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John G.

ETIOLOGY AND DISTRIBUTION OF CORAL DISEASES

and

PESTICIDE, HERBICIDE AND HEAVY METALS IN
DISEASED CORALS

TECHNICAL PROPOSAL

by

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Abstract

Certain reef corals of the Florida Keys are showing signs of disease. The elkhorn coral Acropora palmata appears to be particularly susceptible to what is commonly called white spot or white band disease. This syndrome is characterized by zones of dead tissue (the spots) that coalesce and spread over the coral, killing it within a short period of time. The southern end of Biscayne National Park has numerous colonies of dead elkhorn presumably killed by this disease. We propose to survey this reef area to determine the extent of diseased corals. The disease process is apparently mediated by bacteria although which type is unknown. We propose to isolate and identify the causative organism. An additional question is whether this disease is natural or induced by conditions relating to water quality. We propose to examine diseased and undiseased elkhorn coral tissue for the presence of five different heavy metals as well as common herbicides and pesticides that are flushed onto the reef from canal effluent. The work proposed here will therefore serve to quantify the disease, characterize the causative agent and determine if the disease is related to chemical pollution.

INTRODUCTION

The susceptibility of stony corals to disease processes was unknown until just over a decade ago (Antonius, 1973). Since that time several studies have made it clear that a variety of organisms are associated with a lethal syndrome generally referred to as "Band Diseases" (Antonius, 1981 a and b) or "Line Diseases" (Peters, 1984). This phenomenon has affected several areas along the Florida Keys, and frequently appears to involve primary reef building corals. In regions outside of Florida (e.g. St. Croix) white line disease has destroyed large portions of the reef tract (Gladfelter, 1982).

Line diseases are characterized by a zone of necrotic tissue that rapidly spreads over the living surfaces of stony corals, leaving a flesh-less, white skeleton behind. The two most readily distinguishable line diseases display zones of necrosis that have either bleached appearance (white line disease) or an advancing area of black tissue (black line disease). Microscopic investigations have shown that a wide variety of organisms are associated with line disease including ciliate Protozoa, acoel Turbellaria, copepod and amphipod Crustacea as well as microorganisms (Antonius, 1981b, Peters, 1984). However, since antibiotics such as penicillin, erythromycin and streptomycin halt the spread of some of the lines, the etiological agent is most likely to be found among the latter. The microbiology of line disease has been the subject of few

studies that lead to an unclear picture of both the causative agent(s) and the relationship between the two different band syndromes. Using light and electron microscopic techniques Peters et al. (1983) described an unidentified Gram-negative rod bacterium from elkhorn and staghorn coral with white line disease. These were the only identifiable microorganisms in diseased tissues taken from both the Virgin Islands and Bonaire. No attempt was made to culture the putative pathogen for experimental reinfection. Ramos-Flores (1983) performed similar studies on the star coral Montastrea annularis infected with black line disease from several caribbean locations as well as from Bermuda and Florida. The black line region contained a wide variety of microorganisms including foreign algae, cyanobacteria and fungi. An unidentified fungus was most consistently associated with the syndrome but no attempt was made to culture the putative pathogen.

Antonius (1973 et seq.) was the first to show that black line disease could be transferred from one coral to another and established a hierarchy of species susceptibility. Antonius claimed to have identified the pathogen as the cyanobacterium, Oscillatoria submembranacea but had done so without the benefit of standard microbiological techniques including culture of the many other organisms found in the infected coral tissue. One of the few published studies involving microscopic examination of both naturally and experimentally infected corals are those of Garrett and Ducklow (1975) and Ducklow and Mitchell (1979a).

These authors concluded that cyanobacteria are not consistently associated with black line disease, but the colorless sulfide bacterium Beggiatoa was. Unfortunately, no cultural studies were done and the authors were unable to identify a primary pathogen.

In 1983 Rutzler and Santavy published the most definitive study to date on black line disease with morphological and ultrastructural studies of the apparent pathogen, the cyanophyte Phormidium (Oscillatoria) corallyticum. Their study was followed by a laboratory examination of axenic culture conditions (Taylor, 1983). Rutzler et al. (1983) continued their study with field observations which showed that a partially purified mixed culture containing an enrichment of Phormidium could transmit the disease to healthy corals. These experiments were done without axenic cultures, suggesting that their conclusions concerning the etiological agent are premature.

It is clear from the above that the final statement has not yet been made in determining what causes line diseases or if these diseases are truly different in their origin. It has been suggested that line disease may be the result of stress-induced population explosion of the bacteria found normally in coral mucus (Ducklow and Mitchell, 1979a and b) or in tissues (Peters, 1984). Thus exists the possibility that these bacterial diseases of stony corals represent a secondary phenomenon induced by some primary stress. There is no shortage of potential primary stress agents for scleractinian corals. Ducklow and Mitchell

on its effects on corals. It appears that one effect of exposure to organochlorine compounds by reef corals is that they are rapidly concentrated by tissues. McLoskey and Chesher (1971) found for example, that Acropora cervicornis contained up to 12 ppb DDT, 320 ppt Dieldrin and 300 ppt DDE and PCB's. They also found that such exposure increased respiration rates and depressed symbiont photosynthesis.

Other organochlorine compounds that act as herbicides may directly affect zooxanthellae, resulting in a wide range of effects. If persistent either in the tissues or the environment, herbicides may cause coral mortality directly or lead to secondary disease states. The recent finding by Glynn et al. (1985)

that bleached corals from Panama contained 20 ppb herbicide in their tissues, is cause for concern suggesting that these substances should be examined more closely.

