southwest to between 0 and 30 g dw m^{-2} in the northeast. Total seagrass leaf standing crop was 8 x 10^{10} g dw in Florida Bay, 90% of which was *Thalassia* leaf material. *Thalassia* mean leaf productivity was 0.97 g dw m^{-2} d^{-1}, with higher values in the southwest and lower values in the northeast portions of the bay. Approximately 1.7 10^{9} g dw d^{-1} of *Thalassia* leaf tissue was produced in Florida Bay during the summer. *Thalassia* had about the same leaf productivity on a per gram leaf dry weight basis throughout the different environments of Florida Bay, therefore variations in areal leaf productivity were caused by variations in leaf standing crop and

not by variations in leaf specific productivity. Distribution, abundance, and productivity data were used to divide the bay into six community types.>

131. Horner, S. M. J. 1987. **Similarity of epiphyte biomass distribution of *Posidonia* and artificial seagrass leaves.** Aquatic Botany. 27: 159-167.

[EPIPHYTES]

<Epiphyte biomass on *Posidonia australis* Hook f. and artificial seagrass leaves was analyzed in relation to distance from leaf tip at different time periods following the autumnal shedding. The distribution pattern indicated no significant difference in the exponential nature of biomass increase. Similarities between epiphyte biomass distribution on real and artificial leaves is consistent with the hypothesis that biomass distribution on real leaves is not influenced significantly by metabolic interactions between host plant and epiphytes. Although a time component is involved in epiphyte biomass accumulation, the major factor in determining epiphyte biomass distribution is the relative position along the leaf.>

132. Flores-Verdugo, F. J., J. W. Day Jr., L. Mee, and R. Briseño-Dueñas. 1988. **Phytoplankton production and seasonal biomass variation of seagrass, *Ruppia maritima* L., in a tropical Mexican lagoon with an ephemeral inlet.** Estuaries. 11: 51-56.

[BIOMASS, RUPPIA, SEASONALITY]

<Plankton metabolism and *Ruppia maritima* biomass were measured seasonally during 1982-83 in El Verde Lagoon, a small coastal lagoon with an ephemeral inlet on the Pacific Coast of Mexico. Total net aquatic primary production was 521 g C m^{-2} y^{-1}. The water column was slightly heterotrophic, with an annual P/R ratio of 0.89. Our analysis indicates that tropical and subtropical coastal lagoons with restricted or seasonal inlets have generally higher net aquatic primary productivity levels than lagoons with permanently open inlets. We hypothesize that this is due to retention of nutrients and plankton stocks during the dry season. The seasonal pattern of water column metabolism was related to rainfall and riverflow, with higher values generally occurring during the wet season. Net production and respiration were about three times lower during the 1982 dry season as compared to the 1983 dry season which received considerable rains due to abnormal climatic conditions. The biomass of *R. maritima* ranged from zero to 620 g dry wt m^{-2}. Growth occurred only during the dry season and there were two distinct biomass peaks representing two separate crops. The second crop was heavily epiphytized with nitrogen-fixing algae. There was an apparent succession in dominance of water column productivity over the year, with *Ruppia* dominating during the dry season and phytoplankton more important during the wet season.>

133. Heijs, F. M. L. 1984. **Annual biomass and production of epiphytes in three monospecific seagrass communities of *Thalassia hemprichii* (Ehrenb.) Aschers.** Aquatic Botany. 20: 195-218.

[EPIPHYTES, THALASSIA]

<The biomass of epiphytes and seagrasses has been measured in relation to leaf age in three monospecific seagrass stands of *Thalassia hemprichii*

(Ehrenb.) Aschers. in Papua New Guinea. From June 1981 through August 1982, biomass values for epiphytes at the three sites ranged from 5 to 70 g ADW m^{-2} sediment surface at site 1, from 5 to 14 g ADW m^{-2} at site 2, and from 3.5 to 7.0 g ADW m^{-2} at site 3. Annual mean epiphyte biomass values for the different sites were 1.3 g ADW m^{-2} leaf surface at site 1, 1.7 g ADW m^{-2} leaf surface at site 2, and 1.5 g ADW m^{-2} leaf surface at site 3. The annual mean standing crop of *T. hemprichii* leaves was highest at site 1 (103 g ADW m^{-2}). Values for site 2 and site 3 were 60 g ADW m^{-2} and 41 g ADW m^{-2}, respectively. Production of epiphytes was calculated in three different ways: firstly, by using biomass values for each specific leaf-age group, with corrections for colonization; secondly, by fitting the biomass values with a specific growth curve; and thirdly, by estimating the rate of biomass accumulation. On an area basis, production of epiphytes on leaves of *T. hemprichii* ranged from 0.55 to 3.97 g ADW m^{-2} day^{-1} at site 1, from 0.17 to 0.73 g ADW m^{-2} day^{-1} at site 2, and from 0.24 to 0.68 g ADW m^{-2} day^{-1} at site 3.>

134. Borum, J. 1985. **Development of epiphytic communities on eelgrass (*Zostera marina*) along a nutrient gradient in a Danish estuary.** Marine Biology (New York). 87: 211-218.

[EPIPHYTES, NUTRIENTS, ZOSTERA]

<The effect of nutrient enrichment on epiphyte development was examined by following the seasonal development of epiphyte biomass on eelgrass (*Zostera marina* L.) at four localities along a nutrient gradient in Roskilde Fjord, Denmark between March and December 1982. In the most nutrient-poor area, epiphyte biomass followed a distinct bimodal seasonal pattern with maxima in spring and early fall. Low nutrient availability and a high rate of eelgrass leaf renewal kept epiphyte biomass at a low level throughout the summer period. Unlike phytoplankton, the epiphytic community was not stimulated by nutrient enrichment during spring, however, from May through August, the biomass of both components increased exponentially with increasing concentrations of total N in the water. Along the nutrient gradient, phytoplankton biomass increased 5- to 10-fold, while epiphyte biomass increased 50- to 100-fold. Thus differences in nutrient conditions among study sites were more clearly reflected by epiphytes than phytoplankton.>

135. Silberstein, K., A. W. Chiffings, and A. J. McComb. 1986. **The loss of seagrass in Cockburn Sound, Western Australia. III. The effect of epiphytes on productivity of *Posidonia australis* Hook. F.** Aquatic Botany. 24: 355-371.

[EPIPHYTES, PRIMARY PRODUCTIVITY]

<The hypothesis was examined that increased epiphyte growth was responsible for a reduction in seagrass meadows in Cockburn Sound during the discharge of nutrient-rich effluent. One study site was in a deteriorating meadow near an effluent outfall, the other at similar depth in an unaffected meadow in more oceanic water. Seagrass production at the first site was less than that at the second, with 33% lower growth per shoot and 29% less dense meadow. Water at the former site had higher mean concentrations of chlorophyll and phosphate than the latter, but light reaching the seagrass meadows was not significantly different. Epiphyte loads (as dry weight or chlorophyll per unit leaf area) were 2-8 times higher at the former site. Seasonal changes in

epiphyte loads were well correlated with periphyton biomass on glass slides or plastic seagrass. Photosynthesis of leaf segments, with and without epiphytes, was measured using an oxygen meter in the laboratory; epiphyte photosynthetic rates were similar to those of periphyton on plastic, expressed per unit chlorophyll. The percentage reduction in light by known periphyton loads was measured, and used to calculate light reduction by epiphytes in the field, which was estimated to be 63% on average at the first site and 15% at the second. Pooling data for sites and seasons, there was a negative log-linear relationship between leaf production and epiphyte load. The observations provide support for the suggestion that seagrass loss in the Sound may be attributed to enhanced epiphyte loads following nutrient enrichment.>

136. Short, F. T. 1987. **Effects of sediment nutrients on seagrasses: literature review and mesocosm experiment.** Aquatic Botany. 27: 41-57.

[NUTRIENTS, SEDIMENTS]

<A review of the literature shows that seagrass growth, abundance and morphology are strongly linked to available nutrient resources. In north temperate climates and in habitats with terrigenous sediments, nitrogen limitation occurs in both intertidal and subtidal beds. Typically, seagrasses growing in terrigenous sediments have ample phosphorus but lack nitrogen, and the plant's chemical composition is depleted in nitrogen. However, seagrasses occurring in tropical environments and carbonate sediments appear to experience phosphorus limitation due to binding of phosphate in the sediments. Thus, it is the sediment geochemistry in seagrass beds that is important in determining the limiting nutrient to seagrass growth. Examination of the literature indicates that field research on seagrass relationships involves too many interactive factors to be able to say certainly that any one plant characteristic is caused by any one environmental factor. Using mesocosms (partially enclosed outdoor experimental set-ups) one environmental factor can be changed between the treatment tank and the control. Therefore, we can determine experimentally that a plant characteristic is affected by a particular altered environmental factor. Experimental mesocosms used to grow eelgrass, *Zostera marina* L., in substrata of varied nitrogen composition showed the dramatic effect of insufficient nitrogen on eelgrass growth, abundance and leaf morphology. Additionally, eelgrass leaf tissue from low ammonium sand substratum is significantly depleted in nitrogen, demonstrating the supposition that nitrogen is limiting in terrigenous environments.>

137. Odum, H. T. 1963. **Productivity measurements in Texas turtle grass and the effects of dredging an intracoastal channel.** Publications of the Institute of Marine Science University of Texas. 9: 48-58.

[DREDGING, PRIMARY PRODUCTIVITY, THALASSIA]

<Measurements of benthic chlorophyll "A" and diurnal oxygen productivity were made in turtle grass beds containing *Thalassia testudinum* and *Diplanthera wrightii* in Redfish Bay, Texas, before and after the dredging of an intracoastal canal. Moderate values of photosynthesis 2 to 8 g O_2/m^2 per day were observed in the spring of 1959 following a period of shading by turbid dredge-waters, but exceptionally high values 12 to 38 g/m^2 per day were recorded

the following spring in those areas not smothered with silt. Chlorophyll "A" in 1959 averaged 0.0338 g/m^2 but increased to 0.68 g/m^2 the following summer.>

138. Penhale, P. A. 1977. **Macrophyte-epiphyte biomass and productivity in an eelgrass (*Zostera marina* L.) community.** Biologie-Ecologie Mediterraneene. 26: 211-224.

[BIOMASS, EPIPHYTES, LIGHT, PHOTOSYNTHESIS, PRIMARY PRODUCTIVITY, TEMPERATURE, ZOSTERA]

<The biomass, productivity (^{14}C), and photosynthetic response to light and temperature of eelgrass, *Zostera marina* L. and its epiphytes was measured in a shallow estuarine system near Beaufort, North Carolina, during 1974. The maximum of the biomass (above-ground) was measured in March; this was followed by a general decline throughout the rest of the year. The average biomass was 105.0 g dry wt m^{-2}; 80.3 g dry wt m^{-2} was eelgrass and 24.7 g dry wt m^{-2} was epiphytes. The productivity of eelgrass averaged 0.88 mg C g^{-1} h^{-1} which was similar to that of the epiphytes, 0.65 mg C g^{-1} h^{-1}. Eelgrass and epiphyte productivity was low during the spring and early summer, was a maximum during late summer and fall, and declined during the winter; this progression was probably due to environmental factors associated with tidal heights. On an areal basis, the average annual productivity was 0.9 g C m^{-2} day^{-1} for eelgrass and 0.2 g C m^{-2} day^{-1} for the epiphytes. Rates of photosynthesis of both eelgrass and epiphytes increased with increasing temperature to an asymptotic value at which the system was light saturated. Both eelgrass and epiphytes had a temperature optimum of <29°C. A negative response to higher temperatures was also reflected in biomass measurements which showed the destruction of eelgrass with increasing summer temperatures. The data suggest that the primary productivity cycles of macrophytes and epiphytes are closely interrelated.>

139. Odum, H. T., P. R. Burkholder, and J. Rivero. 1959. **Measurements of productivity of turtle grass flats, reefs, and Bahia Fosforescente of southern Puerto Rico.** Publications of the Institute of Marine Science University of Texas. 6: 159-170.

[PRIMARY PRODUCTIVITY, THALASSIA]

<Measurements of oxygen, gross production and community respiration were made in two seasons and in 15 environments of southern Puerto Rico including coral reefs, sheets of anemones, turtle grass, and a luminescent bay. Metabolism ranged from 1 to 44 gm oxgyen/m^2/day. Production and respiration were greatest on the coral and anemone reefs and least in the phosphorescent bay. Seasonal exchanges were relatively small. New ways are given for analyzing diurnal curves of oxygen to obtain estimates of community metabolism.>

140. Powell, G. V. N. and F. C. Schaffner. 1991. **Water trapping by seagrasses occupying bank habitats in Florida Bay.** Estuarine Coastal and Shelf Science. 32: 43-60.

[FLORIDA BAY, MUDBANKS, SEAGRASS, THALASSIA, TIDAL DECELERATION, WATER LEVEL RECESSION, WATER TRAPPING]

<Seagrasses, largely *Thalassia testudinum*, occupy habitats atop shallow (<0.5 m deep) carbonate mudbanks adjoining basins up to 3 m deep in Florida Bay. We quantified the phenomenon of water trapping whereby, during low tides, the

seagrass meadow matrix retains a thin (<20 cm) layer of water high on the bank top despite water levels in the adjoining basins being some 25-70 cm lower. The matrix slows water flow off the banks such that changes in the rate at which water recedes through time approximates a sigmoid function of water level. A meadow with a large seagrass standing crop (59.0 g dry mass m^{-2} held a 17.4 cm layer of water atop the bank, while a meadow of lesser standing crop (less biomass per area, 13.0 g dry mass m^{-2}) that may have been facilitated by a topographical berm held just 3.3 cm of water. Similarly, on the bank slope the higher standing crop meadow held 10.4 cm of water while the bank slope meadow at the site with lesser standing crop held only 1.6 cm of water. Water trapping by seagrass can keep water on the banks for up to 8 h during low tides, preventing desiccation of the bank, and thereby providing permanent habitat for a diverse community of epibenthic fishes and invertebrates. The water trapping phenomenon presumably enhances overall prey abundance and diversity, and regulates the temporal patterns of prey exposure to different types of predation risk, e.g. to wading birds *vs* predatory fishes.>

141. Roth, N. C. and A. M. Pregnall. 1988. **Nitrate reductase activity in *Zostera marina*.** Marine Biology (New York). 99: 457-463.

[NITRATE NITROGEN, NUTRIENTS, ZOSTERA]

<Eelgrass (*Zostera marina* L.) has access to nutrient pools in both the water column and sediments. We investigated the potential for eelgrass to utilize nitrate nitrogen by measuring nitrate reductase (NR) activity with an *in vivo* tissue assay. Optimal incubation media contained 60 mM nitrate, 100 mM phosphate, and 0.5% 1-propanol at pH 7.0. Leaves had significantly higher NR activity than roots (350 vs 50 nmoles NO^-_2 produced g FW^{-1} h^{-1}). The effects of growing depth (0.8 m MLW, 1.2 m, 3.0 m, 5.0 m) and location within the eelgrass meadow (patch edge vs middle) on NR activity were examined using plants collected from three locations in the Woods Hole area, Massachusetts, USA, in July 1987. Neither depth nor position within the meadow appear to affect NR activity. Nitrate enrichment experiments (200 μM NO^-_3 for 6 d) were conducted in the laboratory to determine if NR activity could be induced. Certain plants from shallow depth (1.2 m) showed a significant response to enrichment, with NR activity increasing from <100 up to 950 nmoles NO^-_2 g FW^{-1} h^{-1} over 6 d. It appears that *Z. marina* growing in very shallow water (0.8 m) near a shoreline may be affected by ground water or surface run-off enrichments, since plants from this area exhibited rates up to 1 600 nmol NO^-_2 g FW^{-1} h^{-1}. Water samples from this location consistently had slightly higher NO^-_3 concentrations (1.4 μM) than all other collection sites (0.7 μM). Thus, it is possible that chronic run-off or localized groundwater inputs can create sufficient NO^-_3 enrichment in the water column to induce nitrate reductase activity in *Zostera* leaves.>

142. Walker, D. I. 1985. **Correlations between salinity and growth of the seagrass *Amphibolis antarctica* (Labill.) Sonder & Aschers., in Shark Bay, Western Australia, using a new method for measuring production rate.** Aquatic Botany. 23: 13-26.

[PRIMARY PRODUCTIVITY, SALINITY]

<A method of estimating above-ground productivity *in situ* of the seagrass *Amphibolis antarctica* (Labill.) Sonder & Aschers. has been devised, using tags to determine rates of leaf turnover. This has proved an effective

tool in establishing the behaviour of the species in relation to the gradient of increasing salinity which is present in Shark Bay. No seagrass was found beyond 64 o/oo, but measurement of production and biomass within dense patches of seagrass at different salinities revealed that these were at a maximum at a salinity of 42 o/oo, decreasing as the salinity increased and also at lower oceanic concentrations. Production rates ranged from 2 to 17 g dry weight m^{-2} day^{-1} with biomass from 600 to 2000 g m^{-2}, thus *Amphibolis antarctica* is one of the more productive Australian seagrass species, even in the hypersaline conditions of the Bay. Despite the obvious correlation between above-ground production and salinity, it is pointed out that the results are not taken to imply causality.>

143. Dawes, C. J. and E. W. Koch. 1990. **Physiological responses of the red algae *Gracilaria verrucosa* and *G. tikvahiae* before and after nutrient enrichment.** Bulletin of Marine Science. 46: 335-344.

[MACROALGAE, NUTRIENTS, PRIMARY PRODUCTIVITY]

<Pigment levels, chemical constituents, and photosynthetic responses of two estuarine populations of *Gracilaria verrucosa* and one neretic population of *G. tikvahiae* were monitored before, during and after culturing in nutrient-enriched seawater. Chlorophyll *a* and phycoerythrin, protein, soluble carbohydrate, lipid, and energy content did not change in both species cultured for 5 weeks in nutrient-enriched seawater and then for another 5 weeks without nutrients. Productivity (P_m) remained high after culture with and then without nutrients and no photoinhibition was evident at irradiances of 1200 μE m^{-2} s^{-1} after culture in any of the populations. An increase in the initial slope of the photosynthesis-irradiance curve (alpha) with no change in the compensation point irradiances (I_c) suggests an increase in photosynthetic efficiencey after culture in nutrient-enriched seawater. Exposure to enriched and then non-enriched seawater did not result in any shift in tolerance to 12 combinations of temperature and salinity based on photosynthetic and respiratory responses. The study extends previous findings regarding nutrient storage by seaweeds by demonstrating the ability of *Gracilaria* to tolerate stress after nutrient deprivation.>

144. Boon, P. I., D. J. W. Moriarty, and P. G. Saffigna. 1986. **Rates of ammonium turnover and the role of amino-acid deamination in seagrass *Zostera capricorni* beds of Moreton Bay, Australia.** Marine Biology (New York). 91: 259-268.

[AMINO ACIDS, AMMONIUM, SEDIMENTS]

<Samples of sediments from Australian seagrass *Zostera capricorni* Aschers.) beds were taken in June to August 1983 (for ^{15}N experiments) and November 1982 to January 1983 (^{14}N experiments). The ammonium pool turned-over every 0.4 to 0.8 d, as determined with a ^{15}N isotope-dilution technique. The ammonium pool in subtidal bare areas turned-over two to three times more slowly than in adjacent seagrass beds. Gross rates of *in situ* ammonium regeneration equalled those of utilization, and ranged from 0.04 to 0.35 μmol cm^{-3} d^{-1}, or from 50 to 490 mg N m^{-2} d^{-1} over the upper 10 cm of the sediment. The potential rate of glycine utilization, measured with a large excess of glycine added to anaerobic incubations, ranged from 0.21 to 0.39 μmol cm^{-3} d^{-1}, but *in situ* rates were probably much lower. Between 35 and 65% of added ^{15}N-glycine was deaminated over 12 h, and the remainder was most likely assimilated by microbes. Evidence

for the seagrasses taking up glycine was equivocal, owing to the rapid deamination of the amino acid and the likelihood that they assimilated the labelled ammonium produced from the glycine.>

145. Williams, S. L. and T. R. Fisher. 1985. **Kinetics of nitrogen-15 labelled ammonium uptake by *Caulerpa cupressoides* (Chlorophyta).** Phycologia. 21: 287-296.

[AMMONIUM, CAULERPA, SATURATION-TYPE KINETICS, SEDIMENT NUTRIENTS]
<The incorporation of $^{15}NH_4^+$ as a function of time and concentration was used to estimate ammonium uptake by *Caulerpa cupressoides* (West) C. Agardh, taken from its habitat on the sediments of Tague Bay lagoon, St. Croix, U.S. Virgin Islands. ^{15}N-based uptake rates followed Michaelis-Menten type saturation kinetics; the maximum uptake rate was 8.7 ± 3.0 μmol N / g dry wt·h at 25°C and the half-saturation constant was 48 ± 10 μM (X ± SE). The high half-saturation constant reflects the dependence of *Caulerpa* on sediment pore waters as a nitrogen source. Calculations of uptake from isotope time course data were compared to estimates made from ammonium depletion. More ammonium disappeared than could be accounted for by the incorporation of ^{15}N in *Caulerpa*, and isotope dilution of the ammonium pool is shown not to be responsible for underestimates of uptake primarily because large ^{15}N additions (40-300 μM) were used. It is suggested that either (1) a secondary ammonium sink such as wall sorption or bacterial uptake significantly influenced ammonium concentrations, or (2) ^{15}N was lost as labelled dissolved organic nitrogen or volatilized during ^{15}N sample preparation.>

146. Williams, S. L. and W. C. Dennison. 1990. **Light availability and diurnal growth of a green macroalga (*Caulerpa cupressoides*) and a seagrass (*Halophila decipiens*).** Marine Biology (New York). 106: 437-443.

[CAULERPA, LIGHT, MACROALGAE, SEAGRASS]
<The effects of daily light period on diurnal growth patterns of a green macroalga (*Caulerpa cupressoides* v. *lycopodium* f. *elegans* (J. Agardh) Weber-van Bosse) and a seagrass (*Halophila decipiens* Ostenfeld) were investigated in Salt River submarine canyon in the US Virgin Islands in summer 1984. The daily light period, in which quantum irradiance exceeded the light saturation point for photosynthesis of the macroalga and seagrass, was manipulated *in situ* using lamps and shades. Plant growth was measured every 6 h for 7 d under natural and experimental daily light periods. *C. cupressoides* grew at the same rate day and night. *H. decipiens* grew more during the day than at night, a pattern that persisted under continuous light and dark treatments, indicating endogenous control of diurnal growth. Growth vs daily light period curves indicate that *C. cupressoides* grew faster than *H. decipiens* in short daily light periods, consistent with the observation that the macroalga penetrates to deeper water than the seagrass in Salt River canyon. Overall growth (day + night) of *H. decipiens* was unaffected in lengthened light periods and reduced in shortened light periods. Chlorophyll content of *C. cupressoides* was not correlated with light availability, while that of *H. decipiens* was positively correlated. The alga and seagrass had different diurnal growth patterns but similar overall growth responses to daily light periods. This study shows that diurnal growth

patterns are probably under endogenous control, while overall growth is a response to *in situ* light conditions.>

147. Williams, S. L. 1988. ***Thalassia testudinum* productivity and grazing by green turtles in a highly disturbed seagrass bed.** Marine Biology (New York). 98: 447-455.

[PRIMARY PRODUCTIVITY, THALASSIA, TURTLE GRAZING]

<There has been an historical decline in the seagrass beds in Maho and Francis Bays, St. John, U.S. Virgin Islands: presently (1986) there are only five small seagrass beds in shallow water. These seagrass beds are highly disturbed by heavy boat usage and are intensively grazed by the green turtle *Chelonia mydas* L. Fifteen to 50 boats anchor each night in the bays: anchor scars cause a loss of up to 6.5 m^2 d^{-1} or 1.8% yr^{-1} of the seagrass beds. Seagrasses regrew into such scars only minimally within a period of 7 mo. The size of the green turtle population was estimated at 50 subadults and their feeding behavior was determined by direct observation and radiotelemetry. The behavior of the green turtles differed from other observations published on the species. Here, the turtles grazed all available *Thalassia testudinum*, their preferred seagrass food, rather than creating discrete grazing scars, and spent all their waking hours (9 h per day) feeding. Areal productivity of *T. testudinum* leaves (33 to 97 mg dry wt m^{-2} d^{-1}) in the bays was at least an order of magnitude lower than published values or than the productivity of another, less-disturbed seagrass bed on St. John, despite having comparable leaf-shoot density. Leaf shoots were stunted, fragile, achlorotic, and had only two leaves as opposed to the five leaves per shoot more typically seen. The green turtle population was near the estimated carrying capacity of *T. testudinum*, based on the standing crop and productivity of *T. testudinum* and the grazing rate of the turtles. The effect of disturbance of *T. testudinum* from boats and turtles was assessed by excluding these with emergent fences. Within 3 months of protection, the areal and shoot-specific productivity of *T. testudinum* leaves as well as leaf size increased significantly compared to unprotected areas. Conservation efforts are recommended in Maho Bays and Francis because seagrass productivity is low, disturbance rates are higher than recovery rates, the turtles cannot increase further their feeding rate in order to compensate for such factors, and there are few alternate sources of *T. testudinum* on the north shore of St. John.>

148. Cowper, S. W. 1978. **The drift algae community of seagrass beds in Redfish Bay, Texas.** Marine Science (New York). 21: 125-132.

[DRIFT ALGAE, LIGHT COMPETITION]

<Large quantities of drift algae found over seagrass beds in Redfish Bay, Texas showed net productivity and competed for light with the seagrasses. The biomass was very small compared to that of the seagrasses; however, it served as resources for animals and most importantly to reduce light over the seagrasses.>

149. Williams, S. L. 1984. **Uptake of sediment ammonium and translocation in a marine green macroalga *Caulerpa cupressoides*.** Limnology and Oceanography. 29: 374-379.

[AMMONIUM, CAULERPA, MACROALGAE, SEDIMENTS]

<$^{15}NH_4^+$ was taken up by algal rhizoids and translocated to photosynthetic portions of the thalli. The half-saturation constant for NH_4^+ uptake (K_s = 107 μM N) was similar to concentrations in interstitial waters, indicating algal adaptation to nutrient sources in the sediment rather than those of the nutrient-limited water.>

150. Williams, S. L. 1984. **Decomposition of the tropical macroalga *Caulerpa cupressoides* (West) c. Agardh: field and laboratory studies.** Journal of Experimental Marine Biology and Ecology. 80: 109-124.

[CAULERPA, DECOMPOSITION, MACROALGAE, NUTRIENT RELEASE]

<The decomposition of the marine tropical green macroalga *Caulerpa cupressoides* (West) C. Agardh was studied in order to assess its importance as a means of supplying nutrients to the sediments of seagrass beds which are in the early stages of colonization. *Caulerpa* is a colonizer species in the succession of seagrass beds. The dynamics of *Caulerpa* decomposition were also compared to that of other macroalgae and marine vascular plants. *Caulerpa* lost 50% of its original biomass in 7 days in litter bags positioned in the water column and sediments of Tague Bay lagoon, St. Croix, U.S. Virgin Islands. This rate is extremely rapid in comparison to that of vascular plants. *Caulerpa* was allowed to decompose in flasks for 141 days. During this time reducing conditions (Eh< -100 mv) were established within 7 days and subsequently up to 1.8 mmol dissolved nitrogen was released from 25 g wet weight algae. The predominant form of nitrogen released was dissolved organics. Nitrate and nitrite were found only in trace concentrations after reducing conditions were established. The C/N ratio in the particulate matter of decomposing *Caulerpa* decreased significantly over time in the flasks and increased significantly in the sediments. The low percent N and high C/N ratios of decomposing *Caulerpa* suggest it would be poor quality food for detritivores. The amount of nitrogen released during the decomposition of *Caulerpa* was extrapolated to conditions in nature and was found sufficient to support a minimum of 10% of the nitrogen requirement of seagrasses as they colonize Tague Bay lagoon.>

151. Williams, S. L., V. A. Breda, T. W. Anderson, and B. B. Nyden. 1985. **Growth and sediment disturbances of *Caulerpa* spp. (Chlorophyta) in a submarine canyon.** Marine Ecology Progress Series. 21: 275-281.

[CAULERPA, GROWTH, SEDIMENT DISTURBANCE]

<Growth rates of 7 species of *Caulerpa* were measured *in situ* at depths of 20 m in Salt River canyon, St. Croix, US Virgin Islands. Mean stolon elongation rate for all species of *Caulerpa* studied was approximately 1 cm d^{-1}. Dry biomass accumulated in this new growth was less than 10 mg d^{-1}, and specific growth rates were less than 10% d^{-1}; these values are low compared to rates of many benthic macroalgae. Macrofauna (conchs, ghost shrimp, hermit crabs, urchins, rays) were observed disturbing sediment. Plants were uprooted or buried by animals that foraged, burrowed, and made excavations or sediment mounds. Plants experimentally uprooted or buried to simulate effects of animal activities had significantly lower stolon elongation, biomass accumulation, and specific growth rates than control plants. We hypothesize that the productivity of these algae is limited in part by animal-mediated sediment disturbances.>

152. Williams, S. L. 1981. ***Caulerpa cupressoides*: The relationship of the uptake of sediment ammonium and of algal decompostion to seagrass bed colonization.** Doctor of Philosophy Thesis, University of Maryland.

[ALGAL DECOMPOSITION, AMMONIUM, CAULERPA, NUTRIENTS, SEDIMENTS]

<*Caulerpa cupressoides* is a member of Caulerpales, an order of siphonous green macroalgae which commonly inhabit tropical and subtropical marine soft bottom environments. These algae are colonizers of seagrass beds which form the climax vegetation in such habitats. The purpose of the research was to investigate aspects of the ecology of *Caulerpa cupressoides* which might have functional importance for its role as a representative colonizer species. Such aspects include the uptake of nitrogen and its subsequent release to the environment following the death and decomposition of the alga. The ability of *C. cupressoides* to take up and translocate ammonium dissolved in sediment interstitial waters was tested by supplying the stable isotope ^{15}N-labelled ammonium to the rhizoids only and analyzing for the appearance of the label in blade tissue, using mass spectrometry. The experiments resulted in the first verification of utilization of sediment nutrient sources by a nonvascular marine plant. The half-saturation constant for ammonium uptake by *Caulerpa cupressoides* was similar to concentrations found dissolved in sediment interstitial waters. These results indicate that in addition to the ability to utilize the sediment nutrient source, *Caulerpa* is adapted to using it, rather than the water column, as the primary source of nutrient supply. *Caulerpa* was allowed to decompose in flasks and in litter bags *in situ* and the resultant changes in wet weight, Eh, pH, carbon, nitrogen, the carbon:nitrogen ratio, and dissolved nitrogen (NH_4, NO_3, NO_2, organic) were monitored for up to 141 days. These experiments indicated that the alga decomposes very rapidly, especially compared to marine vascular plants and other macroalgae. *Caulerpa*'s decomposition represents a rapid means of nutrient input to the sediments and results in detritus which is not suitable for detritivore nutrition, based on carbon:nitrogen ratios. The conclusion reached is that the manner of nutrient uptake and decomposition of *Caulerpa* contribute to nitrogen accumulation in the sediments. This function of a colonizer species is probably more important in terms of seagrass bed succession than is that of sediment stabilization.>

153. Holmes, M. G. and W. H. Klein. 1987. **The light and temperature environments.** In: Plant life in aquatic and amphibious habitats. Special Publication Number 5 of the British Ecological Society. Edited by R. M. M. Crawford, 3-22. Oxford: Blackwell Scientific Publications.

[ATTENUATION, LIGHT, TEMPERATURE]

<The light environment experienced by aquatic plants is reviewed in terms of both the energy input from radiation and the information about the environment which an aquatic organism can derive from the quantity and quality of the radiation. Account is taken of the spectral attenuation of natural radiation by surrounding objects such as vegetation, water and suspended particles. The additional influence of screening by tissue surrounding the photoreceptor is incorporated into the analysis. The implications for photoresponses under water are then derived from knowledge about the spectral

and quantum operating ranges of plant photoreceptors. Conclusions about photosynthetic limitations, photomorphogenesis, and photoperiodism under water are discussed in relation to the restrictions imposed by the underwater temperature environment.>

154. Szmant, A. M. 1987. **Biological investigations of the Black Creek vicinity, Biscayne National Park.** Research/Resources Management Report Ser-87. Springfield, VA: US Department of Commerce, National Technical Information Service.

[DISTRIBUTION, HALODULE, NUTRIENTS, SALINITY, TANNINS, THALASSIA]

<This report describes the results of a series of studies conducted for Biscayne National Park that sought to determine (a) whether there had been a shift in floral composition of the grassbed communities within the Black Creek area of the park, and if so, (b) what might be the factors responsible for the changes in floral composition. Specifically, the National Park Service was concerned that *Thalassia* was being replaced by *Halodule* in certain affected areas. The study found lower water-column salinities, higher water-column nutrient concentrations, and more intense water color (brown tannins) in the affected where *Thalassia* was being replaced by *Halodule*. The likely source for these nutrient, salinity, and color anomalies is discharge water from the various drainage canals in the area from Military Canal to Fender Point.>

155. Armstrong, N. E. and V. N. Gordon. 1979. **Nutrient exchange studies on the seagrasses of Texas.** Final Report Submitted to the Texas Department of Water Resources - Interagency Cooperation Contract No. IAC (78-79)-0914. Austin: The University of Texas at Austin.

[GROWTH, NUTRIENTS, SALINITY, TEMPERATURE]

<The seagrasses of Redfish Bay and the upper Laguna Madre have been studied for their growth rate characteristics and nutrient exchange rates in order to estimate the contribution seagrasses make to the nutrient budget of estuaries and the importance of freshwater inflows to maintaining the seagrass systems. This study consisted of a review of the literature, a determination of the standing stock of three seagrasses (*Thalassia testudinum*, *Halodule beaudettii*, and *Ruppia maritima*) near Stedman Island in Redfish Bay, Texas and in the upper Laguna Madre, the distribution of plant biomass among plant components, the measurement of leaf growth rates as a function of temperature and salinity, and the measurement of nutrient exchange rates from seagrass microcosms.>

156. Moffler, M. D. and M. J. Durako. 1987. **Reproductive biology of the tropical-subtropical seagrasses of the southeastern United States.** In: Proceedings of the Symposium on Subtropical-Tropical Seagrasses of the Southeastern United States. Florida Marine Research Publications No. 42. Edited by M. J. Durako, R. C. Phillips, and R. R. Lewis III, 77-88. St. Petersburg: Florida Department of Natural Resources, Bureau of Marine Research.

[REPRODUCTION]

<Studies of reproductive biology in seagrasses of the southeastern United States have addressed descriptive morphology and anatomy, reproductive

physiology, seed occurrence, and germination. *Halodule wrightii* Aschers., *Halophila engelmannii* Aschers., *Syringodium filiforme* Kütz., and *Thalassia testudinum* Banks ex König are dioecious; *Halophia decipiens* Ostenfeld and *Ruppa maritima* L. are monoecious. In *Halophila johnsonii* Eiseman, only female flowers are known. With the exception of *R. maritima*, which has hydroanemophilous pollination, these species have hydrophilous pollination. Recent reproductive-ecology studies suggest that reproductive patterns are due to phenoplastic responses and/or genetic adaptation to physico-chemical environmental conditions. Laboratory and field investigations indicate that reproductive periodicity is temperature controlled, but proposed mechanisms are disputed. Water temperature appears to influence floral development and may be important in determining subsequent flower densities and fruit/seed production. Flowering under continuous light *in vitro* suggests that photoperiod plays a limited role in floral induction. Flower expression and anthesis, however, may be influenced by photoperiod. Floral morpho-ontogenetic studies of *T. testudinum* field populations demonstrated the presence of early-stage inflorescences during short- and long-day photoperiods, further suggesting day neutrality in this species. High initial reproductive efforts, annual variation in male sex expression, secondary sex characters, and possible interaction of ramet age with sex expression have also been detected.>

157. Fry, B., S. A. Macko, and J. C. Zieman. 1987. **Review of stable isotopic investigations of food webs in seagrass meadows.** In: Proceedings of the symposium on subtropical-tropical seagrasses of the southeastern United States. Florida Marine Research Publications No. 42. Edited by M. J. Durako, R. C. Phillips, and R. R. Lewis III, 191-209. St. Petersburg: Florida Department of Natural Resources, Bureau of Marine Research.

[CARBON ISOTOPES, NUTRIENTS]

<Seagrasses are important sources of organic matter for food webs in many coastal ecosystems. However, stable isotopic investigations conducted over the past decade have shown that phytoplankton and epiphytic algae can have an equal or greater nutritional importance than seagrasses for consumers in many seagrass meadows. Nutrient availability may govern the relative importance of algal and seagrass foods, with the result that eutrophic waters favor food webs based on algae, but detrital seagrasses are more important in oligotrophic waters. This review summarizes many previously unpublished stable isotopic studies of seagrass ecosystems. Assumptions commonly made in interpretation of isotopic values are evaluated, and four main conclusions are drawn: (1) Within one species, seagrass $\delta^{13}C$ varies significantly between individuals, populations, and seasons. (2) Carbon isotopic changes during seagrass decomposition are small, ca. 1%. (3) Little fractionation of carbon isotopes occurs during food web processing of live or detrital seagrasses. (4) Benthic algae can have carbon isotopic values close to those of seagrasses; consequently, $\delta^{13}C$ measurements are not always unambiguous tracers of seagrass carbon. Latter sections show that stable hydrogen, nitrogen, and sulfur isotopic measurements can be used in conjunction with carbon isotopic measurements to show consumer dependence on seagrass organic matter, and that isotopic measurements can be useful for mapping highly localized food webs.>

158. Bell, C. K. 1979. **Nitrogen fixation (acetylene reduction) associated with seagrasses along the northern Florida Gulf coast.** Master of Science Thesis, The Florida State University, College of Arts and Sciences.