We propose to examine the coral reefs primarily in the northern sector of Biscayne National Park to determine the answers to the following questions.

- 1) What is the geographical extent of line disease in the northern portion of Biscayne National Park as well as control areas to the South and which coral species are most often affected?
- 2) Is there any evidence of pesticides, herbicides or heavy metals in the tissues of affected corals, and if so, are their levels significantly higher than in control corals?

(1979 a and b) employed hypoxia and elevated temperature to induce disease susceptibility experimentally. Certainly temperature stresses are inimical to coral growth and development (see summary by Johannes, 1975) As is excessive turbidity is a potent stress to stony corals (Dodge et al., 1974; Bak, 1978; Rodgers, 1983; Dodge and Brass, 1984) and has also been implicated in initiating line disease (Antonius, 1981 a and b). Other sources of stress include sewage, especially from high levels of phosphate (Walker and Ormons, 1982; Dodge et al., 1984), oil (Loya and Rinkevich, 1979, 1980; Peters et al., 1981), and heavy metals (Veeh and Turekian, 1968; St. John, 1974).

The relationship of these materials to disease processes is unknown. However, other subtle effects of pollutants, such as the effect of soluble oil fractions in decreasing the reproductive capacity of corals, are just beginning to be understood (Loya and Rinkevich, 1979; 1980). Very little is known about the effects of heavy metals on coral except that their aragonite skeletons are useful indicators of the chemistry of the seawater in which they were formed (Flor and Moore, 1977). However, we are unaware of any published literature dealing with bioaccumulation of toxic metals in tissues of living coral. Metals in tissues may or may not be reflected in a qualitative or quantitative fashion by examining skeletal aragonite.

The effect of organochlorine substances on metabolism is both subtle and complex. However, in spite of a substantial literature in general, there is very little information published

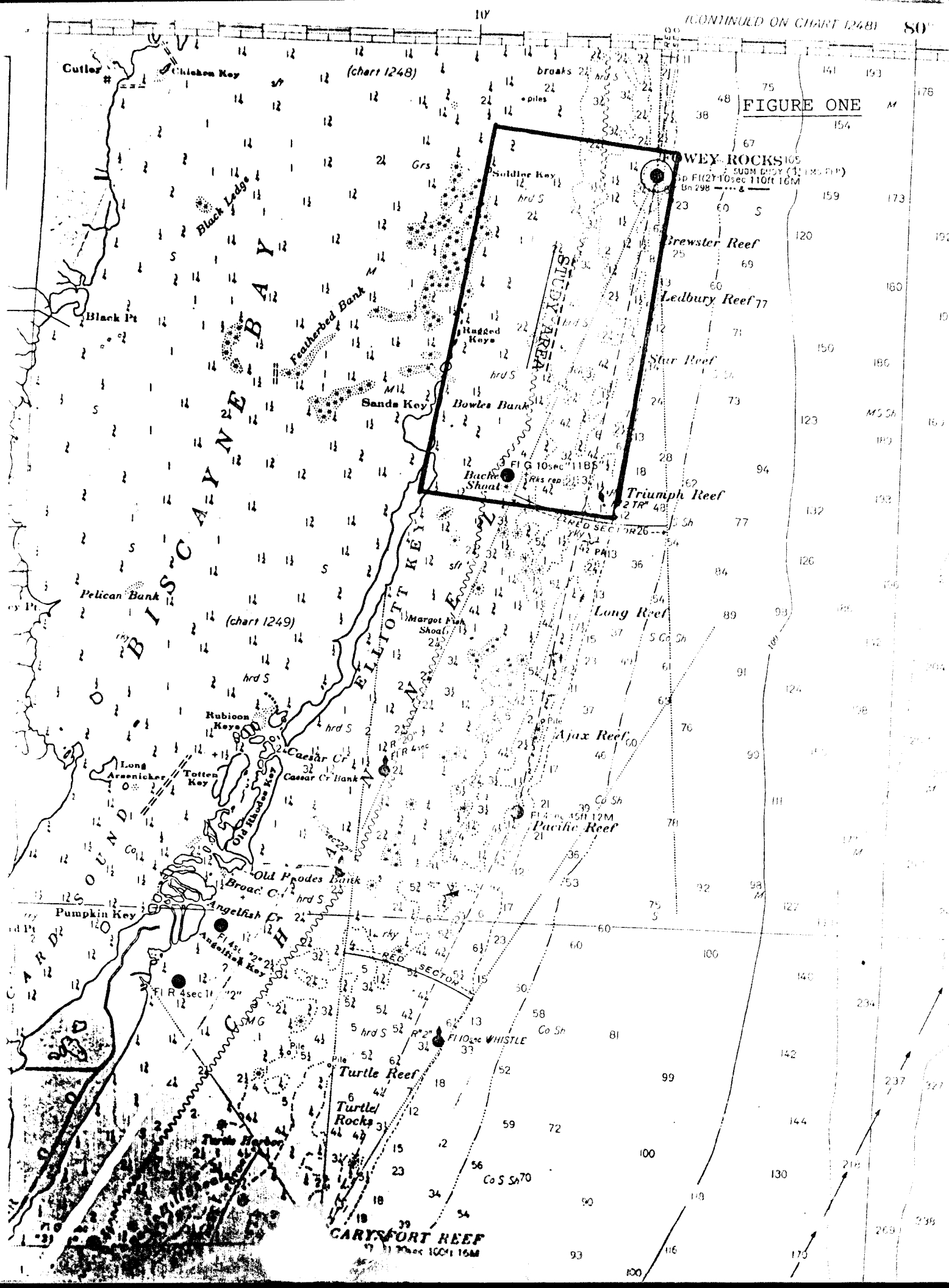
- 3) What is the nature of the bacterial populations associated with a tissue lesions and is there a pattern pointing to a causative organism when compared to the healthy corals, or is there no pattern suggesting a secondary, opportunistic disease state with common external characteristics.
- 4) Can axenic cultures of disease-associated organisms reproduce the disease state.

Our aim is to develop these baseline and survey data into points of departure for a laboratory oriented, experimental infection proposal to the National Science Foundation as we have done in the past with gorgonian coral pathology (Goldberg and Makemson, 1981; 1984).

METHODS

a. Field Methods

The study site will be a rectangular area bounded on the northeast by Fowey Rocks and northwest by Soldier Key. The southeast corner will be marked by Triumph Reef and the southwest by Bache Shoal. The center of the study area is marked by Ragged Keys to the west and Star Reef to the east. The central area is due east of Black Point (Figure 1). We propose to set up survey areas in each of these six sites. The precise location of each site and control sites to the south will be chosen with regard to scleractinian diversity in consultation with National Park personnel. Each of the six sites will be surveyed by



swimming compass courses so that a total reef area of at least 10,000 m² will be examined (60,000 m² total for the project area).

Each incidence of disease or bleaching will be scored as a percentage of the total colony surface as estimated by measuring maximum/minimum dimensions using a tape measure. In cases of highly branched corals (e.g. A. cervicornis) the total thicket volume will be measured and the diseased portions given as a percentage. The species of affected coral will be noted and designated as having white band, black band or bleaching syndrome. Random 25 m² quadrats will be set up at each study site to determine the number and size of coral species displaying disease symptoms. In this way, estimates can be made of the proportion of diseased individuals to total numbers of individuals at that site. For example, we may find that at Bache Shoal a total of 100 m² and 50 colonies of Montastrea annularis was measured. Ten colonies and a total of 25 m² showed symptoms of black line disease. This could then be reported as 20% of the colonies or 25% of the surface area of that species. Statistical treatment of data will be according to methods in Goldberg and Makemson (1981).

b. Microbiological Methods

Samples of diseased material from species determined to be the most consistently affected will be taken for microbiological analysis. The intent of this work is to fulfill

Koch's Postulates: 1) the putative causative agent must be

found in every case of the disease 2) the agent must be isolated from the infected host and grown in pure culture for proper identification 3) the cultured organism must reproduce the disease and 4) the organism must be recoverable from diseased tissue. Healthy control corals will also be examined from both the northern and southern ends of the Park.

It will be necessary to examine all major groups of suspected microbes: cyanobacteria, Beggiatoa-like organisms (mixotrophic, filamentous gliding bacteria), unicellular marine heterotrophic bacteria and fungi (yeasts and molds). Mucus and infected tissue lesions will be plated on:

<u>Microbial Group</u>	<u>Medium</u>	<u>Reference</u>
Cyanobacteria	Modified Provasoli's Agar	Goldberg & Makemson, 1981
<u>Beggiatoa</u>	Thiosulfate-Peptone Agar	Larkin, 1980
Vibrios and other heterotrophs	TCBS-Agar	Sayler <u>et al.</u> , 1976
	Glycerol Marine Agar	Makemson and Hastings, 1979
	Vibrionaceae-Agar	Simidu and Tsukamoto, 1980
Yeasts/Molds	Yeast-Agars	VanUden and Castelo-Branco, 1963

Samples of line disease tissue and mucus as well as bleached and control corals will all be examined if sufficient replicate material is available at each of the six sites. Cultures purified by plating and restreaking will be identified to the lowest possible taxon using criteria of gram staining, colonial morphology and biochemical characterization with API-20E strips (Baumann et al., 1971; Murray, 1984). Populations of microflora held in common for a given species with a given disease type should occur in

every instance of the disease and must differ qualitatively or quantitatively from the control microflora in healthy corals for these populations to be considered the putative pathogens. If no consistent pattern is found, secondary or opportunistic infections may then be suspected.

c. Experimental Infections

Although several types of diseases may be demonstrable in the study area we propose to concentrate on the type found to be most prevalent by our survey. Our approach to establishing infections will include the use of axenic cultures applied by swabbing the coral surface or by injection. Several experimental animals will be employed but our first attempts will focus on Porites porites Lamarck as a model, primarily because of its adaptability to closed aquarium conditions and ready availability. Control swabbing/injection will also be employed so that we will quantitatively describe the lowest concentration of pathogen capable of initiating a lesion and there will be no doubt as to its identity.

d. Chemical Methods

We have contracted with Florida International University's Water Quality Center to analyse coral tissue for organochlorine compounds and selected heavy metals. We will choose for analysis the most often affected coral species as determined from our field work and microbiological analysis. Coral samples will be placed in plastic bags on ice in the field and subsequently frozen in the laboratory. Tissue will be separated