[BIOMASS, NITROGEN FIXATION, NUTRIENTS]

<Nitrogen fixation associated with the seagrasses *Thalassia testudinum*, *Syringodium filiforme*, and *Halodule wrightii* was investigated at two sites on the northern Florida Gulf coast. At the Edward Ball Marine Laboratory, N-fixation on an areal basis, leaf area index, and leaf plus epiphyte biomass decreased with depth suggesting that light has a major influence on seagrass and epiphyte growth and the N-fixation associated with epiphytes. In monotypic *T. testudinum* stands in St. Joe Bay, the amount of organic matter in the sediment increased from west to south to east stations. This increase was accompanied by increases in epiphyte biomass and N-fixation on an areal basis and by a decrease in root biomass. These patterns support the hypothesis that the morphology of *T. testudinum* is related to the percentage of ash-free dry weight of the sediment, which indirectly affects N-fixation. N-fixation by the rhizosphere-bacteria systems was difficult to interpret, although it was determined to be an order of magnitude lower than N-fixation by the leaf-epiphyte systems. Increasing amounts of N-fixation and increase in total amount of ammonium in the samples were found when larger amounts of sediment were added to south St. Joe Bay root samples suggesting that energy limitation may play a role in the rhizosphere-bacteria N-fixation in these grassbeds.>

159. Osborne, N. M. 1979. **The influence of sediment characteristics and seagrass species on the distribution and abundance of polychaetous annelids in north Florida seagrass beds.** Master of Science Thesis, The Florida State University, College of Arts and Sciences.

[ORGANIC CONTENT, SEDIMENTS]

<Seagrass species composition and leaf area, sediment organic content, and sediment stability induced by seagrasses influence the distribution and abundance of polychaetes in north Florida seagrass beds. An investigation of the polychaete communities at three geographically close *Thalassia testudinum* stands which differed strongly in sediment characteristics revealed two species groups apparently influenced by the sediment composition. Differences in leaf biomass apparently influenced a third species group. No large change in infauna trophic structure was observed between the different stations. A study of the polychaete community at five stations along a transect through a grassbed containing three seagrass species revealed a sharp change in species composition and infauna trophic structure. The sites with high plant density contained numerous tubicolous and surface crawling polychaetes, while the site with a low standing crop of seagrass contained numerous burrowing mobile deposit feeders. This dramatic change appears to result from the change in sediment stability. The sites which contained a dense seagrass cover and tube building polychaetes had a stable sediment surface creating a favorable environment for numerous small, surface crawling syllids. Sediment reworking by mobile deposit feeders at the site with sparse seagrass cover together with exposure to water movement resulted in an unstable sediment surface and an unfavorable environment for tube building and small crawling polychaetes. Differences in species composition

among the sites with high seagrass density may be related to preferences of certain polychaetes for particular seagrass species.>

160. Bittaker, H. F. 1975. **A comparative study of the phytoplankton and benthic macrophyte primary productivity in a polluted versus and unpolluted coastal area**. Master of Science Thesis, Florida State University, College of Arts and Sciences.

[COLOR, NUTRIENTS, PRIMARY PRODUCTIVITY, TURBIDITY]
<A two-year long study of corresponding stations in two adjacent and similar coastal systems, the polluted Fenholloway and the unpolluted Econfina, showed striking differences between the two areas. In comparison to the Econfina stations, Fenholloway stations were generally characterized by: (1) Higher phosphate, nitrate and nitrite concentrations, along with larger month-to-month station nutrient variations. (2) Higher turbidities. (3) Higher color values, with greater light absorbances for all wavelengths measured (400 - 700 nm). (4) Shallower secchi disk readings. (5) Higher vertical extinction coefficient values. (6) Higher chlorophyll *a* concentrations. (7) Lower benthic macrophyte biomasses. (8) Greater surface and water column phytoplankton productivity rates (on an areal basis). (9) Smaller phytoplankton assimilation numbers. (10) Lower benthic macrophyte productivity rates (on an areal basis). (11) Larger benthic macrophyte assimilation numbers. (12) Lower total water column productivity rates (on an areal basis). Productivity differences between the two regions were hypothesized to be due to the increased nutrient concentrations and decreased benthic light conditions present at the Fenholloway stations. Calculations of seagrass turnover times indicated that pioneer species *Halodule wrightii* and probably *Halophila engelmanni* had the shortest turnover times, whereas "climax" species *Thalassia testudinum* and perhaps *Syringodium filiforme* had the longest. Except in the case of *Halophila*, roots and rhizomes averaged turnover times on the order of a whole growing season. Seed production by *Thalassia* (by far the most important meadow-forming species) has not been observed or recorded in the northeast Gulf of Mexico. Therefore, although some indications of possible first stage recovery were noted in the Fenholloway area five to six months after the initiation of a water pollution abatement program by the river's main polluter, it is unlikely, due to continuing high light extinction and probable slow dominant species invasion rates, that the nearshore Fenholloway area will support well-developed seagrass communities in the immediate future.>

161. Goering, J. J. and P. L. Parker. 1972. **Nitrogen fixation by epiphytes on sea grasses**. Limnology and Oceanography. 17: 320-323.

[EPIPHYTES, NITROGEN FIXATION, NUTRIENTS]
<Four species of sea grasses in Redfish Bay, Texas, *Thalassia testudinum*, *Cymodocea manatorum*, *Diplanthera wrightii*, and *Ruppia maritima*, showed nitrogen-fixing activity as measured by the acetylene reduction technique. Evidence that epiphytes and not the macrophytes are responsible for the observed fixation is presented that leads to the suggestion that nitrogen-fixing epiphytes play an important role in the nitrogen economy of sea-grass communities.>

162. Fenchel, T. 1970. **Studies on the decomposition of organic detritus dervied from the turtle grass *Thalassia testudinum***. Limnology and Oceanography. 15: 14-20.

[DECOMPOSITION, DETRITUS, THALASSIA]

<A study was made of the quantitative composition of the microbial communities living on detrital particles derived from the turtle grass *Thalassia testudinum*. The number of organisms on and the rate of oxygen consumption of the detritus are approximately proportional to the total surface area. Field samples of detritus harbored about 3 X 10^9 bacteria, 5 X 10^7 flagellates, 5 X 10^4 ciliates, and 2 X 10^7 diatoms and consumed from 0.7 to 1.4 mg O_2/hr per g dry wt. The detritus-consuming amphipod *Parhyalella whelpleyi* feeds on detrital particles and on its own fecal pellets but it only uses the microorganisms; the dead plant residue passes undigested through the intestine. After a few days the microbial communities living on fecal pellets are qualitatively and quantitatively comparable to those living on other detrital particles. The amphipods decrease the particle size of the detritus thereby increasing it total surface and thus the microbial activity. In less than 4 days, the mechanical activity of the amphipods may increase the detrital O_2 uptake by 110% of their own metabolic rate. Measurements of respiratory rates of the amphipods will therefore give a much too low estimate of their total role in the ecosystem.>

163. Millhouse, J. and S. Strother. 1986. **The effect of pH on the inorganic carbon source for photosynthesis in the seagrass *Zostera muelleri* Irmisch ex Aschers.** Aquatic Botany. 24: 199-209.

[CARBON, NUTRIENTS, PHOTOSYNTHESIS, ZOSTERA]

<The ability of the seagrass *Zostera muelleri* Irmisch ex Aschers. to use HCO_3^- as well as CO_2 for photosynthesis was investigated by measuring photosynthetic O_2 evolution over a range of pH values. It was found that the apparent K_m CO_2 fell from 0.128 mM at pH 7.9 to 0.016 mM at pH 9.1 indicating that HCO_3^- as well as CO_2 may act as a substrate for photosynthesis. The true K_m CO_2 could not be determined due to inhibition of photosynthesis at pHs less than 7.8.K_m CO_2 must be at least 0.128 mM, the apparent K_m at pH 7.9, and is probably of the order 0.200 mM CO_2, the same as that reported for other marine plants. K_m HCO_3^- is about 20 mM when CO_2 dependent photosynthesis is minimal. Such a high K_m HCO_3^- resembles values reported for freshwater, rather than marine plants. Photosynthetic O_2 evolution is not saturated with respect to total inorganic carbon in natural seawater (pH 8.2). It is suggested that the distinctive shoulder from pH 8.1 to 8.5 in the pH profile of photosynthetic O_2 evolution at a constant concentration of inorganic carbon is caused by an effect of pH on HCO_3^- uptake. The effect of pH on HCO_3^- uptake was determined by constructing a pH profile of photosynthesis at constant HCO_3^- concentration, and subtracting the estimated contribution of CO_2 to photosynthesis from this rate. The resultant curve has a maximum at pH 8.4 and declines sharply at pHs less than 8.>

164. Andrews, T. J. and K. M. Abel. 1979. **Photosynthetic carbon metabolism in seagrasses, ^{14}C-labeling evidence for the C_3 pathway.** Plant Physiology (Bethesda). 63: 650-656.

[CARBON METABOLISM, PHOTOSYNTHESIS]

<The $\delta^{13}C$ values of several seagrasses were considerably less negative than those of terrestrial C_3 plants and tended toward those of terrestrial C_4 plants. However, for *Thalassia hemprichii* (Ehrenb.) Aschers and *Halophila spinulosa*(R. Br.) Aschers, phosphoglycerate and other C_3 cycle intermediates

predominated among the early labeled products of photosynthesis in ^{14}C-labeled seawater (more than 90% at the earliest times) and the labeling pattern at longer times was brought about by the operation of the C_3 pathway. Malate and aspartate together accounted for only a minor fraction of the total fixed label at all times and the kinetic data of this labeling were not at all consistent with these compounds being early intermediates in seagrass photosynthesis. Pulse-chase ^{14}C-labeling studies further substantiated these conclusions. Significant labeling of photorespiratory intermediates was observed in all experiments. The kinetics of total fixation of label during some steady-state and pulse-chase experiments suggested that there may be an intermediate pool of inorganic carbon of variable size closely associated with the leaves, either externally or internally. Such a pool may be one cause for the C_4-like carbon isotope ratios of seagrasses.>

165. Moriarty, D. J. W., R. L. Iverson, and P. C. Pollard. 1986. **Exudation of organic carbon by the seagrass *Halodule wrightii* Aschers. and its effect on bacterial growth in the sediment.** Journal of Experimental Marine Biology and Ecology. 96: 115-126.

[BACTERIA, EXUDATES, HALODULE, PHOSPHOLIPID, SEAGRASS, THYMIDINE]

<Between 6 and 28% (mean: 14%) of ^{14}C fixed by the leaves of *Halodule wrightii* Aschers. was translocated to the rhizomes and roots within 6 h. In the same time period 6 to 17% (mean: 11%) of total fixed ^{14}C was exuded into the sediment. About 1% was excreted into the water column. Bacterial production was determined using two methods: the rate of tritiated thymidine incorporation into DNA and the rate of ^{32}P incorporation into phospholipid. Bacterial production was 180 to 190 mg C m^{-2} day^{-1} and was probably dependent on root decomposition as well as exudation. From the results of lipid analyses and synthesis it was concluded that bacteria were utilizing all the exuded organic ^{14}C. Most bacterial production was in the top 20 mm of sediment, which was the zone with the greatest root and rhizome biomass. Most of the ^{14}C exudate was also found in this zone.>

166. Cooper, L. W. and C. P. McRoy. 1988. **Stable carbon isotope ratio variations in marine macrophytes along intertidal gradients.** Oecologia (Berlin). 77: 238-241.

[CARBON ISOTOPES, EGREGIA, HALOSACCION, PHYLLOSPADIX, SEAGRASS]

<The hypothesis that relative water motion and boundary layer diffusion processes affect carbon isotope ratios of aquatic plants was tested in tidal pool and surge zone comparisons of the surfgrass *Phyllospadix* spp. No evidence was found that submerged plants growing in still upper tidal pools were istopically diffrent from those growing submerged in lower tidal surge zones. Significant decreases in ^{13}C/^{12}C ratios for plants growing emersed in the intertidal may have been caused by uptake of atmospheric carbon dioxide. Marine algae (*Egregia menziesii* and *Halosaccion americanum*) growing at the same location and tidal elevations as the seagrasses showed somewhat different isotopic fractionation patterns, suggesting that causes of isotopic variability in the seagrasses were not necessarily the same as those in the two marine algae.>

167. Frankignoulle, M. and A. Distèche. 1984. **CO_2 chemistry in the water column above a *Posidonia* seagrass bed and related air-sea exchanges.** Oceanologica Acta. 7: 209-219.

[AIR-SEA EXCHANGES, BUFFER FACTOR, CO_2/PH, POSIDONIA, SEAWATER]

<An often sinusoidal diel pH signal is detectable at -0.5 m and -8 m above a *Posidonia oceanica* (L.) Delile seagrass bed (Bay of Calvi, Corsice). Total alkalinity, temperature and pH measurements permit description of the CO_2 chemistry in the 8 m water column, and its daily and yearly fluctuations. The homogenous buffer factor $[(\beta=\delta \ln PCO_2 \text{ water}/\delta \ln \Sigma\ CO_2)]$ and the physicochemical buffer factor $[(\beta'=\delta\Sigma\ CO_2 \text{ water}/\delta pH)]$ are calculated and shown, as expected, to depend essentially on temperature and mean pH. The yearly variation of total alkalinity shows a sudden drop (0.06 meq./l) during summer, which most probably finds its explanation in the sudden increase of activity of Melobesiae epiphytes. However, carbonate losses and gains in the water column are balanced out over a yearly period. The mean pH is lowest in June-July. 90% of the corresponding maximum acidification is explained by the temperature increase and the total alkalinity diminution. CO_2 diel oscillation is largest close to the annual acidity maximum, and drops to zero in winter, accurately reflecting the biological activity of the seagrass bed. The corresponding $\Sigma\ CO_2$ change permits estimation of the net production and respiration rates of the total ecosystem. Net production at its highest is 5.3 g C m^{-2} d^{-1} in agreement with observations by Bay (1978). Air-sea CO_2 exchanges were measured while monitoring the CO_2 chemistry in the water column. The observed out-fluxes vary considerably from hour to hour. Mean values show a yearly maximum in summer (mean September $F_o=11.7.10^{-6}$ mg Co_2 cm^{-2} min^{-1}), but there is no flux during winter and an influx has so far never been measured. The atmospheric partial CO_2 pressure is 325-330 ppm. It would appear that the reentry of CO_2 into the sea requires $\beta = 10$ at pH = 8.29, t = 12°C, PCO_2 water = 300 ppm (lowest observed β value is 10.45, pH 8.23, t = 11.8°C, PCO_2 water = 360 ppm). Slight overpressure (25 to 50 ppm) appears to be required to force the surface microlayer. The whole Posidonia belt in the Mediterranean basin may be considered as a CO_2 emitter which ceases in winter and is modulated by the ecosystem photosynthesis and respiration, temperature and sea-state.>

168. Pulich, W. M., Jr. 1982. **Culture studies of *Halodule wrightii* Aschers. edaphic requirements.** Botanica Marina. 25: 477-482.

[GROWTH, HALODULE, NUTRIENTS, SEDIMENTS]

<Growth rates of *Halodule wrightii* Aschers. were compared during laboratory culture on artificial sediments containing varying amounts of soluble sulfide and iron, but similar amounts of nitrogen, phosphorus, and manganese. These experiments documented that moderate levels of H_2S (ca 0.5 mM) and very low levels of soluble Fe (0.5-2.0 μg ml^{-1}) in the sediment water correlated with maximal *Halodule* growth rates. Interstitial water-soluble Fe above 20 μg ml^{-1} appeared to inhibit *Halodule* growth, possibly by interfering with sulfur metabolism or limiting the availability of phosphorus to the plants. Excess phosphate, but not Mn, added to the sediments containing low H_2S levels counteracted some degree of Fe inhibition. Sediment H_2S concentrations greater than 1 mM were also correlated with decreased growth rates, verifying that a poised level of H_2S between 0.2-1.0 mM favored *Halodule* growth. The methodology described herein is proposed for laboratory culture studies of other seagrasses.>

169. Millhouse, J. and S. Strother. 1987. **Further characteristics of salt-dependent bicarbonate use by the seagrass *Zostera muelleri*.** Journal of Experimental Botany. 38: 1055-1068.

[BICARBONATE, SALINITY, ZOSTERA]

<The contribution of HCO_3^- to photosynthetic O_2 evolution in the seagrass *Zostera muelleri* Irmisch ex Aschers. increased with increasing salinity of the bathing seawater when the inorganic carbon concentration was kept constant. $K_{1/2}$ (seawater salts) for HCO_3^--dependent photosynthesis was 66% of seawater salinity. Both short- and long-term pretreatment at low salinities stimulated photosynthesis in full strength seawater. Twenty four hours pre-incubation of seagrass plants in 3.0 mol m^{-3} $NaHCO_3$ resulted in increased photosynthesis at all salinities, apparently due to stimulation of HCO_3^- use ($K_{1/2}$(seawater salts)= 26%)$\cdot V_{max}(HCO_3^-)$ was not affected by low salinity pretreatment. The kinetics of HCO_3^- stimulation by the major seawater cations was investigated. Ca^{2+} was the most effective cation with the highest $V_{max}(HCO_3^-)$ and with $K_{1/2}(Ca^{2+}) = 14$ mol m^{-3}. Mg^{2+} was also very effective at less than 50 mol m^{-3} but higher concentrations were inhibitory. This inhibition cannot be accounted for solely by precipitation of $MgCO_3$. Na^+ and K^+ were both capable of stimulating HCO_3^- use. Stimulation was in two distinct parts. Up to 500 mol m^{-3}, both citrate and chloride salts gave similar results ($K_{1/2}(Na^+)$ 81 mol m^{-3}, $V_{max}(HCO_3^-)$ 0.26 μmol O_2 mg^{-1} chl min^{-1}), but use of citrate salts above 500 mol m^{-3} caused a second stimulation of HCO_3^- use ($K_{1/2}(Na^+)$ 830 mol m^{-3}, $V_{max}(HCO_3^-)$ 0.68 μmol 02 mg^{-1} chl min-1). $V_{max}(HCO_3^-)$ for the second-phase Na^+ or K^+ stimulation was of the same order as for Ca^{2+}-stimulated HCO_3^- use. To further characterize salt-dependent HCO_3^- use, the sensitivity of photosynthesis to Tris and TES buffers was investigated. The effects of Tris appear to be due to the action of $Tris^+$ causing stimulation of HCO_3^--dependent photosynthesis in the absence of salt, but inhibition of HCO_3^- use in saline media. TES has no effect on photosynthesis. External carbonic anhydrase, although implicated in salt-dependent HCO_3^- use in Z. muelleri, could not be detected in whole leaves.>

170. Penhale, P. A. and W. O. Smith Jr. 1977. **Excretion of dissolved organic carbon by eelgrass (*Zostera marina*) and its epiphytes.** Limnology and Oceanography. 22: 400-407.

[CARBON DISSOLVED ORGANIC, EPIPHYTES, ZOSTERA]

<The release of dissolved organic carbon (DOC) by eelgrass (*Zostera marina*) and its epiphytic community was examined in a shallow estuarine system near Beaufort, North Carolina. Excretion by eelgrass alone, by epiphytes alone, and by heavily epiphytized eelgrass was determined by radiocarbon techniques. The percent of total photosynthate excreted was small in all cases: 0.9% for heavily colonized plants, 1.5% for *Zostera* alone, and 2.0% for the epiphytic community. The amount released by the eelgrass and epiphytes was proportional to the total amount of carbon fixed. Excretion rates in the dark were much lower than in the light. The rate of excretion increased after the plant underwent desiccation. The annual primary production and DOC excretion by phytoplankton, cordgrass (*Spartina alterniflora*), and the eelgrass community was estimated: 47% of the total annual primary production and 14% of the total excreted material was contributed by eelgrass and its epiphytes. Thus the eelgrass and epiphytes can play an important role in carbon cycling in estuarine systems.>

171. Thayer, G. W., P. L. Parker, M. W. LaCroix, and B. Fry. 1978. **The stable carbon isotope ratio of some components of an eelgrass *Zostera marina* bed.** Oecologia (Berlin). 35: 1-12.

[CARBON ISOTOPES, SEDIMENTS, ZOSTERA]

<Living and dead *Zostera marina* blades, plankton samples, sediments, and several animal components of an eelgrass bed near Beaufort, N.C. were collected and analyzed for $^{13}C/^{12}C$ ratios ($\delta\ ^{13}C$). The $\delta\ ^{13}C$ values of producer and consumer organisms were compared in order to examine the possible origins of organic matter present in the consumers. Living and dead eelgrass blades displayed similar $\delta^{13}C$ values. -12.2 and -10.6 per mil o/oo respectively, while the epiphytic community growing on the grass blades had a mean isotope ratio of -16.0 o/oo. Animal components analyzed represented five major feeding-mode categories: invertebrates living on grass blades an presumably feeding on the epibiota (-15.1 o/oo), deposit feeding invertebrates (-15.0 o/oo), predatory and omnivorous invertebrates (-16.7 o/oo), suspension and surface feeding invertebrates (-18.3 o/oo) and omnivorous fish (-16.8 o/oo). Organisms commonly found on the grass blades appeared to feed primarily on the epibiota growing on the blades. It is hypothesized that the epibiota derive some of their carbon from DOC released by the *Zostera* blade. The urchin, *Lytechinus variegatus*, and the brittle star, *Ophioderma brevispinum*, both deposit feeders, appeared to derive a major proportion of their carbon from eelgrass. With the exception of the shrimp, *Alpheus heterochaelis*, and the pipefish, Syngnathus floridae, the majority of other organisms analyzed appeared to be linked more directly to a plankton-carbon food chain than to a seagrass-carbon system in this relatively young eelgrass bed.>

172. Fry, B., R. Lutes, M. Northam, and P. L. Parker. 1982. **A $^{13}C/^{12}C$ comparison of food webs in Caribbean seagrass meadows and coral reefs.** Aquatic Botany. 14: 389-398.

[CARBON ISOTOPES, SEDIMENTS]

<Stable carbon isotope analyses of more than 140 plant, animal, and sediment samples from the Miskito Banks, Nicaragua and St. Croix, U.S. Virgin Islands, were used to assess carbon flow in Caribbean seagrass meadows and coral reefs. Plants at the base of food webs had widely divergent $\delta^{13}C$ values, ranging from -4.0 (*Syringodium filiforme* Kütz)to -37 o/oo (an unidentified red alga). Isotopic values of 13 to 35 algal species ranged from -8.8 to -15.0 o/oo, and were similar to the -9.9 to -13.2 o/oo values of the dominant Caribbean seagrass, *Thalassia testudinum* Banks ex König. This isotopic similarity prevented a clear assessment of the role that *Thalassia* plays in supporting Caribbean food webs. However, a 4-6 o/oo ^{13}C enrichment was found among fish from seagrass meadows and coral reefs vs. fish collected offshore. This enrichment indicated that benthic algae and seagrasses together contribute at least 48-76% of the carbon found in fish from the former, shallow-water habitats.>

173. Beer, S. and Y. Waisel. 1979. **Some photosynthetic carbon fixation properties of seagrasses.** Aquatic Botany. 7: 129-138.

[BICARBONATE, CARBON FIXATION, PHOTOSYNTHESIS]

<*Cymodocea nodosa* (Ucria) Aschers. and *Halophila ovalis* (R. Br.) Hook. fil., two seagrass species from the Mediterranean and Red Sea, respectively, were investigated for their ability to use HCO_3^- and CO_2 as exogenous carbon substrates in photosynthesis. Two other Red Sea species, *Halodule uninervis* (Forsk.) Aschers. and *Syringodium isoetifolium* (Aschers.) Dandy, were subjected to short time ^{14}C pulse-chase experiments in order to classify them as C_3 or C_4 plants. Experiments show that *Cymodocea nodosa* and *Halophila ovalis* use HCO_3^- as their principal exogenous carbon source when photosynthesizing in natural conditions. Rates of net photosynthesis at saturating HCO_3^- concentrations, which also occur in a natural seawater, 0.4 and 0.05 μmoles O_2 min^{-1} mg^{-1} chlorophyll, respectively. When additional CO_2 was provided to this system, photosynthetic rates increased. This effect was especially marked in *Cymodocea nodosa*. In this species, photosynthetic rates were three times higher at saturating CO_2 than they were at saturating HCO_3^- concentrations. This agrees with earlier results for different seagrasses including the two other species dealt with in this paper. In *Halophila ovalis*, photosynthetic rates were similar at saturating concentrations of both forms of carbon. The significance of these findings is discussed. The ^{14}C pulse-chase experiments show that *Halodule uninervis* and *Syringodium isoetifolium* are C_3 plants, even though they do possess features that might indicate C_4 metabolism. These plants are unlike *Thalassia testudinum* Banks ex König which was shown earlier to be a C_4 plant. The diversity of photosynthetic pathways in seagrasses is discussed.>

174. Benedict, C. R. and J. R. Scott. 1976. **Photosynthetic carbon metabolism of a marine grass.** Plant Physiology (Bethesda). 57: 876-880.

[CARBON METABOLISM, PHOTOSYNTHESIS, THALASSIA]

<The $\delta^{13}C$ value of a tropical marine grass *Thalassia testudinum* is -9.04 o/oo. This value is similar to the $\delta^{13}C$ value of terrestrial tropical grasses. The $\delta^{13}C$ values of the organic acid fraction, the amino acid fraction, the sugar fraction, malic acid, and glucose are: -11.2 o/oo, -13.1 o/oo, -10.1 o\oo, -11.1 o/oo, and -11.5 o/oo, respectively. The $\delta^{13}C$ values of malic acid and glucose of *Thalassia* are similar to the δ13C values of these intermediates in sorghum leaves and attest to the presence of the photosynthetic C_4-dicarboxylic acid pathway in this marine grass. The inorganic HCO_3^- for the growth of the grass fluctuates between -6.7 to -2.7 o/oo during the day. If CO_2 fixation in *Thalassia* is catalyzed by phosphoenolpyruvate carboxylase (which would result in a -3 o/oo fractionation between HCO_3^- and malic acid), the predicted $\delta^{13}C$ value for *Thalassia* would be -9.7 to -5.7 o/oo. This range is close to the observed range of -12.6 to -7.8 o/oo for *Thalassia* and agree with the operation of the C_4-dicarboxylic acid pathway in this plant. The early products of the fixation of HCO_3^- in the leaf sections are malic acid and aspartic acid which are similar to the early products of CO_2 fixation in C_4 terrestrial plants. Electron microscopy of the leaves of *Thalassia* reveal thick walled epidermal cells exceedingly rich in mitochondria and C_3-type chloroplasts. The mesophyll cells have many different shapes and surround air lacunae which contain O_2 and CO_2. The mesophyll cells are highly vacuolated and the parietal cytoplasm contains an occasional chloroplast. This chloroplast contains grana but the lamellar system is not as developed as the system in epidermal chloroplasts. Extensive phloem tissue is present but the xylem elements are reduced in this aquatic grass. The vascular tissue is

not surrounded by bundle sheath cells. This work does not establish the exact relation between structure and function in *Thalassia*, but it does show the C_4-type photosynthetic carbon metabolism in this grass involves epidermal and mesophyll cells and internally produced O_2 and CO_2 in the air lacunae.>

175. Frankignoulle, M. and J. M. Bouquegneau. 1987. **Seasonal variation of the diel carbon budget of a marine macrophyte ecosystem.** Marine Ecology Progress Series. 38: 197-199.

[CARBON BUDGET, POSIDONIA]

<Seasonal variation of the diel carbon budget of a *Posidonia oceanica* seagrass ecosystem was estimated in the Bay of Calvi (Corsica): the ecosystem served as a carbon sink from December to July and as a source from August to November. Comparison of these results with net primary production of the vegetation suggests that organisms associated with the seagrasses consume a quantity of oxygen, expressed as inorganic carbon, equal to about 55% of net organic carbon production. The quantitative significance of the annual carbon sink constituted by *P. oceanica* seagrass beds when determined using only vegetative biomass and turnover is discussed.>

176. Boon, P. I., D. J. W. Moriarty, and P. G. Saffigna. 1986. **Nitrate metabolism in sediments from seagrass (*Zostera capricorni*) beds of Moreton Bay, Australia.** Marine Biology (New York). 91: 269-275.

[NITRATE NITROGEN, NUTRIENTS, SEDIMENTS, ZOSTERA]

<The fate of nitrate in sediments from seagrass (*Zostera capricorni* Aschers.) beds of Moreton Bay on the subtropical eastern coast of Queensland, Australia, was investigated. Added nitrate was metabolized at rates of 0.4 to 3.4 $\mu g\ N\ cm^{-3}\ d^{-1}$ when sediments were incubated under anaerobic conditions with a large excess of nitrate. The potential rate of nitrate utilization was as rapid in sediments from subtidal bare areas as from adjacent seagrass beds. Ammonium was produced rapidly from ^{15}N-nitrate by microbial action in all the subtidal sediments examined. After 12 h of incubation, 13 to 28% of the ^{15}N initially added as labelled nitrate was detected as labelled ammonium in the sediments. Denitrification, although not measured directly, appeared to be a relatively minor fate of nitrate. Benthic microbes took up large amounts of ^{15}N but only after a delay of 6 h, this pattern could have been due to induction and synthesis of the enzymes necessary for nitrate uptake, and the assimilation of labelled ammonium. Under field conditions, assimilation by seagrasses and denitrification by bacteria were probably not significant sinks for nitrate in comparison with uptake by benthic microbes and dissimilatory reduction to ammonium.>

177. Morse, J. W., J. J. Zullig, R. L. Iverson, G. R. Choppin, A. Mucci, and F. J. Millero. 1987. **The influence of seagrass beds on carbonate sediments in the Bahamas.** Marine Chemistry. 22: 71-83.

[NUTRIENTS, SEDIMENTS]

<Chemical variables were measured in calcium-carbonate-rich sediments inhabited by the dominant tropical seagrass, *Thalassia testudinum*, and in adjacent seagrass-free sediments at several locations in the Bahamas Islands. Pore-water alkalinity and p_{co_2} were consistently greater, while pH was consistently lower in sediment-pore waters within seagrass beds. The ammonium

and molybdate-reactive phosphate concentrations in sediment-pore water were variable for vegetated, compared with unvegetated, sample locations. *Thalassia testudinum* can generate very large amounts of organic matter within calcium-carbonate-rich sediments. However, little of the organic matter is retained in the sediment and the effect of that organic matter on pore water chemical factors appears to be surprisingly small. These observations are markedly different from those for seagrass beds in high latitude clastic sediments and in *Syringodium filiforme* seagrass beds near San Salvador Island, where major influences of the seagrass beds on sediment chemistry have been observed. The generally coarser grain size of the carbonate sediments may be a primary factor contributing to these differences.>

178. Boon, P. I. 1986. **Uptake and release of nitrogen compounds in coral reef and seagrass, *Thalassia hemprichii* (Ehrenb.) Aschers., bed sediments at Lizard Island, Queensland.** Australian Journal of Marine and Freshwater Research. 37: 11-19.

[NUTRIENTS]

<The interstitial water in sediments from coral reef areas and seagrass *T. hemprichii* beds at Lizard Island contained 6-48 μmol l^{-1} ammonium, 4-7 μmol l^{-1} nitrate plus nitrite, and 1.5-2.5 μmol l^{-1} soluble reactive phosphorus. Concentrations of total dissolved primary amines were an order of magnitude higher in sediments from seagrass beds (about 140 μmol l^{-1}) than from coral reef areas (about 10 μmol l^{-1}). Ammonium-nitrogen was produced at rates of 0.7, 6, and 10 nmol g^{-1} h^{-1} in sediments from a bare beach, reef flat and seagrass bed, respectively. Added glycine and nitrate were also rapidly metabolized by microbes in the sediment (3 to >5 nmol g^{-1} h^{-1}).>

179. Klumpp, D. W. and A. Van Der Valk. 1984. **Nutritional quality of seagrasses (*Posidonia australis* and *Heterozostera tasmanica*): comparison between species and stages of decomposition.** Marine Biology Letters. 5: 67-83.

[DECOMPOSITION, DETRITUS, HETEROZOSTERA, NUTRIENT CONTENT, POSIDONIA]

<The nutritional qualities of seagrass fronds (*Posidonia australis* and *Heterozostera tasmanica*), both living and at various stages of decomposition, were compared and related to observations on the feeding preferences of animals for particular seagrass species. Components analyzed were carbon, nitrogen, phosphorus, calcium, magnesium, potassium, sodium, energy content, organic matter and fibre. The enhancement of nutrient quality with the formation of detritus was found to be a long term process. Compared with living fronds, the debris from the natural system and that produced by ageing in mesh bags or exposed bundles were depleted in most nutrient components. Carbon, nitrogen and energy content of natural *Posidonia* debris were approximately 50% of that in living material. The majority of mass loss from fronds during decomposition was attributed to leaching and saprophytic decay, and this proceeded more rapidly in *Heterozostera* than in *Posidonia*. Both species of seagrass were typically high in fibre (50-60% of dry weight) but some structural components, especially hemicellulose, degraded rapidly in nature. For Posidonia, the formation of large deposits of detritus, and a prevalence of epiphytes on fronds, both living and dead, make this species a major food source to detritivores and epiphyte-grazers. Zosteracean seagrasses by comparison have a higher porportion of soluble organic

substances and these are utilized by those animals which feed by rupturing plant cells. It was concluded that seagrass tissue is nutritionally inadequate as a complete diet for most marine animals.>

180. Pregnall, A. M., R. D. Smith, and R. S. Alberte. 1987. **Glutamine synthetase activity and free amino acid pools of eelgrass (*Zostera marina* L.) roots**. Journal of Experimental Marine Biology and Ecology. 106: 211-228.

[AMINO ACIDS, AMMONIA UPTAKE, GLUTAMINE SYNTHETASE, HALODULE, ZOSTERA]

<Activity of the enzyme glutamine synthetase (GS, EC 6.3.1.2) was determined *in vitro* for roots of the marine angiosperm *Zostera marina* L. (eelgrass) collected from a population in Great Harbor, Woods Hole, Massachusetts, U.S.A. The GS synthetase activity was lowest in roots of plants collected from the shallow region of the eelgrass bed (12.0 μmol$\cdot$g^{-1} (fresh wt)$\cdot$h^{-1}) and increased in the mid (3.0 m, 40.3 μmol$\cdot$g^{-1}(fresh wt)$\cdot$h^{-1}) and deep (5.0 m, 72.3 μmol$\cdot$g^{-1}(fresh wt)$\cdot$h^{-1}) plant collection depths. GS transferase activity increased with collection depth in a similar manner: shallow, 28.6 μmol$\cdot$g^{-1}(fresh wt)$\cdot$h^{-1}; mid, 52.0 μmol$\cdot$g^{-1} (fresh wt)$\cdot$h^{-1}; deep, 92.8 μmol$\cdot$g^{-1} (fresh wt)$\cdot$h^{-1}. When sediment-embedded plants were held in continuous darkness for 2 days to create extended root anoxia, root GS activities nearly doubled. In contrast, *in vivo* incorporation of ^{14}C-glutamate into glutamine and protein residue remained constant or declined under short-term hypoxia and anoxia. During aerobic recovery from anoxia, root labelling of glutamine and protein increased markedly. Free amino acid patterns of eelgrass roots growing *in situ* were determined over a diurnal cycle. Total free amino acid content was maximal at dawn and decreased 50% by noon. In contrast, the proportion of glutamine was lowest at dawn and maximal at noon for both shallow and deep growing plants. Despite differences in depth-specific plant sizes, root/rhizome/shoot ratios, and relative growth rates, the daily whole plant nitrogen demand of shallow and deep growing plants were equivalent. When corrected for assay temperature response, the enzyme synthetase activities measured *in vitro* suggest that all of the plant nitrogen assimilation requirements can be met within daylight hours during the period of peak summer biomass.>

181. Smith, G. W., S. S. Hayasaka, and G. W. Thayer. 1984. **Ammonification of amino acids by the rhizoplane microflora of *Zostera marina* L. and *Halodule wrightii* Aschers**. Botanica Marina. 27: 23-27.

[AMINO ACIDS, AMMONIA UPTAKE, RHIZOPLANE BACTERIA]

<Rhizoplane bacteria associated with *Zostera marina* and *Halodule wrightii* were shown to deaminate selected amino acids, including some of those found in plant root exudate and tissue. Subsequently, ammonia was absorbed by the root-rhizomes and liberated from the leaves into the surrounding medium. Ammonification of glutamate was temperature dependent and increased up to 45°C. Approximately one-third of the rhizoplane isolates were obligate aerobes, the remaining being facultative anaerobes. Relative rates of glutamate ammonification were inversely related to the active growth season of these seagrasses, with the highest seasonal ammonification rates occurring during the summer and late fall for *Z. marina* and *H. wrightii*, respectively. Our results

indicate that rhizoplane associated ammonification of amino acids should play an important role in the cycling of nitrogen in seagrass ecosystems.>

182. Lindeboom, H. J. and B. H. H. De Bree. 1982. **Daily production and consumption in an eelgrass (*Zostera marina*) community in saline Lake Grevelingen; discrepancies between the O_2 and ^{14}C method.** Netherlands Journal of Sea Research. 16: 362-379.

[PRIMARY PRODUCTIVITY, ZOSTERA]

<During seven 28-hour measurement periods in 1980 and 1981 the oxygen production and consumption in an eelgrass community in Lake Grevelingen were determined using light and dark plexiglass enclosures. Applying an oxygen to carbon conversion factor of 0.29 the amount of carbon fixed and the amount of organic carbon consumed were estimated. During the daylight period a net production was found, whereas over 24 hours a net production in spring and a net consumption later in the year were found. On an annual basis, production and consumption were approximately equal, with a net production occurring in the over-ground eelgrass community and a net consumption in the sediment. Close to the plexiglass enclosures samples were taken in order to measure primary production with the ^{14}C method. Comparison of the results of the O_2 and ^{14}C methods showed that the first yielded considerably higher C fixation values (1.2 to 2.0 times for the production of *Zostera marina* and 2.7 to 5.4 times for that of the microphytobenthos). Production values assessed with the ^{14}C method in comparison with the consumption values assessed with the O_2 method were always much too low, and a carbon mass balance based on the two methods fails.>

183. Powell, G. V. N., W. J. Kenworthy, and J. W. Fourqurean. 1989. **Experimental evidence for nutrient limitation of seagrass growth in a tropical estuary with restricted circulation.** Bulletin of Marine Science. 44: 324-340.