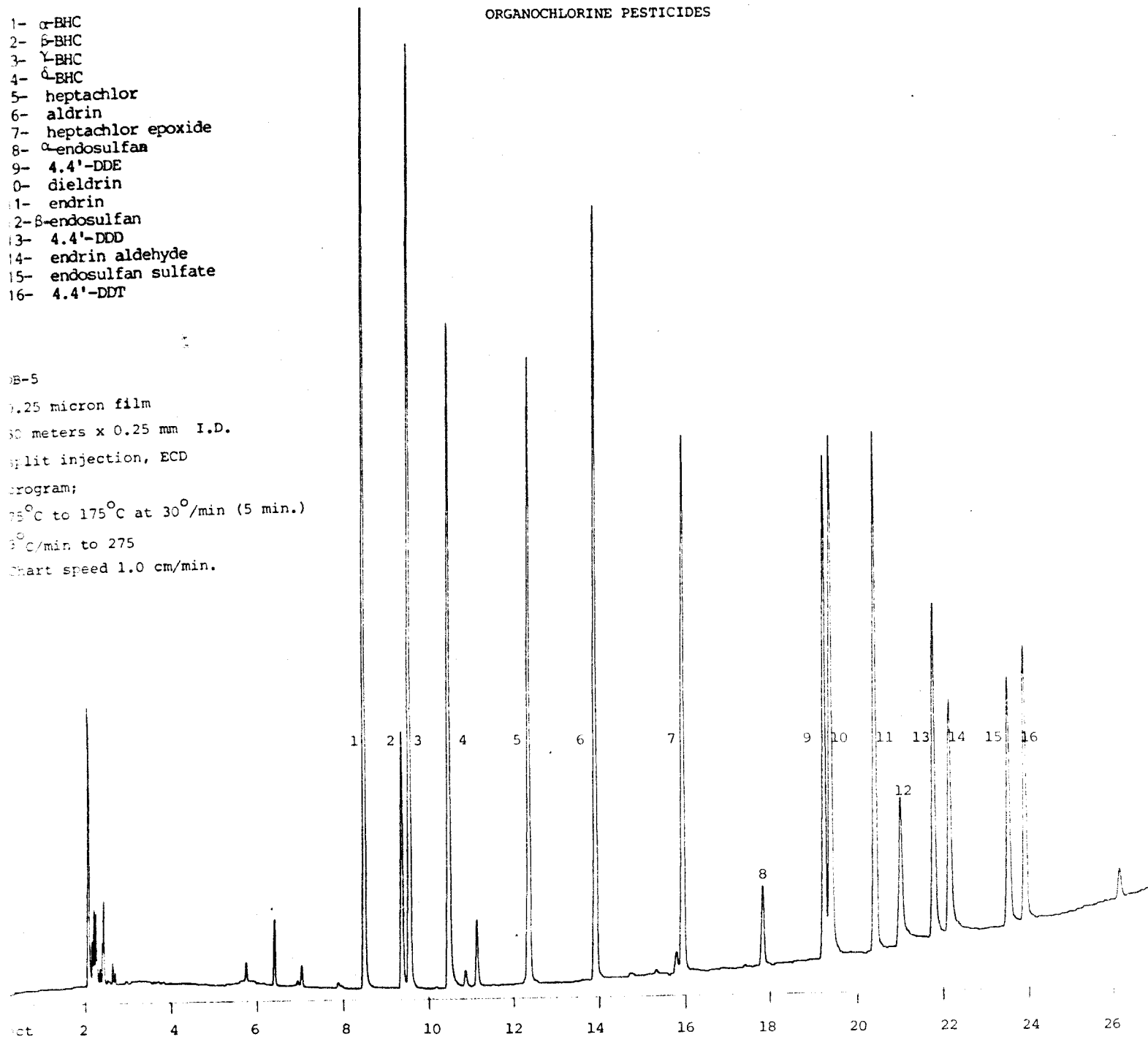
from skeletal material by thawing followed by jets of distilled water from a Water-Pik device (Johannes and Wiebe, 1970). The aqueous suspensions will be sonicated briefly and evaporated to reduce the volume.

For analysis of organochlorine pesticides, an aliquot will be homogenized with an equal weight of sodium sulfate and extracted with n-hexane in a soxhlet for 2 hours. After sample concentration, the material is applied to the capillary columns of a Varian 3700 gas chromatography system with an electron capture detector for halogenated compounds. Quantitative analysis employs a Hewlett-Packard 3390 Peak Integrator, giving results as depicted in Figure 2 for the separation of 16 different pesticides. We will analyse 30 samples qualitatively and 10 samples quantitatively. For analysis of the herbicides 2,4-D, 2,4,5-T and Silvex, a Varian 5000 HPLC reverse phase column will be employed in conjunction with a variable wavelength UV detector set at 280 nm. We will analyse 30 samples quantitatively.

Tissue samples will be examined quantitatively for the presence of five heavy metals (Hg, Zn, Cu, Pb and Cd) employing a Perkin-Elmer 503 Atomic Absorption Spectrometer. We will quantitatively analyse 20 separate samples for each of the five metals.

Samples from control sites will be included among all of the above analyses to establish background levels of pesticides, herbicides and metals.

FIGURE 2



FIU GAS CHROMATOGRAPHY STANDARDS

PERSONNEL

Walter M. Goldberg (Ph.D. 1973) Associate Professor (Coral Biology),
Department of Biological Sciences, Florida International
University since 1973.

Resume is appended.

John C. Makemson (Ph.D. 1970)
Associate Professor (Marine Microbiology),
Department of Biological Sciences, Florida International
University since 1978.

Resume is appended.