[CIRCULATION, NUTRIENT LIMITATION]

<We studied the impacts of additions of nutrients to a seagrass community on a carbonate mud bank in Florida Bay. Shallow mud banks dampen lunar tide in Florida Bay, and empoundment and channelization of the upland watershed (the Everglades) have reduced freshwater input, resulting in restricted circulation and reduced nutrient availability. Nutrients were supplied by seabirds defecating from experimental roosts. Seabirds used the roosts 87% of the time so the input of nutrients was constant and quantifiable. The birds delivered approximately 2-4 g of excrement per day, resulting in an average loading rate of 0.052 g N and 0.009 g P m^{-2} d^{-1}. Only a portion of the excrement is immediately released as inorganic NH_3 and PO_4; about 80% reaches the sediment surface in a relatively insoluble form. There was a significant buildup of phosphate and ammonium in the pore water at the enriched sites. The ammonium profile of low concentrations at the surface and then increasing with a steep slope through 20 cm suggests a rapid uptake and demand for mineralized nitrogen. Phosphorus in contrast had relatively high levels at the surface. Nutrient addition significantly increased areal leaf production and standing crop of *Thalassia testudinum* and *Halodule wrightii*. Above ground biomass at enriched sites averaged twice controls while below ground biomass was not significantly different between fertilized and control plats. Increased standing crop was produced primarily through longer, wider blades by *Thalassia* and longer blades

and increased short shoot density by *Halodule*. *Thalassia* areal leaf production was 60% greater at enriched sites than at controls. *Halodule* areal leaf production increased by three orders of magnitude at enriched sites. Tissue nutrient content and nitrogen fixation assays suggest that phosphorus availability limits seagrass growth in unenriched conditions, but that nitrogen becomes limiting with the addition of bird excrement.>

184. Mackin, J. E. and R. C. Aller. 1984. **Ammonium adsorption in marine sediments.** Limnology and Oceanography. 29: 250-257.

[AMMONIUM, NITROGEN, SEDIMENTS]

<One important reaction which affects dissolved NH_4^+ distributions in marine sediments is reversible adsorption on sediment solids. We investigate both the temperature dependency and spatial variability of the NH_4^+ linear adsorption coefficient, K, in marine sediments. For a wide range of environments, because of approximately offsetting variations in sediment porosity and properties such as clay mineral and organic matter content, K is nearly constant (1.2 ± 0.1) in terrigenous, surface, marine sediments. The value of K also does not vary significantly as a function of temperature. In biogenic and very high porosity (≥ 0.95) sediments, K may be somewhat lower than for other sedimentary environments. Sediments containing seagrass detritus such as *Thalassia* may be expected to exhibit relatively high K values.>

185. Dawes, C. J., C. P. Chen, J. Jewett-Smith, A. Marsh, and S. A. Watts. 1984. **Effect of phosphate and ammonium levels on photosynthetic and respiratory responses of the red alga *Gracilaria verrucosa*.** Marine Biology (New York). 78: 325-328.

[GRACILARIA, NUTRIENTS, PHOTOSYNTHESIS, SALINITY, TEMPERATURE]

<*Gracilaria verrucosa* (Hudson) Papenfuss exposed to nutrient enriched media (0.1 mM PO_4; 1.0 mM NH_4^+) by pulse feeding 2 h every third day for a period of 5 wk at 20°C and 25-30 o/oo salinity showed significantly higher rates of photosynthesis regardless of photon flux density correlated with increased pigment levels. Algae in non-enriched media showed significantly higher levels of soluble carbohydrates and decreased levels of phycoerythrin and chlorophyll *a*. Photosynthetic and respiratory responses to temperature (15°, 25°, 30°C and salinity (15, 25, 30 o/oo S) combinations indicate broad tolerances by both nutrient enriched and non-nutrient enriched algae. Photosynthetic and respiratory rates were highest at the high temperature. Pulse-fed algae had significantly higher photosynthetic rates than non-nutrient enriched plants at all temperature and salinity combinations. Non-nutrient enriched algae had significantly higher respiratory rates that nutrient enriched algae at only 30°C and 15 o/oo S. The respiratory rates of both nutrient enriched and non-nutrient algae decreased under combinations of higher temperatures and salinities. *G. verrucosa*, grown without nutrients, has lower tolerances to environmental stresses.>

186. Zimmerman, R. C., R. D. Smith, and R. S. Alberte. 1987. **Is growth of eelgrass nitrogen limited? A numerical simulation of the effects of light and nitrogen on the growth dynamics of *Zostera marina*.** Marine Ecology Progress Series. 41: 167-176.

[LIGHT, NITROGEN UPTAKE, NUTRIENTS, ZOSTERA]

<A numerical model of nitrogen uptake and growth was developed for the temperate seagrass *Zostera marina* L. Goals were to evaluate the relative effects of light and nitrogen availability on nitrogen uptake and partitioning between leaf and root tissue, and to estimate nitrogen concentrations in the sediment and water column required to saturate growth. Steady-state predictions are quite robust with respect to a range of parameter values justified by available data. The calculations indicated that roots are probably more important in overall nitrogen acquisition in most light and nitrogen environments encountered *in situ*, but may contribute less than 50% of the total uptake in low light. The model also predicted ammonium to be a much more important source of nitrogen than nitrate. Nitrogen concentrations required to saturate growth (even for nitrate) were estimated to be at least 50% below concentrations commonly reported *in situ*, an indication that nitrogen limitation of *Z. marina* is probably very rare in nature.>

187. Boon, P. I. 1986. **Nitrogen pools in seagrass beds of *Cymodocea serrulata* and *Zostera capricorni* of Moreton Bay, Australia.** Aquatic Botany. 25: 1-19.

[NITROGEN, SEDIMENTS]

<The sediments from seagrass beds and adjacent bare areas on the subtropical, eastern coast of Australia had total nitrogen contents of 80-400 μg N g^{-1}, or 25-78 g N m^{-2} to a depth of 20 cm. The seagrasses had biomasses of 300-600 g DW m^{-2}, and total nitrogen contents of 4-15 mg N g^{-1}, respectively; this corresponded to a nitrogen content of 2.8-5.8 g N m^{-2}, or about 6% of the total amount of nitrogen in the seagrass bed. Particulate detritus in the sediments, and dissolved compounds in the interstitial water accounted for 92-99%, and 0.4-0.9% of the total amount of nitrogen in the bed, respectively. The major contributor to the interstitial nitrogen was dissolved organic nitrogen of unkown composition (170-300 mg N m^{-2}); other components included ammonium (20-56 mg N m^{-2}, nitrate plus nitrite (3-15 mg N m^{-2}) and dissolved primary amines 10-37 mg N m^{-2}). The concentration of the major dissolved free amino acid in the interstitial water (glutamic acid; 2-30 μmol^{-1}) was slightly less than that of ammonium (15-60 μmol l^{-1}). The presence of seagrasses had a strong effect on concentrations of nitrate plus nitrite, soluble reactive phosphorus, and dissolved free amino acids in the interstitial water. Nitrogen, rather than phosphorus, was implicated as the nutrient most likely to limit the growth of the seagrasses.>

188. Pirc, H. and B. Wollenweber. 1988. **Seasonal changes in nitrogen, free amino acids, and C/N ratio in Mediterranean seagrasses.** Marine Ecology Progress Series. 9: 167-179.

[AMINO ACIDS, CARBON, CYMODOCEA, NITROGEN, POSIDONIA, SEASONALITY, ZOSTERA]

<Seasonal changes in nitrogen, free amino acids, and carbon were investigated in the three Mediterranean seagrasses *Posidonia oceanica*, *Cymodocea nodosa*, and *Zostera noltii*. Leaves, rhizomes, roots, as well as dead plant material were analyzed separately. Highest N-concentrations were obtained in the winter months, regardless of species or plant part. In contrast to the other two species, the N-content in *Posidonia* was higher in the rhizomes than in the leaves. In the investigated species, marked differences in the free amino acid (FAA) composition were detected between species: Proline, lacking in *Posidonia*,

was the main component in *Cymodocea*. In *Posidonia*, FAA decreased from 320 $\mu mol \cdot g^{-1}$(dry wt) in leaf sheaths to 1.5 $\mu mol \cdot g^{-1}$(dry wt) in the leaf tips. The function of proline as a possible storage and/or stress metabolite is discussed. High C/N values in dead *P. oceanica* and *C. nodosa* rhizomes as well as in *P. oceanica* wrack seem to be related to considerable resistance to decomposition. Low C/N ratios did not increase in detached *C. nodosa* and *Z. noltii* leaves, which began to decompose shortly after detachment from the plants.>

189. Kenworthy, W. J., J. C. Zieman, and G. W. Thayer. 1982. **Evidence for the influence of seagrasses on the benthic nitrogen cycle in a coastal plain estuary near Beaufort, North Carolina.** Oecologia (Berlin). 54: 152-158.

[NUTRIENTS, SEDIMENTS]

<A study was undertaken to evaluate the interrelationship between the presence of seagrasses, *Zostera marina* and *Halodule wrightii*, and the physical and chemical properties of sediments in a coastal plain estuary near Beaufort, North Carolina. In sediments underlying a cover of seagrass, silt-clay, organic matter, exchangeable ammonium, ammonium dissolved in pore waters and total nitrogen were larger than in unvegetated profiles. The magnitude of the physical and chemical properties of sediments varied according to the location of the station in relation to the vegetation, as well as the continuity in the distribution of the seagrass. The largest pools of nitrogen, the finest sediment texture, and the greatest organic matter content were in sediments associated with the mid bed regions of seagrass meadows, intermediate at the edges of the bed and small isolated patches of grass, and least in unvegetated substrate. General conclusions from this study are: 1) once established, seagrasses appear capable of modifying the sediment texture as well as the organic matter and nitrogen content; 2) nitrogen accumulates beneath the vegetation suggesting that vegetated sediments are sinks; however, functional recycling mechanisms seem to be operating as suggested by the larger magnitude of remineralized nitrogen in the vegetated profiles; and 3) the establishment of seagrasses in this geographical region are not necessarily restricted by the sediment properties measured in this study. These data and conclusions are discussed in regard to an application of contemporary theories of ecosystem development to seagrass systems.>

190. Short, F. T. and C. P. McRoy. 1984. **Nitrogen uptake by leaves and roots of the seagrass *Zostera marina* L.** Botanica Marina. 27: 547-555.

[NITROGEN UPTAKE, ZOSTERA]

<Nitrogen uptake by eelgrass, *Zostera marina* L., was measured using ^{15}N-labelled ammonium and nitrate. Ammonium was the preferred nitrogen resource, as demonstrated by its rapid uptake in both leaves and roots. Eelgrass leaves rapidly accumulated ammonium by adsorption and absorption in direct proportion to the ammonium concentration in the water column. Due to higher sediment ammonium concentration, ammonium uptake by eelgrass roots appears to be the major source of nitrogen to the plant. These studies indicate that eelgrass can utilize both sediment and water column nitrogen sources to attain high production rates.>

191. Kemp, W. M., L. Murray, J. Borum, and K. Sand-Jensen. 1987. **Diel growth in eelgrass *Zostera marina*.** Marine Ecology Progress Series. 41: 79-86.

[LEAF GROWTH, OXYGEN, ZOSTERA]

<Growth of eelgrass *Zostera marina* leaves was determined by sequential measurements of leaf length at time intervals of 4 to 12 h. Leaf growth rates at night were consistently lower (30 to 40%) compared to daytime rates, and night-time rates were highly correlated with growth during the previous day. Diel patterns of O_2 metabolism (measured at 2 to 4 h intervals) and leaf growth (at 4 h intervals) generally followed the daily irradiance cycle, with maximum growth and O_2 production rates both occurring near midday. Rapid (hours to days) responses to changes in environmental conditions such as light and sediment fertility were detected using this leaf growth method. Quantitative comparison of diel integrals of growth (increases in leaf, root, and rhizome biomass) and net O_2 production indicated that the two processes were in relative balance. Although eelgrass leaf growth was determined readily here on short time-scales, measurement of total plant growth required a longer study period approaching the plastochrone interval (leaf formation time). It was demonstrated, however, that separate calibration studies relating root-rhizome growth to leaf growth can be conducted (over 1 to 2 wk) to allow estimates of short-term (4 to 12 h) responses of total plant growth to changes in environmental conditions.>

192. Pellikaan, G. C. and P. H. Nienhuis. 1988. **Nutrient uptake and release during growth and decomposition of eelgrass, *Zostera marina* L., and its effects on the nutrient dynamics of Lake Grevelingen.** Aquatic Botany. 30: 189-214.

[DECOMPOSITION, GROWTH, NUTRIENT UPTAKE, ZOSTERA]

<Since 1971, when the Grevelingen estuary was turned into a shallow saline lake, meadows of eelgrass have extended rapidly. The role of eelgrass, *Zostera marina* L., in the uptake and release of nutrients was investigated for 1977 in relation to studies on the nutrient dynamics of Lake Grevelingen. The internal concentrations of carbon, nitrogen and phosphorus in the above-ground parts showed minima for nitrogen (2% of dry weight (DW)) and phosphorus (0.15% of DW) in summer. The total year's production of above-ground biomass was calculated as 8510 tons ash-free dry weight (AFDW) for the entire Lake Grevelingen; 93% of eelgrass biomass entered the detritus pool. The decomposition processes of leaching, fragmentation, mineralization, transport and burial are presented in a descriptive model, and input and output data are given. An eelgrass sub-system in shallow water and a gully sub-system in the deeper parts where eelgrass detritus is deposited have been recognized. In autumn, ca.2% of the eelgrass annual production accumulated near the seawalls. In spring, only 4% of the eelgrass production of the previous year was detected as coarse and fine detritus on the bottom of gullies and sandflats. Eelgrass decomposes slowly and it is likely that, according to the model calculations, after 1 year about one-third of the total eelgrass detritus pool finally accumulates as ultrafine particulate organic matter (POM) on the anoxic gully bottom. From 1971 until 1978, Lake Grevelingen was isolated from the North Sea and rivers. During this period, the dissolved organic carbon (DOC) pool in the water column increased by 2-3 mg l^{-1}. Refractory DOC derived from leaching eelgrass detritus contributed 25-40% of this increase. The amounts of nutrients

fixed by eelgrass during the growing season, May-August, were estimated at 3829 tons of carbon, 178 tons of nitrogen and 29 tons of phosphorus. These amounts are quite high compared to the results of nutrient balance studies of Lake Grevelingen. It can be concluded that eelgrass is of such importance for the nutrient cycling in Lake Grevelingen that its role must be integrated in the existing nutrient balance model.>

193. Kenworthy, W. J., C. Currin, G. Smith, and G. Thayer. 1987. **The abundance, biomass and acetylene reduction activity of bacteria associated with decomposing rhizomes of two seagrasses, *Zostera marina* and *Thalassia testudinum*.** Aquatic Botany. 27: 97-119.

[ACETYLENE REDUCTION, BACTERIA, DECOMPOSITION]

<Bacteria growing on and in close association with the rhizome detritus of two seagrasses, *Zostera marina* L. and *Thalassia testudinum* Banks ex König, were examined using epiflurescence and scanning electron microscopy. The microbial community consisted of a diverse assemblage of bacteria dominated in biomass by large rod-shaped and filamentous cells. The large size of cells and the occurrence of measurable acetylene reduction activity suggested that a healthy, growing population of bacteria was associated with the rhizome detritus. Bacteria carbon biomass ranged between 5.2 X 10^{-5} and 1.7 X 10^{-3} g C gdw^{-1} of rhizome detritus. Depending on cell doubling times, bacterial metabolism could account for a substantial portion of the turnover of rhizome detritus. Estimates of potential microbial production, nitrogen fixation and the physico-chemical nature of rhizome detritus are discussed and we propose hypotheses for the disposition of this detrital organic matter.>

194. Kirkman, H., F. B. Griffiths, and R. R. Parker. 1979. **The release of reactive phosphate by a *Posidonia australis* seagrass community.** Aquatic Botany. 6: 329-337.

[NUTRIENTS, PHOSPHORUS]

<Reactive phosphate was released into the water over a bed of seagrass *Posidonia australis* Hook. *f.*, both day and night. No release occurred over a similar unvegetated area nearby. Estimates of release rate were between 0.055 and 0.17 μg at. P h^{-1} g^{-1} leaf dry wt. It was shown that the plants themselves were not responsible for releasing this reactive phosphate into the water column. It is postulated, instead, that the seagrass bed released reactive phosphate through microbiological remineralization of detritus accumulated from the water column, seagrass leaves and epibiota. The reactive phosphate thus produced entered the water column either by diffusion or by tidal flow mechanisms.>

195. Short, F. T., W. C. Dennison, and D. G. Capone. 1990. **Phosphorus-limited growth of the tropical seagrass *Syringodium filiforme* in carbonate sediments.** Marine Ecology Progress Series. 62: 169-174.

[GROWTH, NUTRIENTS, PHOSPHORUS, SYRINGODIUM]

<Seagrasses, along with all other marine primary producers, are generally considered to be nitrogen limited. Now experimental enrichments of the tropical seagrass *Syringodium filiforme* Kütz. show that phosphorus, rather than nitrogen, can be the primary limiting nutrient in a marine carbonate

environment. Phosphorus enrichment of carbonate sediments resulted in dramatic increases in seagrass growth, biomass, and tissue phosphorus composition. Additionally, rhizosphere nitrogen fixation increased in response to phosphorus enrichment, potentially making more nitrogen available to the plants.>

196. Delgado, O. and M. Vidal. 1989. **Phosphorus cycling in Mediterranean seagrass ecosystems: Phosphorus content of vegetal tissues and sediments.** In: International Workshop on *Posidonia* Beds. Vol. 2. Edited by C. F. Boudouresque, A. Meinesz, E. Fresi, and V. Gravez, 10-20. France: GIS Posidonie.

[NUTRIENTS, PHOSPHORUS]

<In order to make a first approach to the phosphorus cycling in seagrass ecosystems, phosphorus content of plants and sediments was evaluated. Four species were studied (*Cymodocea nodosa* (Ucria) Ascherson, *Zostera noltii* Horneman, *Ruppia cirrhosa* (Petagna) Grande and *Posidonia oceanica* (Linnaeus) Delile, from two stations in the Catalan Coast (Ebro Delta and Medes Islands). Values found in the leaves ranged from 1.0 to 2.5 mg/g dw and in rhizomes from 0.5 to 2.1 mg/g dw, with significant differences between species. A seasonal pattern in the phosphorus content of leaves and rhizomes was found. In *Posidonia* and *Cymodocea* this pattern clearly suggests that rhizomes could act as a phosphorus reservoir. Total phosphorus content of sediment of seagrass bed ranged between 164 and 179 µgP/g d.w., while the values found for interstitial water were more variable ranging from 1.01 to 2.12 µg at. P-PO$_4$/l. Some laboratory experiments and field data shows that *Posidonia* could play an important role in the sediment phosphorus mobilization.>

197. Smith, W. O., Jr. and P. A. Penhale. 1980. **The heterotrophic uptake of dissolved organic carbon by eelgrass (*Zostera marina* L.) and its epiphytes.** Journal of Experimental Marine Biology and Ecology. 48: 233-242.

[CARBON DISSOLVED ORGANIC, EPIPHYTES, HALODULE, NUTRIENTS]

<The uptake of ^{14}C labeled organic compounds by *Zostera marina* L. (eelgrass) and its epiphytes was examined in an eelgrass community near Beaufort, North Carolina. Assimilation and respiration by new leaf growth (few epiphytes) heavily colonized *Zostera*, and an epiphytized artificial substratum were determined. Glutamic acid was removed from the medium most rapidly, followed by acetate, glucose, and glycine, which were removed at approximately equal rates. The compound with the highest assimilation efficiency was glucose (90.4%), but all compounds were incorporated with efficiencies of >75%. Incorporation by epiphytes on the artificial substratum was greater than uptake by epiphytes on eelgrass. The leaves of *Zostera* also accumulated radioactive material but at low rates, and when combined with uptake by the epiphytic community, resulted in average turnover times for the tested compounds of 7 h. Artificial epiphyte communities had similar turnover times. Kinetic analysis showed no saturation effect, with uptake being linear for the concentrations of substrata tested. We hypothesize that heterotrophic epiphytes are potentially a significant source of new particulate matter in estuarine food webs, and that the microbial communities play a significant role in seagrass carbon cycles.>

198. Zieman, J. C. J. 1970. **The effects of a thermal effluent stress on the seagrasses and macroalgae in the vicinity of Turkey Point, Biscayne Bay, Florida.** Doctor of Philosophy Thesis, University of Miami, Coral Gables, Florida.

[MACROALGAE, THALASSIA, THERMAL EFFECTS]

<Heated effluents from the Turkey Point effluent canals caused considerable modification to the temperature field of southern Biscayne Bay, but virtually no modification of the salinity field. Average temperature rise immediately off the effluent canal mouth was 5°C. above the intake water temperature. Naturally occurring plant distributions are due primarily to substrate type. Decreases in the plant populations due to the heated effluent were detected when the ambient bay temperature reached 26-28°C. Changes in the plant populations frequently followed reductions in salinity due to rainfall by 4-6 weeks. The elevated temperatures in the summer caused depressions in both species numbers and algal species diversity. This was accompanied by an increase in blue-green algae. *Thalassia testudinum* was the most resistant of the plants studied to heat stress. However, once it was killed off in an area it did not return, whereas many algae did. Algal tolerance to the thermal stress, in decreasing order, was: *Acetabularia crenulata*, *Batophora oerstedi*, *Penicillus capitatus*, *Halimeda incrassata*, *Udotea conglutinata*, *Digenia simplex*, and *Anadyomene stellata*. Virtually no plants seem to be able to withstand a raising of temperature 4°C. above the normal summer temperatures in the Turkey Point area, and severe effects were felt with a raising of only 2°C. At the end of June 1968, the beginning of the first summer of full operation of the two conventional generating units, approximately 5-10 acres immediately off the effluent canal nouth were damaged. At the end of September 1969 approximately 50-60 acres off the effluent canal mouth was barren of nearly all plant life, 70-75 additional acres had some *Thalassia* cover but nearly all the macroalgae were destroyed, and an additional 160-170 acres showed damage to the algal communities. The results indicate that the plants are able to tolerate the natural salinity fluctuations when the temperatures are low, but are unable to do so when the temperatures are elevated.>

199. Schroeder, P. B. 1975. **Thermal stress in *Thalassia testudinum*.** Doctor of Philosophy Thesis, University of Miami, Coral Gables, Florida.

[THALASSIA, THERMAL EFFECTS]

<A study of the effect of a thermal effluent on *Thalassia testudinum* was made at Guayanilla Bay, Puerto Rico, and at the laboratory of the Puerto Rico Nuclear Center at Mayaguez, Puerto Rico. Biomass of *Thalassia* was inversely correlated with temperature in established turtle grass flats near a thermal plume. Visual signs of stress were noted in transplanted *Thalassia* samples after two weeks of exposure to temperatures of 34.5° - 35°C. Mortality occurred in transplanted *Thalassia* after seven weeks of exposure to 35.0° - 36.4°C. Biomass and pigment values varied nonlinearly with temperature. There was strong correlation between the effect of temperature on biomass and on the absorption ratio 410nm/665nm of acetone extracts of leaf material between 28° - 36°C. This absorption ratio was proposed as an index of thermal stress in the plant. Radionuclide uptake experiments demonstrated that osmoregulation in *Thalassia* was affected by temperature. Sodium and certain other cations were

preferentially excluded from *Thalassia* at temperatures normally experienced by the plant. Between 32° - 34.5°C accelerated uptake of these cations in leaves occurred. Sodium poisoning and breakdown of osmoregulatory processes were proposed as the cause of visual signs of thermal stress and mortality in *Thalassia*.>

200. Thorhaug, A. 1974. **An ecological study of south Biscayne Bay and Card Sound, the *Thalassia* microcosm.** Annual Report to the U.S. Atomic Energy Commission (AT-(40-1)-4493). Miami: University of Miami.

[DISTRIBUTION, GROWTH, MACROALGAE, PRIMARY PRODUCTIVITY, REPRODUCTION, SALINITY, TEMPERATURE, THALASSIA]

<This report summarizes the research that has been done during 1973-1974 on the distribution, abundance, growth, productivity and reproductive patterns of the seagrasses and macroalgal communities in Card Sound and Turkey Point, Florida. Conclusions from past years are also presented in summary form. This study is a part of a larger study of this area which included chemical and physical oceanography as well as biological aspects, and was coordinated with other investigators at the School of Marine and Atmospheric Science. The primary change that occurred in the study area during 1973-1974 was the completion of the self circulating cooling canal system at the Turkey Point facility. The result was that no effluent was discharged into Card Sound as was done on an intermittent basis during 1971-1972. Also, the regrowth of seagrasses and algal communities at Turkey Point was monitored at seven stations during 1973-1974 as a continuation of the previous four years work there. In addition, a *Thalassia* transplant experiment was carried out at the mouth of the old effluent canal at Turkey Point. With full cooperation from the Bahamian government several thousand *Thalassia* seedlings were brought from the Bahamas and planted in transects on each side of the old Turkey Point effluent canal, and their growth is presently being monitored on a monthly basis. Also laboratory studies were performed to determine the combined salinity and temperature tolerances of the *Thalassia* seedlings. The effects of concentrations of growth promoting hormone on root development of the seeds was also examined in the field. The purpose of these studies was to determine the tolerance of the seedlings to various times of exposure to different salinity and temperature combinations so that actual power plant effluent salinities and temperatures could be controlled in such a way as to stay within these limits, thus preventing damage to the *Thalassia*.>

201. Short, F. T., M. W. Davis, R. A. Gibson, and C. F. Zimmermann. 1985. **Evidence for phosphorus limitation in carbonate sediments of the seagrass *Syringodium filiforme*.** Estuarine Coastal and Shelf Science. 20: 419-430.

[BAHAMAS, CARBONATE SEDIMENTS, GEOCHEMISTRY, NUTRIENTS, PHOSPHORUS, SYRINGODIUM]

<The seagrass *Syringodium filiforme* was examined in an ecological analysis of plant nutrient requirements and nutrient resource availability. Assessment of the sediment geochemistry in a San Salvador Island seagrass bed indicated that phosphorus was not readily accessible to the plants. Ammonium regeneration in the fine-grained carbonate sediments was high, and interstitial concentrations averaged *ca*. 100 μM while phosphate replenishment to interstitial water was low; and concentrations were generally less than 2 μM. Analysis of

the seagrass leaf tissue content (C:N:P=1390:47:1, atomic wt) suggested that nitrogen and phosphorus were both depleted relative to carbon. However, this high N:P for *S. filiforme* and the low concentration of phosphate available in the interstitial water established the likelihood that plant acquisition of phosphorus was limited. The finding of high root biomass relative to leaf biomass in these seagrass beds corroborates this evidence by depicting a method of plant adaptation that increases nutrient absorptive root surface area.>

202. Kelly, J. R., D. T. Rudnick, R. D. Morton, L. A. Buttel, S. N. Levine, and K. A. Carr. 1990. **Tributyltin and invertebrates of a seagrass ecosystem exposure and response of different species.** Marine Environmental Research. 29: 245-276.

[BENTHIC INVERTEBRATES, MICROCOSMS, THALASSIA, TRIBUTYLTIN]
<^{14}C-labeled tributyltin-chloride (TBT-Cl) was delivered to the water column of seagrass microcosms held in the laboratory under flow-through conditions. Benthic macroinvertebrate abundances across a three treatment, largarithmic dose gradient were compared to untreated control microcosms. Within 3 to 6 weeks, statistically significant mortality appeared in the high treatment. Sensitive species included surface deposit feeders of several phyla, as well as a suspension feeding mollusc. Results suggest that effects can arise because TBT is rapidly accumulated in surface sediments, as well as in *Thalassia* tissues. Concentration of tracer in plant tissues, animals, and sediments suggests that measurement of TBT (and total butyltin) in these components of seagrass beds would provide a better indicator of exposure regimes than occasional measurements in the water. A propensity for accumulation, along with a biological vulnerability, suggests a sentinel role for seagrass ecosystems in some shallow coastal areas. Experimental findings demonstrate concern for some key invertebrates within beds proximal to TBT sources, and ecological risks could radiate through coastal food webs dependent on these productive vegetated shallows.>

203. Tomasko, D. A. and C. J. Dawes. 1990. **Influences of season and water depth on the clonal biology of the seagrass *Thalassia testudinum*.** Marine Biology (Berlin). 105: 345-351.

[CHLOROPHYLL, CLONAL BIOLOGY, DEPTH, GROWTH, PROXIMATE CONSTITUENTS, THALASSIA]
<Ramet density, leaf relative growth rates, leaf chlorophyll levels, and proximate constituent levels were determined on three dates in 1988 at three water depths for a *Thalassia testudinum* Banks ex König meadow in lower Tampa Bay, Florida, USA. Density varied seasonally in patterns unique to each depth. Leaf relative growth rates indicated a unimodal, rather than bimodal, growth pattern at this site. Leaf chlorophyll levels reflected both depth-related and seasonal influences, with levels at all depths increasing in times of high light attenuation. Based on results from leaf relative growth rates and proximate constituent levels, the degree of ramet interdependence appears to vary with sampling date and water depth. The degree of ramet interdependence appears to be maximal in times of genet expansion (June and August) and minimal in times of energy storage (November). Interdependence of ramets varies spatially as well; ramets are maximally integrated in shallow regions (on those dates when genet proliferation occurs), and minimally integrated at deep edges. Depth-related differences in ramet integration are probably due to the spatial

heterogeneity of the primary resources limitation varying with water depth, and to depth-related differences in ramet population dynamics. Patterns of ramet physiological integration in *T. testudinum* are similar to the patterns reported for terrestrial clonal plants.>

204. Levine, S. N., D. T. Rudnick, J. R. Kelly, R. D. Morton, L. A. Buttel, and K. A. Carr. 1990. **Pollutant dynamics as influenced by seagrass beds experiments with tributyltin in *Thalassia* microcosms.** Marine Environmental Research. 30: 297-322.

[MICROCOSMS, POLLUTANTS, THALASSIA, TRIBUTYLTIN]

<Seagrass beds are highly productive ecosystems whose leaves and sediments provide considerable surface area for interactions with seawater; thus, they may be foci for the sorption, accumulation and degradation of pollutants. The fate of the potent biocide tributyltin (TBT) in water that passes through seagrasses and over sediments was studied in marine microcosms containing sediment cores from a subtropical seagrass bed (including *Thalassia testudinum* and associated fauna) and seawater. Over 3 or 6 weeks, 48 of these microcosms were dosed weekly for 24 h with ^{14}C-labelled TBT at three different doses (initial concentrations of 0.2, 2 and 20 μg TBT liter-1) and flushed with flowing seawater between dose periods. The TBT was rapidly removed from the water column (half times of 10-20 h), primarily through adsorption onto sediments and seagrass leaves. By contrast, 12 microcosms that received similar TBT doses but that contained only seawater had TBT removal half times of 2-7 days. Accumulation of TBT in sediments and grasses was temporary, however; at harvest, the seagrass microcosms contained just 20-30% of the ^{14}C that had been adsorbed or assimilated during dose periods, and half of this label was in degradation products. The principal mechanism of TBT loss from solids was degradation followed by desorption of degradation products (largely monobutyltin and CO_2, which are more soluble than TBT). Despite relatively rapid TBT degradation, TBT accumulated in fauna; at harvest, 2-6% of the ^{14}C in microcosms was in invertebrates. Thus seagrass beds can be viewed as foci for the concentration of TBT, as processors of TBT to less toxic degradation products, and as vectors for distribution of TBT through coastal food chains.>

205. Buesa, R. J. 1990. **Light assimilation curves of some tropical macroscopic marine plants**. Aquatic Botany. 37: 315-324.

[LIGHT ASSIMILATION CURVES, MACROALGAE, SEAGRASS]

<The light assimilation curves of 10 Cuban macroscopic marine plants (*Caulerpa paspaloides*, *Padina sanctae crucis*, *Turbinaria turbinata*, *Ulva fasciata*, *Chaetomorpha media*, *Halimeda gracilis*, *Dictyota dichotoma*, *Caulerpa cypressoides*, *Syringodium filiforme*, *Thalassia testudinum*) presented assimilation plateaus except for those few cases with photoinhibition due to excess light, high temperature, or water stagnation inside unshaken incubation bottles. The studied brown algae had an average compensation irradiance (J_k) value lower than the I_k for both green algae and seagrasses. As bottles cannot be adequately agitated during *in situ* experiments at different depths, this type of field work should be designed only to determine relative photosynthesis values. Because of temperature increments due to artificial lighting, laboratory experiments should provide temperature control during incubations.>

206. Tomasko, D. A. and C. J. Dawes. 1989. **Effects of partial defoliation on remaining intact leaves in the seagrass *Thalassia testudinum* Banks ex König**. Botanica Marina. 32: 235-240.

[CHLOROPHYLL, DEFOLIATION, PHOTOSYNTHESIS, PROTEIN, THALASSIA]

<Partial defoliation of *Thalassia testudinum* Banks ex König short shoots results in intact remaining blades having leaf growth rates 21% higher than the same age blades in non-defoliated short shoots. Photosynthetic rates were 38% higher for intact blades from partially defoliated shoots than for controls. Chlorophyll *a* and *b* levels were not significantly different, but the intact blades from partially defoliated shoots had 30% higher protein levels than controls. Densitometer results from protein electrophoresis and subsequent staining techniques indicate ribulose-1,5-bisophosphate carboxylase oxygenase levels are elevated in relation to an internal protein standard (actin) in blades from partially defoliated shoots. The study suggests an increase in available nutrients occurs within intact remaining blades following partial defoliation. The increased nutrient availability appears to result in increased photosynthetic rates in remaining intact blades.>

207. Tomasko, D. A. and C. J. Dawes. 1989. **Evidence for physiological integration between shaded and unshaded short shoots of *Thalassia testudinum***. Marine Ecology Progress Series. 54: 299-305.

[GROWTH, PROXIMATE CONSTITUENTS, SHADING, THALASSIA]

<Physiological integration of *Thalassia testudinum* short shoots enables clones to function at a higher level of physiological organization than that of the short shoots themselves. Shaded short shoots connected to non-shade short shoots had blade growth rates and proximate organic constituent levels equal to non-shaded controls. Shaded short shoots physically isolated from neighboring short shoots had blade growth rates and organic constituent levels different from both controls and shaded short shoots connected to non-shaded short shoots. Support of shaded short shoots appeared to be primarily from older short shoots connected to the shaded short shoots. The amelioration of localized light limitation results in an increased ability of clones to persist in heterogeneous environments. This increases the probability of the clone later encountering more favorable sites through a wider physical spread.>

208. Wahbeh, M. I. 1988. **Seasonal distribution and variation in the nutritional quality of different fractions of two seagrass species from Aqaba Red Sea Jordan**. Aquatic Botany. 32: 383-392.

[DISTRIBUTION, NUTRIENTS]

<The distribution and nutritive value of living, dead and detrital blades and rhizomes of the two seagrass species, *Halophila stipulacea* (Forsk.) Aschers. and *Halodule uninervis* (Forsk.) Aschers. have been investigated monthly over the period March 1986 through February 1987. Except for lipids in *Halophila stipulacea* the organic matter, organic carbon, inorganic carbon, total nitrogen and lipid mean contents of the different seagrass fractions of both species were significantly different. Seasonal variations in the distribution of these components were also detected in the various plant parts. Green blades of both species had the highest content of organic matter, organic carbon, total nitrogen and lipid, while dead and detrital blades contained the highest amounts of

inorganic carbon. The C/N ratio suggests that *Halodule uninervis* has a considerably higher nutritive value than *Halophila stipulacea*.>

209. Macauley, J. M., J. R. Clark, and W. A. Price. 1988. **Seasonal changes in the standing crop and chlorophyll content of *Thalassia testudinum* Banks ex König and its epiphytes in the northern Gulf of Mexico.** Aquatic Botany. 31: 277-288.

[CHLOROPHYLL, EPIPHYTES, STANDING CROP, THALASSIA]

<The seasonal cycles for standing crop and chlorophyll content of *Thalassia testudinum* Banks ex König and its epiphytes are described from monitoring data collected at a study site in Santa Rosa Sound, northeastern Florida [USA], from December 1983 through March 1987. Water temperature correlated more highly with standing crop and chlorophyll measurements than did salinity or incident light. The seasonal cycle described for *Thalassia* was positively correlated with temperature, whereas epiphyte standing crop was negatively correlated with water temperature.>

210. Dawes, C. J. and D. A. Tomasko. 1988. **Depth distribution of *Thalassia testudinum* in two meadows on the east coast of Florida USA: A difference in effect of light availability.** Marine Ecology Progress Series. 9: 123-130.

[BIOMASS, DEPTH, LIGHT, THALASSIA]

<Shoot density was lower, while leaf area index and above- to below-ground biomass ratios were higher for *Thalassia testudinum* collected from the deep edge when compared to the shallow edge of a meadow off Anclote Key, Florida. These three characters followed patterns predicted from previous studies. The characters were reversed in order for plants from shallow and deep edges of a meadow off Egmont Key, about 50 km south of Anclote Key. Causes other than light were not evident to explain this reversal in the Egmont Key meadow. This study suggests that although light limitation may be the usual limiting factor for depth distribution in seagrass meadows, other factors cannot be ignored in many meadows along the west coast of Florida.>

211. Newell, S. Y., J. W. Fell, and C. Miller. 1986. **Deposition and decomposition of turtlegrass leaves.** Internationale Revue der Gesamten Hydrobiologie. 71: 363-369.

[DECOMPOSITION, THALASSIA]

<In coastal zones where prevailing winds are onshore, seagrasses are regularly deposited at the shoreline, often forming large accumulations. We have compared the rates of loss of dry matter, organic carbon, and nitrogen for turtlegrass (*Thalassia testudinum*) when it decays at the shoreline or continuously submerged nearby. Loss rates were either delayed (by 30 days or more) or were significantly slower for decay undersubmerged conditions.>

212. Walker, D. I. and R. I. T. Prince. 1987. **Distribution and biogeography of seagrass species on the northwest coast of Australia.** Aquatic Botany. 29: 19-32.

[BIOGEOGRAPHY, DISTRIBUTION]

<Fourteen species of seagrass have been found on the northwest Australian coast, from 24 degree S to 12 degree S. These species are generally Indo-West Pacific species, similar to the seagrass assemblages of Papua New Guinea and the Torres Straits. Records of *Enhalus acoroides* (L.f.) Royle and *Thalassodendron ciliatum* (Forssk.) den Hartog are the first published for the state of Western Australia. Descriptions of the habitat characteristics of the species are provided, as well as considerations of their biogeography and the possible influence of temperature as a factor controlling their distribution. Other species discussed are *Thalassia hemprichii*, *Halophila ovalis*, *H. ovata*, *H. spinulosa*, *H. decipiens*, *Halodule uninervis*, *H. pinifolia*, *Cymodocea angustata*, *C. serrulata*, *Syringodium isoetifolium*, *Amphibolis antarctica*, and *Posidonia coriacea*.>

213. Roberts, D. G. and D. J. W. Moriarty. 1987. **Lacunal gas discharge as a measure of productivity in the seagrasses *Zostera capricorni*, *Cymodocea serrulata* and *Syringodium isoetifolium*.** Aquatic Botany. 28: 143-160.

[LACUNAE, PRIMARY PRODUCTIVITY]

<A new method for estimating the rate of photosynthetic fixation of carbon in seagrasses is described. This method, which is sensitive and simple to apply, is based on the close relationship between photosynthetic rate and the volume of gas discharged through the lacunae. During photosynthesis, the gas discharged from the lacunae was composed primarily of oxygen (32.5%) and nitrogen (67.5%). The rate of discharge was proportional to the rate of photosynthesis and hence was a function of light intensity. There was a linear relationship between gases discharged from the lacunar and oxygen released into the water column. Calibration curves were derived relating volume of gases (oxygen and nitrogen) released from the lacunae to total oxygen produced during photosynthesis for three species of seagrasses (*Zostera capricornia* Aschers., *Cymodocea serrulata* (R. Br.) Aschers. & Magnus and *Syringodium isoetifolium* (Aschers.) Dandy). Molar ratios of ^{14}C fixed to oxygen produced were close to unity (1.008 +/- 0.016; n = 8) indicating that measurements of lacunal gas released may be used to measure productivity.>

214. Almasi, M. N., C. M. Hoskin, J. K. Reed, and J. Milo. 1987. **Effects of natural and artificial *Thalassia* on rates of sedimentation.** Journal of Sedimentary Petrology. 57: 901-906.

[CURRENTS, DEPOSITION, THALASSIA]

<Sediment traps were used to measure the rate of deposition in a *Thalassia* seagrass meadow and in an adjacent (sandy) grass-free area. The average depositional rate of mud in the *Thalassia* bed was 4.96 g trap, week,, and in the sandy area, it was 3.04 g trap, week, in the summer. In winter, these rates were 1.60 and 1.50 g mud trap, week,, respectively. Electromagnetic current-meter measurements showed that the mean flow velocity in the grass-free area is higher than in the seagrass area. Therefore, the increased depositional rate of mud within the seagrass is due to slowing of water currents by the grass blades. Confirmation of the blade baffle effect was obtained by placing a 1 m^2 plot of artificial *Thalassia* in a grass-free area. Sediment traps in the artificial *Thalassia* contained 5.45 g mud trap, week, as compared to 3.04 g mud

trap$_1$ week$_1$ in the adjacent grass-free area in summer. In winter, these rates were 1.82 and 1.50 g mud trap$_1$ week$_1$, respectively. Epiphytes in the Indian River Lagoon (Florida, USA) had no detectable effect on the amount of mud deposited in *Thalassia* beds.>

215. Mitchell, C. A. 1987. **Growth of *Halodule wrightii* in culture and the effects of cropping, light, salinity and atazine.** Aquatic Botany. 28: 25-38.

[CROPPING, GROWTH, HALODULE, LIGHT, SALINITY]

<The interaction of three environmental variables, light, salinity and cropping, with the effects of the herbicide atrazine on *Halodule wrightii* Ascherson was investigated in the laboratory. Atrazine at 30 ppm caused a significant reduction in survival of ramets, production of new ramets, above-ground biomass and growth, when compared to *Halodule wrightii* not exposed to atrazine. The three levels of each environmental condition did not alter the toxicity of atrazine to *Halodule wrightii*.>

216. McMillian, C. and L. H. Bragg. 1987. **Comparison of fruits of *Syringodium cymodoceaceae* from Texas, the U.S. Virgin Islands, and the Philippines.** Aquatic Botany. 28: 97-100.

[REPRODUCTION, SYRINGODIUM]

<Fruits of *Syringodium*, described by den Hartog (1970) in "The Sea-Grasses of the World", were with an intact exocarp, but the mature fruit in marine sediment loses the fleshy exocarp and retains only the stony endocarp. The mature fruits of *S. filiforme* Kütz. from Texas and the US Virgin Islands taper in two directions, but the smaller fruits of *S. isoetifolium* (Aschers.) Dandy from the Philippines are rounded at the base. The fruits of *S. filiforme* have a lacinia with a long tapering point, but those of *S. isoetifolium* have a blunt-tipped lacinia.>

217. Brouns, J. J. W. M. 1987. **Aspects of production and biomass of four seagrass species *Cymodoceoideae* from Papua New Guinea.** Aquatic Botany. 27: 333-362.

[BIOMASS, PRIMARY PRODUCTIVITY]

<Biomass and production data of the seagrasses *Cymodocea serrulata*(R. Brown) Aschers. and Magnus, *Cymodocea rotundata* Ehrenb. et Hempr. ex Aschers., *Halodule uninervis* (Forssk.) Aschers. and *Syringodium isoetifolium* (Aschers.) Dandy were collected in monospecific stands in Bootless Inlet, Papua New Guinea. *Cymodocea serrulata* and *Cymodocea rotundata* were studied from November 1980 to November 1981. Total annual mean biomass was 354 and 201 g ADW m_2, respectively. The largest proportion of these biomass values was contributed by the rhizomes (49 and 36%, respectively) and leaf biomass was ± 30% for both species. *Halodule uninervis* was studied at an intertidal and a subtidal site. The highest total annual mean biomass (600 g ADW m_2) was recorded at the intertidal site, of which 85% was found below ground. The largest proportion of the biomass, at both sites, was contributed by the below-ground vertical axes of the shoots. The biomass of the rhizomes was relatively low (9-12%) for *Halodule uninervis*. Proportionally, the largest above-ground biomass (40%) was recorded for *Syringodium isoetifolium*, of which the annual mean biomass was 481 g ADW m_2.

Total production (above and below ground) was 4.9 and 3.0 g ADW m$_2$ day$_1$ for *Cymodocea serrulata* and *Cymodocea rotundata*, respectively. Approximately 70% was production of leaves. Total production amounted to 6.0 and 4.0 g ADW m$_2$ day$_1$ for *Halodule uninervis* at the intertidal and subtidal sites, respectively. The maximum production was recorded for *Syringodium isoetifolium*, 60% of the 9.0 g ADW m$_2$ day$_1$ was contributed by the leaves. All species reached the maximum production during February and March, when the water temperatures were highest and water was retained above all sites, at all times. The increase of leaf production was mainly due to the increase in biomass of the mature leaves. Significant changes in the plastochrone interval of the leaves were not observed during this period.>

218. Heijs, F. M. L. 1987. **Qualitative and quantitative aspects of the epiphytic component in a mixed seagrass meadow from Papua New Guinea.** Aquatic Botany. 27: 363-384.

[EPIPHYTES]

<During 1982, structural and functional aspects of the epiphytic component in a tropical mixed seagrass meadow, have been investigated for each seagrass species separately. This meadow consisted of the seagrasses *Thalassia hemprichii*(Ehrenb.) Aschers., *Cymodocea serrulata* (R. Br.) Aschers. et Magnus, *C. rotundata* Ehrenb. et Hempr. ex Aschers., *Halodule uninervis* (Forssk.) Aschers. and *Syringodium isoetifolium* (Aschers.) Dandy. No significant differences were observed in floristic composition, number of algal species, abundance and diversity of the epiphytic component. On an area basis, annual mean above-ground biomass (seagrass leaves and epiphytes), amounted to 82 g ADW, of which 18% could be ascribed to the epiphytic component. The contribution of the epiphytic component to the annual mean above-ground production ranged from 16% on leaves of *Thalassia hemprichii* to 33% on leaves of *Cymodocea serrulata*. Total annual mean epiphyte production was 4.6 g ADW m$_2$ sediment surface day$_1$ (19%). When including the macroalgal component of this mixed seagrass meadow, total annual mean above-ground plant biomass amounted to 93 g ADW (212 g DW) on an area basis, of which the epiphytes contributed 15.5% (28.5% DW), the macroalgal component 12% (32.5% DW) and the seagrass leaves 72.5% (39.5% DW). Aspects of the epiphytic component (e.g., floristic composition, abundance, biomass and production) in monospecific and mixed seagrass communities are discussed.>

219. Price, W. A., Jr., J. M. Macauley, and J. R. Clark. 1986. **Effects of drilling fluids on *Thalassia testudinum* and its epiphytic algae.** Environmental and Experimental Botany. 26: 321-330.

[DRILLING FLUIDS, EPIPHYTES, THALASSIA]

<A flow-through microcosm system was developed to assess the potential influence of drilling fluids on *Thalassia testudinum* and its epiphytic algae. Two treatments (drilling fluid and a montmorillonite clay) and a control were used for seven tests: two 10-day, 200 μl/L exposures; two 10-day, 1000 μl/L; and three 6-week, 190 μl/L. Six-week exposure to drilling fluid reduced epiphyte biomass (measured as ash free dry weight/cm^2), but surviving algae did not differ (measured as chlorophyll a/g epiphyte ash free dry weight) from controls. *Thalassia* productivity (carbon uptake and growth rate) was reduced by 10-day exposure to drilling fluid concentrations of 200 μl/L. *Thalassia* productivity was reduced by drilling fluid exposure in summer and fall but not in spring.

The variation in response is attributed to seasonal changes in *Thalassia* allotment and storage of carbohydrates. The effect of montmorillonite clay exposure varied inconsistently among all tests for both *Thalassia* and epiphytes.>

220. Nelsen, J. E., Jr. and R. N. Ginsburg. 1986. **Calcium carbonate production by epibionts on *Thalassia* in Florida Bay, Florida USA.** Journal of Sedimentary Petrology. 56: 622-628.

[CALCIUM CARBONATE PRODUCTION, EPIPHYTES, THALASSIA]

<Annual production of lime mud by two genera of red algae and one genus of serpulid worms was estimated for an area of modern lime mud accumulation in Eastern Florida Bay. The red algae *Melobesia membranacea* and *Fosliella farinosa* and the serpulid worm *Spriorbis* sp. live as epibionts on the leaves of *Thalassia testudinum*, the extensive marine grass. The lime mud produced by the epibionts was estimated by quantifying 1) the life span of *Thalassia*; 2) the abundance of *Thalassia*; and 3) the average amount of epibiont calcium carbonate per blade. The estimate also accounts for both aerial variations in standing crop and seasonal variations in growth rate of *Thalassia*. The estimated annual production of epibiont carbonate is 118 ± 44 g/m^2/yr, over six times more than the estimated production by the green alga *Penicillus capitatus* from the same area (Stockman et al. 1967). This leads to the conclusion that the epibionts on *Thalassia* produce significant amounts of lime mud in Florida Bay. This result is close to the published estimate for epibiont production in Jamaica of 180 g/m^2/yr (Land 1970), but it is significantly less than a published estimate for epibiont production in Barbados (Patriquin 1972). Turtle grass has been around since the cretaceous (Eva 1980), and algae most likely has had a longer history. Therefore, epibionts may have been significant contributors since the late Cretaceous.>

221. Heijs, F. M. L. 1985. **Some structural and functional aspects of the epiphytic component of four seagrass species *Cymodceoideae* from Papua New Guinea.** Aquatic Botany. 23: 225-248.

[EPIPHYTES]

<The epiphytic component of four monospecific seagrass beds from Papua New Guinea was studied structurally and functionally. The floristic composition and abundance of the epiphytes on leaves of four seagrass species *Cymodoceoideae* showed considerable variation, but on all four seagrass species, the same algae were among the five quantitatively most important epiphytes: encrusting coralline algae, Cyanophyta, *Ceramium gracillimum* (Harv.) Mazoyer, *Polysiphonia savatierii* Hariot and *Audouinella* spp. The temporal pattern of the epiphytic algae showed more or less the same features on the four seagrass species. Annual mean biomass of epiphytes and seagrass leaves ranged from 54 g ADW m-2 in a community of *Cymodocea rotundata* Ehrenb. and Hempr. ex Aschers. to 169 g ADW m$_2$ in a community of *Syringodium isoetifolium* (Aschers.) Dandy. The contribution of the epiphytic component to the total above-ground biomass ranged from 22 to 24%. Productivity of epiphytes was highest on leaves of *Halodule uninervis* (Forssk.) Aschers. (2.12 g ADW m$_2$ sediment surface day$_1$) and the epiphytic community contributed 35-44% of the total above-ground production of these four seagrass communities. (The 4th seagrass species was *C. serrulata*).>

222. McMillan, C. 1985. **The seed reserve for *Halodule wrightii*, *Syringodium filiforme* and *Ruppia maritima* in Laguna Madre, Texas (USA).** Contributions in Marine Science. 28: 141-150.

[REPRODUCTION, SEED RESERVES]

<For the submerged marine macrophytes that occur in bays and estuaries of the Texas Coast, seed reserves for *Halodule wrightii* Aschers., and *Ruppia maritima* L. were widely distributed in sediments in both Upper and Lower Laguna Madre (26° - 27° 40 N, lat.), but those for *Syringodium filiforme* Kütz. were recorded only in the Lower Laguna Madre with the highest incidence in the southernmost portion. Fruits and/or fruit fragments of at least one of the three species were found in 79% of the sediment samples. The highest number of one-seeded fruits for *H. wrightii* was recorded as 1154 m_2, for *S. filiforme*, 1642 m_2, and *R. maritima*, 4110 nm_2. The recent changes in the composition of the vegetation of the Lower Laguna Madre, with *Syringodium* invading areas previously recorded with only *Halodule*, probably reflect an active role for the seed reserves of marine macrophytes.>

223. Pulich, W. M., Jr. 1986. **Variations in leaf soluble amino-acids and ammonium content in subtropical seagrasses related to salinity stress.** Plant Physiology (Bethesda). 80: 283-286.

[AMINO ACIDS, AMMONIUM, NUTRIENTS, OSMOREGULATION, SALINITY]

<A survey of leaf soluble amino acids was conducted for four subtropical seagrasses grown at several salinities. Proline functioned as an organic osmoticum in *Halodule wrightii* Aschers., *Thalassia testudinum* Banks ex König, and *Ruppia maritima* L., while alanine functioned in an osmoregulatory capacity in *Halophila engelmanni* Aschers. When light and salinity induced variations in leaf NH_4 and amide-N levels were compared in *Halodule*, *Thalassia*, and *Halophila*, ability to regulate leaf NH_4 levels was correlated with osmoregulatory capacity and maintenance of selected amino acid contents.>

224. Dawes, C. J. 1986. **Seasonal proximate constituents and caloric values in seagrasses and algae on the west coast of Florida (USA).** Journal of Coastal Research. 2: 25-32.

[CALORIC CONTENT, MACROALGAE, PROXIMATE CONSTITUENTS, SEAGRASS]

<Levels of ash, protein, carbohydrate, and caloric values of blades of three species collected at seven sites on the west coast of Florida were similar. Blades of *Thalassa testudinum* had the highest ash content (41%) and those of *Syringodium filiforme*, the highest level of soluble carbohydrate (16%). Winter caloric levels were low at the time of low growth rates and dieback in the two seagrass species (2.4 to 2.8 kcal g dry wt^{-1}), while late spring levels were high (3.1 to 3.2 kcal g dry wt^{-1}) at the time of new growth. Caloric levels were similar to terrestrial grasses. Hemicellulose and cellulose content in blades of the three seagrasses ranged from 1 to 15% and 18 to 32%, respectively, while lignin was almost undetectable (1-3%), and thus the structural components were less than that found in terrestrial grasses. The proximate constituents in dominant seaweeds common to seagrass beds were similar to previous studies and non-calcified seaweeds had caloric levels which were similar to those found in seagrass blades. A complete random block ANOVA and the Student-Newman-Keul's test found no significant differences in levels of proximate constituents and

caloric values between sites for the seagrasses or the drift red alga, *Laurencia poitei*.>

225. Virnstein, R. W. and P. A. Carbonara. 1985. **Seasonal abundance and distribution of drift algae and seagrasses in the mid-Indian River lagoon, Florida (USA).** Aquatic Botany. 23: 67-82.

[ABUNDANCE, DEPTH, DISTRIBUTION, MACROALGAE, SEAGRASS]

<The distribution of seagrasses in a 15-ha area in the mid-Indian River lagoon on Florida's central east coast was mapped. *Halodule wrightii* Aschers. dominated in shallow (< 0.4 m) and *Syringodium filiforme* Kütz. in deeper water (> 0.5 m). *Thalassia testudinum* Banks ex König occurred at scattered patches. Areal coverage of monospecific stands of the three major seagrasses was: *Syringodium* 35%, *Halodule* 14%, *Thalassia* 6% and bare sand 21%. Mixed species stands, mostly *Syringodium* with *Halodule*, covered 25% of the total study area. Above-ground seagrass biomass was maximum in summer (June-July) and minimum in late winter (February-March). Summer maxima ranged from 60 g dry wt m^{-2} for *Syringodium* to *ca* 300 g dry wt m^{-2} for *Thalassia*, with *Halodule* intermediate at 160 g dry wt m^{-2}. Because distribution of unattached benthic macroalgae ("drift algae"), primarily *Gracilaria* spp., was highly aggregated, aggregations were first mapped, followed by stratified quadrat sampling in order to estimate total drift algal abundance. In April 1982, high-density patches covering a few hectares averaged 409 g dry wt m^{-2}. At maximum abundance, averaged over the entire 15-ha mapped area, drift algal biomass was 164 g dry wt m^{-2}; mean above-ground seagrass biomass was only 49 g dry wt m^{-2}. Other large expanses of the lagoon had similar accumulations of drift algae; densities variability of seagrass and drift algal abundance was high and may be related to variations in light levels. Drift algae harbor high densities of animals and at times may be quantitatively more important locally than seagrasses in terms of habitat, nutrient dynamics and primary production.>

226. Littler, M. M., P. R. Taylor, D. S. Littler, R. H. Sims, and J. N. Norris. 1985. **The distribution abundance and primary productivity of submerged macrophytes in a Belize barrier-reef mangrove system.** Atoll Research Bulletin. 0: 1-20.

[ABUNDANCE, DISTRIBUTION, MACROALGAE, PRIMARY PRODUCTIVITY, THALASSIA]

<The comparison of wave-exposed (bay) to sheltered (channel) macrophyte assemblages in a Belize mangrove system revealed higher standing stocks of productive filamentous algae in the latter, correlated with relatively low levels of physical disturbance from sea urchin herbivory and wave turbulence. The sheltered channel site, while containing fewer total species and lower species richness, exceeded the bay site in total cover and species evenness. The Shannon-Weaver index of diversity was nearly equal at both sites. Five species comprised 96% of the cover at the bay site, led by the jointed calcareous alga *Halimeda opuntia* f. triloba (37%) and *Thalassia testudinum* (26%); whereas, *H. opuntia* f. *triloba* (40%), *Amphiroa fragilissima* (22%) and *T. testudinum* (16%) provided the majority of the total community productivity. At the channel site, six taxa contributed 96% of the cover, dominated by a mat-forming, gelatinous, filamentous species of naviculoid diatom (29%) and *Caulerpa verticillata* (28%). Major primary producers at the channel site were the three cover dominants, the gelatinous diatom (24% of the total community carbon fixed), *C. verticillata*

(22%) and *H. opuntia* f. *triloba* (20%). The total daylight community primary productivities at the two sites (bay = 17.2, channel = 13.4 grams carbon fixed per meter squared of substratum per day) ranked among the higher rates recorded for dense seagrass beds and were considerably higher than those reported for most calcareous reef flat habitats. This high apparent photosynthetic potential may be related to reduced levels of herbivory and a greater availability of recycled nutrients near mangrove islands.>

227. Barber, B. J. and P. J. Behrens. 1985. **Effects of elevated temperature on seasonal *in situ* leaf productivity of *Thalassia testudinum* and *Syringodium filiforme*.** Aquatic Botany. 22: 61-70.

[PRIMARY PRODUCTIVITY, TEMPERATURE]

<Net leaf productivities of *T. testudinum* Banks ex König and *S. filiforme* Kützing, measured *in situ* over a 1-yr period in a sub-tropical estuary that receives thermal addition from a local power plant, were significantly temperature dependent. Primary production in both species followed seasonal temperature variation, with increase in leaf dry weight as a proportion of total leaf biomass ranging from 0.12% to 2.54% day^{-1} for *T. testudinum* and 0.33%-3.80% day^{-1} for *S. filiforme*. From September to May, *S. filiforme* exhibited significantly higher productivity at the thermally-impacted (experimental) station than at the control station. However, from June to August, *S. filiforme* productivity at the experimental station was significantly lower than at the control station. *T. testudinum* productivity showed similar trends, but interstation differences were not statistically different. Maximal growth occurred between 23 and 29°C for *S. filiforme* and 23 and 31°C for *T. testudinum*. Thus, the thermal addition generally enhanced the seagrass productivity of both species in the autumn, winter and spring, but reduced that of *S. filiforme* in the summer, as the optimal temperature range of this species was exceeded. The fact that *T. testudinum* exhibited a less marked response to the thermal addition and had a greater optimal temperature range than *S. filiforme* supports its status as the more eurythermal of the 2 spp.>

228. Abel, K. M. 1984. **Inorganic carbon source for photosynthesis in the seagrass *Thalassia hemprichii*.** Plant Physiology (Bethesda). 76: 776-781.

[PHOTOSYNTHESIS, PRIMARY PRODUCTIVITY, THALASSIA]

<Photosynthetic carbon uptake of the tropical seagrass T. hemprichii (Ehrenb.) Aschers was studied by several methods. Photosynthesis in buffered seawater in media in the range of pH 6-9 showed an exponentially increasing rate with decreasing pH, indicating that free CO_2 was a photosynthetic substrate. However, these experiments did not determine whether photosynthesis at alkaline pH also contained some component due to HCO_3 uptake. This aspect was further investigated by studying photosynthetic rates in a number of media of varying pH (7.8-8.61) and total inorganic carbon (0.75-13.17 mM). In these media, photosynthetic rate was correlated with free CO_2 concentration and was independent of the HCO_3 concentration in the medium. Short time-course experiments were conducted during equilibration of free CO_2 and HCO_3 after injection of ^{14}C-labeled solution at acid or alkaline pH. High initial photosynthetic rates were observed when acidic solutions (largely free CO_2) were

used but not with alkaline solutions. The concentration of free CO_2 was a limiting factor for photosynthesis in this plant.>

229. Morgan, M. D. and C. L. Kitting. 1984. **Productivity and utilization of the seagrass *Halodule wrightii* and its attached epiphytes.** Limnology and Oceanography. 29: 1066-1076.

[BIOMASS, EPIPHYTES, HALODULE, PRIMARY PRODUCTIVITY]

<Epiphytic algae growing attached to shoalgrass (*H. wrightii*) blades accounted for nearly half of the aboveground live biomass and primary productivity for 2 seagrass meadows in southern Texas (USA) from June-Dec. 1980. They also accounted for the major fraction of recognizable diet material of common seagrass meadow macroinvertebrates such as grass shrimp (Palaemonetes), crabs (Callinectes), snails (Anachis and Bittium) and amphipods (Cymadusa). Significant shading of seagrass by epiphytes did not appear evident at the light intensities normally encountered by these populations. The passage of Hurricane Allen near the area in early Aug. 1980 did not seem to have a major impact on the seagrass meadow, despite wind gusts of 150 km/h and storm tides of +3 m.>

230. Thursby, G. B. and J. S. Davis. 1984. **Species composition and relative abundance of attached diatoms and other algae in the coastal waters adjacent to Seahorse Key, Florida, USA.** Florida Scientist. 47: 130-140.

[EPIPHYTES]

<Five collections of attached diatoms and other algae obtained during warm and cold seasons yielded 111 spp. Seventy-nine percent were diatoms, the rest blue-green, green, red and brown algae. During the warmer months, most species occurred on leaves of 3 seagrasses *Thalassia testudinum*, *Syringodium filiforme*, *Diplanthera wrightii*); the smallest number was on smooth cordgrass (*Spartina alterniflora*) stems, mangrove (*Avicennia germinans*) pneumatophores and oyster shells (*Crassostrea virginical*). During most of the coldest months, a reversal of this distribution was observed which was attributed to the disappearance of most seagrass leaves during the winter.>

231. Newell, S. Y., J. W. Fell, A. Statzell-Tallman, C. Miller, and R. Cefalu. 1984. **Carbon and nitrogen dynamics in decomposing leaves of three coastal marine vascular plants of the subtropics.** Aquatic Botany. 19: 183-192.

[CARBON, DECOMPOSITION, NITROGEN, NUTRIENTS, THALASSIA]

<Leaves of red mangrove (*Rhizophora mangle* L.), needle rush (*Juncus roemerianus* Scheele) and turtlegrass (*Thalassia testudinum* Banks ex König) from litterbags were sampled by removal of pieces of measured volume rather than or in addition to using the entire contents of bags as unit samples. Dead mangrove and turtlegrass leaves decomposed rapidly, approaching the point of full breakdown to fine-particulate and dissolved state within 6 mo. after litterbag placement. By contrast, net loss of dry matter from rush leaves after 2 yr was about 50%. Net immobilization of N (0.1-0.7 mg cm^{-3} leaf $month^{-1}$) occurred in mangrove leaves decaying in the summer, as established by use of the standard-volume sampling method. Rush and mangrove leaves decreased sharply in mean mass-ratio of C to N during decomposition, from about 75-125:1 to about

30-40:1. Turtlegrass leaves were consistently low in mean ratio of C to N (15-18:1). The measured-volume sampling, in comparison to whole-bag results, revealed that early losses of pieces of leaf by fragmentation were negligible for mangrove leaves. However, for turtlegrass leaves, which do not immediately die and decompose upon detachment, loss of leaf portions was apparently a major contributor to total dry matter output. Rush leaves exhibited erratic rates of loss of dry matter as assessed with the measured-volume technique; significant increases in density of dry matter were recorded, apparently due to increases in ash content and to active infiltration by cyanobacteria.>

232. Montague, C. 1989. **The distribution and dynamics of submerged vegetation along gradients of salinity in northeast Florida Bay.** Bulletin of Marine Science. 44: 521.

[MACROALGAE, SALINITY, SEAGRASS]
<Submerged vegetation, important habitat for juvenile states of many fish and shellfish, has been sampled along salinity gradients in three tributary-to-bay transects (west, central and east) each with four stations (bay to upstream). The three transects are 10 to 12 km apart on the eastern 20 km of the mainland coast that borders northeast Florida Bay. The objective is to collect information relevant to the effects of changes in freshwater delivery to this area. Samples have been collected eight times during the last year to document changes in vegetation. The stations differ in both mean salinity and salinity variation. Mean surface salinities at the outermost stations range from 31 ppt (western transect) to 23 ppt (eastern). At the uppermost stations, mean surface salinities are: 15 ppt (western), 10 ppt (central) and 11 ppt (eastern). Temporal variation in salinity is highest at the upstream stations and lowest at the outer stations, except in the central transect, where all stations are variable. Upper stations have ranged from near fresh to over 30 ppt during the past year. The western outermost station was the least variable, ranging from 28 to 34 ppt. Vegetation in the entire area is sparse (0 to 600 g dry mass m^{-2}), perhaps owing in part to fluctuation in salinity. Least variable stations have the greatest biomass. The outermost stations are dominated by turtlegrass (*Thalassia testudinum*) or the calcareous alga *Penicillus*. Dominants change to widgeongrass (*Ruppia maritima*), and the algae *Chara* and *Batophora* at the upstream stations. Shoalgrass (*Halodule wrightii*) is common at intermediate stations. Vegetation at upstream stations is dynamic. In March 1986, the upstream stations of the central transect were covered with dense stands of *Ruppia*, *Chara* and *Batophora*. Salinity was 13 ppt and the vegetation had disappeared. Despite the return of lower salinities, vegetation at these stations remains sparse. Vegetation at the other upstream stations has been sparse throughout the study period. The potential for dense stands of submerged vegetation is perhaps present at some or all of these upstream stations, but the frequency and magnitude of fluctuations in salinity may prevent stand development.>

233. Wetzel, R. G. and P. A. Penhale. 1979. **Transport of carbon and excretion of dissolved organic carbon by leaves and roots/rhizomes in seagrasses and their epiphytes.** Aquatic Botany. 6: 149-158.

[CARBON DISSOLVED ORGANIC, CARBON UPTAKE, EPIPHYTES, NUTRIENTS]

<Transport of carbon between the rooting organs and foliage and the extra cellular release of dissolved organic carbon (DOC) was examined experimentally in three species of seagrasses. Carbon taken up by roots/rhizomes was transported to the leaves and to water surrounding the leaves. Carbon fixation in leaves was small in *Zostera marina* L. and *Thalassia testudinum* Banks ex König (5-20% of C taken up by roots) but nearly equal to that incorporated in the roots in *Halodule wrightii* Aschers. A greater percentage of carbon transferred from the roots accumulated in the leaves and epiphytes of *Halodule* than in the other two species. Altering the oxygen concentrations of water surrounding the roots/rhizomes had only minor effects on the uptake and transport of carbon from either the roots or the leaves. Excretion of DOC as a percentage of carbon fixed was low but was consistently lower from *Halodule* than from *Zostera* or *Thalassia*. Generally, over 50% of the excreted DOC was of a molecular weight > 10,000 Daltons. Low molecular weight (< 500 Daltons) excreted DOC was less than 30% of the total and decreased in the presence of epiphytes.>

234. Penhale, P. A. and G. W. Thayer. 1980. **Uptake and transfer of carbon and phosphorus by eelgrass (*Zostera marine* L.) and its epiphytes**. Journal of Experimental Marine Biology and Ecology. 42: 113-123.

[CARBON, EPIPHYTES, NUTRIENTS, PHOSPHORUS, ZOSTERA]

<The uptake of carbon and phosphorus by eelgrass (*Zostera marina* L.) and its epiphytes under laboratory conditions was examined by the use of ^{14}C and ^{32}P in partitioned chamber experiments. Both carbon and phosphorus were taken up by eelgrass roots and subsequently transferred through the plants to epiphytes on the grass blades. The data suggested that only a small portion of carbon fixed in photosynthesis is supplied through the roots and rhizomes. There was very little transfer of phosphorus through the plants during the 12-h experiments; the most active movement of phosphorus was from the water into the roots where most of the material remained. Phosphorus uptake was dependent on the concentration of dissolved inorganic phosphorus in the medium. An increase in phosphorus concentration of the medium resulted in increased uptake rates; however, the portion of accumulation of ^{32}P in the roots, leaves, and epiphytes remained similar. Experimental design should be carefully considered when comparing the results of various phosphorus uptake studies. The data indicated that a close relationship exists between eelgrass and its epiphytic community; with 15 to 100% of the phosphorus released by the leaves was taken up by the epiphytes.>

235. Sand-Jensen, K. and D. M. Gordon. 1984. **Differential ability of marine and freshwater macrophytes to utilize HCO_3^- and CO_2.** Marine Biology (New York). 80: 247-253.

[MACROALGAE, PHOTOSYNTHESIS]

<Six marine macroalgae and two angiosperms were examined for their ability to use HCO_3^- and CO_2 for photosynthesis. All species used HCO_3^- despite wide taxonomic differences. They also used HCO_3^- with high affinity: natural HCO_3^- concentrations (22 mM) were close to saturation, and the apparent half-saturation constants were low, i.e. $K^{1/2}$ (HCO_3^-) = 0.54 to 0.80 mM HCO_3^-. Expressed as a ratio, the affinity for CO_2 relative to HCO_3^- under rate-limiting

concentrations was about 2 for the marine species compared to much higher values, 5.4 to 10.1 among freshwater species examined previously. This difference was due to a higher affinity for HCO_3^- among marine species, whereas the affinity for CO_2 was in the same range for marine and freshwater species, i.e. $K_{1/2}$ (CO_2) = 0.08 to 0.30 mM. The high affinity for HCO_3^- of marine species is consistent with the high and constant availability of HCO_3^- and the low availability of CO_2 in seawater. In freshwaters availability of HCO_3^- and CO_2 varies considerably, depending on habitat. The difference in HCO_3^- affinity may be due to different electrogenic ion-pumps and thus mechanisms of HCO_3^- use, operating in freshwater and marine species. Photosynthetic rates in natural seawater were close to maximum at atmospheric equilibrium (pH 8.2 to 8.4) and declined at high pH approaching zero between pH 9.5 and 10.5. This reduction may be due to the conversion of HCO_3^- to CO_2, followed by $CaCO_3$ precipitation, and/or to a direct pH-effect. *Ulva lactuca* and *Enteromorpna* sp. retained photosynthetic activity at the highest pH tested (10.5) consistent with the high pH recorded in mats of these species.>

236. Davis, G. J. and M. M. Brinson. 1976. **The submersed macrophytes of the Pamlico River estuary, North Carolina.** Water Resources Research Institute Report No. 112. Chapel Hill: University of North Carolina.

[BIOMASS, DECOMPOSITION, DISTRIBUTION, MACROALGAE, NUTRIENTS]

<The ecology of the submersed aquatic macrophytes (including filamentous algae) of the Pamlico River N. C. estuary was studied from the summer of 1973 through the summer of 1975. Rooted macrophytes were not found in the lower half of the estuary proper. The distribution and biomass of the plants were an expression of physical factors associated with the morphology of a shallow turbid coastal plain estuary in a temperate region along with the inherent variability of the species present. Nutrients, at least N and P, did not appear to be limit distribution. Phosphate is extremely high in this estuary, partly in association with a phosphate mine on the south shore. Biomass was estimated with aerial photography and ground truth studies. *Vallisneria americana* was the dominant rooted macrophyte, comprising 85% or more of the rooted biomass. This species turns over in biomass several times a year as leaves continually die and are lost. The red alga, *Compsogogon coeruleus*, accounted for most of the total biomass in 1973 and 1974 but was sparse in 1975. *In situ* mesh bag experiments indicated rapid decay of macrophytes with the half-life of organic dry weight being less than two weeks in the summer. Decay dynamics of N, P, Ca, Mg, K and Na were followed. Results of laboratory studies of the effects of environmental factors on photosynthesis and respiration in three species of filamentous algae were in agreement with ecological factors associated with the distribution of these plants in the estuary. It is suggested that the irruptions of filamentous algae documented here are harbingers of things to come if management practices cannot reduce the movement of inorganic N into the system.>

237. Macauley, J. M., J. R. Clark, and A. R. Pitts. 1990. **Use of *Thalassia* and its epiphytes for toxicity assessment effects of a drilling fluid and**

tributyltin. In: Plants for Toxicity Assessment: Symposium on Use of Plants for Toxicity Assessment. Special Technical Publication No. 1091. Edited by W. Wang, J. W. Gorsuch, and W. R. Lower, 255-266. Philidelphia: American Society for Testing and Materials.

238. Clark, J. R. and J. M. Macauley. 1990. **Comparison of the seagrass *Thalassia testudinum* and its epiphytes in the field and in laboratory tests systems.** In: Plants for Toxicity Assessment: Symposium on Use of Plants for Toxicity Assessment. Special Technical Publication No. 1091. Edited by W. Wang, J. W. Gorsuch, and W. R. Lower, 59-68. Philadelphia: American Society for Testing and Materials.

239. Quammen, M. L. and C. P. Onuf. 1990. **Responses of seagrasses to major hydrological alterations in the Laguna Madre of Texas USA.** Bulletin of the Ecological Society of America. 71: 292.

240. Harrison, P. G. 1989. **Detrital processing in seagrass systems: a review of factors affecting decay rates, remineralization and detritivory.** Aquatic Botany. 35: 263-288.

[DETRITUS, REVIEW, SEAGRASS]

<The literature on three related aspects of the ecological role of seagrass detritus was analyzed for clues to the factors that determine the rates of decomposition, the amount of remineralization vs. immobilization of nitrogen and the nutritional value of the detritus to animals. Rates of decomposition (usually <1% of dry wt. day^{-1}) are generally low compared with other vascular macrophyte sources of detritus, but are influenced by many variables, e.g., chemical composition and growth state of the plant when decay begins, pre-treatments given the plant material (drying, grinding), methods of incubating (litterbags, enclosed microcosms), and the physical and chemical environment in which decay occurs. Standard techniques are lacking, making comparisons difficult. Seagrass detritus undergoes an initial period of leaching, leaving a poor substrate for bacteria because what soluble material remains is deficient in inorganic nutrients, contains inhibitory phenolic compounds, and is protected by cellulose and lignin. During decay, there is little evidence for the net immobilization of nitrogen on seagrass detritus that has been reported for other types of vascular plant detritus; instead, nitrogen and other elements are gradually released. The difference may arise from the quantity and nature of the lignin and phenolic materials in different plants, since those compounds are the source of some of the molecules that form resistant complexes with microbial proteins and lead to a build-up of nitrogen. Since fungi seem to be unimportant in seagrass decay, the development of anaerobic conditions (usually through burial of detritus in sediments) promotes decay by anaerobic cellulolytic bacteria. Fragmentation by detritivores also increases decay rates in the egested detritus by reducing particle sizes, increasing surfaces available for microbial attack and (sometimes) adding amino-nitrogen to the detritus. Some animals can assimilate the cell contents in seagrass leaves while others exhibit cellulolysis in their guts (probably as a result of the gut microflora) and are efficient assimilators of seagrass structural carbohydrates. Compared to other vascular plants, the pattern of detrital processing for seagrasses exhibits several unusual features that require further study: 1) slow rates of loss of biomass despite relatively low initial phenolic contents; 2) low rates of

microbial metabolism despite relatively high initial nitrogen contents; 3) no build-up of nitrogen.>

241. Stevenson, J. C. 1988. **Comparative ecology of submersed grass beds in freshwater, estuarine, and marine environments.** Limnology and Oceanography. 33: 867-893.