Mehrzaad Mehran (D. Pharm. 1969) Research Associate (Analytical
Chemistry), Water Quality Center, Florida International
University since 1980.

Resume is appended.

LITERATURE CITED

1. Antonius, A. 1973. New observations on coral destruction in reefs. Assn. Isl. Mar. Lab. Carib. 10:3 (Abstract).
2. Antonius, A. 1977. Coral mortality in reefs: a problem for science and management. Proc. 3rd Intl. Coral Reef Symp. Miami, 2:618-623.
3. Antonius, A. 1981a. Coral reef pathology: a review. Proc. 4th Intl. Coral Reef Symp. Manila, 2:3-6.
4. Antonius, A. 1981b. The "Band" diseases in coral reefs. Proc. 4th Intl. Coral Reef Symp. Manila, 2:7-14.
5. Bak, R.P.M. 1978. Lethal and sublethal effects of dredging on reef corals. Mar. Poll. Bull. 9:14-16.
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9. Dodge, R.E. and G.W. Brass. 1984. Skeletal extension, density and calcification of the reef coral Montastrea annularis: St. Croix, U.S. Virgin Islands. Bull. Mar. Sci. 34:288-307.
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11. Ducklow, H.W. and R. Mitchell. 1979b. Bacterial populations and adaptations in the mucus layers on living corals. Limnol. Oceanogr. 24:715-725.
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15. Goldberg, W.M. and J.C. Makemson. 1981. Description of a tumorous condition in a gorgonian coral associated with a filamentous green alga. Proc. 4th Intl. Coral Reef Symp. Manila, 2:685-697.
16. Goldberg, W.M., J.C. Makemson and S.B. Colley. 1984. Entocladia endozoica sp. nov., a pathogenic chlorophyte: structure, life history, physiology, and effect on its coral host. Biol. Bull. 166:368-282.
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36. Veeh, H.H. and K.K. Turekian. 1968. Cobalt, silver and uranium concentrations in reef-building corals in the Pacific Ocean. *Limnol. Oceanogr.* 13:304-308.
37. Walker, D.I. and R.F.G. Ormond. 1982. Coral death from sewage and phosphate pollution at Aqaba, Red Sea. *Mar. Poll. Bull.*

BUDGET

1. Salaries (2 Princ. Invest.) - ½ summer salaries	----\$4,802
fringe-----	1,440
2. Field Sampling, 3 field assistants-----	1,500
3. Laboratory Assistants (2 Lab and Field)-----	3,200
4. Expendible Supplies-----	3,783
5. Pesticide/Herbicide/Heavy Metals Analysis of Coral Tissue (Drinking Water Res.Center, FIU)-----	2,250
6. Preparation and Presentation of Results-----	2,500
7. State of Florida Personnel Assessment Fee-----	50
Total Costs-----	\$19,525

Curriculum Vitae

Name: Walter M. Goldberg, Ph.D.

Date and Place of Birth: 9 January, 1946; Fitchburg, Mass.

Marital Status: Married (1971) Rosalie J. Goldberg, Electronics Technician, Southern Bell Telephone Co.

Two children: Ian born 1/79 and Jill born 7/85

Home Address: 6450 S.W. 73 Street
South Miami, Florida 33143

Education:

The American University, Washington, D.C.: 1964-1968
B.S., Biology

Florida Atlantic University, Boca Raton, Florida. 1968-1970.
M.S., Zoology, Ecology

Thesis: Some aspects of the ecology of the reefs off Palm Beach County, Florida, with emphasis on the Gorgonacea and their bathymetric distribution. 108 pp.

University of Miami, School of Marine and Atmospheric Sciences, Miami, Florida. 1970-1973. Ph.D., Marine Science.

Dissertation: The chemistry, structure and growth of the gorgonian and antipatharian coral skeleton. 82 pp.

Professional Affiliations:

International Society for Reef Studies
American Association for the Advancement of Science
American Society of Zoologists
Western Society of Naturalists
American Society of Limnology and Oceanography

Honors, Fellowships, etc.:

Upjohn Research Fellow, 1970-1973 (fellowship from Upjohn Pharmaceuticals).
Oak Ridge Faculty Fellowship, 1975.
Listed in Who's Who in the South and Southwest
National Science Foundation Grantee

Tools of Research:

Histochemical and Histological techniques
Electron microscopy
Radioisotope methodology and radiography
Oceanographic technique
Certification for decompression SCUBA diving (100 hour NAUI)

Post-Doctoral Training and Experience:

Post-Doctoral Associate in Biochemistry,
Papanicolaou Cancer Research Institute 1973.

Oak Ridge Associated Universities Summer Faculty Research
Fellowship: Neutron activation analysis of coral
skeletons. Puerto Rico Nuclear Center 1975.

Assistant Professor, Department of Biological Sciences,
Florida International University 1973-1977.

Associate Professor 1977 to present. Tenure awarded
1978.