[ESTUARY, FRESHWATER, NUTRIENT CONTENT, PRIMARY PRODUCTIVITY, REVIEW, SEAGRASS]
<Worldwide, there are 500-700 species of submersed angiosperms adapted to freshwater and estuarine environments compared with 50 species adapted to marine waters. In their evolution from freshwater ancestors, seagrasses have undergone extensive anatomical changes (e.g. reduction in floral and leaf structures, reduction of xylem tissue with a lacunal gas transport system), as well as physiological adaptations (bicarbonate utilization in photosynthesis). Seagrasses appear to have more annual production than do their freshwater counterparts because they develop greater standing crops and have the capacity to store photosynthetic products in extensive rhizome systems in the sediments. For example, maximum productivity of >10 g C m^{-2} d^{-1} has been reported for tropical seagrass species (*Cymodocea nodosa* and *Thalassia testudinum*), but the maximum productivity of temperate freshwater species such as *Myriophyllum* or tropical freshwater species such as *Hydrilla* is usually <5 g C m^{-2} d^{-1}. In addition, the marine environment provides ample supplies of inorganic carbon (C) and increased mixing energies, making CO_2 limitation less likely. One calculation suggests that marine macrophytes impact the global C budget by sequestering as much as 10^9 t of C per year. Secondary productivities of seagrass communities can also be high. For example, stable isotopic ratios suggest that macrophytic C is important in sustaining several species of commercial fish species in Australia, accounting for >50% of their diets. Also, sea urchins (*Diadema antilarum*) consume plant material, creating bare halos around tropical patch reefs in the Caribbean Sea. It is difficult to generalize regarding brackish submersed aquatics in estuaries because their coverage is variable due to light limitation and algal overgrowth from eutrophication. Freshwater macrophytes seem rarely grazed by fish (except via exotic introductions of *Tilapia* or carp), but waterfowl use is often significant at the end of the growing season. Thus, trophic relations in freshwater macrophyte beds may be qualitatively different and much more pulsed than in seagrass systems, with more *r*-selection in lakes and more *K*-selection in marine environments.>

242. Zieman, J. C. 1985. **Nutrient cycling production and detrital processing in subtropical seagrass systems of the southeastern USA.** American Journal of Botany. 72: 843.

[DETRITUS, NUTRIENT CYCLING]
<The subtropical marine meadows in the bays, lagoons, and shallow coastal waters of Florida constitute one of the largest seagrass resources on earth. By the action of their leaves and rhizomes, they provide a highly structured habitat that offers shelter and food to numerous other organisms. In highly disturbed of pioneering seagrass systems, the biomass and production may be low, but in well developed climax meadows the biomass is large, and the productivity rivals that of subsidized tropical agriculture. While the pioneer seagrass systems are loosely organized, the climax *Thalassia* systems retain much of their produced material and tightly recycle nutrients. Detrital processing

is highly active, and certain species, especially *Syringodium*, release blade material into the water column that is exported and utilized distant from the parent beds.>

243. Moffler, M. D. and M. J. Durako. 1985. **Reproductive biology of the tropical subtropical seagrasses of the southeastern USA**. American Journal of Botany. 72: 842.

[REPRODUCTION]

<Reproductive biology studies of southeastern U.S. seagrasses have addressed descriptive morphology and anatomy, reproductive physiology, seed occurrence and germination. *Halodule wrightii* Aschers., *Halophila engelmannii* Anchers., *Syringodium filiforme* Kütz. and *Thalassia testudinum* Banks ex König are dioecious. *Halophilia decipiens* Ostenfeld and *Ruppia maritima* L. are monoecious. In *Halophila johnsonii* Eiseman, only female flowers are known. These species have hydrophilous pollination, except *R. maritima* which has hydroanemophilous pollination. Recent reproductive ecology studies suggest that reproductive patterns are due to phenoplastic responses and/or genetic adaptation to physico-chemical environmental conditions. Laboratory and field investigations indicate that reproductive periodicity is under temperature control, although proposed mechanisms are disputed. Water temperature appears to influence floral development and may be important in determining subsequent flower densities and fruit/seed production. Flowering under continuous light *in vitro* suggests that photoperiod plays a limited role in floral induction. Flower expression and anthesis, however, may be influenced by photoperiod. Floral morpho-ontogenetic studies of *T. testudinum* field populations demonstrated the presence of early stage inflorescences during short- and long-day photoperiods, further suggesting day neutrality in this species. High initial reproductive efforts, annual variation in male sex expression, secondary sex characters and possible interaction of ramet age with sex expression have also been detected.>

244. Dawes, C. J. 1985. **The energetic seagrasses of the west coast of Florida USA**. American Journal of Botany. 72: 839.

[BIOMASS, PROXIMATE CONSTITUENTS, SEAGRASS]

<*Thalassia testudinum* Banks ex König, *Syringodium filiforme* Kützing, and *Halodule wrightii* Ascherson dominate the shallow water seagrass communities on the eastern Gulf of Mexico. Based on comparisons of proximate constituents, the former species has a "k" type ecology while the latter two species show opportunistic or "r" type ecology. *Halophila decipiens* Ostenfeld forms meadows in deeper water (5 to 100 m) and *H. englemannia* Ascherson occurs among the dominant three seagrasses. *Ruppia maritima* Linnaeus is common in areas of low salinities (>10 ppt) such as mouths of rivers. A total of 66 epialgae have been identified on seagrass blades of all species found near Anclote Key, Florida. Macroalgae common to seagrass communities include 30 species of attached and drift seaweeds. The mean biomass for six seagrass communities from Anclote to Cedar Keys, Florida was 385 g dry wt m^{-2}, or 1.42 tons dry wt m^{-2}. Available kilocalories range from a winter low of 344 to a summer high of 1837 kcal m^{-2}, of which macroalgae contributed about 20%. The rhizome in the three dominant seagrasses functions as a storage organ, the level of soluble carbohydrate changing seasonally. Newly formed blades had higher levels of protein (12%) than

either the short shoots (7 to 10%) or rhizome (8%). Cellulose fiber levels in the blades of the three dominant seagrasses varied and was positively correlated with water movement in *T. testudinum*. Based on blade regrowth studies, above ground biomass for *T. testudinum* can be replaced in 4 to 8 weeks during the growth cycle. The seagrass communities are highly productive and energetically important to the marine environment of the west coast of Florida.>

245. Zimmermann, C. F. and J. R. Montgomery. 1984. **Effects of a decomposing drift algal mat on sediment pore water nutrient concentrations in a Florida USA seagrass bed.** Marine Ecology Progress Series. 19: 299-302.

[DECOMPOSITION, HALODULE, MACROALGAE, NUTRIENTS, SEDIMENTS]

<A rapid increase in sediment pore water nutrient concentrations, from 300 to 900 µM ammonium-N and 20 to 200 µM dissolved reactive phosphate-P, followed by an equally rapid decline to initial concentrations, was noted between May and July 1978 in the Indian River lagoon, Florida, USA. These events coincided with the occurrence and physical state of a drift algal mat composed of *Microcoleus lyngbyaceus* and various seagrasses. It is suggested that the sinking and decomposition of the algal mat over the sample site reversed the nutrient concentration gradient and caused a buildup of nutrients in the sediment.>

246. Heijs, F. M. L. 1985. **The seasonal distribution and community structure of the epiphytic algae on *Thalassia hemprichii* from Papua New Guinea.** Aquatic Botany. 21: 295-324.

[EPIPHYTES]

<Algae growing as epiphytes on leaves of *T. hemprichii* (Ehrenb.) Aschers. were studied Nov. 1980-Dec. 1981, in the Port Moresby area, Papua New Guinea. The epiphytic communities of 3 different monospecific seagrass meadows are compared for species richness, abundance and temporal pattern. Seagrass shoots were studied separately, using the method of Braun-Blanquet, as adapted by Boudouresque. By differentiating between the leaves of one single shoot, the inner- and outer-face of each leaf and the upper- and lower-part of each leaf, the epiphytic community was studied from its initial colonization (Leaf 1) to the final "climax" situation (leaf 4). The diversity and abundance were strongly related to the age of the seagrass leaves. The Rhodophyta were best represented, with the Cryptonemiales dominating the community quantitatively; the Ceramiales predominated qualitatively. The phaeophyta were negligible in terms of abundance and diversity. Differences between the 3 study sites are presented.>

247. Eleuterius, L. N. 1987. **Seagrass ecology along the coasts of Alabama, Louisiana, and Mississippi.** In: Proceedings of the Symposium on Subtropical-Tropical Seagrasses of the Southeastern United States. Florida Marine Reasearch Publications No. 42. Edited by M. J. Durako, R. C. Phillips, and R. R. Lewis III, 11-42. St. Petersburg: Florida Department of Natural Resources, Bureau of Marine Research.

[BIOMASS, DISTRIBUTION, ECOLOGY, GROWTH]

<The seagrasses *Thalassia testudinum* Banks ex König (turtle grass), *Syringodium filiforme* Kützing (manatee grass), *Halodule wrightii* Ascherson (shoal grass), and *Halophila engelmannii* Ascherson occur in greatest abundance 30 to 50 miles offshore of Louisiana, east of Chandeleur Island, and 8 to 12 miles off the mainland shore of Mississippi, north of Horn and Petit Bois Islands. These species characteristically occupy sandy bottoms in estuarine and marine waters (20-35%). Only *Halodule* is presently known to occur in Alabama waters. *Ruppia maritime* L. (widgeon grass) occurs on muddy bottoms, in waters of relatively low salinity (2-10%), in bays, bayous, and river mouths along mainland Alabama, Louisiana, and Mississippi, and in tidal lagoons and certain ponds that are infrequently flooded on the barrier islands. It often grow associated with *Vallisneria*, *Najas*, *Zannichellia*, and other freshwater aquatics. Hurricanes have eroded or buried in sand thousands of acres of seagrass beds near the offshore barrier islands. Freshwater discharges through the Bonnet Carré Spillway have also contributed to the loss of *Thalassia*, *Syringodium*, *Halodule*, and *Halophila*. However, because of its tolerance to brackish waters, *Ruppia* has spread over a greater portion of the local bay, bayou, and river bottoms. During years when optimum conditions for growth occurred in Mississippi Sound, average short-shoot densities were 720 m^{-2} for *Thalassia* (range:80 to 1200 m^{-2}), 400 m^{-2} for *Syringodium* (range:150 to 1600 m^{-2}), and 2400 m^{-2} for *Halodule* (range:300 to 3200 m^{-2}. Average leaf lengths were 24 cm for *Thalassia* (range:8 to 41 cm), 43 cm for *Syringodium* (range:18 to 65 cm), and 14 cm for *Halodule* (range:6 to 21 cm). Biomass averaged 1100 g dry wt m^{-2} for *Thalassia* (range:30 to 3200 g dry wt m^{-2}), with a shoot-to-rhizome-and-root ratio of 1:4. *Syringodium* biomass averaged 250 g dry wt m^{-2} (range:20 to 650 g dry wt m^{-2}), with a shoot-to-rhizome-and-root ratio of 1:2. *Halodule* biomass averaged 138 g dry wt m^{-2} (range:30 to 870 g dry wt m^{-2}), but in this species, biomass and leaf length increase with distance from shore and water depth, while shoot density decreases. In each species, biomass varies seasonally, annually, and between beds, and continuous movement of sand bars affects leaf length, shoot density, and biomass. In 1968, a period of prolonged, extremely high salinity, epiphytic algae and bryozoans accounted for 70% of the total biomass of certain deepwater seagrass beds (*Thalassia*: epiphytes + bryozoans, 69:159 g dry wt m^{-2}). During this same period, about 100 species of marine invertebrates were found in seagrass beds in Mississippi Sound. Thalassia beds had the largest number of animal species (59), with 20 species found there exclusively. In contrast, during a period of prolonged low salinity in 1973, only 63 animal species were found among all beds. Catastrophic death of marine invertebrates and vertebrates (seahorses) occurs when massive amounts of fresh water are discharged during periodic openings of the Bonnet Carré Spillway. Transplanting of seagrass, using coated metal anchors, has been very successful with *Halodule*. Some beds of *Thalassia* have been established, but no *Syringodium* transplants have survived. Information is seriously lacking concerning all aspects of seagrass biology and ecology for the Alabama, Louisiana, and Mississippi coastal region; less than two dozen reports or papers currently exist.>

248. Dawes, C. J. 1987. **The dynamic seagrasses of the Gulf of Mexico and Florida Coasts.** In: Proceedings of the Symposium on Subtropical-Tropical Seagrasses of the Southeastern United States. Florida Marine Research Publications No. 42. Edited by M. J. Durako, R. C. Phillips, and R. R. Lewis III, 25-38. St. Petersburg: Florida Department of Natural Resources, Bureau of Marine Research.

[INCOMPLETE, CALORIC CONTENT, DISTRIBUTION, NUTRIENTS, PROXIMATE CONSTITUENTS]

<Of the seven species of seagrasses that occur in Florida and the Gulf of Mexico, three species form the dominant biomass in open shallow water (0.5-5 m): *Thalassia testudinum* (turtle grass), *Syringodium filiforme* (manatee grass), and *Halodule wrightii* (shoal grass). Although a much smaller plant by comparison, *Halophila decipiens* forms large meadows in deep waters (5-100 m). *Halophila johnsonii* and *H. englemannii* occur mixed in shallow-water seagrass communities. *Ruppia maritima* forms dense stands at the mouths of rivers where salinities rarely exceed 10 o/oo, on tidal flats where it is exposed to desiccation, and in subtidal areas of higher salinity. One hundred and thirteen algal epiphytes have been identified in seagrass blades around Florida. Up to 120 macroalgal species have been identified in seagrass communities. Proximate constituent and kilocalorie levels have been used to demonstrate that the rhizome of the larger seagrass species is a storage organ with soluble carbohydrate changing seasonally. Cellulose fiber levels in the blades of the three larger seagrasses are similar to those of true terrestrial grasses, being highest in the blades of *H. wrightii*, and correlating with water movement. The biomass of six seagrass communities on Florida's west coast averaged 385 g dry wt m^{-2}, and energy levels averaged 981 kcal m^{-2}. Caloric values are highest in seagrass communities during the summer, and range from a 15-month winter low of 344 to a summer-fall high of 1837 kcal m^{-2}, of which drift and attached seaweeds account for 75%. The lack of information regarding epiphyte biomass, energetics, and productivity, as well as the need to model a *T. testudinum* seagrass community, and the need for more growth and energetics information on the below-ground component of seagrass communities are pointed out.>

249. Pulich, W. M., Jr. 1987. **Subtropical seagrasses and trace metals cycling**. In: Proceedings of the Symposium on Subtropical-Tropical Seagrasses of the Southeastern United States. Florida Marine Research Publications No. 42. Edited by M. J. Durako, R. C. Phillips, and R. R. Lewis III, 39-52. St. Petersburg: Florida Department of Natural Resources, Bureau of Marine Research.

[SEDIMENTS, SULFIDE CHEMISTRY, TRACE METALS]

<Over the past 20 years, studies of trace metal budgets in seagrass ecosystems dominated by *Thalassia testudinum*, *Halodule wrightii*, and *Zostera marina* have established that sediments and seagrasses comprise the major reservoirs of trace metals in these systems. In this review, the following aspects of trace-metal-cycling research will be discussed: 1) storage and seasonal variations in essential metal contents of seagrass tissues; 2) eventual fate of metals in live seagrass and detritus; 3) characteristics of metal uptake and translocation processes in the plants; and 4) mechanisms by which seagrasses affect sediment trace metal chemistry. Research shows that seagrass roots or leaves can rapidly take radioisotopes of zinc, manganese, and cadmium from the water column; however, root uptake of metals from the sediment and subsequent translocation to the leaves also occur, but at rates that are much lower, though still sufficient to sustain normal growth. Trace metal chemistry in estuarine sediments is closely governed by sediment microbial sulfate reduction activity. Seagrass roots can affect sediment trace metal bioavailability by excretion of organic materials, diffusion of O_2 into the rhizosphere, and root oxidation of metallic sulfides. Different metabolic capabilities for utilizing metal-sulfide

complexes may form the basis for edaphic growth requirements of some species of seagrasses, as illustrated by studies of *Ruppia maritima* and *H. wrightii* from south Texas sites. Major gaps in our understanding of trace metal cycling in seagrass ecosystems exist in three areas: i) heavy metal bioaccumulation and environmental impact to seagrass-based food chains; ii) effects of sediment organic compounds (e.g., humic substances) and sulfide chemistry on trace metal availability; and iii) seagrass autecology and growth requirements involving sediment trace metal dynamics.>

250. Zieman, J. C. 1987. **A review of certain aspects of the life, death, and distribution of the seagrasses of the southeastern United States, 1960-1985.** In: Proceedings of the Symposium on Subtropical-Tropical Seagrasses of the Southeastern United States. Florida Marine Research .Publications No. 42. Edited by M. J. Durako, R. C. Phillips, and R. R. Lewis III, 53-76. St. Petersburg: Florida Department of Natural Resources, Bureau of Marine Research.

[DISTRIBUTION, EPIPHYTES, NUTRIENTS, PRIMARY PRODUCTIVITY]

<Seagrass meadows are among the richest and ecologically most important coastal habitats. In the United States, the greatest seagrass resources are along the south and west coasts of Florida, with over 5,500 km^2 of seagrass in south Florida, and a second extensive bed covering over 3,000 km^2 between Tampa and Apalachee Bay. Well developed seagrass meadows occur at depths over 10 m in clear waters, but are often limited to less than 2 m in turbid, polluted estuaries. In these latter areas, suspended particulate matter, as well as overgrowths of epiphytic algae, brought about by excess nutrients in the water column, can stress the seagrasses. In more pristine waters, seagrasses maintain high productivity by obtaining nutrients from the sediments via extensive root and rhizome systems, which, coupled with the current-baffling effect of the leaf canopy, protect and stabilize the sediments. In turbid, shallow seagrass systems, much of the food web is based on epiphytic algal grazing, but the dominant trophic pathway in most seagrass systems seems to be via the detrital food web. Seagrass leaves are a relatively rich food source, compared to saltmarsh plants and mangroves, but are grazed directly by few organisms, especially outside of tropical Caribbean waters. In addition to contributing to local food webs, detached seagrass blades are often exported great distances and serve as food sources hundred of kilometers from their source beds.>

251. Orth, R. J. 1977. **Effect of nutrient enrichment on growth of the eelgrass *Zostera marina* in the Chesapeake Bay, Virginia, USA.** Marine Biology (New York). 44: 187-194.

[NUTRIENTS, SEDIMENTS, ZOSTERA]

<The addition of two commercial fertilizers, one 5 % NH_4NO_3, 10% P_2O_5, 10% K_2O, and the other 10% NH_4NO_3, 10% K_2O, had a dramatic effect on the growth of *Zostera marina* in the Chesapeake Bay. There was a significant increase in the length, biomass and total number of turions of fertilized plots compared with controls during a 2 to 3 month period. Data from this short-term field experiment suggest that *Z. marina* beds in the Chesapeake Bay are nutrient-limited, that the growth form of *Z. marina* may be related to the

sediment nutrient supply, and that *Z. marina* may competitively exclude *Ruppia maritima* by light-shading.>

252. Brylinsky, M. 1977. **Release of dissolved organic matter by some marine macrophytes**. Marine Biology (New York). 39: 213-220.

[AQUATIC MACROPHYTES, CARBON DISSOLVED ORGANIC, CARBON RELEASE, NUTRIENTS]
<The amount of photoassimilated carbon released as dissolved organic carbon was investigated for 5 species of benthic marine macrophytes (*Thalassia testudinum*, *Diplanthera wrightii*, *Acanthophora spicifera*, *Chondria dasyphylla*, and *Dictyota dichotoma*) and 1 species of pelagic marine macrophyte (*Sargassum natans*). Release rates ranged between 0.006 and 0.053 mg C g^{-1} h^{-1}. Percent release values ranged from 1.1 to 3.8%. Spermatophytes had slightly lower percent release values than algae. Investigations performed on the ability of release products to be utilized by heterotrophic organisms showed that 20 to 30% of the released organic carbon was assimilated within a 2-h period.>

253. Lewis, J. B. and C. E. Hollingworth. 1982. **Leaf epifauna of the seagrass *Thalassia testudinum***. Marine Biology (New York). 71: 41-49.

[EPIFAUNA, THALASSIA]
<The abundance, composition and trophic relationships of metazoan leaf epifauna of the marine angiosperm *Thalassia testudinum* König were studied in Barbados, West Indies. Approximately 90 species from 11 phyla consisted chiefly of nematodes, harpacticoid copepods, crustacean nauplii, ostracods, and turbellarians. Epiflora and detritus-feeders dominated the epifauna. Increasing leaf epiphytism was accompanied by faunal changes, most notably increased nematode, harpacticoid and polychaete density. Faunal composition was very similar to that of the temperate seagrass analogue *Zostera marina*.>

254. Thursby, G. B. and M. M. Harlin. 1982. **Leaf-root interaction in the uptake of ammonia by *Zostera marina***. Marine Biology (New York). 72: 109-112.

[AMMONIA UPTAKE, NUTRIENTS, ZOSTERA]
<The effect of ammonia uptake by one organ on the uptake of that nutrient by another organ was determined for the seagrass *Zostera marina* L. under laboratory conditions. Leafy shoots with roots attached were incubated in two-compartment chambers, with the roots in one compartment and the leaves in the other. Rates of ammonia uptake were compared when roots and leaves were supplied with ammonia separately and simultaneously. Root uptake of ammonia had no influence on the rate of ammonia uptake by leaves. However, leaf uptake of ammonia caused a 77% decrease in the maximum rate of ammonia uptake by roots. The K_m values for ammonia uptake by leaves and roots were 9.2 and 104 μM respectively, showing that leaves had a greater affinity for ammonia than roots.>

255. Iizumi, H., A. Hattori, and C. P. McRoy. 1982. **Ammonium regeneration and assimilation in eelgrass (*Zostera marina*) beds**. Marine Biology (New York). 66: 59-65.

[AMMONIUM, NUTRIENTS, SEDIMENTS, ZOSTERA]

<Regeneration and assimilation of ammonium in the water column and in sediments of eelgrass (*Zostera marina* L.) beds of Izembek Lagoon and Crane Cove, Alaska, USA and Mangoku-Ura, northeastern Japan, were investigated by using a ^{15}N isotope dilution technique. In the water column of Mangoku-Ura, ammonium was regenerated at a rate of 12 nmol l^{-1} h^{-1} and assimilated at a rate of 74 nmol l^{-1} h^{-1}. The ammonium regeneration rate in sediments ranged from 2 to 150 nmol g^{-1} h^{-1}, and with one exception, exceeded ammonium assimilation in sediments (0.3 to 77 nmol g^{-1} h^{-1}). The ammonium regeneration in the water column was of little significance for the nitrogen supply to the eelgrass bed ecosystem. Net ammonium production (regeneration minus assimilation) in the sediment of Izembek Lagoon met nitrogen demand for eelgrass growth, suggesting that ammonium regeneration in the sediments was very important for the nitrogen cycle in the eelgrass bed ecosystem.>

256. Biebl, R. and C. P. McRoy. 1971. **Plasmatic resistance and rate of respiration and photosynthesis of *Zostera marina* at different salinities and temperatures**. Marine Biology (New York). 8: 48-56.

[PHOTOSYNTHESIS, SALINITY, TEMPERATURE, ZOSTERA]

<*Zostera marina* L. was studied at the Izembek Lagoon, Alaska Peninsula. Two morphologically different forms, tidepool and subtidal, can be distinguished. Both show a high tolerance to different salinities and temperatures. The plasmatic resistance was found in a range of distilled H_2O up to 3.0 seawater (24 h) and between -6° and 34°C (12 h). Within these resistance limits, the photosynthesis, which has its maximum in normal (1.0) seawater, decreases nearly to zero not only in distilled H_2O but even in 2.0 seawater, and increases with the temperature in the tidepool form up to 35°C, but in the subtidal form up to 30°C only. At higher temperatures photosynthesis declines sharply in both forms. Respiration has its minimum in distilled H_2O and at 0°C and increases with increasing salinity and temperature.>

257. Bittaker, H. F. and R. L. Iverson. 1976. ***Thalassia testudinum* productivity: a field comparison of measurement methods**. Marine Biology (New York). 37: 39-46.

[CARBON UPTAKE, PRIMARY PRODUCTIVITY, THALASSIA]

<A 6-day *in situ* comparison between the Wetzel inorganic ^{14}C uptake and Zieman leaf-biomass techniques for measuring net primary production rates in the seagrass *Thalassia testudinum* was performed in the northeastern Gulf of Mexico. Measurement differences between the two methods were insignificant when the ^{14}C uptake technique was corrected for sediment ^{14}C "uptake" (13%), incubation-chamber light-energy absorption (14%) and differences in total light-energy which resulted from the experimental design (7.7%). These results reinforce previous observations that the ^{14}C technique estimates net particulate-carbon production.>

258. Brinkhuis, B. H., W. F. Penello, and A. C. Churchill. 1980. **Cadmium and manganese flux in eelgrass *Zostera marina* II. Metal uptake by leaf and root-rhizome tissues**. Marine Biology (New York). 58: 187-196.

[NUTRIENTS, TRACE METALS, ZOSTERA]

<Cadmium and manganese radionuclide uptake by *Zostera marina* L. tissues and translocation between root-rhizomes and leaves was examined. Cadmium concentrations in root-rhizomes increased with incubation time but appeared to reach saturation levels at 24 h of exposure. Translocation of cadmium between root-rhizomes and leaves occurred in both directions. A greater flux of cadmium downward suggested that root-rhizomes were a cadmium sink. Cadmium flux in either direction could be enhanced by a salt gradient. Cadmium appears to move through eelgrass by diffusion or mass flow through vascular tissues and apparent free spaces. Manganese is less mobile but is more readily fixed by leaves. Manganese mobility is not enhanced by salt gradients. Incorporation of cadmium and manganese into root-rhizomes from labelled anoxic sediments was several orders of magnitude less than that from labelled anoxic seawater media.>

259. Backman, T. W. and D. C. Barilotti. 1976. **Irradiance reduction: effects on standing crops of the eelgrass *Zostera marina* in a coastal lagoon.** Marine Biology (New York). 34: 33-40.

[ABUNDANCE, DEPTH, IRRADIANCE, ZOSTERA]

<Abundance of the eelgrass *Zostera marina* L. was studied in a coastal lagoon in southern California (USA), and was found to correlate with the level of irradiance at depths greater than 0.5 m below tidal datum. Results of controlled field experiments, using canopies to reduce downwelling illuminance by 63%, confirmed that turion density is a function of the irradiance the plants receive. By Day 18 of the experiment, turion density in the shaded experimental areas had decreased compared to the density of adjacent unshaded controls. Turion densities were continually lower throughout the 9-month study in the experimental areas, which at the end of the study had a turion density only 5% that of the control areas. Flowering in the experimental areas was also inhibited by shading. The biological implications of these findings are discussed with respect to seasonal changes in incident solar radiation, water transparency, and changes in water quality due to man's increased intervention in the natural processes of coastal lagoons.>

260. Zieman, J. C. 1976. **The ecological effects of physical damage from motor boats on turtle grass beds in southern Florida.** Aquatic Botany. 2: 127-139.

[BOAT TRAFFIC, PHYSICAL DAMAGE, SEDIMENTS, THALASSIA]

<Observation has shown that beds of turtle grass, *Thalassia testudinum*, although highly productive, do not recover rapidly following physical disturbance of the rhizome system. In shallow waters the most common form of rhizome disturbance is from the propellers of motor boats. In turtle grass beds which are otherwise thriving, tracks resulting from propellers have been observed to persist from 2 to 5 years. The proportion of fine sediment components is reduced in the sediments from the boat tracks, and the pH and EH are reduced in comparison to the surrounding grass bed. Damage of this type is most likely to occur in the shallow passes between islands and keys. These areas are also the slowest to recover due to the rapid tidal currents present in the shallow passes.>

261. McMillan, C. 1976. **Experimental studies on flowering and reproduction in seagrasses.** Aquatic Botany. 2: 87-92.

[PHOTOPERIOD, REPRODUCTION, SALINITY, TEMPERATURE]

<Flowering and reproduction of seagrasses in laboratory cultures were compared with responses of the same clones in Redfish Bay, Texas. *Halophila engelmanni* Aschers. produced flowers continuously from January to September under controlled conditions. Flower production in the bay was confined to the period from April to mid-June. The possible effects of salinity, temperature and photoperiod were studied in the laboratory and monitored in the bay. Of these, temperature seemed to be the chief control of the flowering period of *Halophila*. Under laboratory conditions, no flowering was recorded in *Thalassia testudinum* Banks ex König, *Syringodium filiforme* Kütz., *Ruppia maritima* L., or *Halodule wrightii* Aschers., but the flowering of *Halodule* in the bay from May to August suggested a response to higher temperatures than indicated for *Halophila*. Fruit development of *Halodule* in the laboratory also indicated a higher temperature response.>

262. Dawes, C. J. and J. M. Lawrence. 1979. **Effects of blade removal on the proximate composition of the rhizome of the seagrass *Thalassia testudinum*.** Aquatic Botany. 7: 255-266.

[CALORIC CONTENT, LEAF REMOVAL, PROXIMATE CONSTITUENTS, THALASSIA]

<Chemical analyses (ash, protein, lipid, soluble and insoluble carbohydrate) indicated that the rhizome of *Thalassia testudinum* Banks ex König functions as a storage organ in supporting blade regeneration after defoliation in the field and laboratory, and in seasonal growth. Soluble carbohydrate is the primary reserve mobilized in the rhizome after defoliation and shows the largest decrease in level and amount during the non-growing season. Protein showed no change in the rhizome of clipped or unclipped plants. The short shoot also contributes to blade regrowth as indicated by depletion of protein and soluble carbohydrate after defoliation. The lipid content was low in all organs with no seasonal pattern or effect of defoliation. Protein levels were high in regenerated blades of clipped plants while ash levels were low. Caloric levels were lower in short shoots and rhizomes and in the regenerated blades of clipped plants due to lower levels of organic constituents.>

263. Beer, S. and Y. Waisel. 1982. **Effects of light and pressure on photosynthesis in two seagrasses.** Aquatic Botany. 13: 331-337.

[LIGHT, PHOTOSYNTHESIS, PRESSURE]

<Photosynthetic responses to light and pressure (up to 4 atm) were measured for two seagrass species abundant in the Gulf of Eilat (Red Sea). In *Halodule uninervis* (Forssk.) Aschers. pressure decreased net photosynthetic rates, while in *Halophila stipulacea* (Forssk.) Aschers. pressure had not effect on net photosynthetic rates. In both species, light saturation was reached at 300 μE (400-700 nm) m^{-2} s^{-2} and the compensation point was at 20-40 μE (400-700 nm) m^{-2} s^{-2}. Comparing these results to *in situ* light measurements, neither species should be light limited to a depth of about 15 m, and *Halophila stipulacea* should reach compensation light intensities at about 50 m. The latter depth corresponds well to the natural depth penetration of this species. *Halodule uninervis* is never found deeper than 5 m in the Gulf of Eilat, and it apprears that pressure rather than light is one of the factors limiting the depth penetration of this

species. The differential pressure response of the two species may be related to aspects of leaf morphology and gas diffusion.>

264. Harlin, M. M. 1975. **Epiphyte-host relations in seagrass communities**. Aquatic Botany. 1: 125-131.

[EPIPHYTES]

<Seagrasses are crucial to the life cycle of many marine organisms including over 100 species of algae. The leaves of seagrasses vastly increase the area on which algae can settle. Certain species of algae have specialized to the point that the surface of seagrass is the only environment in which they are found. Epiphytes are distributed through the water column where they are advantageously exposed to light, nutrients and wave action. Nitrate and phosphate absorbed from leaves and roots of seagrass eventually leak into adjacent water where they are available to attached organisms before excessive dilution. Transfer of organic carbon is unlikely to be important as a metabolic substrate. Potential applications that could result from an understanding of relationships between epiphytes and seagrasses might be: (a) suppression of growth where epiphytes are unwanted; (b) promotion, where they are considered desireable; and (c) observation of epiphytes to monitor environmental changes in seagrass communities. Future work should focus on: (1) what controls settlement of epiphytes; (2) whether the presence of epiphytes affects the host, and if so how; (3) exchange and/or competition for nutrients; (4) regulation of epiphytes by metabolic products from the host; (5) relative sensitivity of algal epiphytes and seagrasses to environmental parameters; (6) determination of the proportion of productivity by each component; and (7) interdependence with animals in the community.>

265. Harrison, P. G. 1982. **Spatial and temporal patterns in abundance of two intertidal seagrasses, *Zostera americana* den Hartog and *Zostera marina* L.** Aquatic Botany. 12: 305-320.

[DISTRIBUTION, GROWTH, POPULATION DYNAMICS, REPRODUCTION]

<The population dynamics of two temperate seagrasses, *Zostera americana* den Hartog and *Z. marina* L., were studied on an intertidal transect in Boundary Bay on the Pacific coast of Canada. *Z. americana* grew over most of the study area below the mean higher high water level, but *Z. marina* grew only below the mean lower low water level. Distributions most likely were restricted by tolerance of exposure to air and were modified by the irregular topography; e.g. two zones of dense *Z. americana* were separated by a channel in which *Z. marina* dominated. Rates of vegetative growth and flowering were not constant over the intertidal range of either seagrass. In May, vegetative shoots of *Z. americana* were more abundant and heavier in the lower intertidal zone than in the upper intertidal, but by the end of September the shoots were more abundant in the upper zone and the mean dry weight was constant over the transect. Flowering spread during the summer from a small portion of the upper zone (in May) both lower and higher on the transect; the heaviest reproductive shoots grew in the lower intertidal zone. In May, *Z. marina* had a high density and biomass of vegetative shoots in the mid-intertidal channel, but during the summer that population declined and plants lower on the transect flourished. Flowering, too, peaked earlier in the channel than in the lower intertidal zone. From early May to late September, *Z. americana* contributed 60-85% of the total shoots on the

transect but only 37-69% of the dry weight. Overall, the density and biomass were less variable in the perennial *Z. marina* than in the annual *Z. americana* which yearly colonized many hectares from seed.>

266. Jacobs, R. P. W. M. 1979. **Distribution and aspects of the production and biomass of eelgrass, *Zostera marina* L., at Roscoff, France.** Aquatic Botany. 7: 151-172.

[BIOMASS, DISTRIBUTION, PRIMARY PRODUCTIVITY, ZOSTERA]

<A survey is given of the changes since 1909 in the area covered with eelgrass at Roscoff, France. In 1976, *Zostera marina* L. was distributed from mean low water mark at neap tide (MLWN) down to a depth of 4 m below mean low water mark at spring tide (MLWS). In these meadows, a relation existed between the aboveground biomass, length of leaves, number of shoots m^{-2} and the time of water coverage. Biomass and production were studied from February 1976 to February 1977. The biomass of leaf blades, leaf sheaths, rhizomes and roots followed the same pattern with increasing total values from February (190 g dry wt m^{-2}) to August (470 g dry wt m^{-2}) and a decline in autumn and winter. Production was measured by a leaf marking technique together with the determination of the plastochrone interval, i.e. the time interval between the initiation of two successive leaves; on the average, this value amounted to 19.3 days. As the production of rhizome segments occurred at the same rate as that of the leaves, it was possible to estimate separately the production of leaf blades, leaf sheaths, rhizomes and roots during the year. The course of the production process, especially of the aboveground parts, seemed to be controlled by insolation. Annual net production was 1608 g dry wt m^{-2}, 69% of this was aboveground production. Turnover rate of aboveground parts (1.5% per day) was higher than of underground parts (0.5% per day), corresponding with a turnover time of 68 and 193 days, respectively.>

267. Kirkman, H. and D. D. Reid. 1979. **A study of the role of the seagrass *Posidonia australis* in the carbon budget of an estuary.** Aquatic Botany. 7: 173-183.

[CARBON ORGANIC, NUTRIENTS, POSIDONIA]

<The budget and fate of organic carbon from the leaves of the seagrass *Posidonia australis* Hooker f. were studied in a small sunken river valley in Port Hacking, New South Wales. Standing stock and leaf growth were measured over 12-month periods. Estimated average relative leaf growth was 2.3 mg C g dry wt^{-1} day^{-1}. Estimated losses totalled 2.6 mg C g dry wt^{-1} day^{-1} of which 48% was in the form of dissolved organic carbon, while grazing by herbivores (3%), leaves floating off (12%) and sinking leaves (37%) accounted for the remainder of the carbonaceous material lost from the seagrass leaves.>

268. McMillan, C. and R. C. Phillips. 1979. ***Halodule wrightii* Aschers. in the Sea of Cortez, Mexico.** Aquatic Botany. 6: 393-396.

[DISTRIBUTION, HALODULE]

<*Halodule wrightii* Aschers. is reported for the first time on the Pacific Coast of Mexico. The population at Punta Chueca, Sonora, is 3200 km northwest of the nearest previously reported *Halodule* population on the Pacific Coast of Central America. The plants occur sympatrically with *Zostera marina*

L. near its southernmost distribution. This disjunct occurrence of *H. wrightii* supports the hypothesis that diversification of the genus *Halodule* took place before the closing of the Panama Isthmus.>

269. Verhoeven, J. T. A. 1975. ***Ruppia*-communities in the Camargue, France. Distribution and structure in relation to salinity and salinity fluctuations**. Aquatic Botany. 1: 217-241.

[COMMUNITY COMPOSITION, DISTRIBUTION, RUPPIA, SALINITY]

<The distribution and structure of communities dominated by representatives of the genus *Ruppia* in the Camargue, France, were investigated during May and June, 1974. With its many isolated "étangs", "marais" and "baisses" having entirely different and markedly varied salinity conditions, the area is very suitable for the growth of *Ruppia*. Three taxa of *Ruppia* appeared to be present: *Ruppia cirrhosa* (Petagna) Grande, *Ruppia maritima* L. and *Ruppia maritima* var. *brachypus* (Gay) Marsson. The roughly determined distribution pattern of these taxa as well as the distribution of *Potamogeton pectinatus* L. and of the rarely encountered *Althenia filiformis* Petit, is presented in a map (Fig.2). Comparison of this map with a detailed 1965 vegetation map shows some differences due mostly to human intervention. The floral and faunal compositions of the *Ruppia* communities were determined and related to available data on environmental conditions such as average salinity, annual salinity fluctuations, permanent or temporary existence of the water body, and temperature. The classification of Camarguan waters by Aguesse proved useful in this respect. Communities dominated by *Ruppia* species were found in waters with considerable salinity fluctuations. *Ruppia maritima* communities only occurred in oligohaline and mesohaline waters (average salinity 2-18 o/oo S), whereas *R. cirrhosa* communities were also present in polyhaline and hyperhaline waters (average salinity 2-40 o/oo S); *Ruppia maritima* was found in small temporary ponds drying out in summer, whereas *R. cirrhosa* was mainly found in large permanent "étangs". The structures of four different kinds of *Ruppia* communities occurring in the Camargue is described in detail. In addition to important environmental factors, the structure of vegetation (zonation, growth forms, spatial patterns, periodicity) and aquatic fauna (position and behavior) are described. Finally, some remarks are made on the significance of *Ruppia* vegetations as initial links of food chains.>

270. Beer, S., A. Eshel, and Y. Waisel. 1977. **Carbon metabolism in seagrasses**. Journal of Experimental Botany. 28: 1180-1189.

[CARBON METABOLISM, NUTRIENTS, PHOTOSYNTHESIS]

<Four species of seagrasses, *Halophila stipulacca*, *Thalassodendron ciliatum*, *Halodule uninerris*, and Syringodium isoetifolium, were investigated for their ability to utilize HCO_3^- and CO_2 as exogenous carbon sources for photosynthesis. Rates of photosynthesis were measured as rates of O_2 evolution in a closed system in which the pH was continuously controlled. A computer program was written to calculate the concentrations of different carbon species as a function of pH and other specified experimental conditions. Bicarbonate as well as CO_2 were readily assimilated by all four seagrass species. Saturating concentrations of HCO_3^- at saturating light intensities, were 0.5-1.8 mM depending on the species. Rates of photosynthesis under such conditions were 0.1-0.55 μmol O_2 min^{-1} mg^{-1} chlorophyll. At saturating CO_2 concentrations, i.e. 0.5-1.3 mM, rates

of photosynthesis were 0.22-1.4 μmol O_2 min^{-1} mg^{-1} chlorophyll. Photosynthetic rates in each species were considerably higher when CO_2 rather than HCO_3^- was supplied at saturating concentrations. The concentration of HCO_3^- in natural seawater was found to be saturating, and that of CO_2 insufficient for considerable photosynthetic rates in these plants under the given conditions. It was thus concluded that HCO_3^- is the major carbon source for photosynthesis in seagrasses.>

271. McRoy, C. P. and J. J. Goering. 1974. **Nutrient transfer between the seagrass *Zostera marina* and its epiphytes.** Nature (London). 248: 173-174.

[EPIPHYTES, NUTRIENTS, ZOSTERA]
<The leaves of seagrasses often harbour dense populations of macroscopic and microscopic algal epiphytes. In many cases seagrasses grow in waters that are extremely low in dissolved inorganic nutrients yet they have high epiphyte standing stocks. These field observations led to direct experiments on the transfer of nitrogen and carbon from the dissolved nutrient pool in the interstitial waters of the sediments into the root system of eelgrass, *Zostera marina*, and through the plant to the algae on its leaves. Previous studies on seagrasses have shown that the high productivity of seagrass meadows is largely maintained by the nutrient pool of the sediments. Since the plant system leaks phosphorus and, presumably, other nutrients, it is possible that the production of the leaf epiphytes is indirectly sustained by the nutrients in the sediments. This mechanism has been suggested by several workers for marine and freshwater macrophytes but definitive experiments are lacking. Here we report the results of experiments designed to test this hypothesis.>

272. Capone, D. G. and J. M. Budin. 1982. **Nitrogen fixation associated with rinsed roots and rhizomes of the eelgrass *Zostera marina*.** Plant Physiology (Bethesda). 70: 1601-1604.

[NITROGEN FIXATION, NUTRIENTS, ZOSTERA]
<Nitrogen fixation was associated with the rinsed roots and rhizomes of the seagrass, *Zostera marina* L. Nitrogenase activity (acetylene reduction) was greater on rhizomes compared to roots, and on older roots and rhizomes relative to younger tissue. Compared to acrobic assays, anacrobic or microacrobic conditions enhanced the rate of acetylene reduction by rhizomes with attached roots, with the highest activity (100 nanomoles per gram dry weight per hour) occurring at pO_2 = 0.01 atmosphere. Addition of glucose, sucrose, or succinate also increased the rate of acetylene reduction under anacrobic conditions, with glucose providing the most stimulation. In one experiment, comparison of acetylene reduction assays with $^{15}N_2$ incorporation yielded a ratio of about 2.6:1. Seagrass communities are thought to be limited by the availability of nitrogen and, therefore, altrogenase activity directly associated with their roots and rhizomes suggests the possibility of a N_2-fixing flora which may subsidize their nutritional demand for nitrogen.>

273. Roberts, M. H. Jr., R. J. Orth, and K. A. Moore. 1984. **Growth of *Zostera marina* L. seedlings under laboratory conditions of nutrient enrichment.** Aquatic Botany. 20: 321-328.

[GROWTH, NUTRIENT ENRICHMENT, SEEDLINGS, ZOSTERA]

<The effect of increased nutrients on growth of *Zostera marina* L. seedlings was tested in the laboratory by adding 2 different formulations (18:6:12 and 14:14:14 Nitrogen:Phosphorus:Potassium (N:P:K), respectively) of a slow release fertilizer, Osmocote. Three different application rates were used with the 2 formulations by placing appropriate amounts in peat pots containing 1 seedling each. The addition of fertilizer to the substrate markedly stimulated the growth of seedlings. Nutrient enrichment promoted growth both in terms of increased leaf length and vegetative production of shoots. The nitrogen rich formulation (18:6:12) produced less growth than the equal balance formulation (14:14:14). For both formulations, the highest concentrations produced greater growth than other concentrations of the same formulation. At equal application rates with respect to nitrogen, less growth occurred in the treatments receiving less phosphorus. Results of this experiment corroborate results from previous work suggesting that addition of nutrients to the sediment can stimulate *Z. marina* growth.>

274. McMillan, C. 1980. **Isozymes of tropical seagrasses from the Indo-Pacific and the Gulf of Mexico-Caribbean**. Aquatic Botany. 8: 163-172.

[DISTRIBUTION, ISOZYMES]

<Seagrasses in the Gulf of Mexico-Caribbean have different isozymes from those of species in the same genera in the Indo-Pacific, but species populations of various origins within each ocean system show little isozyme variation. The populations of *Thalassia*, *Syringodium* and *Halodule* from the Gulf-Caribbean have a wide range of morphological and physiological variation under controlled conditions, but show no intraspecific isozyme differences. The same isozymes appear in populations of seven species within six genera (*Thalassia*, *Syringodium*, *Halodule*, *Cymodocea*, *Thalassodendron* and *Halophila*) from the Kenya coast of the Indian Ocean and from Micronesia in the western Pacific. The reported distribution of *Halodule wrightii* Aschers. in the Indian Ocean, based on vegetative characteristics, is not supported by isozyme data from plants. The lack of intraspecific isozyme variability within an ocean system may be related to electrophoretic bias, but the differentiation of isozymes in the plants from the two ocean systems suggests that these submerged marine angiosperms of the *Potamogetonaceae* and *Hydrocharitaceae* have diverged as a consequence of spatial isolation.>

275. Lyngby, J. E. and H. Brix. 1982. **Seasonal and environmental variation in cadmium, copper, lead and zinc concentrations in eelgrass (*Zostera marina* L.) in the Limfjord, Denmark**. Aquatic Botany. 14: 59-74.

[HEAVY METALS, SEDIMENTS, ZOSTERA]

<The seasonal variation of cadmium, copper, lead, zinc and ash content in above and below-ground parts of eelgrass (*Zostera marina* L.) was studied at three locations in the Limfjord, Denmark. Heavy metal concentrations in eelgrass from the three locations differed significantly, and reflected either the concentrations in the sediment (Cu, Pb, Zn) or the concentrations in the ambient water (Cd). Above-ground parts of eelgrass contained significantly higher concentrations of cadmium, copper and zinc than below-ground parts, while no

significant difference was observed for lead. Ash content in above-ground parts of eelgrass showed a significant seasonal variation with lowest ash content in spring. A general seasonal variation pattern of heavy metal concentrations in above and below-ground parts of eelgrass was observed. Maximum concentrations were encountered in late winter-early spring and minimum concentrations in the autumn. This seasonal variation pattern of heavy metals can be explained by the growth dynamics of eelgrass.>

276. Harlin, M. M., B. Thorne-Miller, and J. C. Boothroyd. 1982. **Seagrass-sediment dynamics of a flood-tidal delta in Rhode Island.** Aquatic Botany. 14: 127-138.

[CURRENTS, DENSITY, SEDIMENTS]
<Interactions between seagrasses and sediment dynamics were examined on a flood-tidal delta of a coastal lagoon in southern Rhode Island from 1978 to 1980. Serial aerial photographs combined with site visits showed that *Zostera marina* L. appeared on a stable portion of the delta in the springs of 1978 through 1980 and also on a new, incipient lobe during 1980. The population of an annual form of *Z. marina* increased rapidly from June (100 plants m^{-2}) to late July and early August (1000 plants m^{-2}), after which it rapidly decreased. In vegetated plots in both areas current measurements fell to zero near the substrate, while in experimentally denuded plots (64 m^2) they simultaneously reached 8 cm s^{-1} in the stable and 14 cm s^{-1} in the unstable portion of the tidal delta. At the margin of the lobe in August 1980 the sediment accreted 2.5 cm in vegetated plots and eroded 1.5 cm in denuded plots. On the stable site short frames (0.25 m^2) protruding 5 cm from the sediment surface prevented sediment removal and prolonged plant life, but these frames set at the margin of a lobe either made no difference or increased the rate of plant burial and subsequent plant loss. Rotted plants trapped dense red algal mats. Where *Z. marina* had been removed in the stable area, *Ruppia maritima* L. appeared. Benthic diatoms quickly covered all denuded areas. This work shows that, even as an ephemeral, *Z. marina* can encourage sediment accumulation by slowing water current on a moderate-energy tidal delta; but the degree to which this factor becomes important depends upon the density of the plant bed.>

277. McMillan, C. 1982. **Reproductive physiology of tropical seagrasses.** Aquatic Botany. 14: 245-258.

[REPRODUCTION, TEMPERATURE]
<Tropical seagrasses have been induced to flower under continuous light, suggesting that day length plays a minor role in reproductive periodicity. Flowering was induced under continuous light in both Indo-Pacific and western Atlantic species and in each of five genera. In *Halodule*, *Thalassia*, *Syringodium* and *Halophila*, plants became reproductive under temperatures in the range from 20-26°C, and certain species of *Halophila* also produced flowers at temperatures above 26°C. In *Cymodocea*, both *C. rotundata* Ehrenb. & Hempr. ex Aschers. and *C. serrulata* (R.Br.) Aschers. & Magnus failed to flower in the range from 20-26°C or if kept continuously above 31°C, but became reproductive in temperatures that fluctuated between 27-31°C. The temperature sequences of local tropical waters are probably the critical environmental events controlling the reproductive periodicity of the seagrasses.>

278. McMillan, C. and B. N. Smith. 1982. **Comparison of $\delta^{13}C$ values for seagrasses in experimental cultures and in natural habitats.** Aquatic Botany. 14: 381-387.

[PHOTOSYNTHESIS, RESPIRATION]

<For seagrasses of 11 genera, most species in experimental cultures had $\delta^{13}C$ values that were more negative than those in natural habitats. In the experimental cultures, 21 out of 25 species had values in the range from -12.0 to -16.9 o/oo, but in natural habitats 18 of the 25 species had values in the range from -3.6 to -12.5 o/oo. *Zostera americana* den Hartog from Washington had nearly identical values under both conditions, -15.3 and -16.3 (field) and -16.9 (laboratory), but *Enhalus acoroides* (L.*f*) Royle, *Thalassia hemprichii* (Ehrenb.) Aschers. and *Cymodocea serrulata* (R.Br.) Aschers. & Magnus from the Palau Islands (Belau) had values of -4.9, -5.7 and -8.0 o/oo, respectively, in the field and -12.3, -12.9 and -15.6 o/oo in the cultures. The values that were lower in the laboratory than in the natural habitats probably reflect differences in refixation of respired and photo-respired carbon dioxide.>

279. McMillan, C., P. L. Parker, and B. Fry. 1980. **$^{13}C/^{12}C$ ratios in seagrasses.** Aquatic Botany. 9: 237-249.

[CARBON METABOLISM, PHOTOSYNTHESIS]

<Seagrasses have a wide range of $\delta^{13}C$ values. For 47 species from 12 genera, the values were within the range of -3.0 to -19.0 o/oo. Only two species, *Halophila tricostata* Greenway and *Halophila beccarii* Aschers., had lower values, of -20.8 and -23.8 o/oo, respectively. Among the 12 genera, *Syringodium* and *Enhalus* had the highest mean values and *Phyllospadix* and *Amphibolis* had the lowest mean values. The $\delta^{13}C$ values for most seagrasses are within the range usually associated with C_4 metabolism, but the status of seagrasses as members of this photosynthetic group has not been confirmed by morphological and physiological studies. The high variability in $\delta^{13}C$ values may reflect a variable photosynthetic metabolism.>

280. Sand-Jensen, K. 1977. **Effect of epiphytes on eelgrass photosynthesis.** Aquatic Botany. 3: 55-63.

[EPIPHYTES, PHOTOSYNTHESIS, ZOSTERA]

<The effect of epiphytes on eelgrass photosynthesis was measured at varying light intensities and HCO_3^- concentrations by means of the ^{14}C-technique. Eelgrass was collected in Vellerup Vig, Denmark during October and November 1975. The epiphytes, mainly diatoms of the species *Cocconeis scutellum* Ehr., formed a crust several layers thick on the older leaves. The epiphytes reduced the photosynthetic rate of the leaves by acting both as a barrier to carbon uptake and by reducing light intensity. At optimal light intensity, the reduction was about 45% at 0.2 meq. HCO_3^- l^{-1} and it gradually decreased to nearly zero at 2.55 meq. l^{-1}. At varying light intensity and a HCO_3^- concentration of 1.7 meq. l^{-1}, corresponding to Vellerup Vig water, both effects of the epiphytes were seen. Above 7.2 mW cm^{-2}, they caused a constant reduction of photosynthesis due to carbon deficiency. Below 7.2 mW cm^{-2}, the reduction increased linearly to about 58% at 0.44 mW cm^{-2} corresponding to the increasing importance of shading from the epiphytes. Influence of epiphytic populations on photosynthesis and survival of aquatic macrophytes is discussed. It is suggested that macrophytes can limit

the epiphytic stands be excreting algal antibiotics or by keeping a high replacement rate of photosynthetic tissues as illustrated by eelgrass in Vellerup Vig.>

281. Orpurt, P. A. and L. L. Boral. 1964. **The flowers, fruits, and seeds of *Thalassia testudinum* König.** Bulletin of Marine Science of the Gulf and Caribbean. 14: 296-302.

[REPRODUCTION, THALASSIA]

<The flowers of turtle-grass *Thalassia testudinum* König, are redescribed from specimens collected in Biscayne Bay, Florida. An account is given of fruit development and structure. Anatomy of the seed and germination of this plant are described for the first time.>

282. Zieman, J. C., S. A. Macko, and A. L. Mills. 1984. **Role of seagrasses and mangroves in estuarine food webs: temporal and spatial changes in stable isotope composition and amino acid content during decomposition.** Bulletin of Marine Science. 35: 380-392.

[AMINO ACIDS, DECOMPOSITION, NUTRIENTS]

<Carbon, nitrogen $\delta^{13}C$, $\delta^{15}N$, amino acid composition and D/L-amino acid ratios were measured during the early stages of decomposition of seagrass and mangrove leaves in two south Florida estuaries. Isotopic compositions for plants and associated consumers were consistent within an estuary. During decomposition seagrasses showed little change in $\delta^{13}C$, $\delta^{15}N$, but showed an increase in the D/L ratio of certain of the amino acids. Mangroves show little $\delta^{13}C$ change but marked reduction in $\delta^{15}N$, and an increase in the D/L ratio of the amino acids. The percentage of total N accounted for by amino acids decreased in the seagrasses over the term of the experiment, but increased for the mangroves. These data suggest a different mode of decomposition for mangroves and seagrasses when decaying under similar conditions. The $\delta^{13}C$ of consumers is closely coupled to the dominant carbon source in each estuary.>

283. Zieman, J. C., Jr. 1972. **Origin of circular beds of *Thalassia* (Spermatophyta: Hydrocharitaceae) in south Biscayne Bay, Florida, and their relationship to mangrove hammocks.** Bulletin of Marine Science. 22: 559-574.

[CIRCULAR BEDS, DISTRIBUTION, SEDIMENTS, THALASSIA]

<Comparisons of aerial photographs of a mangrove shoreline and an adjacent estuarine area in southwestern Biscayne Bay, Florida, showed the presence of numerous circular to teardrop-shaped areas. The circular areas on shore are hammocks of mangroves and other tropical trees and they are over depressions in the bedrock which are filled with mangrove peat. The circular areas in the estuary are beds of *Thalassia testudinum*. These nearly always occur over depressions in the bedrock that are filled with autochthonous mangrove (*Rhizophora*) peat. The peats reach a pH of 4.9 and a depth of 5 meters. *Thalassia* beds are often surrounded by a white halo of worm and callianassid burrows in the broken area at the periphery of the depressions in the bedrock. The effect of sediment depth on density and length of blades is shown. Dated mangrove peat from beneath a *Thalassia* bed 3 meters below present sea level was 3680 years old. Interpretation is that in this area the mangrove shoreline

receded as sea level rose, and that the beds of *Thalassia* then colonized the planed-off hammocks.>

284. Odum, H. T. 1957. **Primary production measurements in eleven Florida springs and a marine turtle-grass community.** Limnology and Oceanography. 2: 85-97.

[NUTRIENTS, PRIMARY PRODUCTIVITY]

<During July and August, 1955, primary production measurements were made in eleven Florida spring communities and a marine turtle-grass community in the Florida Keys by means of the diurnal curve method. Diurnal measurements of oxygen and carbon dioxide made at a station downstream from the main springs were used in estimating gross primary production and community photosynthetic quotients. These curves show in detail the course of production hour by hour under various conditions in whole natural communities. The primary production values obtained ranged from 0.7 g oxygen/m^2/day in a small, heavily shaded, anaerobic spring on a rainy day to 64 g oxygen/m^2/day on a sunny day in an aerobic spring where the plant beds trailed at the water surface. A comparison of the chemostatic properties in the springs studied suggests that oxygen, phosphate, nitrate, and carbon-dioxide levels are relatively unimportant in determining the magnitude of primary production in these spring communities. Light as influenced by cloud cover, trees, and water depth is the main controlling factor. Approximate efficiencies found were 0.5 to 10% (mean 4%) of the visible light energy reaching plant level. Downstream increases in planktonic chlorophyll and oxygen suggested a steady state in 7 km of longitudinal succession in Rainbow Springs River. Net production of benthic algae of 1.5 g/m^2/day was estimated in Orange Springs from the rate of bubble release into funnels placed on the bottom.>

285. McRoy, C. P. and R. J. Barsdate. 1970. **Phosphate absorption in eelgrass.** Limnology and Oceanography. 15: 6-13.

[NUTRIENTS, PHOSPHORUS, ZOSTERA]

<The absorption of phosphate by eelgrass (*Zostera marina* L.) was studied using ^{32}P in a partitioned container where leaves were separated from roots and rhizomes. Absorption, which was greatest in the light, occurred through both leaves and roots, and the absorbed phosphorus was transported rapidly to all parts of the plant. It therefore appears that eelgrass can use phosphate from sediments and from water. Phosphate removed from solution by the roots and rhizomes was returned in part to the surrounding water through the leaves, suggesting that in nature seagrass may act either as a sink or as a source for dissolved phosphorus in estuarine waters.>

286. Knauer, G. A. and A. V. Ayers. 1977. **Changes in carbon, nitrogen, adenosine triphosphate, and chlorophyll *a* in decomposing *Thalassia testudinum* leaves.** Limnology and Oceanography. 22: 408-416.

[DECOMPOSITION, NUTRIENTS, THALASSIA]

<Fresh *Thalassia* leaf discs were allowed to decompose for 52 days in a continuous flow system. On a per disc basis, C decreased by 57% over the course of decomposition. N changed only slightly during the first 31 days but dropped to <50% of initial values during the final stages. Changes in ATP

content of leaf discs were not linear with time; a rapid initial decrease was followed by a slower loss. C and ATP were significantly correlated in a linear manner throughout the experiment. Total C:N ratios decreased slightly over the first 31 days (avg=17.0) but tended to increase during days 36-52. In contrast, living C (from ATP):N ratios tended to decrease throughout the experiment, averaging 4.1 during days 36-52.>

287. Fonseca, M. S., J. S. Fisher, J. C. Zieman, and G. W. Thayer. 1982. **Influence of the seagrass, *Zostera marina* L., on current flow.** Estuarine Coastal and Shelf Science. 15: 351-364.

[CURRENTS, FROUDE NUMBER, NORTH CAROLINA, SCOURING, SEAGRASS, SHEAR VELOCITY]

<A salt-water flume was used to describe the mechanics of current flow around an artificial *Zostera marina* meadow. Shear velocity and roughness height were positively correlated with seagrass surface area, and were positively/negatively correlated with current velocity. Current velocity intrusion into the meadow before diminution and maximum reduction (both at the 2 cm height line) proceed by factors 1.25 and 2.07 cm into the meadow per cm s^{-1} of current velocity, respectively. Froude number was correlated with mean bending angle of the canopy as a whole. Maximum bending had occurred with Froude = 1, but most bending had taken place by Froude = 0.4, a velocity of 40-50 cm s^{-1} in this experiment. The meadow edge is the most dynamic zone of a seagrass meadow in regard to current flow. Bending of the shoot canopy is a mechanism for re-direction of current flow and in-canopy reduction of current velocity. Meadow dimensions may be regulated by scouring processes in different hydraulic regimes. Shoot bending and subsequent in-meadow current velocity reduction are mechanisms that affect self-shading and photosynthetic capabilities as well as providing habitat stability.>

288. Fonseca, M. S., J. C. Zieman, G. W. Thayer, and J. S. Fisher. 1983. **The role of current velocity in structuring eelgrass (*Zostera marina* L.) meadows.** Estuarine Coastal and Shelf Science. 17: 367-380.

[CURRENTS, EQUILIBRIUM, SEDIMENT DISTRIBUTION, SHEAR VELOCITY]

<Measurements of velocity profiles, bathymetry, and surface sediment characteristics across eelgrass (*Zostera marina* L.) meadows yielded information on community development processes and functional attributes of this ecosystem. Height/length ratios of the meadows were positively correlated with tidal current velocity. Low, medium, and high current regimes were separated by surface current velocities of approximately 50 and 90 cm s^{-1}. *Z. marina* can tolerate approximately 120-150 cm/sec current velocities in the areas studied. Per cent silt-clay and organic matter content of the surface sediments are negatively associated with shear velocity, suggesting that meadows in high current areas are sources while meadows in low current areas are sinks of autochthonous detritus. Current velocity maintains seagrass meadows at different equilibrium levels (relative climaxes). We theorize these different equilibrium levels provide unequal habitat utilization potentials for the associated faunal community.>

289. Conover, J. T. 1968. **The importance of natural diffusion gradients and transport of substances related to benthic marine plant metabolism.** Botanica Marina. 11: 1-9.

[CURRENTS, DIFFUSION GRADIENTS, NUTRIENTS]

<Laboratory and field experiments were carried out in order to determine the effect of current velocity in lagoons and coastal waters on the metabolism and grgowth of benthic marine plants. In order to confirm other observations throughout much of the plant community that metabolism increases with increasing current velocity, the author of this reference demonstrated this relationship with *Zostera marina*. Through the use of ink as a simulated permeable substance, administered through an air current into a circulating water bath until uniformly dispersed, aliquots of the ink were collected on Millipore filter membranes for different current velocities, the number of particles on the membranes being directly proportional to the current velocity. The dissolved substances necessary for plants could in this way be taken up by the cell membrane at different rates and in turn support the diffusion and influence the metabolites. Growth data for different types of attached plants show significant correlations with respect to the rate of current flow in their habitat. One method for the determination of the arte of current velocity is described for application to water ecology. A spatial separation of still water species from species from open, exposed coasts would account for the differences in metabolic activity of each species. It is possible that the metabolic rates for each species, determined genetically or defined by the habitat, are characterized by the rate of flow of the medium and adapted through selection by the specific plant.>

290. Pulich, W. M., Jr. 1982. **Edaphic factors related to shoalgrass (*Halodule wrightii* Aschers.) production.** Botanica Marina. 25: 467-475.

[HALODULE, NUTRIENTS, SEDIMENTS, TRACE METALS]

<A field study was conducted at two south Texas sites to determine the relationship of Fe-Mn-S edaphic conditions to colonizing growth by the seagrass, *Halodule wrightii* Aschers. Concentrations of soluble Fe and Mn, free H_2S and FeS (acid-volatile H_2S), and dissolved PO_4^{3-} and NH_4^+, were measured in rhizosphere sediments *before* and *after* growth of *Halodule* into barren areas over the course of a single growing season. Plant tissue contents of Fe, Mn, Total S, HCl-insoluble S, and total N were also measured. This work was based on the hypothesis that, during *Halodule* colonization of bare sediments, levels of soluble Fe, Mn and S species should change as a result of microbial activity; and the concentrations of these chemical species reflect the sediment environment critical to *Halodule* growth. The study indicated that net H_2S production was higher in *Halodule* sediments than bare sediments; thus a larger steady state pool of soluble sulfide occurred in the former sediments. This correlated with undetectable (<4 μM) soluble Fe, but measurable quantities of soluble Mn, in *Halodule* sediments. The results suggested that *Halodule* grows best in reduced sediments with free H_2S present, very low in soluble Fe, but with significant amounts of soluble Mn. Mechanisms to protect *Halodule* from H_2S toxicity and trace metal toxicity appear operative, similar to other waterlogged plant systems (eg. rice, sugarcane, *Spartina*).>

291. Smith, G. W., A. M. Kozuchi, and S. S. Hayasaka. 1982. **Heavy metal sensitivity of seagrass rhizoplane and sediment bacteria.** Botanica Marina. 25: 19-24.

[BACTERIA, HEAVY METALS, RHIZOSPHERE]

<The effect of soluble manganese, copper, zinc and iron (metal chlorides) on the growth of bacteria isolated from the rhizoplane of *Zostera marina* and *Halodule wrightii* was observed. The response of these isolates to heavy metals were compared to each other and to rhizosphere sediment bacteria. Both percent and average zone of heavy metal inhibition were significantly higher for *Zostera* and *Halodule* rhizoplane bacteria than for rhizosphere sediment bacteria. *In situ* iron concentration was especially high in the seagrass rhizosphere and was toxic to most rhizoplane isolates. Possible means by which bacteria may be protected from heavy metals on the roots of seagrasses are discussed.>

292. Trocine, R. P., J. D. Rice, and G. N. Wells. 1981. **Inhibition of seagrass photosynthesis by ultraviolet-B radiation.** Plant Physiology (Bethesda). 68: 74-81.

[EPIPHYTES, PHOTOSYNTHESIS, ULTRAVIOLET RADIATION]

<Effects of ultraviolet-B radiation on the photosynthesis of seagrasses (*Halophila engelmanni* Aschers., *Halodule wrightii* Aschers., and *Syringodium filiforme* Kütz) were examined. The intrinsic tolerance of each seagrass to ultraviolet-B, the presence and effectiveness of photorepair mechanisms to ultraviolet-B-induced photosynthetic inhibition, and the role of epiphytic growth as a shield from ultraviolet-B were investigated. *Halodule* was found to possess the greatest photosynthetic tolerance for ultraviolet-B. Photosynthesis in *Syringodium* was slightly more sensitive to ultraviolet-B while *Halophila* showed relatively little photosynthetic tolerance. Evidence for a photorepair mechanism was found only in *Halodule*. This mechanism effectively attenuated photosynthetic inhibition induced by ultraviolet-B dose rates and dosages in excess of natural conditions. *Syringodium* appeared to rely primarily on a thick epidermal cell layer to reduce photosynthetic damage. *Halophila* seemed to have no morphological or photorepair capabilities to deal with ultraviolet-B. This species appeared to rely on epiphytic and detrital shielding and the shade provided by other seagrasses to reduce ultraviolet-B exposure in all species. Observations obtained in this study seem to suggest the possibility of anthocyanin and/or other flavonoid synthesis as an adaptation to long term ultraviolet-B irradiation by these species. In addition, *Halophila* appears to obtain an increased photosynthetic tolerance to ultraviolet-B as an indirect benefit of chloroplast clumping to avoid photo-oxidation by intense levels of photosynthetically active radiation.>

293. Thayer, G. W., D. W. Engel, and M. W. LaCroix. 1977. **Seasonal distribution and changes in the nutritive quality of living, dead and detrital fractions of *Zostera marina* L.** Journal of Experimental Marine Biology and Ecology. 30: 109-127.

[DISTRIBUTION, NUTRIENTS, ZOSTERA]

<Samples of eelgrass, *Zostera marina* L., were collected monthly from December 1974 through December 1975 in a shallow embayment near Beaufort, N.C., and separated into green leaves, dead leaves, and leaf detrital material. Each component was analyzed for dry weight, organic matter, inorganic and organic carbon, nitrogen and amino compounds. The standing crop of green and dead blades

reached a maximum in April through June, while detrital matter had peaks in December, April and July-September. Inorganic carbon in the three grass fractions showed seasonal variations similar to those observed for epiphytic biomass in previous years, and represented 14, 24, and 30% of the total carbon associated with the green and dead leaves and detrital fragments, respectively. Organic carbon represented a decreasing proportion of the dry weight of these three fractions on a dry weight basis while there was a significant increase in organic carbon on an ash-free dry weight basis in the detrital fragments relative to the dead blades. During senescence there was a loss of nitrogen from the leaves and an increase in the nitrogen content of the organic matter of the detritus relative to the dead leaves. The latter suggests that there was microbial growth on the detritus and subsequent nitrogen immobilization from the surrounding medium. There were significant decreases of lysine, histidine, arginine, glycine, tyrosine, and glucosamine in the dead leaves relative to the detritus. The glucosamine, derived from N-acetyl-glucosamine, a product of murein which is a component of microbial cell walls, had a seasonal distribution similar to that of the epiphytic community and available inorganic nitrogen in the surrounding water. The relative proportions of N-acetyl-glucosamine, nitrogen and organic carbon were all higher in the fall and winter.>

294. Drew, E. A. 1978. **Factors affecting photosynthesis and its seasonal variation in the seagrasses *Cymodocea nodosa* (Ucria) Aschers, and *Posidonia oceanica* (L.) Delile in the Mediterranean.** Journal of Experimental Marine Biology and Ecology. 31: 173-194.

[CHLOROPHYLL, LIGHT, PHOTOSYNTHESIS]

<Measurements of photosynthesis, dark respiration, and leaf chlorophyll content were made in the laboratory on both shallow (1 to 5 m) and deep (25 to 33 m) leaves of *Cymodocea nodosa* (Ucria) Aschers. and *Posidonia oceanica* (L.) Delile in Malta in April and August. Light saturated photosynthetic rates in *Cymodocea* were similar in spring (18 μg C cm^{-2} h^{-1}) and summer (25 μg C cm^{-2} h^{-1}) if the 9°C increase in water temperature in summer is taken into account: However, photosynthetic rates in *Posidonia* were higher in spring than in summer, especially in shallow leaves which fixed ≈ 10 μg C cm^{-2} h^{-1} in spring but less than half that in summer when rates of carbon accretion were close to compensation point. Levels of irradiance at which photosynthesis was light saturated (I_k) were ≈ 3 mW cm^{-2} PAR for *Cymodocea* and 2 mW cm^{-2} PAR for *Posidonia*; underwater irradiance at the lower depth limit for these plants (≈ 33 m) was ≈ 3 mW cm^{-2} PAR, corresponding closely to the saturation irradiances. Compensation irradiance for both species was between 0.3 and 0.5 mW cm^{-2} PAR. Photosynthesis in both species had a temperature optimum at about 30°C (slightly higher in *Cymodocea* in summer). Dark respiration rates were generally similar in spring and summer, in the region of 3 μg C cm^{-2} h^{-1} in *Cymodocea* and 1.5 to 2 μg C cm^{-2} h^{-1} in *Posidonia*. Increase in dark respiration rates with increased temperature was considerably greater in spring than in summer in both species. Photosynthesis was directly proportional to chlorophyll content in *Posidonia* in the range encountered (up to 58 μg Chl cm^{-2}) and the summer reduction in photosynthesis was closely correlated with reduction in chlorophyll content. It seems unlikely that environmental factors such as seasonal changes in light intensity, nutrient availability or water temperature were directly responsible for this loss of chlorophyll and it is suggested that this is a manifestation of general leaf senescence, probably induced by daylength changes but possibly enhanced by

increased water temperature. *Cymodocea* showed a similar reduction in chlorophyll content in summer but this was not reflected in reduced photosynthesis. Thus, although *Cymodocea* may grow rapidly throughout the spring and summer with an overall productivity of 3.6 g C m^{-2} day^{-1} in shallow water, the luxuriant growths of *Posidonia* must develop in the first half of the year when a dense meadow may produce up to 2.1 g C m^{-2} day^{-1} in shallow water, declining to -0.6 g C m^{-2} day^{-1} in summer.>

295. Iizumi, H., A. Hattori, and C. P. McRoy. 1980. **Nitrate and nitrite in interstitial waters of eelgrass beds in relation to the rhizosphere.** Journal of Experimental Marine Biology and Ecology. 47: 191-201.

[NITROGEN, NUTRIENTS, ZOSTERA]
<The distributions of nitrate and nitrite in the interstitial water of the sediment of eelgrass (*Zostera marina*) bed of Izembek Lagoon, Alaska, were investigated. Their concentrations were relatively high (0 to 9.8 μg-at. N l^{-1}, average 4.8 for nitrate; 0 to 4.0 μg-at. N l^{-1}, average 1.9 for nitrite) although the sediments were anoxic and contained hydrogen sulphide. The rates of bacterial denitrification measured by ^{15}N tracer technique ranged from 0.49 x 10^{-10} to 1.2 x 10^{-9} g-at. N g^{-1} h^{-1}. When a steady state is maintained, the loss of nitrate and nitrite must be balanced by their production by bacterial nitrification. Experimentally determined rate of nitrification in the sediment was of the same order. A model experiment demonstrated that oxygen is transported from leaves to rhizomes and roots of eelgrass and released into the sediment. The oxygen is used for nitrification in the rhizosphere in anoxic sediments.>

296. Lyngby, J. E., H. Brix, and H. H. Schierup. 1982. **Absorption and translocation of zinc in eelgrass (*Zostera marina* L.).** Journal of Experimental Marine Biology and Ecology. 58: 259-270.

[NUTRIENTS, TRACE METALS, ZINC, ZOSTERA]
<The absorption and translocation of zinc in eelgrass (*Zostera marina* L.) were examined in a two-compartment system, using ^{65}Zn and autoradiography. The experiments showed that eelgrass absorbed ^{65}Zn and carrier-Zn in the same relative proportions, and that all parts of the plant had the ability to absorb zinc. The concentrations of absorbed zinc in the roots were significantly higher than in the rhizomes. Translocation was extremely low; after 21 days only 0.28 and 0.21% of total absorbed zinc had been translocated to the upper plant parts and root-rhizomes. The translocated zinc was mainly localized in emerging new leaves or in the new roots and younger nodes of the rhizomes. The significance of eelgrass in the cycling of heavy metals in the aquatic environment is discussed, and it is concluded that the translocation of zinc in eelgrass is of minor importance in the exchange of zinc between sediment and water.>

297. Short, F. T. 1983. **The response of interstitial ammonium in eelgrass (*Zostera marina* L.) beds to environmental perturbations.** Journal of Experimental Marine Biology and Ecology. 68: 195-208.

[NITROGEN, NUTRIENTS, SEDIMENTS, ZOSTERA]

<Natural and human-induced perturbations of eelgrass (*Zostera marina* L.) beds were used to examine the interaction between the sediment interstitial ammonium pool and nitrogen uptake by the plants. Eelgrass colonization of unvegetated areas was accompanied by a substantial decrease in the interstitial ammonium pool over a 4-yr period. The changes in interstitial ammonium and shoot density during colonization support an already determined relationship between shoot density and ammonium pool measurements. In field perturbation experiments, removing eelgrass leaves and sealing the sediment surface altered the flux of ammonium from the interstitial ammonium pool, and resulted in a rapid increase in interstitial ammonium concentrations. Measurements of ammonium accumulation under the various perturbation conditions and a control permitted calculation of the sediment ammonium flux. These estimates include uptake by eelgrass roots, regeneration in the root zone, and diffusion from the sediments. Nitrogen limitation was observed in some eelgrass beds.>

298. Drifmeyer, J. E., G. W. Thayer, F. A. Cross, and J. C. Zieman. 1980. **Cycling of Mn, Fe, Cu and Zn by eelgrass, *Zostera marina* L.** American Journal of Botany. 67: 1089-1096.