Professional Activities:

Teaching History:

A. Full Term Courses

<u>TITLE</u>	<u>LEVEL</u>	<u>YEAR</u>
Fundamentals of Ecology	Junior	1973-1980
Ecology Laboratory	Junior	1978
Biological Oceanography	Junior	1974-1982
Histochemistry and Microtechnique	Graduate	1981 only
Marine Invertebrate Zoology & Lab	Junior	1975-present
Techniques in Biological Oceanography	Junior	1977-present
Coral Reef Ecology	Graduate	1977-present
Marine Biology	University Core	1984-present
Electron Microscopy	Graduate	1984-present

Professional Activities: (CONTINUED)

Teaching History:

B. Team-Taught Courses

<u>TITLE</u>	<u>SECTION</u>	<u>LEVEL</u>	<u>YEAR</u>
Caribbean Shallow Marine Environments (taught in Jamaica)	Reef Ecology	Graduate	1976 only
Invertebrate Physiology	Various	Graduate	1974 only
General Biology I	Zoology	University Core	1980-present
General Biology II	Structural Biochemistry	University Core	1980, 1984
Biological Instrumentation	Electron Microscopy	Graduate	1984

Program Involvement:

- .Director, Marine Science Certificate Program 1979-present.
- .Environmental Studies Program 1973-present.

Research Interests:

Coral Biochemistry, histology, pathology and ultrastructure;
Coral Reef Ecology.

Thesis Supervision:

Charles M. Courtney. (1978-1979). Title: A Limnological
Description of Lake Marco Shores - A Manmade Brackish
Water Lake (169 pp).

Susan B. Colley. (1979-present). Title: Histochemical and
Structural Studies of the Relationship Between a Green
Algae and its Coral Host.

Publication Record:

A. Refereed Journal Articles.

1971. A note on the feeding behavior of the snapping shrimp
Synalpheus fritzmuelleri Coutiere (Decapoda, Alpheidae).
Crustaceana, 21 (3):318-20.

1973. The ecology of the coral-octocoral communities of the
southeast Florida coast: Geomorphology, species composition
and zonation. Bulletin of Marine Science, 23 (3):465-488.

Publication Record: (CONTINUED).

1973. Ecological aspects of salinity and temperature tolerances of some reef-dwelling gorgonians from Florida. Caribbean Journal of Science, 13 (3-4):173-177.

1974. With R.D. Hamilton. The sexual cycle in Plexaura homomalla. In: Prostaglandins from Plexaura homomalla: ecology, utilization and conservation of a major medical marine resource (F.M. Bayer and A.J. Weinheimer, eds.). Studies in tropical oceanography #12, University of Miami press. pp. 58-61.

1974. Evidence of a sclerotized collagen from the skeleton of a gorgonian coral. Comparative Biochemistry and Physiology, 49 (3B):525-29.

1976. A comparative study of the chemistry and structure of gorgonian and antipatharian coral skeletons. Marine Biology, 35:253-267.

1977. Complete separation of iodotyrosine-iodohistidine-iodide mixtures on thin layer plates with a single solvent system. J. Chromotography 134:246-248.

1977. Radioiodine as an Indicator of Skeletogenesis in Gorgonian and Antipatharian Corals. In: Proc. 3rd Intl. Coral Reef Symp. Miami 1:pp.511-516.

1978. Chemical Changes Accompanying Maturation of the Connective Tissue Skeltons of Gorgonian and Atipatharian Corals. Marine Biology. 49:203-210.

1979. Shelf Temperatures and Reef Growth on the Southeast Florida Coast. Nature 278:669-670.

1980. Fluorescent Compounds from the Connective Tissue Skelton of A Gorgonian Coral and Their Possible Role in Cross-Linking. Comparative Biochemistry and Physiology. 66B(1):33-42.

1981. With J.C. Makemson. Description of a Tumorous Condition in a Gorgonian Coral Associated with a filamentous Green Alga. in:proc. Fourth Intl. Coral Reef Symp, Manila, Vol. 2, pp. 685-697.

1983. Cay Sal Bank: A Biologically Impoverished, Physically Controlled Environment. Atoll Research Bulletin. #271, pp. 1-35.

1984. With J.C. Makemson and S. Colley. Entocladia endozoica sp. nov., A Pathogenic Chlorophyte: Structure, Life History, Physiology and Effect on its Coral Host. Biological Bulletin. 166:368-383.

Publication Record: (CONTINUED).

1986. With Y. Benayahu. Spicule formation in the gorgonian coral Pseudoplexaura flagellosa 1. Demonstration of intracellular and extracellular growth and the effect of ruthenium red during decalcification. In Press.

1986. With Y. Benayahu. Spicule formation in the gorgonian coral Pseudoplexaura flagellosa 2. Calcium localization by antimonate precipitation. In Press.

B. Monographs/Special Reports.

Environmental Impact Statement: Fisheries Management Plan for Corals and Coral Reefs of the Eastern United States & Gulf of Mexico (co-author).

- .Technical compendium for Coral Biology
- .Recommends limits on use of coral or coral products
- .Limits activities injurious to corals
- .Regulations published in Fed. Reg. 49: 29607-29611, 1984.
- .Became law under Magnuson Fishery Conservation and Management Act on 22 August, 1984

C. Non-Refereed Publications/Reports.

1975. Marine Ecological Considerations. An evolution of Florida Power and Light Co. Environmental Impact Report for operation of St. Lucie Nuclear Unit #2. (D.F.Jackson,ed.).

1975. Comparative study of iodine fixation by gorgonian and black corals. Report to mid-pacific marine laboratory summarizing research activities.

1981. With D.Lee. A laboratory manual for introductory biology (used by all students taking General Biology Laboratory).

1980A. Analysis of meiofauna associated with potential sand, borrow sites from Broward County, Florida.

1980B. Biological effects of beach restoration.

1981-84 Macro-benthic survey of beach restoration sites, Broward County, Florida. Several reports.

1985. Biological effects of beach restoration: a three year overview. Summary report to Broward County Environmental Quality Control Board.