[NUTRIENTS, TRACE METALS, ZOSTERA]

<Significant ($P < 0.005$) differences in Mn, Fe, Cu and Zn concentrations were found in different parts of eelgrass plants; i.e., roots and rhizomes, live blades, attached dead blades, and detritus. Imported vs. exported suspended particles of eelgrass blades did not differ in Mn, Fe, Cu or Zn content. Significant location effects, which varied with the type of plant tissue, were noted for Mn, Fe, Cu and Zn for three grass beds in the vicinity of Beaufort, NC. In simplified Mn, Fe, Cu and Zn budgets, eelgrass biomass is the largest biological reservoir, while eelgrass growth, senescence, and decomposition constitute the largest biological flux of these elements in this ecosystem.>

299. Nixon, S. W. and C. A. Oviatt. 1972. **Preliminary measurements of midsummer metabolism in beds of eelgrass, *Zostera marina*.** Ecology. 53: 150-153.

[COMMUNITY METABOLISM, OXYGEN, ZOSTERA]

<Measurement of community metabolism in a coastal pond eelgrass bed gave values of 2.9 g O_2 m^{-2} day^{-1} for apparent production and 3.6 g O_2 m^{-2} day^{-1} for night respiration. The excess of consumption over production during a full day in early August is indicative of the declining state of the plants by midsummer. Measurements of upstream-downstream dissolved oxygen in a tidal river eelgrass bed showed unusual transients and occasional high values for production and respiration. These observations may have been related to turbulent tidal transport, to exchanges of oxygen between the water and lacunar spaces within the *Zostera*, and to higher metabolic rates in faster currents.>

300. Bragg, L. H. and C. McMillan. 1986. **SEM comparison of fruits of a seagrass, *Halodule* (Cymodoceaceae) from Australia and Texas.** American Journal of Botany. 73: 815-821.

[FRUITS, HALODULE, REPRODUCTION]

<Fruits of *Halodule* were collected from marine sediments in Shark Bay, Western Australia, and in Laguna Madre, Texas, and compared using scanning electron microscopy. The fruits of the Australian collection had a more deeply furrowed wall surface, and the fruits of the Texas collection had a more prominent stylar beak. The fruits of both collections had walls that were composed of irregularly interlocking cells, each with multilayered, concentric cell walls. The fruit wall separates into nearly equal halves along a cleavage line composed of cells that are not interlocked. The seed coats are composed of flattened cells with annular thickenings and the oblong hypocotyls are composed of large, polygonal cells that contain starch grains. The cotyledon and plumule are folded into a hypocotylary invagination along the line of wall separation. A radicle hump or short radicle develops during germination in seawater. Although the taxonomy of *Halodule* has been based on a vegetative feature, the leaf tips, fruit differences may be of diagnostic value.>

301. Cox, P. A. and P. B. Tomlinson. 1988. **Pollination ecology of a seagrass, *Thalassia testudinum* (Hydrocharitaceae), in St. Croix.** American Journal of Botany. 75: 958-965.

[REPRODUCTION, THALASSIA]

<The reproductive ecology of a dioecious Caribbean seagrass, *Thalassia testudinum* was studied in St. Croix, U.S. Virgin Islands. Flowering in *Thalassia* coincided with spring tides with anthesis and anther dehiscence in staminate plants occurring at night. As predicted by search theory, pollen is dispersed in negatively buoyant rafts of pollen grains (that superficially resemble strings of frog spawn) which are bound by a slime of apparent thecal origin. Dispersal of pollen is submarine and approximately two-dimensional along the plane of the substratum. The stigmas on pistillate plants are linear, stiff, and densely papillate; they protrude from the mouth of the subtending leaf. Floral ratios of staminate to pistillate flowers are 60 to 1 with an average distance of 4.0 cm from pistillate flower to the closest staminate flowers. Populations included a high proportion of short shoots with numerous (< 100) leaf scars indicating ages for these axes of up to 3-4 years. Nonflowering shoots can be sexed and frequency of flowering can be assessed from scars of old inflorescences. Preliminary results suggest that there is no regular pattern of flowering, since the interval between flowering events is variable.>

302. Cox, P. A. and R. B. Knox. 1989. **Two-dimensional pollination in hydrophilous plants; convergent evolution in the genera *Halodule* (Cymodoceaceae), *Halophila* (Hydrocharitaceae), *Ruppia* (Ruppiaceae), and *Lepilaena* (Zannichelliaceae).** American Journal of Botany. 76: 164-175.

[POLLINATION, REPRODUCTION]

<In most plant species with abiotic pollination systems, pollen is dispersed in three dimensions. Theoretical considerations suggest, however, that there are significant advantages for two-dimensional pollination systems over three-dimensional systems, especially if pollen is dispersed in conveyances or aggregations of large diameter. We report that two-dimensional pollination systems occur in the genera *Halodule*, *Halophila*, *Lepilaena*, and *Ruppia*, where pollen grains are not transported through the water singly, but in rafts or search vehicles. These genera possess unusual pollen morphologies which

facilitate assemblage of pollen grains into search vehicles. These floating search vehicles have large diameters, thus greatly increasing probability of encountering a stigma. The grains have a hydrophobic surface that appears to mediate adhesion by an external coating of proteins and carbohydrates. Similar adaptations to two-dimensional pollination are found in the target organs, the stigmas. The long filamentous stigmas of the marine genera float, as do the indusiate stigmas of the freshwater genera, creating small depressions in the water surface. Pollination occurs through the collision of a moving search vehicle with a floating stigma. The existence of similar pollen search vehicles, stigma morphologies, and flowering phenologies in these unrelated hydrophilous genera evidences convergent evolution towards efficient search strategies in surface-pollinated aquatic plants.>

303. Capone, D. G., P. A. Penhale, R. S. Oremland, and B. F. Taylor. 1979. **Relationship between productivity and N_2 (C_2H_2) fixation in a *Thalassia testudinum* community**. Limnology and Oceanography. 24: 117-125.

[NITROGEN FIXATION, PRIMARY PRODUCTIVITY, THALASSIA]

<N_2 (C_2H_2) fixation and primary production were measured in communities of *Thalassia testudinum* at two sites in Bimini Harbor (Bahamas). Production was determined by uptake of [^{14}C]$NaHCO_3$, by leaf growth measurements, and by applying an empirical formula based on leaf dimensions. The last two methods gave similar results but the ^{14}C method gave higher values. Anaerobic sediment N_2 fixation supplied about 1/4 to 1/2 of the nitrogen demand for leaf production (by leaf growth method) and there was a significant correlation between N_2 fixation and CO_2 fixation rates when all components of the communities were considered (macrophyte, phyllosphere epiphytes, and detrital leaves). N_2 fixation is important to production in *Thalassia* communities and the plant and its leaf epiphytes may be distinct entities in terms of nitrogen and carbon metabolism.>

304. Kitting, C. L., B. Fry, and M. D. Morgan. 1984. **Detection of inconspicuous epiphytic algae supporting food webs in seagrass meadows**. Oecologia (Berlin). 62: 145-149.

[DETRITUS, EPIPHYTES]

<Detritus from common seagrasses and other marine angiosperms may often be a less important basis for estuarine food webs than previously believed. In NW Gulf of Mexico seagrass meadows, epiphytic algae have high productivities, palatability, and a more important trophic role than common large plants have. Interdisciplinary field experiments show (1) intensive night-time ingestion of epiphytes by various invertebrate "detritivores", (2) very high productivity of epiphytic algae on seagrasses, and (3) assimilation of epiphytes rather than seagrasses, as measured by δ^{13}C comparisons. These combined data show that many naturally concentrated and potentially competing invertebrates in Gulf of Mexico seagrass meadows feed largely on the algal overgrowth on seagrass blades, even when such algae appear to be sparse. Primary productivity of these epiphytic algae can equal that of the seagrasses, per blade or per unit biomass. Animal δ^{13}C values tracked epiphytic values rather than seagrass values when comparisons were made over six sites. These measurements reinforce the view that epiphytic algae can be the primary basis of the food web in seagrass meadows.>

305. Ford, E., S. Moore, and H. J. Humm. 1974. **Benthic plants: effect of the Anclote River power plant on seagrass beds in the discharge area.** Chap. 7. In: Anclote Environmental Project Report. Prepared for Florida Power Corporation. Edited by G. F. Mayer and V. Maynard, 315-331. St. Petersburg: Department of Marine Science, University of South Florida.

[INCOMPLETE, GROWTH, TEMPERATURE]

<*Thalassia* and *Syringodium* both continue to grow at measurable rates during the winter and do not enter a dormant stage. Growth for both *Thalassia* and *Syringodium* is higher at the experimental station than at the control station. This may result from increased water temperatures at the experimental station produced by power plant effluent. However, a complete evaluation of the effects of the heated discharge must await the collection of additional data. On the basis of these results, it appears that the operation of the power plant has stimulated seagrass growth during the winter months by producing more favorable water temperatures. Monitoring of seagrass growth rates at these stations during the summer months will determine whether the power plant inhibits growth of seagrasses more or less than the winter stimulation, or whether there is, in fact, any inhibition during the summer. It is of major importance that these seagrass growth studies be continued during at least two months of the summer of 1975.>

306. Sand-Jensen, K. and J. Borum. 1983. **Regulation of growth of eelgrass (*Zostera marina* L.) in Danish coastal waters.** Marine Technology Society Journal. 17: 15-21.

[BIOMASS, GROWTH, PRIMARY PRODUCTIVITY, ZOSTERA]

<Eelgrass is the dominant macrophyte in coastal Danish waters. The productivity of eelgrass is at the same level as fertile terrestrial crops and it can be substantially higher than the phytoplankton production in open waters when compared per unit surface area. Eelgrass may contribute significantly to the total production of all autotrophic components in shallow coastal areas. The above-ground biomass of eelgrass is more variable than the below-ground biomass due to a higher turnover rate and exposure to physical factors of the former. In shallow water, biomass of eelgrass increases rapidly from spring to early summer and stabilizes at a high level during a late summer. Growth is continuous throughout the year although it occurs at a higher rate during spring and summer. Individual plants produce about 16 leaves and rhizome segments per year. During spring and summer each plant produces a new leaf every 9-15 days and their life span is about 2 months. The rapid turnover is important in keeping down the epiphytic load by producing new tissue. It also produces a continuous supply of senescing leaves which presumably leads to stabilized energy transformations within the detritus food web. The net productivity of eelgrass leaves is closely related to surface irradiance and biomass. Since the leaf biomass increases from spring to summer, the ratio of daily productivity to biomass (P/B) falls because of increased self-shading. Water temperature and availability of nutrients do not affect seasonal variation in leaf productivity. Nutrient availability may, however, affect the biomass as a yield limiting factor. Eutrophication of coastal waters changes the balance among different autotrophic components. Growth of phytoplankton, epiphytes and free-floating algae, which take up inorganic nutrients from the free water phase, is greatly

stimulated. This will result in decreased growth rates, depth penetration and, eventually, survival of eelgrass through shading. Biomass and growth measurements of epiphytic algae provide a convenient method for assessing the effect of inorganic nutrient loading in different parts of a receiving area. Eelgrass is suitable as an indicator of trace-metal pollution as it occurs over a widespread area and chemical analysis for trace metals is a relatively simple procedure. Due to the high growth potential of eelgrass leaves (about 5-6 cm leaf turion^{-1} day^{-1}, growth rates of leaves can be used as a very sensitive method of assessing the effects of industrial waste products both in the field and in laboratory test.>

307. Wetzel, R. L. and P. A. Penhale. 1983. **Production ecology of seagrass communities in the lower Chesapeake Bay.** Marine Technology Society Journal. 17: 22-31.

[LIGHT, SALINITY, TEMPERATURE]

<Ecological investigations on submerged aquatic macrophyte communities in the lower Chesapeake Bay have lagged contemporary research on both a national and international scale. We report here recent findings on structural and functional aspects of the ecology of a seagrass meadow that characteries lower bay submerged aquatic vascular plant communities. These vascular plant communities are dominated by two species; *Ruppia maritima* L. and *Zostera marina* L. They experience annual variation in salinity of 10%, a near 0 to 30°C temperature range and wide variation in submarine light regimes and water column light attenuation. Photosynthetically, the two dominant species are distinct and exhibit different P vs I relationships and temperature response characteristics. Submarine light in the photosynthetically active wavelengths and light-temperature interactions are principal environmental controls on seagrass distribution and abundance in the lower Chesapeake Bay.>

308. Capone, D. G. 1983. **N_2 fixation in seagrass communities.** Marine Technology Society Journal. 17: 32-37.

[EPIPHYTES, NITROGEN FIXATION, SEDIMENTS]

<Seagrass communities are the habitats of several presumptive N_2 fixing procaryotes as well as sites of active N_2 fixation. Nitrogenase activity occurs in both the phyllosphere and rhizosphere of tropical (*Thalassia testudinum*) and temperate (*Zostera marina*) seagrass systems, and can exhibit substantial spatial and seasonal variation. While highest specific (per g dry wt) activities are associated with *Thalassia testudinum* leaves bearing cyanobacterial epiphytes, greater areal (per m^2) inputs occur in rhizosphere sediments. N_2 fixation appears to be more important in tropical seagrass ecosystems, accounting for from 20 to 50 percent of estimated plant demands, while a similar analysis for a temperate *Zostera marina* community ranged from 3 to 28 percent. The importance of N_2 fixation needs to be placed in perspective to other nitrogen transformations within these systems.>

309. Orth, R. J. and K. A. Moore. 1983. **Submersed vascular plants: techniques for analyzing their distribution and abundance.** Marine Technology Society Journal. 17: 38-52.

[ABUNDANCE, DISTRIBUTION, REMOTE SENSING]

<Beds of submersed vascular plants represent distinct features of shallow water environments. Examination of their distribution and abundance patterns is possible both spatially and temporally using field and remote sensing techniques. Generally used field techniques include qualitative observations and quantitative sampling with transects, completely random and stratified random analyses. Sampling must involve an adequate number of samples and sample size but also appropriate collection devices, such as corers. Remote sensing techniques rely on the acquisition of imagery, either from planes or satellites. Grass beds appearing as distinct features in imagery can be mapped and areal distributions computed. Historical photographs can provide information on these systems for earlier years. The acquisition of adequate imagery for mapping depends on sun angle, wind velocity, and cloud cover. A combination of remote sensing information and field survey data enables an efficient, effective and productive analysis of the distribution and abundance of submersed vascular plants.>

310. Phillips, R. C. and R. R. Lewis III. 1983. **Influence of environmental gradients on variations in leaf widths and transplant success in North American seagrasses.** Marine Technology Society Journal. 17: 59-68.

[LEAF WIDTH, LIGHT, THERMAL EFFECTS]

<Experimental transplants of *Zostera marina* L. (eelgrass) and *Thalassia testudinum* Banks ex König (turtlegrass) were made over temporal, spatial and eco-genetic gradients in North America. For both species narrow leaf width correlated with environmental stress. Eelgrass habitats in the intertidal zone, the Bering Sea, the Atlantic coastline, and the Sea of Cortez experience extremes of temperature, and plants from these areas had narrower leaf widths than those from the subtidal zone along the Pacific coast. The wide leaf eelgrass plants occurring in Puget Sound, Washington (an area with minimal temperature extremes) exhibited broad adaptive tolerance to transplantation in Alaska. However, alaskan plants did not survive transplantation in Puget Sound. Turtlegrass transplants exhibited a narrow tolerance to reduced light and appeared highly stressed when planted deeper. Both genotypic and phenotypic responses to environmental conditions were evident for eelgrass transplants, while genotypic responses characterized turtlegrass transplants. These studies indicate that the use of vegetative turtlegrass should be discouraged in transplantation, whereas the use of fertilizer in vegetative eelgrass transplantation is encouraged in areas of environmental stress.>

311. Kemp, W. M., W. R. Boynton, R. R. Twilley, J. C. Stevenson, and L. G. Ward. 1984. **Influences of submersed vascular plants on ecological processes in upper Chesapeake Bay.** In: The estuary as a filter. Edited by V. S. Kennedy, 367-394. Orlando: Academic Press.

[DETRITUS, SEAGRASS, TURBIDITY]

<Physical, chemical and biological influences of submersed vascular plants (dominated by *Potamogeton perfoliatus* and *Ruppia maritima*) on their surrounding environment are summarized for portions of upper Chesapeake Bay. Rates of accretion of organic matter in these ecosystems were high owing to the combined effects of vascular plant and associated algal production and the

trapping of particulate organics of phytoplanktonic origin. Time-series observations of seston along transects traversing vegetated bottoms indicated significantly less turbid water over the plant beds, due both to increased deposition and to decreased resuspension of fine-grain sediments. Submersed plants provided a preferred habitat for many animal populations.>

312. Short, F. T. and C. A. Short. 1984. **The seagrass filter: purification of estuarine and coastal waters.** In: The estuary as a filter. Edited by V. S. Kennedy, 395-413. Orlando: Academic Press.

[LIGHT, NUTRIENT UPTAKE, SEAGRASS, SEDIMENTS, SUSPENDED SOLIDS]

<Seagrasses can provide a "filtering" mechanism in estuarine waters by trapping suspended sediments and taking up dissolved water column nutrients. These two processes are discussed from the perspective of water filtration by seagrasses in an effort to establish the plants' benefit to the estuarine system. Previous examinations of such processes have stressed environmental influences on seagrass plants, overlooking the impact that seagrasses may have on the environment. Our approach to the concept of seagrass as a filter has been to examine previous work and combine it with results of measurements of suspended sediment and dissolved nutrient removal in culture tank systems with and without seagrasses. In manipulation experiments, suspended sediment removal was measured by the increase in light penetration, and varied according to added sediment type. Nutrient addition and subsequent depletion in the water column of the culture tanks was measured to determine seagrass community uptake rates. These rates were then extrapolated to a somewhat eutrophic coastal environment for evaluation of potential nutrient removal by seagrasses. A synopsis of these filtering experiments and other studies indicates that seagrass communities remove material of natural or human origin from estuarine waters, but excessive loading of nutrients or suspended material upsets the balance of the seagrass ecosystem, promoting degradation of the seagrass beds and loss of the filtering mechanism.>

313. Zieman, J. C. 1975. **Quantitative and dynamic aspects of the ecology of turtle grass, *Thalassia testudinum*.** In: Estuarine Research. Vol. 1, Chemistry, Biology, and the Estuarine System. Edited by L. E. Cronin, 541-562. New York: Academic Press, Inc.

[BIOMASS, DECOMPOSITION, PRIMARY PRODUCTIVITY, SEASONALITY, THALASSIA]

<In recent years the vast beds of seagrasses bordering the temperate and tropical coastlines have been recognized as a valuable resource. Techniques were developed to measure the production and seasonal dynamics of *Thalassia testudinum*, the dominant marine grass of the Caribbean. Conventional productivity measures are subject to error from gas storage within the leaves. Production of leaf material varied from 0.3 to 10.0 g dry wt m^{-2} day^{-1} in the south Florida area, with mean values of 2.3-5.0 g m^{-2} day^{-1}. Leaf growth rates averaged 2-5 mm day^{-1} with maximum values exceeding 10 mm day^{-1}. The rhizomes of *Thalassia* were found 5-25 cm in the sediment, and roots penetrate to 4-5 m. Leaves constituted 15-22% of the total plant biomass, and leaf standing crops were found from 30-650 g dry wt m^{-2}, with average values of 126 and 280 in inshore and off shore waters, respectively. Leaf densities averaged 3460-4300 blades per m^2.

Thalassia was found to have an optimum temperature near 30°C and an optimum salinity near 30%. Standing crop varied by about 50% throughout the year, with leaf decreases during flower and fruit production and again in the fall. *Thalassia* produced about 6.8 crops of leaves per year. Few were directly grazed. The leaves decayed rapidly, losing 65% of their original weight in seven weeks. Drying and agitation greatly accelerated decomposition. Turtle grass contributes to the maintenance of the high production of estuaries in many other ways also.>

314. Van Tine, R. F. 1977. **An ecological comparison of the benthic macroflora of a power plant impacted estuary and an adjacent estuary.** Master of Science Thesis, University of Florida.

[BIOMASS, DISTRIBUTION, MACROALGAE, SEAGRASS, THERMAL EFFECTS]

<The ecology of the benthic seaweeds and seagrasses of two adjacent estuaries in the eastern Gulf of Mexico, one impacted by a steam electric generating facility, is considered. Species composition, biomass, seasonality, diversity and distribution of the macrophytes of these two ecosystems are compared with respect to pertinent physical parameters, including effects of the power plant. The biomass and diversity of the benthic flora decrease with proximity to the thermal plume: there are barren areas coincident with it. Both diversity and biomass are much higher in the unimpacted estuary. An extremely simple system consisting of but a single species of seagrass (*Halodule beaudettei*) has developed in the area adjacent to the immediate discharge of heated effluent. Blue-green algae are found in sparse patches at the site of immediate discharge. It is suggested that temperatures in the thermal plume exceed the thermal tolerances of marine algae, which are totally absent from the most thermally stressed areas. It is also suggested that, in areas where the temperature does not exceed the thermal maxima, the combination of high temperature and high turbidity causes increased respiration and decreased photosynthesis, resulting in a low or negative net productivity. Sublittoral algae appear to be most susceptible to heat stress from the inverse layering of the plume waters. There is a significant sublittoral region which is barren of macrophytes due to high temperature, low water clarity and unconsolidated sediments carried by the plume waters. With the addition of the nuclear unit, the thermal plume is expected to cover an area 2 1/2 times as great as the pre-existing plume, in excess of 1500 acres. It is predicted that, with turn on of the nuclear cooling system: 1) there will be a temporary die-back of all macrophytes in a substantial area, due to increased turbidity; 2) a larger area without any macrophytes but with blue-green algae will develop; 3) a simple eco-system revolving around *Halodule beaudettei* will come to dominate the shallow basins; 4) increased sedimentation will expand those sublittoral areas which are presently barren due to the combination of high temperature, poor water clarity and unconsolidated substrate. The above predictions are based on the proposed addition of a nuclear unit (unit 3) and do not take into account any other future enlargements of the power facility.>

315. Pangallo, R. 1985. **The root and rhizome dynamics of *Halodule wrightii* and its relation to meiofauna abundance.** Master of Science Thesis, University of South Florida.

[BIOMASS, HALODULE, MEIOFAUNA]

<An examination of the dynamics of both the aboveground and belowground structure of the seagrass *Halodule wrightii* (Asherson) Asherson showed a strong seasonality in aboveground and belowground biomass. There was an inverse relationship between root biomass, which reaches a maximum in January, February and March and rhizomes, which reach their maximum biomass in August. This pattern is similar to that found in grasses of salt marsh ecosystems in the northeastern U.S.A. The low ratios between aboveground and belowground biomass indicated that, in general, the seagrass belowground system possesses higher complexity than the rhizomatous plants of the terrestrial system. Both natural monitoring and experimental evidence indicated no strong relationship between abundance of major meiofauna taxa and the abundances of either aboveground or belowground plant structures. Examination of copepod taxa also failed to detect any significant response of meiofauna to experimental manipulation of rhizome density. These results also parallel findings for salt marsh fauna and belowground structures of salt marsh grasses. The density of belowground structures of *H. wrightii* did not influence meiofaunal abundance.>

316. Kenworthy, W. J. and G. W. Thayer. 1984. **Production and decomposition of the roots and rhizomes of seagrasses, *Zostera marina* and *Thalassia testudinum*, in temperate and subtropical marine ecosystems**. Bulletin of Marine Science. 35: 364-379.

[BIOMASS, DECOMPOSITION, PRIMARY PRODUCTIVITY]

<Seagrasses, *Zostera marina* in temperate regions and *Thalassia testudinum* in subtropical and tropical areas, form the basis of highly productive subtidal wetlands. We present our research results and a review of the literature concerning production, biomass and decompsition of roots and rhizomes of these seagrass species. *Zostera* rhizomes and roots are a substantial source of organic matter to estuarine sediments. During early stages of decay the roots and rhizomes leach soluble organic matter that is readily utilized by bacteria. The remaining particulate fraction decomposes slowly and has a larger pool of refractory material than the leaves. Thus, the particulate fraction of *Zostera* roots and rhizomes provides a large and relatively enduring source of organic detritus, which is available even during periodic fluctuations in above-ground production by this seagrass and other autotrophs. Under ambient conditions *Thalassia* rhizome decay was significantly slower than that for *Zostera*, while root decay rates were similar. The turnover rates for these two seagrasses suggest differences in the potential sources and availability of nutrients in sediments of temperate and tropical seagrass meadows. The contribution of seagrass root and rhizome detritus to the energetics and nutrient cycles of benthic ecosystems is discussed.>

317. Zieman, J. C., R. L. Iverson, and J. C. Ogden. 1984. **Herbivory effects on *Thalassia testudinum* leaf growth and nitrogen content.** Marine Ecology Progress Series. 15: 151-158.

[LEAF WIDTH, NUTRIENTS, SEDIMENTS, THALASSIA]

<The pattern of turtle grazing on *Thalassia testudinum* in St. Croix seagrass beds begins with the establishment of a grazing plot by initial removal of leaf blades, followed by repeated grazing of several centimeter-long leaf blades within a maintained grazing area. Plants within the grazed area exhibit increased specific growth rate as a consequence of increased light flux to

unepiphytized leaf bases. Leaf width is reduced in the grazed area as a consequence of grazing stress. The leaf bases contain a higher proportion of nitrogen and a lower lignin content than the leaf tips, in addition to lacking epiphytes. Our data suggest that the grazing areas are abandoned when the sediment ammonium concentration is reduced, leading to reduced growth rates of *T. testudinum*. Effects of sea urchin grazing on *T. testudinum* were similar to effects of turtle grazing but were reduced in magnitude as a consequence of lower urchin grazing pressure.>

318. Orth, R. J. 1977. **The importance of sediment stability in seagrass communities**. In: Ecology of Marine Benthos. Edited by B. C. Coull, 281-300. Columbia: University of South Carolina Press.

[MACROFAUNAL DISTRIBUTION, SEDIMENT GRAIN SIZE]

<Dense stands of seagrass are shown to stabilize sediments from studies of *Zostera* beds in the Chesapeake Bay and *Thalassia* beds in Bermuda. Particle size distribution, and degree of sorting decreased and organic content increased from bare sand to the center of a seagrass bed. Macrofaunal distribution in seagrass beds and experimental manipulation of *Zostera* beds in the Chesapeake Bay indicate that sediment stability results in high infaunal diversity and density. The dense rhizome mat also serves to decrease the effects of predation by preventing blue crabs from digging beneath the sediment surface layer.>

319. Strawn, K. 1961. **Factors influencing the zonation of submerged monocotyledons at Cedar Key, Florida**. Journal of Wildlife Management. 25: 187-188.

[TIDES, ZONATION]

<Five species of submerged monocotyledons occur on the grass flats at Cedar Key: *Diplanthera wrightii* (Ascherson); widgeon grass (*Ruppia maritima* L.); *Halophila engelmanni* Ascherson; turtle grass (*Thalassia testudinum* König); and manatee grass (*Syringodium filiforme* Kützing). The zonation of these plants in shallow inshore water is determined by tidal level and is modified by tide pools and by water draining across the grass flats during low tide. Plant zonation at Cedar Key, where two low and two high tides per day are of usual occurrence, differs from that found in areas where one high and one low tide per day are frequent. Plant parts exposed to air are desiccated and die. Prolonged exposure to dry, cold winds occurs during the day in winter and limited exposure to humid air occurs in the late afternoon and after sundown during summer. Shallow water and the winter environment are less severe on species with flexible leaves than on species with stiff leaves. Deeper water and summer conditions favor plants with stiff leaves. The distance between the mean low water level and the bottom in grass-flat areas is controlled by an equilibrium between particle sizes of bottom deposits, ground cover provided by plants, and the depth of the water covering vegetated areas during low winter tides. Plants limit erosion of the grass flats during hurricanes. Dredging and filling based on a thorough knowledge of the ecology of the seagrasses can be used to restore grass flats to areas where they have been destroyed and to enlarge existing grass flats.>

320. Tomlinson, P. B. 1974. **Vegetative morphology and meristem dependence - the foundation of productivity in seagrasses**. Aquaculture. 4: 107-130.

[MERISTEM DEPENDENCE, PRIMARY PRODUCTIVITY]

<Shoot organization in seagrasses varies from the unspecialized condition of *Enhalus* and *Posidonia* to the highly differentiated shoot systems of plants like *Halophila*, *Thalassodendron* and *Thalassia*. In the former type proliferation of vegetative meristems seems to be an unordered process, whereas in the latter type proliferation can be very ordered. In some examples, e.g. *Syringodium*, proliferation of rhizomes is not regularized in shoot organization but is largely a consequence of perturbation by the environment. Since production of new organs and proliferation of indeterminate shoot systems is dependent entirely on continually active meristems, with either a limited tendency to form resting meristems or often no such ability at all, seagrasses show a high degree of meristem dependency.>

321. Tomlinson, P. B. and G. A. Vargo. 1966. **On the morphology and anatomy of turtle grass *Thalassia testudinum* (Hydrocharitaceae). I. Vegetative morphology**. Bulletin of Marine Science. 16: 748-761.

[MORPHOLOGY, THALASSIA]

<In an introductory account of the vegetative morphology of *Thalassia testudinum* König, a very constant organ symmetry is described. A horizontal long-shoot bearing only scale-leaves produces lateral buds alternately on opposite sides at regular intervals separated by 9 to 13 internodes. No buds are associated with intervening scales. Buds are opposite, not axillant to the subtending leaf and because of this unusual position and their precocious development it can be disputed that they are lateral. Buds become erect short-shoots bearing, initially, scale-leaves but soon, foliage-leaves. Long- and short-shoots have the same fundamental symmetry. Each is autonomous so that the one can only become the other by branching. Because of the absence of residual meristems, growth of *Thalassia* is largely dependent on activity of shoot apical meristems, even root production being limited to apical regions. In the absence of rhizome apices, isolated fragments do not regenerate.>

322. Lyngby, J. E. and H. Brix. 1989. **Heavy metals in eelgrass (*Zostera marina* L.) during growth and decomposition**. Hydrobiologia. 176/177: 189-196.

[DECOMPOSITION, GROWTH, HEAVY METALS, ZOSTERA]

<The distributions of cadmium, chromium, lead, and zinc in eelgrass were studied in samples collected from the field, and the loss/accumulation of the metals during decomposition of eelgrass leaves was studied in laboratory experiments. Concentrations of heavy metals in the below grounds parts were greater in the roots than in the different age groups of the rhizomes. In the rhizomes, the highest concentrations of lead were recorded in the oldest parts, whereas highest chromium and zinc concentrations were found in the youngest parts. The concentration of cadmium did not vary. In the above ground parts, the concentrations of cadmium, lead and zinc increased with age of the leaves, and concentrations in the leaves were greater than in the stem fraction. The concentrations of chromium decreased with age of the leaves. In the laboratory study of decomposition of leaf material, the concentrations of chromium, lead and zinc increased significantly and a net absorption from the surrounding water

was recorded. Cadmium concentrations were relatively constant and a loss of cadmium was proportional to the release of soluble organic compounds indicating an association of cadmium with the soluble phase. The investigation demonstrated the utility of compositional analyses and decomposition experiments in assessing the significance of eelgrass in the heavy metal cycling in coastal areas. Furthermore, significant differences in the fate of heavy metals associated with eelgrass detritus are discussed.>

323. Kramer, R. J. and C. J. Dawes. 1987. **Comparison of proximate constituents in two seagrasses from the Gulf of Mexico, Florida Keys, and Belize, Central America.** Journal of Coastal Research. 3: 445-450.

[PRIMARY PRODUCTIVITY, SEAGRASS, SYRINGODIUM, THALASSIA]

<The levels of soluble carbohydrate, protein, lipid, and ash in seagrasses *Thalassia testudinum* Banks ex König and *Syringodium filiforme* Kützing were determined from collections made during a single month from subtropical populations on the west coast of Florida and the Florida Keys, and tropical populations from an atoll of Belize, Central America. A high similarity was found for proximate constituents when populations of *T. testudinum* from subtropical and tropical sites were compared. Larger differences in levels of proximate constituents occurred between species and plant components (blade, short shoot, rhizome) than between tropical and subtropical populations of *T. testudinum*. On the other hand, *S. filiforme* populations showed significant differences for all four proximate constituents when subtropical and tropical populations were compared. Total caloric values of plant segments, based on dry weight, were very similar between populations and species. The data are interpreted as demonstrating a strong uniformity in levels of proximate constituents between populations regardless of latitudinal distribution, although seasonal and plant components may vary.>

324. Hine, A. C., M. W. Evans, J. Davis RA, and D. F. Belknap. 1987. **Depositional response to seagrass mortality along a low-energy, barrier-island coast: West-central Florida.** Journal of Sedimentary Petrology. 57: 431-439.

[AERIAL PHOTOGRAPHY, SEDIMENTS]

<Analysis of aerial photographs and nearshore surficial sediment samples from the northern islands of the west-central barrier system of Florida indicates that 1) seagrass beds in the nearshore zone have controlled onshore/longshore sand transport, and 2) resulting sedimentary accumulations within nearshore seagrass beds make differentiation between nearshore and backbarrier facies difficult. Between 1957 and 1967, an extensive seagrass community occupying the nearshore zone off Anclote Key disappeared, thus allowing the sudden and rapid onshore and longshore transport of sand. The 1,000-year-old barrier island lengthened 30 percent by recurved spit growth in a 15-year period from 1967-82. Although there are no direct observations, four possible causes of seagrass mortality have been postulated, which are as follows: 1)physical destruction by storms; 2) infection by pathogens; 3) decline of water quality due to human development; and 4) overgrazing by sea urchins. Because of the ability of seagrasses to trap fine-grained sediments, contribute organic matter, and provide for low-energy, sheltered molluscan biocoenose, strong similarities

remain between surficial sediments of recently devegetated, active nearshore zones and backbarrier/lagoonal facies. The stable carbon isotopic ratios and the molluscan assemblages within the ubiquitous fine quartz sands, in particular, are similar within these two normally disparate environments. This study indicates that the development and destruction of benthic floral communities should be considered as a process that generates episodic/cyclic depositional events in the sedimentary record. Additionally, such changes in seagrass communities should be expected to present a blurred distinction between nearshore and backbarrier sedimentary facies.>

325. Twilley, R. R., W. M. Kemp, K. W. Staver, J. C. Stevenson, and W. R. Boynton. 1985. **Nutrient enrichment of estuarine submersed vascular plant communities. 1. Algal growth and effects on production of plants and associated communities.** Marine Ecology Progress Series. 23: 179-191.

[EPIPHYTES, NUTRIENT ENRICHMENT, PAR]

<Eight experimental ponds containing submersed vascular plants (predominantly *Potamogeton perfoliatus* and *Ruppia maritima*) were subjected in duplicate to 4 levels (including controls) of fertilization from June to August 1981. Seston and phytoplankton chlorophyll *a* increased with fertilization, and pronounced algal blooms were evident under high dosage. Of the total seston, phytoplankton exerted the greatest influence on attenuation of photosynthetically active radiation (PAR), such that there was insufficient light for submersed vascular plant growth at the sediment surface during blooms. An extensive epiphytic community developed on plants in all nutrient-treated ponds at densities similar to those observed in nature on senescent plants. At high nutrient treatments the accumulation of epiphytic material resulted in >80% attenuation of the incident radiation at the leaf surface. Biomass of submersed macrophytes decreased significantly under high and medium nutrient treatments compared to control and low treatments within 60 d following initial fertilization. Apparent production of vascular plants (based on oxygen production and ^{14}C-bicarbonate uptake) was reduced at the higher nutrient treatments for both *R. maritima* and *P. perfoliatus*. Most of this reduction in macrophyte photosynthesis could be explained by attenuation of PAR associated with epiphytic material. However, without PAR attenuance in the overlying water, observed levels of epiphytic growth would be insufficient to reduce light below compensation levels needed to sustain vascular plant growth. At the high fertilization rates, integrated primary production of pond communities was significantly reduced with the loss of the vascular plants, even though phytoplankton and epiphytic growth were enhanced.>

326. Robertson, M. L., A. L. Mills, and J. C. Zieman. 1982. **Microbial synthesis of detritus-like particulates from dissolved organic carbon released by tropical seagrasses.** Marine Ecology Progress Series. 7: 279-285.

[CARBON DISSOLVED ORGANIC, DETRITUS]

<Dried leaves of *Thalassia testudinum* and *Syringodium filiforme* released 12.6% and 19.4%, respectively, of their organic carbon as dissolved organic carbon (DOC) during 3 d of axenic leaching. When inoculated with microbes, the DOC was rapidly converted to bacterial aggregates of a size that

could be ingested by macroconsumers. Large populations of ciliates and flagellates also developed, presumably feeding on the unaggregated bacteria. In treatments containing the residual macroparticulate organic carbon (MPOC), 75-95% of the bacteria present were attached to the leaves, and suspended aggregates were not observed. The protozoan community was dominated by free-swimming flagellates that grazed on the suspended bacteria and were thus responsible for the absence of those forms. Total microbial populations in the DOC treatments were 10-12 times greater per unit of seagrass carbon originally added than in the MPOC containing flasks. These results show that seagrass DOC may rapidly be made available to higher consumers through processes that produce suitable sized food particles: viz., growth of protozoans on bacteria and formation of bacterial aggregates.>

327. Capone, D. G. 1982. **Nitrogen fixation (acetylene reduction) by rhizosphere sediments of the eelgrass *Zostera marina*.** Marine Ecology Progress Series. 10: 67-75.

[NITROGEN FIXATION, SEDIMENTS, ZOSTERA]

<Nitrogen fixation (acetylene reduction) was consistently and immediately detectable in rhizosphere sediments of the eelgrass *Zostera marina* L. collected from several stations and at various times of the year. Nitrogenase activity was detected down to 12 cm with the major fraction occurring in the 0 to 6 cm segment. Nitrate and NH_4^+ (100 to 200 μM) inhibited nitrogenase activity, while glucose (1 mM) accelerated rates of C_2H_2 reduction. Much of the nitrogenase activity appears to be associated with sulfate-respiring bacteria. During the summer, rates of C_2H_2 reduction to 10 cm averaged about 1.5 to 2.5 nmol C_2H_4 x cm^{-2} h^{-1} (0.1 to 0.2 nmol x g dry sed^{-1} h^{-1}). This could account for from 3 to 28% of the net nitrogen demand of the plant. While supplying a substantial fraction of the nitrogen required by eelgrass, rhizosphere N_2 fixation in *Z. marina* communities may represent a lesser input when compared to the tropical seagrass *Thalassia testudinum*. Information on the magnitude of other nitrogen transformations is needed to evaluate fully the importance of N_2 fixation in these systems.>

328. Fry, B., R. S. Scalan, J. K. Winters, and P. L. Parker. 1982. **Sulphur uptake by salt grasses, mangroves, and seagrasses in anaerobic sediments.** Geochimica et Cosmochimica Acta. 46: 1121-1124.

[SEDIMENTS, SULFUR, UPTAKE]

<Stable sulfur isotope analyses show that rooted estuarine plants growing in anoxic sediments incorporate substantial amounts of ^{34}S-depleted sulfides, or oxidation products thereof. In roots, this incorporation predominates over sulfate uptake from interstitial porewater. Either the plants incorporate normally toxic sulfides, or they are creating and using a specialized nutrient pool of oxidized sulfides at the root-sediment interface.>

329. McRoy, C. P. 1974. **Seagrass productivity: carbon uptake experiments in eelgrass, *Zostera marina*.** Aquaculture. 4: 131-137.

[LIGHT, PRIMARY PRODUCTIVITY, SEASONALITY, ZOSTERA]

<The productivity of eelgrass, *Zostera marina* L., was measured in relation to light and season using ^{14}C. Net productivity during the summer averaged 56 μg C/g dry weight per langley and on an areal basis 4.8 g C/m^2 per day. The total production during the growing season was calculated to be 812 g C/m^2 with at least a twofold turnover of the standing stock during this period. The uptake of carbon in relation to light intensity is hyperbolic below 50% light followed by some inhibition at higher intensities. This response is described using Michaelis-Menton kinetic equations. These experiments indicate that light saturation occurs at very low intensity. The half-saturation constant (K_m) was 12.5% of surface light.>

330. Zieman, J. C. 1974. **Methods for the study of the growth and production of turtle grass, *Thalassia testudinum* König**. Aquaculture. 4: 139-143.

[GROWTH, PRIMARY PRODUCTIVITY, THALASSIA]

<Research has shown that the measurement of the productivity of vascular hydrophytes by gas exchange methods is inaccurate due to the storage of gases within the leaves. Methods were developed for the study of turtle grass, *Thalassia testudinum* König, which allow: (a) the monitoring of the blade populations without disturbing the plant, and (b) the determination of leaf growth and net production of the blades, in addition to other biotic variables associated with the growth and development of the plant. The technique involves the marking of individual blades with a modified stapler, and the retrieval of the marked blades after a 2-3 week interval. The production measured is that which is readily available to the consumers of the *Thalassia* community.>

331. Robertson, M. L. 1982. **The effects of species origin and environmental setting on the decomposition of two tropical seagrasses, *Thalassia testudinum* and *Syringodium filiforme*.** Master of Science Thesis, Department of Environmental Sciences, University of Virginia, Charlottesville, VA.

[DECOMPOSITION, DETRITUS, SEDIMENTS]

<Field studies of decomposition of leaves from the seagrasses *Thalassia testudinum* and *Syringodium filiforme* were made using litter containers in two environments: the sea surface and the grassbed sediment surface. In 1979, weight loss measured as ash free dry weight (AFDW) change was faster for *Syringodium* than *Thalassia* during 40 days on the sea surface (no sediment surface samples). Initially there was a net accumulation of AFDW for both species, attributed to seagrass photosynthesis. From initial populations that were approximately equal, the number of bacteria per g AFDW increased 4 times faster on the *Syringodium* litter than the *Thalassia* litter. In 1980, AFDW loss was faster for *Syringodium* than *Thalassia* in both environments and faster on the sea surface than the sediment surface for both grasses during the 59 day study. The nitrogen content per g AFDW was 50-100% higher in the *Syringodium* litter; no clear effect of environment on N content was observed. The oxygen utilization rate of the litter increased during the study; the rate per g AFDW was 10-100% higher for *Syringodium* than *Thalassia*, significantly higher on the sea surface for both seagrasses. From these results two general conclusions were drawn. First, *Syringodium* detritus would be a food source of greater potential value

to consumers than *Thalassia* detritus, due to faster particle size reduction, higher N content, and more abundant and metabolically active microbes. Second, sea grass litter decomposing on the sea surface as drift export would become available to consumers faster than litter retained on the grassbed sediment surface, due to faster physical fragmentation and microbial decomposition.>

332. Kenworthy, W. J. 1981. **The interrelationship between seagrasses, *Zostera marina* and *Halodule wrightii*, and the physical and chemical properties of sediments in a mid-Atlantic coastal plain estuary near Beaufort, North Carolina.** Master of Science Thesis, Department of Environmental Sciences, University of Virginia, Charlottesville,VA.

[NUTRIENTS, SEDIMENT GRAIN SIZE, SEDIMENT NUTRIENTS]

<A study was undertaken to evaluate the interrelationship between the growth of seagrasses, *Zostera marina* and *Halodule wrightii*, and the physical and chemical properties of sediments in a coastal plain estuary near Beaufort, North Carolina. Sediment profiles in vegetated and unvegetated substrates were analyzed for % silt-clay, % organic matter, exchangeable ammonium, ammonium dissolved in pore water, total nitrogen, Eh and pH. Plant growth for both species was evaluated in a year long study (1978-1979) of biomass and canopy surface area. A technique was developed for measurement of the *in situ* net production of leaves, rhizomes and roots of *Z. marina*, and used to estimate the net productivity of this plant growing in sediments having different physical and chemical properties. In sediments underlying a cover of seagrass the measured parameters were larger in magnitude than in unvegetated profiles and appear to have accumulated in the upper 15 to 18 cm. A gradient analysis of sediment profiles within and between different habitats showed that the magnitude of the physical and chemical properties varied according to the location in the vegetation. The largest pools of nitrogen, the finest sediment texture, and the greatest organic matter content were in stations associated with the mid-bed regions of seagrass meadows; areas having a cover of grass established for the longest period of time. The lowest values for each measured variable were observed in unvegetated substrate; areas not directly influenced by the seagrass. Intermediate values were found in edge and patch stations; substrates most recently colonized by the vegetation. These data were discussed in regard to contemporary theories of ecosystem development and ecological succession. Seasonal measurements of plant biomass showed that the seagrass communities consisted of both monospecific and mixed species meadows. In mixed communities the species exhibited a bimodal seasonal pattern of abundance. *Z. marina* dominated the community in winter, spring and early summer, while *H. wrightii* was more abundant in late summer and early fall. This bimodal pattern of species abundance may be important in maintaining an extended period of influence in mixed stands of seagrass. *Z. marina* allocated more net production to roots in coarse textured sediments, low in organic matter, and deficient in nitrogen relative to other stations. Total shoot net production was highest in sediments with the finer texture, greatest organic matter content and largest pools of nitrogen. General conclusions from this study are: 1) once established, seagrasses appear capable of modifying the sediment texture, organic matter content, and the magnitude of the intermediate polls in the cycle of nitrogen; 2) nitrogen accumulates beneath the vegetation suggesting that these areas are sinks; however, functional recycling mechanisms appear to be operating as suggested by the larger magnitude of remineralized nitrogen in the vegetated

profiles; and 3) although the establishment of seagrasses are not necessarily restricted by the sediment properties measured in this study, total shoot net production and the allocation of net production varied as a function of the physical and chemical properties of the sediments.>

333. McMillan, C. 1983. **Seed germination in *Halodule wrightii* and *Syringodium filiforme* from Texas and the U.S. Virgin Islands.** Aquatic Botany. 15: 217-220.

[REPRODUCTION, SEED GERMINATION]
<Seed germination under laboratory conditions was nearly continuous in both *Halodule wrightii* Aschers. and *Syringodium filiforme* Kütz. *Halodule* seeds that were sieved from sediments in Texas and St. Croix in 1978 continued to germinate for over 3 years in artificial seawater. *Syringodium* seeds that were collected on reproductive shoots in 1979 continued to germinate for 3 years. The potential longevity of seeds of *Halodule* and *Syringodium* may exceed that of seeds of any other seagrass.>

334. Grey, W. F. and M. D. Moffler. 1978. **Flowering of the seagrass *Thalassia testudinum* (Hydrocharitaceae) in the Tampa Bay, Florida area.** Aquatic Botany. 5: 251-259.

[FLOWERING, REPRODUCTION, THALASSIA]
<Nine sites in the Tampa Bay area were sampled during June 1976 to document flowering occurrence and obtain baseline data for the study of flowering populations of *Thalassia testudinum* Banks ex König. Flowering occurred at all sites. Qualitative information was obtained on three distinct floral stages: bed, anthesis, and fruit. Comparison between two sites showed that frequency of sexual reproduction varied from 35 to 56%. Average densities of reproductive short-shoots ranged from 8 to 19 m^{-2}. Sex ratios from individual sites indicated general predominance of female over male short-shoots, with an average overall ratio of 3:1. Field observations and transect data demonstrated patchiness in the spatial pattern of reproductive short-shoots. Limited evidence provided additional information indicating that short-shoots on a common rhizome (i.e. an individual *Thalassia* plant) are dioecious.>

335. Craven, P. A. and S. S. Hayasaka. 1982. **Inorganic phosphate solubilization by rhizosphere bacteria in a *Zostera marina* community.** Canadian Journal of Microbiology. 28: 605-610.

[PHOSPHORUS, RHIZOSPHERE, ZOSTERA]
<Actively growing *Zostera marina* plants had a greater rhizosphere inorganic phosphate solubilizing potential than dormant plants. Rhizosphere bacteria that were capable of calcium phosphate solubilization were obligate aerobes and numbered approximately 4×10^6 colony-forming units/g dry weight root. Bacterial isolates solubilized calcium phosphate when cultured with glucose as the sole carbon and energy source but not when cultured with amino acids. Both calcium phosphate (hydroxyapatite) and glucose were found in sea grass bed sediment. Acetic acid was also detected from roots plus clinging sediment, from sediment, and from cultured bacterial isolates in a glucose-supplemented medium. The minimum concentration of acetic acid that showed detectable solubilization of calcium phosphate was 10^{-5} *M*. It is suggested

that acetic acid, a product of glucose metabolism in the rhizosphere flora, is responsible for phosphate solubilization in the environment.>

336. Smith, G. W. and S. S. Hayasaka. 1982. **Nitrogenase activity associated with *Zostera marina* from a North Carolina estuary.** Canadian Journal of Microbiology. 28: 448-451.

[GROWTH, NITROGENASE ACTIVITY, ZOSTERA]

<Nitrogenase activity (at *in situ* temperatures) associated with *Zostera marina* reflected the active growth periods of this plant in North Carolina coastal waters. During the plants most active growth period (late winter - spring) nitrogenase activity was primarily rhizospheric (8.47 µmol nitrogen fixed m^{-2} day^{-1}), while during its fall - early winter period it was primarily phyllospheric (8.03 µmol nitrogen fixed m^{-2} day^{-1}). No nitrogenase activity was detected during the warmer summer months when the plant is dormant. Phyllospheric nitrogenase activity (possibly the result of epiphytic heterocystic blue-green bacteria) was highest when plants were incubated aerobically in the presence of light.>

337. Johnson, E. A. and S. L. Williams. 1982. **Sexual reproduction in seagrasses: reports for five Caribbean species with details for *Halodule wrightii* Aschers. and *Syringodium filiforme* Kütz.** Caribbean Journal of Science. 18: 61-78.

[SEXUAL REPRODUCTION]

<Sexual reproduction occurred in the spring of 1975 in all seagrass species from the waters of St. Croix, U.S. Virgin Islands: *Thalassia testudinum* (Hydrocharitaceae), *Syringodium filiforme* (Potamogetonaceae), *Halodule wrightii* (Potamogetonaceae), *Halophila decipiens* (Hydrocharitaceae), and *Ruppia maritima* (Ruppiaceae). Relatively pure stands of *S. filiforme* and *H. wrightii* were found with abundant flowering material and morphological description and quantitative analyses of key phenological events in their reproductive episodes are given.>

338. Penhale, P. A. and R. G. Wetzel. 1983. **Structural and functional adaptations of eelgrass (*Zostera marina* L.) to the anaerobic sediment environment.** Canadian Journal of Botany. 61: 1421-1428.

[ROOT RESPIRATION METABOLISM, SEDIMENTS, ZOSTERA]

<Structural and functional adaptations of the seagrass *Zostera marina* L. to the anaerobic sediment environment were examined both experimentally and under natural conditions along a transect including environmentally different sites in Izembek Lagoon, Bering Sea, Alaska. Aerobic root respiration rates, end products of anaerobic metabolism in roots and rhizomes, lacunal development, and internal gas volume and gas composition were compared among plants from three sites. Root respiration decreased across the transect from the intertidal site to the two subtidal stations of increased sediment anaerobiosis. Ethanol concentrations of roots and rhizomes were very low in all cases and shikimate could not be detected. Malate concentrations in the rhizome tissues were high in the midbed portion of the transect and lower at both the intertidal and deep edges of the bed; malate concentrations of root tissue followed a reciprocal pattern. The internal gas volume (lacunal space) of leaves and roots increased along the transect of increased sediment anaerobiosis. Anatomical observations

of roots showed a similar trend with enhanced lacunal development at the most anaerobic site. Data collected in field and laboratory experiments in which the hydrogen sulfide concentration surrounding the roots and rhizomes was enhanced showed physiological adaptations characteristic of tolerance to anaerobiosis. The collective data indicate that *Zostera marina* is capable of responding to markedly different microenvironments.>

339. Harrison, P. G. 1979. **Reproductive strategies in intertidal populations of two co-occurring seagrasses (*Zostera* spp.).** Canadian Journal of Botany. 57: 2635-2638.

[REPRODUCTION, ZOSTERA]

<Reproductive strategies were analyzed in intertidal populations of two seagrasses of the genus *Zostera* to test the application of *r*-K selection theory to a novel habitat. *Zostera americana* has appeared in the study area recently and is spreading rapidly. It grows in the mid to upper intertidal regions and is an *r*-strategist: i.e., a rapidly growing, essentially annual plant that uses a large proportion (up to 25%) of its resources for flowering. *Zostera marina*, the native eelgrass, grows in the mid to low intertidal regions and is a K-strategist; i.e., a perennial that uses a large proportion of its resources for maintenance via rhizomes and roots. Considering that the environment becomes less predictable for marine plants on a gradient from the lower to the upper end of the intertidal zone, then the two seagrasses behaved as predicted by the theory.>

340. Harrison, P. G. and K. H. Mann. 1975. **Chemical changes during the seasonal cycle of growth and decay in eelgrass (*Zostera marina*) on the Atlantic coast of Canada.** Journal of the Fisheries Research Board of Canada. 32: 615-621.

[DECOMPOSITION, GROWTH, NUTRIENTS, ZOSTERA]

<In a submerged bed of eelgrass, newly formed leaves in winter and spring had their maximum levels of total organic matter (90% of dry weight), soluble organic fraction (45%), carbon (42%), and nitrogen (4.8%). These components all decreased as the leaves matured, aged, and died. Soon after death, a leaf had only 70% total organic matter, 28% soluble organic matter, 30% carbon, and 1.5% nitrogen. Intact dead leaves showed little further change in chemical composition. The commonly used crude protein determination (6.25 x nitrogen content) overestimated true protein by up to 180%. The carbon to nitrogen ratio (C:N) was an unreliable index of the nutritional value of the plant. Two growth forms were present, most probably in response to wave action and substrate composition. Daylength, not temperature, most probably controls the seasonal cycle of growth.>

341. Harlin, M. M. 1973. **Transfer of products between epiphytic marine algae and host plants.** Phycologia. 9: 243-248.

[CHEMICAL EXCHANGE, EPIPHYTES]

<The red alga *Smithora naiadum* is normally found only as an epiphyte on the sea grasses *Phyllospadix scouleri*] and *Zostera marina*. I used ^{32}P and $^{14}CO_2$ to examine the chemical communication between host and alga. Both ^{32}P and the product of $^{14}CO_2$ light fixation moved from the host to the alga. Reverse movement

between host and epiphyte was also demonstrated. Part of this transfer occurred through the plant and part occurred by leakage from the host into the medium and subsequent uptake by the alga. Although plants were initially labeled in the light, transfer of ^{14}C was light independent. Transfer of ^{14}C-labeled products between host and epiphyte was also shown for *Punctaria orbiculata* and *Z. marina*; for *Microcladia coulteri* on *Grateloupia doryphora*, and between *Gonimophyllum skottsbergii* and *Botryoglossum ruprechtiana*. Epiphyte-host associations do not require a penetrating rhizoid for an exchange of the isotopes tested. By their proximity alone, epiphytic flora are apparently capable of exchanging products before these are diluted by the sea.>

342. Patriquin, D. G. 1972. **Carbonate mud production by epibionts on *Thalassia*: An estimate based on leaf growth rate data.** Journal of Sedimentary Petrology. 42: 687-689.

[EPIBIONTS, SEDIMENTS, THALASSIA]

<An estimate of the carbonate mud production by epibionts on *Thalassia* at Barbados, 2800 g/m^2-year for a typical stand, is 16 times Land's estimate for Jamaican *Thalassia* beds. The difference is considered in part real, and in part due to Land's estimate being somewhat low.>

343. Scoffin, T. P. 1970. **The trapping and binding of subtidal carbonate sediments by marine vegetation in Bimini lagoon, Bahamas.** Journal of Sedimentary Petrology. 40: 249-273.

[CURRENTS, MACROALGAE, SEDIMENTS]

<In the shallow water lagoon of Bimini, Bahamas, the following plants are sufficiently abundant to influence sedimentation locally-mangroves (*Rhizophora mangle*), marine grass (*Thalassia testudinum*), macroscopic green algae (*Penicillus*, *Batophora*, *Halimeda*, *Rhipocephalus* and *Udotea*) and miscroscopic red, green and blue-green algae forming surface mats of intertwining filaments (*Laurencia*, *Enteromorpha*, *Lyngbya* and *Schizothrix*). Plants were observed under conditions of natural tidal currents and artificial unidirectional currents produced in an underwater flume and measurements were made of the abilities of the plants to trap and bind the carbonate sediment. The density of plant growth is crucial in the reduction of current strength at the sediment-water interface. The most effective baffles are *Rhizophora* roots exposed above the sediment, dense *Thalassia* blades and *Thalassia* blades with dense epiphytic algae, *Laurencia intricala* and *Polysiphonia havanensis*. All three types can reduce the velocity of water from a speed sufficiently high to transport loose sand grains along the bottom in clear areas (30 cm/sec) to zero at the sediment-water interface in the vegetated areas. The strongest binders of sediment are the roots of *Rhizophora* and *Thalassia*. These two hardy plants trap and bind sediment for a sufficient time to produce an accumulation higher than in nearby areas without dense mangroves or grass. Macroscopic green algae growth is not sufficiently dense and the holdfasts too weak to appreciably affect the accumulation of sediment although they provide a degree of stabilization to the substrate. Algal mats trap sediment chiefly by adhesion of grains to the sticky filaments. Their ability to resist erosion by unidirectional currents varies considerably depending on mat type, smoothness of surface and continuity of the cover. The intact areas of dense *Enteromorpha* mat can withstand currents five times stronger than those that erode loose unbound sand grains. Premature erosion of mats by

currents occurs at breaks in the mat surface caused by the burrowing or browsing action of animals. Algal mats were found to be ephemeral features and consequently do not build up thick accumulations of sediment as do dense grass and mangroves. The thickest accumulations of sediment in the lagoon is directly or indirectly controlled by the depth to bedrock; for example, mangroves on bedrock highs, marine grass in sediment-filled depressions.>

344. Land, L. S. 1970. **Carbonate mud: production by epibiont growth on *Thalassia testudinum*.** Journal of Sedimentary Petrology. 40: 1361-1363.

[EPIBIONTS, SEDIMENTS, THALASSIA]

<Epibiotic growth of coralline red algae and serpulid worms on the marine turtle grass *Thalassia testudinum* is sufficient to produce carbonate mud at rates comparable to the rates of accumulation of ancient platform carbonates.>

345. Brauner, J. F. 1975. **Seasonality of epiphytic algae on *Zostera marina* at Beaufort, North Carolina.** Nova Hedwigia. 26: 125-133.

[EPIPHYTES, SEASONALITY, ZOSTERA]

<The epiphytic flora of *Zostera marina* in the Beaufort, North Carolina area exhibits seasonal characteristics intermediate between those of the northeastern and southeastern coasts of the United States with just over 10% of the epiphytes of *Z. marina* present the year round. There are several periods during the year that different groups of species are present. Three species of Phaeophyta, *Desmotrichum balticum*, *D. undalatum*, and *Giffordia sandriana* are newly recorded for North Carolina. One species of Rhodophyta, *Polysiphonia flaccidissima*, is first reported for the Atlantic Ocean.>

346. Lazar, A. C. 1987. **A seasonal study of photosynthesis and respiration and levels of proximate constituents in two Tampa Bay populations of the seagrass, *Ruppia maritima* Linnaeus.** Master of Science Thesis, University of South Florida.

[NUTRIENTS, PHOTOSYNTHESIS, RESPIRATION, RUPPIA]

<Populations of *Ruppia maritima* Linnaeus, widgeon grass, exist in upper Tampa Bay along the Courtney Campbell Causeway and in lower Tampa Bay at Piney Point. The two areas show similar fluctuations in photosynthesis-irradiance response throughout the year with low compensation points and high photosynthetic maxima in March through May and high compensation points and low photosynthetic maxima values in September through November. Protein concentration at the two sites was highest in late winter implying a winter early growth period. Soluble carbohydrate was highest in the rhizome in the late summer suggesting early storage of nutrients compared to other seagrasses of the area. Plants from both sites demonstrated high rates of photosynthesis in high temperatures and salinities and low rates in low temperatures or salinities.>

347. Eleuterius, L. N. 1985. **Seagrass ecology along the coasts of Alabama, Louisiana and Mississippi.** American Journal of Botany. 72: 839-840.

[ECOLOGY, NORTHERN GULF COAST]

<This paper summarizes work accomplished since 1960 on seagrasses along the north-central coastal region of the Gulf of Mexico. The distribution of *Thalassia testudinum*, *Syringodium filiforme*, *Halodule wrightii*, *Halophila engelmannii* and *Ruppia maritima* along the coast of Alabama, Louisiana and Mississippi is described. The peculiar environmental factors affecting plant growth, horizontal and vertical displacement, and migration in this region are discussed. Variation in the number of shoots and leaves per unit area of sea bottom are shown in relation to water depth for *Halodule*. Seasonal and annual differences in plant productivity are shown to vary. Epiphytic algae and attached animals account for more than 70 percent of the total biomass for some seagrass beds. More animal species are found in *Thalassia* beds than those of other seagrasses. Along the Alabama, Louisiana, and Mississippi coasts, *Thalassia*, *Syringodium* and *Halophila* are in decline. In some places, *Syringodium* and *Halophila* have disappeared. Decline of *Halodule* seems to have stopped following a serious decline during the 1970's. *Ruppia* has become more abundant in the bays, bayous, and riverine estuaries along the mainland. Human related impacts include freshwater discharge from the Bonnet Carre Spillway on the Mississippi River, propeller ruts from power boats, shrimp trawls, alteration of habitat, erosion and probably pollution. Restoration (transplanting) work is reviewed.>

348. Pulich, W. M. 1985. **Role of subtropical seagrasses in trace metal cycling**. American Journal of Botany. 72: 842.

[SEDIMENTS, TRACE METALS, UPTAKE]

<This presentation will selectively review the processes of trace metal uptake and accumulation in subtropical seagrasses, the eventual fate of metals incorporated into seagrass tissues, and mechanisms by which seagrass colonization and production may affect estuarine trace metal cycling. Major reservoirs and flux pathways between reservoirs will be emphasized, and the chemical speciation and reactions undergone during migration of physiological trace metals (Fe, Mn, Zn, Cu) through estuarine systems will be illustrated. Biological uptake by seagrasses constitutes a major recycling mechanism for trace metals which could otherwise be lost to the estuarine sediment sink. Through the microbial process of sulfate reduction, trace metal cycling is closely interrelated with sulfur cycling; hence, factors which control sulfate reduction activity in estuarine sediments also govern the availability of trace metals. Seagrass root and rhizome systems may modify trace metal cycles through effects on sediment metal-sulfide chemistry. A case study of *Halodule wrightii* growth dynamics in southern Texas suggests how trace metal chemical transformations in sediments are directly influenced by the presence of seagrasses. The future directions of trace metal research in seagrass systems should focus on 1) the roles of organic-metal complexes and ionic (especially sulfur-metal) complexes in regulating seagrass production and species succession and 2) assessment of heavy metal bioaccumulation potential by seagrasses in contaminated areas.>

349. Zieman, J. C. and R. G. Wetzel. 1980. **Productivity in seagrasses: methods and rates**. Chap. 7. In: Handbook of seagrass biology: an ecosystem perspective. Edited by R. C. Phillips and C. P. McRoy, 87-116. New York: Garland STPM Press.

[METHODS, PRIMARY PRODUCTIVITY, REVIEW]

<A review of the methods of determining production in seagrasses is presented. An attempt is made to select the most pertinent measurements for seagrass biology. Units of measure are defined, seagrass physiology is summarized, and productivity techniques are explained in detail.>

350. Harlin, M. M. 1980. **Seagrass epiphytes**. Chap. 8. In: Handbook of seagrass biology: an ecosystem perspective. Edited by R. C. Phillips and C. P. McRoy, 117-131. New York: Garland STPM Press.

[EPIPHYTES]
<This chapter reviews work on floral and faunal epiphytes on seagrasses in different parts of the world. Three appendices are included that compile previously published species lists and note the seagrass on which each epiphyte was observed.>

351. Drew, E. A. 1980. **Soluble carbohydrate composition of seagrasses.** Chap. 13. In: Handbook of seagrass biology: an ecosystem perspective. Edited by R. C. Phillips and C. P. McRoy, 247-259. New York: Garland STPM Press.

[CARBOHYDRATES, NUTRIENTS]
<The chemical composition, physiology and biochemistry of seagrasses are reviewed. Samples from sixteen species have been analyzed by gas-liquid chromatography. The soluble carbohydrates include fructose, glucose, myo-inasitol, sucrose, and several unverified compounds. The data obtained indicate an interesting correlation between soluble carbohydrate content and taxonomic position.>

352. Dunton, K. H. and D. A. Tomasko. 1990. **Seasonal variations in the photosynthetic performance of *Halodule wrightii* measured *in situ* in Laguna Madre, Texas**. In: Results and recommendations of a workshop convened to examine the capability of water quality criteria, standards and monitoring programs to protect seagrasses from deteriorating water transparency. Edited by W. J. Kenworthy and D. Haunert, 63-70. West Palm Beach: South Florida Water Management District.

[HALODULE, LIGHT, P-I CURVES, PHOTOSYNTHESIS, RESPIRATION]
<Seasonal variations in the photosynthetic performance of the seagrass *Halodule wrightii* were determined from whole plants incubated *in situ* within a subtropical Texas seagrass community. Photosynthesis-irradiance (P-I) curves were calculated from rates of oxygen evolution within four 5.0 L chambers placed on the seabed. Oxygen measurements were collected continuously at 15-min intervals. Underwater photosyntheticall active radiation (PAR) was measured at one-minute intervals and integrated every 5 minutes on a continuous basis. The dry weight of the seagrass within each chamber was used in the rate calculations of photosynthesis and respiration, expressed as μmol O_2 evolved or consumed mg^{-1} hr^{-1}. No clear pattern in the seasonal measurements in root/rhizome and blade respiration or P-I parameters could be detected.>

353. Tomasko, D. A. and K. H. Dunton. 1990. **Growth and production of *Halodule wrightii* in relation to continuous measurements of underwater light levels in south Texas.** In: Results and recommendations of a workshop convened to examine the capability of water quality criteria, standards and monitoring programs to protect seagrasses from deteriorating water transparency. Edited by W. J. Kenworthy and D. Haunert, 71-76. West Palm Beach: South Florida Water Management District.

[GROWTH, HALODULE, LIGHT, PRIMARY PRODUCTIVITY]

<A comparison was made between continuous underwater light measurements and information on productivity and growth of *Halodule wrightii* in Laguna Madre, Texas. The relationship between underwater light and blade growth was complex, and varied with season. Maximum daily underwater irradiance (in μmoles photons m^{-2} s^{-1}) varied between less than 100 to over 1300. Using an average surface irradiance value of 2000 μmoles m^{-2} s^{-1}, it would seem that *H. wrightii* requires at least 2 to 5 percent of the surface irradiance just to maintain a positive energy balance during daylight hours.>

354. Fourqurean, J. W. and J. C. Zieman. 1990. **Photosynthesis, respiration and whole plant carbon budgets of *Thalassia testudinum*, *Halodule wrightii* and *Syringodium filiforme*.** In: Results and recommendations of a workshop convened to examine the capability of water quality criteria, standards and monitoring programs to protect seagrasses from deteriorating water transparency. Edited by W. J. Kenworthy and D. Haunert, 58-62. West Palm Beach: South Florida Water Management District.

[CARBON BUDGET, MODELS, PHOTOSYNTHESIS, RESPIRATION]

<Models were developed for the whole plant carbon budget of the three major seagrass species in south Florida, *Thalassia testudinum*, *Halodule wrightii*, and *Syringodium filiforme*. Laboratory measures of photosynthesis vs irradiance curves were generated using the oxygen evolution of intact shoots in sealed chambers. Apportionment of biomass into photosynthetic and nonphotosynthetic tissue was measured in the field, and the respiration rates of the individual tissues were measured. The P/I curves and apportionment and respiration data were used to build carbon budgets for each species.>

355. Gallegos, C. L., D. L. Correll, and J. Pierce. 1990. **Modeling spectral light available to submerged aquatic vegetation.** In: Results and recommendations of a workshop convened to examine the capability of water quality criteria, standards and monitoring programs to protect seagrasses from deteriorating water transparency. Edited by W. J. Kenworthy and D. Haunert, 106-118. West Palm Beach: South Florida Water Management District.

[AQUATIC MACROPHYTES, LIGHT, MODELS]

<A model was developed relating optical properties of the water column to the concentrations of light-absorbing and scattering materials dissolved and suspended in the water. The model partitions the contribution to total absorption and scattering coefficients amongst the various suspended and dissolved materials. The model was used to predict photic depths as a function

of water quality constituents for a range of assumed compensation points. The site-specificity of the model was examined using data from the Indian River, Florida.>

356. Hall, M. O., D. A. Tomasko, and F. X. Courtney. 1990. **Responses of *Thallassia testudinum* to *in situ* light reduction.** In: Results and recommendations of a workshop convened to examine the capability of water quality criteria, standards and monitoring programs to protect seagrasses from deteriorating water transparency. Edited by W. J. Kenworthy and D. Haunert, 77-86. West Palm Beach: South Florida Water Management District.

[LIGHT, SHADING, THALASSIA]
<The effects of decreased light availability on the morphology, growth, and production of *Thalassia testudinum* were investigated in a meadow near the mouth of Tampa Bay, Florida. Three shade and three control plots were established at both the shallow (0.75 m below MLW) and the deep (2 m below MLW) edges of the *Thalassia* bed in late February, 1989. Ambient light reduction by shading screens averaged 60% near the shallow edge, and 65% at the deep margin. Plants living near the deep edge of the *Thalassia* meadow were more responsive to light reduction than plants at the shallow edge. Experimental light reduction appeared to elicit both a short-term and a long-term response in leaf area. Response times of seagrasses to shading appear to be species specific. LRGR, shoot turnover time, and plastochrone interval appeared to rebound from the effects of shading during the 13th month of the study, which coincided with the beginning of the spring growing season. Many of the characteristics of *Thalassia* that vary with depth may be attributable to a corresponding decrease in ambient light availability.>

357. Kenworthy, W. J., M. S. Fonseca, and S. J. DiPiero. 1990. **Defining the ecological light compensation point for seagrasses *Halodule wrightii* and *Syringodium filiforme* from long-term submarine light regime monitoring in the southern Indian River.** In: Results and recommendations of a workshop convened to examine the capability of water quality criteria, standards and monitoring programs to protect seagrasses from deteriorating water transparency. Edited by W. J. Kenworthy and D. Haunert, 98-105. West Palm Beach: South Florida Water Management District.

[CURRENTS, DEPTH, DISTRIBUTION, LIGHT, PAR]
<Between March, 1987 and September, 1990, the attenuation of photosynthetically active radiation (PAR) was measured in a shallow system of coastal lagoons at the southern end of the Indian River Lagoon in Florida. The areal distribution of seagrasses was determined with 1/10,000 scale color aerial photography and ground verified throughout the study period. A seasonal cycle was evident in the amount of light transmitted to 2.0 m, the lower depth limit of *Halodule wrightii* and *Syringodium filiforme*. Neither water currents nor sediment characteristics could explain the sharp threshold of depth distribution for *H. wrightii* and *S. filiforme* at 2.0 m.>

358. Neckles, H. 1990. **Complex interactions among light-reducing variables in seagrass systems: simulation model predictions for long-term community stability.** In: Results and recommendations of a workshop convened to examine the capability of water quality criteria, standards and monitoring programs to protect seagrasses from deteriorating water transparency. Edited by W. J. Kenworthy and D. Haunert, 119-121. West Palm Beach: South Florida Water Management District.

[EPIPHYTES, LIGHT, MODELS]

<An evaluation of the complex interactions among light-reducing variables in seagrass systems is presented. Variables include the well documented parameters of dissolved compounds and suspended particles, and lesser studied components including epiphytic fouling. A model of eelgrass production in the Chesapeake Bay which addresses the combined effects of various light-reducing factors on macrophyte community is presented as an example.>

359. Onuf, C. P. 1990. **Light requirements of *Halodule wrightii*, *Syringodium filiforme*, and *Halophila engelmanni* in a heterogeneous and variable environment inferred from long-term monitoring.** In: Results and recommendations of a workshop convened to examine the capability of water quality criteria, standards and monitoring programs to protect seagrasses from deteriorating water transparency. Edited by W. J. Kenworthy and D. Haunert, 87-97. West Palm Beach: South Florida Water Management District.

[DEPTH, DISTRIBUTION, LIGHT]

<Extinction coefficients were calculated from light vs depth profiles obtained on 56 days in 20 months between January, 1988, and September, 1989 in the Laguna Madre near Port Mansfield, Texas. No demonstrable differences were observed in the lower light limits of *Halodule wrightii*, *Syringodium filiforme*, and *Halophila engelmanni*. At least 15% transmission of PAR is required to sustain meadow development in this mixed assemblage, shallow subtropical system.>

360. Zimmerman, R. C. and R. S. Alberte. 1990. **Prediction on the light requirements for eelgrass (*Zostera marina*) growth from numerical models.** In: Results and recommendations of a workshop convened to examine the capability of water quality criteria, standards and monitoring programs to protect seagrasses from deteriorating water transparency. Edited by W. J. Kenworthy and D. Haunert, 25-36. West Palm Beach: South Florida Water Management District.

[GROWTH, LIGHT, MODELS, ZOSTERA]

<Model calculations of carbon-balance based on assessment of daily metabolic activity indicate that *Zostera marina* requires somewhere between 3 and 10 h of irradiance-saturated photosynthesis (H_{sat}) each day to meet the demands of respiration and growth. Current modelling efforts are focusing on more detailed examinations of carbon partitioning between shoots and roots, and how these dynamics are affected by the length of the daily light (or aerobic) period. The model simulates the transport of carbohydrate from leaves to roots as regulated by the daily light period through the activities of the enzymes sucrose phosphate synthase and sucrose synthase. Rates of photosynthesis, growth,

sucrose synthesis, transport and catabolism are driven by light availability and coupled to each other by a series of partial differential equations based conceptually on the cell quota model. Current laboratory experiments will provide physiological data to parameterize the model. Field data on *in situ* light availability, growth, and carbon partitioning with both subtidal and intertidal populations of eelgrass to test the model are being collected.>

361. Short, F. T. 1990. **Light limitation on seagrass growth.** In: Results and recommendations of a workshop convened to examine the capability of water quality criteria, standards and monitoring programs to protect seagrasses from deteriorating water transparency. Edited by W. J. Kenworthy and D. Haunert, 37-40.

[LIGHT, LIGHT LIMITATION, ZOSTERA]

<A series of mesocosm experiments were designed to examine the effects of reduced light intensity on the production, growth, and potential biomass of eelgrass, *Zostera marina*. Through the use of neutral density screening, six outdoor tanks (1.5-2 m) were established with a gradient of light intensity from 11% of surface light to full sunlight (94% 1 cm below surface). The tanks were planted with eelgrass seedlings in early june and the plants were allowed to grow to maturity. The plants responded to decreased light levels physiologically by lower growth ratio and biomass production and morphologically by increasing leaf size and decreasing density.>

362. Moore, K. A. 1990. **Field studies of the effects of variable water quality on temperate seagrass growth and survival.** In: Results and recommendations of a workshop convened to examine the capability of water quality criteria, standards and monitoring programs to protect seagrasses from deteriorating water transparency. Edited by W. J. Kenworthy and D. Haunert, 41-57.

[GROWTH, LIGHT, PAR, SURVIVAL, WATER QUALITY, ZOSTERA]

<A series of studies was undertaken to determine the potential for environmental conditions to limit seagass distribution in the lower York River, Chesapeake Bay. Samples of transplanted *Zostera marina* were analyzed for biomass, growth, density and epiphyte loading. Water column sampling included measurements of nitrite, mitrate, ammonium, inorganic phosphorus, chlorophyll a, suspended solids, salinity and temperature. Concurrently, diffuse downwelling attenuation of photosynthetically active radiation (PAR) was determined through water column profiles of photosynthetic photon flux density (PPFD). Additionally, underwater PPFD was measured continuously from August, 1986 to September, 1987, at Gloucester Point and Claybank using arrays of two underwater cosine corrected sensors placed vertically a fixed distance apart. A bimodal seasonal pattern of aboveground growth was observed in *Z. marina* with highest growth rates in spring and a second period of increased growth in the fall. The period critical to seagrass survival in the Chesapeake Bay region may not be the summer with its stressful high temperatures alone, but rather other periods when relative decreases in light availability may be greatest.>

VII. LISTING BY KEYWORD