Manuscripts in Preparation

1. Biochemistry of spicule formation in a gorgonian coral.
2. Cellular response to pathogens by a gorgonian coral.

Grant History:

- 1) 1974. Atomic Energy Commission Travel and Support Grant to Enewetak, Marshall Islands: Radioiodine accumulation by Black Corals. No dollar amount. Status: Funded and Completed.
- 2) 1975. Oak Ridge National Laboratory Summer Faculty Fellowship to Puerto Rico Nuclear Center: Neutron Activation Analysis of Coral Skeletons. \$3750. Status: Funded and Completed.
- 3) 1977. Florida Institute for Oceanography: A training and research cruise aboard R/V Bellows. \$4,000.00. Status: Funded and completed.
- 4) 1977. Florida International University, College of Arts and Sciences Faculty Development: Biochemical mechanisms of iodination in gorgonian corals. \$750.00. Status: Funded and completed.
- 5) 1978. Florida Institute for Oceanography Training and Research Cruise: \$3,400. Status: Funded and Completed.
- 6) 1979. Florida Institute for Oceanography Training and Research Cruise: \$5,700. Status: Funded and completed.
- 7) 1980. National Science Foundation Cell Biology Program: A study of pathogenesis in a gorgonian coral by a filamentous alga (with J. Makemson as Co-Principal Investigator). \$47,000 (2 years). Status: Funded and completed.
- 8) 1980. FAU-FIU Joint Center for Environmental and Urban Problems: Distribution and Ecology of Algal Tumors in Gorgonian Corals. \$8,700. Status: Funded and completed.
- 9) 1980. Florida Institute for Oceanography. Oceanographic Studies on Cay Sal Bank, Bahamas. \$8,800. Status: Funded and completed.
- 10) 1981. Florida Institute for Oceanography. Benthic community analysis of Cay Sal Bank, Bahamas. \$8,200. Status: Funded and completed.
- 11) 1982. FIU College of Arts & Sciences Faculty Development: An aerial survey of Cay Sal Bank, Bahamas: \$500. Status: Funded and completed.
- 12) 1982. Florida Institute for Oceanography. Oceanographic and Benthic community analysis of Cay Sal Bank, Bahamas. \$16,200. Status: Funded and completed.

Grant History;

- 13) 1983. FIU Latin American-Caribbean Center. Survey of black coral populations on Roatan, Honduras. \$1,200. Status: Funded and completed.
- 14) 1983. National Science Foundation Research Instrumentation: Aquisition of a quantitative microscopy system for histochemical analysis. \$20,000 plus \$15,000 in FIU. Matching funds. Status: Funded and completed.
- 15) 1983. Florida Institute for Oceanography: Oceanography and benthic community analysis of Cay Sal Bank, Bahamas. \$19,500. Status: Funded and completed.
- 16) 1983. Weitzmann Foundation for Scientific Research: Post-doctoral fellowship for Dr. Y. Benayahu to study at FIU. \$20,000. Status: Funded and completed.
- 17) 1984. FIU College of Arts and Sciences Faculty Development: Biochemical analyses to support calcification studies funded by Weizmann Foundation Award: \$500.00. Status: Funded and completed.
- 18) 1984. Florida Institute for Oceanography: Oceanography and Benthic communities of Cay Sal Bank, Bahamas. \$9,000. Status: Funded and Active.
- 19) 1984. Florida Institute for Oceanography: Continuation of above project. \$11,100. Status: Funded for 1985.
- 20) 1984. FAU-FIU Joint Center for Environmental and Urban Problems. A study of the etiology, distribution and induction of diseases affecting stony corals in Florida waters (with J. Makemson, Co-Principal Investigator). \$1100.00 (1 year). Status: Funded.
- 21) 1985.⁶ National Science Foundation. Short term visit to develop cooperative research on skeletal growth in black coral populations. Status: Pending. *Funded 1985*
43400-
- 22) 1985.⁶ Florida Institute for Oceanography. Studies on Cay Sal Bank continued. Status: Pending. *Funded 1985*
15000

Conferences/Symposia Presentations:

- 1977. 3rd International Coral Reef Symposium, Miami.
- 1981. 4th International Coral Reef Symposium, Manila.
- 1982. International Colloquium for Invertebrate Pathology, Brighton, England (poster session).
- 1983. American Society of Zoologists, Philadelphia (co-chairman for invertebrate immunology section).
- 1984. International Society for Reef Studies, Miami (Editorial Board Member for Proceedings and Contributor).
- 1985. 5th International Coral Reef Symposium, Tahiti

Service Activities:

A. University, College and Departmental Activities

- .OE Electron microscope facility: planning & acquisition of equipment - 1975-1976.
- .Departmental curriculum and planning committee - 1976-1978.
- .Library Committee Departmental Representative - 1973-1977.
- .Environmental sciences task force - 1976-1977.
- .Chair, Departmental Promotion and Tenure Committee - 1976-1980.
- .Chair, Departmental Budget Committee - 1977-1982.
- .Graduate Council, School of Technology - 1976-1980.
- .Chair/Member departmental search and screen committees; Genetics, 1976; Microbiology, 1977; Anatomy, 1978; Environmental Studies, 1980; Botany, 1981.
- .Management of electron microscope facilities - 1982-present.
- .University Representative and Member of Advisory Council, Florida Institute for Oceanography - 1973-present.
- .Pre-medical advisement committee - 1982-1985
- .Chair, Departmental laboratory committee - 1983-present.
- .Chair, University radiation safety committee - 1974-present.

B. Seminar Presentations

- 1975. Aspects of the Biology and Ecology of Reef-Dwelling Gorgonians in Florida.
- 1977. The Mechanical Significance of Gorgonian Skeletal Structure.
- 1980. Cybernetic Control of Phosphate in Fresh Water and Marine Ecosystems.
- 1981. The Nature of a Pathogenic Relationship Between a Gorgonian Coral and a Filamentous Green Alga.
- 1982. Cay Sal Bank: A Biologically Stressed Environment.
- 1983. Electron Microscopy and Cytochemistry of the Immune Response of a Gorgonian Coral.
- 1984. Calcium Uptake and Spicule Formation in a Gorgonian Coral
- 1985. Morphogenesis and calcification during spicule formation in a gorgonian coral.

C. Professional

- Expert witness and consultant to State of Florida Department of Environmental Regulation: Impact of Nuclear Power Plants on Florida Coastal Environment (1975).
- Public Debate Participant: Nuclear Power: Pro or Con Sponsored by FAU-FIU Joint Center (1976).
- Manuscript Reviewer, Bulletin of Marine Science (1979, 1980).
- Proposal Reviewer, National Science Foundation (1979).
- Consultant for Beach Restoration Projects - Environmental Impact Assessment: Broward County Environmental Quality Control Board (1980-present) and Palm Beach County Public Works Department (1981-present).
- Expert Witness - Effect of Marina Enlargement by Port Bougainville Development on Corals in Pennekamp Park (1984).
- Expert Witness and Consultant: Effects of grounding of M/V Wellwood on the marine ecosystem of Molasses Reef, Florida (1985-present)

BIBLIOGRAPHICAL SKETCH

JOHN C. MAKEMSON

Birth: 20 September 1942 - San Francisco, California

EDUCATION:

High School: Ankara Dependents High School, Ankara, Turkey, 1960.

University: 1. San Francisco State College, 1964 B.A. Biology, 1966 M.A. Biology
2. Washington State University, 1970 Ph.D. Bacteriology-Biochemistry

PROFESSIONAL EXPERIENCE:

1970-1975 Assistant Professor, American University of Beirut.
1975-1977 Research Fellow, Harvard University, Cambridge, MA.
1977-1978 Lecturer, San Francisco State University, San Francisco, CA.
1978 (summer) Visiting Lecturer, Department of Biochemistry, University of Illinois, Urbana, IL.
1978-1980 Assistant Professor, Department of Biological Sciences, Florida International University, Miami, Florida.
1980 (summer) Visiting Faculty, Harvard University, Cambridge, MA.
1980-present Associate Professor, Florida International University.

PUBLICATIONS (Meeting Abstracts not included):

- Makemson, J.C. and R. Darwish. 1972. Calcium requirement and magnesium stimulation of Escherichia coli L-form induction. Infection and Immunity. 6:880-882.
- Makemson, J.C. 1972. An interstitial water sampler for sandy beaches. Limnol. Oceanog. 17:626-628.
- Khiyama, H.M. and J.C. Makemson. 1973. Sand beach bacteria: enumeration and characterization. Appl. Microbiol. 26:292-297.
- Makemson, J.C. 1973. Oxygen and carbon dioxide in interstitial water of two Lebanese sand beaches. Netherlands J. Sea Res. 7:223-232.
- Makemson, J.C. 1973. Control of in vivo luminescence in psychrophilic marine photobacterium. Arch. Mikrobiol. 93:347-358.
- Majj, H. and J. C. Makemson. 1976. Determination of growth of Sphaerotilus discophorus in the presence of manganese. Appl. Environ. Microbiol. 32:699-702.
- Tu, S.-C., J.C. Makemson, J.E. Becvar and J.W. Hastings. 1977. Bacterial luciferase subunits are synthesized in equal quantities. J. Biol. Chem. 252:803-805.
- Makemson, J.C. and J.W. Hastings. 1979. Poising of the arginine pool and the control of bioluminescence in Beneckea harveyi. J. Bacteriol. 140:532-542.
- Makemson, J.C. and J.W. Hastings. 1979. Glutamate is an osmoregulatory molecule in Beneckea harveyi. Appl. Environ. Microbiol. 38:178-180.

- Makemson, J.C. and J.W. Hastings. 1979. Inhibition of bacterial bioluminescence by pargyline. Arch. Biochem. Biophys. 196:396-402.
- Goldberg, W.M. and J.C. Makemson. 1981. Description of a tumorous condition in a gorgonian coral associated with a filamentous green alga. Proc. 4th Coral Reef Symp. 2:685-697.
- Makemson, J.C. and J.W. Hastings. 1982. Iron represses bioluminescence and affects catabolite repression of luminescence in Vibrio harveyi. Curr. Microbiol. 7:181-186.
- Makemson, J.C. 1983. A simple assay of cyclic-AMP phosphodiesterase in the presence of interfering enzymes. J. Microbiol. Meth. 1:283-290.
- Goldberg, W.M., J.C. Makemson, and S.B. Colley. 1984. Entocladia endozoica sp. nov., a pathogenic chlorophyte: structure, life history, physiology, and effect on its coral host. Biol. Bull. 166:368-383.
- Hastings, J.W., C.J. Potrikus, S.C. Gupta and J.C. Makemson. 1985. Biochemistry and physiology of bioluminescent bacteria. Adv. Microbial Physiol. (In press). Vol 26.